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APPLICATIONS OF A TRANSONIC WING DESIGN METHOD

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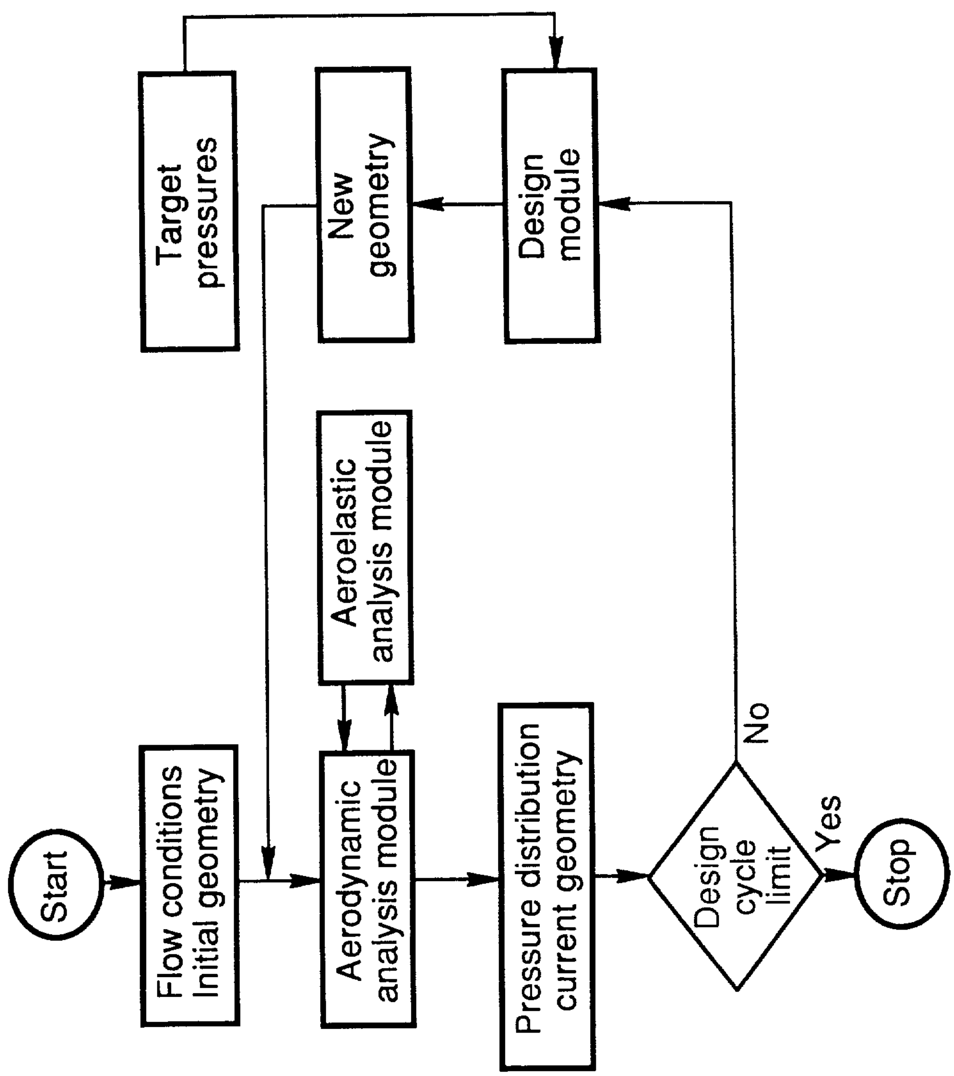
ABSTRACT

The development of transonic computational fluid dynamic methods over the last fifteen years has had a tremendous impact on the design of airfoils and wings. A variety of approaches to automated design have been developed, such as the hodograph and fictitious gas methods for shock-free design, and inverse, numerical optimization, and predictor/corrector methods for the more general cases. Each of these techniques has advantages as well as limitations, and the designer must choose the one that best suits his specific task.

A method for designing wings and airfoils at transonic speeds using a predictor/corrector approach has been developed. The procedure iterates between an aerodynamic code, which predicts the flow about a given geometry, and the design module, which compares the calculated and target pressure distributions and modifies the geometry using an algorithm that relates differences in pressure to a change in surface curvature. The modular nature of the design method makes it relatively simple to couple it to any analysis method. The iterative approach allows the design process and aerodynamic analysis to converge in parallel, significantly reducing the time required to reach a final design. Viscous and static aeroelastic effects can also be accounted for during the design or as a post-design correction.

Results from several pilot design codes indicated that the method accurately reproduced pressure distributions as well as the coordinates of a given airfoil or wing by modifying an initial contour. The codes were applied to supercritical as well as conventional airfoils, forward- and aft-swept transport wings, and moderate-to-highly swept fighter wings. The design method was found to be robust and efficient, even for cases having fairly strong shocks. Comments from a user in industry indicated that for a specific design problem, this design method was about 25 times faster than a numerical optimization approach that utilized the same aerodynamic analysis code.


Start
Flow conditions
Initial geometry
Aerodynamic
analysis module
Aeroelastic
analysis module
Pressure distribution
current geometry
Design
cycle
limit
Yes
Stop
No
Design
module
New
geometry
Target
pressures

