

NASA Technical Memorandum 87737

NASA-TM-87737 19860022061

USER'S MANUAL FOR XTRAN2L (VERSION 1.2): A PROGRAM
FOR SOLVING THE GENERAL-FREQUENCY UNSTEADY
TRANSONIC SMALL-DISTURBANCE EQUATION

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JULY 1986

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Summary

The development, use, and operation of the XTRAN2L program that solves the two-dimensional unsteady transonic small-disturbance potential equation are described. The XTRAN2L program is used to calculate steady and unsteady transonic flow fields about airfoils and is capable of performing self-contained transonic flutter calculations. Operation of the XTRAN2L code is described, and tables defining all input variables, including default values, are presented. Sample cases that use various program options are shown to illustrate operation of XTRAN2L. Computer listings containing input and selected output are included as an aid to the user.

Introduction

Considerable research is presently being conducted to develop computational methods for calculating transonic unsteady aerodynamics for aeroelastic applications. The methods are being developed to provide accurate yet cost efficient means for calculating unsteady transonic airloads for the prediction of aeroelastic characteristics such as flutter and divergence. Computational developments and advances that are possible because of improvements made in computer technology and numerical solution techniques are described in Ref. 1.

Solutions for unsteady transonic flows about oscillating airfoils have been made possible using computer codes such as LTRAN2.² The original

LTRAN2 code was developed to compute time-accurate solutions of the low-frequency approximation of the transonic small-disturbance (TSD) equation. Houwink and Van der Vooren³ extended the range of applicability of the LTRAN2 code by incorporating the time-derivative terms in the airfoil and wake boundary conditions. The resulting code was termed LTRAN2-NLR. The XTRAN2L code,⁴ developed at NASA Langley Research Center, is an extensive modification of LTRAN2-NLR that includes monotone differencing, nonreflecting farfield boundary conditions, an improved computational grid, a pulse transient capability, and an aeroelastic transient capability. Details of the algorithm used in XTRAN2L and the modifications made to LTRAN2-NLR are given by Whitlow.⁴ Details of the grid development and pulse transient capability are given by Seidel, Bennett, and Whitlow.⁵ The development of the aeroelastic transient capability was reported by Edwards, Bennett, Whitlow, and Seidel.⁶

The XTRAN2L program is operational at the NASA Langley Research Center on a CYBER-175 computer using FORTRAN IV. The program uses the OVERLAY capability to segment the program into 3 parts and reduce the field length required to load and run the program. The program requires 120 kbytes to load and run in overlaid form. On the CYBER-175, the program requires 0.25 CPU seconds per time step.

The purpose of the present report is: (1) to summarize the XTRAN2L developments of Refs. 4-6, and (2) to describe the operation of the XTRAN2L (Version 1.2) code. The report reiterates the governing equations and program input descriptions given in the LTRAN2-NLR user's manual,⁷ and extends the information to include the XTRAN2L modifications and improvements. A brief description of XTRAN2L is presented first, highlighting the relevant equations and computational procedures. Operation of XTRAN2L is described next, along with tables defining all input variables, including default values. Finally,

application of XTRAN2L is illustrated by sample calculations for the NACA 64A010A airfoil at a freestream Mach number of 0.78 and a mean angle of attack of 1.0° . In these calculations, various program options are used. Computer listings containing input and selected output are included as an aid to the user.

Symbols

a	pulse amplitude in Eqs. (8a), (8b) and (8c)
a_h	distance in semichords from midchord to elastic axis
a_n	harmonic coefficient in Eq. (7)
A	coefficient defined in Eq. (2a)
b	semichord, $c/2$
b_n	harmonic coefficient in Eqs. (6a) and (6b)
B	coefficient defined in Eq. (2b)
c	chordlength
c_a	axial force coefficient
c_n	normal force coefficient, positive up
c_{n_f}	control surface normal force coefficient, positive up
c_m	pitching moment coefficient about pitch axis x_r , positive nose down
c_{m_f}	control surface moment coefficient about hinge line x_h , positive trailing-edge up
c_β	distance in semichords from midchord to hinge axis
C	coefficient defined in Eq. (2c)
C_p	pressure coefficient
C_{p_u}	upper surface pressure coefficient
C_{p_ℓ}	lower surface pressure coefficient
C_p^*	critical pressure coefficient

f instantaneous position of airfoil, defined in Eqs. (4a) and (4b)
 $f_0(x)$ airfoil contour
 $g(x,t)$ chord deformation
 $g_1(x)$ amplitude of harmonic chord deformation
 $h(t)$ plunge displacement of elastic axis nondimensionalized by semichord, positive down (used for aeroelastic motion)
 $H(t)$ function for forced harmonic motion
 k reduced frequency, $\omega b/U$
 $[K]$ stiffness matrix, defined in Eq. (10b)
 m airfoil mass per unit span
 M local Mach number
 M_∞ freestream Mach number
 $[M]$ mass matrix, defined in Eq. (10a)
 $p(x,t)$ arbitrary motion specified by the user
 r_α radius of gyration of airfoil about elastic axis
 r_β radius of gyration of control surface about hinge line
 r_1 parameter to turn on/off time dependent term in airfoil boundary condition, defined in Eq. (3)
 r_2 parameter to turn on/off time dependent term in airfoil wake condition, defined in Eq. (12)
 r_3 parameter to turn on/off time dependent term in C_p and Mach number formulas, defined in Eqs. (14) and (16)
 t scaled time, kT
 \bar{t} nondimensional time for print and plot output, $k\tau$
 T time, (sec.)
 T_c time at pulse center in Eqs. (8a), (8b) and (8c)
 U freestream speed
 U_F flutter speed
 $\{u\}$ aerodynamic load vector for aeroelastic motion, defined in Eq. (10d)

w	parameter that controls pulse width in Eqs. (8a), (8b) and (8c)
x	streamwise coordinate relative to leading edge, measured in chordlength
x_f	control surface leading edge location
x_h	control surface hinge axis location
x_r	pitch axis location
x_α	distance in semichords from elastic axis to center of mass
x_β	distance in semichords from hinge axis to control surface center of mass
$\{x\}$	displacement vector for aeroelastic motion, defined in Eq. (10c)
z	coordinate normal to freestream, measured in chordlength, positive up
$Z(t)$	nondimensional plunge displacement, positive up (used for forced harmonic and pulse motions)
Z_1	harmonic plunge amplitude
$\alpha(t)$	pitch motion, positive nose up
α_0	mean angle of attack
α_1	harmonic pitch amplitude
$\beta(t)$	control surface motion, positive trailing edge down
β_0	control surface mean deflection angle
β_1	control surface harmonic amplitude
γ	ratio of specific heats
ΔC_p	lifting pressure coefficient
ΔT	time step size
δ	airfoil maximum thickness-to-chord ratio
$[\theta]$	integral of state-transition matrix, used for aeroelastic motion
μ	airfoil mass ratio, $m/\pi\rho_\infty b^2$
ρ	density
ρ_∞	freestream density

τ	nondimensional time, UT/b
ϕ	disturbance velocity potential
$[\phi]$	state-transition matrix, used for aeroelastic motion
ω	angular frequency
ω_h	uncoupled natural frequency of plunge, rad/sec
ω_α	uncoupled natural frequency of pitch, rad/sec
ω_β	uncoupled natural frequency of control surface deflection, rad/sec

Description of XTRAN2L

The XTRAN2L code is used to calculate time-accurate, finite-difference solutions of the nonlinear, small-disturbance, potential equation for two-dimensional transonic flow. The code can be used to calculate steady and unsteady transonic flow fields about airfoils and is capable of treating forced harmonic, pulse, or aeroelastic transient type motions. In this section, the XTRAN2L code is described including the relevant equations and computational procedures.

Transonic Small-Disturbance Equation

The flow field is described by the complete unsteady transonic small-disturbance equation

$$A\phi_{tt} + B\phi_{xt} = C\phi_{xx} + \phi_{zz} \quad (1)$$

where ϕ is a disturbance velocity potential scaled by $c[\delta M_\infty^2 (\gamma^* + 1)]^{2/3}$,

$\gamma^* = 2 - (2 - \gamma)M_\infty^2$, and the spatial coordinates x and z and time t are

normalized from the physical quantities by c , $c/[\delta M_\infty^2 (\gamma^* + 1)]^{1/3}$ and k^{-1} ,

respectively. The coefficients A , B , and C are defined as

$$A = c^2 k^2 M_\infty^2 / U^2 [\delta M_\infty^2 (\gamma^* + 1)]^{2/3} \quad (2a)$$

$$B = 2 c k M_\infty^2 / U [\delta M_\infty^2 (\gamma^* + 1)]^{2/3} \quad (2b)$$

$$C = (1 - M_\infty^2) / [\delta M_\infty^2 (\gamma^* + 1)]^{2/3} - M_\infty^2 (\gamma^* + 1) \phi_x \quad (2c)$$

A time-accurate alternating-direction implicit (ADI) finite-difference scheme is used to solve Eq. (1). Details of the ADI algorithm are given by Whitlow.⁴

Airfoil Boundary Condition

The airfoil flow tangency boundary condition⁷ is

$$\phi_z^\pm = f_x^\pm + r_1 f_t \quad (3)$$

where

$$f = f_0(x) + g(x,t) + Z(t) - \alpha(t) [x - x_r] + p(x,t) \quad ; \quad x < x_f \quad (4a)$$

and

$$f = f_0(x) + g(x,t) + Z(t) - \alpha(t) [x - x_r] + p(x,t) \\ - \beta(t) [x - x_h] \quad ; \quad x \geq x_f \quad (4b)$$

In Eq. (3), r_1 is a parameter specified by the user to be either 0 or 1. The low frequency airfoil boundary condition is selected by setting r_1 to be equal to zero. In Eqs. (4a) and (4b), $f_0(x)$ describes the airfoil contour, $g(x,t)$ is the chord deformation, and $Z(t)$, $\alpha(t)$, and $\beta(t)$ are the nondimensional plunge displacement, pitch, and trailing edge control surface deflection, respectively. Three types of motion may be analyzed using XTRAN2L as described below. The motion types are forced harmonic, pulse, and aeroelastic. The capability for specifying an arbitrary motion is provided through the use of the function $p(x,t)$.

Forced Harmonic Motion. - Typically, unsteady aerodynamic forces are determined by calculating several cycles of forced harmonic oscillation with the last cycle providing the estimate of the forces. Following Ref. 7, the equations describing forced harmonic motion are

$$g(x,t) = g_1(x) H(t) \quad (5a)$$

$$Z(t) = Z_1 H(t) \quad (5b)$$

$$\alpha(t) = \alpha_0 + \alpha_1 H(t) \quad (5c)$$

$$\beta(t) = \beta_0 + \beta_1 H(t) \quad (5d)$$

where α_0 and β_0 are the airfoil mean angle of attack and control surface mean deflection angle, respectively; $g_1(x)$ is the amplitude of harmonic chord deformation, and Z_1 , α_1 , and β_1 are the amplitudes of harmonic plunge, pitch, and control surface motions, respectively. Two alternatives exist for the definition of the harmonic function $H(t)$. The first definition is

$$H(t) = \sum_{n=1}^N b_n \sin^2 nk\tau \quad ; \quad 0 \leq \tau \leq \frac{\pi}{2nk} \quad (6a)$$

$$H(t) = \sum_{n=1}^N b_n \sin nk\tau \quad ; \quad \tau > \frac{\pi}{2nk} \quad (6b)$$

where N is the number of harmonics to be selected by the user. Equation (6a) is used to provide a smooth start over the first quarter period of each harmonic which reduces the starting transient. The second definition for $H(t)$ is

$$H(t) = \sum_{n=1}^N a_n \cos nk\tau \quad ; \quad \tau \geq 0 \quad (7)$$

Real and imaginary parts of the unsteady aerodynamic forces in the frequency domain may be determined two ways. First, the method used in the LTRAN2-NLR code was retained. This method calculates the coefficients of the first harmonics of the airloads based on information from each quarter period of the last cycle of harmonic motion. The procedure assumes that the time histories of the normal force and moment coefficients are periodic and simple harmonic. The relevant equations are presented in Ref. 7. In the second procedure, Fourier analyses of the last cycle of motion are performed to determine all relevant harmonic components. This procedure is the preferred method since the only assumption is that of periodicity.

Pulse Motion. - As an alternative to calculating unsteady aerodynamic forces by forced harmonic oscillation, the unsteady forces may be obtained indirectly from the response due to a smoothly varying, exponentially shaped pulse.⁵ In this procedure, the airfoil is given a small prescribed pulse in a given mode of motion and the aerodynamic transients are calculated. For plunge motion, the input pulse is given by

$$Z(t) = ae^{-w (T - T_c)^2} \quad (8a)$$

for pitch motion, the input pulse is given by

$$\alpha(t) = \alpha_0 + ae^{-w (T - T_c)^2} \quad (8b)$$

and for control surface motion, the input pulse is given by

$$\beta(t) = \beta_0 + ae^{-w (T - T_c)^2} \quad (8c)$$

where a is the pulse amplitude, w is a parameter that controls the pulse width, and T_c is the time at the pulse center. The pulse width is inversely

proportional to w , such that as the value of w increases, the width of the pulse decreases. To ensure adequate resolution of harmonic components up to a reduced frequency of $k = 2.0$, the product of the chosen values of w and ΔT^2 should be near the product of the default values. The harmonic response is obtained by a transfer-function analysis using fast Fourier transforms (FFT). Specifically, the aerodynamic forces in the frequency domain are determined by dividing the FFT of the time histories of the output normal force and moment coefficients by the FFT of the input airfoil pulse motion. The calculation is performed external to the XTRAN2L code as a separate job step and thus the post-processing program is not included within XTRAN2L. Use of the pulse transfer-function analysis gives considerable detail in the frequency domain with a significant reduction in cost over the alternative method of calculating multiple oscillatory responses, as shown in Fig. 13 of Ref. 5. As an example, Fig. 1 shows a pitch pulse input (Fig. 1(a)), a typical normal force coefficient output (Fig. 1(b)), and the resulting unsteady forces (Fig. 1(c)).

Aeroelastic Motion. - An aeroelastic transient capability is available within XTRAN2L wherein the structural equations of motion are coupled with the aerodynamic solution procedure for simultaneous time-integration. The equations of motion for a three degree-of-freedom (plunge, pitch, and control surface motions) aeroelastic system may be written as

$$[M] \{\ddot{x}\} + [K] \{x\} = \frac{1}{\pi \mu} \left(\frac{U}{b}\right)^2 \{u\} \quad (9)$$

where $[M]$, the mass matrix, $[K]$, the stiffness matrix, $\{x\}$, the displacement vector, and $\{u\}$, the aerodynamic load vector, are defined as

$$[M] = \begin{bmatrix} 1 & x_\alpha & x_\beta \\ x_\alpha & r_\alpha^2 & (c_\beta - a_h)x_\beta + r_\beta^2 \\ x_\beta & (c_\beta - a_h)x_\beta + r_\beta^2 & r_\beta^2 \end{bmatrix} \quad (10a)$$

$$[K] = \begin{bmatrix} \omega_h^2 & 0 & 0 \\ 0 & r_\alpha^2 \omega_\alpha^2 & 0 \\ 0 & 0 & r_\beta^2 \omega_\beta^2 \end{bmatrix} \quad (10b)$$

$$\{x\} = \begin{Bmatrix} h \\ \alpha \\ \beta \end{Bmatrix} \quad (10c)$$

$$\{u\} = \begin{Bmatrix} -(c_n - c_{n_0}) \\ 2(c_m - c_{m_0}) \\ 2(c_{m_f} - c_{m_{f_0}}) \end{Bmatrix} \quad (10d)$$

The dot ($\dot{\cdot}$) above a variable denotes differentiation with respect to time T , and the structural parameters appearing in Eqs. (9) and (10) are defined in Fig. 2. In the aerodynamic load vector, the steady-state coefficients c_{n_0} , c_{m_0} , and $c_{m_{f_0}}$ are subtracted from the total coefficients. Thus the aeroelastic response (i.e., $h(t)$, $\alpha(t)$, and $\beta(t)$) represents motion

about the steady-state condition. Aeroelastic equations of motion for any of the three possible two degree-of-freedom systems are determined by deleting the appropriate rows and columns in Eqs. (9) and (10).

The aeroelastic response is determined by numerically integrating the equations of motion in time using a structural integrator based on the state-transition matrix.⁶ More specifically, the time-integration of Eq. (9) is performed by advancing the aeroelastic solution from time level n to time level $n+1$ using an algorithm described by

$$\begin{Bmatrix} \{x\} \\ \{\dot{x}\} \end{Bmatrix}^{n+1} = [\Phi] \begin{Bmatrix} \{x\} \\ \{\dot{x}\} \end{Bmatrix}^n + \frac{1}{\pi u} \left(\frac{U}{b}\right)^2 [\Theta] \begin{Bmatrix} [0] \\ [M]^{-1} \end{Bmatrix} \left[\frac{3}{2} \{u\}^n - \frac{1}{2} \{u\}^{n-1} \right] \quad (11)$$

where $[\Phi]$ and $[\Theta]$ are the state-transition matrix and its integral matrix, respectively. These matrices are functions of the aeroelastic parameters and are computed within the XTRAN2L code. Details of the aeroelastic solution procedure may be found in Ref. 6. In general, several aeroelastic responses are calculated for a range of freestream speeds, U , at a given Mach number. The values for U are selected such that stable (converging) and unstable (diverging) responses result. The flutter speed U_f , where the damping is zero, is calculated by interpolating the critical damping of the responses. Damping of the aeroelastic transients is typically determined using the modal identification program of Bennett and Desmarais.⁸ The program uses complex exponential functions and a least-squares curve-fitting technique to estimate damping, frequency, magnitude, and phase of the aeroelastic modes from the transient responses. This calculation is performed as a separate post-processing job step and thus the program of Ref. 8 is not included within the XTRAN2L code.

Wake Condition

The wake is represented as a slit downstream of the airfoil trailing edge. Along the slit the condition⁷

$$[\phi_x] + r_2[\phi_t] = 0 \quad ; \quad z = 0, \quad x > 1 \quad (12)$$

is imposed, where $[\quad]$ denotes the jump in the indicated quantity across the wake. The parameter r_2 is specified by the user to be either 0 or 1. The low frequency version of the wake condition is specified by setting r_2 to be equal to zero.

Nonreflecting Farfield Boundary Conditions

The LTRAN2 and LTRAN2-NLR codes use steady-state farfield boundary conditions which cause disturbances to be reflected from the computational boundaries. The boundaries were subsequently located far away to minimize the possibility of disturbances reflecting back into the flow field and contaminating the solution. Therefore, nonreflecting farfield boundary conditions were developed and implemented in XTRAN2L by Whitlow.⁴ These boundary conditions, consistent with the TSD equation (Eq. (1)), are summarized in Fig. 3, taken from Ref. 4.

Pressure Coefficient and Mach Number

The pressure coefficient C_p , may be calculated using either of two formulae.⁷ The exact expression is given by

$$C_p = \frac{2}{\gamma M_\infty^2} (\rho^\gamma - 1) \quad (13a)$$

where

$$\rho = \left[1 - \frac{\gamma-1}{2} M_\infty^2 (2\phi_x + \phi_x^2 + \phi_z^2 + 2\phi_t) \right]^{\frac{1}{\gamma-1}} \quad (13b)$$

The linearized TSD approximation is given by

$$C_p = -2(\phi_x + r_1 r_3 \phi_t) \quad (14)$$

The local Mach number M , may also be calculated by either of two formulae.⁷ The exact expression is

$$M^2 = M_\infty^2 \frac{(1+\phi_x)^2 + \phi_z^2}{\rho^{\gamma-1}} \quad (15)$$

and the linearized TSD approximation is

$$M^2 = M_\infty^2 [1 + (\gamma^* + 1)\phi_x + r_1 r_3 (\gamma - 1)M_\infty^2 \phi_t] \quad (16)$$

The user may also select low-frequency versions of the linearized equations, Eq. (14) and Eq. (16), whereby the time-derivative terms are omitted. This is done by defining the product $r_1 r_3$ to be equal to zero. Otherwise the product $r_1 r_3$ is set equal to unity.

Normal Force, Axial Force, and Pitching Moment Coefficients

For the airfoil, the normal force coefficient c_n , axial force coefficient c_a , and pitching moment coefficient c_m , are defined as

$$c_n = - \int_0^1 \Delta C_p \, dx \quad (17a)$$

$$c_a = \int_0^1 (C_{p_u} f_{x_u} - C_{p_\ell} f_{x_\ell}) \, dx \quad (17b)$$

$$c_m = - \int_0^1 \Delta C_p (x - x_r) \, dx \quad (17c)$$

where $\Delta C_p = C_{p_u} - C_{p_\ell}$, and the subscripts u and ℓ denote the upper and lower airfoil surfaces, respectively.

For the control surface, the normal force coefficient c_{n_f} , and pitching moment coefficient c_{m_f} are defined as

$$c_{n_f} = - \int_{x_f}^1 \Delta C_p \, dx \quad (18a)$$

$$c_{m_f} = \int_{x_f}^1 \Delta C_p (x - x_h) \, dx \quad (18b)$$

By substituting Eq. (14) for the pressure coefficients appearing in Eqs. (17) and (18), and evaluating several of the integrals by parts leads to

$$c_n = 2 \Delta\phi_{TE} + 2r_1 r_3 \int_0^1 \Delta\phi_t \, dx \quad (19a)$$

$$c_a = \int_0^1 (C_{p_u} f_{x_u} - C_{p_\ell} f_{x_\ell}) \, dx \quad (19b)$$

$$c_m = 2(1 - x_r) \Delta\phi_{TE} + 2 \int_0^1 \Delta\phi \, dx + 2r_1 r_3 \int_0^1 \Delta\phi_t (x - x_r) \, dx \quad (19c)$$

for the airfoil, and

$$c_{n_f} = 2 \Delta\phi_{TE} - 2 \Delta\phi_{x_f} + 2r_1 r_3 \int_{x_f}^1 \Delta\phi_t \, dx \quad (20a)$$

$$c_{m_f} = 2(1 - x_h) \Delta\phi_{TE} - 2(x_f - x_h) \Delta\phi_{x_f} + 2 \int_{x_f}^1 \Delta\phi \, dx + 2r_1 r_3 \int_{x_f}^1 \Delta\phi_t (x - x_h) \, dx \quad (20b)$$

for the control surface. In Eqs. (19) and (20), $\Delta\phi = \phi_u - \phi_l$, and $\Delta\phi_{TE}$ and $\Delta\phi_{x_f}$ are the values of $\Delta\phi$ at the airfoil trailing edge and control surface leading edge, respectively. In XTRAN2L, the normal force, axial force, and pitching moment coefficients are calculated using Eqs. (19) and (20) when the linearized equation is selected for the pressure coefficient (Eq. (14)). This is computationally more accurate than integrating the lifting pressure coefficients as indicated in Eqs. (17) and (18). Note that if a particular case has no control surface then $x_f = x_h = 1$ leads to $c_{n_f} = 0$ and $c_{m_f} = 0$.

Operation of XTRAN2L

General Information and Input Data

In this section, general information is given on the operation of XTRAN2L including input data and recommended operating procedures. Data to define the problem and control program execution are defined using six namelists. The input data consists of a single TITLE card followed by the six namelists in the following order:

- AEROEL - Definition of airfoil motion and aeroelastic parameters
- INPUT - Definition of program solution parameters and constants
- MESH - Definition of user-input extended fine grid
- AMPLI - Definition of periodic time-dependent airfoil motion
- ORD - Definition of airfoil geometry
- COND - Definition of airfoil chord deformation

Namelists INPUT, MESH, AMPLI, ORD, and COND have been retained from the LTRAN2-NLR code. A new namelist, AEROEL, has been added to allow for specification of the type of airfoil motion (forced harmonic, pulse,

aeroelastic, or no motion) and for input of pulse or aeroelastic parameter values. Tables 1-6 list the parameters input in each namelist and give a short description of each parameter including its default value. The tables are presented in the same format as that of the LTRAN2-NLR user's manual.⁷ Any parameter not explicitly defined in a NAMELIST statement assumes its default value.

To start the solution of the unsteady flow equation, the program requires an initial, steady-state solution for the flow field at $T = 0$. The steady-state solution can be calculated in one of three ways which are selected using the IREAD parameter in namelist INPUT. The first method is to define the initial flow field as an undisturbed stream (IREAD = 0). The second method is to solve for a steady-state solution using a successive line-overrelaxation (SLOR) scheme (IREAD = 1). The third method is to solve for a steady-state solution using the unsteady TSD scheme, termed the "unsteady solver", with no airfoil motion (IREAD = 0 and IRESP = 5). Once a converged steady-state solution has been achieved, the program is then restarted using the converged solution as the initial condition (IREAD = 5). The SLOR solution procedure normally involves using a sequence of three default grids defined as coarse, fine, and extended fine, to accelerate convergence. The default extended fine grid used in XTRAN2L was developed to increase the accuracy of the unsteady solution while decreasing the number of grid points used in the LTRAN2-NLR code.⁵ Grid point locations for the default extended fine grid are listed in Table 7. The grid distribution in the vicinity of the airfoil is shown in Fig. 4. The coarse and fine grids were defined to be subsets of the extended fine grid. The user may choose to use the default extended fine grid or input a new extended fine grid using namelist MESH.

Calculating steady solutions using the unsteady solver requires starting from an initial undisturbed stream and solving the unsteady TSD equation for no airfoil motion until a converged steady-state solution is reached. All computations using the unsteady solver are performed on the extended fine grid only. Experience has shown that for most cases the unsteady solver converges to a steady-state solution as fast or faster than the SLOR algorithm. Use of the unsteady solver is the preferred approach since for lifting cases the two algorithms converge to slightly different steady-state solutions.⁵ For consistency with the unsteady solution it is therefore recommended that the steady-state starting solution be calculated using the unsteady solver.

The unsteady solver can solve three combinations of the TSD equation and boundary conditions. These are denoted as the LTRAN, HYTRAN, and EXTRAN options. The equation set to be solved is chosen using the IEQFLAG parameter in namelist AEROEL. Selecting the LTRAN option gives the low-frequency approximation to the complete unsteady TSD equation (Eq. (1)) by defining the coefficient "A" in the equation to be zero. In addition, the time-derivative terms in the airfoil and wake boundary conditions (Eqs. (3) and (12), respectively), and in the pressure and local Mach number equations (Eqs. (14) and (16), respectively), are automatically deleted by the program setting the parameters r_1 and r_2 (variables IR and IMODFR in namelist INPUT) to be equal to zero. Selecting the HYTRAN option defines the coefficient "A" in Eq. (1) to be zero. The time derivative terms are included in the airfoil and wake boundary condition equations and in the pressure and local Mach number equations by setting r_1 and r_2 to be equal to unity. This option is the capability implemented in LTRAN2-NLR.⁷ In choosing the LTRAN and HYTRAN options, the farfield boundary conditions in Fig. 3 reduce to a set consistent

with the low frequency approximation. Selecting the EXTRAN option defines the coefficient "A" in Eq. (1) to be as described in Eq. (2a). The time derivative terms are also included in the associated boundary conditions.

The unsteady solver calculates the time varying flow field by employing a time marching solution procedure. For oscillatory cases, the time step is implicitly defined by the user based upon the reduced frequency k , scaled velocity U/c , and number of time steps per cycle NSPC, as

$$\Delta T = \frac{\pi}{\text{NSPC} * k * U/c} \quad (21)$$

For cases other than oscillatory motion, the time step is explicitly defined by the user. In these cases, the reduced frequency k is implicitly defined based on ΔT , U/c , and NSPC, using Eq. (21).

