SONIC-BOX METHOD EMPLOYING LOCAL MACH NUMBER FOR OSCILLATING WINGS WITH THICKNESS

By S. Y. Ruo

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SONIC-BOX METHOD EMPLOYING LOCAL MACH NUMBER
FOR OSCILLATING WINGS WITH THICKNESS

By S. Y. Ruo
Lockheed-Georgia Company

SUMMARY

A computer program has been developed to account approximately for the effects of finite wing thickness in the transonic potential flow over an oscillating wing of finite span. The program is based on the original sonic-box program of Rodemich and Andrew and has been extended to include the effects of the swept trailing edge and the thickness of the wing. Account for the non-uniform flow caused by finite thickness is made by application of the local linearization concept. The thickness effect, expressed in terms of the local Mach number, is included in the basic solution to replace the coordinate transformation method used in the earlier work. Calculations were made for a delta wing and a rectangular wing performing plunge and pitch oscillations, and the results were compared with those obtained from other methods. An input guide and a complete listing of the computer code are presented.

INTRODUCTION

In reference 1, the sonic-box method computer program was developed for calculation of unsteady transonic flow aerodynamics for oscillating planar wings with unswept trailing edge by approximating the wing planform with a matrix of square boxes. Later, it was extended to include the swept trailing edge and control surfaces in reference 2. The sonic-box method uses a doublet velocity potential as the basic solution to satisfy the linearized transonic flow, unsteady small-perturbation velocity-potential equation with the associated boundary conditions.

In references 3 and 4, the wing thickness effect is partially recovered by the inclusion of local Mach number in the governing equation for the
unsteady transonic flow. It uses the concept of local linearization to reduce the nonlinear small-perturbation equation to a linear one with non-constant coefficients. This is further reduced to a linear equation with constant coefficients by an appropriate coordinate transformation. This final equation and the associated boundary condition in the transformed space become identical to those treated in the physical space by Rodemich and Andrew in reference 1. The numerical results for the wing with thickness were obtained by adopting the sonic-box method in the transformed space. Because of the assumptions made in deducing the governing equation to a manageable form, this technique is applicable only to relatively thin wings. That is, the local mean Mach number on the wing surface must not be very different from unity. Further, it is assumed that there is no flow separation and no strong shock waves on the wing surface.

The computer programs developed in references 1, 2, and 3 use the least-square method to fit some of the input data, such as wing deflection or steady Mach number distribution on the wing, and to fit the computed velocity potential with a form of pre-determined polynomial surface for the subsequent calculation of the unsteady pressure and the generalized aerodynamic force coefficients. The computer program described in reference 4 adopts the natural cubic spline for fitting calculated velocity potential and the spline-surface for fitting input modal deflections and Mach number distribution instead of the polynomial-surface fitting used in references 1, 2, and 3. The codes in references 3 and 4 allow the computation of generalized aerodynamic force coefficients for wings of zero and finite thickness; the swept trailing edges are allowed but not the control surfaces.

The computer program presented in this report is developed according to the "alternate technique" described in reference 5. The coordinate transformation technique as used in references 3 and 4 fails when the mean local Mach number on the wing becomes very different from unity. In order to avoid this problem, an alternate technique was proposed in reference 5 to approximately account for the thickness effect, expressed in terms of mean local Mach number on the wing, by including it directly in the basic doublet solution to replace the coordinate transformation. The computer program thus developed is smaller
than that of reference 4 and the amount of computation required has also been reduced.

In general, the basic assumptions and limitations applied to the computer code in reference 4 also apply to the present code. However, the present formulation avoids the difficulties associated with the artificial wake and wing-surface fold-over due to multivalued transformation which limits the usefulness of the coordinate transformation formulation of reference 4. The zero thickness wing portion of the computer code is unchanged from that of reference 4. Input is identical in both codes and the output differs very little between them.

SYMBOLS

\( b \) reference length \((\text{dimension} = L)\)
\( C_p \) pressure coefficient
\( \exp, e \) exponential function
\( i \) \( \sqrt{-T} \)
\( k \) reduced frequency, \( \omega b/U_\infty \)
\( L \) unit of length
\( L_{ij} \) generalized aerodynamic force coefficient
\( M \) local Mach number
\( T \) unit of time
\( U_\infty \) reference velocity (freestream), \((\text{dimension} = L/T)\)
\( x, y, z \) dimensionless Cartesian coordinates \((\text{reference length} = b)\)
\( \Theta_{ij} \) phase angle of \( L_{ij} \)
\( \tau \) maximum thickness to root chord ratio
\( \Phi_0 \) magnitude of oscillatory dimensionless small perturbation velocity potential
\( \omega \) angular velocity \((\text{dimension} = \text{radian}/T)\)
\( ( )_L \) subscripts denote quantity at leading edge
\( ( )_E \) subscripts denote quantity at trailing edge
METHOD

The computer program described in reference 4 is based on the coordinate transformation technique to reduce the locally linearized equation with non-constant coefficients for nonzero thickness wing at sonic speed to a linear one with constant coefficients. This linear equation with the associated boundary conditions can, then, be solved with sonic-box method. When the mean local Mach number on the wing becomes very different from that of the free-stream, the transformation may become multivalued and consequently an artificial wake or wing-surface fold-over may be created in the transformed space. This technique fails once it happens. In order to avoid this problem, an alternate technique was proposed in reference 5 to approximately account for the thickness effect, expressed in terms of mean local Mach number on the wing, by including it in the basic doublet solution.

The governing equation for unsteady transonic small perturbation velocity potential is

\[ \varphi_{yy} + \varphi_{zz} - M^2 (2ik\varphi_{x} - k^2 \varphi) = 0, \quad (1) \]

where

\[ \varphi(x,y,z) = \varphi(x,y,z,t) e^{-ikt}, \]

which is also equation (1) of reference 4.

The basic solution for equation (1), representing a point doublet oriented parallel to the z-axis at the origin and satisfying the required condition at infinity for a small finite region on the wing where the value of \( M \), the Mach number, is considered to be constant, may be written as

\[
\varphi_o = \begin{cases} 
0, & x \leq 0, \\
\frac{ik}{2\pi} \frac{zM^2}{x^2} \exp \left\{ -\frac{1}{2}ik \left[ x + \frac{M^2(y^2+z^2)}{x} \right] \right\}, & x > 0,
\end{cases} \quad (2)
\]
in which $M$ is regarded as a parameter. This solution satisfies equation (1) only in a small finite region of the wing; so the solution may be considered to be of the locally linearized form.

The only quantity in the program of reference 4 requiring modification is the velocity influence coefficient for the wings with thickness. It is presently written as

$$A = \frac{1}{2\pi} \frac{kM^2}{E} \int \int \frac{1}{(x-\xi)^2} \exp \left\{ - \frac{k}{2} \left[ (x-\xi) + \frac{M^2(y-\eta)^2}{(x-\xi)^2} \right] \right\} \, d\xi d\eta$$

$$= \frac{1}{2\pi} \frac{kM}{E} \int \int \frac{1}{u^2} \exp \left\{ - \frac{M^2}{2} \left( \frac{u + v^2}{u} \right) \right\} \, du dv$$

(3)

(4)

where

- $H =$ length of the box side
- $k =$ reduced frequency
- $M =$ mean local Mach number
- $i = \sqrt{-1}$
- $\xi = kH$
- $E =$ box at $(\xi,\eta)$
- $u = (x-\xi)/H$
- $v = M(y-\eta)/H$

The value of the velocity influence coefficient computed in the sonic-box computer program is with $M = 1.0$ in equations (3) and (4). Under this condition, the velocity influence coefficient is function of the wing geometry only. For $M \neq 1.0$, it becomes function of the Mach number also. The value of the modified velocity influence coefficient required in this alternate technique to account for the wing thickness effect may be evaluated from the table computed for $M = 1.0$ condition for the same reduced frequency.

To evaluate the modified velocity influence coefficient for this alternate technique, one may do the following:

1. take the average value of the mean local Mach number at the center of the receiving, $(x,y)$, and sending, $(\xi,\eta)$, boxes,
2. multiply the spanwise distance between these two box centers by the value of the average Mach number,

3. interpolate the modified velocity influence coefficient from the original table for $M = 1.0$ with the value of the modified spanwise distance, $\nu$,

4. multiply this value by the mean local Mach number at the center of the sending box.

The rest of the computation remains practically unchanged except that the computation in the transformed space is totally eliminated.

**COMMENTS ON THE PROGRAM**

The velocity potential influence coefficients for a wing of zero thickness at a given frequency are only a function of the geometry. However, in addition to the geometry, they are also a function of the local Mach number distribution for the nonzero thickness wing under present formulation. It may be possible to perform the integration in equation (3) analytically with a new formula or with that already in the earlier program with some approximation. No attempt was made to derive the totally new formulation. One of the approximate methods which was studied but not implemented in the present program is to substitute the local Mach number, $M$, in the integrand of equation (3) with $(1-\varepsilon)$, where $\varepsilon$ is a positive or a negative small number. After expanding the exponential function involving $\varepsilon$ term and neglecting all $\varepsilon^2$ or higher terms, one obtains an approximate form of the integrand, for a doublet at the origin and $z = 0$, as follows:

$$
\left(\frac{1}{x^2} + i\varepsilon \frac{y^2}{x^3}\right) \cdot \exp\left[-\frac{ik}{2} \left(x + \frac{y^2}{x}\right)\right].
$$

The exponential function in equation (5) is the same as that used in the case for $M = 1.0$ and the routines in the earlier sonic-box computer program may be utilized to perform the integration. Due to its complexity, and the additional computer storage and time required, this approximate method was not adopted to generate the new velocity influence coefficient matrix with the Mach number effect. Instead, it is interpolated from the velocity influence
coefficient matrix for the zero thickness wing as described in the preceding section. The Mach number appearing in the exponential function in equation (3) is only associated with the distance between receiving and sending points and it is regarded as to modify the effective distance between these two points. Therefore, the average Mach number is used to maintain its interchangeability. Another Mach number in equation (3) is regarded as to modify the doublet strength. Since the integration is performed over the surface of the sending box, it is logical to use the Mach number at that point. This simplification in coupling the Mach number effect enables a reduction of the size of the computer code and the computation time. The computed results appeared to be reasonable under the assumptions of small perturbation theory and local linearization concepts.

In the present formulation, it implies as in the coordinate transformation formulation (ref. 4) that the Mach number variation in the spanwise direction is not large. The accuracy of these methods decreases when a large Mach number variation in spanwise direction exists. The present method, however, does not fail abruptly as does the coordinate transformation method when spanwise variation of Mach number becomes large enough to cause multi-valued transformation and hence fold-over of wing-surface.

Since no smoothing has been applied on either the input data or any computed values in the data fitting process during the computation, the calculated unsteady pressure coefficient distribution may not be smooth and should be used with caution. In order to use it, the computed pressure coefficient should be put through a smoothing process such as the smoothing portion of the two-dimensional cubic-spline fitting routines in the present program. The pressure coefficient is obtained by differentiation of a set of numerical values whereas the generalized aerodynamic force coefficient is obtained by integration. Since integration itself is a smoothing process, the resulting generalized aerodynamic force coefficient is considered to be acceptable within the bounds of the accuracy of the numerical techniques and the adequacy of the sonic-box method. The option of data smoothing is not provided in the three-dimensional spline-surface fitting process used in the present code for
input data such as wing deflections and mean local Mach number. The spline-surface is required to go through all input points.