HYBRID DESIGN ALGORITHM

- Subsonic regions

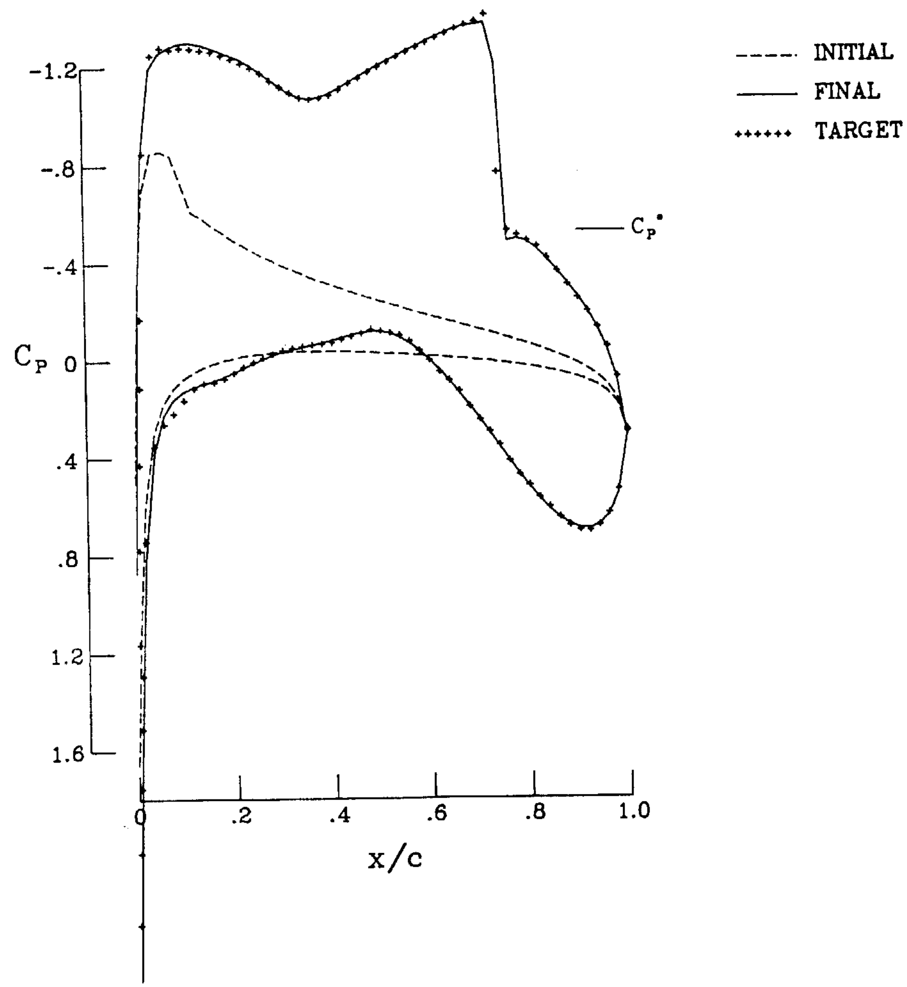
  $$\Delta C = \Delta C_P \; A \, (1 + C^2)^B$$

- Supersonic regions ($M > 1.15$)

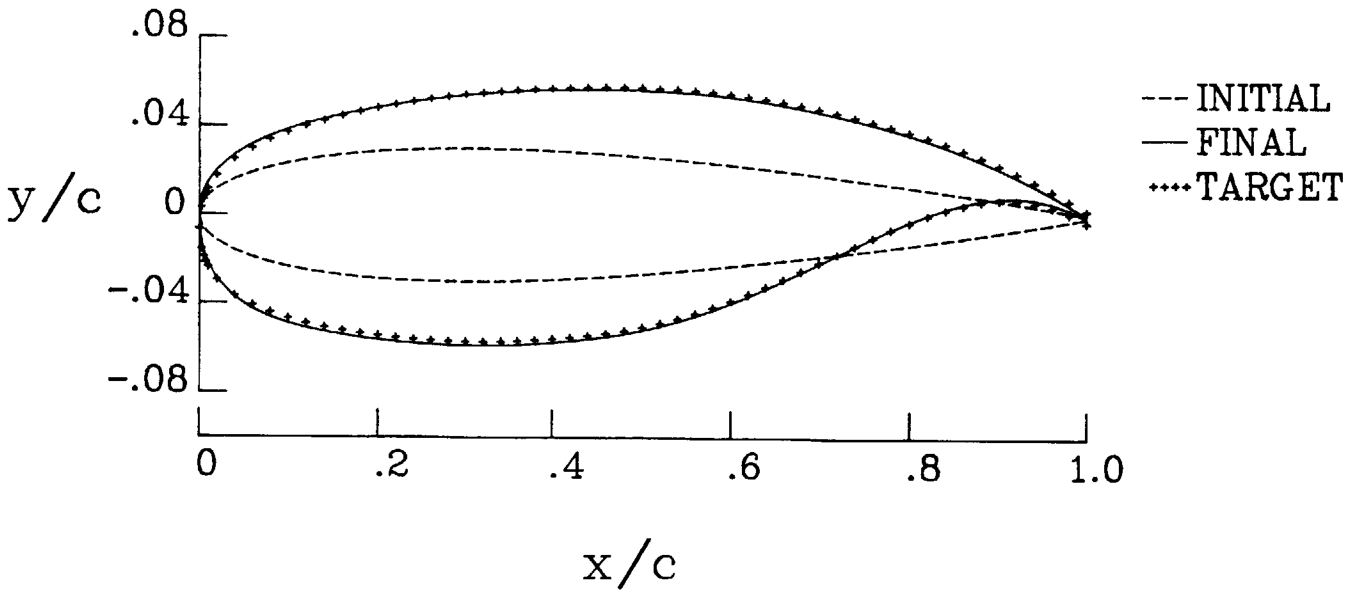
  $$\Delta C = \frac{0.05\,A}{(1 + (y')^2)^{1.5}} \frac{d}{dx} (\Delta C_P)$$

