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SUMMARY

This report represents a continuation of research on the static aeroelastic analysis of a generic wing configuration. Results of the study of the asymmetric oblique-wing model developed by Rockwell International, in conjunction with the NASA Oblique Wing Research Aircraft Program, are reported. The capability to perform static aeroelastic analyses of an oblique wing at arbitrary skew positions is demonstrated by applying the MSC/NASTRAN static analysis scheme modified by the aerodynamic influence coefficient matrix created by the NASA Ames Research Center aerodynamic panel codes. The oblique wing is studied at two skew angles, and, in particular, the capability to calculate three-dimensional thickness effects on the aerodynamic properties of the wing is investigated. The ability to model asymmetric wings in both subsonic and supersonic Mach numbers is shown. The aerodynamic influence coefficient matrix computed by the external programs is inserted in MSC/NASTRAN static aeroelasticity analysis run stream to compute the aeroelastic deformation and internal forces. Various aerodynamic coefficients of the oblique wing were computed for two Mach numbers, 0.7 and 1.4, and the angle of attack -5° through 15° .

INTRODUCTION

The work presented in this report is a continuation of the work of Lee, Miura, and Chargin (1987) on the static aeroelastic analysis of a generic wing configuration. Results of the study of the asymmetric oblique-wing model, developed by Rockwell International in conjunction with the NASA Oblique Wing Research Aircraft Program, are reported.

The purpose of the work is to prepare the aerodynamic programs that will be required to perform structural optimization, including aeroelastic effects, for this type of aircraft. The end product of this study is the ability to use the aerodynamic matrices computed by external three-dimensional (3-D) panel codes in the framework of the MSC/NASTRAN static aeroelastic option.

The 3-D panel codes, WING3D and VORTESS, are used to compensate the aerodynamic analysis capabilities of MSC/NASTRAN (Rodden, Harder, and Bellinger, 1979). The MSC/NASTRAN aerodynamic option covers aeroelastic analyses of conventional symmetric aircraft configurations. However, it is insufficient for the aeroelastic analyses of oblique-wing configurations for two reasons. First, the Mach Box aerodynamics module for the supersonic regime is incapable of handling asymmetric configuration and the alternative piston theory is inapplicable to the low supersonic range of our interest. Second, the leading-edge suction force that might be critically important to the performance of the oblique-wing aircraft cannot be included in the analyses. Our strategy is to use the framework of the MSC/NASTRAN aeroelasticity analysis capabilities, while replacing the aerodynamic matrices generated by the Doublet lattice module of MSC/NASTRAN with the aerodynamic influence coefficient

matrices generated by the external programs that can consider all of the significant effects for the oblique-wing configurations.

Rockwell International created the NASTRAN finite element model used in this study as a part of the preliminary design of the Oblique Wing Research Aircraft. The aerodynamic panel models were developed as a part of this study. This aerodynamic grid depends on the skew angle, because two sides of each of the aerodynamic quadrilateral panels must lie parallel to the free-stream direction. Two flat-panel models are created for two skew angles: the symmetric unskewed position and the 45° skew angle (right wing forward). Subsequently, by modeling the upper and lower surfaces independently to incorporate the 3-D effects of the airfoil, a supercritical airfoil profile can be represented accurately at each of the skewed positions.

The aerodynamics programs, WING3D and VORTESS, were provided by Mr. Ralph L. Carmichael of NASA Ames Research Center and Prof. Iran Kroo of Stanford University. Support for implementation of MSC/NSATRAN interface was provided by Mr. Mladen Chargin of NASA Ames Research Center. This study was supported by the NASA Oblique Wing Research Aircraft Program.

THREE-DIMENSIONAL MODEL

The finite element structural analysis model provides a 3-D description of the wing and defines the geometry of the wing to be analyzed. Some remodeling of the wing-root pivot area is performed to calculate the effect of the leading-edge suction forces on the pivot.

The validity of the basic scheme that replaces the aerodynamic matrices generated by the MSC/NASTRAN internal aerodynamics module with the externally generated aerodynamic influence coefficient matrices was demonstrated in reference 1. In this study, the effects of the 3-D aerodynamic model are examined in detail.

First, the aerodynamic properties of the rigid wing are calculated at two skew positions, 0° and 45° by the WING3D and VORTESS programs. Subsequently, aeroelastic effects are included in the calculation of the aerodynamic coefficients by the MSC/NASTRAN static aeroelasticity analysis capability modified by the externally generated aerodynamic influence coefficient matrices.

WING3D and VORTESS

WING3D was developed by Ralph Carmichael and Ilan Kroo at NASA Ames Research Center. These programs are based on a panel method (Woodward, 1968), and are able to accommodate the 3-D effects of thickness, wing camber, twist, and incidence. WING3D is capable of computing a variety of aerodynamic properties of a lifting surface (see Appendix for a more detailed description). It is possible to calculate the integrated aerodynamic force and moment coefficients, and it is also possible to calculate the aerodynamic influence coefficient matrix and output it to a FORTRAN readable file.

Another important requirement (specific to the oblique-wing configuration) is the ability to calculate the effects of leading-edge suction. Because the oblique-wing aircraft could assume asymmetric configurations, and the forces acting on the pivot structure are of prime importance, it is valuable to calculate the leading-edge suction forces acting on the wing and then on the fuselage through the pivot. A revised version of WING3D, known as VORTESS, was developed by Ilan Kroo. VORTESS includes the following modifications to WING3D to incorporate the effects of leading-edge suction:

1. A Riegel's correction is included.
2. The effect of spanwise vorticity on nonrectangular panels is modeled.
3. An option for a second-order pressure distribution is included.

Although these modifications have not been formally documented, sufficient comment statements have been written inside the FORTRAN program.

Wing Profile Modeling

Both WING3D and VORTESS can be used to model a flat-plate wing as a collection of flat panels; however, it is possible to model the 3-D wing by a collection of panels placed on the top and the bottom surfaces of the wing.

The oblique-wing aircraft under consideration uses an SC(2)-0714 supercritical airfoil section at all spanwise stations. The thickness-to-chord ratio is maintained at 14% throughout the span. The profile of this airfoil section is shown in figure 1. Knowing the values of the z coordinates as a function of x , it is a simple matter to calculate the required values of dz/dx and dt/dx .

However, when the wing is skewed, the problem becomes more complex. Because the WING3D program requires that two sides of each aerodynamic panel run parallel to the free-stream direction, the thickness and slope information must be computed for the section of the wing parallel to the free stream. This section profile is different from the original SC(2)-0714 airfoil when the wing is skewed, and the aerodynamic models must take that difference into account.

Currently, only one skewed position (45°) is considered; thus, the new section properties are computed by means of interactive computer graphics capability. If several arbitrary skew angles must be considered, it may be preferable to develop an algorithm to compute $z(x,y)$. In this study, the wing was modeled using a Hewlett-Packard HPSX workstation running the I-DEAS object-modeling software. First, the unskewed wing-surface model was created and the model was rotated through 45° (right wing forward). The skewed model was sliced at the desired spanwise stations. This gave values for $z(x)_{45}$, and it was straightforward to process the section data to obtain the required thickness and slope information. In general, there are five distinct regions for these values, which are shown in figure 2. Over the central and midspan regions, dz/dx and dt/dx are almost constant. In the two areas near the tips, the section profiles are extremely distorted compared to the airfoil at the central section.

RESULTS

The first part of this section presents the results of the study of aerodynamic forces and moments on a rigid wing calculated by WING3D and VORTESS. In the second part, we discuss the effect of flexibility using the aeroelastic analysis capability of MSC/NASTRAN modified by aerodynamic influence coefficient matrices generated by WING3D.

Results are presented in plots by considering the following variations: 0° and 45° wing skew angles, 2- and 3-D aerodynamic models, and several Mach numbers including subsonic and supersonic ranges.