RESULTS

Sample calculations are made for a delta wing and a rectangular wing oscillating in plunge (Mode 1) and in pitch about the apex (Mode 2). The mean angle of attack is zero and the freestream is at sonic speed.

Delta Wing

The delta wing considered here is a flattened elliptic cone of aspect ratio 1.5 and thickness-to-root-chord ratio \( \tau = 0.1 \). Convergence with respect to the number of boxes along the root chord for the generalized force coefficients \( (L_{ij}) \) due to plunge and pitch about the apex, at a reduced frequency of \( k = 0.2 \), is shown in figure 2. The maximum numerical difference within the applied range of 15 and 30 boxes along the root chord is about 4 percent, and the trend of convergence with and without thickness is essentially the same. Based on the results shown in figure 2, it appears that the gain in convergence by using a large number of boxes to represent the wing is not obvious as compared with a fortuitous selection of the number of boxes to use. The numerical fluctuation in the convergence plot is largely caused by the box arrangement along the wing leading edge which, in turn, is dependent on the number of boxes selected for use along the wing root chord. Contribution from the partial boxes along the leading edge has been taken into account, but the fluctuation still exists.

The variation of each force coefficient, using 30 boxes along the root chord, versus the reduced frequency is plotted in figure 3. The results from figure 7 of reference 4 are also shown. The numerical difference between the results for wings with and without thickness is very small, generally less than one percent. This is a result of the Mach number, at each box-center used in the computation, lying within the narrow range of 0.92 and 0.98 in chordwise direction and remaining constant in spanwise direction (see fig. 8.
of ref. 4). However, the thickness effect on flutter speed can be significant (ref. 6). The results for the case with thickness obtained from the present method and that of reference 4 are not very different.

Rectangular Wing

The rectangular wing considered here has aspect ratio 2.0 and a biconvex (circular arc) airfoil with thickness-to-chord ratio $T = 0.0521$. The variation of each force coefficient, using 20 boxes along the root chord, versus the reduced frequency is plotted in figure 4. The results obtained from the present method, and from references 4 and 7, are included in the figure. The thickness effect on the rectangular wing is seen to be slightly larger than that on the delta wing. This is probably caused by the wide range of Mach number variation (fig. 6) on the rectangular wing, even though the thickness ratio is only 0.0521 for the rectangular wing against 0.1 for the delta wing.

The present method predicts values higher than either Landahl's results (ref. 7) for the zero thickness case or the results of reference 4 for the non-zero thickness case. The difference of the generalized aerodynamic force coefficients for the nonzero-thickness case between the results obtained from the present method and that of reference 4 is quite large. This might be caused by the difference in interpretation of the effective distance between the sending and the receiving points in the present method and the coordinate transformation method used in reference 4. It is felt, however, that the interpretation used in the present program is more physically sound than that used in reference 4. The phase angle predicted by the sonic-box method at very low reduced frequency becomes meaningless when the magnitude of any force coefficient approaches to zero with decreasing reduced frequency (for example, see figs. 4(b) and 4(d)). This is due to numerical inaccuracy and not to any inadequacy of the method.

The steady-state pressure coefficient obtained from reference 8 for the rectangular wing considered here is shown in figure 5(a) for the chordwise (x-direction) distribution and in figure 5(b) for the spanwise (y-direction) distribution. The corresponding Mach numbers at the box-centers, interpolated.
from the fitted spline-surface, are plotted in figures 6(a) and 6(b). The interpolated values deviate from the input data more near the leading edge than near the trailing edge. This probably was caused by the use of more dense spacing of input points near the leading edge as compared with those near the trailing edge in chordwise direction and by the lack of input points near the leading edge in spanwise direction, especially in the inboard portion of the wing. A better fit than that shown in figures 6(a) and 6(b) may be obtained by using more evenly spaced input points than those shown in figures 5(a) and 5(b).

CONCLUDING REMARKS

A sonic-box method computer program is presented for the application of a local linearization concept capable of accounting approximately for wing thickness effects in unsteady sonic flow. The thickness effect, expressed in terms of the local steady Mach number, is directly included in the basic solution. The local doublet strength is adjusted from the sonic flow condition to that for the local flow, and the governing equation is reduced to the one used in the original sonic-box method for zero thickness wings. Thus, the original sonic-box method concept can be used directly to treat nonzero thickness wings.

Convergence of the numerical results with respect to the number of boxes used in representing the wing planform seemed to depend more on the arrangement of the boxes along a swept leading edge than on the total number of boxes used, even though the partial boxes along the leading edge were included in the computation. For a wing with unswept leading edge, the use of a small number of boxes (say, 15 to 20 along the root chord) appeared to be sufficient to obtain results that were essentially converged.

When the input data require spline-surface fitting, the input points must be selected in such a way that they are as uniformly spaced as possible to avoid locally-concentrated large errors. A smoothing option for the two-dimensional cubic-spline has been included in the present program, but it was
not utilized in the sample runs shown in this report. Since the box method itself is numerical in nature, the distribution of calculated values may not always be smooth; and it may become necessary to perform the smoothing before any gradients are evaluated.

Based on the sample runs made, the contribution due to thickness was not found to be very large in comparison with the results calculated from the coordinate transformation method. Due to the lack of reliable experimental data, it is rather difficult to assess the validity of the present approach in accounting for thickness effects.
REFERENCES


Figure 1. - Half wing geometry.
Figure 2. - Convergence of force coefficients due to plunge and pitch for delta wing of aspect ratio 1.5 at reduced frequency 0.2.
Figure 2. - Concluded.

(c) Lift due to pitch.
(d) Moment due to pitch.
Figure 3. - Force coefficients due to plunge and pitch for delta wing of aspect ratio 1.5 with 30 boxes along root chord.
Figure 3. - Concluded.
Figure 4. - Force coefficients due to plunge and pitch for rectangular wing of aspect ratio 2.0 with 20 boxes along root chord.
$\tau = 0.0 \quad \{ \quad \text{O reference 6} \quad \}
\tau = 0.0521 \quad \{ \quad \text{present} \quad \}
\tau = 0.0521 \quad \{ \quad \text{square reference 4} \quad \}

(c) Lift due to pitch.

(d) Moment due to pitch.

Figure 4. - Concluded.
Figure 5. - Input steady state (mean) pressure coefficient on rectangular wing of aspect ratio 2.0 and thickness ratio 0.0521 (reference 8).
Figure 5. - Concluded.
Figure 6. - Computed steady state (mean) Mach number on rectangular wing of aspect ratio 2.0 and the thickness ratio 0.0521.
Figure 6. - Concluded.
The computer program listed in this appendix is dimensioned to handle a maximum of 30 boxes, either in chordwise or spanwise directions, in approximating the wing planform. The maximum numbers of leading and trailing edge segments are, respectively, 7 and 2 per semispan. The program can handle up to 3 wing deflection mode shapes. The maximum number of points used in spline-surface fitting is 100, so the maximum number of input points to describe the wing deflections and the Mach number or pressure coefficient distribution is also 100. These limitations can easily be increased by changing the dimensions of the corresponding variables in the computer program.

In order to activate the smoothing option in two-dimensional cubic-spline data fitting, it is required that a two-digit fixed point number be assigned to the last argument, NSMOS, of subroutine SPLNI. The right digit is for the control of the number of smoothings desired; and the left-digit is for pre-interpolation, zero for omitting pre-interpolation and non-zero for including pre-interpolation. The pre-interpolation is a process to increase the number of known points to be used in the interpolation by inserting an additional point between every successive pair of input points in the original set.
Input Guide

Data are input through the subroutine TARDG using the one dimensional array DA with a size of 1005. The allowable maximum number for some of the input data as indicated below may be changed if the dimensions of the corresponding storage array and computational operations are also changed accordingly. Subroutine TARDG initializes DA(1) through DA(22) to blank, the weighting factors in DA(104), DA(108), ..., DA(500) to 1.0, and the remaining portion of the DA array to 0.0. Consequently, these are the default values. The layout of the array DA(k) as it is presently used is similar to that in reference 4 and is as follows:

1-7: Title
8-12: Not used
13-19: Mode title
20-22: Not used
23: Frequency, (cycle/sec)
24: Overall length of wing in streamwise direction, (ft or meter)
25: Speed of sound of the freestream, (ft/sec or meter/sec)
26: (0) - indicates the frequency is the first one for a new wing
     (1) - indicates the frequency is the additional one for the same wing
27: Number of boxes in streamwise direction (maximum 30)
28: Number of deflection modes (maximum 3)
29: Number (m) of segments of leading edge per semispan to be given, excluding segment from origin to y0 (m_max = 7)
30-44: Coordinates of points on the leading edge, (ft or meter)
     (in sequence of y0, x1, y1, x2, y2, ..., x_m, y_m), m_max = 7
45: Number (n) of segments of trailing edge per semispan to be given, (default: unswept trailing edge), n_max = 2
46-48: Coordinates of points on the trailing edge, (ft or meter)
     (in sequence of x0, y1, x1 for n = 2,
      or x0 (only) for n = 1,
      no input for n = 0;
     last trailing edge point coincides with the last leading edge point and is set internally)
49: Number of boxes allowed for upstream influence (if this location is left blank or assigned a zero, it will assume DA(49)=DA(27) and in no case DA(49)>DA(27) is allowed).

50: (0) - indicates to calculate cases with and without thickness effect
(1) - indicates to calculate case without thickness effect only
(2) - indicates to calculate case with thickness effect only

51: Indicator to suppress calculation of potential for a mode
(0) - no suppression
(1) - suppression

52-53: Coefficients of the deflection polynomial (in the sequence of a₀ and a₁)

54-70: Not used*

71-72: Coefficients of the Mach number distribution polynomial (in the sequence of a₀ and a₁)

73-95: Not used*

96: Indicator of the type of wing thickness effect input
(1) - pressure coefficient
(2) - Mach number

97: Number of points at which pressure coefficient or Mach number to be given

98: Number of points on which deflections to be given

99-100: Not used*

101-500: Deflection data for a maximum of 100 points (in the sequence of x, y, deflection and weighting factor)

501-700: Not used**

701-1000: Pressure coefficient or Mach number data for a maximum of 100 points (in the sequence of x, y and pressure coefficient or Mach number)

The remaining part of DA array is used for the control of intermediate results print out. When the latter is desired, a non-zero positive integer number should be entered at locations in the DA array corresponding to the information from the one particular subroutine that is needed.
1001: CBA: for wing deflection (DRED)
   A=1, for NEW=1
   B=1, for NEW=2
   C - not applicable

1002: BA: for wing upwash (WVAL)
   A=1, - upwash
   B - not applicable

1003: FEDCBA for velocity potential (BOXP and BOXPO)
   A=1, for NEW=1
   B=1, for NEW=2
   C=1 - velocity potential
   D=1, for NEW=1
   E=1, for NEW=1
   F=1, for NEW=2
   - influence coefficient and solution matrices
   pressure coefficient

1004: A: for Mach number (MRED)
   A=1 - spline-surface fitted results

1005: DCBA: for wing shape (SHAPE and PLNFM)
   A=1, for NEW=1
   B=1, for NEW=2
   C=1 - Mach number at box centers
   D - not applicable

The format of the input data card is (A1, A5, 16, 6A10, A8). The first field is for the control of clearing the data array, DA, for a new wing (+) and the control to indicate the end of the set of data (-). The second field is the indicator for the type of data, either numeric (blank) or alphameric (ALPHA). The third field is the designator for the relative location in the data array of the first number to follow in the fourth field. If this field is left blank, or a zero is entered, the execution will be terminated. The fourth and fifth fields are for five consecutive input data each occupying 12 columns plus 8 blank columns at the end. All the fixed point numbers are right-adjusted and the decimal point for the floating point number must be included. If an input datum is left blank, no change at the storage location for that particular datum in the data array will occur unless the set of the input data is for a new wing.
Those storages currently not used in array DA marked with * are reserved for future improvements in the method used for the functional form of data input. Those marked with ** are reserved for the case where large numbers of data input points for deflections or Mach numbers are required.
Sample Input

A typical input data deck set-up for an aspect ratio 1.5 delta wing having an elliptic lateral cross-section with 10% thickness ratio performing plunge and pitch about its apex are given below.