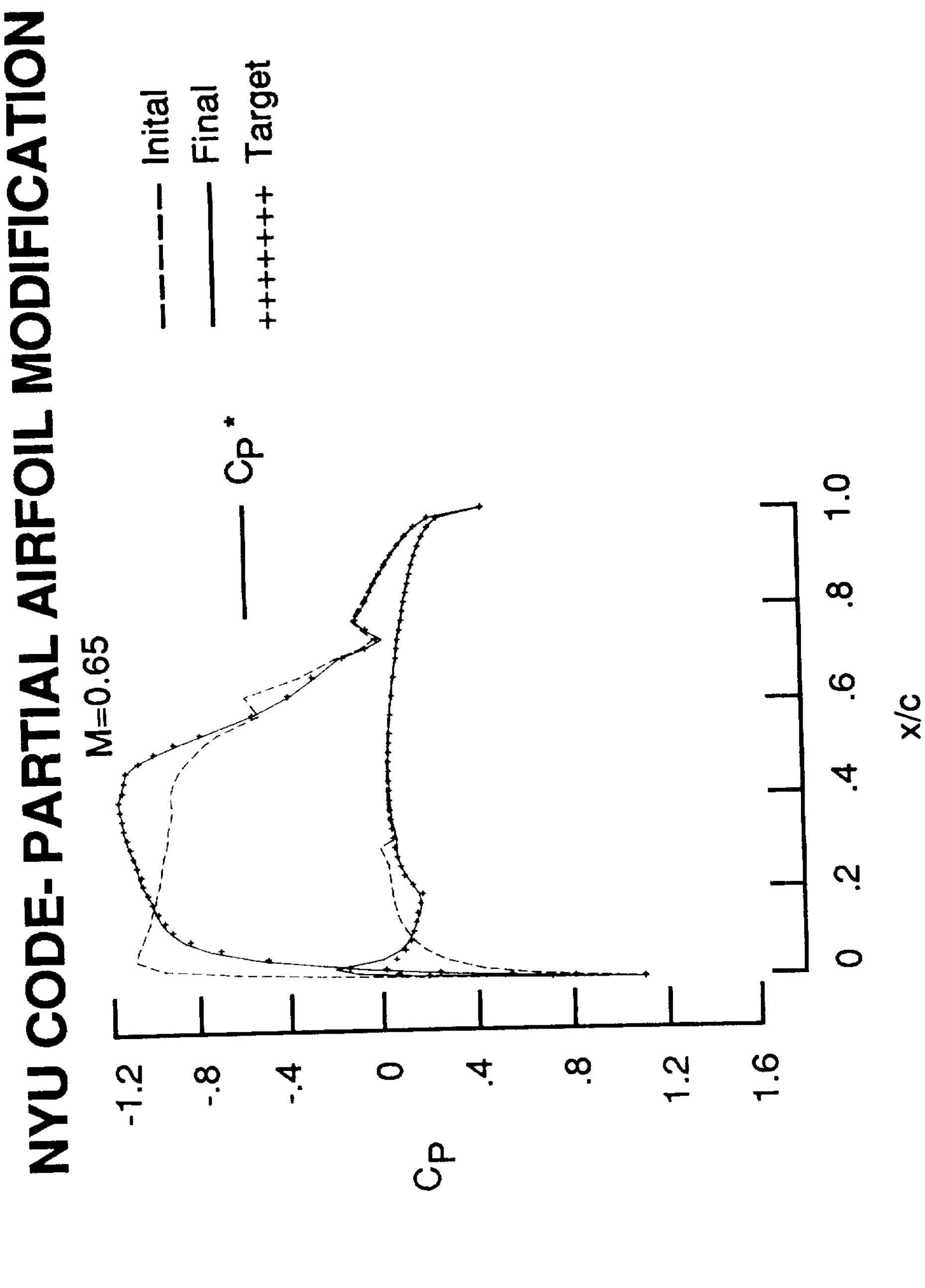
SUPERCRITICAL AIRFOIL DESIGN

$M = 0.77$ $\alpha = 1.0$

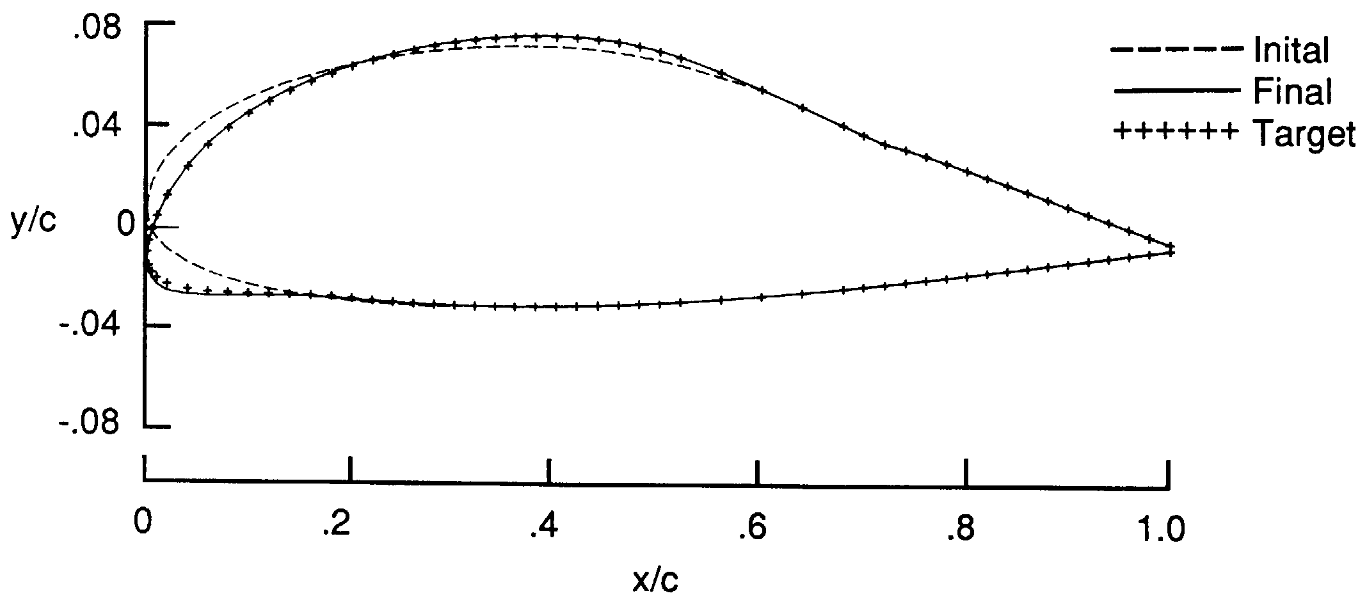


SUPERCRITICAL AIRFOIL DESIGN

