4-28-1992

NACA four-digit airfoil section generation using cubic parametric curve segments and the golden section

William T. Scarbrough

Recommended Citation

Scarbrough, William T., "NACA four-digit airfoil section generation using cubic parametric curve segments and the golden section" (1992). Thesis. Rochester Institute of Technology. Accessed from

NACA FOUR-DIGIT AIRFOIL SECTION GENERATION USING CUBIC PARAMETRIC CURVE SEGMENTS AND THE GOLDEN SECTION

William T. Scarbrough

Department of Mechanical Engineering
Rochester Institute of Technology
One Lomb Memorial Drive
Rochester, New York

Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Science of Mechanical Engineering

28 APRIL 1992

Dr. Panchapakesan Venkataraman, Graduate Thesis Advisor

Dr. Hany Ghoneim, Professor of Mechanical Engineering

Dr. Amitabha Ghosh, Professor of Mechanical Engineering

Dr. Joseph Torok, Professor of Mechanical Engineering

R·I·T

Rochester Institute of Technology

Wallace Library
Post Office Box 9887
Rochester, New York 14623-0887
716-475-2562 Fax 716-475-6490

SAMPLE statements to reproduce an RIT thesis:

PERMISSION GRANTED

Title of thesis NACA FOUR-DIGIT AIRFOIL SECTION GENERATION USING CUBIC PARAMETRIC CURVE SEGMENTS AND THE GOLDEN SECTION

I William Scarbrough hereby grant permission to the Wallace Memorial Library of the Rochester Institute of Technology to reproduce my thesis in whole or in part. Any reproduction will not be for commercial use or profit.

Date: 03JN92 Signature of Author:

PERMISSION FROM AUTHOR REQUIRED

Title of thesis ____________________

I ____________________ prefer to be contacted each time a request for reproduction is made. I can be reached at the following address:

____
____
____

PHONE: ____________

Date: ____________ Signature of Author: ____________________

PERMISSION DENIED

Title of thesis ____________________

I ____________________ hereby deny permission to the Wallace Memorial Library of the Rochester Institute of Technology to reproduce my thesis in whole or in part.

Date: ____________ Signature of Author: ____________________

Table of Contents

Appendices

ABSTRACT

A simple, elegant and modern method of geometric description of NACA Four-digit airfoil shapes is presented. Results are found to closely match conventionally described NACA Four Digit airfoil shapes. The method developed allows user flexibility, and is easily adaptable to manufacturing processes.

Acknowledgements

The author gratefully acknowledges the following people, without whose help this project might never have occurred.

Dr. Charles W. Haines, Dr. Panchapakesan Venkataraman, Dr. Mark H. Kempski, Dr. Chris Nilsen (who unknowingly led me on the path to the Bézier curve), Mr. George Komorowski and David Hathaway, all faculty and staff of the Mechanical Engineering Department at RIT.

Mr. Ralph Culliton, my supervisor at AC Rochester, for his patience and understanding during the last months of this project.

My daughters, Kelly and Megan, who never questioned my absence during the many long nights away from home.

Lastly, but most importantly, my wife Coleen, who gave me moral support and took control of all family matters during the course of my education.

This manuscript was prepared on an IBM PS/2 with WordPerfect Version 5.1; imbedded figures were generated using DrawPerfect Version 1.1. The majority of the plots were generated using the Professional Graphics Facility (PGF) on an IBM mainframe. The remainder of the plots were produced with DIS8, a plotting package available on the Digital Equipment VAX at RIT.

List of Symbols

a_i, b_i, c_i, d_i	cubic spline interpolant coefficients
$Bern(x)$	Bernstein basis polynomial
$\mathbf{B}_i$	Bézier curve defining polygon vertex
c	chordlength
E	Young's modulus of elasticity
f, g	arbitrary functions
F_n	*n*th number in Fibonacci sequence
I	moment of inertia
$J_{n,i}$	*i*th *n*th-order Bernstein basis function
m	maximum camber
$M(x)$	bending moment
p	chordwise position of maximum camber
$\mathbf{P}(\nu)$	parametric description of a point
$P_n(x)$	generic polynomial
r	leading edge radius
$S_i(x)$	cubic spline interpolant
t	thickness ratio/distribution
x	chordwise position
$x_{int(r)}$	chordwise position of intersection of leading edge radius and thickness distribution;
x_{int}	chordwise position of intersection of trailing edge angle and the line $y=t/2$
$x_{t_{max}}$	chordwise position of maximum thickness (symmetric airfoils)
y_c	ordinate of camber line
y_{int}	ordinate of intersection of leading edge radius and thickness distribution
y_l	lower surface ordinate (cambered airfoils)
y_t	ordinate of thickness distribution
y_u	upper surface ordinate (cambered airfoils)

α	correction factor
θ	angle between camber line tangent and horizontal
ν	parameter
ξ	trailing edge angle
$\rho(x)$	radius of curvature
τ	golden section number (0.618033989)
Φ^*	golden number (1.618033989)
Π_i	dimensionless parameter

List of Figures

List of Tables

1. Introduction

1.1 A Brief History of Airfoils and Aeronautical Development[§]

From the earliest of times, man has been enthralled with the idea of flight. From the myth of Icarus to the first powered flight by the Wright brothers, the human spirit has longed to mingle with the clouds.

The first manifestations of man's attempts at flight came directly from birds. Various unnamed persons throughout ancient and medieval times attached some sort of wings to their arms in an always futile attempt at flight. The Renaissance period was characterized by mechanical devices driven by arms, legs or some type of body movement. These machines are known as *ornithopters*. The surviving manuscripts of Leonardo da Vinci contain over 35,000 words and 500 sketches that deal with flight[1]. The great majority of them were of proposed ornithopters.

In the late 1700's, the Montgolfier brothers, French paper makers, constructed a balloon which trapped hot air produced by a fire contained within a wicker basket hanging below it. Man was finally airborne. Although hot air balloons actually did nothing as far as advancing the cause of powered flight, they did prove publicly that man could rise above the surface of the earth. In this respect, they fueled the notion that flight was indeed possible. Balloons were the only means of flight for over one hundred years.

The first major breakthrough in aeronautics came from a now obscure English nobleman, Sir George Cayley. In 1799, he inscribed on a silver disc the concept of a fixed wing craft which had a separate means of propulsion. On the opposite side of the disc is an illustration of the resultant forces on a wing, indicating clearly what are known as lift and drag today. Though this may seem trivial today, given man's major advances in the field of aeronautics, it was a major breakthrough at the time. He fashioned the first emulation of a wind tunnel, a long mechanical arm at the end of which he could attach primitive models of aircraft, although at the time he had no inclination that after repeated revolutions the air would begin to move with the arm. In 1804, Cayley designed, built and flew a small model glider which represented the first modern configuration aircraft in history[2]. In 1809 and 1810, Cayley authored a monumental triple paper entitled "On Aerial Navigation", published in various issues of Nicholson's *Journal of Natural Philosophy*. It was the first treatment of theoretical and applied aerodynamics ever published. In these papers, Cayley's contention was that the basic function of a flying machine is "to make a surface support a given weight by the application of power to the resistance of air." He was the first to realize that lift on a curved surface (airfoil) is due to a region of low pressure on the top of the surface. Cayley built and tested a full-size airplane in 1849. During some of these tests, a young boy rose several meters off the ground while the craft glided down an incline. This craft was a triplane, and Cayley's idea of using multiple wings was prevalent for quite some years afterward. In 1852, he published a paper, "Sir George Cayley's Governable Parachutes" which appeared in *Mechanics Magazine*. This monumental paper gave illustrations of a craft which contained nearly all necessary parts for a modern aircraft. It is unfortunate that his works drifted into obscurity shortly after his death in 1857.

[§] Much of the material for this section was obtained from Introduction to Flight, Third Edition, reference (2).

The next great pioneer of aviation was Otto Lilienthal, a German. He recognized the fact that in order to produce a machine capable of flight, one had to have a good grasp of the "feel" of an aircraft. His book, entitled *Der Vogelflug als Grundelage der Fliegekunst* (Bird Flight as the Basis of Aviation) was an early classic in aviation literature. In it, Lilienthal studied the structure of bird's wings and applied the aerodynamic information to the design of mechanical flight. In 1891, Lilienthal made his first successful flight in a glider of his own design. He made over 2500 flights in various gliders over the next five years. He experimented with slats at the end of each wing, but these efforts result ended in failure. His death in 1896 was the result of a crash.

Among the pioneers in America, the director of the Smithsonian Institute and distinguished scholar Samuel Pierpont Langley began his studies of powered flight in 1887; Langley coined the term "aerodromes" for his designs. In 1903, he attempted two highly publicized piloted flights, the last just weeks before Wilbur and Orville Wright's historic flights at Kill Devil Hills, North Carolina. In both instances, his aerodromes left their launch platform and went straight into the Potomac River. Following this public humiliation, he retired in despair.

The Wright brothers hailed from Dayton, Ohio where they ran a successful bicycle shop. Their interest in flight was largely due to the exploits of Otto Lilienthal, whose pictures in flight were distributed worldwide. Wilbur's studies of birds in flight led him to the conclusion that birds "regain their lateral balance when partly overturned by a gust of wind, by a torsion of the tips of the wings"[3]. This was one of the most important developments in aviation history; ailerons are a direct result. After much experimentation with gliders, the Wright brothers decided that a significant portion of the aerodynamic data published by Lilienthal and Langley was in error. They constructed a wind tunnel in their bicycle shop in Dayton and tested over 200 different airfoils. Additionally, they designed a force balance to accurately measure lift and drag. Their research culminated on December 17, 1903 when the Wright Flyer took to the air off the sand dunes at Kill Devil Hills. Aviation would never look back.

The Wright brothers made numerous technical advances after that first flight, but became very secretive until their machine was finally patented in 1906. After 1910, the Wright's influence declined due to legal battles between them and another aviation pioneer, Glenn Curtis. During this time, the Europeans took the forefront in aeronautical research. In France, Gustav Eiffel built a wind tunnel complex at the base of his magnificent tower; the French Army built a laboratory at Chalais-Meudon and there existed also a facility at the Institut Aerotechnique de St.-Cyr. Germany held facilities at Göttingen University, the technical colleges of Aachen and Berlin, a government operated laboratory at Adlershof as well as numerous industrial research sites[3]. Russia and Italy had advanced laboratories also. Some early work was also performed by the British Government at the National Physical Laboratory, leading to a series of airfoils used during World War I.

With the outbreak of war on the European continent, aircraft became more than just an item of curiosity; leaders saw it as an effective and efficient tool of war. In 1915, the Smithsonian Institution sponsored a resolution in the U.S. Congress to legislate a committee to explore and continue aeronautical research. The political leaders and scientific community of America realized that they had fallen behind the Europeans in this area. On March 3, 1915 the Advisory Committee for Aeronautics was formed. At the first meeting, the word "National" was added to the name. Thus the NACA was born.

One of the first acts of the NACA was to survey existing facilities in the military, private industry, and educational institutions in the area of flight research. From this survey it was concluded that a new facility was required, one that would encompass both facets of flight as it was then known: a laboratory for small scale simulation, and facilities to study full size aircraft in flight. It was decided that ground be broken at a site near Hampton, Virginia. This laboratory was to be known as Langley Field, named after Samuel Pierpont Langley.[3]

From the wind tunnels at Langley poured tremendous amounts of data. In 1917, Lt. Col. Edgar S. Gorrell and Major H. S. Martin presented NACA report no. 18, "Aerofoils and Aerofoil Structural Combinations". In this report, Gorrell and Martin reported that

> ... we are able to design aerofoils only by consideration of those forms which have been successful, by applying general rules learned by experience, and by then testing the aerofoils in a reliable wind tunnel.

For the first time, the United States was able to systematically study airfoils. The research center at Langley soon became the world leader in aeronautics. In 1933, NACA report no. 460, "The Characteristics of 78 Related Airfoil Sections from Tests in the Variable-Density Wind Tunnel" was presented by Eastman N. Jacobs, Kenneth E. Ward, and Robert M. Pinkerton. It was discovered that airfoil effects could be attributed to two geometric quantities: thickness distribution and mean line (camber). Out of this work came the NACA four-digit airfoil series. ***They are the ones researched in this paper, as they are derived from purely geometric, versus aerodynamic, parameters.*** It was found that the thickness distributions of some of the early, more efficient airfoils such as the Göttingen 398 and the Clark 'Y' were essentially similar to the NACA four-digit families once the mean lines were removed and they were reduced to the same maximum thickness.[4] It is important to note here that the NACA Five-digit series of airfoils utilizes the same thickness distribution as the Four-digit series, though camber lines for the Five-digit series rely on aerodynamic performance for their generation.

In 1949 a monumental work, *Theory of Wing Sections (Including a Summary of Airfoil Data)*, was published by Abbott and von Doenhoff. This work summarized the work done to that point by NACA and included wind tunnel test results for many of the airfoil sections then in use. It is still considered the definitive reference on wing sections. The work of Abbott, von Doenhoff and others continued at Langley until 1958, when the Russians launched Sputnik I. NACA was disbanded and absorbed into the newly formed National Aeronautics and Space Administration (NASA). Very little research went into conventional airfoil design at this time, as all available resources were utilized in the attempt to catch up to the Russians in the "space race".

With the dawn of the computer age came parallel advances in airfoil design and analysis. Boundary Layer theory, first introduced by Ludwig Prandtl in 1904, gave future designers the mathematical tools for airfoil analysis, but not until the advent of high-speed computers were researchers able to exploit this theory to the fullest. Modern day airfoils are designed using a process known as *conformal mapping*, where a known two-dimensional shape (in this case an airfoil section) is algebraically transformed into a simple shape (an off-center circle) in the complex plane and a simple flow is then analyzed around it. Results of this analysis are then mapped back into the real plane. While this method yields results which compare quite favorably with wind tunnel testing, the ability to slightly alter the shape with the intent of optimizing aerodynamic performance can currently only be accomplished between successive iterations. The speed of new computers and efficiency of new algorithms are such that one should be able to analyze fluid flow in the real plane, "tweaking" the airfoil shape along the way to produce the desired results.

1.2 Direction of Research

Advances in both mathematics and the ability to process calculations quickly and accurately have radically changed technology. These advances, coupled with the rapidly growing field of computer graphics, have revolutionized approaches to design. With these advances, it seems logical that airfoil design should proceed along the same lines. In the case of the NACA four-digit airfoils, it has not. As previously mentioned, the definitive reference on this important family of airfoils was first published in 1949[5]. In order to facilitate geometric reproduction of these shapes as a prelude to Computational Fluid Dynamic (CFD) analysis, it was desirable to determine a method whereby airfoils could be emulated with a minimum of both geometric parameters and arithmetic operations, while control over their shape and transformation are kept relatively simple. The importance of redescribing airfoils is to be able to effectively attain local control of the shape.

In this regard, it was first desired to determine a method whereby the aesthetically pleasing shape of the airfoil section could be emulated, then modified. Since the concepts of flight and airfoil sections were first influenced by nature, it seemed logical that nature would be an appropriate starting point in the attempt to generate these shapes. This seeming "regression" of technology -getting back to the basics - was fundamental in this research. This return to nature begins with the Golden Section.

1.3 The Golden Section

Also known as the Golden Ratio or Golden Number, this ratio and its properties pervade nature and has intrigued man through the ages. Its existence has been known since ancient times, and many cultures have attempted to incorporate this proportion into aesthetically pleasing shapes. Throughout history men have attempted to tie this number into everything from architecture to the stock market[6], and this work will attempt to make a connection with geometric forms originally derived by other means. While a thorough treatment would encompass many volumes, a minor overview of this fascinating relationship and numerous examples are included for reference in Appendix A.

2. NACA Four-Digit Airfoils

2.1 Symmetric Airfoils

2.1.1 Nomenclature

As previously mentioned, the NACA four-digit families can be described in terms of geometric parameters. The symmetric airfoils are the simplest case; they will be discussed first. Figure 2.1. provides an illustration of required geometric parameters common to all NACA four-digit symmetric airfoil sections.

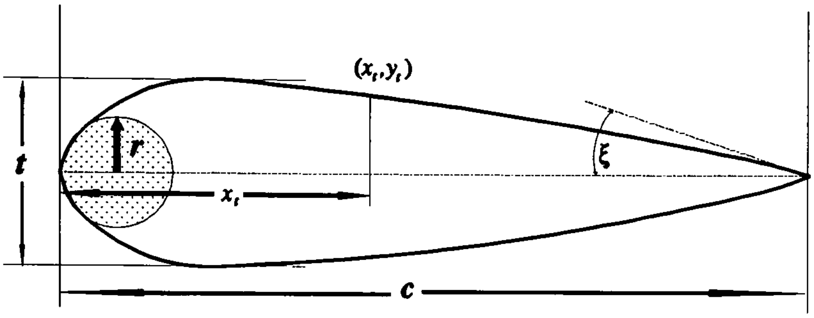


Figure 2.1. Typical Symmetric Airfoil Section

Given parameters are defined as:

c	chordlength
t	maximum thickness
r	leading edge radius
ξ	trailing edge angle

2.1.2 Thickness distribution

The NACA investigations previously mentioned (for the four-digit families) led to a unified method for defining the thickness distribution for these symmetric airfoil sections which was dependent only on the maximum thickness, t. The best-fit curve to define these experimentally derived airfoils is

$$\pm y_t = \frac{t}{.2}\left(.2969\sqrt{x} - .126x - .3516x^2 + .2843x^3 - .1015x^4 \right) \qquad [2.1]$$

where y_t is the ordinate (y-coordinate) at any chordwise position x. The chordwise position can take any value from $x=0$ to $x=1$. Thus x and y are not actual numerical values, but ratios of chordwise position and thickness to chordlength. Established convention dictates that the use of x,t, or y (or in the case of cambered airfoils x, y_t, m, p, t, y_c, x_u, x_l, y_u and y_l) are assumed to be decimal of chordlength. The use of this convention allows for ease of notation and will prevent "notational clutter", aiding the reader.

In order to determine the position on the chord where the airfoil attains its maximum thickness, the root of the derivative of [2.1] , given by

$$\pm y_t' = \frac{t}{.2}\left(\frac{.14845}{\sqrt{x}} - .126 - .7032x + .8529x^2 - .406x^3 \right) \qquad [2.2]$$

must be found.

The resultant value, solved using the Newton-Raphson technique, is $x_{t_{max}} = 0.299827878c$. For practical purposes, this value is assumed to be $0.3c$ and is independent of the value of t.

2.1.3 Leading Edge Radius

The leading edge radius, r, varies with the square of t and is given by

$$r = 1.1019t^2 \qquad [2.3]$$

2.1.4 Trailing Edge Angle

Trailing edge angle, ξ is determined by inserting a value of $x=1$ in equation [2.2]. At $x=1$,

$$\tan \xi = y_t'(1) = -1.16925t \qquad [2.4]$$

Prior to the advent of computers, it was standard practice to look up a table of coordinates for these airfoils. Because [2.1] is linearly dependent on t, all one needed to do to reproduce a four-digit symmetric airfoil of arbitrary thickness was to scale between ordinates of a given thickness airfoil and the thickness of the desired airfoil. Table 2.1 is an example of published information[5] from which a new airfoil could be constructed.

Table 2.1 Coordinates for 12 Percent Thick NACA Four-Digit Symmetric Airfoil (NACA0012)

x, percent chord	y, percent chord	x, percent chord	y, percent chord
0.5	.....	30.	6.002
1.25	1.894	40.	5.803
2.5	2.615	50.	5.294
5.0	3.555	60.	4.563
7.5	4.200	70.	3.664
10.	4.683	80.	2.623
15.	5.345	90.	1.448
20.	5.737	95.	0.807
25.	5.941	100.	0.126

2.2 Cambered Airfoils

Cambered (asymmetric) airfoil sections are more complex in nature, requiring more geometric parameters to define. They are assumed to be a superposition of a symmetric thickness distribution over a curved line known as the camber, or mean, line. Figure 2.2. illustrates this scheme.

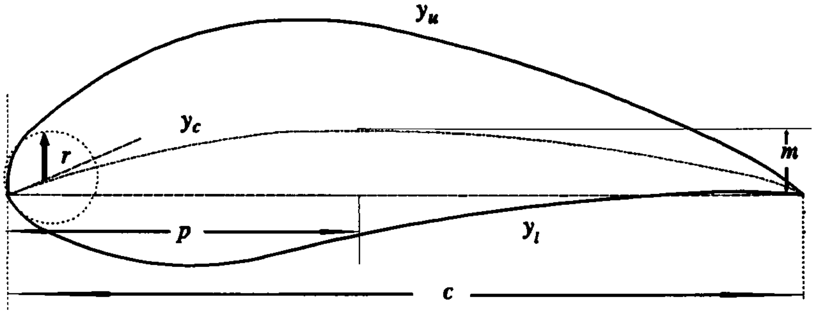


Figure 2.2. Typical Cambered Airfoil Section

2.2.1 Nomenclature

New parameters, in addition to those listed for the symmetric airfoil, are

y_u	upper surface ordinate
y_l	lower surface ordinate
y_c	camber line
m	maximum camber in percent of chord
p	chordwise position of maximum camber

2.2.2 Mean Line

The mean line has been defined as two parabolic arcs which are tangent at the chordwise position of maximum camber. For NACA four-digit airfoils, these arcs are given by

$$y_c = \frac{m}{p^2}\,(2px - x^2)\ , \qquad 0 \le x \le p$$

$$y_c = \frac{m}{(1-p)^2}\,[(1-2p) + 2px - x^2]\ , \qquad p \le x \le c \qquad [2.5]$$

The slope of the camber line at any point x is an important quantity in generating airfoil coordinates. For an arbitrary x $(0 \le x \le 1)$ the tangent is determined by

$$y_c{}' = \tan\theta = \frac{2m}{p^2}\,(p - x)\ , \qquad 0 \le x \le p$$

$$y_c{}' = \tan\theta = \frac{2m}{(1-p)^2}(p - x)\ , \qquad p \le x \le c \qquad [2.6]$$

2.2.3 Method of Combining Thickness Distribution and Mean Line

Generation of cambered airfoils is accomplished in the following manner. The slope of the camber line at any arbitrary position x ($0 \leq x \leq c$) is equal to $\tan\theta$, as shown in Figure 2.3.

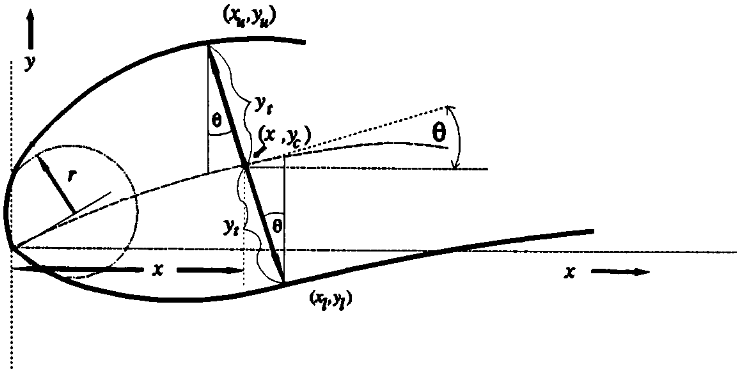


Figure 2.3. Detail of Cambered Airfoil Generation

Mathematically, thickness distributions are combined with the camber line by the following method. The upper surface coordinates are computed by

$$\begin{aligned} x_u &= x - y_t \sin\theta \\ y_u &= y_c + y_t \cos\theta \end{aligned} \qquad [2.7a]$$

The corresponding expressions for the lower surface coordinates are determined by

$$\begin{aligned} x_l &= x + y_t \sin\theta \\ y_l &= y_c - y_t \cos\theta \end{aligned} \qquad [2.7b]$$

In order to generate a set of coordinates for a four-digit airfoil, a table similar to that illustrated in Table 2.2 must be constructed.

Table 2.2 Coordinate Generation for NACA2412 Airfoil

x	y_t	y_c	$\tan\theta$	$\sin\theta$	$\cos\theta$	$y_t \sin\theta$	$y_t \cos\theta$	x_U	y_U	x_L	y_L
0	0	0	...	...	...	0	0	0	0	0	0
0.005	0.01221	0.00050	0.09875	0.09827	0.99516	0.00120	0.00122	0.00380	0.00172	0.00620	-0.0007
0.05	0.03555	0.00469	0.08750	0.08717	0.99619	0.00310	0.03541	0.04690	0.04010	0.05310	-0.0307
0.25	0.05941	0.01719	0.03750	0.03747	0.99930	0.00227	0.05937	0.24773	0.07656	0.25227	-0.0422
0.50	0.05294	0.00588	-0.2381	-0.2316	0.97281	-0.0123	0.05150	0.51230	0.05738	0.48770	-0.0456
0.75	0.03160	.003990	-0.8333	-0.6402	0.76822	-0.0202	0.02428	0.77020	0.02827	0.72980	-0.0203
1.00	0	0	...	...	...	0	0	1.00000	0	1.00000	0

It is easily seen that construction of a table similar to that shown on the previous page could be very time consuming, given that the preferred method of calculation of the day was the slide rule. Even with the new technology, it is estimated that airfoil coordinate generation can consume up to sixty percent of total processing time.

2.3 NACA Designation Scheme

The four-digit airfoil section family received its name from the fact that any airfoil in the series, whether symmetric or cambered could be described using four digits. The designation rules are as follows: for an airfoil designated NACA*wxyz*, the following rules apply:

w	denotes maximum camber in percent of chord
x	denotes chordwise position of maximum camber in tenths of chord
yz	denotes maximum thickness in percent of chord

Thus a NACA2412 is a twelve percent thick airfoil with two percent maximum camber, located at .4*c*; a NACA0018 is an eighteen percent thick symmetric airfoil.

2.4 Method of Manual Layout

The first item to be generated is the leading edge radius. On a cambered airfoil, the center of the radius is assumed to lie tangent to the mean-line at a chordwise position $x = 0.005c$.
To correlate data as generated in Table 2.2 to a physical medium, a process known as *lofting* is used. Given specified data points, a long, narrow plastic or wooden strip, or *spline*, is shaped by lead weights called *ducks*. By varying the number and position of the ducks, the loftsman's spline is made to pass through the given data points such that the curve appears "smooth, fair or pleasing to the eye"[7]. In the case of the airfoil, the loftsman's spline may be clamped at either end in order to specify a slope. Figure 2.4. shows details of this process as applied to airfoil layout.

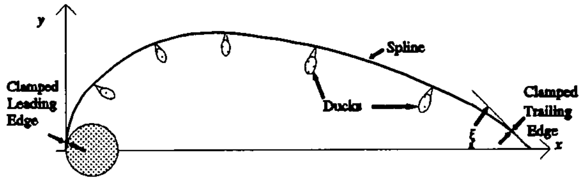


Figure 2.4. Illustration of Airfoil Layout (Upper Surface) Using Loftsman's Spline and Ducks

Considering the spline as a thin elastic beam, the shape of the spline, corresponding to the deflection of the beam y, is obtained from the bending moment $M(x)$ along the length of the beam. From Euler's equation[8],

$$M(x) = \frac{EI}{\rho(x)} \qquad [2.8]$$

Where:

E is Young's Modulus, determined by material properties of the beam
I is the moment of inertia, determined by the cross-sectional shape of the beam
$\rho(x)$ is the radius of curvature at any point x along the beam

For small deflections ($y' \ll 1$), the radius of curvature is closely approximated by

$$\frac{1}{\rho(x)} = \frac{y''}{[1 + (y')^2]^{3/2}} \approx y'' \qquad [2.9]$$

Thus, according to Euler's equation,

$$y'' = \frac{M(x)}{EI} \qquad [2.10]$$

Assuming the ducks act as simple supports and the spline is of uniform material and cross-section (E and I are constant over the entire length of the spline), the bending moment is known to vary linearly between supports[8]. Making the substitution $M(x) = Ax + B$, Euler's equation becomes

$$y'' = \frac{Ax + B}{EI} \qquad [2.11]$$

Integration twice yields

$$y = Ax^3 + Bx^2 + Cx + D \qquad [2.12]$$

Where the flexural modulus (EI) has been absorbed into the coefficients A,B,C and D. Thus between any two supports (data points), the geometric description of the shape of the loftsman's spline is a cubic real polynomial. This is used as a starting point for further research.

3. Approximation Techniques

3.1 Polynomial Approximation

3.1.1 Cubic Spline Interpolation

As previously mentioned, the loftman's spline can be described mathematically as a piecewise cubic polynomial. Given $n+1$ data points, (x_i,y_i) $\{i=0,1,\ldots,n\}$, the (n-1) cubic spline segments $S_i(x)$ that make up the set of spline interpolants S for a function f is a function that must satisfy the following conditions[9]:

a) S is a cubic polynomial, denoted S_i, on the sub-interval $[x_i,x_{i+1}]$ for each $i=0,1,\ldots,n-1$;
b) $S_i(x_i)=f(x_i)$ for each $i=0,1,\ldots,n$;
c) $S_{i+1}(x_{i+1})=S_i(x_{i+1})$ for each $i=0,1,\ldots,n-2$;
d) $S'_{i+1}(x_{i+1})=S'_i(x_{i+1})$ for each $i=0,1,\ldots,n-2$;
e) $S''_{i+1}(x_{i+1})=S''_i(x_{i+1})$ for each $i=0,1,\ldots,n-2$;
f) one of the following sets of boundary conditions is satisfied:

i) $S''(x_0)=S''(x_n)=0$	(Free boundary)
ii) $S'(x_0)=f'(x_0)$ and $S'(x_n)=f'(x_n)$	(Clamped boundary)

Mixed boundary conditions are also possible, but will not be considered. A thorough treatment of the theory of cubic splines and the mathematical derivations of both types is contained in Appendix B.

The $n+1$ data points are used to generate n cubic spline segments of the form

$$S_i(x) = a_i(x - x_i)^3 + b_i(x - x_i)^2 + c_i(x - x_i) + d_i \qquad [3.1]$$

One of the disadvantages of natural cubic splines is that end conditions are assumed. If slopes at the ends are specified, more useful information is used in generating the spline coefficients.

3.1.2 Discrete Least-Squares Approximations

The concept behind least-squares approximation theory is one of minimizing the square of the error involved in fitting a polynomial to a data set. For the problem attempted in this research, a linear fit to data corresponding to an airfoil would be ridiculous, and will not be considered. Higher order (rational) polynomials, however will be investigated, and as such will be discussed here[9].

The general objective boils down to approximating a data set $\{(x_i, y_i) \mid i=0,1,\ldots,M\}$, with a polynomial, $P_n(x)$, given by

$$P_n(x) = \sum_{k=0}^{n} a_k x^k \qquad\qquad n < M$$

which requires finding the optimum polynomial coefficients, a_k, to minimize the least-squares error

$$E = \sum_{i=0}^{M} (y_i - P(x_i))^2$$

$$= \sum_{i=0}^{M} y_i^{\,2} - 2\sum_{i=0}^{M} P(x_i) y_i + \sum_{i=0}^{M} (P(x_i))^2$$

$$= \sum_{i=0}^{M} y_i^{\,2} - 2\sum_{i=0}^{M} \left[\sum_{j=0}^{n} a_j x_i^{\,j} \right] y_i + \sum_{i=0}^{M} \left[\sum_{j=0}^{n} a_j x j \right]^2$$

$$= \sum_{i=0}^{M} y_i^{\,2} - 2\sum_{j=0}^{n} a_j \left[\sum_{i=0}^{M} y_i x_i^{\,j} \right] + \sum_{j=0}^{n} \sum_{k=0}^{n} a_j a_k \left[\sum_{i=0}^{M} x_i^{\,j+k} \right]$$

For E to be minimized, it is necessary that $\partial E / \partial a_j = 0$ for each $j=0,1,\ldots,n$. Thus for each j,

$$0 = \frac{\partial E}{\partial a_j} = -2\sum_{i=0}^{M} y_i x_i^j + 2\sum_{k=0}^{n} a_k \sum_{i=0}^{M} x_i^{j+k} \tag{3.2}$$

This yields $(n+1)$ equations in $(n+1)$ unknowns, called the *normal equations*,

$$\sum_{k=0}^{n} a_k \sum_{i=0}^{M} x_i^{j+k} = \sum_{i=0}^{M} y_i x_i^j \,, \qquad\qquad j = 0,1,\ldots,n \tag{3.3}$$

The solution to this set of equations is unique provided that the x_i, for $i=0,1,\ldots,M$ are distinct. The scope of this research entailed analyzing least-squares polynomials of orders two and three, as it was felt that any higher-order polynomials would not add any value in reaching the final objective; there is also a serious drawback prohibiting the use of these polynomials, which will be explained in section 3.2.1.

3.2 Parametric Curves

In two dimensions, a curve is commonly represented as the *explicit* relation

$$y = F(x) \tag{3.4}$$

For a single value of x, a distinct value of y is obtained. Equation [2.1] is the thickness distribution for a NACA four-digit airfoil section in explicit form. The explicit form cannot represent a multi-valued curve that loops over itself or a closed curve[11]. An alternative in this situation is to utilize the *implicit* form

$$G(x,y) = 0 \tag{3.5}$$

Finding a point on the curve $G(x,y)$ may, however, require determining the root of an algebraic or transcendental equation. Both the explicit and implicit forms of curve representation are axis-dependent. Thus the choice of coordinate axes affects their ease of use. For example, if, in the chosen coordinate system, an infinite slope is required as a boundary condition, difficulties arise. This infinite slope cannot, therefore, be directly used as a boundary condition. Either the coordinate system orientation must be changed (coordinate transformation), or the infinite slope boundary condition must be represented by a very large (but finite) positive or negative value. Furthermore, when points on an axis-dependent non-parametric curve are computed at equal increments in either x or y, they are not evenly distributed along the length of the curve. This unequal distribution of points affects the graphical quality of the curve[11]. An alternative to this approach is the use of parametric curves. These geometric representations use an arbitrary parameter ν to specify both x and y coordinates, such that

$$\begin{aligned} x &= f(\nu) \\ y &= g(\nu) \end{aligned} \tag{3.6}$$

There are several advantages to the parametric form over the explicit form. Each parametric value, ν, defines a unique pair of coordinates, x and y, for a point on the curve. A bounded segment on the curve can be obtained by limiting the values of ν to lie within a specified range. It is usually possible to express parametric curves as a matrix, a form that will be useful in computer implementation of coordinates for these curves. A point P thus described can be put into matrix form as

$$\mathbf{P}(\nu) = \begin{Bmatrix} x \\ y \end{Bmatrix} = \begin{Bmatrix} f(\nu) \\ g(\nu) \end{Bmatrix}$$

The derivative of the curve for any value of the parameter, ν, is given by

$$\mathbf{P}'(\nu) = \begin{Bmatrix} x'(\nu) \\ y'(\nu) \end{Bmatrix}$$

where the $'$ denotes differentiation with respect to ν.

According to the chain rule, the slope of the curve, dy/dx, is given by

$$\frac{dy}{dx} = \frac{dy/d\nu}{dx/d\nu} = \frac{y'(\nu)}{x'(\nu)} \tag{3.7}$$

Note that when $x'(v)=0$, the slope of the curve is infinite. Therefore, an infinite slope can be easily specified by making one component of the tangent vector equal to zero. In this way, computational difficulties arising from specifying an infinite slope as a boundary condition are easily overcome.

3.2.1 Bézier Curves

The cubic spline interpolant curves described in section 3.1 are constrained by the fact that the curve is required to pass through existing data points. In order to efficiently reproduce a NACA four-digit airfoil, a minimum number of function evaluations of equation [2.1] are desired (one evaluation to determine the ordinate for a given chordwise position). The Bézier curve, introduced by French mathematician Pierre Bézier, is a parametric curve which was developed from both functional and aesthetic concerns. Although this *ab initio* design tool was initially derived through geometric considerations, it has been shown that the result of the curve is a special case of the Bernstein basis, or polynomial approximation function[7]. Given a function f defined on [0,1], the Bernstein polynomial of degree n for f is defined[9] as

$$Bern(x) = \sum_{k=0}^{n} \begin{bmatrix} n \\ k \end{bmatrix} f \begin{bmatrix} \frac{k}{n} \end{bmatrix} x^k (1 - x)^{n-k} \qquad [3.18]$$

In the case of the Bézier curve, $f(x) \equiv 1$.

A Bézier curve is determined by a defining polygon as shown in Figure 3.1, below.

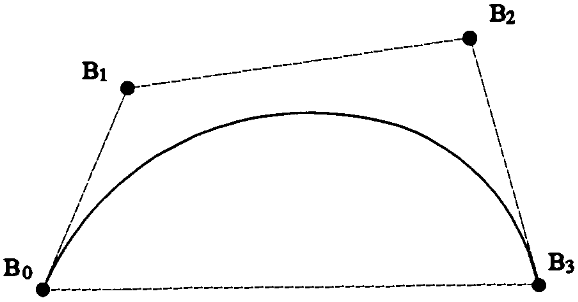


Figure 3.1 Bézier Curve and Defining Polygon

Because the Bézier curve can be derived from the Bernstein basis, several properties of these curves are known[7]. Some of the more important are:

- The basis functions are real.
- The degree of the polynomial defining the curve segment is one less than the number of defining polygon points.
- The curve generally follows the shape of the defining polygon.
- The first and last points on the curve are coincident with the first and last points of the defining polygon.

- The tangent vectors at the ends of the curve have the same direction as the first and last polygon spans, respectively.

- The curve is contained within the convex hull of the defining polygon, i.e., within the largest convex polygon obtainable with the defining polygon vertices. In Figure 3.1, the convex hull is shown by the dashed lines.

- The curve exhibits the variation diminishing property: the curve does not oscillate about any straight line more often than the polygon itself.

- The curve is invariant under an affine (linear) transformation.

Mathematically, a parametric Bézier curve is defined by

$$\mathbf{P}(\nu) = \sum_{i=0}^{n} \mathbf{B}_i \, J_{n,i}(\nu) \qquad 0 \leq \nu \leq 1 \qquad [3.9]$$

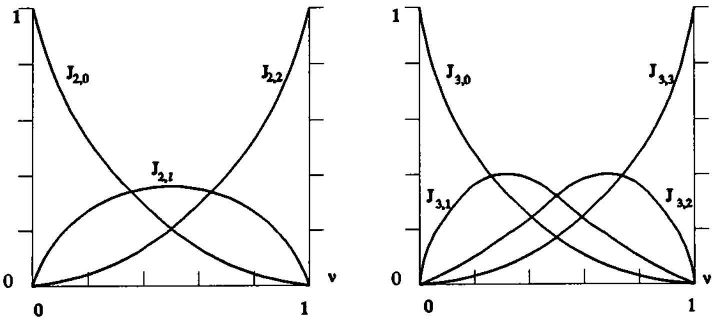
where $\mathbf{B}_i$ denotes the (2x1) matrix for the ith defining polygon vertex and the Bézier, or Bernstein basis[¶] is

$$J_{n,i}(\nu) = \begin{bmatrix} n \\ i \end{bmatrix} \nu^i (1 - \nu)^{n-i} \qquad [3.10]$$

with

$$\begin{bmatrix} n \\ i \end{bmatrix} = \frac{n!}{i!(n-i)!}$$

$J_{n,i}(\nu)$ is the ith nth-order Bernstein basis function. In this notation, n is the degree of the defining Bernstein basis function and also the degree of the Bézier curve. It is also one less than the number of vertices in the defining polygon. Figure 3.2, on the following page, illustrates the Bernstein basis functions for (a) n=2, (b) n=3.



(a) (b)

Figure 3.2 Bernstein Basis Functions

[¶] The terminology $J_{n,i}$ is consistent with the source of this material, Mathematical Elements for Computer Graphics, reference (7), and should not be confused with similar terminology denoting Bessel functions.

Another useful property of Bézier curves is the ability to specify the slope of the curve at a predetermined point. This is accomplished by utilizing two curves and two defining polygons, with the two polygons having an aggregate three consecutive collinear vertices, ABC, as illustrated in Figure 3.3 below.

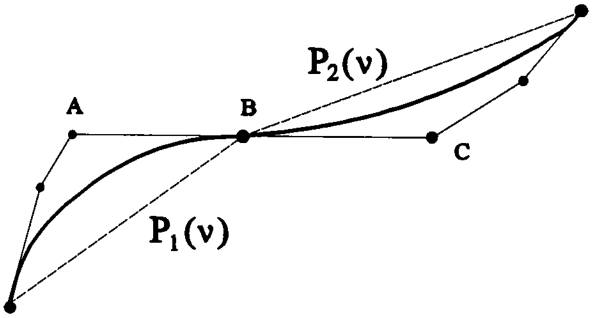


Figure 3.3 Method of Combining Two Bézier Curves

3.2.2 Matrix Formulation for Bézier Curve

The equation for a Bézier curve can be expressed in matrix form as

$$\mathbf{P}(\nu) = [F]\,[G]$$

where

$$[F] = \begin{bmatrix} J_{n,0} & J_{n,1} & \cdots & J_{n,n} \end{bmatrix} \quad \text{and} \quad [G] = \begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \vdots \\ \mathbf{B}_n^{\mathrm{T}} \end{bmatrix}$$

Of particular interest are Bézier curves of order n=2 and n=3. Recall that previously for n=2, the resulting curve is parabolic in nature, and the defining polygon is described by three points. Thus

$$\mathbf{P}(\nu) = \begin{bmatrix} (1-\nu)^2 & 2\nu(1-\nu) & \nu^2 \end{bmatrix} \begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \end{bmatrix}$$

Expanding the preceding into powers of the parameter ν, the following is obtained

$$\mathbf{P}(\nu) = \begin{bmatrix} \nu^2 & \nu & 1 \end{bmatrix} \begin{bmatrix} 1 & -2 & 1 \\ -2 & 2 & 0 \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \end{bmatrix}$$

Similarly, for $n=3$ (a cubic curve with four defining polygon vertices),

$$\mathbf{P}(\nu) = \begin{bmatrix} \nu^3 & \nu^2 & \nu & 1 \end{bmatrix} \begin{bmatrix} -1 & 3 & -3 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & 3 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \\ \mathbf{B}_3^{\mathrm{T}} \end{bmatrix}$$

3.2.3 Derivatives of Bézier Curve

For any point on the Bézier curve, the first derivative $\mathbf{P}'(\nu)$, is computed by

$$\mathbf{P}'(\nu) = \sum_{i=0}^{n} \mathbf{B}_i J'_{n,i}$$

The second derivative, $\mathbf{P}''(\nu)$ is given by

$$\mathbf{P}''(\nu) = \sum_{i=0}^{n} \mathbf{B}_i J''_{n,i}$$

By formal differentiation,

$$\begin{aligned} J'_{n,i}(\nu) &= \binom{n}{i} \left\{ i\,\nu^{i-1}(1-\nu)^{n-i} - (n-i)\,\nu^i(1-\nu)^{n-i-1} \right\} \\ &= \binom{n}{i} \nu^i(1-\nu)^{n-i} \left\{ \frac{i}{\nu} - \frac{(n-i)}{(1-\nu)} \right\} \\ &= \frac{(i-n\nu)}{\nu(1-\nu)} J_{n,i}(\nu) \end{aligned} \qquad [3.11]$$

and

$$J''_{n,i}(\nu) = \left\{ \frac{(i-n\nu)^2 - n\nu^2 - i(1-2\nu)}{\nu^2(1-\nu)^2} \right\} J_{n,i}(\nu) \qquad [3.12]$$

Numerical evaluation of equations [3.11] and [3.12] at $\nu=0$ and $\nu=1$ creates difficulties. Thus the rth derivative at $\nu=0$ is given by

$$\mathbf{P}^{r}(0) = \frac{n!}{(n-r)!} \sum_{i=0}^{r} (-1)^{r-i} \begin{bmatrix} r \\ i \end{bmatrix} \mathbf{B}_i \qquad [3.13]$$

The derivative at $\nu=1$ is

$$\mathbf{P}^{r}(1) = \frac{n!}{(n-r)!} \sum_{i=0}^{r} (-1)^{i} \begin{bmatrix} r \\ i \end{bmatrix} \mathbf{B}_{n-i} \qquad [3.14]$$

First derivatives at both ends of the Bézier curve are therefore

$$\begin{aligned} \mathbf{P}'(0) &= n(\mathbf{B}_1 - \mathbf{B}_0) \\ \mathbf{P}'(1) &= n(\mathbf{B}_n - \mathbf{B}_{n-1}) \end{aligned} \qquad [3.15]$$

Thus the tangent vector at each end of the parametric curve segment has the same direction as its respective polygon span. (Recall that each $\mathbf{B}_i$ is a (2x1) matrix in itself).

Second derivatives at the ends are given as

$$\begin{aligned} \mathbf{P}''(0) &= n(n-1)(\mathbf{B}_0 - 2\mathbf{B}_1 + \mathbf{B}_2) \\ \mathbf{P}''(1) &= n(n-1)(\mathbf{B}_n - 2\mathbf{B}_{n-1} + \mathbf{B}_{n-2}) \end{aligned} \qquad [3.16]$$

For the cubic Bézier curves used in this analysis the first and second derivatives can be expressed in matrix form as

$$\mathbf{P}'(\nu) = \begin{bmatrix} \nu^2 & \nu & 1 \end{bmatrix} \begin{bmatrix} -3 & 9 & -9 & 3 \\ 6 & -12 & 6 & 0 \\ -3 & 3 & 0 & 0 \end{bmatrix} \begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \\ \mathbf{B}_3^{\mathrm{T}} \end{bmatrix}$$

and

$$\mathbf{P}''(\nu) = \begin{bmatrix} \nu & 1 \end{bmatrix} \begin{bmatrix} -6 & 18 & -18 & 6 \\ 6 & -12 & 6 & 0 \end{bmatrix} \begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \\ \mathbf{B}_3^{\mathrm{T}} \end{bmatrix}$$

This method alleviates difficulties in computing slope and curvature at endpoints and will simplify coding to determine derivatives at the endpoints of the curves.

4. Results of Analysis

The schemes presented in the previous sections were implemented in the attempt to discover an efficient method of reproducing the NACA four-digit airfoils. FORTRAN computer programs for all the routines involved in the analysis are included as Appendix F, in order of appearance in this section. Because symmetric airfoil sections are computationally less complex than their cambered counterparts, a decision was made not to attempt to emulate cambered airfoils with methods that proved unsuitable in the symmetric case. In the analysis that follows, symmetric airfoil sections are discussed and a viable method for reproducing them is finally established.

4.1 Symmetric Airfoils

4.1.1 Cubic Spline Interpolation

As previously mentioned, cubic spline interpolants have some distinct disadvantages in emulating the shape of the airfoils in question. Among these are:

- The curve must pass through the specified data points. Logically, one may infer that the interpolant need not necessarily pass through points on the desired curve which are not specified.

- A predefined slope at some intermediate point on the desired curve cannot be specified.

- It is possible for the cubic spline interpolant between two consecutive data points to possess two points of inflection[12]. In effect, the cubic spline interpolant will vary along the length of the desired shape, with error between the two curves becoming less as the slope of the desired curve decreases. This property shall be referred to as the *oscillation phenomenon.* See Figure 4.1 on the following page for an illustration.

- All the symmetric airfoils discussed possess the property of having an infinite leading edge slope. (This is evident from equation [2.2] with $x=0$).

4.1.1.1 Natural Cubic Splines

The last disadvantage listed above proved to be the most limiting. From this property, a cubic spline segment to fit the leading edge portion of the curve must possess a first-order variable coefficient of infinity. This obstacle alone eliminates natural splines from contention in the search for a more computationally efficient method of airfoil emulation.

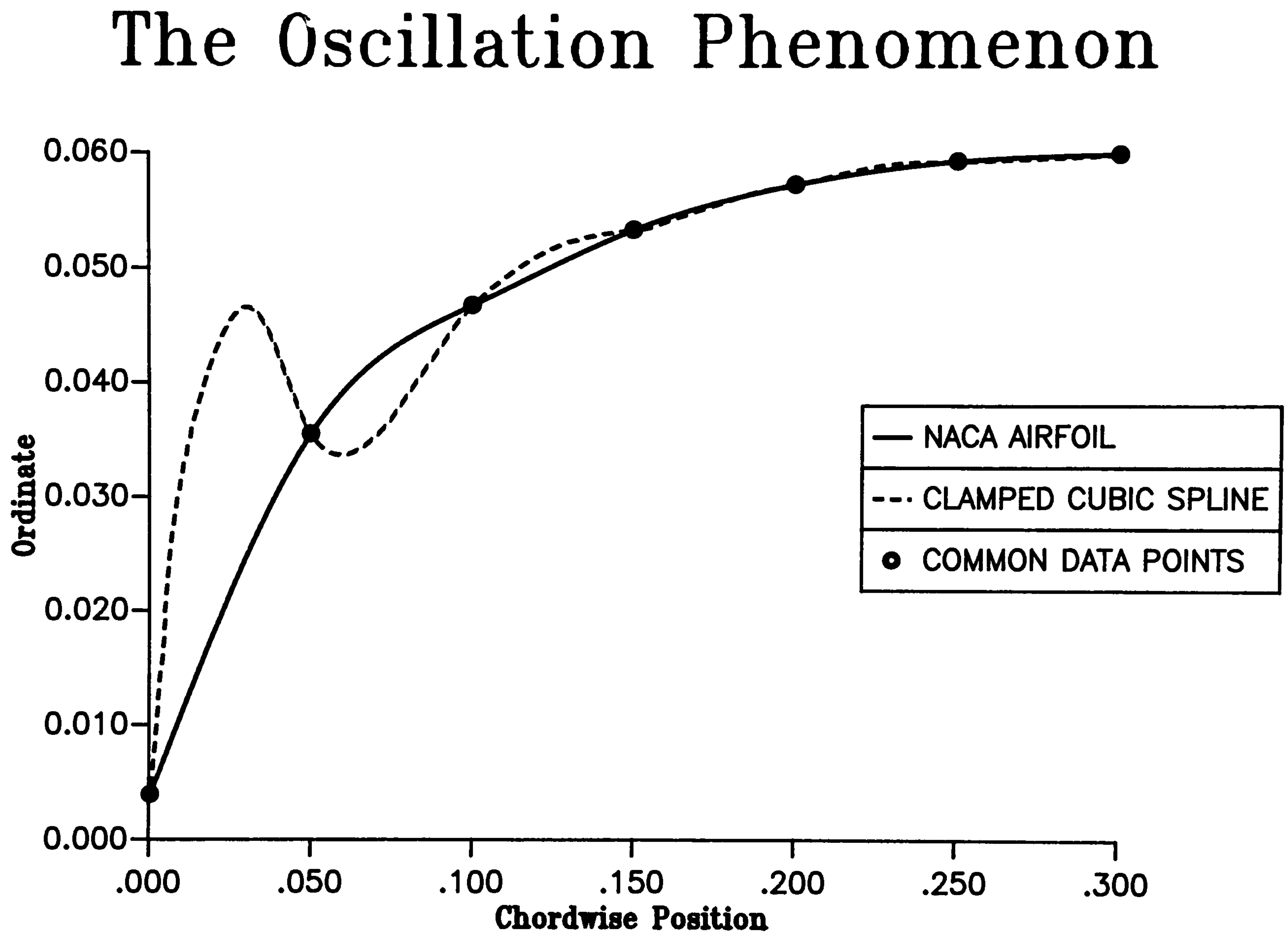


Figure 4.1 - The Oscillation Phenomenon

4.1.1.2 Clamped Cubic Splines

In order to bypass the infinite leading edge slope difficulty, recall from section 2.2.2 that equation [2.1] describes a circle for the initial portion of its path. Thus it seems logical that finding the point where the prescribed curve departs from the circle defining the leading edge radius is a natural first step in attempting to overcome the problem of infinite slope at the leading edge, as illustrated in Figure 4.2 below.

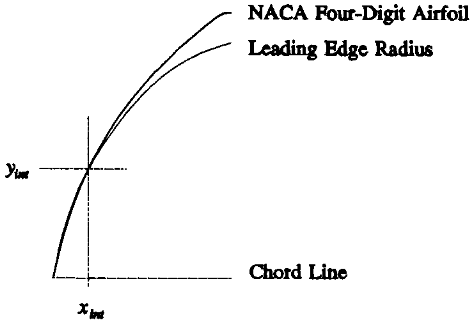


Figure 4.2 Detail of Intersection of NACA Airfoil and Leading Edge Radius

Knowing the leading edge radius of the airfoil from equation [2.3], it is a simple matter to determine the formula for a circle having this radius in Cartesian coordinates. Defining the origin as the leading edge,

$$(x - r)^2 + y^2 = r^2$$

or

$$y = \pm\sqrt{x(2r - x)} = \pm\sqrt{x(2.2038\, t^2 - x)} \qquad [4.1]$$

The positive and negative values of [4.1] correspond to the upper and lower surfaces, respectively. For the upper surface, the point of intersection of the leading edge radius and NACA thickness distribution is obtained by solving

$$0 = 5t(.2969\sqrt{x} - .126x - .3516x^2 + .2843x^3 - .1015x^4) - \sqrt{x(2.2038t^2 - x)} \qquad [4.2]$$

Note that [4.2] is dependent upon the thickness distribution of the airfoil section, t. It is obvious from this equation that a root lies at $x=0$, yet this root is meaningless to the task at hand. The FORTRAN program NEWTON.FOR was implemented in order to attempt find the root to [4.2] for numerous values of t. Newton-Raphson did not converge to a solution, although the reason for this was not obvious until the true root was found (this equation possesses a local minimum between $x=0$ and the desired root).

It should be noted here that conventionally this particular point is taken to be the airfoil coordinate at .0005c. The ordinate values at $x = .0005c$ are .003945479 for the defined shape of the NACA0012 airfoil, and .003951881 for the ordinate of the circle which describes the leading edge radius of the same airfoil. This represents a relative error of .16225 percent, acceptable at this point, but when the two slopes are computed, the relative error grows to nearly half a percent. This may seem insignificant, however experience shows that a very minor deviation between the true curve and the leading edge radius is greatly amplified by the cubic spline interpolant.

The bisection method, guaranteed to provide meaningful results without regard to computational efficiency, was then employed. A plot of chordwise position of leading edge radius and NACA four-digit airfoil upper surface intersection points versus thickness ratio is given as Figure 4.3 for $.02 \leq t \leq .40$ on the following page. Additionally, tangents to the leading edge radius at these points, given by

$$y'_{radius} = \frac{(1.1019\,t^2 - x_{int(r)})\sqrt{x_{int(r)}(2.2038\,t^2 - x_{int(r)})}}{x_{int(r)}(2.2038\,t^2 - x_{int(r)})} \qquad [4.3]$$

as a function of thickness ratio were also tabulated. Figure 4.4, page 29, was generated using these results. This data is compiled in the files S_INT.DAT and S_SLOPE.DAT, located in Appendix G.

Least-squares curve fitting techniques were used to determine if any functional relationship existed between (a) thickness ratio and point of intersection, and (b) thickness ratio and the slope at the point determined from (a). For the point of intersection, (x_{int}, y_{int}), the least-squares approximating function is given by

$$\begin{aligned} x_{int(r)} &= .00488874 - .190253\,t + 2.22379\,t^2 - 9.96043\,t^3 + 18.657\,t^4 \\ y_{int(r)} &= \sqrt{x_{int(r)}(2.2038\,t^2 - x_{int(r)})} \end{aligned} \qquad [4.4]$$

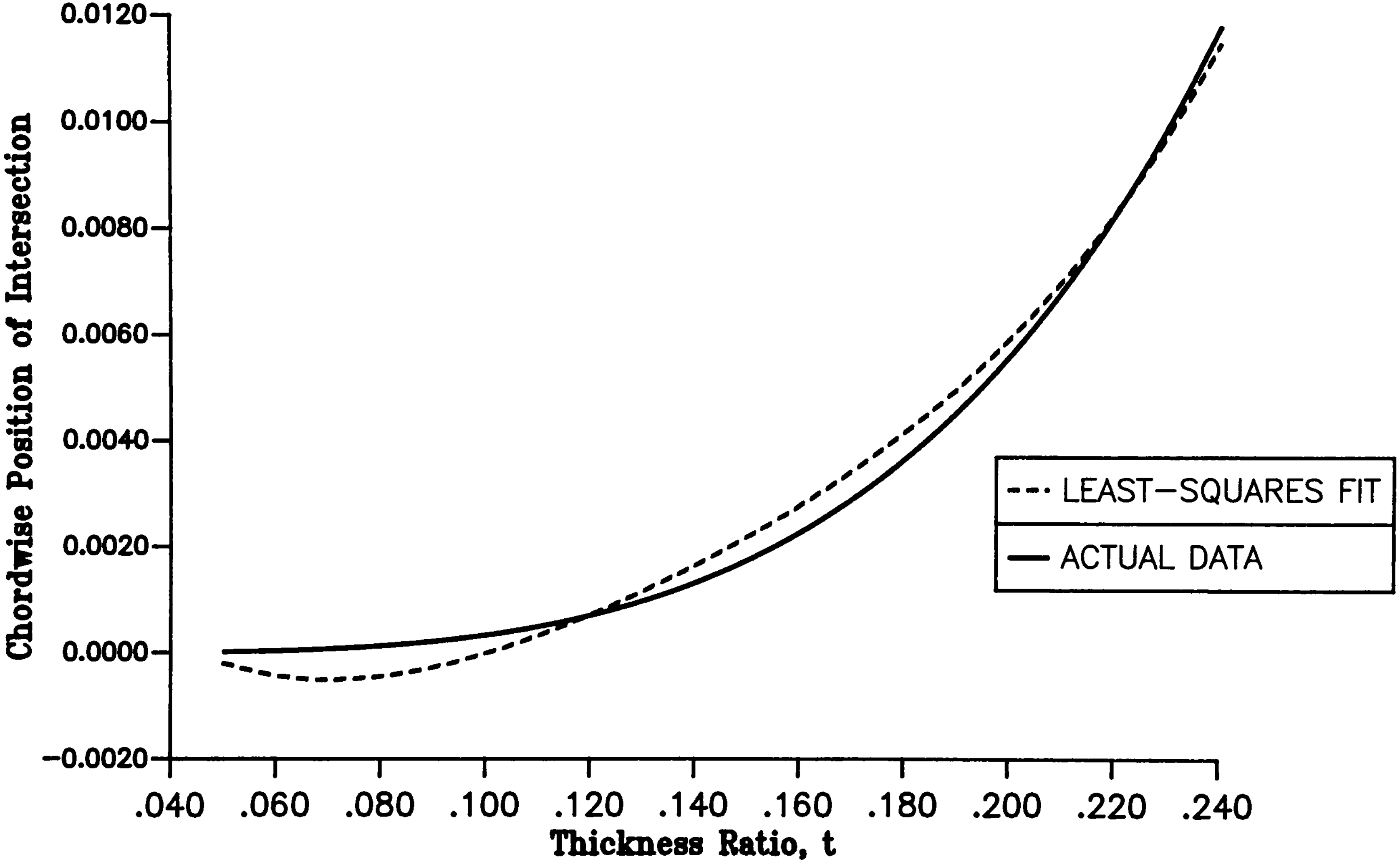
The slope at this point is given by the least-squares approximating function

$$y'_{radius} = .418408 - 2.11113\,t + \frac{.369872}{t} + \frac{.00283632}{t^2} \qquad [4.5]$$

Computationally, [4.5] is not nearly as efficient as desired, yet it fits very well to the data from which it came. The fit of intersection points given by [4.4] is marginal, and not nearly accurate enough for the purpose of this research. Regardless of efficiency, the cubic spline technique still requires function evaluations at a number of points on the desired airfoil, which is contrary to the objective of this research. Increasing the number of data points supplied to generate the cubic spline interpolant did lessen the magnitude of overshoot on the leading edge, but even with 200 points supplied on the upper surface as data points, the rippling effect on the leading edge could not be totally eliminated.

Point of Departure

NACA Airfoil and Leading Edge Radius



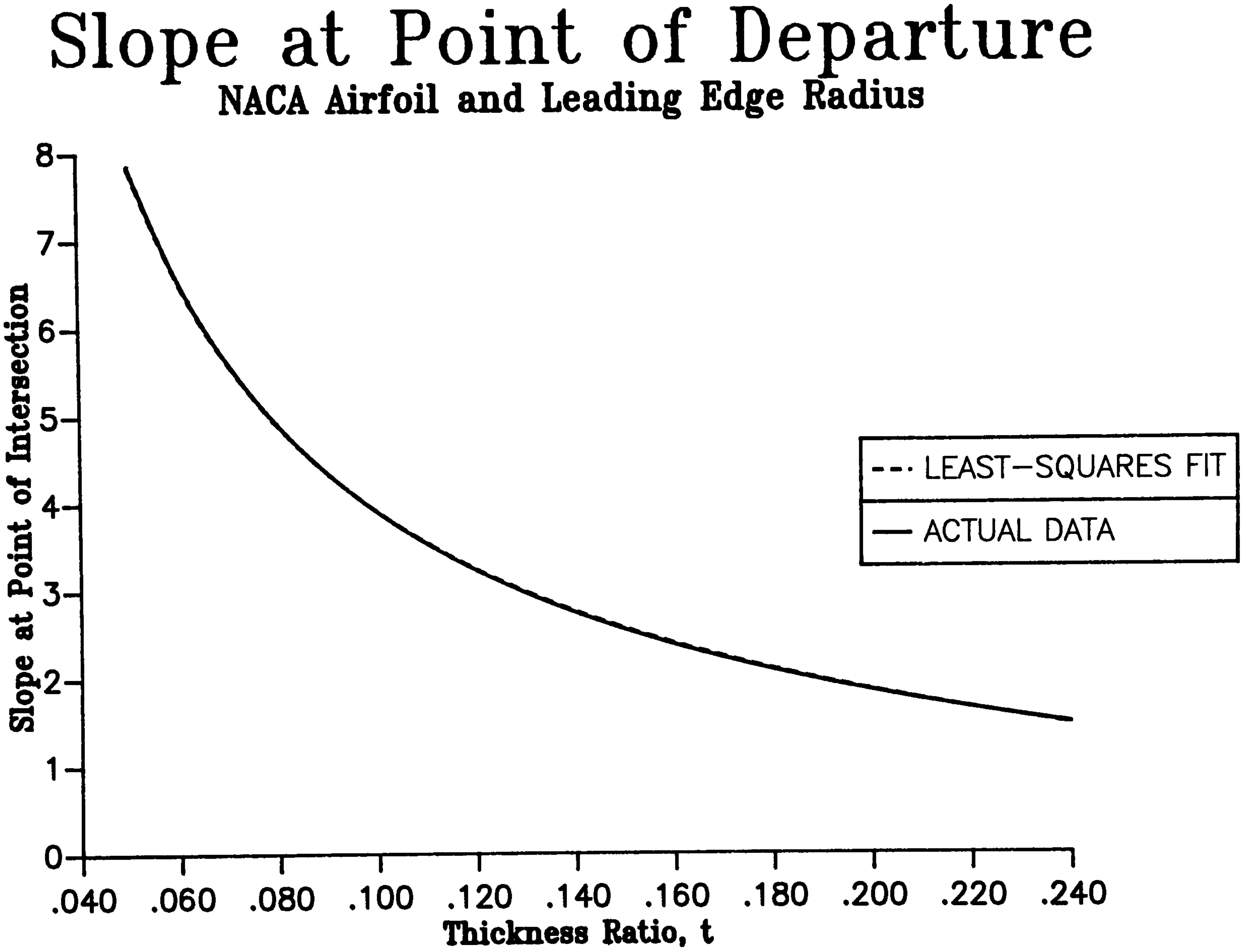


Figure 4.4 - Slope at Point of Departure - NACA Airfoil and Leading Edge Radius

4.1.1.3 Overcoming the Problem of Specifying Zero Slope

In order to circumvent the zero slope requirement at the point of maximum thickness, it was decided that perhaps an effective method may be to break the airfoil into two distinct portions. By splitting the airfoil at the $x=.3$ point, a clamped cubic spline could feasibly be used to fix the slope at zero at this point. Although the cubic spline methods discussed in this section were deemed unsuitable for the purpose, this was an important step in reaching the final objective. The technique of splitting the airfoil at the $x=.3c$ point proved vital to the eventual success encountered in this research.

4.1.2 **Least-Squares Polynomial Approximations**

Least-squares curve fitting techniques were attempted for this application. Due to the fact, however, that even with a significant number of generated data points, no great degree of accuracy in emulation was achieved, this technique was dropped from contention as a viable method to achieve the final objective.

4.1.3 **Parametric Bézier Curves**

The properties of Bézier curves seem ideally suited to fulfill the objective of this research. By sectioning the airfoil at the chordwise position of maximum ordinate, zero slope at this point is easily attained. In addition, by placing successive defining polygon vertices along the line $x=0$ (the y-axis), the heretofore troublesome problem of infinite slope at the leading edge is overcome, while placement of a polygon vertex along the line $y=t/2$ somewhere between $x=0$ and $x=.3$ will ensure zero slope at the point of maximum thickness. These requirements of the Bézier curve thus eliminate the investigation of quadratics; the lowest order Bézier curve to accomplish the objective will be a cubic one. Further, because the Bézier curve utilizes only the defining polygon points in its generation, the specification of large numbers of points through which the curve must pass is unnecessary; only the points which determine the first and last vertices of each defining polygon (and are coincident with the airfoil) must be specified.

4.1.3.1 Leading Edge Surface

The question that now arises is one of how to go about determining the optimum placement of the two remaining defining polygon vertices to minimize error between the Bézier curve and the true (desired) shape. Upon further inspection, it is noted from Figure 4.5 on the following page that of the two undetermined polygon vertices, one coordinate of each is predetermined.

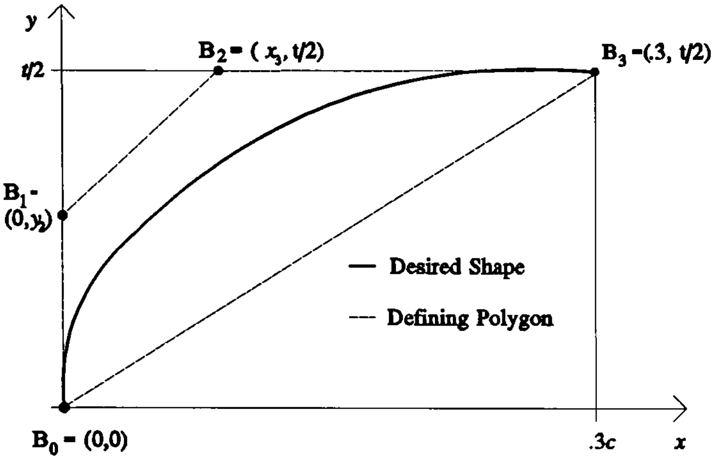


Figure 4.5 Leading Edge of Airfoil and Bézier Defining Polygon

Thus it is desired to find only two values: the y-coordinate for the vertex B_1 on the y-axis, and the x-coordinate for the vertex B_2 on the line $y=t/2$. For the initial portion of the analysis, the NACA0012 airfoil was chosen as the target of the attempt to fit a Bézier curve to the actual shape.

The matrix formulation for the Bézier curve now becomes

$$\mathbf{P}(\nu) = \begin{bmatrix} \nu^3 & \nu^2 & \nu & 1 \end{bmatrix} \begin{bmatrix} -1 & 3 & -1 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & 3 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 \\ 0 & y_1 \\ x_2 & 0.06 \\ 0.3 & 0.06 \end{bmatrix}$$

There are a multitude of optimization methods that could have been employed to hone in on the two values required, but as a first approach, it was thought that some ballpark estimates of these values should be obtained. In order to arrive at some preliminary estimates for the y-coordinate of polygon vertex B_1, integer multiples of the leading edge radius were thought to be good starting points. A preliminary (and purely arbitrary) assumption that polygon vertex B_1 have a y-coordinate value no larger than $t/2$ was made. This limited possible values of y_1 for the initial attempt to emulate the NACA0012 to

$$y_1 = \begin{cases} r = 0.015867 & (1) \\ 2r = 0.031735 & (2) \\ 3r = 0.047602 & (3) \end{cases}$$

In the matter of selecting the x-coordinate of polygon vertex $\mathbf{B}_2$, the interval [0,.3] (assuming a standard chord length of unity) was divided by golden section (see Appendix A for details of this method). Thus

$$x_2 = \begin{cases} (1 - \tau)(0.3) + \tau(0.0) = 0.11459 & (1) \\ (1 - \tau)(0.0) + \tau(0.3) = 0.18541 & (2) \end{cases}$$

Where, from Appendix A,

$$\tau = \frac{\sqrt{5} - 1}{2} = 0.6180339$$

This scheme led to six possible Bézier curves. Each of the possible combinations is plotted in Figures 4.6-4.11, pages 33-38. They are designated as "Case (a,b), where a denotes the y_1 value of vertex $\mathbf{B}_1$ and b denotes the x_2 value of vertex $\mathbf{B}_2$. Note here the indices are in order of the Bézier defining polygon vertices and not of the form $(x_{2(i)},y_{1(j)})$, where the subscripts i and j denote the various values of y_1 and x_2 as given above.

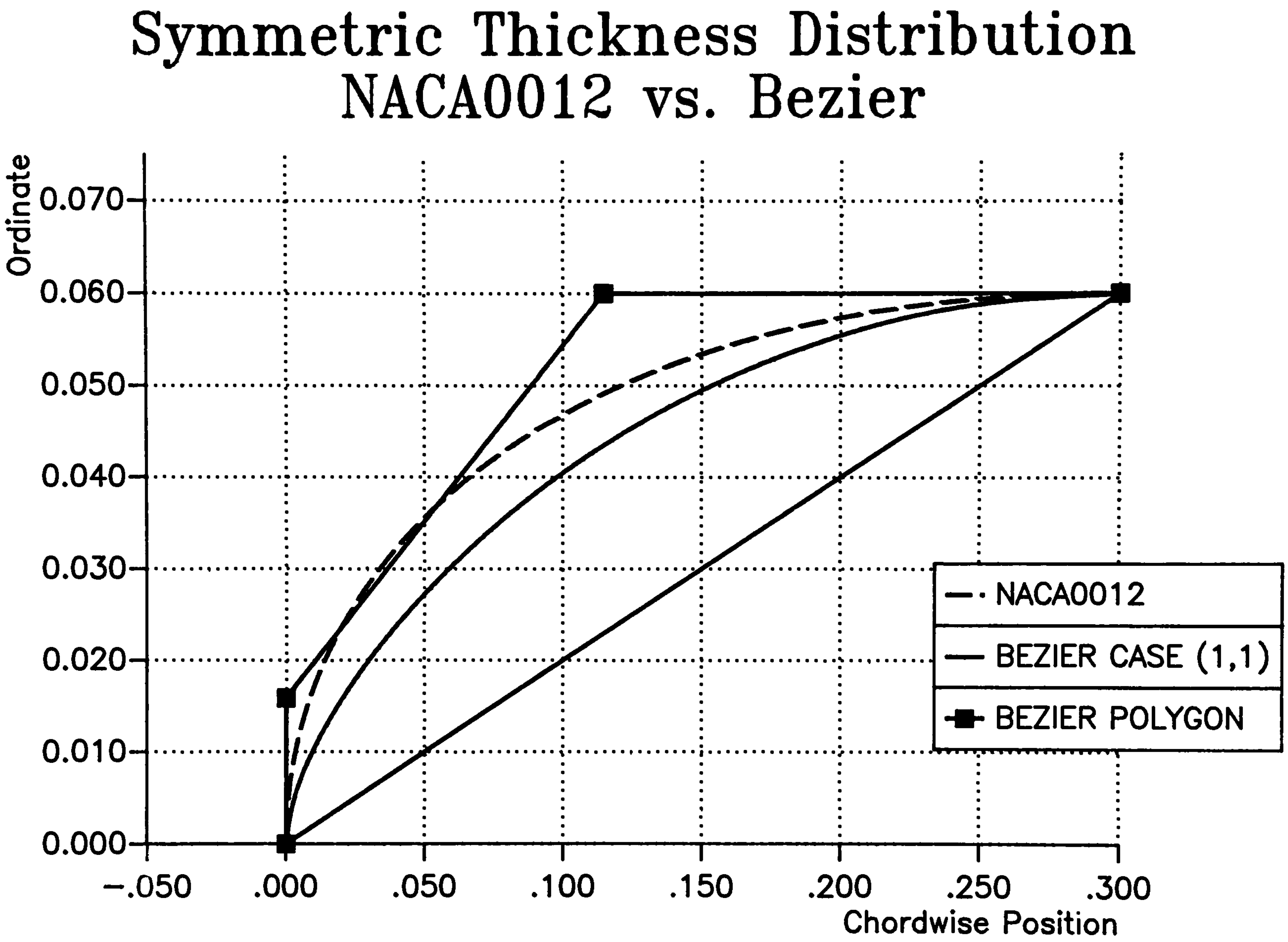


Figure 4.6 - Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(1,1)

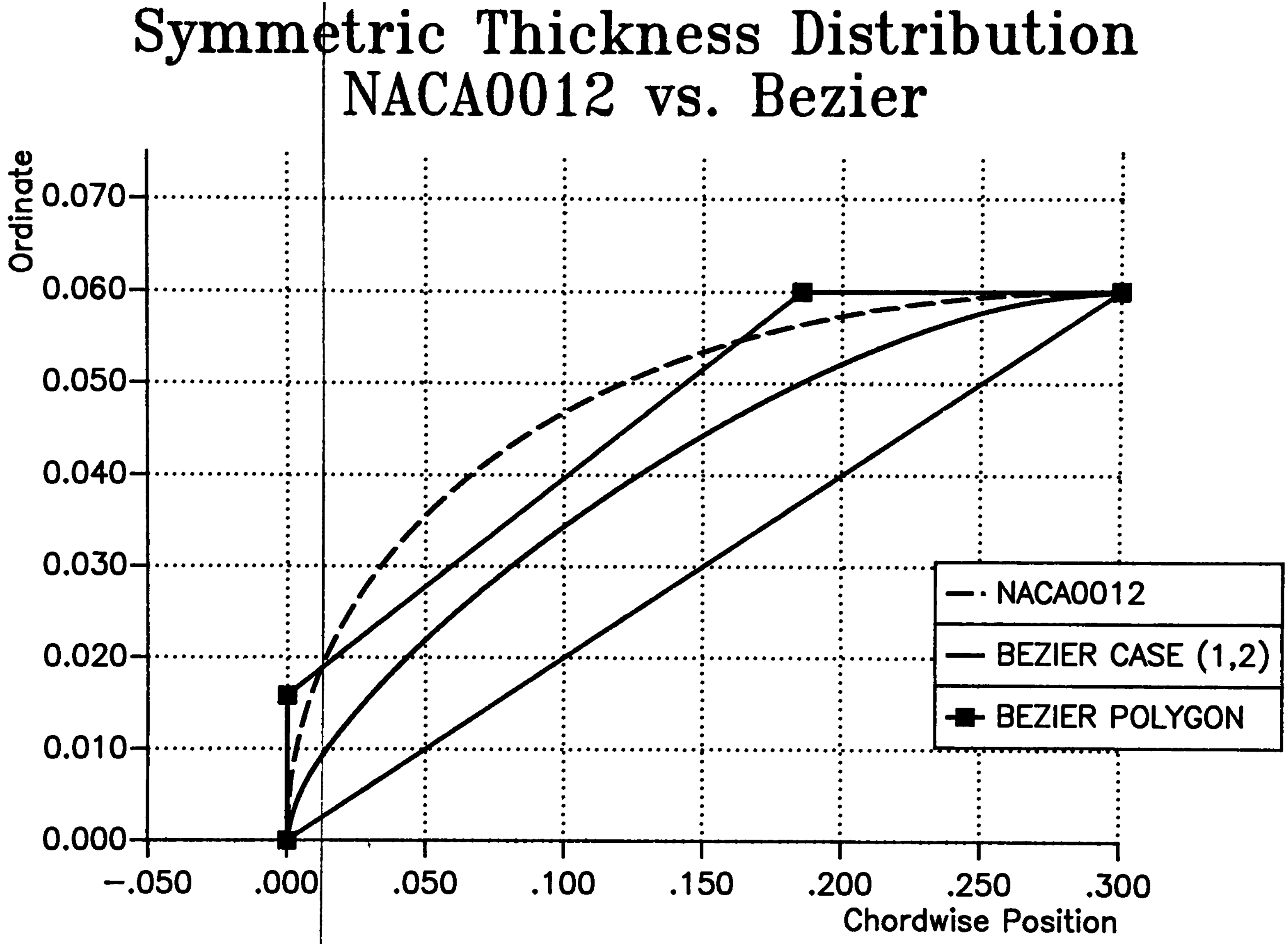


Figure 4.7 - Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(1,2)

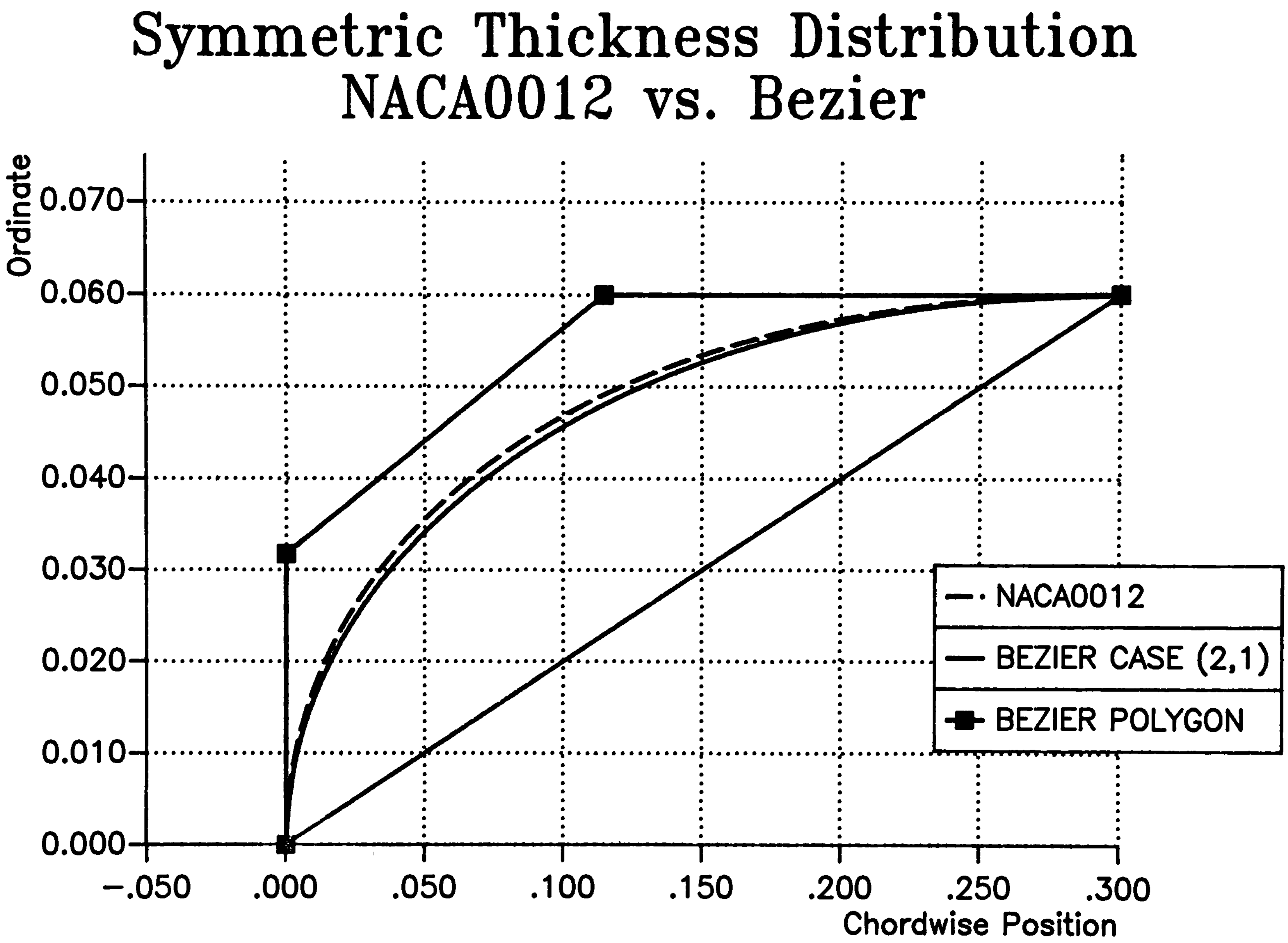


Figure 4.8 - Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(2,1)

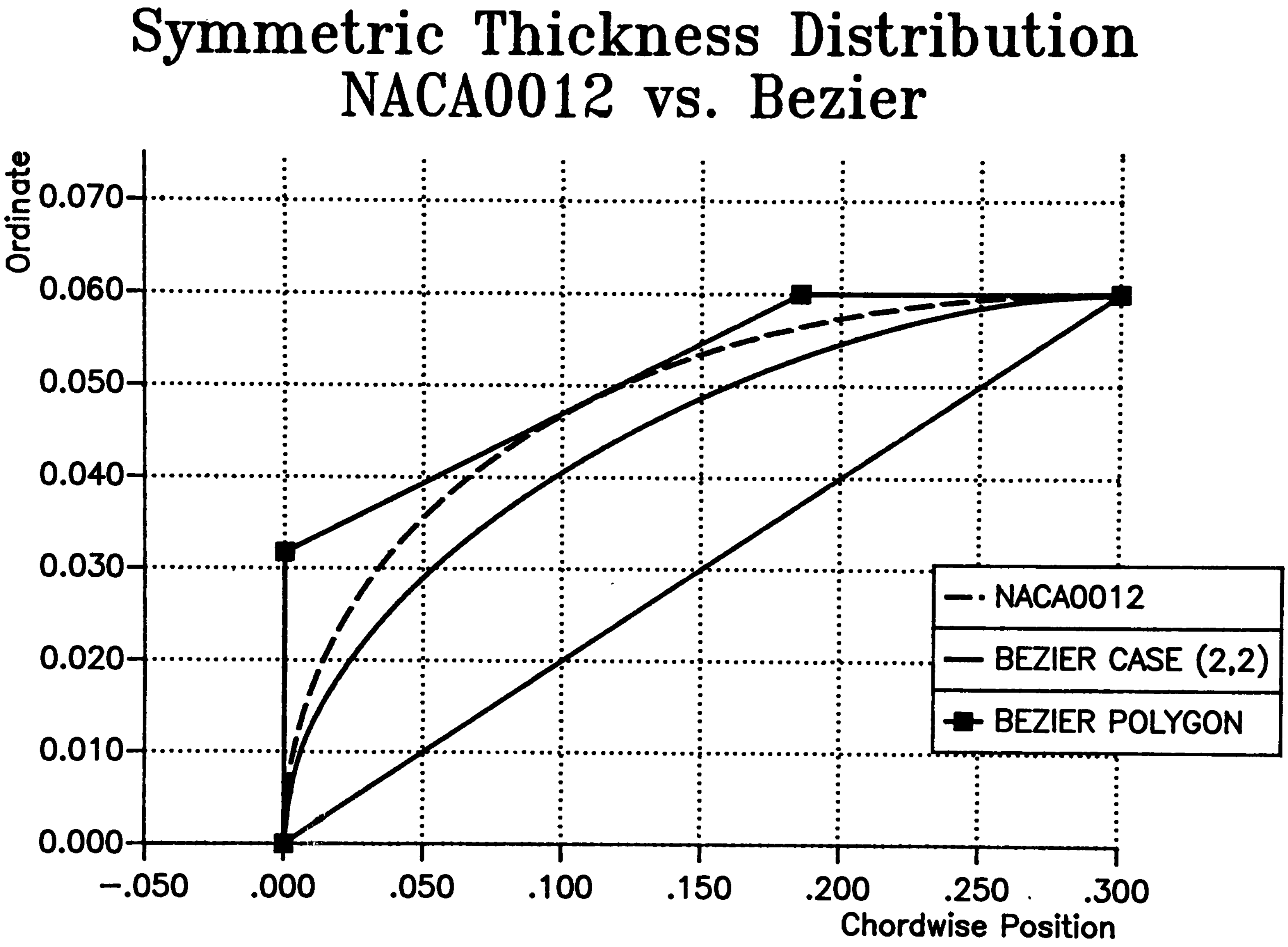


Figure 4.9 - Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(2,2)

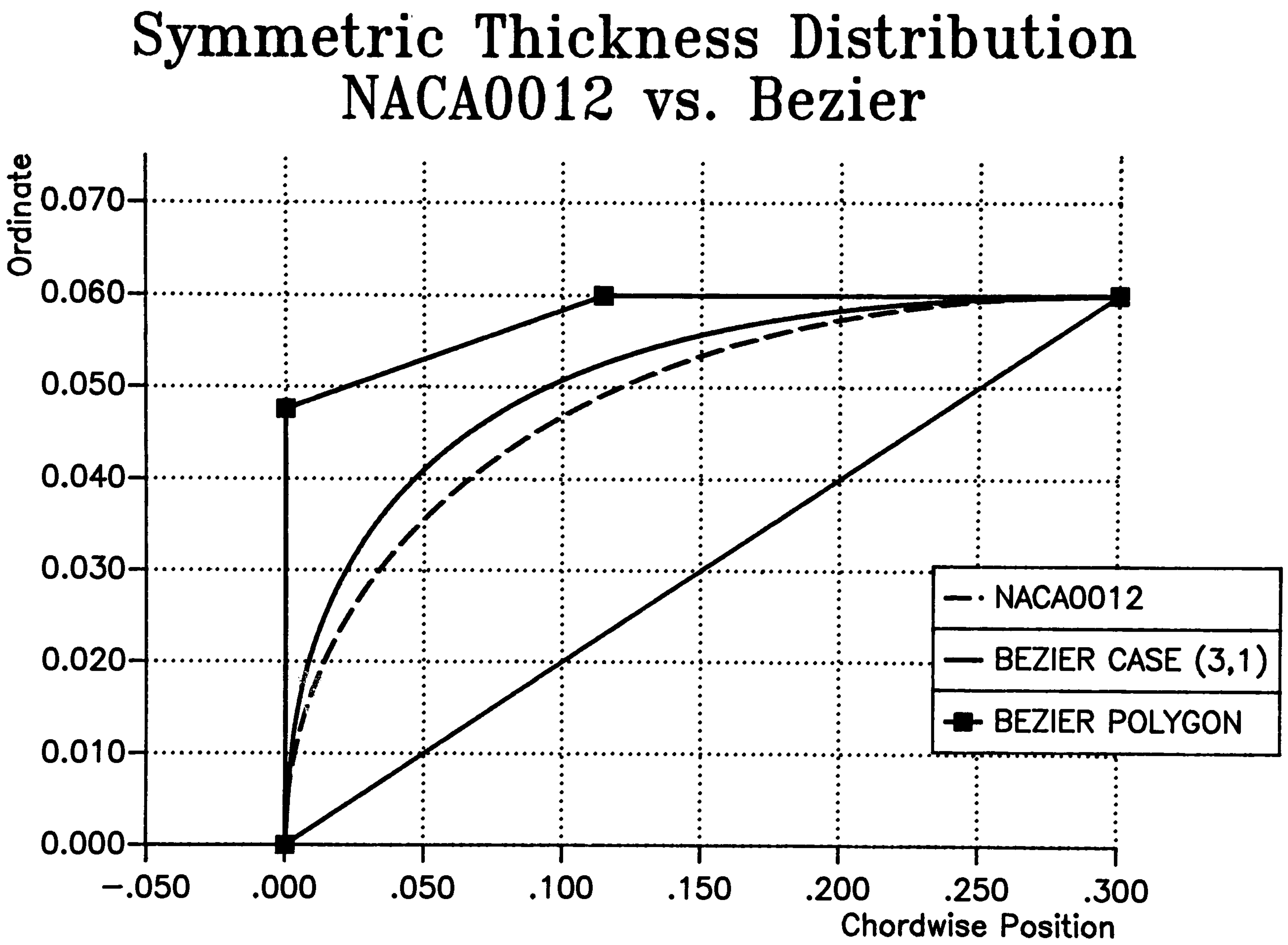


Figure 4.10 - Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(3,1)

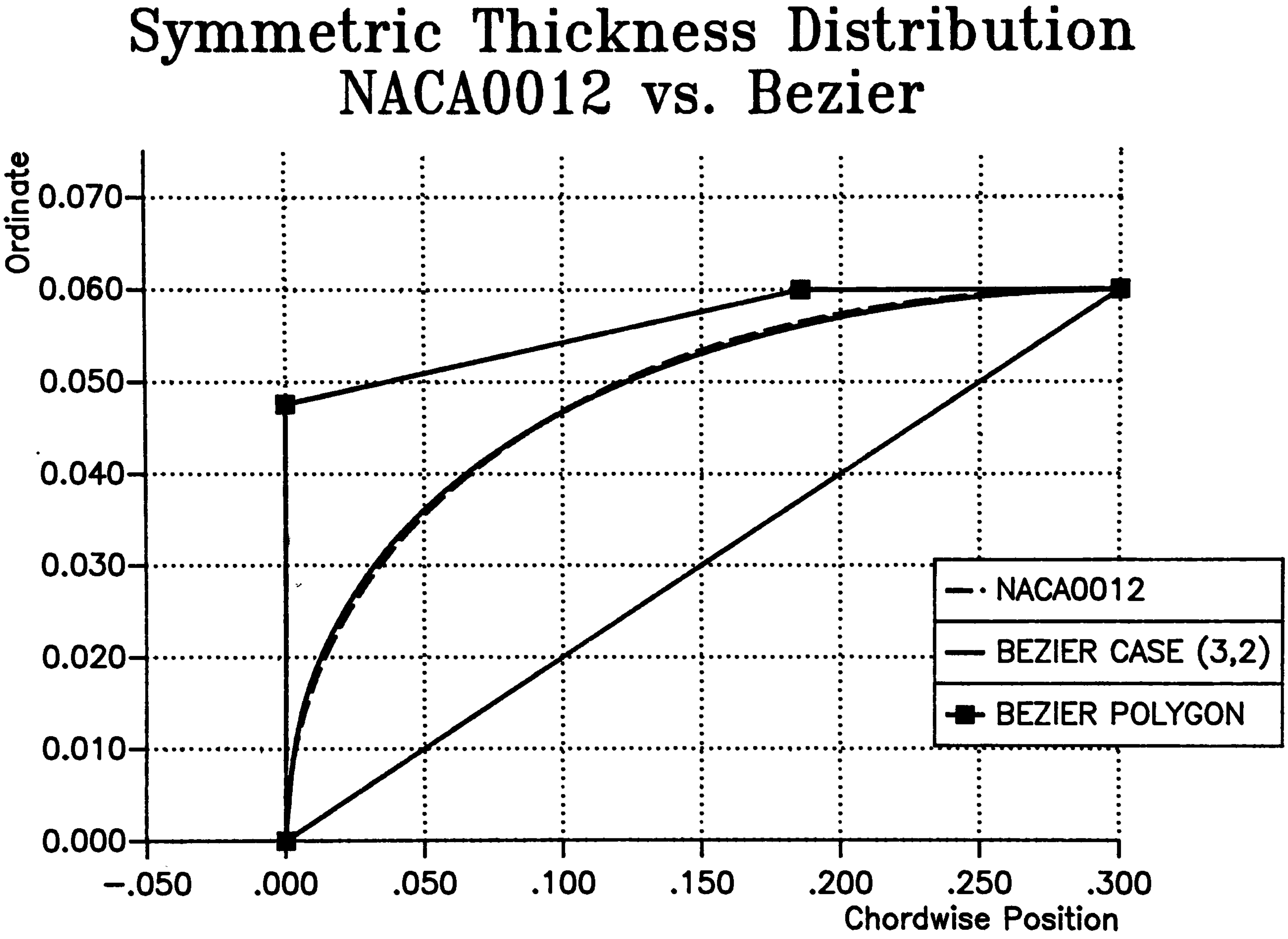


Figure 4.11 - Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(3,2)

Some observations on the previous plots, Figures 4.6-4.11, are in order. Varying the two inner defining polygon vertices changes the nature of the Bézier curve that lies within the polygon. Table 4.1 below summarizes the effects of changing y_1 and x_2 from their smallest to largest values (intermediate values of y_1 are not included).

Table 4.1 Visual Effects of Variation of Bézier Defining Polygon Inner Vertices

Case	y_1 value	x_2 value	Effect
(1,1)	0.015867	0.11459	sharp nose
(1,2)	0.015867	0.18541	sharpest nose thin leading edge
(3,1)	0.047602	0.11459	blunt nose
(3,2)	0.047602	0.18541	best fit

Noting the changes in Bézier curve shape attained by varying the defining polygon inner vertices ($\mathbf{B}_1$ and $\mathbf{B}_2$) will be useful should one desire to manipulate or perturb a shape generated using Bézier curves. It should be noted here that changing only one of these inner vertices will affect a change on the entire leading edge surface.

It is noted that case (3,2), Figure 4.11, seems to be a relatively good fit to the desired shape. Although further refinement of the defining polygon vertices is in order, the results thus far were checked against other airfoils in the NACA00*xy* family. A number of these surfaces (from the leading edge to the point of maximum thickness) were generated and compared against the corresponding NACA four-digit thickness distribution (equation [2.1], shown again for reference).

$$\pm y_t = \frac{t}{.2}\left(.2969\sqrt{x} - .126x - .3516x^2 + .2843x^3 - .1015x^4 \right) \qquad [2.1]$$

It is further observed from plots generated using the Bézier curve versus the true shapes, that the reasonably good fit obtained in the case of the NACA0012 does not carry over to airfoils of different maximum thicknesses (see Figures 4.12 and 4.13, pages 40-41). Again the conventionally described NACA thickness distribution has been provided for comparison.

Reflecting upon the outcome of Figures 4.12 and 4.13, it is recognized from section 4.1 that " the curve is invariant under an affine (*linear*) transformation"[7]. Because the leading edge radius was used to determine y_1 of polygon vertex B_1, the relative distance from the leading edge to vertex $\mathbf{B}_1$ changes with thickness ratio in a non-linear manner (recall from equation [2.3] that leading edge radius, *r*, varies with t^2).

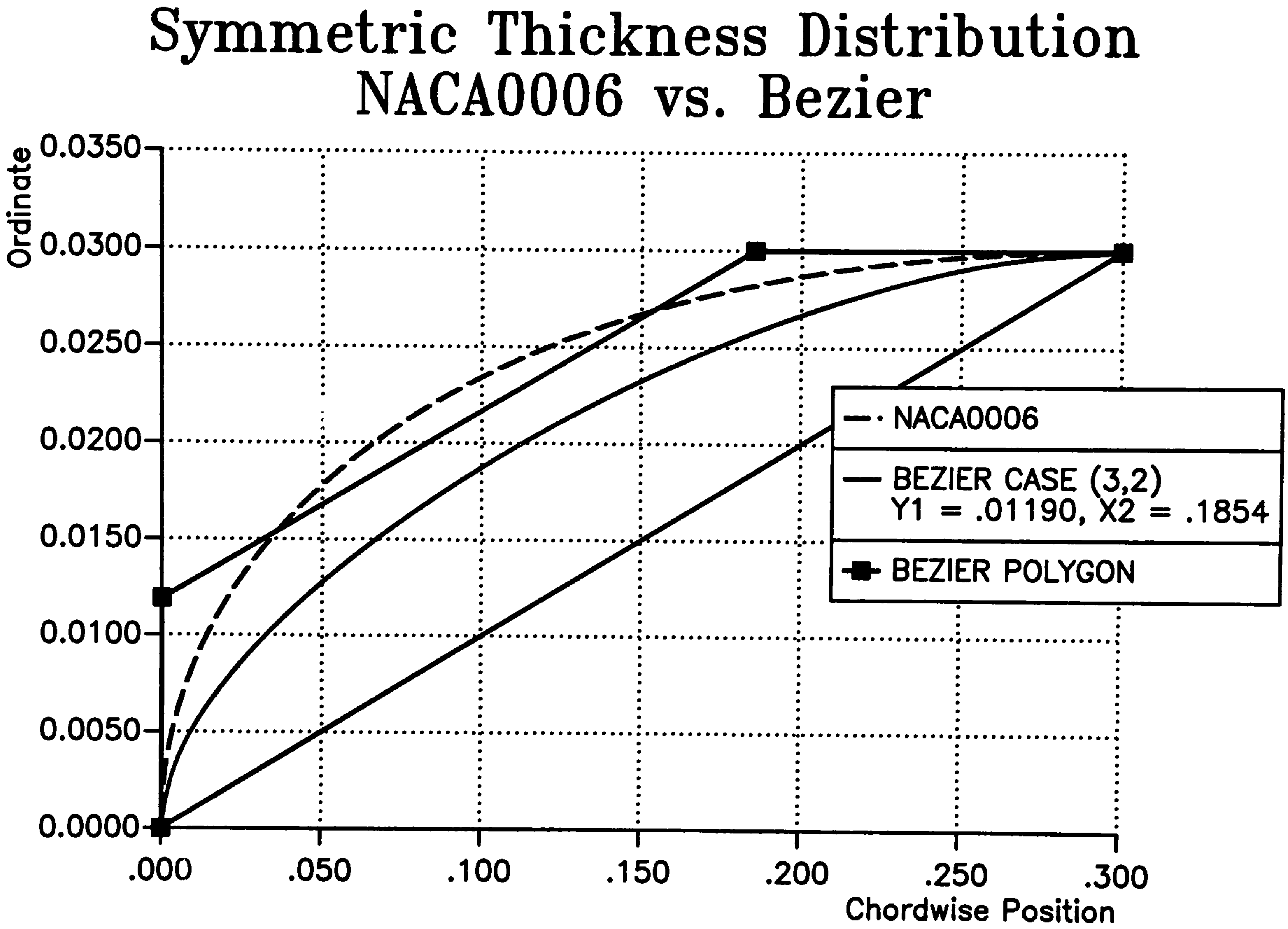


Figure 4.12 - Symmetric Thickness Distribution - NACA0006 vs. Bézier - Case(3,2)

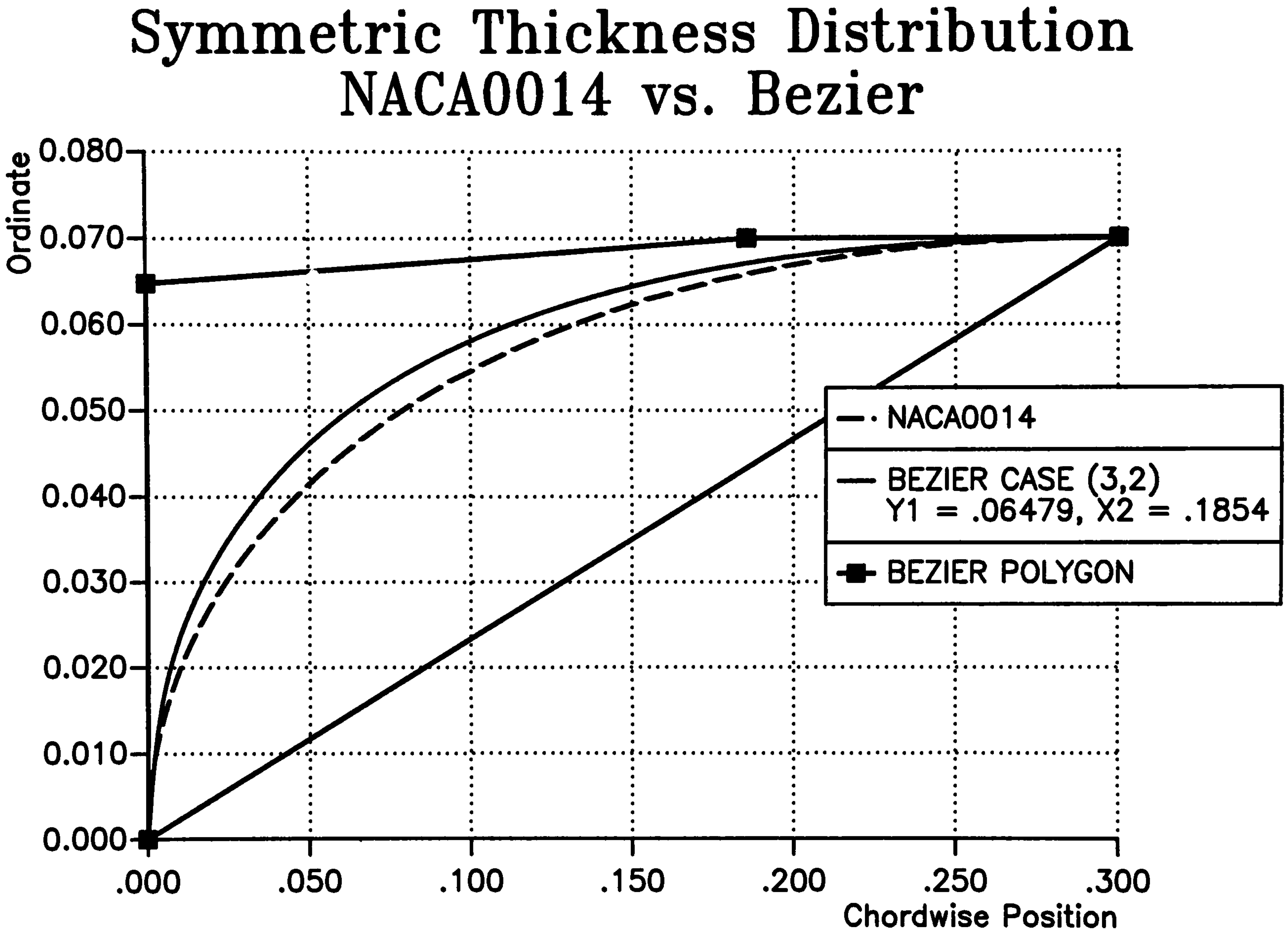


Figure 4.13 - Symmetric Thickness Distribution - NACA0014 vs. Bézier - Case(3,2)

Thus for the affine transformation property to hold, the defining polygon vertices must be generated using a term that is linear in t (or independent of t). Since good first approximation results were obtained on x_2 using the golden section method, this was deemed a good place to continue in the search for y_1. Figure 4.14 illustrates the manual refinement that went into determining a value of y_1 that would hold for any value of t. Because this golden section search was performed with the aid of a hand calculator, it was possible in some instances to select new bounds on both ends of the shortened search interval.

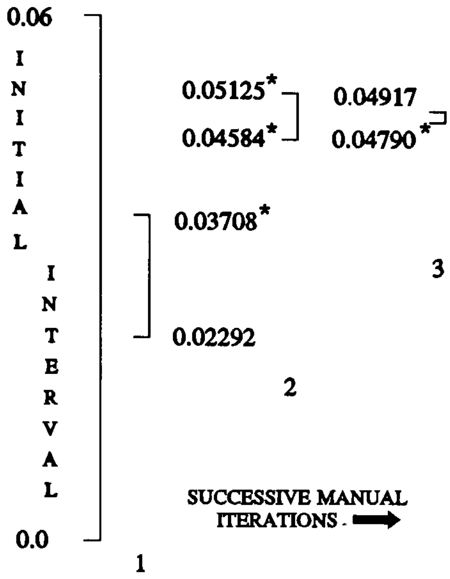


Figure 4.14 Steps in Golden Section Refinement to Determine y_1

Prior to the first iteration above, the search interval is [0,0.06]. Because the desired value of y_1 is known to be in the vicinity of 0.047602, the next interval subject to golden section search is [0.03708,0.06]. The second iteration of the golden section yields two values which bracket the desired value, and thus both endpoints of the interval may be replaced. The search interval then becomes [0.04584,0.05125]. The asterisk (*) in Figure 4.14 above denotes the fact that it has replaced one of the interval bounds. It was felt that after the first iteration y_1 would not be close enough to the desired value of 0.047602 to warrant plotting the result. Successive iterations, however, bracketed the desired value on a small enough interval to deserve a closer look.

Figures 4.15 - 4.17 (denoted cases (4,2), (5,2) and (6,2), pages 43-45) show the results of this further manual refinement in the emulation of the NACA0012. Because the value for y_1 obtained above are linear in t (see Appendix A for an explanation), it is logical to assume that employing this method to generate airfoils of varying thicknesses will provide accuracy for all t. Figures 4.18 - 4.24, (pages 46-52), show the results as applied to airfoil leading edges of various thickness ratios. It should be mentioned here that the refinement was accomplished leaving the x-value of polygon vertex B_2 at $x_2=\tau(.3c)=.1854c$.