The input format is (A1, A5, 16, 6A10, A8).

Card 1: title of the case under consideration.
Card 2: title of the first mode of deflection.
Card 3: first frequency (cycle/sec), centerline chord length (ft), reference velocity (ft/sec).
Card 4: number of boxes along the centerline chord, number of deflection modes, number of total leading edge segments of the wing.
Card 5: spanwise coordinate (ft) of the first section of the leading edge, chordwise and spanwise coordinates (ft) of the next section (the sequence is \( y_0, x_1, y_1 \) -- e.g., see figure 1).
Card 6: first mode of deflection \( f = 1.0 \), the "-" sign indicates the end of the group of data cards to be read at this stage.
Card 7: title of the second mode.
Card 8: second mode of deflection \( f = 0.1x \).
Card 9: identification of the type of input regarding the wing thickness effect (Mach number for this case), number of points on the wing this information to be given.
Cards 10 to 69:
chordwise and spanwise coordinates (ft) of a point on the wing, and the Mach number at this point.
the "-" sign on the last card indicates the end of the group of data cards to be read at this stage.
Cards 70 and 71: additional frequencies for the same wing, one card is read in at one time.
Card 72: blank card to make an exit from the computer.
The card images are as follows:

<table>
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<th>ASPECT RATIO</th>
<th>DELTA WING (TAU=0.10)</th>
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<td>1.0 100000</td>
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<td>2.2 131275</td>
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</table>
Sample Output

**ASPECT RATIO 1.5 DELTA WING (TAU=0.10)**

30 BOXES ALONG ROOT CHORD ROOT CHORD LENGTH = 10.00 FT

REDUCED FREQUENCY = 0.010 FREE STREAM VELOCITY = 1000.00 FT/SEC

FREQUENCY = 1.592E-01 CYCLE/SEC

**MODE NO. 1** PLUNGE

**MODE NO. 2** PITCH ABOUT ROOT LEADING EDGE X=0.0

### GENERALIZED FORCES (NE THICKNESS EFFECT)

<table>
<thead>
<tr>
<th>MODES</th>
<th>DRES.</th>
<th>DEFL.</th>
<th>REAL PART</th>
<th>IMAG PART</th>
<th>ABS. VALUE</th>
<th>PHASE ANGLE</th>
</tr>
</thead>
<tbody>
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### GENERALIZED FORCES (WITH THICKNESS EFFECT)

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**MODE NO. 1**

**MODE NO. 2**

### GENERALIZED FORCES (WITH THICKNESS EFFECT)

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### GENERALIZED FORCES (WITH THICKNESS EFFECT)

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ASPECT RATIO 1.5 DELTA WING (TAU=0.10)

REDSRED FREQUENCY = .100
FREE STREAM VELOCITY = 1000.00 FT/SEC

MODE NO. 1

MODE NO. 2

GENERALIZED FORCES (N" THICKNESS EFFECT)

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GENERALIZED FORCES (WITH THICKNESS EFFECT)

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MODE NO. 1

MODE NO. 2

GENERALIZED FORCES (WITH THICKNESS EFFECT)

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GENERALIZED FORCES (WITH THICKNESS EFFECT)

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ASPECT RATIO 1.5 DELTA WING (\(\tau = 0.10\))

30 BOXES ALONG ROOT CHORD

REDUCED FREQUENCY = .400

FREQUENCY = 6.366E+00 CYCLE/SEC

MODE NO. 1

MODE NO. 2

GENERALIZED FORCES (NO THICKNESS EFFECT)

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<th>ABS. VALUE</th>
<th>PHASE ANG ((^\circ))</th>
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GENERALIZED FORCES (WITH THICKNESS EFFECT)

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Program Listing

I PUT, JTPUT, TAT51 = NPUT, TAPE6 OUTPUT

SBOXR2

LA Ll IJXES THE CEBTNERLINE CHORD ALLOWED 4 STATEMENT

SBOXR2

I M ALLOWED IN DIMENSION STATEMENT

SBOXR2

L (I=NtP ); F A LING SBOXR2 I MM ALLOWED FOR SPLINE FITTING

SBOXR2

I M - ALLOWED IN DIMENSION STATEMENT

SBOXR2

L MATCH ADDITIONAL NUMBERS TO THE DEFINED DIMENSION IN STORAGE ARRAYS

SBOXR2

100 READ DATA FOR THE ACTUAL WING

SBOXR2

100 CALL DATRD (DA)

SBOXR2

NE=1

SBOXR2

TEST1 = DA (1001) = DA (1002) = DA (1003) = DA (1004) + DA (1005)

SBOXR2

CK = DA (21) = DA (24) = DA (25) = DA (28) = DA (29) = DA(28) = DA(29)

SBOXR2

D=1.0/D1

SBOXR2

DM=0.049

SBOXR2

110 IF (L) = 606, 608, 120

SBOXR2

120 IF (MB-L) = 600, 130, 130

SBOXR2

130 WRITE (IM, 651) L, DA (241), CK, DA (25), DA (231)

SBOXR2

150 CALL SHAPE

SBOXR2

IF (NEW.EQ.2) GO TO 180

SBOXR2

AC = G/AREA

SBOXR2

160 IF (LIM-HL) = 170, 170, 650

SBOXR2

170 LIM=2*NMB

SBOXR2

WLMS = DA (491)

SBOXR2

LPBT = NTR0.01 WLMS = L

SBOXR2

CALL P0T2 (LMI, LNM, LPBT, CK, D, A)

SBOXR2

180 CONTINUE

SBOXR2

180 GO TO 230

SBOXR2

C PRELIMINARY CALCULATIONS ARE FINISHED.

SBOXR2

C THE NEXT SECTION IS GONE THROUGH FOR EACH MODE.

SBOXR2

200 IF (DA (26)) = 230, 210, 230

SBOXR2

210 IF (NEW.EQ.2) GO TO 230

SBOXR2

CALL DATRD (DA)

SBOXR2

34
230 IF (TEST1.LT.1.0) GO TO 250
      WRITE(*,557)
      250 WRITE(*,151) M
      WRITE(*,161) TDATA(I1-13,19)
      15 FORMAT(M0,15X,0M0,1)
      16 FORMAT(*,36X,720)
      IF (DATA(I20,1) .LE. 290,290)
      WRITE(*,151) M
      WRITE(*,151) M
      290 IF (K.XEQ.2) GO TO 250
      WRITE(*,151) M
      WRITE(*,151) M
      300 IF (M+UT.EQ.200+310+20)
      CONTINUE
      310 CONTINUE
      IF (*EQ.31501)+.1,2,4,6,NEW.EQ.3) GO TO 490
      0U X.X=1,6
      IF (K=1,6) 42,5,4,40
      CONTINUE
      IF (PRINT.1.LL.1)
      CALL DRED(SFDX,SDY,SDH,KSF,SDN,SMY,SMH,KSFS,IPRINT)
      3C
      300 IF (K.XEQ.2) GO TO 250
      WRITE(*,151) M
      WRITE(*,151) M
      400 IF (K.XEQ.2)
      WRITE(*,151) M
      WRITE(*,151) M
      410 WRITE(*,151) M
      IF (K.XEQ.2) WRITE(*,151) M
      IF (K.XEQ.2) WRITE(*,151) M
      WRITE(*,151) M
      20 FORMAT(*,160X,1HUNLIZED FORCES)
      22 FORMAT(*,160X,1HNO THICKNESS EFFECT)
      24 FORMAT(*,160X,1HTHICKNESS EFFECT)
      25 FORMAT(*,160X,1HVALUES, VALUE,6X,1HINCASE ANGLE)
      CALL FYC1XX,YY,SS,SDX,SDY,SDH,KSF,SFS,SMY,SMH,KSTK
      1
      CALL FYC1XX,YY,SS,SDX,SDY,SDH,KSF,SFS,SMY,SMH,KSTK
      1
      31=ACOS(1,1)
      32=ACOS(2,1)
      33=ACOS(SIN(S20+280))
      34=37,2970*ATAN2(32,31)
450 WRITE (1W,30) M1,M2,S1,S2,S3,S4
30 FORMAT (1H0,1E19.5,1PE16.4)
470 CONTINUE
480 WRITE (1W,53)
490 CONTINUE
1F10(A16,G12.8) GO TO 510
500 DATA (1)
510 IF (I10EQ(16)) GO TO 100
IF (NEW.EQ.2) GO TO 100
NEW=
IF (I10EQ(10)) WRITE (1W,50)
GO TO 510
S80XR2
S80XR2
520 IPRINT=DA(40)
CALL NRED(DA,T,NH,KSFH,SMX,SMY,SFMH,IK,IPRINT)
GO TO 150
C
C ERROR EXITS
C
530 IF (IPR-30) GO TO 60
600 IPR=27
610 WRITE (1W,50) IPR
35 FORMAT (1H0,L0X,EMBAD DATA14)
GO TO 700
540 WRITE (1W,4C)
46 FORMAT (1H0,L0X,2HORIZONTAL LIMIT ON NUMBER OF BOXES EXCEEDED.)
700 STOP
55 FORMAT (1H1)
60 FORMAT (1H0,L0X,A10)
65 FORMAT (1H0,L0X,12,23H BOXES ALONG ROOT CHORD)
1 1H0,L0X,15X,22HROOT CHORD LENGTH =F6.2,F2.3H FT
2 1H0,L0X,31X,22HREDUCED FREQUENCY =F6.3
3 15X,22HSTREAM VELOCITY =F8.2,F7H FT/SEC
4 1H0,L0X,12H FREQUENCY =,1PE11.3,10H CYCLE/SEC
ENG
SUBROUTINE DATRD(data)
C
DIMENSION DORBU(10), DATA(10:20)

DATA READ/ALPHA/, DTEST/IN/, ETEST/IN/, FTEST/IN/
DATA TEST/

IR=5
IW=6

READ (IR,2) EMINE, ALS, IND, (DORBU(I),I=1,7)

2 FORMAT(A3,4*E10:1)

IF(IND.EQ.0) GO TO 20

IF (EMINE.EQ.TEST) GO TO 105

C NEW WING IF COLUMN 1 CONTAINS A PLUS SIGN

C INITIALIZATION OF DATA ARRAY

DO 101 I=1,3
101 DATA(I)=1.0

DO 102 I=1,22
102 DATA(I)=1.0

DO 103 I=10,16
103 DATA(I)=1.0

105 CONTINUE

IF (ALP.EQ.TEST) GO TO 9
IF (ALS.NE.TEST) GO TO 8

C NUMERIC CARD

C CONTINUE

GO TO 105

C TEST FOR BLANK FIELD

IF (I.EQ.21) GO TO 20

C CONTINUE

C RETURN IF COLUMN 1 CONTAINS A PLUS SIGN

C END

C END OF PROCESSING DATA CARD
SHAPE 2

SHAPE 3

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ORIGINAL PAGE 13
OF POOR QUALITY