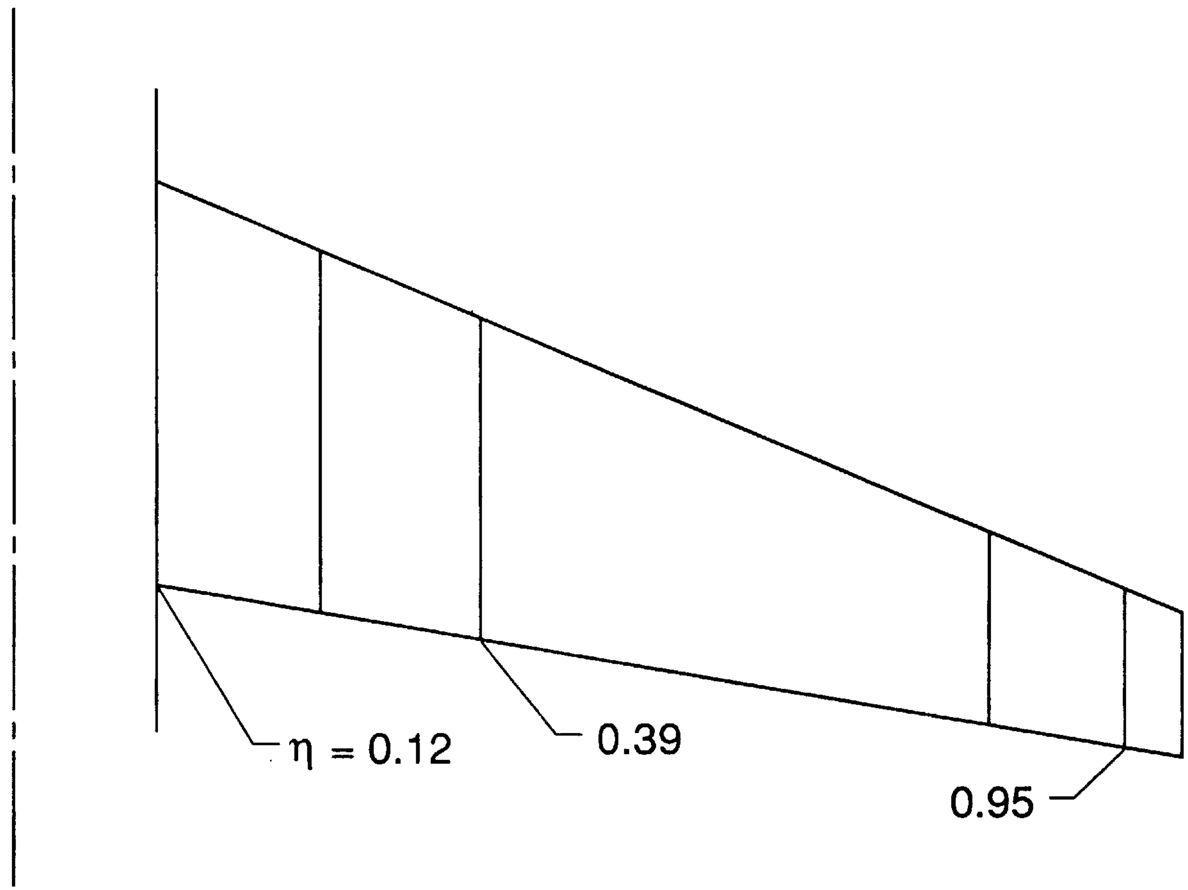



NYU CODE- PARTIAL AIRFOIL MODIFICATION
M=0.65
Inital
Final
Target
C_P *
C_P
-1.2
-.8
-.4
0
.4
.8
1.2
1.6
0
.2
.4
.6
.8
1.0
x/c