For both steady and unsteady cases, the airfoil contour is defined in terms of the upper and lower surface slopes at the grid points, input in namelist ORD. The program will interpolate airfoil slopes which are not defined at the grid points and thus calculate new slopes, but this approach is not recommended. Before running the XTRAN2L program, a pre-processor is normally used to convert the airfoil geometry into slopes and displacements at the grid points. This allows the user to view the geometry to be input to the program and to take any required corrective action. This is especially true for measured airfoil ordinates where errors or inaccuracies in the ordinates may cause unrealistic airfoil slopes to be calculated.

The program has a restart capability designed for continuing the steady SLOR solution or the unsteady solver from a previously saved flow field solution. The restart capability is typically used to restart the SLOR solution to achieve better steady-state convergence (IREAD = 3 or 4), to start

an unsteady computation from a previously calculated steady-state solution (IREAD = 5), or to continue an unsteady computation further in time (IREAD = 5).

Files and Logical Units

The XTRAN2L program uses the logical units TAPE3, TAPE4, TAPE5, TAPE6, TAPE7, and TAPE8. The logical units TAPE5 and TAPE6 are used for program input and output, respectively. The logical units TAPE3 and TAPE4 are used for restart files. The data to be saved for a restart is written to TAPE4 and a restart reads the required data from TAPE3. The data is in unformatted binary form and is input and output using BUFFER IN and BUFFER OUT statements. The BUFFER IN and BUFFER OUT statements are called in subroutines GETS and PUTS, respectively. The call to GETS and PUTS is of the form:

```
CALL GETS (INDEX, ARRAY, NELEMNT)
```

where,

INDEX - logical unit number

ARRAY - array of data to be input/output

NELEMNT - number of data elements to be input/output

The data is written to TAPE4 using the following FORTRAN statements:

```
CALL PUTS (4,BUF1,2)
```

```
CALL PUTS (4,BUF2,40)
```

```
CALL PUTS (4,BUF3,5)
```

```
CALL PUTS (4,VU0,80)
```

```
CALL PUTS (4,VLO,80)
```



```

CALL PUTS (4,PTU(1,ITM1),JMAX1)
CALL PUTS (4,POU,JMAX1)
CALL PUTS (4,PTL(1,ITM1),JMAX1)
CALL PUTS (4,POL,JMAX1)
DO 704 J=1, JMAX1
704 CALL PUTS (4,PO(1,J),LMAX1)
CALL PUTS (4,PTT(1,1),4880)
CALL PUTS (4,PTTU(1),80)
CALL PUTS (4,PTTL(1),80)

```

where,

BUF1 - Array containing circulation value and time from last time step

BUF2 - Array containing array sizes, airfoil aeroelastic response from last time step and calculated forces from last time step

BUF3 - Array containing calculated forces from last time step

VU0/VL0 - Array of airfoil upper/lower surface boundary condition values from last time step

PTU/PTL - Array of airfoil upper/lower surface potentials from the next to last time step

JMAX1/LMAX1 - Number of points in extended fine grid in x/z, respectively

POU/POL - Array of airfoil upper/lower surface potentials from last time step

PO - Array of flow field potentials from last time step

PTT - Array of flow field potentials from next to last time step

PTTU/PTTL - Array of airfoil upper/lower surface potentials from next to last time step

The logical units TAPE7 and TAPE8 are used for storing results at each time step for post-processing. If the IBUF parameter in namelist INPUT is set equal to 1, the program outputs time histories of aeroelastic quantities,

pressure coefficients, and forces in unformatted binary to TAPE8. For restarts, TAPE7 is provided to allow the merging of previous time histories from a TAPE8 file onto a new file TAPE8. The program copies TAPE7 onto TAPE8 and then proceeds as normal. This option is not recommended due to the large size required to store a TAPE8 file. A blank TAPE7 file causes the program to skip the copying step on restarts and continues with normal execution. The data is written to TAPE8 using the following FORTRAN statements:

```
CALL PUTS (8,TITLE,8)
CALL PUTS (8,IINPUT,49)
CALL PUTS (8,X,NPTSARF)
CALL PUTS (8,FXU,NPTSARF)
CALL PUTS (8,FXL,NPTSARF)
DO 10 IA=1, NITER
CALL PUTS (8,BUF4,9)
CALL PUTS (8,CPU,NPTSARF)
CALL PUTS (8,CPL,NPTSARF)
CALL PUTS (8,XN,6)
10 CONTINUE
```

where,

TITLE - array containing 80 character title
IINPUT - array containing program variables and constants
X - array containing x coordinates of grid points on airfoil
NPTSARF - number of x-grid points on airfoil
FXU/FXL - array containing airfoil upper/lower surface
displacements at x-grid points

NITER - number of iterations of time history data written
=1 - steady solver solution only
=MAXIT - unsteady solution only, no restart
=MAXIT+1 - unsteady solution started from steady solver or
restart file

BUF4 - array containing nondimensional time and calculated force
coefficients

CPU/CPL - array containing upper/lower surface pressure coefficients
on airfoil

XN - array containing aeroelastic displacements of airfoil

The do-loop illustrated above is executed at every time step. If a restart is performed, the first set of data written by the do-loop is for the data read from the restart file.

Sample Calculations

Sample calculations were performed for the NACA 64A010A airfoil⁹ (NASA Ames model) to illustrate various program options. Four cases were run to demonstrate the program's capabilities. The first case is a steady-state solution using the unsteady solver. The next three cases are a simple harmonic pitching motion of the airfoil, an airfoil pitch pulse which is used to calculate the generalized aerodynamic forces, and a transient aeroelastic response of the airfoil at a condition just above the flutter speed. The last three cases are restarted from the steady-state solution.

Steady Calculations

Results from the steady calculation are listed in Appendix A. The input file read by the program is listed first, followed by the program output. For brevity, the output included in Appendix A is only a partial listing of the output generated by the program for the case run. The output shown includes the banner page, echo of input parameters, airfoil description,

computational grid listing and output of pressure distributions and forces calculated at selected iterations. The unsteady solver was used to converge to a steady flow field solution at $M_\infty = 0.78$ and $\alpha_0 = 1.0^\circ$ starting from freestream initial conditions with no airfoil motion. The calculation was run for 1024 iterations to ensure convergence to a steady-state solution. Airfoil pressures and forces are printed every 128 iterations. The pressure distributions and forces listed in Appendix A are for the first and last iterations for which calculations were performed. The time listed with each set of pressure output is a nondimensional time based on harmonic motion, \bar{t} . For harmonic motion, \bar{t} is the measure of the angular position in radians in the harmonic cycle. Also output is the equivalent angular position in degrees. For other than harmonic motion, the time output can be considered as a nondimensional time. The time histories of airfoil force coefficients and the final pressure distributions are shown in Fig. 5. The plots were created by a post-processing program which reads the TAPE8 file and uses the information to generate appropriate plots for the case run.

Unsteady Calculations

Forced Harmonic Motion. - Results from a forced harmonic oscillation of the airfoil in pitch are listed in Appendix B1. The input file is listed first, followed by selected program output. The airfoil was oscillated for four cycles about the quarter-chord at a reduced frequency of $k = 0.075$ with an amplitude of $\alpha_1 = 0.5^\circ$ about the mean angle of attack $\alpha_0 = 1.0^\circ$. The flow field was calculated in 1° increments of a cycle of motion. Included in the output are the pressure distributions for the first and last iterations and time histories of the airfoil forces for the last cycle of oscillation. In the output, the pitching moment coefficient, normal force coefficient, and

control surface moment coefficient are labeled as "CM", "CN", and "CMF", respectively. A Fourier analysis of the forces is performed using the last cycle of airfoil motion and the first nine harmonics are output. The real and imaginary components of the forces, labeled as "RE" and "IM", respectively, are scaled by the amplitude of the motion (in radians for both airfoil pitch and control surface motions). Also included in the harmonic quantities output is a measure of the amount of higher harmonic components in the force time histories, labeled as "ECM", "ECN", and "ECMF". The quantities are defined as the magnitude of the nth harmonic component divided by the magnitude of the fundamental, or first harmonic component. The zeroth harmonic is defined as the mean or average value.

The first five harmonics of the airfoil pressures calculated for the last cycle of motion are included in Appendix B1 for reference. The pressure harmonics are calculated by a post-processing program using the information stored on TAPE8. The time histories of the airfoil motion and corresponding force coefficients are plotted in Figs. 6(a) and 6(b), respectively. Figures 6(c)-6(f) show the mean pressure distribution and the first harmonic pressure distributions calculated by the post-processor.

Pulse Motion. - Results from an airfoil pitch pulse are listed in Appendix B2. The input file is listed first followed by selected program output. The airfoil was pitched about the quarter-chord with maximum amplitude of $\alpha = 0.5^\circ$ from the mean angle of attack of $\alpha_0 = 1.0^\circ$. The exponential pulse was centered at iteration 30, and the unsteady solver was run until the flow field returned to the steady-state condition. It is important to ensure that the flow field returns to steady-state conditions in order to allow accurate calculation of the generalized aerodynamic forces. The pressure distributions for the first and last iteration are listed.

Included in the output are the generalized aerodynamic forces calculated by a post-processing program from the information contained on TAPE8. The time histories of the airfoil motion and resulting force coefficients are plotted in Figs. 7(a) and 7(b), respectively. Figures 7(c) and 7(d) show the generalized aerodynamic forces calculated by the post-processor.

Aeroelastic Motion. - Results from aeroelastic motion of the airfoil are listed in Appendix B3. The input file is listed first followed by selected program output. The aeroelastic parameters used were the program default values: $a_h = -2.0$, $x_\alpha = 1.8$, $r_\alpha = 1.865$, $\mu = 60.0$, $\omega_h = 100.0$ rad/sec, and $\omega_\alpha = 100.0$ rad/sec. The default values are those of Case A of Isogai¹⁰ which were chosen to have normal modes similar to those of a streamwise section near the tip of a sweptback wing. The wind-off coupled plunge and pitch frequencies are 71.3 and 535.7 rad/sec, respectively. The pivotal point for the plunge mode is located 1.44 chordlengths forward of the leading edge; the pivotal point for the pitch mode is located 0.068 chordlengths ahead of midchord. For the sample aeroelastic calculation presented here, the scaled velocity U/c was set equal to 330.0, which is slightly above the flutter speed of the NACA 64A010A airfoil at $M = 0.78$ and $\alpha_0 = 1.0^\circ$. The program automatically calculates the state-transition matrix $[\phi]$ and its integral matrix $[\theta]$ in Eq. (11) from the aeroelastic quantities input in namelist AEROEL. The output from this calculation is included in Appendix B3. The $[\phi]$ matrix is labeled in the output as "PHI" and the "THETA*B-PRIME" matrix is defined as

$$\text{THETA*B-PRIME} = \frac{1}{\pi\mu} \left(\frac{U}{b}\right)^2 [\theta] \begin{Bmatrix} [0] \\ [M]-1 \end{Bmatrix} \quad (22)$$

The "I.C. VECTOR" listed in the output contains the initial values used for the aeroelastic displacement vector $\{x\}$. The pressure distributions output

for the first and last iterations are included in the Appendix. The time histories of the airfoil motion and corresponding force coefficients are plotted in Fig. 8. As shown, the airfoil motion is slightly divergent for the case selected.

Acknowledgment

The authors wish to acknowledge the National Aerospace Laboratory, NLR, the Netherlands, for the thorough presentation of equations and detailed input description for the LTRAN2-NLR code reported in their user's manual,⁷ the organization and format of which were adopted in the present report.

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Table 1. Description of input parameters to NAMELIST AEROEL.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
IRESP		0	Selects type of airfoil motion 0 - Harmonic oscillation 1 - Aeroelastic transient response 2 - Plunge pulse transient response 3 - Pitch pulse transient response 4 - Control surface pulse transient response 5 - No airfoil motion allowed
NELAST		1	Selects type of aeroelastic motion 1 - 2-DOF, plunge and pitch 2 - 2-DOF, plunge and control surface 3 - 2-DOF, pitch and control surface 4 - 3-DOF, plunge pitch and control surface
UC	U/c	100.0	Scaled freestream velocity, used to define time step ΔT (IRESP = 0) or reduced frequency k (IRESP \neq 0), Eq.(21)
XMU	μ	60.0	Airfoil mass ratio
DELTA	ΔT	.002618	Time step (sec), calculated by program using Eq. (21) if IRESP = 0
IEQFLAG		3	Selects equation set 1 - LTRAN option 2 - HYTRAN option 3 - EXTRAN option
AMPLTD	a	.017435	Amplitude of pulse transient
WDTHPLS	w	10000.0	Exponential constant for pulse
TZEROST	$T_c/\Delta T$	17.5	Center of pulse (iterations)
XALPHA	x_α	1.8	Nondimensional distance from elastic axis to airfoil center of mass
XBETA	x_β	.020833	Nondimensional distance from hinge line to control surface center of mass
RALPHA	r_α	1.865	Radius of gyration of airfoil about elastic axis
RBETA	r_β	.027169	Radius of gyration of control surface about hinge line

Table 1. Concluded.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
OMEGA _H	ω_h	100.	Uncoupled natural frequency of plunge
OMEGA _A	ω_α	100.	Uncoupled natural frequency of pitch about elastic axis
OMEGA _B	ω_β	500.	Uncoupled natural frequency of control surface deflection about hinge line
AH	a_h	-2.	Nondimensional elastic axis location
CBETA	c_β	.5	Nondimensional control surface hinge location
XIC(1)	$h(0)$.01	Initial plunge displacement
XIC(2)	$\alpha(0)$	0.	Initial pitch rotation
XIC(3)	$\beta(0)$	0.	Initial control surface deflection
XIC(4)	$\dot{h}(0)$	0.	Initial plunge velocity
XIC(5)	$\dot{\alpha}(0)$	0.	Initial pitch velocity
XIC(6)	$\dot{\beta}(0)$	0.	Initial control surface velocity

Table 2. Description of input parameters to NAMELIST INPUT.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
XK	$2k$.2	Reduced frequency (based on chord), calculated by program using Eq. (21) if IRESP \neq 0
XM	M_{∞}	.85	Freestream Mach number
GAM	γ	1.4	Ratio of specific heats
IREAD		1	Starting conditions 0 - Unsteady computation starting from zero initial conditions 1 - Compute steady-state initial conditions starting from zero, then do the unsteady computation 2 - Compute steady-state solution starting from zero and stop 3 - Read starting solution, compute steady-state solution and stop 4 - Read starting solution and compute steady-state initial conditions, then do the unsteady computation 5 - Read initial conditions and do the unsteady computation Options 3, 4, and 5 require a file which has been generated in a previous run
ICNVRG		1	Selects method for converging steady-state solution 0 - Converge solution on extended fine grid only 1 - Converge to approximations to steady-state on coarse and fine spaced grids, then final solution on extended fine grid
MAXIT		360	Number of time steps
NSPC		120	Number of steps taken per cycle of oscillation (IRESP \neq 0), used to define time step ΔT (IRESP = 0) or reduced frequency k (IRESP \neq 0), Eq. (21)

Table 2. Continued.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
ITRAN		0	Selects airfoil motion 0 - Pitch, plunge and control surface deflection 1 - Pitch, plunge, control surface deflection and chord deformation 2 - Arbitrary user-specified time-dependent motion only, user specifies $p(x,t)$, Eqs. (4)
ISICO		0	Selects method for calculating the time-dependent angle of attack, Eqs.(6) & (7) 0 - Sinusoidal variation 1 - Cosinusoidal variation
ICPRNT		60	Time step print increment for intermediate C_p output
JFIRST		JFWLE	Index of first x-grid point to be included in C_p output, JFWLE is the index of the first x-grid point on the airfoil in the extended fine grid
JLAST		JFWTE	Index of last x-grid point to be include in C_p output, JFWTE is the index of the last x-grid point on the airfoil in the extended fine grid
IBUF		0	Storage on logical unit 8 0 - No storage 1 - Unsteady results are being stored
LIN		0	Selects formulas for C_p and local Mach number computations 0 - Linearized expressions 1 - Exact expressions
IR	r_1	1	Program selected airfoil boundary condition based on IEQFLAG, Eq. (3) 0 - No time-derivative terms (IEQFLAG = 0) 1 - Include time-derivative terms (IEQFLAG = 1 or 2)
DEL	δ	.1	Airfoil maximum thickness to chord ratio
XAR	x_r	0.	Location of airfoil pitch axis

Table 2. Continued.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
ALFZRO	α_0	0.	Mean angle of attack of airfoil (in degrees)
ALFONE	α_1	1.	Harmonic pitch amplitude of airfoil (in degrees)
XFLAP	x_f	1.	Control surface leading edge location
XFR	x_h	1.	Control surface hinge location
BETZRO	β_0	0.	Mean control surface angle with respect to airfoil (in degrees)
BETONE	β_1	0.	Harmonic control surface amplitude (in degrees)
Z1	Z_1	0.	Plunge amplitude
IMODFR	r_2	1	Program selected wake condition based on IEQFLAG, Eq. (11) 0 - No time-derivative terms (IEQFLAG=0) 1 - Include time-derivative terms (IEQFLAG = 1 or 2)
RSUB		1.4	Subsonic relaxation factor
RSUP		1.0	Supersonic relaxation factor
MITC		500	Maximum number of iterations
MITM		100	on coarse, fine, and extended fine grids
MITEF		25	for steady calculations, respectively
TOLC		.00001	Convergence tolerance parameters in
TOLM		.000001	steady calculations on coarse, fine
TOLEF		.000001	and extended fine grids, respectively
ICPRUN		0	Output request for unsteady pressures 0 - No output 1 - Output of unsteady pressures, if ISICO = 0
LINDIF		0	Selects differential equation 0 - TSD equation 1 - TSD equation, nonlinear term omitted

Table 2. Concluded.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
ICPT	r_3	1	<p>Selects time derivative in linearized formulas for C_p and local Mach number</p> <p>$r_3 = 0$ - Time derivative is set equal to zero</p> <p>$r_3 = 1$ - Time derivative included in calculation of C_p and local Mach number</p>

Table 3. Description of input parameters to NAMELIST MESH.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
JFMAX		* 80	Number of x-grid points in extended fine grid (Maximum value is 80)
LFMAX		61	Number of z-grid points in extended fine grid (Maximum value is 61)
XFINE			Array of increasing x-coordinates specifying the vertical lines in the extended fine grid (JFMAX elements)
ZFINE			Array of increasing z-coordinates specifying the horizontal lines in the extended fine grid (LFMAX elements)

*In case the default extended fine grid is used, it is sufficient to input the empty namelist \$MESH \$

Table 4. Description of input parameters to NAMELIST AMPLI.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
N	N	1	Number of terms in Eqs. (6) and (7)
AB	a_n, b_n	1	Array a_n, b_n in Eqs. (6) and (7) (N elements)

Table 5. Description of input parameters to NAMELIST ORD.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
NINU		*	Number of points on upper side of airfoil
NINL			Number of points on lower side of airfoil
XINU			Array of increasing x-coordinates of points specifying upper side of airfoil (NINU elements)
ZINU			Array of corresponding z-coordinates specifying upper side of airfoil (NINU elements)
VINU			Array of corresponding slopes specifying upper side of airfoil (NINU elements)
XINL			Array of increasing x-coordinates of points specifying lower side of airfoil (NINL elements)
ZINL			Array of corresponding z-coordinates specifying lower side of airfoil (NINL elements)
VINL			Array of corresponding slopes specifying lower side of airfoil (NINL elements)

* Default is the biconvex airfoil, $\delta = .1$

Table 6. Description of input parameters to NAMELIST COND.

PARAMETER	VARIABLE	DEFAULT	DESCRIPTION
NIN			Number of points at which chord deformation $g_1(x)$ is specified, Eq. (5a)
XIN			Array of increasing x-coordinates of points where the chord deformation is specified (NIN elements)
COND1	g_1	0	Array of corresponding g_1 -values (NIN elements)
COND2	$\frac{dg_1}{dx}$	0	Array of corresponding dg_1/dx -values (NIN elements)

Table 7. XTRAN2L extended fine default grid.

INDEX	x	z
1	-20.00000	-25.00000
2	-16.30961	-23.36111
3	-13.10054	-21.77778
4	-10.33987	-20.25000
5	-7.99453	-18.77778
6	-6.03136	-17.36111
7	-4.41705	-16.00000
8	-3.11817	-14.69444
9	-2.10110	-13.44444
10	-1.33204	-12.25000
11	-.77699	-11.11111
12	-.40170	-10.02778
13	-.17160	-9.00000
14	-.05175	-8.02778
15	-.00667	-7.11111
16	.00667	-6.25000
17	.02000	-5.44444
18	.04000	-4.69444
19	.06000	-4.00000
20	.08000	-3.36111
21	.10000	-2.77778
22	.12000	-2.25000
23	.14000	-1.77778
24	.16000	-1.36111
25	.18000	-1.00000
26	.20000	-.69444
27	.22000	-.44444
28	.24000	-.25000
29	.26000	-.11111
30	.28000	-.02778
31	.30000	0.00000
32	.32000	.02778
33	.34000	.11111
34	.36000	.25000
35	.38000	.44444
36	.40000	.69444
37	.42000	1.00000
38	.44000	1.36111
39	.46000	1.77778
40	.48000	2.25000
41	.50000	2.77778
42	.52000	3.36111
43	.54000	4.00000
44	.56000	4.69444
45	.58000	5.44444

Table 7. Concluded.

INDEX	x	z
46	.60000	6.25000
47	.62000	7.11111
48	.64000	8.02778
49	.66000	9.00000
50	.68000	10.02778
51	.70000	11.11111
52	.72000	12.25000
53	.74000	13.44444
54	.76000	14.69444
55	.78000	16.00000
56	.80000	17.36111
57	.82000	18.77778
58	.84000	20.25000
59	.86000	21.77778
60	.88000	23.36111
61	.90000	25.00000
62	.92000	
63	.94000	
64	.96000	
65	.98000	
66	1.00000	
67	1.02000	
68	1.12274	
69	1.35473	
70	1.75323	
71	2.35080	
72	3.17695	
73	4.25898	
74	5.62249	
75	7.29170	
76	9.28970	
77	11.63860	
78	14.35968	
79	17.47352	
80	21.00000	

Appendix A - Results from Steady Calculations

XTRAN2L Input

```

NACA 64A010 AMES AIRFOIL  M=0.780  ALFZRO=1.0  STEADY=STATE CONVERGENCE
SAEHDEL INESP=5, UELT=0.002454569, UCR=100.0, SEND
SINRIT X=0.780, IPEAU=0, MAXIT=1024, NSPG=128, ICPRNT=128, IPUF=1,
DEL=0.10, XAR=0.25, ALFZHU=1.00, ALFONE=0.00, SEND
SMESH 5
SAMPLI 5
SDRD NINU = 51, NINL = 51,
XINU =
.000000, .020000, .040000, .060000, .080000, .100000, .120000, .140000,
.160000, .180000, .200000, .220000, .240000, .260000, .280000,
.300000, .340000, .360000, .380000, .400000, .420000, .440000,
.460000, .500000, .520000, .540000, .560000, .580000, .600000,
.640000, .660000, .680000, .700000, .720000, .740000, .760000,
.800000, .820000, .840000, .860000, .880000, .900000, .920000,
.940000, .960000, 1.000000,
ZINU =
.010144, .016499, .022381, .026732, .030412, .033687, .036532, .039113,
.041413, .043449, .045258, .046874, .048300, .049535, .050589, .051485,
.052232, .052792, .053113, .053200, .053113, .052903, .052533, .051921,
.051033, .049999, .048815, .047508, .046078, .044524, .042865, .041114,
.039240, .037367, .035365, .033343, .031251, .029124, .026980, .024828,
.022672, .020513, .018343, .016152, .013958, .011794, .009665, .007538,
.005196, .002650, 0.000000,
VINU =
.666396, .373086, .247503, .201161, .174588, .150587, .135658, .121236,
.108069, .095780, .085469, .076080, .068554, .062051, .048547, .041197,
.033109, .022385, .009743, .000503, .007639, .013740, .023947, .037336,
.048629, .056247, .062229, .066451, .074733, .080404, .085320, .089694,
.093739, .097436, .100687, .103473, .105608, .106902, .107439, .107720,
.107831, .108131, .108463, .110036, .109200, .106129, .103359, .111490,
.122939, .130770, .133386,
XINL =
.000000, .020000, .040000, .060000, .080000, .100000, .120000, .140000,
.160000, .180000, .200000, .220000, .240000, .260000, .280000,
.300000, .340000, .360000, .380000, .400000, .420000, .440000,
.460000, .500000, .520000, .540000, .560000, .580000, .600000,
.640000, .660000, .680000, .700000, .720000, .740000, .760000,
.800000, .820000, .840000, .860000, .880000, .900000, .920000,
.940000, .960000, 1.000000,
ZINL =
.009941, .016598, .022527, .026839, .030529, .033748, .036542, .039014,
.041272, .043251, .045019, .046644, .048113, .049395, .050483, .051393,
.052138, .052706, .053081, .053258, .053248, .053049, .052658, .052038,
.051206, .050192, .049027, .047730, .046317, .044793, .043155, .041401,
.039558, .037654, .035699, .033678, .031584, .029437, .027265, .025083,
.022891, .020688, .018469, .016229, .013974, .011722, .009482, .007219,
.004875, .002458, 0.000000,
VINL =
.1755623, .364001, .243107, .199126, .169990, .147623, .134054, .117215,
.105643, .092960, .084615, .077614, .069016, .059127, .049812, .041371,
.032950, .023693, .013753, .004057, .005243, .014597, .025101, .036447,
.046437, .054702, .061695, .067874, .073371, .079002, .084907, .091180,
.093908, .096372, .099285, .102933, .106253, .108179, .108674, .109377,
.109858, .110486, .111125, .112519, .112822, .112177, .112272, .114804,
.114226, .122216, .123215,
SEND
SCDND 5

```

Appendix A - Concluded

XTRAN2L Output

PROGRAM XTRAN2L - VERSION 1.2

IMPLICIT FINITE DIFFERENCE PROGRAM SOLVING THE COMPLETE
UNSTEADY TRANSONIC SMALL DISTURBANCE EQUATION
INCLUDING AEROELASTIC RESPONSE

UNSTEADY AERODYNAMICS BRANCH

NASA LANGLEY RESEARCH CENTER

HAMPTON, VA 23065

CONTACT: DAVID A. SEIDEL (804) 865-4236
JOHN T. BATINA (804) 865-4236

NACA 64A010 AMES AIRFOIL M80,780 ALPZHD1,0 STEADY-STATE CONVERGENCE

AERODELTAIC SYSTEM

IRESP	5	NO AIRFOIL MOTION	NELAST	1	2=00P, PLUNGE AND PITCH
UC	100,00000	NONDIMENSIONAL VELOCITY	XMU	80,00000	MASS RATIO
DELT	,00245	TIME STEP, SECONDS	IEOPLAG	3	EXTRIN EQUATION
AMPLTD	,01745	AMPLITUDE OF PULSE	WOTHPLS	10000,0	PULSE EXPONENTIAL FACTOR
TZEROST	17,50000	CENTER OF PULSE			