JL = MLC(2,1) - MLC(1,1) + 1

IF (JL .EQ. 0) GO TO 230

WRITE(6,70) 1

JLP = JL / 6
IF (JL .LE. 6 .AND. JLP .EQ. 0) JLP = JLP + 1

K1 = MLC(1,1) + 1
JL = MLC(2,1)
GO TO 225

WRITE (6,80) (J1, AMAX(J1,1), J1 = K1, JL, JLP)

230 CONTINUE

C

235 CONTINUE

GO TO 750

550 Y1 = YEDGE(J1)

YMAX = YEDGE(MSP)
IF (Y1 .GT. 0.0) GO TO 860

AREA = 0.0

XXI = J1
YY(1) = X/H

DO 560 J = 2, MB
YY(J) = YY(J-1) + D

560 XX(J) = XX(J-1) + E

C

CALCULATE PHYSICAL FULL WING AREA AND MLC(NEW,1)

C

COMPARE AND IDENTIFY BOX DISTRIBUTION ON THE WING PLANFORM

565 CALL PLKFMX(EDG, YEDGE, YDG, XDG, XX, YY, XLE, XTE, AR, AREA, D)

C

IF (ML(1), GT, MB) GO TO 825

C

JMAX = 0

JMAX = 0

DO 570 I = 1, L

JMAX = MAX0(JMAX, MLC(2, I))

570 JMAX = JMAX

C

FIND ORDER OF LEADING EDGE BOX AT J-TH CHORDWISE ROW

C

DO 620 J = 1, JMAX

EDG(1) = 0.0

DO 620 K = 1, 2

620 MLT(K, J) = 0

II = 1
I2 = 1
K1 = 0

G55 J = 1, JMAX

630 IF (MLC(2,1), GE, 1) GO TO 632

II = II + 1
GO TO 630

632 N2 = 11

C

FIND ORDER OF TRAILING EDGE BOX AT J-TH CHORDWISE ROW

634 IF (MLC(2, J), GE, 1) GO TO 638

IF (MLC(2, J), GT, 0) K1 = 1
IF (K1 .GE. 0) GO TO 635
IF (MLC(2, J), EQ, 0 .AND. M2 .NE. 0) GO TO 646

635 MLS = IABS(MLW(J2))

IF (MLW(J2), NE, 0) GO TO 636

I2 = I2 + 1

636 IF (N5 .GE. 1) GO TO 642

IF (MLW(J2), .GE, 0) GO TO 634

N2 = 12
GO TO 652

642 K2 = MLW(J2) / MLS

39
GO TO 642
646 NZ2=Z-1
GO TO 652
648 NZ2=Z
652 CONTINUE
MLTl,1)=N/2
MLT z,JZ)=NZ2
653 CONTINUE
C
C FIND ORDER OF WING BOXES AT EACH I-TH SPANWISE COLUMN
DO 670 I=1,L
IF (MLC(1+I)) 664,662,662
IF (MLC(1+I),EQ.0) MLC(1+I)=0
GO TO 670
664 MLC(Z+I)=1ABS(MLM(I+I))-1
MLC(1+I)=1
665 CONTINUE
C
IF (WRITE.EQ.0) GO TO 678
WRITE(IW,65)
IF (NEW.EQ.1) WRITE(IW,77)
IF (NEW.EQ.2) WRITE(IW,78)
WRITE(IW,82)
DD 672 J=1,JM X
672 WRITE(IW,85) J,MLT(I,J),MLT(Z+J)
WRITE(IW,83)
DD 674 J=M L
674 WRITE(IW,85) J,MLC(I,J),MLC(Z,J),MLM(J),ML(J)
678 CONTINUE
C
IF (EDG(NSP).CT.1.) GO TO 966
NSP=NSP-1
DY=EDG(NSP)-YLEG(ISM)
IF (ABS(DY),LE.,LAMAX) C=0
IF (DY,LT.0.) GT TJ 627
C COMPUTE VALUES FOR LEADING EDGE CORRECTION
YMAX2=YMAX/YMAX

GO 720 J=1,JMX

C
C GO IN FOLLOWING EQUATION IS ARBITRARY

710 EGG(J+1)=SORT((YPAR-ZYY(J))/LMM(Z+1,YMAX-DY))
IF (Z(J).EQ.LG) GO T 715
715 EDG(J)=L
720 CONTINUE
C
750 CONTINUE
C
790 CONTINUE
C
RETURN
C
800 IF(ISHRM,GE.300)
801 T(J+1,1)=EDG(K)
810 IF (T(J+1,1),GE.Z) IEK=Z
GO TO 643
804 IEPR=0805
GO TO 640
810 IEPR=065
GO TO 840
820 IEPR=065
GO TO 840
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(2,1) - YEDG(INS)
(2,1) - MSP
IER = 3
GO TO 840
825 IERROR = 825
(1,1) - NTH
(2,1) - YEDG
(2,1) - YEDG(INS)
(1,1) - MSP
(4,1) - NTH
IER = 4
GO TO 840
827 IERROR = 827
(1,1) - YEDG(INS)
(2,1) - YEDG(INS)
(1,1) - MSP
(4,1) - NTH
IER = 4
GO TO 840
830 IERROR = 230
(1,1) - I
(2,1) - J
(2,1) - X
(4,1) - Y
(5,1) - TH
(5,1) - EHY
(7,1) - DEL
IER = 7
840 WRITE(1,2) IERROR, (T(I,1), I=1, IER)
STOP
850 IPR = 29
GO TO 890
855 IPR = 24
GO TO 890
860 IPR = 30
GO TO 890
865 K = NINOK(INS)
IER = 429
GO TO 890
871 IPR = 45
890 WRITE
SHAPE 247
0 (1,10) IPR
10 FORMAT(10X,17SHAPE — BAD DATA,15)
20 FORMAT(10X,38BAD NUMBER IN SHAPE NEAR STATEMENT NO.,15)
1
1/14,15X,1PBE114,63
40 FORMAT(10X,5X,3HNG,12,43H REDISTRIBUTION OF WING LEADING EDGES,
1 N5(1,14,N) = ,12+7N, IEDG,3H = ,11)
45 FORMAT(10X,5X,25M WING TRAILING EDGES, MST(1,11,4H) = ,12,
5
50 FORMAT(10X,10M LOCAL MACH NUMBER DISTRIBUTION ON PHYSICAL WING)
60 FORMAT(10X,5X,7HLOCAL MACH NUMBER DISTRIBUTION ON PHYSICAL WING)
65 FORMAT(10H1)
70 FORMAT(10X,5X,12,19M SPANWISE COLUMN)
75 FORMAT(10X,5X,12,19M CHORDWISE ROW)
77 FORMAT(10X,13M PHYSICAL WING)
78 FORMAT(10X,10M TRANSFORMED WING)
80 FORMAT(10X,5X,6(2X,13,1PE13,15))
82 FORMAT(10X,6BORDER OF FIRST(LEADING) AND LAST(TRAILING) WING BOX,
1 IN CHORDWISE ROW // UX,1HJ,3A,12HMLT(INEWJ,1),J,3X,12HMLT(INEW2,J),J1/1
1AN COLUMN/12UX,1H1,3X,12HMLT(INEW1,1),J,3X,12HMLT(INEW2,J),J1/1
2UX,1H1,3X,12HMLT(INEW1,1),J,3X,12HMLT(INEW2,J),J1/1
85 FORMAT(10X,5X,15,5X,15,T10X,15)
86 FORMAT(10X,5X,58GAUSSIAN INTEGRATION POINTS IN CHORDWISE ROW — GKINE
1X,17/7
87 FORMAT(10X,5X,58GAUSSIAN INTEGRATION POINTS IN SEMI-SPAN — GYNEW
1X,17/7
88 FORMAT(10X,5X,58GAUSSIAN INTEGRATION POINTS IN SEMI-SPAN — GYNEW
1X,17/7
89 FORMAT(10X,5X,10M LOCAL MACH NUMBER DISTRIBUTION ON PHYSICAL WING)
ST GXI(,A,J))/1
2
ST GXI(,A,J))/1
ST GXI(,A,J))/1
ST GXI(,A,J))/1
90 FORMAT(10X,5X,15,5X,15,10X,15)
END
280 IF(YL+ERR2, GE, O) GO TO 290
   X1=XL
   YL=0
   IF(IICHQ.NE, I) GO TO 310
   IF(JX) 284, 285
284 IF(YE<=EY, D) GO TO 320
   GO TO 286
285 IF(YE2,GE,Y) GO TO 320
   CONTINUE
   IF(XE1.GT.XL) GO TO 400
      IEDZ=0
      GO TO 400
290 X1=X2
   Y1=Y2
295 IEDZ=0
   IF(IICHQ.NE, 1) GO TO 310
      YR=YE2
      GO TO 315
310 YR-YE1+TNG*XG*(XR-XE1)
315 IF(JX) 317, 318, 318
316 IF(YR, GE, Y) GO TO 320
   GO TO 318
317 IF(YR, LE, D) GO TO 320
318 CONTINUE
   IF(IICHQ.EQ, 1) GO TO 325
      IED=1
      X2=XR
      Y2=YZ
      GO TO 330
320 JFIN=1
   IF(JX) 322, 321, 321
321 Y2=Y
      GO TO 323
322 Y2=Y-D
      GO TO 330
323 X2=CL+YZ-YE1)/TNG
   IF(ABS[X2-XR].GT. ERRR) GO TO 330
   IFN=1
      JFIN=0
      GO TO 330
325 JFIN=1
5    X2=K2
5   Y2=Y2
   GO TO 330
330 ART31=ART31+0.5*ASNG* [2.*XR-X2-XI] * (Y2-Y)/02
   CONTINUE
   IF(J=1) 332, 331, 331
331 IF(JLT. LE, 3) GO TO 334
   XLT=X1+YY(JLT)-Y1)/TNG
   IF(XLT.GT.XE1+ASNH+0.5 0 ) GO TO 334
   IF(YE1.GT.1, XE1+ASNH+0.5, O) XLT=0
   IF(YL(YLT).LE.TL(NSTP)) XLT=AT.G(NSTP)
   IF (XLT.GT.XE1+ASNH) XLT=XLT+XLT
   GO TO 333
332 IF(JLT+JLT) 0 TO 334
   XLT=X1+YY(JLT)-Y1)/TNG
   IF(YL(JLT).LE.TL(NSTP)) XLT=AT.G(NSTP)
   JLT=JLT+JLT
   GO TO 1331
333 JLT=JLT+J
   GO TO 1334
334 CONTINUE
   IF(JFIN) 342, 341, 341
341 IF(JK) 342, 341, 341
   CONTINUE
GO TO 350

344 IF(JFIN.EQ.1) GO TO 475
350 IF(JWIN) GT 360 GO TO 475
355 IF(JFIN.EQ.1) GO TO 475
GO TO 330
360 IF(JFIN.EQ.1) GO TO 455

C LEADING EDGE AIRCRAFT TRAILING EDGE COMPUTATION

400 IF(ASNC) 440,450,465
405 IF(JK) 430,440,450,460

410 K1=K1+JK
IF(K1.GE.NSP) GO TO 420
X1=XEDG(K1)
Y1=YEDG(K1)
K=K1+JK
X2=XEDG(K1)
420 IF(JK.LT.0) GO TO 240
JL=J
MLC(JL)=0