NYU CODE- PARTIAL AIRFOIL MODIFICATION

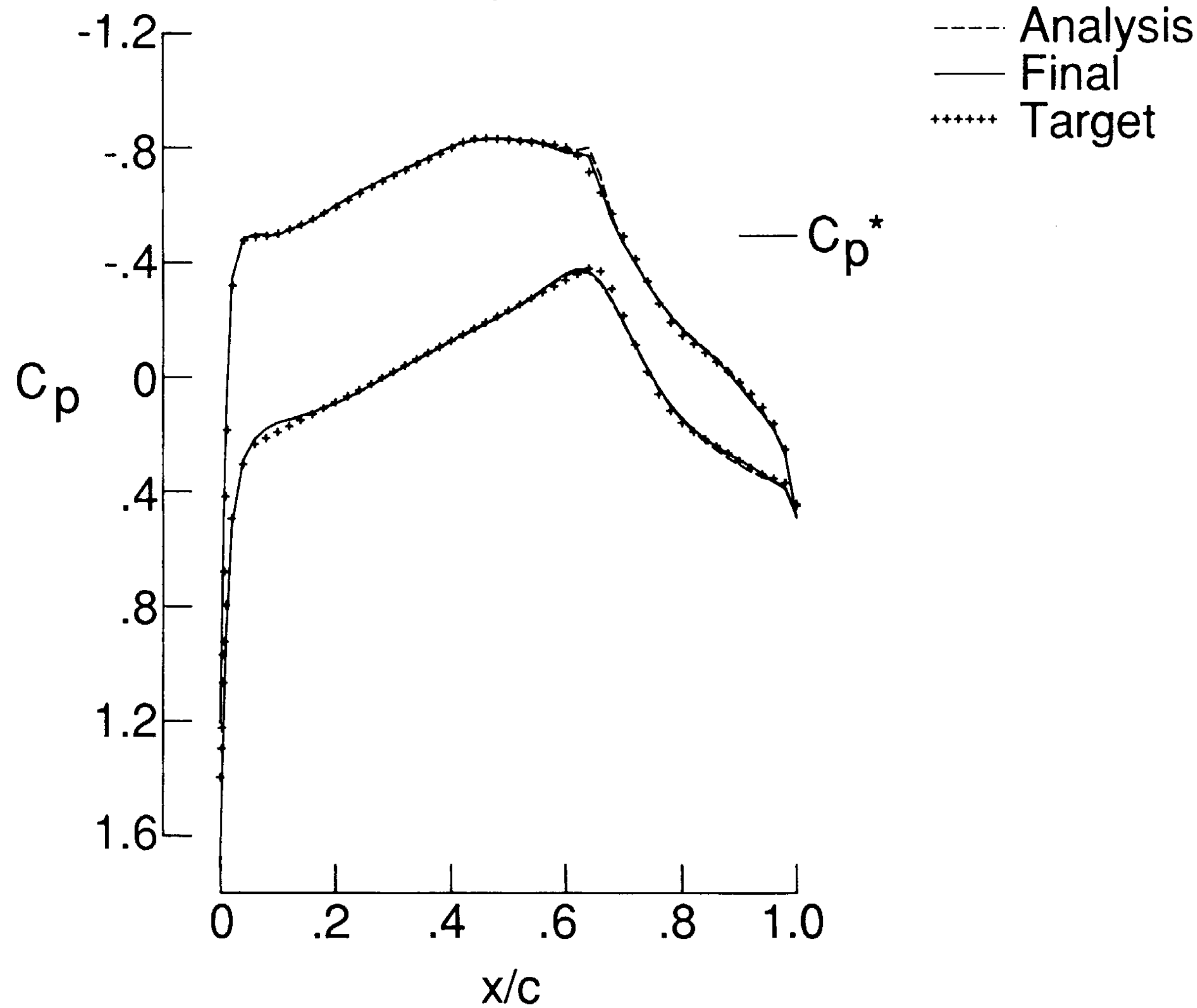


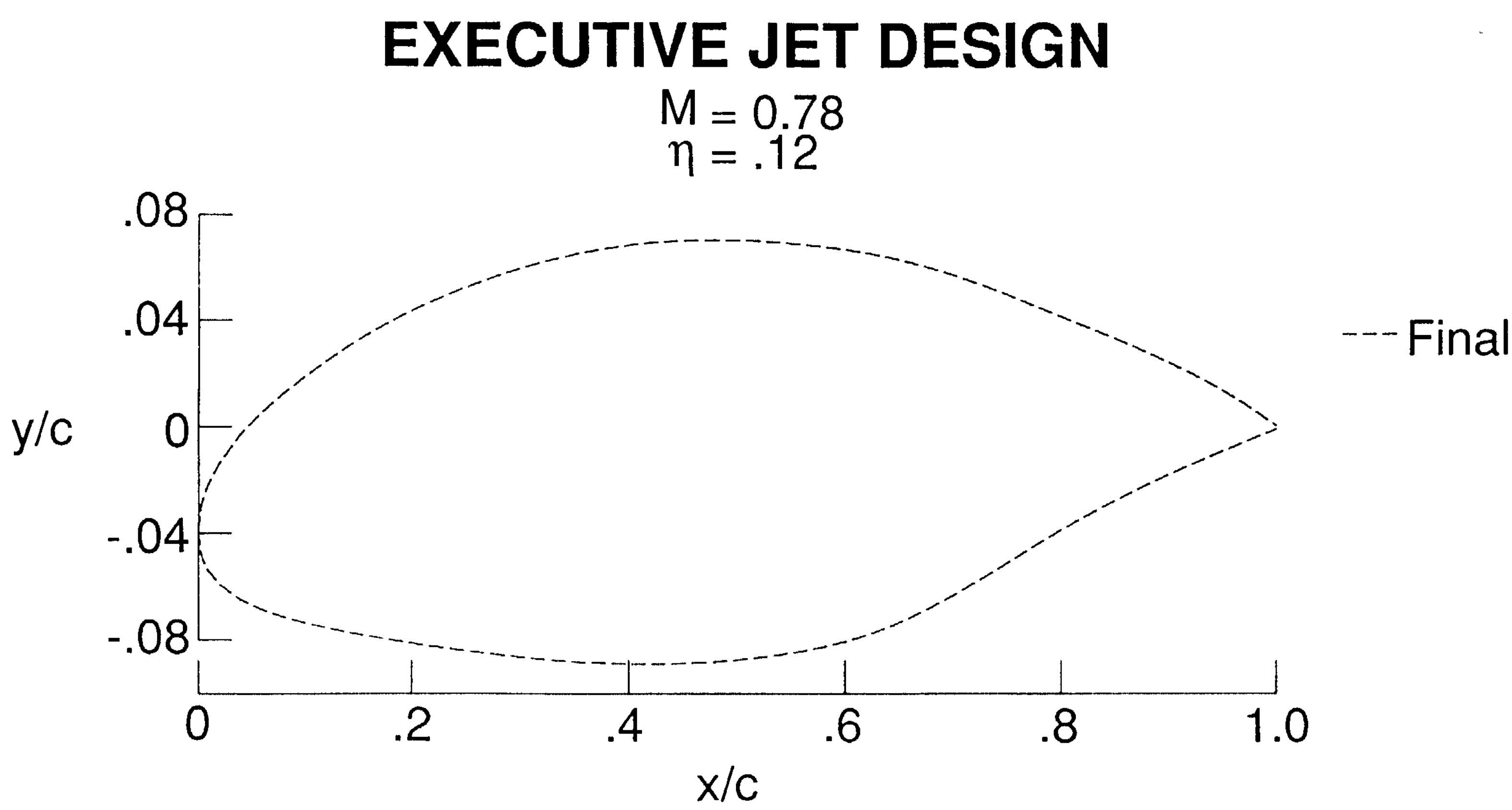
EXECUTIVE JET DESIGN



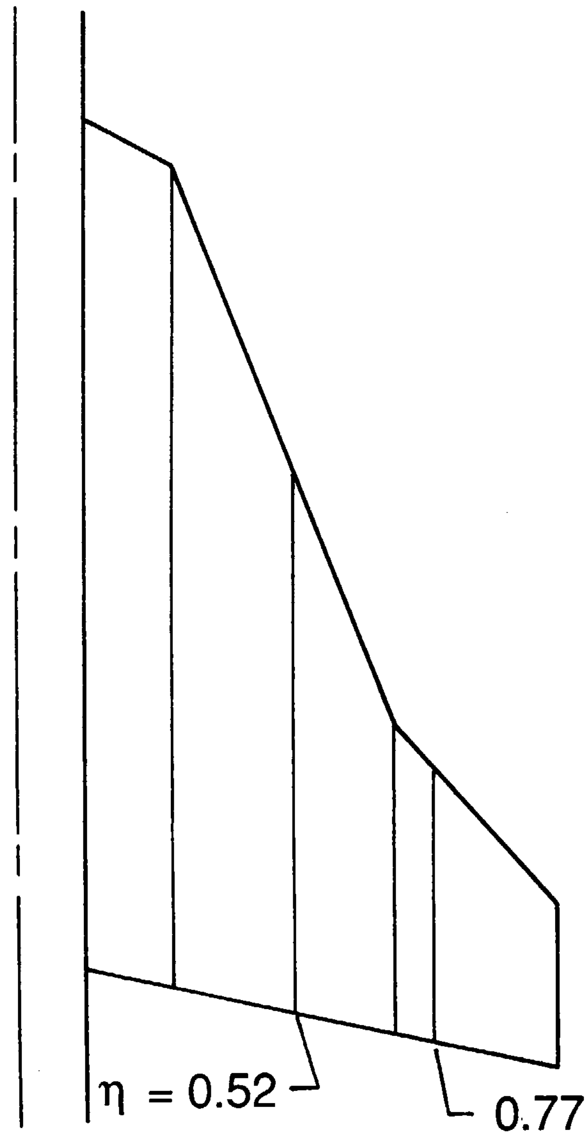