Forces and Moments on a Rigid Wing

The VORTESS program is required to calculate the integrated forces and moments acting on the oblique wing, because it is capable of incorporating the effects of leading-edge suction. In general, the lift coefficient gives a good measure of basic performance of the wing in terms of the changing parameters, whereas the rolling and yawing moment coefficients provide some insight into the effects of asymmetric configurations. The unskewed configuration is examined at Mach numbers of 0.5 and 0.7, and results for the 45° skewed configuration are computed for Mach numbers of 0.7 and 1.4.

Figure 3 shows the difference in the lift coefficient as a function of angle of attack for the 2- and 3-D aerodynamic models at a Mach number of 0.5. As may be expected, the lift curve slope is essentially linear up to an angle of attack of 15° , and the effect of including thickness and camber is simply to shift the curve upward. A similar effect is shown in figure 4, although at this higher Mach number, 0.7, some nonlinearity is seen in the lift-curve slope.

Figures 5 through 7 show the differences of aerodynamic models for a skew angle of 45° and at a Mach number of 0.7. The effect on lift and rolling moment is again to produce a vertical shift. Note that in figure 6 the rolling moment starts decreasing when $\alpha \approx 12.5^\circ$, but this transition angle of attack is the same for both the 2- and 3-D models. The trends commonly observed for the lift and the rolling moment are not found for the yawing moment as shown in figure 7.

When the Mach number is increased to the supersonic range, the differences between the 2- and 3-D aerodynamic models become more significant. At a Mach number of 1.4 and a 45° skew angle, aerodynamic coefficients are shown in figures 8 through 10. The slopes of the lift curve, (dc_l/da) , are no longer the same with the 2-D aerodynamic model, predicting a much higher slope of the lift curve than that in the 3-D model. The effect on the rolling and yawing moments shown in figures 9 and 10 is even more dramatic. These results indicate that the flat-plate aerodynamic model is inadequate to predict the basic performance of the oblique wing in the supersonic range.

Figures 11 through 16 present the same results shown in figures 5 through 10 to contrast the difference of aerodynamic performance in subsonic and supersonic speed range. Figures 11 through 13 are for the 2-D flat-plate aerodynamic models and figures 14 through 16 are for the 3-D aerodynamic models.

As indicated in figure 2, there are five distinct regions for the thickness properties of the 45° wing. Over the central parts of the wing, the data produced by the interactive graphics method is consistent over all the sections, but at the wing tips the reduction in the chord made it more difficult to obtain accurate section profile data. To check if the accuracy of the tip-thickness data significantly affect the computed aerodynamic performances, the VORTESS program was run with a modified tip-thickness distribution. The modification was to use the section data at the boundary of the tip and the main wing throughout the tip region for each of the right and left tips. Insignificant differences are found in the lift coefficients as shown in figure 17. The yawing moment characteristics at a Mach number of 1.4 are strongly affected by the tip models as shown in figure 18; however, their magnitudes were extremely small.

Forces and Moments on Flexible Wing

In the following, the results of aeroelastic analyses obtained by substituting the aerodynamic influence coefficient matrices generated by WING3D into the MSC/NASTRAN finite element program are presented. The procedure used in the present study is outlined in the Appendix, and the required DMAP statements are also included for reference purposes. Note that the DMAP statements included here are applicable only to version 64 of MSC/NASTRAN.

The aerodynamic influence coefficient matrix required for the MSC/NASTRAN static aeroelastic analysis consists of the effect on the normal component of velocity on a particular panel because of the existence of all the other panels. For the 2-D flat-plate model, there is a normal component corresponding to ΔC_p and for the 3-D model, there is an additional normal component resulting from thickness variations. After running WING3D, some processing of the data is required to arrive at a form that is compatible with the MSC/NASTRAN input requirements.

Computation of the aerodynamic coefficients of a flexible wing may be carried out either by processing the reaction forces at the pivot or by processing the deformed shape by the WING3D program. Unfortunately, prior to launching the calculation of the aerodynamic coefficients of a flexible wing, the Oblique Wing Research Aircraft Program was cancelled for reasons beyond the control of the authors. Consequently, the results summarized in this report are limited to those obtained at the beginning of the analysis of the flexible wing.

An aeroelastic analysis is performed for the 45° skewed wing at a Mach number of 0.7 for both the 2-D flat-panel model and the 3-D wing model. The results are summarized in the form of pressure coefficients at the centers of the aerodynamic panels, and nodal displacements.

Figure 19 shows the spanwise quarter-chord pressure distribution at several spanwise locations for both the 2- and 3-D aerodynamic models. The main difference between the two occurs near the tips, particularly in the forward swept tip. It is also observed that the spanwise pressure distribution obtained by the 3-D model is not smooth, and this is perhaps an indication that the mesh sizes may require further refinements. It is clear that the 3-D model predicts slightly higher lift coefficients than the 2-D model does, resulting in slightly larger aeroelastic deformation as shown in figure 20. Figure 20 shows the leading-edge displacement for both the 2- and 3-D models. For the 2-D model the maximum vertical displacement is 26.53 in. at the leading edge of the forward wing-tip (node 551), and for the 3-D model,

the maximum displacement is 29.62 in. at the same node. The difference in displacement is primarily attributed to the extra lift due to the thickness and camber.

RECOMMENDATIONS FOR FUTURE STUDY

First, it is highly recommended that the aerodynamic coefficients for the flexible wing be calculated. The performance of the flexible wing is significantly different from that of the rigid wings. The design of the oblique-wing structures must take the aeroelastic effects into account, and possibly, even take advantage of them.

As described in the Appendix, aeroelastic analyses of oblique-wing configurations require a significant amount of manual labor. It is recommended that the operation of the programs be streamlined by integrating all the programs on one computer, possibly on a high-performance workstation. If the proprietary program MSC/NASTRAN is not available on a particular computer, alternative aeroelastic analysis shells should be considered. The aerodynamic programs WING3D and VORTESS reside on a VAX/780 and their processing speed is unacceptable for practical applications. Also, a number of minor discrepancies between these two programs should be resolved. Currently, VORTESS provides more accurate integrated coefficients than WING3D, but it is not set up to output the aerodynamic influence coefficient matrices. Since VORTESS is capable of including the corrections needed to account for the leading-edge suction, it should be modified to produce the relevant aerodynamic influence coefficient matrices.

The aerodynamic programs used in this study require that two sides of the quadrilateral panels be parallel to the free-stream line direction. This means we have to create a new aerodynamic panel arrangement for each of the different skew angles to be analyzed. It is not acceptable to use the manual process with the interactive computer graphics software to generate the aerodynamic panel data for the skewed configuration, because the resolution is not satisfactory and the process requires extraordinary amounts of time. It is necessary to develop a new automated method for calculating the wing geometry. The problem of changing the geometric model for every change in skew angle would be avoided if the aerodynamic code did not require that two of the edges of the panel are parallel to the free stream. An example of such a code is PANAIR. However, capability of such programs must be evaluated with particular emphasis on the flexibility of generating the aerodynamic influence coefficient matrices in a compatible form with the aeroelastic analysis code and also on possible modifications to predict the leading-edge suction forces.

Finally, aeroelastic tailoring of the composite wing should be undertaken with aeroelastic analysis and sensitivity analysis capability. It is expected that the performance of the oblique wing is sensitive to the aeroelastic responses and by taking advantage of the design flexibility provided by the applications of modern composite materials, we may be able to exploit the potential of this new concept. Structural optimization technology is readily incorporated once the sensitivity analysis capability becomes available.

CONCLUSIONS

Based on the results reported in this study and the results given in reference 1, we can conclude that the use of the three-dimensional aerodynamic model is essential to the analysis and design of the oblique wing. Even though most of the aeroelastic analysis capabilities are developed to analyze symmetric aircraft, they can be applicable to the oblique wing configurations by generating the aerodynamic matrices externally, considering the specific features of the asymmetric configurations of the oblique wing.

APPENDIX

The sequence in which a set of programs is activated to perform aerodynamic and aeroelastic analyses is shown in figure A.1. The ovals represent data files (both input and output), the rectangles represent VAX FORTRAN programs, and the double rectangles represent the Job Control Language (JCL) file together with the relevant data to run the jobs on the Cray-XMP/48 at NASA Ames Research Center.