INPUT PARAMETERS

XX	,20000	REDUCED FREQUENCY BASED ON CHORD	XM	,78000	MEAN FREE-STREAM MACH NO.
GAM	1,40000	RATIO OF SPECIFIC HEATS	ICNYRG	1	GET 8-8 SOL. ON COARSE, THEN FINER GRIDS
INEAD	0	INITIAL CONDITIONS	NSPC	128	NO. STEPS PER CYCLE
MAXIT	1024	MAX. NU. TIME STEPS	ISICO	0	SINUSOIDAL VARIATION
ITRAN	0	PITCH, PLUNGE, FLAP MOTION	IRUP	1	OUTPUT TO LU 8
ICPRNT	128	ITERATION PRINT INCREMENT FOR CP	JLAST	60	LAST CHORDWISE GRIDPT FOR CP PRINTING
JFIRST	16	FIRST CHORDWISE GRIDPT FOR CP PRINTING	IN	1	TIME-DEHY. IN AIRFOIL D.C.
LIN	0	LINEARIZED CP	XAR	,25000	POSITION OF PITCH AXIS
DEL	,10000	AIRFOIL THICKNESS RATIO	ALFONE	0,00000	PITCHING AMPLITUDE
ALFZRD	1,00000	MEAN ANGLE OF ATTACK	IMODFN	1	TIME-DERIVATIVE IN WAKE CONDITION
ZI	0,00000	PLUNGE AMPLITUDE	NSUP	1,00000	SUPERSONIC RELAXATION FACTOR
NSUB	1,40000	SUBSONIC RELAXATION FACTOR	TOLC	,10E-04	TOLERANCE PARAMETERS IN STEADY
MITC	500	MAXIMUM NUMBER OF ITERATIONS	TOLM	,10E-03	CALCULATIONS ON COARSE, FINE
MITH	100	ON COARSE, FINE AND EXT, FINE GRID	TOLF	,10E-03	AND EXT, FINE GRID RESPECTIVELY
MITEF	25	RESPECTIVELY	LINDIF	0	MLN=TOP EQUATION (WITH NON-LINEAR TERM)
ICPRUN	0	NO REQUEST FOR OUTPUT OF UNSTEADY PRESSURES			
ICPT	1	TIME-DEP. CONTRIBUTES TO CP AND MACH, IF IN=1			
N	1	NUMBER OF (CO)SIN HARMONICS			
MULTIPLIERS OF (CO)SIN HARMONICS	1,00000				

NACA 64A010 AMES AIRFOIL MPO,780 ALPZNO=1.0 STEADY=STATE CONVERGENCE

ITERATION NO. # 1 ALF (DEG) # 1.0000000 PLUNGE # 0.0000000
 TIME # .0490874 T (DEG) # 8.8125000

INDEX	X	CPU	CPL	MU	ML	DCP=CPL-CPU
16	.00867	1.06394	1.36001	.10750	0.00000	.29807
17	.02000	.24443	.33751	.81098	.77837	.09108
18	.04000	.33224	.48393	.76917	.71666	.13169
19	.06000	.25166	.36842	.80760	.76872	.11876
20	.08000	.20978	.32287	.82438	.79061	.11309
21	.10000	.17898	.29272	.83847	.80312	.11374
22	.12000	.15381	.26456	.84161	.81382	.11077
23	.14000	.12844	.23882	.84875	.82283	.11196
24	.16000	.10166	.21795	.85440	.82806	.11649
25	.18000	.07919	.19944	.85861	.83221	.12024
26	.20000	.05739	.18191	.86229	.83574	.12433
27	.22000	.03373	.15752	.86636	.84220	.12379
28	.24000	.00901	.12883	.87102	.85009	.11982
29	.26000	-.01528	.10121	.87500	.85869	.11669
30	.28000	-.04030	.07524	.87907	.86249	.11533
31	.30000	-.06957	.04807	.88478	.86825	.11784
32	.32000	-.10406	.01830	.89233	.87476	.12236
33	.34000	-.13855	-.01277	.89931	.88139	.12579
34	.36000	-.16586	-.04294	.90268	.88714	.12292
35	.38000	-.18701	-.07197	.90331	.89203	.11804
36	.40000	-.21086	-.10120	.90316	.89669	.10964
37	.42000	-.24326	-.13110	.91061	.90135	.11217
38	.44000	-.27841	-.15925	.91675	.90494	.11116
39	.46000	-.30339	-.18150	.91813	.90579	.12189
40	.48000	-.31680	-.19747	.91667	.90398	.11932
41	.50000	-.32716	-.21034	.91030	.90107	.11662
42	.52000	-.33951	-.22229	.90713	.89603	.11722
43	.54000	-.35289	-.23413	.90465	.89521	.11875
44	.56000	-.36458	-.24630	.90167	.89279	.11828
45	.58000	-.37407	-.25807	.89802	.89040	.11800
46	.60000	-.38223	-.26718	.89409	.88705	.11505
47	.62000	-.38951	-.27273	.89011	.88244	.11676
48	.64000	-.39566	-.27693	.88595	.87734	.11492
49	.66000	-.40028	-.28226	.88142	.87368	.11798
50	.68000	-.40300	-.28693	.87644	.87062	.11407
51	.70000	-.40383	-.29335	.87096	.86679	.11048
52	.72000	-.40289	-.29381	.86513	.86148	.10909
53	.74000	-.40049	-.29194	.85928	.85554	.10905
54	.76000	-.39926	-.29059	.85393	.85027	.10666
55	.78000	-.39807	-.29044	.84921	.84592	.10763
56	.80000	-.39710	-.29067	.84498	.84205	.10843
57	.82000	-.39560	-.29039	.84069	.83824	.10920
58	.84000	-.39143	-.28814	.83552	.83377	.10129
59	.86000	-.38205	-.28211	.82828	.82745	.09994
60	.88000	-.36873	-.27193	.81967	.82039	.09680
61	.90000	-.35871	-.25881	.81229	.81194	.09810
62	.92000	-.34327	-.23960	.80460	.80123	.10367
63	.94000	-.30834	-.20506	.78666	.78342	.10248
64	.96000	-.22268	-.14051	.74346	.75109	.08217
65	.98000	-.06779	-.03354	.66164	.69654	.03423
66	1.00000	.38144	.34040	.31166	.44627	-.04104

FORCE COEFFICIENTS AT ANGLE OF ATTACK # 1.0000000 PLUNGE DISP. # 0.0000000
 AIRFOIL PITCHING MOMENT (ABOUT X # .25000) # .2336854E+01 NORMAL FORCE # .1164373E+00 AXIAL FORCE # .3691019E+01

NACA 64A010 AMES AIRFOIL H=0.780 ALFZND=1.0 STADY=STATE CONVEGENCE

ITERATION NO. = 1024 ALF. (DEG) = 1.0000000 PLUNGE = 0.0000000
 TIME = 50.2654823 T (DEG) = 2680.0000000

INDEX	X	CPU	CPL	MU	ML	DCP/CPL=CPU
16	.00887	.35440	.97191	.56809	0.00000	.81550
17	.02000	.22203	.36687	.88676	.56066	.58490
18	.04000	.39426	.12741	.98147	.71153	.54167
19	.06000	.41056	.03057	.96824	.76413	.44113
20	.08000	.44964	.03271	.98428	.79863	.41693
21	.10000	.47603	.07995	.99497	.82005	.39608
22	.12000	.49381	.12362	1.00211	.84113	.37019
23	.14000	.52687	.16203	1.01524	.85923	.36484
24	.16000	.55418	.19189	1.02596	.87305	.36249
25	.18000	.57305	.21605	1.03331	.88407	.35700
26	.20000	.58709	.23519	1.03874	.89270	.35190
27	.22000	.60388	.26051	1.04520	.90400	.34337
28	.24000	.62357	.28984	1.05276	.91691	.33383
29	.26000	.64170	.31540	1.05960	.92801	.32640
30	.28000	.65854	.33537	1.06445	.93660	.31917
31	.30000	.66657	.35399	1.06897	.94453	.31258
32	.32000	.66708	.37427	1.07663	.95310	.31262
33	.34000	.67182	.39438	1.08823	.96152	.32404
34	.36000	.67492	.40942	1.09948	.96777	.33970
35	.38000	.67851	.41792	1.10653	.97128	.35059
36	.40000	.67847	.42273	1.11027	.97326	.35614
37	.42000	.67933	.42644	1.11541	.97479	.36070
38	.44000	.68194	.42498	1.12481	.97419	.39442
39	.46000	.68655	.40970	1.13444	.96788	.43864
40	.48000	.68263	.38281	1.14011	.95668	.47982
41	.50000	.68757	.35359	1.14184	.94437	.51337
42	.52000	.65718	.32605	1.13819	.93260	.55113
43	.54000	.65066	.30059	1.06294	.92159	.59007
44	.56000	.62049	.27742	.93021	.91147	.63037
45	.58000	.19646	.25557	.87514	.90181	.65911
46	.60000	.20798	.23197	.86040	.89125	.62599
47	.62000	.20587	.20547	.87944	.87926	.60040
48	.64000	.19565	.17867	.87477	.86696	.61698
49	.66000	.18007	.15522	.86760	.85805	.62445
50	.68000	.16097	.13474	.85874	.84840	.62623
51	.70000	.13951	.11332	.84866	.83620	.62619
52	.72000	.11652	.08909	.83774	.82451	.62743
53	.74000	.09319	.06363	.82650	.81214	.62436
54	.76000	.07060	.04036	.81557	.80047	.63044
55	.78000	.04964	.01910	.80510	.78975	.63054
56	.80000	.02946	.00097	.79499	.77950	.63043
57	.82000	.00985	.02061	.78504	.76934	.63045
58	.84000	.01077	.04089	.77445	.75870	.63012
59	.86000	.03457	.06315	.76203	.74685	.62858
60	.88000	.06019	.08723	.74844	.73381	.62704
61	.90000	.08144	.11111	.73697	.72063	.62967
62	.92000	.09689	.13478	.72852	.70736	.63790
63	.94000	.11807	.16343	.71677	.69094	.64536
64	.96000	.16362	.20616	.69083	.66570	.64256
65	.98000	.24543	.27420	.64162	.62339	.62877
66	1.00000	.38669	.39473	.54777	.54037	.61004

FORCE COEFFICIENTS AT ANGLE OF ATTACK = 1.0000000

PLUNGE DISP. = 0.0000000

AIRFOIL PITCHING MOMENT (ABOUT X = .25000) = .9293374E+02

NORMAL FORCE = .2319429E+00

AXIAL FORCE = -.8359764E+02

Appendix B1 - Results from Unsteady Calculations for Harmonic Motion

XTRAN2L Input

```

NACA 64A010 AMEB AIRFOIL MW0.780 ALFZRD=1.0 ALFDNE=0.5 K=0.075
SAERDEL INESP=0, UC=100.0, SEND
INPUT XK=0.15, XM=0.780, INEAD=5, MAXIT=1440, N5PC=360, ICPRT=90, I8UF=1,
DEL=0.10, XAR=0.25, ALFZND=1.00, ALFDNE=0.50, SEND
MESH 3
SAMPLI 3
SORD NINU = 51, NINL = 51;
XINU =
.006667, .020000, .040000, .060000, .080000, .100000, .120000, .140000,
.160000, .180000, .200000, .220000, .240000, .260000, .280000, .300000,
.320000, .340000, .360000, .380000, .400000, .420000, .440000, .460000,
.480000, .500000, .520000, .540000, .560000, .580000, .600000, .620000,
.640000, .660000, .680000, .700000, .720000, .740000, .760000, .780000,
.800000, .820000, .840000, .860000, .880000, .900000, .920000, .940000,
.960000, .980000, 1.000000;
ZINU =
.010144, .016499, .022381, .026732, .030412, .033687, .036532, .039115,
.041413, .043449, .045258, .046874, .048300, .049535, .050589, .051483,
.052232, .052792, .053115, .053200, .053113, .052905, .052535, .051921,
.051053, .049999, .048815, .047508, .046076, .044524, .042865, .041114,
.039250, .037167, .035165, .033343, .031251, .029124, .026980, .024828,
.022672, .020513, .018343, .016152, .013956, .011799, .009695, .007538,
.005196, .002650, 0.000000;
VINU =
.666396, .373066, .247503, .201161, .174588, .150567, .135658, .121236,
.108089, .095780, .085489, .076040, .068354, .062051, .048547, .041197,
.035109, .022385, .009743, .000303, .007639, .013740, .021947, .031534,
.040829, .056247, .062229, .068431, .074753, .080404, .085320, .089684,
.093739, .097436, .100687, .103473, .105608, .106902, .107439, .107720,
.107831, .108131, .108983, .110036, .109200, .106129, .103359, .111450,
.122939, .130770, .133386;
XINL =
.006667, .020000, .040000, .060000, .080000, .100000, .120000, .140000,
.160000, .180000, .200000, .220000, .240000, .260000, .280000, .300000,
.320000, .340000, .360000, .380000, .400000, .420000, .440000, .460000,
.480000, .500000, .520000, .540000, .560000, .580000, .600000, .620000,
.640000, .660000, .680000, .700000, .720000, .740000, .760000, .780000,
.800000, .820000, .840000, .860000, .880000, .900000, .920000, .940000,
.960000, .980000, 1.000000;
ZINL =
.009941, .016598, .022527, .026839, .030529, .033748, .036542, .039014,
.041272, .043251, .045019, .046644, .048113, .049395, .050483, .051393,
.052138, .052706, .053081, .053258, .053246, .053049, .052654, .052038,
.051206, .050192, .049027, .047730, .046317, .044793, .043155, .041401,
.039558, .037654, .035699, .033678, .031584, .029437, .027265, .025083,
.022891, .020688, .018469, .016229, .013974, .011722, .009482, .007213,
.004873, .002458, 0.000000;
VINL =
.755823, .384001, .245107, .199126, .169990, .147823, .130054, .117815,
.105443, .092960, .080415, .077618, .069018, .059127, .049812, .041371,
.032950, .023693, .013753, .004037, .005245, .014597, .025101, .036447,
.046437, .054702, .061695, .067874, .073371, .079002, .084907, .090180,
.093908, .096372, .099285, .102933, .106253, .108179, .108874, .109377,
.109856, .110486, .111425, .112319, .112822, .112177, .112272, .114804,
.119226, .122214, .123215;
SEND
SCDND 3

```

Appendix B1 - Continued

XTRAN2L Output

NACA 644010 AHB AIRFOIL M=0.780 ALFZRD=1.0 ALFONE=0.5 K=0.075

AERDELASTIC SYSTEM

IRESP	0	HARMONIC OSCILLATION	NELAST	1	2-DOF, PLUNGE AND PITCH
UC	100.00000	NONDIMENSIONAL VELOCITY	KMU	60.00000	MASS RATIO
DELT	.00116	TIME STEP, SECONDS	IEGFLAG	1	EXTRAN EQUATION
AMPLTD	.01745	AMPLITUDE OF PULSE	MDTHPLS	10000.0	PULSE EXPONENTIAL FACTOR
TZEROST	17.50000	CENTER OF PULSE			

INPUT PARAMETERS

XX	.15000	REDUCED FREQUENCY BASED ON CHORD	XH	.78000	MEAN FREE-STREAM MACH NO.
GAM	1.40000	RATIO OF SPECIFIC HEATS	ICNVRG	1	GET 8=8 SOL, ON COARS, THEN FINER GRID
IREAD	5	READ INITIAL CONDITIONS	NSPC	360	NO. STEPS PER CYCLE
MAXIT	1440	MAX. NO. TIME STEPS	ISICO	0	SINUSOIDAL VARIATION
ITRAN	0	PITCH, PLUNGE, FLAP MOTION	ISUP	1	OUTPUT TO LU 8
ICPRNT	90	ITERATION PRINT INCREMENT FOR CP	JLAST	66	LAST CHORDWISE GRIDPT FOR CP PRINTING
JFIRST	16	FIRST CHORDWISE GRIDPT FOR CP PRINTING	IR	1	TIME-DERIV. IN AIRFOIL B.C.
LIN	0	LINEARIZED CP	XAR	.25000	POSITION OF PITCH AXIS
DEL	.10000	AIRFOIL THICKNESS RATIO	ALFONE	.50000	PITCHING AMPLITUDE
ALFZRD	1.00000	MEAN ANGLE OF ATTACK	IMODPH	1	TIME-DERIVATIVE IN WAKE CONDITION
ZI	0.00000	PLUNGE AMPLITUDE	RSUP	1.00000	SUPERSONIC RELAXATION FACTOR
RSUB	1.40000	SUBSONIC RELAXATION FACTOR	TOLC	.10E-04	TOLERANCE PARAMETERS IN STEADY
MITC	500	MAXIMUM NUMBER OF ITERATIONS	TOLM	.10E-05	CALCULATIONS ON COARSE, FINE
MITH	100	ON COARSE, FINE AND EXT. FINE GRID	TOLEF	.10E-05	AND EXT. FINE GRID RESPECTIVELY
MITEP	25	RESPECTIVELY	LINDIF	0	NLR-TSP EQUATION (WITH NON-LINEAR TERM)
ICPRM	0	NO REQUEST FOR OUTPUT OF UNSTEADY PRESSURES			
ICPT	1	TIME-DEK. CONTRIBUTES TO CP AND MACH, IF IRN1			
N	1	NUMBER OF (CO)SIN HARMONICS			
MULTIPLIERS OF (CO)SIN HARMONICS	1.00000				

NACA 64A010 AMES AIRFOIL MRO,780 ALFZNR01,0 ALFONE0,5 KRO,075

ITERATION NO. = 1 ALP (DEG) = 1,0087262 PLUNGE = 0,0000000
 TIME = 50,2829357 T (DEG) = 2861,0000000

INDEX	X	CPU	CPL	MU	ML	DCP=CPL-CPU
16	.00667	.35687	.97144	.56781	0,00000	.61437
17	.02000	-.22173	.36656	.88669	.56079	.58829
18	.04000	-.39406	.12722	.96144	.71156	.52128
19	.06000	-.41042	.03043	.96824	.76413	.44084
20	.08000	-.44954	-.03281	.94430	.79661	.41673
21	.10000	-.47598	-.08000	.99499	.82002	.39597
22	.12000	-.49381	-.12363	1,00214	.84108	.37018
23	.14000	-.52691	-.16196	1,01529	.89918	.36493
24	.16000	-.55427	-.19179	1,02602	.87296	.36248
25	.18000	-.57320	-.21590	1,03337	.88400	.35730
26	.20000	-.59729	-.23499	1,03881	.89263	.35230
27	.22000	-.60414	-.24625	1,04527	.90392	.34389
28	.24000	-.62398	-.28953	1,05283	.91682	.33446
29	.26000	-.64207	-.31503	1,05968	.92792	.32704
30	.28000	-.65497	-.33495	1,06453	.93651	.32002
31	.30000	-.66705	-.35350	1,06905	.94443	.31356
32	.32000	-.68763	-.37372	1,07672	.95300	.31191
33	.34000	-.71902	-.39377	1,08833	.96141	.32525
34	.36000	-.74979	-.40875	1,09958	.96766	.34104
35	.38000	-.76924	-.41719	1,10662	.97117	.35205
36	.40000	-.77966	-.42194	1,11037	.97315	.35772
37	.42000	-.79399	-.42558	1,11531	.97467	.36640
38	.44000	-.82031	-.42406	1,12491	.97407	.39625
39	.46000	-.84753	-.40873	1,13455	.96776	.43880
40	.48000	-.86367	-.38177	1,14022	.95655	.46191
41	.50000	-.86867	-.35249	1,14195	.94423	.51618
42	.52000	-.85835	-.32488	1,13831	.93246	.53347
43	.54000	-.85189	-.29935	1,106311	.92145	.55254
44	.56000	-.82179	-.27612	.93036	.91132	.04567
45	.58000	-.79782	-.25420	.87530	.90165	-.05638
46	.60000	-.20941	-.23058	.88056	.89109	-.02113
47	.62000	-.20736	-.20398	.87961	.87909	.00339
48	.64000	-.19721	-.17711	.87494	.86678	.02010
49	.66000	-.18170	-.15360	.86778	.85567	.02810
50	.68000	-.16267	-.13305	.85892	.84622	.02962
51	.70000	-.14127	-.11157	.84665	.83602	.02970
52	.72000	-.11835	-.08727	.83793	.82431	.03107
53	.74000	-.09508	-.06195	.82669	.81194	.03314
54	.76000	-.07275	-.03840	.81377	.80026	.03435
55	.78000	-.05166	-.01708	.80531	.78954	.03458
56	.80000	-.03155	-.00306	.79521	.77928	.03460
57	.82000	-.01200	.02276	.78526	.76911	.03476
58	.84000	.00855	.04311	.77467	.75847	.03456
59	.86000	.01228	.06494	.76226	.74661	.03315
60	.88000	.05788	.08956	.74868	.73357	.03174
61	.90000	.07902	.11353	.73722	.72040	.03451
62	.92000	.09440	.13727	.72877	.70710	.04287
63	.94000	.11552	.16498	.71703	.69067	.05047
64	.96000	.15101	.20878	.69111	.66541	.04777
65	.98000	.24274	.27689	.64192	.62308	.03414
66	1,00000	.36359	.39604	.54692	.54108	.01245

FORCE COEFFICIENTS AT ANGLE OF ATTACK = 1,0087262

PLUNGE DISP. = 0,0000000

AIRFOIL
 PITCHING MOMENT (ABOUT X = .25000) = .1038569E+01

NORMAL FORCE = .2342189E+00

AXIAL FORCE = -.6340326E+02

NACA 66A010 AMES AIRFOIL MHO,780 ALPZRO=1.0 ALPONE=0.5 MHO,075

ITERATION NO. = 1840 ALF (DEG) = 1.0000000 PLUNGE = 0.0000000
 TIME = 75.3982237 T (DEG) = 4320.0000000

INDEX	X	CPU	CPL	MU	ML	DCP=CPL-CPU
16	.00687	.40822	.92937	.93056	0.00000	.52114
17	.02000	-.16362	.32377	.86007	.59123	.46739
18	.04000	-.34308	.09094	.93987	.73235	.43402
19	.06000	-.36888	-.00023	.95055	.78074	.36825
20	.08000	-.40829	-.06062	.96712	.81122	.34796
21	.10000	-.43818	-.10580	.97933	.83332	.33238
22	.12000	-.45974	-.14796	.98807	.85341	.31179
23	.14000	-.49128	-.18508	1.00072	.87074	.30620
24	.16000	-.52130	-.21369	1.01262	.88386	.30781
25	.18000	-.54240	-.23666	1.02087	.89427	.30374
26	.20000	-.55401	-.25459	1.02537	.90233	.29942
27	.22000	-.56995	-.27921	1.03132	.91324	.29073
28	.24000	-.59210	-.30824	1.04005	.92595	.28386
29	.26000	-.61333	-.33348	1.04814	.93685	.27983
30	.28000	-.62733	-.35291	1.05344	.94518	.27442
31	.30000	-.63918	-.37103	1.05790	.95287	.26816
32	.32000	-.65974	-.39111	1.06561	.96133	.26863
33	.34000	-.69187	-.41123	1.07758	.96973	.26069
34	.36000	-.72333	-.42596	1.08917	.97584	.25737
35	.38000	-.74278	-.43355	1.09627	.97900	.30924
36	.40000	-.75272	-.43716	1.09986	.98053	.31554
37	.42000	-.76667	-.43982	1.10488	.98166	.32685
38	.44000	-.79298	-.43696	1.11434	.98053	.35602
39	.46000	-.81968	-.41945	1.12386	.97338	.40023
40	.48000	-.83308	-.39030	1.12858	.96134	.44278
41	.50000	-.82891	-.35952	1.12704	.94845	.46940
42	.52000	-.70356	-.33090	1.08144	.93630	.37266
43	.54000	-.41870	-.30463	.96945	.92502	.11406
44	.56000	-.25683	-.28085	.89998	.91466	.02403
45	.58000	-.26264	-.25849	.90266	.90885	.00415
46	.60000	-.25718	-.23443	.90029	.89414	.02276
47	.62000	-.24329	-.20750	.89413	.88201	.03379
48	.64000	-.22479	-.18032	.88582	.86959	.04447
49	.66000	-.20335	-.15659	.87609	.85860	.04675
50	.68000	-.18001	-.13589	.86536	.84889	.04412
51	.70000	-.15542	-.11427	.85391	.83864	.04115
52	.72000	-.13008	-.08985	.84193	.82890	.04022
53	.74000	-.10493	-.06442	.82988	.81449	.04050
54	.76000	-.08110	-.04032	.81830	.80280	.04028
55	.78000	-.05879	-.01947	.80730	.79208	.03932
56	.80000	-.03766	.00066	.79674	.78184	.03832
57	.82000	-.01724	.02034	.78641	.77169	.03758
58	.84000	.00404	.04064	.77547	.76108	.03657
59	.86000	.02851	.06291	.76274	.74927	.03441
60	.88000	.05469	.08698	.74886	.73629	.03229
61	.90000	.07846	.11083	.73712	.72320	.03437
62	.92000	.09240	.13443	.72840	.71001	.04203
63	.94000	.11407	.16299	.71639	.69370	.04892
64	.96000	.16008	.20581	.69017	.68663	.04553
65	.98000	.24226	.27351	.64068	.62661	.03125
66	1.00000	.56270	.39386	.54580	.54422	.01116