EXECUTIVE JET DESIGN

$M = 0.78$
$\eta = .12$

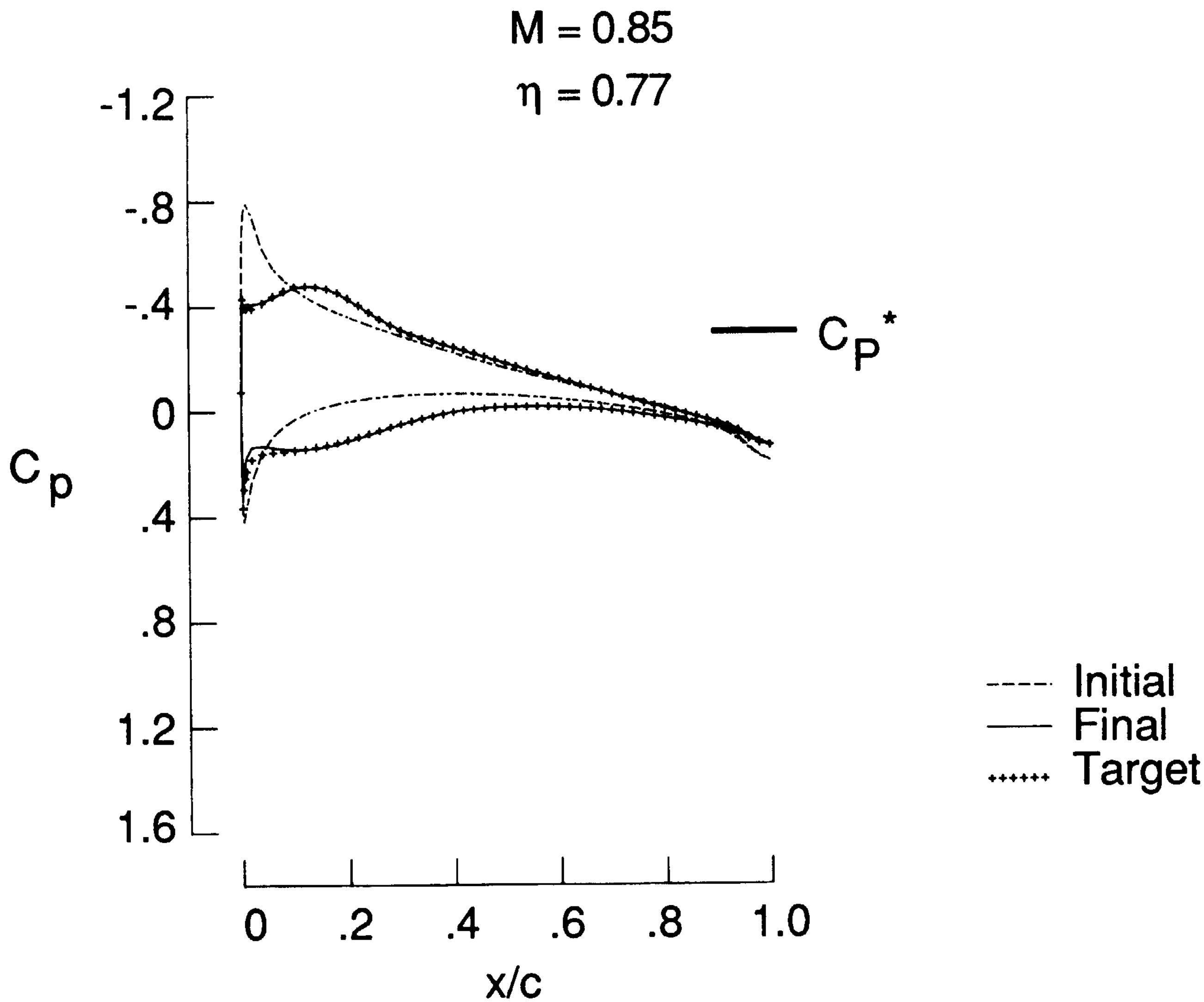



EXECUTIVE JET DESIGN
M = 0.78
η = .12
y/c
.08
.04
0
-.04
-.08
0
.2
.4
.6
.8
1.0
x/c
Final