GEOMWBODY generates the aerodynamic panel data for the specified plan-form, and can also generate the 3-D data for a limited set of airfoil sections. If the airfoil is not one of the preselected airfoils included in the GEOMWBODY internal library, then dz/dx data are required to generate the thickness information for an airfoil section. This is the case for the oblique wing analyzed in this study, which has a unique supercritical airfoil section, and, when skewed, these sections are also distorted. In order to execute either VORTESS or WING3D, the output from GEOMWBODY and dz/dx must be combined by the GEO program.

At this point, VORTESS may be executed if integrated aerodynamic coefficients are desired, but in order to compute the aerodynamic influence coefficient matrices, WING3D must be activated. The output from WING3D is then converted to a binary form by TESTINPUT on the same computer that processes MSC/NASTRAN, so that it is compatible with the MSC/NASTRAN input requirements. This binary file is catalogued on CRAY-XMP/48 as CRAY.PDN. When the static aeroelasticity analysis job is prepared as CRAY.DAT and submitted to CRAY for execution, the file CRAY.RUN is recognized as a file that contains the aerodynamic influence coefficient matrices.

Figure A.2 is a listing of a sample terminal session to run the interactive GEOMWBODY program. Terminal sessions for VORTESS and WING3D are shown in figures A.3 and A.4, respectively. Finally, figure A.5 lists the Cray JCL to run MSC/NASTRAN with the AIC matrices replaced by the output of WING3D. This JCL contains the DMAP alter statements which are required to substitute the AIC matrices.

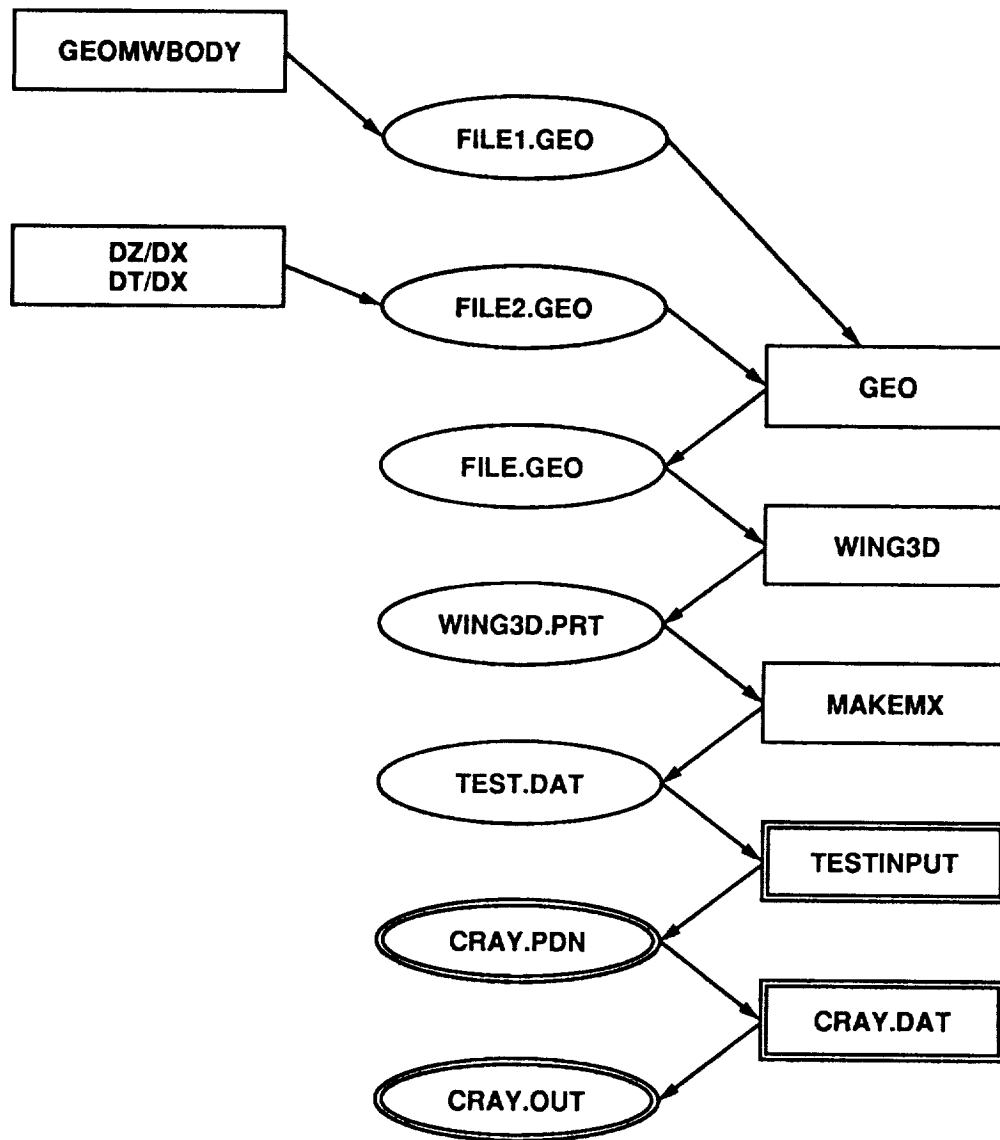


Figure A.1.- Analysis process flow diagram.

```

$ run geombody
NASA-AMES WING-BODY GEOMETRY PROGRAM
ENTER NAME OF OUTPUT FILE: test.geo
IS OUTPUT FILE TO BE FORMATTED FOR
  1 PANAIR
  2 WINGBODY
2
SELECT FUNCTION TO BE PERFORMED
-1 EXIT
  0 END DEFINITION OF THIS VEHICLE
  1 DEFINE A BODY SEGMENT
  2 DEFINE A DISK (PANAIR ONLY)
  3 DEFINE A WING REGION
  4 ADD AN END-TIP TO A PREVIOUSLY DEFINED WING
3
DEFINE WING ROOT CHORD:
LEADING EDGE, X= 660.46
TRAILING EDGE, X= 688.59
Y= -235.17
Z= 0
DEFINE WING TIP CHORD:
LEADING EDGE, X= 628.4
TRAILING EDGE, X= 685.71
Y= -203.11
Z= 0
ENTER NO. OF ROWS OF PANELS: 10
ENTER NO. OF COLUMNS OF PANELS: 2
THE ROOT, TIP, AND SPAN ARE SUBDIVIDED ACCORDING TO VARIOUS
SPACING RULES
THE ACCEPTABLE RULES ARE:
  0 SPECIFIED SPACING
  1 UNIFORM SPACING
  2 FULL COSINE SPACING (DENSE NEAR BOTH ENDPOINTS)
  3 HALF COSINE SPACING (DENSE NEAR FIRST POINT)
  4 HALF SINE SPACING (DENSE NEAR LAST POINT)
ENTER SPACING RULE FOR ROOT CHORD: 1
ENTER SPACING RULE FOR TIP CHORD: 1
ENTER SPACING RULE FOR SPAN: 1
ACCEPTABLE CHOICES FOR AIRFOIL SECTION ARE:

```

Figure A.2.- Interactive processing of the geometry definition program.