FORCE COEFFICIENTS AT ANGLE OF ATTACK = 1.000000

PLUNGE DISP. = 0.0000000

AIRFOIL PITCHING MOMENT (ABOUT X = .25000) = .1049763E+01

NORMAL FORCE = .2013339E+00

AXIAL FORCE = -.3739490E+02

Appendix B1 - Concluded

Post-Processed Pressure Harmonics

**PRESSURE COEFFICIENT HARMONICS
UPPER PRESSURE COEFFICIENT**

X #	.0067		.0200		.0400		.0600		.0800		.1000		.1200		.1400	
	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
0	.3563	0.0000	-.2238	0.0000	-.3963	0.0000	-.4116	0.0000	-.4519	0.0000	-.4792	0.0000	-.4948	0.0000	-.5242	0.0000
1	-10.1855	5.8240	-11.3662	6.6943	-9.8447	5.9175	-7.9572	4.8422	-7.8733	4.8854	-7.4138	4.5958	-6.3753	3.9399	-5.9261	3.6826
2	-.2053	-.0608	-.0629	.0154	-.0113	.0216	-.0866	-.0268	.0406	-.0030	.1767	.0539	-.0700	-.0230	-.4170	-.1537
3	.0150	-.0046	.0192	-.0151	.0187	-.0280	.0183	-.0219	.0139	-.0019	-.0066	-.0865	.0329	-.0266	-.0664	-.0852
4	.0018	.0050	.0051	-.0037	-.0004	.0075	-.0012	.0064	.0119	-.0005	.0054	.0132	-.0037	-.0138	-.0203	.0363
5	-.0010	.0006	-.0050	-.0013	-.0010	.0003	-.0022	.0009	-.0025	-.0002	-.0138	-.0024	.0072	-.0075	.0207	-.0016
X #	.1600		.1800		.2000		.2200		.2400		.2600		.2800		.3000	
0	-.5515	0.0000	-.5730	0.0000	-.5879	0.0000	-.6044	0.0000	-.6241	0.0000	-.6425	0.0000	-.6556	0.0000	-.6676	0.0000
1	-5.6793	3.5452	-5.7301	3.6401	-5.9621	3.8406	-5.8841	3.8138	-5.5921	3.5990	-5.3387	3.3956	-5.2023	3.3444	-5.3432	3.3956
2	-.3839	-.1637	-.2051	-.1364	-.1023	-.1177	-.0824	-.1063	-.0906	-.1105	-.0752	-.1268	-.0488	-.1479	-.0387	-.1671
3	.0081	-.0536	.0097	-.0769	.0843	.0341	.1119	.1098	.0773	.0811	.0372	-.0009	.0210	-.0252	.0215	-.0279
4	-.0143	.0293	.0123	-.0194	.0039	-.0062	-.0104	.0286	-.0093	.0203	-.0023	-.0093	.0031	-.0174	-.0061	-.0186
5	-.0144	.0030	-.0091	.0011	.0090	-.0080	.0028	-.0059	-.0044	-.0023	.0003	-.0031	-.0018	-.0011	-.0033	-.0002
X #	.3200		.3400		.3600		.3800		.4000		.4200		.4400		.4600	
0	-.6884	0.0000	-.7197	0.0000	-.7503	0.0000	-.7695	0.0000	-.7795	0.0000	-.7935	0.0000	-.8196	0.0000	-.8463	0.0000
1	-5.3107	3.3844	-5.1382	3.2599	-4.9962	3.1366	-5.0001	3.1081	-5.1168	3.1911	-5.2361	3.1944	-5.3044	3.2039	-5.4796	3.2887
2	-.0235	-.1707	-.0033	-.1631	-.0021	-.1627	-.0237	-.1782	-.0562	-.2067	-.0863	-.2398	-.1113	-.2727	-.1734	-.3273
3	.0314	-.0120	.0429	-.0105	.0486	-.0241	.0498	.0267	.0483	.0233	.0480	.0195	.0475	.0142	.0465	-.0127
4	-.0095	-.0130	-.0123	-.0022	-.0139	.0068	-.0146	.0106	-.0151	.0109	-.0156	.0081	-.0138	.0023	-.0026	-.0091
5	-.0024	-.0017	-.0019	-.0028	-.0021	-.0027	-.0017	-.0024	-.0007	-.0020	-.0006	-.0015	-.0039	-.0001	-.0084	-.0029
X #	.4800		.5000		.5200		.5400		.5600		.5800		.6000		.6200	
0	-.8408	0.0000	-.8510	0.0000	-.7704	0.0000	-.6345	0.0000	-.4825	0.0000	-.3086	0.0000	-.2063	0.0000	-.1927	0.0000
1	-6.0122	3.6099	-9.2412	5.4083	-22.6313	12.8245	-36.5953	21.2836	-32.3097	19.4620	-10.7151	5.1966	4.5566	-5.5836	5.0708	5.4357
2	-.3578	-.4940	-2.1998	-1.7403	-7.2331	-5.3557	-1.9376	-3.2191	13.9317	4.5857	12.3363	4.5420	1.0579	.6837	-1.2359	.1398
3	.0488	-.0493	.2471	-1.2940	.7491	-1.0534	.9911	6.0405	-.8782	3.3509	-1.9660	-4.3805	-.6323	-1.6576	.0633	-.0448
4	.0189	-.0199	.5286	-.1327	-1.0844	.9216	-1.2913	-.0009	1.6410	-1.9555	.7625	.0537	-.5636	.9718	.0066	.0018
5	.0088	.0090	.0429	-.1291	-.6037	-.4791	.9810	.0727	.1362	.8020	-.9983	-.2204	.4868	-.0861	-.0026	-.0022
X #	.6400		.6600		.6800		.7000		.7200		.7400		.7600		.7800	
0	-.1851	0.0000	-.1716	0.0000	-.1542	0.0000	-.1340	0.0000	-.1120	0.0000	-.0894	0.0000	-.0676	0.0000	-.0469	0.0000
1	3.6357	-4.6034	2.6330	-3.7024	1.9182	-3.0319	1.4028	-2.5264	1.0272	-2.1399	.7516	-1.8390	.5488	-1.6023	.3987	-1.4119
2	-.9929	.1291	-.8028	.1144	-.6508	.1006	-.5309	.0884	-.4369	.0776	-.3639	.0688	-.3057	.0611	-.2598	.0544
3	.0370	-.0349	.0508	-.0242	.0439	-.0174	.0370	-.0133	.0309	-.0108	.0257	-.0092	.0215	-.0080	.0181	-.0071
4	.0038	.0045	.0017	.0040	.0007	.0031	.0003	.0023	.0001	.0019	.0001	.0014	.0001	.0011	.0001	.0009
5	-.0033	-.0015	-.0025	-.0010	-.0019	-.0007	-.0014	-.0004	-.0011	-.0003	-.0009	-.0002	-.0007	-.0001	-.0006	-.0001
X #	.8000		.8200		.8400		.8600		.8800		.9000		.9200		.9400	
0	-.0271	0.0000	-.0078	0.0000	.0126	0.0000	.0361	0.0000	.0616	0.0000	.0824	0.0000	.0980	0.0000	.1190	0.0000
1	.2873	-1.2949	.2051	-1.1226	.1450	-1.0083	.1016	-.9073	.0728	-.8172	.0586	-.7381	.0586	-.6607	.0679	-.5876
2	-.2226	.0487	-.1923	.0438	-.1667	.0394	-.1445	.0354	-.1253	.0319	-.1093	.0288	-.0959	.0261	-.0834	.0235
3	.0152	-.0063	.0129	-.0057	.0110	-.0051	.0093	-.0046	.0079	-.0042	.0067	-.0038	.0057	-.0034	.0048	-.0031
4	.0002	.0006	.0002	.0007	.0002	.0006	.0002	.0005	.0002	.0004	.0002	.0004	.0002	.0003	.0002	.0003
5	-.0005	-.0001	-.0004	-.0000	-.0003	-.0000	-.0003	-.0000	-.0002	-.0000	-.0002	-.0000	-.0002	-.0000	-.0001	-.0000
X #	.9600		.9800		1.0000											
0	.1644	0.0000	.2461	0.0000	.3852	0.0000										
1	-.0805	-.5177	-.0957	-.4553	-.1715	-.2968										
2	-.0702	-.0210	-.0560	.0167	-.0413	.0149										
3	.0039	-.0027	.0024	-.0022	.0020	-.0017										
4	.0002	.0002	.0002	.0001	.0001	.0001										
5	-.0001	.0000	-.0001	.0000	-.0001	.0000										

PRESSURE COEFFICIENT HARMONICS
 DELTA PRESSURE COEFFICIENT

X #	.0067		.0200		.0400		.0600		.0800		.1000		.1200		.1400	
	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
0	.6150	0.0000	.5900	0.0000	.5232	0.0000	.4418	0.0000	.4188	0.0000	.3990	0.0000	.3709	0.0000	.3619	0.0000
1	19.1991	-10.5141	20.4181	-11.4363	17.6046	-9.9324	14.6574	-8.2311	14.0534	-7.9337	13.2369	-7.4366	11.9694	-8.6139	11.2984	-8.2161
2	.4408	.1031	.3147	.0318	.2127	.0086	.2314	.0439	.1119	.0185	-.0350	-.0402	.2043	.0354	.3456	.1683
3	-.0166	-.0159	-.0194	.0280	-.0177	.0380	-.0166	.0299	-.0116	.0094	.0092	.0932	-.0300	.0330	-.0633	-.0791
4	-.0033	-.0064	-.0067	-.0048	-.0008	-.0080	.0003	-.0066	-.0127	.0004	-.0061	-.0131	.0031	-.0136	.0198	-.0360
5	.0021	-.0009	.0060	.0011	.0018	-.0005	.0029	-.0011	.0030	-.0000	.0143	.0023	-.0064	.0073	-.0203	.0015
X #	.1600		.1800		.2000		.2200		.2400		.2600		.2800		.3000	
	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
0	.3394	0.0000	.3568	0.0000	.3526	0.0000	.3438	0.0000	.3361	0.0000	.3269	0.0000	.3200	0.0000	.3136	0.0000
1	10.6550	-5.9420	10.7401	-5.9070	10.7625	-5.9771	10.5948	-5.8761	10.2959	-5.6261	10.0348	-5.3870	9.9348	-5.2793	9.9627	-5.2784
2	.5065	.1763	.3212	.1486	.2102	.1285	.1893	.1192	.2031	.1295	.1927	.1820	.1667	.1760	.1571	.2024
3	-.0048	.0594	-.0064	.0823	-.0010	-.0493	-.1083	-.1050	-.0738	-.0534	-.0334	.0074	-.0180	.0319	-.0177	.0349
4	.0138	-.0290	-.0127	.0198	-.0043	.0086	.0101	-.0282	.0090	-.0197	.0019	.0099	.0028	.0181	.0057	.0193
5	.0147	-.0031	.0094	-.0012	-.0087	.0059	-.0025	.0036	.0047	.0022	-.0001	.0031	.0020	.0010	.0035	.0002
X #	.3200		.3400		.3600		.3800		.4000		.4200		.4400		.4600	
	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
0	.3138	0.0000	.3249	0.0000	.3403	0.0000	.3509	0.0000	.3563	0.0000	.3667	0.0000	.3943	0.0000	.4367	0.0000
1	9.9631	-5.2470	9.8801	-5.1257	9.7818	-4.9764	9.7163	-4.8558	9.7038	-4.7796	9.7115	-4.7155	9.5780	-4.5798	9.5125	-4.4234
2	.1505	.2170	.1464	.2292	.1590	.2492	.1724	.2752	.1861	.3072	.2029	.3475	.2024	.3760	.2156	.4988
3	-.0279	.0206	-.0400	.0025	-.0477	-.0066	-.0511	-.0095	-.0528	-.0091	-.0546	-.0061	-.0557	-.0050	-.0527	.0131
4	.0090	.0139	.0111	.0035	.0117	-.0054	.0121	-.0097	.0129	-.0104	.0133	-.0086	.0120	-.0036	.0025	.0078
5	.0026	.0017	.0019	.0028	.0020	.0023	.0016	.0020	.0008	.0014	-.0004	.0011	-.0035	-.0003	.0060	-.0030
X #	.4800		.5000		.5200		.5400		.5600		.5800		.6000		.6200	
	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
0	.4784	0.0000	.4979	0.0000	.4444	0.0000	.3344	0.0000	.2056	0.0000	.0335	0.0000	-.0252	0.0000	-.0123	0.0000
1	9.3401	-4.4967	12.1888	-6.1193	25.3022	-13.4133	39.0504	-21.7812	34.5891	-19.8887	12.6434	-5.5455	2.5713	3.2677	3.2235	3.3695
2	.1631	.4940	2.1922	1.7661	7.2212	5.3756	1.9240	3.2359	13.9462	-4.3706	12.3314	-4.3279	-1.0736	-.8726	1.2196	-.1276
3	-.0522	.0854	-.2492	1.2903	-.7505	1.0504	-1.0001	-6.0430	.8773	-3.3531	1.9674	4.3586	.6318	1.8558	-.0637	.0432
4	-.0185	.0190	-.5283	.1322	1.0846	-.9219	1.2914	.0006	-1.6409	1.9553	-.7625	-.0339	.5636	-.9719	-.0086	-.0019
5	-.0084	-.0090	-.0426	-.1291	.8039	.4791	-.9809	-.0727	-.1361	-.6020	.9984	.2204	-.4667	.0861	.0027	.0022
X #	.6400		.6600		.6800		.7000		.7200		.7400		.7600		.7800	
	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
0	.0070	0.0000	.0169	0.0000	.0199	0.0000	.0211	0.0000	.0233	0.0000	.0280	0.0000	.0276	0.0000	.0282	0.0000
1	-1.9133	4.3799	-1.0163	3.5113	-.3936	2.8638	.0333	2.3827	.3211	2.0174	.5130	1.7360	.6391	1.5137	.7184	1.3331
2	.9762	-.1174	.7658	-.1030	.6335	-.0893	.5133	-.0773	.4169	-.0668	.3450	-.0579	.2869	-.0502	.2406	-.0436
3	-.0572	.0333	-.0510	.0227	-.0439	.0180	-.0370	.0120	-.0308	.0095	-.0255	.0079	-.0212	.0067	-.0177	.0058
4	-.0038	-.0046	-.0016	-.0041	-.0007	-.0032	-.0003	-.0024	-.0001	-.0019	-.0001	-.0013	-.0001	-.0012	-.0001	-.0010
5	.0034	.0019	.0026	.0010	.0020	.0007	.0015	.0004	.0012	.0003	.0009	.0002	.0008	.0001	.0006	.0001
X #	.8000		.8200		.8400		.8600		.8800		.9000		.9200		.9400	
	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
0	.0283	0.0000	.0288	0.0000	.0287	0.0000	.0274	0.0000	.0261	0.0000	.0249	0.0000	.0372	0.0000	.0448	0.0000
1	.7624	1.1625	.7793	1.0539	.7749	.9411	.7535	.8401	.7173	.7480	.6663	.6618	.6003	.5764	.5212	.4908
2	.2030	-.0378	.1720	-.0328	.1457	-.0283	.1228	-.0283	.1028	-.0207	.0859	-.0179	.0714	-.0146	.0576	-.0118
3	-.0148	.0051	-.0125	.0044	-.0104	.0039	-.0087	.0034	-.0072	.0029	-.0060	.0023	-.0049	.0021	-.0039	.0017
4	-.0001	-.0008	-.0001	-.0007	-.0001	-.0006	-.0001	-.0005	-.0001	-.0004	-.0001	-.0003	-.0001	-.0003	-.0001	-.0002
5	.0005	.0001	.0004	.0001	.0004	.0000	.0003	.0000	.0002	.0000	.0002	.0000	.0002	.0000	.0001	.0000
X #	.9600		.9800		1.0000											
	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG	REAL	IMAG
0	.0421	0.0000	.0285	0.0000	.0099	0.0000										
1	.4312	.4066	.3243	.3260	.1324	.1435										
2	.0430	-.0092	.0267	-.0066	.0091	-.0026										
3	-.0029	.0013	-.0017	.0008	-.0004	.0003										
4	-.0001	-.0002	-.0001	-.0001	-.0000	.0000										
5	.0001	.0000	.0001	.0000	.0000	-.0000										

Appendix B2 - Results from Unsteady Calculations for Pulse Motion

XTRAN2L Input

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NACA 64A010 AMEB AIRFOIL M=0.780 ALFZRO=1.0 PITCH=PULSE = 0.3
BAERDEL IRESP=3, DELT=0.002454369, UC=100.0, AMPLTD=0.0087266463,
MDTHPLS=8000.0, TZEADST=30.0, SEND
SINPUT IM=0.780, IREADS, MAXIT=1024, NSPC=128, ICPRNTR=128, ISUPR=1,
DEL=0.10, XAR=0.25, ALFZMU=1.00, ALFUNEM=0.00, SEND
SMESH 3
SAMPLI 3
SORD NINU = 51, NINL = 51,
XINU =
.006667, .020000, .040000, .060000, .080000, .100000, .120000, .140000,
.160000, .180000, .200000, .220000, .240000, .260000, .280000, .300000,
.320000, .340000, .360000, .380000, .400000, .420000, .440000, .460000,
.480000, .500000, .520000, .540000, .560000, .580000, .600000, .620000,
.640000, .660000, .680000, .700000, .720000, .740000, .760000, .780000,
.800000, .820000, .840000, .860000, .880000, .900000, .920000, .940000,
.960000, .980000, 1.000000,
ZINU =
.010144, .016499, .022381, .026732, .030412, .033687, .036532, .039113,
.041413, .043449, .045258, .046874, .048300, .049535, .050589, .051465,
.052232, .052792, .053113, .053200, .053113, .052905, .052585, .052121,
.051533, .049999, .048615, .047508, .046678, .045528, .044285, .042814,
.039200, .037367, .035389, .033343, .031231, .029124, .026980, .024828,
.022672, .020513, .018343, .016152, .013956, .011799, .009693, .007530,
.005196, .002650, 0.000000,
VINU =
.666396, .373066, .247303, .201161, .174588, .150587, .135858, .121238,
.108089, .095780, .085469, .076080, .066554, .057051, .048587, .041197,
.033109, .022305, .009743, -.000503, -.007639, -.013740, -.022947, -.037534,
-.048629, -.056247, -.062229, -.066431, -.074733, -.080404, -.083320, -.089694,
-.093739, -.097436, -.100687, -.103473, -.105808, -.106902, -.107439, -.107720,
-.107831, -.108131, -.108983, -.110038, -.109200, -.106129, -.105359, -.111430,
-.122939, -.130770, -.133586,
XINL =
.006667, .020000, .040000, .060000, .080000, .100000, .120000, .140000,
.160000, .180000, .200000, .220000, .240000, .260000, .280000, .300000,
.320000, .340000, .360000, .380000, .400000, .420000, .440000, .460000,
.480000, .500000, .520000, .540000, .560000, .580000, .600000, .620000,
.640000, .660000, .680000, .700000, .720000, .740000, .760000, .780000,
.800000, .820000, .840000, .860000, .880000, .900000, .920000, .940000,
.960000, .980000, 1.000000,
ZINL =
.009941, .016598, .022527, .026839, .030529, .033748, .036582, .039014,
.041272, .043251, .045019, .046644, .048113, .049395, .050483, .051393,
.052138, .052708, .053081, .053258, .053246, .053049, .052654, .052036,
.051208, .050192, .049027, .047730, .046317, .044793, .043153, .041401,
.039558, .037626, .035699, .033678, .031564, .029437, .027283, .025083,
.022891, .020688, .018469, .016229, .013978, .011722, .009482, .007215,
.004873, .002458, 0.000000,
VINL =
.755623, .364001, .245107, .199126, .169990, .147823, .134024, .117215,
.105843, .092980, .084815, .077818, .069018, .059127, .049812, .041371,
.032950, .023693, .013753, .004057, .005243, .014397, .023101, .031447,
.046437, .054702, .061893, .067874, .073371, .079002, .084907, .090180,
.093908, .096372, .099263, .102933, .106253, .108179, .108674, .109377,
.109858, .110488, .111423, .112319, .112822, .112777, .112274, .111804,
.119226, .122218, .123213,
SEND
SCOND 3

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Appendix B2 - Continued

XTRAN2L Output

NACA 64A010 AMES AIRFOIL M=0.780 ALPZRD=1.0 PITCH=PULSE W 0.5

AEROELASTIC SYSTEM

IRESP	3	PITCH PULSE TRANSIENT	NELAST	1	2-DOF, PLUNGE AND PITCH
UC	100.00000	NONDIMENSIONAL VELOCITY	XMU	80.00000	MASS RATIO
DELT	.00245	TIME STEP, SECONDS	IEDFLAG	3	EXTRN EQUATION
AMPLTD	.00873	AMPLITUDE OF PULSE	WOTMPLS	8000.0	PULSE EXPONENTIAL FACTOR
TZEROST	30.00000	CENTER OF PULSE			

INPUT PARAMETERS

XK	.20000	REDUCED FREQUENCY BASED ON CHORD	XM	.78000	MEAN FREE-STREAM MACH NO.
GAM	1.40000	RATIO OF SPECIFIC HEATS	ICNVG	1	GET 8-8 SOL. UN COARSE, THEN FINER GRID
IREAD	5	READ INITIAL CONDITIONS	NSPC	128	NO. STEPS PER CYCLE
MAXIT	1024	MAX. NO. TIME STEPS	ISICU	0	SINUSOIDAL VARIATION
ITRAN	0	PITCH, PLUNGE, FLAP MOTION	IBUF	1	OUTPUT TO LU 8
ICPRNT	128	ITERATION PRINT INCREMENT FOR CP	JLAST	60	LAST CHORDWISE GRIDPT FOR CP PRINTING
JFIRST	16	FIRST CHORDWISE GRIDPT FOR CP PRINTING	IN	1	TIME-DEVI. IN AIRFOIL S.C.
LIN	0	LINEARIZED CP	XAX	.25000	POSITION OF PITCH AXIS
DEL	.10000	AIRFOIL THICKNESS RATIO	ALPUNE	0.00000	PITCHING AMPLITUDE
ALPZRD	1.00000	MEAN ANGLE OF ATTACK	IMDUPN	1	TIME-DERIVATIVE IN WAKE CONDITION
ZI	0.00000	PLUNGE AMPLITUDE	NSUP	1.00000	SUPERSONIC RELAXATION FACTOR
RSUB	1.40000	SUBSONIC RELAXATION FACTOR	TOLC	.10E+04	TOLERANCE PARAMETERS IN STEADY
HITC	500	MAXIMUM NUMBER OF ITERATIONS	TOLM	.10E+03	CALCULATIONS UN COARSE, FINE
HITH	100	UN COARSE, FINE AND EXT. FINE GRID	TOLF	.10E+03	AND EXT. FINE GRID RESPECTIVELY
HITF	25	RESPECTIVELY	LINDIF	0	NLN-TSP EQUATION (WITH NON-LINEAR TERM)
ICPHN	0	NO REQUEST FOR OUTPUT OF UNSTEADY PRESSURES			
ICPT	1	TIME-DEVI. CONTRIBUTES TO CP AND MACH, IF IR=1			
N	1	NUMBER OF (CO)SIN HARMONICS			
MULTIPLIERS OF (CO)SIN HARMONICS	1.00000				

NACA 644010 AMES AIRFOIL H80,780 ALF=0.10 PITCH=PULSE # 0.5

ITERATION NO. # 1 ALF (DEG) # 1.0000000 PLUNGE # 0.0000000
 TIME # 50.3145698 T (DEG) # 2662.8125000

INDEX	X	CPU	CPL	MU	ML	DCP#CPL#CPU
16	.00887	.35640	.97191	.56809	0.00000	.61550
17	.02000	.22203	.36687	.88678	.36066	.56890
18	.04000	.19426	.12741	.96147	.71133	.52187
19	.06000	.41056	.03037	.96824	.76413	.44113
20	.08000	.44964	.03271	.98428	.79663	.41693
21	.10000	.47603	.07995	.99497	.82005	.39608
22	.12000	.49381	.12362	1.00211	.84113	.37019
23	.14000	.52687	.16203	1.01524	.85923	.36484
24	.16000	.55418	.19189	1.02396	.87305	.36229
25	.18000	.57305	.21605	1.03331	.88407	.35700
26	.20000	.58709	.23519	1.03874	.89270	.35190
27	.22000	.60388	.26051	1.04520	.90400	.34337
28	.24000	.62367	.28984	1.05276	.91691	.33383
29	.26000	.64170	.31540	1.05960	.92801	.32640
30	.28000	.65454	.33537	1.06445	.93660	.31917
31	.30000	.66657	.35399	1.06897	.94453	.31258
32	.32000	.68708	.37427	1.07663	.95310	.31402
33	.34000	.71842	.39438	1.08823	.96152	.32404
34	.36000	.74912	.40942	1.09948	.96777	.33770
35	.38000	.76851	.41792	1.10653	.97128	.35059
36	.40000	.77887	.42273	1.11027	.97326	.35814
37	.42000	.79313	.42644	1.11541	.97479	.36470
38	.44000	.81940	.42898	1.12481	.97419	.39442
39	.46000	.84655	.40970	1.13444	.97288	.43044
40	.48000	.86283	.38281	1.14011	.95668	.47942
41	.50000	.86757	.35360	1.14184	.94437	.51397
42	.52000	.85718	.32605	1.13819	.93260	.53113
43	.54000	.85066	.30059	1.06298	.92159	.55007
44	.56000	.82049	.27742	.93021	.91187	.60307
45	.58000	.81966	.25557	.87514	.90181	.65911
46	.60000	.80798	.23197	.88040	.89125	.72399
47	.62000	.80587	.20547	.87944	.87926	.80040
48	.64000	.819565	.17867	.87477	.86696	.81698
49	.66000	.80007	.15522	.86760	.85805	.82485
50	.68000	.816097	.13474	.85874	.84840	.82623
51	.70000	.813951	.11332	.84866	.83620	.82819
52	.72000	.811652	.08909	.83774	.82451	.82743
53	.74000	.809319	.06383	.82650	.81214	.82936
54	.76000	.807080	.04036	.81557	.80047	.83044
55	.78000	.804964	.01910	.80510	.78975	.83054
56	.80000	.802946	.00097	.79499	.77950	.83043
57	.82000	.800985	.02061	.78504	.76934	.83045
58	.84000	.801077	.04089	.77445	.75870	.83012
59	.86000	.803457	.06315	.76203	.74685	.82858
60	.88000	.806019	.08723	.74844	.73381	.82704
61	.90000	.808144	.11111	.73697	.72065	.82567
62	.92000	.809889	.13478	.72852	.70736	.82490
63	.94000	.811807	.16343	.71677	.69094	.82456
64	.96000	.81362	.20616	.69083	.66570	.82454
65	.98000	.814543	.27420	.64162	.62339	.82477
66	1.00000	.81649	.39473	.54777	.54037	.81004

FORCE COEFFICIENTS AT ANGLE OF ATTACK # 1.0000000

PLUNGE DISP. # 0.0000000

AIRFOIL
 PITCHING MOMENT (ABOUT X # .25000) # .9293374E+02

NORMAL FORCE # .2319428E+00 AXIAL FORCE # -.6339783E+02

NACA 66A010 AMES AIRFOIL M=0.760 ALFZHO=1.0 PITCH=PULSE = 0.5

ITERATION NO. = 1024 ALF (DEG) = 1.0000000 PLUNGE = 0.0000000
 TIME = 100.5309649 T (DEG) = 5700.0000000

INDEX	X	CPU	CPL	MU	HL	DCPRCPL=CPU
16	.00667	.35640	.97191	.56809	0.00000	.61550
17	.02000	.22203	.36687	.88678	.56056	.58890
18	.04000	.39426	.12741	.96147	.71153	.52167
19	.06000	.41056	.03057	.98628	.76413	.44113
20	.08000	.44964	.03271	.98428	.79663	.41693
21	.10000	.47603	.07995	.99497	.82005	.39608
22	.12000	.49381	.12362	1.00211	.84113	.37019
23	.14000	.52687	.16203	1.01524	.85923	.36684
24	.16000	.55418	.19149	1.02596	.87505	.36229
25	.18000	.57305	.21605	1.03351	.88407	.35700
26	.20000	.58709	.23519	1.03874	.89270	.35190
27	.22000	.60588	.26051	1.04520	.90400	.34537
28	.24000	.62367	.28984	1.05276	.91691	.33863
29	.26000	.64170	.31540	1.05960	.92801	.32630
30	.28000	.65454	.33537	1.06445	.93660	.31917
31	.30000	.66657	.35399	1.06847	.94453	.31258
32	.32000	.68708	.37427	1.07663	.95310	.31262
33	.34000	.71642	.39438	1.08623	.96152	.32404
34	.36000	.74412	.40942	1.09948	.96777	.33970
35	.38000	.76851	.41792	1.10653	.97128	.35059
36	.40000	.77887	.42273	1.11027	.97326	.35614
37	.42000	.79113	.42644	1.11541	.97479	.36670
38	.44000	.81940	.42498	1.12481	.97419	.39442
39	.46000	.84655	.40970	1.13444	.96768	.43684
40	.48000	.86263	.38281	1.14011	.95666	.47982
41	.50000	.86756	.35359	1.14184	.94437	.51597
42	.52000	.85718	.32605	1.13819	.93260	.53113
43	.54000	.83065	.30059	1.08298	.92159	.55006
44	.56000	.82049	.27742	.93021	.91147	.04307
45	.58000	.81946	.25557	.87514	.90181	.05911
46	.60000	.80798	.23197	.86040	.89125	.02199
47	.62000	.80587	.20547	.87944	.87926	.00040
48	.64000	.81565	.17887	.87477	.86696	.01648
49	.66000	.81807	.15522	.86760	.85603	.02865
50	.68000	.81697	.13474	.85874	.84640	.02824
51	.70000	.81351	.11332	.84866	.83620	.02619
52	.72000	.81162	.08909	.83774	.82451	.02743
53	.74000	.80931	.06383	.82650	.81214	.02956
54	.76000	.80780	.04036	.81557	.80047	.03044
55	.78000	.80964	.01910	.80510	.78975	.03054
56	.80000	.80246	.00097	.79499	.77950	.03043
57	.82000	.80084	.02061	.78504	.76938	.03045
58	.84000	.81077	.04089	.77445	.75870	.03012
59	.86000	.83857	.06315	.76203	.74685	.02958
60	.88000	.86019	.08723	.74844	.73381	.02704
61	.90000	.88144	.11111	.73697	.72065	.02967
62	.92000	.89689	.13478	.72852	.70736	.03790
63	.94000	.11807	.16343	.71677	.69094	.04536
64	.96000	.16362	.20616	.69083	.66570	.04254
65	.98000	.24543	.27420	.64162	.62339	.02677
66	1.00000	.38469	.39473	.54777	.54037	.01004