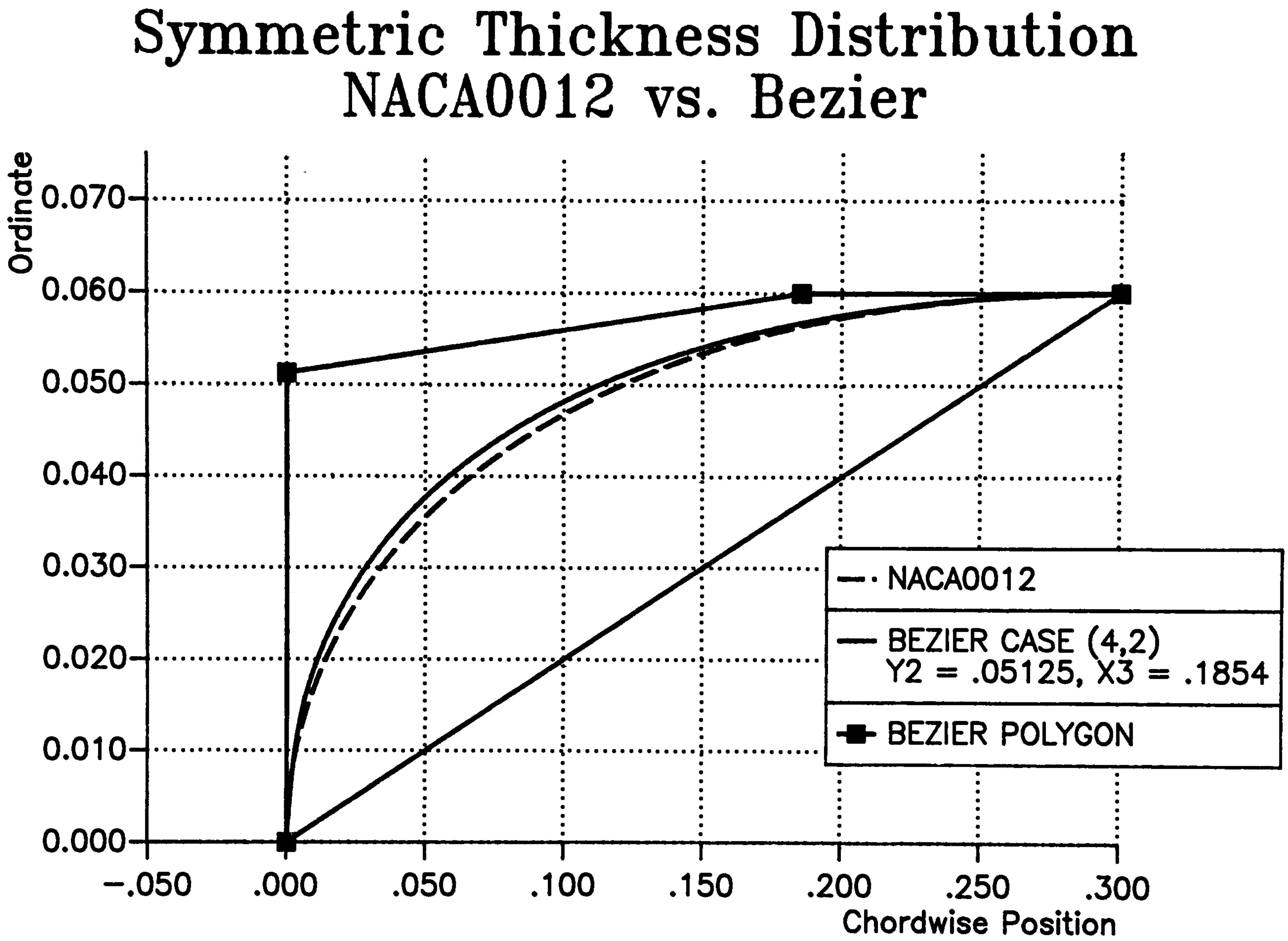


Figure 4.15 - Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(4,2)

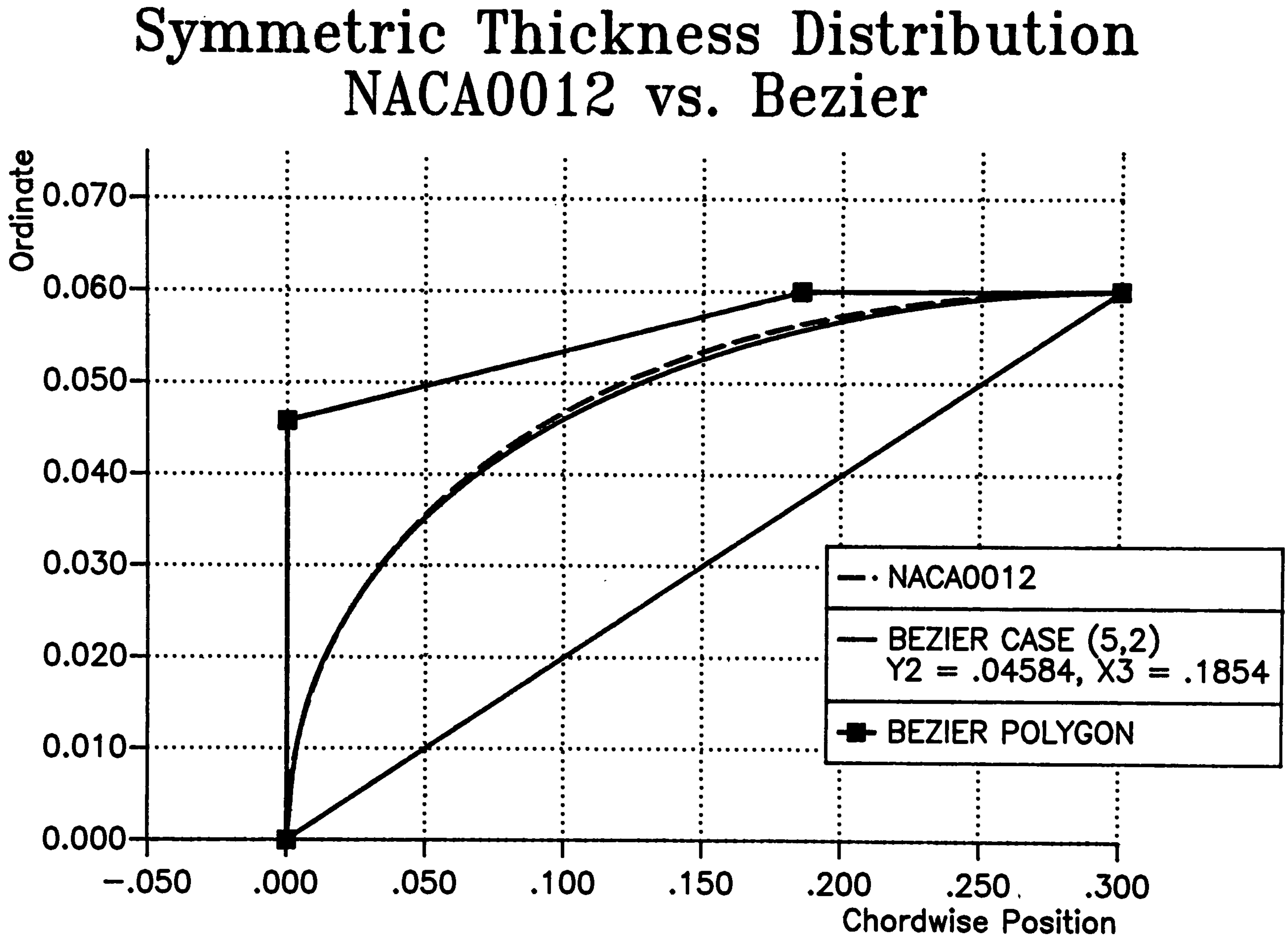


Figure 4.16 - Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(5,2)

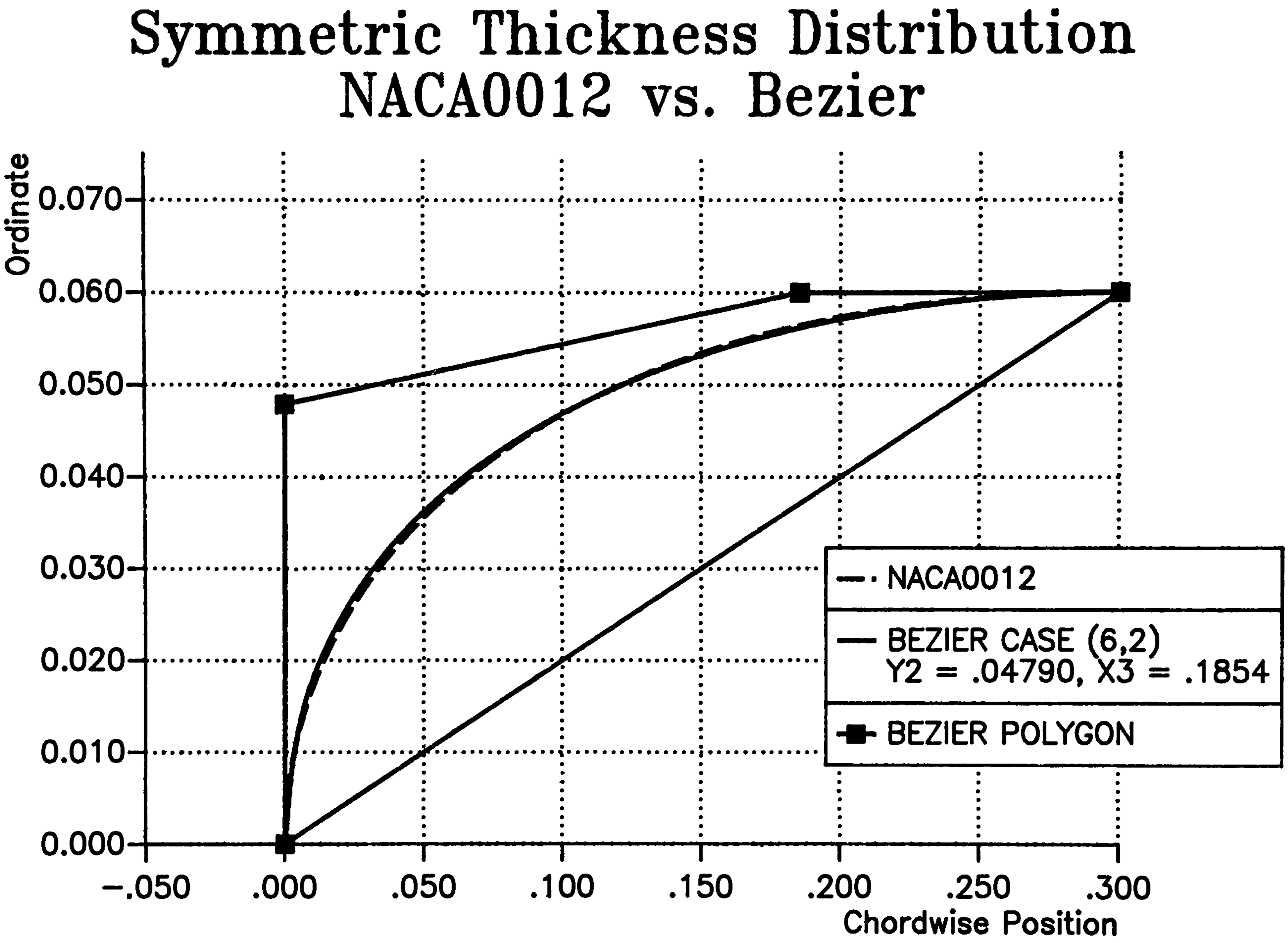


Figure 4.17 - Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(6,2)

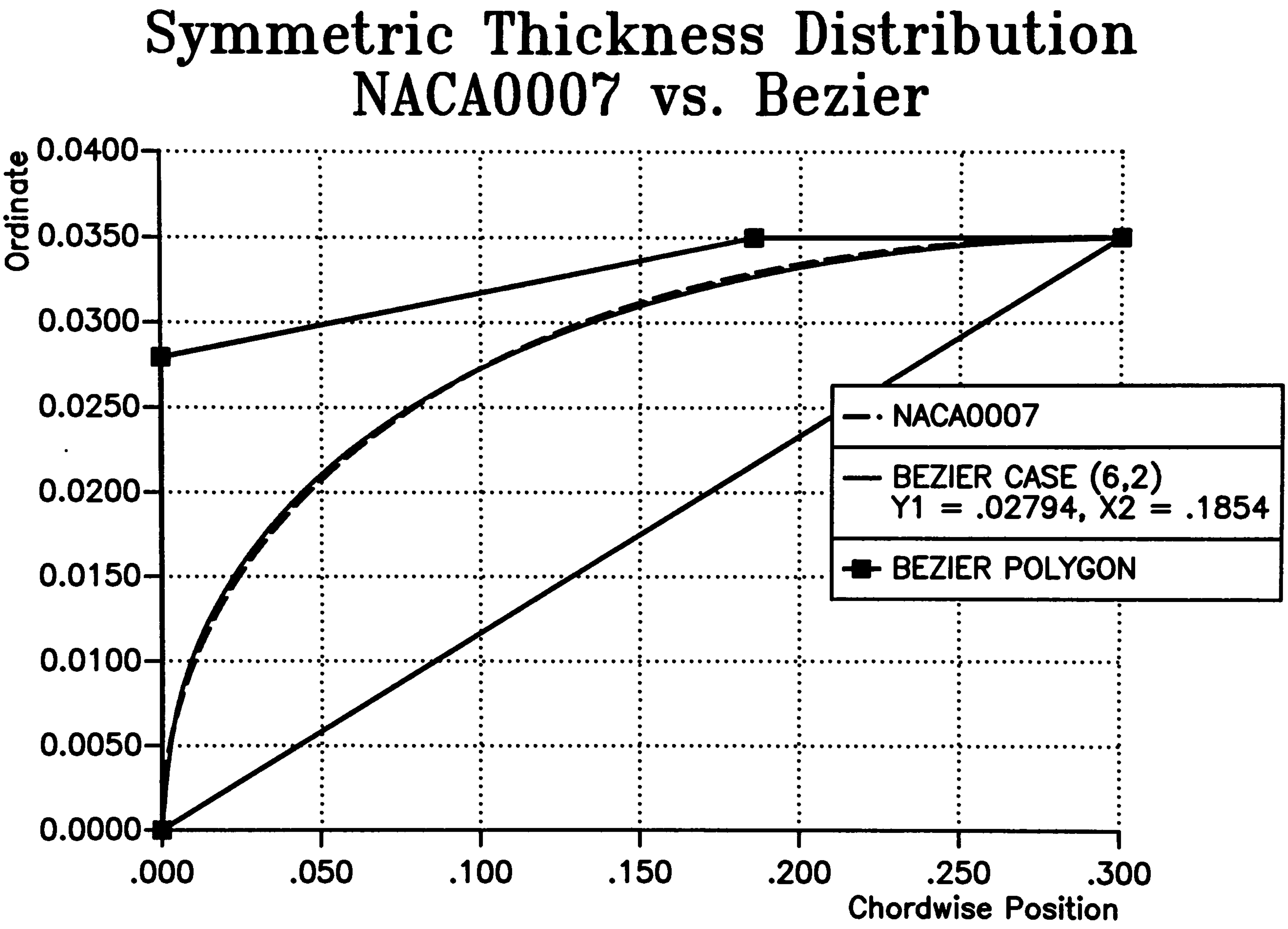


Figure 4.18 - Symmetric Thickness Distribution - Leading Edge, Upper Surface - NACA0007 vs. Bézier

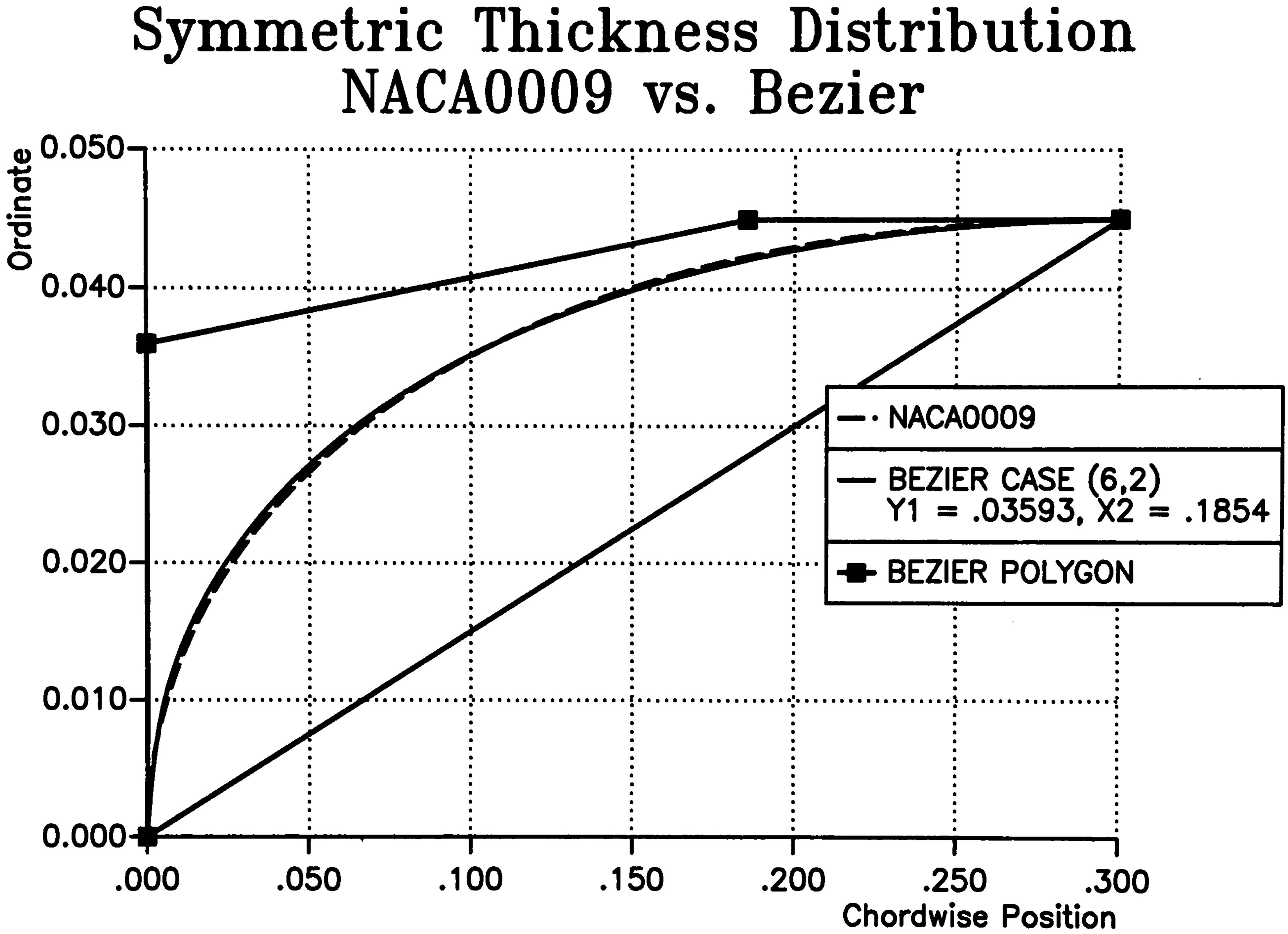


Figure 4.19 - Symmetric Thickness Distribution - Leading Edge, Upper Surface - NACA0009 vs. Bézier

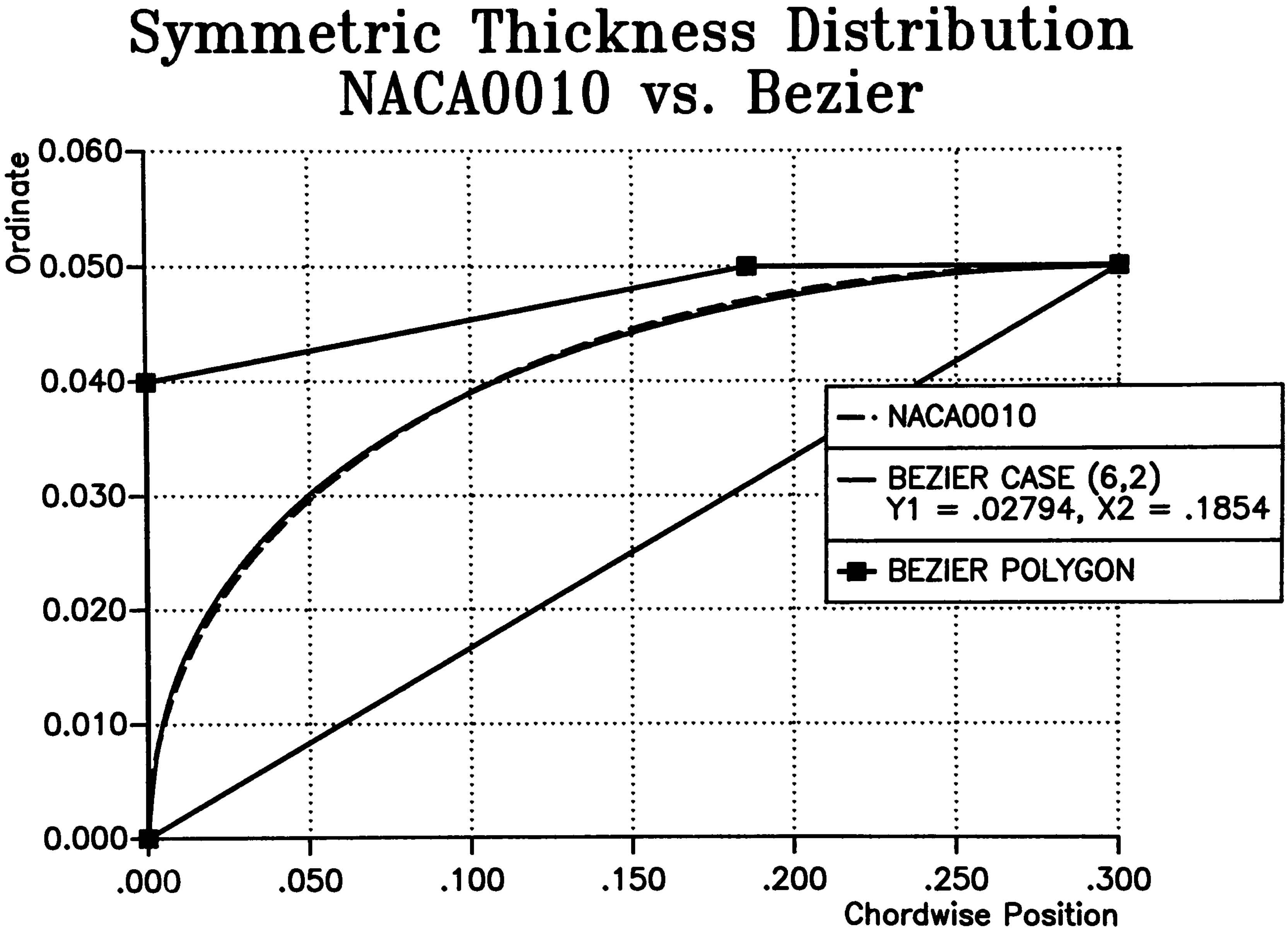


Figure 4.20 - Symmetric Thickness Distribution - Leading Edge, Upper Surface - NACA0010 vs. Bézier

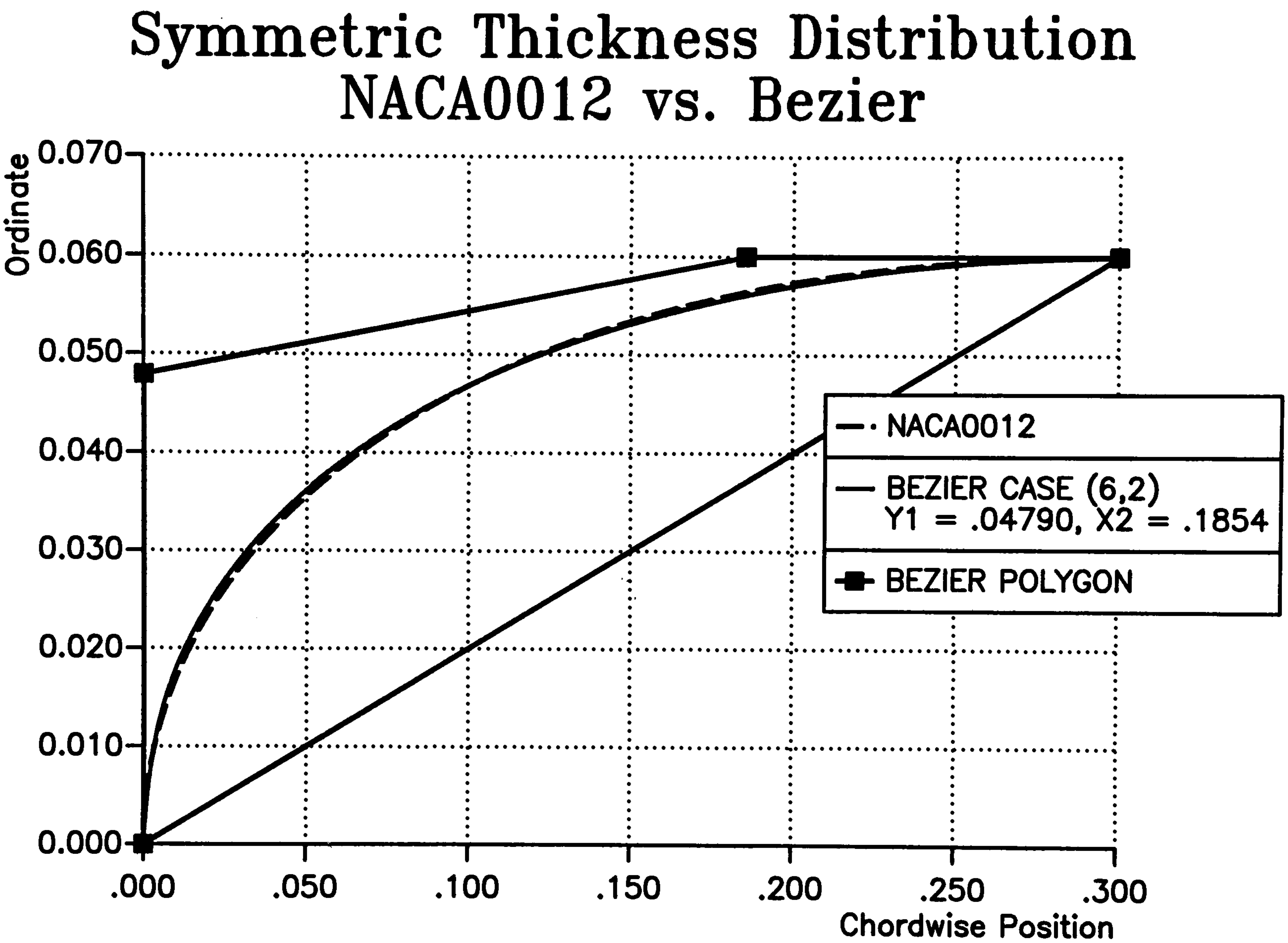


Figure 4.21 - Symmetric Thickness Distribution - Leading Edge, Upper Surface - NACA0012 vs. Bézier

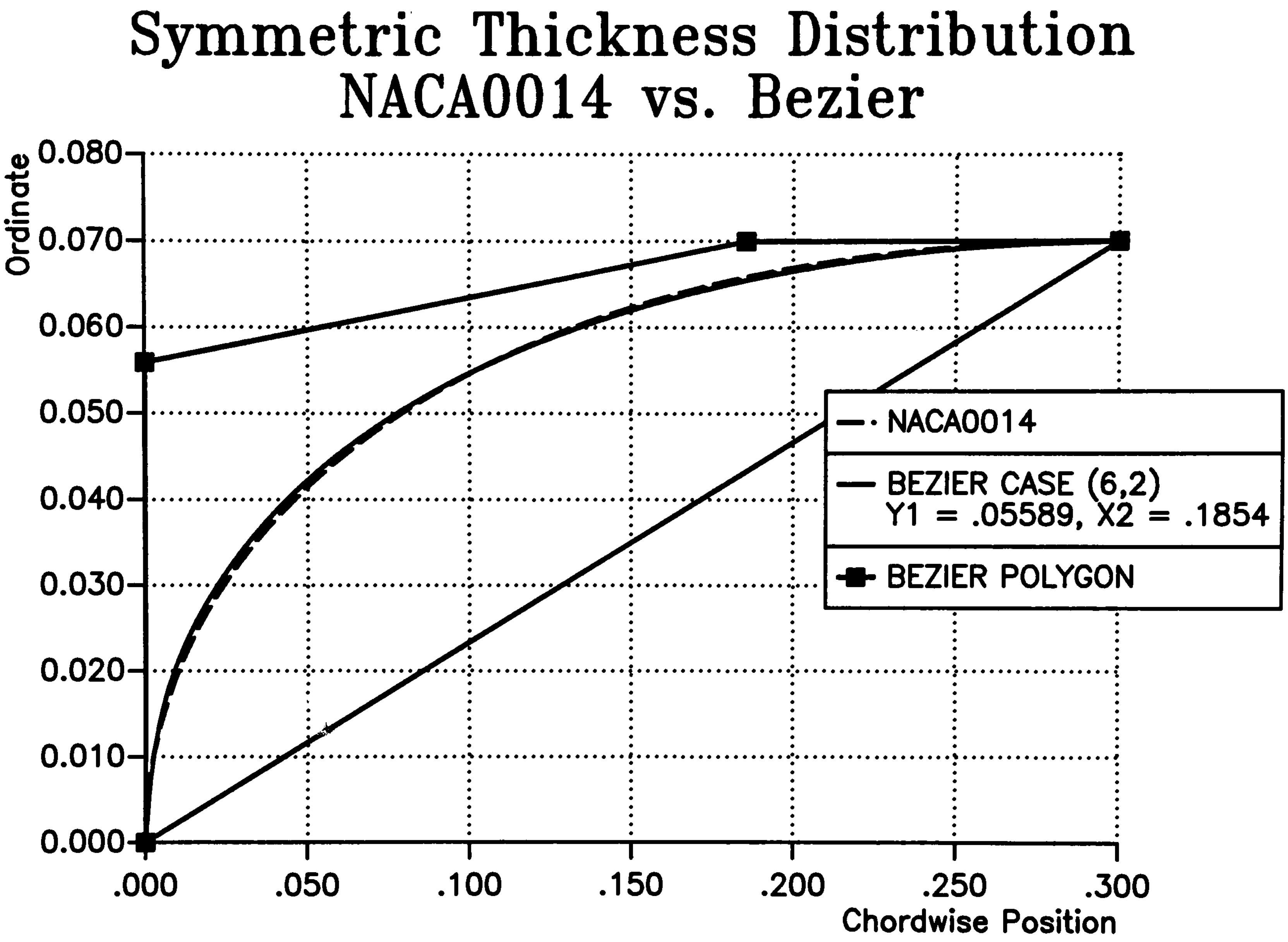


Figure 4.22 - Symmetric Thickness Distribution - Leading Edge, Upper Surface - NACA0014 vs. Bézier

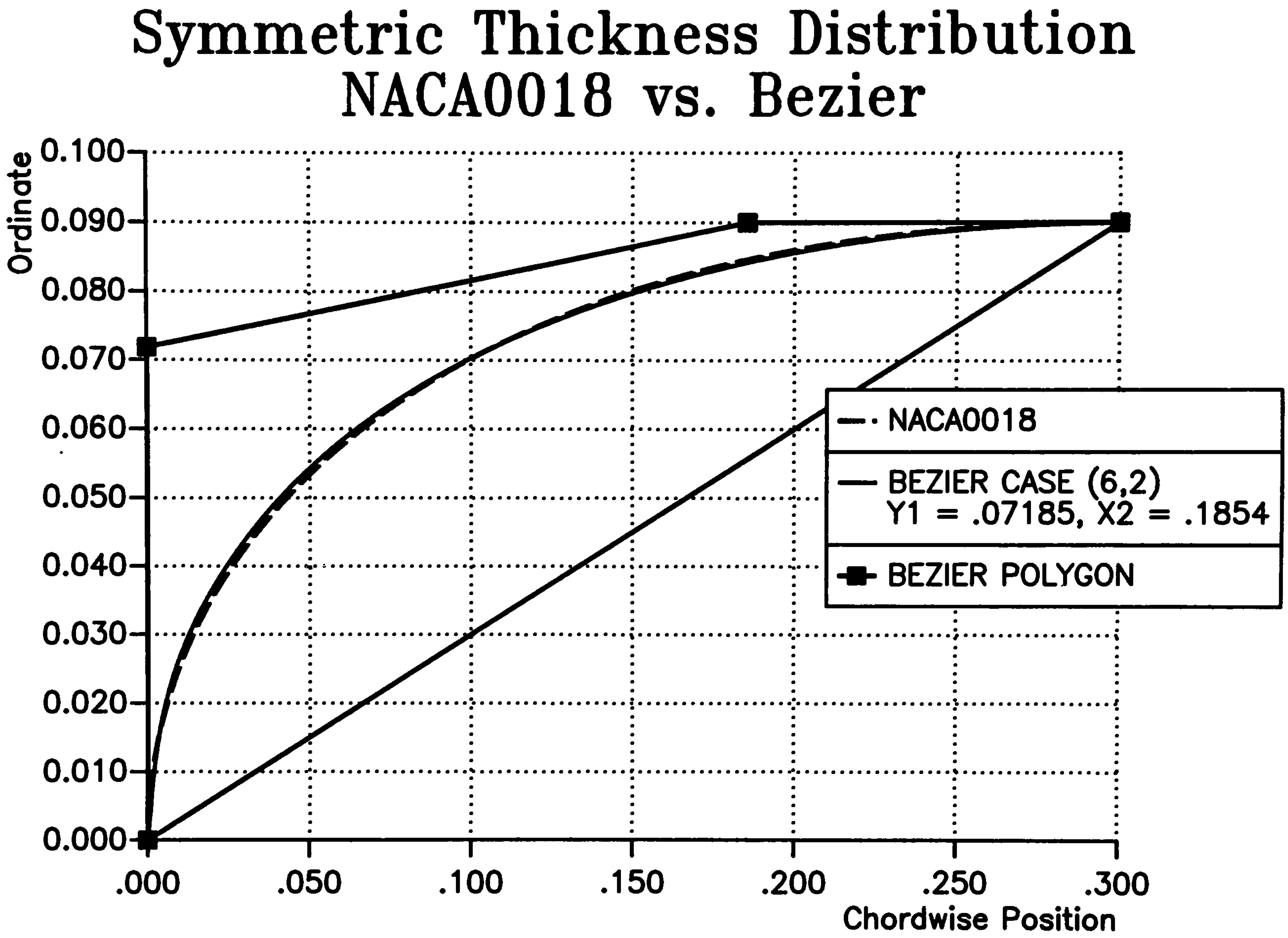


Figure 4.23 - Symmetric Thickness Distribution - Leading Edge, Upper Surface - NACA0018 vs. Bézier

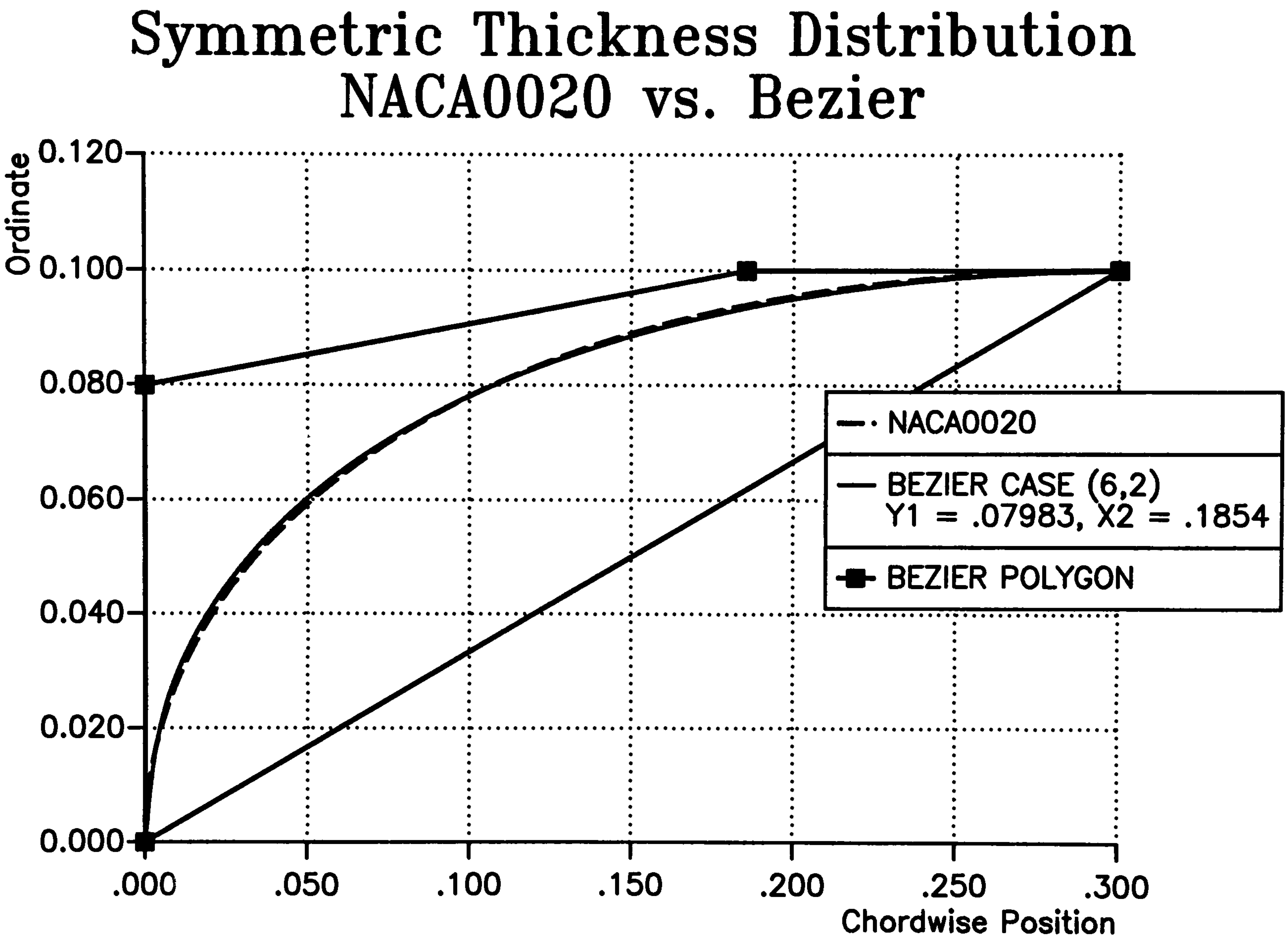


Figure 4.24 - Symmetric Thickness Distribution - Leading Edge, Upper Surface - NACA0020 vs. Bézier

Cubic Bézier curves were plotted against the desired curves after each iteration; it was determined that the best fit was obtained in iteration 2, case (4,2), with

$$\begin{aligned} y_1 &= (1 - \tau)(0.06) + \tau^2(0.06) \\ &= (1 - \tau)(0.06) + (1 - \tau)(0.06) \\ &= 2(1 - \tau)(0.06) \\ &= 2(1 - \tau)\frac{t}{2} \\ &= (1 - \tau)t \end{aligned}$$

Refinement of the x-value of polygon vertex B_2 was accomplished in a similar manner. Figure 4.25 illustrates this refinement process.

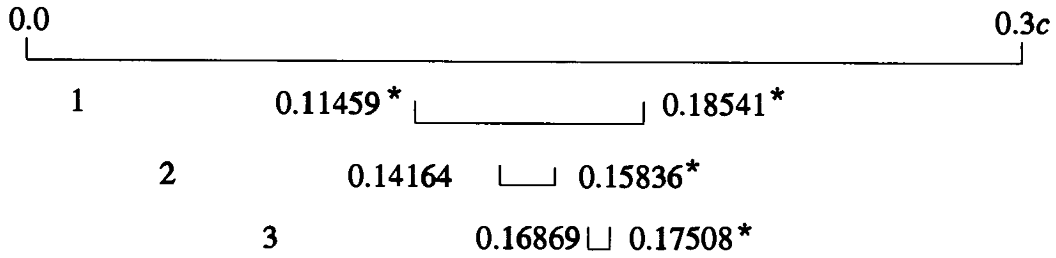


Figure 4.25 Refinement of x_2 Using Golden Section Method

Table 4.2 below will serve to clarify the iterative process illustrated in figure 4.25. As in the refinement process for y_1, the asterisks above denote a change in the interval bound.

Table 4.2 Manual Refinement Process to Determine x_2

Iteration	Lower Bound	Upper Bound
0	0.0	0.3
1	0.11459	0.18541
2	0.15836	0.18541
3	0.17508	0.18541
4	0.17902	0.18146

The final result of the refinement on x_2 is

$$x_2 = .3(22\tau - 13)$$

and is independent of the maximum thickness.

There may be some confusion as to the origin of the last equation. Because of the nature of the golden section, and the value of zero of the lower bound on the initial search interval, any iteration of the golden section division of this interval can simplified to an equation that is linear in τ. Furthermore, one of the coefficients will be a Fibonacci number, and the other will be an integer either one less or one more than the next number in the Fibonacci sequence.

For the segment of the NACA symmetric airfoil of arbitrary thickness t from the leading edge to the chordwise position of maximum thickness, the polygon that best defines the cubic Bézier curve is

$$\begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \\ \mathbf{B}_3^{\mathrm{T}} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & (1-\tau)t \\ .3(22\tau - 13) & \frac{t}{2} \\ .3 & \frac{t}{2} \end{bmatrix}$$

Plots of the front section for airfoils of various thickness ratios between seven and twenty percent thick are provided as Figures 4.26 - 4.32 on the pages immediately following. Notice that the Bézier curves follow their respective NACA curves very closely, regardless of the thickness ratio. Results thus far are promising.

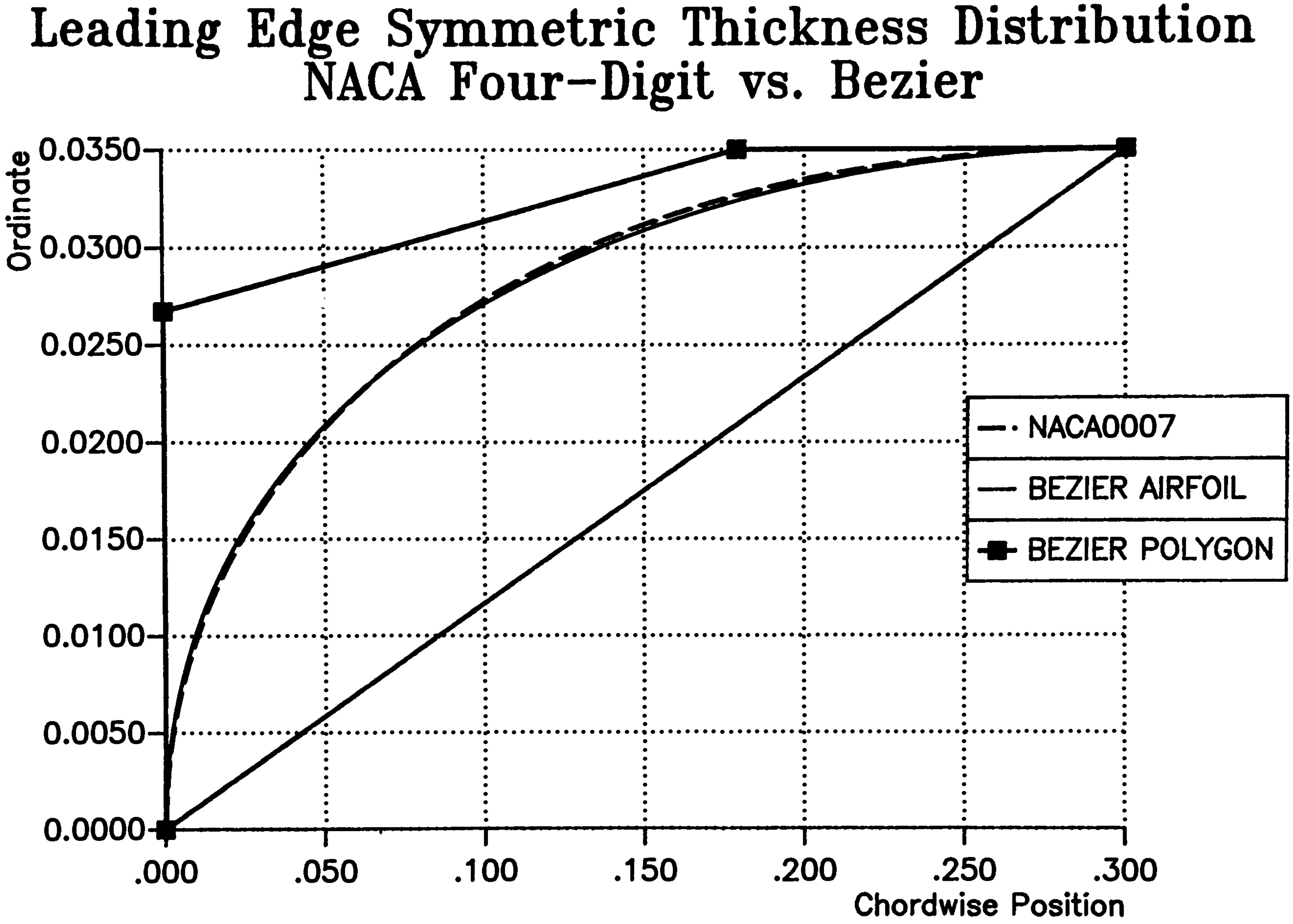


Figure 4.26 - Leading Edge Symmetric Thickness Distribution - NACA0007 vs. Bézier - Final Iteration

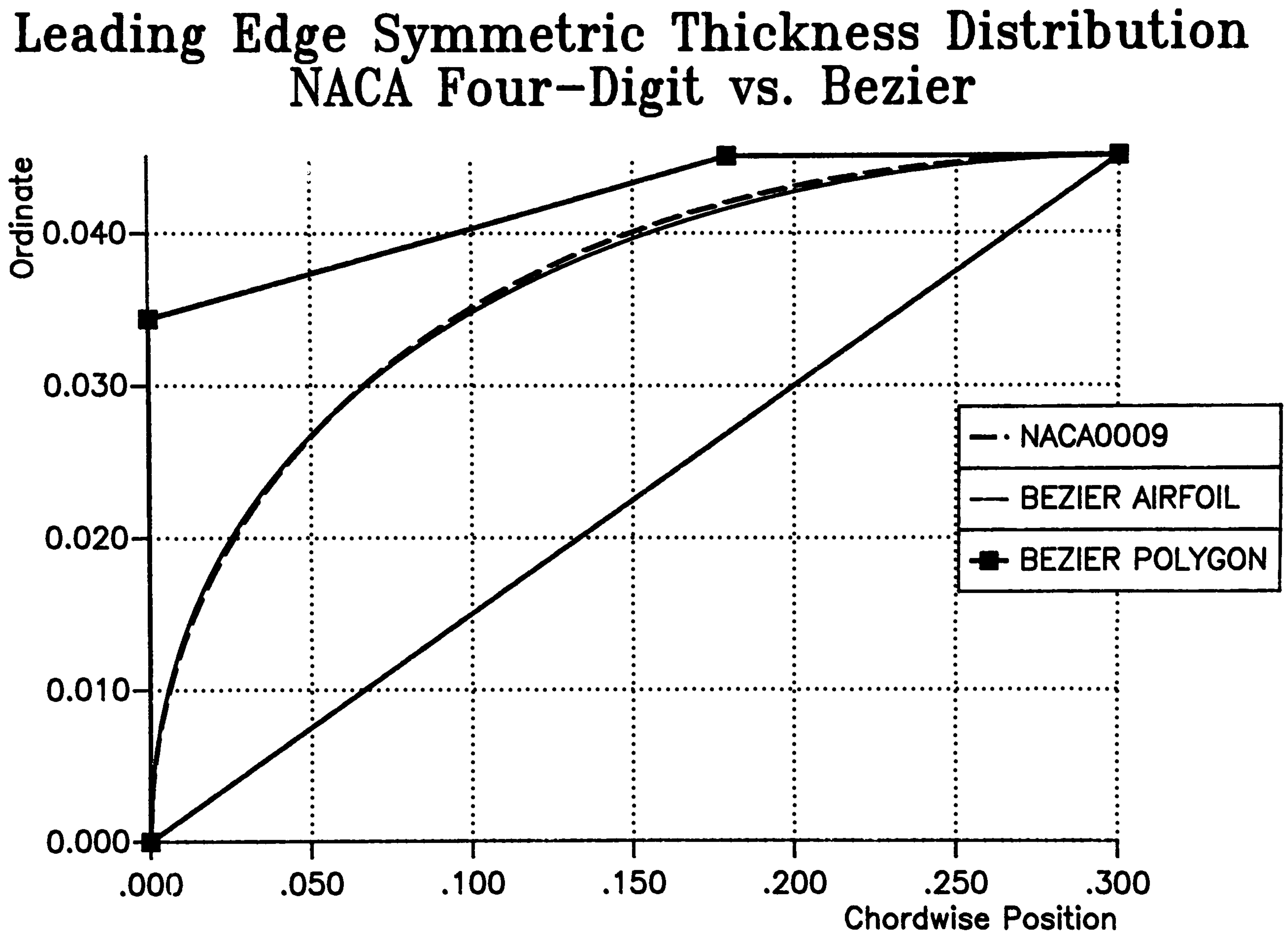


Figure 4.27 - Leading Edge Symmetric Thickness Distribution - NACA0009 vs. Bézier - Final Iteration

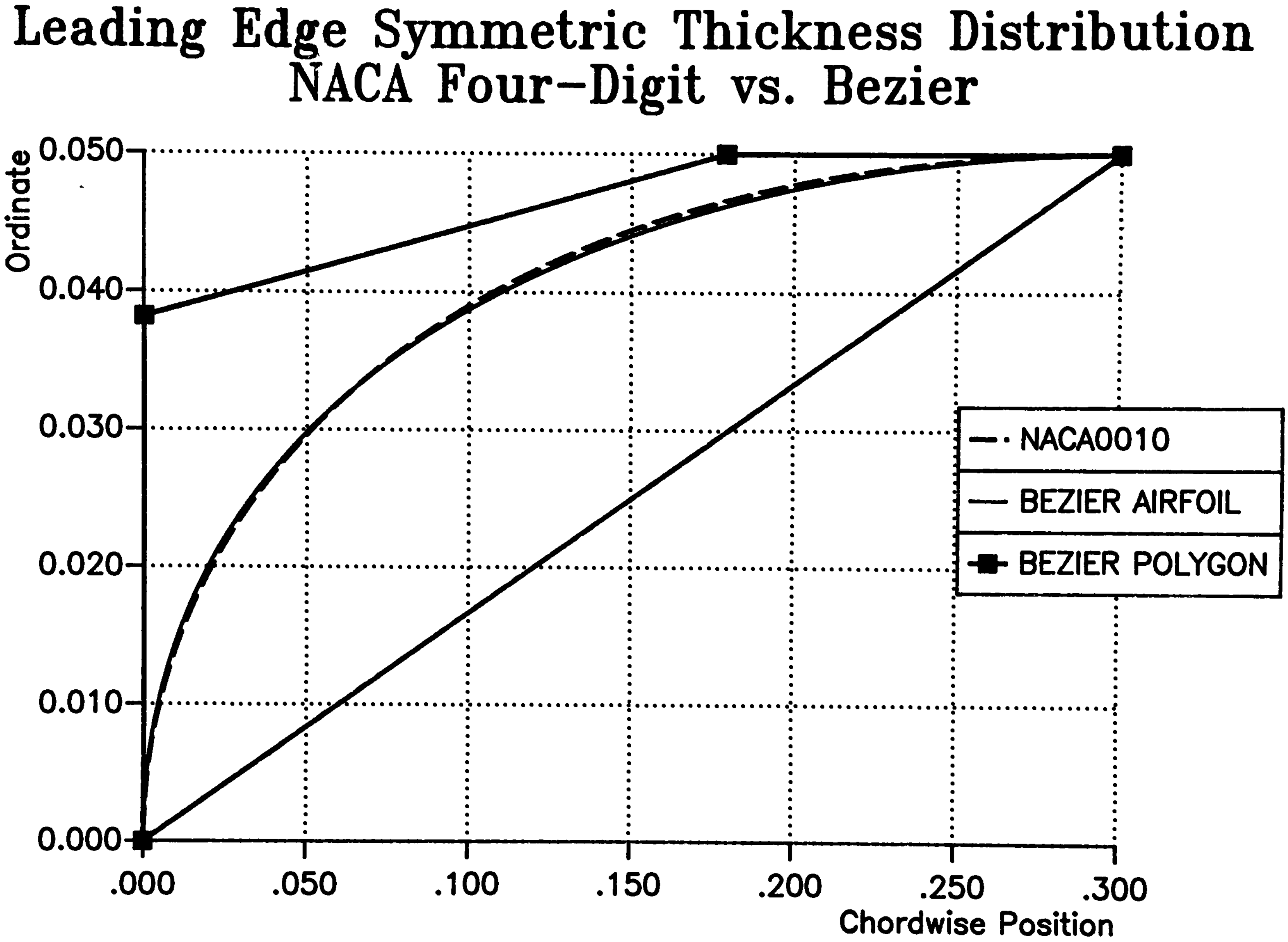


Figure 4.28 - Leading Edge Symmetric Thickness Distribution - NACA0010 vs. Bézier - Final Iteration

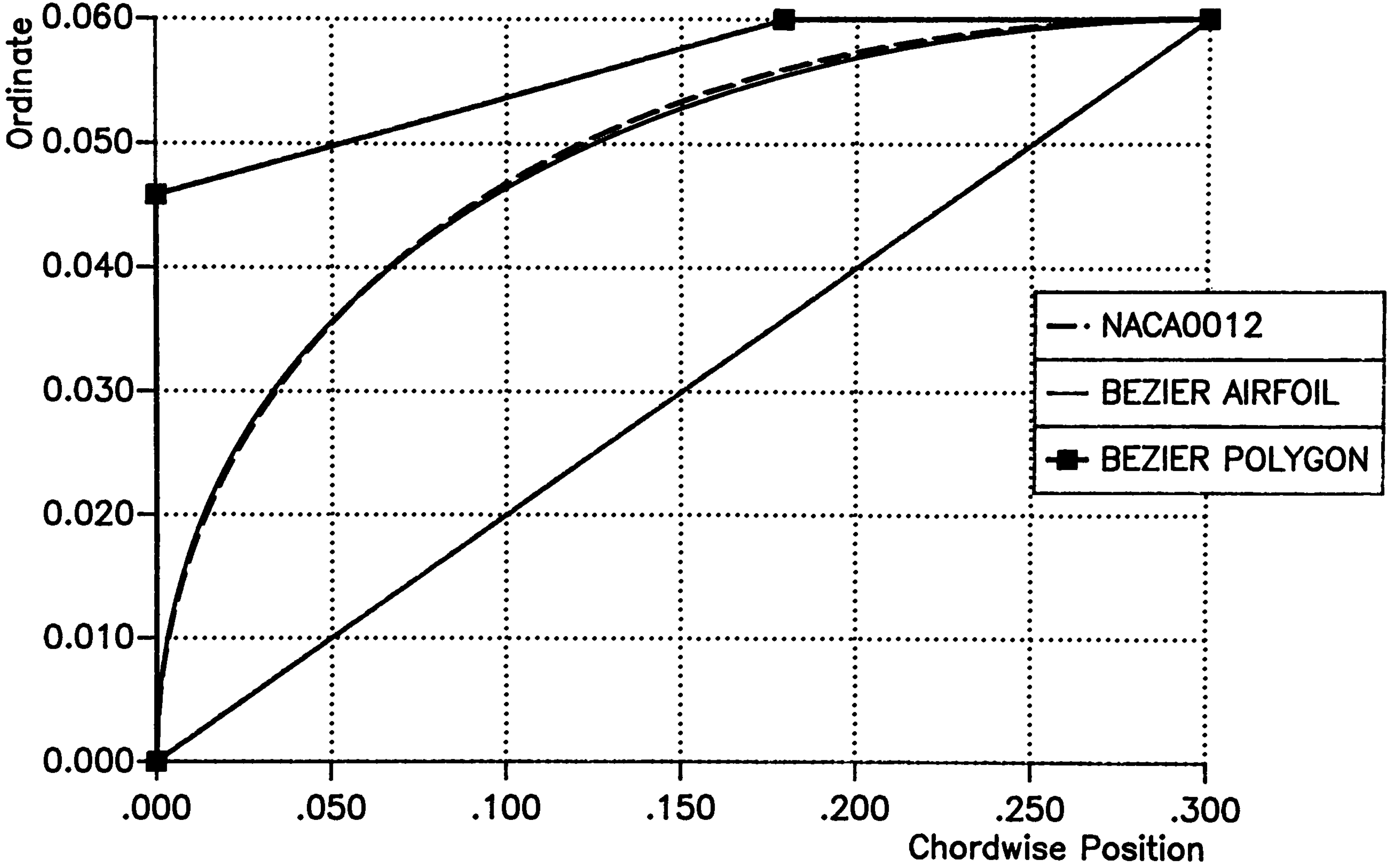

Leading Edge Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier

Figure 4.29 - Leading Edge Symmetric Thickness Distribution - NACA0012 vs. Bézier - Final Iteration

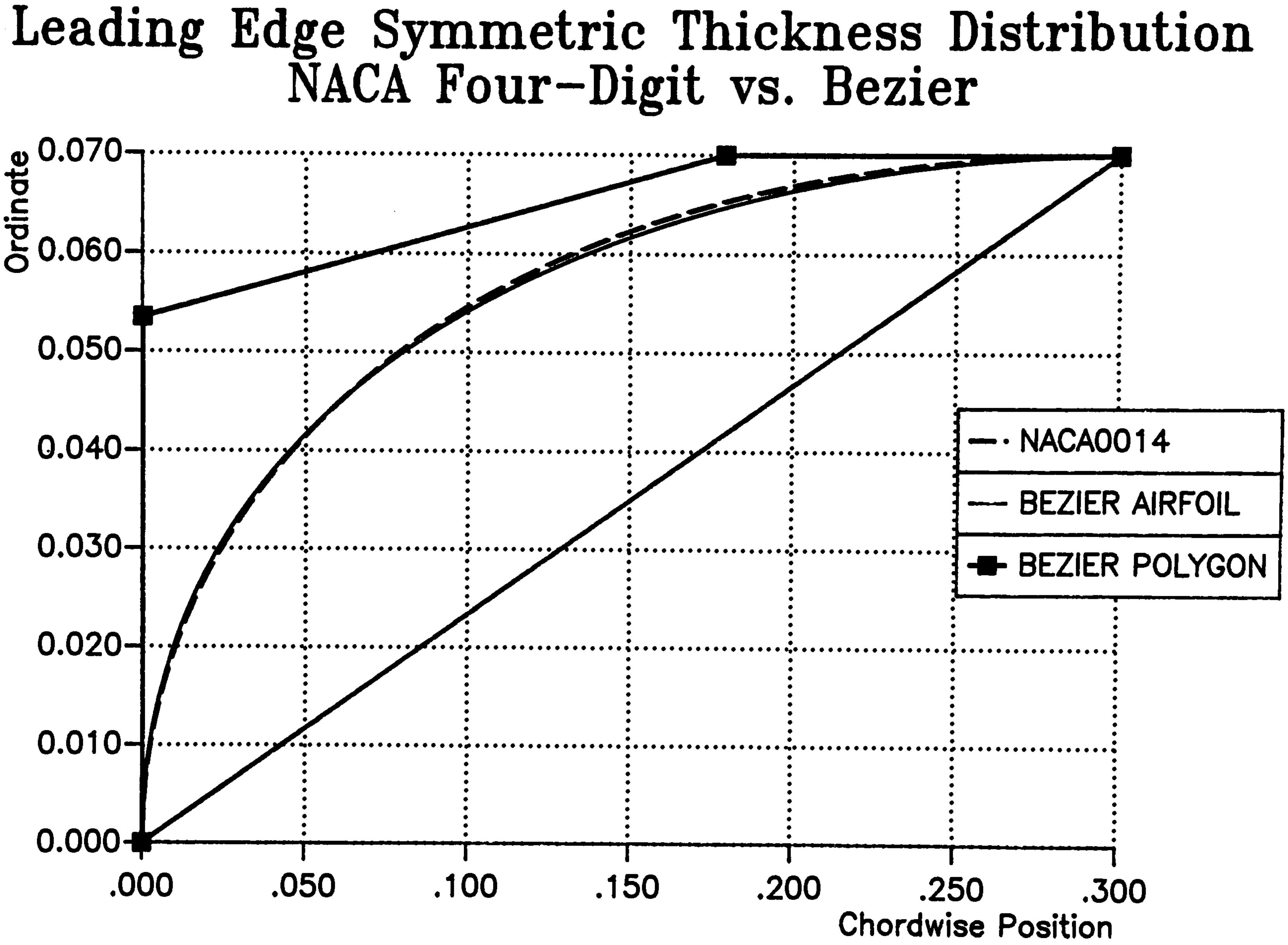


Figure 4.30 - Leading Edge Symmetric Thickness Distribution - NACA0014 vs. Bézier - Final Iteration

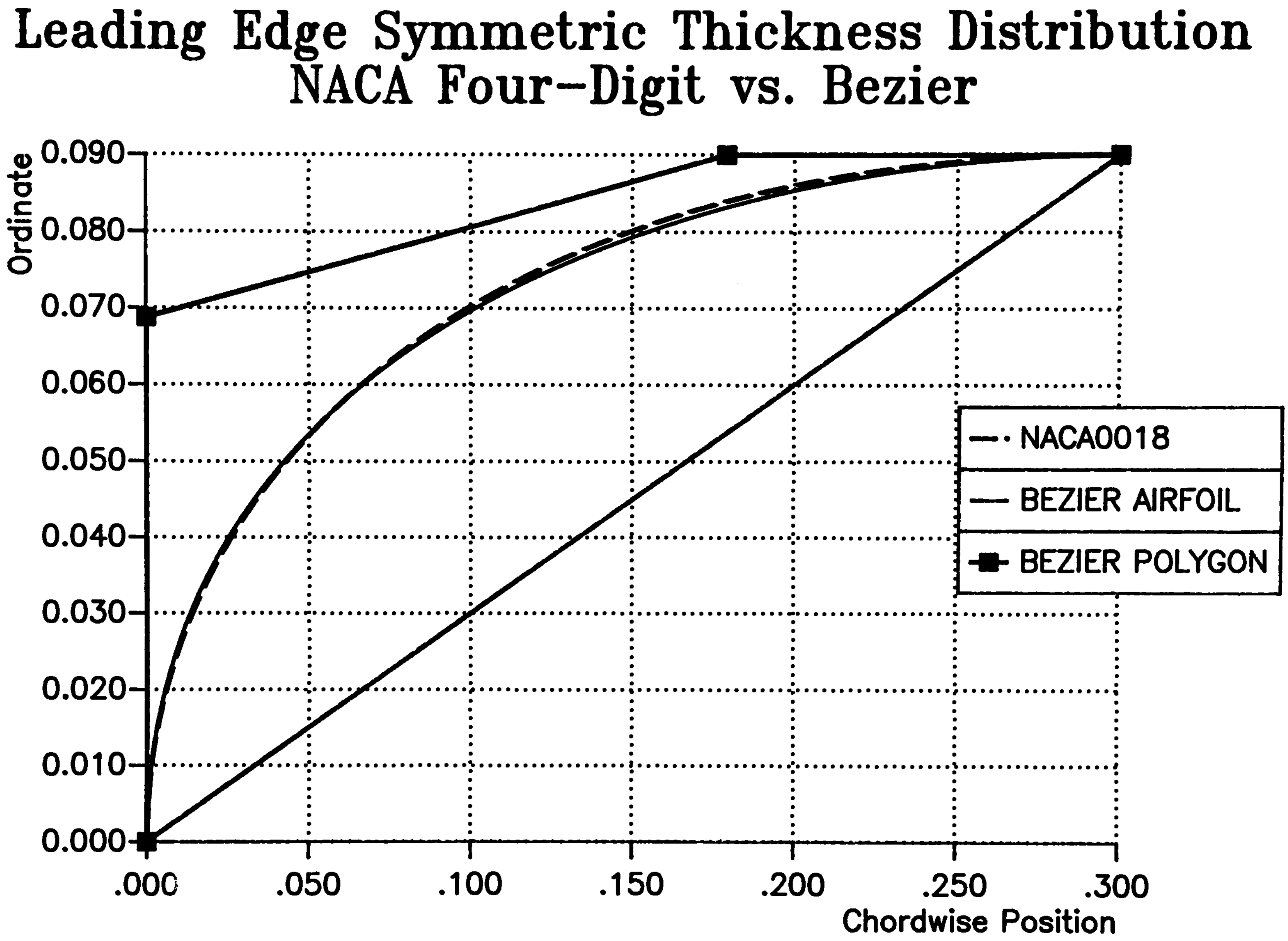


Figure 4.31 - Leading Edge Symmetric Thickness Distribution - NACA0018 vs. Bézier - Final Iteration

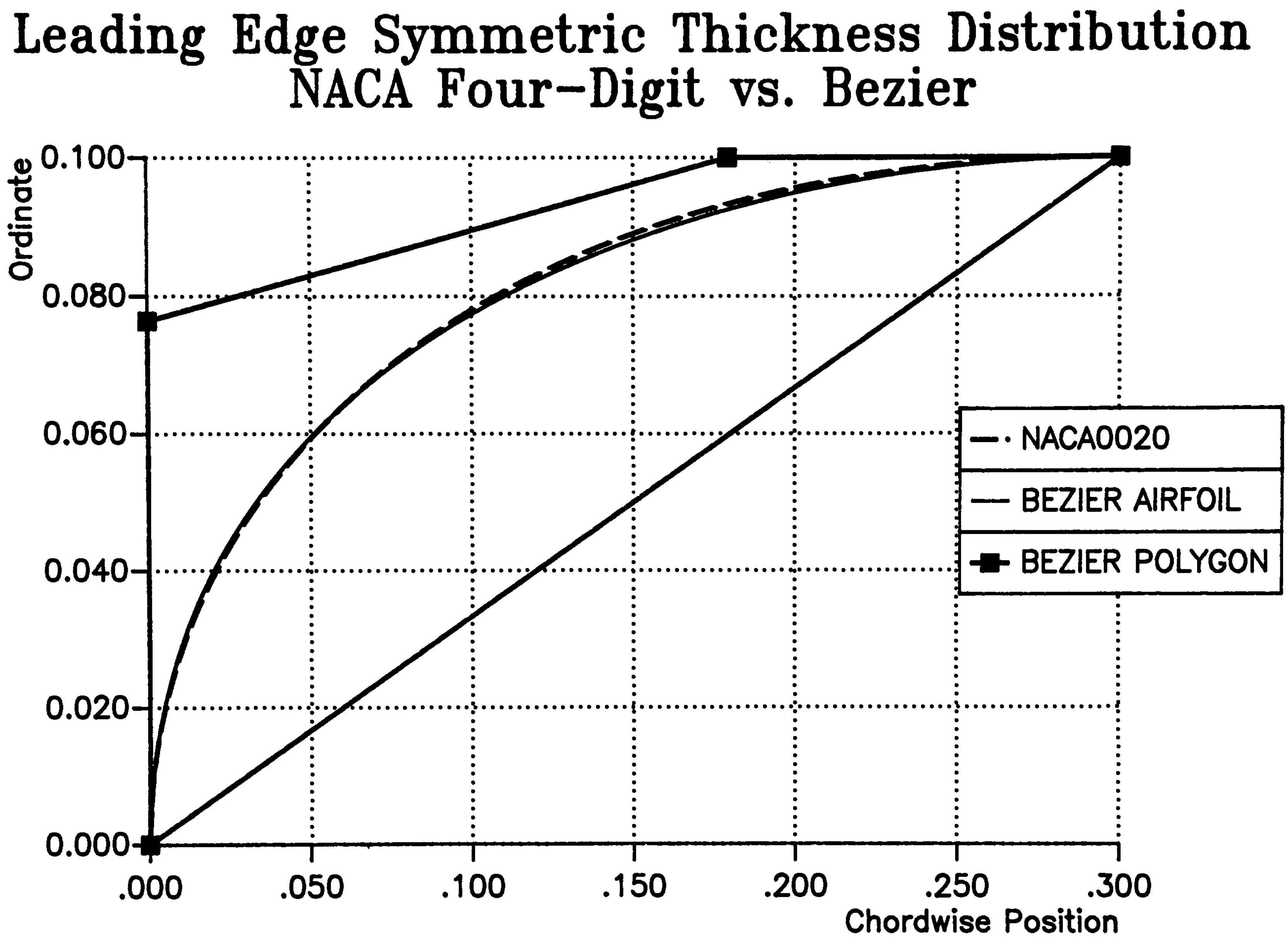


Figure 4.32 - Leading Edge Symmetric Thickness Distribution - NACA0020 vs. Bézier - Final Iteration

4.1.3.2 Trailing Edge Surface

A strategy similar to that employed for determining the defining polygon of the third order Bézier curve of the leading edge section will be attempted for the section of the airfoil aft of the maximum thickness point.

Recall from equation **[2.4]** that the trailing edge angle is given by

$$\tan \xi = -1.16925\, t \qquad \textbf{[2.4]}$$

To ensure that the trailing edge slope is identical to that defined for the NACA four-digit airfoil, a polygon vertex must be placed on the line (in point-slope form) such that

$$(y - 0.0105\, t) = -1.16925\, t(x - 1.0) \qquad \textbf{[4.6]}$$

The reader should observe here that the ordinate at the trailing edge is a small number, but not zero. This can be verified by inserting an *x*-value of 1 in equation [2.1].

Simplifying into slope-intercept form,

$$y = f(x, t) = t(-1.16925x + 1.17975) \qquad \textbf{[4.7]}$$

The chordwise position at which the line defined by **[4.7]** and the line $y=t/2$ intersect will be denoted x_{int} and is determined by solving

$$\frac{t}{2} = t(-1.16925x_{int} + 1.17975) \qquad \textbf{[4.8]}$$

This yields

$$x_{int} = 0.58135557$$

Note that this value is independent of the thickness ratio *t*.

In order to maintain continuity at $x=.3c$, a polygon vertex $\mathbf{B}_1$ must be placed on the line $y=t/2$. The cubic Bézier defining polygon at this stage is illustrated in Figure 4.33.

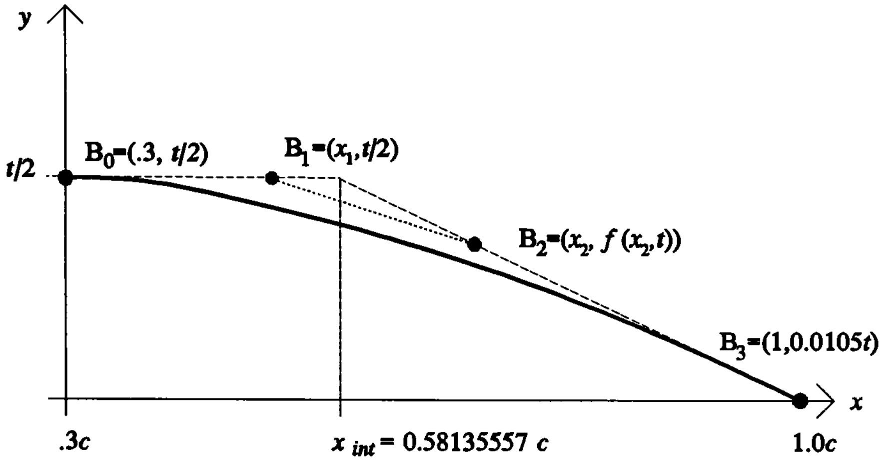


Figure 4.33 Trailing Edge Bézier Defining Polygon

The Bézier curve defining polygon for the segment aft of the chordwise position of maximum thickness becomes

$$\begin{bmatrix} \mathbf{B}_0^T \\ \mathbf{B}_1^T \\ \mathbf{B}_2^T \\ \mathbf{B}_3^T \end{bmatrix} = \begin{bmatrix} .3c & \frac{t}{2} \\ x_1 & \frac{t}{2} \\ x_2 & f(x_2,t) \\ 1.0 & 0.0105\,t \end{bmatrix}$$

where, from equation [4.7], $f(x,t)$ is given as

$$f(x,t) = t(1.17975 - 1.16925x)$$

As in the case of the leading edge segment, only two coordinates of the defining polygon vertices are left undetermined. Proceeding as before, the golden section method was utilized to divide each of the intervals $.3 \le x_1 \le x_{int}$ and $x_{int} \le x_2 \le 1.0$. Four possible cases were thus created, denote as before "Case (a,b)" with a denoting the values for x_1 and b representing the values for x_2 as determined by golden section on their respective intervals. These are included as Figures 4.34 - 4.37, pages 65-68.

These values are

$$x_1 = \begin{cases} (1-\tau)(0.58135557) + \tau(0.3) = 0.407468 & (1) \\ (1-\tau)(0.3) + \tau(0.58135557) = 0.473887 & (2) \end{cases}$$

and

$$x_2 = \begin{cases} (1-\tau)(1.0) + \tau(0.58135557) = 0.741263 & (1) \\ (1-\tau)(0.58135557) + \tau(1.0) = 0.840092 & (2) \end{cases}$$

Surprisingly, only one iteration of the golden section method was required to achieve excellent results; this corresponds to case (2,1). From these results, the matrix formulation for the cubic Bézier curve emulating the section of a NACA00*xy* airfoil from $.3c \leq x \leq 1.0c$ is

$$\mathbf{P}(\nu) = \begin{bmatrix} \nu^3 & \nu^2 & \nu & 1 \end{bmatrix} \begin{bmatrix} -1 & 3 & -1 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & 3 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} .3c & t/2 \\ \alpha & t/2 \\ \beta & f(\beta, t) \\ 1.0 & 0.0105\,t \end{bmatrix}$$

where

$$\alpha = 0.3 + 0.2813557\tau = 0.473887$$

$$\beta = 1 + \tau(x_{int} - 1) = 0.741263$$

And $f(\beta,t)$ is as given in [4.7].

As in the case of the leading edge section, because the cubic Bézier defining polygon vertices are linear in t, the affine transformation property guarantees that the shape of the curve is invariant regardless of the value of t. Figures 4.38 and 4.39, pages 69-70 will visually confirm this.

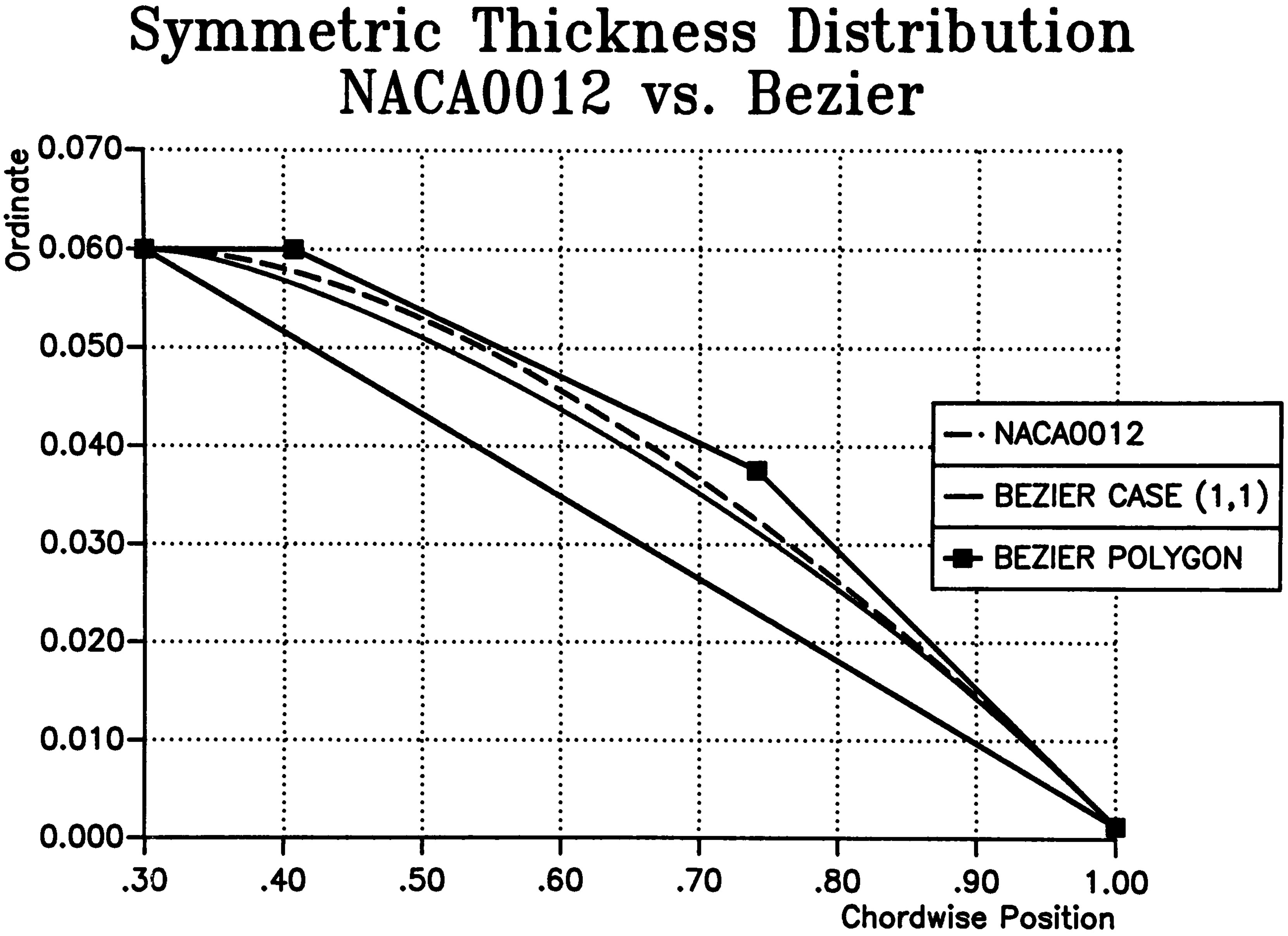


Figure 4.34 - Trailing Edge Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(1,1)

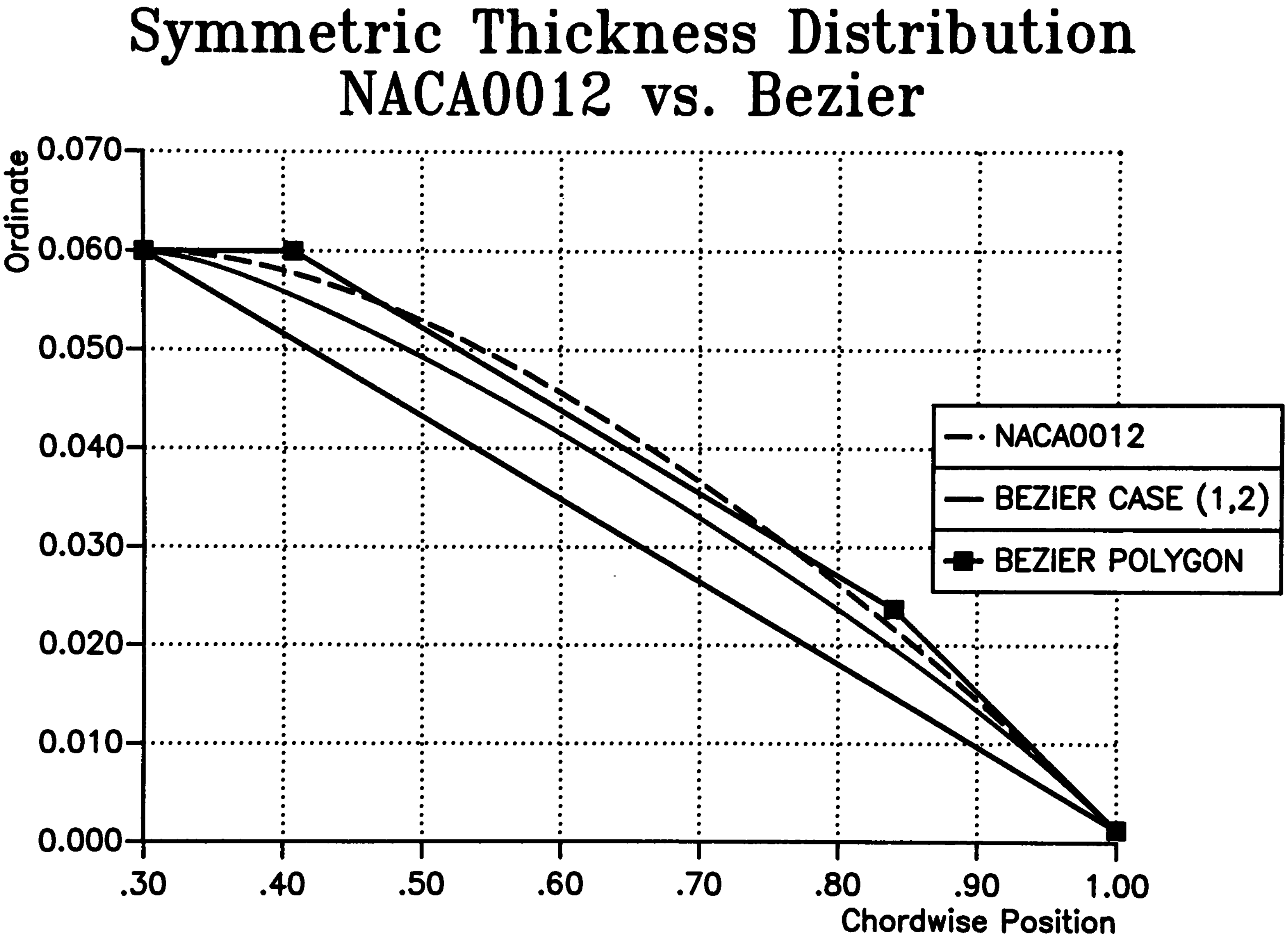


Figure 4.35 - Trailing Edge Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(1,2)

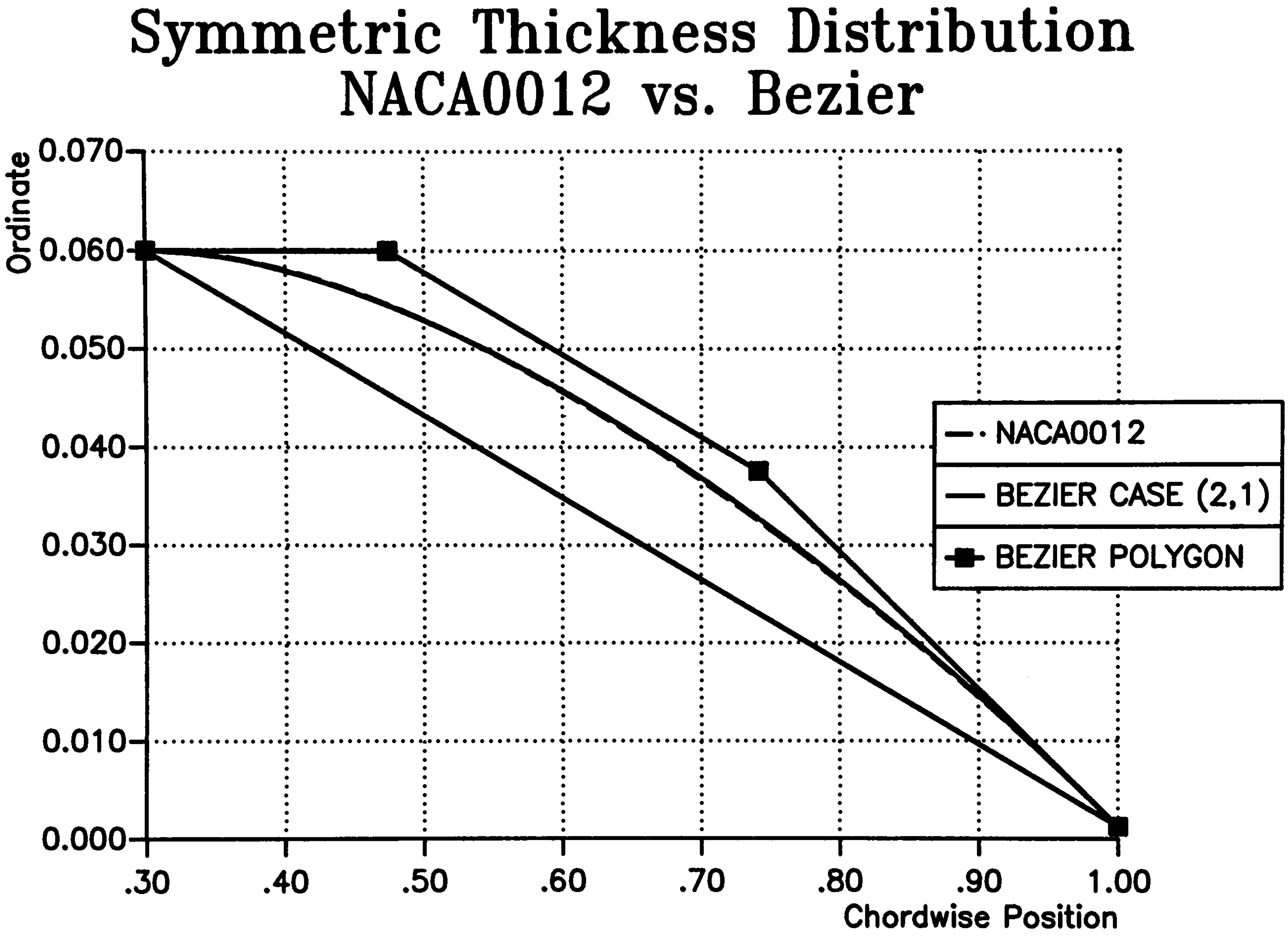


Figure 4.36 - Trailing Edge Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(2,1)

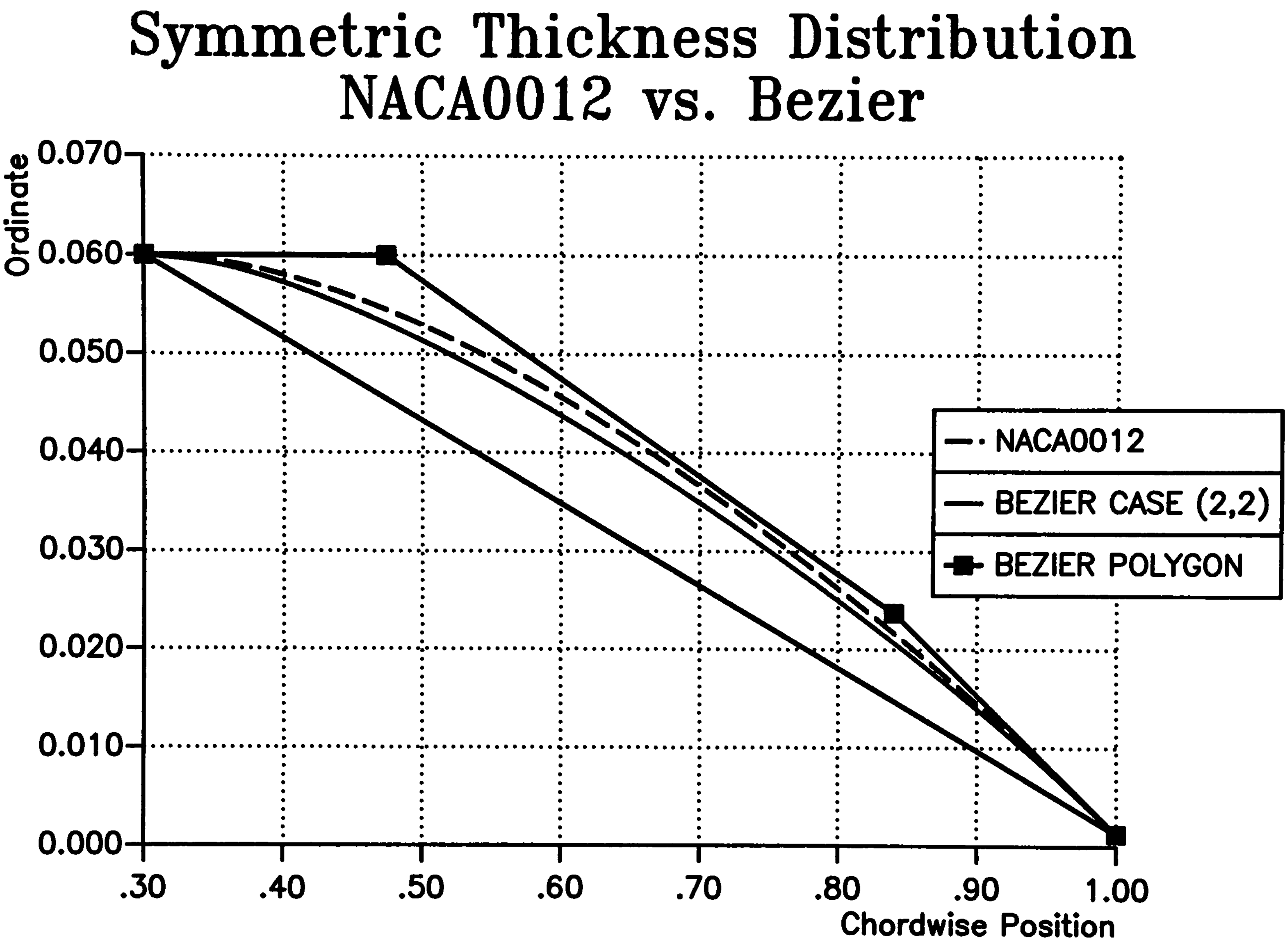


Figure 4.37 - Trailing Edge Symmetric Thickness Distribution - NACA0012 vs. Bézier - Case(2,2)

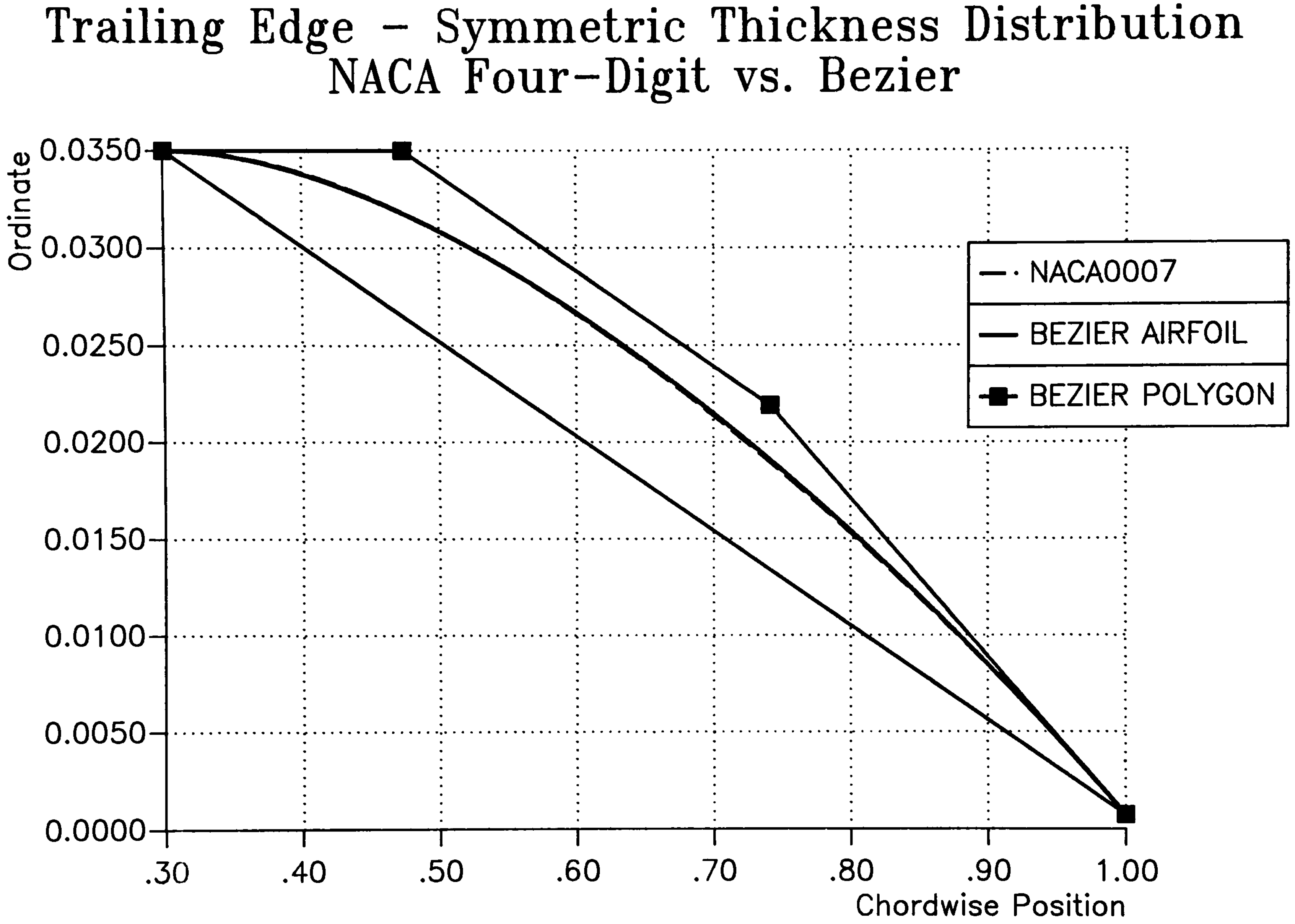


Figure 4.38 - Trailing Edge Symmetric Thickness Distribution - NACA0007 vs. Bézier - Case(2,1)

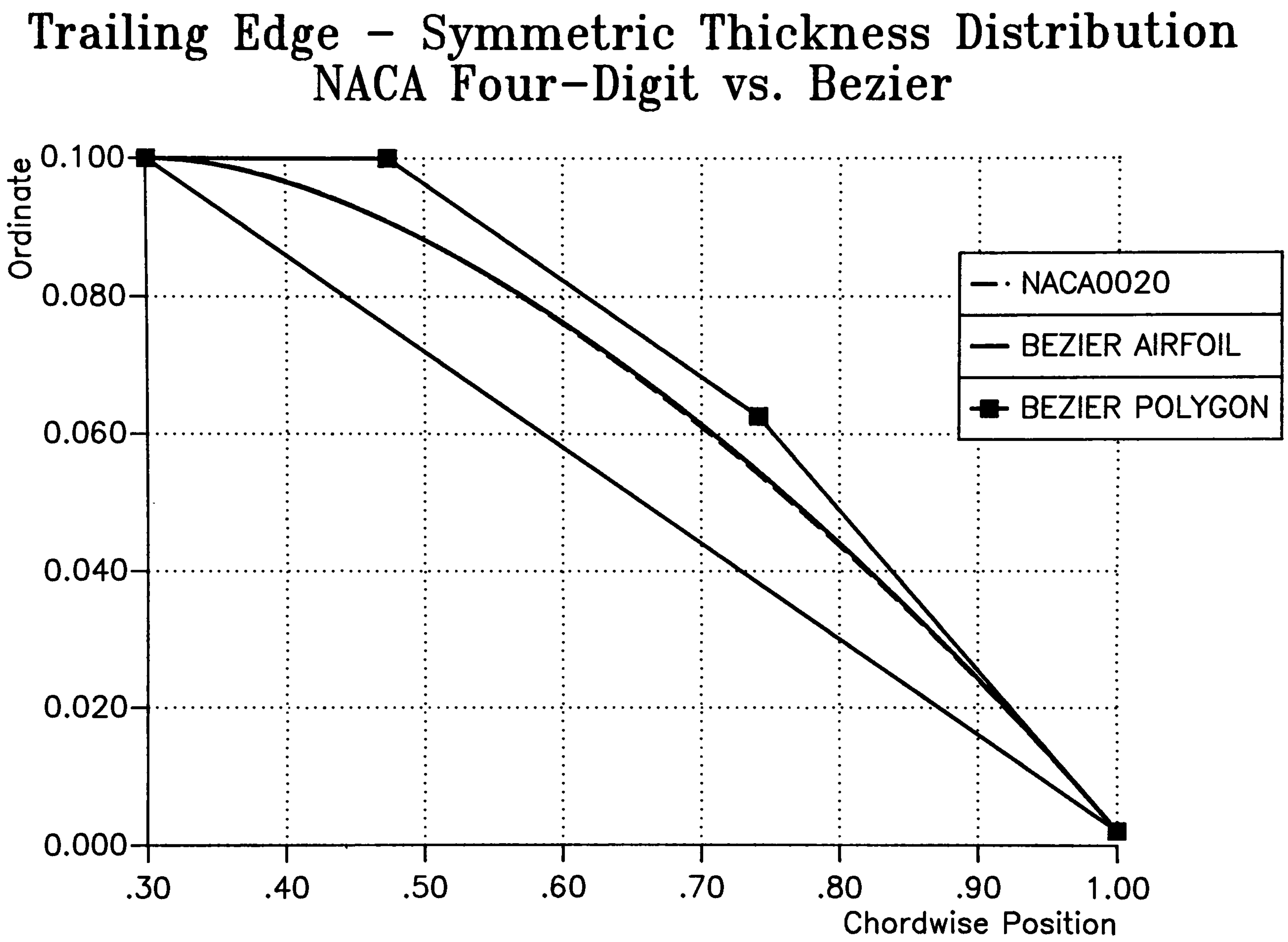


Figure 4.39 - Trailing Edge Symmetric Thickness Distribution - NACA0020 vs. Bézier - Case(2,1)

4.1.3.3 Assembling the Pieces

By first generating the leading edge section coordinates and appending to them the list of Bézier points generated on the trailing section, a close fitting replica of the upper surface may be obtained. Because thus far only symmetric airfoils have been considered, the ordinates on the lower surface are simply the negative of their upper surface counterparts.

Since the intermediate polygon vertices at $\mathbf{B}_2$ and $\mathbf{B}_3$ for the leading edge and $\mathbf{B}_0$ and $\mathbf{B}_1$ for the trailing edge are collinear ($\mathbf{B}_{3_{leading}}$ and $\mathbf{B}_{0_{trailing}}$ are coincident), continuity at $x=.3c$ is maintained. Should, however, tangent or curvature information be required (for example, in generation of an orthogonal coordinate system with the entire airfoil as the origin) the tangent and curvature vectors, though possessing identical directions, do not share the same magnitude. This minor inconvenience is easily overcome by normalizing all tangent and curvature vectors and using a slope-intercept form in conjunction with the airfoil coordinates at the point of computation.

The FORTRAN program SYMMFOIL.FOR, located in Appendix F, will generate both upper and lower surfaces of NACA four-digit symmetric airfoils using the material presented here. Examples of NACA0005 through NACA0024 airfoils are illustrated in Appendix D.

4.1.3.4 Error Analysis

There are some minor differences between the desired shape and that generated using the Bézier curves. First, the chordwise position of maximum thickness for the true airfoil section lies very close to $.3c$, but not exactly; the maximum thickness at $x=.3c$ exceeds the maximum thickness by a minute amount. The Bézier curve allows the user to place this point precisely at the desired coordinate. These differences are minimal, however. Table 4.3 on the following page shows both absolute and sum-of-squares error between the two types of airfoil for various values of the thickness distribution t, computed by generating 99 points on the upper surface of each airfoil.

Table 4.3 Absolute and Least-Squares Error for Various Thickness Ratios Bézier vs. Conventional

Thickness Ratio, t (Percent of Chord)	$\sum_{i=1}^{99} \lvert y_{true} - y_{Bezier} \rvert$	$\sum_{i=1}^{99} (y_{true} - y_{Bezier})^2$
5	0.0084086656	1.2260476×10^{-6}
6	0.0100903911	1.7655083×10^{-6}
8	0.0134538600	3.1386803×10^{-6}
10	0.0168173172	4.9041857×10^{-6}
12	0.0201807829	7.0620328×10^{-6}
13	0.0218625263	8.2880832×10^{-6}
15	0.0252259816	1.1034424×10^{-5}
17	0.0285894519	1.4173112×10^{-5}
20	0.0336346468	1.9616762×10^{-5}
23	0.0386798413	2.5943183×10^{-5}
24	0.0436159884	2.8248186×10^{-5}

4.2 Cambered Airfoils

With the success obtained in the attempt to emulate NACA Four-digit symmetric airfoils, it seems logical that a similar strategy be employed for the cambered case. The generation of cambered airfoil surface data points as described in section 2.2 is a tedious procedure. Because the upper surface of a generic NACA four-digit airfoil has only one point of zero slope, the investigation will concentrate on this surface. Any viable method (or methods) can then be extended later to the lower surface.

4.2.1 Review

The coordinates of the upper surface of a NACA four-digit cambered airfoil are defined as the combination of the mean line coordinate and the thickness distribution along a line perpendicular to the mean line. Mean lines, given by equations [2.5] are

$$
\begin{aligned}
y_c &= \frac{m}{p}\,(2px - x^2)\,, && 0 \le x \le p \\
y_c &= \frac{m}{(1-p^2)}\,[(1-2p) + 2px - x^2]\,, && p \le x \le c
\end{aligned}
\qquad [2.5]
$$

where m is the maximum ordinate of the camber line and p is the chordwise position where the maximum ordinate occurs.

The tangent to the camber line is obtained via

$$y_c' = \tan\theta = \frac{2m}{p^2}(p - x)\ , \qquad 0 \le x \le p$$
$$y_c' = \frac{2m}{(1 - p)^2}(p - x)\ , \qquad p \le x \le c \tag{2.6}$$

and the upper surface coordinates are computed from

$$x_u = x - y_t \sin\theta$$
$$y_u = y_c + y_t \cos\theta \qquad [2.7]\ (a)$$

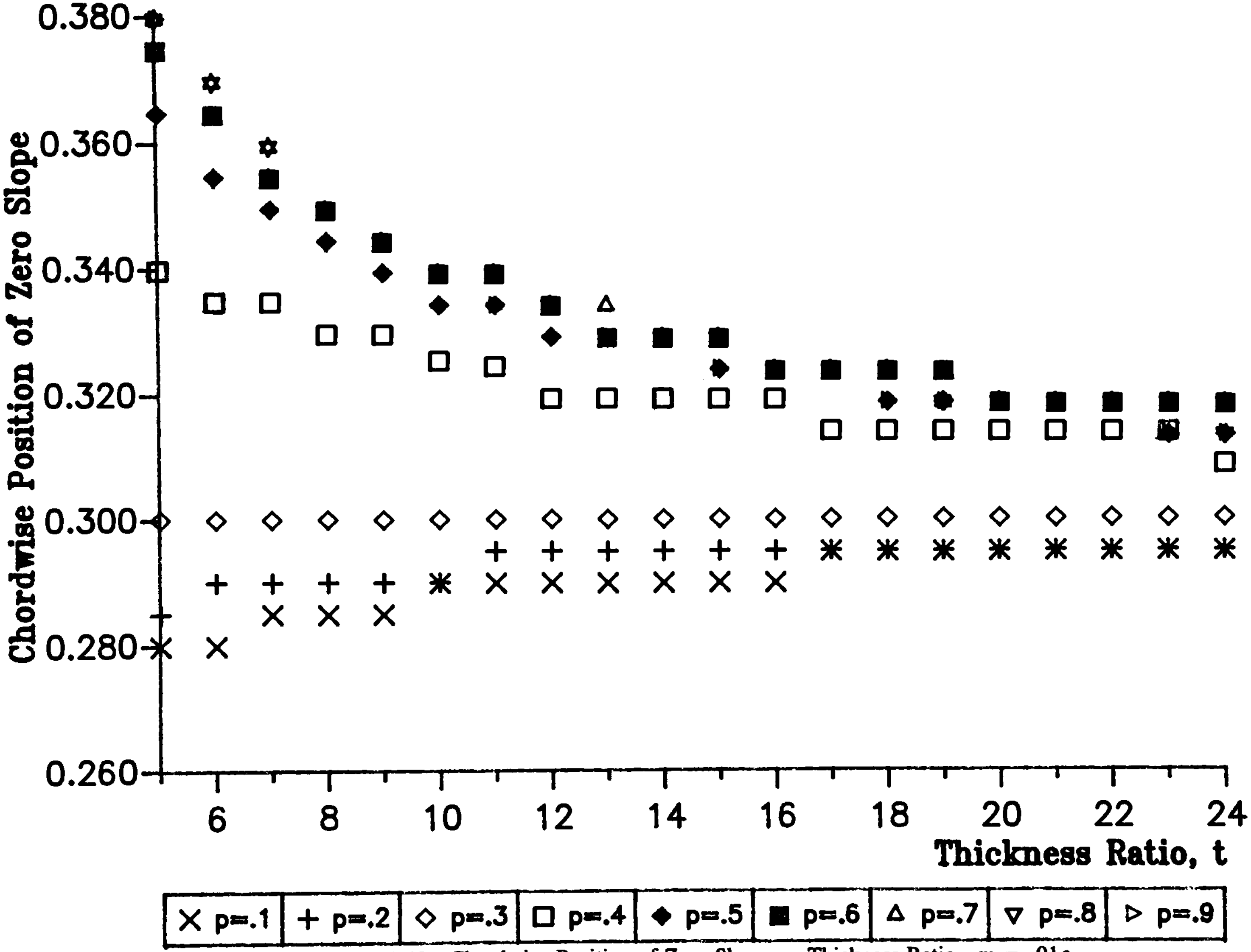
4.2.2 Determining the Points of Zero Slope

Theoretically, the most accurate method of determining zero slope points is to find the root(s) of the derivative of the cambered airfoil (equations [2.6]). Equations [4.9] show the derivatives of these equations for the upper surface.

$$\frac{\partial x_u}{\partial x} = 1 - \frac{\partial y_t \sin\theta}{\partial x} - \frac{y_t \cos\theta\, \partial\theta}{\partial x}$$
$$\frac{\partial y_u}{\partial x} = \frac{\partial y_c}{\partial x} + \frac{\partial y_t \cos\theta}{\partial x} - \frac{y_t \sin\theta\, \partial\theta}{\partial x} \tag{4.9}$$

When the root of $\partial y_u/\partial x_u$ is found, the chordwise position of zero slope is obtained. Obviously, determining the root of this equation requires a numerical evaluation; an analytical solution is impractical. For the task attempted, this equation would have to be solved for nine values of maximum camber, nine values of chordwise position of maximum camber and twenty values of thickness ratio - for a total of 1620 iterations. Discounting the combinations where $p = .3c$ (and the zero slope point lies at $(.3, t/2+m)$), the total decreases to a still unmanageable 1440.

Using small angle approximations will simplify the computations with the cost of this simplification being a loss of accuracy; due to this inaccuracy, this approach was abandoned. A decision was made to find these zero-slope points using a simple scheme whereby the entire data file of each cambered airfoil is scanned for a maximum value in the case of the upper surface, and a minimum and maximum value on the lower surface (it is possible for the lower surface to possess two points of zero slope). The FORTRAN program CAMBER.FOR (Appendix F) was written for this purpose. The results of these tedious comparisons are contained in the data files UTRENDS.DAT and LTRENDS.DAT, located in Appendix G. Plots of the upper surface data are included as Figures 4.40 - 4.57 on the pages following.