- 0 ZERO THICKNESS
- 1 PARABOLIC ARC
- 2 DOUBLE WEDGE
- 3 30-70 HEX
- 4 WEDGE (THICK BASE)
- 5 NACA 000X
- 6 NACA 6400X
- 7 NACA 6500X
- 8 RAE 101

SELECT AIRFOIL SECTION FOR THIS WING: 0
 NASA/AMES WING BODY GEOMETRY PROGRAM
 WING GRID DEFINITION POINTS

| Y-SPAN | Z-SPAN | X-ROOT | X-TIP |
|------------|---------|-----------|-----------|
| -235.17000 | 0.00000 | 660.46002 | 628.40002 |
| -219.14000 | 0.00000 | 663.27301 | 634.13104 |
| -203.11000 | 0.00000 | 666.08600 | 639.86206 |
| | | 668.89899 | 645.59308 |
| | | 671.71198 | 651.32410 |
| | | 674.52496 | 657.05511 |
| | | 677.33759 | 662.78613 |
| | | 680.15094 | 668.51715 |
| | | 682.96393 | 674.24817 |
| | | 685.77692 | 679.97919 |
| | | 688.59003 | 685.71002 |

SELECT FUNCTION TO BE PERFORMED

- 1 EXIT
- 0 END DEFINITION OF THIS VEHICLE
- 1 DEFINE A BODY SEGMENT
- 2 DEFINE A DISK (PANAIR ONLY)
- 3 DEFINE A WING REGION
- 4 ADD AN END-TIP TO A PREVIOUSLY DEFINED WING

-1
 FORTRAN STOP
 \$

Figure A.2.- Concluded.

\$ run vortess

```
Three-Dimensional Wing Program
Enter name of geometry file:r45tv.geo
Reading geometry file...
  300 panels read from input file.
Enter the output level code:
=0 no output
=1 integrated forces and moments
=2 local pressures
=3 panel corner points
=4 local velocity components
=8 panel areas and centroids
=9 aerodynamic matrices
1
Enter the free-stream Mach number: 0.7
Specify the symmetry of the configuration.
  0 No symmetry
  1 Right/Left symmetry
Enter Symmetry code: 0
Enter SREF: 42241.8
Enter CBAR: 87.78
Enter SPAN: 481.22
Enter reference axis position XREF: 425.29
Enter reference axis position YREF: 0.0
Enter reference axis position ZREF: 54.32
Computing aerodynamic matrices...
Enter (1) to design for a given Cp
      (2) to analyze a given design
2
Performing L-U decomposition...
Condition number= 1.4462E+01
Enter angle of attack (or ^Z to quit) : 5.0
Formula for pressures (3-2nd order, 4-isen): 4
Computing aerodynamic matrices...
Enter (1) to design for a given Cp
      (2) to analyze a given design
2
Performing L-U decomposition...
Condition number= 1.4462E+01
Enter angle of attack (or ^Z to quit) : ^Z
Files VORTESS.CPS, VORTESS.POU, and VORTESS.FNM created.
Normal termination of VORTESS.
$
```

Figure A.3.— Interactive processing of VORTESS program.

```

$ run wing3D
Three-Dimensional Wing Program
Enter name of geometry file: r45t.geo
Reading geometry file...
  300 panels read from input file.
The remaining data (parameters and cases) may be read from an
external file or entered interactively (with prompting).
To enter data interactively, type <RETURN> when asked for
the name of the data file.
Enter the name of the data file: <return>
Enter the output level code:
  =0 no output
  =1 integrated forces and moments
  =2 local pressures
  =3 panel corner points
  =4 local velocity components
  =8 panel areas and centroids
  =9 aerodynamic matrices
  9
Enter the free-stream Mach number: 1.4
Specify the symmetry of the configuration.
  0 No symmetry
  1 Right/Left symmetry
Enter Symmetry code: 0
Enter SREF: 42241.8
Enter CBAR: 87.78
Enter SPAN: 481.22
Enter pitching moment reference axis, x= 425.29
Computing aerodynamic matrices...
Aerodynamic matrices computed in 434.75 seconds.
Performing L-U decomposition...
L-U decomposition computed in 68.16 seconds.
Condition number= 1.3632E+03
Enter angle of attack (or ^Z to quit) : 10.0
Performing L-U decomposition...
L-U decomposition computed in 68.16 seconds.
Condition number= 1.3632E+03
Enter angle of attack (or ^Z to quit) : ^Z
Files WING3D.PRT and WING3D POU added to your directory.
Normal termination of WING3D.
$

```

Figure A.4.— Interactive processing of WING3D.


```

JOB, JN=OBLIQUE, T=600.
ACCOUNT, AC=xxxxxxx, US=xxxxxx, UPW=xxxx.
ACCESS, DN=NASTRUN, PDN=NASTRAN, ID=EEEMKC, OWN=EEMKC.
ACCESS, DN=FT11, PDN=R45TA, ID=PANEL.
CALL, DN=NASTRUN, CNS.
NASTRAN, GREEN, NELSON.
/EOF
*IDENT GET
/EOF
*DECK X
NASTRAN PREFOPT=2, SYSTEM(7)=10 $
ID STATIC AERO TEST
SOL 21, 0
DIAG 8, 13
TIME 50.
ALTER 2
FILE      UX=SAVE $
ALTER 751, 751 $ ERROR IN DMAP
ALTER 966, 966
ALTER 881, 881
INPUT4   /XAJJ,,,,/1/11/-1 $
ADD      XAJJ,/AJJ/(-1.,0.) $
ALTER 971, 971
ALTER 880
$
$ ELIMINATE MOMENT TERMS FROM SKJ FOR WOODWARD
$ AERONAUTICS
$
PARAML   SKJ//TRAILER/2/U,N,NWOOD $
MATGEN   ,/PWOOD/4/1/NWOOD/0/1/2/2 $
PARTN    SKJ,,PWOOD/SKJ1,,,,/1 $
MERGE    SKJ1,,,,,PWOOD/SKJW/1 $
EQUIV    SKJW,SKJ/ALWAYS $
ALTER 968
PARAML   PSAL//TRAILER/5/U,N,NPSAL $
PARAM    //SUB/NPSAL/NPSAL/1 $
COND     UNTRM3,NPSAL $
ALTER    970
LABEL    UNTRM3 $
CEND
TITLE = STATIC AERO TEST
SUBTITLE = 300 SQ. FT. OBLIQUE WING
LABEL = 3-D AERODYNAMIC MODEL, 45 DEG.

```

Figure A.5.— MSC/NASTRAN aeroelastic analysis deck setup on CRAY XMP/48.

```
SEALL = ALL
ECHO=SORT(AELIST,AEROS,AESTAT,CAERO1,MAT1,MAT2,MPC,PAERO1)
ECHO=SORT(PARAM,PBAR,PSHELL,SET1,SPC1,SPLINE1,TRIM)
SPC = 1
$MPC = 201
DISP = ALL
AEROF = ALL
APRES = ALL
SUBCASE 1
  SUBTITLE = Q = 5.047 (M = 0.7)
  TRIM = 1
BEGIN BULK
  --- NASTRAN BULK DATA ---
```

Figure A.5.- Concluded.

REFERENCES

- Lee, I.; Miura, H.; and Chargin, M. K.: Static Aeroelastic Analysis for Generic Configuration Aircraft. NASA TM-89423, 1987.
- Rodden, W. P.; Harder, R. L.; and Bellinger, E. D.: Aeroelastic Addition to NASTRAN. NASA CR-3094, 1979.
- Woodward, F. A.: An Improved Method for the Aerodynamic Analysis of Wing-Body-Tail Configurations in Subsonic and Supersonic Flow. NASA CR-2228, 1973.

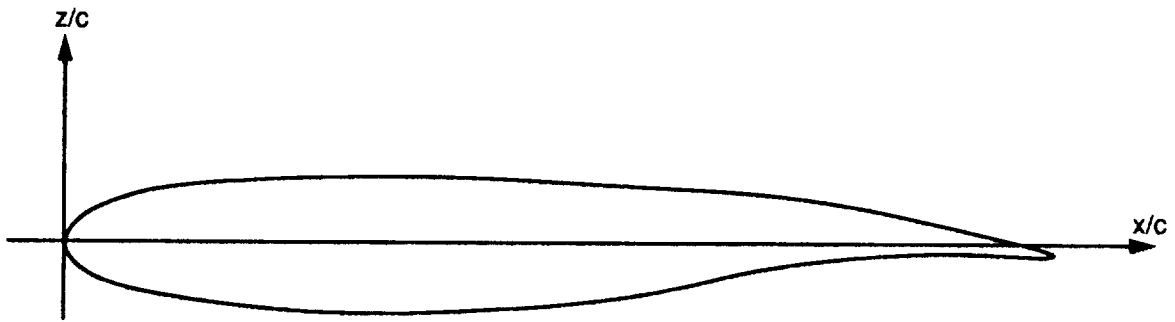


Figure 1.— Airfoil section SC0714.