FORCE COEFFICIENTS AT ANGLE OF ATTACK = 1.0000000

PLUNGE DISP. = 0.0000000

AIRFOIL
 PITCHING MOMENT (ABOUT X = .25000) = .9295373E+02

NORMAL FORCE = .2319426E+00

AXIAL FORCE = -.6339768E+02

Appendix B2 - Concluded

Post-Processed Generalized Aerodynamic Forces

POINT	FREQUENCY	REQ FREQ	CM (REAL)	CM (IMAG)	CM (REAL)	CM (IMAG)
1	0.	0.	.733091364E+00	0.	.140948825E+02	0.
2	.250000027E+01	.125000013E-01	.712931312E+00	-.402138855E+01	.118755840E+02	-.222895875E+01
3	.500000053E+01	.250000027E-01	.680184321E+00	-.548164274E+01	.119218549E+02	-.365711055E+01
4	.750000080E+01	.375000040E-01	.603567008E-01	-.230994413E+01	.103811496E+02	-.386447494E+01
5	1.00000011E+02	.500000053E-01	.583903412E+00	.260274770E+01	.982000441E+01	-.377440571E+01
6	1.25000013E+02	.625000066E-01	.578360052E+00	.372500902E+01	.892101721E+01	-.38849418E+01
7	1.50000016E+02	.750000080E-01	.563647928E+00	.493438641E+01	.821981283E+01	-.382913884E+01
8	1.75000019E+02	.875000093E-01	.551596235E+00	.625930822E+00	.76388804E+01	-.36272332E+01
9	2.00000021E+02	1.00000011E+00	.547100301E+00	.76727030E+00	.725906867E+01	-.33788313E+01
10	2.25000024E+02	1.12500012E+00	.530682927E+00	.923212204E+00	.696131848E+01	-.324226364E+01
11	2.50000027E+02	1.25000013E+00	.513392176E+00	1.092326663E+00	.668371629E+01	-.311042068E+01
12	2.75000029E+02	1.37500015E+00	.502264753E+00	1.261408435E+00	.643503698E+01	-.292650166E+01
13	3.00000032E+02	1.50000016E+00	.51177933E+00	1.42937403E+00	.61243220E+01	-.271580034E+01
14	3.25000035E+02	1.62500017E+00	.554908457E+00	1.59321517E+00	.596374094E+01	-.254374437E+01
15	3.50000037E+02	1.75000019E+00	.580330260E+00	1.754167953E+00	.580201451E+01	-.240480311E+01
16	3.75000040E+02	1.87500020E+00	.562678773E+00	1.91231792E+00	.563309225E+01	-.225456536E+01
17	4.00000043E+02	2.00000021E+00	.560000269E+00	2.068348453E+00	.549491003E+01	-.20834472E+01
18	4.25000045E+02	2.12500023E+00	.56321941E+00	2.221496136E+00	.539104050E+01	-.192537788E+01
19	4.50000048E+02	2.25000024E+00	.56621950E+00	2.371929248E+00	.52992994E+01	-.179493286E+01
20	4.75000050E+02	2.37500025E+00	.568367021E+00	2.51986401E+00	.52044427E+01	-.168593726E+01
21	5.00000053E+02	2.50000027E+00	.568270405E+00	2.66476982E+00	.511822367E+01	-.15957130E+01
22	5.25000056E+02	2.62500028E+00	.56793230E+00	2.803048012E+00	.503047844E+01	-.152632948E+01
23	5.50000058E+02	2.75000029E+00	.56715871E+00	2.93207015E+00	.49531262E+01	-.14768496E+01
24	5.75000061E+02	2.87500031E+00	.567097598E+00	3.052486617E+00	.48820042E+01	-.144287791E+01
25	6.00000064E+02	3.00000032E+00	.567208049E+00	3.162837778E+00	.48199293E+01	-.142006951E+01
26	6.25000066E+02	3.12500033E+00	.567291876E+00	3.261796134E+00	.476512273E+01	-.140884858E+01
27	6.50000069E+02	3.25000035E+00	.567300365E+00	3.34987474E+00	.471682175E+01	-.140770820E+01
28	6.75000072E+02	3.37500036E+00	.567165749E+00	3.42718074E+00	.467489407E+01	-.141605035E+01
29	7.00000074E+02	3.50000037E+00	.561465128E+00	3.49391749E+00	.463825076E+01	-.143442288E+01
30	7.25000077E+02	3.62500039E+00	.56104019E+00	3.5491607E+00	.460537842E+01	-.14613535E+01
31	7.50000080E+02	3.75000040E+00	.569785832E+00	3.59330709E+00	.4572297334E+01	-.149682761E+01
32	7.75000082E+02	3.87500041E+00	.569433626E+00	3.62730762E+00	.45378180E+01	-.153940972E+01
33	8.00000085E+02	4.00000043E+00	.601585960E+00	3.65384514E+00	.450932869E+01	-.158290395E+01
34	8.25000088E+02	4.12500044E+00	.60833703E+00	3.67459418E+00	.448395458E+01	-.162941813E+01
35	8.50000090E+02	4.25000045E+00	.615975566E+00	3.6893129E+00	.44617126E+01	-.16782497E+01
36	8.75000093E+02	4.37500047E+00	.624365252E+00	3.69707603E+00	.444199335E+01	-.172951825E+01
37	9.00000096E+02	4.50000048E+00	.63329837E+00	3.69716078E+00	.44242891E+01	-.17832030E+01
38	9.25000098E+02	4.62500049E+00	.642842830E+00	3.6911184E+00	.440909344E+01	-.18391303E+01
39	9.50000101E+02	4.75000050E+00	.653026943E+00	3.67943241E+00	.44059028E+01	-.189748662E+01
40	9.75000104E+02	4.87500052E+00	.663712404E+00	3.6621268E+00	.440534063E+01	-.19583067E+01
41	1.00000011E+03	5.00000053E+00	.674826244E+00	3.63977180E+00	.44156260E+01	-.20216874E+01
42	1.02500011E+03	5.12500054E+00	.686348559E+00	3.6123287E+00	.442884425E+01	-.20876191E+01
43	1.05000011E+03	5.25000055E+00	.698194947E+00	3.57983804E+00	.444434402E+01	-.21562024E+01
44	1.07500011E+03	5.37500057E+00	.710275402E+00	3.5427025E+00	.446173114E+01	-.22273162E+01
45	1.10000012E+03	5.50000058E+00	.722519760E+00	3.4996741E+00	.448061235E+01	-.2300881E+01
46	1.12500012E+03	5.62500060E+00	.734844210E+00	3.45193420E+00	.44997777E+01	-.237622881E+01
47	1.15000012E+03	5.75000061E+00	.747161707E+00	3.39916393E+00	.45191066E+01	-.24533786E+01
48	1.17500012E+03	5.87500062E+00	.759385944E+00	3.341822078E+00	.453843483E+01	-.25321482E+01
49	1.20000013E+03	6.00000064E+00	.771431753E+00	3.27941358E+00	.45574029E+01	-.26123074E+01
50	1.22500013E+03	6.12500065E+00	.783217631E+00	3.21184435E+00	.457585502E+01	-.2693821E+01
51	1.25000013E+03	6.25000066E+00	.794661263E+00	3.13958686E+00	.459353741E+01	-.27764389E+01
52	1.27500014E+03	6.37500068E+00	.805689258E+00	3.0635009E+00	.461031781E+01	-.28609691E+01
53	1.30000014E+03	6.50000069E+00	.816238746E+00	2.97394424E+00	.46261026E+01	-.29471554E+01
54	1.32500014E+03	6.62500070E+00	.82584428E+00	2.8717540E+00	.46408701E+01	-.3034882E+01
55	1.35000014E+03	6.75000072E+00	.835655978E+00	2.7572749E+00	.46546020E+01	-.31239428E+01
56	1.37500015E+03	6.87500073E+00	.84444521E+00	2.6309000E+00	.46673467E+01	-.3214189E+01
57	1.40000015E+03	7.00000074E+00	.852581451E+00	2.49306462E+00	.46791094E+01	-.3305304E+01
58	1.42500015E+03	7.12500076E+00	.860003655E+00	2.3439280E+00	.46898895E+01	-.33971440E+01
59	1.45000015E+03	7.25000077E+00	.866815938E+00	2.1834967E+00	.46996895E+01	-.3489489E+01
60	1.47500016E+03	7.37500078E+00	.872946334E+00	2.01160904E+00	.47084249E+01	-.3582095E+01
61	1.50000016E+03	7.50000080E+00	.878439251E+00	1.8290909E+00	.47160994E+01	-.3674849E+01
62	1.52500016E+03	7.62500081E+00	.883303381E+00	1.63687394E+00	.47227394E+01	-.3766704E+01
63	1.55000016E+03	7.75000082E+00	.887586759E+00	1.4352869E+00	.4728309E+01	-.3857187E+01
64	1.57500017E+03	7.87500084E+00	.891370615E+00	1.22402034E+00	.47328751E+01	-.3945731E+01
65	1.60000017E+03	8.00000085E+00	.894718350E+00	1.00397486E+00	.47364394E+01	-.4032703E+01
66	1.62500017E+03	8.12500086E+00	.897658314E+00	.77502136E+00	.47390035E+01	-.4117499E+01
67	1.65000018E+03	8.25000088E+00	.900227147E+00	.53767923E+00	.47406109E+01	-.4200304E+01
68	1.67500018E+03	8.37500089E+00	.902509504E+00	.2937773E+00	.47413001E+01	-.4281334E+01
69	1.70000018E+03	8.50000090E+00	.904616519E+00	.16111654E+00	.47410825E+01	-.4360387E+01
70	1.72500018E+03	8.62500092E+00	.906627414E+00	.102691040E+00	.47400361E+01	-.4437460E+01
71	1.75000019E+03	8.75000093E+00	.908564250E+00	.64696548E+00	.47381268E+01	-.4512499E+01
72	1.77500019E+03	8.87500094E+00	.910427123E+00	.3632528E+00	.47353697E+01	-.4585697E+01
73	1.80000019E+03	9.00000096E+00	.912248359E+00	.168402025E+00	.47318870E+01	-.4656887E+01
74	1.82500019E+03	9.12500097E+00	.914107736E+00	.170308194E+00	.47276459E+01	-.4726147E+01
75	1.85000020E+03	9.25000098E+00	.915989464E+00	.172240675E+00	.47226426E+01	-.4793369E+01
76	1.87500020E+03	9.37500100E+00	.917825622E+00	.17419371E+00	.4716903E+01	-.4858279E+01
77	1.90000020E+03	9.50000101E+00	.919573489E+00	.176163121E+00	.47104063E+01	-.4920971E+01
78	1.92500020E+03	9.62500102E+00	.921299190E+00	.178138814E+00	.47031388E+01	-.4981328E+01
79	1.95000021E+03	9.75000104E+00	.922946333E+00	.180124303E+00	.46951681E+01	-.5039309E+01
80	1.97500021E+03	9.87500105E+00	.924500716E+00	.18212444E+00	.4686440E+01	-.5094937E+01
81	2.00000021E+03	1.00000011E+01	.92597946E+00	.184139989E+00	.46769720E+01	-.5148280E+01
82	2.02500022E+03	1.01250011E+01	.92734821E+00	.186168789E+00	.46667230E+01	-.5199353E+01
83	2.05000022E+03	1.02500011E+01	.928513457E+00	.18820861E+00	.46557600E+01	-.5248158E+01
84	2.07500022E+03	1.03750011E+01	.92957352E+00	.190237388E+00	.46440992E+01	-.5294709E+01
85	2.10000022E+03	1.05000011E+01	.93053668E+00	.192246283E+00	.46317693E+01	-.5339131E+01
86	2.12500023E+03	1.06250011E+01	.93140344E+00	.19422413E+00	.46187354E+01	-.5381421E+01
87	2.15000023E+03	1.07500011E+01	.93217987E+00	.19617088E+00	.46050081E+01	-.5421552E+01
88	2.17500023E+03	1.08750012E+01	.9328627E+00	.1980877E+00	.45906893E+01	-.5459535E+01
89	2.20000023E+03	1.10000012E+01	.93345158E+00	.20003407E+00	.45757794E+01	-.549537E+01
90	2.22500024E+03	1.11250012E+01	.93394778E+00	.20193814E+00	.45602803E+01	-.552907E+01
91	2.25000024E+03	1.12500012E+01	.93435864E+00	.20378143E+00	.45442031E+01	-.556064E+01
92	2.27500024E+03	1.13750012E+01	.93468313E+00	.20556406E+00	.4527549E+01	-.559013E+01
93	2.30000024E+03	1.15000012E+01	.93492534E+00	.20728614E+00	.45103281E+01	-.561754E+01
94	2.32500024E+03	1.16250012E+01	.935091794E+00	.2089479E+00	.44925505E+01	-.564286E+01

95	.235000025E+03	.117500012E+01	.981406170E+00	.212493757E+01	.465756120E+01	.339731621E+01
96	.237500025E+03	.118750013E+01	.985898812E+00	.214465266E+01	.467069047E+01	.343993620E+01
97	.240000026E+03	.120000013E+01	.990346117E+00	.216419724E+01	.468337717E+01	.348208137E+01
98	.242500026E+03	.121250013E+01	.994714070E+00	.218362842E+01	.46955551E+01	.352394022E+01
99	.245000026E+03	.122500013E+01	.999003991E+00	.220300642E+01	.470780842E+01	.356567022E+01
100	.247500026E+03	.123750013E+01	.100324756E+01	.222237595E+01	.471948844E+01	.360731288E+01
101	.250000027E+03	.125000013E+01	.100749339E+01	.224175357E+01	.473099420E+01	.364892358E+01
102	.252500027E+03	.126250013E+01	.101178958E+01	.226112392E+01	.474262794E+01	.369043038E+01
103	.255000027E+03	.127500014E+01	.101616755E+01	.228044531E+01	.475428129E+01	.373175645E+01
104	.257500027E+03	.128750014E+01	.102063128E+01	.229966212E+01	.476592910E+01	.377283068E+01
105	.260000028E+03	.130000014E+01	.102515423E+01	.231872035E+01	.477750205E+01	.381361156E+01
106	.262500028E+03	.131250014E+01	.102968403E+01	.233750211E+01	.478890976E+01	.385410674E+01
107	.265000028E+03	.132500014E+01	.103433124E+01	.235623350E+01	.480008844E+01	.389437675E+01
108	.267500028E+03	.133750014E+01	.103849251E+01	.237470005E+01	.481094547E+01	.393432444E+01
109	.270000029E+03	.135000014E+01	.104264427E+01	.239302110E+01	.482147626E+01	.397467580E+01
110	.272500029E+03	.136250014E+01	.104657404E+01	.241126474E+01	.48316971E+01	.401493478E+01
111	.275000029E+03	.137500015E+01	.105027463E+01	.242954688E+01	.484150239E+01	.405344191E+01
112	.277500030E+03	.138750015E+01	.105376721E+01	.244781124E+01	.485089543E+01	.409023472E+01
113	.280000030E+03	.140000015E+01	.105709597E+01	.246623678E+01	.485987820E+01	.412539975E+01
114	.282500030E+03	.141250015E+01	.106031964E+01	.248482054E+01	.486845700E+01	.415986700E+01
115	.285000030E+03	.142500015E+01	.106335015E+01	.250350445E+01	.487663788E+01	.419270835E+01
116	.287500031E+03	.143750015E+01	.10669941E+01	.252224746E+01	.48844169E+01	.422417908E+01
117	.290000031E+03	.145000015E+01	.106995814E+01	.254146556E+01	.48917902E+01	.425431978E+01
118	.292500031E+03	.146250015E+01	.107330504E+01	.256054592E+01	.489876385E+01	.42831885E+01
119	.295000032E+03	.147500015E+01	.107674842E+01	.257963203E+01	.49053397E+01	.431094971E+01
120	.297500032E+03	.148750015E+01	.108027944E+01	.259874127E+01	.491153691E+01	.433759011E+01
121	.300000032E+03	.150000016E+01	.108387434E+01	.261778034E+01	.491735810E+01	.436313484E+01
122	.302500032E+03	.151250016E+01	.108750242E+01	.263674866E+01	.492280424E+01	.438768425E+01
123	.305000032E+03	.152500016E+01	.109112851E+01	.265563984E+01	.492789244E+01	.441124732E+01
124	.307500033E+03	.153750016E+01	.109471950E+01	.267443494E+01	.493262464E+01	.443392422E+01
125	.310000033E+03	.155000016E+01	.109828450E+01	.269322744E+01	.493700284E+01	.445561522E+01
126	.312500033E+03	.156250017E+01	.11018673E+01	.27119763E+01	.494102704E+01	.447632022E+01
127	.315000033E+03	.157500017E+01	.110550596E+01	.273070487E+01	.494470824E+01	.449604922E+01
128	.317500034E+03	.158750017E+01	.110933166E+01	.274940377E+01	.494804644E+01	.451489222E+01
129	.320000034E+03	.160000017E+01	.11133281E+01	.276815372E+01	.495104264E+01	.453284922E+01
130	.322500034E+03	.161250017E+01	.111746796E+01	.27872262E+01	.495369684E+01	.454992222E+01
131	.325000035E+03	.162500017E+01	.112179632E+01	.280622866E+01	.495600804E+01	.456611122E+01
132	.327500035E+03	.163750017E+01	.112608874E+01	.28253280E+01	.495797624E+01	.458141622E+01
133	.330000035E+03	.165000018E+01	.113042466E+01	.28445215E+01	.495950044E+01	.459583722E+01
134	.332500035E+03	.166250018E+01	.113472203E+01	.28638065E+01	.496068064E+01	.460937222E+01
135	.335000036E+03	.167500018E+01	.113908001E+01	.28831497E+01	.496151684E+01	.462201322E+01
136	.337500036E+03	.168750018E+01	.114337724E+01	.290255035E+01	.496200904E+01	.463376022E+01
137	.340000036E+03	.170000018E+01	.114771710E+01	.292192866E+01	.496225724E+01	.464461322E+01
138	.342500036E+03	.171250018E+01	.115202902E+01	.29414251E+01	.496225724E+01	.465457222E+01
139	.345000037E+03	.172500018E+01	.115642290E+01	.296065809E+01	.496200904E+01	.466363722E+01
140	.347500037E+03	.173750018E+01	.116086938E+01	.298026382E+01	.496151684E+01	.467181822E+01
141	.350000037E+03	.175000019E+01	.116537124E+01	.299946276E+01	.496077064E+01	.467911522E+01
142	.352500037E+03	.176250019E+01	.116992967E+01	.301843669E+01	.495968244E+01	.468552822E+01
143	.355000038E+03	.177500019E+01	.117459958E+01	.303714000E+01	.495825724E+01	.469105722E+01
144	.357500038E+03	.178750019E+01	.117932891E+01	.305568382E+01	.495649204E+01	.469570222E+01
145	.360000038E+03	.180000019E+01	.118412874E+01	.30739700E+01	.495438684E+01	.469946322E+01
146	.362500039E+03	.181250019E+01	.118900007E+01	.309200882E+01	.495194164E+01	.470234022E+01
147	.365000039E+03	.182500019E+01	.119394490E+01	.31108001E+01	.494915644E+01	.470433322E+01
148	.367500039E+03	.183750020E+01	.119895423E+01	.312946882E+01	.494603124E+01	.470544222E+01
149	.370000039E+03	.185000020E+01	.120402906E+01	.31479481E+01	.494256604E+01	.470566722E+01
150	.372500040E+03	.186250020E+01	.120916989E+01	.316623882E+01	.493876084E+01	.470500822E+01
151	.375000040E+03	.187500020E+01	.121436972E+01	.31843411E+01	.493461564E+01	.470346522E+01
152	.377500040E+03	.188750020E+01	.121962955E+01	.320225582E+01	.493013044E+01	.470103822E+01
153	.380000040E+03	.190000020E+01	.122494938E+01	.32200721E+01	.492530524E+01	.469772722E+01
154	.382500041E+03	.191250020E+01	.123032921E+01	.323778982E+01	.492014004E+01	.469353222E+01
155	.385000041E+03	.192500020E+01	.123576904E+01	.32554085E+01	.491463484E+01	.468845322E+01
156	.387500041E+03	.193750021E+01	.124126887E+01	.327292822E+01	.490877964E+01	.468249022E+01
157	.390000041E+03	.195000021E+01	.124682870E+01	.32903479E+01	.490258444E+01	.467564322E+01
158	.392500042E+03	.196250021E+01	.125244853E+01	.330766762E+01	.489604924E+01	.466791222E+01
159	.395000042E+03	.197500021E+01	.125812836E+01	.33247873E+01	.488917404E+01	.465929722E+01
160	.397500042E+03	.198750021E+01	.126386819E+01	.334170702E+01	.488195884E+01	.464980822E+01
161	.400000043E+03	.200000021E+01	.126966802E+01	.33584267E+01	.487440364E+01	.463944522E+01

Appendix B3 - Results from Unsteady Calculations for Aeroelastic Motion

XTRAN2L Input

```

NACA 64A010 AMES AINFUL M=0.780 ALFZRN=1.0 U/C=330.0 AEMOELASTIC
SAEROEL IRESP=1, DELT=0.00050, UCM=330.0, NELA=31, SEND
SINPUT XM=0.780, IHEAD=5, MAXIT=1024, NSPC=128, ICHRNT=128, IDUP=1,
DEL=0.10, XAH=0.25, ALFZMU=1.00, ALFONE=0.00, SEND
SMESH 3
SAMPL 3
SORD NINU = 51, NINL = 51,
XINU =
.000000, .020000, .040000, .060000, .080000, .100000, .120000, .140000,
.160000, .180000, .200000, .220000, .240000, .260000, .280000,
.300000, .340000, .360000, .380000, .400000, .420000, .440000,
.460000, .500000, .520000, .540000, .560000, .580000, .600000,
.640000, .660000, .680000, .700000, .720000, .740000, .760000,
.800000, .820000, .840000, .860000, .880000, .900000, .920000,
.940000, .960000, .980000, 1.000000,
ZINU =
.010144, .016499, .022381, .026732, .030412, .033687, .036532, .039115,
.041413, .043449, .045256, .046874, .048300, .049535, .050589, .051485,
.052232, .052792, .053113, .053200, .053113, .052905, .052535, .051921,
.051053, .049999, .048815, .047506, .046076, .044524, .042863, .041114,
.039280, .037367, .035385, .033343, .031251, .029124, .026980, .024828,
.022672, .020513, .018343, .016152, .013956, .011794, .009643, .007538,
.005196, .002650, 0.000000,
VINU =
.666396, .373066, .247503, .201181, .174586, .150587, .130858, .121236,
.104089, .095780, .085469, .076080, .066554, .057051, .048547, .041177,
.033109, .022385, .009743, -.000503, -.007659, -.013740, -.023447, -.037534,
-.046629, -.056247, -.062229, -.066431, -.074733, -.080404, -.085320, -.089694,
-.093739, -.097436, -.100687, -.103473, -.105608, -.106902, -.107459, -.107720,
-.107831, -.106131, -.104983, -.110036, -.109200, -.106129, -.105359, -.111450,
-.122939, -.130770, -.133386,
XINL =
.000000, .020000, .040000, .060000, .080000, .100000, .120000, .140000,
.160000, .180000, .200000, .220000, .240000, .260000, .280000,
.300000, .340000, .360000, .380000, .400000, .420000, .440000,
.460000, .500000, .520000, .540000, .560000, .580000, .600000,
.640000, .660000, .680000, .700000, .720000, .740000, .760000,
.800000, .820000, .840000, .860000, .880000, .900000, .920000,
.940000, .960000, .980000, 1.000000,
ZINL =
-.009941, -.016596, -.022527, -.026839, -.030529, -.033748, -.036542, -.039014,
-.041272, -.043251, -.045019, -.046644, -.048113, -.049593, -.050881, -.051993,
-.052136, -.052706, -.053081, -.053256, -.053246, -.053044, -.052654, -.052038,
-.051206, -.050192, -.049027, -.047730, -.046317, -.044793, -.043155, -.041401,
-.039558, -.037654, -.035699, -.033678, -.031584, -.029437, -.027265, -.025083,
-.022891, -.020688, -.018469, -.016224, -.013974, -.011722, -.009482, -.007215,
-.004875, -.002450, 0.000000,
VINL =
.755623, .364001, .245107, .199126, .169990, .147623, .134034, .117215,
.105643, .092960, .084615, .077616, .069016, .059127, .049812, .041371,
.032950, .023693, .013753, .004037, .005245, .014597, .025101, .036447,
.046437, .054702, .061645, .067874, .073371, .079002, .084907, .090160,
.093908, .096372, .099285, .102933, .106255, .108179, .108874, .109377,
.109658, .110486, .111425, .112519, .112822, .112177, .112272, .114804,
.119226, .122216, .123215,
SEND
SCOND 3

```

Appendix B3 - Concluded

XTRAN2L Output

NACA 64A010 AMES AIRFOIL M80,780 ALPZRO=1.0 U/C=330.0 AEROELASTIC

AEROELASTIC SYSTEM

IREBP	1	AEROELASTIC TRANSIENT	NELAST	1	2-DOF ; PLUNGE AND PITCH
UC	330,00000	NONDIMENSIONAL VELOCITY	MRU	60,00000	MASS RATIO
DELT	0,00050	TIME STEP, SECONDS	IEQPLG	5	EXTNAM EQUATION
AMPLTD	0,01745	AMPLITUDE OF PULSE	WTHMPLS	10000,0	PULSE EXPONENTIAL FACTOR
TZEROST	17,50000	CENTER OF PULSE	XALPHA	1,80000	DIST FROM ELAST AXIS TO INFL MASS CENTER
XALPHA	1,86500	AIRFOIL RADIUS OF GYRATION	OMEGAH	100,00000	UNCOUPLED PLUNGE NAT FREQ (RAD/SEC)
OMEGAA	100,00000	UNCOUPLED PITCH NAT FREQ (RAD/SEC)	AM	2,00000	ELASTIC AXIS LOCATION

INPUT PARAMETERS

KK	0,29750	REDUCED FREQUENCY BASED ON CHORD	M	0,78000	MEAN FREE-STREAM MACH NO.
GAM	1,40000	RATIO OF SPECIFIC HEATS	ICNVNG	1	GET 8=8 SOL, UN GUARD, THEN FINER GRID
IREAD	5	READ INITIAL CONDITIONS	NSPC	128	NO. STEPS PER CYCLE
MAXIT	1024	MAX. NO. TIME STEPS	ISICU	0	SINUSOIDAL VARIATION
ITRAN	0	PITCH, PLUNGE, FLAP MOTION	IDUP	1	OUTPUT TO LU 8
ICPRNT	124	ITERATION PRINT INCREMENT FOR CP	JLAST	66	LAST CHORDWISE GRIDPT FOR CP PRINTING
JFIRST	16	FIRST CHORDWISE GRIDPT FOR CP PRINTING	IN	1	TIME-DERIV. IN AIRFOIL B.C.
LIN	0	LINEARIZED CP	XAN	0,50000	POSITION OF PITCH AXIS
DEL	0,10000	AIRFOIL THICKNESS RATIO	ALPUME	0,00000	PITCHING AMPLITUDE
ALPZRO	1,00000	MEAN ANGLE OF ATTACK	IMDDFN	1	TIME-DERIVATIVE IN WAKE CONDITION
Z1	0,00000	PLUNGE AMPLITUDE	NSUP	1,00000	SUPERSONIC RELAXATION FACTOR
RSUB	1,40000	SUBSONIC RELAXATION FACTOR	TOLC	0,10E-04	TOLERANCE PARAMETERS IN STEADY
MITC	500	MAXIMUM NUMBER OF ITERATIONS	TOLM	0,10E-05	CALCULATIONS UN GUARD, FINE
MITH	100	UN GUARD, FINE AND EXT, FINE GRID	TOLF	0,10E-05	AND EXT, FINE GRID RESPECTIVELY
MITEP	25	RESPECTIVELY	LINDIF	0	NLW=TSP EQUATION (WITH NON-LINEAR TERM)
ICPRUN	0	NO REQUEST FOR OUTPUT OF UNSTEADY PRESSURES			
ICPT	1	TIME-DEH, CONTRIBUTES TO CP AND MACH, IF IRN1			
N	1	NUMBER OF (CO)SIN HARMONICS			
MULTIPLIERS OF (CO)SIN HARMONICS	1,00000				