Upper Surface Points of Zero Slope

Maximum Camber = .01c

Figure 4.40 - Chordwise Position of Zero Slope vs. Thickness Ratio - $m = .01c$

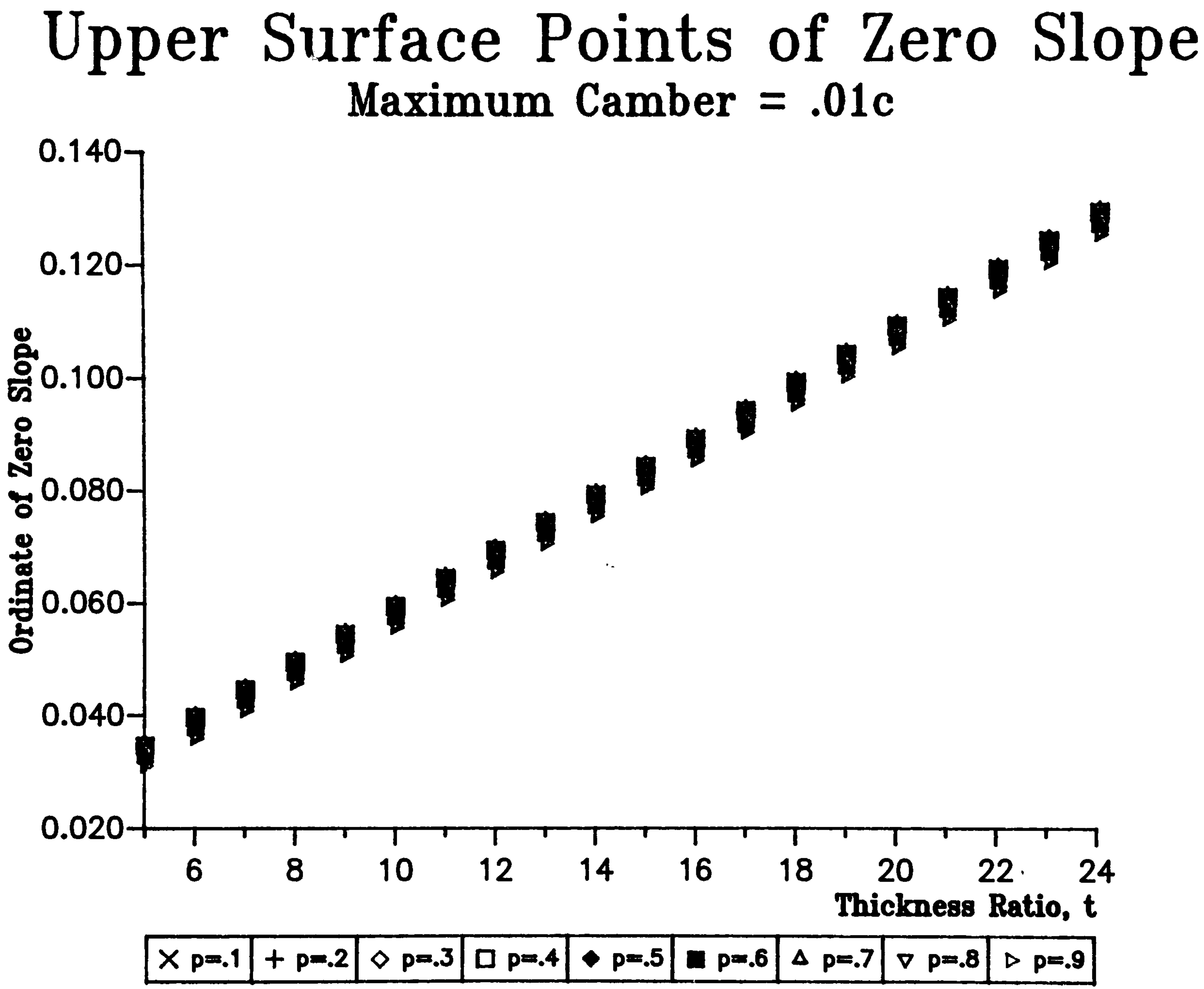


Figure 4.41 - Ordinate of Zero Slope vs. Thickness Ratio - $m = .01c$

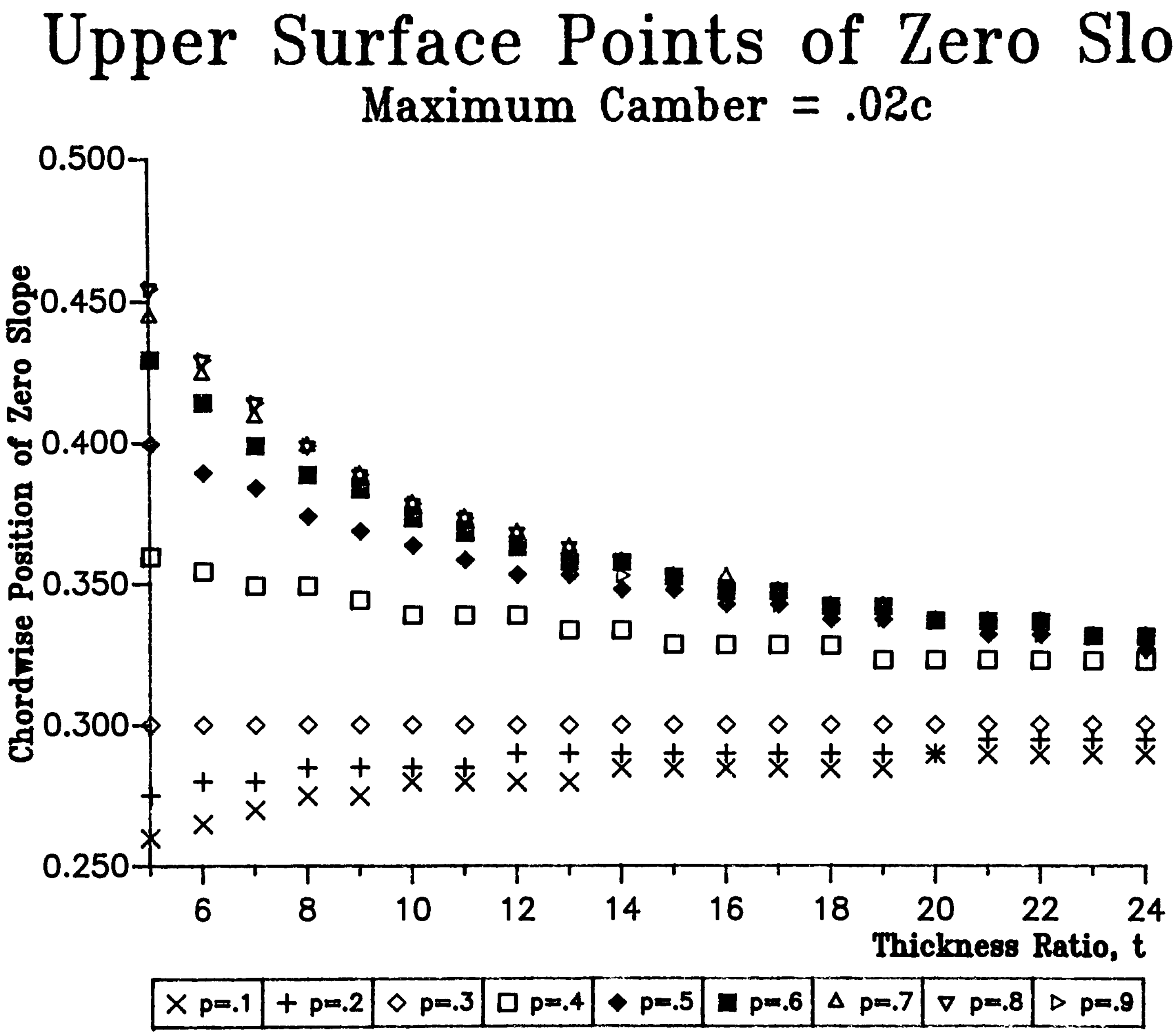


Figure 4.42 - Chordwise Position of Zero Slope vs. Thickness Ratio - m = .02c

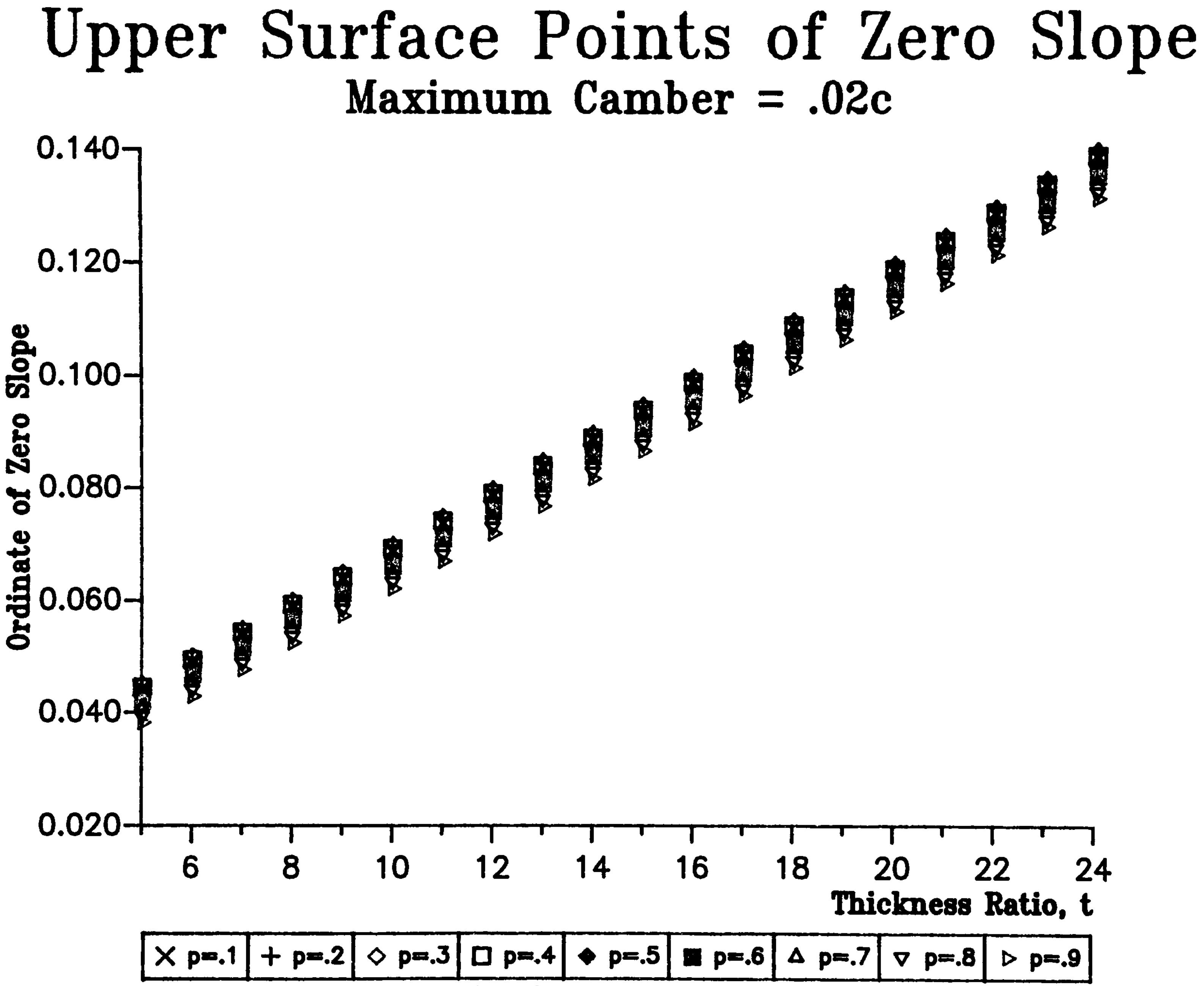


Figure 4.43 - Ordinate of Zero Slope vs. Thickness Ratio - $m = .02c$

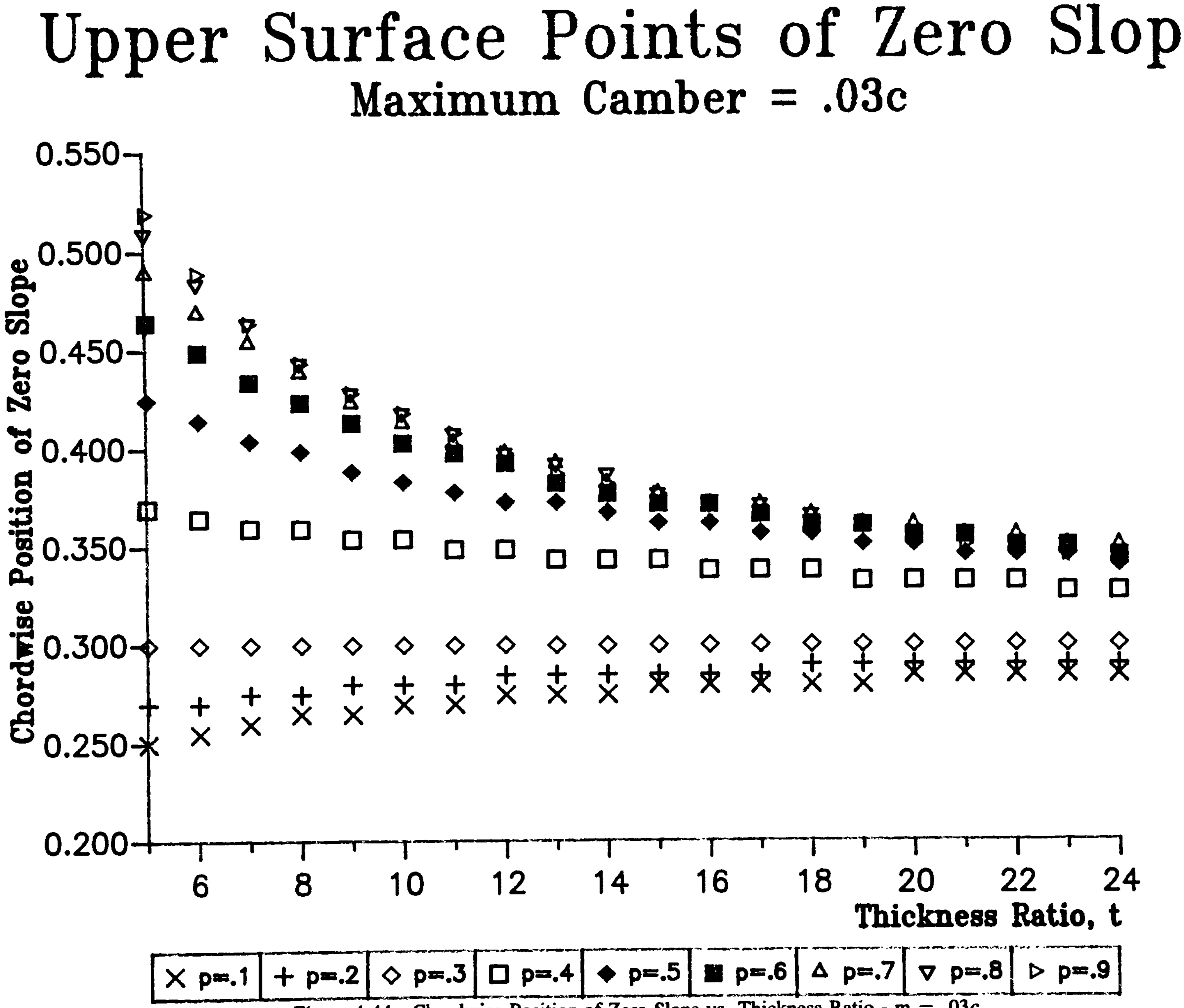


Figure 4.44 - Chordwise Position of Zero Slope vs. Thickness Ratio - m = .03*c*

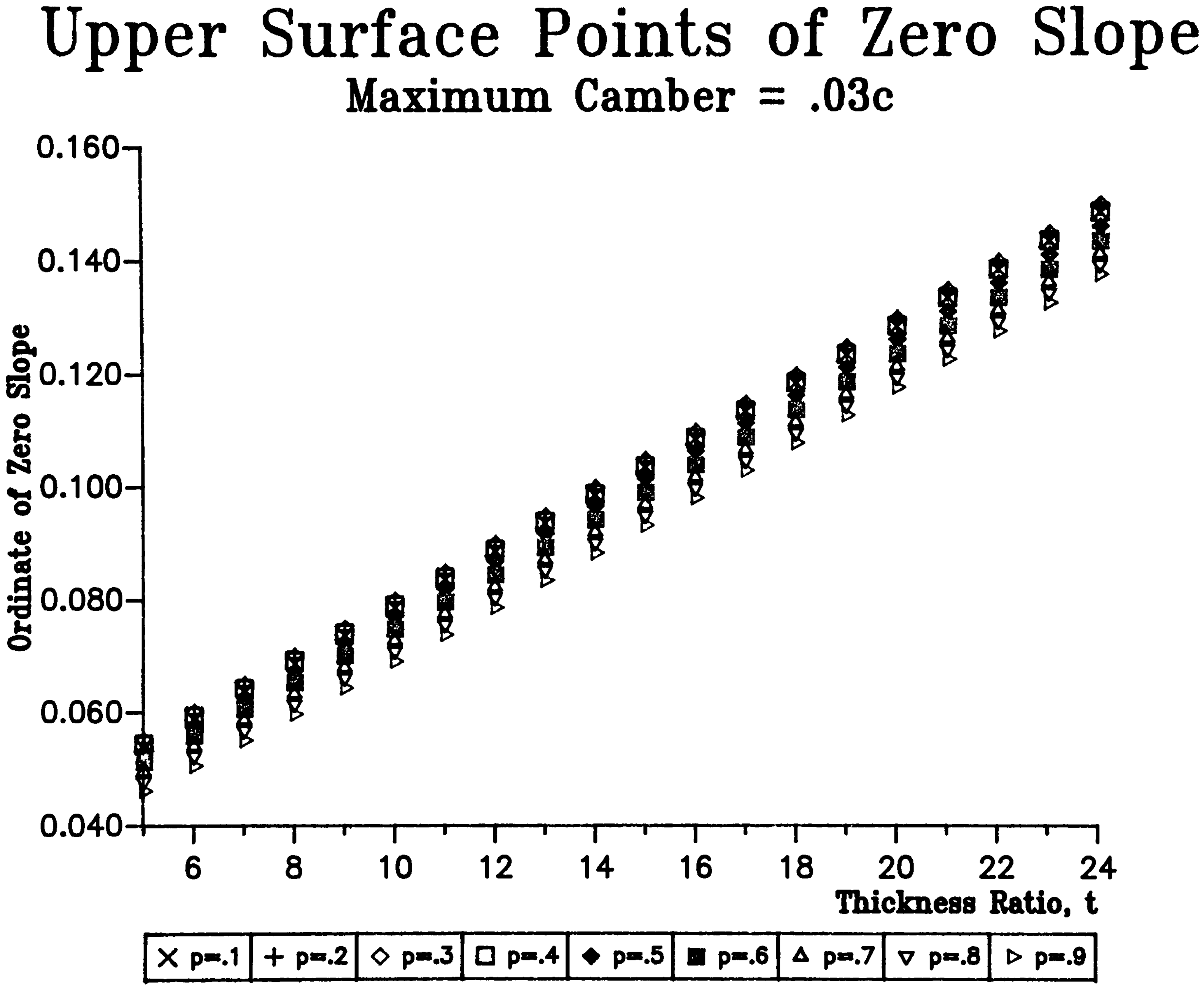


Figure 4.45 - Ordinate of Zero Slope vs. Thickness Ratio - *m* = .03*c*

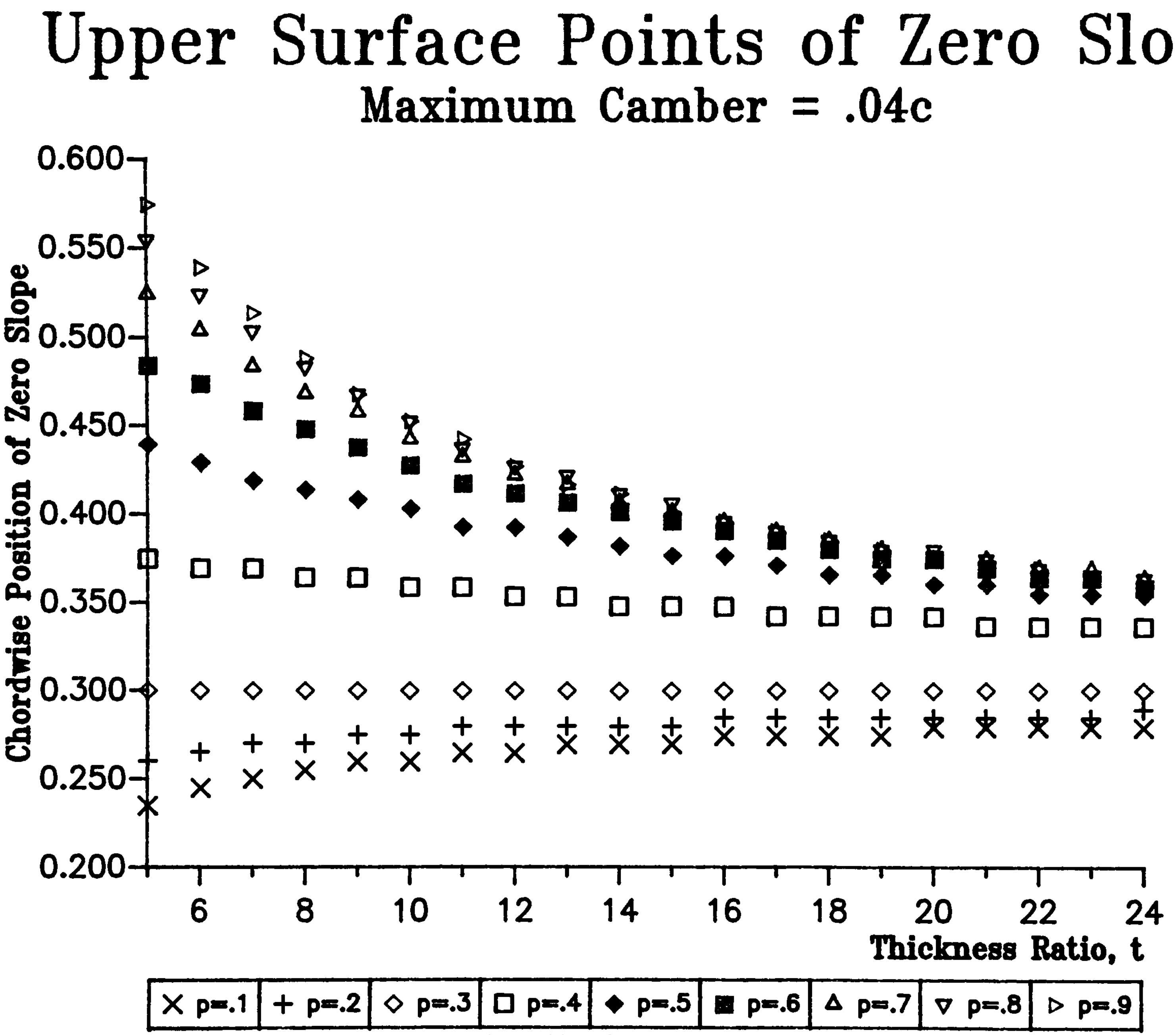


Figure 4.46 - Chordwise Position of Zero Slope vs. Thickness Ratio - $m = .04c$

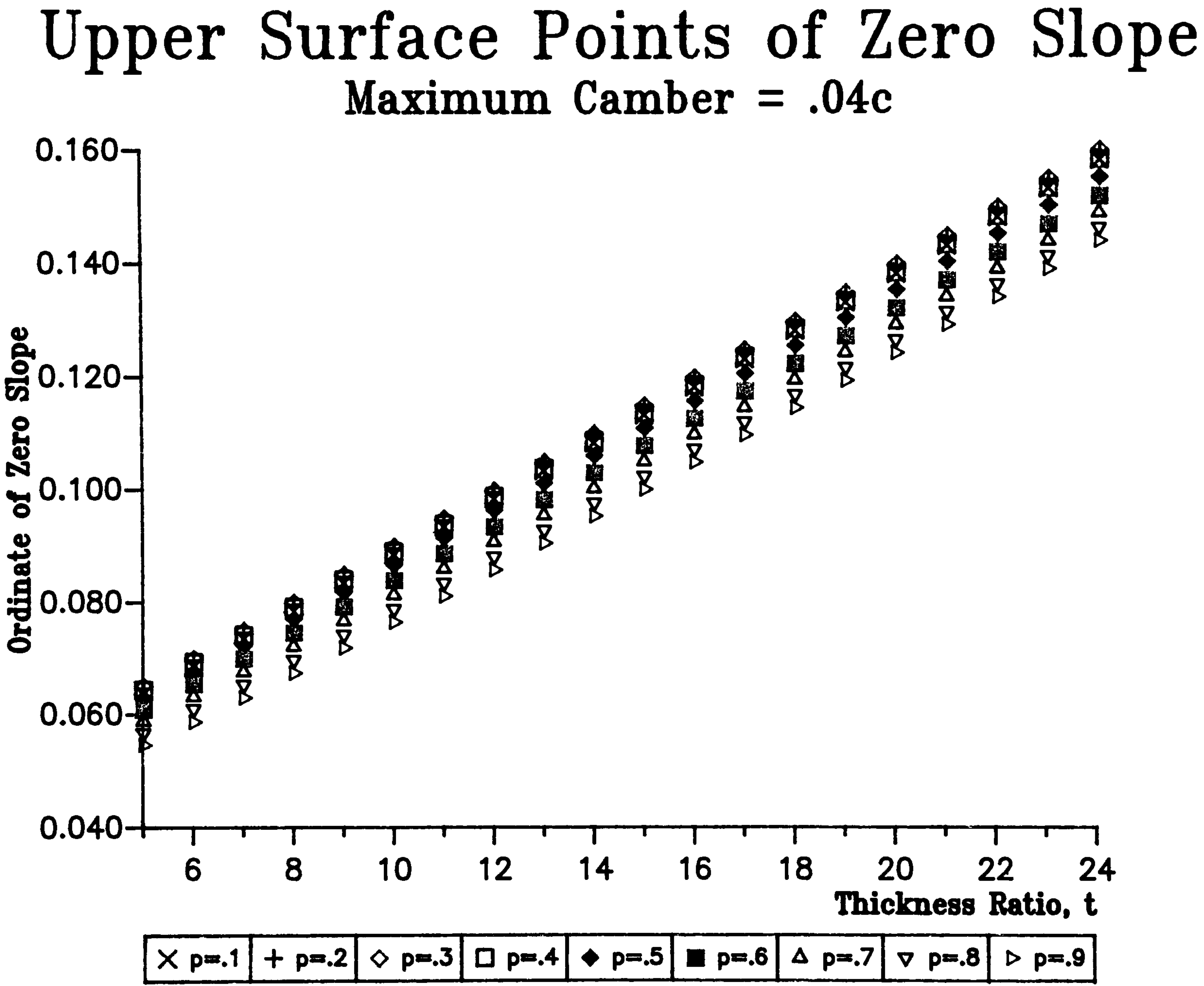


Figure 4.47 - Ordinate of Zero Slope vs. Thickness Ratio - $m = .04c$

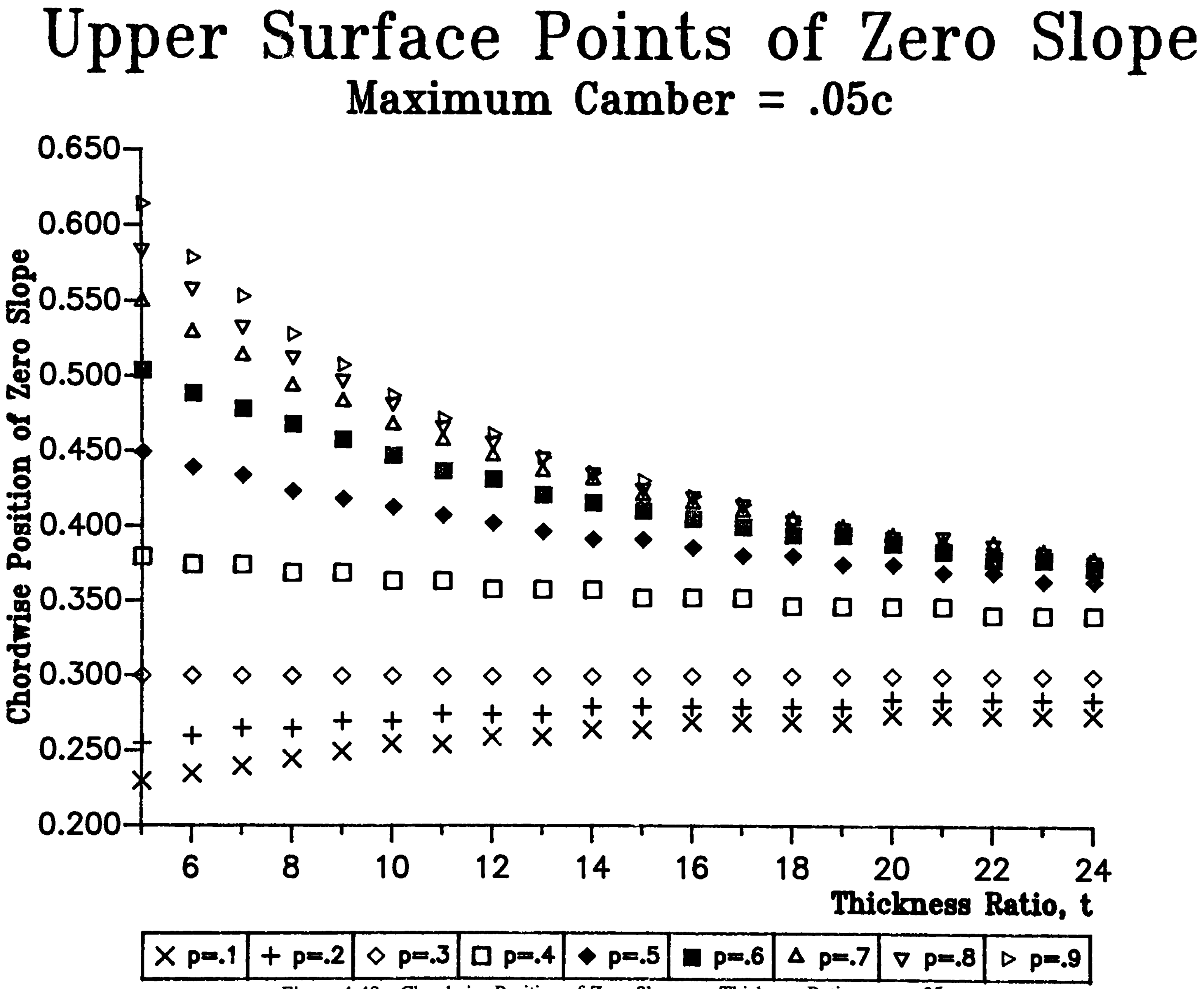


Figure 4.48 - Chordwise Position of Zero Slope vs. Thickness Ratio - $m = .05c$

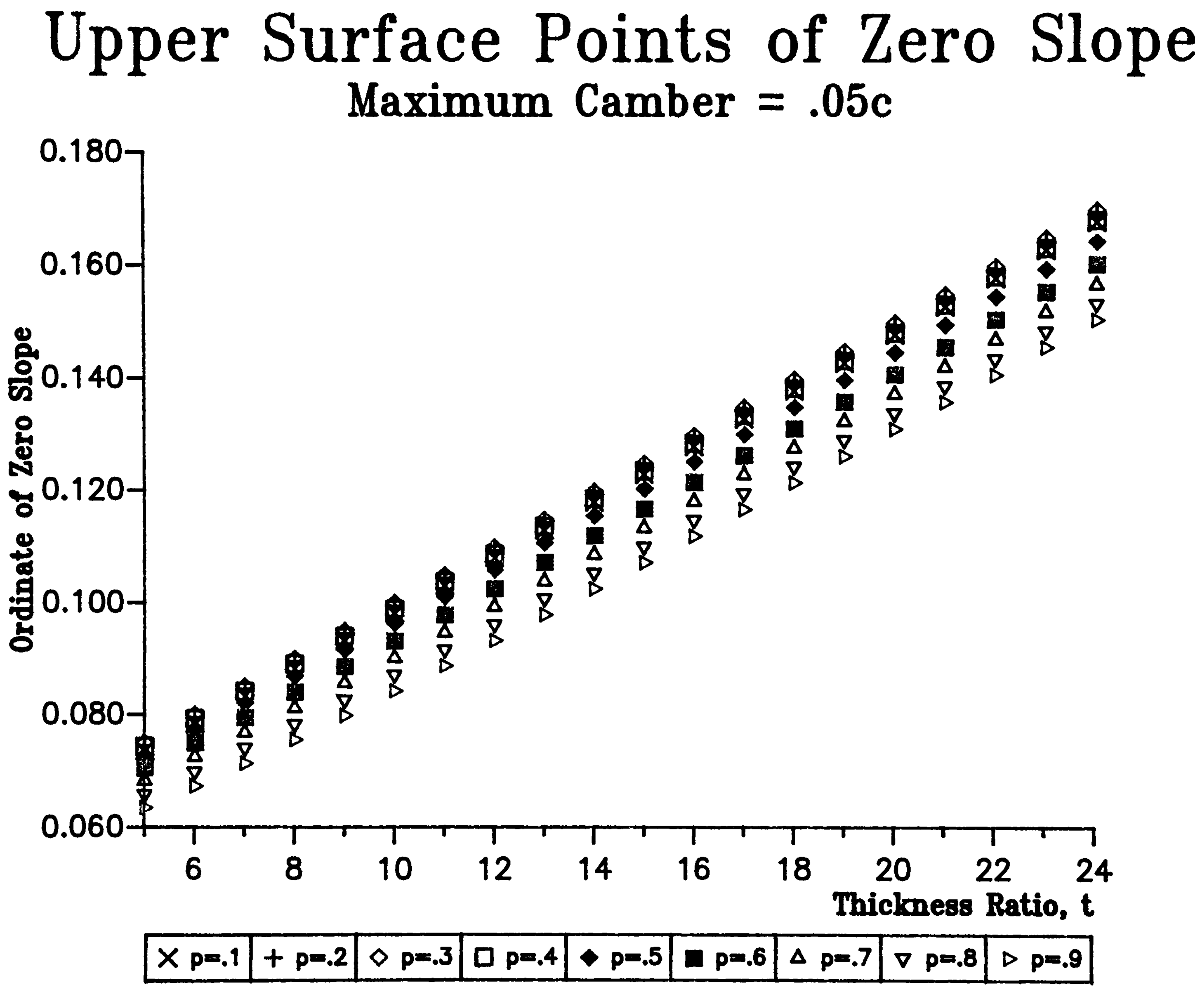


Figure 4.49 - Ordinate of Zero Slope vs. Thickness Ratio - $m = .05c$

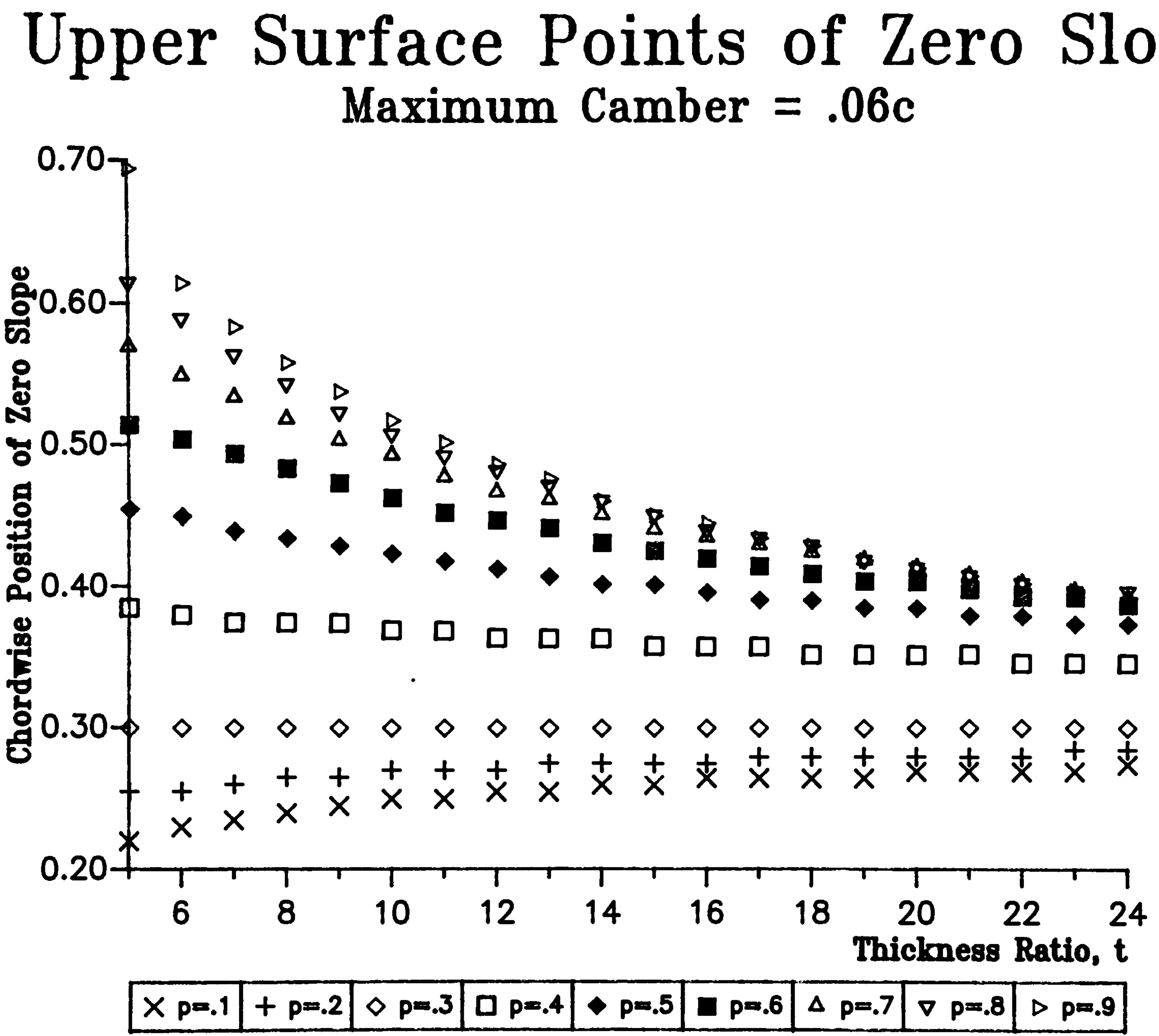


Figure 4.50 - Chordwise Position of Zero Slope vs. Thickness Ratio - $m = .06c$

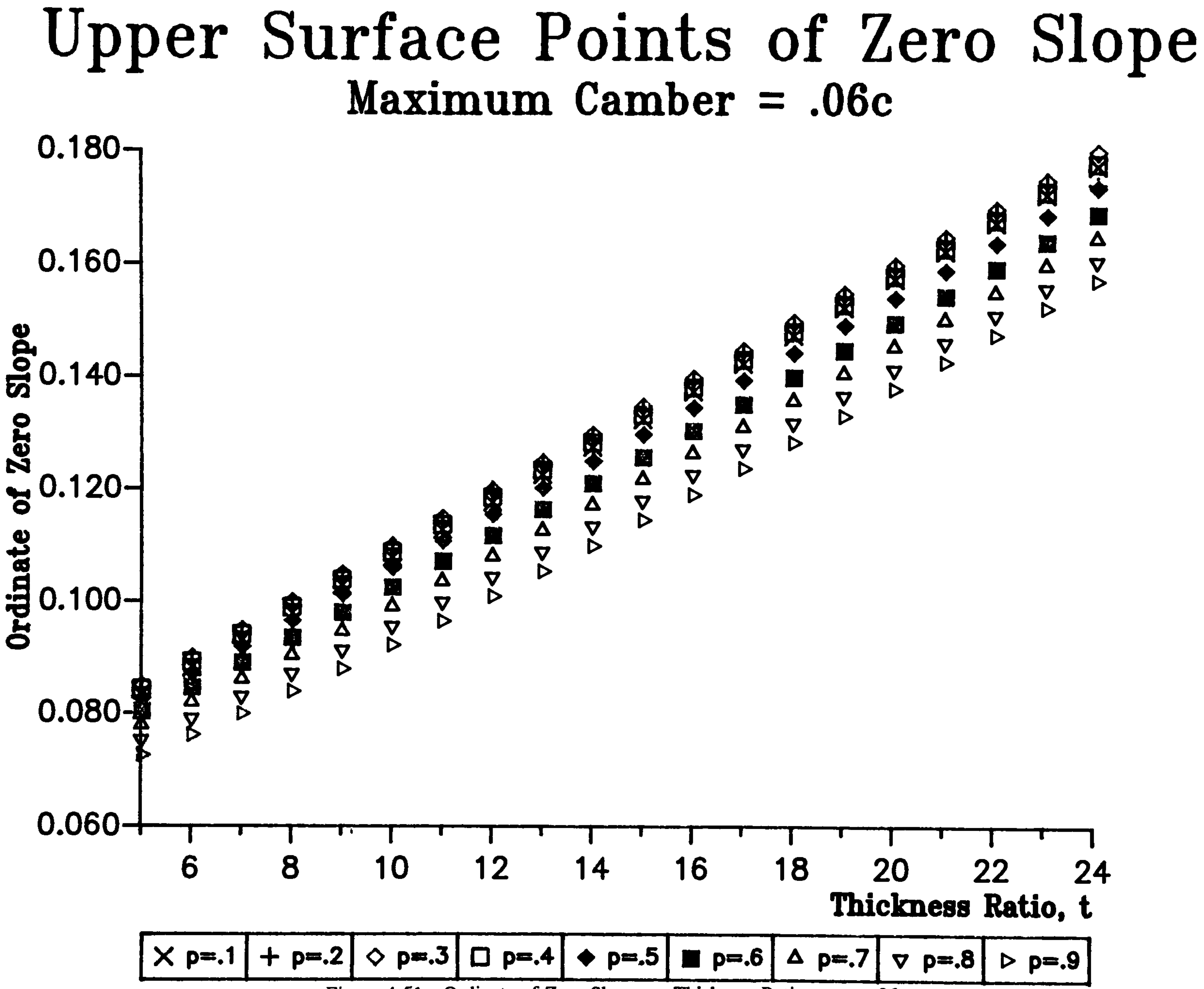


Figure 4.51 - Ordinate of Zero Slope vs. Thickness Ratio - $m = .06c$

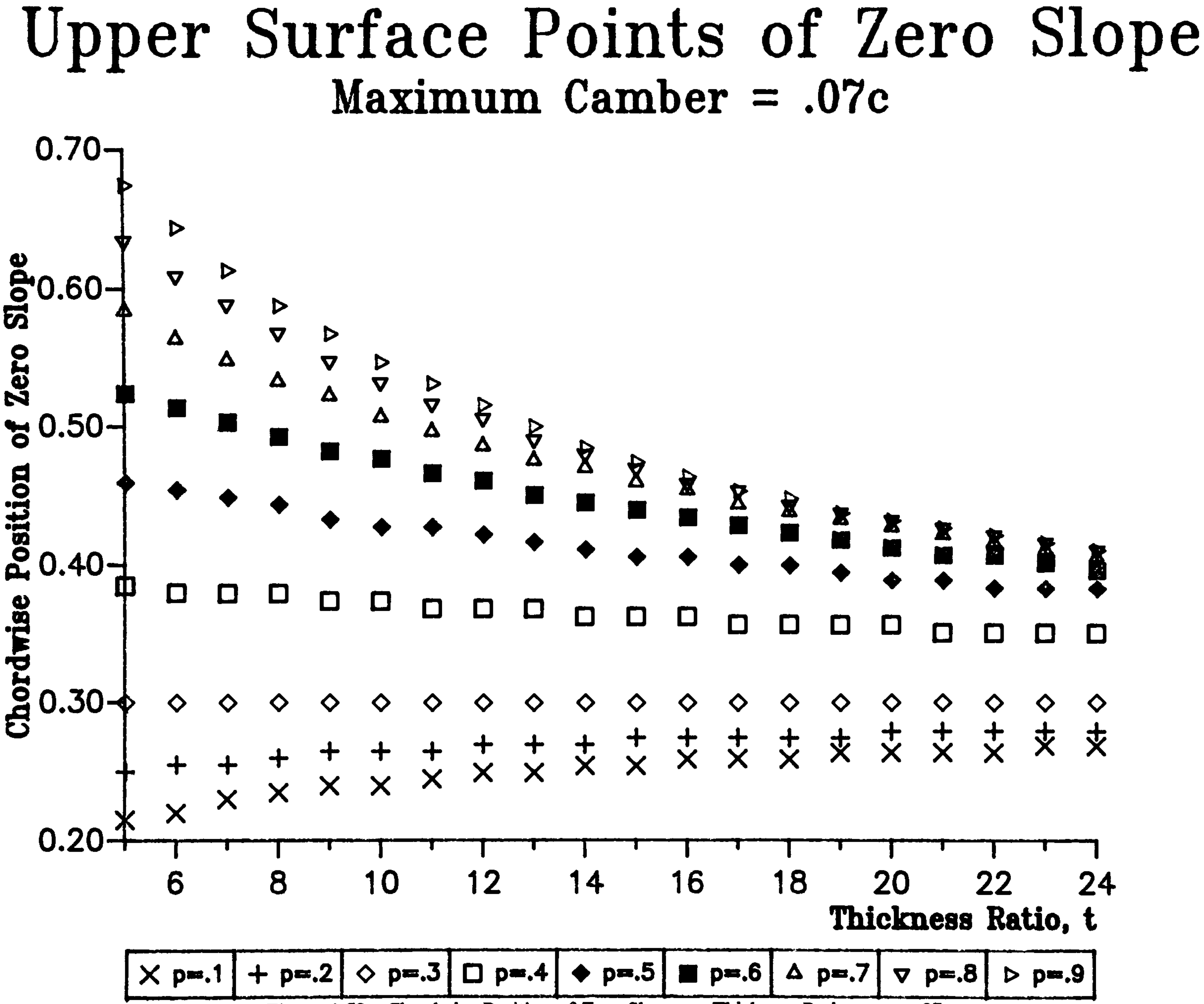


Figure 4.52 - Chordwise Position of Zero Slope vs. Thickness Ratio - m = .07*c*

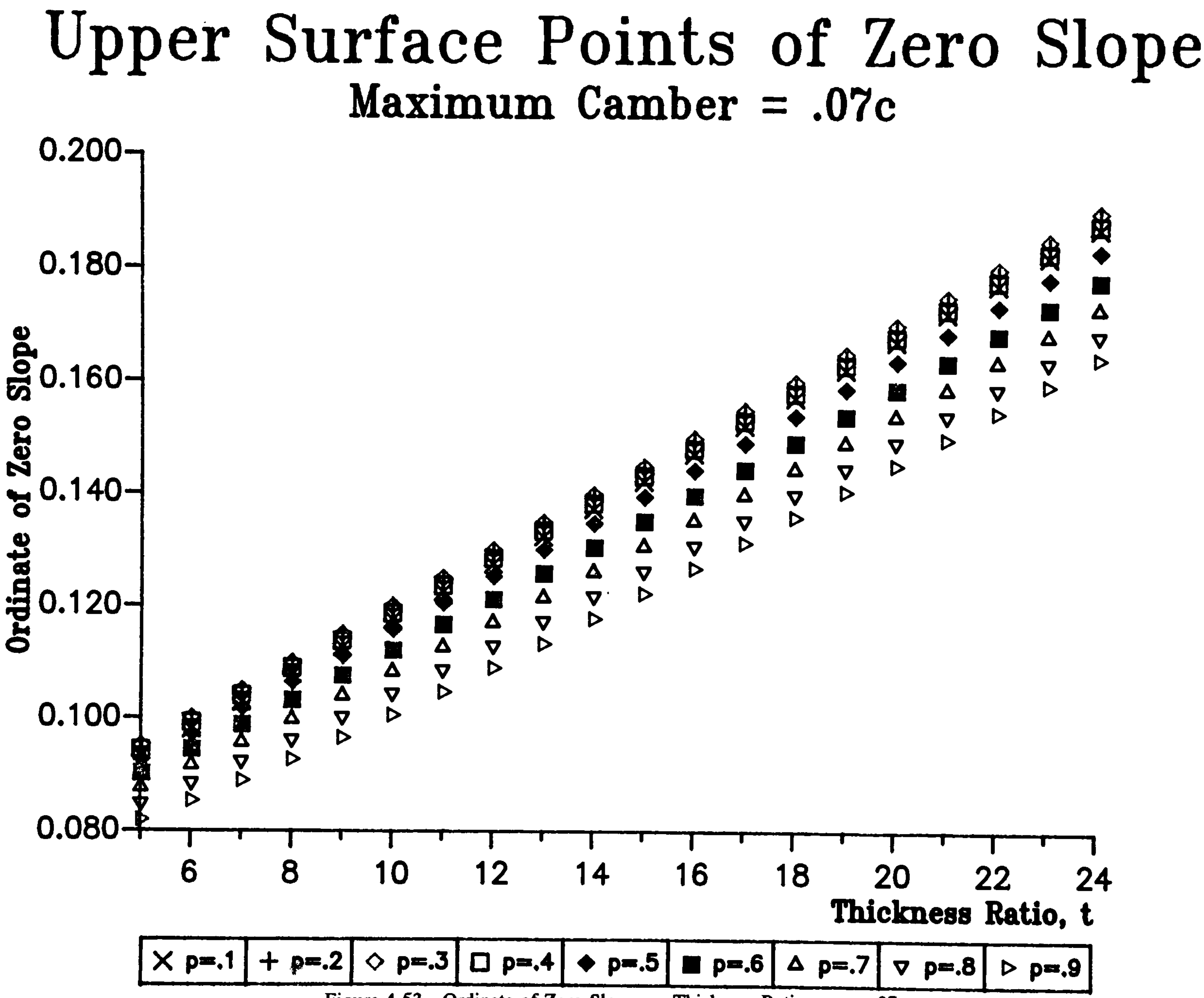


Figure 4.53 - Ordinate of Zero Slope vs. Thickness Ratio - $m = .07c$

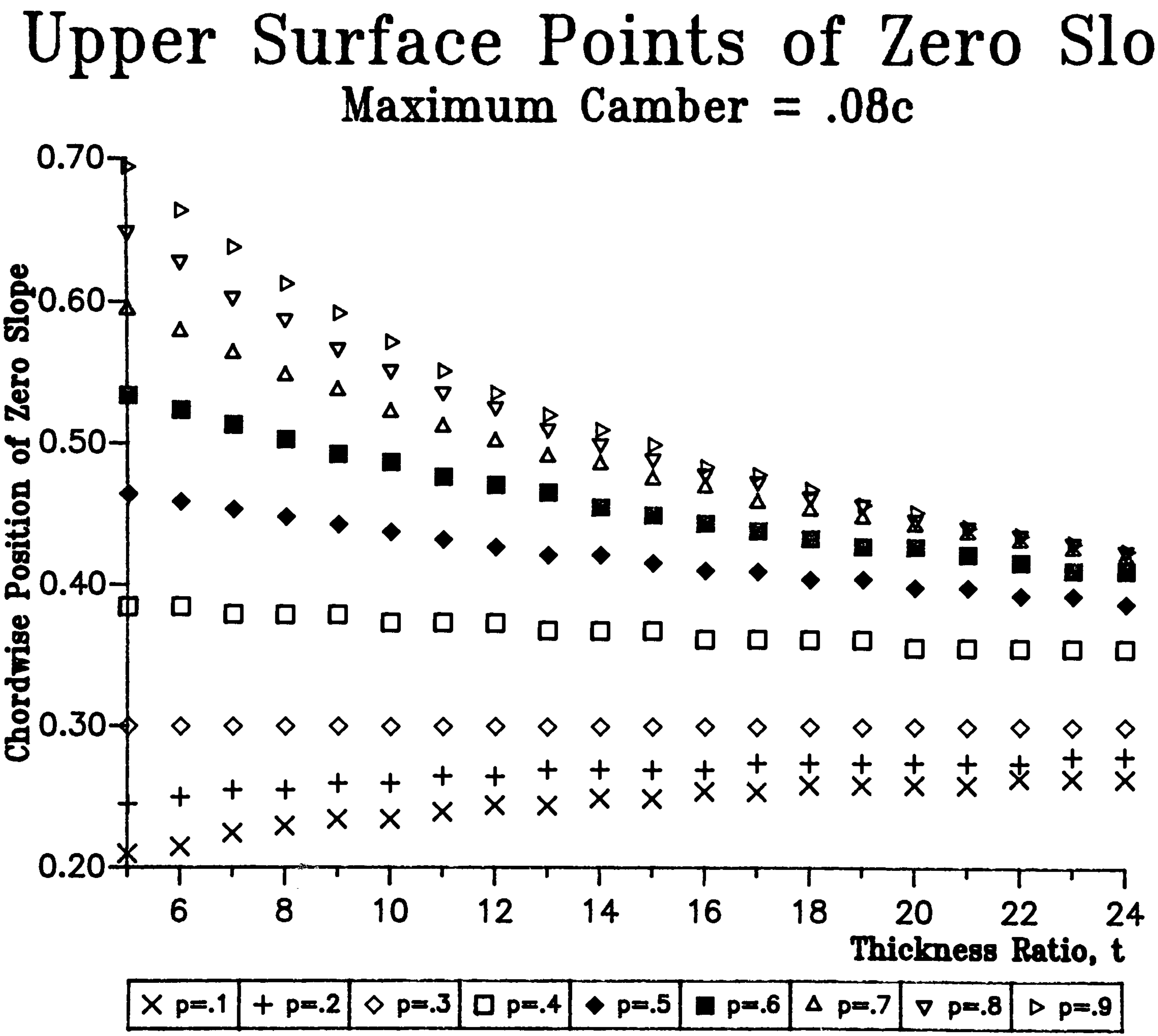


Figure 4.54 - Chordwise Position of Zero Slope vs. Thickness Ratio - $m = .08c$

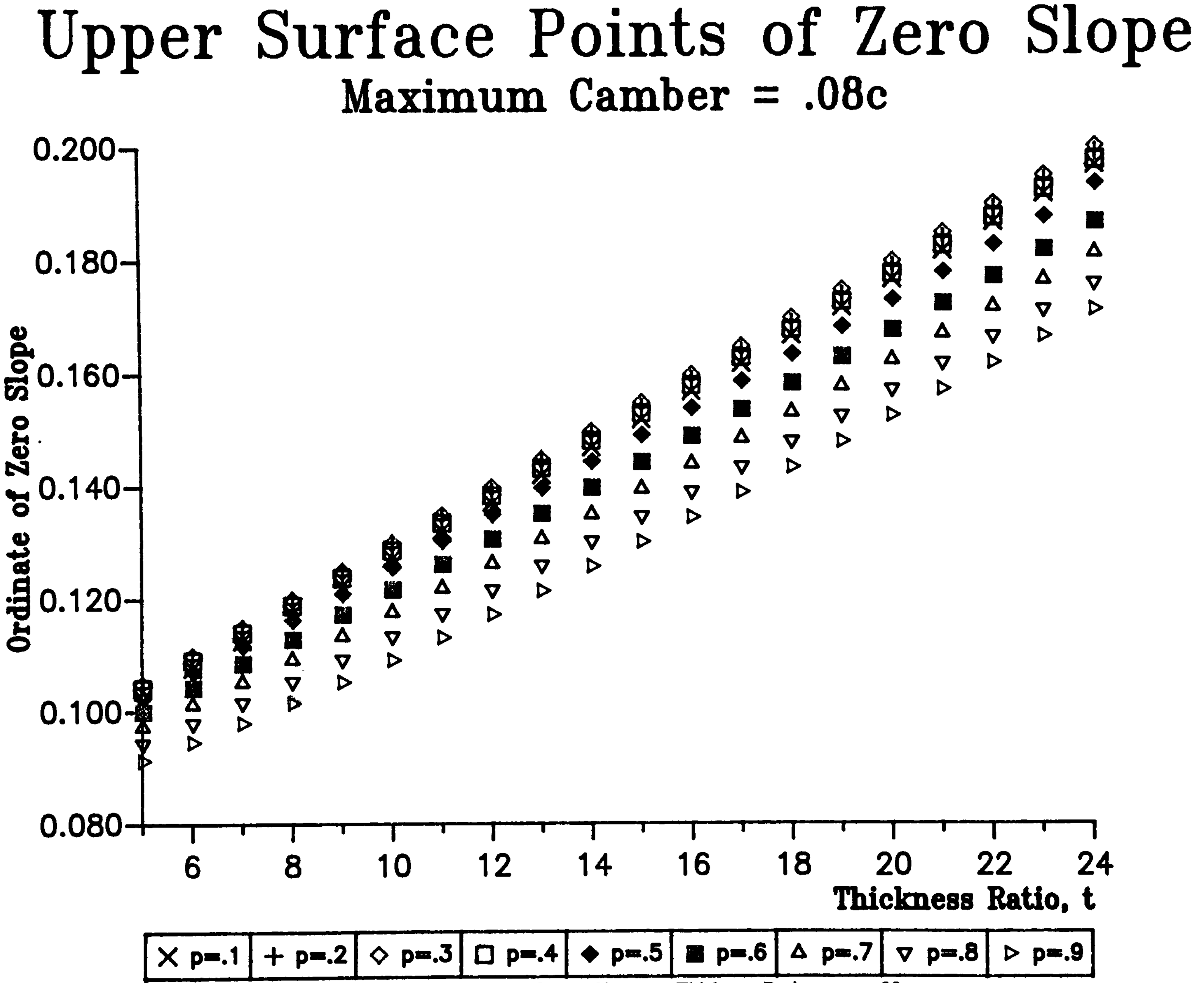


Figure 4.55 - Ordinate of Zero Slope vs. Thickness Ratio - $m = .08c$

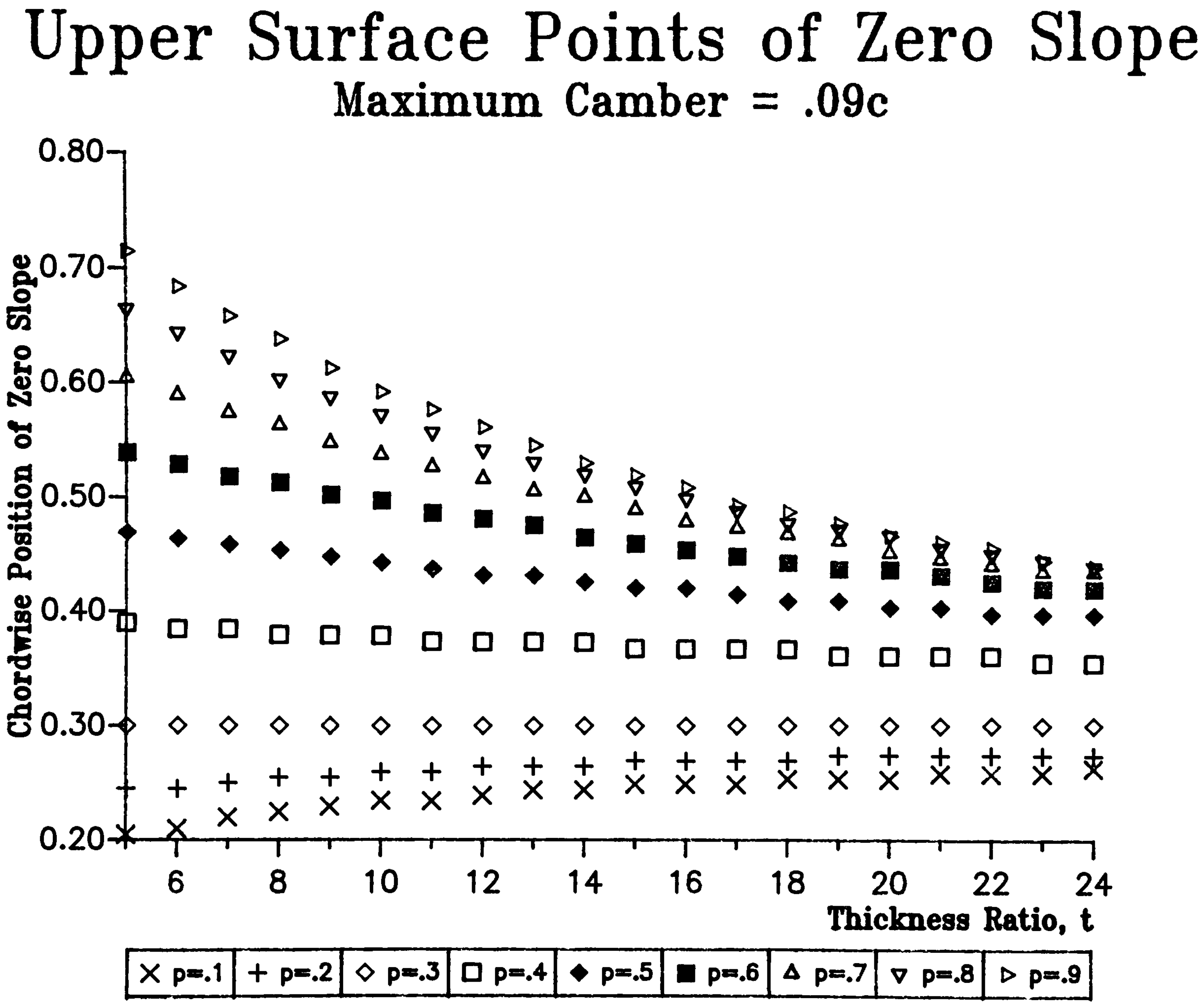


Figure 4.56 - Chordwise Position of Zero Slope vs. Thickness Ratio - *m* = .09*c*

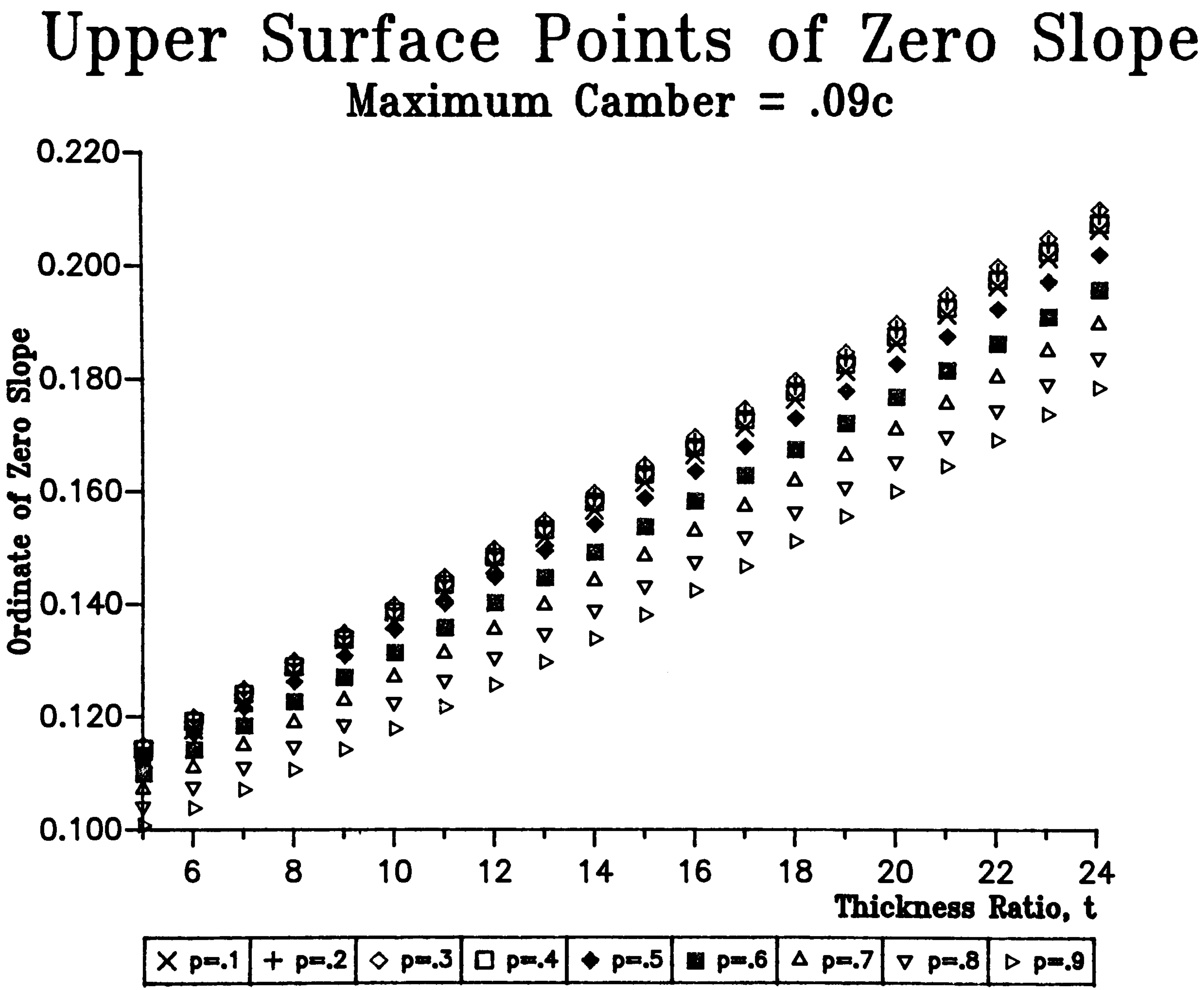


Figure 4.57 - Ordinate of Zero Slope vs. Thickness Ratio - $m = .09c$

4.2.2.1 Linear Fit of Upper Surface Ordinate

From these plots, it appears visually that the ordinates of zero slope points behave linearly for given values of the maximum camber. Linear regression (i.e. the line which minimizes least-squares error) on a line of the form

$$y = at + b \qquad (m, p \ \text{constant}) \qquad [4.10]$$

performed on this data, however, shows it to be nonlinear, though only slightly so. Table 4.4 illustrates the results of this regression. ***Because of the affine transformation property (the key to golden section division of intervals between successive iterations to determine unknown polygon vertex coordinates in the symmetric case), it is imperative that a linear relationship between the zero slope points and the descriptive parameters defining the airfoil be determined.***

Table 4.4 Coefficients of [4.10] As Determined By Linear Regression

		p=.1	.2	.3	.4	.5	.6	.7	.8	.9
m=.01	a	.5	.5	.5	.5	.5	.5	.5	.49	.49
	b	.0096	.019	.029	.0386	.048	.05827	.0681	.078	.0876
.02	a	.5	.5	.5	.5	.5	.5	.5	.5	.5
	b	.0099	.02	.03	.04	.05	.06	.069	.079	.089
.03	a	.5	.5	.5	.5	.5	.5	.5	.5	.5
	b	.01	.02	.03	.04	.05	.06	.07	.08	.09
.04	a	.5	.5	.5	.5	.49	.49	.49	.49	.49
	b	.0096	.01952	.029	.04	.05	.06	.07	.08	.09
.05	a	.5	.49	.49	.49	.48	.48	.48	.48	.47
	b	.0089	.018	.028	.038	.048	.058	.0683	.078	.088
.06	a	.5	.49	.49	.48	.47	.47	.46	.46	.45
	b	.0081	.017	.026	.036	.046	.056	.066	.076	.086
.07	a	.5	.49	.48	.48	.47	.46	.45	.44	.44
	b	.0073	.016	.025	.034	.044	.054	.064	.074	.084
.08	a	.5	.49	.48	.47	.46	.45	.44	.43	.42
	b	.0067	.014	.023	.032	.041	.051	.061	.071	.081
.09	a	.5	.49	.48	.47	.46	.45	.44	.43	.41
	b	.0061	.013	.021	.03	.039	.048	.058	.071	.077

Due to the non-linearity of the coefficients, other methods were investigated.

The chordwise positions of zero slope, as evidenced by Figures 4.40 - 4.56 (even) proved to be highly nonlinear, and will not be discussed until a workable method for determining ordinates of zero slope have been obtained.

Using the least information known about a particular cambered airfoil, there some points that are to be considered significant. For the upper surface considered, they are:

- The origin
- The symmetric thickness distribution point of maximum thickness at $(.3c, t/2)$
- The point at which maximum camber occurs (p, m)
- The maximum ordinate $y=t/2+m$ when $p=.3c$

4.2.2.2 Polynomial Fits

Attempts at fitting a series of polynomials through the "given" points discussed above were made. Because of the non-linearity of the zero slope points, not much in the way of useful information from these techniques was expected. In the case of linear fit between the points $(.3c, t/2)$ and $(p, t/2+m)$, as illustrated in Figure 4.58, no clear pattern emerged. Under no circumstances did the zero slope point lie on this line.

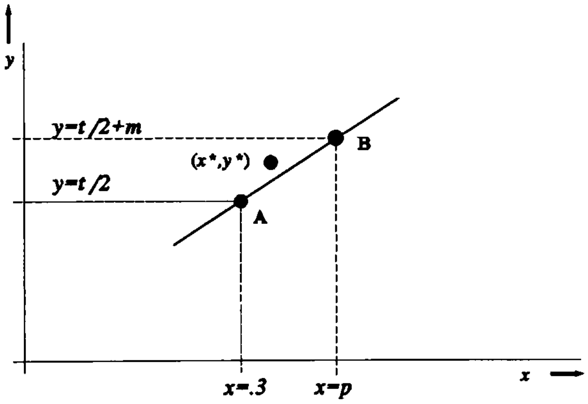


Figure 4.58 Attempt At Line Fit To Determine Zero Slope Point

4.2.2.3 The Arc Method

If a circular arc is drawn connecting the last three points mentioned above, the following, as shown in Figure 4.59 must be true:

- The y-coordinate of the center of the circle must lie on the line $y = (t/2 + m)/2$
- The three points define a unique circle passing through them

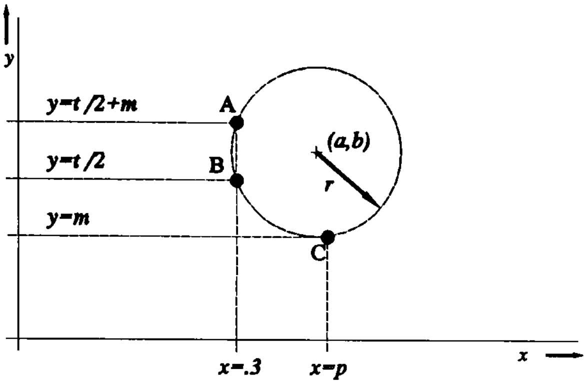


Figure 4.59 Illustration of The Arc Method

Analytically, a circle of the form

$$(x - a)^2 + (y - b)^2 = r^2$$

fits the above criteria. Given the three points mentioned above, a system of three equations in three unknowns may be generated, as illustrated in equations [4.11].

$$\begin{aligned}
(.3 - a)^2 + \left(\frac{t}{2} - b\right)^2 &= r^2 && \text{(a)}\\
(.3 - a)^2 + \left(\frac{t}{2} + m - b\right)^2 &= r^2 && \text{(b)} \qquad [4.11]\\
(p - a)^2 + (m - b)^2 &= r^2 && \text{(c)}
\end{aligned}$$

Subtracting (c) from (a), it can be shown that

$$p^2 - 2pa = .09 - .6a$$

This method proved unacceptable for the following reasons:

- The ordinate of the center of the circle is independent of the chordwise position of maximum camber, p. From the data generated (UTRENDS.DAT), this is not the case.

- The x-coordinate of the center of the circle is independent of the maximum camber.

4.2.2.4 The Curve Method

The next attempt at the task was to try and identify a curve that passed through the points $(.3c, t/2+m)$, (x_{true}, y_{true}) and (p,m), as shown in Figure 4.60. The results of this analysis, done by HP-15C programmable hand calculator, show no correlation between airfoils for curves of second and third order passing through these points.

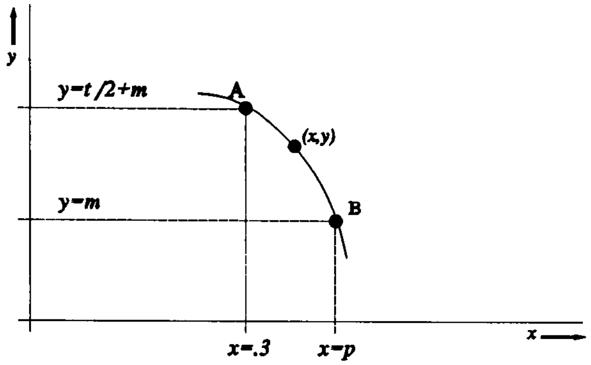


Figure 4.60 Illustration of the Curve Method

4.2.2.5 Areas of Triangles

For triangles drawn between the origin, the x-axis and the points $(.3c, t/2+m)$ and (p,m) as shown in Figure 4.61, the areas can be expressed as $xy/2$.

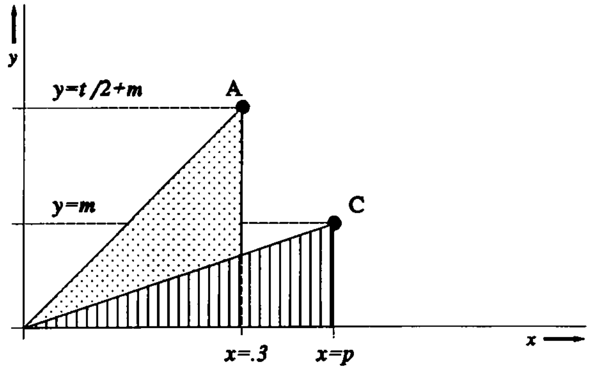


Figure 4.61 Area of Triangles Method

Thus the areas of the two triangles shown are

$$A_1 = \frac{1}{2}(.3)(\frac{t}{2} + m)$$

$$A_2 = \frac{1}{2}(p)(m)$$

and the ratio of areas A_2/A_1 is

$$\frac{A_2}{A_1} = \frac{\frac{1}{2}mp}{\frac{1}{2}(.3)(\frac{t}{2} + m)} = \frac{mp}{.3(\frac{t}{2} + m)}$$

It was desired to determine the range of the ratio of these two areas for any combination of NACA four-digit airfoil considered. Figure 4.62 gives values of A_2/A_1 for the descriptive parameters *m*, *p* and t, and the vertices of the cube correspond to minimum and maximum values of the respective parameter.

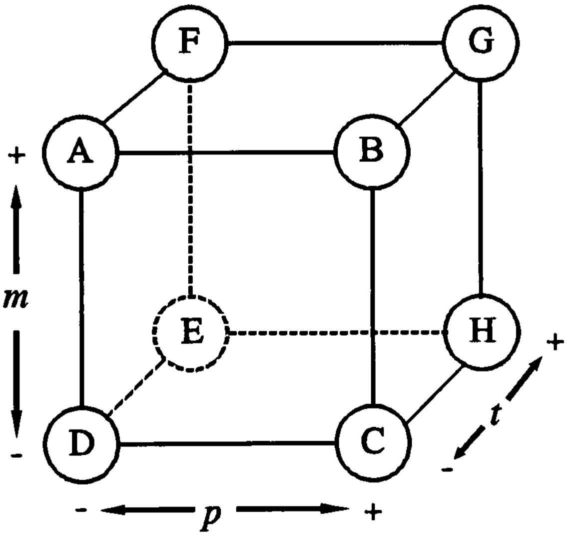


Figure 4.62 Cube Plot of Area Ratio for Limit Values of Parameters

Table 4.5 shows the limit values used for this analysis, and Table 4.6 provides the resultant area ratios.

Table 4.5 Limit Values For Descriptive Parameters

Parameter	Minimum Value (-)	Maximum Value (+)
m	.01	.09
p	.1	.9
t	.05	.24

Table 4.6 Area Ratios For Limit Values of Descriptive Parameters

Vertex	A	B	C	D	E	F	G	H
NACA	9105	9905	1905	1105	1124	9124	9924	1924
A_2/A_1	.2609	2.348	.8571	.0952	.02564	.01429	1.2857	.23077

Figure 4.63 illustrates the results of this analysis.

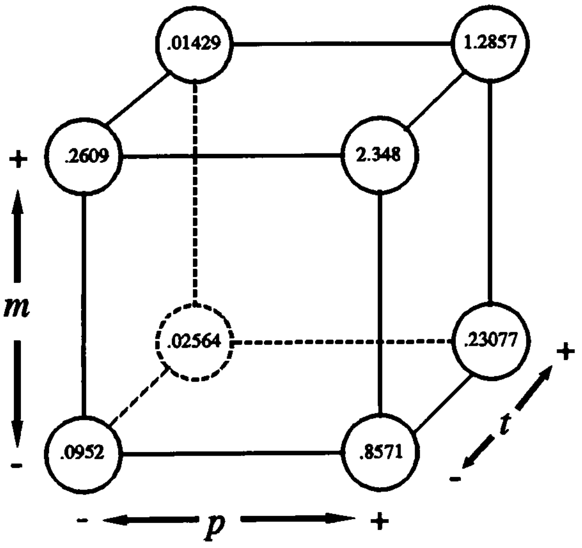


Figure 4.63 Results of Area Ratio Analysis

Thus each of the descriptive parameters produces significant effects on the area ratio. This method was deemed unusable due to the fact that there is no systematic way to arrive at an area whose value is between A_1 and A_2 without first knowing the coordinates of the zero slope point.

4.2.2.6 Dimensionless Parameter Combinations

Often in the field of fluid mechanics, it is helpful to represent flow characteristics in terms of dimensionless quantities. Reynolds, Froude and Prandtl numbers are examples. For the NACA Four-Digit airfoils discussed, it was desired to determine whether any trends could be observed in the points of zero slope when the parameters *m*, *p*, and *t* were combined. Although each of these parameters is non-dimensional, they may, for the purpose of this analysis, be considered as having a "length". In order to arrive at a non-dimensional number using first order combinations of these numbers, the chordwise position of maximum thickness of the symmetric thickness distribution ($x=.3c$) was included also.

With *m* and *t* representing quantities closely related to ordinate, it would seem logical that they be lumped together. The quantities *p* and .3*c* are descriptive of chordwise position and initially they will be used in a similar manner. A decision was made to alter the parameter *p* to reflect the fact that when $p=.3c$, there is no effect on the *x*-coordinate of zero slope for the upper surface.

This leads to the following possibilities:

$$\begin{aligned} \Pi_1 &= \frac{x_1 x_2}{y_1 y_2} = \frac{mt}{.3\,(p-.3)} \\ \Pi_2 &= \frac{x_1 y_1}{x_2 y_2} = \frac{m(p-.3)}{.3\,t} \\ \Pi_3 &= \frac{x_1 y_2}{x_2 y_1} = \frac{.3\,m}{t(p-.3)} \end{aligned} \qquad [4.12]$$

Choosing an arbitrary airfoil (for this analysis, the NACA 4412) this yields

$$\begin{aligned} \Pi_1 &= \frac{(.04)(.12)}{.3\,(.4-.3)} = .16 \\ \Pi_2 &= \frac{(.04)(.4-.3)}{(.3)(.12)} = .111 \\ \Pi_3 &= \frac{(.3)(.04)}{(.12)(.4-.3)} = 1.0 \end{aligned}$$

Zero slope points of other airfoils having the same dimensionless numbers were then analyzed. Table 4.7 illustrates the results of this analysis.

Table 4.7 Results of Dimensionless Parameter Analysis

Π Group	Π Value	NACA Airfoil	$x_{zero\ slope}$	$y_{zero\ slope}$
1	.16	4412	.35355	.10380
	.16	2424	.32275	.13903
	.16	4524	.35470	.15527
	.16	8512	.42746	.13516
2	.111	4412	.35355	.10380
	.111	8424	.35526	.19763
	.111	6418	.35200	.14826
	.111	2512	.35362	.077681
3	1.0	4412	.35355	.10380
	1.0	2406	.35467	.04935
	1.0	8424	.35526	.19763
	1.0	6418	.35200	.14826

Clearly, the results in Table 4.7 show no correlation between these dimensionless numbers and the points of zero slope. Other combinations were attempted, all of which failed the objective.

4.2.2.7 The Linear Correction Factor

A final attempt to determine some relationship between the descriptive parameters and the points of zero slope was to assume that, for the upper surface, the ordinate of zero slope could be expressed as a function of m,p, and t. Taking into account the fact that at $p=.3c$, $y=t/2 + m$, an expression of this form is given by

$$y = \frac{t}{2} + m + \alpha(p-.3)$$

where α is a correction factor intended to account for the effects of chordwise position of maximum camber on the ordinate of zero slope. It is evident from Figures 4.64 - 4.84 (pages 100-120) that a simple linear relationship for alpha does not exist.