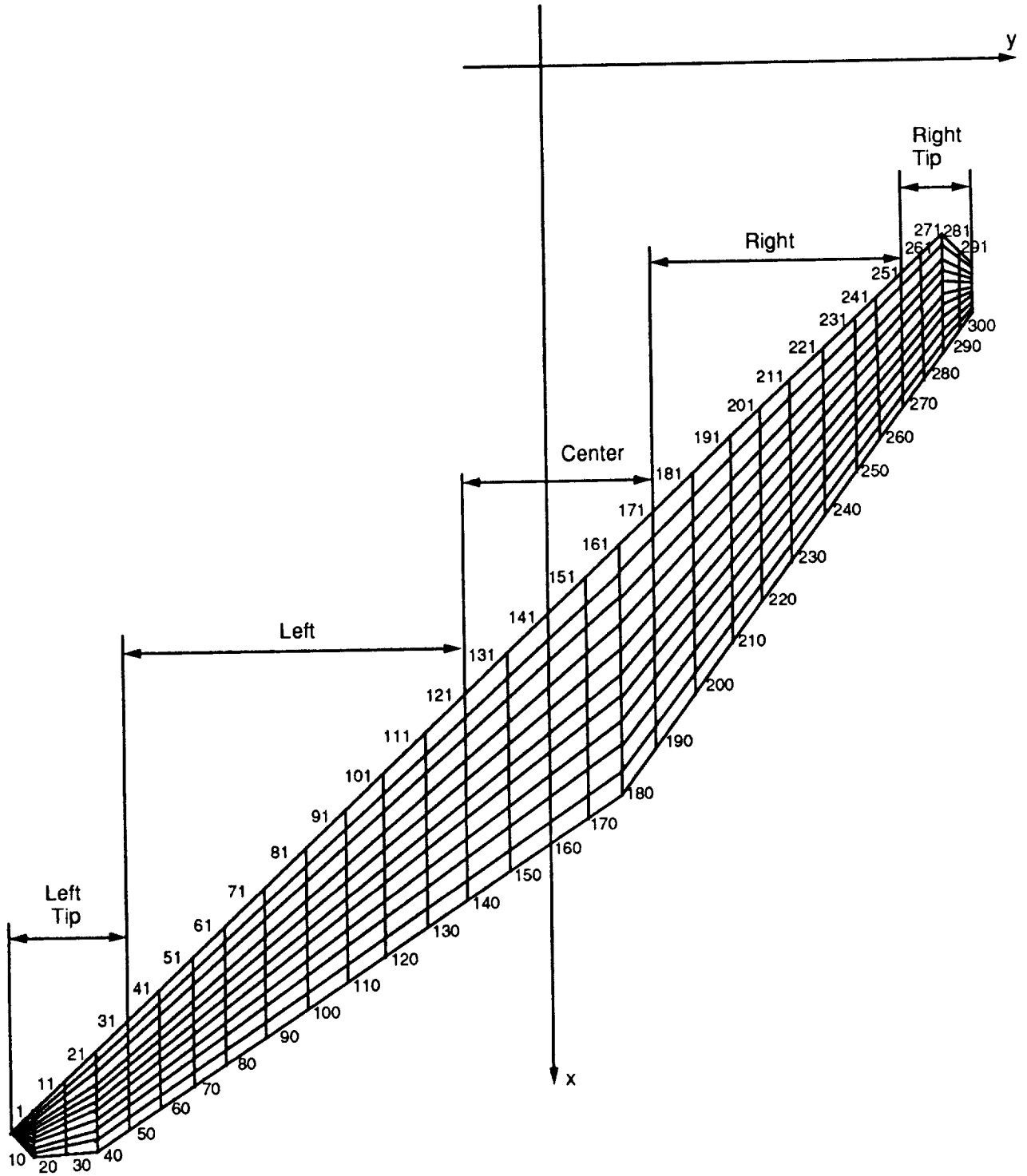


Figure 2.- Aerodynamic panel arrangement for sweep angle 45°.

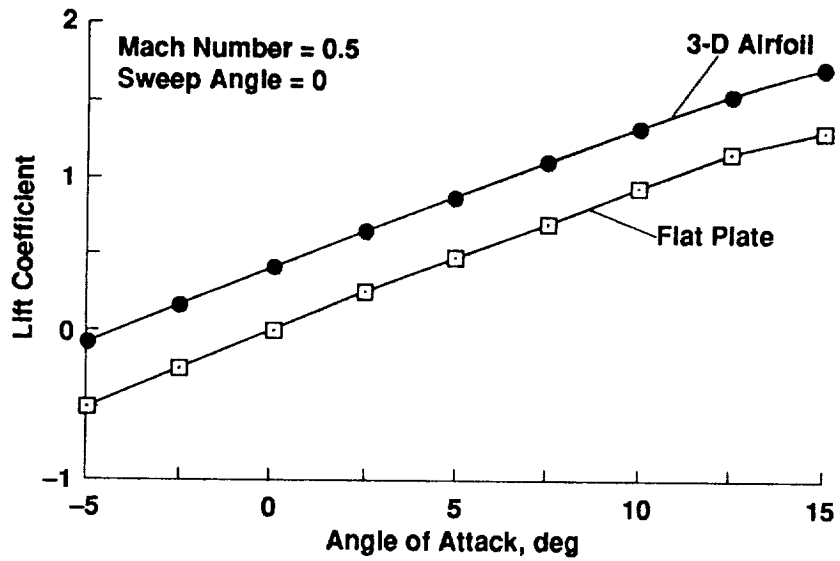


Figure 3.- Effect of thickness on lift coefficient.

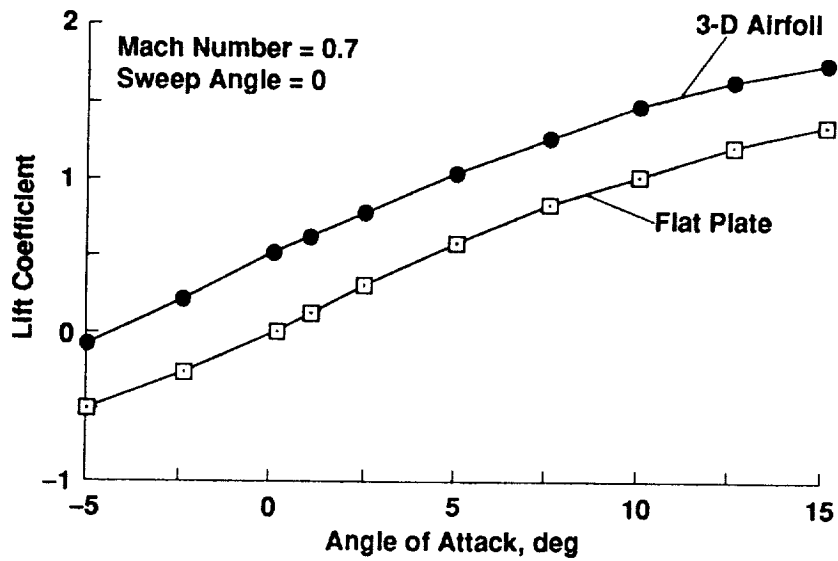


Figure 4.- Effect of thickness on lift coefficient (M = 0.7).