K2=K2+JK
430 K2=K2+JK
X1=XTOG(K2)
Y1=YTOG(K2)
K=K2+JK
X2=XTOG(K2)
YE2=YTOG(K2)
GO TO 450

440 K2=K2+1
X1=XTOG(K2)
Y1=YTOG(K2)
X2=XTOG(K2+1)

450 IF(XG) 446,450,460
455 IF(JK) 470,475,480
460 JJ=0
IF(JJ.EQ.1) GO TO 470
ML (JJ=J
DO 471 K=1,JK

IF (AREJ.J,J.LT.ERR2) JJ=1
ML(JJ=JJ
471 CONTINUE

MLC(JL)=K
GO TO 473
472 ML C(JL)=K
473 CONTINUE

C ADJUSTMENT OF FIRST BOX AT LEADING EDGE ALONG KK-TH CHORDWISE ROW
KK=MLC(JL)
IF (XXII.EQ.KLEMKK) GO TO 474

C NUMBER OF BOXES IN SPANWISE COLUMN

C WAKE TYPE AND ORDER OF WAKE BOX

465 IF(ASNC) 470,475,480
475 IF(JK) 480,485,490
480 JJ=0
IF (AREJ.J,J.LT.ERR2) JJ=1
ML(JJ=JJ
485 CONTINUE

JL=ML(J)
DO 471 K=1,JK

IF (AREK.K,J,LHMKK) GO TO 472
471 CONTINUE

MLC(JL)=KK
GO TO 473
472 MJC(JL)=KK
473 CONTINUE

C ADJUSTMENT OF FIRST BOX AT LEADING EDGE ALONG KK-TH CHORDWISE ROW
KK=MLC(JL)
IF (XXII.EQ.KLEMKK) GO TO 474

C NUMBER OF BOXES IN SPANWISE COLUMN

C WAKE TYPE AND ORDER OF WAKE BOX

465 IF(ASNC) 470,475,480
475 IF(JK) 480,485,490
480 JJ=0
IF (AREJ.J,J.LT.ERR2) JJ=1
ML(JJ=JJ
485 CONTINUE

JL=ML(J)
DO 471 K=1,JK

IF (AREK.K,J,LHMKK) GO TO 472
471 CONTINUE

MLC(JL)=KK
GO TO 473
472 ML C(JL)=KK
473 CONTINUE

C ADJUSTMENT OF FIRST BOX AT LEADING EDGE ALONG KK-TH CHORDWISE ROW
KK=MLC(JL)
IF (XXII.EQ.KLEMKK) GO TO 474

C NUMBER OF BOXES IN SPANWISE COLUMN

C WAKE TYPE AND ORDER OF WAKE BOX

465 IF(ASNC) 470,475,480
475 IF(JK) 480,485,490
480 JJ=0
IF (AREJ.J,J.LT.ERR2) JJ=1
ML(JJ=JJ
485 CONTINUE

JL=ML(J)
DO 471 K=1,JK

IF (AREK.K,J,LHMKK) GO TO 472
471 CONTINUE

MLC(JL)=KK
GO TO 473
472 ML C(JL)=KK
473 CONTINUE

C ADJUSTMENT OF FIRST BOX AT LEADING EDGE ALONG KK-TH CHORDWISE ROW
KK=MLC(JL)
IF (XXII.EQ.KLEMKK) GO TO 474

C NUMBER OF BOXES IN SPANWISE COLUMN

C WAKE TYPE AND ORDER OF WAKE BOX

465 IF(ASNC) 470,475,480
475 IF(JK) 480,485,490
480 JJ=0
IF (AREJ.J,J.LT.ERR2) JJ=1
ML(JJ=JJ
485 CONTINUE

JL=ML(J)
DO 471 K=1,JK

IF (AREK.K,J,LHMKK) GO TO 472
471 CONTINUE

MLC(JL)=KK
GO TO 473
472 ML C(JL)=KK
473 CONTINUE

C ADJUSTMENT OF FIRST BOX AT LEADING EDGE ALONG KK-TH CHORDWISE ROW
KK=MLC(JL)
IF (XXII.EQ.KLEMKK) GO TO 474

C NUMBER OF BOXES IN SPANWISE COLUMN

C WAKE TYPE AND ORDER OF WAKE BOX

465 IF(ASNC) 470,475,480
475 IF(JK) 480,485,490
480 JJ=0
IF (AREJ.J,J.LT.ERR2) JJ=1
ML(JJ=JJ
485 CONTINUE

JL=ML(J)
DO 471 K=1,JK

IF (AREK.K,J,LHMKK) GO TO 472
471 CONTINUE

MLC(JL)=KK
GO TO 473
472 ML C(JL)=KK
473 CONTINUE

C ADJUSTMENT OF FIRST BOX AT LEADING EDGE ALONG KK-TH CHORDWISE ROW
KK=MLC(JL)
IF (XXII.EQ.KLEMKK) GO TO 474
Ye2 = YTDG(1)
X2 = XE2
Y2 = YE2
ASIN = 1.0
JL = JL/5
GO TO 220

ERROR MESSAGE
650 K = 450
A = G
Z = 22
WRITE(IW,156) K, Z, A
STOP

700 CONTINUE
IF(JRXY.EQ.0) GO TO 700
WRITE(IW,65)
IF(NEW.EQ.0) WRITE(IW,66)
DG = 750 I = 1, L
JL = ML/5
K = JL/5
IF(JL/EQ.5) GO TO 710
PLNFH

710 WRITE(IW,70) I
WRITE(IW,72) PC(I)
IF(NEW.EQ.2) WRITE(IW,67)

720 GO TO 715
PLNFH

725 DO 740 J = 1, K

740 WRITE(IW,80) PLNFH

750 CONTINUE

C
PLNFH

SUB = C = SUM(PLNFH)
WRITE(IW,81) SUB
PLNFH

760 RETURN

65 FORMAT(1H1,2G9.4,17H(DIMENSIONAL BOX AREA DISTRIBUTION))
PLNFH

66 FORMAT(1H1,2G9.4,17H(TRANSFORMED WING)))
PLNFH

67 FORMAT(1H1,2G9.4,17H(SUM))
PLNFH

70 FORMAT(1H1,2G9.4,17H(TRANSMETED BOX AREA FROM WING ROOT))
PLNFH

72 FORMAT(1H1,2G9.4,17H(FIRST EA BOX = I3, I2H-TH BOX FROM WING ROOT))
PLNFH

75 FORMAT(1H1,2G9.4,17H(LAST BOX = I3, I2H-TH BOX FROM WING ROOT))
PLNFH

85 FORMAT(1H1,2G9.4,17H(NEGATIVE BOX AREA))
PLNFH

90 FORMAT(1H1,2G9.4,17H(WEEK BOX) AREA CALCULATED FROM)
PLNFH

15X,26HEADING AND TRAILING EDGE POINTS AT EACH CHORD IS
PLNFH

16 FORMAT(1H1,2G9.4,17H(LEADING,6X,8HTRAILING))
PLNFH

145 FORMAT(1H1,2G9.4,17H(INCOMPUTATION CONTINUES))
PLNFH

140 FORMAT(1H1,2G9.4,17H(NEGATIVE BOX AREA EXCEEDS ALLOWABLE LIMIT (=)
PLNFH

15X,26HSUMMATION OF AREA OF BOXES = 1PE11,4)
PLNFH

196 FORMAT(1H1,2G9.4,17H(ORDER OF WING TIP BOX IN 12, 3H-TH SPANWISE COLUMN))
PLNFH

15 FORMAT(1H1,2G9.4,17H(EDGE POINTS AT EACH CHORD IS))
PLNFH

SE ROW(1H1,2G9.4,17H(LEADING,6X,8HTRAILING))
PLNFH

336 FORMAT(1H1,2G9.4,17H(NEGATIVE VALUE NEAR SH,14,2X,4A1E11,4))
PLNFH

155 FORMAT(1H1,2G9.4,17H(WING TIP BOX IN 12, 3H-TH SPANWISE COLU))
PLNFH

1IM IS NOT PROPERLY DEFINED/
PLNFH

2 15X,8HMW(MEW = 13, I2H-3H) = 13/15X,8HMW(MEW = 13, I2H-3H) = 013)
PLNFH

END
SUBROUTINE PO12(N2,M0,NOK,DA)

THE VELOCITY FIELD OF A UNIFORM DOUBLET DISTRIBUTION
OVER A BOX IS COMPUTED AT ALL POINTS AT WHICH IT WILL BE
NEEDED AND STORED IN THE ARRAY A IN COMMON

M0 AND DA CONTROL THE NUMBER OF VALUES COMPUTED

N2 IS THE RANGE OF THE SECOND SUBSCRIPT IN THE ARRAY.
DIMENSIONED A(2+N2,2), BUT TREATED HERE AS AN ARRAY
WITH TWO SUBSCRIPTS

DIMENSION A(2,1)
N=M0
DK=CK*D
DK2=DK*DK
K=0
DL bonding

DLD=K2/8.0
DL1=K2/12.0
CCP=0.5
DH=KK*D
DH2=K*K
DD=2.0*DK

K=K+1
DL bonding

DL bonding

D2 J=1+N
A1=DM/CN
C1=CC* COS(A1)
C2=CM* SIN(A1)
C5=CM*C1+A1+C6
C6=CM*C6
C9=CI-C3
C10=CC-C4
C11=CC-C7
C12=CC-C3
A11*K=C6+C6-C11-C11-C11
A12*K=C4+C9+C6+C10+C3+C11-C11-C11
A13=K4+C1+C1+C1+C1
23 C3=C1
C4=C2
C7=C5
C8=C6
C6=C8
C5=C4
C3=C1

DL bonding

DL bonding

DL bonding

DL bonding

DL bonding

DL bonding

DL bonding
DO 5 J=1,N

4 A1(I,K)=X(I,K)-X(I,K-1)
    A2(I,K)=2.*0*A1(I,K)

5 K=1

C4=0.0
C5=G

DO 10 J=1,N
A1=CM/CN
A2=DM/CN
IF (A1-0.2) 7,7,8

7 B1M=2.0-A10*273.0
B2=0/(1.0*CN)

GU TO 9
8 B3= SIN(A1)/A1

B1=0F3
B2=0F3

9 B3= COS(A2)/CN
B4= SIN(A2)/CN
C3=BI*BS*B2*B4
C4=BS*B3-B1*B4
C5=DS+CN
C6=C4+2.0*C3
C7=2.0*C4-B5*C3
C8=C1-C7
C9=C2-C8
C10=C4

80=80+6DK12

10 K=M2
CM=CM+DK
DN=DM+DD

12 DN=DK+DD
D3=CN/(12.0*3.14159265)
N1=M2-N

K=1
A1=0.0

DO 14 J=1,N
C1=03* SIN(A1)
C2=03* COS(A1)

DO 13 J=1,N
DFE = A1(*)K1*E1*E2*E3*K1*E2
A12(*)K1*E2*E3*K1=O
A1(*)K1*DFE

13 K=K+1

RETURN
SUBROUTINE DRED(SFDH, SFDY, SFDM, SFHM, SFMY, SFMH, KSF, DAT
5 KSF, Y(NB, L), SFDY(NB, M), SFDM(NM, M), KSF, IPRINT)

DIMENSION SFDH(NB, L), SFDM(NM, M), KSF(NB, L)
1 SFDY(NB, M), SFHM(L), DA(1), T(NM, M), MLC(L, 2)
4 X(NB, L), Y(NB, L)

ERR=1.0D-06
PRINT=IPRINT/10
APIRINT=IPRINT/10
IF(NL*Q=M, L)$PRINT=IPRINT-10*PRINT
KSF(I)=DA(58)
MP=$5(F)
IF(NP) 730, 170, 100