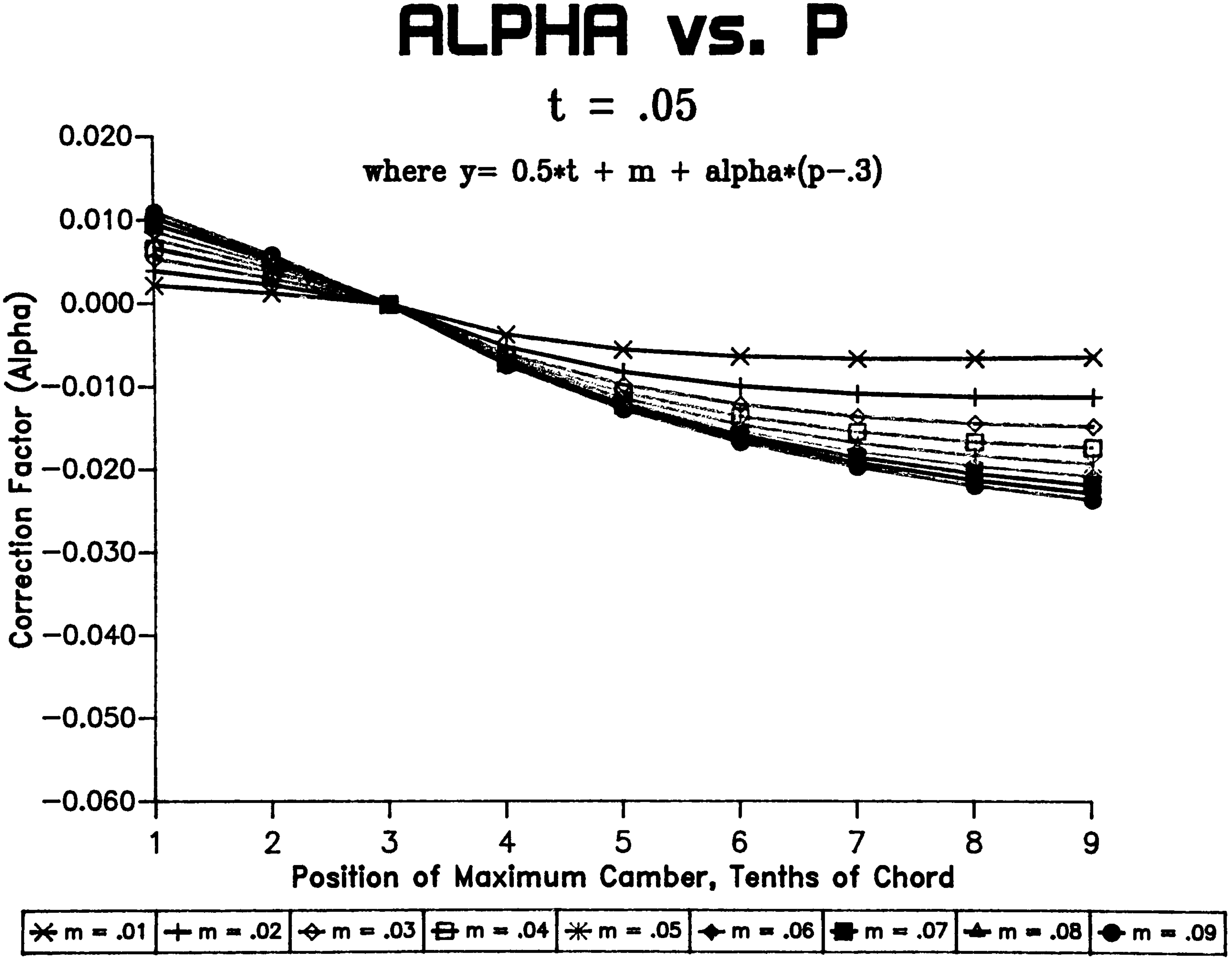


Figure 4.64 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .05c

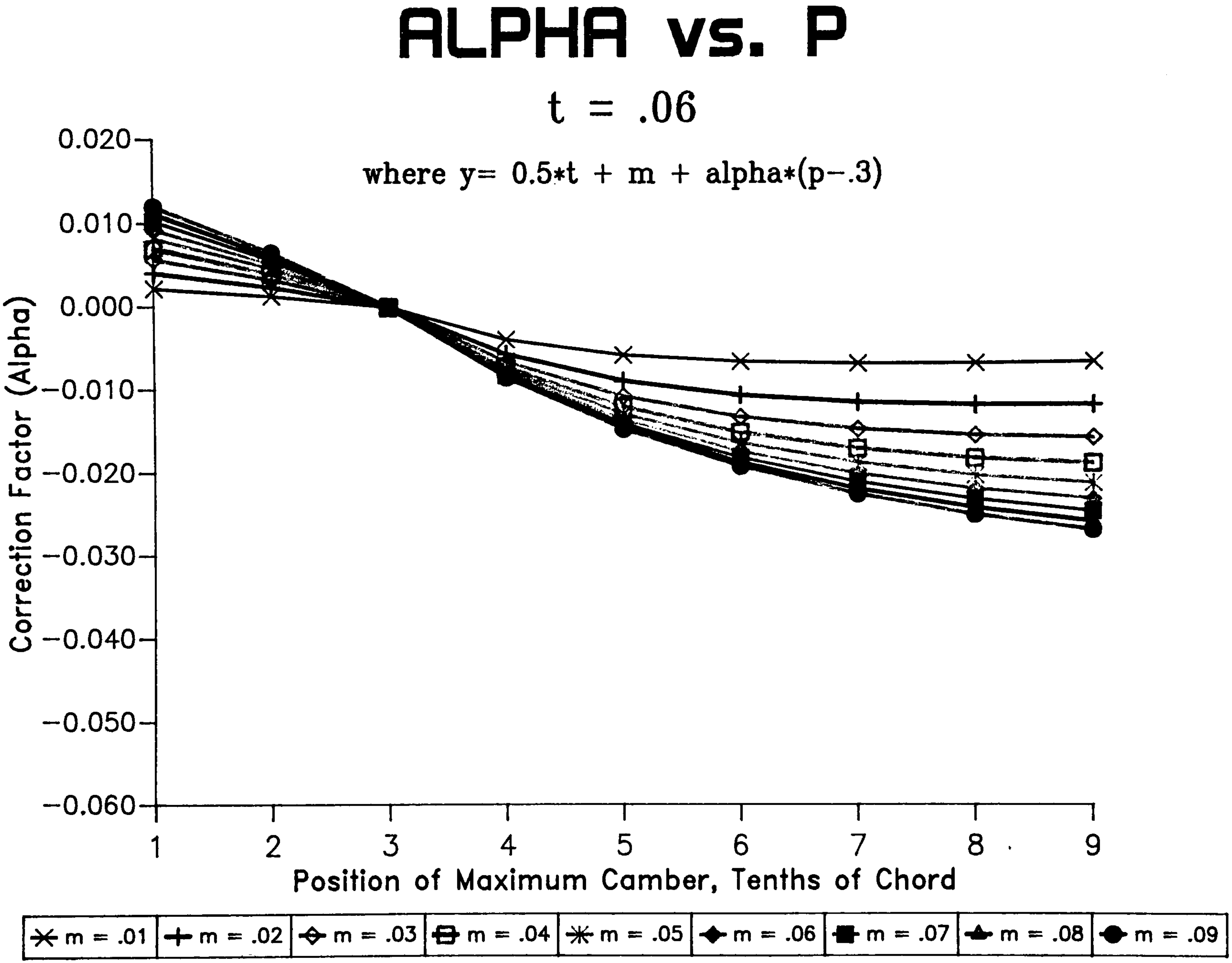


Figure 4.65 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .06c

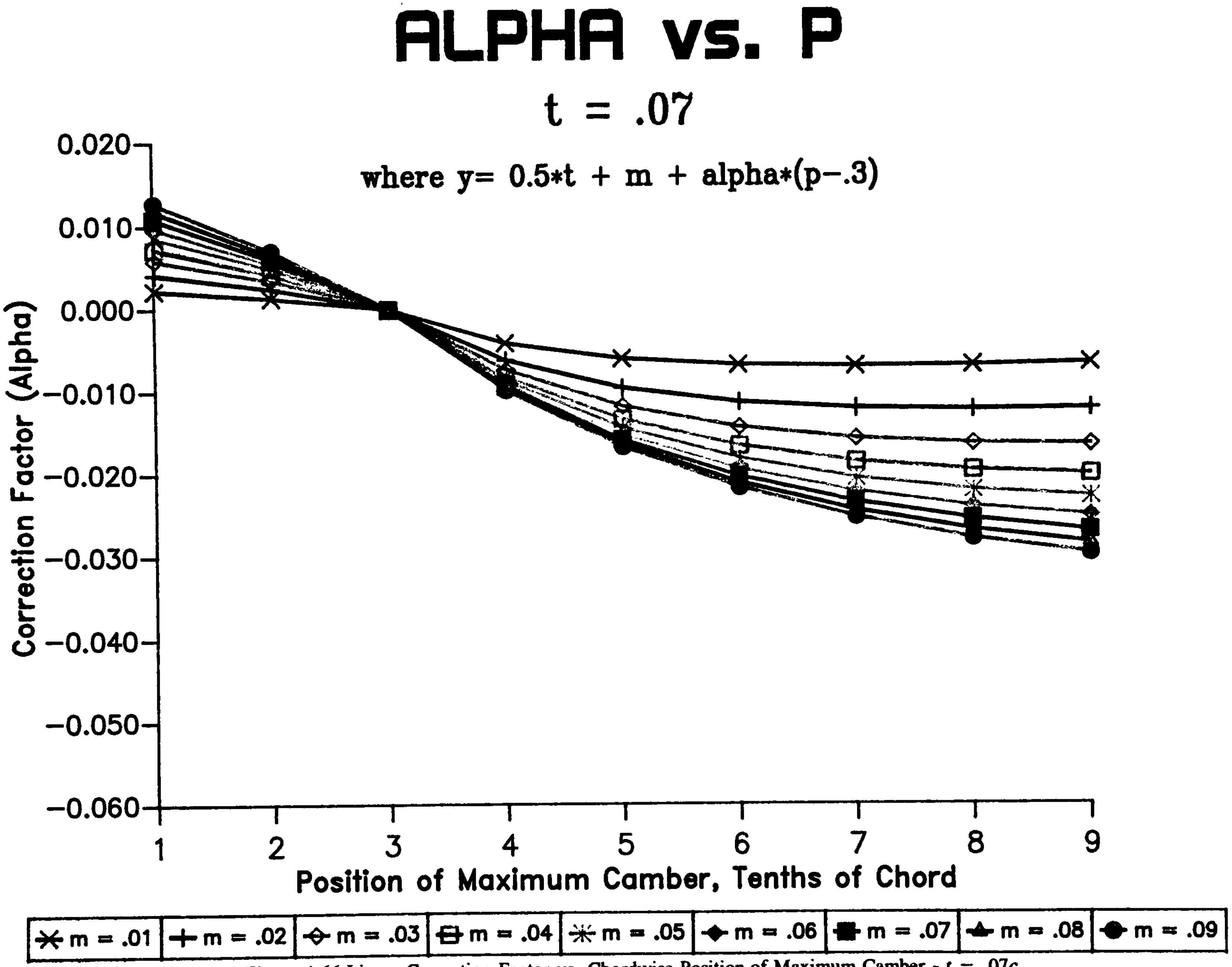


Figure 4.66 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .07c

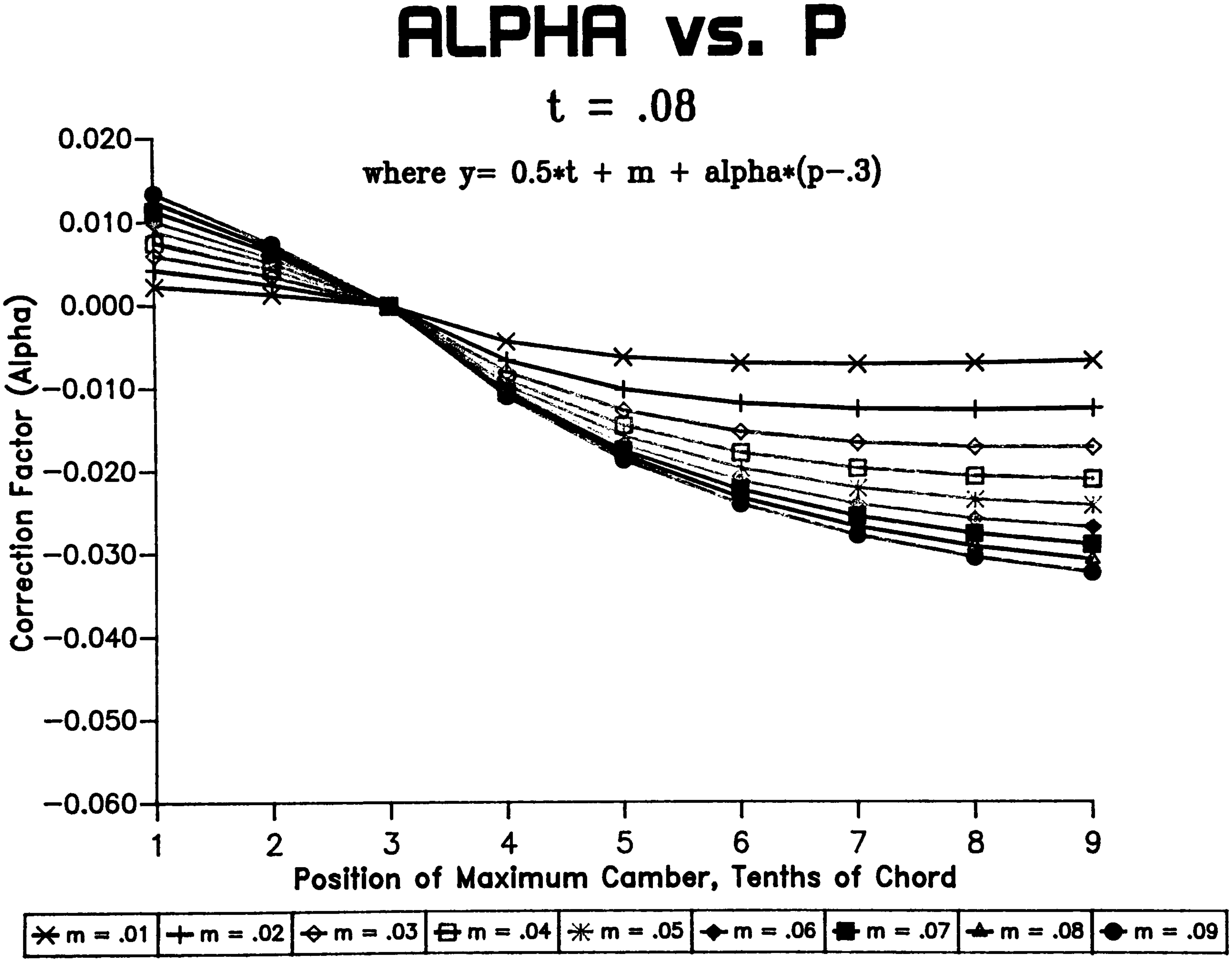


Figure 4.67 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .08c

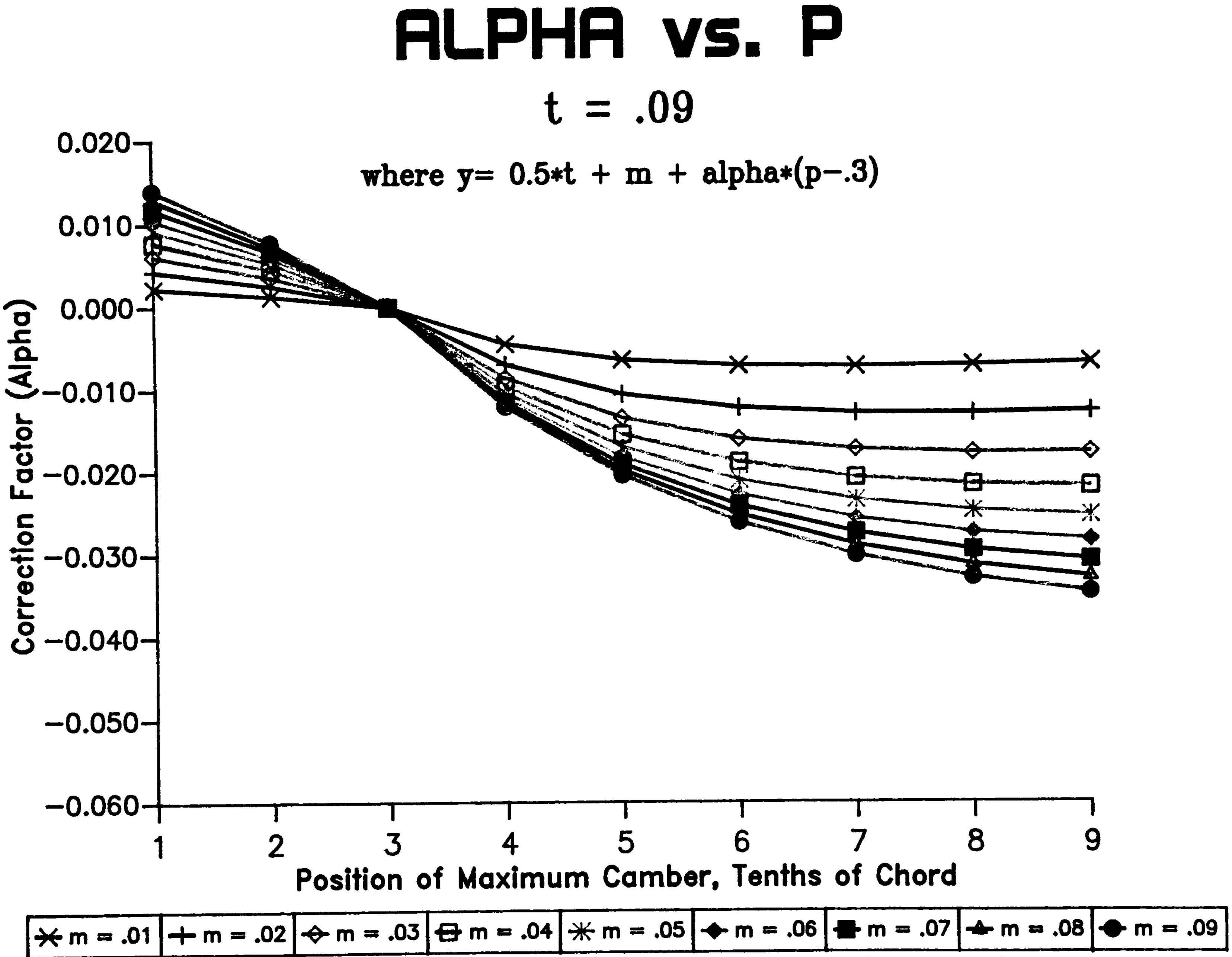


Figure 4.68 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .09c

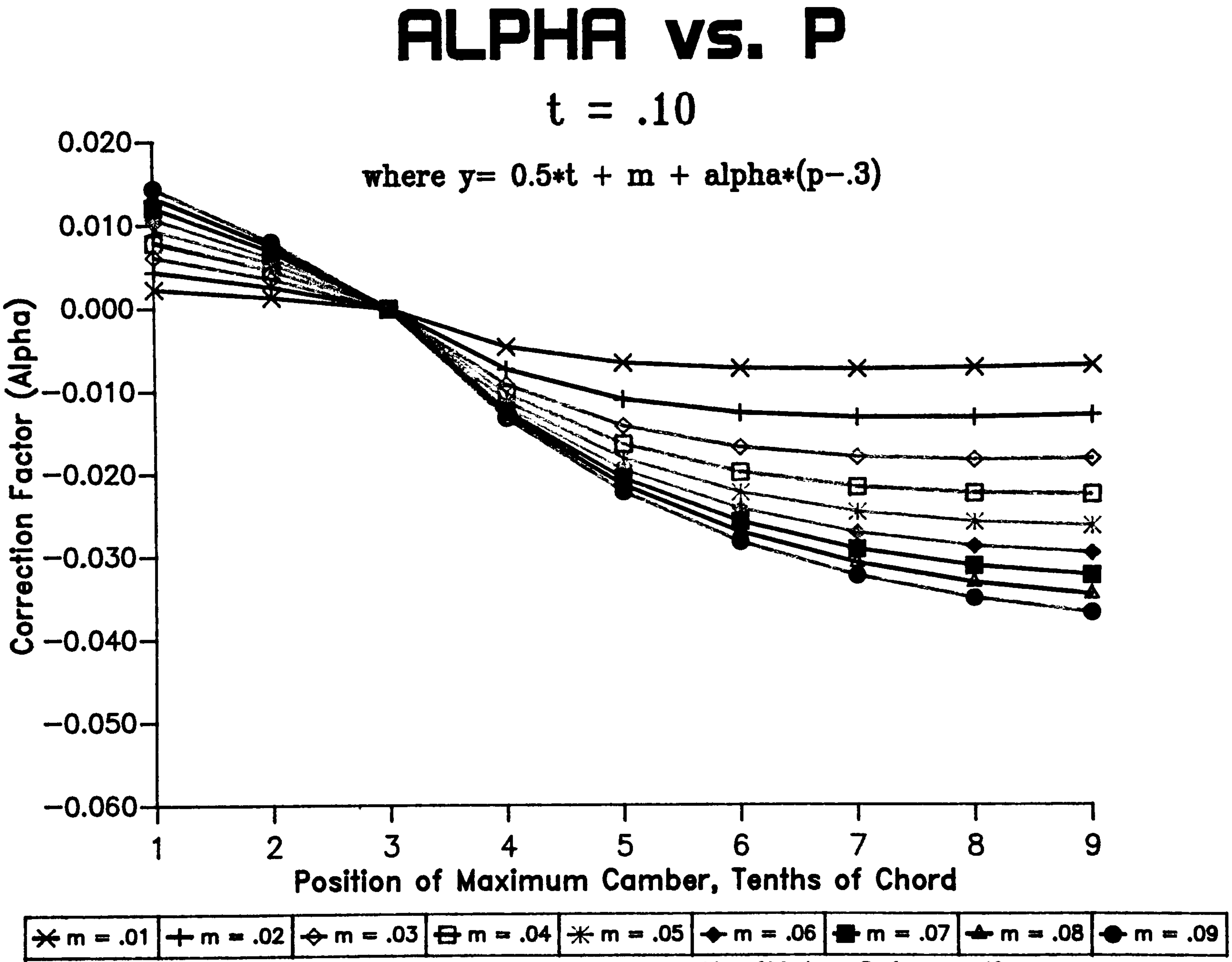


Figure 4.69 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .10c

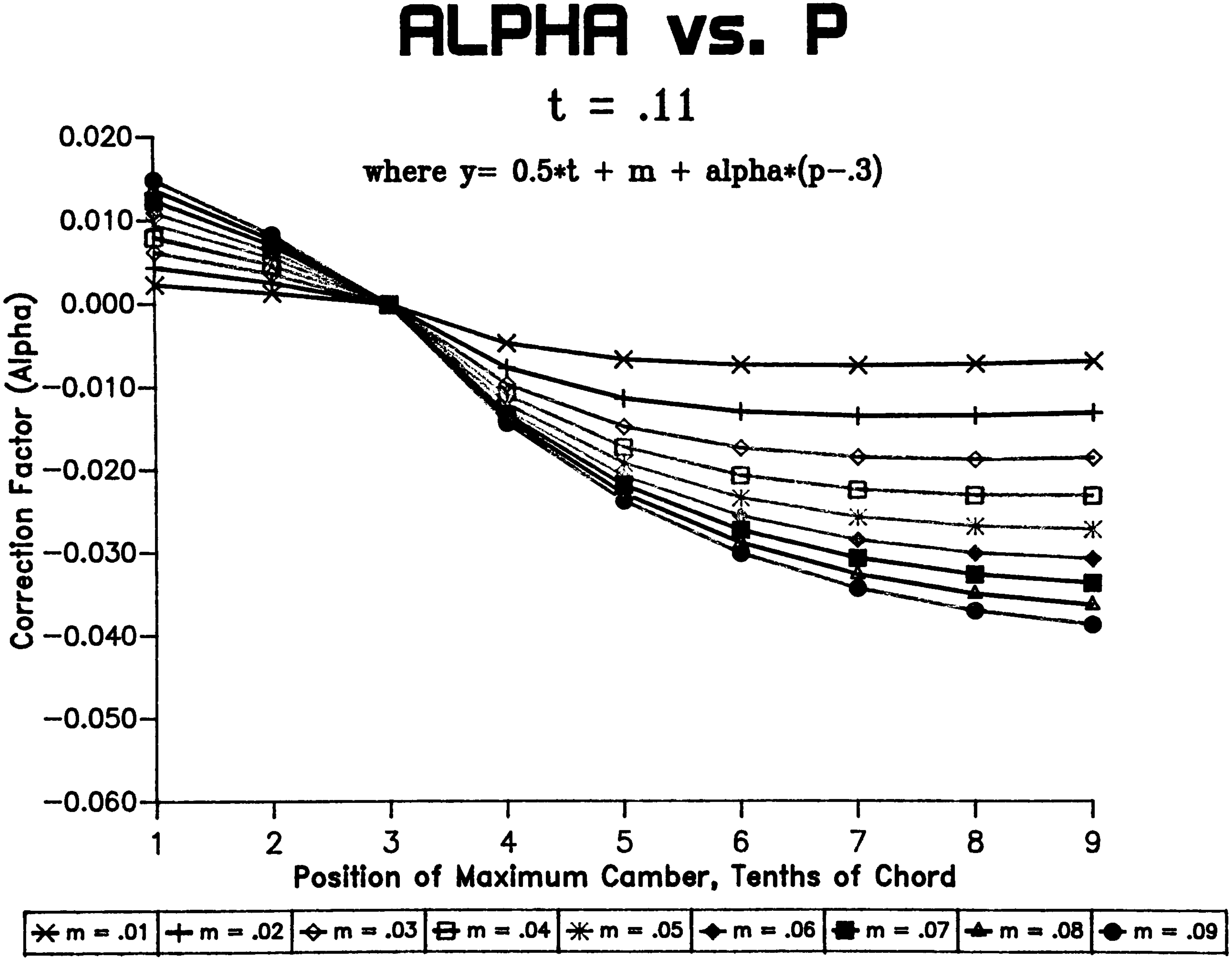


Figure 4.70 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .11c

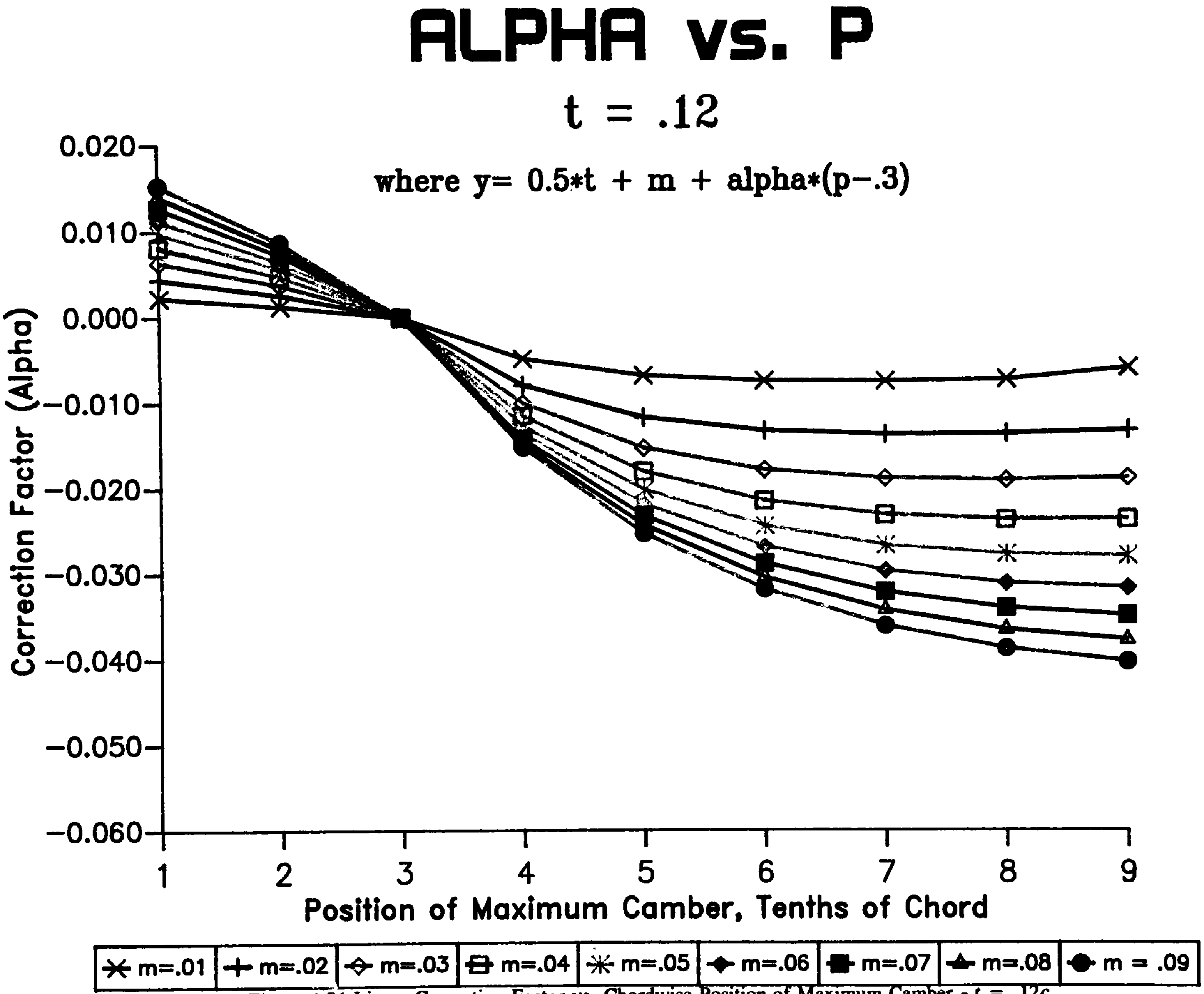


Figure 4.71 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .12c

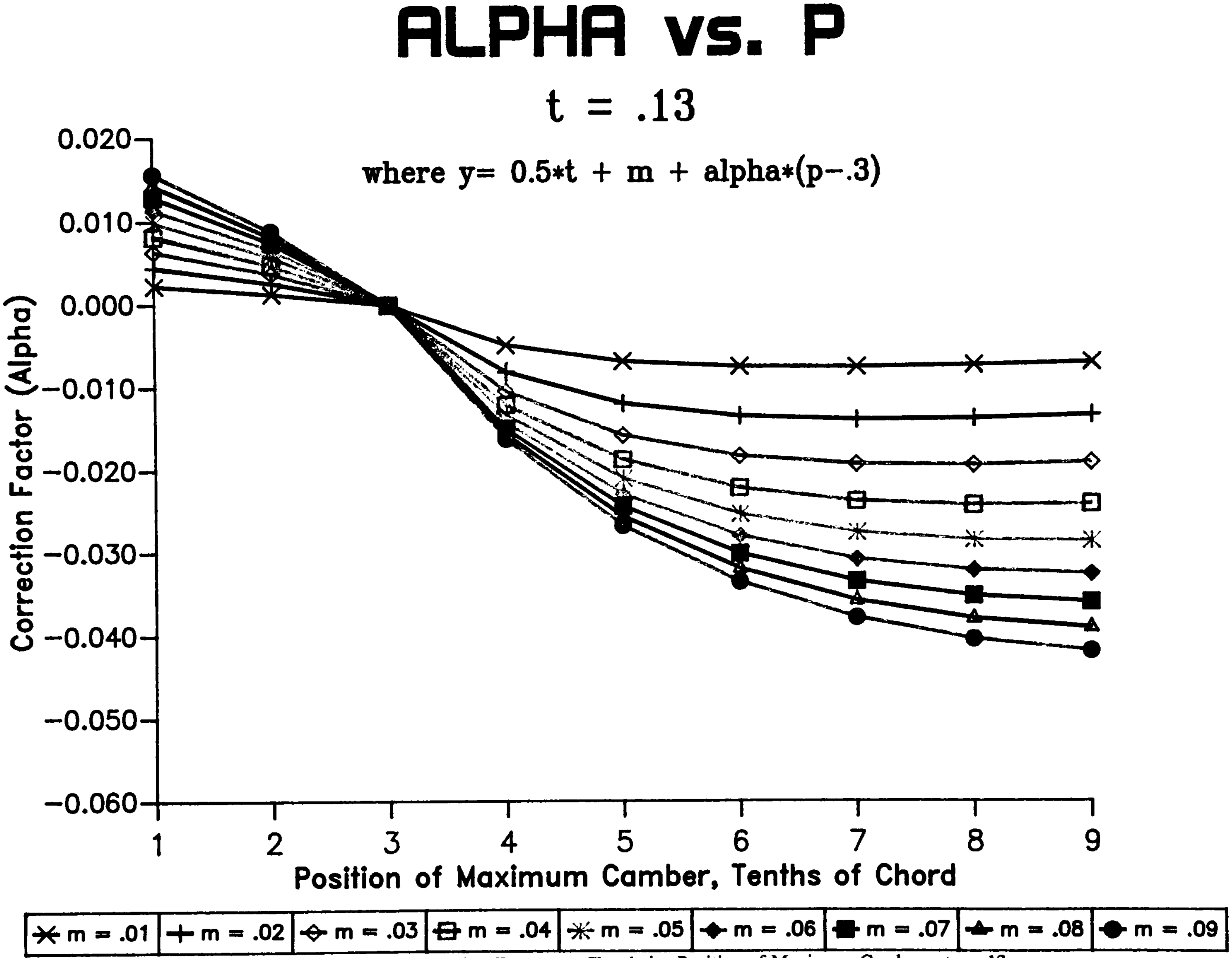


Figure 4.72 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .13c

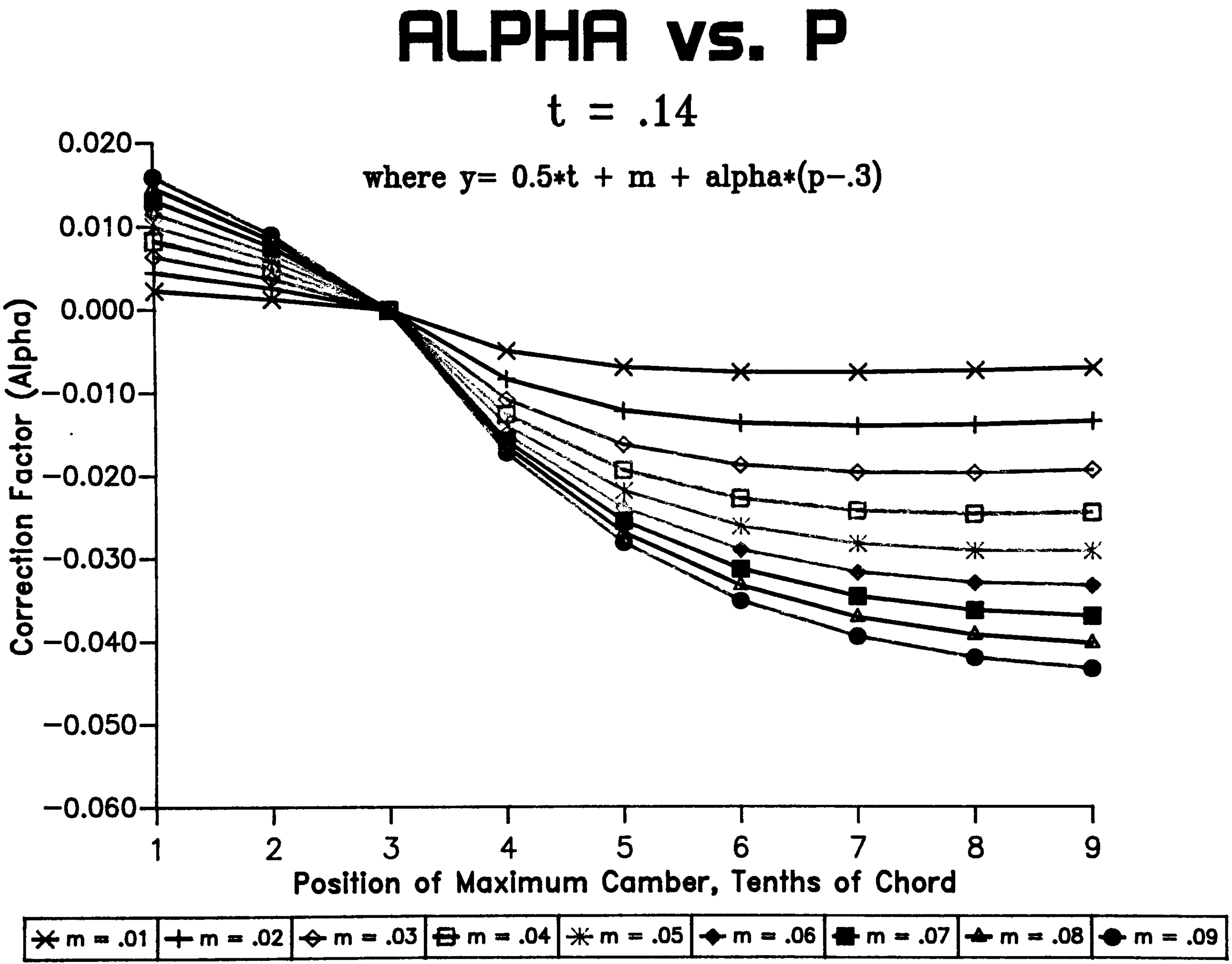


Figure 4.73 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .14c

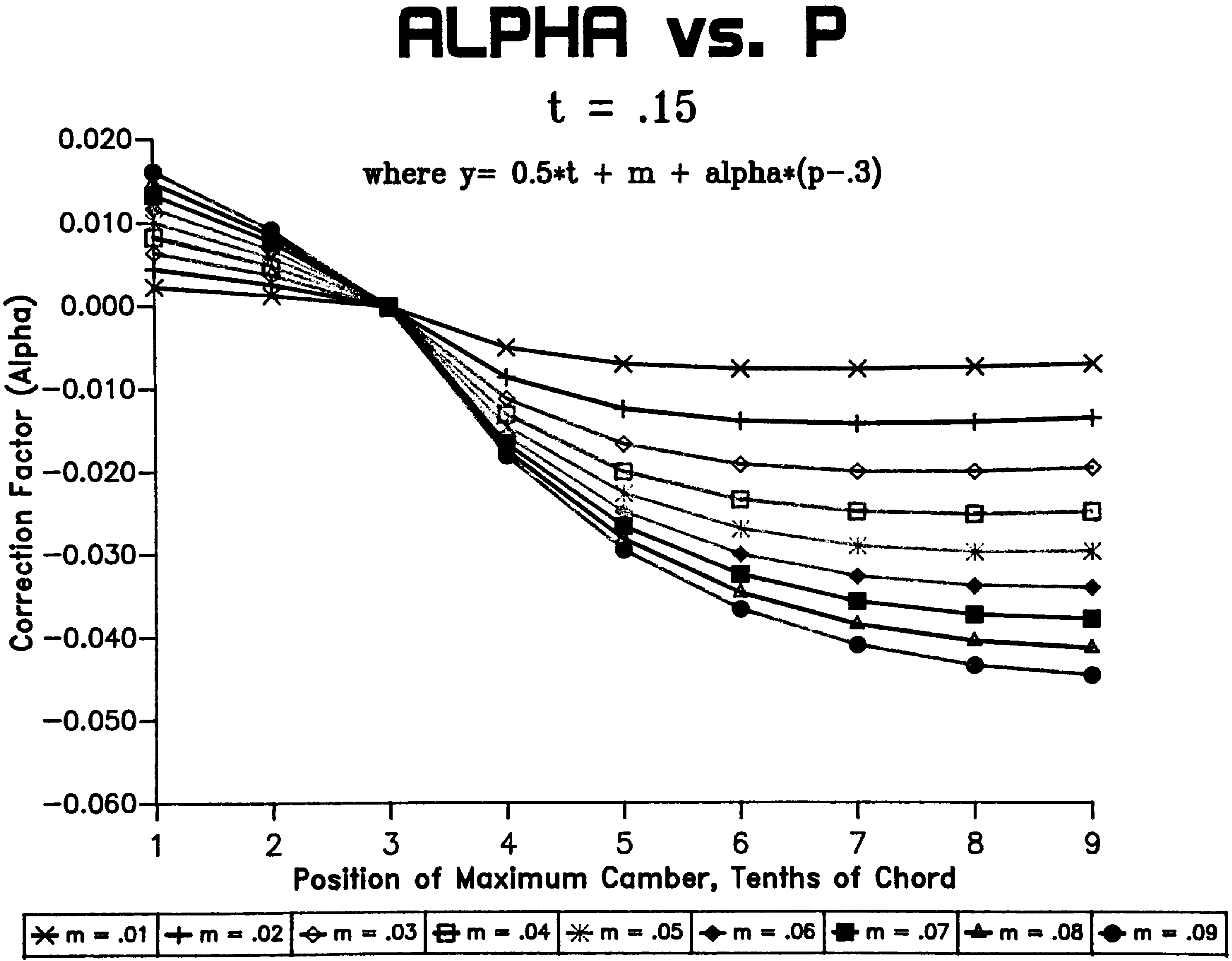


Figure 4.74 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .15c

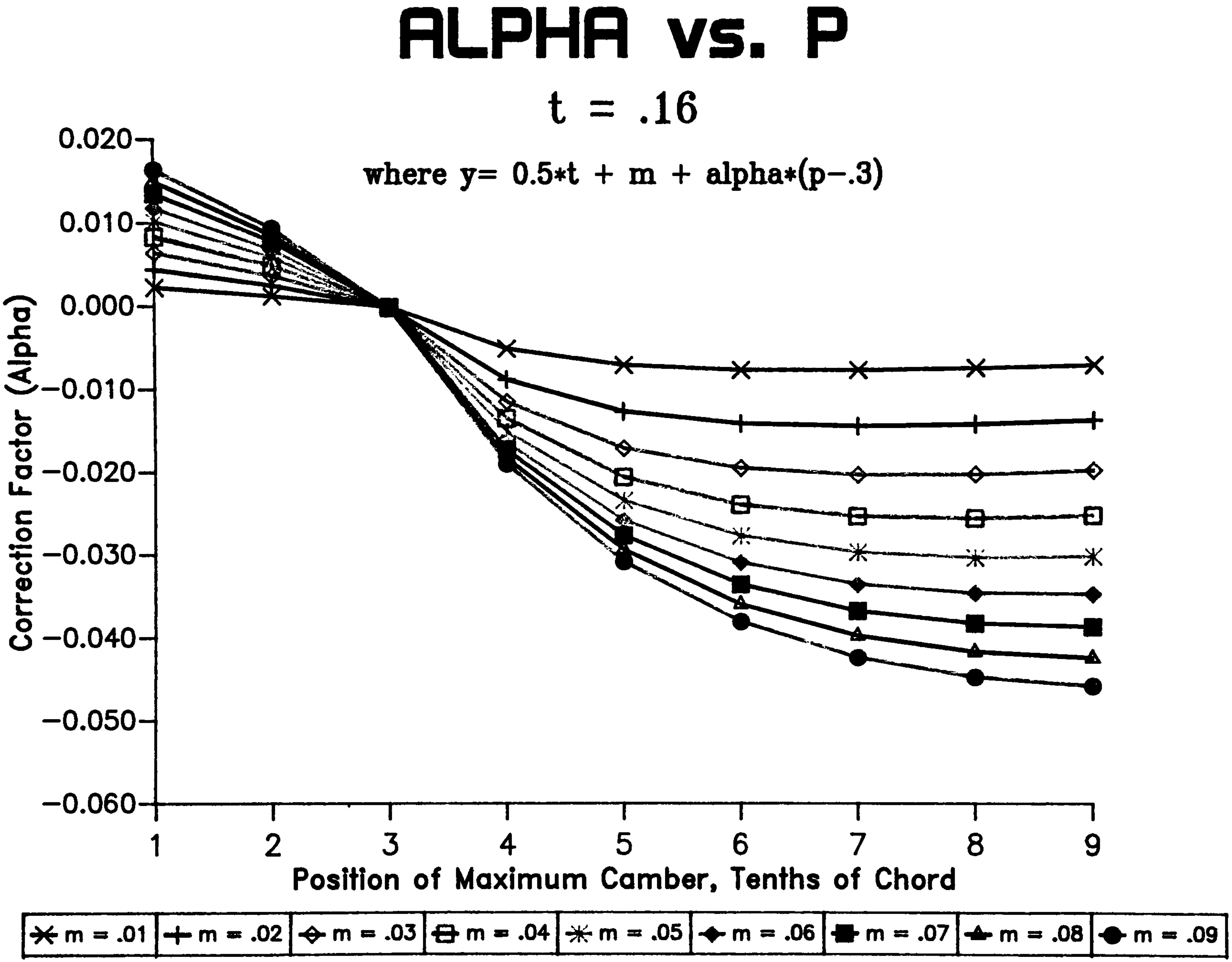


Figure 4.75 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .16c

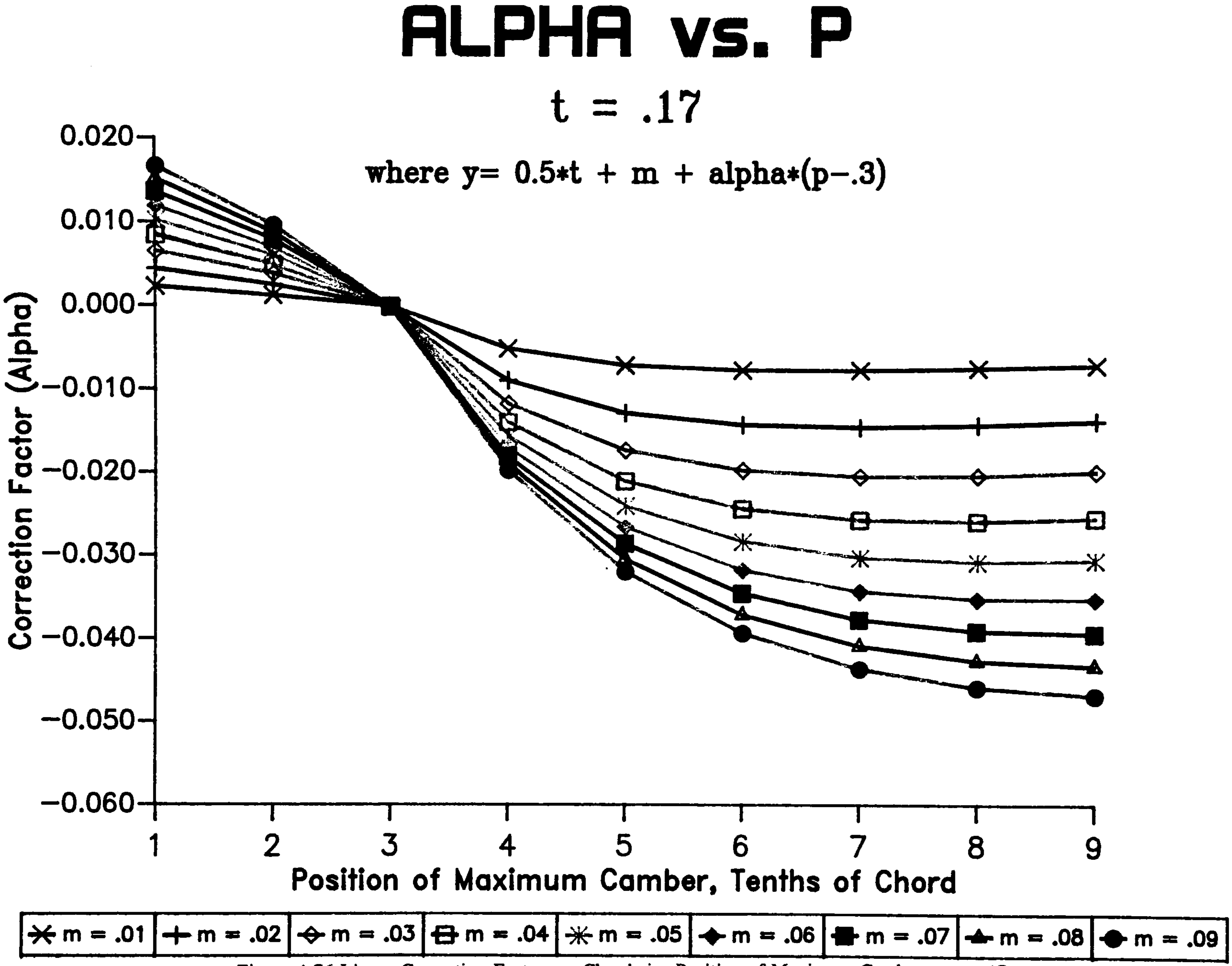


Figure 4.76 Linear Correction Factor vs. Chordwise Position of Maximum Camber - $t = .17c$

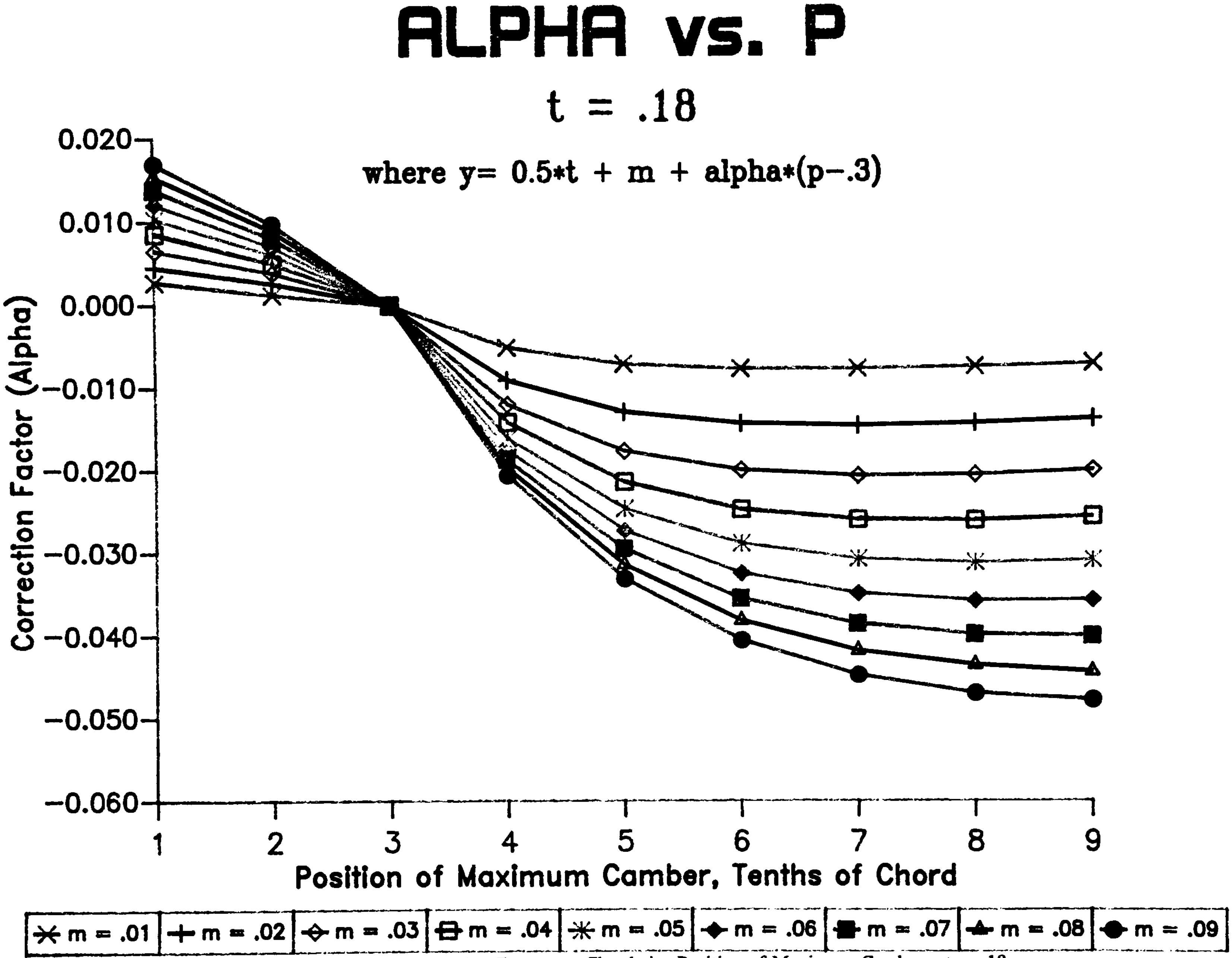


Figure 4.77 Linear Correction Factor vs. Chordwise Position of Maximum Camber - *t* = .18*c*

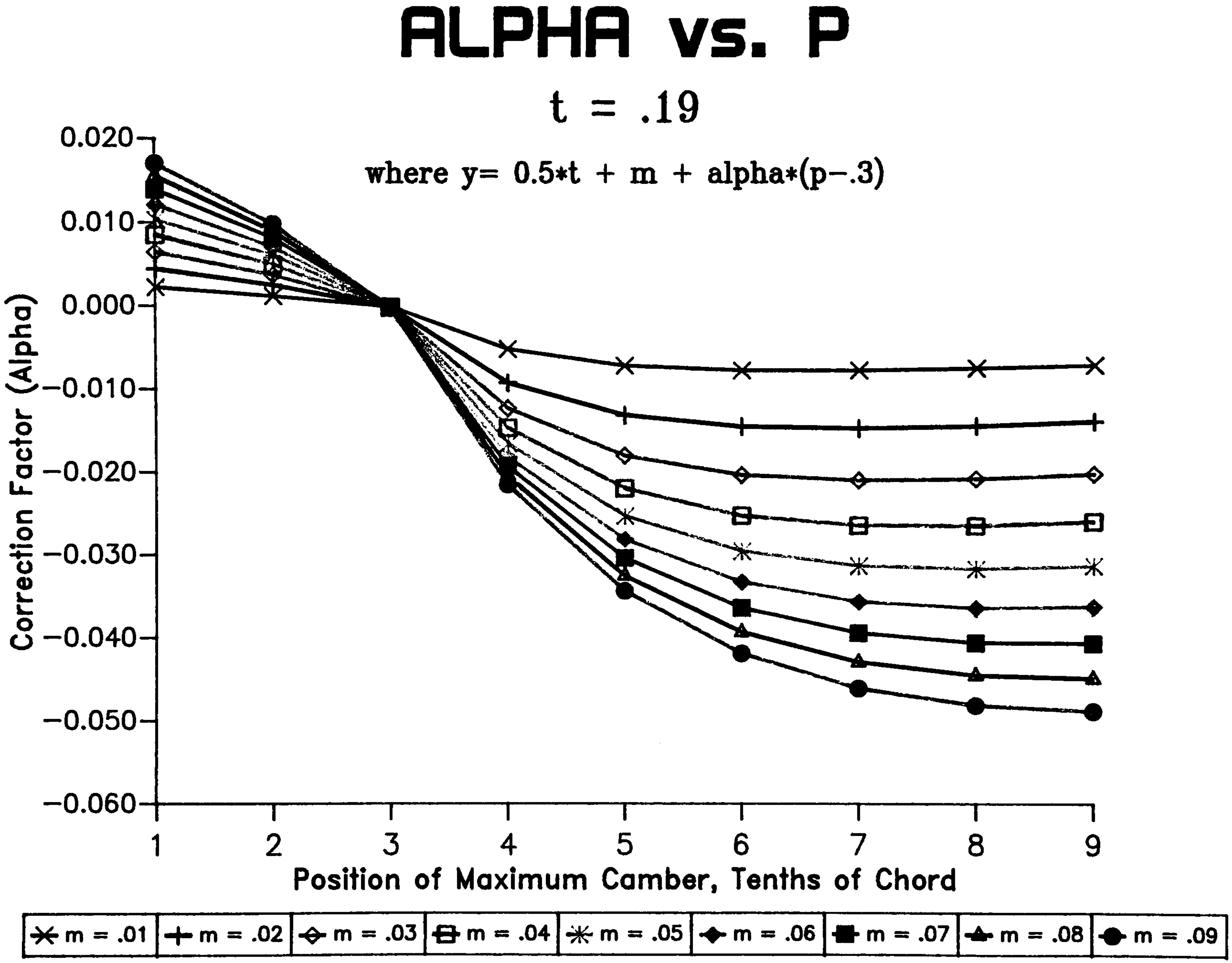


Figure 4.78 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .19c

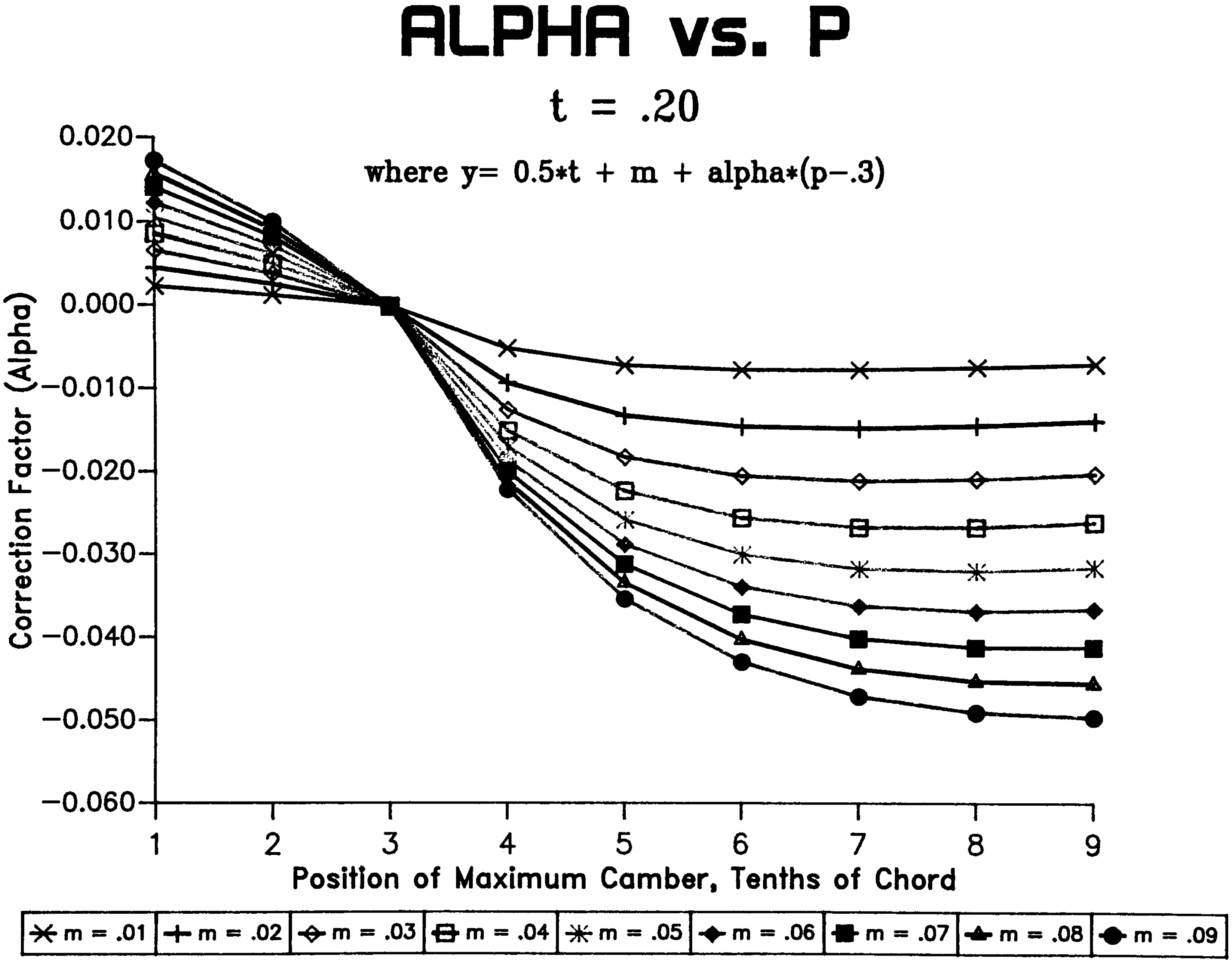


Figure 4.79 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .20c

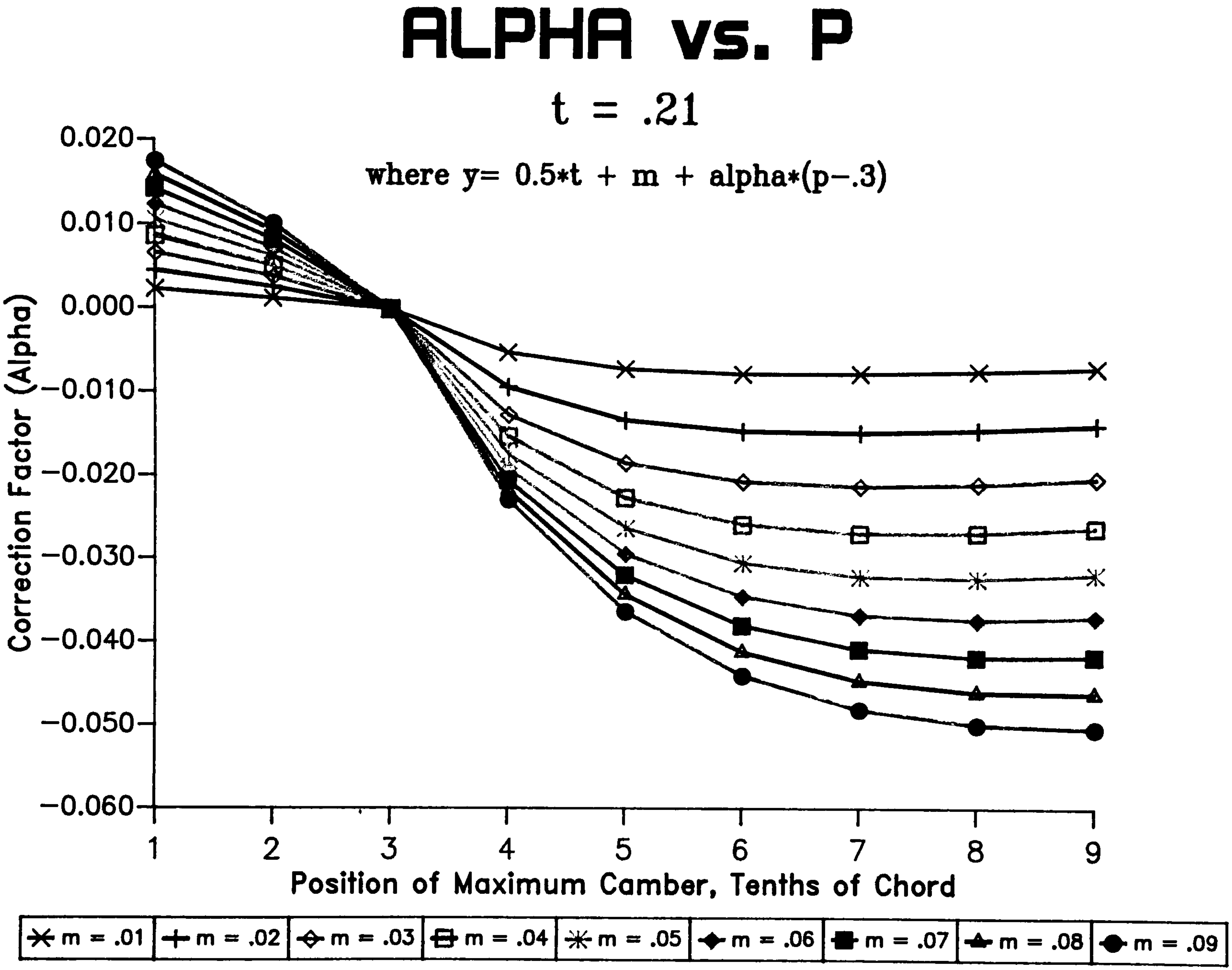


Figure 4.80 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .21c

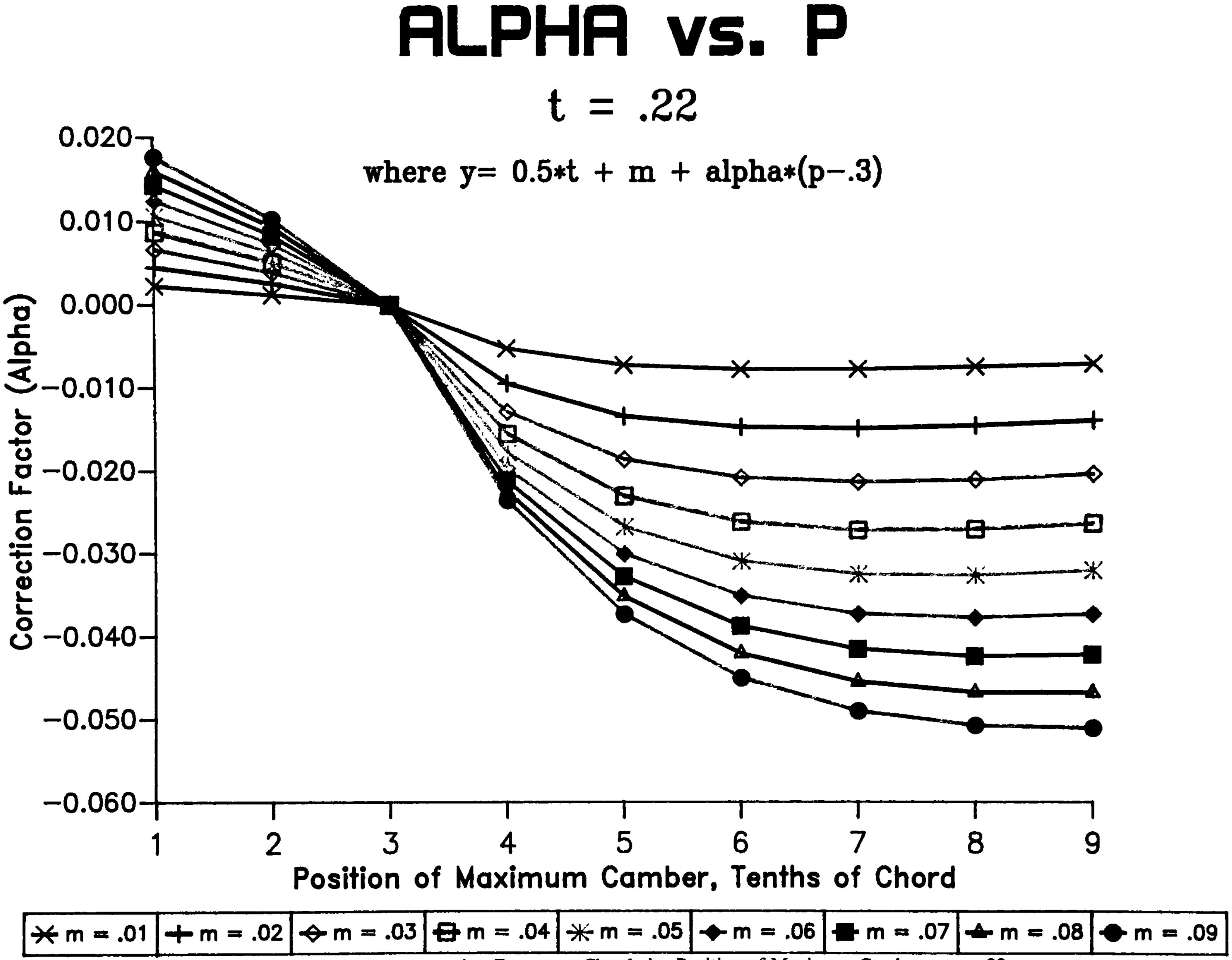


Figure 4.81 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .22c

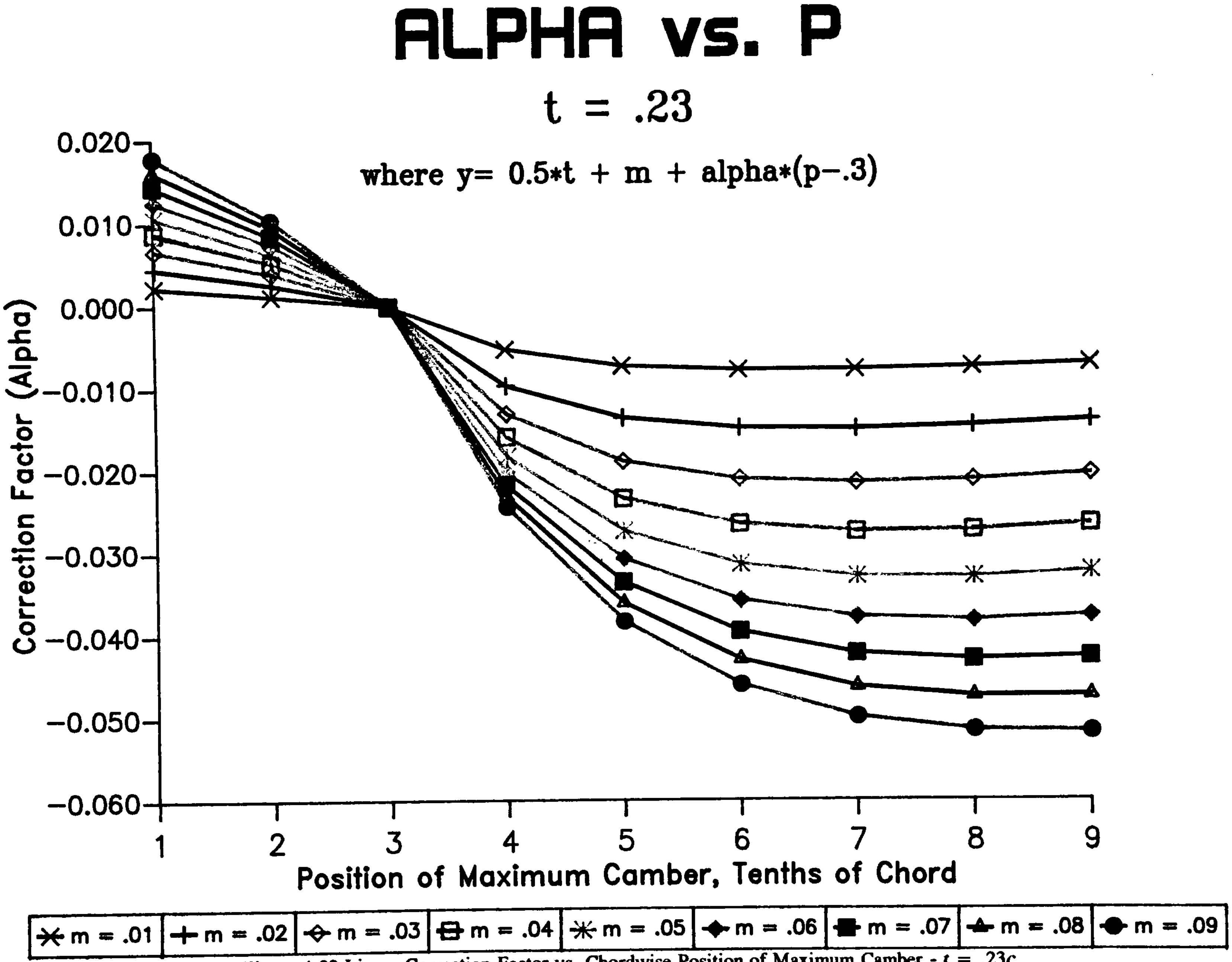


Figure A 82 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .23c

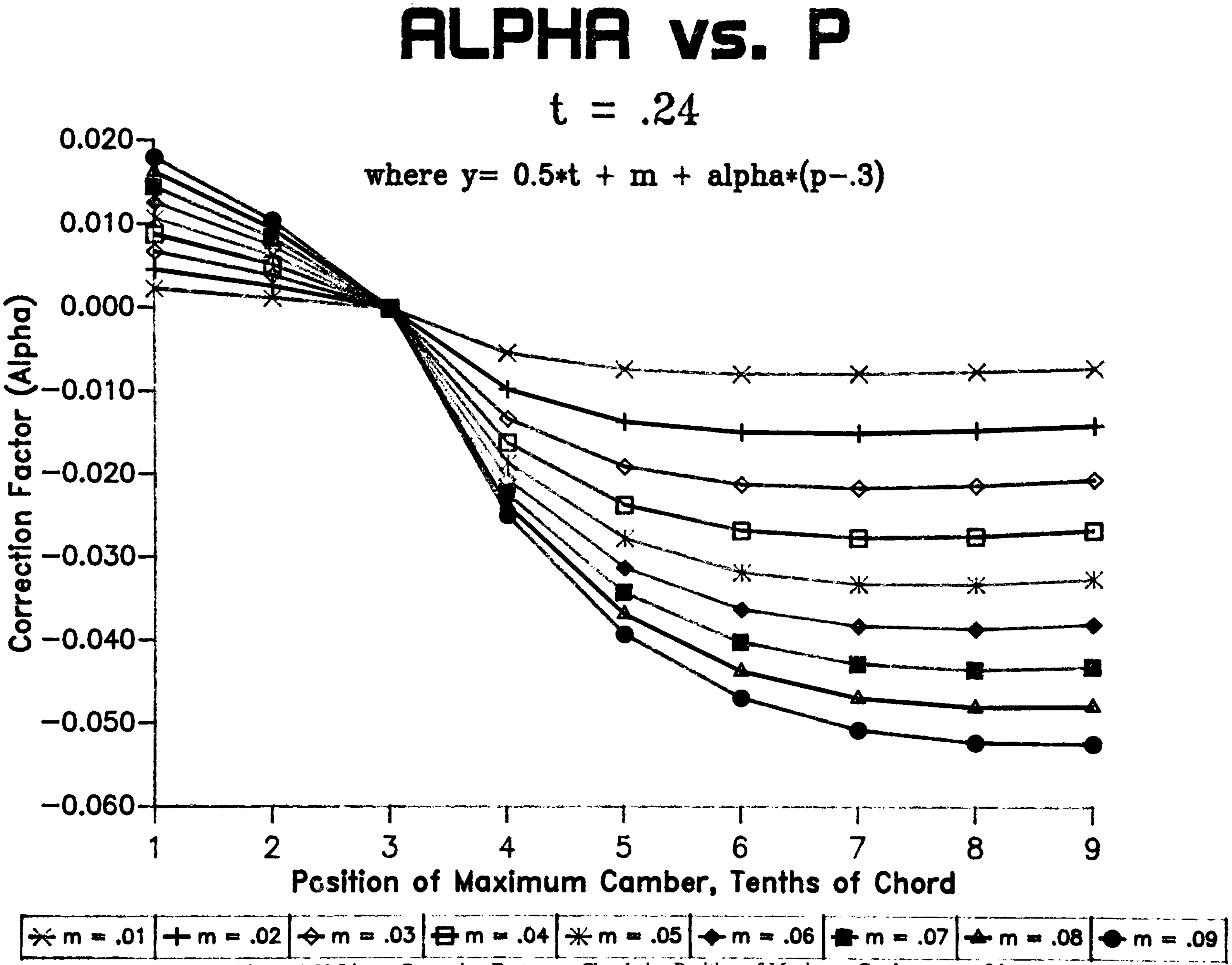


Figure 4.83 Linear Correction Factor vs. Chordwise Position of Maximum Camber - t = .24c

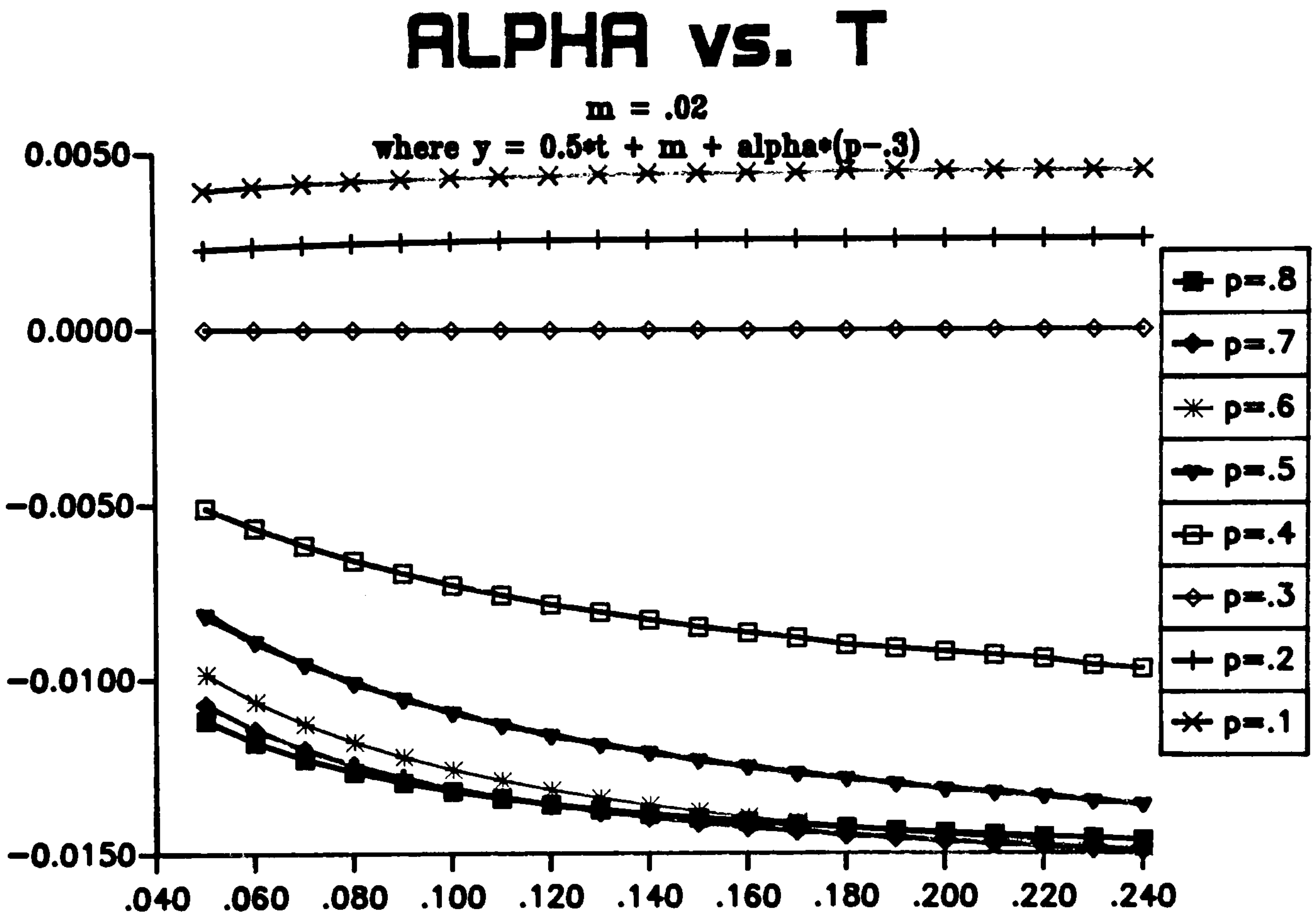


Figure 4.84 Linear Correction Factor vs. Thickness Ratio - m = .02c

4.2.3 Utilization of Properties at Point of Maximum Camber

Somewhere late in the course of this research, this researcher had the notion that for the cambered case, quite possibly the wrong track was taken. The futility in attempting to fit cambered airfoils by determining relationships for the points of zero slope as a function of descriptive parameters is evident from the previous examples. The thought occurred that rather than finding the point of zero slope and generating a curve from these points, a more viable method may be one of using the airfoil coordinates at the $x=p$ chordwise position and this point's corresponding ordinates and tangents.

4.2.3.1 Further Review

Recall from equations [2.7a] and [2.7b] that the relations which govern the combination of mean line and thickness distribution are

$$\begin{aligned} x_u &= x - y_t \sin\theta \\ y_u &= y_c + y_t \cos\theta \end{aligned} \qquad [2.7a]$$

and

$$\begin{aligned} x_l &= x + y_t \sin\theta \\ y_l &= y_c - y_t \cos\theta \end{aligned} \qquad [2.7b]$$

It is important to note from the mean line, given by equation [2.5]

$$y_c = \begin{cases} \dfrac{m}{p^2}\,(2px - x^2)\ , & 0 \le x \le p \\ \dfrac{m}{(1-p)^2}\left[(1-2p) + 2px - x^2\right], & p \le x \le c \end{cases} \qquad [2.5]$$

that at $x=p$, the ordinate of the camber line is $y_c=m$. Similarly,the camber line tangent at any chordwise position x is given by [2.6], below.

$$y_c{}' = \tan\theta = \begin{cases} \dfrac{2m}{p^2}\,(p - x)\ , & 0 \le x \le p \\ \dfrac{2m}{(1-p)^2}\,(p - x)\ , & p \le x \le c \end{cases} \qquad [2.6]$$

Of interest in [2.6] is the fact that the camber line possesses (with the exception of the case $p=.5$) only C_1 continuity. This point will be important as the discussion progresses.

4.2.3.2 Enclosing Tangent Triangle

A triangle constructed about the leading edge of the upper surface of any arbitrary airfoil is shown in Figure 4.85. This triangle is unique for each combination of m,p and t. In Figure 4.85 the line **AB** is perpendicular to the camber line tangent at the origin (leading edge); the line **BC** is the tangent to the airfoil at the point $(p,y_u(p))$.

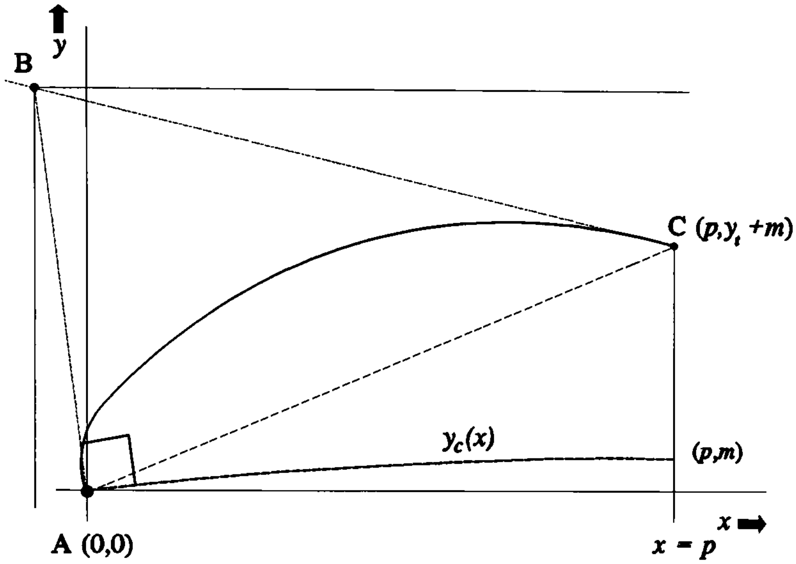


Figure 4.85 Arbitrary Cambered Airfoil Upper Surface, $0 \leq x \leq p$, and Tangent Triangle

In order to compute the equations for tangent line AB, it is a simple matter to determine the camber line slope at the origin and find its negative reciprocal. Because the leading edge lies on the origin, the equation for this line is

$$y = \frac{-p}{2m} x \qquad [4.13]$$

The slope of the tangent BC is determined with much more difficulty, by determining an expression for $\partial y_u / \partial x_u$ at $x = p$.

From the chain rule it is known that

$$\frac{\partial y_u}{\partial x_u} = \frac{\partial y_u}{\partial x} \frac{\partial x}{\partial x_u} \qquad [4.14]$$

For the upper surface, differentiating [2.7a] yields

$$\begin{aligned} \frac{\partial x_u}{\partial x} &= 1 - y_t \cos\theta \frac{\partial \theta}{\partial x} - \frac{\partial y_t}{\partial x} \sin\theta \\ \frac{\partial y_u}{\partial x} &= \frac{\partial y_c}{\partial x} - y_t \sin\theta \frac{\partial \theta}{\partial x} + \frac{\partial y_t}{\partial x} \cos\theta \end{aligned} \qquad [4.15]$$

For the lower surface, differentiating [2.7b] yields

$$\begin{aligned} \frac{\partial x_l}{\partial x} &= 1 + y_t \cos\theta \frac{\partial \theta}{\partial x} + \frac{\partial y_t}{\partial x} \sin\theta \\ \frac{\partial y_l}{\partial x} &= \frac{\partial y_c}{\partial x} + y_t \sin\theta \frac{\partial \theta}{\partial x} - \frac{\partial y_t}{\partial x} \cos\theta \end{aligned} \tag{4.16}$$

The slope of the airfoil surface at any chordwise position x is given by

$$\begin{aligned} \frac{\partial y_u}{\partial x_u} &= \frac{\partial y_u}{\partial x} \frac{\partial x}{\partial x_u} \\ \frac{\partial y_l}{\partial x_l} &= \frac{\partial y_l}{\partial x} \frac{\partial x}{\partial x_l} \end{aligned} \tag{4.17}$$

In order to obtain an expression for $\partial\theta/\partial x$, differentiation of [2.6] is necessary, and yields

$$\sec^2\theta \frac{\partial \theta}{\partial x} = \begin{cases} \dfrac{-2m}{(p)^2}, & 0 \le x \le p \\ \dfrac{-2m}{(1-p)^2}, & p \le x \le c \end{cases} \tag{4.18}$$

One may determine expressions for $\sin\theta$ and $\cos\theta$ by squaring [2.6] and implementing the trigonometric identity $\sec^2\theta = \tan^2\theta + 1$. After some algebraic manipulation, this yields

$$\sin\theta = \begin{cases} \dfrac{2m(p-x)}{\sqrt{[2m(p-x)]^2 + p^4}}, & 0 \le x \le p \\ \dfrac{2m(p-x)}{\sqrt{[2m(p-x)]^2 + (1-p)^4}}, & p \le x \le c \end{cases} \tag{4.19}$$

and

$$\cos\theta = \begin{cases} \dfrac{p^2}{\sqrt{[2m(p-x)]^2 + p^4}}, & 0 \le x \le p \\ \dfrac{(1-p)^2}{\sqrt{[2m(p-x)]^2 + (1-p)^4}}, & p \le x \le c \end{cases} \qquad [4.20]$$

Solving **[4.18]** for $\partial\theta/\partial x$ gives

$$\frac{\partial\theta}{\partial x} = \begin{cases} \dfrac{-2mp^2}{[2m(p-x)]^2 + p^4}, & 0 \le x \le p \\ \dfrac{-2m(1-p)^2}{[2m(p-x)]^2 + (1-p)^4}, & p \le x \le c \end{cases} \qquad [4.21]$$

Rather than expending effort to obtain an expression for the slope of the airfoil at some arbitrary chordwise position, it will be more efficient to determine the slope only at the leading edge, the chordwise position of maximum camber, and the trailing edge (the use of the Bézier curve precludes the determination of the slope at any other points).

At the chordwise position of maximum camber ($x=p$), the following simplifications can be made:

$$\frac{\partial y_c}{\partial x} = 0$$

$$\cos\theta = 1$$

$$\sin\theta = 0$$

and

$$\frac{\partial\theta}{\partial x} = \frac{-2m}{p^2}, \qquad x \to p^-$$

$$\frac{\partial\theta}{\partial x} = \frac{-2m}{(1-p)^2}, \qquad x \to p^+$$

Given the above simplifications, at $x=p$

$$\begin{aligned} \frac{\partial x_u}{\partial x} &= 1 - y_t \frac{\partial \theta}{\partial x} \\ \frac{\partial y_u}{\partial x} &= \frac{\partial y_t}{\partial x} \end{aligned} \qquad [4.22]$$

and the slope at the chordwise position of maximum camber is thus

$$\frac{\partial y_u}{\partial x_u} = \begin{cases} \dfrac{\partial y_t}{\partial x} \dfrac{p^2}{2 y_t m + p^2} , & x \to p^- \\ \\ \dfrac{\partial y_t}{\partial x} \dfrac{(1 - p)^2}{2 y_t m + (1 - p)^2} , & x \to p^+ \end{cases} \qquad [4.23]$$

In a similar manner, the slope of the lower surface at $x=p$ is

$$\frac{\partial y_l}{\partial x_l} = \begin{cases} \dfrac{\partial y_t}{\partial x} \dfrac{p^2}{2 m y_t - p^2} , & x \to p^- \\ \\ \dfrac{\partial y_t}{\partial x} \dfrac{(1 - p)^2}{2 m y_t - (1 - p)^2} , & x \to p^+ \end{cases} \qquad [4.24]$$

At the trailing edge ($x=1$), the simplifications below may be made:

$$\begin{aligned} \sin \theta &= \frac{-2 m}{\sqrt{4 m^2 + (1 - p)^2}} \\ \cos \theta &= \frac{1 - p}{\sqrt{4 m^2 + (1 - p)^2}} \\ \frac{\partial \theta}{\partial x} &= \frac{-2 m}{[4 m^2 + (1 - p)^2]} \end{aligned} \qquad [4.25]$$

and the slope of the upper surface "reduces" to

$$\frac{\partial y_u}{\partial x_u} = \frac{\frac{-2m}{1-p}\left[4m^2 + (1-p)^2\right]^{3/2} - 4m^2 y_t + \frac{\partial y_t}{\partial x}(1-p)\left[4m^2 + (1-p)^2\right]}{\left[4m^2 + (1-p)^2\right]^{3/2} + 2m y_t (1-p) + 2m\frac{\partial y_t}{\partial x}\left[4m^2 + (1-p)^2\right]} \qquad [4.26]$$

Similarly, the lower surface slope at the trailing edge is defined by

$$\frac{\partial y_l}{\partial x_l} = \frac{\frac{-2m}{1-p}\left[4m^2 + (1-p)^2\right]^{3/2} + 4m^2 y_t - \frac{\partial y_t}{\partial x}(1-p)\left[4m^2 + (1-p)^2\right]}{\left[4m^2 + (1-p)^2\right]^{3/2} - 2m y_t (1-p) - 2m\frac{\partial y_t}{\partial x}\left[4m^2 + (1-p)^2\right]} \qquad [4.27]$$

where y_t and $\partial y_t/\partial x$ are evaluated at $x=1$.

This may, at this point, seem a tedious process, but one must keep in mind that if this method is successful, these formulae are used only to compute the Bézier defining polygon vertices, and as such will be evaluated only once for each airfoil. Additionally, many of the "sub-quantities" used in equations [4.23], [4.24], [4.26] and [4.27] may be computed once and combined differently to obtain the slope of the upper or lower surface at either the chordwise position of maximum camber or at the trailing edge.

Thus the triangles which are generated by this method (there are four) are as shown in Figure 4.86 below.

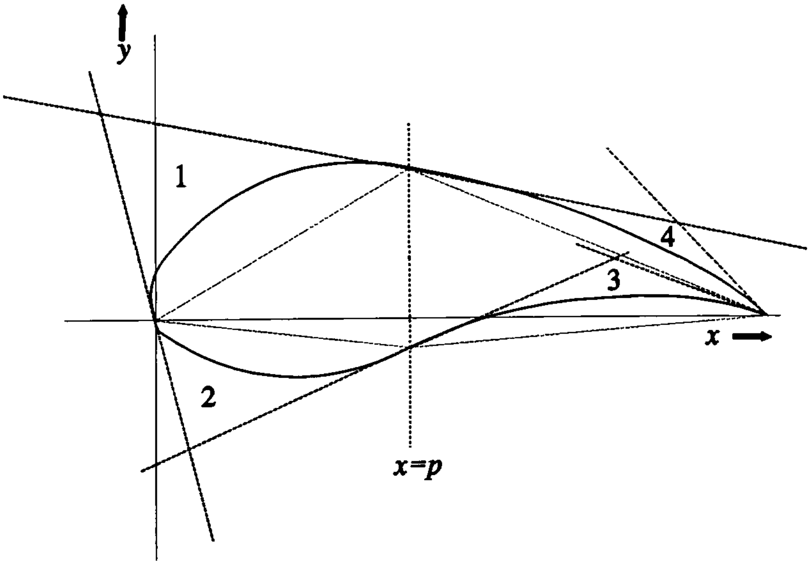


Figure 4.86 Triangles Generated About Cambered Airfoil

This analysis will concentrate on the leading edge of the upper surface of the NACA2412 airfoil. Should promising results be obtained, the method will be checked against the same surface of other airfoils. Pending the results of the second objective, the method will be expanded to the remaining portions of the NACA2412, and continue to other airfoils.

As in the case of the symmetric airfoils, the intervals over which the legs of the enclosing triangles traverse will be divided by golden section. There are three choices of the interval to be divided for each leg, however. They are:

1. Golden section search along the x-axis projection
2. Golden section search along the y-axis projection
3. Golden section search along the triangle side itself

The third option listed above was ruled out due to over-complicated axis shifts. In order to perform either of the first two, the point at which the two sides of the triangle intersect must be determined. The sides of the triangle in question can be expressed in point-slope form as

$$\begin{aligned} y &= \frac{-p}{2m} x \\ y - (y_t + m) &= \frac{\partial y_u}{\partial x_u} (x - p) \end{aligned} \qquad [4.28]$$

As $x \to p^-$, these equations become

$$\begin{aligned} y &= \frac{-p}{2m} x \\ y - (y_t + m) &= \frac{\partial y_t}{\partial x} \frac{p^2}{2 y_t m + p^2} (x - p) \end{aligned} \qquad [4.29]$$

They represent a system of linear equations, and a unique solution exists. All the quantities in [4.29] may be computed from [2.1] and [2.2] (with $x = p$) or obtained directly from the NACA designation.

The discussion here should mention the discontinuity that exists using this method. At the chordwise position of maximum camber, the slope of the tangent forward of p for the NACA2412 is computed to be $\partial y_u / \partial x_u = -0.036715316$. The corresponding tangent at $x = p$ for the upper surface trailing edge is $\partial y_u / \partial x_u = -0.037009336$. This represents an absolute error of 0.00029402 and a relative error of approximately 0.8 percent. This difference is minimal, and most likely is indiscernible to the eye.

In the case of the NACA2412, the point of intersection of the two tangent lines is given by the solution to the set of linear equations as determined by [4.29] on the previous page. The matrix formulation becomes

$$\begin{bmatrix} 10 & 1 \\ 0.036715316 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 0 \\ 0.092716235 \end{bmatrix} \tag{4.30}$$

the solution of which is

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} -0.00930579 \\ .0930579 \end{bmatrix}$$

As in the case of the symmetric NACA Four-Digit airfoil, golden section on the projection on the x-axis is the initial starting point for the attempt to fit the Bézier curve to the conventionally defined shape. This leads to four possibilities, denoted as before by the notation Case (a,b) Golden section search performed on the interval [-0.00930579,0] yields

$$(1-\tau)(0) + \tau(-0.00930579) = -0.005751295 \qquad (1)$$

$$(1-\tau)(-0.00930579) + \tau(0) = -0.003554495 \qquad (2)$$

and also on [-0.00930579,.4] yields

$$(1-\tau)(0.4) + \tau(-0.00930579) = 0.14703511 \qquad (1)$$

$$(1-\tau)(-0.00930579) + \tau(0.4) = 0.2436591 \qquad (2)$$

According to the conventions set forth above, case (1,1) will be a third-order Bézier curve whose defining polygon vertices are:

$$\begin{bmatrix} \mathbf{B}_0^{\mathbf{T}} \\ \mathbf{B}_1^{\mathbf{T}} \\ \mathbf{B}_2^{\mathbf{T}} \\ \mathbf{B}_3^{\mathbf{T}} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.005751295 & 0.05751295 \\ 0.14703511 & 0.087317794 \\ 0.4 & 0.078030109 \end{bmatrix}$$

The Bézier defining polygon for case (1,2) is given by

$$\begin{bmatrix} B_0^T \\ B_1^T \\ B_2^T \\ B_3^T \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.005751295 & 0.05751295 \\ 0.2436591 & 0.083770214 \\ 0.4 & 0.078030109 \end{bmatrix}$$

Similarly, case (2,1) is defined by

$$\begin{bmatrix} B_0^T \\ B_1^T \\ B_2^T \\ B_3^T \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.003554495 & 0.03554495 \\ 0.14703511 & 0.087317794 \\ 0.4 & 0.078030109 \end{bmatrix}$$

Lastly, the defining polygon vertices for case (2,2) are:

$$\begin{bmatrix} B_0^T \\ B_1^T \\ B_2^T \\ B_3^T \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.003554495 & 0.03554495 \\ 0.2436591 & 0.083770214 \\ 0.4 & 0.078030109 \end{bmatrix}$$

Figures 4.87 through 4.90, on the pages following, illustrate each of the four cases along with the desired curve. It is observed that case (2,1) is apparently a very good fit to the leading edge upper surface of the NACA2412. In order to determine if the above method provides similar results with others, this method was attempted on NACA3612 and NACA4412 airfoils.

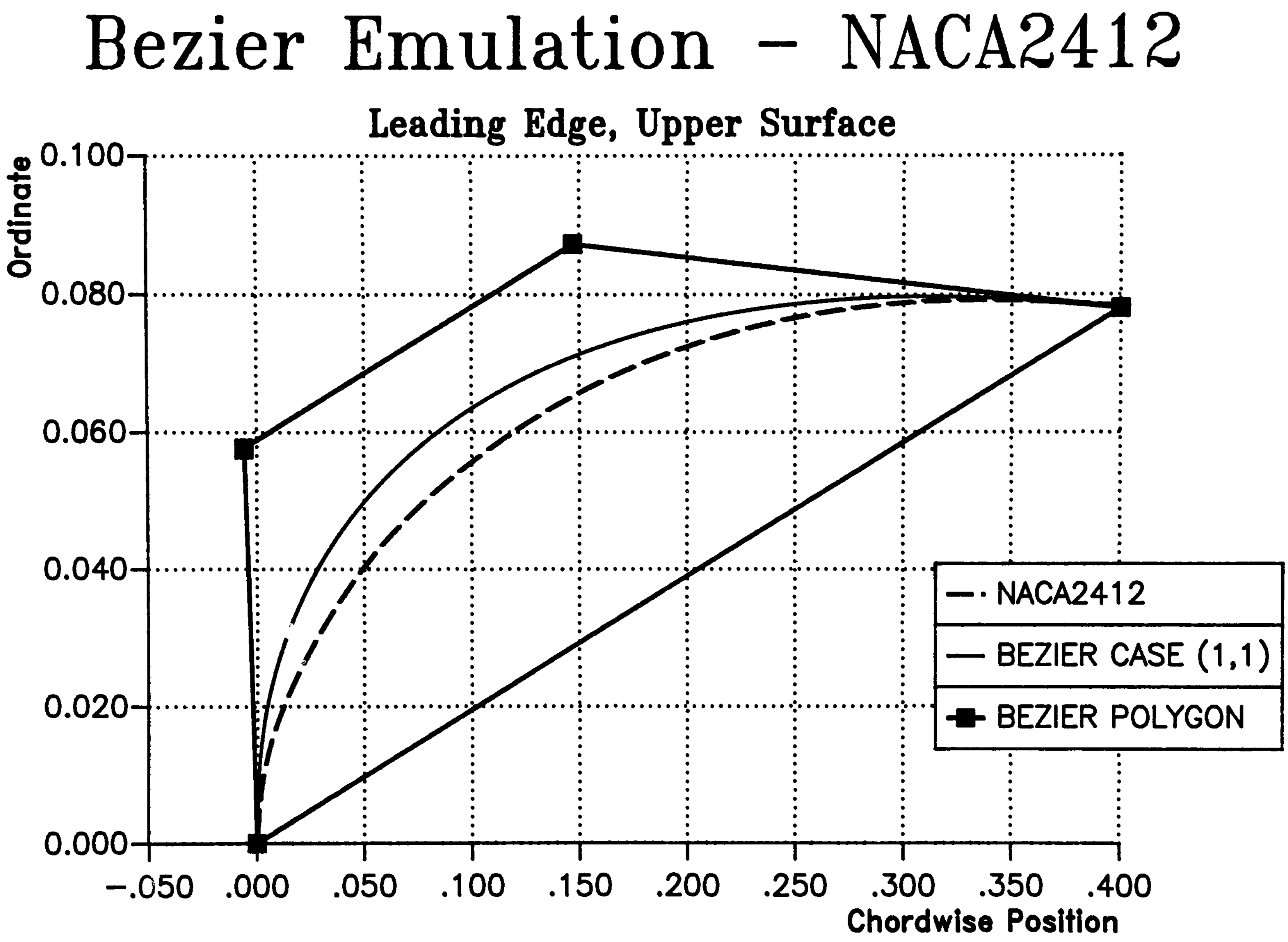


Figure 4.87 - Bézier Emulation - NACA2412 - Case (1,1)

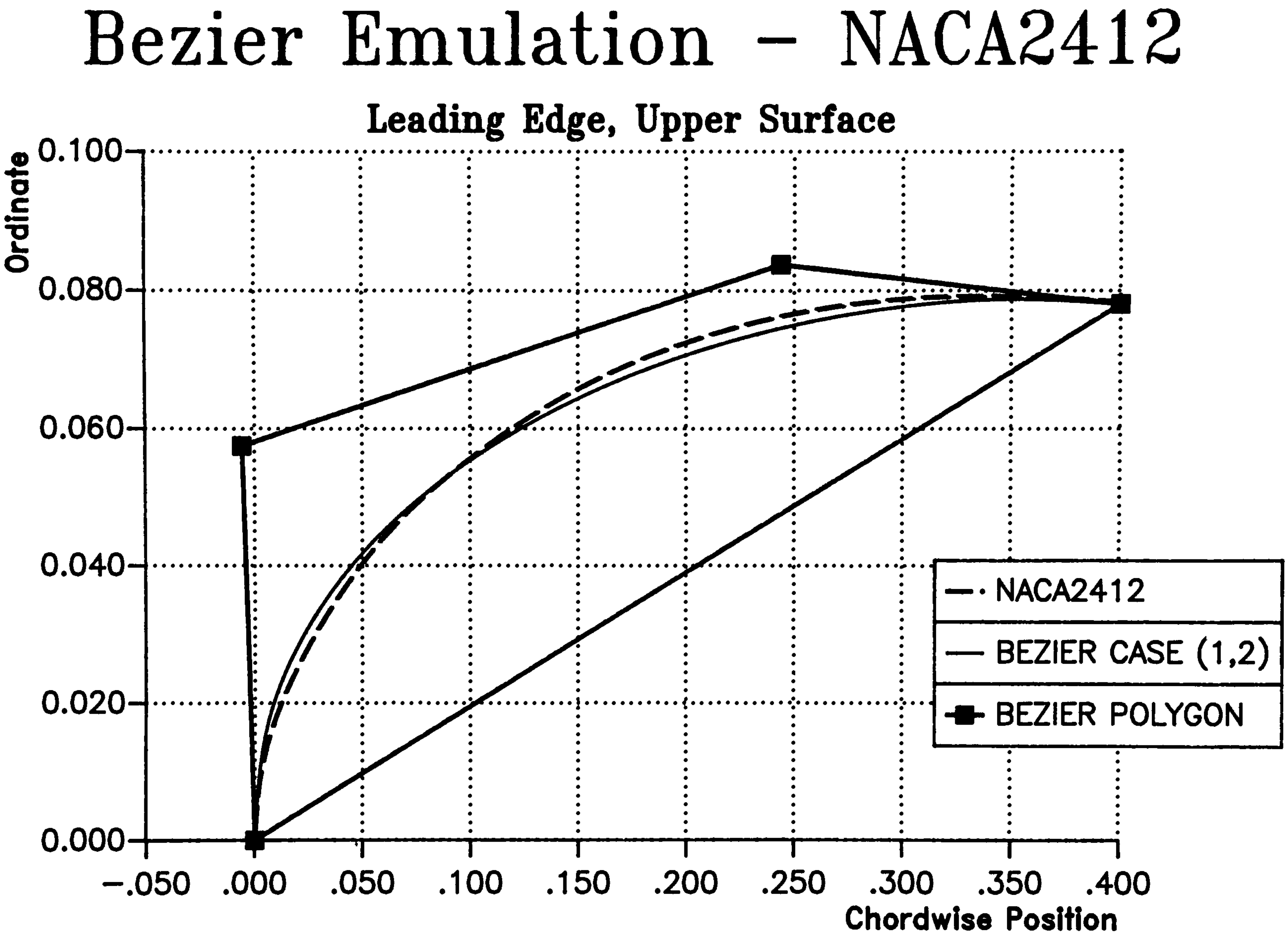


Figure 4.88 - Bézier Emulation - NACA2412 - Case (1,2)

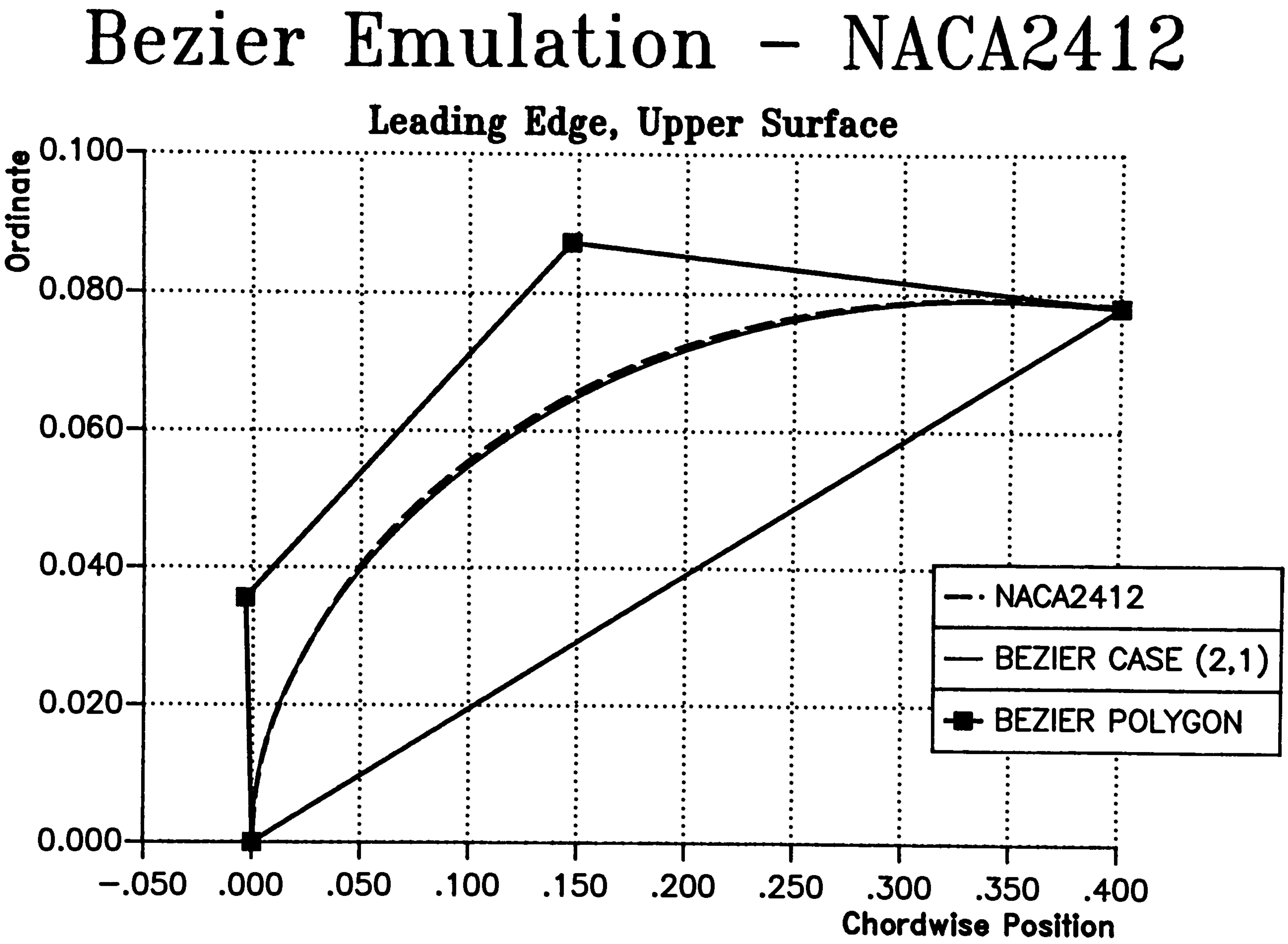


Figure 4.89 - Bézier Emulation - NACA2412 - Case (2,1)

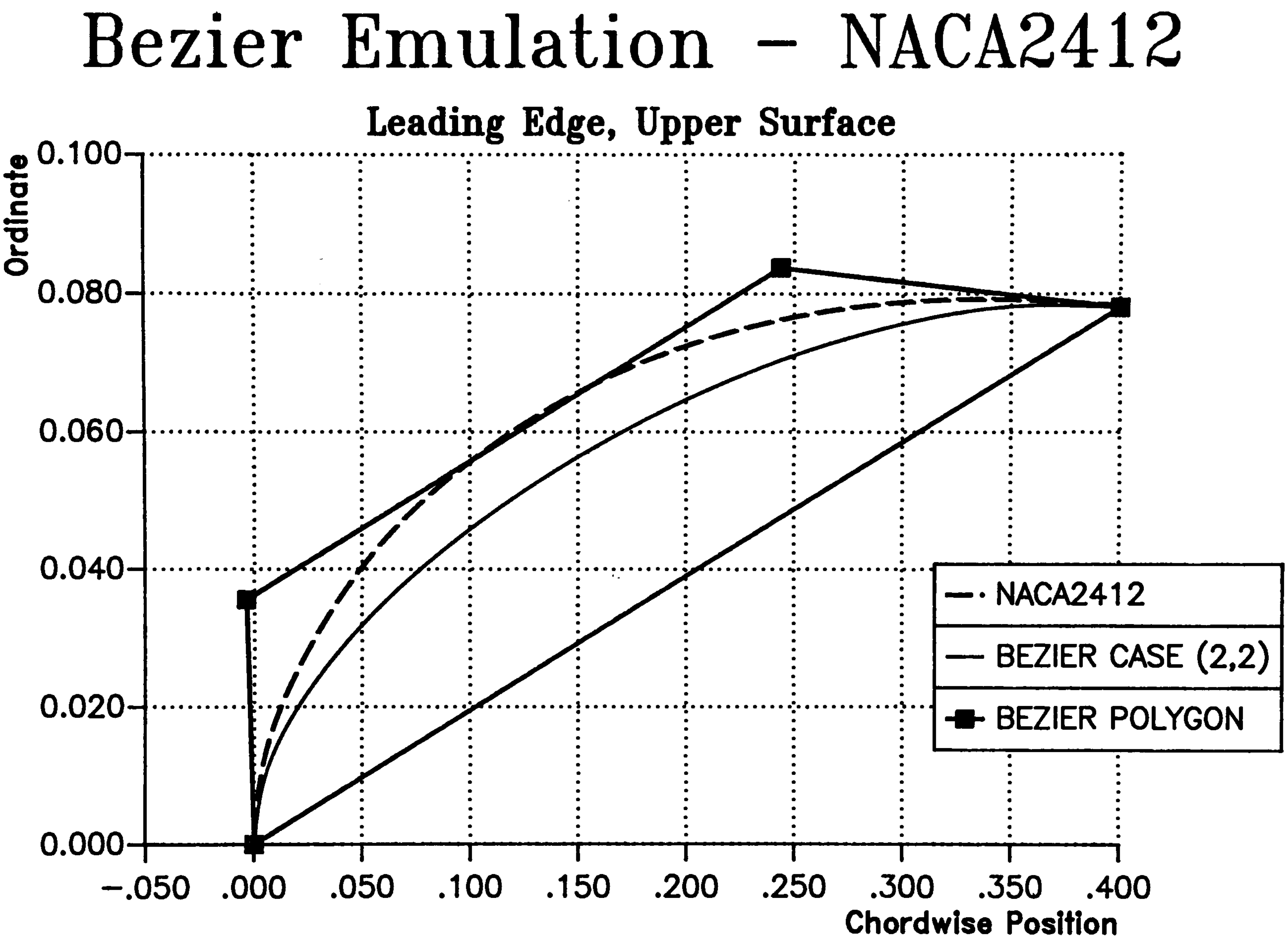


Figure 4.90 - Bézier Emulation - NACA2412 - Case (2,2)

In the case of the NACA3612 airfoil leading edge upper surface, the point of intersection of the two tangents is

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} -0.012557811 \\ 0.12557811 \end{bmatrix}$$

Golden section search performed on the interval [-0.012557811,0] led to the following initial values

$$(1-\tau)(0) + \tau(-0.012557811) = -0.007761154 \qquad (1)$$

$$(1-\tau)(-0.012557811) + \tau(0) = -0.004796657 \qquad (2)$$

search of [-0.12557811,0.6] led to

$$(1-\tau)(0.6) + \tau(-0.012557811) = 0.221418453 \qquad (1)$$

$$(1-\tau)(-0.012557811) + \tau(0.6) = 0.366023736 \qquad (2)$$

By the conventions outlined for this airfoil, the four initial Bézier curves generated to mimic the NACA3612 are (Case (1,1)):

$$\begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \\ \mathbf{B}_3^{\mathrm{T}} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.007761154 & 0.07761154 \\ 0.221418453 & 0.106501037 \\ 0.6 & 0.075633691 \end{bmatrix}$$

Case (1,2):

$$\begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \\ \mathbf{B}_3^{\mathrm{T}} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.007761154 & 0.07761154 \\ 0.366023736 & 0.094710760 \\ 0.6 & 0.075633691 \end{bmatrix}$$

Case (2,1) is defined by the control points

$$\begin{bmatrix} B_0^T \\ B_1^T \\ B_2^T \\ B_3^T \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.004796657 & 0.04796657 \\ 0.221418453 & 0.106501037 \\ 0.6 & 0.075633691 \end{bmatrix}$$

and Case (2,2) is the curve defined by

$$\begin{bmatrix} B_0^T \\ B_1^T \\ B_2^T \\ B_3^T \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.004796657 & 0.04796657 \\ 0.366023736 & 0.094710760 \\ 0.6 & 0.075633691 \end{bmatrix}$$

The resulting curves, compared with a conventionally generated NACA3612 leading edge upper surface are provided as Figures 4.91 through 4.94 on pages 136-139. By visual inspection, it is seen that Case (2,1) also provides a good fit to the desired curve.

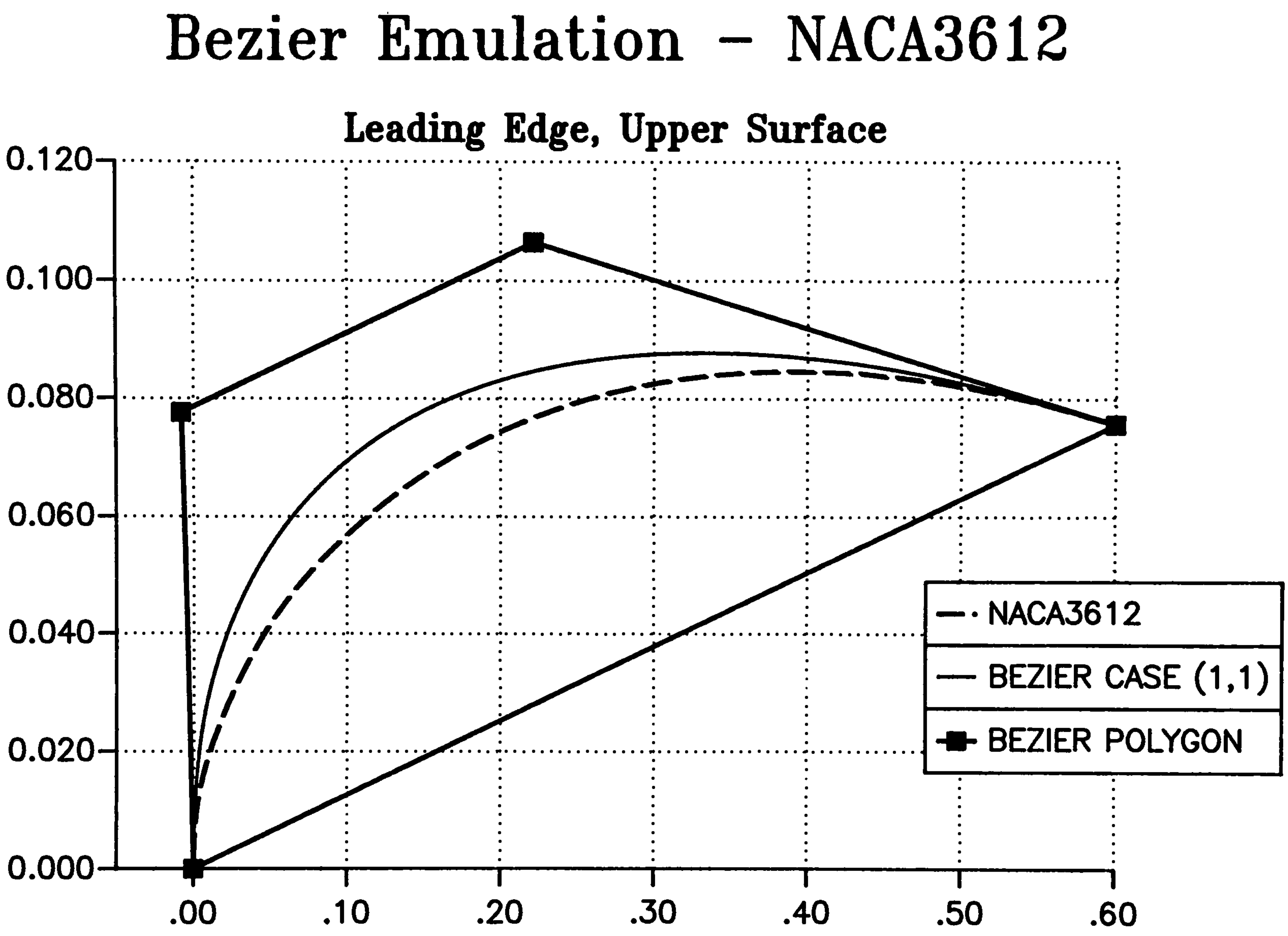


Figure 4.91 - Bézier Emulation - NACA3612 - Case (1,1)

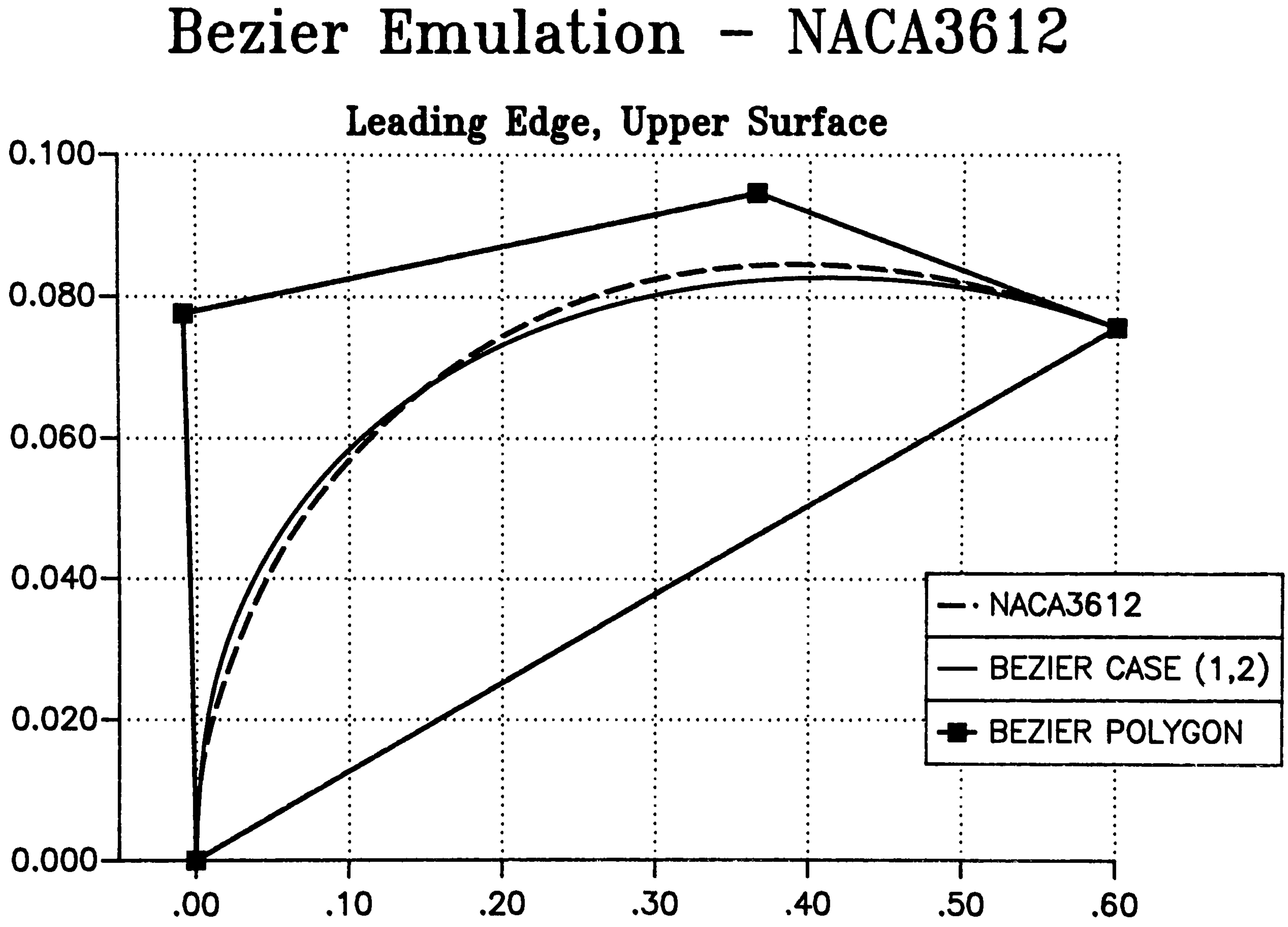


Figure 4.92 - Bézier Emulation - NACA3612 - Case (1,2)

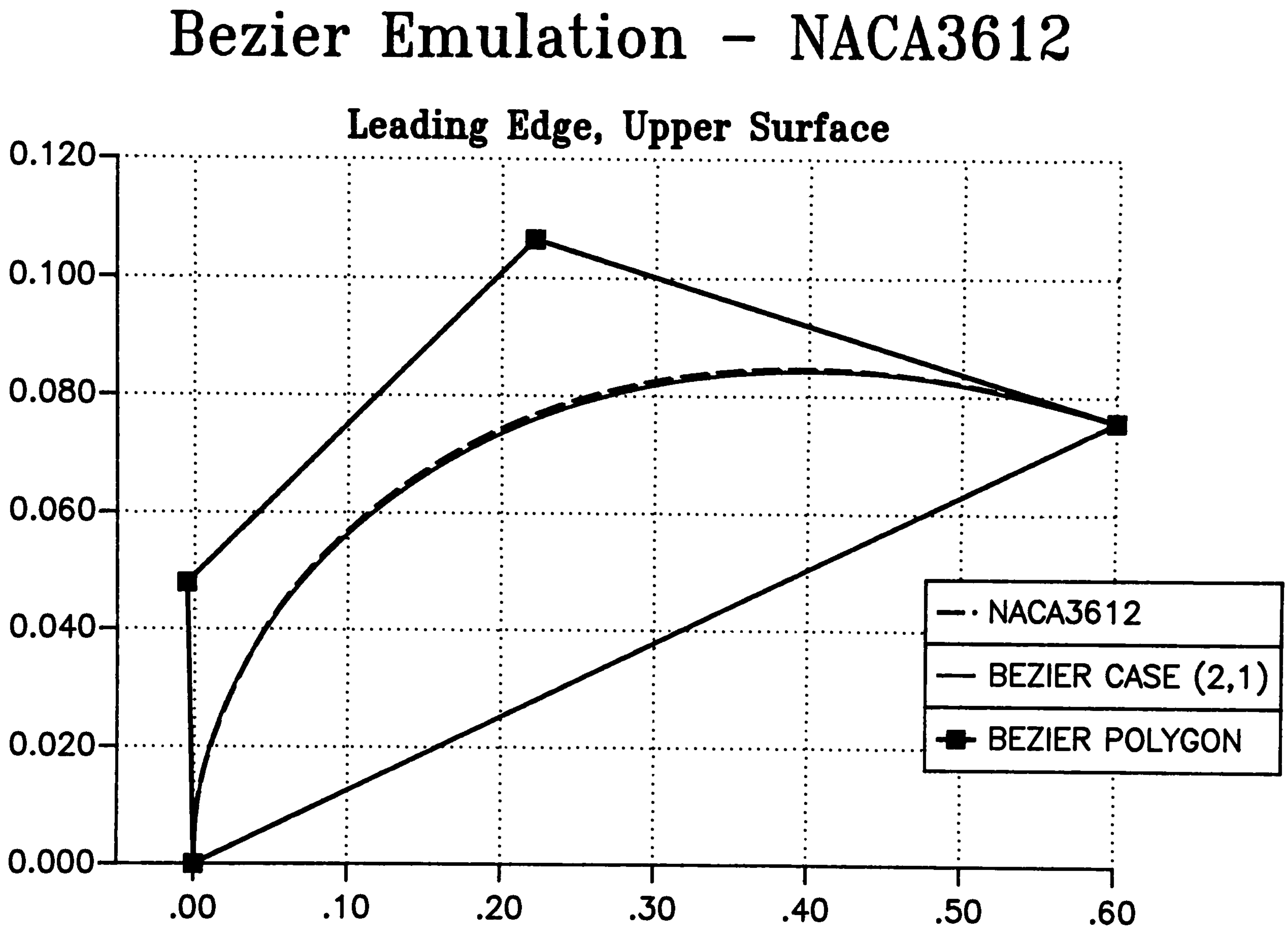


Figure 4.93 - Bézier Emulation - NACA3612 - Case (2,1)

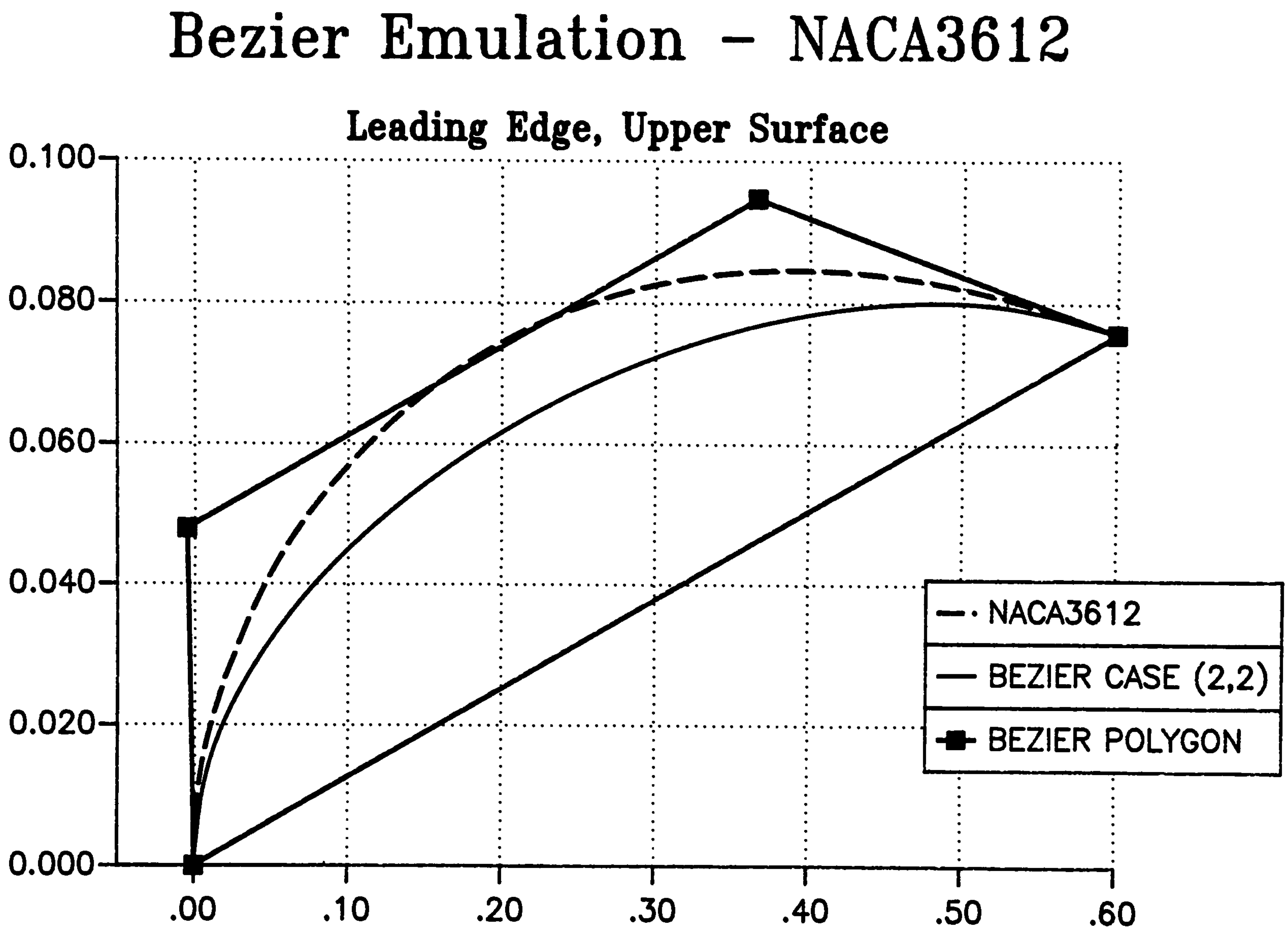


Figure 4.94 - Bézier Emulation - NACA3612 - Case (2,2)

In a manner similar to that developed for the NACA2412, the results for the NACA4412 show that the intersection of leading edge upper surface tangents occurs at

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} -0.022665927 \\ 0.113329637 \end{bmatrix}$$

As before, Golden section division of the interval [-0.022665927,0] yields

$$(1 - \tau)(0) + \tau(-0.022665927) = -0.014008314 \qquad (1)$$

$$(1 - \tau)(-0.022665927) + \tau(0) = -0.008657614 \qquad (2)$$

Division of the interval [-0.022665927,0.4] yields

$$(1 - \tau)(0.4) + \tau(-0.22665927) = 0.138778091 \qquad (1)$$

$$(1 - \tau)(-0.02266597) + \tau(0.4) = 0.238555982 \qquad (2)$$

and the matrix containing the Bézier defining polygon vertices for Case (1,1) is

$$\begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \\ \mathbf{B}_3^{\mathrm{T}} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.014008314 & 0.070041568 \\ 0.138778091 & 0.107485737 \\ 0.6 & 0.098030109 \end{bmatrix}$$

The defining polygon vertices for Case (1,2) are

$$\begin{bmatrix} \mathbf{B}_0^{\mathrm{T}} \\ \mathbf{B}_1^{\mathrm{T}} \\ \mathbf{B}_2^{\mathrm{T}} \\ \mathbf{B}_3^{\mathrm{T}} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.014008314 & 0.070041568 \\ 0.238555982 & 0.103874009 \\ 0.6 & 0.098030109 \end{bmatrix}$$

For Case (2,1), the defining polygon matrix becomes

$$\begin{bmatrix} \mathbf{B}_0^{T} \\ \mathbf{B}_1^{T} \\ \mathbf{B}_2^{T} \\ \mathbf{B}_3^{T} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.008657614 & 0.04328807 \\ 0.138778091 & 0.107485737 \\ 0.6 & 0.098030109 \end{bmatrix}$$

Finally, Case (2,2) is determined by

$$\begin{bmatrix} \mathbf{B}_0^{T} \\ \mathbf{B}_1^{T} \\ \mathbf{B}_2^{T} \\ \mathbf{B}_3^{T} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ -0.008657614 & 0.04328807 \\ 0.238555982 & 0.103874009 \\ 0.6 & 0.098030109 \end{bmatrix}$$

As is evidenced by Figures 4.95 through 4.98, pages 142-145, none of these cases provided any accurate of emulation to the NACA4412. This was not totally unexpected. The reader should notice that the airfoils analyzed in this section were not chosen at random; they all possess the same thickness ratio, and were also chosen such that effects of changing only the maximum could be discovered. Additionally, the NACA3612 was chosen because the ratio $-p/2m$ is the same as that for the NACA2412. A fourth airfoil, NACA2418 was also plotted utilizing the same strategy (Figures 4.99 through 4.102, pages 146-149) to visualize effects of thickness ratio variation. It is clear that the defining parameters have significant effects on the placement of the defining polygon vertices. Had this researcher more time available to mount the task, it is quite possible that relationships between m,p and t could be found that would be used to generate Bézier polygon vertices to generate NACA Four-Digit airfoils without having to resort to the conventional method of cambered airfoil generation. This would represent a significant jump in computational efficiency in comparison to conventional airfoil generation. Also, under ideal circumstances, coefficients used in golden section division of the triangles generated about the airfoil would default to the symmetric case when $m=0$ and $p=.3$.