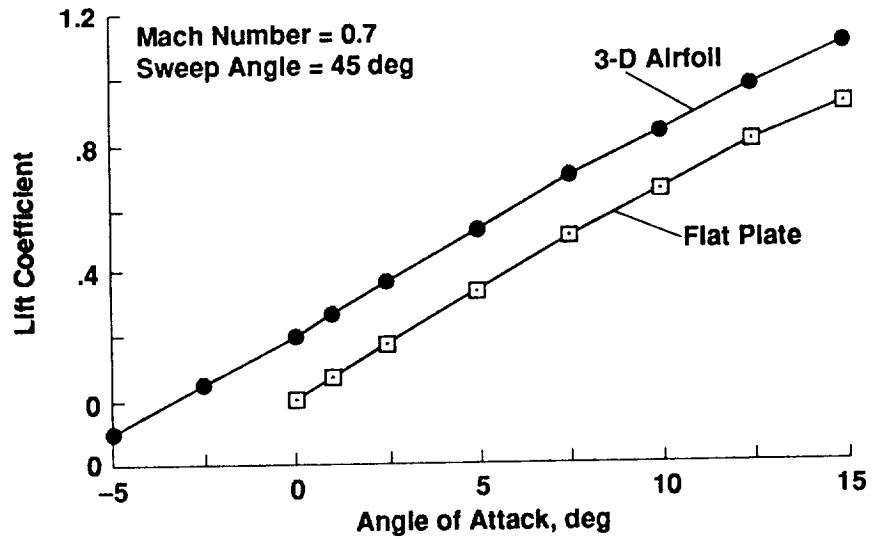


Figure 5.— Effect of thickness on lift coefficient.

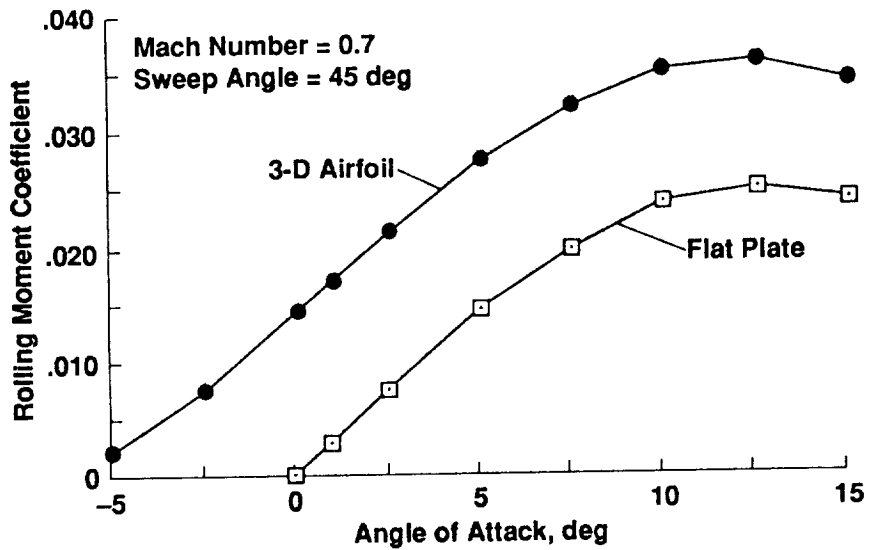


Figure 6.— Effect of thickness on rolling moment coefficient.

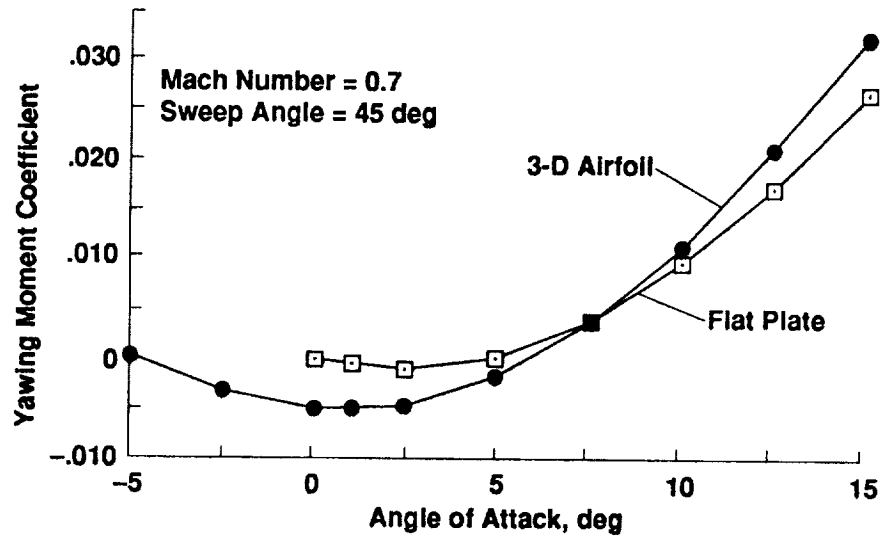


Figure 7.— Effect of thickness on yawing moment coefficient.

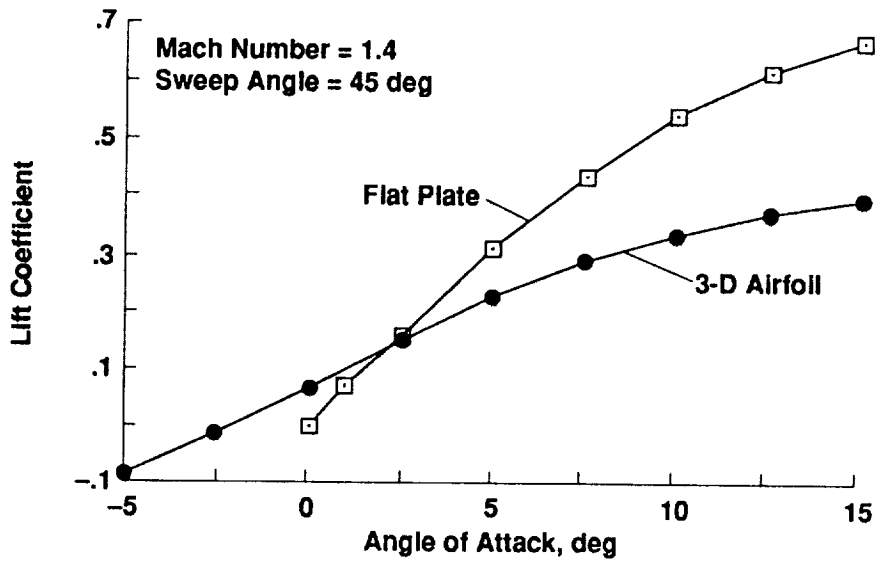


Figure 8.— Effect of thickness on lift coefficient.

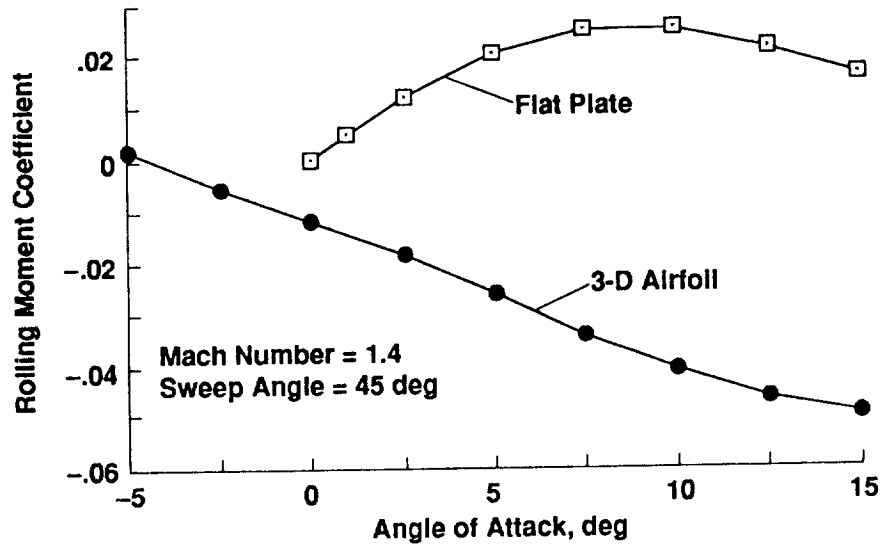


Figure 9.— Effect of thickness on rolling moment coefficient.