THE A MATRIX IS:

```
      4      4
0.      0.      .1000E+01 0.
0.      0.      0.      .1000E+01
-.1000E+05 0.      0.      0.
0.      -.86956E+04 0.      0.
```

THE B MATRIX IS:

```
      4      2
0.      0.
0.      0.
.1000E+01 0.
0.      .1000E+01
```

THE C MATRIX IS:

```
      4      4
.1000E+01 0.      0.      0.
0.      .1000E+01 0.      0.
0.      0.      .1000E+01 -.9000E+00
0.      0.      -.9000E+00 .86956E+00
```

MATRIX ENTERING INVMX IS:

```
      4      4
.1000E+01 0.      0.      0.
0.      .1000E+01 0.      0.
0.      0.      .1000E+01 -.9000E+00
0.      0.      -.9000E+00 .86956E+00
```

INVENSE OF MATRIX IS:

```
      4      4
.1000E+01 0.      0.      0.
0.      .1000E+01 0.      0.
0.      0.      .14601E+02 .15112E+02
0.      0.      .15112E+02 .16791E+02
```

THE REDUCED SYSTEM IS =

THE A MATRIX IS:

```
      4      4
0.      0.      .1000E+01 0.
0.      0.      0.      .1000E+01
-.14601E+06 -.13141E+06 0.      0.
-.15112E+06 -.14601E+06 0.      0.
```

THE B MATRIX IS:

```
      4      2
0.      0.
0.      0.
.14601E+02 .15112E+02
.15112E+02 .16791E+02
```

THE TRANSITION MATRIX 7 TENMS IS:

```
      4      4
.98186E+00 -.16326E+01 .49697E-03 -.27276E-03
-.15775E+01 .98186E+00 -.31368E-05 .49697E-03
-.72148E+02 -.64906E+02 .98186E+00 -.16326E+01
.74643E+02 -.72148E+02 .15775E+01 .98186E+00
```

THE INTEGRAL OF THE TRANSITION MATRIX IS:

```
      4      4
.49697E+03  .27276E+05  .12462E+06  .34137E+09
.31368E+05  .49697E+03  .39238E+09  .12462E+06
.18144E+01  .16326E+01  .49697E+03  .27276E+05
.18775E+01  .18144E+01  .31368E+05  .49697E+03
```

THE FINAL MATRICES =

THE PHI MATRIX IS:

```
      4      4
.98186E+00  .16326E+01  .49697E+03  .27276E+05
.18775E+01  .98186E+00  .31368E+05  .49697E+03
.72148E+02  .64906E+02  .98186E+00  .16326E+01
.74643E+02  .72148E+02  .18775E+01  .98186E+00
```

THE THETA=B-PRIME MATRIX IS:

```
      4      2
.18144E+05  .18775E+05
.18775E+05  .20866E+05
.72148E+02  .74643E+02
.74643E+02  .82971E+02
```

** WARNING ** NEW PITCH AXIS LOCATION (XAW) DOES NOT MATCH OLD PITCH AXIS LOCATION = CMO REDEFINED FOR INSTANT

RESTART VALUES

```
CNO = .2319429E+00
CMO = .1632505E+00
CMFO = 0.
```

THE I. C. VECTOR IS:

```
.10000E+01  0.      0.      0.      0.      0.
```

NACA 66A010 ANES AIRFOIL MHO,780 ALF/MO=1.0 U/C=130.0 AERODLASTIC

ITERATION NO. = 1 ALF (DEG) = .9892427 PLUNGE = .0098188
 TIME = 50.3145648 T (DEG) = 2682.8125000

INDEX	X	CPU	CPL	MU	ML	DCP=CPL*CPU
16	.00687	.35348	.97482	.56990	0.00000	.62154
17	.02000	.22404	.36888	.88743	.35962	.59242
18	.04000	.39579	.12895	.96181	.71106	.52474
19	.06000	.41196	.03197	.98849	.76382	.44394
20	.08000	.45095	.03140	.98446	.79641	.41453
21	.10000	.47725	.07872	.99509	.81990	.39853
22	.12000	.49496	.12247	1.00219	.84103	.37249
23	.14000	.52794	.16095	1.01529	.85917	.36649
24	.16000	.55518	.19089	1.02594	.87302	.36429
25	.18000	.57398	.21512	1.03331	.88407	.35886
26	.20000	.58794	.23834	1.03872	.89273	.35360
27	.22000	.60465	.25974	1.04516	.90405	.34891
28	.24000	.62456	.28915	1.05270	.91698	.34521
29	.26000	.64231	.31480	1.05953	.92810	.34251
30	.28000	.65506	.33485	1.06436	.93770	.34021
31	.30000	.66700	.35355	1.06887	.94665	.33845
32	.32000	.67843	.37392	1.07652	.95322	.33730
33	.34000	.68767	.39412	1.08811	.96165	.33655
34	.36000	.69428	.40926	1.09935	.96791	.33602
35	.38000	.70657	.41785	1.11063	.97144	.33572
36	.40000	.71884	.42276	1.11101	.97343	.33507
37	.42000	.72900	.42657	1.11526	.97496	.33444
38	.44000	.73917	.42520	1.12465	.97437	.33396
39	.46000	.74822	.41003	1.13427	.96808	.33318
40	.48000	.75620	.38324	1.13993	.95689	.32796
41	.50000	.76303	.35413	1.14166	.94438	.31240
42	.52000	.76554	.32644	1.13800	.93283	.29266
43	.54000	.76499	.30133	1.06278	.92183	.27438
44	.56000	.76165	.27827	.92997	.91171	.04138
45	.58000	.75550	.25652	.87467	.90206	.08102
46	.60000	.74692	.23303	.84013	.89152	.02611
47	.62000	.73470	.20470	.87916	.87454	.00194
48	.64000	.71937	.17994	.87448	.86725	.01442
49	.66000	.70688	.15661	.86731	.85635	.02207
50	.68000	.69548	.13624	.85843	.84672	.02328
51	.70000	.68390	.11493	.84834	.83633	.02247
52	.72000	.67148	.09081	.83740	.82484	.02400
53	.74000	.65913	.06566	.82616	.81246	.02570
54	.76000	.64666	.04230	.81521	.80043	.02656
55	.78000	.63459	.02115	.80474	.79012	.02643
56	.80000	.62229	.00120	.79462	.77969	.02610
57	.82000	.60757	.01833	.78465	.76973	.02540
58	.84000	.59316	.03850	.77405	.75911	.02534
59	.86000	.57707	.06065	.76162	.74727	.02557
60	.88000	.56261	.08461	.74801	.73425	.02161
61	.90000	.54817	.10836	.73653	.72110	.02421
62	.92000	.53497	.13194	.72806	.70783	.02220
63	.94000	.52103	.16047	.71630	.69143	.03444
64	.96000	.50670	.20309	.69034	.66621	.03639
65	.98000	.48862	.27101	.64108	.62394	.02240
66	1.00000	.38600	.39324	.54859	.53967	.00725

FORCE COEFFICIENTS AT ANGLE OF ATTACK = .9892427 PLUNGE DISP. = .0098188
 AIRFOIL PITCHING MOMENT (ABOUT X = .30000) = .1811804E+00 NORMAL FORCE = .2307509E+00 AXIAL FORCE = -.0338438E+02

NACA 64A010 AMES AIRFOIL M=0.780 ALFZMO=1.0 U/CW=350.0 AERODELASTIC

ITERATION NO. = 1024 ALF (DEG) = .6718140 PLUNGE = .0044074
 TIME = 100.3509649 T (DEG) = 5760.0000000

INDEX	X	CPU	CPL	MU	ML	DCP=CPL-CPU
16	.00667	.41625	.91995	.52420	0.00000	.50369
17	.02000	.15552	.31405	.85618	.54739	.46957
18	.04000	.35661	.08223	.93708	.73673	.41684
19	.06000	.36342	-.00814	.94645	.78439	.35246
20	.08000	.40359	-.06824	.96526	.81456	.33335
21	.10000	.43366	-.11324	.97773	.83644	.32061
22	.12000	.45584	-.15533	.98668	.85640	.30050
23	.14000	.48749	-.19243	.99944	.87362	.29507
24	.16000	.51758	-.22099	1.01142	.88686	.29639
25	.18000	.53850	-.24391	1.01966	.89699	.29859
26	.20000	.54965	-.26176	1.02411	.90496	.28808
27	.22000	.56572	-.28643	1.03029	.91584	.27929
28	.24000	.58775	-.31561	1.03882	.92855	.27215
29	.26000	.60864	-.34099	1.04664	.93947	.26785
30	.28000	.62226	-.36052	1.05203	.94779	.26175
31	.30000	.63375	-.37872	1.05639	.95549	.25503
32	.32000	.65409	-.39899	1.06407	.96398	.25509
33	.34000	.66609	-.41940	1.07005	.97246	.26669
34	.36000	.71730	-.43433	1.08761	.97863	.28296
35	.38000	.73623	-.44188	1.09455	.98175	.29435
36	.40000	.74538	-.44531	1.09789	.98318	.30007
37	.42000	.75842	-.44771	1.10264	.98419	.31071
38	.44000	.78386	-.44441	1.11183	.98288	.33945
39	.46000	.80931	-.42605	1.12096	.97540	.38325
40	.48000	.82011	-.39601	1.12480	.96301	.42410
41	.50000	.79762	-.36459	1.11673	.94986	.45304
42	.52000	.59080	-.33549	1.03973	.93753	.25531
43	.54000	.33179	-.30885	.93424	.92609	.02294
44	.56000	.26350	-.28475	.90446	.91562	-.02126
45	.58000	.26919	-.26211	.90696	.90567	.00708
46	.60000	.26045	-.23778	.90308	.89485	.02267
47	.62000	.24466	-.21061	.89603	.88261	.03405
48	.64000	.22501	-.18321	.88718	.87009	.04141
49	.66000	.20289	-.15928	.87710	.85901	.04357
50	.68000	.17908	-.13839	.86615	.84922	.04066
51	.70000	.15421	-.11660	.85459	.83888	.03761
52	.72000	.12870	-.09202	.84251	.82706	.03669
53	.74000	.10346	-.06643	.83041	.81457	.03703
54	.76000	.07960	-.04267	.81880	.80240	.03843
55	.78000	.05729	-.02118	.80761	.79201	.03611
56	.80000	.03619	-.00091	.79726	.78168	.03329
57	.82000	.01562	.01891	.78696	.77146	.03173
58	.84000	.00543	.03935	.77608	.76076	.03392
59	.86000	.02478	.06175	.76338	.74887	.03197
60	.88000	.05568	.08596	.74955	.73579	.03008
61	.90000	.07755	.10994	.73769	.72261	.03240
62	.92000	.09337	.13369	.72925	.70931	.04032
63	.94000	.11490	.16240	.71733	.69289	.04750
64	.96000	.16078	.20519	.69123	.66767	.04440
65	.98000	.24244	.27330	.64188	.62543	.03043
66	1.00000	.36294	.39377	.54750	.54275	.01083

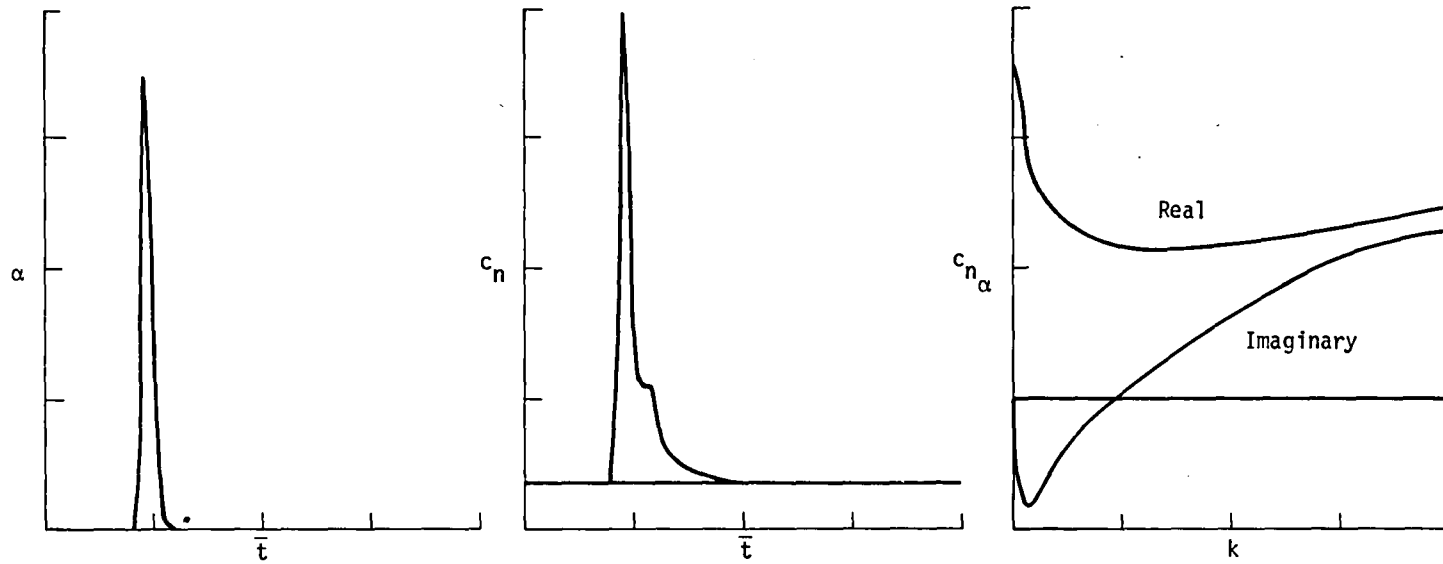
FORCE COEFFICIENTS AT ANGLE OF ATTACK = .6718140

PLUNGE DISP. = .0044074

AIRFOIL PITCHING MOMENT (ABOUT X = .50000) = .1502362E+00

NORMAL FORCE = .1887418E+00

AXIAL FORCE = -.0042326E+02



(a) Pulse input.

(b) Force output.

(c) Unsteady force response.

Fig. 1 Pulse transfer-function analysis for unsteady aerodynamic forces;

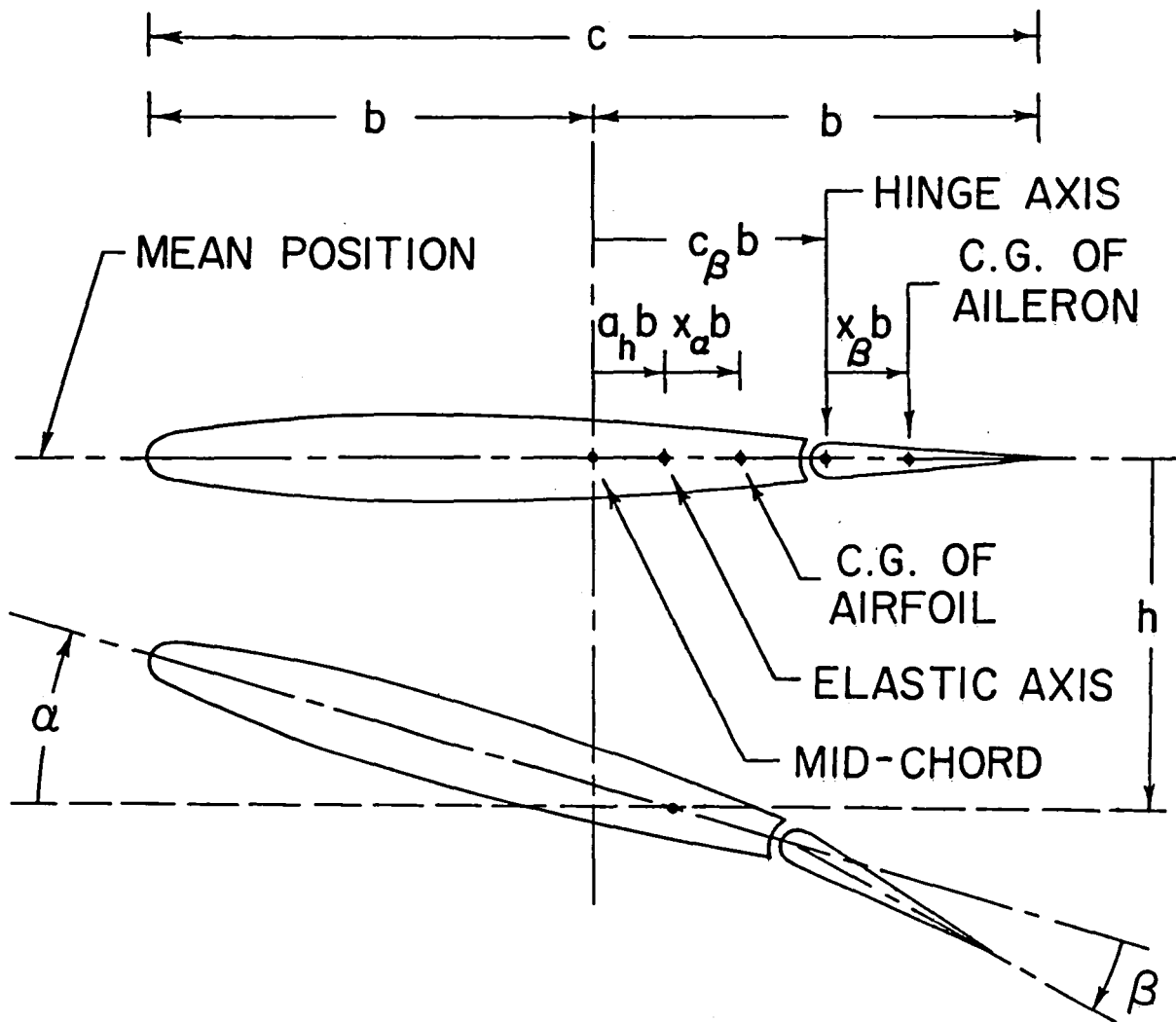


Fig. 2 Definition of structural parameters for three degree-of-freedom aeroelastic analysis.

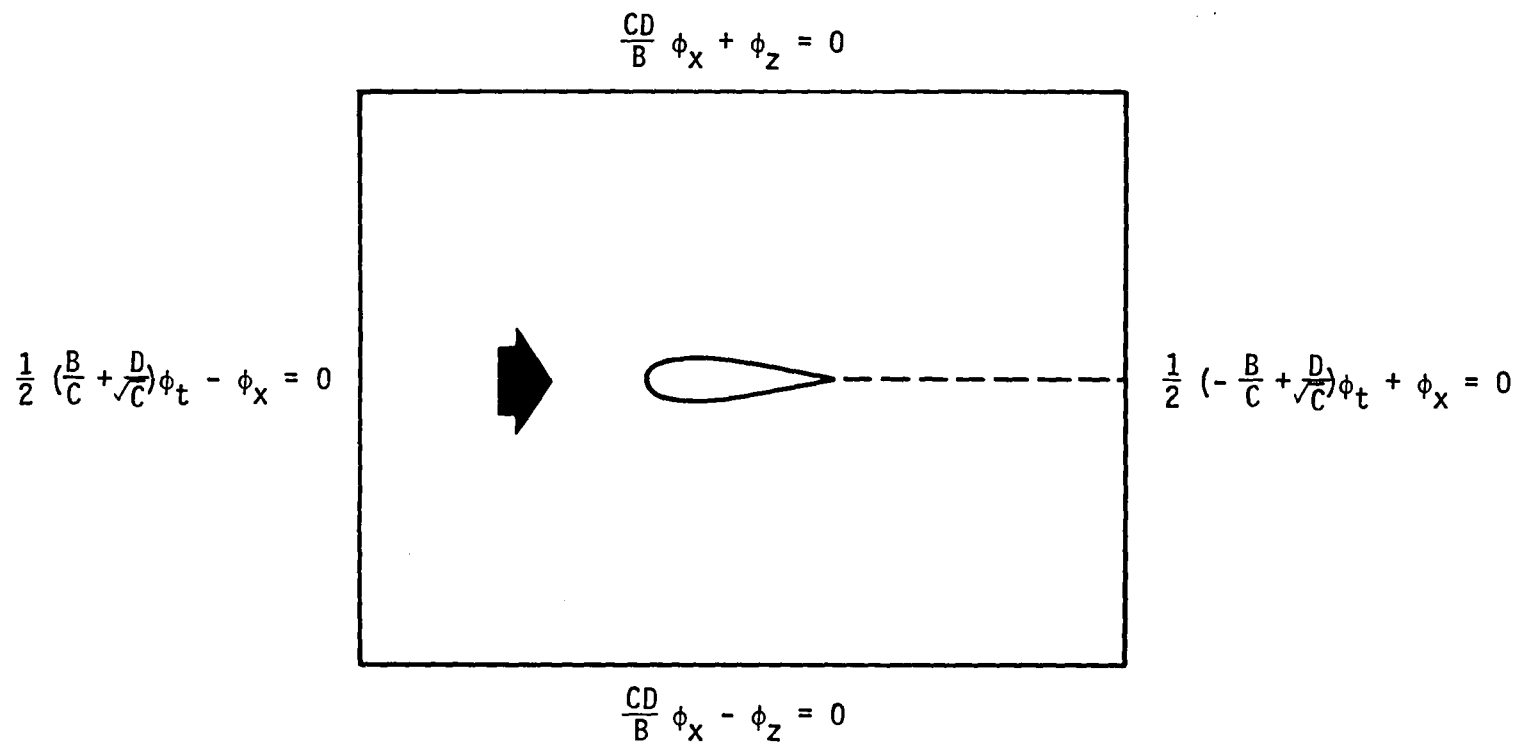


Fig. 3 Nonreflecting farfield boundary conditions.