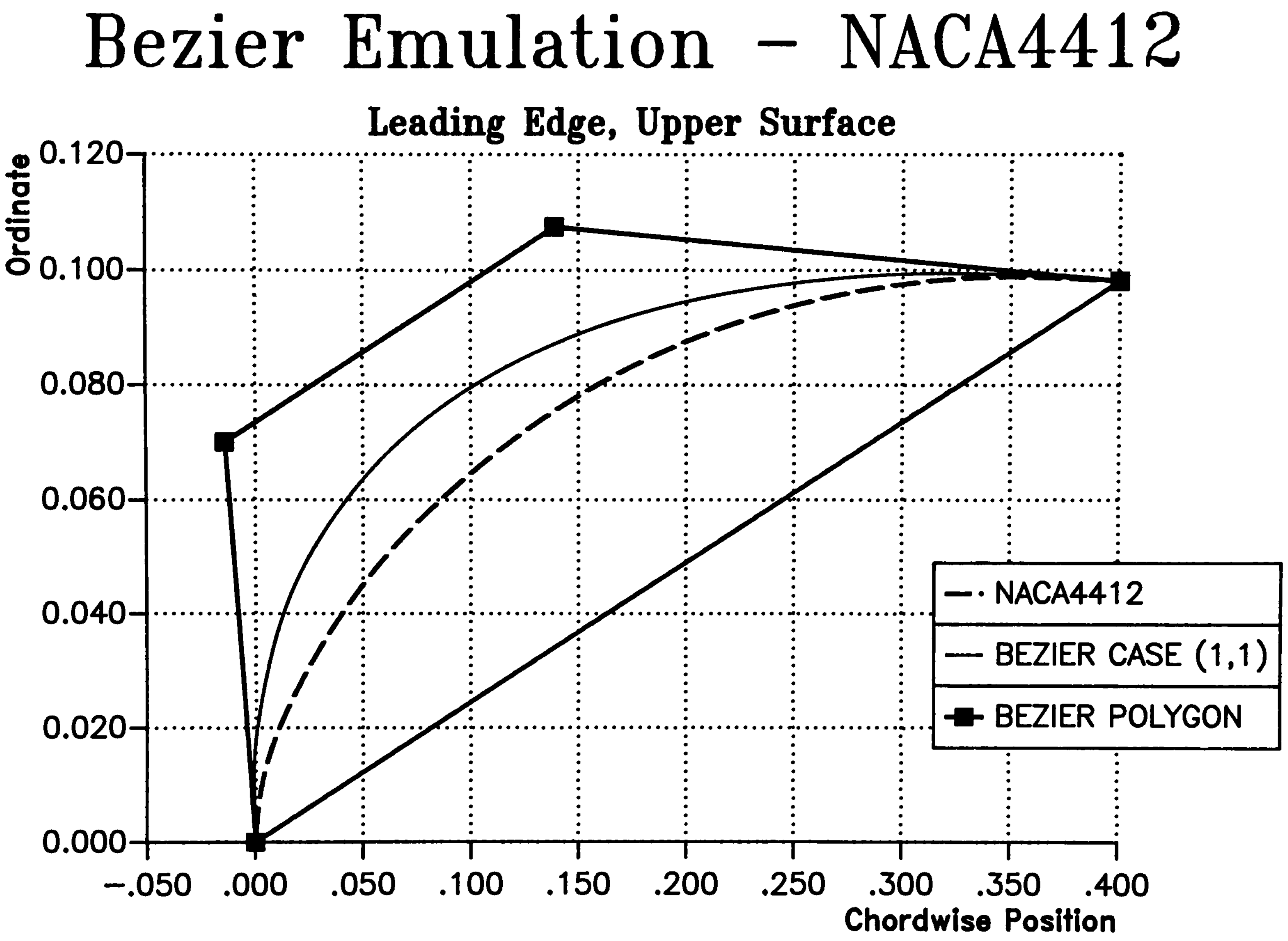


Figure 4.95 - Bézier Emulation - NACA4412 - Case (1,1)

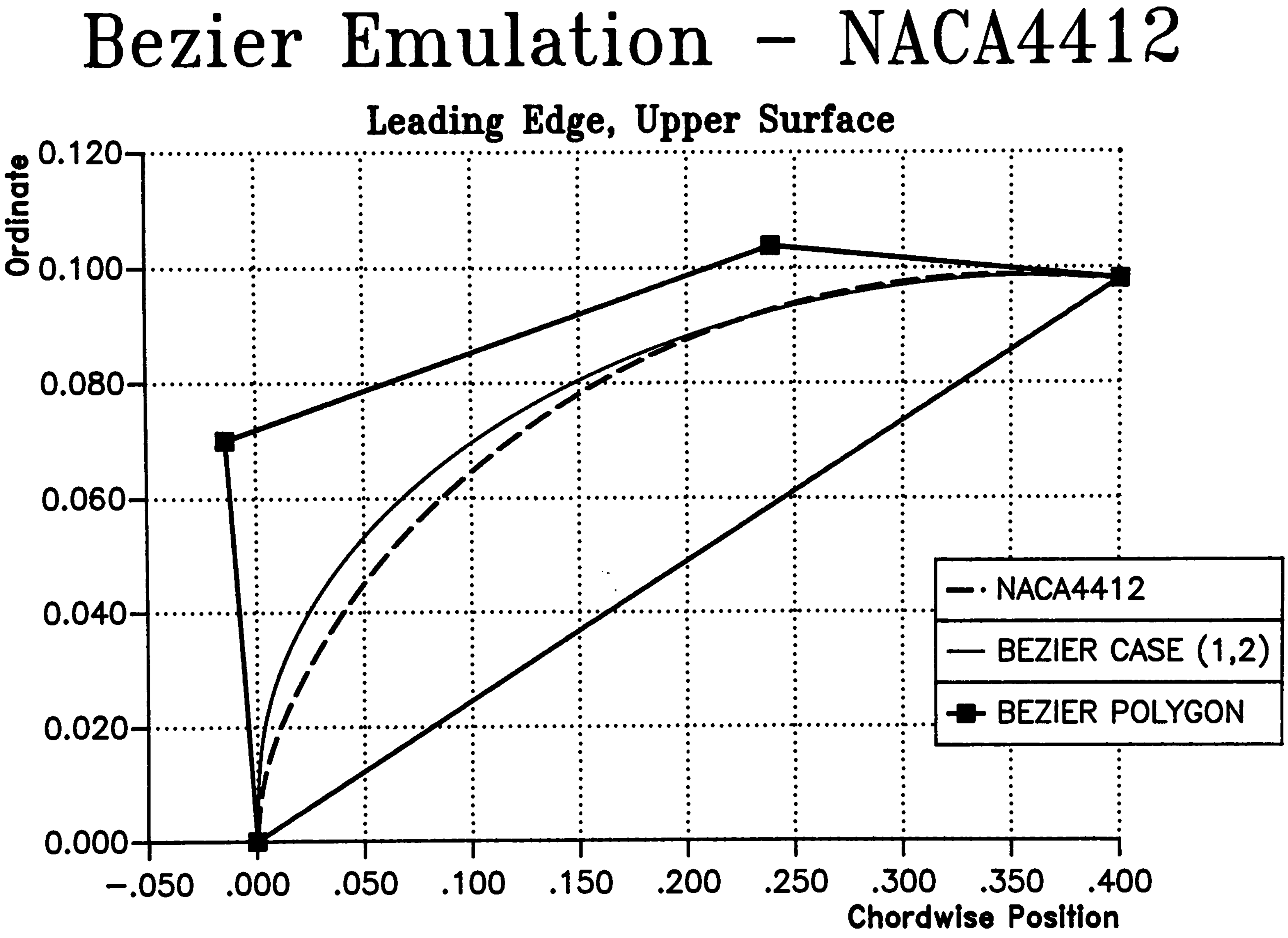


Figure 4.96 - Bézier Emulation - NACA4412 - Case (1,2)

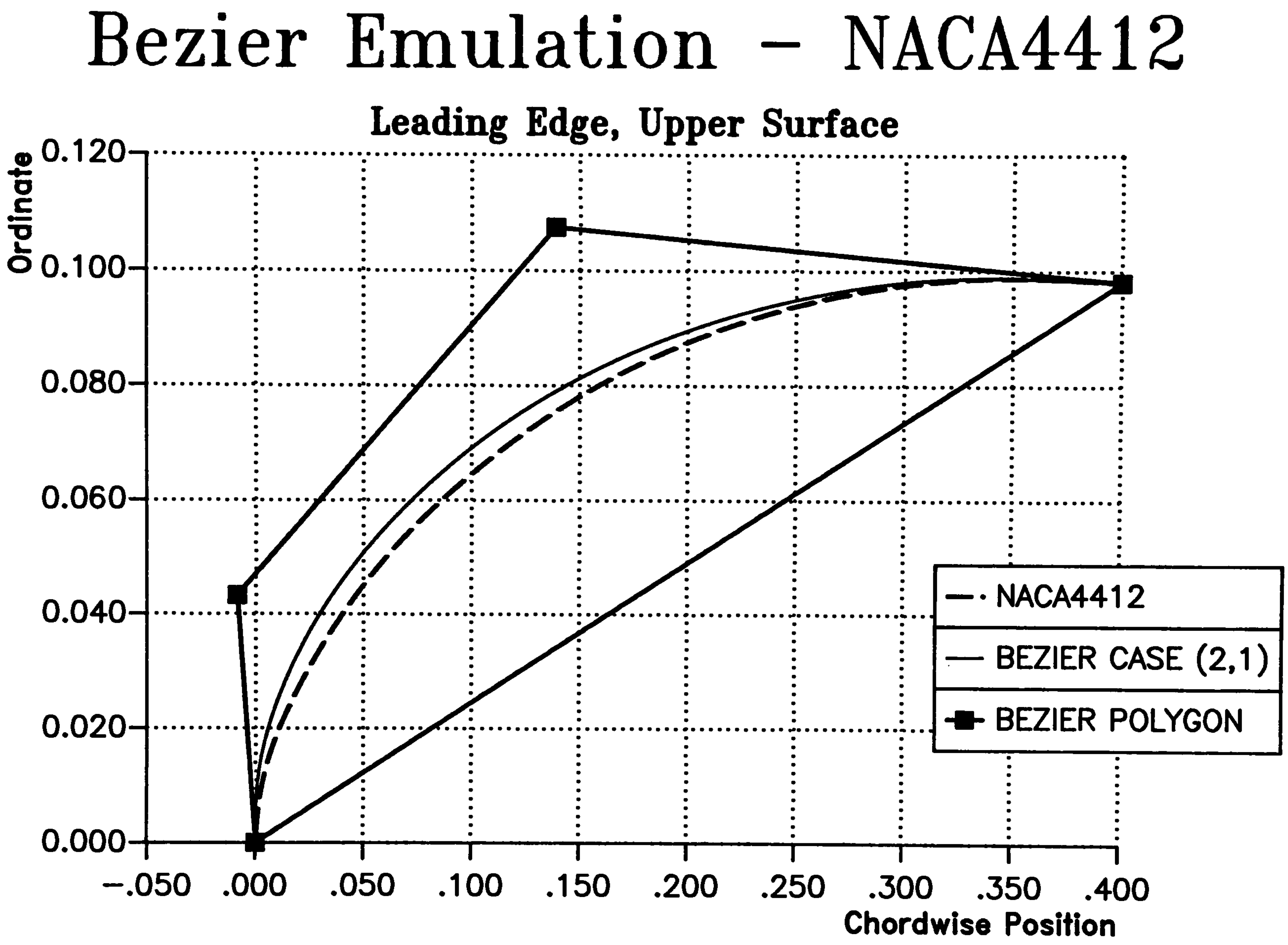


Figure 4.97 - Bézier Emulation - NACA4412 - Case (2,1)

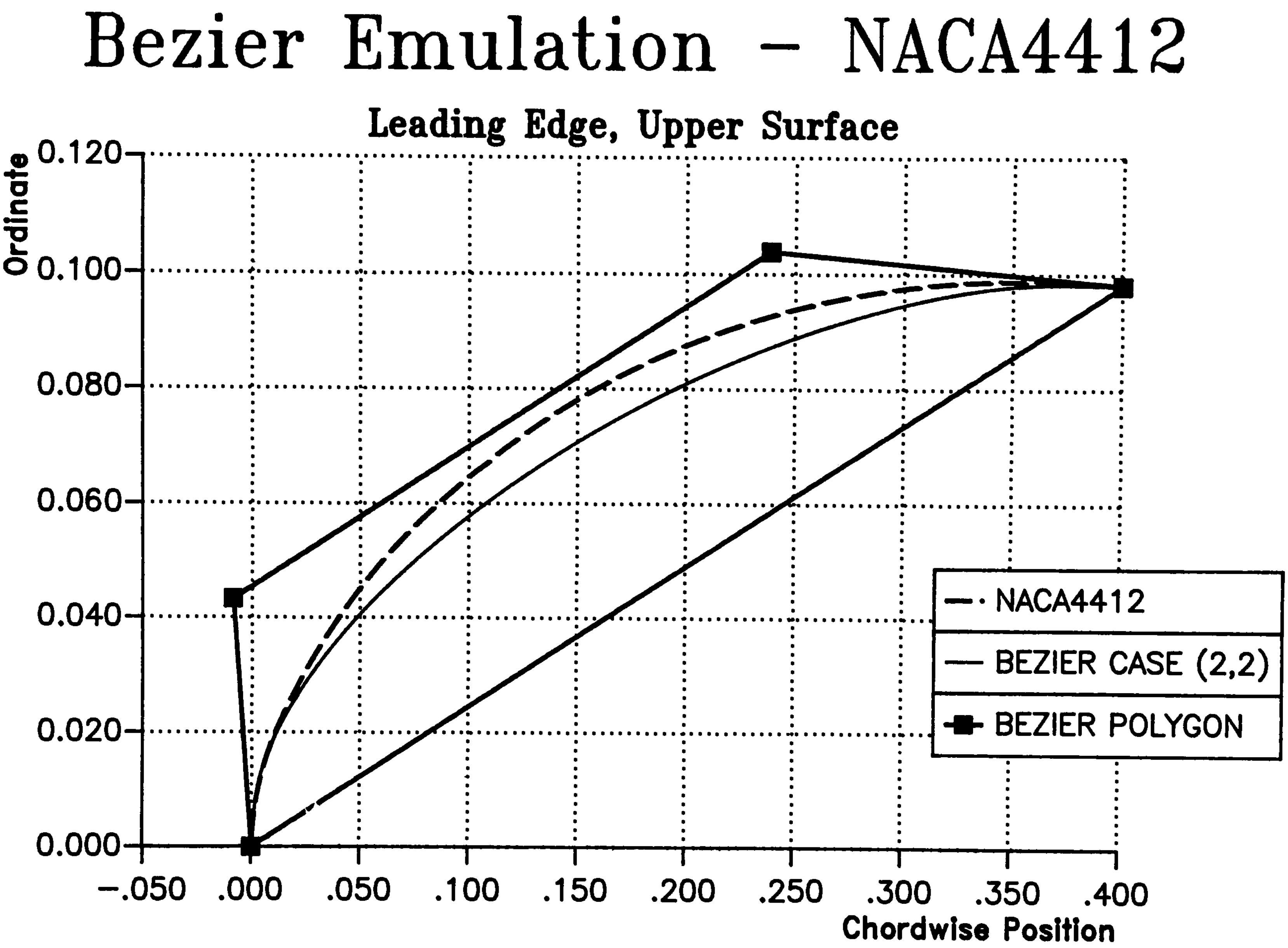


Figure 4.98 - Bézier Emulation - NACA4412 - Case (2,2)

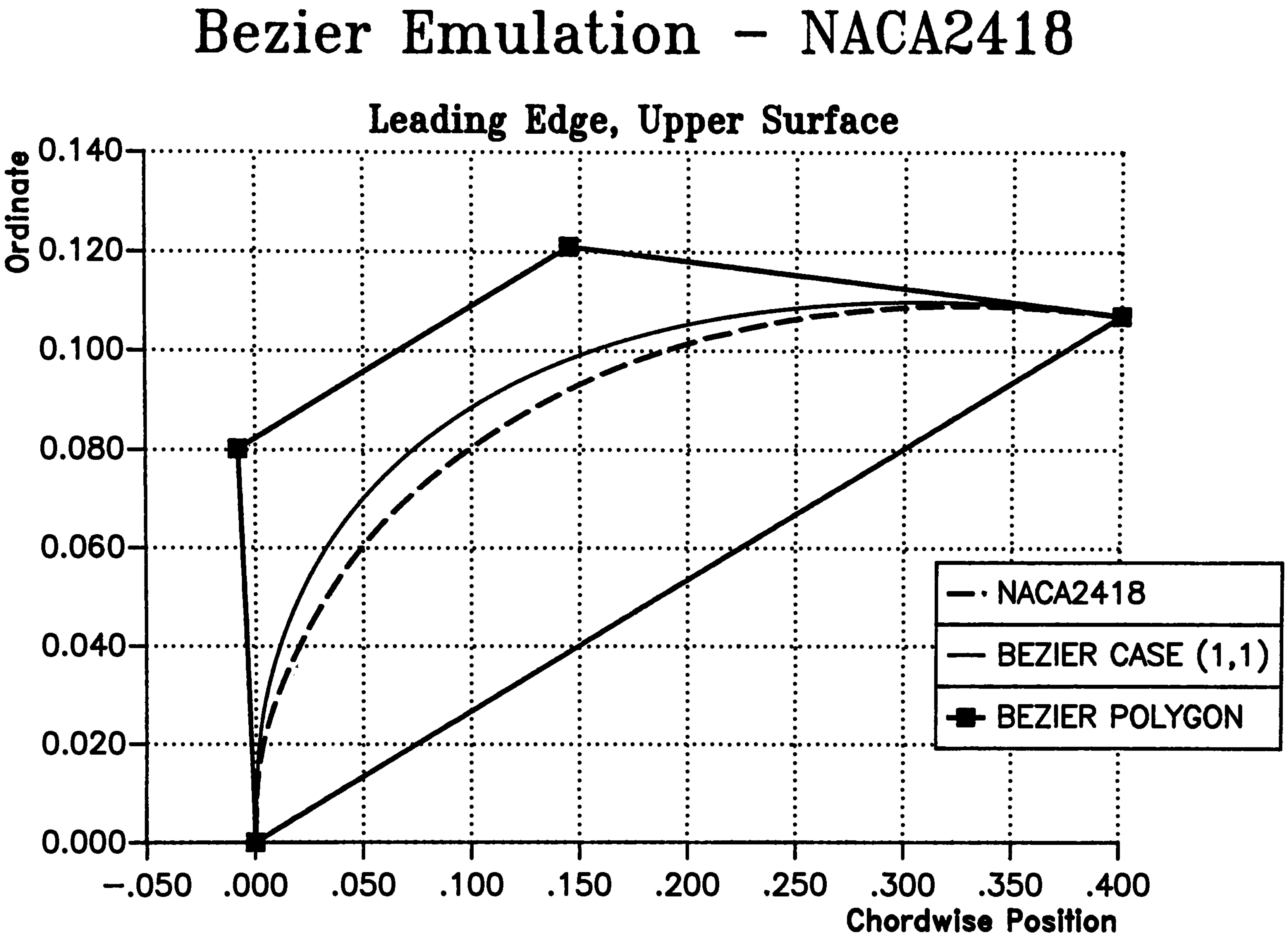


Figure 4.99 - Bézier Emulation - NACA2418 - Case (1,1)

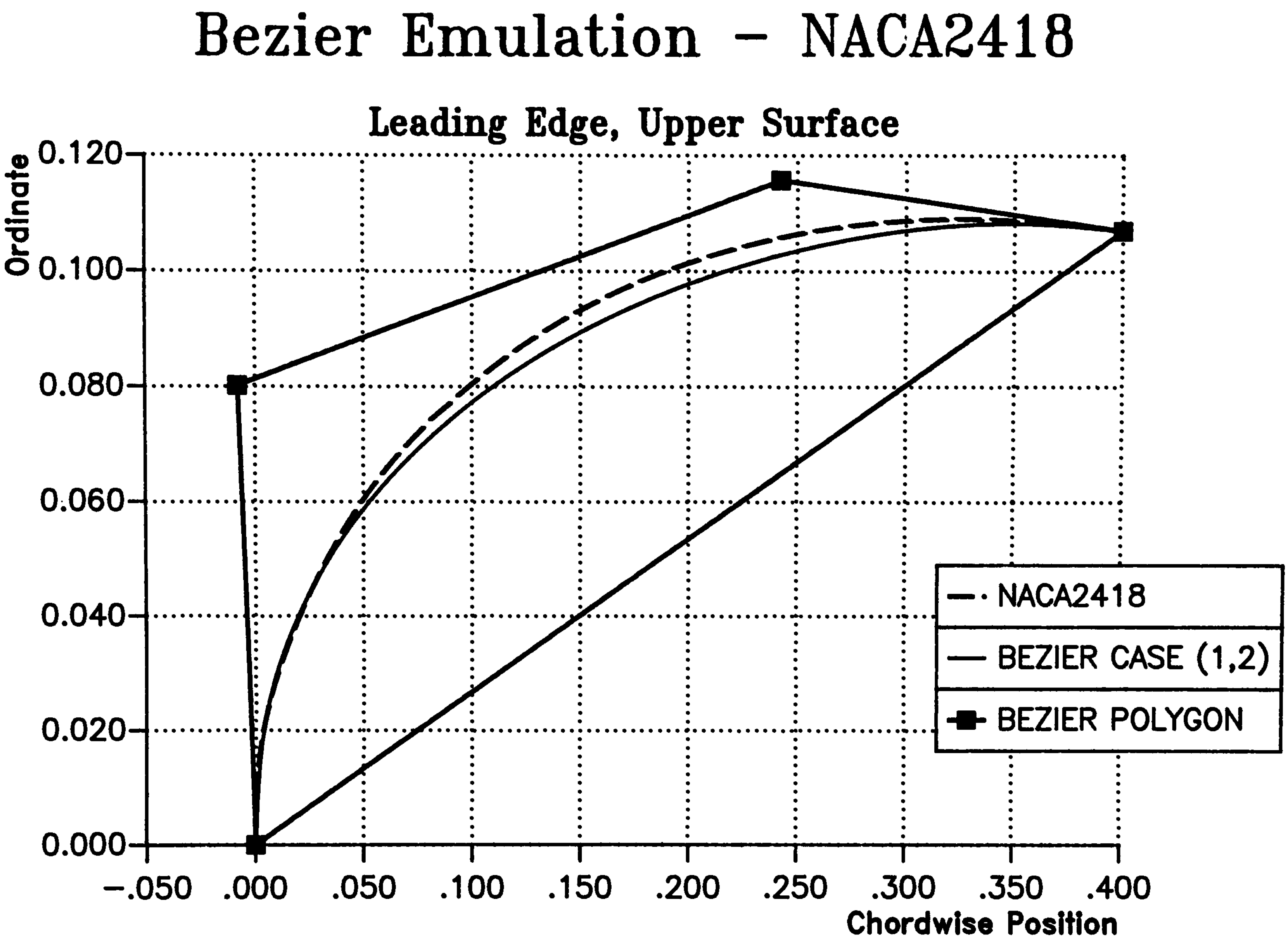


Figure 4.100 - Bézier Emulation - NACA2418 - Case (1,2)

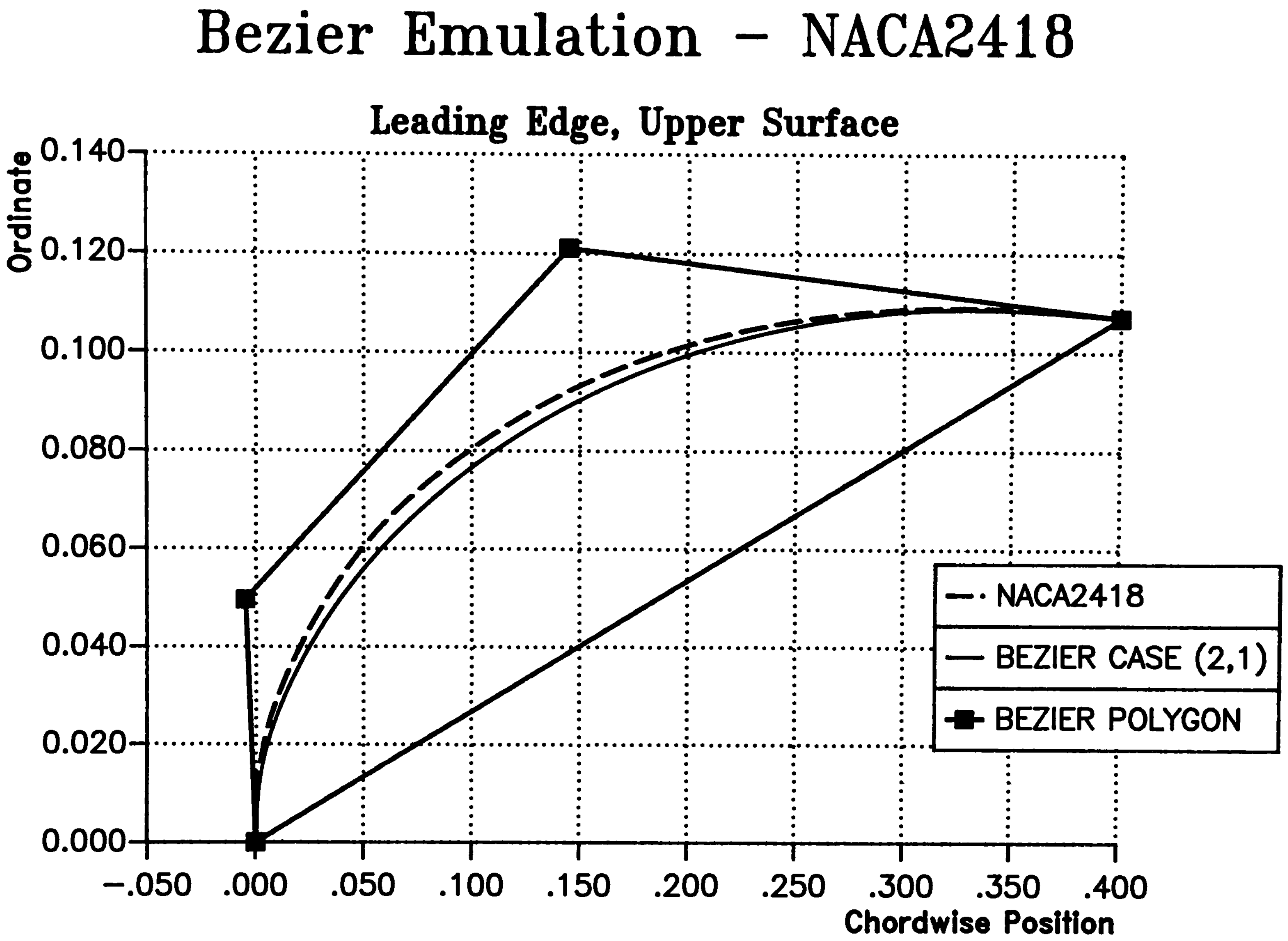


Figure 4.101 - Bézier Emulation - NACA2418 - Case (2,1)

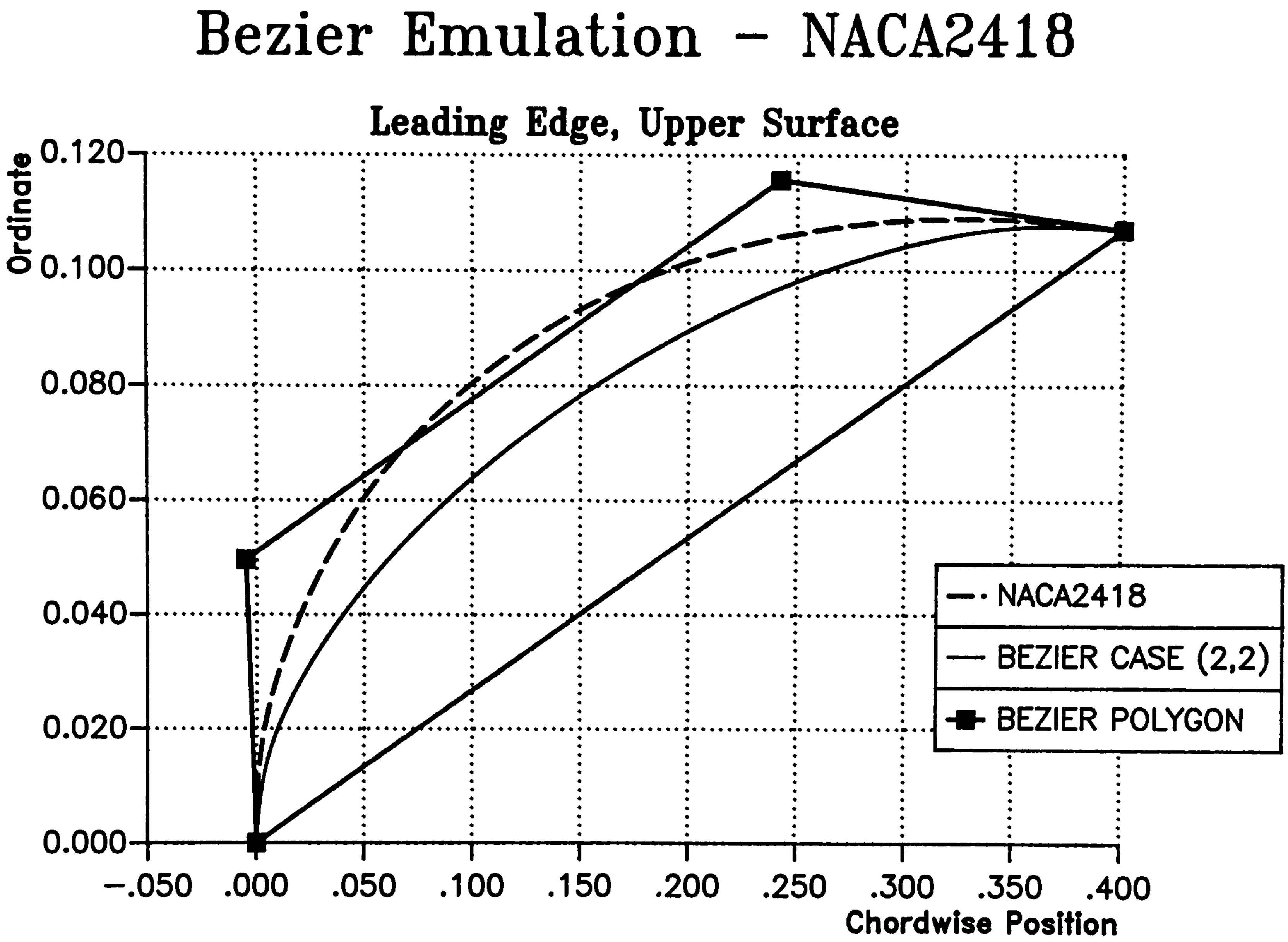


Figure 4.102 - Bézier Emulation - NACA2418 - Case (2,2)

4.2.4 Conventional Airfoil Generation

As a last resort, the method of combining thickness distributions and camber lines described in section 2.2.2 can be employed to generate cambered airfoils using the Bézier symmetric thickness distribution. The non-linearity of the trigonometric terms would seem to be the deciding factor in the determination that the successful method found in the symmetric case would not work for cambered airfoils, due to the affine transformation property.

The user interactive FORTRAN program GENFOIL.FOR (Appendix E) was written to generate NACA Four-Digit airfoils of the user's choice. The difference between the conventional method and the method outlined in this paper is that the *x*-coordinates of the symmetric thickness distribution must be generated by the Bézier algorithm. It is these values that must be used to determine final chordwise positions on a cambered airfoil. Figure 4.103 shows the logical flow path of this program.

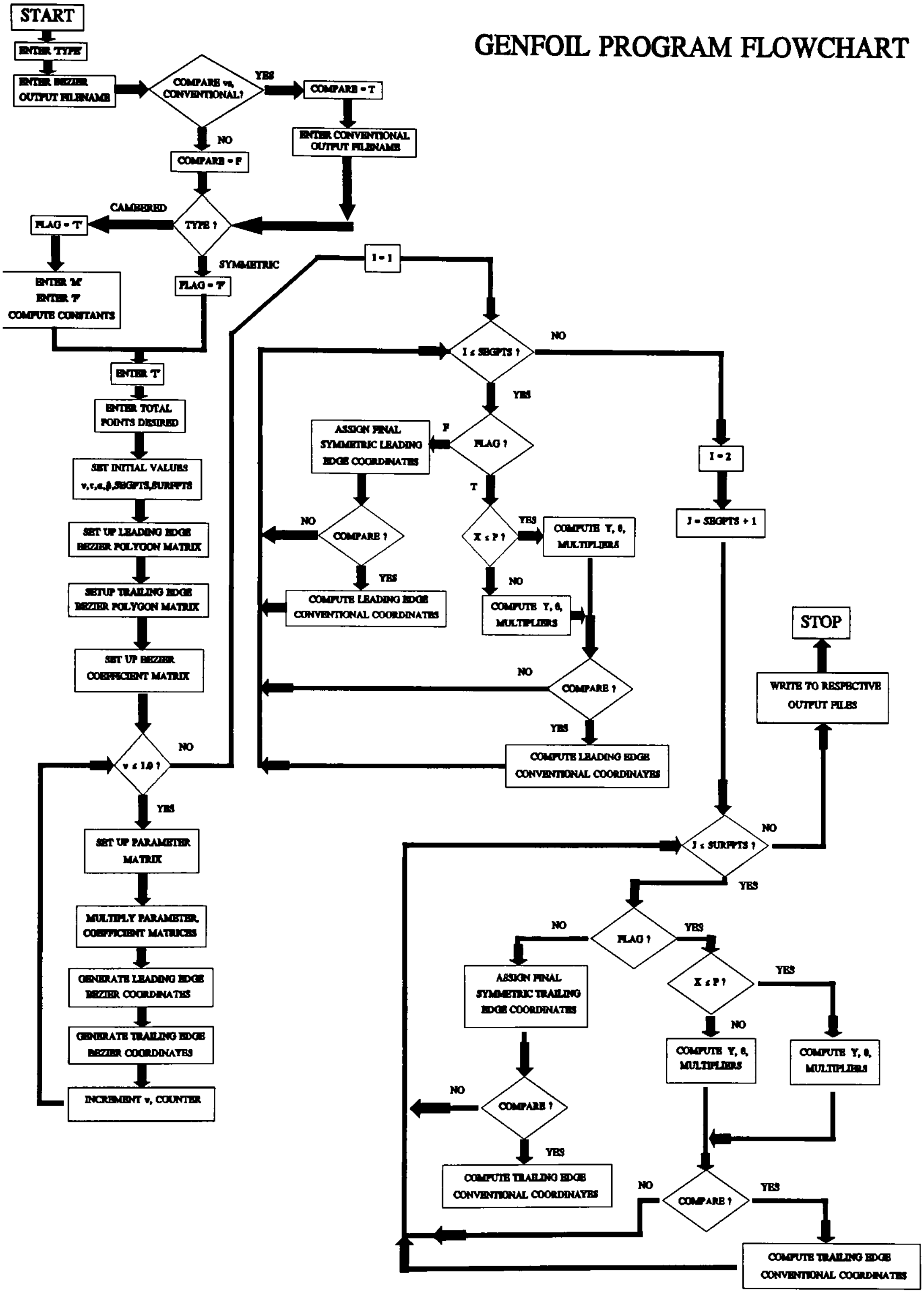


Figure 4.103 Genfoil Program Flowchart

5. Conclusions

The intent of this research was to develop a computationally efficient method to generate a NACA family of airfoil sections. Considering only the number of basic operations to compute ordinates for the conventionally defined airfoil versus both chordwise position and ordinate with the Bézier curve, **the method presented fails in this respect**. The findings of this research, however, have shown the airfoil shape to be linked with the golden section, a ratio which pervades nature. Additionally, the method presented has some benefits not available to conventionally described NACA airfoils. Airfoils generated using this method can be readily altered according to the user's discretion. One disadvantage of employing Bézier curves as compared to B-splines is the fact that changing one of the defining polygon vertices on the Bézier curve affects a global change on the curve (and the corresponding segment of the airfoil), whereas local control can be obtained through the use of B-splines.

Perhaps there exists a method whereby these shapes can be generated without resorting to conventional methodology. Evidence would seem to suggest this to be the case. It is hoped that this project will not end here; plenty of opportunity for potential research exists in this area.

Appendix A. The Golden Section

A.1 Origin and Early Uses

Consider a number Φ^* such that, when squared, yields Φ^* plus one; or a number Ω whose reciprocal equals the original number minus one. Mathematically, these two statements can be expressed as:

$$(\Phi^*)^2 = \Phi^* + 1 \qquad \text{[A.1]}$$

and

$$\frac{1}{\Omega} = \Omega - 1 \qquad \text{[A.2]}$$

By some minor algebraic manipulation, it is easily seen that [A.1] and [A.2] are equivalent, and one can therefore safely assume that Φ^* equals Ω. In this text, this number will be denoted by Φ^*. The solution to [A.1], from the quadratic formula, is given by

$$\Phi^* = \frac{1 \pm \sqrt{5}}{2} \qquad \text{[A.3]}$$

The numerical values of which are

$$\Phi^* = \{\ 1.618033989, -0.618033989\ \}$$

For the purposes of this discussion, only the positive root of [A.1] will be considered.

The value of Φ^* has, through the ages, been called many things: the golden number, the divine proportion, the golden mean and the golden ratio to name but a few. While the origin of mans awareness of this particular number is obscure, the earliest use of Φ^* is in the construction of the Great Pyramid at Gizeh[A-1], whose faces have a slope height of exactly 1.618 (Φ^*) times half the base length. This ensures that the height of the Pyramid is at the same time the square root of Φ^* times half the base. Additionally, the area of the faces is Φ^* times the base area. For a graphical illustration, refer to Figure A.1-1.

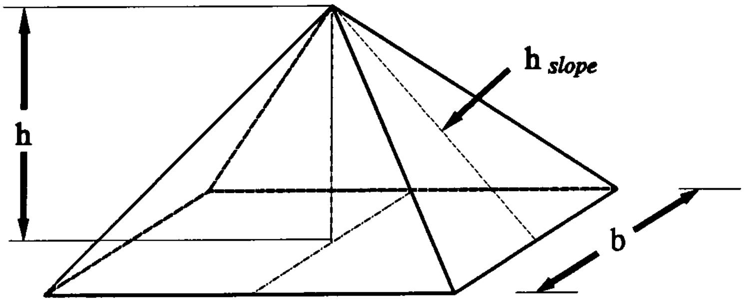


Figure A-1.1 The Great Pyramid of Gizeh

Mathematically, the Great Pyramid exhibits the following characteristic:

$$h_{slope} = \Phi^* \left[\frac{b}{2}\right] \qquad \textbf{[A.4]}$$

Thus, from the Pythagorean Theorem (which was non-existent at the time),

$$h^2 + \frac{b^2}{4} = (\Phi^*)^2 \left[\frac{b^2}{4}\right]$$

$$h^2 = \{(\Phi^*)^2 - 1\} \left[\frac{b^2}{4}\right]$$

$$h^2 = \Phi^* \left[\frac{b^2}{4}\right] \qquad \text{(from equation [A.1])}$$

$$h = \sqrt{\Phi^*} \left[\frac{b}{2}\right]$$

The area of the faces is given by

$$A = 4 \left[\frac{1}{2} h_{slope} b\right]$$

$$= 4 \left[\frac{1}{2} \left\{\Phi^* \frac{b}{2}\right\} b\right]$$

$$= \Phi^* b^2$$

The ancient Greeks were well aware of the aesthetic values of the golden mean also. A rectangle drawn around the front of the Parthenon will be a golden rectangle whose length is Φ^* times its height. A golden rectangle as shown in Figure A-1.2 below has the property that when a square is removed from it, the remaining portion is itself a golden rectangle, and this process may be carried on indefinitely.

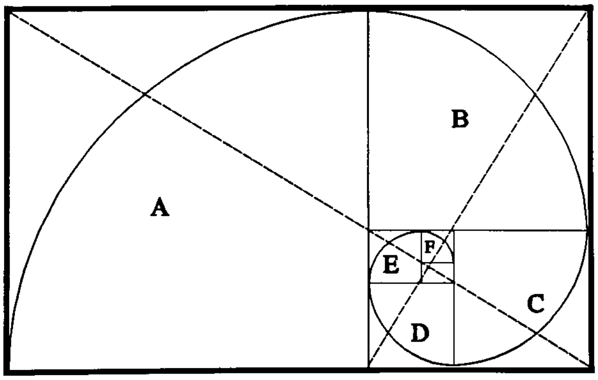


Figure A-1.2 Golden Rectangles

The diagonals of the two largest rectangles as shown in Figure A-1.2 have some interesting properties as well. The longest diagonal is Φ^* times the length of the next longest diagonal, and their point of intersection is the theoretical point from which the "whirling squares", **A,B,C,D,E** and **F** emanate. The spiral in Figure A-1.2 is generated by connecting the intersection points of adjacent squares. This shape is known as the golden, or logarithmic, spiral, and is found in a multitude of places throughout nature. Swirling galaxies, hurricane clouds, snail shells, sea horses, ocean waves, animal horns, and the seed patterns of sunflowers and daisies all take the form of the golden spiral. A curled human finger (the bones of which are in golden proportion to one another) also takes the shape of the golden spiral.

The Order of Pythagoras, an ancient Greek society, took as its symbol the five-pointed star, shown as Figure A-1.3 below.

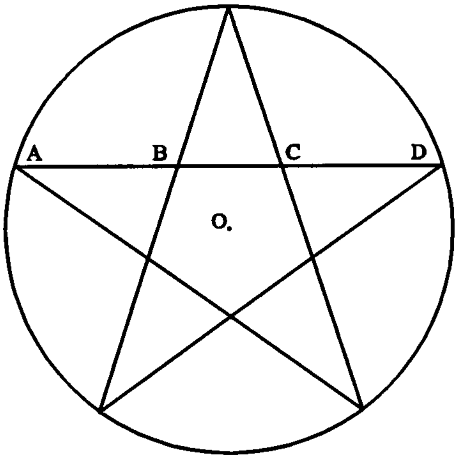


Figure A-1.3 The Badge of the Order of Pythagoras

The star in Figure A-1.3 has the following properties: for any line segment, the next larger segment is Φ^* times the length of that segment, or

$$\overline{AC} = \Phi^* (\overline{CD})$$

$$\overline{AB} = \Phi^* (\overline{BC})$$

Mathematically, if one assumes beforehand that the line segments of the star are all in constant ratio to each other, it can be said that

$$\overline{CD} = \overline{AD} - \overline{AC}$$

$$\frac{\overline{AD}}{\overline{AC}} = \frac{\overline{AC}}{\overline{CD}}$$

If we arbitrarily assign the values m to AD, n to AC, and o to CD, we obtain

$$o = m - n$$

$$\frac{m}{n} = \frac{n}{o}$$

from which

$$m(m - n) = n^2$$

$$m^2 - mn = n^2$$

Dividing by n^2 yields

$$\left[\frac{m}{n}\right]^2 - \frac{m}{n} = 1$$

Solving this quadratic shows that $m/n = \Phi^*$

A.2 The Fibonacci Sequence and the Golden Section

Leonardo Fibonacci da Pisa was the son of a prominent merchant and city official. Fibonacci became one of the most prominent mathematicians of the thirteenth century. The sequence of numbers that bears his name originated from a problem posed to him by ruler of the Holy Roman Empire, Emperor Frederick II. The problem:

> How many pairs of rabbits placed in an enclosed area can be produced in a year from one pair of rabbits if each pair gives birth to a new pair each month starting with the second month?

The "Rabbit Family Tree" as shown in Figure A-2.1 does not take into account the mortality rate for the rabbits, and assumes that the rabbit pairs are incapable of reproduction until they reach the age of one month. Upon close inspection, a mathematical pattern emerges.

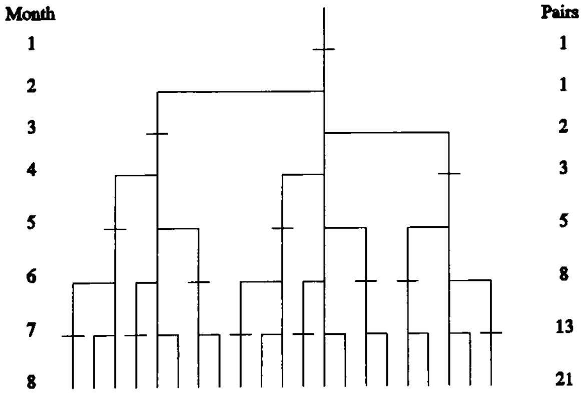


Figure A-2.1 Propagation of Rabbit Pairs

Fibonacci came up with a sequence of numbers describing the solution to the problem posed, a sequence which has proved to be descriptive of much more than merely the population growth of rabbits. The Fibonacci sequence, denoted F_n, is defined as the sequence of numbers such that

$$F_0 = 1, \quad F_1 = 1, \quad F_n = F_{n-2} + F_{n-1} \qquad n = 2,3,\ldots \qquad [A.4]$$

The Fibonacci sequence has many interesting properties. Most importantly,

$$\lim_{n\to\infty} \frac{F_{n+1}}{F_n} = \Phi^* \qquad [A.5]$$

and

$$\lim_{n\to\infty} \frac{F_n}{F_{n+1}} = \frac{1}{\Phi^*} = \tau \qquad [A.6]$$

where

$$\tau = \frac{\sqrt{5} - 1}{2} = 0.618033989$$

It is τ and not Φ^* that will be used most extensively in this research.

Additionally, the Fibonacci sequence appears as the sum of the diagonals of Pascal's triangle, shown in Figure A-2.2, below.

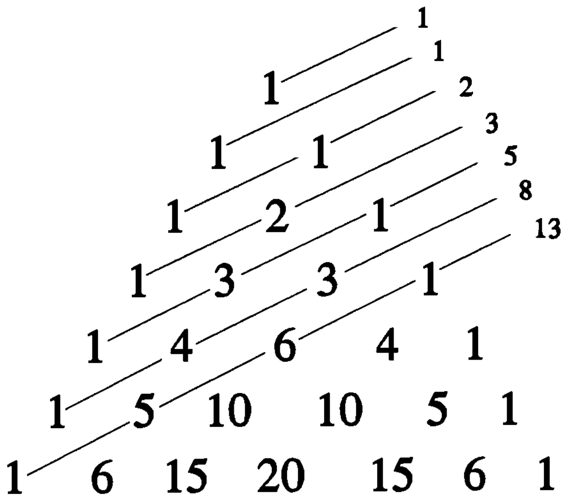
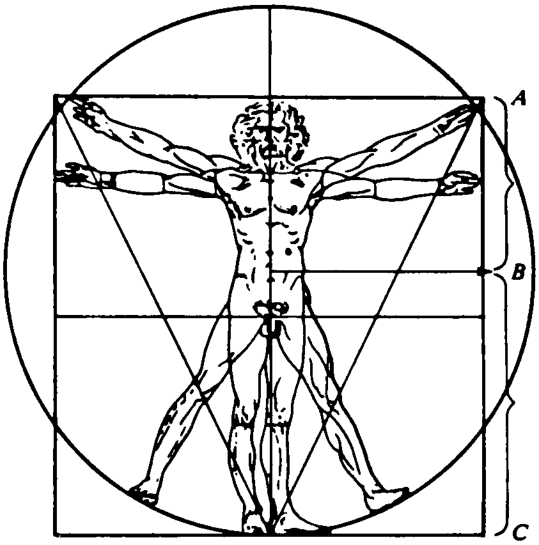


Figure A-2.2 Pascal's Triangle

A.3 Leonardo da Vinci

The great Renaissance artist and scientist Leonardo da Vinci was well aware of the aesthetic value of the golden section. In one of his most famous drawings, shown as Figure A-3.1, he realized that proportion would play a vital part in making his paintings seem realistic.



BC/AB = Golden section ratio

Figure A-3.1 Leonardo da Vinci's Study of the Human Proportion

Interestingly enough, on a statistical basis, the average ratio of BC/AB above is equal to Φ^*, and it holds separately for both genders.

A.4 The Golden Section and Univariate Optimization Theory

Consider a function of one independent variable whose minimum value is to be found. There are a variety of methods to accomplish this task, the golden section interval search is a method which is very versatile in cases where the function is not well behaved. The method performs equally well when the function is well behaved. It has the added advantage of being easily implemented on the computer; hence its wide appeal.
It is τ and not Φ^* that will be used most extensively in this research.

Consider the function F on the interval $[a,b]$ as illustrated in Figure A-4.1. The independent variable in this instance is x such that $a \leq x \leq b$. The assumption must be made that a single minimum exists on $[a,b]$ and that the function can be evaluated for any x in the interval. If we now pick two intermediate points x_1 and x_2 such that $x_1 \leq x_2$ and evaluate the function, we obtain F_1 and F_2. Because the assumption in this case was made that the function was unimodal, either x_1 or x_2 must form a new bound on the minimum.

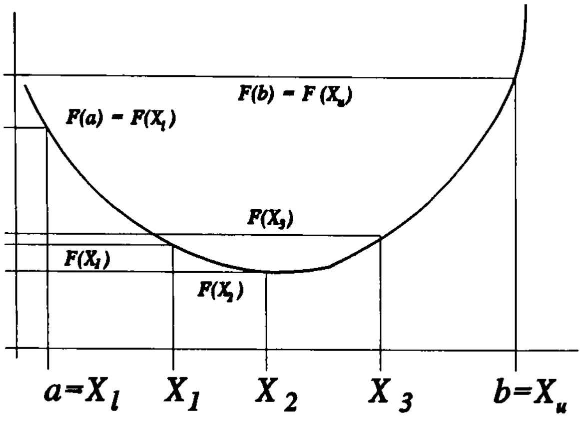


Figure A-4.1 The Golden Section Method

In the figure above, $F(x_1)$ is greater than $F(x_2)$ so that the new lower bound becomes x_1. If $F(x_2)$ had been larger than $F(x_1)$, x_2 would become the new upper bound. One of the objectives of this type of optimization technique is to reduce the bounds on the minimum as rapidly as possible. Because x_1 or x_2 will become the new bound, both x_1 and x_2 should be chosen to be symmetric about the center of the interval such that

$$X_u - X_2 = X_1 - X_l \qquad [A.7]$$

The values of x_1 and x_2 are picked such that

$$\frac{X_1 - X_l}{X_u - X_l} = \frac{X_2 - X_1}{X_u - X_1} \qquad [A.8]$$

Thus, if x_1 becomes the new lower bound x_l, then x_2 will become the new x_1 such that the ratio of x_2-x_1 to the total interval x_u-x_l will remain constant. Normalizing the interval, we set $x_l=0$ and $x_u=1$ so that $x_2=1-x_1$. Equation [A.8] now becomes

Solving for x1, we obtain the following result:

$$X_1 = \frac{3 - \sqrt{5}}{2} = 0.38197$$

$$X_2 = 1 - X_1 = 0.61803$$

and

$$\frac{X_2}{X_1} = 1.61803 = \Phi\,^*$$

For each iteration of the golden section method, only one new function evaluation is required, and the new bounds (original) interval become

$$\begin{aligned} X_1 &= (1 - \tau)X_l + \tau X_u \\ X_2 &= \tau X_l + (1 - \tau)X_u \end{aligned} \qquad [A.10]$$

Had x_2 become the new bound, the equations in [A.10] would be reversed. This procedure has the added attraction that a specific number of iterations can be specified to achieve a given accuracy.

Because use of the golden section in this research was limited to analysis of data points, all of the iterations were performed by programmable hand calculator. After using the method to refine locations for the undetermined defining polygon vertices, some simplification was desired to make FORTRAN coding simpler and more understandable. A useful property of τ was found to be:

1	-1	$\tau^2 =$	$1 - \tau$
-1	2	$\tau^3 =$	$-1 + 2\tau$
2	-3	$\tau^4 =$	$2 - 3\tau$
-3	5	$\tau^5 =$	$-3 + 5\tau$
5	-8	$\tau^6 =$	$5 - 8\tau$
-8	13	$\tau^7 =$	$-8 + 13\tau$

$$\tau^n = (-1)^n \, F_{n-2} + (-1)^{n+1} \, F_{n-1}\tau$$

and τ to any (integer) power becomes linear in τ, with the resultant coefficients successive numbers in the Fibonacci sequence.

In conclusion, it should be noted that there is a wealth of published material dealing with the golden section, and that this section has barely made a scratch in the uses and occurrences of the "divine proportion".

Appendix B. Cubic Spline Derivation

For a piecewise cubic spline, the conditions above can be applied to the cubic polynomials described as

$$S_i(x) = a_i(x - x_i)^3 + b_i(x - x_i)^2 + c_i(x - x_i) + d_i \qquad \textbf{[B.1]}$$

Equation **[B.1]** holds for each $i=0,1,\ldots,n$-1. It is clear that

$$S_i(x_i) = d_i = f(x_i) = y_i$$

If condition (c) is applied,

$$\begin{aligned} d_{i+1} = S_{i+1}(x_{i+1}) &= S_i(x_{i+1}) \\ &= a_i(x_{i+1} - x_i)^3 + b_i(x_{i+1} - x_i)^2 + c_i(x_{i+1} - x_i) + d_i \end{aligned} \qquad \textbf{[B.2]}$$

for each $i=0,1,\ldots,n$-2.

Because the term $(x_{i+1}-x_i)$ will be used repeatedly, the substitution

$$h_i = x_{i+1} - x_i$$

for $i=0,1,\ldots,n$-1 will be much simpler and more convenient.

If we also define $d_n=f(x_n)=y_n$ it can be seen that

$$d_{i+1} = a_i h_i^3 + b_i h_i^2 + c_i h_i + d_i \qquad \textbf{[B.3]}$$

holds for each $i=0,1,\ldots,n$-1.

Similarly, define $c_n=S'(x_n)$ and notice that

$$S_i'(x) = c_i + 2b_i(x - x_i) + 3a_i(x - x_i)^2$$

which implies that $S'(x_i)=c_i$ for each $i=0,1,\ldots,n$-1. By applying condition (d),

$$c_{i+1} = c_i + 2b_i h_i + 3a_i h_i^2 \qquad \textbf{[B.4]}$$

for each $i=0,1,\ldots,n$-1.

By defining $b_n=S''(x_n)/2$ and applying condition (e), another relationship between coefficients may be obtained.

$$b_{i+1} = b_i + 3a_i h_i \tag{B.5}$$

for each $i=0,1,\ldots,n-1$.

Solving **[B.5]** for a_i and substituting into equations **[B.3]** and **[B.4]** yields a new set of equations

$$d_{i+1} = d_i + c_i h_i + \frac{h_i^2}{3}(2b_i + b_{i+1}) \tag{B.6}$$

and

$$c_{i+1} = c_i + h_i(b_i + b_{i+1}) \tag{B.7}$$

for each $i=0,1,\ldots,n-1$.

By solving **[B.6]**, first for c_i

$$c_i = \frac{1}{h_i}(d_{i+1} - d_i) - \frac{h_i}{3}(2b_i + b_{i+1}) \tag{B.8}$$

and, with a reduction of the index, for c_{i-1},

$$c_{i-1} = \frac{1}{h_{i-1}}(d_i - d_{i-1}) - \frac{h_{i-1}}{3}(2b_{i-1} + b_i)$$

When the index of equation **[B.7]** is reduced by one and the values immediately above are inserted, the following linear system of equations results:

$$h_{i-1}b_{i-1} + 2(h_{i-1} + h_i)b_i + h_i b_{i+1} = \frac{3}{h_i}(d_{i+1} - d_i) - \frac{3}{h_{i-1}}(d_i - d_{i-1}) \tag{B.9}$$

3.1.1.1 Natural Cubic Splines

By specifying the free, or natural, boundary conditions $S''(x_0)=S''(x_n)=0$, then

$$0 = S''(x_0) = 2b_0 + 6a_0(x_0 - x_0) \qquad \Rightarrow b_0 = 0$$

and the boundary conditions also imply that $b_n=S''(x_n)/2=0$, and thus $b_n=0$.

The two equations $b_0=0$ and $b_n=0$, along with the equations described by **[B.9]** produce a linear system described by the vector equation $A\mathbf{x}=\mathbf{b}$, where A is the $(n+1)$ by $(n+1)$ matrix

$$A = \begin{bmatrix} 1 & 0 & 0 & \cdot & \cdot & \cdot & 0 \\ h_0 & 2(h_0 + h_1) & h_1 & \cdot & & & \cdot \\ 0 & h_1 & 2(h_1 + h_2) & h_2 & & \cdot & \cdot \\ \cdot & \cdot & & \ddots & & & 0 \\ \cdot & & \cdot & h_{n-2} & 2(h_{n-2} + h_{n-1}) & & h_{n-1} \\ 0 & \cdot & \cdot & 0 & 0 & & 1 \end{bmatrix}$$

and $\mathbf{b}$ and $\mathbf{x}$ are the vectors

$$\mathrm{b} = \begin{bmatrix} 0 \\ \frac{3}{h_1}(d_2 - d_1) - \frac{3}{h_0}(d_1 - d_0) \\ \vdots \\ \frac{3}{h_{n-1}}(d_n - d_{n-1}) - \frac{3}{h_{n-2}}(d_{n-1} - d_{n-2}) \\ 0 \end{bmatrix} \quad \text{and} \quad \mathbf{x} = \begin{bmatrix} b_0 \\ b_1 \\ \vdots \\ b_n \end{bmatrix}$$

Because matrix A is strictly diagonally dominant, a unique solution is guaranteed for this system of equations^{10}. Once this system is solved for the b_i's, it becomes a simple matter to determine the other coefficients of each spline, a_i and c_i, by utilizing equations [B.5] and [B.8] (the coefficients d_i are the y-values of the data points).

3.1.1.2 Clamped Cubic Splines

The derivation for clamped cubic splines follows in much the same manner as that for free splines. For the beginning condition $S'(x_0)=f'(x_0)=c_0$, it can be observed from [B.8], with $i=0$ that

$$f'(x_0) = \frac{d_1 - d_0}{h_0} - \frac{h_0}{3}(2b_0 + b_1)$$

Consequently,

$$2h_0b_0 + h_0b_1 = \frac{3}{h_0}(d_1 - d_0) - 3f'(x_0) \qquad \text{[B.10]}$$

Similarly,

$$f'(x_n) = c_n = c_{n-1} + h_{n-1}(b_{n-1} + b_n)$$

so that equation [B.8] with $i = n$-1 implies that

$$\begin{aligned} f'(x_n) &= \frac{d_n - d_{n-1}}{h_{n-1}} - \frac{h_{n-1}}{3}(2b_{n-1} + b_n) + h_{n-1}(b_{n-1} + b_n) \\ &= \frac{d_n - d_{n-1}}{h_{n-1}} + \frac{h_{n-1}}{3}(b_{n-1} + 2b_n) \end{aligned}$$

and

$$h_{n-1}b_{n-1} + 2h_{n-1}b_n = 3f'(x_n) - \frac{3}{h_{n-1}}(d_n - d_{n-1}) \qquad \text{[B.11]}$$

Equations [B.9], [B.10], and [B.11] form the linear system $Ax=\mathrm{b}$, where A is the $(n+1)$ by $(n+1)$ matrix

$$A = \begin{bmatrix} 2h_0 & h_0 & 0 & \cdot & \cdot \quad \cdot & 0 \\ h_0 & 2(h_0 + h_1) & h_1 & \cdot & & \cdot \\ 0 & h_1 & 2(h_1 + h_2) & h_2 & \cdot & \cdot \\ \cdot & \cdot & & \ddots & & 0 \\ \cdot & & \cdot & h_{n-2} & 2(h_{n-2} + h_{n-1}) & h_{n-1} \\ 0 & \cdot & \cdot & 0 & h_{n-1} & 2h_{n-1} \end{bmatrix}$$

and **b** and **x** are the vectors defined such that

$$\mathrm{b} = \begin{bmatrix} \frac{3}{h_0}(d_1 - d_0) - 3f'(x_0) \\ \frac{3}{h_1}(d_2 - d_1) - \frac{3}{h_0}(d_1 - d_0) \\ \vdots \\ \frac{3}{h_{n-1}}(d_n - d_{n-1}) - \frac{3}{h_{n-2}}(d_{n-1} - d_{n-2}) \\ 3f'(x_n) - \frac{3}{h_{n-1}}(d_n - d_{n-1}) \end{bmatrix} \quad \text{and} \quad \mathrm{x} = \begin{bmatrix} b_0 \\ b_1 \\ \vdots \\ b_n \end{bmatrix}.$$

This linear system is also diagonally dominant, thus a unique solution exists for it as well. As in the case of natural splines, the remaining coefficients can be obtained through the use of equations [B.5] and [B.8]. Computer programs to perform cubic spline interpolation (both types discussed) are included for reference in Appendix F.

Appendix C. References

1. Gibbs-Smith, Charles H., The Aeroplane: An Historical Survey, Her Majesty's Stationery Office, London 1960

2. Anderson, John D. Jr., Introduction to Flight, 3rd ed., McGraw-Hill,New York 1989

3. Anderton, David A., Sixty Years of Aeronautical Research 1917-1977, NASA/ U.S. Government Printing Office, Washington 1980

4. Bertin, John J., and Smith, Michael L., Aerodynamics for Engineers, 2nd ed., Prentice-Hall, Englewood Cliffs, New Jersey 1989

5. Abbott, Ira H., and von Doenhoff, Albert E., Theory of Wing Sections, McGraw-Hill, New York 1949 (also Dover, New York 1959)

6. Frost, and Prechter, The Elliot Wave Theory: Your Key to Financial Success New Age Press, New York 1989

7. Rogers, David F., and Adams, J. Alan, Mathematical Elements for Computer Graphics, 2nd ed., McGraw-Hill, New York 1990

8. Beer, Ferdinand P. and Johnston, E. Russell, Jr., Mechanics of Materials, McGraw-Hill, New York 1981

9. Burden, Richard L., and Faires, J. Douglas, Numerical Analysis, 3rd ed., PWS-Kent, Boston 1985

10. Noble, Benjamin, and Daniels, James, Applied Linear Algebra, Prentice-Hall, Englewood Cliffs, New Jersey 1988

11. Akin, J. Ed, Computer-Assisted Mechanical Design Prentice-Hall, Englewood Cliffs, New Jersey 1990

12. de Boor, Carl, A Practical Guide to Splines, Springer-Verlag, New York 1978

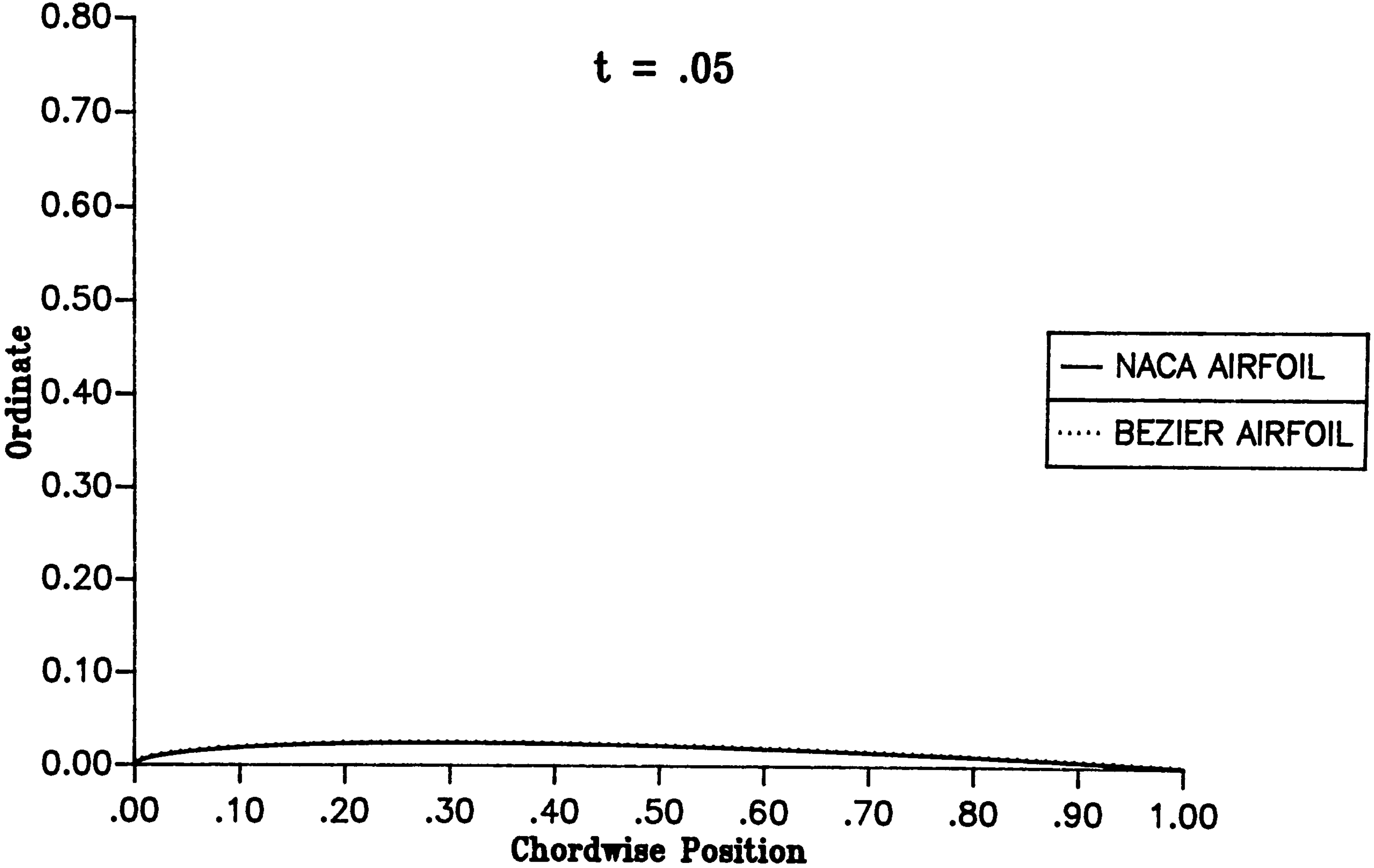
13. Huntley, H. E., The Divine Proportion: A Study in Mathematical Beauty, Dover, New York 1970

14. Gibbs-Smith, Charles H., and Rees, Gareth, The Inventions of Leonardo Da Vinci, Charles Scribner's Sons, New York 1978

15. Vanderplaats, Garret N., Numerical Optimization Techniques for Engineering Design: With Applications, McGraw-Hill, New York 1984

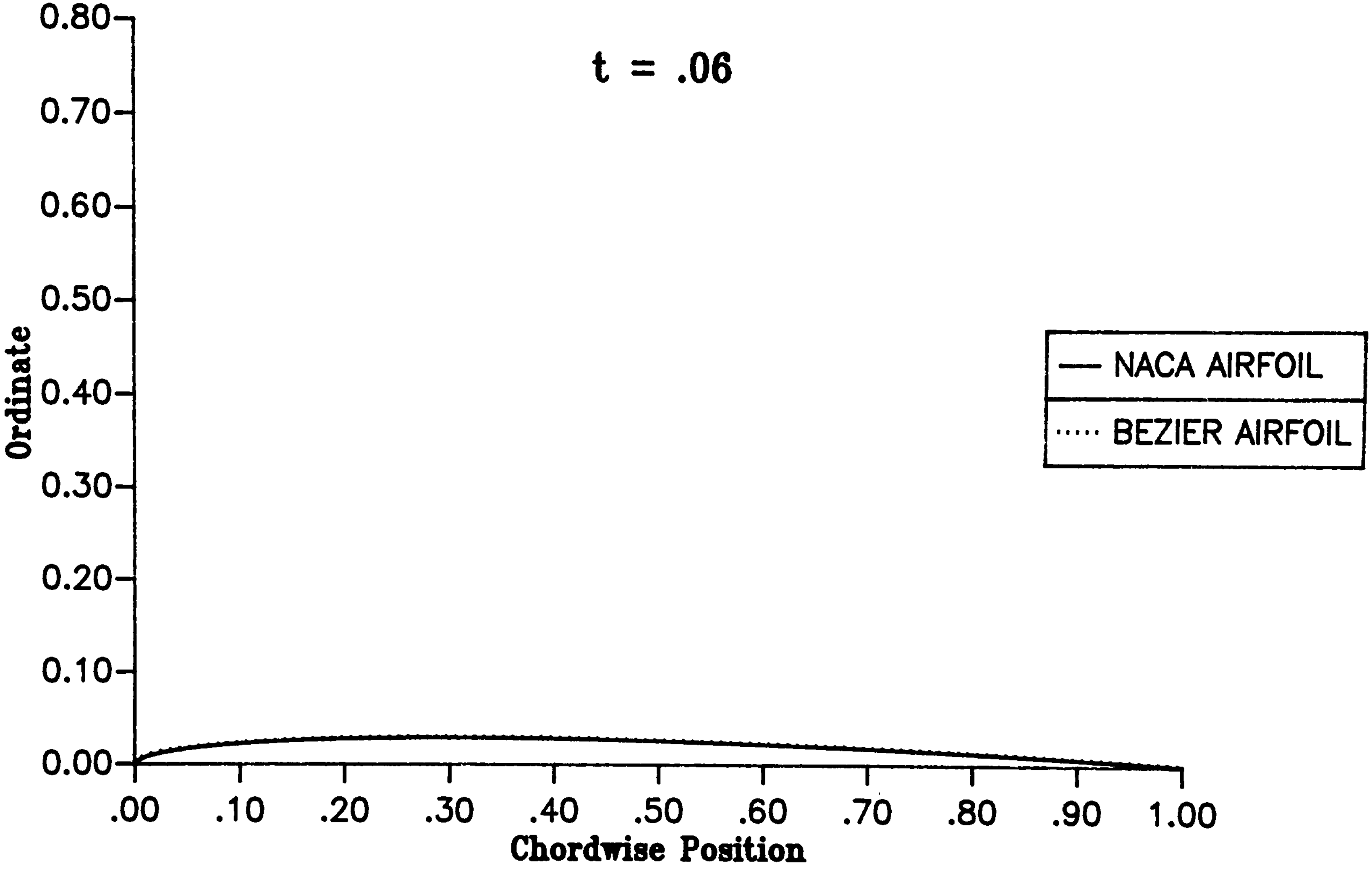
Appendix D. Comparative Graphs of NACA Four-Digit Symmetric Airfoil Sections and Bézier Curve Emulations

Note: The plots contained in this appendix were generated using both the conventional and Bézier methods. Each plot shows the conventionally described airfoil section with a solid red line, and the Bézier emulation with a dotted blue line. The plots were produced using the IBM Professional Graphics Facility (PGF).

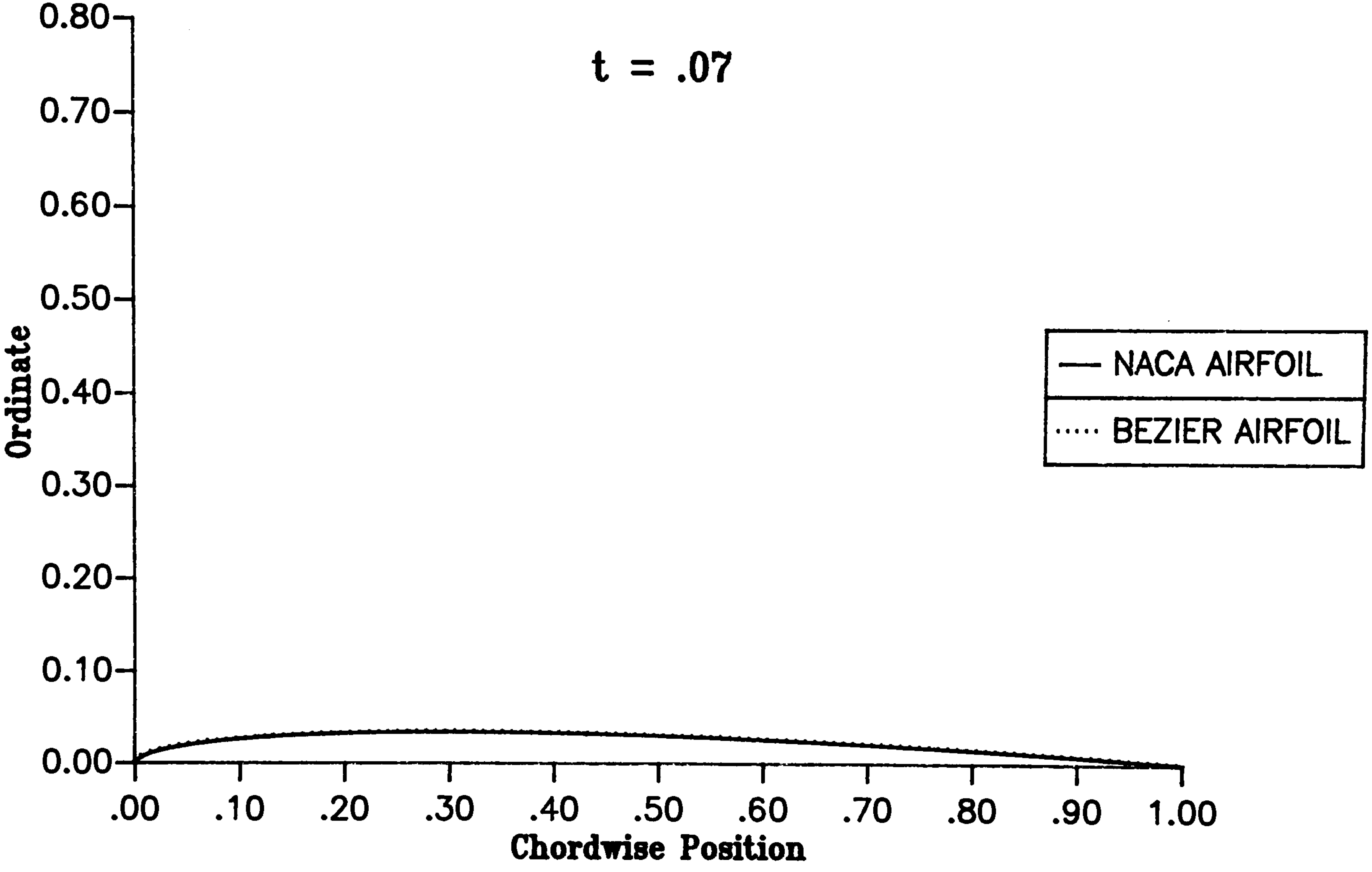


Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier

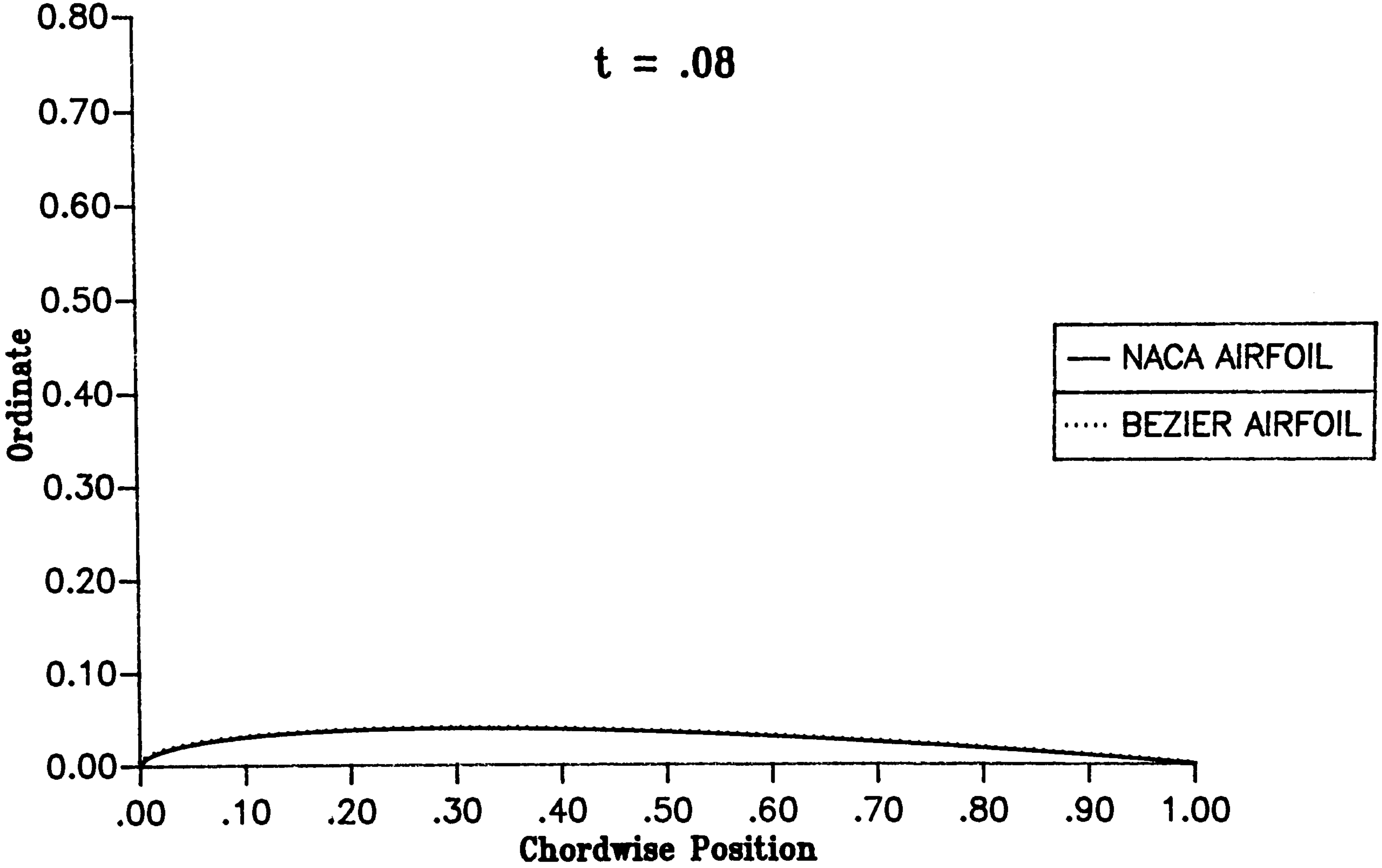
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



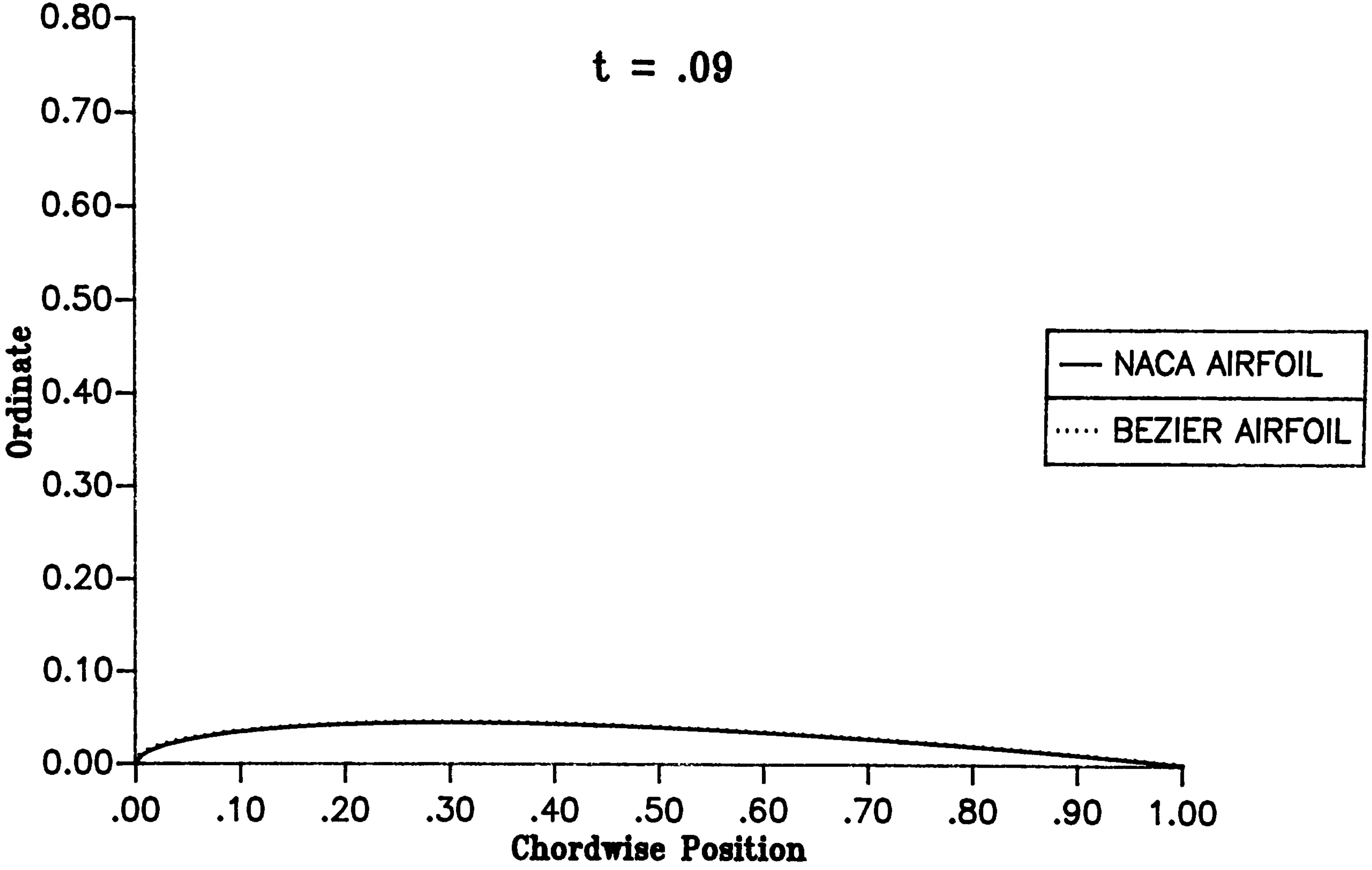
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



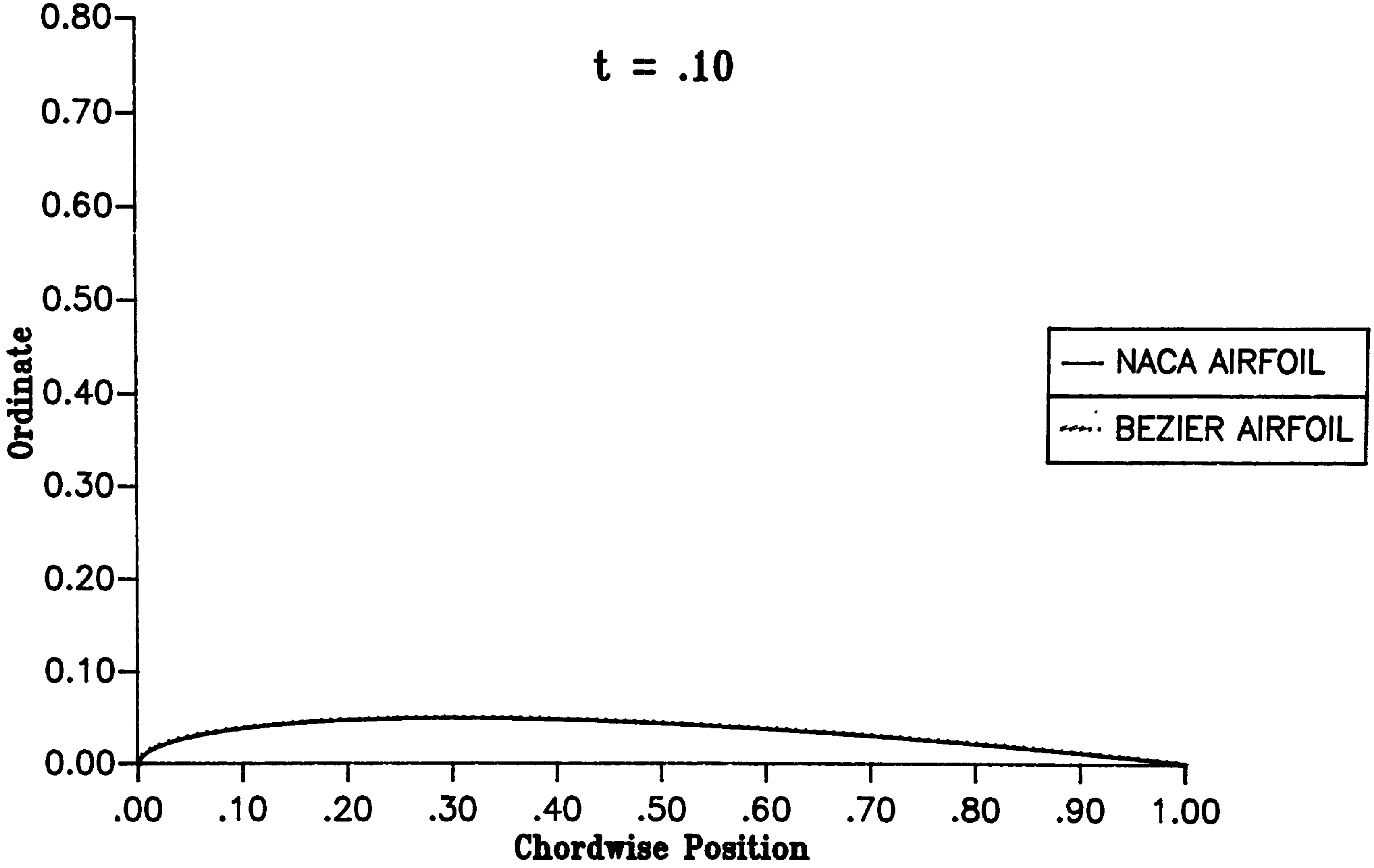
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



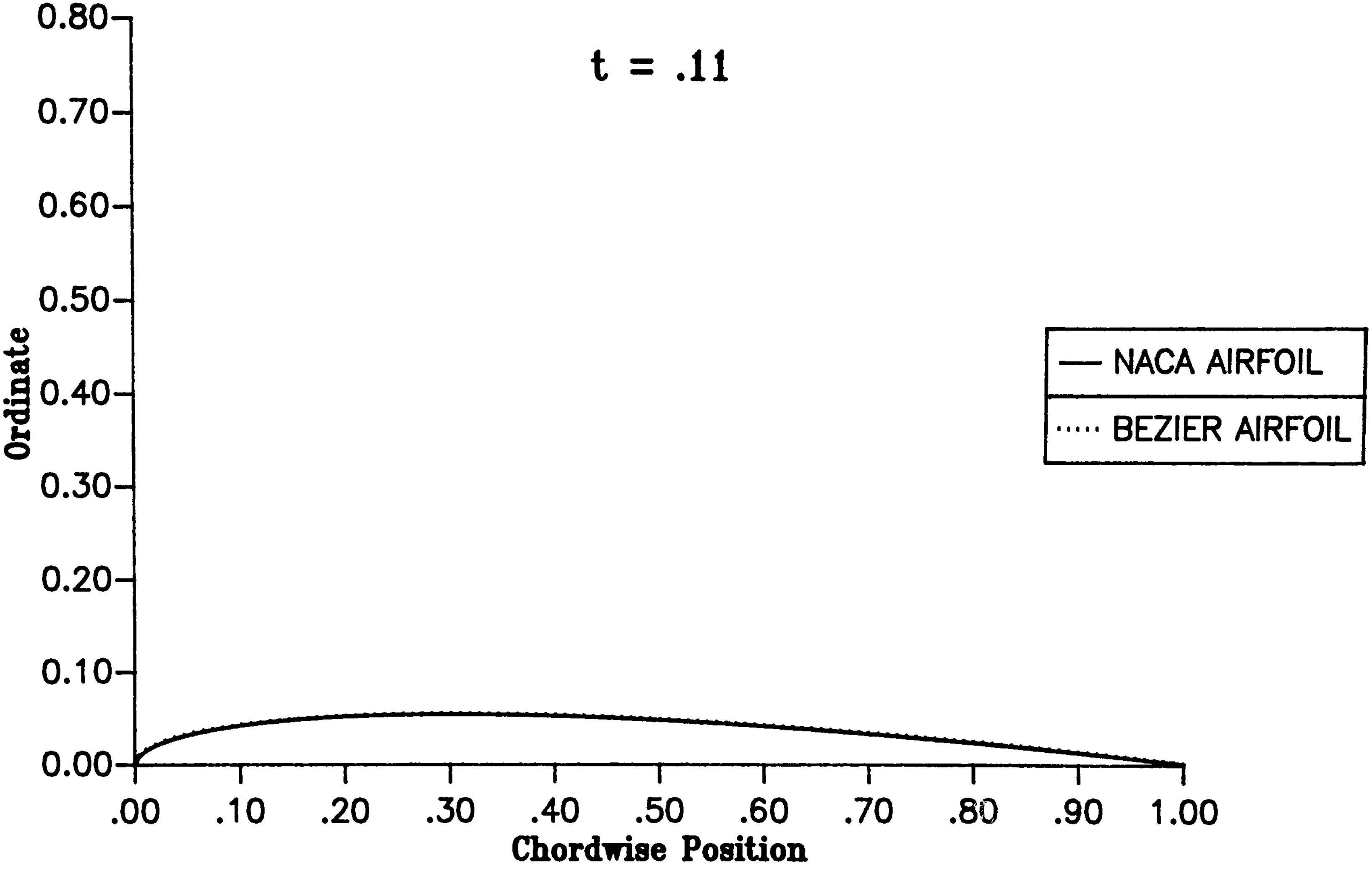
Symmetric Thickness Distribution
NACA Four–Digit vs. Bezier



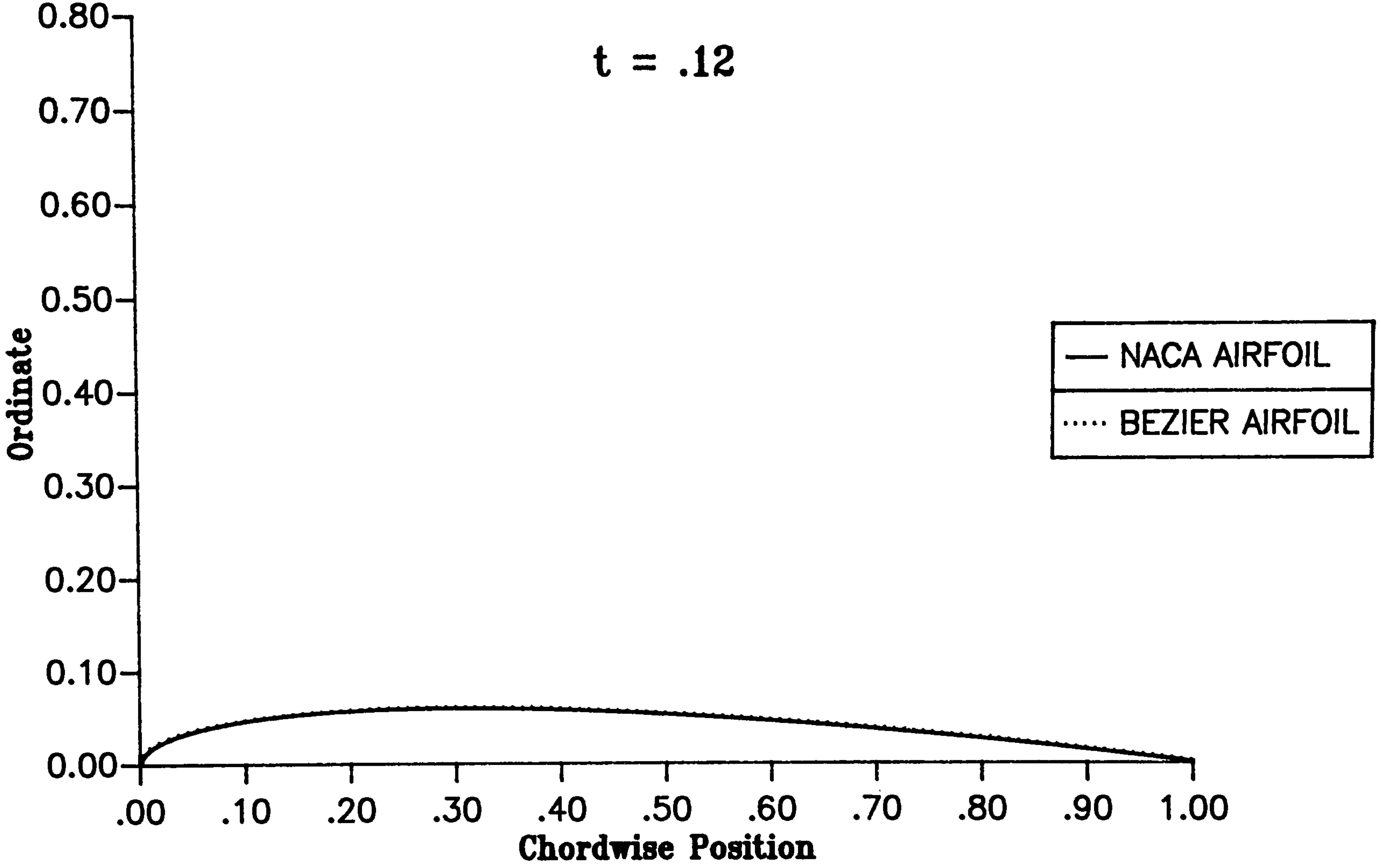
Symmetric Thickness Distribution
NACA Four–Digit vs. Bezier



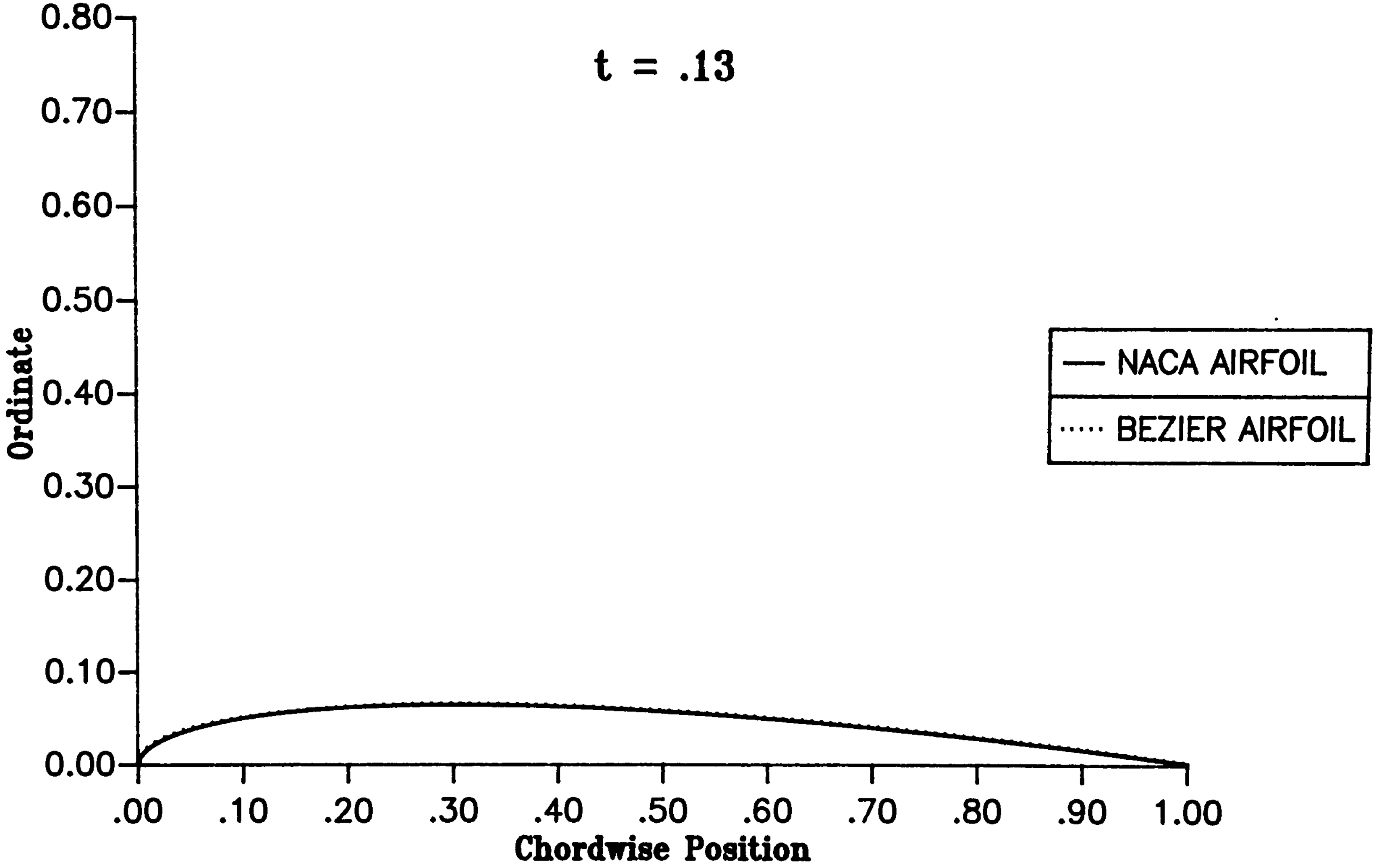
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



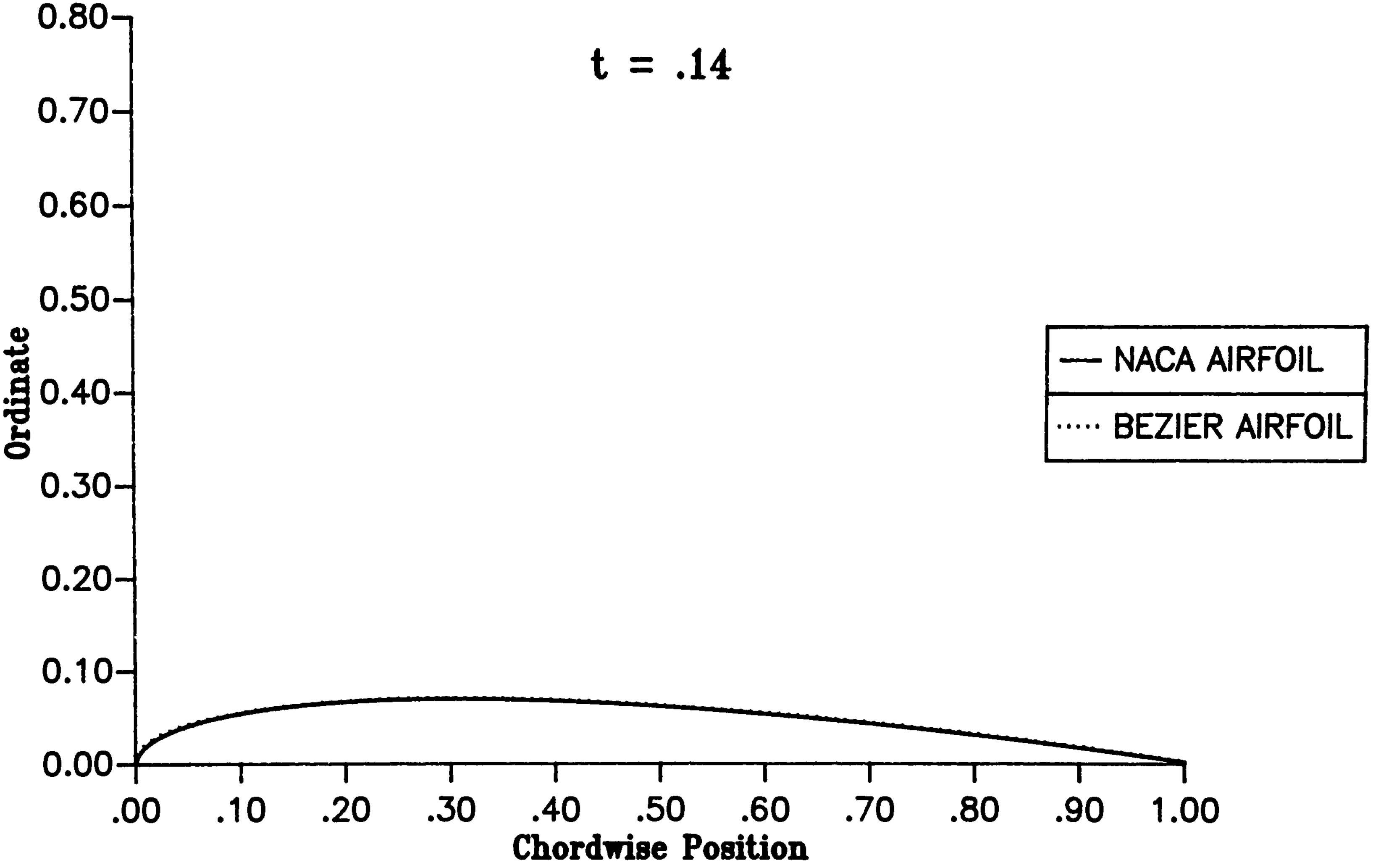
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



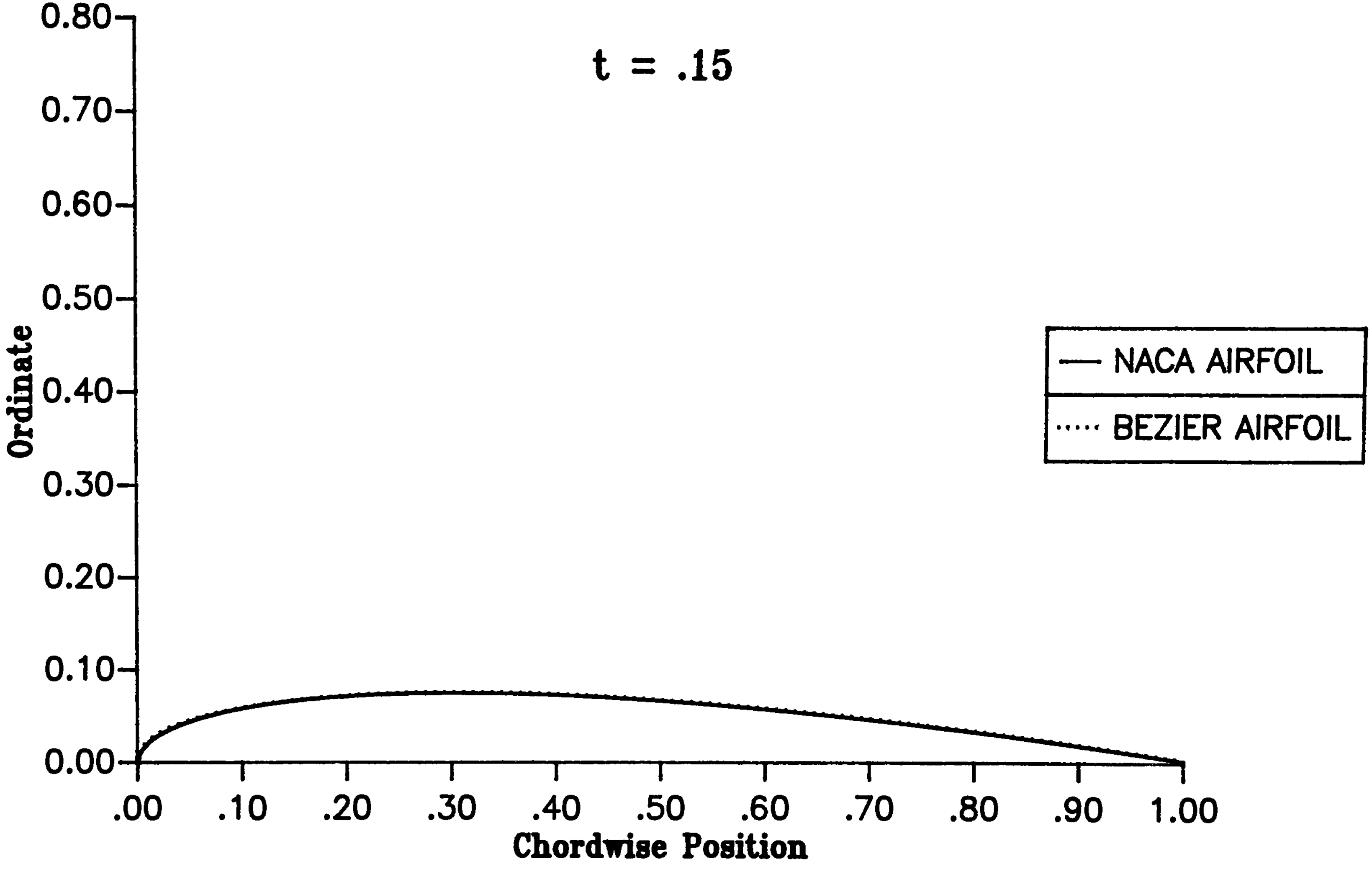
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



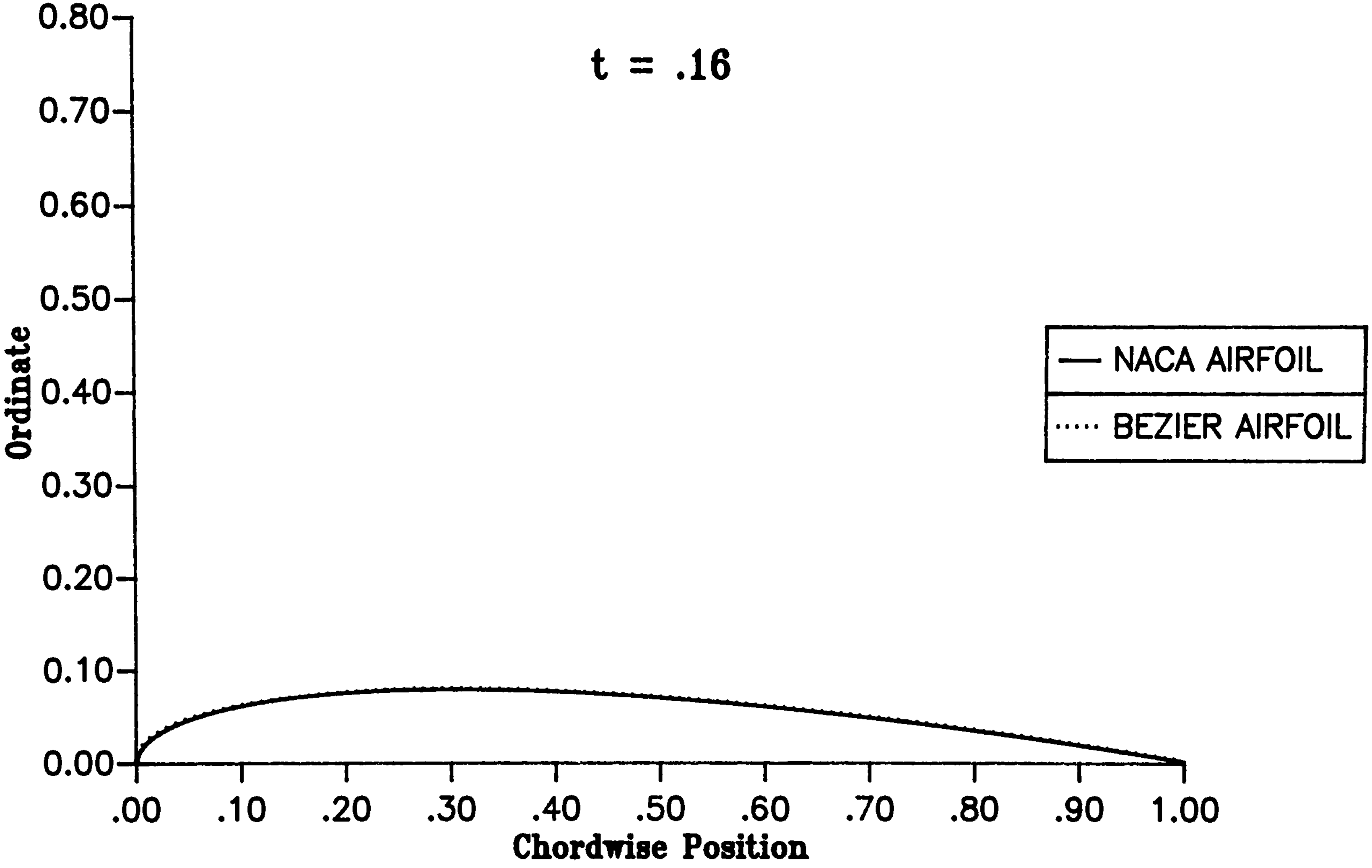
Symmetric Thickness Distribution
NACA Four–Digit vs. Bezier



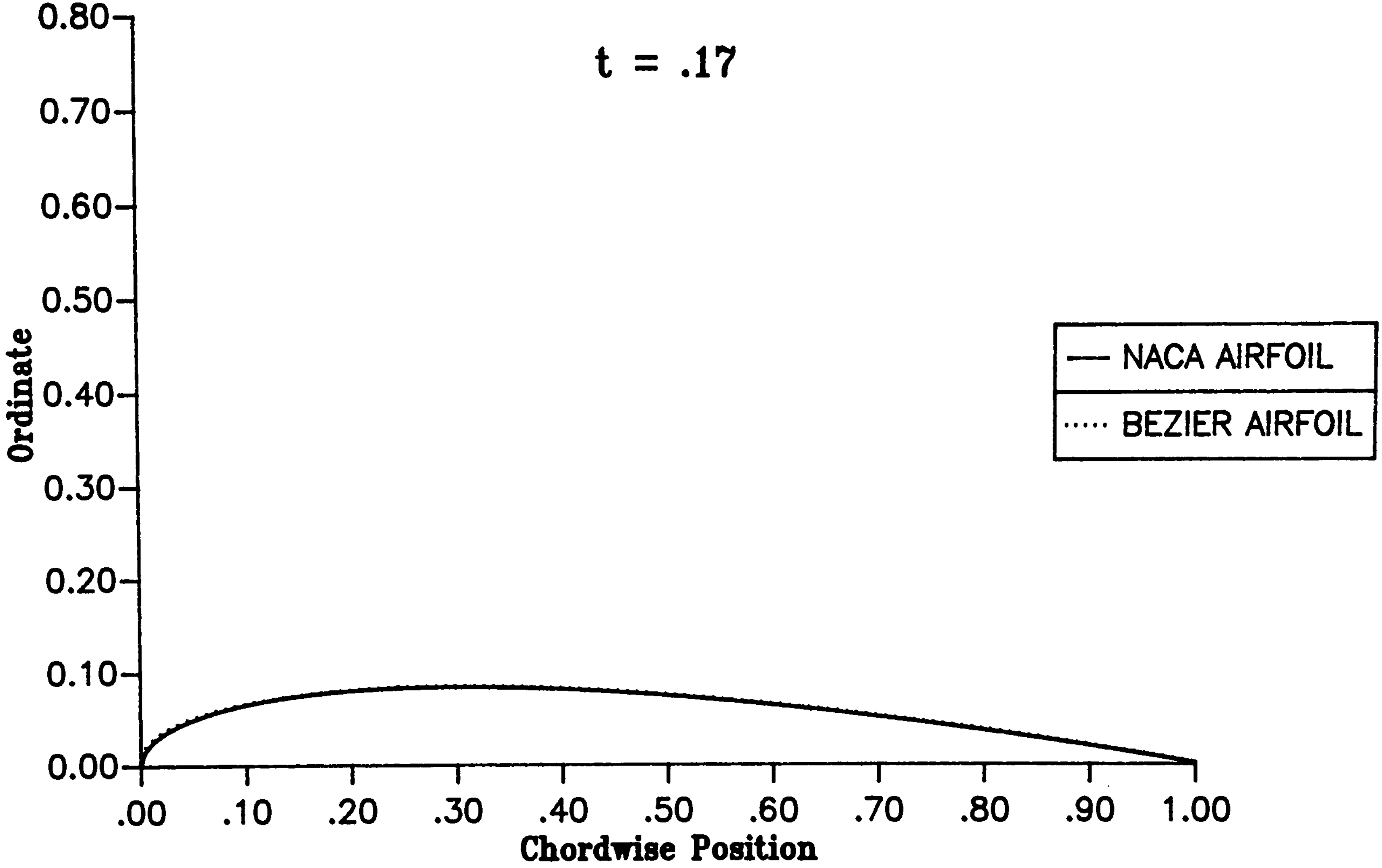
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



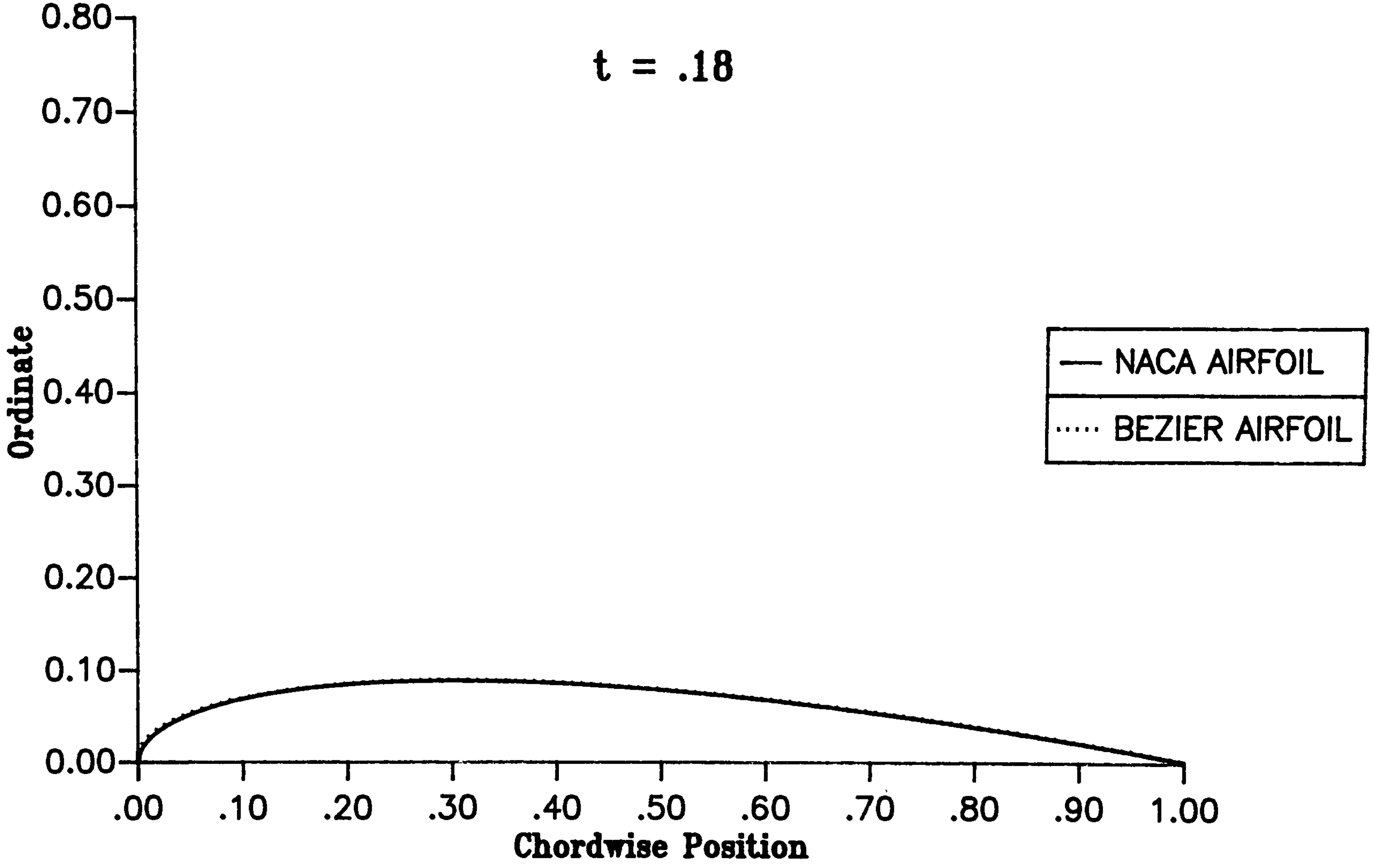
Symmetric Thickness Distribution
NACA Four–Digit vs. Bezier