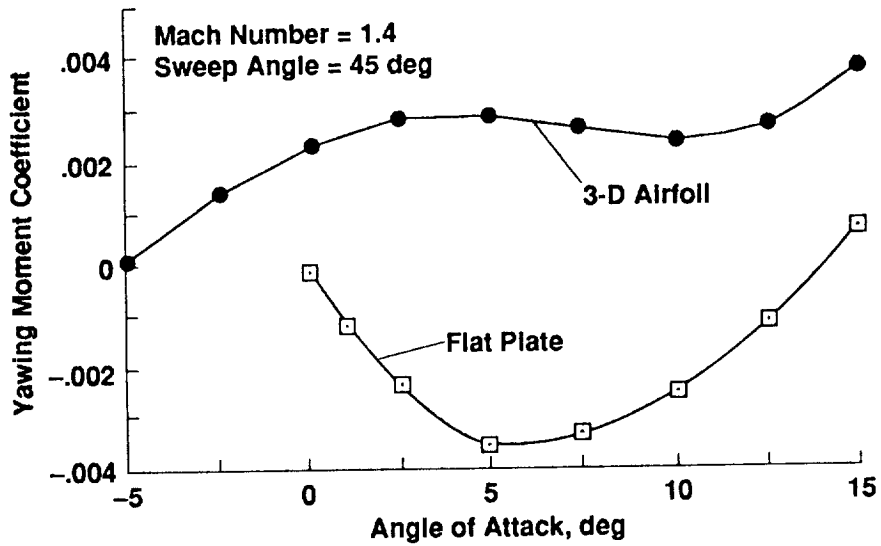


Figure 10.— Effect of thickness on yawing moment coefficient.

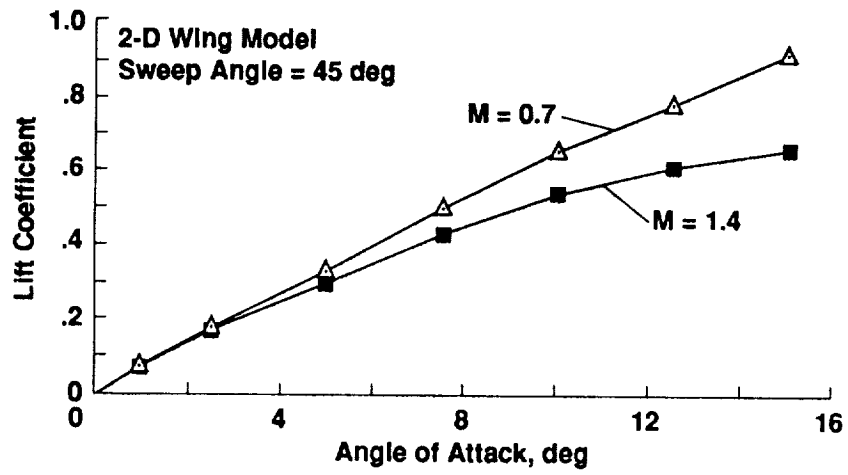


Figure 11.— Effect of Mach number on lift coefficient (2-D model).

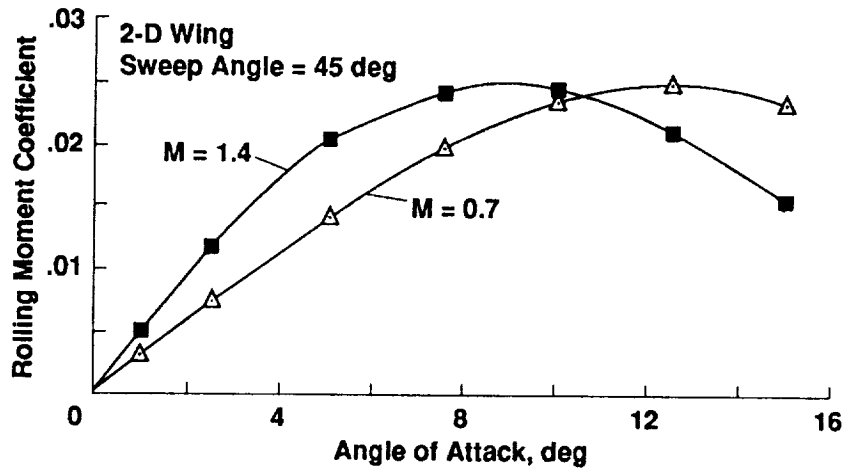


Figure 12.— Effect of Mach number on rolling moment coefficient.

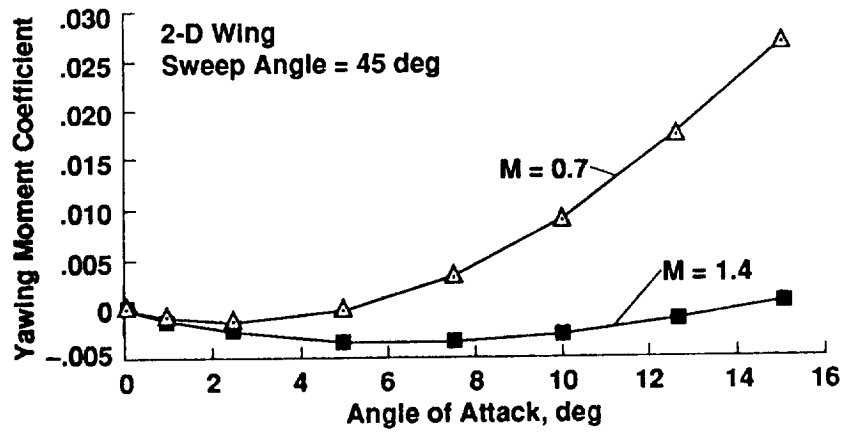


Figure 13.- Effect of Mach number on yawing moment coefficient.

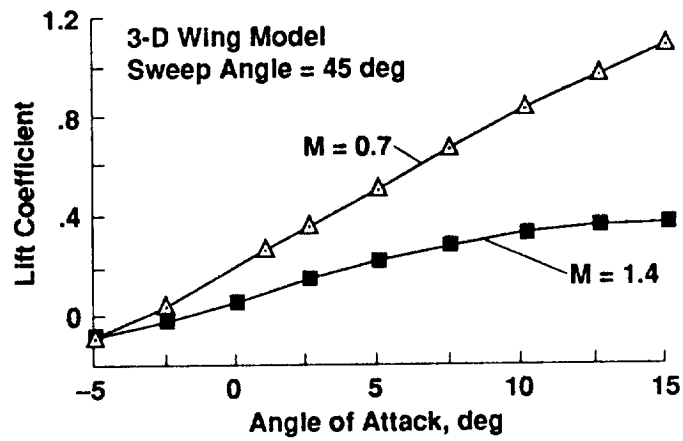


Figure 14.- Effect of Mach number on lift coefficient.

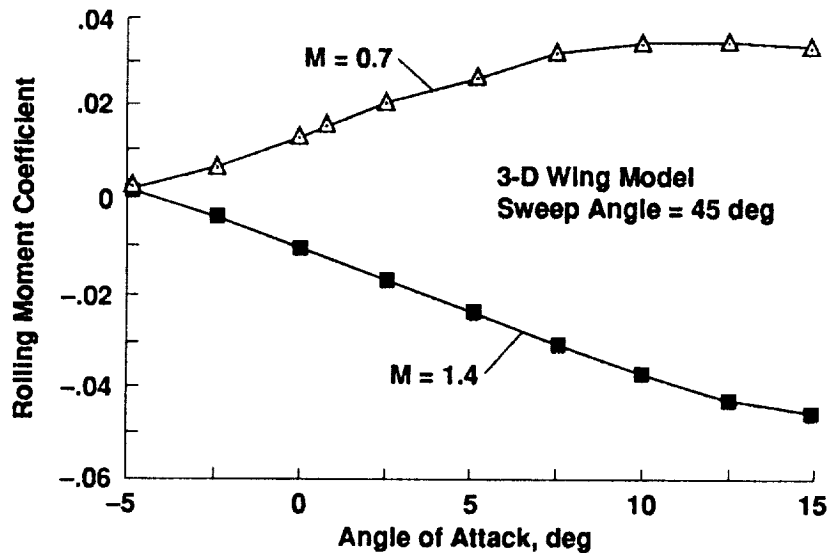


Figure 15.— Effect of Mach number on rolling moment coefficient.