HIGHLY SWEPT FIGHTER WING GEOMETRY



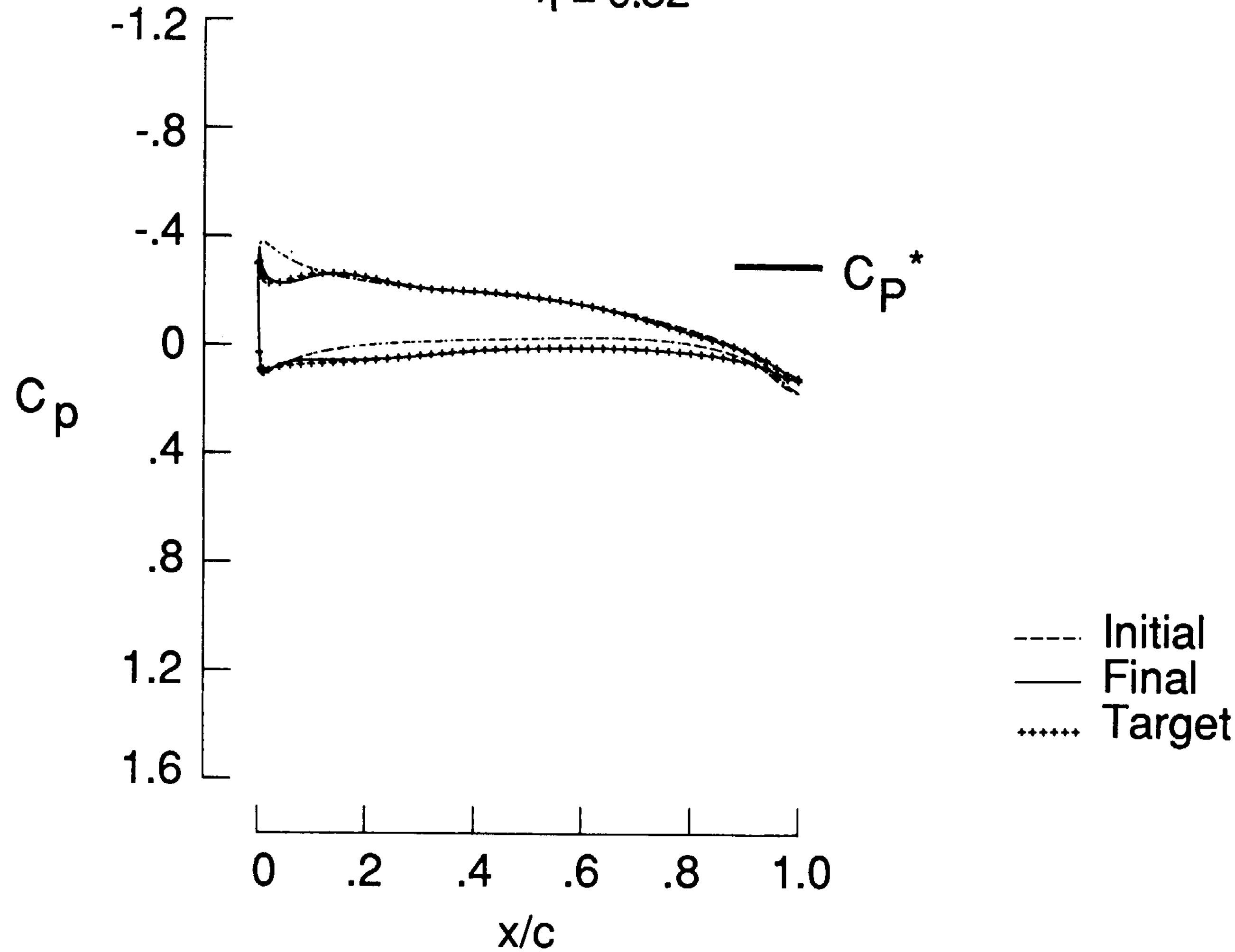
HIGHLY-SWEPT FIGHTER WING CASE



HIGHLY-SWEPT FIGHTER WING CASE

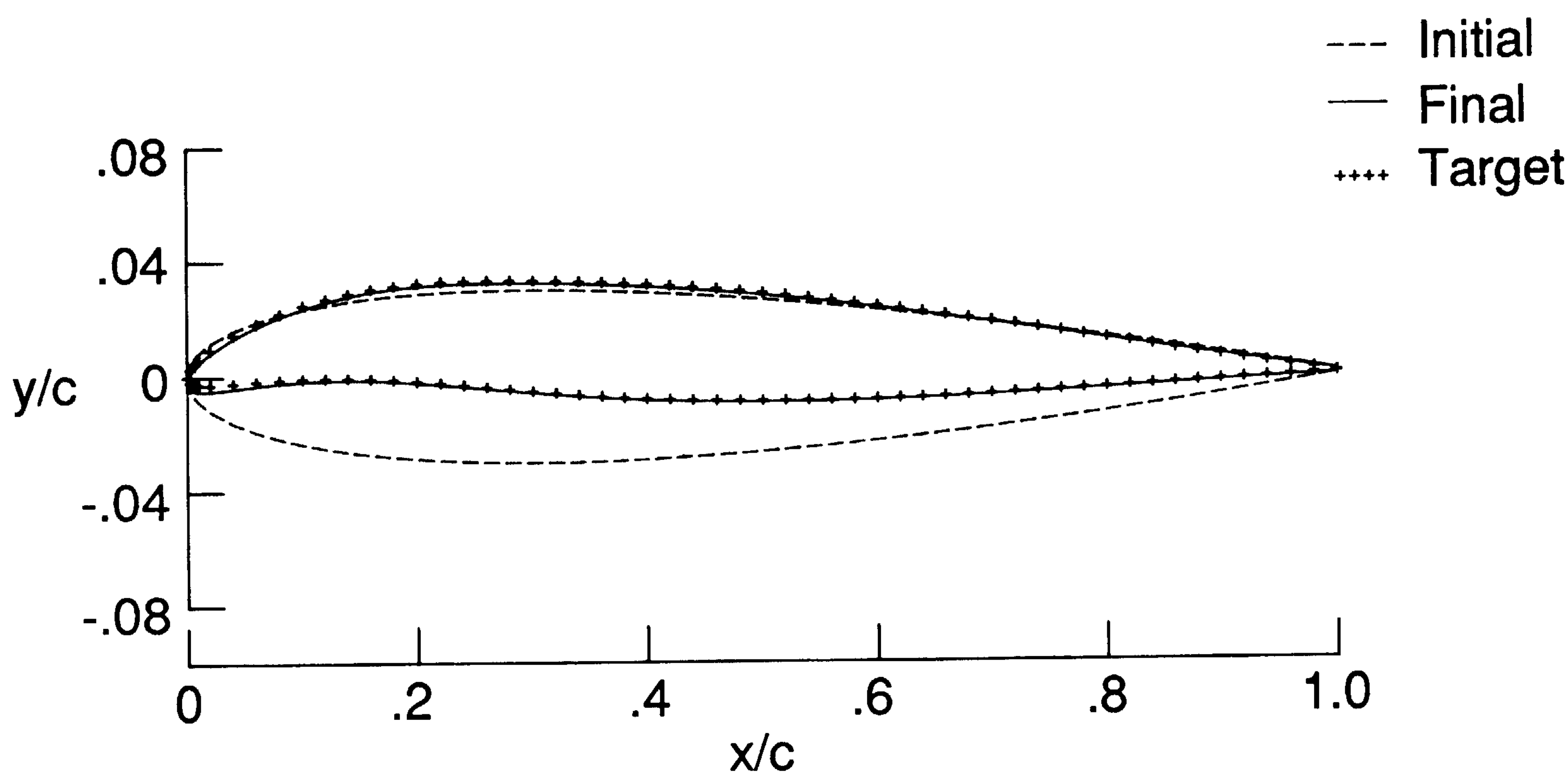
$M = 0.85$

$\eta = 0.52$



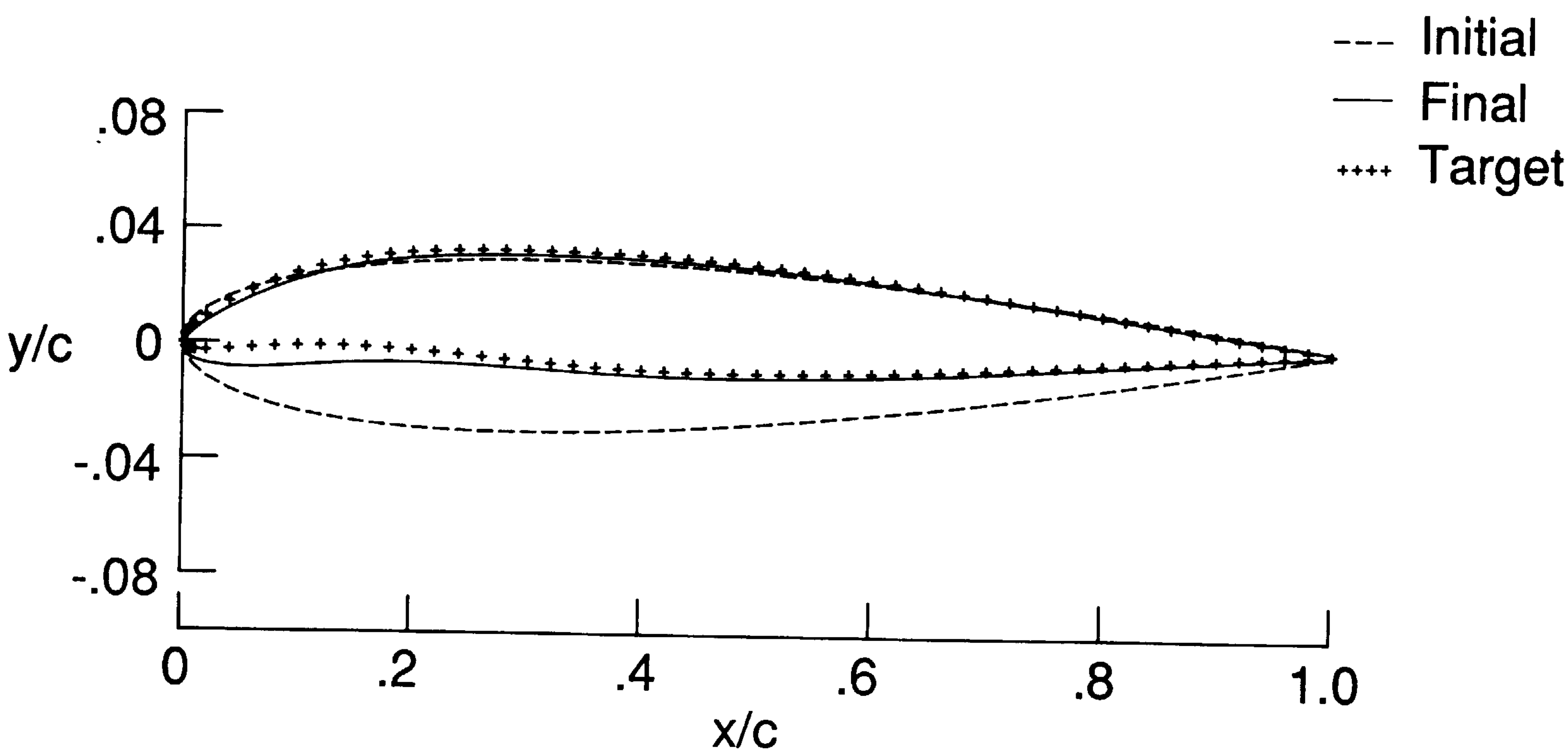
HIGHLY-SWEPT FIGHTER WING CASE

$\eta = 0.77$



HIGHLY-SWEPT FIGHTER WING CASE

$\eta = 0.52$



CONCLUDING REMARKS

- A predictor/corrector method for designing airfoils and wings at transonic speeds has been developed
- Hybrid algorithm used in strongly supercritical regions to improve convergence of design process
- Predictor/corrector approach allows geometry constraints to be easily included
- Results from airfoil and wing design pilot codes indicate that the method is robust, efficient, and accurate for a wide variety of configurations
- Techniques for accounting for viscous and aeroelastic effects have been included