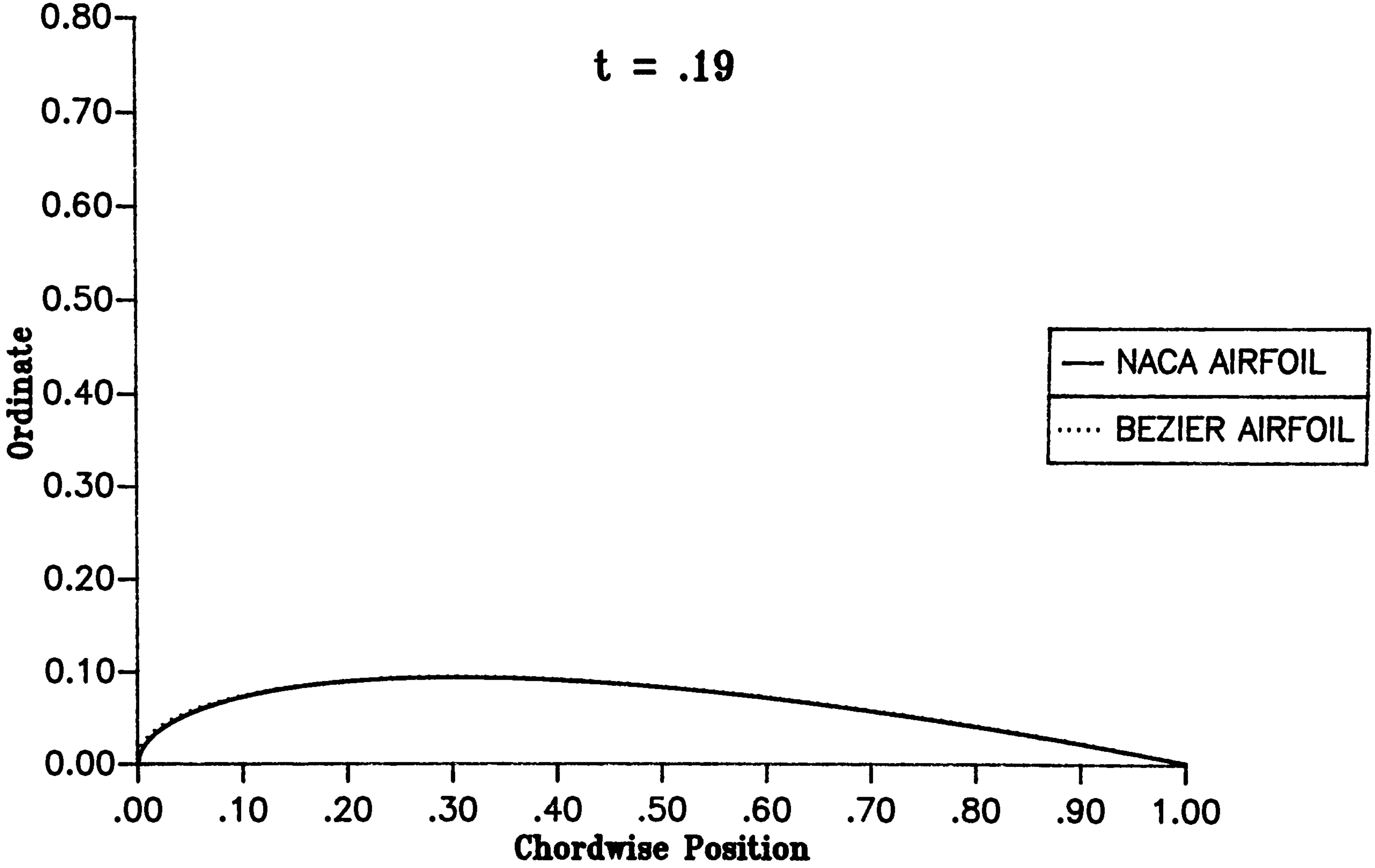
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



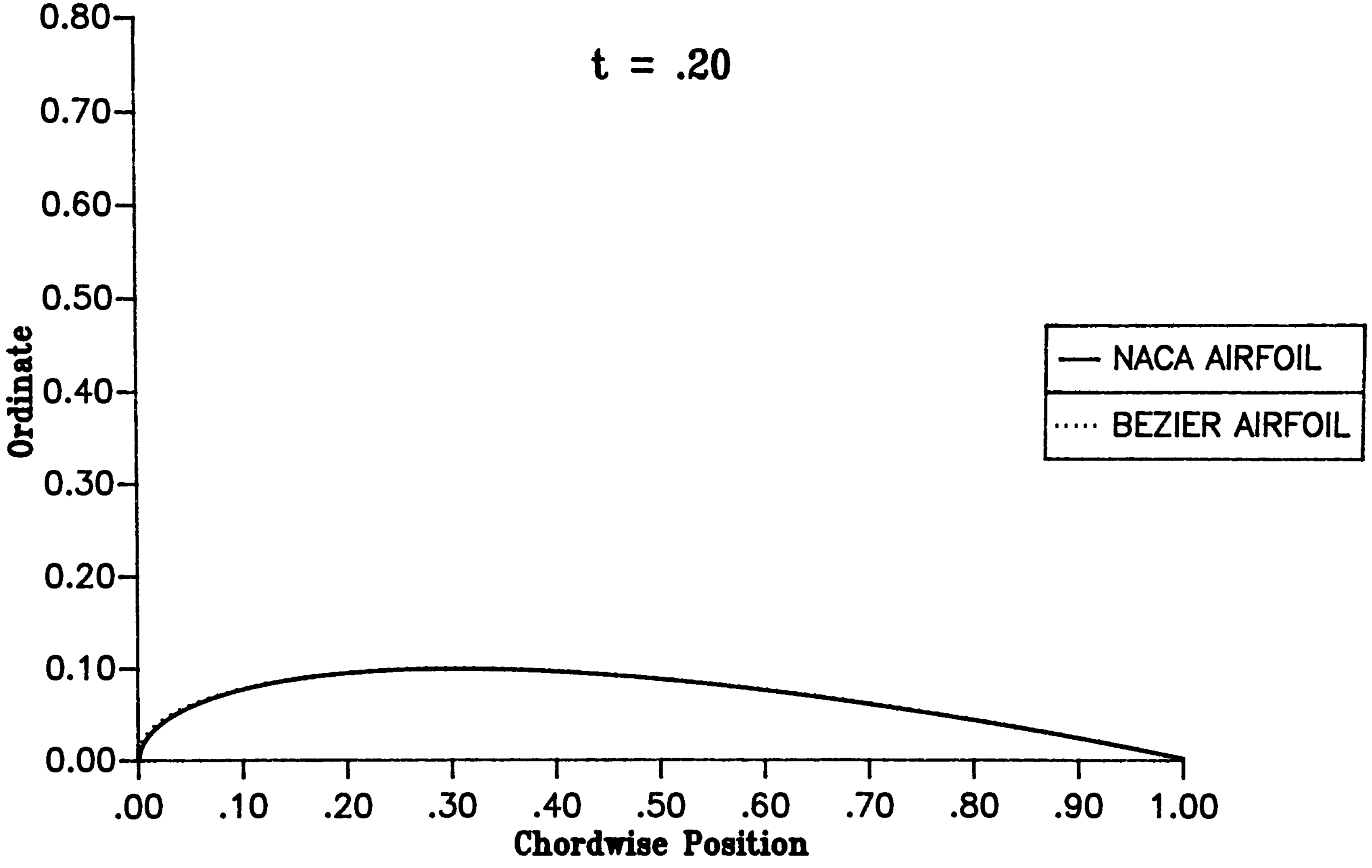
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



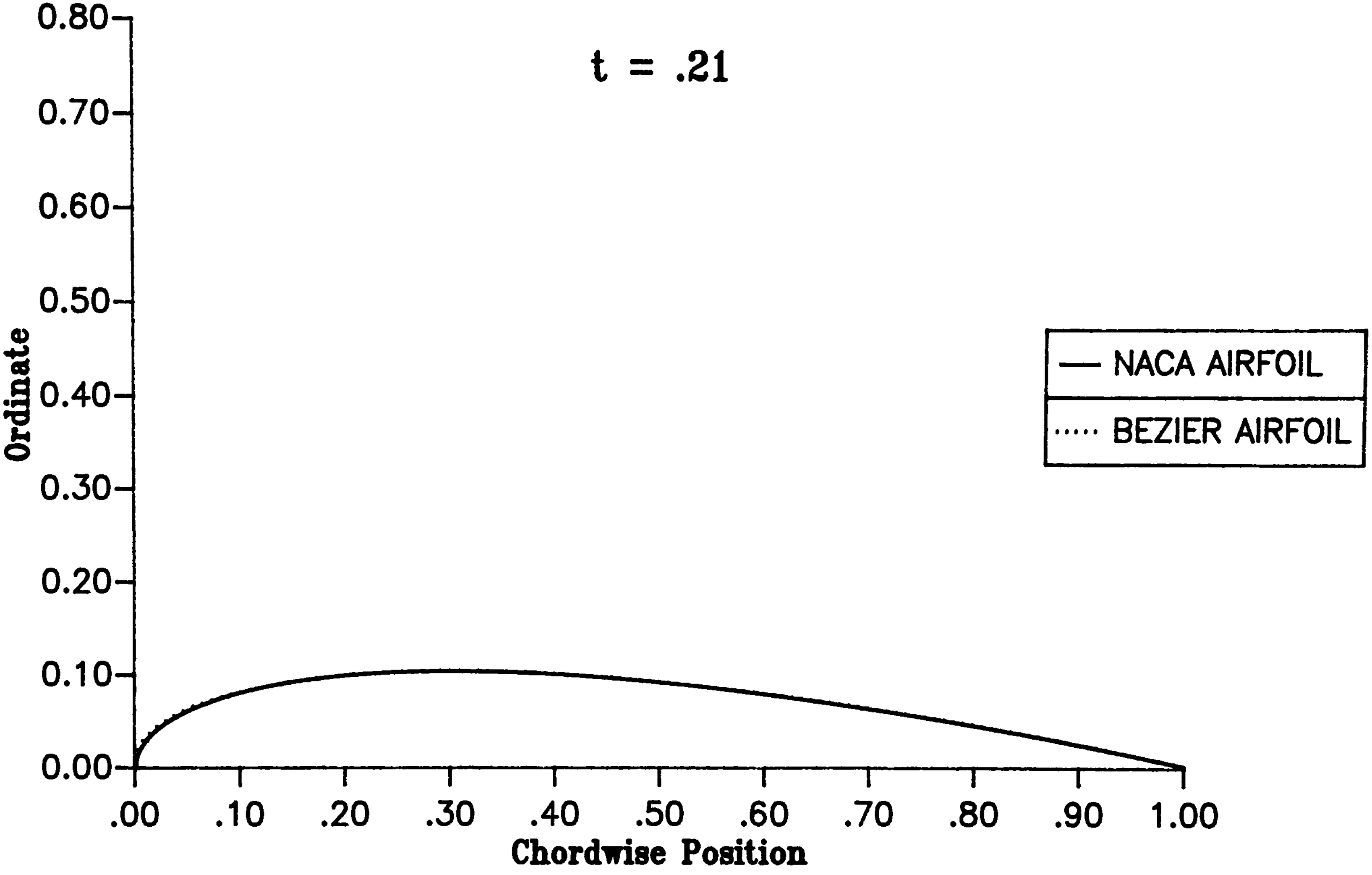
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



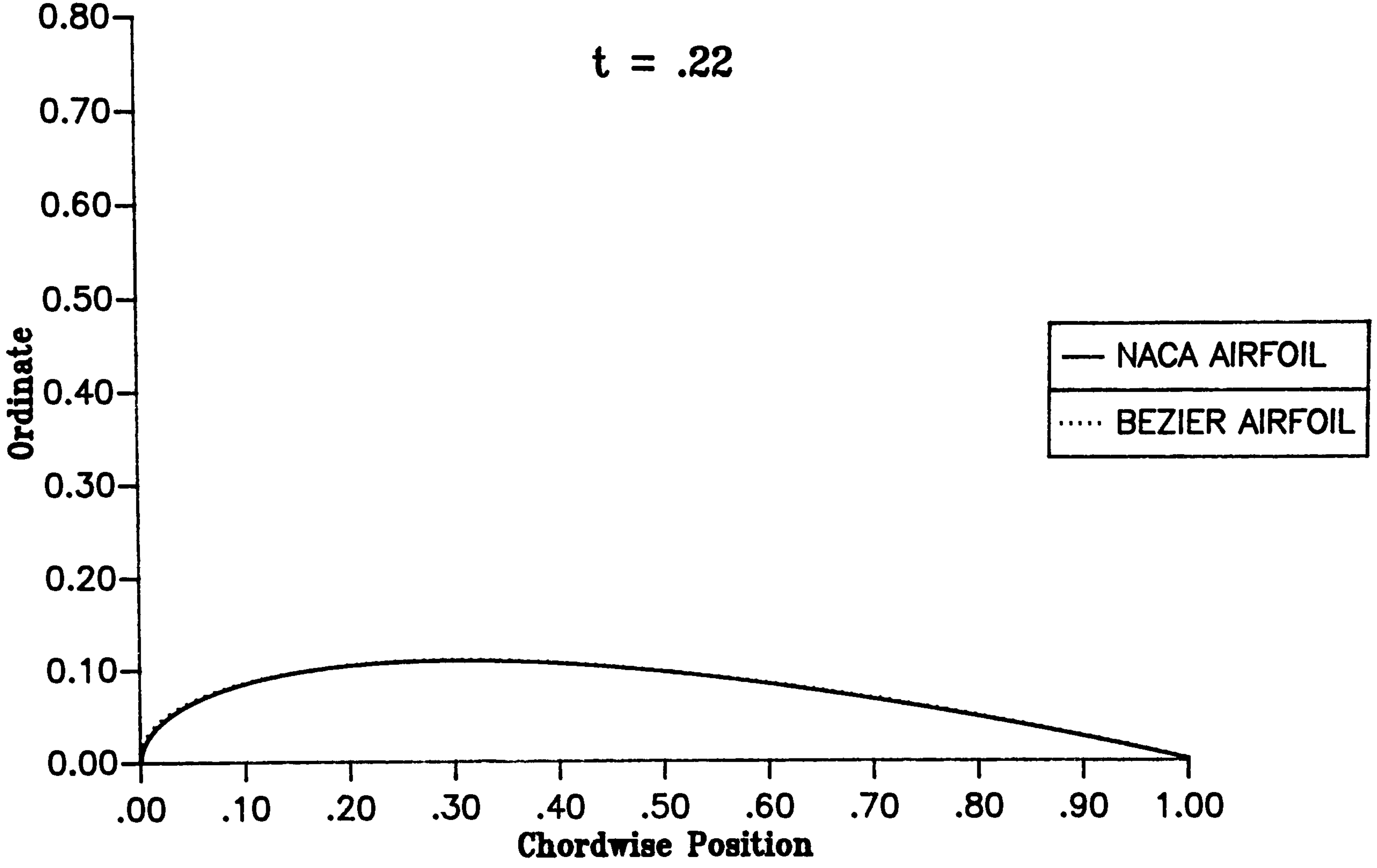
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



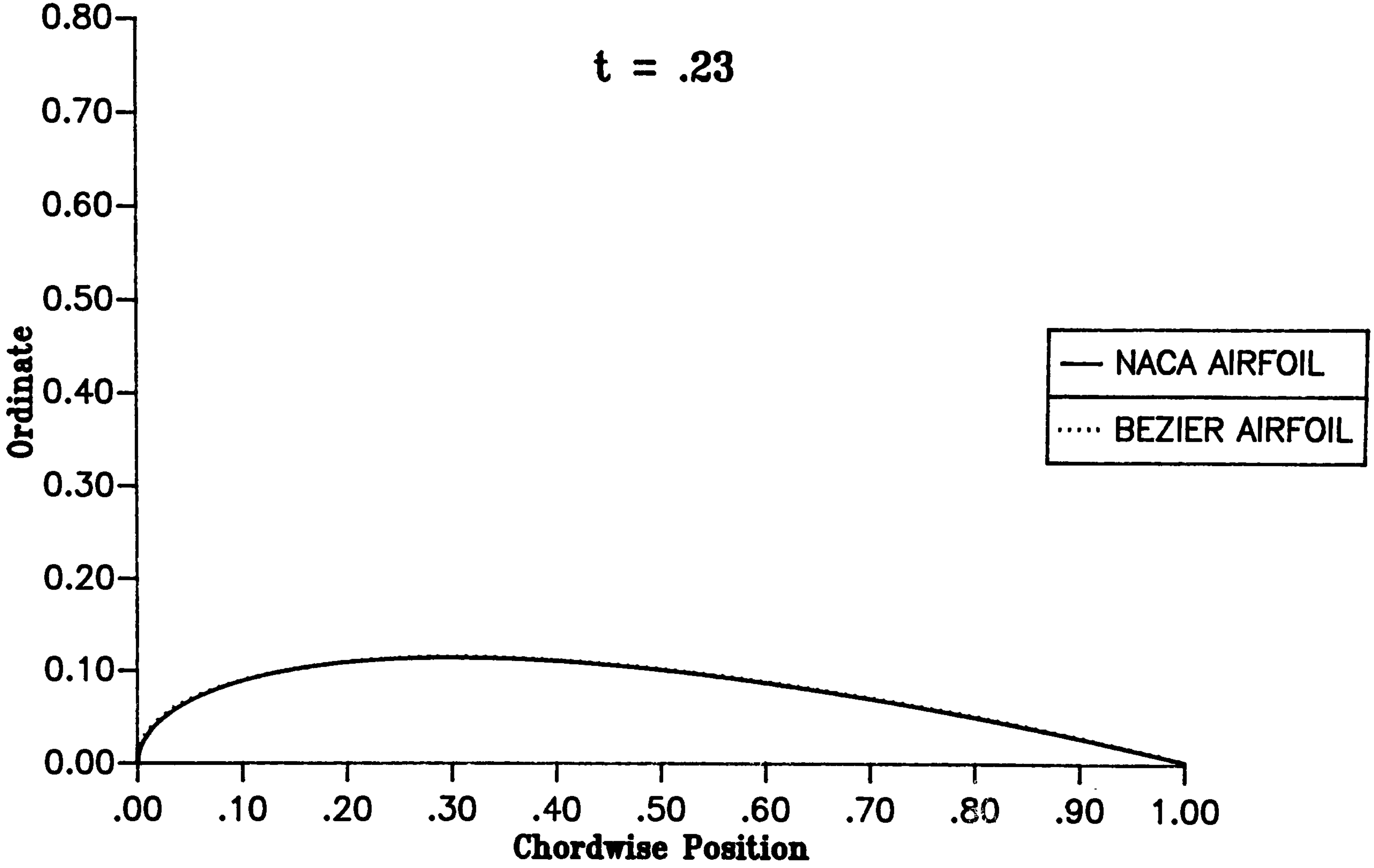
Symmetric Thickness Distribution
NACA Four–Digit vs. Bezier



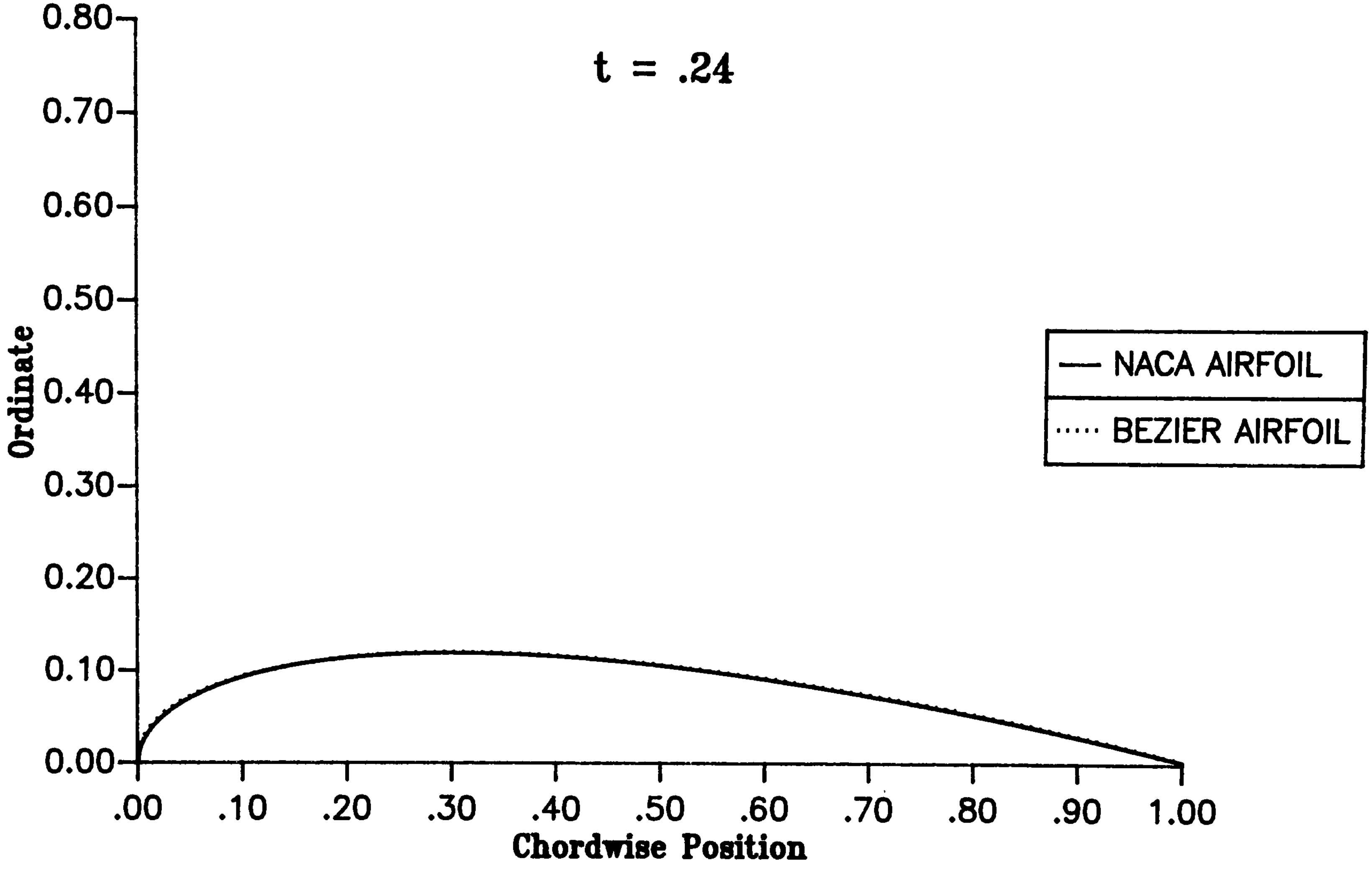
Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



Symmetric Thickness Distribution
NACA Four–Digit vs. Bezier

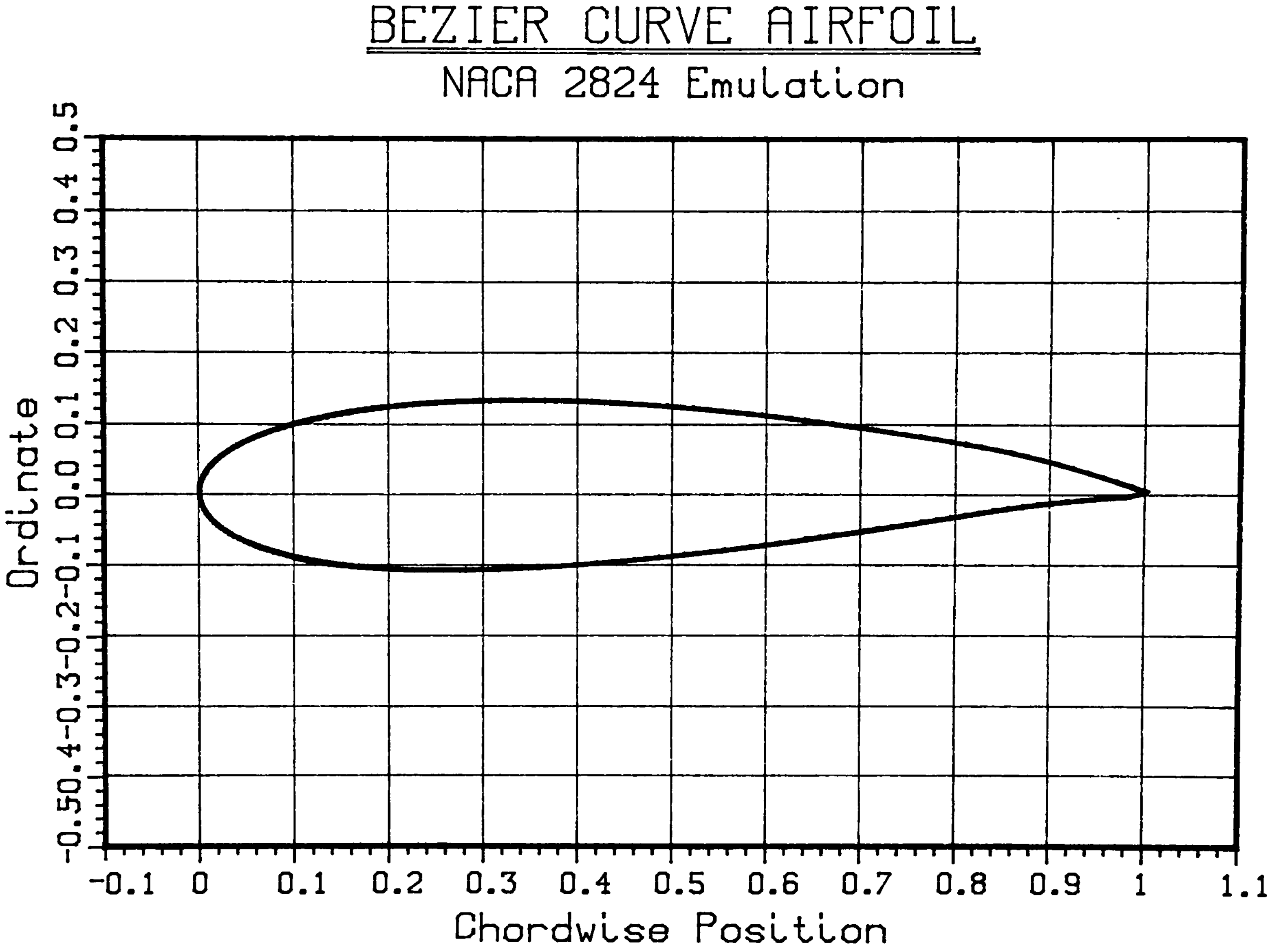


Symmetric Thickness Distribution
NACA Four-Digit vs. Bezier



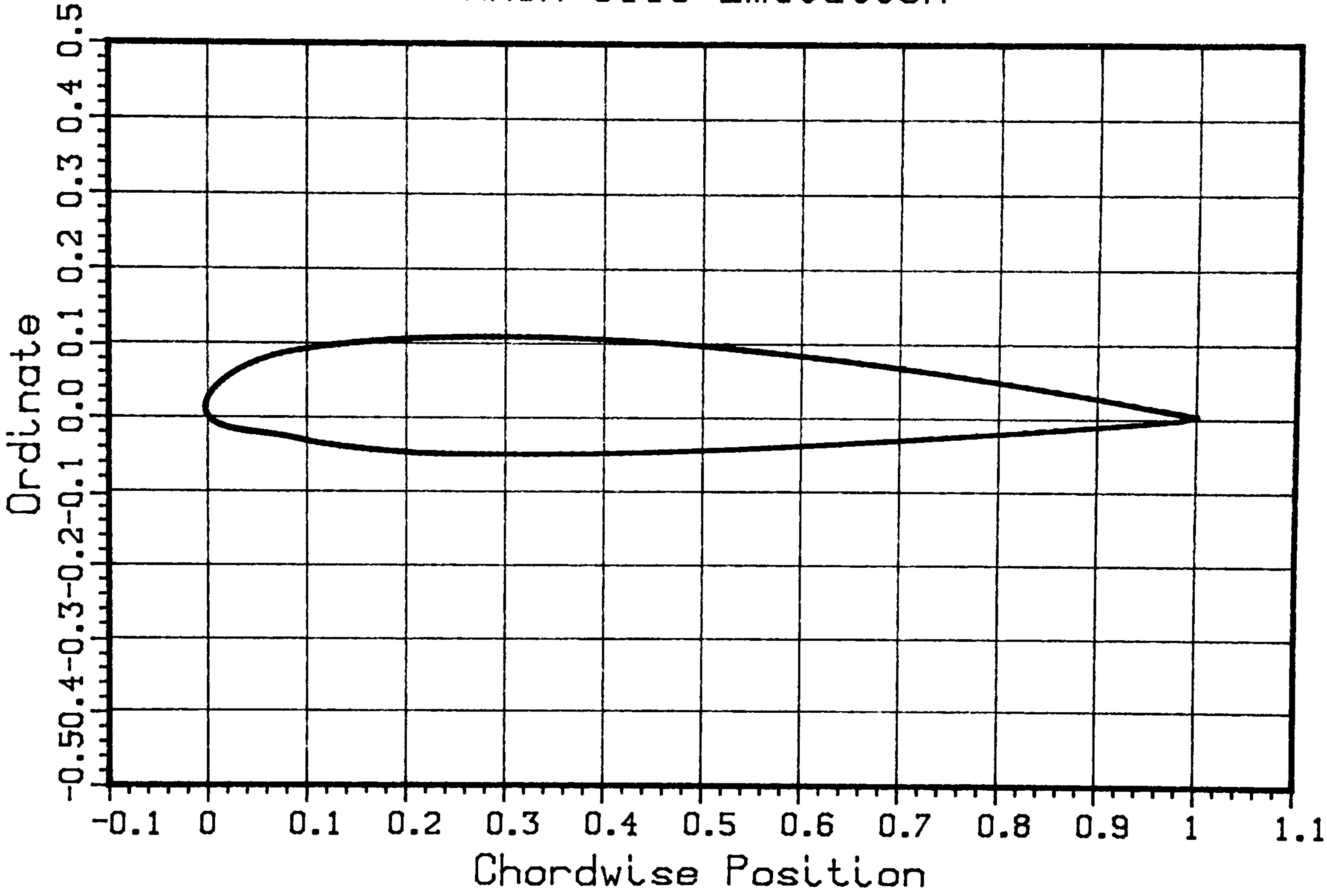
Appendix E. Comparative Graphs of NACA Four-Digit Cambered Airfoil Sections and Bézier Curve Emulations

Note: The plots contained in this appendix were generated using both the conventional and Bézier methods. Each plot shows the conventionally described airfoil section as the corresponding Bézier emulation . The plots were produced using the DIS8 plotting package on the VAX at RIT (a legend for the plot is not available using this software).


BEZIER CURVE AIRFOIL
NACA 2824 Emulation
Ordinate
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
Chordwise Position

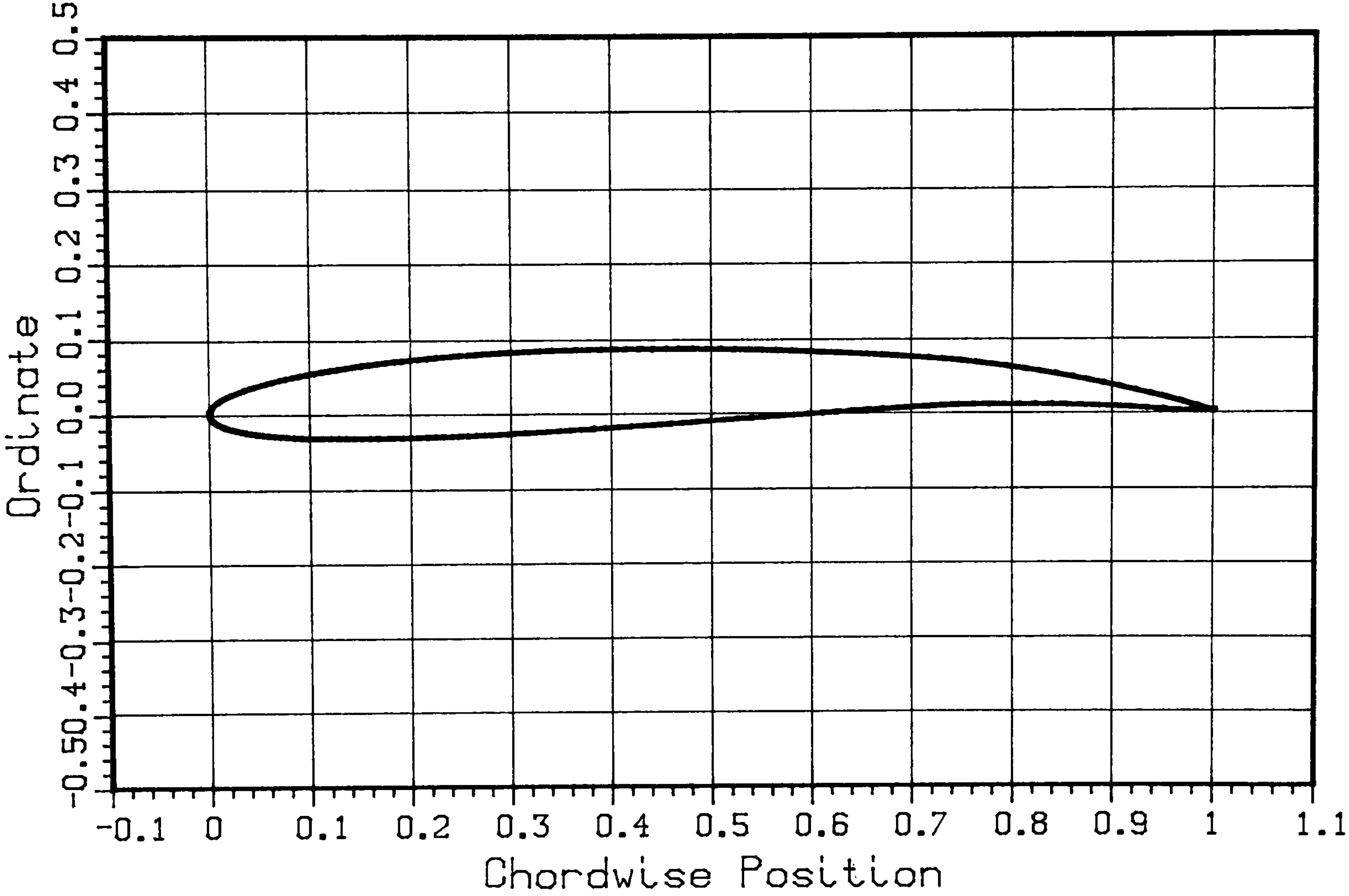
BEZIER CURVE AIRFOIL

NACA 3116 Emulation



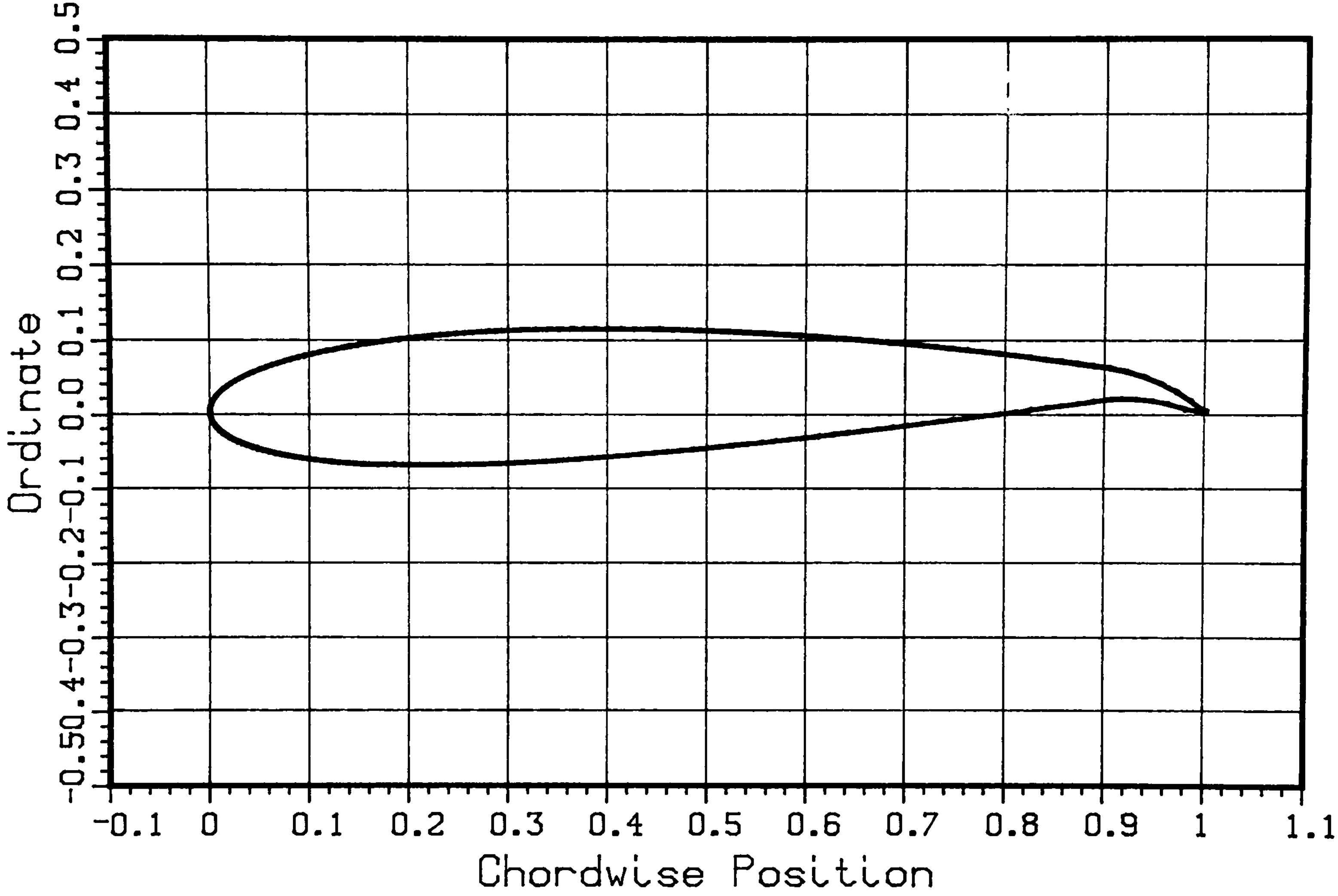
BEZIER CURVE AIRFOIL

NACA 4711 Emulation



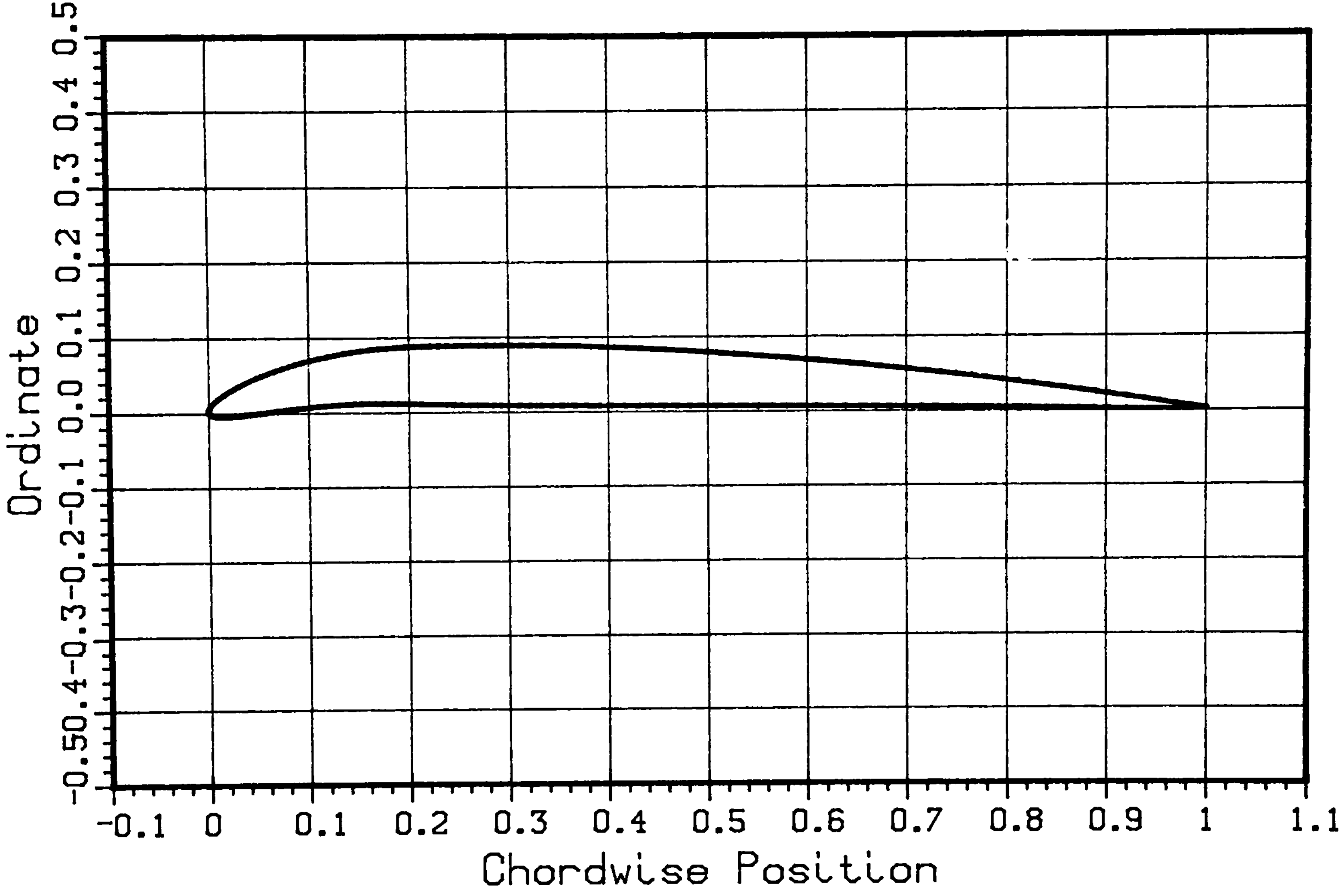
BEZIER CURVE AIRFOIL

NACA 4918 Emulation



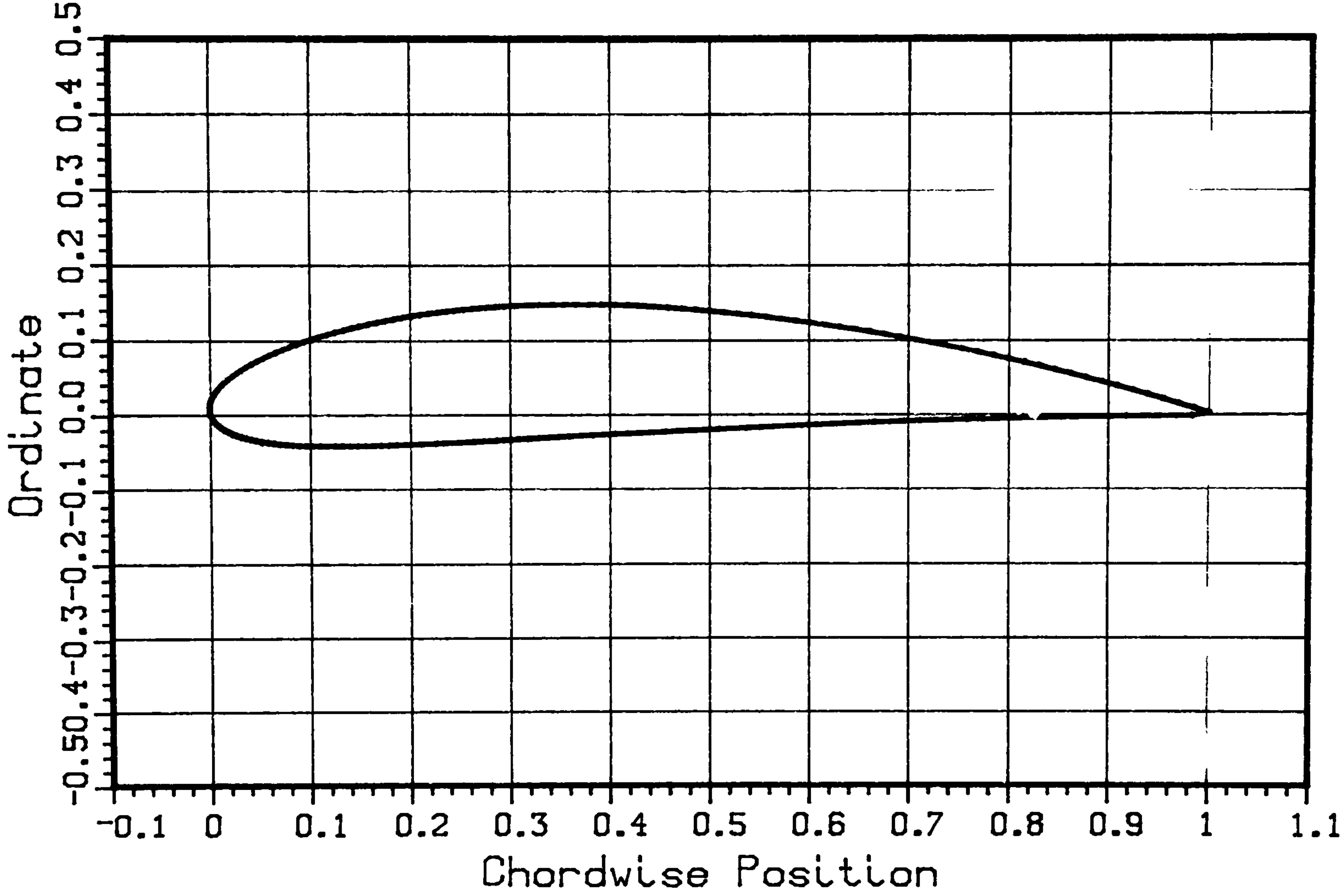
BEZIER CURVE AIRFOIL

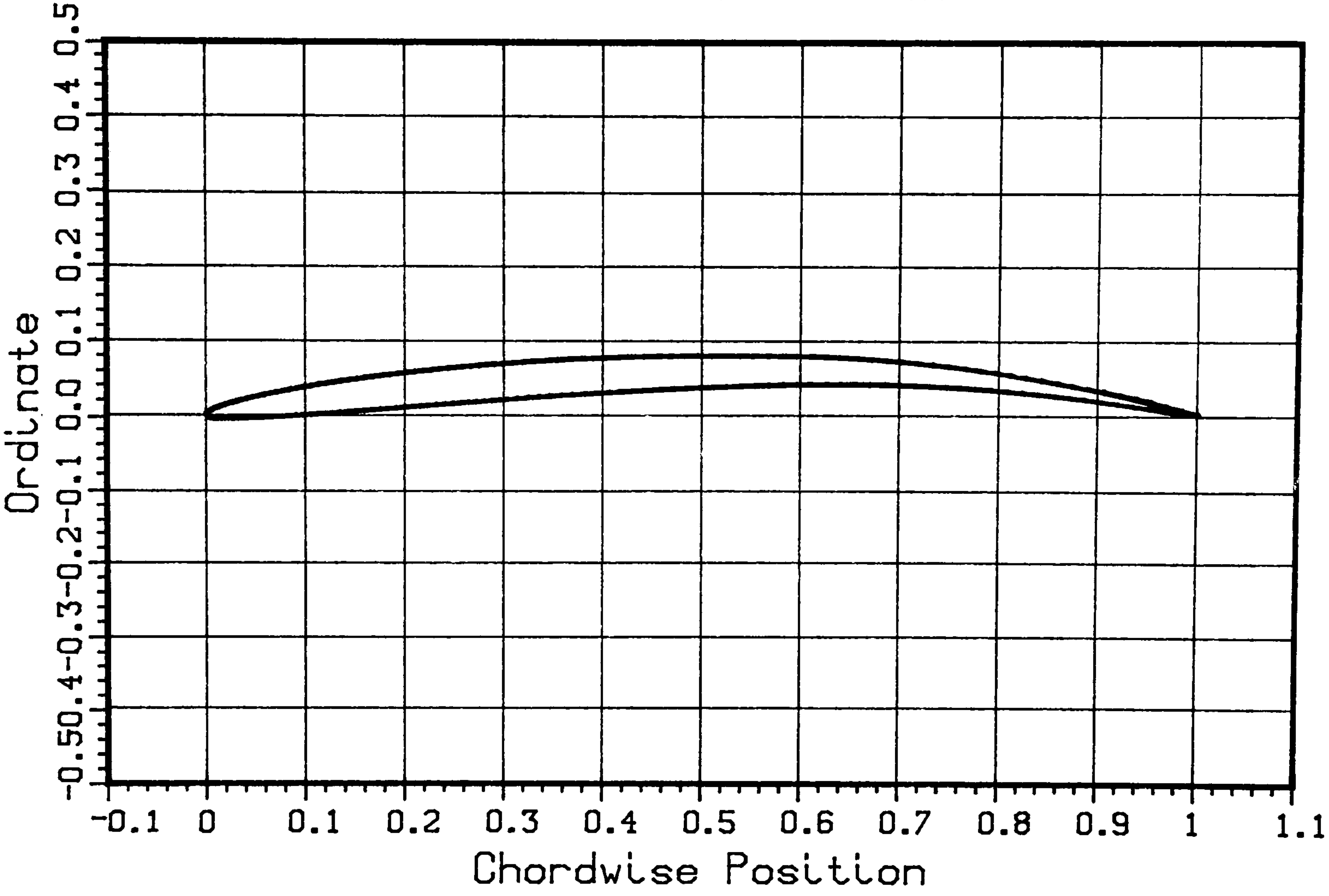
NACA 5208 Emulation



BEZIER CURVE AIRFOIL

NACA 6418 Emulation



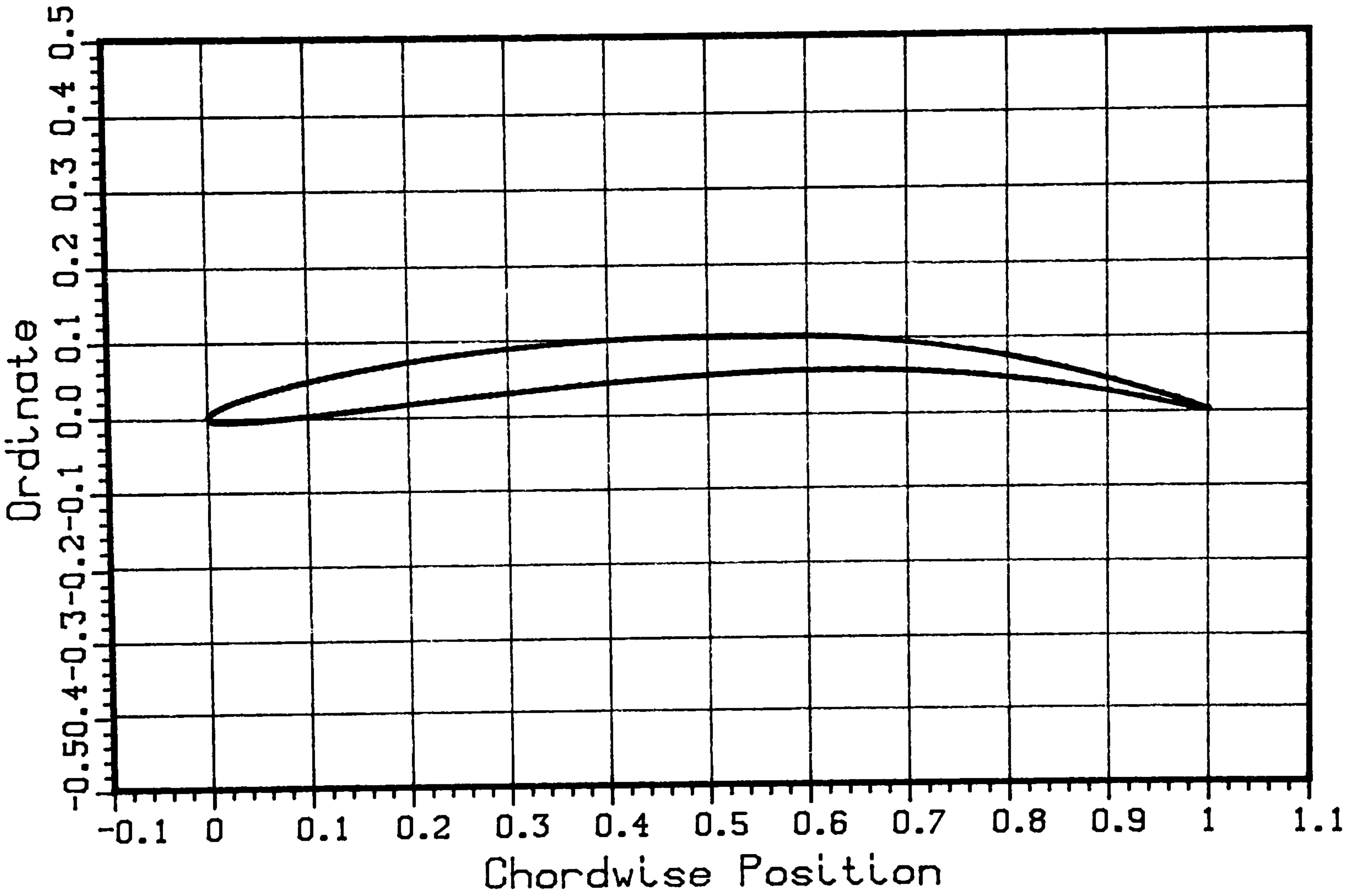


BEZIER CURVE AIRFOIL

NACA 6605 Emulation

BEZIER CURVE AIRFOIL

NACA 8606 Emulation



Appendix F. FORTRAN Computer Programs

```
*MODULE NAME      :     NEWTON
*
*PROGRAMMER :     BILL SCARBROUGH
*
*CREATION DATE    :     JUNE 12, 1987
*
*OBJECTIVE  :     THE PURPOSE OF THIS SUBROUTINE IS TO DETERMINE THE
*                 ROOT OF A SPECIFIED EQUATION USING THE NEWTON-
*                 RAPHSON METHOD OF TANGENTS.
*
*VARIABLE         DESCRIPTION
*
* XOLD            ORIGINAL ESTIMATE OF ROOT
* XNEW            NEW ESTIMATION OF ROOT
* FOLD            FUNCTIONAL VALUE OF XOLD
* FPRIME    DERIVATIVE OF FUNCTION AT XOLD
* EPSX            ABSOLUTE ERROR BOUND OF X VALUE
* REPSX           RELATIVE ERROR BOUND OF X VALUE
* EPSF            ABSOLUTE FUNCTIONAL UNCERTAINTY
* ITMAX           MAXIMUM NUMBER OF ITERATIONS ALLOWED
* IT        COUNTER FOR NUMBER OF ITERATIONS
*
        SUBROUTINE NEWTON(W,T,FHAT,FHPRIME,XOLD,
     &           EPSX,REPSX,EPSF,ITMAX,XNEW)
*
      IMPLICIT NONE
*
      EXTERNAL FHAT
      INTEGER*4  IT, ITMAX ,I,MAXPTS

      REAL  FHAT, FHPRIME, XOLD, XNEW, FOLD, FNEW, FPRIME
      REAL  EPSX, REPSX, EPSF, T, W
*
*
      LOGICAL*1  ENCLOSED, CONDITION(3), CONVNR
*
*****************************************************************
*
      IT = 1
      WRITE(6,*) 'IT =',IT
      FOLD = FHAT(T,XOLD)
      FPRIME = FHPRIME(T,XOLD)
*
      IF(ABS(FPRIME).GT.1/EPSF .OR. ABS(FPRIME).LT. EPSF) THEN
            WRITE(6,*)' STOP. DERIVATIVE TOO LARGE OR TOO SMALL.
*           WRITE(6,2004) IT, XOLD, FOLD, FPRIME
            RETURN
      ENDIF
*
            XNEW = XOLD - FOLD/FPRIME
            FNEW = FHAT(T,XNEW)
*

* OUTPUT TABLE HEADINGS
*     WRITE(6,2002) 'NEWTON-RAPHSON METHOD FOR DETERMINING ROOT'
*
*     WRITE(6,2006) 'INITIAL GUESS =',XOLD
*     WRITE(6,*)  '     '
*     WRITE(6,2007) 'FUNCTIONAL ERROR BOUND =',REPSX
* 2006      FORMAT(/,T10,A15,F6.2)
* 2007      FORMAT(T10,A24,E10.5,/)
*     WRITE(6,2003) 'ITERATION # ','ORIGINAL X','F OF X',
       +                  'DERIVATIVE AT X',
```

```
     +                   ' NEW X','F OF NEW X'
      DOWHILE(IT .LE. ITMAX.AND.
     +                  .NOT.CONVNR(XOLD,XNEW,FOLD,FNEW,EPSX,
     +                  REPSX, EPSF, ENCLOSED, CONDITION))
*
*           WRITE(6,2004) IT, XOLD, FOLD, FPRIME, XNEW, FNEW
            FOLD = FNEW
            XOLD = XNEW
            FPRIME = FHPRIME(T,XOLD)
         IF(ABS(FPRIME).GT.1/EPSF .OR. ABS(FPRIME).LT. EPSF) THEN
              WRITE(6,*)' STOP. DERIVATIVE TOO LARGE OR TOO SMALL.
*             WRITE(6,2004) IT, XOLD, FOLD, FPRIME
              RETURN
         ENDIF
*
            XNEW = XOLD - FOLD/FPRIME
            FNEW = FHAT(XNEW)
            IT = IT+1
      WRITE(6,*) 'IT =',IT
      ENDDO
*
*           WRITE(6,2004) IT,XOLD,FOLD,FPRIME,XNEW,FNEW
*
*       IF(CONDITION(3)) THEN
*           WRITE(6,2005)'ABSOLUTE BOUND ON FUNCTIONAL UNCERTAINTY
*     +     SATISFIED. '
*       ENDIF
*
* FORMAT SECTION
*
* 2002      FORMAT(40X,A45//)
* 2003      FORMAT(10X,A12,10X,A10,8X,A6,10X,A15,10X,A6,9X,A10,//)
* 2004      FORMAT(10X,I4,15X,E15.7,5X,E15.7,5X,E15.7,5X,E15.7,5X,E15.7,/)
* 2005   FORMAT(10X,A55)
        RETURN
        END
*
      FUNCTION    DNACA4DIG(T,X)
*
      IMPLICIT NONE
*
      INTEGER N
      DOUBLE PRECISION   DNACA4DIG,X,T,B(4)
*
      B(1) = X
      B(2) = B(1) * X
      B(3) = B(2) * X
      B(4) = B(3) * X
      DNACA4DIG = 5*T*(.2969*SQRT(X)-.126*B(1)-.3516*B(2)+.2843*B(3)-
     &                .1015*B(4))
*
      RETURN
      END

*
*     PROGRAM NAME       F2
*
*     PROGRAMMER  BILL SCARBROUGH
*
*     CREATION DATE      13 NOVEMBER 1989
*
*.............................................................................
..
*
*
      FUNCTION DF2(T,X)
```

```
*
      IMPLICIT NONE
*
      DOUBLE PRECISION DF2,T,X,R,NACA4DIG,F1
*
      R = 1.1019 * T * T
      F1 = 5.0*T*(.2969*SQRT(X)-.126*X-.3516*X*X+.2843*X*X*X-.1015*X*X*X*X)
      DF2 = F1 - SQRT(X*(2*R-X))
*
      RETURN
      END
```

```
*MODULE NAME      :CONVERGE
*
*PROGRAMMER :BILL SCARBROUGH
*
*DATE       :JUNE 8, 1987
*
*PURPOSE    : TO DETERMINE IF A ROOT SEARCHING METHOD HAS CONVERGED
*
******************************************************************************
**
*
*     VARIABLE    DESCRIPTION
*
*     XLEFT       LEFT BOUND ON ROOT VALUE
*     XRIGHT            RIGHT BOUND ON ROOT VALUE
*     FLEFT       FUNCTION VALUE OF XLEFT
*     FRIGHT            FUNCTION VALUE OF XRIGHT
*     EPSX        ACCEPTABLE ABSOLUTE UNCERTAINTY BOUND OF ROOT
*     REPSX       ACCEPTABLE RELATIVE UNCERTAINTY BOUND ON ROOT
*     EPSF        ACCEPTABLE ABSOLUTE BOUND ON FUNCTION VALUES
*     ENCLOSED    FLAG TO DETERMINE IF XLEFT < ROOT < XRIGHT
*     CONDITION   ARRAY OF FLAGS TO DETERMINE WHICH CONDITION(S)
*                 ARE SATISFIED
*
******************************************************************************
*
*
*SUBROUTINE AND FUNCTION SUBPROGRAMS REQUIRED
*     NONE
*
      FUNCTION CONVNR(XLEFT,XRIGHT,FLEFT,FRIGHT,EPSX,REPSX,EPSF,
     +                    ENCLOSED,CONDITION)
*
      IMPLICIT NONE
*
      REAL  XLEFT,XRIGHT,FLEFT,FRIGHT,EPSX,REPSX,EPSF
      LOGICAL*1 CONVNR , ENCLOSED, CONDITION(3)
*
      ENCLOSED = .TRUE.
      CONDITION(1) = ENCLOSED .AND. ABS(XRIGHT-XLEFT)/2.0 .LE. EPSX
      CONDITION(2) = ENCLOSED .AND. ABS(XLEFT + XRIGHT) .NE. 0.0 .AND.
     +                 ABS((XLEFT-XRIGHT)/(XLEFT + XRIGHT)) .LE. REPSX
      CONDITION(3) = ABS(FLEFT) .LE. EPSF .OR. ABS(FRIGHT) .LE. EPSF
*
      CONVNR     = CONDITION(1) .OR. CONDITION(2) .OR. CONDITION(3)
*
      RETURN
      END
```

```
*
      PROGRAM BCALL
*
      IMPLICIT NONE
*
      DOUBLE PRECISION AAA,BBB,T,R,DF2,DFPRIME,DNACA4DIG,ROOT,SLOPE
*
      DO T = 0.01,0.40,.01
      R = 1.1019 *T*T
      AAA = 1.0E-6
      BBB = R
      CALL DBISECT(T,AAA,BBB,ROOT)
*     SLOPE = DFPRIME(T,ROOT)
      WRITE(6,*) 'ROOT =',ROOT
*     WRITE(6,*) 'SLOPE =',SLOPE
      WRITE(12,10) T,ROOT
*     WRITE(13,10) T,SLOPE
      ENDDO
 10   FORMAT(T5,F6.3,3X,D12.7)
      STOP
      END
```

```
*
      SUBROUTINE DBISECT(T,A,B,P)
*
      IMPLICIT NONE
*
      INTEGER I,ITMAX
      DOUBLE PRECISION  A,B,DF2,P,EPSX,T,X1,X2,DFPRIME
*
      I = 1
      ITMAX = 1000
      EPSX = 5.0E-12
      DOWHILE(I.LE.ITMAX)
         P = A+(B-A)/2
         IF(ABS(DF2(T,P)).LE.EPSX.OR.(B-A)/2.0.LE.EPSX)THEN
          PRINT *, 'SUCCESSFUL BISECTION'
          PRINT *, 'ROOT EQUALS',P,'ITERATIONS REQUIRED =',I
          RETURN
         ENDIF
          I  = I+1
          X1 = DFPRIME(T,A)
          X2 = DFPRIME(T,P)
         IF(X1*X2.GT.0)THEN
          A=P
         ELSE
          B=P
         ENDIF
        ENDDO
       PRINT *,'BISECTION FAILED AFTER',ITMAX,'ITERATIONS'
       RETURN
       END
```

```
      PROGRAM BEZCALL
*
      IMPLICIT NONE
*
      INTEGER MAXN,NPTS,CPTS,I,J
      PARAMETER(MAXN=500)
      DOUBLE PRECISION DBEZIER3,B(4,2),P(MAXN,2)
*
      B(1,1) = 0.0
      B(1,2) = 0.0
      B(2,1) = 0.0
      B(2,2) = 2.5787E-2
      B(3,1) = 1.185307E-1
      B(3,2) = .06
      B(4,1) = .3
      B(4,2) = .06
*
      NPTS = 4
      CPTS = 201
*
      CALL DBEZIER3(NPTS,B,CPTS,P)
*
      OPEN(UNIT=6,FILE='BEZIER.OUT',STATUS='NEW',DISP='SAVE')
*
      DO I = 1,CPTS,1
         WRITE(6,10) (P(I,J),J=1,2)
      ENDDO
 10   FORMAT(3X,D14.6,5X,D14.6)
      STOP
      END
```

```
*
*        PROGRAM NAME    MINPOINTS
*
*        PROGRAMMER      BILL SCARBROUGH
*
*        CREATION DATE   12 NOVEMBER 1989
*
*        DESCRIPTION
*
*                THIS FORTRAN PROGRAM UTILIZES CLAMPED CUBIC SPLINES
*                TO FIND A FUNCTION TO FIT THE SHAPE OF A SYMMETRIC AIRFOIL.
*                ITERATIONS WILL PROCEED UNTIL THE BEST FIT IS OBTAINED. THE
*                PROGRAM WILL THEN INFORM THE USER OF THE NUMBER OF POINTS
*                REQUIRED TO ACHIEVE THAT 'BEST FIT'.
*
*        SUBROUTINES REFERENCED
*
*                NEWTON- NEWTON-RAPHSON METHOD FOR DETERMINING ROOTS
*
*                CLAMPS- CLAMPED CUBIC SPLINE ROUTINE
*
*.............................................................................
..
*
*        VARIABLE        DESCRIPTION
*
*
       PROGRAM MINPOINTS
*
       IMPLICIT NONE
*
       INTEGER MAXPTS,I,J,N,ITMAX,K,NPTS,NBEST
       PARAMETER(MAXPTS=500)
       REAL NACA4DIG,X(1:MAXPTS,0:MAXPTS),Y(1:MAXPTS,0:MAXPTS)
       REAL A(0:MAXPTS),B(0:MAXPTS),Q(1:MAXPTS,0:MAXPTS),FSPLINE,FIXPT
       REAL C(0:MAXPTS),D(0:MAXPTS),H(0:MAXPTS),L(0:MAXPTS),MU(0:MAXPTS)
       REAL T,ALPHA(0:MAXPTS),Z(0:MAXPTS),FP0,FPN,XOLD,FPRIME
       REAL EPSX,REPSX,EPSF,FHPRIME,CHORD,XSTART,MAXERR,P,AAA
       REAL YCALC(1:MAXPTS,0:MAXPTS),ERROR(MAXPTS),SUM,X0,R,BBB
*
       PRINT *,'ENTER DESIRED THICKNESS IN DECIMAL FORM'
       READ(5,*) T
*
       I = 1
       DOWHILE(T.EQ.0.0.OR.T.GT.1.0.AND.I.LE.3)
              PRINT *,'INVALID INPUT. TRY AGAIN'
              READ(5,*) T
              I = I+1
       ENDDO
*
       IF(T.EQ.0.0.OR.T.GT.1.0.AND.I.GE.3)THEN
              PRINT *,'THREE TRIES AND YOU ARE OUTTA HERE'
              STOP
       ENDIF
       R = 1.1019*T*T
*
       J = 1
       NPTS = 2
*
       PRINT *,'ENTER LENGTH OF CHORD'
       READ(5,*) CHORD
*
       FPN = 0.0
*
      AAA=1.0E-6
      BBB = R
```

```
*       CALL FIXPT(T,X0,XSTART)
*     CALL BISECT(T,AAA,BBB,XSTART)
       FP0 = .0671927 - .017408*T - 3.55908*T**2 + .388474/T
*
      XSTART = .00488874 -.190253*T +2.22379*T**2 - 9.96043*T**3 +
     &           18.6574*T**4
      PRINT *,'STARTING POINT EQUALS',XSTART
      PRINT *,'STARTING SLOPE EQUALS',FP0
      PRINT *,'TRAILING EDGE SLOPE: ',FPN
       MAXERR = 100.0
        N=1
        X(N,0) = XSTART
        Y(N,0) = SQRT(X(N,0)*(2.*R-X(N,0)))
      PRINT *,'ORDINATE AT STARTING POINT = ',Y(N,0)
*       ENDDO
*
*       N = 4
*       DOWHILE(N.LE.NPTS)
*         P = (CHORD - XSTART)/(N-1)
*      H(0) = P
*          DO I = 1,N-1,1
*               H(I) = P
*               X(N,I) = X(N,I-1) + P
*               Y(N,I) = NACA4DIG(T,X(N,I))
*          ENDDO
*
      X(N,1) = .2999491
      Y(N,1) = T/2.
*     X(N,2) = 1.
*     Y(N,2) = .0105*T
        CALL CLAMPS(MAXPTS,T,X,Y,N,FP0,FPN,H,A,B,C,D,L,MU,Z,ALPHA)
          Q(N,0) = X(N,0)
*
      K = 1
          DOWHILE(K.LE.MAXPTS-1)
               Q(N,K) = Q(N,0) + FLOAT(K)/FLOAT(MAXPTS)
               YCALC(N,K) = FSPLINE(MAXPTS,N,X,Q(N,K),A,B,C,D)
             K = K+1
          ENDDO
          ERROR(J) = 0.0
*
          DO I = 0,NPTS,1
           SUM = (YCALC(N,I)-NACA4DIG(T,Q(N,I)))**2
           ERROR(J) = ERROR(J) + SUM
          ENDDO
*
          IF(ERROR(J).LT.MAXERR)THEN
               MAXERR = ERROR(J)
               NBEST  = N
          ENDIF
*

          J = J+1
          N = N+1
*
*       ENDDO
      DO I = 0,MAXPTS,1
            WRITE(6,*) Q(NBEST,I),  YCALC(NBEST,I)
      ENDDO
      PRINT*,'NBEST = ',NBEST
      PRINT*,'ERROR = ',ERROR(NBEST-3)
       STOP
       END
```

```
*
*     SUBROUTINE NAME         CLAMPS
*
*     PROGRAMMER        BILL SCARBROUGH
*
*     CREATION DATE           12 NOVEMBER 1989
*
*     DESCRIPTION
*
*           THIS FORTRAN SUBROUTINE WILL COMPUTE CLAMPED CUBIC SPLINE
*           COEFFICIENTS FOR A GIVEN INPUT OF A SET OF X-Y DATA POINTS
*           AND THE SLOPE OF THE CURVE AT THE END POINTS
*
*     VARIABLE          DESCRIPTION
*
*     X,Y               ARRAY OF DATA POINTS TO WHICH CURVE IS TO BE
*                       FIT
*     I                 INTEGER, ARRAY SUBSCRIPT, LOOP COUNTER
*
*
      SUBROUTINE CLAMPS(MAXPTS,T,X,Y,N,FP0,FPN,H,A,B,C,D,L,MU,Z,ALPHA)
*
      IMPLICIT NONE
*
      INTEGER     N,MAXPTS,I,J,NPTS
      REAL  X(1:MAXPTS,0:MAXPTS),Y(1:MAXPTS,0:MAXPTS),ALPHA(0:MAXPTS)
      REAL  A(0:MAXPTS)
      REAL  B(0:MAXPTS),C(0:MAXPTS),D(0:MAXPTS),MU(0:MAXPTS)
      REAL  L(0:MAXPTS),H(0:MAXPTS),Z(0:MAXPTS),FP0,FPN,T,NACA4DIG
*
      EXTERNAL NACA4DIG
*
      DO I = 0,N-1,1
*
            A(I) = Y(N,I)
              H(I) = X(N,I+1)-X(N,I)
      PRINT *,'H(',I,') = ',H(I)
*
      ENDDO
*
      ALPHA(0) = 3*(A(1)-A(0))/H(0) - 3*FP0
      ALPHA(N) = 3*FPN - 3*(A(N)-A(N-1))/H(N-1)
*
      DO I = 1,N-1,1
*
         ALPHA(I) = 3.0*(A(I+1)*H(I-1)-A(I)*(X(N,I+1)-X(N,I-1))+A(I-1)*
     &                    H(I))/(H(I-1)*H(I))
*
      ENDDO
*
      L(0)  = 2.0*H(0)
      MU(0) = 0.5
      Z(0)  = ALPHA(0)/L(0)
*
      DO I = 1,N-1,1
*
            L(I)  = 2.0*(X(N,I+1)-X(N,I-1)) - H(I-1)*MU(I-1)
            MU(I) = H(I)/L(I)
            Z(I)  = (ALPHA(I) - H(I-1)*Z(I-1))/L(I)
*
      ENDDO
*
      L(N)  = H(N-1)*(2.0 - MU(N-1))
      Z(N)  = (ALPHA(N) - H(N-1)*Z(N-1))/L(N)
      C(N)  = Z(N)
*
```

```
      DO J = N-1,0,-1
*
           C(J) = Z(J) - MU(J)*C(J+1)
           B(J) = (A(J+1) - A(J))/H(J) - H(J)*(C(J+1) + 2.0*C(J))/3.0
           D(J) = (C(J+1) - C(J))/(3.0*H(J))
*
      ENDDO
*
      RETURN
      END
```

```
******************************************************************************
*                                                                            *
*  PROGRAM NAME:  DBEZIER3                                                   *
*                                                                            *
*  PROGRAMMER:    BILL SCARBROUGH                                            *
*                                                                            *
*  CREATION DATE: 10 APRIL 1990                                              *
*                                                                            *
******************************************************************************
*                                                                            *
*  DESCRIPTION:   THIS FORTRAN ROUTINE WILL, FOR A GIVEN SET OF DEFINING     *
*                 POLYGON VERTICES, GENERATE THE THIRD-ORDER TWO-DIMENSIONAL *
*                 BEZIER CURVE AND ITS FIRST AND SECOND DERIVATIVES.         *
*                                                                            *
******************************************************************************
*                                                                            *
*  USAGE:         THIS ROUTINE IS CALLED BY DBEZIER3(NPTS,B,P,DP)            *
*                                                                            *
*  USER INPUTS:   B - THE 4x2 MATRIX OF DEFINING POLYGON VERTEX COORDINATES  *
*                 NPTS - THE NUMBER OF POINTS ON THE CURVE TO BE COMPUTED,   *
*                        NOT TO EXCEED 500                                   *
*                                                                            *
*  OUTPUTS:       P(NPTS,2)  - MATRIX OF X,Y COORDINATES OF POINTS ON THE    *
*                              CURVE                                         *
*                                                                            *
*                 DP(NPTS,2) - MATRIX CONTAINING DERIVATIVE INFORMATION;     *
*                              FIRST COLUMN, FIRST DERIVATIVE, SECOND        *
*                              COLUMN, SECOND DERIVATIVE AT P.               *
*                                                                            *
******************************************************************************
*                                                                            *
*  INTERMEDIATE VARIABLES:                                                   *
*                                                                            *
*     INTEGERS                                                               *
*                                                                            *
*           MAXN   - MAXIMUM ARRAY SIZE (SET AT 500)                         *
*           ICOUNT - INDEX COUNTER FOR P, DP ARRAYS                          *
*           I      - COLUMN COUNTER                                          *
*                                                                            *
*     REALS                                                                  *
*                                                                            *
*           T      - PARAMETER VALUE, 0 .LE T .LE 1                          *
*           TSTEP  - INCREMENT ON T, DETERMINED BY NPTS                      *
*           COEFF  - 4x4 COEFFICIENT MATRIX USED IN COMPUTATIONS             *
*           TMAT   - 1x4 MATRIX OF CURRENT PARAMETER VALUE TO THE J-1 POWER  *
*                                                                            *
******************************************************************************
*                                                                            *
*     SUBROUTINES REFERENCED:                                                *
*                                                                            *
*           MATPROD - PERFORMS MATRIX MULTIPLICATION                         *
*                                                                            *
******************************************************************************

      SUBROUTINE DBEZIER3(NPTS,B,P,DP,DDP)
*
      IMPLICIT NONE
*
      INTEGER MAXN,NPTS,NPTS2,I,J,K
      PARAMETER (MAXN=500)
      DOUBLE PRECISION B(4,2),P(MAXN,2),DP(MAXN,2),COEFF(4,4),TSTEP,TMAT(1,4)
      DOUBLE PRECISION DCOEFF(3,4),DDCOEFF(2,4),DTMAT(1,3),DDTMAT(1,2)
      DOUBLE PRECISION TEMP(1,4),TEMP2(1,2),DTEMP(1,4),TEMP3(1,2),DDTEMP(1,4)
      DOUBLE PRECISION TEMP4(1,2),DDP(MAXN,2)
```

```
*
*****************************************************************************
*
* determine if number of points requested is larger than memory alloted...
*
      DOWHILE(MAXN.LT.NPTS)

         PRINT *, 'ERROR:', NPTS,'POINTS REQUESTED IS LARGER THAN ALLOCATED
                   MEMORY OF',MAXN,'POINTS.'
         PRINT *, 'ENTER NUMBER OF POINTS DESIRED (LESS THAN',MAXN,').'
         READ(5,*) NPTS2
         NPTS = NPTS2
      ENDDO
*
*****************************************************************************
*
* initialize variables...
*
      ICOUNT = 0
      T = 0.0
      TSTEP = 1.0/(NPTS-1)
      TMAT(1,4) = 1.0
*
* set up coefficient matrix...
*
      DO I=1,4,1
         DO J=1,4,1
            COEFF(I,J) = 0.0
         ENDDO
      ENDDO
*
      COEFF(1,1) = -1.0
      COEFF(1,2) = 3.0
      COEFF(1,3) = -1.0
      COEFF(1,4) = 1.0
      COEFF(2,1) = 3.0
      COEFF(2,2) = -6.0
      COEFF(2,3) = 3,0
      COEFF(3,1) = -3.0
      COEFF(3,2) = 3.0
      COEFF(4,1) = 1.0
*
*****************************************************************************
*
* time for computation...
*
      DOWHILE(T.LE.1.0)
         ICOUNT = ICOUNT + 1
*
            DO J=3,1,-1
               TMAT(1,J) = TMAT(1,J+1) * T
            ENDDO
*
         CALL MATPROD (TMAT,COEFF,TEMP)
* note: the matrix temp is the 1x4 matrix product of TMAT and COEFF...
         CALL MATPROD (TEMP,B,TEMP2)
*
         DO I=1,2,1
               P(ICOUNT,I) = TEMP2(1,I)
         ENDDO
*
*  generate first and second derivative coefficient matrices...
*
         DO I = 1,3,1
            DO J = 1,4,1
               DO K = 1,2,1
```

```
                 DCOEFF(I,J) = 0.0
                 DDCOEFF(K,J) = 0.0
              ENDDO
           ENDDO
        ENDDO
*
        DCOEFF(1,1) = -3.0
        DCOEFF(1,2) = 9.0
        DCOEFF(1,3) = -9.0
        DCOEFF(1,4) = 3.0
        DCOEFF(2,1) = 6.0
        DCOEFF(2,2) = -12.0
        DCOEFF(2,3) = 6.0
        DCOEFF(3,1) = -3.0
        DCOEFF(3,2) = 3.0
*
        DDCOEFF(1,1) = 6.0
        DDCOEFF(1,2) = 18.0
        DDCOEFF(1,3) = -18.0
        DDCOEFF(1,4) = 6.0
        DDCOEFF(2,1) = 6.0
        DDCOEFF(2,2) = -12.0
        DDCOEFF(2,3) = 6.0
*
* generate DTMAT and DDTMAT parameter matrices...
*
        DTMAT(1,1) = TMAT(1,2)
        DTMAT(1,2) = TMAT(1,3)
        DTMAT(1,3) = TMAT(1,4)
*
        DDTMAT(1,1) = TMAT(1,3)
        DDTMAT(1,2) = TMAT(1,4)
*
* compute derivatives...
*
       CALL MATPROD(DTMAT,DCOEFF,DTEMP)
        CALL MATPROD(DDTMAT,DDCOEFF,DDTEMP)
        CALL MATPROD(DTEMP,B,TEMP3)
        CALL MATPROD(DDTEMP,B,TEMP4)
*
             DO I = 1,2,1
                DP(ICOUNT,I) = TEMP3(1,I)
                DDP(ICOUNT,I) = TEMP4(1,I)
             ENDDO
*
        T = T + TSTEP
*
      ENDDO
      RETURN
      END
```

```
************************************************************************
*  PROGRAM NAME:  SYMMFOIL                                             *
*                                                                      *
*  PROGRAMMER:    BILL SCARBROUGH                                      *
*                                                                      *
*  CREATION DATE: 15 MAY 1990                                          *
*                                                                      *
************************************************************************
*                                                                      *
*  DESCRIPTION:   THIS FORTRAN MAIN PROGRAM WILL GENERATE A TWO-DIMENSIONAL *
*                 NACA FOUR-DIGIT SYMMETRIC AIRFOIL WITH MAXIMUM THICKNESS  *
*                 SPECIFIED BY THE USER USING CUBIC BEZIER CURVE SEGMENTS.  *
*                 THE PROGRAM WILL AUTOMATICALLY GENERATE DEFINING POLYGON  *
*                 VERTICES FROM THE MAXIMUM THICKNESS PARAMETER AND         *
*                 DETERMINE FIRST AND SECOND DERIVATIVES.                   *
*                                                                      *
************************************************************************
*                                                                      *
*  USER INPUTS:   THE USER IS PROMPTED FOR THE THICKNESS RATIO AND A NAME   *
*                 FOR THE OUTPUT FILES. THE PROGRAM DOES EVERYTHING ELSE.   *
*                 NUMBER OF DATA POINTS GENERATED IS LIMITED TO 400 POINTS  *
*                 ON EACH (UPPER AND LOWER) SURFACE.                        *
*                                                                      *
*  OUTPUTS:       THE USER-SPECIFIED DATAFILES.                        *
*                                                                      *
************************************************************************
*                                                                      *
*  INTERMEDIATE VARIABLES:                                             *
*                                                                       *
*          INTEGERS                                                     *
*                                                                       *
*                 MAXN    - PARAMETER, LIMIT ON ARRAY SIZE, NUMBER OF  *
*                           POINTS GENERATED PER AIRFOIL SURFACE        *
*                 SEGMENT - DENOTES SEGMENT OF AIRFOIL BEING GENERATED -   *
*                            FORWARD OR AFT OF POINT OF MAXIMUM THICKNESS  *
*                 I,J,NN  - LOOP COUNTERS                               *
*                 FILENO  - LOCATIONS OF FILES TO MAINFRAME            *
*                 NPTS    - NUMBER OF DESIRED DATA POINTS PER SEGMENT   *
*                                                                       *
*          REALS                                                        *
*                                                                       *
*                 B       - 4x2 ARRAY OF DEFINING POLYGON VERTICES     *
*                 P       - MAXNx2 ARRAY OF AIRFOIL SEGMENT SURFACE    *
*                           COORDINATES                                 *
*                 DP      - MAXNx2 ARRAY OF FIRST DERIVATIVE VECTOR    *
*                           COMPONENTS                                  *
*                 DDP     - MAXNx2 ARRAY OF SECOND DERIVATIVE VECTOR   *
*                           COMPONENTS                                  *
*                 T       - MAXIMUM THICKNESS RATIO                     *
*                 TAU     - GOLDEN SECTION NUMBER                       *
*                                                                       *
*          CHARACTERS                                                   *
*                                                                       *
*                 FILE1    - FILENAME FOR OUTPUT STORAGE               *
*                 TEMPFILE - STORAGE OF DEFINING POLYGON VERTEX         *
*                            COORDINATES FOR EACH SEGMENT               *
*                                                                       *
*************************************************************************
```

```
      PROGRAM  SYMMFOIL
*
      IMPLICIT NONE
*
      INTEGER MAXN,NPTS,I,J,NN,SEGMENT,FILENO
      PARAMETER(MAXN=500)
      DOUBLE PRECISION DBEZIER3,B(4,2),P(MAXN,2)
      DOUBLE PRECISION T,SURF(MAXN,2)
      CHARACTER*30 FILE1,TEMPFILE
*
*  user inputs...
*
      PRINT *,'ENTER THICKNESS RATIO'
      READ(5,*) T
*
      PRINT *,'ENTER NAME OF FILE FOR AIRFOIL COORDINATES'
      READ(5,'(A)') FILE1
*
*
*  define tau...
*
      TAU = (DSQRT(5) - 1.0)/2.0
*
*  begin algorithm...
*
      DO SEGMENT = 1,2,1
         IF(SEGMENT.EQ.1)THEN
            TEMPFILE = 'TEMP1.DAT'
            FILENO = 9
            B(1,1) = 0.0
            B(1,2) = 0.0
            B(2,1) = 0.0
            B(2,2) = (1.0 - TAU) * T
            B(3,1) = (22.0 * T - 13.0) * .3
            B(3,2) = T/2.0
            B(4,1) = 0.3
            B(4,2) = T/2.0
         ELSE
            TEMPFILE = 'TEMP2.DAT'
            FILENO = 8
            B(1,1) = 0.3
            B(1,2) = T/2.0
            B(2,1) =
            B(2,2) = T/2.0
            B(3,1) =
            B(3,2) = (-1.16925*B(3,1) + 1.17975) * T
            B(4,1) = 1.0
            B(4,2) = .0105 * T
         ENDIF
*
         NPTS = 201
*
         CALL DBEZIER3(NPTS,B,P,DP,DDP)
*
         OPEN (UNIT=FILENO1,FILE=TEMPFILE1,STATUS='NEW',DISP='SAVE')
*
         DO I = 1,NPTS,1
            WRITE(FILENO1,10) (P(I,J),J=1,2)
         ENDDO
*
         CLOSE(FILENO1)
*
  10     FORMAT(3X,D14.6,5X,D14.6)
*
      ENDDO
*
```

```
*      PROGRAM NAME:     GENFOIL
*
*      PROGRAMMER: BILL SCARBROUGH
*
*      CREATION DATE:    NOVEMBER 10, 1990
*
*******************************************************************
*
*      PURPOSE:
*             THIS USER-INTERACTIVE FORTRAN PROGRAM UTILIZES BEZIER CURVES TO
              GENERATE
*             A NACA FOUR-DIGIT AIRFOIL OF THE USERS CHOICE. THE PROGRAM ASSUMES
*             A CHORD OF UNIT LENGTH FOR EASE OF COMPUTATION. THE PROGRAM WILL
*             ALSO ALLOW THE USER TO GENERATE A CONVENTIONALLY DEFINED AIRFOIL
*             FOR PURPOSES OF COMPARISON.
*
*      USER INPUTS:
*
*             THE USER IS PROMPTED FOR THE TYPE OF AIRFOIL, THEN THE NAME OF THE
*             DATA FILE TO WHICH THE GENERATED DATA POINTS ARE TO BE WRITTEN.
*             THE USER IS THEN PROMPTED FOR THE THICKNESS RATIO OF THE SYMMETRIC
*             THICKNESS DISTRIBUTION. IF A SYMMETRIC AIRFOIL IS CHOSEN, A FLAG
*             IS SET TO THE FALSE POSITION, AND SUPERPOSITION OF THICKNESS
*             DISTRIBUTION ON THE CAMBER LINE IS NOT PERFORMED. IF A CAMBERED
*             AIRFOIL IS CHOSEN, THE USER IS THEN PROMPTED TO INPUT VALUES FOR
*             THE MAXIMUM CAMBER AND CHORDWISE POSITION WHERE MAXIMUM CAMBER
*             OCCURS.
*
*      SUBROUTINES REFERENCED:
*
*             NONE
*
*      INPUT VARIABLES:
*
*             T            -     SYMMETRIC THICKNESS DISTRIBUTION
*             TYPE         -     DENOTES EITHER CAMBERED OR SYMMETRIC AIRFOIL
*             COMP         -     DENOTES USERS CHOICE OF WHETHER OR NOT TO
*                                GENERATE CONVENTIONALLY GENERATED AIRFOIL FOR
*                                PURPOSE OF COMPARISON
*             NPOINTS      -     TOTAL NUMBER OF POINTS TO BE GENERATED ON
*                                AIRFOIL
*             FILENAME     -     FILE TO WHICH BEZIER OUTPUT IS TO BE WRITTEN
*             FILE2        -     FILE TO WHICH CONVENTIONALLY GENERATED
*                                COORDINATES IS TO BE WRITTEN
*             M            -     MAXIMUM CAMBER OF AIRFOIL, EXPRESSED AS A
*                                DECIMAL OF  CHORD
*             P            -     CHORDWISE POSITION OF MAXIMUM CAMBER, EXPRESSED
*                                AS A DECIMAL OF CHORD
*
*      INTERMEDIATE VARIABLES:
*
*             MAXN         -     PARAMETER, LIMIT ON ARRAY SIZE
*             FLAG         -     LOGICAL VARIABLE TO DENOTE "TYPE" FROM ABOVE
*             COMPARE      -     LOGICAL VARIABLE TO DENOTE "COMP" FROM ABOVE
*             TAU          -     GOLDEN SECTION NUMBER
*             XINT         -     INTERSECTION OF TRAILING EDGE ANGLE AND THE LINE
*                                Y=T/2
*             ALPHA        -     NUMBER DERIVED FROM GOLDEN SECTION SEARCH ON
*                                [.3,XINT]
*             BETA         -     NUMBER DERIVED FROM GOLDEN SECTION SEARCH ON
*                                [XINT,1.0]
*             POLY1        -     4x2 MATRIX CONTAINING COORDINATES OF LEADING
*                                EDGE BEZIER DEFINING POLYGON
*             POLY2        -     4x2 MATRIX CONTAINING COORDINATES OF TRAILING
*                                EDGE BEZIER DEFINING POLYGON
*             SEGPTS       -     NUMBER OF POINTS GENERATED ON EACH SEGMENT OF
*                                THE CURVE, BETWEEN [0,.3] AND [.3,1.0]
*             SURFPTS      -     NUMBER OF DATA POINTS GENERATED ON EITHER THE
*                                UPPER OR LOWER SURFACE OF THE AIRFOIL (SEGPTSx2)
```

```
*           COORD1        -      SEGPTSx2 MATRIX, OUTPUT OF SUBROUTINE DBEZIER3,
*                                COORDINATES OF SYMMETRIC THICKNESS DISTRIBUTION
*                                FROM [0,.3]
*           COORD2        -      SEGPTSx2 MATRIX, OUTPUT OF SUBROUTINE DBEZIER3,
*                                COORDINATES OF SYMMETRIC THICKNESS DISTRIBUTION
*                                FROM [.3,1.0]
*           YC            -      ORDINATE OF CAMBER LINE
*           CONST1        -      CONSTANT TERM USED FOR CAMBER LINE FROM [0,P]
*           CONST2        -      CONSTANT TERM USED FOR CAMBER LINE FROM [P,1.0]
*           YCP           -      TANGENT OF CAMBER LINE
*           MULT(n)       -      CONSTANTS USED IN GENERATION OF CAMBERED
*                                COORDINATES
*           XU            -      UPPER SURFACE COORDINATE OF CHORDWISE POSITION
*           YU            -      UPPER SURFACE ORDINATE
*           XL            -      LOWER SURFACE COORDINATE OF CHORDWISE POSITION
*           YL            -      LOWER SURFACE ORDINATE
*
      PROGRAM GENFOIL
*
      IMPLICIT NONE
*
      INTEGER MAXN
      PARAMETER(MAXN=2000)
      INTEGER I,TYPE,NPOINTS,SEGPTS,SURFPTS,COMP
      INTEGER     N,ICOUNT,I,II,J,JJ,K,KK,L,LL
      LOGICAL*1 FLAG,COMPARE
      CHARACTER*30 FILENAME,FILE2
      DOUBLE PRECISION  T,M,P,TAU,XINT,ALPHA,BETA,POLY1(4,2),POLY2(4,2)
      DOUBLE PRECISION  COORD1(MAXN,2),COORD2(MAXN,2),XU(MAXN),YU(MAXN),
      DOUBLE PRECISION  XL(MAXN),YL(MAXN),CONST1,CONST2,MULT(6)
      DOUBLE PRECISION  NU,NUSTEP,TEMP1(4,4),POLY(4,2),NUMAT(1,4)
      DOUBLE PRECISION  OUT(MAXN,2),TEMP2(1,4),TEMP3(1,2),TEMP4(1,2)
*
      PRINT *,'WELCOME TO THE INTERACTIVE AIRFOIL GENERATION PROGRAM'
      PRINT *,' '
      PRINT *,'PLEASE INDICATE CHOICE OF AIRFOIL TYPE (1=SYMMETRIC,2=CAMBERED)
      READ(5,*) TYPE
*
*     must now check to see that user inputs are within expected values
*
      IF(TYPE.NE.1.OR.TYPE.NE.2) THEN
            PRINT *,'ERROR:INCORRECT INPUT. PROGRAM TERMINATED.'
            STOP
      ENDIF
*

      PRINT *,'PLEASE ENTER NAME FOR OUTPUT FILE'
      READ(5,'(A)') FILENAME
*
      OPEN (UNIT=12,FILE='FILENAME',STATUS='NEW')
*
      PRINT *,'WOULD YOU LIKE TO COMPARE BEZIER vs. CONVENTIONAL AIRFOILS?'
      PRINT *,'(1 = NO, 2 = YES)
      READ(5,*) COMP
*
      IF(COMP.EQ.1)THEN
         COMPARE = .FALSE.
      ELSEIF(COMP.EQ.2)THEN
         COMPARE = .TRUE.
      ELSE
         PRINT *,'ERROR: INCORRECT INPUT. PROGRAM TERMINATED.'
         STOP
      ENDIF
*
      IF(COMPARE)THEN
       PRINT *,'ENTER NAME OF OUTPUT FILE FOR NACA AIRFOIL.'
        READ(5,'(A)') FILE2
        OPEN(UNIT=6,FILE=FILE2,STATUS='NEW')
      ENDIF
```

```
*
*
      IF(TYPE.EQ.1) THEN
            FLAG = .FALSE.
      ELSE
            FLAG = .TRUE.
      ENDIF
*
      IF(FLAG) THEN
            PRINT *,'ENTER AMOUNT OF MAXIMUM CAMBER IN DECIMAL OF CHORD'
            READ(5,*) M
            PRINT *,'ENTER CHORDWISE POSITION OF MAXIMUM THICKNESS IN DECIMAL
FORM'
            READ(5,*) P
*
            CONST1 = M/(P*P)
            CONST2 = M/((1.0 - P)*(1.0 - P)
*
      ENDIF
*
      PRINT *,'ENTER MAXIMUM THICKNESS OF SYMMETRIC DISTRIBUTION'
      READ(5,*) T
*
      PRINT *,'ENTER TOTAL NUMBER OF POINTS DESIRED ON ENTIRE ARIFOIL (2000
MAX)'
      READ(5,*) NPOINTS
*
*     set initial values and counters
*
      TAU = (SQRT(5.0) - 1.0)/2.0 (= 0.618033988852495 - approximately)
      XINT = .58135557
      ALPHA = .473887
      BETA = 1.0 + TAU*(XINT - 1.0)
      SEGPTS = NPOINTS/4
      SURFPTS = SEGPTS + SEGPTS
      II= 1
      JJ = 4
      KK = 4
      LL = 2
      ICOUNT = 1
      NU = 0.0
      NUSTEP = 1.0/DFLOAT(N-1)
*
*
*
*     setup defining bezier polygons - leading edge surface
*
      POLY1(1,1) = 0.0
      POLY1(1,2) = 0.0
      POLY1(2,1) = 0.0
      POLY1(2,2) = (1.0 - TAU)*T
      POLY1(3,1) = (22.0*TAU - 13.0)*.3
      POLY1(3,2) = T/2.0
      POLY1(4,1) = .3
      POLY1(4,2) = POLY1(3,2)
*
*     setup defining bezier polygons - trailing edge surface
*
      POLY2(1,1) = .3
      POLY2(1,2) = POLY1(3,2)
      POLY2(2,1) = ALPHA
      POLY2(2,2) = POLY1(3,2)
      POLY2(3,1) = BETA
      POLY2(3,2) = T*(1.17975 - 1.16925*BETA)
      POLY2(4,1) = 1.0
      POLY2(4,2) = 0.0105*T
*
      TEMP1(1,1) = -1.0
      TEMP1(1,2) = 3.0
```

```
      TEMP1(1,3) = -3.0
      TEMP1(1,4) = 1.0
      TEMP1(2,1) = 3.0
      TEMP1(2,2) = -6.0
      TEMP1(2,3) = 3.0
      TEMP1(2,4) = 0.0
      TEMP1(3,1) = -3.0
      TEMP1(3,2) = 3.0
      TEMP1(3,3) = 0.0
      TEMP1(3,4) = 0.0
      TEMP1(4,1) = 1.0
      TEMP1(4,2) = 0.0
      TEMP1(4,3) = 0.0
      TEMP1(4,4) = 0.0
*
      DOWHILE(NU.LE.1.0)
*
            NUMAT(1,4) = 1.0
            NUMAT(1,3) = NU
            NUMAT(1,2) = NU * NU
            NUMAT(1,1) = NUMAT(1,2) * NU
*
*     note: this step computes an intermediate matrix of the parameter values
*           and coefficients of those values as defined by the third order
*            Bezier curve.
*
            DO I = 1,JJ,1
                 TEMP2(1,I) = 0.0
              DO J = 1,KK,1
                  TEMP2(1,I) = TEMP2(1,I) + NUMAT(1,J)*TEMP1(J,I)
              ENDDO
            ENDDO
*
*
*     note: this step computes actual coordinates of the leading edge using
the
*            intermediate result obtained above

            DO I = 1,JJ,1
                 TEMP3(1,I) = 0.0
              DO J= 1,LL,1
                  TEMP3(1,I) = TEMP3(1,I) + TEMP2(1,J)*POLY1(J,I)
              ENDDO
            ENDDO
*
*     note: this step uses the same intermediate result as employed above to
*            compute the trailing edge coordinate
*
            DO I = 1,LL,1
                  TEMP4(1,I) = 0.0
              DO J = 1,JJ,1
                  TEMP4(1,I) = TEMP4(1,I) + TEMP2(1,I)*POLY2(J,I)
              ENDDO
            ENDDO
*
            COORD1(ICOUNT,1) = TEMP3(1,1)
            COORD1(ICOUNT,2) = TEMP3(1,2)
            COORD2(ICOUNT,1) = TEMP4(1,1)
            COORD2(ICOUNT,2) = TEMP4(1,2)
*
            ICOUNT = ICOUNT + 1
            NU = NU + NUSTEP
*
      ENDDO
*
*
*     if cambered, now is the time to generate mean line and its components
*
      DO I=1,SEGPTS,1
```

```
*
           IF(FLAG) THEN
*
             IF(COORD1(I,1).LE.P)THEN
                 YC = CONST1*COORD1(I,1)*(2.0*P - COORD1(I,1))
                 YCP = CONST1 * 2.0 * (P - COORD1(I,1))
             ELSE
                 YC = CONST2*(1.0 - 2.0*P + COORD1(I,1)*(2.0*P - COORD1(I,1))
                 YCP = CONST2 *2.0*(P-COORD1(I,1))
             ENDIF
*
                 THETA = DATAN(YCP)
                 MULT(1) = DCOS(THETA)
                 MULT(2) = MULT1*YCP
                 MULT(3) = COORD1(I,2)*MULT(1)
                 MULT(4) = COORD1(I,2)*MULT(2)
                 XU(I) = COORD1(I,1) - MULT(4)
                 YU(I) = YC + MULT(3)
                 XL(I) = COORD1(I,1) + MULT(4)
                 YL(I) = YC - MULT(3)
*
             IF(COMPARE)THEN
                 MULT(5) = DNACA(T,COORD1(I,1))*MULT1
                 MULT(6) = DNACA(T,MULT1)*YCP
                 NACAXU(I) = COORD1(I,1) - MULT(2)
                 NACAYU(I) = YC + MULT(1)
                 NACAXL(I) = COORD1(I,1) + MULT(2)
                 NACAYL(I) = YC - MULT(1)
             ENDIF
*
           ELSE
*
                 XU(I) = COORD1(I,1)
                 YU(I) = COORD1(I,2)
                 XL(I) = XU(I)
                 YL(I) = - YU(I)
*
             IF(COMPARE)THEN
                 NACAXU(I) = COORD1(I,1)
                 NACAYU(I) = DNACA(T,COORD1(I,1))
                 NACAXL(I) = COORD1(I,1)
                 NACAYL(I) = -NACAYU(I)
             ENDIF
*
           ENDIF
*
      ENDDO
*
      I = 2
      J = SEGPTS + 1
*
      DOWHILE(J.LE.SURFPTS)
*
           IF(FLAG) THEN
*
             IF(COORD2(I,1).LE.P)THEN
                 YC = CONST1*(1.0 - 2.0*P + COORD2(I,1)*(2.0*P -
COORD2(I,1)))
                 YCP = CONST1 * 2.0 * (P - COORD2(I,1))
             ELSE
                 YC = CONST2*(1.0 - 2.0*P + COORD2(I,1)*(2.0*P -
COORD2(I,1)))
                 YCP = CONST2 * 2.0 * (P - COORD2(I,1))
             ENDIF
*
                 THETA = DATAN(YCP)
                 MULT1 = DCOS(THETA)
                 MULT2 = MULT1*YCP
                 MULT5 = COORD2(I,2)*MULT1
```

```
                 MULT6 = COORD2(I,2)*MULT2
                 XU(J) = COORD2(I,1) - MULT6
                 YU(J) = YC + MULT5
                 XL(J) = COORD1(I,1) + MULT6
                 YL(J) = YC - MULT5
*
             IF(COMPARE)THEN
                 NACAMULT3 = DNACA(T,COORD1(I,1))*MULT1
                 NACAMULT4 = NACAMULT1*YCP
                 NACAXU(I) = COORD1(I,1) - NACAMULT4
                 NACAYU(I) = YC + NACAMULT3
                 NACAXL(I) = COORD1(I,1) + NACAMULT4
                 NACAYL(I) = YC - NACAMULT3
             ENDIF
*
           ELSE
*
                 XU(J) = COORD2(I,1)
                 YU(J) = COORD2(I,2)
                 XL(J) = XU(J)
                 YL(J) = - YU(J)
*
             IF(COMPARE)THEN
                 NACAXU(J) = COORD2(I,1)
                 NACAYU(J) = DNACA(T,COORD1(I,1))
                 NACAXL(J) = COORD2(I,1)
                 NACAYL(J) = -NACAYU(I)
             ENDIF
           ENDIF
         ENDIF
*
      ENDDO
*
*     output data points
*
      DO I = 1,SURFPTS-1,1
*
            WRITE(12,101) XU(I),YU(I)
*
      ENDDO
*
      DO I = SURFPTS-2,1,-1
*
            WRITE(12,101) XL(I),YL(I)
*
      ENDDO
*
  101 FORMAT(5X,D14.8,5X,D14.8)
*
      STOP
      END
```

Appendix G. Pertinent Data Files

NACA Designation	x	y
1105	0.27994D+00	0.34569D-01
1106	0.27993D+00	0.39563D-01
1107	0.28492D+00	0.44558D-01
1108	0.28491D+00	0.49555D-01
1109	0.28490D+00	0.54552D-01
1110	0.28988D+00	0.59550D-01
1111	0.28987D+00	0.64550D-01
1112	0.28986D+00	0.69549D-01
1113	0.28985D+00	0.74549D-01
1114	0.28984D+00	0.79548D-01
1115	0.28982D+00	0.84548D-01
1116	0.28981D+00	0.89548D-01
1117	0.29480D+00	0.94547D-01
1118	0.29478D+00	0.99548D-01
1119	0.29477D+00	0.10455D+00
1120	0.29476D+00	0.10955D+00
1121	0.29475D+00	0.11455D+00
1122	0.29474D+00	0.11955D+00
1123	0.29472D+00	0.12455D+00
1124	0.29471D+00	0.12955D+00
1205	0.28497D+00	0.34873D-01
1206	0.28996D+00	0.39871D-01
1207	0.28995D+00	0.44871D-01
1208	0.28994D+00	0.49870D-01
1209	0.28994D+00	0.54870D-01
1210	0.28993D+00	0.59869D-01
1211	0.29492D+00	0.64870D-01
1212	0.29491D+00	0.69871D-01
1213	0.29490D+00	0.74872D-01
1214	0.29490D+00	0.79873D-01
1215	0.29489D+00	0.84874D-01
1216	0.29488D+00	0.89875D-01
1217	0.29487D+00	0.94876D-01
1218	0.29487D+00	0.99877D-01
1219	0.29486D+00	0.10488D+00
1220	0.29485D+00	0.10988D+00
1221	0.29484D+00	0.11488D+00
1222	0.29484D+00	0.11988D+00
1223	0.29483D+00	0.12488D+00
1224	0.29482D+00	0.12988D+00
1305	0.30000D+00	0.35007D-01
1306	0.30000D+00	0.40009D-01
1307	0.30000D+00	0.45010D-01
1308	0.30000D+00	0.50012D-01
1309	0.30000D+00	0.55013D-01
1310	0.30000D+00	0.60014D-01
1311	0.30000D+00	0.65016D-01
1312	0.30000D+00	0.70017D-01
1313	0.30000D+00	0.75019D-01
1314	0.30000D+00	0.80020D-01
1315	0.30000D+00	0.85022D-01
1316	0.30000D+00	0.90023D-01
1317	0.30000D+00	0.95024D-01
1318	0.30000D+00	0.10003D+00
1319	0.30000D+00	0.10503D+00
1320	0.30000D+00	0.11003D+00
1321	0.30000D+00	0.11503D+00
1322	0.30000D+00	0.12003D+00
1323	0.30000D+00	0.12503D+00
1324	0.30000D+00	0.13003D+00