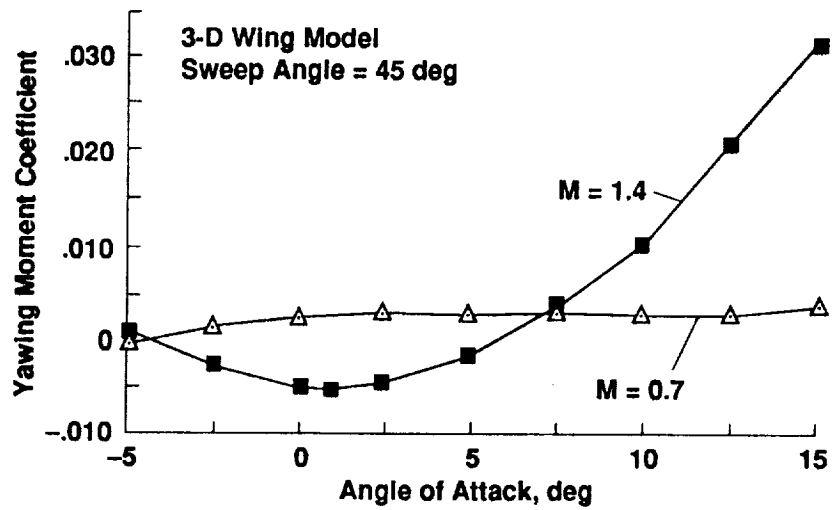


Figure 16.— Effect of Mach number on yawing moment coefficient.

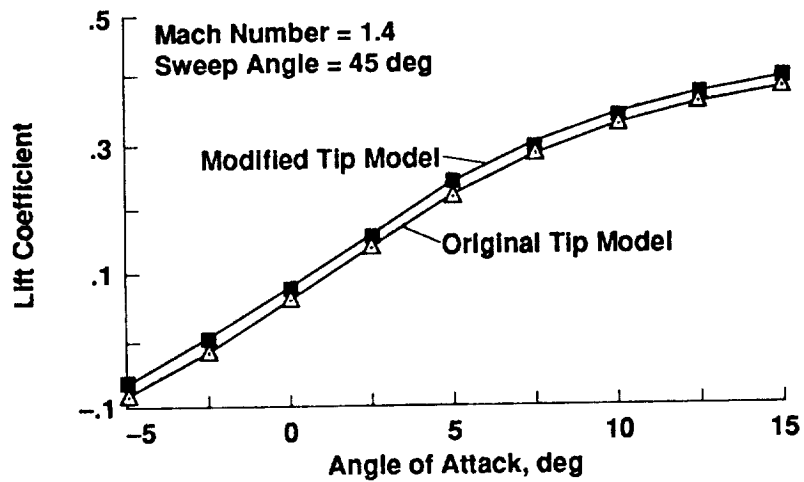


Figure 17.- Effect of tip model on lift coefficient.

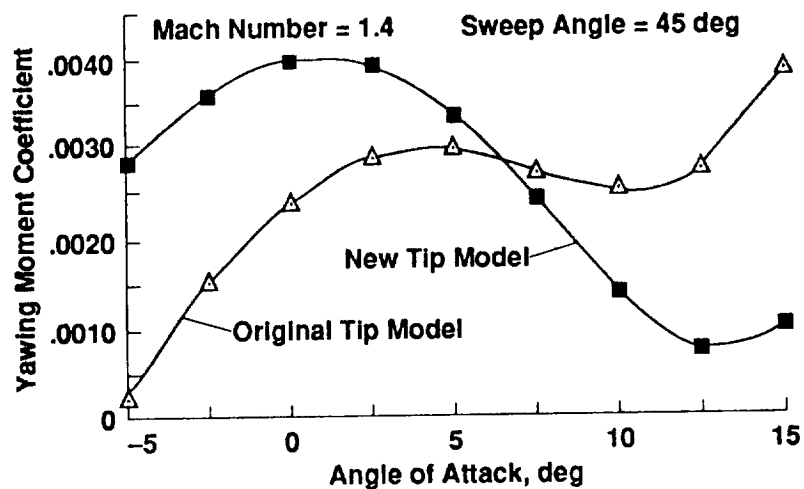


Figure 18.- Effect of tip models on yawing moment coefficient.

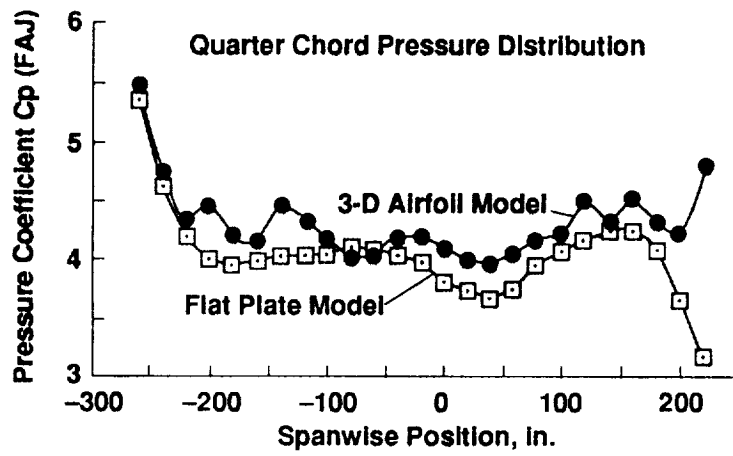


Figure 19.- Spanwise pressure distribution.

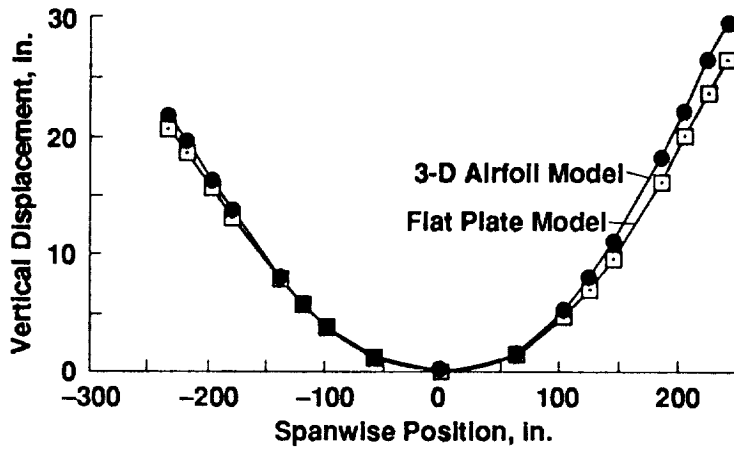


Figure 20.- Quarter chord static displacement.



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| 16. Abstract <p>This report represents a continuation of research on the static aeroelastic analysis of a generic wing configuration. Results of the study of the asymmetric oblique-wing model developed by Rockwell International, in conjunction with the NASA Oblique Wing Research Aircraft Program, are reported. The capability to perform static aeroelastic analyses of an oblique wing at arbitrary skew positions is demonstrated by applying the MSC/NASTRAN static analysis scheme modified by the aerodynamic influence coefficient matrix created by the NASA Ames aerodynamic panel codes. The oblique wing is studied at two skew angles, and in particular, the capability to calculate three-dimensional thickness effects on the aerodynamic properties of the wing is investigated. The ability to model asymmetric wings in both subsonic and supersonic Mach numbers is shown. The aerodynamic influence coefficient matrix computed by the external programs is inserted in MSC/NASTRAN static aeroelasticity analysis run stream to compute the aeroelastic deformation and internal forces. Various aerodynamic coefficients of the oblique wing were computed for two Mach numbers, 0.7 and 1.4, and the angle of attack -5° through 15°.</p> | | | | | |
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