100 IF (NB-NP) 730, 120, 120
120 CONTINUE

C A SPLINE-SURFACE FOR THE DEFLECTION IS FITTED TO VALUES
C OF DEFLECTION AT GIVEN POINTS.
C
145 CONTINUE

150 MWRITE(N+30, P4)

C SPLINE - SURFACE FIT DATA
C
160 CONTINUE

C PRESENTLY FOR PITCH AND PLUNGE OF FORM Z=AX+AYX
C
170 SFDM(NM, M)$DAT(N3)*DAT(24)

C GO TO 145
C
200 G1.CHECK=0

730 IF (IPR$98

750 WRITE(3, 99)

C FORMAT 10X, Y, Z
C
10 FORMAT(10X, Y, Z, 9HCOMPUTED DEFLECTION = A0 + A1*Y + A2*Y + SUM OF HI*HI$3(1)**2)$ALCG(R(1)**2))

20 FORMAT(10X, Y, Z, 9HSHOWED -- BAD DATA, 15)

END
SUBROUTINE CALMNE_V, Y, XTDG, YUDG, XTDG, XE, SFDX, SFDY, SFDH, KSF, SDF, SDFMN

C CALCULATES DOWNWASH VELOCITY DISTRIBUTION (REAL AND IMAGINARY)

DIMENSION XX(I), YY(I), XTDG(I), YUDG(I), XTDG(I), XE(I), SFDX(I), SFDY(I), SFDH(I), KSF(I), SDF(I), SDFMN(I)

IRITE = IPRINT/10
IF(NEC.EQ.11) IRITE = IPRINT/10*IRITE
JLP = KSF(N)
IF(KSF(N).EQ.0.AND.NEC.EQ.2) JLP = KSFS
JL = ML(I)
DO 5 I = 1,L
DO 5 J = 1,JL
5 STK(J) = 0.0
DO 80 I = 1,L
JL = ML(I)
IF(JL).EQ.0.RA.E0.NE.0.0.JLP = JLP
CALL SURFZXX(I, YY(I), XX(I), VALU, VALU, OM, SFDX(I), SFDY(I), SFDH(I), JLP, Z)
5 S(I, J) = VALUE
STZ(I, J) = CR*VALU
70 CONTINUE
80 CONTINUE
IF(IRITE).EQ.100,200,100
100 WRITE (1W, 12) W
WRITE (1W, 12) #1
WRITE (1W, 12) #1
12 FORMAT(1H1, 5x, 2(ZXL3, 1P#E13.5))
DO 170 I = 1, L
JL = ML(I)
110 WRITE (1W, 10) W
110 WRITE (1W, 10) W
10 WRITE (1W, 10) W
100 WRITE (1W, 10) W
100 WRITE (1W, 10) W
100 WRITE (1W, 10) W
150 CONTINUE
160 WRITE(1W, 15) W
170 CONTINUE
C THESE ARE THE LPWASHES
C
200 CONTINUE
RETURN
20 FORMAT(1H1, 5x, 2(ZXL3, 1P#E13.5))
25 FORMAT(1H1, 5x, 2(ZXL3, 1P#E13.5))
END
SUBROUTINE BOXP(XX,YY,XTDG,YTDG,XTE,XLE,A,AR,DAN,T,EDG,S,CK,D,YE)

1 I 6 IPRINT,MLT,NST,ANA  
2 4 XMAX,XMIN,MLT,MLW,MC,MB,MC,MB,MC,MB)  
C ICHCK=0 = POTENTIAL AS COMPUTED IN BOXPU  
C ICHCK=1 = K-LEADING EDGE CORRECTION  
C ICHCK=2 = PRESSURE COEFFICIENT COMPUTED FROM CORRECTED POTENTIAL  
C ICHCK=3 = PRESSURE COEFFICIENT COMPUTED FROM TRANSFORMED VALUE  

DIMENSION XX(1),YY(1),XTDG(1),YTDG(1),XTE(1),XLE(1),A(2,MC+MB)  
1 4 XMAX,XMIN,MLT,MLW,MC,MB,MC,MB,MC,MB)  
2 XMAX,XMIN,MLT,MLW,MC,MB,MC,MB,MC,MB)  

IP=IN=IPRINT
WRITE(6,IPRINT) I
KRITE=IPRINT/100
IPRINT=IPRINT/100
JRITE=KRITE
IRITE=IRITE+1
IF(NLW.LT.1) GOTO 20

CONTINUE:  
NSMOD=0
DHA=6.50
C  
CALL BOXP(XX,YY,XTDG,YTDG,XTE,XLE,A,AR,DAN,T,EDG,S,CK,D,YE)
C BOXPU COMPUTES THE POTENTIAL VALUES IN EACH BOX  
C THEY ARE STORED IN THE ARRAY S
C  
ICHCK=0
ME=NLW
JM=JMAX
IF(IRITE.EQ.0) GOTO 270
WRITE(6,IRITE) I
200 DO 205 I=1,TL
WRITE(6,IRITE) I
205 CONTINUE
215 WRITE(6,IRITE) I
30 FORMAT(I14)
31 FORMAT(I14,1X)
32 FORMAT(I14,1X)
C PRINT-OUT
C BOXP Computes the potential values in each box.
C They are stored in the array S.
C
ICHCK=0
ME=NLW
JM=JMAX
IF(IRITE.EQ.0) GOTO 270
WRITE(6,IRITE) I
200 DO 205 I=1,TL
WRITE(6,IRITE) I
205 CONTINUE
215 WRITE(6,IRITE) I
30 FORMAT(I14)
31 FORMAT(I14,1X)
32 FORMAT(I14,1X)
C PRINT-OUT
C BOXP Computes the potential values in each box.
C They are stored in the array S.
C
ICHCK=0
ME=NLW
JM=JMAX
IF(IRITE.EQ.0) GOTO 270
WRITE(6,IRITE) I
200 DO 205 I=1,TL
WRITE(6,IRITE) I
205 CONTINUE
215 WRITE(6,IRITE) I
30 FORMAT(I14)
31 FORMAT(I14,1X)
32 FORMAT(I14,1X)
C PRINT-OUT
C BOXP Computes the potential values in each box.
C They are stored in the array S.
C
ICHCK=0
ME=NLW
JM=JMAX
IF(IRITE.EQ.0) GOTO 270
WRITE(6,IRITE) I
200 DO 205 I=1,TL
WRITE(6,IRITE) I
205 CONTINUE
215 WRITE(6,IRITE) I
30 FORMAT(I14)
31 FORMAT(I14,1X)
32 FORMAT(I14,1X)
C PRINT-OUT
C BOXP Computes the potential values in each box.
C They are stored in the array S.
C
ICHCK=0
ME=NLW
JM=JMAX
IF(IRITE.EQ.0) GOTO 270
WRITE(6,IRITE) I
200 DO 205 I=1,TL
WRITE(6,IRITE) I
205 CONTINUE
215 WRITE(6,IRITE) I
30 FORMAT(I14)
31 FORMAT(I14,1X)
32 FORMAT(I14,1X)
C PRINT-OUT
C BOXP Computes the potential values in each box.
C They are stored in the array S.
C
ICHCK=0
ME=NLW
JM=JMAX
IF(IRITE.EQ.0) GOTO 270
WRITE(6,IRITE) I
200 DO 205 I=1,TL
WRITE(6,IRITE) I
205 CONTINUE
215 WRITE(6,IRITE) I
30 FORMAT(I14)
31 FORMAT(I14,1X)
32 FORMAT(I14,1X)
C PRINT-OUT
C BOXP Computes the potential values in each box.
C They are stored in the array S.
C
ICHCK=0
ME=NLW
JM=JMAX
IF(IRITE.EQ.0) GOTO 270
WRITE(6,IRITE) I
200 DO 205 I=1,TL
WRITE(6,IRITE) I
205 CONTINUE
215 WRITE(6,IRITE) I
30 FORMAT(I14)
31 FORMAT(I14,1X)
32 FORMAT(I14,1X)
C PRINT-OUT
C BOXP Computes the potential values in each box.
C They are stored in the array S.
C  GO TO 200  
D  CONTINUE  
F  CONTINUE

C TRANSE TO THE PRINT-OUT OF CORRECTED VELOCITY POTENTIAL

C CALCULATE AND PRINT PRESSURE COEFFICIENT

C  CHECK OUT IN 380 TO 500


```
T(I, 6, 5)=XLE(J)
T(I, 8, 5)=XLE(J)
T(I, 10, 5)=0.0
T(I, 12, 5)=0.0
IF (ABS(T(I)-XX(I)), GT, 1.6-05) GO TO 445

C ADJUSTMENT -- LEADING EDGE AND FIRST BOX COINCIDES
II=II+1
IK=IK-1

445 CONTINUE
DO 450 I=2,IK

T(I, 6, 5)=XX(I)
T(I, 8, 5)=XX(I)
T(I, 10, 5)=T(J, 1, 3)
T(I, 12, 5)=T(J, 1, 4)
T(I-1, 5, 5)=XX(I)

450 II=II+1
CALL SPLNI(I,II, 1, 5), T(I, 2, 5), T(I, 4, 5)

CALL SPLNI(I,II, 1, 5), T(I, 2, 5), T(I, 4, 5), T(I, 5, 5)

DO 470 I=1,12

T(J, II, 1)=T(J, IV, 5)-CRLY(T(J, 3, 5)
T(J, II, 2)=T(J, IV, 5)+CRLY(T(J, 2, 5)

470 II=II+1

500 CONTINUE
WRITE(IW, 401)

40 FORMAT(1X, 10X, IMPRESSURE COEFFICIENT (REAL, IMAGINARY, ABSOLUTE, PHASE ANGLE))

C TRANSFER TO PRINT-OUT SECTION
GO TO 715

520 CONTINUE

700 CONTINUE

RETURN

20 FORMAT(10X, 5X, 12, 9H-TH SPANWISE COLUMN)
25 FORMAT(1X, 5X, 2(13, 1P4E13.5))
END
```
SUBROUTINE BOXPO(xx,yy,xtg,ystg,xte,ate,a,ar,dan,t,s,ck,d,ama) BOXPO 2
C SOLUTION OF SIMULTANEOUS EQUATIONS FOR THE POTENTIAL BOXPO 3
DIMENSION xx(11),yy(11),xtg(11),ystg(11),xte(11),ate(11),a(11),d(11),n(11),m(11),t(11),s(11),ck(11),d(11) BOXPO 4
1 ar(1:m)+t(1:m+1)t(2:m+1)d(1:m)+ama(1:m) BOXPO 6
2
3 BOXPO 7
4 ch=0.5Ho BOXPO 8
5 do z=0,ro BOXPO 9
6 if (write.eq.0) go to 25 BOXPO 10
7 if (new.eq.2.eq.0) go to 25 BOXPO 12
C PRINT INFLUENCE COEFFICIENT BOXPO 13
WRITE(11,100) BOXPO 14
10 je=2*me(l) BOXPO 15
k=jl+4 BOXPO 16
if (jl-4.k.ne.0) k=k+1 BOXPO 17
do 20 i=1,k BOXPO 18
20 il=1-il... BOXPO 19
WRITE(11,110) il BOXPO 20
30 continue BOXPO 21
40 continue BOXPO 22
50 continue BOXPO 23
60 continue BOXPO 24
70 continue BOXPO 25
80 continue BOXPO 26
90 continue BOXPO 27
100 continue BOXPO 28
110 continue BOXPO 29
120 continue BOXPO 30
130 continue BOXPO 31
140 continue BOXPO 32
150 continue BOXPO 33
160 continue BOXPO 34
170 continue BOXPO 35
180 continue BOXPO 36
190 continue BOXPO 37
200 continue BOXPO 38
210 continue BOXPO 39
220 continue BOXPO 40
230 continue BOXPO 41
240 continue BOXPO 42
250 continue BOXPO 43
260 continue BOXPO 44
270 continue BOXPO 45
280 continue BOXPO 46
290 continue BOXPO 47
300 continue BOXPO 48
310 continue BOXPO 49
320 continue BOXPO 50
330 continue BOXPO 51
340 continue BOXPO 52
350 continue BOXPO 53
360 continue BOXPO 54
370 continue BOXPO 55
380 continue BOXPO 56
390 continue BOXPO 57
400 continue BOXPO 58
410 continue BOXPO 59
420 continue BOXPO 60
430 continue BOXPO 61
440 continue BOXPO 62
450 continue BOXPO 63
460 continue BOXPO 64
470 continue BOXPO 65
480 continue BOXPO 66
490 continue BOXPO 67
500 continue BOXPO 68
510 continue BOXPO 69
520 continue BOXPO 70
C SLT ACTION OF Contributions of PRECEDING ROWS TO UPWASH BOXPO 71
GO TO 47 JS=JS,JS BOXPO 72
GO TO 25
56 CONTINUE
DO 59 N=1,JE
58 T(I,J,N)=T(I,J,N)
59 CONTINUE