NACA Designation	x	y
1405	0.33981D+00	0.34638D-01
1406	0.33476D+00	0.39610D-01
1407	0.33472D+00	0.44590D-01
1408	0.32965D+00	0.49572D-01
1409	0.32961D+00	0.54557D-01
1410	0.32453D+00	0.59545D-01
1411	0.32449D+00	0.64535D-01
1412	0.31940D+00	0.69525D-01
1413	0.31935D+00	0.74519D-01
1414	0.31930D+00	0.79512D-01
1415	0.31925D+00	0.84506D-01
1416	0.31920D+00	0.89500D-01
1417	0.31410D+00	0.94496D-01
1418	0.31404D+00	0.99493D-01
1419	0.31399D+00	0.10449D+00
1420	0.31394D+00	0.10949D+00
1421	0.31389D+00	0.11448D+00
1422	0.31383D+00	0.11948D+00
1423	0.31378D+00	0.12448D+00
1424	0.30865D+00	0.12947D+00
1505	0.36473D+00	0.33911D-01
1506	0.35466D+00	0.38847D-01
1507	0.34958D+00	0.43798D-01
1508	0.34451D+00	0.48759D-01
1509	0.33943D+00	0.53727D-01
1510	0.33434D+00	0.58699D-01
1511	0.33428D+00	0.63678D-01
1512	0.32919D+00	0.68658D-01
1513	0.32912D+00	0.73643D-01
1514	0.32905D+00	0.78628D-01
1515	0.32395D+00	0.83616D-01
1516	0.32388D+00	0.88606D-01
1517	0.32381D+00	0.93595D-01
1518	0.31871D+00	0.98587D-01
1519	0.31863D+00	0.10358D+00
1520	0.31856D+00	0.10857D+00
1521	0.31849D+00	0.11357D+00
1522	0.31842D+00	0.11856D+00
1523	0.31330D+00	0.12355D+00
1524	0.31323D+00	0.12855D+00
1605	0.37469D+00	0.33118D-01
1606	0.36461D+00	0.38033D-01
1607	0.35453D+00	0.42967D-01
1608	0.34945D+00	0.47918D-01
1609	0.34437D+00	0.52877D-01
1610	0.33928D+00	0.57844D-01
1611	0.33921D+00	0.62816D-01
1612	0.33412D+00	0.67794D-01
1613	0.32903D+00	0.72773D-01
1614	0.32895D+00	0.77757D-01
1615	0.32888D+00	0.82742D-01
1616	0.32378D+00	0.87729D-01
1617	0.32370D+00	0.92718D-01
1618	0.32363D+00	0.97707D-01
1619	0.32355D+00	0.10270D+00
1620	0.31845D+00	0.10769D+00
1621	0.31837D+00	0.11268D+00
1622	0.31829D+00	0.11768D+00
1623	0.31821D+00	0.12267D+00
1624	0.31814D+00	0.12766D+00

NACA Designation	x	y
1705	0.37968D+00	0.32372D-01
1706	0.36960D+00	0.37277D-01
1707	0.35952D+00	0.42208D-01
1708	0.34943D+00	0.47153D-01
1709	0.34435D+00	0.52111D-01
1710	0.33927D+00	0.57077D-01
1711	0.33920D+00	0.62049D-01
1712	0.33411D+00	0.67026D-01
1713	0.33404D+00	0.72004D-01
1714	0.32895D+00	0.76988D-01
1715	0.32887D+00	0.81973D-01
1716	0.32378D+00	0.86959D-01
1717	0.32370D+00	0.91949D-01
1718	0.32363D+00	0.96938D-01
1719	0.31853D+00	0.10193D+00
1720	0.31845D+00	0.10692D+00
1721	0.31837D+00	0.11191D+00
1722	0.31830D+00	0.11691D+00
1723	0.31822D+00	0.12190D+00
1724	0.31814D+00	0.12689D+00
1805	0.37968D+00	0.31705D-01
1806	0.36960D+00	0.36611D-01
1807	0.35952D+00	0.41542D-01
1808	0.34944D+00	0.46489D-01
1809	0.34436D+00	0.51449D-01
1810	0.33929D+00	0.56415D-01
1811	0.33921D+00	0.61388D-01
1812	0.33413D+00	0.66366D-01
1813	0.32905D+00	0.71346D-01
1814	0.32898D+00	0.76331D-01
1815	0.32890D+00	0.81315D-01
1816	0.32382D+00	0.86305D-01
1817	0.32374D+00	0.91294D-01
1818	0.32367D+00	0.96283D-01
1819	0.31858D+00	0.10128D+00
1820	0.31850D+00	0.10627D+00
1821	0.31843D+00	0.11126D+00
1822	0.31835D+00	0.11626D+00
1823	0.31828D+00	0.12125D+00
1824	0.31318D+00	0.12624D+00
1905	0.37969D+00	0.31123D-01
1906	0.36461D+00	0.36033D-01
1907	0.35453D+00	0.40968D-01
1908	0.34946D+00	0.45919D-01
1909	0.34439D+00	0.50881D-01
1910	0.33931D+00	0.55851D-01
1911	0.33424D+00	0.60825D-01
1912	0.33417D+00	0.65804D-01
1913	0.32909D+00	0.70787D-01
1914	0.32902D+00	0.75772D-01
1915	0.32394D+00	0.80759D-01
1916	0.32387D+00	0.85749D-01
1917	0.32380D+00	0.90738D-01
1918	0.31871D+00	0.95730D-01
1919	0.31864D+00	0.10072D+00
1920	0.31857D+00	0.10572D+00
1921	0.31850D+00	0.11071D+00
1922	0.31843D+00	0.11570D+00
1923	0.31334D+00	0.12070D+00
1924	0.31327D+00	0.12570D+00

NACA Designation	x	y
2105	0.25990D+00	0.44216D-01
2106	0.26488D+00	0.49192D-01
2107	0.26985D+00	0.54174D-01
2108	0.27483D+00	0.59159D-01
2109	0.27481D+00	0.64148D-01
2110	0.27978D+00	0.69138D-01
2111	0.27976D+00	0.74131D-01
2112	0.27973D+00	0.79125D-01
2113	0.27971D+00	0.84119D-01
2114	0.28468D+00	0.89115D-01
2115	0.28466D+00	0.94112D-01
2116	0.28463D+00	0.99109D-01
2117	0.28461D+00	0.10411D+00
2118	0.28459D+00	0.10910D+00
2119	0.28457D+00	0.11410D+00
2120	0.28953D+00	0.11910D+00
2121	0.28951D+00	0.12410D+00
2122	0.28948D+00	0.12910D+00
2123	0.28946D+00	0.13410D+00
2124	0.28944D+00	0.13910D+00
2205	0.27494D+00	0.44771D-01
2206	0.27993D+00	0.49763D-01
2207	0.27991D+00	0.54757D-01
2208	0.28489D+00	0.59752D-01
2209	0.28488D+00	0.64749D-01
2210	0.28487D+00	0.69746D-01
2211	0.28485D+00	0.74743D-01
2212	0.28983D+00	0.79742D-01
2213	0.28982D+00	0.84741D-01
2214	0.28980D+00	0.89741D-01
2215	0.28979D+00	0.94740D-01
2216	0.28978D+00	0.99740D-01
2217	0.28976D+00	0.10474D+00
2218	0.28975D+00	0.10974D+00
2219	0.28973D+00	0.11474D+00
2220	0.28972D+00	0.11974D+00
2221	0.29469D+00	0.12474D+00
2222	0.29467D+00	0.12974D+00
2223	0.29466D+00	0.13474D+00
2224	0.29464D+00	0.13974D+00
2305	0.30000D+00	0.45007D-01
2306	0.30000D+00	0.50009D-01
2307	0.30000D+00	0.55010D-01
2308	0.30000D+00	0.60012D-01
2309	0.30000D+00	0.65013D-01
2310	0.30000D+00	0.70014D-01
2311	0.30000D+00	0.75016D-01
2312	0.30000D+00	0.80017D-01
2313	0.30000D+00	0.85019D-01
2314	0.30000D+00	0.90020D-01
2315	0.30000D+00	0.95022D-01
2316	0.30000D+00	0.10002D+00
2317	0.30000D+00	0.10502D+00
2318	0.30000D+00	0.11003D+00
2319	0.30000D+00	0.11503D+00
2320	0.30000D+00	0.12003D+00
2321	0.30000D+00	0.12503D+00
2322	0.30000D+00	0.13003D+00
2323	0.30000D+00	0.13503D+00
2324	0.30000D+00	0.14003D+00

NACA Designation	**x**	**y**
2405	0.35975D+00	0.44492D-01
2406	0.35467D+00	0.49435D-01
2407	0.34957D+00	0.54385D-01
2408	0.34950D+00	0.59342D-01
2409	0.34439D+00	0.64306D-01
2410	0.33925D+00	0.69271D-01
2411	0.33918D+00	0.74243D-01
2412	0.33911D+00	0.79216D-01
2413	0.33395D+00	0.84194D-01
2414	0.33387D+00	0.89172D-01
2415	0.32869D+00	0.94151D-01
2416	0.32860D+00	0.99135D-01
2417	0.32852D+00	0.10412D+00
2418	0.32843D+00	0.10910D+00
2419	0.32322D+00	0.11409D+00
2420	0.32313D+00	0.11908D+00
2421	0.32304D+00	0.12407D+00
2422	0.32294D+00	0.12906D+00
2423	0.32285D+00	0.13404D+00
2424	0.32275D+00	0.13903D+00
2505	0.39961D+00	0.43376D-01
2506	0.38949D+00	0.48221D-01
2507	0.38437D+00	0.53093D-01
2508	0.37422D+00	0.57984D-01
2509	0.36908D+00	0.62892D-01
2510	0.36394D+00	0.67813D-01
2511	0.35878D+00	0.72743D-01
2512	0.35362D+00	0.77681D-01
2513	0.35351D+00	0.82628D-01
2514	0.34833D+00	0.87581D-01
2515	0.34822D+00	0.92536D-01
2516	0.34303D+00	0.97499D-01
2517	0.34291D+00	0.10246D+00
2518	0.33771D+00	0.10743D+00
2519	0.33758D+00	0.11240D+00
2520	0.33745D+00	0.11737D+00
2521	0.33224D+00	0.12235D+00
2522	0.33211D+00	0.12733D+00
2523	0.33198D+00	0.13230D+00
2524	0.32675D+00	0.13728D+00
2605	0.42955D+00	0.42049D-01
2606	0.41441D+00	0.46811D-01
2607	0.39925D+00	0.51620D-01
2608	0.38909D+00	0.56464D-01
2609	0.38395D+00	0.61335D-01
2610	0.37377D+00	0.66225D-01
2611	0.36862D+00	0.71131D-01
2612	0.36346D+00	0.76050D-01
2613	0.35829D+00	0.80979D-01
2614	0.35816D+00	0.85916D-01
2615	0.35298D+00	0.90862D-01
2616	0.34780D+00	0.95812D-01
2617	0.34766D+00	0.10077D+00
2618	0.34247D+00	0.10573D+00
2619	0.34233D+00	0.11069D+00
2620	0.33713D+00	0.11566D+00
2621	0.33698D+00	0.12063D+00
2622	0.33684D+00	0.12560D+00
2623	0.33163D+00	0.13057D+00
2624	0.33148D+00	0.13555D+00

NACA Designation	x	y
2705	0.44451D+00	0.40699D-01
2706	0.42436D+00	0.45409D-01
2707	0.40920D+00	0.50183D-01
2708	0.39905D+00	0.55002D-01
2709	0.38889D+00	0.59854D-01
2710	0.37872D+00	0.64731D-01
2711	0.37357D+00	0.69627D-01
2712	0.36841D+00	0.74539D-01
2713	0.36325D+00	0.79462D-01
2714	0.35808D+00	0.84396D-01
2715	0.35291D+00	0.89336D-01
2716	0.35277D+00	0.94283D-01
2717	0.34759D+00	0.99238D-01
2718	0.34241D+00	0.10419D+00
2719	0.34227D+00	0.10916D+00
2720	0.33708D+00	0.11412D+00
2721	0.33693D+00	0.11909D+00
2722	0.33679D+00	0.12406D+00
2723	0.33159D+00	0.12903D+00
2724	0.33144D+00	0.13401D+00
2805	0.45450D+00	0.39420D-01
2806	0.42934D+00	0.44104D-01
2807	0.41419D+00	0.48864D-01
2808	0.39903D+00	0.53675D-01
2809	0.38888D+00	0.58523D-01
2810	0.37872D+00	0.63398D-01
2811	0.37357D+00	0.68294D-01
2812	0.36841D+00	0.73206D-01
2813	0.36326D+00	0.78130D-01
2814	0.35810D+00	0.83064D-01
2815	0.35294D+00	0.88007D-01
2816	0.34777D+00	0.92955D-01
2817	0.34763D+00	0.97911D-01
2818	0.34246D+00	0.10287D+00
2819	0.34232D+00	0.10783D+00
2820	0.33714D+00	0.11280D+00
2821	0.33700D+00	0.11777D+00
2822	0.33686D+00	0.12274D+00
2823	0.33167D+00	0.12772D+00
2824	0.33153D+00	0.13269D+00
2905	0.45449D+00	0.38250D-01
2906	0.42934D+00	0.42928D-01
2907	0.41420D+00	0.47688D-01
2908	0.39905D+00	0.52502D-01
2909	0.38890D+00	0.57354D-01
2910	0.37874D+00	0.62234D-01
2911	0.37360D+00	0.67134D-01
2912	0.36344D+00	0.72051D-01
2913	0.35829D+00	0.76979D-01
2914	0.35314D+00	0.81917D-01
2915	0.35300D+00	0.86863D-01
2916	0.34785D+00	0.91817D-01
2917	0.34269D+00	0.96773D-01
2918	0.34255D+00	0.10174D+00
2919	0.33739D+00	0.10670D+00
2920	0.33725D+00	0.11167D+00
2921	0.33711D+00	0.11664D+00
2922	0.33194D+00	0.12162D+00
2923	0.33181D+00	0.12660D+00
2924	0.33167D+00	0.13157D+00

NACA Designation	x	y
3105	0.24986D+00	0.53921D-01
3106	0.25483D+00	0.58875D-01
3107	0.25979D+00	0.63839D-01
3108	0.26476D+00	0.68810D-01
3109	0.26473D+00	0.73787D-01
3110	0.26969D+00	0.78768D-01
3111	0.26965D+00	0.83752D-01
3112	0.27461D+00	0.88737D-01
3113	0.27458D+00	0.93727D-01
3114	0.27455D+00	0.98716D-01
3115	0.27950D+00	0.10371D+00
3116	0.27947D+00	0.10870D+00
3117	0.27943D+00	0.11369D+00
3118	0.27940D+00	0.11869D+00
3119	0.27937D+00	0.12368D+00
3120	0.28432D+00	0.12867D+00
3121	0.28428D+00	0.13367D+00
3122	0.28425D+00	0.13867D+00
3123	0.28421D+00	0.14367D+00
3124	0.28418D+00	0.14866D+00
3205	0.26992D+00	0.54690D-01
3206	0.26990D+00	0.59674D-01
3207	0.27488D+00	0.64662D-01
3208	0.27486D+00	0.69651D-01
3209	0.27983D+00	0.74644D-01
3210	0.27981D+00	0.79638D-01
3211	0.27979D+00	0.84632D-01
3212	0.28476D+00	0.89627D-01
3213	0.28474D+00	0.94625D-01
3214	0.28472D+00	0.99622D-01
3215	0.28470D+00	0.10462D+00
3216	0.28468D+00	0.10962D+00
3217	0.28466D+00	0.11461D+00
3218	0.28962D+00	0.11961D+00
3219	0.28960D+00	0.12461D+00
3220	0.28958D+00	0.12961D+00
3221	0.28956D+00	0.13461D+00
3222	0.28954D+00	0.13961D+00
3223	0.28951D+00	0.14461D+00
3224	0.28949D+00	0.14961D+00
3305	0.30000D+00	0.55007D-01
3306	0.30000D+00	0.60009D-01
3307	0.30000D+00	0.65010D-01
3308	0.30000D+00	0.70012D-01
3309	0.30000D+00	0.75013D-01
3310	0.30000D+00	0.80014D-01
3311	0.30000D+00	0.85016D-01
3312	0.30000D+00	0.90017D-01
3313	0.30000D+00	0.95019D-01
3314	0.30000D+00	0.10002D+00
3315	0.30000D+00	0.10502D+00
3316	0.30000D+00	0.11002D+00
3317	0.30000D+00	0.11502D+00
3318	0.30000D+00	0.12003D+00
3319	0.30000D+00	0.12503D+00
3320	0.30000D+00	0.13003D+00
3321	0.30000D+00	0.13503D+00
3322	0.30000D+00	0.14003D+00
3323	0.30000D+00	0.14503D+00
3324	0.30000D+00	0.15003D+00

NACA Designation	x	y
3405	0.36972D+00	0.54415D-01
3406	0.36461D+00	0.59337D-01
3407	0.35948D+00	0.64266D-01
3408	0.35941D+00	0.69204D-01
3409	0.35425D+00	0.74148D-01
3410	0.35417D+00	0.79096D-01
3411	0.34898D+00	0.84051D-01
3412	0.34888D+00	0.89007D-01
3413	0.34367D+00	0.93968D-01
3414	0.34357D+00	0.98933D-01
3415	0.34346D+00	0.10390D+00
3416	0.33821D+00	0.10887D+00
3417	0.33810D+00	0.11384D+00
3418	0.33799D+00	0.11881D+00
3419	0.33269D+00	0.12379D+00
3420	0.33257D+00	0.12876D+00
3421	0.33245D+00	0.13374D+00
3422	0.33233D+00	0.13872D+00
3423	0.32699D+00	0.14370D+00
3424	0.32686D+00	0.14868D+00
3505	0.42457D+00	0.53074D-01
3506	0.41441D+00	0.57846D-01
3507	0.40423D+00	0.62648D-01
3508	0.39907D+00	0.67476D-01
3509	0.38884D+00	0.72323D-01
3510	0.38365D+00	0.77189D-01
3511	0.37845D+00	0.82069D-01
3512	0.37323D+00	0.86961D-01
3513	0.37309D+00	0.91864D-01
3514	0.36785D+00	0.96778D-01
3515	0.36261D+00	0.10170D+00
3516	0.36245D+00	0.10662D+00
3517	0.35718D+00	0.11156D+00
3518	0.35701D+00	0.11649D+00
3519	0.35173D+00	0.12144D+00
3520	0.35156D+00	0.12638D+00
3521	0.34625D+00	0.13133D+00
3522	0.34608D+00	0.13629D+00
3523	0.34590D+00	0.14124D+00
3524	0.34057D+00	0.14620D+00
3605	0.46448D+00	0.51396D-01
3606	0.44930D+00	0.56020D-01
3607	0.43409D+00	0.60704D-01
3608	0.42389D+00	0.65436D-01
3609	0.41367D+00	0.70206D-01
3610	0.40343D+00	0.75006D-01
3611	0.39823D+00	0.79831D-01
3612	0.39301D+00	0.84676D-01
3613	0.38273D+00	0.89541D-01
3614	0.37749D+00	0.94419D-01
3615	0.37224D+00	0.99308D-01
3616	0.37206D+00	0.10421D+00
3617	0.36680D+00	0.10912D+00
3618	0.36153D+00	0.11404D+00
3619	0.36134D+00	0.11896D+00
3620	0.35605D+00	0.12389D+00
3621	0.35585D+00	0.12883D+00
3622	0.35056D+00	0.13377D+00
3623	0.35036D+00	0.13871D+00
3624	0.34505D+00	0.14366D+00

NACA Designation	x	y
3705	0.48943D+00	0.49609D-01
3706	0.46923D+00	0.54116D-01
3707	0.45403D+00	0.58713D-01
3708	0.43881D+00	0.63380D-01
3709	0.42356D+00	0.68100D-01
3710	0.41333D+00	0.72863D-01
3711	0.40309D+00	0.77657D-01
3712	0.39787D+00	0.82481D-01
3713	0.39265D+00	0.87324D-01
3714	0.38237D+00	0.92187D-01
3715	0.37713D+00	0.97065D-01
3716	0.37188D+00	0.10195D+00
3717	0.37168D+00	0.10686D+00
3718	0.36643D+00	0.11177D+00
3719	0.36116D+00	0.11669D+00
3720	0.36096D+00	0.12161D+00
3721	0.35569D+00	0.12654D+00
3722	0.35548D+00	0.13148D+00
3723	0.35020D+00	0.13642D+00
3724	0.34999D+00	0.14137D+00
3805	0.50941D+00	0.47841D-01
3806	0.48421D+00	0.52268D-01
3807	0.46399D+00	0.56813D-01
3808	0.44376D+00	0.61446D-01
3809	0.42852D+00	0.66142D-01
3810	0.41830D+00	0.70889D-01
3811	0.40807D+00	0.75674D-01
3812	0.39783D+00	0.80489D-01
3813	0.39261D+00	0.85329D-01
3814	0.38738D+00	0.90188D-01
3815	0.37711D+00	0.95065D-01
3816	0.37188D+00	0.99955D-01
3817	0.37168D+00	0.10486D+00
3818	0.36643D+00	0.10977D+00
3819	0.36118D+00	0.11469D+00
3820	0.35593D+00	0.11961D+00
3821	0.35573D+00	0.12455D+00
3822	0.35046D+00	0.12948D+00
3823	0.35026D+00	0.13443D+00
3824	0.34499D+00	0.13937D+00
3905	0.51939D+00	0.46158D-01
3906	0.48919D+00	0.50542D-01
3907	0.46397D+00	0.55064D-01
3908	0.44374D+00	0.59685D-01
3909	0.42852D+00	0.64378D-01
3910	0.41831D+00	0.69124D-01
3911	0.40808D+00	0.73912D-01
3912	0.39785D+00	0.78731D-01
3913	0.38761D+00	0.83574D-01
3914	0.38240D+00	0.88440D-01
3915	0.37718D+00	0.93321D-01
3916	0.37195D+00	0.98216D-01
3917	0.36672D+00	0.10312D+00
3918	0.36149D+00	0.10804D+00
3919	0.36129D+00	0.11296D+00
3920	0.35605D+00	0.11789D+00
3921	0.35081D+00	0.12283D+00
3922	0.35061D+00	0.12777D+00
3923	0.34536D+00	0.13272D+00
3924	0.34516D+00	0.13767D+00

NACA Designation	**x**	**y**
4105	0.23484D+00	0.63670D-01
4106	0.24479D+00	0.68601D-01
4107	0.24974D+00	0.73545D-01
4108	0.25470D+00	0.78500D-01
4109	0.25965D+00	0.83462D-01
4110	0.25961D+00	0.88432D-01
4111	0.26455D+00	0.93405D-01
4112	0.26451D+00	0.98382D-01
4113	0.26946D+00	0.10336D+00
4114	0.26941D+00	0.10835D+00
4115	0.26937D+00	0.11333D+00
4116	0.27431D+00	0.11832D+00
4117	0.27427D+00	0.12330D+00
4118	0.27422D+00	0.12829D+00
4119	0.27418D+00	0.13328D+00
4120	0.27911D+00	0.13827D+00
4121	0.27907D+00	0.14327D+00
4122	0.27902D+00	0.14826D+00
4123	0.27898D+00	0.15325D+00
4124	0.27893D+00	0.15825D+00
4205	0.25991D+00	0.64624D-01
4206	0.26488D+00	0.69600D-01
4207	0.26985D+00	0.74581D-01
4208	0.26983D+00	0.79565D-01
4209	0.27479D+00	0.84553D-01
4210	0.27477D+00	0.89542D-01
4211	0.27973D+00	0.94531D-01
4212	0.27970D+00	0.99525D-01
4213	0.27968D+00	0.10452D+00
4214	0.27965D+00	0.10951D+00
4215	0.27963D+00	0.11451D+00
4216	0.28458D+00	0.11950D+00
4217	0.28455D+00	0.12450D+00
4218	0.28452D+00	0.12950D+00
4219	0.28450D+00	0.13449D+00
4220	0.28447D+00	0.13949D+00
4221	0.28444D+00	0.14449D+00
4222	0.28442D+00	0.14949D+00
4223	0.28439D+00	0.15448D+00
4224	0.28933D+00	0.15948D+00
4305	0.30000D+00	0.65007D-01
4306	0.30000D+00	0.70009D-01
4307	0.30000D+00	0.75010D-01
4308	0.30000D+00	0.80012D-01
4309	0.30000D+00	0.85013D-01
4310	0.30000D+00	0.90014D-01
4311	0.30000D+00	0.95016D-01
4312	0.30000D+00	0.10002D+00
4313	0.30000D+00	0.10502D+00
4314	0.30000D+00	0.11002D+00
4315	0.30000D+00	0.11502D+00
4316	0.30000D+00	0.12002D+00
4317	0.30000D+00	0.12502D+00
4318	0.30000D+00	0.13003D+00
4319	0.30000D+00	0.13503D+00
4320	0.30000D+00	0.14003D+00
4321	0.30000D+00	0.14503D+00
4322	0.30000D+00	0.15003D+00
4323	0.30000D+00	0.15503D+00
4324	0.30000D+00	0.16003D+00

NACA Designation	**x**	**y**
4405	0.37469D+00	0.64368D-01
4406	0.36956D+00	0.69274D-01
4407	0.36948D+00	0.74191D-01
4408	0.36431D+00	0.79113D-01
4409	0.36422D+00	0.84041D-01
4410	0.35901D+00	0.88976D-01
4411	0.35891D+00	0.93914D-01
4412	0.35366D+00	0.98858D-01
4413	0.35355D+00	0.10380D+00
4414	0.34827D+00	0.10875D+00
4415	0.34814D+00	0.11371D+00
4416	0.34802D+00	0.11867D+00
4417	0.34268D+00	0.12362D+00
4418	0.34254D+00	0.12859D+00
4419	0.34241D+00	0.13355D+00
4420	0.34227D+00	0.13851D+00
4421	0.33687D+00	0.14348D+00
4422	0.33672D+00	0.14845D+00
4423	0.33657D+00	0.15342D+00
4424	0.33642D+00	0.15839D+00
4505	0.43955D+00	0.62881D-01
4506	0.42936D+00	0.67599D-01
4507	0.41915D+00	0.72347D-01
4508	0.41396D+00	0.77122D-01
4509	0.40876D+00	0.81918D-01
4510	0.40354D+00	0.86734D-01
4511	0.39321D+00	0.91567D-01
4512	0.39305D+00	0.96416D-01
4513	0.38777D+00	0.10128D+00
4514	0.38249D+00	0.10615D+00
4515	0.37718D+00	0.11103D+00
4516	0.37700D+00	0.11592D+00
4517	0.37167D+00	0.12082D+00
4518	0.36632D+00	0.12573D+00
4519	0.36612D+00	0.13064D+00
4520	0.36075D+00	0.13556D+00
4521	0.36053D+00	0.14048D+00
4522	0.35514D+00	0.14540D+00
4523	0.35492D+00	0.15034D+00
4524	0.35470D+00	0.15527D+00
4605	0.48443D+00	0.60966D-01
4606	0.47424D+00	0.65477D-01
4607	0.45900D+00	0.70055D-01
4608	0.44876D+00	0.74684D-01
4609	0.43850D+00	0.79359D-01
4610	0.42821D+00	0.84072D-01
4611	0.41790D+00	0.88815D-01
4612	0.41264D+00	0.93586D-01
4613	0.40737D+00	0.98379D-01
4614	0.40208D+00	0.10319D+00
4615	0.39678D+00	0.10802D+00
4616	0.39147D+00	0.11287D+00
4617	0.38614D+00	0.11773D+00
4618	0.38081D+00	0.12259D+00
4619	0.37546D+00	0.12747D+00
4620	0.37522D+00	0.13236D+00
4621	0.36986D+00	0.13726D+00
4622	0.36448D+00	0.14216D+00
4623	0.36423D+00	0.14707D+00
4624	0.35883D+00	0.15198D+00

NACA Designation	x	y
4705	0.52439D+00	0.58865D-01
4706	0.50416D+00	0.63194D-01
4707	0.48390D+00	0.67627D-01
4708	0.46863D+00	0.72144D-01
4709	0.45838D+00	0.76728D-01
4710	0.44306D+00	0.81368D-01
4711	0.43276D+00	0.86053D-01
4712	0.42244D+00	0.90775D-01
4713	0.41717D+00	0.95530D-01
4714	0.40682D+00	0.10031D+00
4715	0.40152D+00	0.10511D+00
4716	0.39621D+00	0.10993D+00
4717	0.39090D+00	0.11477D+00
4718	0.38557D+00	0.11962D+00
4719	0.38024D+00	0.12449D+00
4720	0.37489D+00	0.12936D+00
4721	0.37464D+00	0.13425D+00
4722	0.36928D+00	0.13914D+00
4723	0.36902D+00	0.14404D+00
4724	0.36365D+00	0.14895D+00
4805	0.55437D+00	0.56720D-01
4806	0.52412D+00	0.60906D-01
4807	0.50387D+00	0.65236D-01
4808	0.48359D+00	0.69679D-01
4809	0.46831D+00	0.74208D-01
4810	0.45301D+00	0.78808D-01
4811	0.43768D+00	0.83463D-01
4812	0.42738D+00	0.88163D-01
4813	0.42211D+00	0.92900D-01
4814	0.41178D+00	0.97669D-01
4815	0.40649D+00	0.10246D+00
4816	0.39614D+00	0.10728D+00
4817	0.39083D+00	0.11211D+00
4818	0.38552D+00	0.11696D+00
4819	0.38020D+00	0.12182D+00
4820	0.37994D+00	0.12669D+00
4821	0.37461D+00	0.13158D+00
4822	0.36928D+00	0.13647D+00
4823	0.36393D+00	0.14137D+00
4824	0.36367D+00	0.14628D+00
4905	0.57436D+00	0.54621D-01
4906	0.53911D+00	0.58708D-01
4907	0.51385D+00	0.62974D-01
4908	0.48856D+00	0.67376D-01
4909	0.46826D+00	0.71881D-01
4910	0.45297D+00	0.76466D-01
4911	0.44269D+00	0.81113D-01
4912	0.42737D+00	0.85810D-01
4913	0.41706D+00	0.90547D-01
4914	0.41179D+00	0.95318D-01
4915	0.40147D+00	0.10011D+00
4916	0.39618D+00	0.10493D+00
4917	0.39089D+00	0.10977D+00
4918	0.38559D+00	0.11463D+00
4919	0.38029D+00	0.11949D+00
4920	0.37498D+00	0.12437D+00
4921	0.36967D+00	0.12926D+00
4922	0.36941D+00	0.13416D+00
4923	0.36409D+00	0.13907D+00
4924	0.35876D+00	0.14398D+00

NACA Designation	x	y
5105	0.22980D+00	0.73452D-01
5106	0.23475D+00	0.78358D-01
5107	0.23970D+00	0.83282D-01
5108	0.24465D+00	0.88220D-01
5109	0.24959D+00	0.93169D-01
5110	0.25453D+00	0.98124D-01
5111	0.25448D+00	0.10309D+00
5112	0.25941D+00	0.10805D+00
5113	0.25936D+00	0.11302D+00
5114	0.26429D+00	0.11800D+00
5115	0.26424D+00	0.12298D+00
5116	0.26916D+00	0.12795D+00
5117	0.26911D+00	0.13294D+00
5118	0.26906D+00	0.13792D+00
5119	0.26901D+00	0.14291D+00
5120	0.27392D+00	0.14789D+00
5121	0.27387D+00	0.15288D+00
5122	0.27381D+00	0.15787D+00
5123	0.27376D+00	0.16286D+00
5124	0.27371D+00	0.16785D+00
5205	0.25489D+00	0.74568D-01
5206	0.25986D+00	0.79537D-01
5207	0.26482D+00	0.84511D-01
5208	0.26480D+00	0.89488D-01
5209	0.26975D+00	0.94472D-01
5210	0.26973D+00	0.99456D-01
5211	0.27468D+00	0.10444D+00
5212	0.27465D+00	0.10943D+00
5213	0.27462D+00	0.11442D+00
5214	0.27956D+00	0.11941D+00
5215	0.27953D+00	0.12441D+00
5216	0.27950D+00	0.12940D+00
5217	0.27947D+00	0.13439D+00
5218	0.27944D+00	0.13939D+00
5219	0.27941D+00	0.14438D+00
5220	0.28434D+00	0.14938D+00
5221	0.28430D+00	0.15437D+00
5222	0.28427D+00	0.15937D+00
5223	0.28424D+00	0.16437D+00
5224	0.28420D+00	0.16937D+00
5305	0.30000D+00	0.75007D-01
5306	0.30000D+00	0.80009D-01
5307	0.30000D+00	0.85010D-01
5308	0.30000D+00	0.90012D-01
5309	0.30000D+00	0.95013D-01
5310	0.30000D+00	0.10001D+00
5311	0.30000D+00	0.10502D+00
5312	0.30000D+00	0.11002D+00
5313	0.30000D+00	0.11502D+00
5314	0.30000D+00	0.12002D+00
5315	0.30000D+00	0.12502D+00
5316	0.30000D+00	0.13002D+00
5317	0.30000D+00	0.13502D+00
5318	0.30000D+00	0.14003D+00
5319	0.30000D+00	0.14503D+00
5320	0.30000D+00	0.15003D+00
5321	0.30000D+00	0.15503D+00
5322	0.30000D+00	0.16003D+00
5323	0.30000D+00	0.16503D+00
5324	0.30000D+00	0.17003D+00

NACA Designation	**x**	**y**
5405	0.37969D+00	0.74337D-01
5406	0.37454D+00	0.79233D-01
5407	0.37446D+00	0.84137D-01
5408	0.36926D+00	0.89048D-01
5409	0.36917D+00	0.93965D-01
5410	0.36392D+00	0.98887D-01
5411	0.36381D+00	0.10381D+00
5412	0.35852D+00	0.10874D+00
5413	0.35840D+00	0.11368D+00
5414	0.35827D+00	0.11862D+00
5415	0.35291D+00	0.12356D+00
5416	0.35277D+00	0.12851D+00
5417	0.35264D+00	0.13345D+00
5418	0.34721D+00	0.13840D+00
5419	0.34706D+00	0.14336D+00
5420	0.34690D+00	0.14831D+00
5421	0.34675D+00	0.15327D+00
5422	0.34125D+00	0.15823D+00
5423	0.34108D+00	0.16319D+00
5424	0.34091D+00	0.16815D+00
5505	0.44954D+00	0.72748D-01
5506	0.43932D+00	0.77425D-01
5507	0.43414D+00	0.82130D-01
5508	0.42386D+00	0.86862D-01
5509	0.41863D+00	0.91617D-01
5510	0.41337D+00	0.96392D-01
5511	0.40810D+00	0.10118D+00
5512	0.40280D+00	0.10599D+00
5513	0.39749D+00	0.11082D+00
5514	0.39215D+00	0.11565D+00
5515	0.39195D+00	0.12050D+00
5516	0.38658D+00	0.12535D+00
5517	0.38119D+00	0.13022D+00
5518	0.38096D+00	0.13509D+00
5519	0.37554D+00	0.13997D+00
5520	0.37531D+00	0.14486D+00
5521	0.36986D+00	0.14976D+00
5522	0.36961D+00	0.15466D+00
5523	0.36413D+00	0.15956D+00
5524	0.36387D+00	0.16447D+00
5605	0.50442D+00	0.70665D-01
5606	0.48918D+00	0.75087D-01
5607	0.47895D+00	0.79575D-01
5608	0.46868D+00	0.84117D-01
5609	0.45839D+00	0.88708D-01
5610	0.44806D+00	0.93341D-01
5611	0.43771D+00	0.98008D-01
5612	0.43241D+00	0.10271D+00
5613	0.42200D+00	0.10743D+00
5614	0.41667D+00	0.11218D+00
5615	0.41132D+00	0.11695D+00
5616	0.40595D+00	0.12174D+00
5617	0.40057D+00	0.12654D+00
5618	0.39517D+00	0.13136D+00
5619	0.39490D+00	0.13618D+00
5620	0.38948D+00	0.14103D+00
5621	0.38405D+00	0.14588D+00
5622	0.37860D+00	0.15074D+00
5623	0.37831D+00	0.15561D+00
5624	0.37284D+00	0.16048D+00

NACA Designation	x	y
5705	0.54937D+00	0.68330D-01
5706	0.52912D+00	0.72511D-01
5707	0.51386D+00	0.76802D-01
5708	0.49352D+00	0.81183D-01
5709	0.48323D+00	0.85641D-01
5710	0.46786D+00	0.90162D-01
5711	0.45752D+00	0.94737D-01
5712	0.44716D+00	0.99357D-01
5713	0.43677D+00	0.10402D+00
5714	0.43144D+00	0.10871D+00
5715	0.42101D+00	0.11343D+00
5716	0.41565D+00	0.11818D+00
5717	0.41028D+00	0.12294D+00
5718	0.40489D+00	0.12773D+00
5719	0.39950D+00	0.13253D+00
5720	0.39409D+00	0.13735D+00
5721	0.38867D+00	0.14218D+00
5722	0.38837D+00	0.14702D+00
5723	0.38293D+00	0.15188D+00
5724	0.37749D+00	0.15674D+00
5805	0.58434D+00	0.65897D-01
5806	0.55909D+00	0.69874D-01
5807	0.53378D+00	0.74006D-01
5808	0.51346D+00	0.78266D-01
5809	0.49814D+00	0.82630D-01
5810	0.48279D+00	0.87079D-01
5811	0.46742D+00	0.91597D-01
5812	0.45707D+00	0.96173D-01
5813	0.44670D+00	0.10080D+00
5814	0.43631D+00	0.10546D+00
5815	0.42590D+00	0.11016D+00
5816	0.42055D+00	0.11489D+00
5817	0.41519D+00	0.11965D+00
5818	0.40474D+00	0.12442D+00
5819	0.39936D+00	0.12922D+00
5820	0.39397D+00	0.13403D+00
5821	0.39367D+00	0.13885D+00
5822	0.38826D+00	0.14370D+00
5823	0.38285D+00	0.14855D+00
5824	0.37742D+00	0.15341D+00
5905	0.61435D+00	0.63468D-01
5906	0.57907D+00	0.67282D-01
5907	0.55378D+00	0.71301D-01
5908	0.52845D+00	0.75482D-01
5909	0.50811D+00	0.79789D-01
5910	0.48774D+00	0.84200D-01
5911	0.47238D+00	0.88692D-01
5912	0.46205D+00	0.93250D-01
5913	0.44665D+00	0.97865D-01
5914	0.43628D+00	0.10252D+00
5915	0.43095D+00	0.10722D+00
5916	0.42055D+00	0.11195D+00
5917	0.41520D+00	0.11671D+00
5918	0.40478D+00	0.12149D+00
5919	0.39941D+00	0.12628D+00
5920	0.39404D+00	0.13110D+00
5921	0.38866D+00	0.13593D+00
5922	0.38327D+00	0.14078D+00
5923	0.38297D+00	0.14563D+00
5924	0.37757D+00	0.15050D+00

NACA Designation	x	y
6105	0.21978D+00	0.83260D-01
6106	0.22972D+00	0.88142D-01
6107	0.23466D+00	0.93046D-01
6108	0.23959D+00	0.97967D-01
6109	0.24452D+00	0.10290D+00
6110	0.24945D+00	0.10784D+00
6111	0.24939D+00	0.11279D+00
6112	0.25432D+00	0.11775D+00
6113	0.25426D+00	0.12271D+00
6114	0.25918D+00	0.12768D+00
6115	0.25912D+00	0.13264D+00
6116	0.26403D+00	0.13762D+00
6117	0.26397D+00	0.14259D+00
6118	0.26391D+00	0.14757D+00
6119	0.26384D+00	0.15255D+00
6120	0.26874D+00	0.15753D+00
6121	0.26868D+00	0.16251D+00
6122	0.26862D+00	0.16750D+00
6123	0.26856D+00	0.17248D+00
6124	0.27345D+00	0.17747D+00
6205	0.25487D+00	0.84521D-01
6206	0.25485D+00	0.89482D-01
6207	0.25980D+00	0.94450D-01
6208	0.26476D+00	0.99422D-01
6209	0.26473D+00	0.10440D+00
6210	0.26967D+00	0.10938D+00
6211	0.26964D+00	0.11436D+00
6212	0.26961D+00	0.11935D+00
6213	0.27454D+00	0.12433D+00
6214	0.27451D+00	0.12932D+00
6215	0.27447D+00	0.13431D+00
6216	0.27444D+00	0.13930D+00
6217	0.27936D+00	0.14429D+00
6218	0.27933D+00	0.14929D+00
6219	0.27929D+00	0.15428D+00
6220	0.27925D+00	0.15927D+00
6221	0.27921D+00	0.16427D+00
6222	0.27918D+00	0.16926D+00
6223	0.28408D+00	0.17425D+00
6224	0.28404D+00	0.17925D+00
6305	0.30000D+00	0.85007D-01
6306	0.30000D+00	0.90009D-01
6307	0.30000D+00	0.95010D-01
6308	0.30000D+00	0.10001D+00
6309	0.30000D+00	0.10501D+00
6310	0.30000D+00	0.11001D+00
6311	0.30000D+00	0.11502D+00
6312	0.30000D+00	0.12002D+00
6313	0.30000D+00	0.12502D+00
6314	0.30000D+00	0.13002D+00
6315	0.30000D+00	0.13502D+00
6316	0.30000D+00	0.14002D+00
6317	0.30000D+00	0.14502D+00
6318	0.30000D+00	0.15003D+00
6319	0.30000D+00	0.15503D+00
6320	0.30000D+00	0.16003D+00
6321	0.30000D+00	0.16503D+00
6322	0.30000D+00	0.17003D+00
6323	0.30000D+00	0.17503D+00
6324	0.30000D+00	0.18003D+00

NACA Designation	x	y
6405	0.38473D+00	0.84312D-01
6406	0.37956D+00	0.89203D-01
6407	0.37436D+00	0.94096D-01
6408	0.37426D+00	0.99001D-01
6409	0.37417D+00	0.10391D+00
6410	0.36889D+00	0.10882D+00
6411	0.36878D+00	0.11374D+00
6412	0.36345D+00	0.11866D+00
6413	0.36332D+00	0.12359D+00
6414	0.36319D+00	0.12851D+00
6415	0.35778D+00	0.13345D+00
6416	0.35763D+00	0.13838D+00
6417	0.35748D+00	0.14332D+00
6418	0.35200D+00	0.14826D+00
6419	0.35183D+00	0.15320D+00
6420	0.35166D+00	0.15815D+00
6421	0.35149D+00	0.16310D+00
6422	0.34591D+00	0.16804D+00
6423	0.34573D+00	0.17300D+00
6424	0.34554D+00	0.17795D+00
6505	0.45450D+00	0.82654D-01
6506	0.44933D+00	0.87296D-01
6507	0.43905D+00	0.91968D-01
6508	0.43382D+00	0.96666D-01
6509	0.42857D+00	0.10138D+00
6510	0.42329D+00	0.10612D+00
6511	0.41799D+00	0.11088D+00
6512	0.41266D+00	0.11566D+00
6513	0.40730D+00	0.12044D+00
6514	0.40193D+00	0.12524D+00
6515	0.40171D+00	0.13006D+00
6516	0.39629D+00	0.13488D+00
6517	0.39085D+00	0.13972D+00
6518	0.39060D+00	0.14456D+00
6519	0.38513D+00	0.14941D+00
6520	0.38487D+00	0.15427D+00
6521	0.37935D+00	0.15914D+00
6522	0.37908D+00	0.16401D+00
6523	0.37353D+00	0.16889D+00
6524	0.37325D+00	0.17377D+00
6605	0.51439D+00	0.80441D-01
6606	0.50417D+00	0.84794D-01
6607	0.49391D+00	0.89208D-01
6608	0.48362D+00	0.93677D-01
6609	0.47330D+00	0.98196D-01
6610	0.46294D+00	0.10276D+00
6611	0.45254D+00	0.10736D+00
6612	0.44721D+00	0.11199D+00
6613	0.44187D+00	0.11665D+00
6614	0.43138D+00	0.12133D+00
6615	0.42598D+00	0.12604D+00
6616	0.42057D+00	0.13078D+00
6617	0.41514D+00	0.13552D+00
6618	0.40970D+00	0.14029D+00
6619	0.40423D+00	0.14507D+00
6620	0.40393D+00	0.14986D+00
6621	0.39843D+00	0.15467D+00
6622	0.39292D+00	0.15949D+00
6623	0.39260D+00	0.16431D+00
6624	0.38706D+00	0.16915D+00

NACA Designation	x	y
6705	0.56936D+00	0.77929D-01
6706	0.54909D+00	0.81990D-01
6707	0.53381D+00	0.86160D-01
6707	0.51848D+00	0.90423D-01
6709	0.50312D+00	0.94765D-01
6710	0.49277D+00	0.99176D-01
6711	0.47733D+00	0.10365D+00
6712	0.46692D+00	0.10817D+00
6713	0.46158D+00	0.11273D+00
6714	0.45112D+00	0.11734D+00
6715	0.44063D+00	0.12198D+00
6716	0.43523D+00	0.12665D+00
6717	0.42981D+00	0.13134D+00
6718	0.42438D+00	0.13606D+00
6719	0.41894D+00	0.14080D+00
6720	0.41348D+00	0.14555D+00
6721	0.40800D+00	0.15033D+00
6722	0.40251D+00	0.15511D+00
6723	0.39701D+00	0.15992D+00
6724	0.39150D+00	0.16473D+00
6805	0.61436D+00	0.75273D-01
6806	0.58909D+00	0.79071D-01
6807	0.56376D+00	0.83031D-01
6808	0.54341D+00	0.87125D-01
6809	0.52302D+00	0.91331D-01
6810	0.50763D+00	0.95633D-01
6811	0.49221D+00	0.10001D+00
6812	0.48182D+00	0.10447D+00
6813	0.47141D+00	0.10897D+00
6814	0.46098D+00	0.11353D+00
6815	0.45052D+00	0.11813D+00
6816	0.44004D+00	0.12277D+00
6817	0.43463D+00	0.12744D+00
6818	0.42921D+00	0.13213D+00
6819	0.41867D+00	0.13685D+00
6820	0.41322D+00	0.14160D+00
6821	0.40776D+00	0.14636D+00
6822	0.40229D+00	0.15114D+00
6823	0.39681D+00	0.15593D+00
6824	0.39646D+00	0.16074D+00
6905	0.64936D+00	0.72577D-01
6906	0.61406D+00	0.76155D-01
6907	0.58373D+00	0.79948D-01
6908	0.55836D+00	0.83917D-01
6909	0.53799D+00	0.88032D-01
6910	0.51758D+00	0.92265D-01
6911	0.50218D+00	0.96597D-01
6912	0.48675D+00	0.10101D+00
6913	0.47636D+00	0.10549D+00
6914	0.46087D+00	0.11003D+00
6915	0.45043D+00	0.11462D+00
6916	0.44505D+00	0.11925D+00
6917	0.43458D+00	0.12391D+00
6918	0.42917D+00	0.12860D+00
6919	0.41866D+00	0.13332D+00
6920	0.41323D+00	0.13807D+00
6921	0.40780D+00	0.14283D+00
6922	0.40235D+00	0.14762D+00
6923	0.39689D+00	0.15241D+00
6924	0.39143D+00	0.15722D+00

NACA Designation	**x**	**y**
7105	0.21476D+00	0.93089D-01
7106	0.21970D+00	0.97947D-01
7107	0.22961D+00	0.10283D+00
7108	0.23454D+00	0.10773D+00
7109	0.23946D+00	0.11265D+00
7110	0.23940D+00	0.11758D+00
7111	0.24432D+00	0.12252D+00
7112	0.24923D+00	0.12746D+00
7113	0.24917D+00	0.13241D+00
7114	0.25407D+00	0.13737D+00
7115	0.25400D+00	0.14233D+00
7116	0.25890D+00	0.14730D+00
7117	0.25883D+00	0.15227D+00
7118	0.25876D+00	0.15723D+00
7119	0.26365D+00	0.16221D+00
7120	0.26358D+00	0.16718D+00
7121	0.26351D+00	0.17216D+00
7122	0.26344D+00	0.17714D+00
7123	0.26832D+00	0.18212D+00
7124	0.26824D+00	0.18710D+00
7205	0.24986D+00	0.94481D-01
7206	0.25482D+00	0.99434D-01
7207	0.25479D+00	0.10440D+00
7208	0.25974D+00	0.10936D+00
7209	0.26468D+00	0.11433D+00
7210	0.26465D+00	0.11931D+00
7211	0.26461D+00	0.12429D+00
7212	0.26954D+00	0.12927D+00
7213	0.26950D+00	0.13425D+00
7214	0.26947D+00	0.13924D+00
7215	0.27439D+00	0.14422D+00
7216	0.27435D+00	0.14921D+00
7217	0.27430D+00	0.15420D+00
7218	0.27426D+00	0.15919D+00
7219	0.27422D+00	0.16418D+00
7220	0.27913D+00	0.16917D+00
7221	0.27908D+00	0.17417D+00
7222	0.27904D+00	0.17916D+00
7223	0.27900D+00	0.18415D+00
7224	0.27895D+00	0.18915D+00
7305	0.30000D+00	0.95007D-01
7306	0.30000D+00	0.10001D+00
7307	0.30000D+00	0.10501D+00
7308	0.30000D+00	0.11001D+00
7309	0.30000D+00	0.11501D+00
7310	0.30000D+00	0.12001D+00
7311	0.30000D+00	0.12502D+00
7312	0.30000D+00	0.13002D+00
7313	0.30000D+00	0.13502D+00
7314	0.30000D+00	0.14002D+00
7315	0.30000D+00	0.14502D+00
7316	0.30000D+00	0.15002D+00
7317	0.30000D+00	0.15502D+00
7318	0.30000D+00	0.16003D+00
7319	0.30000D+00	0.16503D+00
7320	0.30000D+00	0.17003D+00
7321	0.30000D+00	0.17503D+00
7322	0.30000D+00	0.18003D+00
7323	0.30000D+00	0.18503D+00
7324	0.30000D+00	0.19003D+00

NACA Designation	x	y
7405	0.38468D+00	0.94297D-01
7406	0.37949D+00	0.99177D-01
7407	0.37940D+00	0.10407D+00
7408	0.37932D+00	0.10896D+00
7409	0.37403D+00	0.11386D+00
7410	0.37393D+00	0.11877D+00
7411	0.36858D+00	0.12368D+00
7412	0.36845D+00	0.12859D+00
7413	0.36832D+00	0.13351D+00
7414	0.36289D+00	0.13843D+00
7415	0.36274D+00	0.14335D+00
7416	0.36259D+00	0.14828D+00
7417	0.35706D+00	0.15320D+00
7418	0.35689D+00	0.15814D+00
7419	0.35672D+00	0.16308D+00
7420	0.35655D+00	0.16801D+00
7421	0.35091D+00	0.17295D+00
7422	0.35072D+00	0.17789D+00
7423	0.35052D+00	0.18284D+00
7424	0.35033D+00	0.18778D+00
7505	0.45948D+00	0.92580D-01
7506	0.45430D+00	0.97198D-01
7507	0.44909D+00	0.10184D+00
7508	0.44385D+00	0.10651D+00
7509	0.43346D+00	0.11120D+00
7510	0.42815D+00	0.11591D+00
7511	0.42796D+00	0.12064D+00
7512	0.42261D+00	0.12538D+00
7513	0.41723D+00	0.13014D+00
7514	0.41181D+00	0.13491D+00
7515	0.40637D+00	0.13969D+00
7516	0.40613D+00	0.14449D+00
7517	0.40065D+00	0.14930D+00
7518	0.40039D+00	0.15411D+00
7519	0.39486D+00	0.15894D+00
7520	0.38931D+00	0.16377D+00
7521	0.38902D+00	0.16861D+00
7522	0.38342D+00	0.17345D+00
7523	0.38312D+00	0.17831D+00
7524	0.38282D+00	0.18317D+00
7605	0.52438D+00	0.90270D-01
7606	0.51414D+00	0.94566D-01
7607	0.50387D+00	0.98920D-01
7608	0.49355D+00	0.10333D+00
7609	0.48320D+00	0.10778D+00
7610	0.47790D+00	0.11228D+00
7611	0.46747D+00	0.11682D+00
7612	0.46212D+00	0.12139D+00
7613	0.45161D+00	0.12599D+00
7614	0.44621D+00	0.13062D+00
7615	0.44078D+00	0.13528D+00
7616	0.43534D+00	0.13995D+00
7617	0.42987D+00	0.14465D+00
7618	0.42438D+00	0.14936D+00
7619	0.41887D+00	0.15410D+00
7620	0.41334D+00	0.15884D+00
7621	0.40779D+00	0.16360D+00
7622	0.40744D+00	0.16838D+00
7623	0.40186D+00	0.17316D+00
7624	0.39625D+00	0.17796D+00

NACA Designation	**x**	**y**
7705	0.58436D+00	0.87620D-01
7706	0.56407D+00	0.91580D-01
7707	0.54876D+00	0.95648D-01
7708	0.53341D+00	0.99808D-01
7709	0.52308D+00	0.10405D+00
7710	0.50764D+00	0.10836D+00
7711	0.49723D+00	0.11274D+00
7712	0.48679D+00	0.11716D+00
7713	0.47632D+00	0.12164D+00
7714	0.47092D+00	0.12616D+00
7715	0.46039D+00	0.13072D+00
7716	0.45496D+00	0.13531D+00
7717	0.44437D+00	0.13993D+00
7718	0.43889D+00	0.14458D+00
7719	0.43340D+00	0.14925D+00
7720	0.42788D+00	0.15394D+00
7721	0.42236D+00	0.15866D+00
7722	0.41681D+00	0.16339D+00
7723	0.41125D+00	0.16813D+00
7724	0.40568D+00	0.17289D+00
7805	0.63436D+00	0.84785D-01
7806	0.60907D+00	0.88434D-01
7807	0.58876D+00	0.92242D-01
7808	0.56839D+00	0.96188D-01
7809	0.54797D+00	0.10025D+00
7810	0.53256D+00	0.10442D+00
7811	0.51711D+00	0.10867D+00
7812	0.50669D+00	0.11299D+00
7813	0.49116D+00	0.11739D+00
7814	0.48068D+00	0.12184D+00
7815	0.47017D+00	0.12634D+00
7816	0.45964D+00	0.13088D+00
7817	0.45419D+00	0.13546D+00
7818	0.44361D+00	0.14007D+00
7819	0.43813D+00	0.14471D+00
7820	0.43263D+00	0.14938D+00
7821	0.42712D+00	0.15407D+00
7822	0.42160D+00	0.15878D+00
7823	0.41607D+00	0.16352D+00
7824	0.41052D+00	0.16826D+00
7905	0.67437D+00	0.81874D-01
7906	0.64408D+00	0.85247D-01
7907	0.61373D+00	0.88839D-01
7908	0.58834D+00	0.92615D-01
7909	0.56795D+00	0.96547D-01
7910	0.54751D+00	0.10061D+00
7911	0.53208D+00	0.10478D+00
7912	0.51662D+00	0.10905D+00
7913	0.50112D+00	0.11339D+00
7914	0.48558D+00	0.11780D+00
7915	0.47510D+00	0.12228D+00
7916	0.46459D+00	0.12680D+00
7917	0.45406D+00	0.13136D+00
7918	0.44861D+00	0.13596D+00
7919	0.43804D+00	0.14060D+00
7920	0.43256D+00	0.14526D+00
7921	0.42707D+00	0.14995D+00
7922	0.42157D+00	0.15466D+00
7923	0.41606D+00	0.15940D+00
7924	0.41054D+00	0.16415D+00

NACA Designation	x	y
8105	0.20974D+00	0.10294D+00
8106	0.21467D+00	0.10777D+00
8107	0.22458D+00	0.11264D+00
8108	0.22950D+00	0.11752D+00
8109	0.23441D+00	0.12242D+00
8110	0.23434D+00	0.12734D+00
8111	0.23925D+00	0.13226D+00
8112	0.24415D+00	0.13720D+00
8113	0.24408D+00	0.14214D+00
8114	0.24897D+00	0.14708D+00
8115	0.24890D+00	0.15204D+00
8116	0.25379D+00	0.15699D+00
8117	0.25371D+00	0.16195D+00
8118	0.25859D+00	0.16692D+00
8119	0.25851D+00	0.17188D+00
8120	0.25843D+00	0.17685D+00
8121	0.25835D+00	0.18182D+00
8122	0.26322D+00	0.18680D+00
8123	0.26313D+00	0.19178D+00
8124	0.26305D+00	0.19675D+00
8205	0.24486D+00	0.10445D+00
8206	0.24981D+00	0.10939D+00
8207	0.25476D+00	0.11435D+00
8208	0.25473D+00	0.11931D+00
8209	0.25966D+00	0.12428D+00
8210	0.25963D+00	0.12925D+00
8211	0.26456D+00	0.13422D+00
8212	0.26451D+00	0.13920D+00
8213	0.26943D+00	0.14418D+00
8214	0.26939D+00	0.14916D+00
8215	0.26935D+00	0.15414D+00
8216	0.26930D+00	0.15913D+00
8217	0.27420D+00	0.16411D+00
8218	0.27416D+00	0.16910D+00
8219	0.27411D+00	0.17409D+00
8220	0.27406D+00	0.17908D+00
8221	0.27402D+00	0.18407D+00
8222	0.27397D+00	0.18906D+00
8223	0.27885D+00	0.19405D+00
8224	0.27880D+00	0.19905D+00
8305	0.30000D+00	0.10501D+00
8306	0.30000D+00	0.11001D+00
8307	0.30000D+00	0.11501D+00
8308	0.30000D+00	0.12001D+00
8309	0.30000D+00	0.12501D+00
8310	0.30000D+00	0.13001D+00
8311	0.30000D+00	0.13502D+00
8312	0.30000D+00	0.14002D+00
8313	0.30000D+00	0.14502D+00
8314	0.30000D+00	0.15002D+00
8315	0.30000D+00	0.15502D+00
8316	0.30000D+00	0.16002D+00
8317	0.30000D+00	0.16502D+00
8318	0.30000D+00	0.17003D+00
8319	0.30000D+00	0.17503D+00
8320	0.30000D+00	0.18003D+00
8321	0.30000D+00	0.18503D+00
8322	0.30000D+00	0.19003D+00
8323	0.30000D+00	0.19503D+00
8324	0.30000D+00	0.20003D+00

NACA Designation	x	y
8405	0.38463D+00	0.10428D+00
8406	0.38456D+00	0.10916D+00
8407	0.37932D+00	0.11404D+00
8408	0.37922D+00	0.11893D+00
8409	0.37912D+00	0.12383D+00
8410	0.37377D+00	0.12872D+00
8411	0.37365D+00	0.13363D+00
8412	0.37353D+00	0.13853D+00
8413	0.36808D+00	0.14344D+00
8414	0.36794D+00	0.14836D+00
8415	0.36779D+00	0.15327D+00
8416	0.36224D+00	0.15819D+00
8417	0.36207D+00	0.16312D+00
8418	0.36190D+00	0.16804D+00
8419	0.36172D+00	0.17297D+00
8420	0.35605D+00	0.17789D+00
8421	0.35585D+00	0.18283D+00
8422	0.35566D+00	0.18776D+00
8423	0.35546D+00	0.19270D+00
8424	0.35526D+00	0.19763D+00
8505	0.46449D+00	0.10252D+00
8506	0.45929D+00	0.10712D+00
8507	0.45407D+00	0.11174D+00
8508	0.44881D+00	0.11639D+00
8509	0.44352D+00	0.12105D+00
8510	0.43820D+00	0.12574D+00
8511	0.43285D+00	0.13044D+00
8512	0.42746D+00	0.13516D+00
8513	0.42204D+00	0.13989D+00
8514	0.42181D+00	0.14463D+00
8515	0.41634D+00	0.14939D+00
8516	0.41084D+00	0.15416D+00
8517	0.41058D+00	0.15894D+00
8518	0.40503D+00	0.16373D+00
8519	0.40475D+00	0.16852D+00
8520	0.39915D+00	0.17333D+00
8521	0.39886D+00	0.17815D+00
8522	0.39321D+00	0.18297D+00
8523	0.39290D+00	0.18780D+00
8524	0.38719D+00	0.19264D+00
8605	0.53439D+00	0.10014D+00
8606	0.52415D+00	0.10438D+00
8607	0.51386D+00	0.10869D+00
8608	0.50352D+00	0.11304D+00
8609	0.49314D+00	0.11745D+00
8610	0.48782D+00	0.12189D+00
8611	0.47736D+00	0.12637D+00
8612	0.47198D+00	0.13089D+00
8613	0.46658D+00	0.13544D+00
8614	0.45599D+00	0.14002D+00
8615	0.45053D+00	0.14462D+00
8616	0.44505D+00	0.14925D+00
8617	0.43954D+00	0.15389D+00
8618	0.43401D+00	0.15856D+00
8619	0.42845D+00	0.16324D+00
8620	0.42811D+00	0.16794D+00
8621	0.42251D+00	0.17266D+00
8622	0.41690D+00	0.17739D+00
8623	0.41125D+00	0.18213D+00
8624	0.41087D+00	0.18689D+00

NACA Designation	**x**	**y**
8705	0.59434D+00	0.97373D-01
8706	0.57908D+00	0.10125D+00
8707	0.56376D+00	0.10523D+00
8708	0.54838D+00	0.10930D+00
8709	0.53803D+00	0.11345D+00
8710	0.52256D+00	0.11768D+00
8711	0.51213D+00	0.12196D+00
8712	0.50166D+00	0.12631D+00
8713	0.49115D+00	0.13070D+00
8714	0.48573D+00	0.13514D+00
8715	0.47515D+00	0.13962D+00
8716	0.46968D+00	0.14414D+00
8717	0.45904D+00	0.14869D+00
8718	0.45352D+00	0.15327D+00
8719	0.44799D+00	0.15787D+00
8720	0.44243D+00	0.16250D+00
8721	0.43686D+00	0.16715D+00
8722	0.43127D+00	0.17182D+00
8723	0.42566D+00	0.17651D+00
8724	0.42003D+00	0.18122D+00
8805	0.64935D+00	0.94394D-01
8806	0.62909D+00	0.97916D-01
8807	0.60372D+00	0.10159D+00
8808	0.58838D+00	0.10541D+00
8809	0.56793D+00	0.10934D+00
8810	0.55250D+00	0.11338D+00
8811	0.53701D+00	0.11751D+00
8812	0.52657D+00	0.12172D+00
8813	0.51100D+00	0.12600D+00
8814	0.50048D+00	0.13035D+00
8815	0.48994D+00	0.13475D+00
8816	0.47936D+00	0.13919D+00
8817	0.47388D+00	0.14368D+00
8818	0.46325D+00	0.14821D+00
8819	0.45773D+00	0.15277D+00
8820	0.44704D+00	0.15736D+00
8821	0.44149D+00	0.16198D+00
8822	0.43591D+00	0.16662D+00
8823	0.43033D+00	0.17129D+00
8824	0.42472D+00	0.17597D+00
8905	0.69437D+00	0.91305D-01
8906	0.66407D+00	0.94503D-01
8907	0.63874D+00	0.97918D-01
8908	0.61334D+00	0.10152D+00
8909	0.59292D+00	0.10528D+00
8910	0.57246D+00	0.10918D+00
8911	0.55194D+00	0.11320D+00
8912	0.53644D+00	0.11732D+00
8913	0.52089D+00	0.12153D+00
8914	0.51040D+00	0.12582D+00
8915	0.49988D+00	0.13017D+00
8916	0.48424D+00	0.13458D+00
8917	0.47877D+00	0.13904D+00
8918	0.46817D+00	0.14355D+00
8919	0.45754D+00	0.14809D+00
8920	0.45202D+00	0.15267D+00
8921	0.44135D+00	0.15728D+00
8922	0.43580D+00	0.16192D+00
8923	0.43023D+00	0.16658D+00
8924	0.42466D+00	0.17126D+00

NACA Designation	**x**	**y**
9105	0.20472D+00	0.11280D+00
9106	0.20965D+00	0.11761D+00
9107	0.21955D+00	0.12246D+00
9108	0.22446D+00	0.12732D+00
9109	0.22936D+00	0.13221D+00
9110	0.23426D+00	0.13711D+00
9111	0.23419D+00	0.14202D+00
9112	0.23908D+00	0.14695D+00
9113	0.24397D+00	0.15187D+00
9114	0.24389D+00	0.15681D+00
9115	0.24876D+00	0.16176D+00
9116	0.24868D+00	0.16671D+00
9117	0.24860D+00	0.17166D+00
9118	0.25346D+00	0.17661D+00
9119	0.25338D+00	0.18157D+00
9120	0.25329D+00	0.18654D+00
9121	0.25814D+00	0.19150D+00
9122	0.25806D+00	0.19647D+00
9123	0.25797D+00	0.20144D+00
9124	0.26281D+00	0.20641D+00
9205	0.24484D+00	0.11441D+00
9206	0.24481D+00	0.11935D+00
9207	0.24976D+00	0.12430D+00
9208	0.25469D+00	0.12926D+00
9209	0.25465D+00	0.13422D+00
9210	0.25958D+00	0.13919D+00
9211	0.25954D+00	0.14416D+00
9212	0.26445D+00	0.14913D+00
9213	0.26441D+00	0.15411D+00
9214	0.26436D+00	0.15909D+00
9215	0.26926D+00	0.16407D+00
9216	0.26922D+00	0.16905D+00
9217	0.26917D+00	0.17403D+00
9218	0.26912D+00	0.17902D+00
9219	0.27400D+00	0.18400D+00
9220	0.27395D+00	0.18899D+00
9221	0.27389D+00	0.19398D+00
9222	0.27384D+00	0.19897D+00
9223	0.27379D+00	0.20396D+00
9224	0.27374D+00	0.20895D+00
9305	0.30000D+00	0.11501D+00
9306	0.30000D+00	0.12001D+00
9307	0.30000D+00	0.12501D+00
9308	0.30000D+00	0.13001D+00
9309	0.30000D+00	0.13501D+00
9310	0.30000D+00	0.14001D+00
9311	0.30000D+00	0.14502D+00
9312	0.30000D+00	0.15002D+00
9313	0.30000D+00	0.15502D+00
9314	0.30000D+00	0.16002D+00
9315	0.30000D+00	0.16502D+00
9316	0.30000D+00	0.17002D+00
9317	0.30000D+00	0.17502D+00
9318	0.30000D+00	0.18003D+00
9319	0.30000D+00	0.18503D+00
9320	0.30000D+00	0.19003D+00
9321	0.30000D+00	0.19503D+00
9322	0.30000D+00	0.20003D+00
9323	0.30000D+00	0.20503D+00
9324	0.30000D+00	0.21003D+00

NACA Designation	x	y
9405	0.38973D+00	0.11427D+00
9406	0.38451D+00	0.11915D+00
9407	0.38442D+00	0.12402D+00
9408	0.37912D+00	0.12891D+00
9409	0.37901D+00	0.13380D+00
9410	0.37890D+00	0.13869D+00
9411	0.37348D+00	0.14358D+00
9412	0.37335D+00	0.14849D+00
9413	0.37321D+00	0.15339D+00
9414	0.37307D+00	0.15829D+00
9415	0.36751D+00	0.16321D+00
9416	0.36735D+00	0.16812D+00
9417	0.36718D+00	0.17304D+00
9418	0.36701D+00	0.17795D+00
9419	0.36132D+00	0.18287D+00
9420	0.36112D+00	0.18780D+00
9421	0.36093D+00	0.19272D+00
9422	0.36073D+00	0.19765D+00
9423	0.35489D+00	0.20257D+00
9424	0.35467D+00	0.20751D+00
9505	0.46951D+00	0.11248D+00
9506	0.46431D+00	0.11706D+00
9507	0.45907D+00	0.12166D+00
9508	0.45380D+00	0.12628D+00
9509	0.44849D+00	0.13093D+00
9510	0.44315D+00	0.13559D+00
9511	0.43777D+00	0.14027D+00
9512	0.43236D+00	0.14496D+00
9513	0.43214D+00	0.14967D+00
9514	0.42667D+00	0.15440D+00
9515	0.42116D+00	0.15913D+00
9516	0.42090D+00	0.16387D+00
9517	0.41534D+00	0.16863D+00
9518	0.40974D+00	0.17339D+00
9519	0.40944D+00	0.17817D+00
9520	0.40379D+00	0.18295D+00
9521	0.40348D+00	0.18775D+00
9522	0.39776D+00	0.19254D+00
9523	0.39743D+00	0.19735D+00
9524	0.39711D+00	0.20216D+00
9605	0.53937D+00	0.11003D+00
9606	0.52911D+00	0.11424D+00
9607	0.51880D+00	0.11850D+00
9608	0.51353D+00	0.12281D+00
9609	0.50313D+00	0.12717D+00
9610	0.49780D+00	0.13156D+00
9611	0.48730D+00	0.13600D+00
9612	0.48191D+00	0.14047D+00
9613	0.47649D+00	0.14497D+00
9614	0.46586D+00	0.14949D+00
9615	0.46037D+00	0.15405D+00
9616	0.45485D+00	0.15863D+00
9617	0.44931D+00	0.16323D+00
9618	0.44374D+00	0.16785D+00
9619	0.43814D+00	0.17249D+00
9620	0.43778D+00	0.17715D+00
9621	0.43214D+00	0.18182D+00
9622	0.42648D+00	0.18651D+00
9623	0.42078D+00	0.19121D+00
9624	0.42038D+00	0.19593D+00

NACA Designation	**x**	**y**
9705	0.60434D+00	0.10717D+00
9706	0.58906D+00	0.11098D+00
9707	0.57373D+00	0.11489D+00
9708	0.56340D+00	0.11888D+00
9709	0.54796D+00	0.12295D+00
9710	0.53754D+00	0.12710D+00
9711	0.52709D+00	0.13131D+00
9712	0.51659D+00	0.13557D+00
9713	0.50606D+00	0.13989D+00
9714	0.50061D+00	0.14425D+00
9715	0.49000D+00	0.14866D+00
9716	0.47935D+00	0.15310D+00
9717	0.47382D+00	0.15758D+00
9718	0.46827D+00	0.16210D+00
9719	0.46270D+00	0.16663D+00
9720	0.45191D+00	0.17120D+00
9721	0.44629D+00	0.17579D+00
9722	0.44064D+00	0.18041D+00
9723	0.43498D+00	0.18504D+00
9724	0.43454D+00	0.18969D+00
9805	0.66437D+00	0.10407D+00
9806	0.64409D+00	0.10749D+00
9807	0.62375D+00	0.11105D+00
9808	0.60335D+00	0.11475D+00
9809	0.58795D+00	0.11857D+00
9810	0.57249D+00	0.12250D+00
9811	0.55699D+00	0.12652D+00
9812	0.54143D+00	0.13062D+00
9813	0.53093D+00	0.13479D+00
9814	0.52039D+00	0.13903D+00
9815	0.50981D+00	0.14333D+00
9816	0.49920D+00	0.14768D+00
9817	0.48855D+00	0.15208D+00
9818	0.47787D+00	0.15652D+00
9819	0.47231D+00	0.16100D+00
9820	0.46674D+00	0.16552D+00
9821	0.45597D+00	0.17006D+00
9822	0.45035D+00	0.17463D+00
9823	0.44472D+00	0.17923D+00
9824	0.43907D+00	0.18385D+00
9905	0.71440D+00	0.10084D+00
9906	0.68409D+00	0.10388D+00
9907	0.65874D+00	0.10714D+00
9908	0.63838D+00	0.11059D+00
9909	0.61290D+00	0.11420D+00
9910	0.59241D+00	0.11794D+00
9911	0.57693D+00	0.12182D+00
9912	0.56141D+00	0.12580D+00
9913	0.54584D+00	0.12988D+00
9914	0.53023D+00	0.13404D+00
9915	0.51968D+00	0.13827D+00
9916	0.50909D+00	0.14257D+00
9917	0.49336D+00	0.14693D+00
9918	0.48784D+00	0.15133D+00
9919	0.47717D+00	0.15578D+00
9920	0.46647D+00	0.16027D+00
9921	0.46089D+00	0.16480D+00
9922	0.45530D+00	0.16936D+00
9923	0.44452D+00	0.17395D+00
9924	0.43889D+00	0.17856D+00

```
NACA     XMIN           YMIN           XMAX           YMAX

1105     0.33007D+00    -0.15578D-01    0.99001D+00    -0.88498D-03
1106     0.32508D+00    -0.20564D-01    0.99001D+00    -0.11062D-02
1107     0.32009D+00    -0.25555D-01    0.99002D+00    -0.13274D-02
1108     0.32011D+00    -0.30549D-01    0.99002D+00    -0.15486D-02
1109     0.31512D+00    -0.35545D-01    0.99002D+00    -0.17697D-02
1110     0.31513D+00    -0.40542D-01    0.99002D+00    -0.19909D-02
1111     0.31515D+00    -0.45540D-01    0.99003D+00    -0.22121D-02
1112     0.31016D+00    -0.50538D-01    0.99003D+00    -0.24333D-02
1113     0.31017D+00    -0.55538D-01    0.99003D+00    -0.26545D-02
1114     0.31018D+00    -0.60537D-01    0.99003D+00    -0.28757D-02
1115     0.31019D+00    -0.65537D-01    0.99004D+00    -0.30969D-02
1116     0.31021D+00    -0.70536D-01    0.99004D+00    -0.33181D-02
1117     0.31022D+00    -0.75536D-01    0.99004D+00    -0.35393D-02
1118     0.31023D+00    -0.80535D-01    0.99004D+00    -0.37605D-02
1119     0.30524D+00    -0.85536D-01    0.99005D+00    -0.39817D-02
1120     0.30525D+00    -0.90537D-01    0.99005D+00    -0.42029D-02
1121     0.30527D+00    -0.95538D-01    0.99005D+00    -0.44241D-02
1122     0.30528D+00    -0.10054D+00    0.99005D+00    -0.46453D-02
1123     0.30529D+00    -0.10554D+00    0.99006D+00    -0.48664D-02
1124     0.30530D+00    -0.11054D+00    0.99006D+00    -0.50876D-02

1205     0.32005D+00    -0.15195D-01    0.99001D+00    -0.85751D-03
1206     0.31505D+00    -0.20190D-01    0.99002D+00    -0.10787D-02
1207     0.31506D+00    -0.25187D-01    0.99002D+00    -0.12999D-02
1208     0.31007D+00    -0.30185D-01    0.99002D+00    -0.15211D-02
1209     0.31008D+00    -0.35185D-01    0.99002D+00    -0.17423D-02
1210     0.31009D+00    -0.40184D-01    0.99003D+00    -0.19635D-02
1211     0.31009D+00    -0.45184D-01    0.99003D+00    -0.21846D-02
1212     0.30510D+00    -0.50183D-01    0.99003D+00    -0.24058D-02
1213     0.30511D+00    -0.55184D-01    0.99004D+00    -0.26270D-02
1214     0.30511D+00    -0.60185D-01    0.99004D+00    -0.28482D-02
1215     0.30512D+00    -0.65186D-01    0.99004D+00    -0.30694D-02
1216     0.30513D+00    -0.70187D-01    0.99004D+00    -0.32906D-02
1217     0.30514D+00    -0.75188D-01    0.99005D+00    -0.35118D-02
1218     0.30515D+00    -0.80189D-01    0.99005D+00    -0.37330D-02
1219     0.30516D+00    -0.85190D-01    0.99005D+00    -0.39542D-02
1220     0.30516D+00    -0.90191D-01    0.99005D+00    -0.41753D-02
1221     0.30517D+00    -0.95192D-01    0.99006D+00    -0.43965D-02
1222     0.30518D+00    -0.10019D+00    0.99006D+00    -0.46177D-02
1223     0.30519D+00    -0.10519D+00    0.99006D+00    -0.48389D-02
1224     0.30520D+00    -0.11019D+00    0.99007D+00    -0.50601D-02

1305     0.23038D+00    -0.15037D-01    0.99002D+00    -0.82225D-03
1306     0.29503D+00    -0.20009D-01    0.99002D+00    -0.10434D-02
1307     0.30000D+00    -0.25010D-01    0.99002D+00    -0.12646D-02
1308     0.30000D+00    -0.30012D-01    0.99002D+00    -0.14858D-02
1309     0.30000D+00    -0.35013D-01    0.99003D+00    -0.17070D-02
1310     0.30000D+00    -0.40014D-01    0.99003D+00    -0.19282D-02
1311     0.30000D+00    -0.45016D-01    0.99003D+00    -0.21494D-02
1312     0.30000D+00    -0.50017D-01    0.99004D+00    -0.23705D-02
1313     0.30000D+00    -0.55019D-01    0.99004D+00    -0.25917D-02
1314     0.30000D+00    -0.60020D-01    0.99004D+00    -0.28129D-02
1315     0.30000D+00    -0.65022D-01    0.99005D+00    -0.30341D-02
1316     0.30000D+00    -0.70023D-01    0.99005D+00    -0.32553D-02
1317     0.30000D+00    -0.75024D-01    0.99005D+00    -0.34765D-02
1318     0.30000D+00    -0.80026D-01    0.99006D+00    -0.36976D-02
1319     0.30000D+00    -0.85027D-01    0.99006D+00    -0.39188D-02
1320     0.30000D+00    -0.90029D-01    0.99006D+00    -0.41400D-02
1321     0.30000D+00    -0.95030D-01    0.99007D+00    -0.43612D-02
1322     0.30000D+00    -0.10003D+00    0.99007D+00    -0.45824D-02
1323     0.30000D+00    -0.10503D+00    0.99007D+00    -0.48036D-02
1324     0.30000D+00    -0.11003D+00    0.99007D+00    -0.50247D-02
```

NACA	XMIN	YMIN	XMAX	YMAX
1405	0.19561D+00	-0.16401D-01	0.99002D+00	-0.77533D-03
1406	0.21567D+00	-0.21211D-01	0.99002D+00	-0.99650D-03
1407	0.23073D+00	-0.26093D-01	0.99003D+00	-0.12177D-02
1408	0.24577D+00	-0.31014D-01	0.99003D+00	-0.14389D-02
1409	0.25084D+00	-0.35958D-01	0.99003D+00	-0.16600D-02
1410	0.25590D+00	-0.40916D-01	0.99004D+00	-0.18812D-02
1411	0.26096D+00	-0.45884D-01	0.99004D+00	-0.21024D-02
1412	0.26601D+00	-0.50859D-01	0.99004D+00	-0.23236D-02
1413	0.27105D+00	-0.55839D-01	0.99005D+00	-0.25447D-02
1414	0.27113D+00	-0.60822D-01	0.99005D+00	-0.27659D-02
1415	0.27617D+00	-0.65808D-01	0.99005D+00	-0.29871D-02
1416	0.27625D+00	-0.70797D-01	0.99006D+00	-0.32083D-02
1417	0.27633D+00	-0.75786D-01	0.99006D+00	-0.34294D-02
1418	0.28135D+00	-0.80779D-01	0.99007D+00	-0.36506D-02
1419	0.28142D+00	-0.85772D-01	0.99007D+00	-0.38718D-02
1420	0.28150D+00	-0.90765D-01	0.99007D+00	-0.40930D-02
1421	0.28157D+00	-0.95758D-01	0.99008D+00	-0.43141D-02
1422	0.28658D+00	-0.10075D+00	0.99008D+00	-0.45353D-02
1423	0.28665D+00	-0.10575D+00	0.99008D+00	-0.47565D-02
1424	0.28672D+00	-0.11075D+00	0.99009D+00	-0.49777D-02
1505	0.20057D+00	-0.17500D-01	0.99002D+00	-0.70982D-03
1506	0.22065D+00	-0.22322D-01	0.99003D+00	-0.93098D-03
1507	0.23074D+00	-0.27202D-01	0.99003D+00	-0.11521D-02
1508	0.24082D+00	-0.32116D-01	0.99003D+00	-0.13733D-02
1509	0.24591D+00	-0.37051D-01	0.99004D+00	-0.15945D-02
1510	0.25597D+00	-0.42001D-01	0.99004D+00	-0.18156D-02
1511	0.25607D+00	-0.46961D-01	0.99005D+00	-0.20368D-02
1512	0.26114D+00	-0.51930D-01	0.99005D+00	-0.22580D-02
1513	0.26622D+00	-0.56904D-01	0.99006D+00	-0.24791D-02
1514	0.26631D+00	-0.61880D-01	0.99006D+00	-0.27003D-02
1515	0.27138D+00	-0.66862D-01	0.99007D+00	-0.29215D-02
1516	0.27147D+00	-0.71845D-01	0.99007D+00	-0.31426D-02
1517	0.27653D+00	-0.76831D-01	0.99007D+00	-0.33638D-02
1518	0.27662D+00	-0.81820D-01	0.99008D+00	-0.35849D-02
1519	0.27671D+00	-0.86808D-01	0.99008D+00	-0.38061D-02
1520	0.28176D+00	-0.91797D-01	0.99009D+00	-0.40273D-02
1521	0.28185D+00	-0.96790D-01	0.99009D+00	-0.42484D-02
1522	0.28193D+00	-0.10178D+00	0.99010D+00	-0.44696D-02
1523	0.28202D+00	-0.10678D+00	0.99010D+00	-0.46908D-02
1524	0.28211D+00	-0.11177D+00	0.99010D+00	-0.49119D-02
1605	0.20553D+00	-0.18351D-01	0.99003D+00	-0.61195D-03
1606	0.22561D+00	-0.23198D-01	0.99003D+00	-0.83309D-03
1607	0.23570D+00	-0.28092D-01	0.99004D+00	-0.10542D-02
1608	0.24079D+00	-0.33013D-01	0.99004D+00	-0.12754D-02
1609	0.25087D+00	-0.37954D-01	0.99005D+00	-0.14965D-02
1610	0.25595D+00	-0.42907D-01	0.99005D+00	-0.17177D-02
1611	0.26103D+00	-0.47868D-01	0.99006D+00	-0.19388D-02
1612	0.26113D+00	-0.52837D-01	0.99006D+00	-0.21599D-02
1613	0.26620D+00	-0.57812D-01	0.99007D+00	-0.23811D-02
1614	0.26630D+00	-0.62789D-01	0.99008D+00	-0.26022D-02
1615	0.27137D+00	-0.67771D-01	0.99008D+00	-0.28234D-02
1616	0.27146D+00	-0.72754D-01	0.99009D+00	-0.30445D-02
1617	0.27653D+00	-0.77740D-01	0.99009D+00	-0.32656D-02
1618	0.27662D+00	-0.82729D-01	0.99010D+00	-0.34868D-02
1619	0.27671D+00	-0.87717D-01	0.99010D+00	-0.37079D-02
1620	0.27680D+00	-0.92706D-01	0.99011D+00	-0.39291D-02
1621	0.28186D+00	-0.97698D-01	0.99011D+00	-0.41502D-02
1622	0.28195D+00	-0.10269D+00	0.99012D+00	-0.43713D-02
1623	0.28204D+00	-0.10768D+00	0.99012D+00	-0.45925D-02
1624	0.28213D+00	-0.11268D+00	0.99013D+00	-0.48136D-02

```
NACA    XMIN           YMIN           XMAX           YMAX

1705    0.21548D+00    -0.19029D-01   0.94510D+00    -0.30305D-03
1706    0.23056D+00    -0.23898D-01   0.99004D+00    -0.67099D-03
1707    0.24065D+00    -0.28805D-01   0.99005D+00    -0.89208D-03
1708    0.24573D+00    -0.33738D-01   0.99006D+00    -0.11132D-02
1709    0.25082D+00    -0.38684D-01   0.99006D+00    -0.13343D-02
1710    0.25590D+00    -0.43643D-01   0.99007D+00    -0.15554D-02
1711    0.26098D+00    -0.48609D-01   0.99008D+00    -0.17764D-02
1712    0.26606D+00    -0.53581D-01   0.99009D+00    -0.19975D-02
1713    0.26615D+00    -0.58558D-01   0.99009D+00    -0.22186D-02
1714    0.27122D+00    -0.63538D-01   0.99010D+00    -0.24397D-02
1715    0.27131D+00    -0.68521D-01   0.99011D+00    -0.26608D-02
1716    0.27638D+00    -0.73505D-01   0.99011D+00    -0.28819D-02
1717    0.27647D+00    -0.78493D-01   0.99012D+00    -0.31030D-02
1718    0.27656D+00    -0.83482D-01   0.99013D+00    -0.33241D-02
1719    0.27664D+00    -0.88471D-01   0.99014D+00    -0.35452D-02
1720    0.28171D+00    -0.93462D-01   0.99014D+00    -0.37663D-02
1721    0.28180D+00    -0.98455D-01   0.99015D+00    -0.39874D-02
1722    0.28188D+00    -0.10345D+00   0.99016D+00    -0.42085D-02
1723    0.28197D+00    -0.10844D+00   0.99016D+00    -0.44295D-02
1724    0.28205D+00    -0.11343D+00   0.99017D+00    -0.46506D-02

1805    0.22044D+00    -0.19580D-01   0.90515D+00     0.14737D-02
1806    0.23552D+00    -0.24467D-01   0.93017D+00     0.44005D-03
1807    0.24060D+00    -0.29388D-01   0.95517D+00    -0.32164D-03
1808    0.25068D+00    -0.34329D-01   0.98510D+00    -0.78407D-03
1809    0.25576D+00    -0.39283D-01   0.99009D+00    -0.10136D-02
1810    0.26084D+00    -0.44247D-01   0.99010D+00    -0.12346D-02
1811    0.26592D+00    -0.49216D-01   0.99012D+00    -0.14555D-02
1812    0.26600D+00    -0.54193D-01   0.99013D+00    -0.16765D-02
1813    0.27107D+00    -0.59171D-01   0.99014D+00    -0.18974D-02
1814    0.27116D+00    -0.64155D-01   0.99015D+00    -0.21184D-02
1815    0.27124D+00    -0.69138D-01   0.99016D+00    -0.23394D-02
1816    0.27631D+00    -0.74126D-01   0.99017D+00    -0.25603D-02
1817    0.27639D+00    -0.79115D-01   0.99018D+00    -0.27813D-02
1818    0.27647D+00    -0.84104D-01   0.99019D+00    -0.30022D-02
1819    0.28154D+00    -0.89095D-01   0.99020D+00    -0.32232D-02
1820    0.28162D+00    -0.94088D-01   0.99021D+00    -0.34441D-02
1821    0.28170D+00    -0.99081D-01   0.99022D+00    -0.36651D-02
1822    0.28179D+00    -0.10407D+00   0.99023D+00    -0.38861D-02
1823    0.28187D+00    -0.10907D+00   0.99024D+00    -0.41070D-02
1824    0.28693D+00    -0.11406D+00   0.99025D+00    -0.43280D-02

1905    0.22541D+00    -0.20037D-01   0.92512D+00     0.46604D-02
1906    0.23548D+00    -0.24940D-01   0.93016D+00     0.37646D-02
1907    0.24556D+00    -0.29872D-01   0.94022D+00     0.29337D-02
1908    0.25064D+00    -0.34819D-01   0.94526D+00     0.21650D-02
1909    0.25571D+00    -0.39779D-01   0.95030D+00     0.14584D-02
1910    0.26079D+00    -0.44748D-01   0.95534D+00     0.81484D-03
1911    0.26586D+00    -0.49723D-01   0.96037D+00     0.23535D-03
1912    0.27093D+00    -0.54700D-01   0.96539D+00    -0.27919D-03
1913    0.27101D+00    -0.59683D-01   0.97538D+00    -0.71795D-03
1914    0.27109D+00    -0.64667D-01   0.98038D+00    -0.10889D-02
1915    0.27615D+00    -0.69655D-01   0.98535D+00    -0.13916D-02
1916    0.27623D+00    -0.74643D-01   0.99032D+00    -0.16250D-02
1917    0.27631D+00    -0.79632D-01   0.99034D+00    -0.18454D-02
1918    0.28138D+00    -0.84624D-01   0.99036D+00    -0.20657D-02
1919    0.28145D+00    -0.89617D-01   0.99038D+00    -0.22860D-02
1920    0.28153D+00    -0.94610D-01   0.99040D+00    -0.25063D-02
1921    0.28161D+00    -0.99604D-01   0.99042D+00    -0.27266D-02
1922    0.28168D+00    -0.10460D+00   0.99044D+00    -0.29469D-02
1923    0.28675D+00    -0.10959D+00   0.99046D+00    -0.31673D-02
1924    0.28682D+00    -0.11459D+00   0.99048D+00    -0.33876D-02
```

NACA	XMIN	YMIN	XMAX	YMAX
2105	0.12404D-01	-0.28792D-02	0.99002D+00	-0.66379D-03
2106	0.18322D-01	-0.42191D-02	0.99003D+00	-0.88494D-03
2107	0.24195D-01	-0.59105D-02	0.99003D+00	-0.11061D-02
2108	0.34524D+00	-0.21204D-01	0.99004D+00	-0.13272D-02
2109	0.33526D+00	-0.26176D-01	0.99004D+00	-0.15484D-02
2110	0.33028D+00	-0.31155D-01	0.99005D+00	-0.17696D-02
2111	0.33031D+00	-0.36140D-01	0.99005D+00	-0.19907D-02
2112	0.32533D+00	-0.41128D-01	0.99006D+00	-0.22119D-02
2113	0.32536D+00	-0.46118D-01	0.99006D+00	-0.24330D-02
2114	0.32038D+00	-0.51110D-01	0.99007D+00	-0.26542D-02
2115	0.32041D+00	-0.56104D-01	0.99007D+00	-0.28753D-02
2116	0.32043D+00	-0.61098D-01	0.99008D+00	-0.30965D-02
2117	0.31545D+00	-0.66092D-01	0.99008D+00	-0.33176D-02
2118	0.31548D+00	-0.71090D-01	0.99009D+00	-0.35388D-02
2119	0.31550D+00	-0.76087D-01	0.99009D+00	-0.37599D-02
2120	0.31553D+00	-0.81084D-01	0.99010D+00	-0.39811D-02
2121	0.31556D+00	-0.86081D-01	0.99010D+00	-0.42022D-02
2122	0.31558D+00	-0.91078D-01	0.99011D+00	-0.44234D-02
2123	0.31060D+00	-0.96076D-01	0.99011D+00	-0.46445D-02
2124	0.31062D+00	-0.10108D+00	0.99012D+00	-0.48657D-02
2205	0.37064D-01	-0.61224D-02	0.99003D+00	-0.60882D-03
2206	0.52637D-01	-0.88268D-02	0.99003D+00	-0.82996D-03
2207	0.33515D+00	-0.15424D-01	0.99004D+00	-0.10511D-02
2208	0.33016D+00	-0.20408D-01	0.99004D+00	-0.12722D-02
2209	0.32518D+00	-0.25397D-01	0.99005D+00	-0.14934D-02
2210	0.32019D+00	-0.30390D-01	0.99005D+00	-0.17145D-02
2211	0.32021D+00	-0.35384D-01	0.99006D+00	-0.19357D-02
2212	0.31522D+00	-0.40379D-01	0.99007D+00	-0.21568D-02
2213	0.31523D+00	-0.45376D-01	0.99007D+00	-0.23779D-02
2214	0.31525D+00	-0.50374D-01	0.99008D+00	-0.25991D-02
2215	0.31527D+00	-0.55371D-01	0.99008D+00	-0.28202D-02
2216	0.31027D+00	-0.60370D-01	0.99009D+00	-0.30413D-02
2217	0.31029D+00	-0.65369D-01	0.99009D+00	-0.32625D-02
2218	0.31031D+00	-0.70369D-01	0.99010D+00	-0.34836D-02
2219	0.31033D+00	-0.75368D-01	0.99010D+00	-0.37048D-02
2220	0.31034D+00	-0.80368D-01	0.99011D+00	-0.39259D-02
2221	0.31036D+00	-0.85367D-01	0.99011D+00	-0.41470D-02
2222	0.31038D+00	-0.90367D-01	0.99012D+00	-0.43682D-02
2223	0.31040D+00	-0.95366D-01	0.99013D+00	-0.45893D-02
2224	0.30539D+00	-0.10037D+00	0.99013D+00	-0.48105D-02
2305	0.66716D-01	-0.87068D-02	0.99003D+00	-0.53824D-03
2306	0.92093D-01	-0.12227D-01	0.99004D+00	-0.75936D-03
2307	0.12729D+00	-0.16207D-01	0.99004D+00	-0.98048D-03
2308	0.16225D+00	-0.20564D-01	0.99005D+00	-0.12016D-02
2309	0.19700D+00	-0.25212D-01	0.99006D+00	-0.14227D-02
2310	0.23642D+00	-0.30059D-01	0.99006D+00	-0.16438D-02
2311	0.27561D+00	-0.35019D-01	0.99007D+00	-0.18650D-02
2312	0.29513D+00	-0.40017D-01	0.99007D+00	-0.20861D-02
2313	0.30000D+00	-0.45019D-01	0.99008D+00	-0.23072D-02
2314	0.30000D+00	-0.50020D-01	0.99009D+00	-0.25283D-02
2315	0.30000D+00	-0.55022D-01	0.99009D+00	-0.27494D-02
2316	0.30000D+00	-0.60023D-01	0.99010D+00	-0.29705D-02
2317	0.30000D+00	-0.65024D-01	0.99011D+00	-0.31917D-02
2318	0.30000D+00	-0.70026D-01	0.99011D+00	-0.34128D-02
2319	0.30000D+00	-0.75027D-01	0.99012D+00	-0.36339D-02
2320	0.30000D+00	-0.80029D-01	0.99012D+00	-0.38550D-02
2321	0.30000D+00	-0.85030D-01	0.99013D+00	-0.40761D-02
2322	0.30000D+00	-0.90032D-01	0.99014D+00	-0.42973D-02
2323	0.30000D+00	-0.95033D-01	0.99014D+00	-0.45184D-02
2324	0.30000D+00	-0.10003D+00	0.99015D+00	-0.47395D-02

```
NACA    XMIN          YMIN           XMAX          YMAX

2405    0.91450D-01   -0.10727D-01   0.83023D+00    0.21040D-03
2406    0.12174D+00   -0.14680D-01   0.99004D+00   -0.66541D-03
2407    0.14696D+00   -0.18941D-01   0.99005D+00   -0.88650D-03
2408    0.16715D+00   -0.23417D-01   0.99006D+00   -0.11076D-02
2409    0.18231D+00   -0.28036D-01   0.99007D+00   -0.13287D-02
2410    0.19743D+00   -0.32755D-01   0.99007D+00   -0.15498D-02
2411    0.21252D+00   -0.37542D-01   0.99008D+00   -0.17708D-02
2412    0.22262D+00   -0.42377D-01   0.99009D+00   -0.19919D-02
2413    0.22777D+00   -0.47247D-01   0.99009D+00   -0.22130D-02
2414    0.23784D+00   -0.52141D-01   0.99010D+00   -0.24341D-02
2415    0.24295D+00   -0.57055D-01   0.99011D+00   -0.26552D-02
2416    0.24806D+00   -0.61983D-01   0.99012D+00   -0.28763D-02
2417    0.25315D+00   -0.66921D-01   0.99012D+00   -0.30974D-02
2418    0.25334D+00   -0.71869D-01   0.99013D+00   -0.33185D-02
2419    0.25841D+00   -0.76825D-01   0.99014D+00   -0.35395D-02
2420    0.26348D+00   -0.81784D-01   0.99014D+00   -0.37606D-02
2421    0.26365D+00   -0.86751D-01   0.99015D+00   -0.39817D-02
2422    0.26869D+00   -0.91718D-01   0.99016D+00   -0.42028D-02
2423    0.26886D+00   -0.96693D-01   0.99017D+00   -0.44239D-02
2424    0.26903D+00   -0.10167D+00   0.99017D+00   -0.46450D-02

2505    0.11626D+00   -0.12309D-01   0.78027D+00    0.18894D-02
2506    0.13651D+00   -0.16515D-01   0.88026D+00   -0.17467D-04
2507    0.16172D+00   -0.20945D-01   0.99006D+00   -0.75525D-03
2508    0.17693D+00   -0.25525D-01   0.99007D+00   -0.97629D-03
2509    0.19211D+00   -0.30206D-01   0.99008D+00   -0.11973D-02
2510    0.20229D+00   -0.34958D-01   0.99009D+00   -0.14184D-02
2511    0.21246D+00   -0.39761D-01   0.99010D+00   -0.16394D-02
2512    0.22261D+00   -0.44600D-01   0.99010D+00   -0.18604D-02
2513    0.22779D+00   -0.49468D-01   0.99011D+00   -0.20815D-02
2514    0.23296D+00   -0.54357D-01   0.99012D+00   -0.23025D-02
2515    0.23812D+00   -0.59262D-01   0.99013D+00   -0.25235D-02
2516    0.24328D+00   -0.64181D-01   0.99014D+00   -0.27446D-02
2517    0.24842D+00   -0.69111D-01   0.99015D+00   -0.29656D-02
2518    0.25356D+00   -0.74047D-01   0.99016D+00   -0.31867D-02
2519    0.25376D+00   -0.78995D-01   0.99016D+00   -0.34077D-02
2520    0.25889D+00   -0.83945D-01   0.99017D+00   -0.36287D-02
2521    0.25908D+00   -0.88902D-01   0.99018D+00   -0.38498D-02
2522    0.26420D+00   -0.93862D-01   0.99019D+00   -0.40708D-02
2523    0.26439D+00   -0.98828D-01   0.99020D+00   -0.42918D-02
2524    0.26458D+00   -0.10379D+00   0.99021D+00   -0.45129D-02

2605    0.13111D+00   -0.13574D-01   0.78027D+00    0.41114D-02
2606    0.15133D+00   -0.17942D-01   0.83033D+00    0.19681D-02
2607    0.17154D+00   -0.22486D-01   0.88534D+00    0.32783D-03
2608    0.18673D+00   -0.27144D-01   0.95522D+00   -0.68385D-03
2609    0.20191D+00   -0.31878D-01   0.99010D+00   -0.10010D-02
2610    0.21209D+00   -0.36668D-01   0.99011D+00   -0.12219D-02
2611    0.21728D+00   -0.41499D-01   0.99012D+00   -0.14429D-02
2612    0.22744D+00   -0.46358D-01   0.99013D+00   -0.16638D-02
2613    0.23262D+00   -0.51241D-01   0.99014D+00   -0.18848D-02
2614    0.23779D+00   -0.56141D-01   0.99015D+00   -0.21057D-02
2615    0.24295D+00   -0.61055D-01   0.99016D+00   -0.23267D-02
2616    0.24812D+00   -0.65979D-01   0.99017D+00   -0.25476D-02
2617    0.24831D+00   -0.70915D-01   0.99018D+00   -0.27685D-02
2618    0.25346D+00   -0.75857D-01   0.99019D+00   -0.29895D-02
2619    0.25366D+00   -0.80804D-01   0.99020D+00   -0.32104D-02
2620    0.25880D+00   -0.85759D-01   0.99022D+00   -0.34314D-02
2621    0.25899D+00   -0.90716D-01   0.99023D+00   -0.36523D-02
2622    0.26413D+00   -0.95679D-01   0.99024D+00   -0.38733D-02
2623    0.26432D+00   -0.10064D+00   0.99025D+00   -0.40942D-02
2624    0.26450D+00   -0.10561D+00   0.99026D+00   -0.43151D-02
```

NACA	XMIN	YMIN	XMAX	YMAX
2705	0.14600D+00	-0.14604D-01	0.80525D+00	0.68547D-02
2706	0.16620D+00	-0.19089D-01	0.83033D+00	0.48251D-02
2707	0.18139D+00	-0.23713D-01	0.85540D+00	0.30384D-02
2708	0.19657D+00	-0.28429D-01	0.88545D+00	0.15178D-02
2709	0.20675D+00	-0.33207D-01	0.91545D+00	0.29377D-03
2710	0.21692D+00	-0.38029D-01	0.94540D+00	-0.59804D-03
2711	0.22210D+00	-0.42884D-01	0.98519D+00	-0.11104D-02
2712	0.23225D+00	-0.47763D-01	0.99017D+00	-0.13379D-02
2713	0.23742D+00	-0.52662D-01	0.99018D+00	-0.15586D-02
2714	0.24259D+00	-0.57575D-01	0.99020D+00	-0.17794D-02
2715	0.24277D+00	-0.62499D-01	0.99021D+00	-0.20001D-02
2716	0.24793D+00	-0.67434D-01	0.99023D+00	-0.22209D-02
2717	0.25309D+00	-0.72376D-01	0.99024D+00	-0.24416D-02
2718	0.25327D+00	-0.77324D-01	0.99026D+00	-0.26624D-02
2719	0.25842D+00	-0.82279D-01	0.99027D+00	-0.28831D-02
2720	0.25860D+00	-0.87237D-01	0.99028D+00	-0.31039D-02
2721	0.26375D+00	-0.92199D-01	0.99030D+00	-0.33246D-02
2722	0.26392D+00	-0.97166D-01	0.99031D+00	-0.35453D-02
2723	0.26410D+00	-0.10213D+00	0.99033D+00	-0.37661D-02
2724	0.26924D+00	-0.10711D+00	0.99034D+00	-0.39868D-02
2805	0.15591D+00	-0.15461D-01	0.85021D+00	0.10200D-01
2806	0.17609D+00	-0.20030D-01	0.86029D+00	0.85324D-02
2807	0.19126D+00	-0.24714D-01	0.87037D+00	0.69700D-02
2808	0.20143D+00	-0.29473D-01	0.88045D+00	0.55165D-02
2809	0.21160D+00	-0.34286D-01	0.89554D+00	0.41768D-02
2810	0.22176D+00	-0.39136D-01	0.90561D+00	0.29594D-02
2811	0.22693D+00	-0.44011D-01	0.91566D+00	0.18629D-02
2812	0.23708D+00	-0.48907D-01	0.93069D+00	0.89694D-03
2813	0.24224D+00	-0.53820D-01	0.94071D+00	0.64987D-04
2814	0.24241D+00	-0.58744D-01	0.95567D+00	-0.62393D-03
2815	0.24757D+00	-0.63680D-01	0.97057D+00	-0.11667D-02
2816	0.25272D+00	-0.68623D-01	0.98541D+00	-0.15539D-02
2817	0.25289D+00	-0.73571D-01	0.99036D+00	-0.17936D-02
2818	0.25804D+00	-0.78528D-01	0.99038D+00	-0.20139D-02
2819	0.25821D+00	-0.83486D-01	0.99040D+00	-0.22341D-02
2820	0.26335D+00	-0.88451D-01	0.99042D+00	-0.24543D-02
2821	0.26352D+00	-0.93418D-01	0.99044D+00	-0.26745D-02
2822	0.26866D+00	-0.98386D-01	0.99046D+00	-0.28947D-02
2823	0.26883D+00	-0.10336D+00	0.99048D+00	-0.31149D-02
2824	0.26899D+00	-0.10834D+00	0.99050D+00	-0.33351D-02
2905	0.16583D+00	-0.16184D-01	0.91516D+00	0.14305D-01
2906	0.18600D+00	-0.20817D-01	0.91519D+00	0.13256D-01
2907	0.20116D+00	-0.25548D-01	0.92028D+00	0.12230D-01
2908	0.21131D+00	-0.30344D-01	0.92032D+00	0.11235D-01
2909	0.22147D+00	-0.35182D-01	0.92542D+00	0.10272D-01
2910	0.22663D+00	-0.40053D-01	0.92547D+00	0.93297D-02
2911	0.23178D+00	-0.44945D-01	0.93059D+00	0.84317D-02
2912	0.23694D+00	-0.49856D-01	0.93570D+00	0.75457D-02
2913	0.24209D+00	-0.54780D-01	0.93576D+00	0.67120D-02
2914	0.24724D+00	-0.59716D-01	0.94087D+00	0.58935D-02
2915	0.25238D+00	-0.64659D-01	0.94093D+00	0.51145D-02
2916	0.25254D+00	-0.69608D-01	0.94604D+00	0.43650D-02
2917	0.25768D+00	-0.74566D-01	0.94611D+00	0.36409D-02
2918	0.25784D+00	-0.79524D-01	0.95120D+00	0.29617D-02
2919	0.26298D+00	-0.84491D-01	0.95628D+00	0.22983D-02
2920	0.26314D+00	-0.89459D-01	0.95635D+00	0.16850D-02
2921	0.26828D+00	-0.94430D-01	0.96140D+00	0.10939D-02
2922	0.26843D+00	-0.99405D-01	0.96147D+00	0.53651D-03
2923	0.26859D+00	-0.10438D+00	0.96650D+00	0.18684D-04
2924	0.27372D+00	-0.10936D+00	0.97150D+00	-0.48127D-03