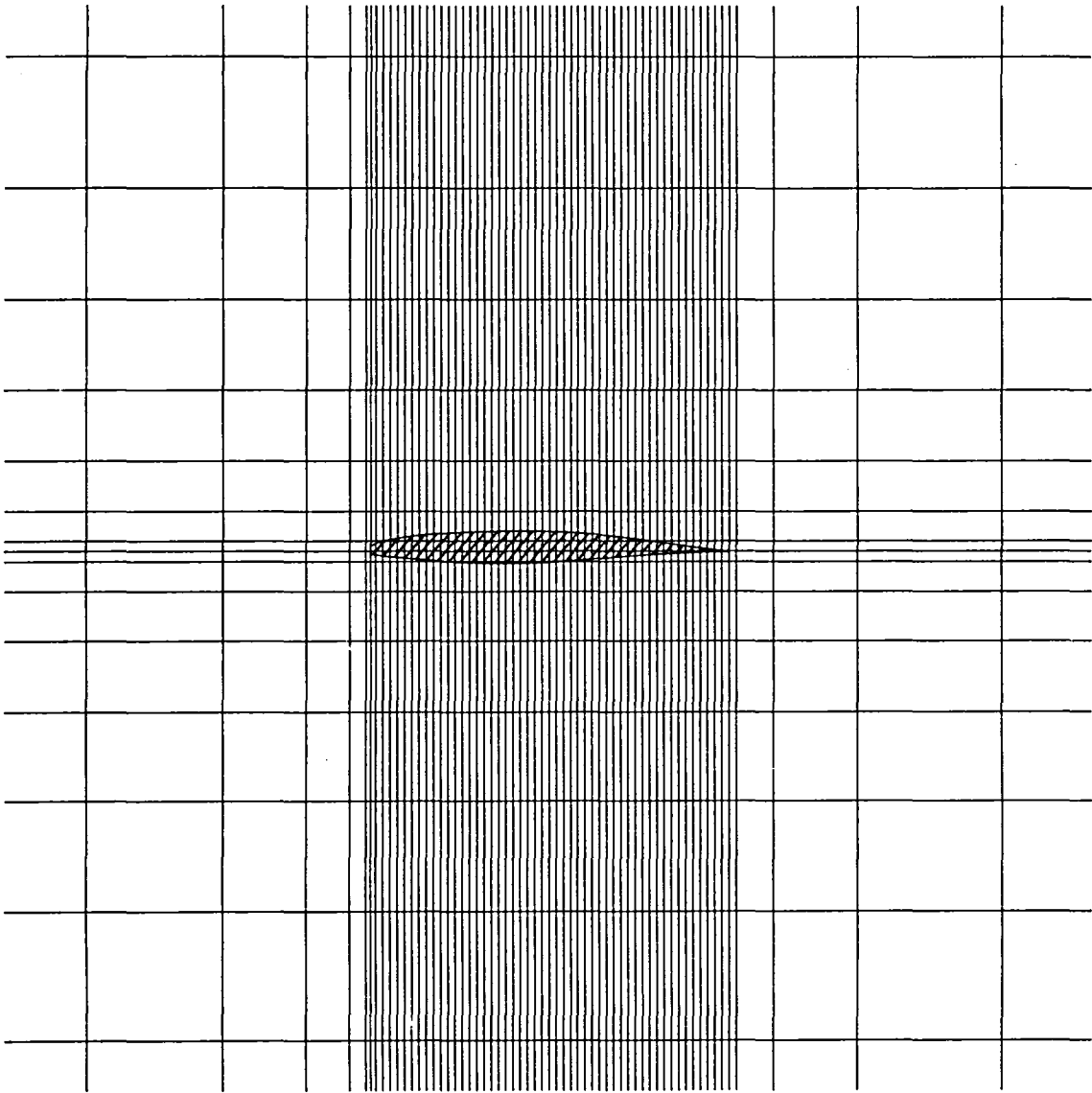
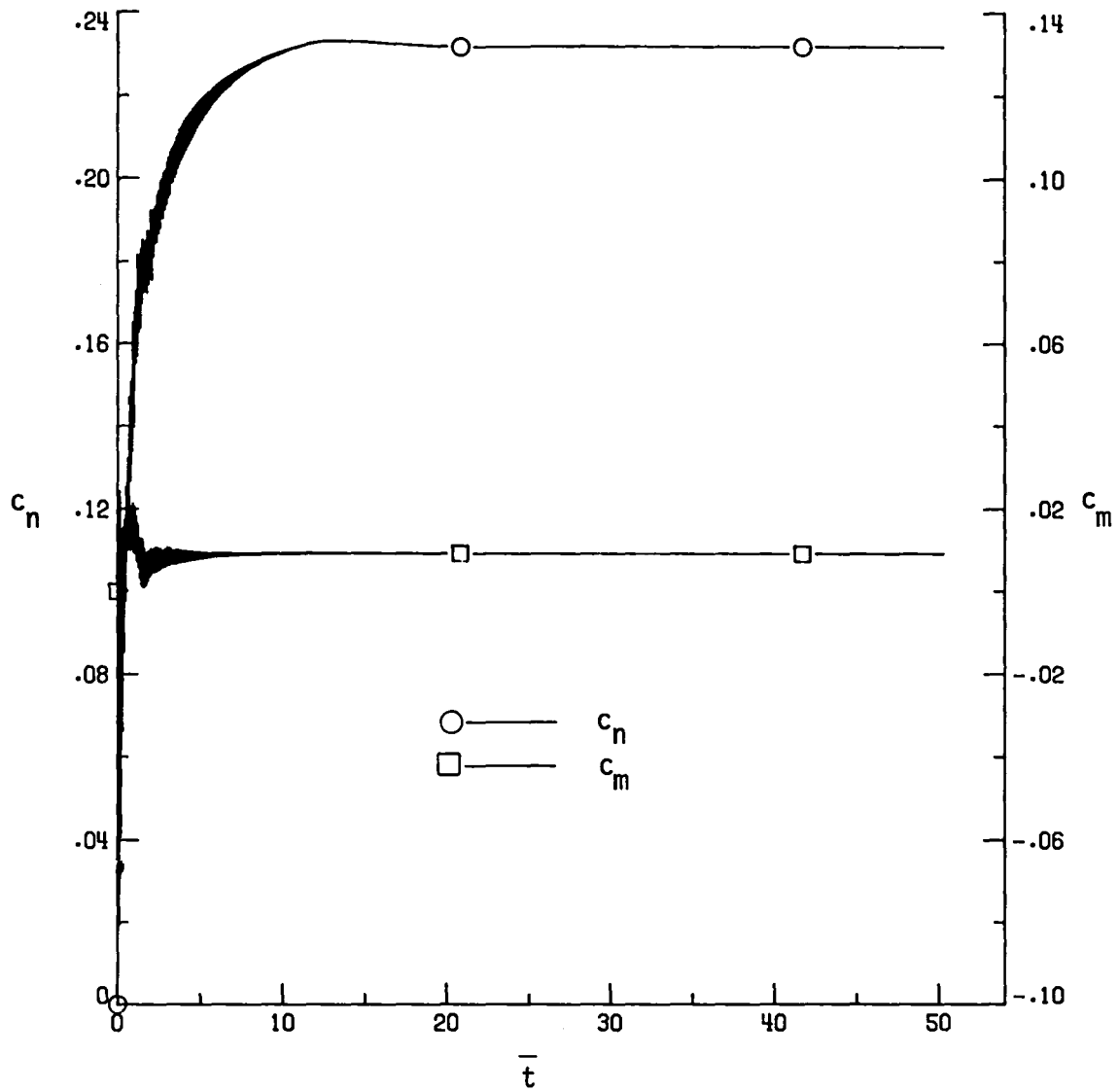
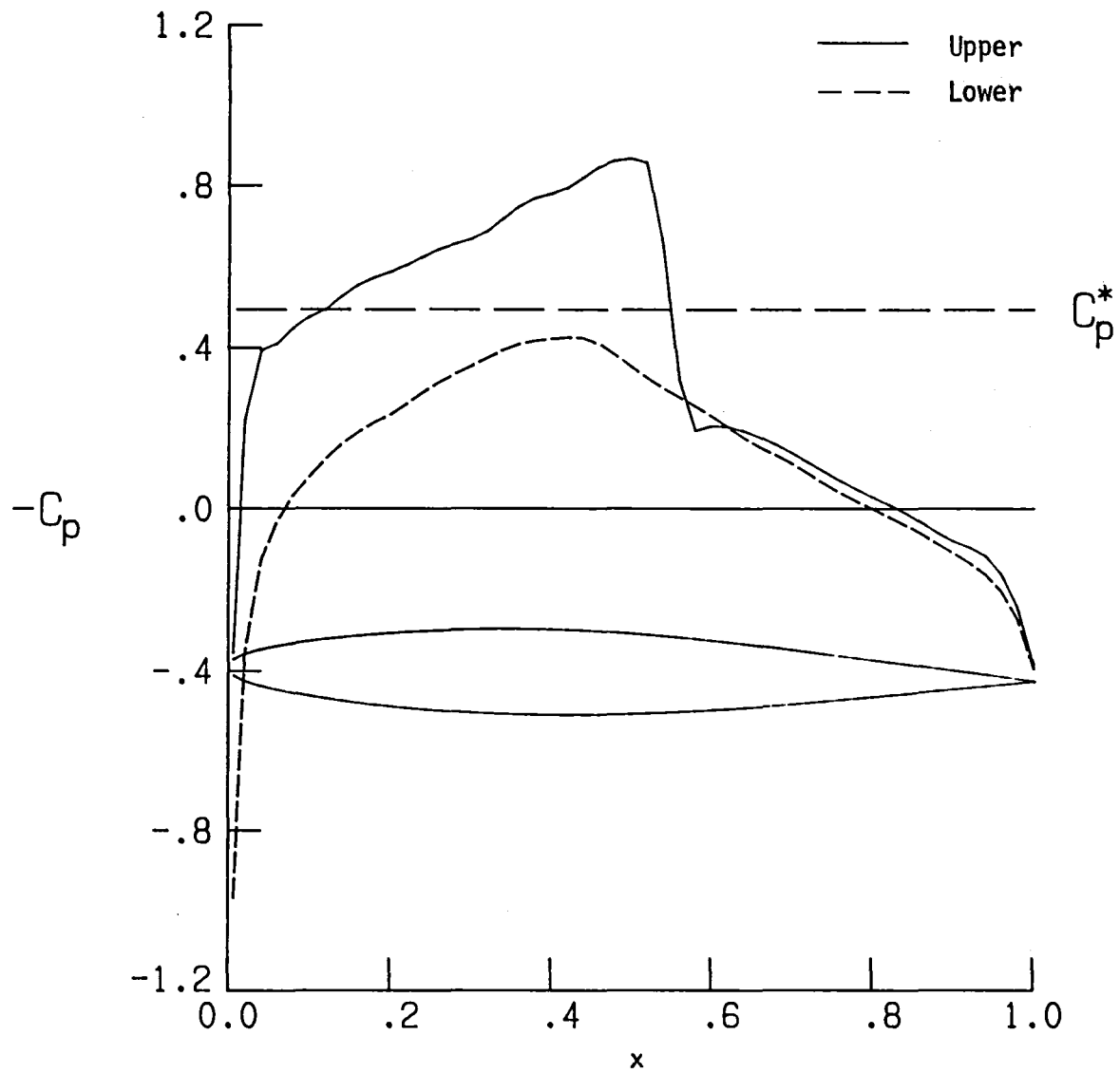


Fig. 4 XTRAN2L default grid near airfoil.



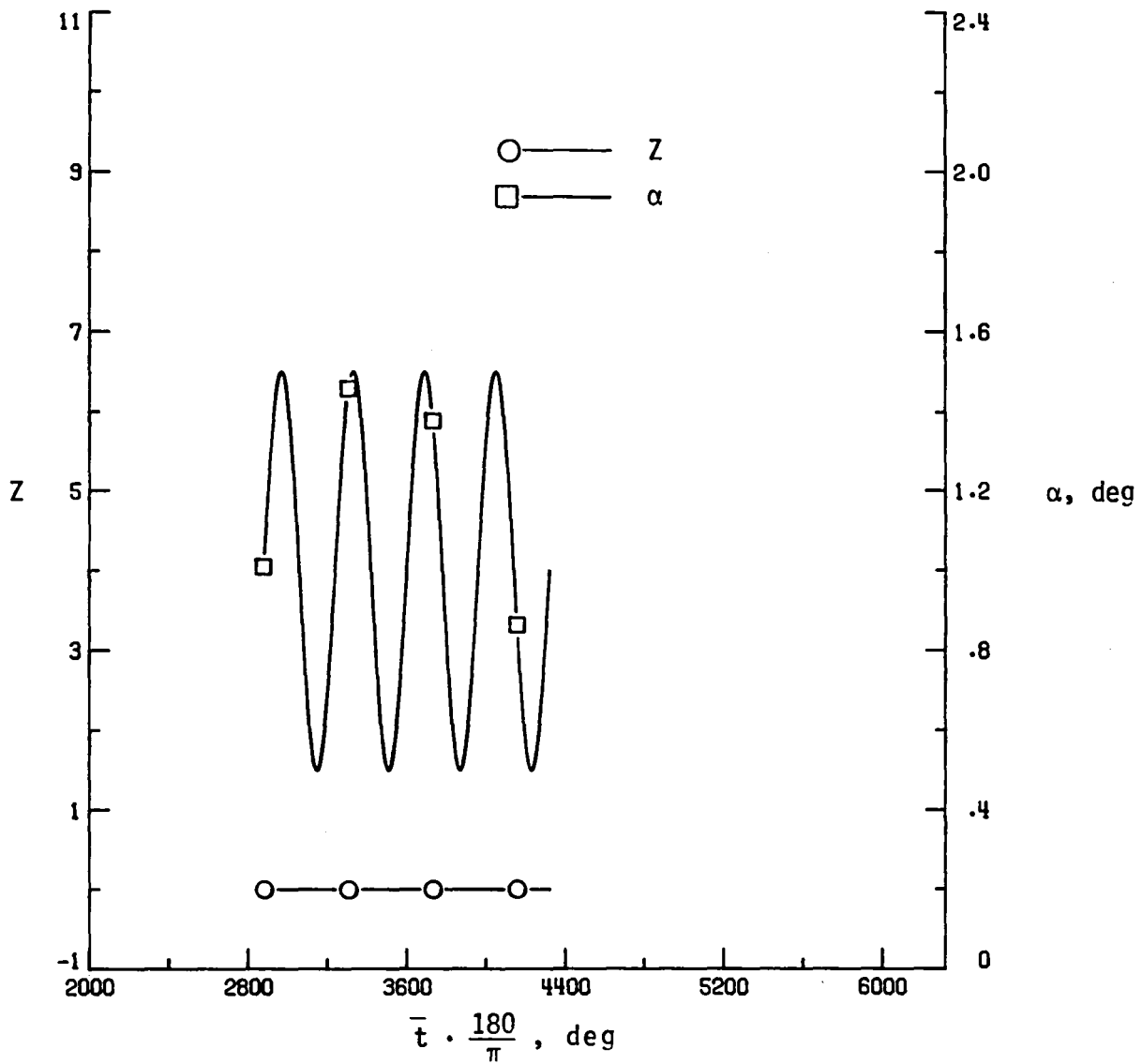
(a) Normal force coefficient and pitching moment coefficient time histories.

Fig. 5 Results from steady calculations (no airfoil motion, IRESP = 5) for the NACA 64A010A airfoil at $M_\infty = 0.78$ and $\alpha_0 = 1.0^\circ$;



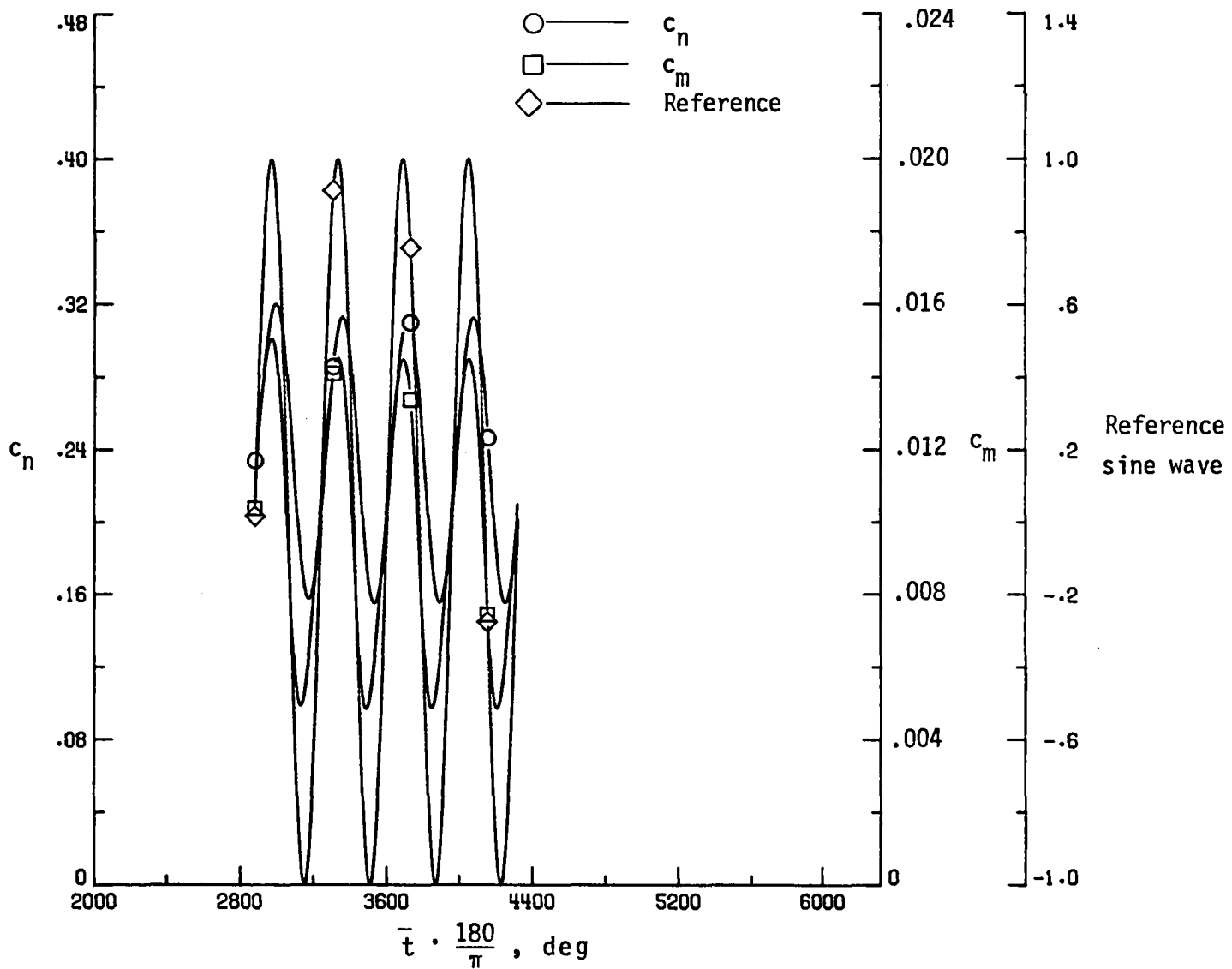
(b) Steady pressure distribution.

Fig. 5 Concluded.



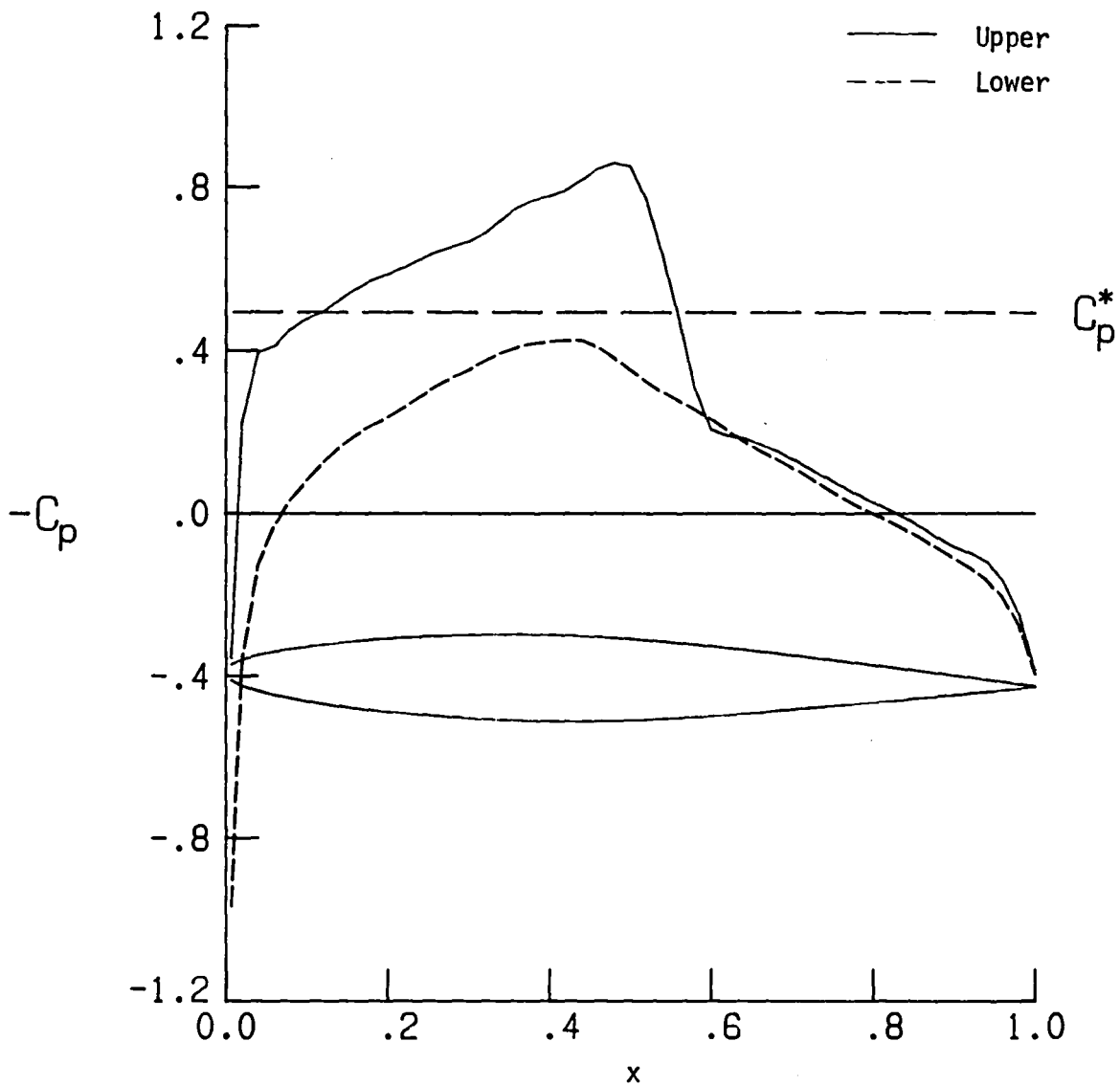
(a) Four cycles of simple harmonic pitching motion about the quarter-chord.

Fig. 6 Results from unsteady calculations due to harmonic pitching motion (IRES P = 0) for the NACA 64A010A airfoil at $M_\infty = 0.78$, $\alpha_0 = 1.0^\circ$, $k = 0.075$, and $\alpha_1 = 0.5^\circ$;



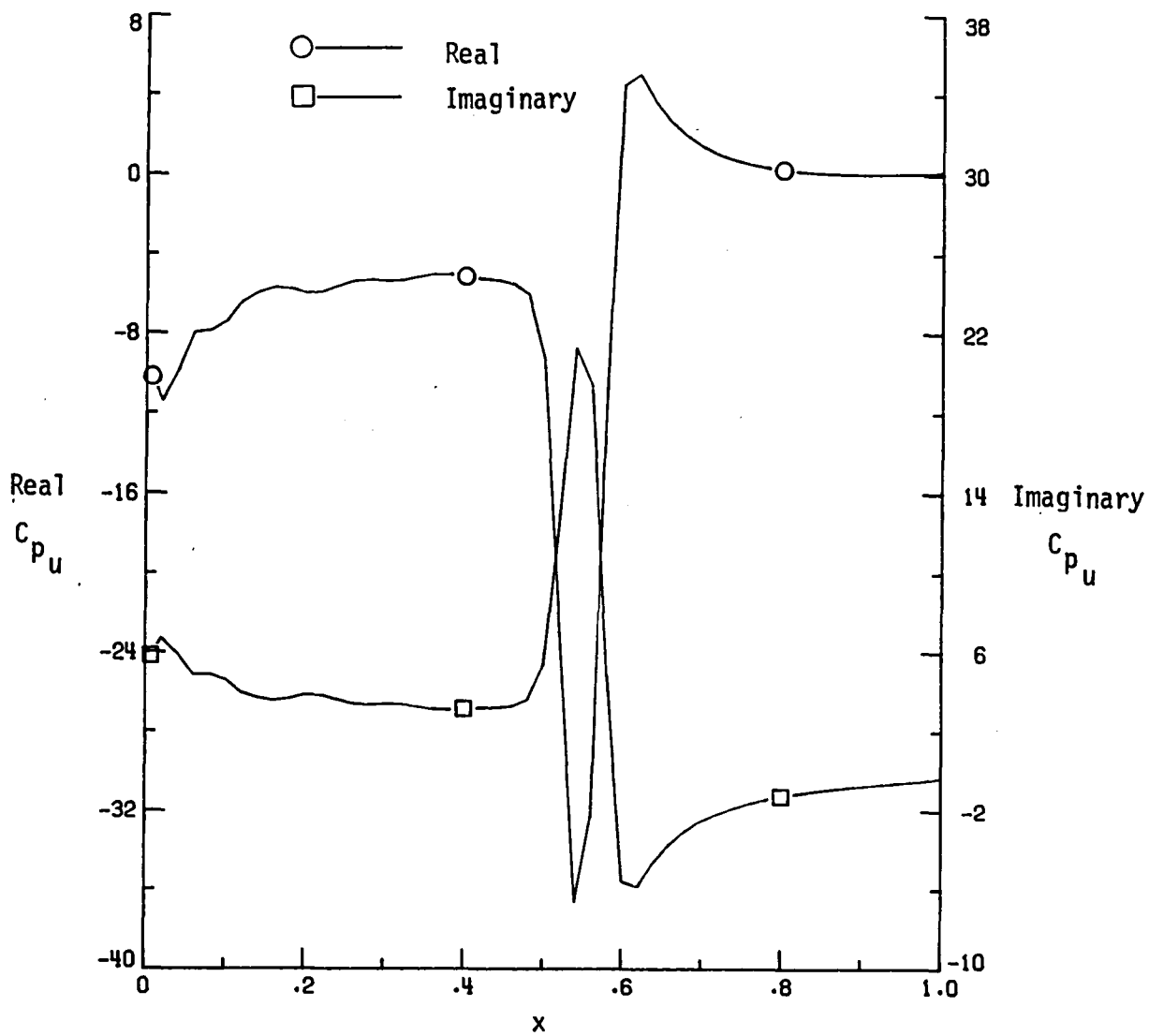
(b) Resulting normal force coefficient, pitching moment coefficient, and reference sine wave.

Fig. 6 Continued.



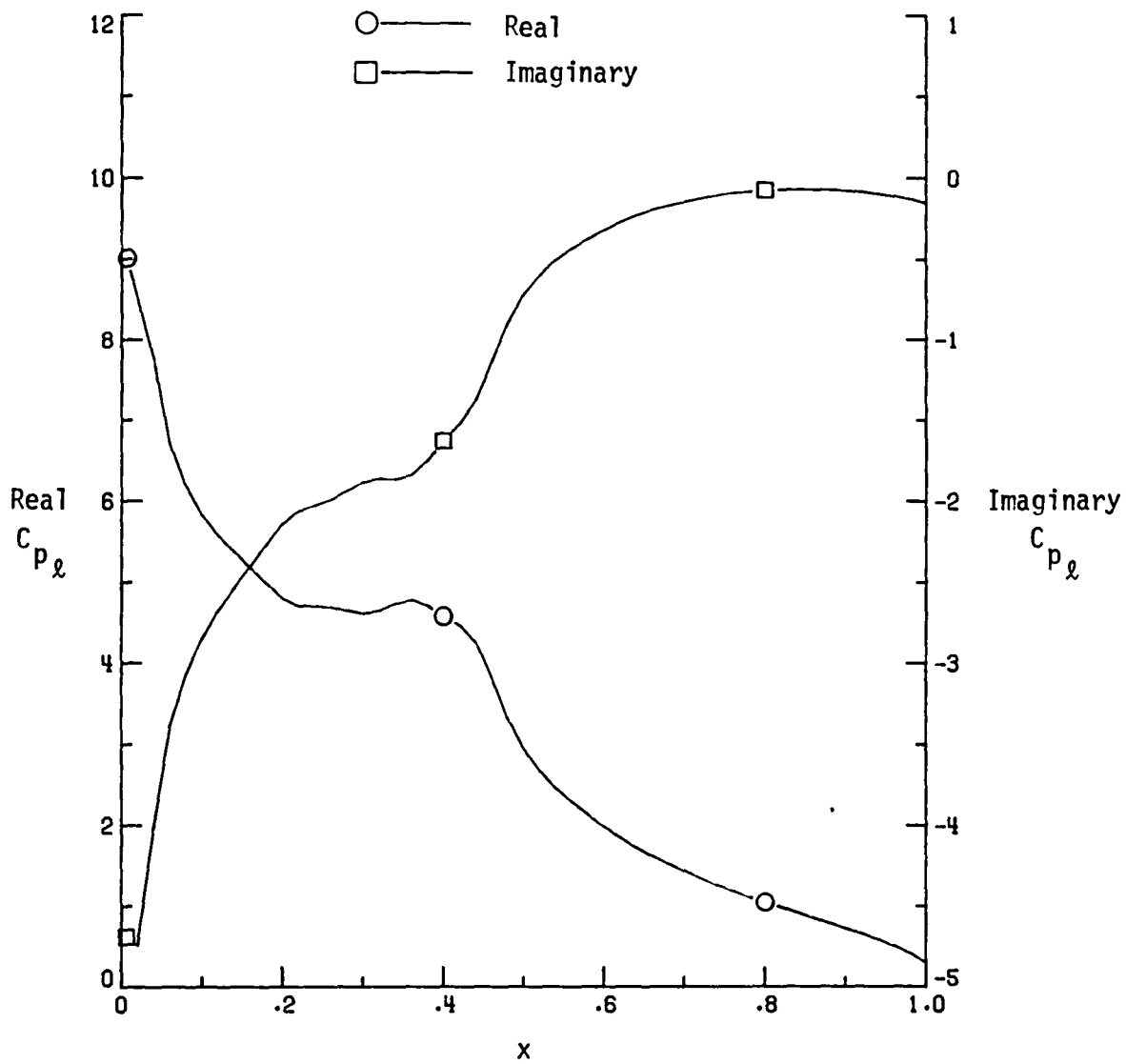
(c) Mean pressure distributions.

Fig. 6 Continued.