C SOLUTION OF EQUATIONS
60 CONTINUE
C WRITE(I+167) I
DO 69 K=1,Z
68 CONTINUE
C XEVERY COLUMN/
167 FORMAT(6X,5X,4(IH,1M-1-I)), SPA=13 COLUMN)
168 FORMAT(1H1,4X,10H,1E13.6))

C COMPUTE WAKE POTENTIALS --
70 CONTINUE
C (I) + (J) FOR VELO
169 FORMAT(8X,4(2X,1H,1Z,1H,Z), 8X,13.6))
170 FORMAT(2X,I4,5H,1Z,6H,1Z,7H,1Z,1Z,1H,8X,1H,1Z,1H,1Z,1H,1Z,1H))
72 CONTINUE

75 Y=YY(J5)
IF (X.GT.1.(XTE(J5)) GO TO 82
IF (X.GE.XTE(J5)) GO TO 82
76 PTR=5(I,J5)
PTI=5(I,J5)
KK=0
X=XM
77 CONTINUE
80 IF (X.GT.1.(XTE(J5))) GO TO 82
82 JS=JS+1
85 CONTINUE
90 I=I+1
C  INTER-PLANE REFLECTION AT PCA CENTER, LEADING AND TRAILING EDGES
CALL SURFZY(*),T(1,...,11,13),T(1,14),SUM,SDFX(1,M2)
C  PERF.SPF.N:IP,QUAN.,AT+.ATN
DG=K=1,
T(K+1,1)=T(K,1)+LUAT1(K,13)+T(K,15)
75 T(K,16)=T(K,15)+LUAT1(K,13)+T(K,14)
CALL INTL1(*),T(*,1,...,11,13),T(1,14)
78 T(J+1)=T(N0,J)+SUM-T(J+1)
79 T(J,18)=T(N0,1)+SUM-T(J,18)

150 CONTINUE
C  PERF.SPF. SPANWISE INTRODUCTION
NC=JM+1
K=17
K2=17
T(1,11)=0.0
105 DC 170 K=1,JM+1
170 T(K, 2)=YY(K)
NC=JM+1
CALL SFLNIT1(T1,...,11,13),T1,14),SUM,SDFX(1,M2)
T(K2,2)=0.0
77 T(1,2)=T(1,1)
175 DC 175 K=1,JM+1
79 T(K*1,2)=T(K,K1)
FR(K1,EQ.00) GC TO 180

180 CONTINUE
NC=JM+1
K2=17
T(NZ,2)=TMAX
DC 195 K=1,JM+1
185 T(K1,2)=YY(K)
K1=0
X=NC-2,T1,+142
FR=TNZ-1,15
PH=TNZ-1,16
IF(T(NZ,2)+.5*O.LT.T(NZ,2)) GO TO 195
190 DC 190=SUM+(T(NZ,2)-T(NZ,1))/X
T(NZ,13)=SUM+PR
T(NZ,15)=SUM+PR
IF(K1.EQ.01) GC TO 196
195 IF (YY(JM)+1.0590.D.E.TMAX) GO TO 196
K1=1
NC=JM+1
NO=NO-1
T(NZ,2)=T(NO-1,2)
T(NZ,2)=T(NO-1,2)+O
T(NQ,15)=T(NO-1,15)
T(NO,16)=T(NO-1,16)
GC TO 190
190 CONTINUE
IF(NZ-NO-2)=T(MN,2)-T(NZ,2)+GC.E.E.05) GO TO 197
NC=JM+1
NO=NO-1
T(NZ,2)=T(NO-1,2)
T(NZ,2)=T(NO-1,2)+O
T(NO,15)=T(NO+1,15)
T(NO,16)=T(NO+1,16)
GO TO 190
197 CONTINUE
C  CALL INTL1(*),T(*,1,...,11,13),T(2,1,...,11,13),T(2,1,...,11,13)

RETURN
END
SUBROUTINE MRED(DA,T,M,N,KSFM,SFMX,SMY,SMH,IPRINT)

C SPLINE-SURFACE FIT OF MACH NUMBER

C
CONST=0.28571429
KSFM=DA(97)
IF(KSFM) 80,56,10

C FITTING OF GIVEN PRESSURE/MACH TO A SPLINE-SURFACE

C 10 IF(NB-KSFH) 8C,15,15
15 CONTINUE

KP=701
DC 30 IP=1,KSFM

C SFMY(IP)=DA(KP)/DA(24)
SMY(IP)=DA(KP+1)/DA(24)
SMH(IP)=DA(KP+3)

C DATA ARE PRESSURE COEFFICIENT

C DATA ARE LOCAL MACH NUMBER

C CONVERT PRESSURE COEFFICIENT INTO LOCAL MACH NUMBER

C SPLINE-SURFACE FITTING OF DATA

C CONTINUE

C PRESENTLY INPUT OF PRESSURE COEFFICIENT IS

C A POLYNOMIAL FORM IS NOT ALLOWED

C THE FOLLOWING INPUT OF MACH NUMBER AS A POLYNOMIAL

C CONTINUE

C GET TO 40

C IF(IPRINT.NE.C) WRITE(IW,100)

C CALL SJRFI(N,KSFM,T,SFMX,SMY,SMH,IPRINT)

C

C THE FOLLOWING INPUT OF MACH NUMBER AS A POLYNOMIAL

C CONTINUE

C GET TO 40

C 75 IPR=96

C 80 IPR=97

C WRITE

C IF(IW,1101)IPR

C STOP

C FORMAT(1H0,10X,73HCOMPUTED MACH(X,Y) = A0*A1*X*A2*Y SUM OF H(I)*
C 110 FORMAT(1H0,10X,14HERROR—BAD DATA,15)

END
SUBROUTINE INTEG(X,Y,VR,VE,MM,H2,H3,H4)
C INTEGRATION BASED ON SPLINE FUNCTION
DIMENSION X(1),Y(2),S(1),MM,1
C DEFINE J(X)
DO 20 I=2,NQ
20 S(I,1)=X(I)-X(I-1)
IF (NQ.EQ.2) GO TO 50
C DEFINE TRI-DIAGONAL COEFFICIENT MATRIX
DO 25 I=2,NZ
S(I,2)=S(I-1,2)/6.0
S(I,3)=(S(I-1,2)+S(I+1,2))/3.0
25 S(I,4)=S(I+1,2)/6.0
Si,2)+0.0
S(NZ,4)=0.0
C DEFINE RIGHT-HAND-SIDE COLUMN MATRIX
K=1
30 DO 40 I=2,NZ
35 DO 40 I=2,NZ
40 S(I,5)=Y(I)-Y(I-1)
DO 45 I=2,NZ
45 S(I,6)=S(I,5)+S(I-1,5)
40 CONTINUE
C SOLVE FOR COEFFICIENTS OF SPLINE FUNCTION M(J)
CALL TRIDI(ZH,SH,TH,TH,TH,TH,TH)
50 CONTINUE
V(1,1)=0.0
V(NQ-1)=0.0
VI=0.0
DO 60 I=2,NQ
60 CONTINUE
IF(K.EQ.2) RETURN
VR=VI
IF(N.EQ.1) RETURN
K=2
GO TO 35
END

SUBROUTINE TRIDI(K1,K2,K3,A,B,C,D,E,F)
DIMENSION A(11),B(11),C(11),D(11),E(11),F(11)
IF (N.EQ.K1) GO TO 5
V(K1)=C(K1)/D(K1)
RETURN
5 CONTINUE
E(K1)=B(K1)/C(K1)
F(K1)=D(K1)/C(K1)
K2=K1+1
C(K1+1)=C(K1)+A(K1+1)6(K1+1)
C(K2)=F(K2)
DO 10 J=1,K2
10 Y(J)=C(J)*E(J)+F(J)*E(J+1)
RETURN
END
SUBROUTINE SPISET(N, X, Y, Z, RMS)

DIMENSION X(1), Y(1), Z(1)

DATA HMS, X(1), Y(1), Z(1), RMS, X(1), Y(1), Z(1), RMS

DO I = 1, N
  X(I) = X(I-1) + Y(I-1) + Z(I-1)
  Y(I) = Y(I-1) + Z(I-1)
  Z(I) = Z(I-1)
END

RETURN
SUBROUTINE SMOOTH (M,N,X,Y,T,SMOOTH)

C THE Y ARRAY IS SMOOTHED BY A LOCAL FIVE POINT LEAST SQUARES
C CUBIC WEIGHTED BY M
C DIMENSION X(I),Y(I),T(I)
C IF(M,LT.5) RETURN
C
DO 10 NS=1,M
T(I)=NS

1 AN=M
S=(T(I)*X(M)-X(I))/AN**2
DO 4 L=1,N
K=MNO(M-4,MAXO(I,L-2))
K4=K+4
DO 1 J=1,20
T(I+J)=S
DO 3 M=K,K4
W=1./S*(X(I+M)-X(I))**2
R=1.0
DO 3 J=1,4
T(I+J)=W*R
RR=R
DO 2 J=1,4
J4=4*J+4
T(J4)=T(J4)+RR
RR=RR*W
2 RR=RR*X(M)
T(I+16)=T(I+16)+RR*Y(M)*W
3 R=R*X(M)
CALL CHLSKY(IT,4,T(I),1)
M=L-(L-1)/5*5
IF(L.GT.5) Y(L-5)=T(M+20)
T(M+20)=0.
R=1.0
DO 4 J=1,4
T(M+20)=T(M+20)+R*T(J+16)
4 R=R*X(L)
I=H-5
DO 5 L=1,5
ML=M-(M+L-1)/5*5
5 Y(J4)=T(ML+20)
CONTINUE
RETURN
END
SUBROUTINE CHLSKY(A,N,B,MX,UX)

DIMENSION A(mx+1),B(mx+1)