NACA	XMIN	YMIN	XMAX	YMAX
3105	0.75200D-02	-0.14960D-02	0.86647D-01	0.11029D-01
3106	0.80240D-02	-0.23803D-02	0.99004D+00	-0.66355D-03
3107	0.85280D-02	-0.32645D-02	0.99005D+00	-0.88464D-03
3108	0.15397D-01	-0.42940D-02	0.99006D+00	-0.11057D-02
3109	0.16071D-01	-0.55433D-02	0.99007D+00	-0.13268D-02
3110	0.22813D-01	-0.69949D-02	0.99007D+00	-0.15479D-02
3111	0.34836D-01	-0.87322D-02	0.99008D+00	-0.17690D-02
3112	0.34554D+00	-0.31805D-01	0.99009D+00	-0.19901D-02
3113	0.34057D+00	-0.36776D-01	0.99009D+00	-0.22112D-02
3114	0.33561D+00	-0.41752D-01	0.99010D+00	-0.24322D-02
3115	0.33064D+00	-0.46732D-01	0.99011D+00	-0.26533D-02
3116	0.33068D+00	-0.51716D-01	0.99012D+00	-0.28744D-02
3117	0.33072D+00	-0.56701D-01	0.99012D+00	-0.30955D-02
3118	0.32575D+00	-0.61690D-01	0.99013D+00	-0.33166D-02
3119	0.32579D+00	-0.66680D-01	0.99014D+00	-0.35377D-02
3120	0.32583D+00	-0.71670D-01	0.99015D+00	-0.37588D-02
3121	0.32085D+00	-0.76663D-01	0.99015D+00	-0.39798D-02
3122	0.32090D+00	-0.81657D-01	0.99016D+00	-0.42009D-02
3123	0.32094D+00	-0.86651D-01	0.99017D+00	-0.44220D-02
3124	0.32098D+00	-0.91644D-01	0.99017D+00	-0.46431D-02
3205	0.17299D-01	-0.39543D-02	0.18070D+00	0.63496D-02
3206	0.23076D-01	-0.56910D-02	0.77039D+00	0.28459D-04
3207	0.34094D-01	-0.77288D-02	0.99006D+00	-0.80207D-03
3208	0.45022D-01	-0.10124D-01	0.99007D+00	-0.10231D-02
3209	0.60899D-01	-0.12892D-01	0.99007D+00	-0.12442D-02
3210	0.86359D-01	-0.16126D-01	0.99008D+00	-0.14652D-02
3211	0.33033D+00	-0.25626D-01	0.99009D+00	-0.16863D-02
3212	0.33036D+00	-0.30611D-01	0.99010D+00	-0.19073D-02
3213	0.32538D+00	-0.35600D-01	0.99011D+00	-0.21284D-02
3214	0.32541D+00	-0.40590D-01	0.99011D+00	-0.23495D-02
3215	0.32042D+00	-0.45584D-01	0.99012D+00	-0.25705D-02
3216	0.32045D+00	-0.50578D-01	0.99013D+00	-0.27916D-02
3217	0.32048D+00	-0.55571D-01	0.99014D+00	-0.30126D-02
3218	0.31548D+00	-0.60568D-01	0.99015D+00	-0.32337D-02
3219	0.31551D+00	-0.65565D-01	0.99016D+00	-0.34547D-02
3220	0.31554D+00	-0.70562D-01	0.99016D+00	-0.36758D-02
3221	0.31557D+00	-0.75560D-01	0.99017D+00	-0.38968D-02
3222	0.31559D+00	-0.80557D-01	0.99018D+00	-0.41179D-02
3223	0.31059D+00	-0.85555D-01	0.99019D+00	-0.43389D-02
4224	0.31062D+00	-0.90554D-01	0.99020D+00	-0.45600D-02
3305	0.32096D-01	-0.59468D-02	0.55032D+00	0.55408D-02
3306	0.42756D-01	-0.84348D-02	0.69545D+00	0.18910D-02
3307	0.58480D-01	-0.11315D-01	0.88035D+00	-0.47063D-03
3308	0.79153D-01	-0.14565D-01	0.99007D+00	-0.91705D-03
3309	0.99668D-01	-0.18162D-01	0.99008D+00	-0.11381D-02
3310	0.12002D+00	-0.22079D-01	0.99009D+00	-0.13591D-02
3311	0.14509D+00	-0.26277D-01	0.99010D+00	-0.15801D-02
3312	0.16992D+00	-0.30719D-01	0.99011D+00	-0.18011D-02
3313	0.19450D+00	-0.35359D-01	0.99012D+00	-0.20221D-02
3314	0.22363D+00	-0.40154D-01	0.99013D+00	-0.22431D-02
3315	0.25247D+00	-0.45058D-01	0.99014D+00	-0.24641D-02
3316	0.27633D+00	-0.50028D-01	0.99015D+00	-0.26851D-02
3317	0.29528D+00	-0.55025D-01	0.99016D+00	-0.29061D-02
3318	0.30000D+00	-0.60026D-01	0.99017D+00	-0.31271D-02
3319	0.30000D+00	-0.65027D-01	0.99018D+00	-0.33481D-02
3320	0.30000D+00	-0.70029D-01	0.99019D+00	-0.35692D-02
3321	0.30000D+00	-0.75030D-01	0.99020D+00	-0.37902D-02
3322	0.30000D+00	-0.80032D-01	0.99021D+00	-0.40112D-02
3323	0.30000D+00	-0.85033D-01	0.99021D+00	-0.42322D-02
3324	0.30000D+00	-0.90035D-01	0.99022D+00	-0.44532D-02

```
NACA    XMIN           YMIN            XMAX           YMAX

3405    0.46868D-01    -0.76623D-02    0.61033D+00     0.76596D-02
3406    0.67472D-01    -0.10716D-01    0.68545D+00     0.41953D-02
3407    0.82994D-01    -0.14147D-01    0.77553D+00     0.13969D-02
3408    0.10349D+00    -0.17898D-01    0.89541D+00    -0.47549D-03
3409    0.12391D+00    -0.21907D-01    0.99010D+00    -0.99679D-03
3410    0.13927D+00    -0.26124D-01    0.99011D+00    -0.12177D-02
3411    0.15457D+00    -0.30502D-01    0.99012D+00    -0.14387D-02
3412    0.16982D+00    -0.35007D-01    0.99013D+00    -0.16596D-02
3413    0.18499D+00    -0.39608D-01    0.99014D+00    -0.18805D-02
3414    0.19520D+00    -0.44285D-01    0.99015D+00    -0.21015D-02
3415    0.20536D+00    -0.49018D-01    0.99016D+00    -0.23224D-02
3416    0.21061D+00    -0.53798D-01    0.99017D+00    -0.25434D-02
3417    0.22070D+00    -0.58612D-01    0.99018D+00    -0.27643D-02
3418    0.22590D+00    -0.63456D-01    0.99020D+00    -0.29852D-02
3419    0.23108D+00    -0.68321D-01    0.99021D+00    -0.32062D-02
3420    0.23623D+00    -0.73204D-01    0.99022D+00    -0.34271D-02
3421    0.24137D+00    -0.78102D-01    0.99023D+00    -0.36481D-02
3422    0.24649D+00    -0.83013D-01    0.99024D+00    -0.38690D-02
3423    0.25159D+00    -0.87931D-01    0.99025D+00    -0.40899D-02
3424    0.25188D+00    -0.92863D-01    0.99026D+00    -0.43109D-02

3505    0.66716D-01    -0.91416D-02    0.66032D+00     0.10091D-01
3506    0.87185D-01    -0.12602D-01    0.70544D+00     0.68870D-02
3507    0.10762D+00    -0.16395D-01    0.75555D+00     0.40750D-02
3508    0.12302D+00    -0.20445D-01    0.81062D+00     0.17350D-02
3509    0.14338D+00    -0.24691D-01    0.88058D+00    -0.18879D-04
3510    0.15373D+00    -0.29087D-01    0.97025D+00    -0.99480D-03
3511    0.16903D+00    -0.33598D-01    0.99014D+00    -0.12411D-02
3512    0.17933D+00    -0.38194D-01    0.99016D+00    -0.14619D-02
3513    0.18961D+00    -0.42859D-01    0.99017D+00    -0.16827D-02
3514    0.19986D+00    -0.47576D-01    0.99018D+00    -0.19035D-02
3515    0.20515D+00    -0.52334D-01    0.99019D+00    -0.21244D-02
3516    0.21536D+00    -0.57127D-01    0.99021D+00    -0.23452D-02
3517    0.22062D+00    -0.61948D-01    0.99022D+00    -0.25660D-02
3518    0.22587D+00    -0.66790D-01    0.99023D+00    -0.27868D-02
3519    0.23111D+00    -0.71651D-01    0.99025D+00    -0.30077D-02
3520    0.23634D+00    -0.76527D-01    0.99026D+00    -0.32285D-02
3521    0.23665D+00    -0.81415D-01    0.99027D+00    -0.34493D-02
3522    0.24186D+00    -0.86318D-01    0.99029D+00    -0.36701D-02
3523    0.24706D+00    -0.91227D-01    0.99030D+00    -0.38910D-02
3524    0.24737D+00    -0.96145D-01    0.99031D+00    -0.41118D-02

3605    0.81550D-01    -0.10413D-01    0.71031D+00     0.12876D-01
3606    0.10194D+00    -0.14166D-01    0.73542D+00     0.10013D-01
3607    0.12232D+00    -0.18205D-01    0.76554D+00     0.73883D-02
3608    0.14267D+00    -0.22451D-01    0.79565D+00     0.50267D-02
3609    0.15799D+00    -0.26852D-01    0.83074D+00     0.29610D-02
3610    0.16831D+00    -0.31370D-01    0.86578D+00     0.12289D-02
3611    0.17861D+00    -0.35972D-01    0.90573D+00    -0.11986D-03
3612    0.18889D+00    -0.40641D-01    0.95549D+00    -0.10167D-02
3613    0.19916D+00    -0.45362D-01    0.99021D+00    -0.13868D-02
3614    0.20445D+00    -0.50123D-01    0.99023D+00    -0.16074D-02
3615    0.21470D+00    -0.54918D-01    0.99024D+00    -0.18280D-02
3616    0.21997D+00    -0.59739D-01    0.99026D+00    -0.20486D-02
3617    0.22523D+00    -0.64582D-01    0.99027D+00    -0.22692D-02
3618    0.23048D+00    -0.69442D-01    0.99029D+00    -0.24899D-02
3619    0.23573D+00    -0.74316D-01    0.99031D+00    -0.27105D-02
3620    0.23603D+00    -0.79206D-01    0.99032D+00    -0.29311D-02
3621    0.24127D+00    -0.84106D-01    0.99034D+00    -0.31517D-02
3622    0.24649D+00    -0.89013D-01    0.99035D+00    -0.33723D-02
3623    0.24679D+00    -0.93931D-01    0.99037D+00    -0.35929D-02
3624    0.25200D+00    -0.98853D-01    0.99039D+00    -0.38136D-02
```

NACA	XMIN	YMIN	XMAX	YMAX
3705	0.96415D-01	-0.11508D-01	0.76527D+00	0.16084D-01
3706	0.11676D+00	-0.15477D-01	0.78038D+00	0.13662D-01
3707	0.13709D+00	-0.19690D-01	0.79549D+00	0.11376D-01
3708	0.15239D+00	-0.24074D-01	0.81563D+00	0.92338D-02
3709	0.16769D+00	-0.28584D-01	0.83074D+00	0.72466D-02
3710	0.17798D+00	-0.33186D-01	0.84585D+00	0.54194D-02
3711	0.18826D+00	-0.37857D-01	0.86594D+00	0.37654D-02
3712	0.19852D+00	-0.42582D-01	0.88601D+00	0.22939D-02
3713	0.20380D+00	-0.47347D-01	0.90602D+00	0.10194D-02
3714	0.21405D+00	-0.52147D-01	0.92599D+00	-0.42883D-04
3715	0.21931D+00	-0.56973D-01	0.94589D+00	-0.87701D-03
3716	0.22457D+00	-0.61820D-01	0.97064D+00	-0.14613D-02
3717	0.22982D+00	-0.66685D-01	0.99036D+00	-0.17764D-02
3718	0.23507D+00	-0.71564D-01	0.99038D+00	-0.19966D-02
3719	0.23535D+00	-0.76455D-01	0.99040D+00	-0.22167D-02
3720	0.24059D+00	-0.81360D-01	0.99043D+00	-0.24369D-02
3721	0.24582D+00	-0.86271D-01	0.99045D+00	-0.26571D-02
3722	0.24610D+00	-0.91191D-01	0.99047D+00	-0.28773D-02
3723	0.25132D+00	-0.96117D-01	0.99049D+00	-0.30975D-02
3724	0.25160D+00	-0.10105D+00	0.99051D+00	-0.33176D-02
3805	0.11130D+00	-0.12455D-01	0.83021D+00	0.19807D-01
3806	0.13160D+00	-0.16589D-01	0.84033D+00	0.17958D-01
3807	0.14689D+00	-0.20928D-01	0.84542D+00	0.16173D-01
3808	0.16217D+00	-0.25414D-01	0.85555D+00	0.14452D-01
3809	0.17744D+00	-0.30005D-01	0.86065D+00	0.12807D-01
3810	0.18771D+00	-0.34671D-01	0.86576D+00	0.11227D-01
3811	0.19796D+00	-0.39395D-01	0.87590D+00	0.97235D-02
3812	0.20821D+00	-0.44160D-01	0.88101D+00	0.82917D-02
3813	0.21347D+00	-0.48964D-01	0.89115D+00	0.69389D-02
3814	0.21872D+00	-0.53793D-01	0.89625D+00	0.56615D-02
3815	0.22396D+00	-0.58644D-01	0.90636D+00	0.44687D-02
3816	0.22921D+00	-0.63513D-01	0.91644D+00	0.33527D-02
3817	0.23444D+00	-0.68397D-01	0.92152D+00	0.23282D-02
3818	0.23968D+00	-0.73292D-01	0.93155D+00	0.13873D-02
3819	0.23994D+00	-0.78200D-01	0.93660D+00	0.53304D-03
3820	0.24517D+00	-0.83116D-01	0.94657D+00	-0.22334D-03
3821	0.24543D+00	-0.88037D-01	0.95650D+00	-0.88797D-03
3822	0.25065D+00	-0.92970D-01	0.96637D+00	-0.14573D-02
3823	0.25090D+00	-0.97903D-01	0.97618D+00	-0.19278D-02
3824	0.25612D+00	-0.10285D+00	0.98108D+00	-0.22914D-02
3905	0.12120D+00	-0.13283D-01	0.91017D+00	0.24192D-01
3906	0.14147D+00	-0.17541D-01	0.91020D+00	0.23091D-01
3907	0.15673D+00	-0.21978D-01	0.91023D+00	0.21989D-01
3908	0.17199D+00	-0.26542D-01	0.91538D+00	0.20938D-01
3909	0.18724D+00	-0.31193D-01	0.91542D+00	0.19890D-01
3910	0.19748D+00	-0.35908D-01	0.92060D+00	0.18853D-01
3911	0.20272D+00	-0.40672D-01	0.92066D+00	0.17859D-01
3912	0.21296D+00	-0.45474D-01	0.92072D+00	0.16864D-01
3913	0.21819D+00	-0.50304D-01	0.92592D+00	0.15898D-01
3914	0.22343D+00	-0.55157D-01	0.92599D+00	0.14957D-01
3915	0.22866D+00	-0.60029D-01	0.92606D+00	0.14017D-01
3916	0.23389D+00	-0.64916D-01	0.93128D+00	0.13123D-01
3917	0.23911D+00	-0.69816D-01	0.93136D+00	0.12237D-01
3918	0.24433D+00	-0.74724D-01	0.93657D+00	0.11364D-01
3919	0.24457D+00	-0.79646D-01	0.93666D+00	0.10533D-01
3920	0.24979D+00	-0.84572D-01	0.93675D+00	0.97017D-02
3921	0.25003D+00	-0.89506D-01	0.94196D+00	0.89049D-02
3922	0.25524D+00	-0.94445D-01	0.94205D+00	0.81289D-02
3923	0.25548D+00	-0.99390D-01	0.94724D+00	0.73545D-02
3924	0.26068D+00	-0.10434D+00	0.94733D+00	0.66341D-02

NACA	XMIN	YMIN	XMAX	YMAX
4105	0.80792D-02	-0.15152D-03	0.91497D-01	0.20889D-01
4106	0.86950D-02	-0.96182D-03	0.87626D-01	0.17213D-01
4107	0.93108D-02	-0.17721D-02	0.83970D-01	0.13590D-01
4108	0.99266D-02	-0.25824D-02	0.99008D+00	-0.88399D-03
4109	0.10542D-01	-0.33927D-02	0.99009D+00	-0.11050D-02
4110	0.11158D-01	-0.42030D-02	0.99010D+00	-0.13260D-02
4111	0.19125D-01	-0.50740D-02	0.99011D+00	-0.15470D-02
4112	0.19955D-01	-0.62262D-02	0.99012D+00	-0.17680D-02
4113	0.27571D-01	-0.73871D-02	0.99013D+00	-0.19890D-02
4114	0.28538D-01	-0.88092D-02	0.99014D+00	-0.22099D-02
4115	0.34590D+00	-0.37439D-01	0.99015D+00	-0.24309D-02
4116	0.34596D+00	-0.42404D-01	0.99016D+00	-0.26519D-02
4117	0.34100D+00	-0.47374D-01	0.99017D+00	-0.28729D-02
4118	0.33604D+00	-0.52348D-01	0.99017D+00	-0.30939D-02
4119	0.33610D+00	-0.57327D-01	0.99018D+00	-0.33149D-02
4120	0.33113D+00	-0.62306D-01	0.99019D+00	-0.35359D-02
4121	0.33119D+00	-0.67291D-01	0.99020D+00	-0.37569D-02
4122	0.33125D+00	-0.72275D-01	0.99021D+00	-0.39779D-02
4123	0.32628D+00	-0.77261D-01	0.99022D+00	-0.41989D-02
4124	0.32633D+00	-0.82251D-01	0.99023D+00	-0.44199D-02
4205	0.68490D-02	-0.27660D-02	0.18570D+00	0.16276D-01
4206	0.13026D-01	-0.40630D-02	0.18112D+00	0.11589D-01
4207	0.19177D-01	-0.55151D-02	0.17662D+00	0.69310D-02
4208	0.25329D-01	-0.72019D-02	0.77070D+00	0.43396D-04
4209	0.31478D-01	-0.91344D-02	0.99010D+00	-0.99468D-03
4210	0.37619D-01	-0.11308D-01	0.99011D+00	-0.12156D-02
4211	0.49018D-01	-0.13780D-01	0.99012D+00	-0.14366D-02
4212	0.65308D-01	-0.16570D-01	0.99013D+00	-0.16575D-02
4213	0.90890D-01	-0.19773D-01	0.99014D+00	-0.18784D-02
4214	0.33559D+00	-0.30846D-01	0.99015D+00	-0.20994D-02
4215	0.33061D+00	-0.35829D-01	0.99016D+00	-0.23203D-02
4216	0.33065D+00	-0.40814D-01	0.99017D+00	-0.25412D-02
4217	0.32566D+00	-0.45803D-01	0.99019D+00	-0.27622D-02
4218	0.32570D+00	-0.50792D-01	0.99020D+00	-0.29831D-02
4219	0.32071D+00	-0.55783D-01	0.99021D+00	-0.32041D-02
4220	0.32075D+00	-0.60777D-01	0.99022D+00	-0.34250D-02
4221	0.32079D+00	-0.65771D-01	0.99023D+00	-0.36459D-02
4222	0.32082D+00	-0.70765D-01	0.99024D+00	-0.38669D-02
4223	0.31583D+00	-0.75759D-01	0.99025D+00	-0.40878D-02
4224	0.31586D+00	-0.80756D-01	0.99026D+00	-0.43087D-02
4305	0.17112D-01	-0.44353D-02	0.37515D+00	0.15015D-01
4306	0.28104D-01	-0.63108D-02	0.48040D+00	0.10279D-01
4307	0.33866D-01	-0.85100D-02	0.58564D+00	0.60493D-02
4308	0.44845D-01	-0.11010D-01	0.69580D+00	0.25270D-02
4309	0.55783D-01	-0.13803D-01	0.82575D+00	-0.49211D-04
4310	0.71757D-01	-0.16894D-01	0.99012D+00	-0.10739D-02
4311	0.87578D-01	-0.20260D-01	0.99014D+00	-0.12947D-02
4312	0.10324D+00	-0.23895D-01	0.99015D+00	-0.15156D-02
4313	0.11874D+00	-0.27780D-01	0.99016D+00	-0.17364D-02
4314	0.13892D+00	-0.31900D-01	0.99017D+00	-0.19573D-02
4315	0.15883D+00	-0.36228D-01	0.99019D+00	-0.21781D-02
4316	0.18320D+00	-0.40741D-01	0.99020D+00	-0.23990D-02
4317	0.20251D+00	-0.45410D-01	0.99021D+00	-0.26199D-02
4318	0.22621D+00	-0.50203D-01	0.99022D+00	-0.28407D-02
4319	0.24499D+00	-0.55091D-01	0.99024D+00	-0.30616D-02
4320	0.26810D+00	-0.60044D-01	0.99025D+00	-0.32824D-02
4321	0.28640D+00	-0.65032D-01	0.99026D+00	-0.35033D-02
4322	0.29549D+00	-0.70032D-01	0.99027D+00	-0.37241D-02
4323	0.30000D+00	-0.75033D-01	0.99029D+00	-0.39450D-02
4324	0.30000D+00	-0.80035D-01	0.99030D+00	-0.41658D-02

NACA	XMIN	YMIN	XMAX	YMAX
4405	0.27008D-01	-0.58643D-02	0.53031D+00	0.16895D-01
4406	0.42859D-01	-0.82834D-02	0.57546D+00	0.12785D-01
4407	0.53574D-01	-0.11050D-01	0.63064D+00	0.89913D-02
4408	0.69368D-01	-0.14131D-01	0.68580D+00	0.55993D-02
4409	0.85104D-01	-0.17499D-01	0.75592D+00	0.27047D-02
4410	0.95750D-01	-0.21123D-01	0.83091D+00	0.43706D-03
4411	0.11137D+00	-0.24968D-01	0.93555D+00	-0.97967D-03
4412	0.12692D+00	-0.29000D-01	0.99017D+00	-0.13266D-02
4413	0.14237D+00	-0.33188D-01	0.99019D+00	-0.15473D-02
4414	0.15281D+00	-0.37511D-01	0.99020D+00	-0.17680D-02
4415	0.16320D+00	-0.41940D-01	0.99022D+00	-0.19888D-02
4416	0.17354D+00	-0.46459D-01	0.99023D+00	-0.22095D-02
4417	0.18382D+00	-0.51053D-01	0.99025D+00	-0.24302D-02
4418	0.19405D+00	-0.55707D-01	0.99026D+00	-0.26510D-02
4419	0.20421D+00	-0.60408D-01	0.99027D+00	-0.28717D-02
4420	0.20952D+00	-0.65151D-01	0.99029D+00	-0.30924D-02
4421	0.21479D+00	-0.69926D-01	0.99030D+00	-0.33132D-02
4422	0.22482D+00	-0.74729D-01	0.99032D+00	-0.35339D-02
4423	0.23003D+00	-0.79557D-01	0.99033D+00	-0.37546D-02
4424	0.23522D+00	-0.84403D-01	0.99035D+00	-0.39754D-02
4505	0.41959D-01	-0.71615D-02	0.61033D+00	0.19399D-01
4506	0.57609D-01	-0.10004D-01	0.64047D+00	0.15760D-01
4507	0.73249D-01	-0.13198D-01	0.67063D+00	0.12346D-01
4508	0.88869D-01	-0.16692D-01	0.70579D+00	0.91884D-02
4509	0.10446D+00	-0.20437D-01	0.74094D+00	0.63240D-02
4510	0.12001D+00	-0.24388D-01	0.78606D+00	0.37967D-02
4511	0.13052D+00	-0.28511D-01	0.83110D+00	0.16609D-02
4512	0.14599D+00	-0.32772D-01	0.88103D+00	-0.11533D-04
4513	0.15645D+00	-0.37146D-01	0.94071D+00	-0.11107D-02
4514	0.16687D+00	-0.41611D-01	0.99024D+00	-0.15034D-02
4515	0.17726D+00	-0.46151D-01	0.99026D+00	-0.17239D-02
4516	0.18268D+00	-0.50752D-01	0.99028D+00	-0.19445D-02
4517	0.19302D+00	-0.55406D-01	0.99029D+00	-0.21650D-02
4518	0.19840D+00	-0.60101D-01	0.99031D+00	-0.23855D-02
4519	0.20378D+00	-0.64829D-01	0.99033D+00	-0.26061D-02
4520	0.21403D+00	-0.69590D-01	0.99035D+00	-0.28266D-02
4521	0.21937D+00	-0.74375D-01	0.99036D+00	-0.30471D-02
4522	0.22468D+00	-0.79181D-01	0.99038D+00	-0.32676D-02
4523	0.22512D+00	-0.84008D-01	0.99040D+00	-0.34882D-02
4524	0.23042D+00	-0.88851D-01	0.99041D+00	-0.37087D-02
4605	0.51797D-01	-0.83129D-02	0.68032D+00	0.22338D-01
4606	0.72390D-01	-0.11502D-01	0.69544D+00	0.19187D-01
4607	0.87924D-01	-0.15020D-01	0.71559D+00	0.16190D-01
4608	0.10345D+00	-0.18805D-01	0.73575D+00	0.13357D-01
4609	0.11895D+00	-0.22805D-01	0.76092D+00	0.10702D-01
4610	0.13443D+00	-0.26975D-01	0.78106D+00	0.82407D-02
4611	0.14488D+00	-0.31277D-01	0.80620D+00	0.59885D-02
4612	0.16031D+00	-0.35688D-01	0.83131D+00	0.39644D-02
4613	0.17072D+00	-0.40186D-01	0.85637D+00	0.21897D-02
4614	0.17614D+00	-0.44754D-01	0.88635D+00	0.69176D-03
4615	0.18651D+00	-0.49379D-01	0.91624D+00	-0.49895D-03
4616	0.19191D+00	-0.54050D-01	0.95094D+00	-0.13382D-02
4617	0.20225D+00	-0.58759D-01	0.99036D+00	-0.17678D-02
4618	0.20762D+00	-0.63503D-01	0.99039D+00	-0.19879D-02
4619	0.21298D+00	-0.68273D-01	0.99041D+00	-0.22081D-02
4620	0.21833D+00	-0.73066D-01	0.99043D+00	-0.24282D-02
4621	0.22368D+00	-0.77878D-01	0.99045D+00	-0.26484D-02
4622	0.22409D+00	-0.82707D-01	0.99047D+00	-0.28686D-02
4623	0.22942D+00	-0.87555D-01	0.99049D+00	-0.30887D-02
4624	0.23473D+00	-0.92413D-01	0.99052D+00	-0.33089D-02

NACA	XMIN	YMIN	XMAX	YMAX
4705	0.66704D-01	-0.93522D-02	0.75029D+00	0.25724D-01
4706	0.87202D-01	-0.12809D-01	0.76041D+00	0.23128D-01
4707	0.10266D+00	-0.16574D-01	0.77054D+00	0.20626D-01
4708	0.11812D+00	-0.20572D-01	0.78067D+00	0.18221D-01
4709	0.13356D+00	-0.24752D-01	0.79585D+00	0.15919D-01
4710	0.14898D+00	-0.29073D-01	0.80600D+00	0.13727D-01
4711	0.15938D+00	-0.33504D-01	0.81615D+00	0.11643D-01
4712	0.16977D+00	-0.38022D-01	0.83132D+00	0.96787D-02
4713	0.18015D+00	-0.42608D-01	0.84146D+00	0.78327D-02
4714	0.18553D+00	-0.47250D-01	0.85660D+00	0.61180D-02
4715	0.19589D+00	-0.51938D-01	0.87171D+00	0.45347D-02
4716	0.20125D+00	-0.56664D-01	0.88678D+00	0.30905D-02
4717	0.20661D+00	-0.61421D-01	0.90182D+00	0.17934D-02
4718	0.21197D+00	-0.66203D-01	0.91680D+00	0.65167D-03
4719	0.21731D+00	-0.71008D-01	0.93172D+00	-0.32642D-03
4720	0.22265D+00	-0.75832D-01	0.94657D+00	-0.11322D-02
4721	0.22798D+00	-0.80672D-01	0.96624D+00	-0.17554D-02
4722	0.23331D+00	-0.85523D-01	0.98091D+00	-0.21797D-02
4723	0.23368D+00	-0.90392D-01	0.99065D+00	-0.24238D-02
4724	0.23900D+00	-0.95268D-01	0.99068D+00	-0.26432D-02
4805	0.76579D-01	-0.10280D-01	0.82524D+00	0.29620D-01
4806	0.97017D-01	-0.13956D-01	0.83034D+00	0.27681D-01
4807	0.11745D+00	-0.17907D-01	0.83545D+00	0.25791D-01
4808	0.13285D+00	-0.22066D-01	0.84058D+00	0.23949D-01
4809	0.14824D+00	-0.26379D-01	0.84571D+00	0.22157D-01
4810	0.15861D+00	-0.30812D-01	0.85085D+00	0.20417D-01
4811	0.16898D+00	-0.35336D-01	0.85600D+00	0.18727D-01
4812	0.17934D+00	-0.39933D-01	0.86116D+00	0.17091D-01
4813	0.18969D+00	-0.44585D-01	0.86632D+00	0.15508D-01
4814	0.19503D+00	-0.49285D-01	0.87148D+00	0.13979D-01
4815	0.20038D+00	-0.54020D-01	0.87664D+00	0.12505D-01
4816	0.21070D+00	-0.58788D-01	0.88180D+00	0.11087D-01
4817	0.21603D+00	-0.63582D-01	0.89200D+00	0.97265D-02
4818	0.22136D+00	-0.68396D-01	0.89714D+00	0.84296D-02
4819	0.22172D+00	-0.73230D-01	0.90228D+00	0.71916D-02
4820	0.22704D+00	-0.78081D-01	0.90741D+00	0.60133D-02
4821	0.23235D+00	-0.82944D-01	0.91253D+00	0.48955D-02
4822	0.23766D+00	-0.87816D-01	0.91764D+00	0.38389D-02
4823	0.23801D+00	-0.92703D-01	0.92769D+00	0.28488D-02
4824	0.24331D+00	-0.97595D-01	0.93275D+00	0.19271D-02
4905	0.86474D-01	-0.11112D-01	0.90512D+00	0.34129D-01
4906	0.10686D+00	-0.14963D-01	0.91026D+00	0.32993D-01
4907	0.12725D+00	-0.19064D-01	0.91031D+00	0.31892D-01
4908	0.14261D+00	-0.23345D-01	0.91035D+00	0.30791D-01
4909	0.15797D+00	-0.27760D-01	0.91040D+00	0.29689D-01
4910	0.16831D+00	-0.32278D-01	0.91563D+00	0.28625D-01
4911	0.17865D+00	-0.36874D-01	0.91569D+00	0.27577D-01
4912	0.18897D+00	-0.41529D-01	0.91575D+00	0.26530D-01
4913	0.19430D+00	-0.46234D-01	0.92103D+00	0.25487D-01
4914	0.20462D+00	-0.50976D-01	0.92111D+00	0.24494D-01
4915	0.20994D+00	-0.55752D-01	0.92119D+00	0.23501D-01
4916	0.21525D+00	-0.60554D-01	0.92127D+00	0.22507D-01
4917	0.22056D+00	-0.65377D-01	0.92660D+00	0.21545D-01
4918	0.22587D+00	-0.70217D-01	0.92669D+00	0.20607D-01
4919	0.23117D+00	-0.75072D-01	0.92678D+00	0.19668D-01
4920	0.23150D+00	-0.79944D-01	0.93212D+00	0.18734D-01
4921	0.23679D+00	-0.84826D-01	0.93223D+00	0.17851D-01
4922	0.23712D+00	-0.89715D-01	0.93233D+00	0.16968D-01
4923	0.24241D+00	-0.94618D-01	0.93244D+00	0.16084D-01
4924	0.24769D+00	-0.99523D-01	0.93778D+00	0.15236D-01

NACA	XMIN	YMIN	XMAX	YMAX
5105	0.24769D+00	-0.99523D-01	0.91868D-01	0.30822D-01
5106	0.24769D+00	-0.99523D-01	0.92241D-01	0.27087D-01
5107	0.99069D-02	-0.29014D-03	0.88815D-01	0.23442D-01
5108	0.10608D-01	-0.10280D-02	0.85631D-01	0.19843D-01
5109	0.11309D-01	-0.17659D-02	0.86335D-01	0.16323D-01
5110	0.12010D-01	-0.25038D-02	0.99012D+00	-0.11038D-02
5111	0.12711D-01	-0.32416D-02	0.99013D+00	-0.13247D-02
5112	0.13412D-01	-0.39795D-02	0.99015D+00	-0.15455D-02
5113	0.14113D-01	-0.47174D-02	0.99016D+00	-0.17664D-02
5114	0.14814D-01	-0.54553D-02	0.99017D+00	-0.19873D-02
5115	0.24247D-01	-0.63294D-02	0.99018D+00	-0.22082D-02
5116	0.25196D-01	-0.73847D-02	0.99019D+00	-0.24290D-02
5117	0.26146D-01	-0.84400D-02	0.99021D+00	-0.26499D-02
5118	0.35048D-01	-0.97109D-02	0.99022D+00	-0.28708D-02
5119	0.34643D+00	-0.48036D-01	0.99023D+00	-0.30916D-02
5120	0.34650D+00	-0.53000D-01	0.99024D+00	-0.33125D-02
5121	0.34155D+00	-0.57971D-01	0.99025D+00	-0.35334D-02
5122	0.34162D+00	-0.62943D-01	0.99027D+00	-0.37543D-02
5213	0.33666D+00	-0.67920D-01	0.99028D+00	-0.39751D-02
5124	0.33673D+00	-0.72898D-01	0.99029D+00	-0.41960D-02
5205	0.72299D-02	-0.21055D-02	0.19059D+00	0.26232D-01
5206	0.76759D-02	-0.30203D-02	0.18606D+00	0.21527D-01
5207	0.14264D-01	-0.41020D-02	0.18163D+00	0.16836D-01
5208	0.14873D-01	-0.53845D-02	0.18187D+00	0.12169D-01
5209	0.21497D-01	-0.68291D-02	0.57104D+00	0.33036D-02
5210	0.28070D-01	-0.84328D-02	0.77109D+00	0.62997D-04
5211	0.34607D-01	-0.10240D-01	0.99015D+00	-0.11865D-02
5212	0.41109D-01	-0.12264D-01	0.99016D+00	-0.14072D-02
5213	0.47571D-01	-0.14506D-01	0.99018D+00	-0.16280D-02
5214	0.59322D-01	-0.16991D-01	0.99019D+00	-0.18488D-02
5215	0.75847D-01	-0.19777D-01	0.99020D+00	-0.20696D-02
5216	0.34087D+00	-0.31089D-01	0.99022D+00	-0.22904D-02
5217	0.33589D+00	-0.36066D-01	0.99023D+00	-0.25112D-02
5218	0.33091D+00	-0.41046D-01	0.99025D+00	-0.27320D-02
5219	0.33096D+00	-0.46030D-01	0.99026D+00	-0.29527D-02
5220	0.33101D+00	-0.51015D-01	0.99027D+00	-0.31735D-02
5221	0.32602D+00	-0.56004D-01	0.99029D+00	-0.33943D-02
5222	0.32607D+00	-0.60994D-01	0.99030D+00	-0.36151D-02
5223	0.32612D+00	-0.65983D-01	0.99031D+00	-0.38359D-02
5224	0.32112D+00	-0.70975D-01	0.99033D+00	-0.40567D-02
5305	0.12177D-01	-0.34789D-02	0.30000D+00	0.24993D-01
5306	0.18115D-01	-0.49619D-02	0.35015D+00	0.20002D-01
5307	0.24089D-01	-0.66995D-02	0.43545D+00	0.15158D-01
5308	0.30094D-01	-0.86845D-02	0.52077D+00	0.10646D-01
5309	0.41446D-01	-0.10907D-01	0.60606D+00	0.66084D-02
5310	0.47465D-01	-0.13397D-01	0.69625D+00	0.31677D-02
5311	0.58721D-01	-0.16118D-01	0.79624D+00	0.47732D-03
5312	0.69888D-01	-0.19080D-01	0.93565D+00	-0.11532D-02
5313	0.80961D-01	-0.22278D-01	0.99020D+00	-0.14502D-02
5314	0.96951D-01	-0.25708D-01	0.99022D+00	-0.16709D-02
5315	0.10776D+00	-0.29365D-01	0.99023D+00	-0.18915D-02
5316	0.12334D+00	-0.33239D-01	0.99025D+00	-0.21122D-02
5317	0.14346D+00	-0.37319D-01	0.99026D+00	-0.23328D-02
5318	0.15848D+00	-0.41589D-01	0.99028D+00	-0.25535D-02
5319	0.17789D+00	-0.46033D-01	0.99030D+00	-0.27742D-02
5320	0.19692D+00	-0.50628D-01	0.99031D+00	-0.29948D-02
5321	0.21559D+00	-0.55352D-01	0.99033D+00	-0.32155D-02
5322	0.23392D+00	-0.60180D-01	0.99034D+00	-0.34361D-02
5323	0.25632D+00	-0.65087D-01	0.99036D+00	-0.36568D-02
5324	0.27398D+00	-0.70048D-01	0.99037D+00	-0.38775D-02

NACA	XMIN	YMIN	XMAX	YMAX
5405	0.22272D-01	-0.46913D-02	0.49028D+00	0.26560D-01
5406	0.27983D-01	-0.66740D-02	0.52043D+00	0.22186D-01
5407	0.38948D-01	-0.89389D-02	0.55562D+00	0.17996D-01
5408	0.49906D-01	-0.11495D-01	0.59583D+00	0.14035D-01
5409	0.60851D-01	-0.14329D-01	0.64105D+00	0.10354D-01
5410	0.71773D-01	-0.17417D-01	0.68626D+00	0.70081D-02
5411	0.82664D-01	-0.20736D-01	0.74141D+00	0.40601D-02
5412	0.93516D-01	-0.24265D-01	0.80146D+00	0.15870D-02
5413	0.10935D+00	-0.27986D-01	0.86631D+00	-0.29915D-03
5414	0.12008D+00	-0.31879D-01	0.96061D+00	-0.13919D-02
5415	0.13075D+00	-0.35919D-01	0.99027D+00	-0.16542D-02
5416	0.14136D+00	-0.40088D-01	0.99029D+00	-0.18747D-02
5417	0.15680D+00	-0.44369D-01	0.99031D+00	-0.20952D-02
5418	0.16238D+00	-0.48747D-01	0.99033D+00	-0.23156D-02
5419	0.17278D+00	-0.53209D-01	0.99034D+00	-0.25361D-02
5420	0.18311D+00	-0.57739D-01	0.99036D+00	-0.27566D-02
5421	0.19337D+00	-0.62326D-01	0.99038D+00	-0.29770D-02
5422	0.19878D+00	-0.66967D-01	0.99040D+00	-0.31975D-02
5423	0.20416D+00	-0.71647D-01	0.99042D+00	-0.34180D-02
5424	0.21423D+00	-0.76365D-01	0.99043D+00	-0.36384D-02
5505	0.27034D-01	-0.58282D-02	0.58533D+00	0.29038D-01
5506	0.37782D-01	-0.82033D-02	0.60547D+00	0.25190D-01
5507	0.53673D-01	-0.10908D-01	0.62563D+00	0.21491D-01
5508	0.64435D-01	-0.13917D-01	0.65083D+00	0.17962D-01
5509	0.75195D-01	-0.17184D-01	0.67602D+00	0.14623D-01
5510	0.91016D-01	-0.20689D-01	0.70623D+00	0.11495D-01
5511	0.10174D+00	-0.24394D-01	0.73643D+00	0.86014D-02
5512	0.11747D+00	-0.28273D-01	0.76659D+00	0.59706D-02
5513	0.12812D+00	-0.32305D-01	0.80170D+00	0.36339D-02
5514	0.13874D+00	-0.36462D-01	0.84172D+00	0.16290D-02
5515	0.14933D+00	-0.40726D-01	0.88160D+00	0.74415D-05
5516	0.15988D+00	-0.45080D-01	0.93122D+00	-0.11617D-02
5517	0.16545D+00	-0.49513D-01	0.98546D+00	-0.17620D-02
5518	0.17593D+00	-0.54013D-01	0.99039D+00	-0.19827D-02
5519	0.18146D+00	-0.58566D-01	0.99041D+00	-0.22029D-02
5520	0.19186D+00	-0.63167D-01	0.99043D+00	-0.24230D-02
5521	0.19734D+00	-0.67812D-01	0.99045D+00	-0.26432D-02
5522	0.20281D+00	-0.72490D-01	0.99047D+00	-0.28633D-02
5523	0.20825D+00	-0.77198D-01	0.99050D+00	-0.30835D-02
5524	0.21367D+00	-0.81933D-01	0.99052D+00	-0.33036D-02
5605	0.36966D-01	-0.68625D-02	0.66032D+00	0.32038D-01
5606	0.52684D-01	-0.95835D-02	0.67546D+00	0.28734D-01
5607	0.63321D-01	-0.12638D-01	0.69062D+00	0.25541D-01
5608	0.79041D-01	-0.15988D-01	0.70579D+00	0.22467D-01
5609	0.94739D-01	-0.19578D-01	0.72097D+00	0.19519D-01
5610	0.10537D+00	-0.23374D-01	0.73616D+00	0.16705D-01
5611	0.12102D+00	-0.27344D-01	0.75638D+00	0.14035D-01
5612	0.13161D+00	-0.31456D-01	0.77156D+00	0.11516D-01
5613	0.14219D+00	-0.35687D-01	0.79175D+00	0.91610D-02
5614	0.15274D+00	-0.40017D-01	0.81192D+00	0.69786D-02
5615	0.16327D+00	-0.44429D-01	0.83205D+00	0.49820D-02
5616	0.16880D+00	-0.48911D-01	0.85213D+00	0.31844D-02
5617	0.17929D+00	-0.53452D-01	0.87713D+00	0.16027D-02
5618	0.18479D+00	-0.58042D-01	0.90203D+00	0.25405D-03
5619	0.19029D+00	-0.62673D-01	0.92681D+00	-0.83698D-03
5620	0.19577D+00	-0.67341D-01	0.95146D+00	-0.16442D-02
5621	0.20617D+00	-0.72041D-01	0.98083D+00	-0.21316D-02
5622	0.20670D+00	-0.76767D-01	0.99059D+00	-0.23620D-02
5623	0.21214D+00	-0.81519D-01	0.99062D+00	-0.25816D-02
5624	0.21758D+00	-0.86292D-01	0.99064D+00	-0.28012D-02

NACA	XMIN	YMIN	XMAX	YMAX
5705	0.46876D-01	-0.78096D-02	0.74030D+00	0.35516D-01
5706	0.62485D-01	-0.10822D-01	0.74540D+00	0.32819D-01
5707	0.78100D-01	-0.14162D-01	0.75555D+00	0.30197D-01
5708	0.93710D-01	-0.17772D-01	0.76572D+00	0.27648D-01
5709	0.10931D+00	-0.21602D-01	0.77590D+00	0.25175D-01
5710	0.11986D+00	-0.25611D-01	0.78105D+00	0.22785D-01
5711	0.13542D+00	-0.29766D-01	0.79125D+00	0.20477D-01
5712	0.14595D+00	-0.34041D-01	0.80146D+00	0.18254D-01
5713	0.15646D+00	-0.38412D-01	0.81166D+00	0.16118D-01
5714	0.16196D+00	-0.42862D-01	0.82186D+00	0.14075D-01
5715	0.17244D+00	-0.47382D-01	0.83206D+00	0.12125D-01
5716	0.18291D+00	-0.51953D-01	0.84224D+00	0.10273D-01
5717	0.18838D+00	-0.56575D-01	0.85241D+00	0.85225D-02
5718	0.19385D+00	-0.61235D-01	0.86257D+00	0.68759D-02
5719	0.19930D+00	-0.65929D-01	0.87270D+00	0.53370D-02
5720	0.20475D+00	-0.70651D-01	0.88778D+00	0.39142D-02
5721	0.21019D+00	-0.75399D-01	0.89785D+00	0.26073D-02
5722	0.21562D+00	-0.80168D-01	0.90787D+00	0.14191D-02
5723	0.22105D+00	-0.84955D-01	0.92278D+00	0.36165D-03
5724	0.22153D+00	-0.89757D-01	0.93271D+00	-0.56777D-03
5805	0.56783D-01	-0.86784D-02	0.82025D+00	0.39508D-01
5806	0.72315D-01	-0.11933D-01	0.82537D+00	0.37514D-01
5807	0.92898D-01	-0.15502D-01	0.82543D+00	0.35564D-01
5808	0.10843D+00	-0.19317D-01	0.83057D+00	0.33654D-01
5809	0.11893D+00	-0.23330D-01	0.83573D+00	0.31780D-01
5810	0.13444D+00	-0.27500D-01	0.84090D+00	0.29944D-01
5811	0.14493D+00	-0.31793D-01	0.84609D+00	0.28147D-01
5812	0.15540D+00	-0.36186D-01	0.84619D+00	0.26391D-01
5813	0.16587D+00	-0.40660D-01	0.85139D+00	0.24682D-01
5814	0.17632D+00	-0.45200D-01	0.85660D+00	0.23014D-01
5815	0.18177D+00	-0.49798D-01	0.86181D+00	0.21388D-01
5816	0.18721D+00	-0.54438D-01	0.86702D+00	0.19804D-01
5817	0.19763D+00	-0.59118D-01	0.87224D+00	0.18263D-01
5818	0.20306D+00	-0.63832D-01	0.87746D+00	0.16766D-01
5819	0.20848D+00	-0.68573D-01	0.88267D+00	0.15313D-01
5820	0.21390D+00	-0.73337D-01	0.88281D+00	0.13909D-01
5821	0.21434D+00	-0.78121D-01	0.88802D+00	0.12553D-01
5822	0.21975D+00	-0.82926D-01	0.89322D+00	0.11245D-01
5823	0.22515D+00	-0.87746D-01	0.89841D+00	0.99829D-02
5824	0.23054D+00	-0.92577D-01	0.90359D+00	0.87692D-02
5905	0.66694D-01	-0.94754D-02	0.90514D+00	0.44105D-01
5906	0.87207D-01	-0.12935D-01	0.90517D+00	0.42951D-01
5907	0.10268D+00	-0.16690D-01	0.90520D+00	0.41797D-01
5908	0.11816D+00	-0.20669D-01	0.91044D+00	0.40695D-01
5909	0.13363D+00	-0.24822D-01	0.91050D+00	0.39594D-01
5910	0.14408D+00	-0.29113D-01	0.91055D+00	0.38493D-01
5911	0.15452D+00	-0.33511D-01	0.91061D+00	0.37392D-01
5912	0.16495D+00	-0.37995D-01	0.91594D+00	0.36317D-01
5913	0.17538D+00	-0.42548D-01	0.91602D+00	0.35271D-01
5914	0.18079D+00	-0.47156D-01	0.91610D+00	0.34224D-01
5915	0.19120D+00	-0.51813D-01	0.91618D+00	0.33178D-01
5916	0.19661D+00	-0.56509D-01	0.92159D+00	0.32136D-01
5917	0.20201D+00	-0.61236D-01	0.92169D+00	0.31144D-01
5918	0.20741D+00	-0.65990D-01	0.92178D+00	0.30153D-01
5919	0.21280D+00	-0.70769D-01	0.92188D+00	0.29161D-01
5920	0.21819D+00	-0.75567D-01	0.92198D+00	0.28170D-01
5921	0.22358D+00	-0.80382D-01	0.92746D+00	0.27221D-01
5922	0.22399D+00	-0.85211D-01	0.92757D+00	0.26285D-01
5923	0.22936D+00	-0.90058D-01	0.92769D+00	0.25349D-01
5924	0.23473D+00	-0.94913D-01	0.92781D+00	0.24413D-01

NACA	XMIN	YMIN	XMAX	YMAX
6105	0.23473D+00	-0.94913D-01	0.92236D-01	0.40763D-01
6106	0.23473D+00	-0.94913D-01	0.92684D-01	0.37036D-01
6107	0.23473D+00	-0.94913D-01	0.89556D-01	0.33339D-01
6108	0.23473D+00	-0.94913D-01	0.90207D-01	0.29723D-01
6109	0.11886D-01	-0.19036D-03	0.87539D-01	0.26188D-01
6110	0.12651D-01	-0.86151D-03	0.85057D-01	0.22727D-01
6111	0.13416D-01	-0.15327D-02	0.71647D+00	-0.21707D-03
6112	0.14181D-01	-0.22038D-02	0.99017D+00	-0.13228D-02
6113	0.14946D-01	-0.28750D-02	0.99019D+00	-0.15435D-02
6114	0.15712D-01	-0.35461D-02	0.99020D+00	-0.17643D-02
6115	0.16477D-01	-0.42173D-02	0.99022D+00	-0.19850D-02
6116	0.17242D-01	-0.48884D-02	0.99023D+00	-0.22057D-02
6117	0.18007D-01	-0.55596D-02	0.99025D+00	-0.24264D-02
6118	0.18772D-01	-0.62307D-02	0.99026D+00	-0.26472D-02
6119	0.29793D-01	-0.69273D-02	0.99028D+00	-0.28679D-02
6120	0.30835D-01	-0.78919D-02	0.99029D+00	-0.30886D-02
6121	0.31877D-01	-0.88565D-02	0.99031D+00	-0.33093D-02
6122	0.42016D-01	-0.98365D-02	0.99032D+00	-0.35301D-02
6123	0.43244D-01	-0.11040D-01	0.99033D+00	-0.37508D-02
6124	0.34716D+00	-0.63594D-01	0.99035D+00	-0.39715D-02
6205	0.75696D-02	-0.14299D-02	0.19071D+00	0.36210D-01
6206	0.80835D-02	-0.23084D-02	0.19085D+00	0.31483D-01
6207	0.85974D-02	-0.31869D-02	0.18648D+00	0.26782D-01
6208	0.91113D-02	-0.40654D-02	0.18224D+00	0.22090D-01
6209	0.16328D-01	-0.52511D-02	0.18252D+00	0.17426D-01
6210	0.17031D-01	-0.64845D-02	0.17847D+00	0.12786D-01
6211	0.24180D-01	-0.78778D-02	0.61158D+00	0.32007D-02
6212	0.25014D-01	-0.93815D-02	0.77157D+00	0.88418D-04
6213	0.32147D-01	-0.11094D-01	0.99021D+00	-0.13772D-02
6214	0.39180D-01	-0.12947D-01	0.99023D+00	-0.15978D-02
6215	0.46129D-01	-0.14976D-01	0.99025D+00	-0.18184D-02
6216	0.52999D-01	-0.17200D-01	0.99026D+00	-0.20390D-02
6217	0.65294D-01	-0.19681D-01	0.99028D+00	-0.22596D-02
6218	0.87330D-01	-0.22473D-01	0.99029D+00	-0.24802D-02
6219	0.34124D+00	-0.36310D-01	0.99031D+00	-0.27008D-02
6220	0.33626D+00	-0.41286D-01	0.99033D+00	-0.29214D-02
6221	0.33632D+00	-0.46264D-01	0.99034D+00	-0.31420D-02
6222	0.33134D+00	-0.51246D-01	0.99036D+00	-0.33626D-02
6223	0.33140D+00	-0.56231D-01	0.99038D+00	-0.35832D-02
6224	0.33146D+00	-0.61215D-01	0.99039D+00	-0.38038D-02
6305	0.68627D-02	-0.27523D-02	0.30000D+00	0.34993D-01
6306	0.13072D-01	-0.40119D-02	0.30000D+00	0.29991D-01
6307	0.19276D-01	-0.54030D-02	0.34017D+00	0.24996D-01
6308	0.19887D-01	-0.70106D-02	0.41052D+00	0.20093D-01
6309	0.26190D-01	-0.88472D-02	0.48090D+00	0.15424D-01
6310	0.32501D-01	-0.10874D-01	0.55126D+00	0.11096D-01
6311	0.44293D-01	-0.13117D-01	0.62158D+00	0.71975D-02
6312	0.50572D-01	-0.15563D-01	0.69679D+00	0.38145D-02
6313	0.62178D-01	-0.18200D-01	0.77682D+00	0.10535D-02
6314	0.68407D-01	-0.21060D-01	0.87644D+00	-0.90363D-03
6315	0.79822D-01	-0.24121D-01	0.99028D+00	-0.16043D-02
6316	0.91091D-01	-0.27387D-01	0.99030D+00	-0.18247D-02
6317	0.10721D+00	-0.30857D-01	0.99032D+00	-0.20451D-02
6318	0.11810D+00	-0.34537D-01	0.99034D+00	-0.22655D-02
6319	0.13365D+00	-0.38411D-01	0.99035D+00	-0.24860D-02
6320	0.14886D+00	-0.42478D-01	0.99037D+00	-0.27064D-02
6321	0.16375D+00	-0.46726D-01	0.99039D+00	-0.29268D-02
6322	0.18282D+00	-0.51144D-01	0.99041D+00	-0.31472D-02
6323	0.20139D+00	-0.55712D-01	0.99043D+00	-0.33676D-02
6324	0.21949D+00	-0.60412D-01	0.99045D+00	-0.35881D-02

NACA	XMIN	YMIN	XMAX	YMAX
6405	0.11993D-01	-0.38508D-02	0.47027D+00	0.36380D-01
6406	0.17862D-01	-0.54977D-02	0.49040D+00	0.31873D-01
6407	0.29130D-01	-0.74172D-02	0.51558D+00	0.27486D-01
6408	0.35063D-01	-0.95823D-02	0.54580D+00	0.23247D-01
6409	0.41026D-01	-0.11972D-01	0.57604D+00	0.19185D-01
6410	0.52284D-01	-0.14619D-01	0.61131D+00	0.15336D-01
6411	0.63498D-01	-0.17478D-01	0.64656D+00	0.11735D-01
6412	0.74664D-01	-0.20546D-01	0.68681D+00	0.84228D-02
6413	0.85775D-01	-0.23814D-01	0.73200D+00	0.54419D-02
6414	0.96826D-01	-0.27267D-01	0.78210D+00	0.28432D-02
6415	0.10781D+00	-0.30890D-01	0.83204D+00	0.69611D-03
6416	0.11872D+00	-0.34668D-01	0.89666D+00	-0.89993D-03
6417	0.12956D+00	-0.38585D-01	0.98055D+00	-0.17521D-02
6418	0.14032D+00	-0.42627D-01	0.99039D+00	-0.19793D-02
6419	0.14609D+00	-0.46781D-01	0.99041D+00	-0.21994D-02
6420	0.15671D+00	-0.51036D-01	0.99043D+00	-0.24196D-02
6421	0.16724D+00	-0.55376D-01	0.99045D+00	-0.26397D-02
6422	0.17767D+00	-0.59789D-01	0.99048D+00	-0.28598D-02
6423	0.18325D+00	-0.64270D-01	0.99050D+00	-0.30800D-02
6424	0.19353D+00	-0.68807D-01	0.99052D+00	-0.33001D-02
6505	0.22208D-01	-0.48774D-02	0.56531D+00	0.38820D-01
6506	0.27906D-01	-0.68965D-02	0.58548D+00	0.34847D-01
6507	0.38867D-01	-0.92184D-02	0.60064D+00	0.30988D-01
6508	0.49833D-01	-0.11815D-01	0.62084D+00	0.27251D-01
6509	0.60798D-01	-0.14671D-01	0.64106D+00	0.23650D-01
6510	0.71755D-01	-0.17764D-01	0.66129D+00	0.20200D-01
6511	0.82695D-01	-0.21072D-01	0.68153D+00	0.16913D-01
6512	0.93613D-01	-0.24572D-01	0.70678D+00	0.13807D-01
6513	0.10450D+00	-0.28243D-01	0.73201D+00	0.10896D-01
6514	0.11536D+00	-0.32065D-01	0.75722D+00	0.82007D-02
6515	0.12617D+00	-0.36019D-01	0.78738D+00	0.57402D-02
6516	0.13694D+00	-0.40089D-01	0.81747D+00	0.35395D-02
6517	0.14268D+00	-0.44263D-01	0.84747D+00	0.16282D-02
6518	0.15338D+00	-0.48526D-01	0.88231D+00	0.40878D-04
6519	0.16402D+00	-0.52862D-01	0.92190D+00	-0.11734D-02
6520	0.16969D+00	-0.57271D-01	0.96612D+00	-0.19432D-02
6521	0.17534D+00	-0.61732D-01	0.99054D+00	-0.22375D-02
6522	0.18586D+00	-0.66248D-01	0.99057D+00	-0.24572D-02
6523	0.19145D+00	-0.70809D-01	0.99059D+00	-0.26769D-02
6524	0.19702D+00	-0.75409D-01	0.99062D+00	-0.28966D-02
6605	0.27051D-01	-0.58041D-02	0.65032D+00	0.41847D-01
6606	0.37816D-01	-0.81562D-02	0.66045D+00	0.38447D-01
6607	0.48605D-01	-0.10826D-01	0.67564D+00	0.35134D-01
6608	0.59410D-01	-0.13780D-01	0.68581D+00	0.31915D-01
6609	0.75332D-01	-0.16996D-01	0.69599D+00	0.28790D-01
6610	0.86130D-01	-0.20433D-01	0.71122D+00	0.25772D-01
6611	0.96921D-01	-0.24061D-01	0.72647D+00	0.22858D-01
6612	0.10770D+00	-0.27857D-01	0.73668D+00	0.20058D-01
6613	0.11846D+00	-0.31798D-01	0.75192D+00	0.17380D-01
6614	0.12919D+00	-0.35865D-01	0.76716D+00	0.14827D-01
6615	0.13990D+00	-0.40037D-01	0.78239D+00	0.12406D-01
6616	0.15059D+00	-0.44300D-01	0.79760D+00	0.10125D-01
6617	0.15624D+00	-0.48640D-01	0.81780D+00	0.79922D-02
6618	0.16687D+00	-0.53050D-01	0.83295D+00	0.60169D-02
6619	0.17250D+00	-0.57517D-01	0.85303D+00	0.42055D-02
6620	0.17812D+00	-0.62032D-01	0.86809D+00	0.25724D-02
6621	0.18867D+00	-0.66594D-01	0.88804D+00	0.11272D-02
6622	0.19425D+00	-0.71195D-01	0.90789D+00	-0.11664D-03
6623	0.19982D+00	-0.75829D-01	0.92762D+00	-0.11437D-02
6624	0.20537D+00	-0.80492D-01	0.95210D+00	-0.19315D-02

NACA	XMIN	YMIN	XMAX	YMAX
6705	0.37038D-01	-0.66642D-02	0.73028D+00	0.45379D-01
6706	0.47691D-01	-0.93069D-02	0.74044D+00	0.42620D-01
6707	0.63466D-01	-0.12271D-01	0.74556D+00	0.39921D-01
6708	0.74154D-01	-0.15523D-01	0.75576D+00	0.37277D-01
6709	0.89925D-01	-0.19010D-01	0.76092D+00	0.34702D-01
6710	0.10061D+00	-0.22707D-01	0.76608D+00	0.32185D-01
6711	0.11130D+00	-0.26573D-01	0.77633D+00	0.29738D-01
6712	0.12197D+00	-0.30583D-01	0.78151D+00	0.27354D-01
6713	0.13264D+00	-0.34717D-01	0.79177D+00	0.25043D-01
6714	0.14328D+00	-0.38954D-01	0.79698D+00	0.22799D-01
6715	0.15391D+00	-0.43276D-01	0.80724D+00	0.20634D-01
6716	0.15951D+00	-0.47672D-01	0.81750D+00	0.18539D-01
6717	0.17011D+00	-0.52133D-01	0.82271D+00	0.16523D-01
6718	0.17569D+00	-0.56647D-01	0.83296D+00	0.14589D-01
6719	0.18127D+00	-0.61206D-01	0.84319D+00	0.12734D-01
6720	0.19180D+00	-0.65805D-01	0.84839D+00	0.10961D-01
6721	0.19736D+00	-0.70442D-01	0.85859D+00	0.92793D-02
6722	0.20290D+00	-0.75107D-01	0.86876D+00	0.76851D-02
6723	0.20348D+00	-0.79801D-01	0.87890D+00	0.61814D-02
6724	0.20901D+00	-0.84519D-01	0.88900D+00	0.47715D-02
6805	0.41897D-01	-0.74643D-02	0.81523D+00	0.49434D-01
6806	0.57560D-01	-0.10360D-01	0.82036D+00	0.47411D-01
6807	0.73232D-01	-0.13576D-01	0.82042D+00	0.45413D-01
6808	0.88905D-01	-0.17059D-01	0.82559D+00	0.43460D-01
6809	0.99517D-01	-0.20770D-01	0.83077D+00	0.41531D-01
6810	0.11518D+00	-0.24661D-01	0.83086D+00	0.39629D-01
6811	0.12578D+00	-0.28708D-01	0.83607D+00	0.37774D-01
6812	0.13638D+00	-0.32879D-01	0.84130D+00	0.35945D-01
6813	0.14697D+00	-0.37153D-01	0.84654D+00	0.34144D-01
6814	0.15754D+00	-0.41512D-01	0.84666D+00	0.32388D-01
6815	0.16310D+00	-0.45949D-01	0.85192D+00	0.30665D-01
6816	0.17365D+00	-0.50442D-01	0.85719D+00	0.28971D-01
6817	0.17919D+00	-0.54992D-01	0.85732D+00	0.27315D-01
6818	0.18472D+00	-0.59585D-01	0.86260D+00	0.25701D-01
6819	0.19025D+00	-0.64215D-01	0.86788D+00	0.24119D-01
6820	0.19577D+00	-0.68879D-01	0.87316D+00	0.22568D-01
6821	0.20129D+00	-0.73572D-01	0.87332D+00	0.21064D-01
6822	0.20679D+00	-0.78290D-01	0.87860D+00	0.19598D-01
6823	0.21229D+00	-0.83030D-01	0.88387D+00	0.18165D-01
6824	0.21778D+00	-0.87788D-01	0.88913D+00	0.16767D-01
6905	0.51850D-01	-0.82137D-02	0.90517D+00	0.54081D-01
6906	0.67434D-01	-0.11325D-01	0.90521D+00	0.52927D-01
6907	0.83030D-01	-0.14750D-01	0.90524D+00	0.51773D-01
6908	0.98629D-01	-0.18427D-01	0.90528D+00	0.50619D-01
6909	0.10918D+00	-0.22309D-01	0.91059D+00	0.49499D-01
6910	0.12477D+00	-0.26360D-01	0.91066D+00	0.48399D-01
6911	0.13532D+00	-0.30543D-01	0.91073D+00	0.47299D-01
6912	0.14586D+00	-0.34836D-01	0.91079D+00	0.46199D-01
6913	0.15639D+00	-0.39218D-01	0.91086D+00	0.45099D-01
6914	0.16692D+00	-0.43673D-01	0.91632D+00	0.44017D-01
6915	0.17242D+00	-0.48194D-01	0.91641D+00	0.42972D-01
6916	0.17793D+00	-0.52763D-01	0.91651D+00	0.41927D-01
6917	0.18842D+00	-0.57379D-01	0.91660D+00	0.40882D-01
6918	0.19392D+00	-0.62033D-01	0.91669D+00	0.39836D-01
6919	0.19940D+00	-0.66718D-01	0.92226D+00	0.38802D-01
6920	0.20488D+00	-0.71431D-01	0.92237D+00	0.37813D-01
6921	0.21036D+00	-0.76168D-01	0.92249D+00	0.36823D-01
6922	0.21583D+00	-0.80924D-01	0.92261D+00	0.35834D-01
6923	0.21632D+00	-0.85703D-01	0.92273D+00	0.34845D-01
6924	0.22178D+00	-0.90498D-01	0.92836D+00	0.33864D-01

NACA	XMIN	YMIN	XMAX	YMAX
7105	0.22178D+00	-0.90498D-01	0.96337D-01	0.50721D-01
7106	0.22178D+00	-0.90498D-01	0.93123D-01	0.46993D-01
7107	0.22178D+00	-0.90498D-01	0.93644D-01	0.43275D-01
7108	0.22178D+00	-0.90498D-01	0.91041D-01	0.39661D-01
7109	0.22178D+00	-0.90498D-01	0.88710D-01	0.36092D-01
7110	0.22178D+00	-0.90498D-01	0.89678D-01	0.32636D-01
7111	0.22178D+00	-0.90498D-01	0.87718D-01	0.29287D-01
7112	0.14762D-01	-0.51463D-03	0.85823D-01	0.26025D-01
7113	0.15575D-01	-0.11263D-02	0.76687D+00	-0.69203D-03
7114	0.16389D-01	-0.17379D-02	0.99024D+00	-0.15409D-02
7115	0.17202D-01	-0.23495D-02	0.99025D+00	-0.17614D-02
7116	0.18016D-01	-0.29612D-02	0.99027D+00	-0.19820D-02
7117	0.18829D-01	-0.35728D-02	0.99029D+00	-0.22025D-02
7118	0.19643D-01	-0.41844D-02	0.99031D+00	-0.24231D-02
7119	0.20456D-01	-0.47961D-02	0.99032D+00	-0.26436D-02
7120	0.21270D-01	-0.54077D-02	0.99034D+00	-0.28642D-02
7121	0.22083D-01	-0.60193D-02	0.99036D+00	-0.30847D-02
7122	0.22896D-01	-0.66310D-02	0.99037D+00	-0.33053D-02
7123	0.23710D-01	-0.72426D-02	0.99039D+00	-0.35258D-02
7124	0.36690D-01	-0.78825D-02	0.99041D+00	-0.37464D-02
7205	0.78687D-02	-0.74693D-03	0.19083D+00	0.46189D-01
7206	0.84424D-02	-0.15876D-02	0.19099D+00	0.41462D-01
7207	0.90161D-02	-0.24282D-02	0.18673D+00	0.36738D-01
7208	0.95899D-02	-0.32688D-02	0.18697D+00	0.32042D-01
7209	0.10164D-01	-0.41095D-02	0.18294D+00	0.27353D-01
7210	0.17862D-01	-0.49972D-02	0.18326D+00	0.22692D-01
7211	0.18648D-01	-0.61794D-02	0.17945D+00	0.18053D-01
7212	0.19434D-01	-0.73616D-02	0.17577D+00	0.13440D-01
7213	0.27151D-01	-0.86598D-02	0.63720D+00	0.31421D-02
7214	0.28086D-01	-0.10103D-01	0.77214D+00	0.12081D-03
7215	0.35723D-01	-0.11657D-01	0.97550D+00	-0.15653D-02
7216	0.43209D-01	-0.13323D-01	0.99030D+00	-0.17871D-02
7217	0.44347D-01	-0.15181D-01	0.99032D+00	-0.20075D-02
7218	0.51784D-01	-0.17187D-01	0.99034D+00	-0.22279D-02
7219	0.64970D-01	-0.19390D-01	0.99036D+00	-0.24482D-02
7220	0.77539D-01	-0.21830D-01	0.99038D+00	-0.26686D-02
7221	0.34665D+00	-0.36558D-01	0.99040D+00	-0.28890D-02
7222	0.34167D+00	-0.41530D-01	0.99042D+00	-0.31094D-02
7223	0.33669D+00	-0.46504D-01	0.99044D+00	-0.33298D-02
7224	0.33676D+00	-0.51482D-01	0.99046D+00	-0.35502D-02
7305	0.71224D-02	-0.23112D-02	0.30000D+00	0.44993D-01
7306	0.75469D-02	-0.32362D-02	0.30000D+00	0.39991D-01
7307	0.14087D-01	-0.44703D-02	0.30000D+00	0.34990D-01
7308	0.14671D-01	-0.57645D-02	0.33017D+00	0.29992D-01
7309	0.21273D-01	-0.73244D-02	0.39056D+00	0.25056D-01
7310	0.27853D-01	-0.90067D-02	0.45100D+00	0.20290D-01
7311	0.34427D-01	-0.10856D-01	0.51144D+00	0.15781D-01
7312	0.40998D-01	-0.12886D-01	0.57185D+00	0.11600D-01
7313	0.47564D-01	-0.15097D-01	0.63220D+00	0.78077D-02
7314	0.54119D-01	-0.17487D-01	0.69744D+00	0.44685D-02
7315	0.60659D-01	-0.20052D-01	0.76749D+00	0.16602D-02
7316	0.72573D-01	-0.22797D-01	0.84718D+00	-0.49571D-03
7317	0.79015D-01	-0.25732D-01	0.96090D+00	-0.17307D-02
7318	0.90648D-01	-0.28856D-01	0.99039D+00	-0.19768D-02
7319	0.10208D+00	-0.32168D-01	0.99041D+00	-0.21969D-02
7320	0.11331D+00	-0.35671D-01	0.99043D+00	-0.24171D-02
7321	0.12921D+00	-0.39372D-01	0.99046D+00	-0.26372D-02
7322	0.14466D+00	-0.43263D-01	0.99048D+00	-0.28573D-02
7323	0.15968D+00	-0.47344D-01	0.99050D+00	-0.30775D-02
7324	0.17429D+00	-0.51607D-01	0.99052D+00	-0.32976D-02

NACA	XMIN	YMIN	XMAX	YMAX
7405	0.12293D-01	-0.32621D-02	0.45525D+00	0.46268D-01
7406	0.18294D-01	-0.46269D-02	0.47540D+00	0.41685D-01
7407	0.18843D-01	-0.62566D-02	0.49055D+00	0.37186D-01
7408	0.24964D-01	-0.81033D-02	0.51577D+00	0.32791D-01
7409	0.36561D-01	-0.10159D-01	0.53600D+00	0.28518D-01
7410	0.42715D-01	-0.12442D-01	0.56629D+00	0.24390D-01
7411	0.48889D-01	-0.14920D-01	0.59157D+00	0.20433D-01
7412	0.60409D-01	-0.17582D-01	0.62188D+00	0.16671D-01
7413	0.66587D-01	-0.20456D-01	0.65719D+00	0.13132D-01
7414	0.78014D-01	-0.23497D-01	0.68746D+00	0.98446D-02
7415	0.84170D-01	-0.26717D-01	0.72769D+00	0.68423D-02
7416	0.95485D-01	-0.30103D-01	0.76783D+00	0.41603D-02
7417	0.10671D+00	-0.33638D-01	0.80786D+00	0.18446D-02
7418	0.11783D+00	-0.37315D-01	0.85764D+00	-0.43198D-04
7419	0.12386D+00	-0.41125D-01	0.91699D+00	-0.14113D-02
7420	0.13483D+00	-0.45059D-01	0.99050D+00	-0.20814D-02
7421	0.14570D+00	-0.49100D-01	0.99053D+00	-0.23012D-02
7422	0.15645D+00	-0.53238D-01	0.99055D+00	-0.25209D-02
7423	0.16227D+00	-0.57468D-01	0.99058D+00	-0.27407D-02
7424	0.17284D+00	-0.61777D-01	0.99061D+00	-0.29605D-02
7505	0.17254D-01	-0.41610D-02	0.55532D+00	0.48674D-01
7506	0.23063D-01	-0.59064D-02	0.57047D+00	0.44622D-01
7507	0.28921D-01	-0.79150D-02	0.58565D+00	0.40657D-01
7508	0.40112D-01	-0.10175D-01	0.60085D+00	0.36789D-01
7509	0.46039D-01	-0.12691D-01	0.61607D+00	0.33027D-01
7510	0.57239D-01	-0.15424D-01	0.63131D+00	0.29379D-01
7511	0.63203D-01	-0.18365D-01	0.64655D+00	0.25852D-01
7512	0.74386D-01	-0.21514D-01	0.66684D+00	0.22462D-01
7513	0.85535D-01	-0.24838D-01	0.68713D+00	0.19216D-01
7514	0.96643D-01	-0.28323D-01	0.70742D+00	0.16126D-01
7515	0.10771D+00	-0.31956D-01	0.72769D+00	0.13205D-01
7516	0.11365D+00	-0.35727D-01	0.75294D+00	0.10465D-01
7517	0.12464D+00	-0.39620D-01	0.77315D+00	0.79234D-02
7518	0.13557D+00	-0.43616D-01	0.79831D+00	0.55944D-02
7519	0.14145D+00	-0.47710D-01	0.82339D+00	0.34966D-02
7520	0.15229D+00	-0.51890D-01	0.85334D+00	0.16537D-02
7521	0.15812D+00	-0.56145D-01	0.88314D+00	0.91560D-04
7522	0.16885D+00	-0.60465D-01	0.91277D+00	-0.11552D-02
7523	0.17461D+00	-0.64849D-01	0.95193D+00	-0.20378D-02
7524	0.18036D+00	-0.69284D-01	0.99072D+00	-0.24877D-02
7605	0.22163D-01	-0.50026D-02	0.64031D+00	0.51712D-01
7606	0.27853D-01	-0.70467D-02	0.65045D+00	0.48249D-01
7607	0.38809D-01	-0.94086D-02	0.66062D+00	0.44857D-01
7608	0.49779D-01	-0.12034D-01	0.67081D+00	0.41539D-01
7609	0.60755D-01	-0.14909D-01	0.68101D+00	0.38300D-01
7610	0.71732D-01	-0.18010D-01	0.69123D+00	0.35143D-01
7611	0.82701D-01	-0.21315D-01	0.70652D+00	0.32073D-01
7612	0.93658D-01	-0.24801D-01	0.71677D+00	0.29094D-01
7613	0.10460D+00	-0.28447D-01	0.72702D+00	0.26209D-01
7614	0.11043D+00	-0.32239D-01	0.73728D+00	0.23419D-01
7615	0.12133D+00	-0.36156D-01	0.75259D+00	0.20737D-01
7616	0.13220D+00	-0.40180D-01	0.76284D+00	0.18159D-01
7617	0.13801D+00	-0.44298D-01	0.77813D+00	0.15696D-01
7618	0.14883D+00	-0.48506D-01	0.79340D+00	0.13349D-01
7619	0.15460D+00	-0.52783D-01	0.80362D+00	0.11125D-01
7620	0.16536D+00	-0.57127D-01	0.81883D+00	0.90318D-02
7621	0.17110D+00	-0.61530D-01	0.83400D+00	0.70728D-02
7622	0.17683D+00	-0.65982D-01	0.84912D+00	0.52553D-02
7623	0.18254D+00	-0.70478D-01	0.86419D+00	0.35868D-02
7624	0.18824D+00	-0.75013D-01	0.87919D+00	0.20748D-02

NACA	XMIN	YMIN	XMAX	YMAX
7705	0.27063D-01	-0.57868D-02	0.72528D+00	0.55282D-01
7706	0.37840D-01	-0.81225D-02	0.73545D+00	0.52479D-01
7707	0.48646D-01	-0.10770D-01	0.74059D+00	0.49726D-01
7708	0.59472D-01	-0.13696D-01	0.74575D+00	0.47023D-01
7709	0.70310D-01	-0.16869D-01	0.75092D+00	0.44371D-01
7710	0.81153D-01	-0.20258D-01	0.75611D+00	0.41770D-01
7711	0.97090D-01	-0.23839D-01	0.76639D+00	0.39225D-01
7712	0.10791D+00	-0.27583D-01	0.77160D+00	0.36738D-01
7713	0.11872D+00	-0.31466D-01	0.77683D+00	0.34306D-01
7714	0.12446D+00	-0.35475D-01	0.78206D+00	0.31930D-01
7715	0.13524D+00	-0.39589D-01	0.79239D+00	0.29618D-01
7716	0.14601D+00	-0.43790D-01	0.79763D+00	0.27367D-01
7717	0.15172D+00	-0.48073D-01	0.80288D+00	0.25173D-01
7718	0.16245D+00	-0.52420D-01	0.81321D+00	0.23051D-01
7719	0.16814D+00	-0.56832D-01	0.81846D+00	0.20990D-01
7720	0.17383D+00	-0.61294D-01	0.82878D+00	0.18996D-01
7721	0.17951D+00	-0.65800D-01	0.83402D+00	0.17074D-01
7722	0.18518D+00	-0.70346D-01	0.84431D+00	0.15217D-01
7723	0.19083D+00	-0.74929D-01	0.84953D+00	0.13439D-01
7724	0.19648D+00	-0.79543D-01	0.85977D+00	0.11728D-01
7805	0.31966D-01	-0.65180D-02	0.81527D+00	0.59379D-01
7806	0.47768D-01	-0.91071D-02	0.81532D+00	0.57333D-01
7807	0.58472D-01	-0.12013D-01	0.82049D+00	0.55315D-01
7808	0.69197D-01	-0.15190D-01	0.82056D+00	0.53317D-01
7809	0.85026D-01	-0.18611D-01	0.82577D+00	0.51358D-01
7810	0.95762D-01	-0.22233D-01	0.83100D+00	0.49411D-01
7811	0.10650D+00	-0.26025D-01	0.83110D+00	0.47510D-01
7812	0.11723D+00	-0.29963D-01	0.83636D+00	0.45625D-01
7813	0.12795D+00	-0.34026D-01	0.83648D+00	0.43773D-01
7814	0.13866D+00	-0.38193D-01	0.84177D+00	0.41952D-01
7815	0.14936D+00	-0.42447D-01	0.84189D+00	0.40149D-01
7816	0.15501D+00	-0.46784D-01	0.84721D+00	0.38395D-01
7817	0.16066D+00	-0.51180D-01	0.85253D+00	0.36658D-01
7818	0.17132D+00	-0.55639D-01	0.85268D+00	0.34954D-01
7819	0.17695D+00	-0.60145D-01	0.85802D+00	0.33285D-01
7820	0.18258D+00	-0.64694D-01	0.86337D+00	0.31636D-01
7821	0.18820D+00	-0.69280D-01	0.86354D+00	0.30033D-01
7822	0.19381D+00	-0.73899D-01	0.86888D+00	0.28456D-01
7823	0.19942D+00	-0.78548D-01	0.86906D+00	0.26903D-01
7824	0.20501D+00	-0.83222D-01	0.87441D+00	0.25398D-01
7905	0.41977D-01	-0.72187D-02	0.90520D+00	0.64057D-01
7906	0.52583D-01	-0.10023D-01	0.90524D+00	0.62903D-01
7907	0.68304D-01	-0.13150D-01	0.90528D+00	0.61749D-01
7908	0.84029D-01	-0.16539D-01	0.90532D+00	0.60595D-01
7909	0.94685D-01	-0.20161D-01	0.90536D+00	0.59442D-01
7910	0.10534D+00	-0.23964D-01	0.91077D+00	0.58306D-01
7911	0.11601D+00	-0.27922D-01	0.91085D+00	0.57207D-01
7912	0.13171D+00	-0.32012D-01	0.91092D+00	0.56108D-01
7913	0.13732D+00	-0.36213D-01	0.91100D+00	0.55008D-01
7914	0.14796D+00	-0.40505D-01	0.91108D+00	0.53909D-01
7915	0.15859D+00	-0.44871D-01	0.91115D+00	0.52809D-01
7916	0.16419D+00	-0.49306D-01	0.91675D+00	0.51726D-01
7917	0.16978D+00	-0.53793D-01	0.91686D+00	0.50682D-01
7918	0.18038D+00	-0.58332D-01	0.91697D+00	0.49639D-01
7919	0.18596D+00	-0.62912D-01	0.91708D+00	0.48595D-01
7920	0.19154D+00	-0.67528D-01	0.91719D+00	0.47551D-01
7921	0.19711D+00	-0.72176D-01	0.91730D+00	0.46508D-01
7922	0.20267D+00	-0.76850D-01	0.92304D+00	0.45489D-01
7923	0.20823D+00	-0.81548D-01	0.92318D+00	0.44503D-01
7924	0.20881D+00	-0.86270D-01	0.92332D+00	0.43516D-01

NACA	XMIN	YMIN	XMAX	YMAX
8105	0.20881D+00	-0.86270D-01	0.96527D-01	0.60710D-01
8106	0.20881D+00	-0.86270D-01	0.93559D-01	0.56958D-01
8107	0.20881D+00	-0.86270D-01	0.94152D-01	0.53251D-01
8108	0.20881D+00	-0.86270D-01	0.91859D-01	0.49620D-01
8109	0.20881D+00	-0.86270D-01	0.92717D-01	0.46047D-01
8110	0.20881D+00	-0.86270D-01	0.90939D-01	0.42614D-01
8111	0.20881D+00	-0.86270D-01	0.89298D-01	0.39254D-01
8112	0.20881D+00	-0.86270D-01	0.90598D-01	0.36005D-01
8113	0.20881D+00	-0.86270D-01	0.89156D-01	0.32891D-01
8114	0.16904D-01	-0.31305D-04	0.87606D-01	0.29832D-01
8115	0.17754D-01	-0.59068D-03	0.80226D+00	-0.11060D-02
8116	0.18604D-01	-0.11501D-02	0.99031D+00	-0.17578D-02
8117	0.19454D-01	-0.17094D-02	0.99033D+00	-0.19782D-02
8118	0.20305D-01	-0.22688D-02	0.99035D+00	-0.21985D-02
8119	0.21155D-01	-0.28282D-02	0.99037D+00	-0.24189D-02
8120	0.22005D-01	-0.33876D-02	0.99039D+00	-0.26392D-02
8121	0.22855D-01	-0.39470D-02	0.99041D+00	-0.28596D-02
8122	0.23706D-01	-0.45063D-02	0.99043D+00	-0.30799D-02
8123	0.24556D-01	-0.50657D-02	0.99045D+00	-0.33003D-02
8124	0.25406D-01	-0.56251D-02	0.99046D+00	-0.35207D-02
8205	0.81298D-02	-0.62540D-04	0.19548D+00	0.56172D-01
8206	0.87557D-02	-0.86505D-03	0.19113D+00	0.51442D-01
8207	0.93817D-02	-0.16676D-02	0.19132D+00	0.46716D-01
8208	0.10008D-01	-0.24701D-02	0.18725D+00	0.42002D-01
8209	0.10634D-01	-0.32726D-02	0.18753D+00	0.37308D-01
8210	0.11260D-01	-0.40751D-02	0.18373D+00	0.32627D-01
8211	0.11886D-01	-0.48776D-02	0.18410D+00	0.27970D-01
8212	0.20309D-01	-0.57643D-02	0.18054D+00	0.23339D-01
8213	0.21168D-01	-0.68946D-02	0.17714D+00	0.18732D-01
8214	0.22027D-01	-0.80250D-02	0.17387D+00	0.14160D-01
8215	0.30345D-01	-0.91858D-02	0.65790D+00	0.31133D-02
8216	0.31367D-01	-0.10568D-01	0.77279D+00	0.16130D-03
8217	0.32390D-01	-0.11951D-01	0.92152D+00	-0.16718D-02
8218	0.40682D-01	-0.13526D-01	0.99039D+00	-0.19749D-02
8219	0.48741D-01	-0.15166D-01	0.99041D+00	-0.21951D-02
8220	0.49991D-01	-0.16951D-01	0.99043D+00	-0.24152D-02
8221	0.57948D-01	-0.18900D-01	0.99046D+00	-0.26353D-02
8222	0.71898D-01	-0.21041D-01	0.99048D+00	-0.28555D-02
8223	0.85053D-01	-0.23422D-01	0.99050D+00	-0.30756D-02
8224	0.34716D+00	-0.41776D-01	0.99052D+00	-0.32957D-02
8305	0.73635D-02	-0.18622D-02	0.30000D+00	0.54993D-01
8306	0.78362D-02	-0.27635D-02	0.30000D+00	0.49991D-01
8307	0.83089D-02	-0.36649D-02	0.30000D+00	0.44990D-01
8308	0.15205D-01	-0.48509D-02	0.30000D+00	0.39988D-01
8309	0.15855D-01	-0.61128D-02	0.32518D+00	0.34989D-01
8310	0.22773D-01	-0.75406D-02	0.37560D+00	0.30033D-01
8311	0.23550D-01	-0.90746D-02	0.43110D+00	0.25204D-01
8312	0.30516D-01	-0.10814D-01	0.48159D+00	0.20576D-01
8313	0.37441D-01	-0.12670D-01	0.53710D+00	0.16205D-01
8314	0.44339D-01	-0.14672D-01	0.58754D+00	0.12143D-01
8315	0.51211D-01	-0.16832D-01	0.64292D+00	0.84352D-02
8316	0.58057D-01	-0.19154D-01	0.69819D+00	0.51308D-02
8317	0.64873D-01	-0.21637D-01	0.75826D+00	0.22898D-02
8318	0.71655D-01	-0.24280D-01	0.82304D+00	-0.18534D-05
8319	0.83845D-01	-0.27087D-01	0.90716D+00	-0.15865D-02
8320	0.90479D-01	-0.30076D-01	0.99050D+00	-0.21269D-02
8321	0.10230D+00	-0.33241D-01	0.99052D+00	-0.23467D-02
8322	0.11386D+00	-0.36589D-01	0.99054D+00	-0.25666D-02
8323	0.12516D+00	-0.40124D-01	0.99057D+00	-0.27864D-02
8324	0.14100D+00	-0.43859D-01	0.99059D+00	-0.30062D-02

NACA	XMIN	YMIN	XMAX	YMAX
8405	0.68695D-02	-0.27455D-02	0.45026D+00	0.56193D-01
8406	0.13095D-01	-0.39863D-02	0.46037D+00	0.51561D-01
8407	0.19325D-01	-0.53467D-02	0.47553D+00	0.46993D-01
8408	0.19943D-01	-0.69516D-02	0.49575D+00	0.42500D-01
8409	0.26287D-01	-0.87441D-02	0.51096D+00	0.38099D-01
8410	0.32651D-01	-0.10714D-01	0.53123D+00	0.33803D-01
8411	0.39034D-01	-0.12867D-01	0.55655D+00	0.29629D-01
8412	0.45434D-01	-0.15198D-01	0.57685D+00	0.25596D-01
8413	0.51844D-01	-0.17700D-01	0.60220D+00	0.21723D-01
8414	0.63700D-01	-0.20393D-01	0.63257D+00	0.18032D-01
8415	0.70088D-01	-0.23245D-01	0.65789D+00	0.14541D-01
8416	0.81796D-01	-0.26250D-01	0.69322D+00	0.11275D-01
8417	0.88141D-01	-0.29423D-01	0.72348D+00	0.82585D-02
8418	0.99691D-01	-0.32735D-01	0.75867D+00	0.55176D-02
8419	0.10597D+00	-0.36193D-01	0.79374D+00	0.30857D-02
8420	0.11735D+00	-0.39783D-01	0.83362D+00	0.10034D-02
8421	0.12859D+00	-0.43493D-01	0.87822D+00	-0.67348D-03
8422	0.13473D+00	-0.47328D-01	0.93229D+00	-0.18597D-02
8423	0.14578D+00	-0.51266D-01	0.99066D+00	-0.24001D-02
8424	0.15181D+00	-0.55301D-01	0.99069D+00	-0.26194D-02
8505	0.12124D-01	-0.36055D-02	0.55033D+00	0.58568D-01
8506	0.18059D-01	-0.51265D-02	0.56047D+00	0.54461D-01
8507	0.24042D-01	-0.68865D-02	0.57063D+00	0.50427D-01
8508	0.30070D-01	-0.88778D-02	0.58585D+00	0.46468D-01
8509	0.36136D-01	-0.11086D-01	0.59605D+00	0.42596D-01
8510	0.47596D-01	-0.13515D-01	0.61131D+00	0.38815D-01
8511	0.53707D-01	-0.16150D-01	0.62659D+00	0.35131D-01
8512	0.65137D-01	-0.18962D-01	0.64189D+00	0.31552D-01
8513	0.71269D-01	-0.21969D-01	0.65719D+00	0.28088D-01
8514	0.82649D-01	-0.25132D-01	0.67250D+00	0.24744D-01
8515	0.88779D-01	-0.28458D-01	0.69285D+00	0.21528D-01
8516	0.10009D+00	-0.31926D-01	0.70816D+00	0.18454D-01
8517	0.10620D+00	-0.35522D-01	0.72848D+00	0.15526D-01
8518	0.11742D+00	-0.39247D-01	0.74877D+00	0.12757D-01
8519	0.12857D+00	-0.43073D-01	0.76902D+00	0.10156D-01
8520	0.13461D+00	-0.47010D-01	0.78922D+00	0.77373D-02
8521	0.14063D+00	-0.51029D-01	0.80936D+00	0.55120D-02
8522	0.15163D+00	-0.55137D-01	0.83440D+00	0.34952D-02
8523	0.15759D+00	-0.59315D-01	0.85931D+00	0.17046D-02
8524	0.16352D+00	-0.63557D-01	0.88409D+00	0.16221D-03
8605	0.17164D-01	-0.43719D-02	0.63531D+00	0.61616D-01
8606	0.22945D-01	-0.61809D-02	0.64547D+00	0.58106D-01
8607	0.34069D-01	-0.82602D-02	0.65566D+00	0.54654D-01
8608	0.39941D-01	-0.10615D-01	0.66081D+00	0.51268D-01
8609	0.51103D-01	-0.13190D-01	0.67104D+00	0.47948D-01
8610	0.57034D-01	-0.15997D-01	0.68128D+00	0.44695D-01
8611	0.68210D-01	-0.19006D-01	0.69155D+00	0.41514D-01
8612	0.79369D-01	-0.22196D-01	0.70183D+00	0.38407D-01
8613	0.85339D-01	-0.25559D-01	0.70705D+00	0.35378D-01
8614	0.96476D-01	-0.29078D-01	0.71736D+00	0.32430D-01
8615	0.10758D+00	-0.32730D-01	0.72766D+00	0.29566D-01
8616	0.11354D+00	-0.36506D-01	0.74304D+00	0.26790D-01
8617	0.12460D+00	-0.40396D-01	0.75335D+00	0.24104D-01
8618	0.13054D+00	-0.44379D-01	0.76365D+00	0.21513D-01
8619	0.14153D+00	-0.48457D-01	0.77396D+00	0.19019D-01
8620	0.14745D+00	-0.52609D-01	0.78425D+00	0.16624D-01
8621	0.15836D+00	-0.56829D-01	0.79955D+00	0.14338D-01
8622	0.16423D+00	-0.61117D-01	0.80980D+00	0.12161D-01
8623	0.17009D+00	-0.65459D-01	0.82503D+00	0.10096D-01
8624	0.17593D+00	-0.69850D-01	0.83522D+00	0.81527D-02

NACA	XMIN	YMIN	XMAX	YMAX
8705	0.22131D-01	-0.50925D-02	0.72532D+00	0.65213D-01
8706	0.33035D-01	-0.71624D-02	0.73045D+00	0.62377D-01
8707	0.38767D-01	-0.95464D-02	0.73560D+00	0.59583D-01
8708	0.49737D-01	-0.12194D-01	0.74077D+00	0.56833D-01
8709	0.60720D-01	-0.15083D-01	0.74596D+00	0.54128D-01
8710	0.71710D-01	-0.18192D-01	0.75117D+00	0.51468D-01
8711	0.82698D-01	-0.21497D-01	0.75639D+00	0.48854D-01
8712	0.93680D-01	-0.24976D-01	0.76163D+00	0.46288D-01
8713	0.99534D-01	-0.28614D-01	0.76688D+00	0.43770D-01
8714	0.11050D+00	-0.32389D-01	0.77214D+00	0.41301D-01
8715	0.12145D+00	-0.36279D-01	0.77741D+00	0.38882D-01
8716	0.12730D+00	-0.40276D-01	0.78269D+00	0.36513D-01
8717	0.13822D+00	-0.44368D-01	0.79309D+00	0.34203D-01
8718	0.14405D+00	-0.48539D-01	0.79838D+00	0.31945D-01
8719	0.15492D+00	-0.52782D-01	0.80368D+00	0.29742D-01
8720	0.16073D+00	-0.57092D-01	0.80898D+00	0.27592D-01
8721	0.16653D+00	-0.61455D-01	0.81428D+00	0.25498D-01
8722	0.17233D+00	-0.65868D-01	0.82466D+00	0.23468D-01
8723	0.17811D+00	-0.70325D-01	0.82996D+00	0.21497D-01
8724	0.18388D+00	-0.74823D-01	0.83525D+00	0.19583D-01
8805	0.27072D-01	-0.57739D-02	0.81021D+00	0.69337D-01
8806	0.37858D-01	-0.80971D-02	0.81537D+00	0.67278D-01
8807	0.48676D-01	-0.10728D-01	0.81543D+00	0.65233D-01
8808	0.59518D-01	-0.13634D-01	0.82064D+00	0.63220D-01
8809	0.70375D-01	-0.16781D-01	0.82072D+00	0.61222D-01
8810	0.81242D-01	-0.20141D-01	0.82597D+00	0.59257D-01
8811	0.92111D-01	-0.23686D-01	0.82607D+00	0.57308D-01
8812	0.10298D+00	-0.27392D-01	0.83137D+00	0.55393D-01
8813	0.11384D+00	-0.31237D-01	0.83148D+00	0.53492D-01
8814	0.12468D+00	-0.35201D-01	0.83681D+00	0.51629D-01
8815	0.13045D+00	-0.39270D-01	0.83694D+00	0.49777D-01
8816	0.14128D+00	-0.43433D-01	0.84231D+00	0.47967D-01
8817	0.14704D+00	-0.47670D-01	0.84245D+00	0.46165D-01
8818	0.15783D+00	-0.51979D-01	0.84784D+00	0.44410D-01
8819	0.16357D+00	-0.56348D-01	0.85323D+00	0.42662D-01
8820	0.16931D+00	-0.60769D-01	0.85340D+00	0.40960D-01
8821	0.17505D+00	-0.65236D-01	0.85881D+00	0.39270D-01
8822	0.18077D+00	-0.69744D-01	0.85900D+00	0.37619D-01
8823	0.18649D+00	-0.74290D-01	0.86442D+00	0.35988D-01
8824	0.19219D+00	-0.78868D-01	0.86461D+00	0.34388D-01
8905	0.32004D-01	-0.64185D-02	0.90523D+00	0.74033D-01
8906	0.42703D-01	-0.89576D-02	0.90528D+00	0.72879D-01
8907	0.58554D-01	-0.11815D-01	0.90532D+00	0.71726D-01
8908	0.69303D-01	-0.14948D-01	0.90537D+00	0.70572D-01
8909	0.80066D-01	-0.18311D-01	0.90542D+00	0.69419D-01
8910	0.90839D-01	-0.21875D-01	0.90546D+00	0.68265D-01
8911	0.10162D+00	-0.25611D-01	0.91097D+00	0.67116D-01
8912	0.11239D+00	-0.29496D-01	0.91105D+00	0.66017D-01
8913	0.12316D+00	-0.33506D-01	0.91114D+00	0.64919D-01
8914	0.13393D+00	-0.37622D-01	0.91123D+00	0.63820D-01
8915	0.14467D+00	-0.41825D-01	0.91132D+00	0.62722D-01
8916	0.15037D+00	-0.46113D-01	0.91141D+00	0.61623D-01
8917	0.15606D+00	-0.50462D-01	0.91149D+00	0.60525D-01
8918	0.16678D+00	-0.54876D-01	0.91725D+00	0.59445D-01
8919	0.17246D+00	-0.59340D-01	0.91738D+00	0.58403D-01
8920	0.17814D+00	-0.63848D-01	0.91750D+00	0.57361D-01
8921	0.18381D+00	-0.68395D-01	0.91763D+00	0.56319D-01
8922	0.18947D+00	-0.72977D-01	0.91775D+00	0.55277D-01
8923	0.19513D+00	-0.77590D-01	0.91788D+00	0.54235D-01
8924	0.20078D+00	-0.82229D-01	0.91800D+00	0.53193D-01

NACA	XMIN	YMIN	XMAX	YMAX
9105	0.20078D+00	-0.82229D-01	0.96717D-01	0.70701D-01
9106	0.20078D+00	-0.82229D-01	0.93990D-01	0.66931D-01
9107	0.20078D+00	-0.82229D-01	0.94655D-01	0.63237D-01
9108	0.20078D+00	-0.82229D-01	0.92661D-01	0.59599D-01
9109	0.20078D+00	-0.82229D-01	0.93619D-01	0.56052D-01
9110	0.20078D+00	-0.82229D-01	0.92158D-01	0.52628D-01
9111	0.20078D+00	-0.82229D-01	0.90799D-01	0.49267D-01
9112	0.20078D+00	-0.82229D-01	0.92235D-01	0.46075D-01
9113	0.20078D+00	-0.82229D-01	0.91034D-01	0.42948D-01
9114	0.20078D+00	-0.82229D-01	0.92652D-01	0.39952D-01
9115	0.20078D+00	-0.82229D-01	0.91424D-01	0.37033D-01
9116	0.20078D+00	-0.82229D-01	0.93185D-01	0.34237D-01
9117	0.20078D+00	-0.82229D-01	0.83757D+00	-0.14732D-02
9118	0.20814D-01	-0.47302D-03	0.99039D+00	-0.19735D-02
9119	0.21693D-01	-0.98680D-03	0.99041D+00	-0.21936D-02
9120	0.22571D-01	-0.15006D-02	0.99044D+00	-0.24138D-02
9121	0.23450D-01	-0.20144D-02	0.99046D+00	-0.26339D-02
9122	0.24328D-01	-0.25281D-02	0.99048D+00	-0.28540D-02
9123	0.25207D-01	-0.30419D-02	0.99050D+00	-0.30742D-02
9124	0.26085D-01	-0.35557D-02	0.99052D+00	-0.32943D-02
9205	0.26085D-01	-0.35557D-02	0.19553D+00	0.66167D-01
9206	0.90277D-02	-0.14622D-03	0.19128D+00	0.61423D-01
9207	0.96990D-02	-0.91122D-03	0.19149D+00	0.56698D-01
9208	0.10370D-01	-0.16762D-02	0.19170D+00	0.51973D-01
9209	0.11042D-01	-0.24412D-02	0.18785D+00	0.47272D-01
9210	0.11713D-01	-0.32062D-02	0.18817D+00	0.42581D-01
9211	0.12384D-01	-0.39712D-02	0.18461D+00	0.37913D-01
9212	0.13055D-01	-0.47362D-02	0.18503D+00	0.33260D-01
9213	0.13727D-01	-0.55012D-02	0.18174D+00	0.28644D-01
9214	0.22917D-01	-0.63324D-02	0.17863D+00	0.24053D-01
9215	0.23839D-01	-0.74115D-02	0.17567D+00	0.19498D-01
9216	0.24762D-01	-0.84906D-02	0.53817D+00	0.68239D-02
9217	0.25685D-01	-0.95697D-02	0.67369D+00	0.31078D-02
9218	0.34805D-01	-0.10796D-01	0.77353D+00	0.21104D-03
9219	0.35906D-01	-0.12118D-01	0.89733D+00	-0.17171D-02
9220	0.44755D-01	-0.13462D-01	0.99049D+00	-0.21611D-02
9221	0.45993D-01	-0.14990D-01	0.99051D+00	-0.23810D-02
9222	0.54658D-01	-0.16567D-01	0.99054D+00	-0.26008D-02
9223	0.56006D-01	-0.18279D-01	0.99056D+00	-0.28207D-02
9224	0.64513D-01	-0.20140D-01	0.99059D+00	-0.30405D-02
9305	0.75859D-02	-0.14078D-02	0.30000D+00	0.64993D-01
9306	0.81030D-02	-0.22844D-02	0.30000D+00	0.59991D-01
9307	0.86202D-02	-0.31610D-02	0.30000D+00	0.54990D-01
9308	0.91374D-02	-0.40375D-02	0.30000D+00	0.49988D-01
9309	0.16411D-01	-0.51532D-02	0.30000D+00	0.44987D-01
9310	0.17123D-01	-0.63813D-02	0.32018D+00	0.39987D-01
9311	0.24368D-01	-0.76596D-02	0.36565D+00	0.35018D-01
9312	0.25219D-01	-0.91537D-02	0.41116D+00	0.30147D-01
9313	0.32491D-01	-0.10705D-01	0.46176D+00	0.25435D-01
9314	0.33452D-01	-0.12421D-01	0.50731D+00	0.20932D-01
9315	0.40751D-01	-0.14263D-01	0.55284D+00	0.16680D-01
9316	0.47993D-01	-0.16221D-01	0.60335D+00	0.12717D-01
9317	0.55188D-01	-0.18315D-01	0.64874D+00	0.90778D-02
9318	0.62337D-01	-0.20555D-01	0.69903D+00	0.58027D-02
9319	0.69440D-01	-0.22947D-01	0.75412D+00	0.29380D-02
9320	0.76495D-01	-0.25490D-01	0.80895D+00	0.54874D-03
9321	0.83498D-01	-0.28184D-01	0.87822D+00	-0.12615D-02
9322	0.90445D-01	-0.31027D-01	0.97606D+00	-0.22636D-02
9323	0.10273D+00	-0.34053D-01	0.99064D+00	-0.24943D-02
9324	0.11469D+00	-0.37249D-01	0.99067D+00	-0.27138D-02

NACA	XMIN	YMIN	XMAX	YMAX
9405	0.70665D-02	-0.24144D-02	0.44023D+00	0.66140D-01
9406	0.13423D-01	-0.33570D-02	0.45035D+00	0.61473D-01
9407	0.13993D-01	-0.46571D-02	0.46552D+00	0.56859D-01
9408	0.20468D-01	-0.60011D-02	0.48072D+00	0.52302D-01
9409	0.21151D-01	-0.75791D-02	0.49595D+00	0.47815D-01
9410	0.27730D-01	-0.93068D-02	0.51120D+00	0.43410D-01
9411	0.34316D-01	-0.11185D-01	0.52647D+00	0.39096D-01
9412	0.40914D-01	-0.13227D-01	0.54681D+00	0.34888D-01
9413	0.47522D-01	-0.15434D-01	0.56716D+00	0.30801D-01
9414	0.54136D-01	-0.17803D-01	0.59257D+00	0.26848D-01
9415	0.60751D-01	-0.20329D-01	0.61294D+00	0.23047D-01
9416	0.67364D-01	-0.23007D-01	0.63834D+00	0.19413D-01
9417	0.73971D-01	-0.25829D-01	0.66371D+00	0.15963D-01
9418	0.85978D-01	-0.28791D-01	0.69408D+00	0.12715D-01
9419	0.92518D-01	-0.31911D-01	0.71937D+00	0.96890D-02
9420	0.99037D-01	-0.35156D-01	0.74960D+00	0.69053D-02
9421	0.11077D+00	-0.38536D-01	0.78470D+00	0.43882D-02
9422	0.11720D+00	-0.42041D-01	0.81470D+00	0.21674D-02
9423	0.12870D+00	-0.45665D-01	0.85440D+00	0.28083D-03
9424	0.13502D+00	-0.49401D-01	0.89382D+00	-0.12220D-02
9505	0.12362D-01	-0.31304D-02	0.54030D+00	0.68490D-01
9506	0.12834D-01	-0.44693D-02	0.55045D+00	0.64342D-01
9507	0.18969D-01	-0.60461D-02	0.56061D+00	0.60254D-01
9508	0.25139D-01	-0.78129D-02	0.57081D+00	0.56232D-01
9509	0.31346D-01	-0.97803D-02	0.58607D+00	0.52280D-01
9510	0.37587D-01	-0.11943D-01	0.59631D+00	0.48405D-01
9511	0.43856D-01	-0.14292D-01	0.60657D+00	0.44608D-01
9512	0.50148D-01	-0.16816D-01	0.62190D+00	0.40899D-01
9513	0.61869D-01	-0.19534D-01	0.63218D+00	0.37280D-01
9514	0.68174D-01	-0.22407D-01	0.64754D+00	0.33762D-01
9515	0.79816D-01	-0.25427D-01	0.66291D+00	0.30346D-01
9516	0.86114D-01	-0.28610D-01	0.67827D+00	0.27042D-01
9517	0.92410D-01	-0.31920D-01	0.69364D+00	0.23855D-01
9518	0.10393D+00	-0.35364D-01	0.70899D+00	0.20792D-01
9519	0.11019D+00	-0.38926D-01	0.72433D+00	0.17860D-01
9520	0.12160D+00	-0.42598D-01	0.74468D+00	0.15070D-01
9521	0.12781D+00	-0.46376D-01	0.75997D+00	0.12427D-01
9522	0.13400D+00	-0.50241D-01	0.78023D+00	0.99423D-02
9523	0.14523D+00	-0.54202D-01	0.80042D+00	0.76233D-02
9524	0.15136D+00	-0.58238D-01	0.82053D+00	0.54822D-02
9605	0.12009D-01	-0.38337D-02	0.63535D+00	0.71540D-01
9606	0.17897D-01	-0.54597D-02	0.64047D+00	0.67996D-01
9607	0.23834D-01	-0.73207D-02	0.64562D+00	0.64501D-01
9608	0.35190D-01	-0.94342D-02	0.65584D+00	0.61063D-01
9609	0.41204D-01	-0.11769D-01	0.66102D+00	0.57680D-01
9610	0.47252D-01	-0.14302D-01	0.67129D+00	0.54358D-01
9611	0.58640D-01	-0.17043D-01	0.67651D+00	0.51093D-01
9612	0.64730D-01	-0.19963D-01	0.68682D+00	0.47897D-01
9613	0.76102D-01	-0.23059D-01	0.69715D+00	0.44763D-01
9614	0.82212D-01	-0.26308D-01	0.70240D+00	0.41697D-01
9615	0.93548D-01	-0.29708D-01	0.71275D+00	0.38705D-01
9616	0.99659D-01	-0.33233D-01	0.72311D+00	0.35784D-01
9617	0.11094D+00	-0.36887D-01	0.73348D+00	0.32938D-01
9618	0.11704D+00	-0.40644D-01	0.74384D+00	0.30170D-01
9619	0.12825D+00	-0.44506D-01	0.75421D+00	0.27483D-01
9620	0.13432D+00	-0.48456D-01	0.75950D+00	0.24880D-01
9621	0.14037D+00	-0.52483D-01	0.76986D+00	0.22365D-01
9622	0.15147D+00	-0.56591D-01	0.78020D+00	0.19938D-01
9623	0.15748D+00	-0.60763D-01	0.79557D+00	0.17604D-01
9624	0.16348D+00	-0.64994D-01	0.80587D+00	0.15367D-01

NACA	XMIN	YMIN	XMAX	YMAX
9705	0.17098D-01	-0.45229D-02	0.72029D+00	0.75159D-01
9706	0.22859D-01	-0.63778D-02	0.72543D+00	0.72299D-01
9707	0.33959D-01	-0.85384D-02	0.73059D+00	0.69475D-01
9708	0.39814D-01	-0.10932D-01	0.73577D+00	0.66689D-01
9709	0.50961D-01	-0.13575D-01	0.74098D+00	0.63942D-01
9710	0.62111D-01	-0.16423D-01	0.74620D+00	0.61234D-01
9711	0.68051D-01	-0.19477D-01	0.75145D+00	0.58567D-01
9712	0.79213D-01	-0.22711D-01	0.75671D+00	0.55941D-01
9713	0.90362D-01	-0.26101D-01	0.76198D+00	0.53358D-01
9714	0.96335D-01	-0.29641D-01	0.76727D+00	0.50818D-01
9715	0.10746D+00	-0.33313D-01	0.77257D+00	0.48322D-01
9716	0.11344D+00	-0.37096D-01	0.77789D+00	0.45872D-01
9717	0.12453D+00	-0.40992D-01	0.78321D+00	0.43467D-01
9718	0.13050D+00	-0.44974D-01	0.78854D+00	0.41109D-01
9719	0.14154D+00	-0.49043D-01	0.79388D+00	0.38798D-01
9720	0.14749D+00	-0.53187D-01	0.79922D+00	0.36536D-01
9721	0.15342D+00	-0.57394D-01	0.80457D+00	0.34323D-01
9722	0.15935D+00	-0.61660D-01	0.80992D+00	0.32160D-01
9723	0.17029D+00	-0.65981D-01	0.81526D+00	0.30048D-01
9724	0.17618D+00	-0.70351D-01	0.82061D+00	0.27987D-01
9805	0.22107D-01	-0.51603D-02	0.81024D+00	0.79312D-01
9806	0.33006D-01	-0.72556D-02	0.81541D+00	0.77223D-01
9807	0.38734D-01	-0.96508D-02	0.81548D+00	0.75178D-01
9808	0.49705D-01	-0.12316D-01	0.81555D+00	0.73133D-01
9809	0.60692D-01	-0.15217D-01	0.82081D+00	0.71126D-01
9810	0.71690D-01	-0.18333D-01	0.82090D+00	0.69129D-01
9811	0.82692D-01	-0.21639D-01	0.82621D+00	0.67159D-01
9812	0.88549D-01	-0.25115D-01	0.82632D+00	0.65210D-01
9813	0.99557D-01	-0.28748D-01	0.83167D+00	0.63279D-01
9814	0.11055D+00	-0.32510D-01	0.83180D+00	0.61379D-01
9815	0.12153D+00	-0.36383D-01	0.83719D+00	0.59489D-01
9816	0.12740D+00	-0.40368D-01	0.83733D+00	0.57639D-01
9817	0.13836D+00	-0.44434D-01	0.84275D+00	0.55791D-01
9818	0.14422D+00	-0.48589D-01	0.84292D+00	0.53990D-01
9819	0.15008D+00	-0.52809D-01	0.84308D+00	0.52190D-01
9820	0.15593D+00	-0.57090D-01	0.84854D+00	0.50437D-01
9821	0.16682D+00	-0.61429D-01	0.84872D+00	0.48687D-01
9822	0.17265D+00	-0.65819D-01	0.85421D+00	0.46981D-01
9823	0.17848D+00	-0.70252D-01	0.85440D+00	0.45281D-01
9824	0.18429D+00	-0.74723D-01	0.85990D+00	0.43623D-01
9905	0.27079D-01	-0.57638D-02	0.90526D+00	0.84009D-01
9906	0.37872D-01	-0.80774D-02	0.90531D+00	0.82856D-01
9907	0.48699D-01	-0.10696D-01	0.90536D+00	0.81702D-01
9908	0.59553D-01	-0.13585D-01	0.90542D+00	0.80549D-01
9909	0.70426D-01	-0.16713D-01	0.90547D+00	0.79396D-01
9910	0.81311D-01	-0.20050D-01	0.90552D+00	0.78243D-01
9911	0.92202D-01	-0.23570D-01	0.90557D+00	0.77089D-01
9912	0.10309D+00	-0.27246D-01	0.90562D+00	0.75936D-01
9913	0.11398D+00	-0.31059D-01	0.91128D+00	0.74831D-01
9914	0.11977D+00	-0.34997D-01	0.91138D+00	0.73733D-01
9915	0.13065D+00	-0.39036D-01	0.91148D+00	0.72636D-01
9916	0.13644D+00	-0.43164D-01	0.91158D+00	0.71538D-01
9917	0.14730D+00	-0.47373D-01	0.91168D+00	0.70440D-01
9918	0.15308D+00	-0.51650D-01	0.91178D+00	0.69343D-01
9919	0.15887D+00	-0.55986D-01	0.91188D+00	0.68245D-01
9920	0.16969D+00	-0.60375D-01	0.91781D+00	0.67175D-01
9921	0.17545D+00	-0.64814D-01	0.91795D+00	0.66135D-01
9922	0.18121D+00	-0.69295D-01	0.91809D+00	0.65095D-01
9923	0.18697D+00	-0.73811D-01	0.91823D+00	0.64055D-01
9924	0.19272D+00	-0.78360D-01	0.91837D+00	0.63015D-01