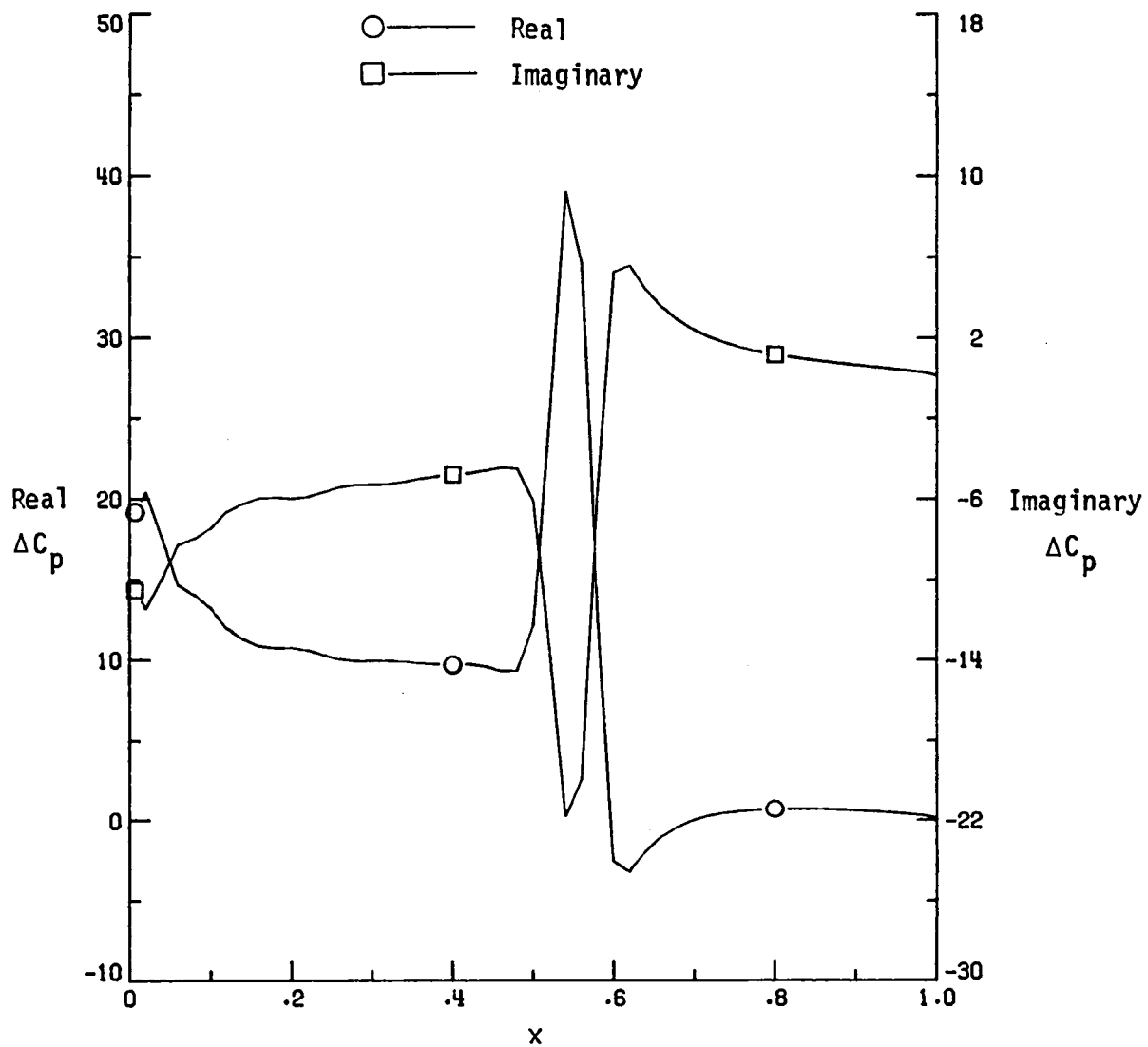
(d) Real and imaginary components of the upper surface pressure coefficient.

Fig. 6 Continued.



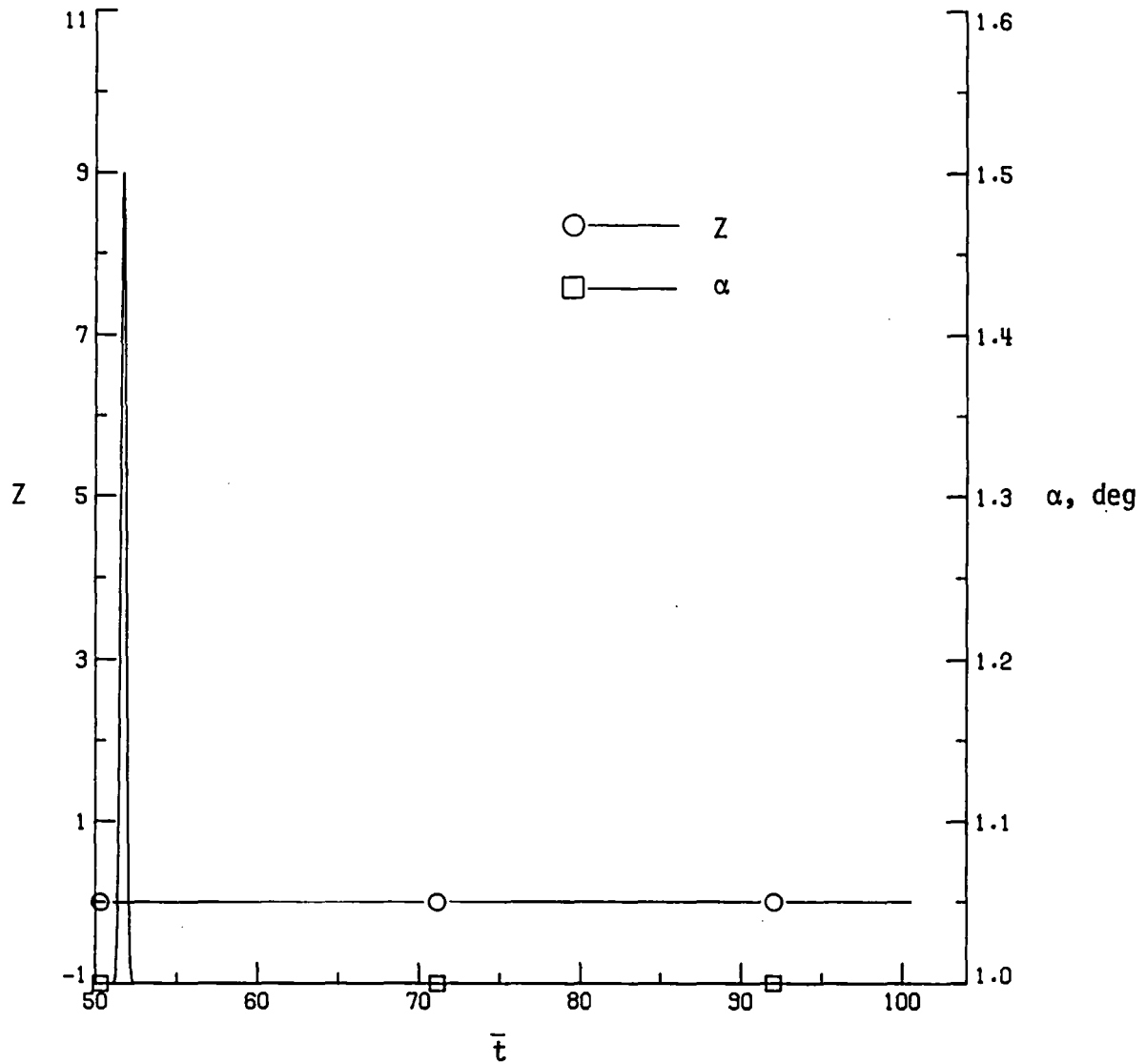
(e) Real and imaginary components of the lower surface pressure coefficient.

Fig. 6 Continued.



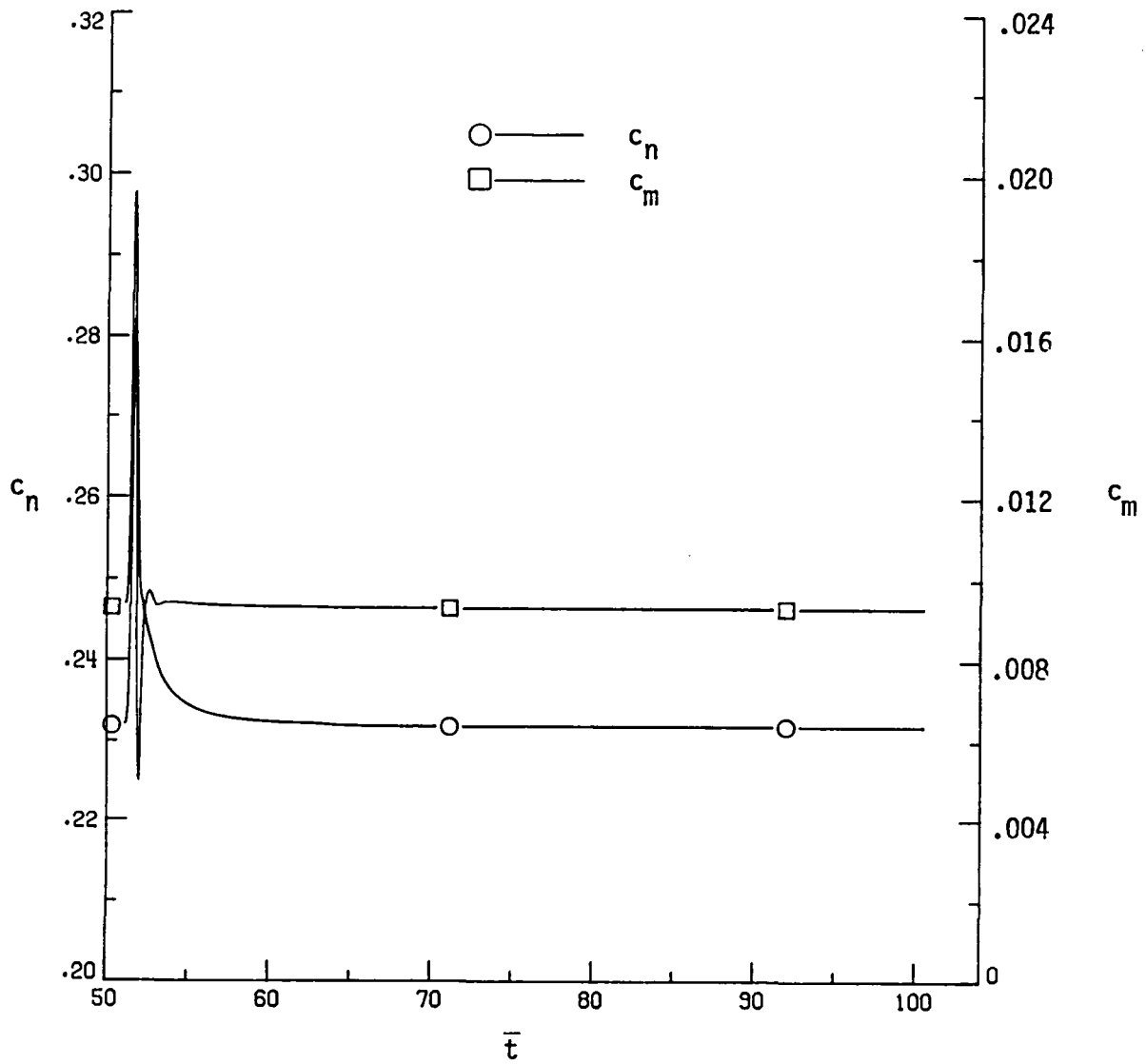
(f) Real and imaginary components of the lifting pressure coefficient.

Fig. 6 Concluded.



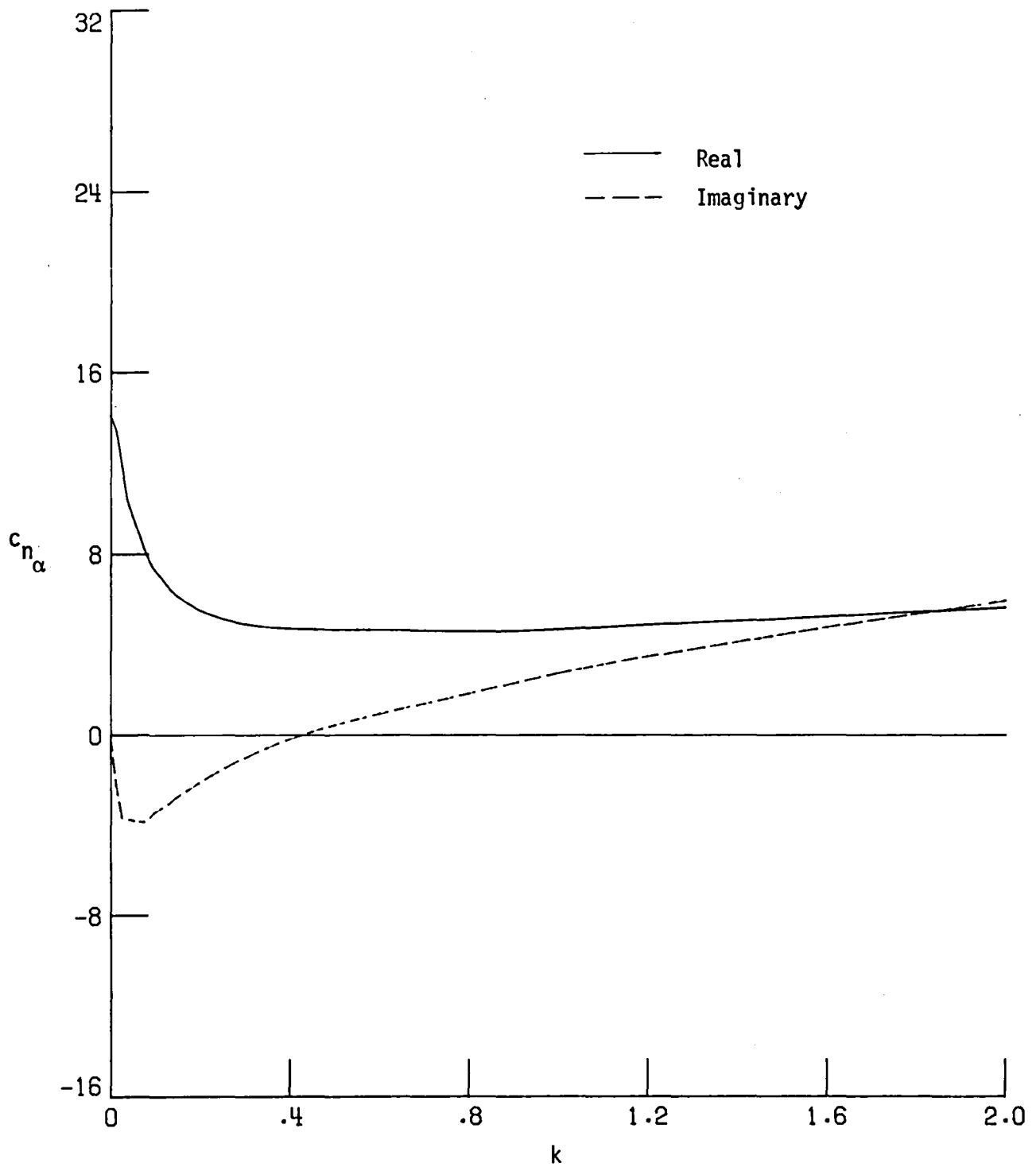
(a) Pitch pulse input.

Fig. 7 Results from unsteady calculations due to pitch pulse (IRES P = 3) for the NACA 64A010A airfoil at $M_\infty = 0.78$ and $\alpha_0 = 1.0^\circ$;



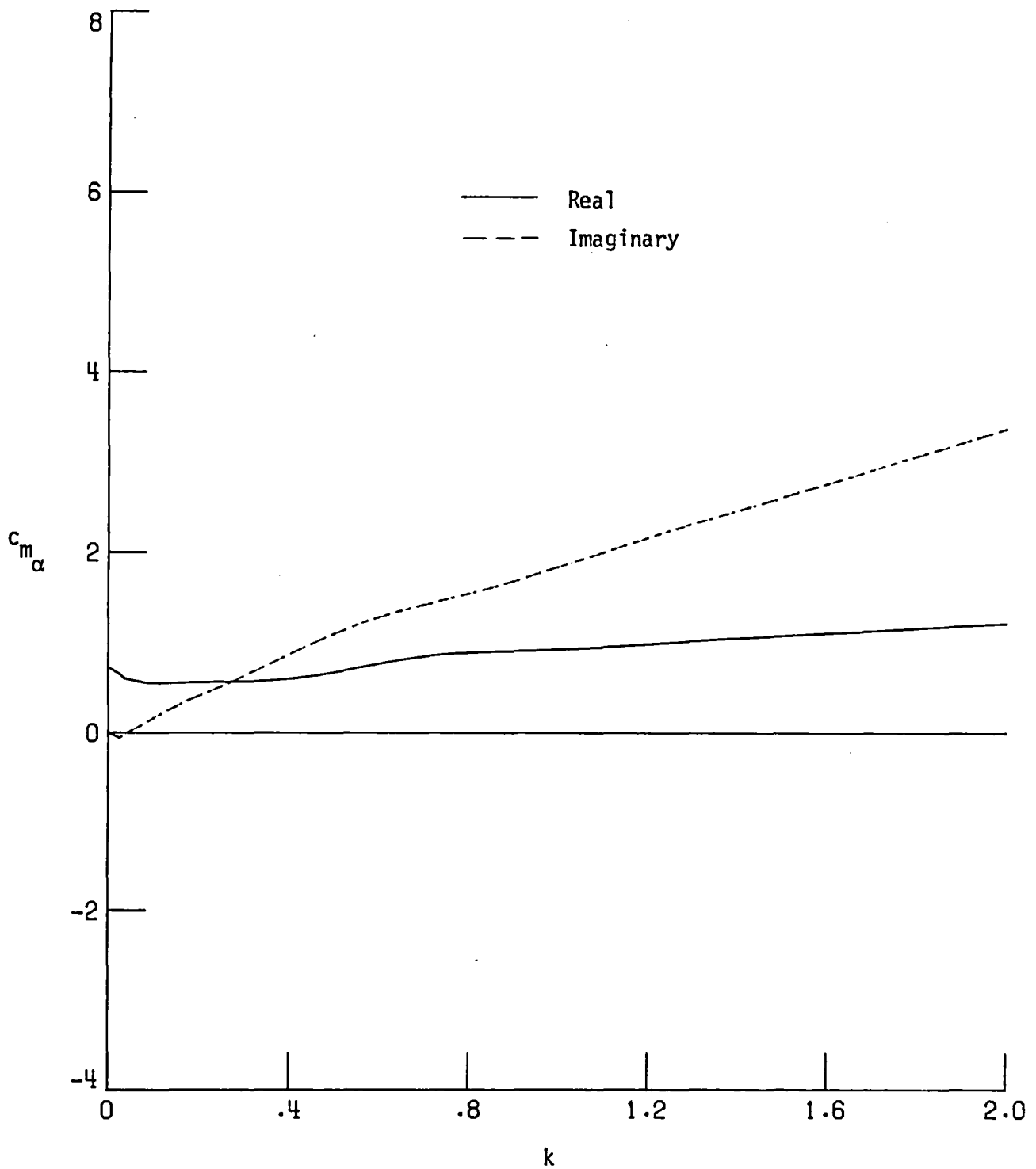
(b) Resulting normal force coefficient and pitching moment coefficient responses.

Fig. 7 Continued.



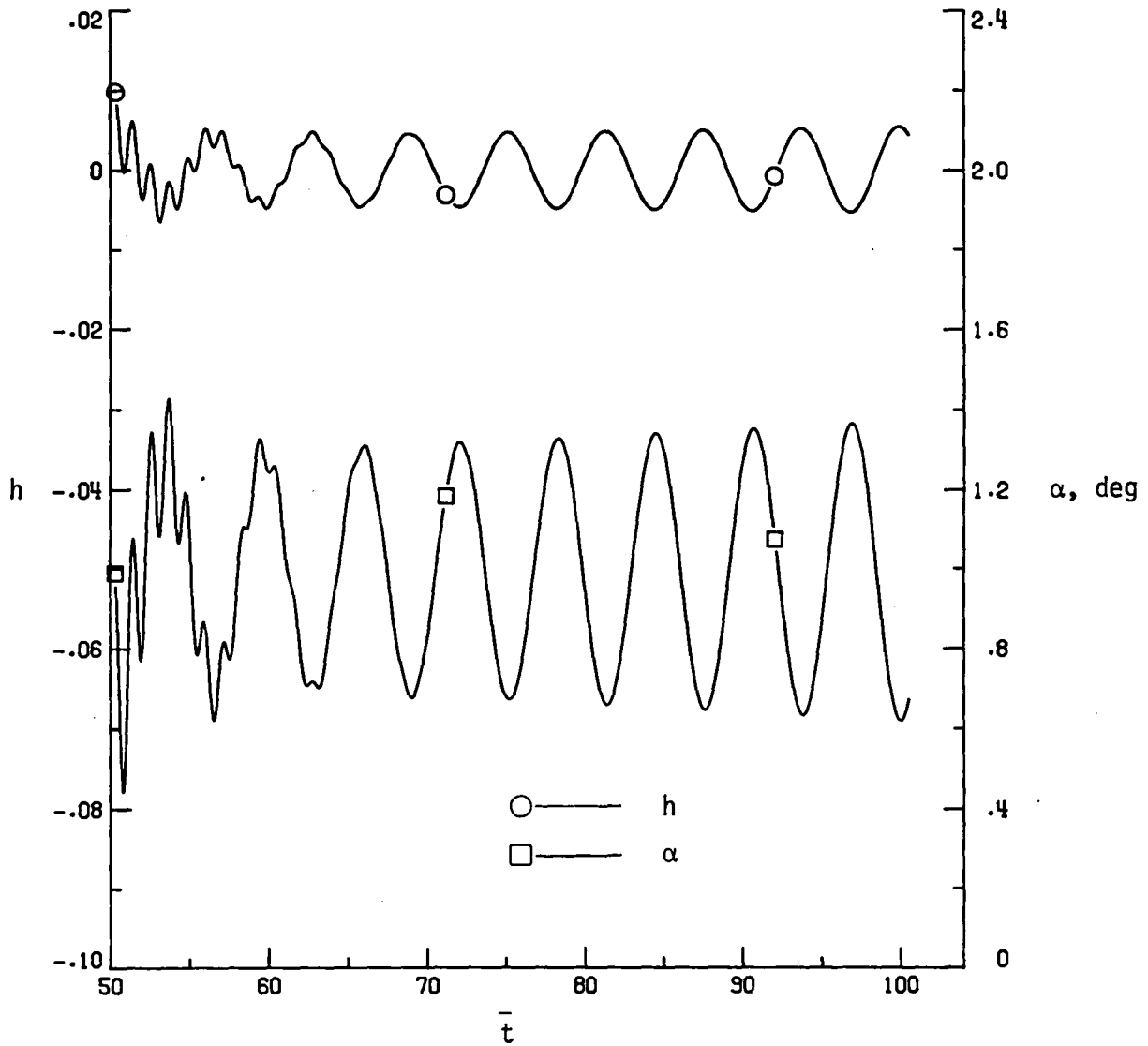
(c) Normal force coefficient due to pitching as a function of reduced frequency k .

Fig. 7 Continued.



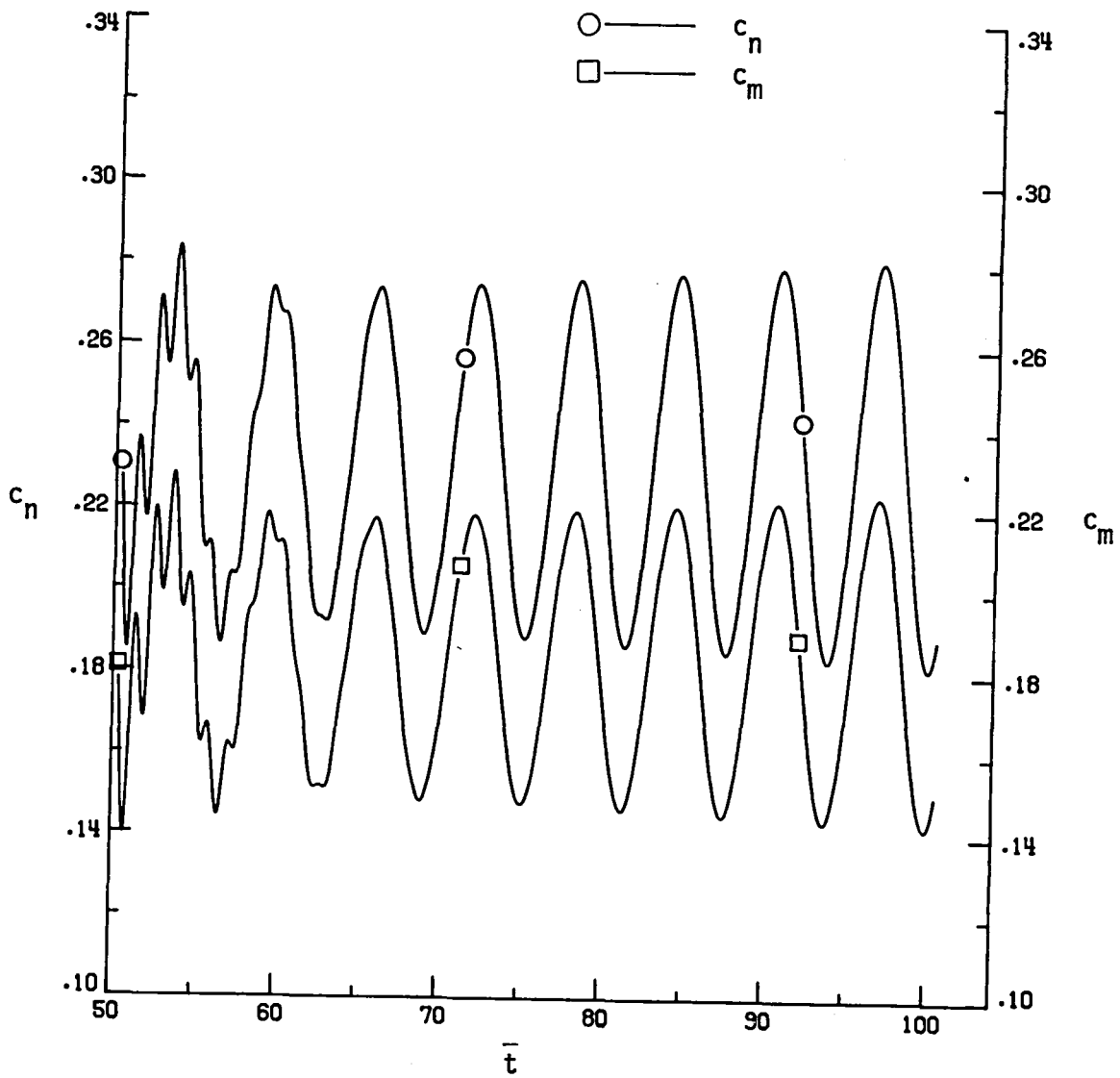
(d) Pitching moment coefficient due to pitching as a function of reduced frequency k .

Fig. 7 Concluded.



(a) Pitch and plunge aeroelastic transients.

Fig. 8 Results from unsteady calculations for aeroelastic motion (IRES P = 1) for the NACA 64A010A airfoil at $M_\infty = 0.78$, $\alpha_0 = 1.0^\circ$, and $U/c = 330.0$;



(b) Normal force coefficient and pitching moment coefficient aeroelastic transients.

Fig. 8 Concluded.

1. Report No. NASA TM-87737	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle USER'S MANUAL FOR XTRAN2L (VERSION 1.2): A PROGRAM FOR SOLVING THE GENERAL-FREQUENCY UNSTEADY TRANSONIC SMALL-DISTURBANCE EQUATION		5. Report Date July 1986	
		6. Performing Organization Code 505-63-21-01	
7. Author(s) David A. Seidel and John T. Batina		8. Performing Organization Report No.	
		10. Work Unit No.	
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665-5225		11. Contract or Grant No.	
		13. Type of Report and Period Covered Technical Memorandum	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		14. Sponsoring Agency Code	
		15. Supplementary Notes	
16. Abstract <p>The development, use, and operation of the XTRAN2L program that solves the two-dimensional unsteady transonic small-disturbance potential equation are described. The XTRAN2L program is used to calculate steady and unsteady transonic flow fields about airfoils and is capable of performing self-contained transonic flutter calculations. Operation of the XTRAN2L code is described, and tables defining all input variables, including default values, are presented. Sample cases that use various program options are shown to illustrate operation of XTRAN2L. Computer listings containing input and selected output are included as an aid to the user.</p>			
17. Key Words (Suggested by Author(s)) Transonic Unsteady Aerodynamics Transonic Small Disturbance Potential Equation Finite Difference, Aeroelastic		18. Distribution Statement Unclassified - Unlimited Subject Category - 02	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 87	22. Price A05

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