CHOLESKY DECOMPOSITION IS USED TO SOLVE THE MATRIX EQUATION AX=B

WHERE THE COEFFICIENT MATRIX, A, IS SYMMETRIC. ON OUTPUT X IS STORED IN B

IF(N.EQ.1) GO TO 6

DO 2 J=1,N

II=I

DO 2 J=1,N

DO 2 L=1,J

2 A(I,J)=A(I,J)-A(I,L)*A(L,J)/A(L,L)

DO 3 K=1,N

DO 3 L=1,J

3 B(I,K)=B(I,K)-B(L,K)*B(L,K)/A(L,L)

DO 4 I=2,N

II=I-1

DO 4 L=1,I

4 N1=H+1-L

4 (N1,K)=B(N1,K)-B(N1,K)*B(N1,K)/B(N1,N1)

DO 5 I=1,N

5 B(I,K)=B(I,K)*B(I,K)

RETURN

6 A(I,I)=1./A(I,I)

DO 7 L=1,N

7 B(L,L)=B(L,L)*B(L,L)

RETURN

END
SUBroutine SUNL_POINTS (ABH, ABX, ABY, ABH, ABY, ABH, ABY)
C
FITS DATA IN POINTS THROUGH ABX, ABY, ABH
C
1. FORM A Spline SURFACE FITTING
C
2. X, Y, Z ARRAYS FOR INPUT POINTS TO BE FITTED
C
3. ABH(I) = INDEPENDENT VARIABLE X
C
4. ABY(J) = INDEPENDENT VARIABLE Y
C
5. ABH(I) - COMES AS A DEPENDENT VARIABLE OF X AND Y
C
6. GOES OUT AS COEFFICIENTS OF SPLINE-SURFACE
C
7. NP1 = 1
C
8. NP2 = NP1 + 1
C
9. NP3 = NP2 + 1
C
10. IF (N.EQ.0) GO TO 20
C
11. LI = 1
C
12. T(L1) = ALX(1)
C
13. TJ = T(J) = AY(1)
C
14. T(J+1) = T(J+2)
C
15. IF (NP3) = AT(J+3)
C
16. IF (I.EQ.0) GO TO 20
C
17. IF (I.EQ.0) GO TO 20
C
18. CONTINUE
C
19. STOP IN NP-COEFFICIENT IN ARRAY ABH.
C
20. DL 12 I = 1, NP3
C
21. IF (I.EQ.0) GO TO 18
C
22. WRITE (1, 200) (ABH(I), 1 = 1, NP3)
C
23. IF (NP3) = 0 THEN
C
24. IF (NP3) = 0 THEN
C
25. CONTINUE
C
26. STOP
C
27. CONTINUE
C
28. RETURN
C
29. 110 FORMAT (10X, 2I1, 1P3E14.7)
C
30. 120 FORMAT (I6, 2I1, 1P3E14.7)
C
31. 200 FORMAT (100X, 2I1, 1P3E14.7)
C
32. 300 FORMAT (I6, 2I1, 1P3E14.7)
C
33. 400 FORMAT (I6, 2I1, 1P3E14.7)
C
34. 500 FORMAT (I6, 2I1, 1P3E14.7)
C
35. 600 FORMAT (I6, 2I1, 1P3E14.7)
C
36. 700 FORMAT (I6, 2I1, 1P3E14.7)
C
37. 800 FORMAT (I6, 2I1, 1P3E14.7)
C
38. 900 FORMAT (I6, 2I1, 1P3E14.7)
C
400 FORMAT (I6, 2I1, 1P3E14.7)
C
410 FORMAT (I6, 2I1, 1P3E14.7)
C
420 FORMAT (I6, 2I1, 1P3E14.7)
C
430 FORMAT (I6, 2I1, 1P3E14.7)
C
440 FORMAT (I6, 2I1, 1P3E14.7)
C
450 FORMAT (I6, 2I1, 1P3E14.7)
C
460 FORMAT (I6, 2I1, 1P3E14.7)
C
470 FORMAT (I6, 2I1, 1P3E14.7)
C
480 FORMAT (I6, 2I1, 1P3E14.7)
C
490 FORMAT (I6, 2I1, 1P3E14.7)
C
500 FORMAT (I6, 2I1, 1P3E14.7)
C
510 FORMAT (I6, 2I1, 1P3E14.7)
C
520 FORMAT (I6, 2I1, 1P3E14.7)
C
530 FORMAT (I6, 2I1, 1P3E14.7)
C
540 FORMAT (I6, 2I1, 1P3E14.7)
C
550 FORMAT (I6, 2I1, 1P3E14.7)
C
560 FORMAT (I6, 2I1, 1P3E14.7)
C
570 FORMAT (I6, 2I1, 1P3E14.7)
C
580 FORMAT (I6, 2I1, 1P3E14.7)
C
590 FORMAT (I6, 2I1, 1P3E14.7)
C
600 FORMAT (I6, 2I1, 1P3E14.7)
C
610 FORMAT (I6, 2I1, 1P3E14.7)
C
620 FORMAT (I6, 2I1, 1P3E14.7)
C
630 FORMAT (I6, 2I1, 1P3E14.7)
C
640 FORMAT (I6, 2I1, 1P3E14.7)
C
END
SUBROUTINE SURF2(J1,J2,J3,MAXY,VALU,VLUX,VLUY,HI,HA) SURF2
C  COMPUTE VALUE OF SPLINE-SURFACE FITTED DATA AT A POINT (X,Y) SURF2
C  X1,J1,J= COORDINATES OF THE POINT WHERE THE FITTED VALUE IS SOUGHT SURF2
C  VALU - FITTED VALUE SOUGHT SURF2
C  VLUX - GRADIENT OF FITTED VALUE IN X SURF2
C  VLUY - GRADIENT OF FITTED VALUE IN Y SURF2
C  XI,J1,J= - ARRAYS FOR KNOWN PROPERTIES IN SPLINE-SURFACE FORM SURF2
C  MX = NUMBER OF POINTS IN XI, YI ARRAYS SURF2
C  MXY - X=Z1(J), Y=Z2(J) WHERE J=J1,J2 SURF2
C  MXY=1 X=Z1(J), Y=Z2(J) WHERE J=J1,J2 SURF2
C  MXY=2 Y=Z1(J), X=Z2(J) WHERE J=J1,J2 SURF2
C  DIMENSION XI(J1),JI(J1),HI(J1) SURF2
C  DIMENSION Z1(J1),Z2(J1),VLUX(J1),VLUY(J1) SURF2
C NP1=M+1 SURF2
C NP2=M+1 SURF2
C NP3=MNP2+1 SURF2
C IF(MXY.EQ.1) X=Z1(J) SURF2
C IF(MXY.EQ.2) Y=Z1(J) SURF2
C DO 40 J=J1,J2 SURF2
C IF(MXY.EQ.1) Y=Z2(J) SURF2
C IF(MXY.EQ.2) X=Z2(J) SURF2
C IF(MXY.NE.0) GO TO 10 SURF2
C IF(K-2) 13,12,11 SURF2
C 11 VLUY(J)=HI(NP3) SURF2
C 12 VLUX(J)=HI(NP2) SURF2
C 13 VALU(J)=HI(NP1)+HI(NP2)+X*HI(NP3)*Y SURF2
C IF(N.EQ.0) GO TO 40 SURF2
C DO 30 I=1,N SURF2
C T=Q-Z1(I) SURF2
C T=Q-Y1(I) SURF2
C H=TX*TQ+TY*TY SURF2
C H=0. SURF2
C IF(H.GT.0.) HA=ALOG(H) SURF2
C H=Q*Q+TQ*TQ SURF2
C IF(K-2) 39,37,35,33 SURF2
C 21 VLUY(J)=VLUY(J)+HA*TY SURF2
C 22 VLUX(J)=VLUX(J)+HA*TX SURF2
C 23 VALU(J)=VALU(J)+HI(I)+H*HA SURF2
C 30 CONTINUE SURF2
C 40 CONTINUE SURF2
C RETURN SURF2
C END SURF2
FUNCTION CIN(X)
C
SINE AND COSINE INTEGRAL SUBROUTINE
C
C IF CALLED BY THE STATEMENT C=CIN(X,5)
C C AND S ARE THE INTEGRALS OVER T FROM 1 TO INFINITY OF
C COS(\pi T/2) AND SIN(\pi T/2)
C
SG=1.0
X=X1
IF (X LE 1.0) 1, 2
1 SG=SG+X
X=X+1
2 X2=X*X
IF (ABS(X) LE 1.0) 3, 4
3 Y=((X2/18.0-.6)/.05*pX2+1.01*X2/16.0-1.01*X+1.57079633
U=((-X2/45.0-1.01)*X2/24.0+1.01*X2/4.0+.5772156665-ALOG(X))
GO TO 5
4 P=((X2+19.394119)*X2+47.411538)*X2+8.4933567/(((X2+21.361055)
1 *X2+70.3764561*X2+30.03822271)*X)
U=((-X2+21.3832249*X2+49.7197751*X2+5.08950417)/(((X2+21.779581)
1 *X2+119.9189321*X2+70.707861*X2)
CO=COS (X)
SI=SIN (X)
U=U-CO-PSI
V=P*CO+Q*SI
5 S=SG
CIN=U
RETURN
END
FUNCTION MSINEC(N,M,L,A) RETURN

DIMENSION A(N+1),B(N+1)

COMPLEX A,B,G

DO 30 I = 1,N
C = 0.0
DO 10 J = 1,N
10 C = MAX1C(ABS(REAL(A(I,J)))+ABS(IMAG(A(I,J))))

IF(C.EQ.0.0) GO TO 1000
DO 20 J = 1,N
20 A(I,J) = A(I,J)/C
DO 30 J = 1,N
30 B(I,J) = B(I,J)/C

IF(H.EQ.1.0) GO TO 205
NM = N - 1
DO 200 J = 1,NM
C = 0.0
K = 0
DO 40 J = 1,NM
G = ABS(REAL(A(I,J)))+ABS(IMAG(A(I,J)))
IF(C.GE.0.0) GO TO 40
40 CONTINUE

DO 50 J = 1,NM
K = 1
C = 0
IF(K.EQ.0.0) GO TO 1000
DO 60 J = 1,NM
60 A(I,J) = A(I,J)/C
B(I,J) = B(I,J)/C

DO 206 JJ = 1,L
DO 207 J = 1,L
G = 1.0/A(I,J)
IF(N.EQ.1.0) GO TO 207
DO 209 JJ = 1,N
207 A(I,J) = A(I,J)/G
B(I,J) = B(I,J)/G
209 CONTINUE

IF (ABS(REAL(A(I,J)))+ABS(IMAG(A(I,J))) LT 1.0E-7) GO TO 1000
DO 210 J = 1,L
210 A(I,J) = A(I,J)/G
DO 220 J = 1,L
220 B(I,J) = B(I,J)/G

DO 230 I = 1,N
230 MSINEC = 2
RETURN
END
SONIC-BOX METHOD EMPLOYING LOCAL MACH NUMBER FOR OSCILLATING WINGS WITH THICKNESS

A computer program has been developed to account approximately for the effects of finite wing thickness in the transonic potential flow over an oscillating wing of finite span. The program is based on the original sonic-box program for planar wing which has previously been extended to include the effects of the swept trailing edge and the thickness of the wing. Account for the non-uniform flow caused by finite thickness is made by application of the local linearization concept. The thickness effect, expressed in terms of the local Mach number, is included in the basic solution to replace the coordinate transformation method used in the earlier work. Calculations were made for a delta wing and a rectangular wing performing plunge and pitch oscillations, and the results were compared with those obtained from other methods. An input guide and a complete listing of the computer code are presented.

Unsteady Transonic Flow
Lifting Surface Theory
Transonic Potential Flow
Aircraft Aerodynamics