(NASA-CR-146067) FULLY UNSTEADY SUBSONIC AND SUPERSONIC POTENTIAL AERODYNAMICS FOR COMPLEX AIRCRAFT CONFIGURATIONS WITH APPLICATIONS TO FLUTTER (Boston Univ.) 31 p HC $4.00 CSCL 01A G3/02

N76-15078

Unclas 08522

BOSTON UNIVERSITY

DEPARTMENT OF AEROSPACE ENGINEERING

BOSTON UNIVERSITY

COLLEGE OF ENGINEERING

BOSTON, MASS. 02215

FULLY UNSTEADY SUBSONIC AND SUPERSONIC POTENTIAL AERODYNAMICS FOR COMPLEX AIRCRAFT CONFIGURATIONS WITH APPLICATIONS TO FLUTTER

Kadin Tseng

and

Luigi Morino

Work supported by NASA Grant NGR 22-004-030

Technical Monitor: Dr. E. Carson Yates, Jr.

Fully Unsteady Subsonic and Supersonic Potential Aerodynamics For Complex Aircraft Configurations With Applications To Flutter

by

Ka Din Tseng and Luigi Morino

Boston University

Presented here is a new general formulation for the analysis of steady and unsteady, subsonic and supersonic aerodynamics for complex aircraft configurations. The paper includes the theoretical formulation, the numerical procedure, the description of the program SOUSSA (Steady, Oscillatory and Unsteady, Subsonic and Supersonic Aerodynamics) and numerical results. In particular, generalized forces for fully unsteady (complex frequency) aerodynamics for a wing-body configuration, AGARD wing-tail interference in both subsonic and supersonic flows as well as flutter analysis results are included in the paper.

The theoretical formulation is based upon an integral equation presented in Refs. 1 and 2, which includes completely arbitrary motion. Steady and oscillatory aerodynamic flows are considered in Refs. 3 and 4 (enclosed here). A review of the problem is given in Ref. 4 and therefore is not included here.

Here small-amplitude, fully transient response in the time domain is considered. This yields the aerodynamic transfer function (Laplace transform of the fully unsteady operator) for frequency domain analysis (Ref. 5 enclosed here). This is particularly convenient for the linear systems analysis of the whole aircraft. The formulation briefly outlined in Ref. 5 has now been completed and implemented in the computer program SOUSSA (Ref. 6, for subsonic and supersonic).

The new formulation, program and results will be fully described in the proposed paper.

METHOD OF SOLUTION

The method presented here is based upon a formulation developed by Morino.[1,2] For simplicity, only the incompressible steady state is briefly described here. The formulation, by making use of the Green function method applied to the equation of the velocity potential, yields an integral equation relating the unknown potential on the surface of the body to its known normal wash. By making use of the finite-element method, and by the assumption that the potential is constant within each quadrilateral element, the integral equation is approximated by a linear system of N equations relating N (unknown) values of the potential to N (known) values of normal wash at the centroids of N elements.

For the sake of generality and flexibility, in particular, for structural analysis, the downwash is expressed in terms of the generalized coordinates and generalized velocities.

From the potentials at centroids of elements, by an averaging scheme (by which the potential at a corner is approximated by the average value of potentials at the centroids of the elements in its immediate surroundings), the potentials at the nodal points are obtained and consequentially the potential at any point on the surface can be expressed by a finite-element interpolating formulation with bi-linear local shape functions. Finally, the pressure coefficients and generalized forces can be evaluated by a simple finite-element procedure.

ASSESSMENT OF METHOD

Next, an assessment of the method is briefly considered. In particular, new unique features of the methodology (not existing in other methods) are highlighted. Also progress with respect to Ref. 4 is emphasized.

(1) The program can analyze steady, oscillatory as well as fully unsteady potential aerodynamics in both subsonic and supersonic regimes. To the authors' knowledge this is the only computer program which can handle fully unsteady (complex frequency) aerodynamics for complex configuration (e.g., wing-body-tail combination). No other program can even handle oscillatory supersonic aerodynamics for complex configurations.

(2) Evaluation of the normal wash for complex configurations from prescribed three dimensional mode shapes (Ref. 4 was limited to thin wings with vertical displacements.) is available. Downwash due to turbalances is also included.

(3) In supersonic flow problems, the present method does not require the use of diaphragms, in which, significantly enough, leads to the unification of the program (i.e.,

the program covers the whole linearized potential flow spectrum - steady, unsteady, subsonic and supersonic). (Ref. 4 requires the use of diaphragms and hence is limited to simple geometries.)

(4) Finite-element evaluation of pressure. (Ref. 4 used finite-difference and was limited to thin wing wings)

(5) Evaluation of the generalized forces for arbitrary geometry and arbitrary three dimensional mode shapes.

(6) The computer code SOUSSA can handle complete wing-body-tail configuration with control surfaces. Results obtained for control surfaces are in excellent agreement with existing ones (see next section).

(7) Another unique feature of the present method on unsteady potential flow problems in that the flutter analysis often requires the analysis on a specific geometry for a wide range of frequencies. In the present method, the frequency-dependent coefficients of the aerodynamic transfer matrix, may be expressed as a combination of complex frequency-independent coefficients* with simple frequency-dependent coefficients: the advantage is that every additional frequency analyses other than the first one requires only a minimal amount of CPU time.

(8) In iterative procedures (for instance for optimal design) it is generally required to predict generalized aerodynamic loads due to a variety of vibration modes. In the present method, the aerodynamic coefficient matrix is written as the product of three matrices. The first and the third

---

*B_{ij}, C_{ij}, D_{ij}, F_{ij}, G_{ij}, O_{ij}, S_{ij}, coefficients of Ref. 5, enclosed here

(for the normal wash and for the evaluation of the generalized forces) are mode dependent but very simple, while the second one (relating pressure distribution to normal wash distribution) is mode independent. By the same reasoning as above, the CPU time required for additional modal analysis is reduced to a relatively negligible level.

(9) Applications to flutter has been considered. The results (see next section) are in good agreement with existing ones.

NUMERICAL RESULTS

Typical numerical results obtained with SOUSSA are presented in this section. Due to space limitations, the results are only very briefly outlined.

Figures 1 and 2 are the lift and moment coefficients of a rectangular wing oscillating in pitch with Mach number ranging from 0 to 2.5. Results for the supersonic flow were obtained without the use of diaphragms and have never been presented before. The comparison against Ref. 11 is in general, in excellent agreements. Figures 3, 4 and 5 present the pressure distributions of a rectangular wing in steady subsonic and supersonic flow, and again they are in very good agreements. Figures 6, 7 and 8 are results for a wing-body configuration in both steady and fully unsteady flow, for both subsonic and supersonic speeds.

Figures 6 and 7 are presented just to demonstrate the unique feature of the present method over all existing ones (i.e., fully unsteady flow). Figures 9 and 10 include the results for simple wings with control surface in steady and oscillatory flows. Figure 11 presents flutter applications (in excellent agreement with the results of Ref. 17). Tables 1 through 3 are the generalized forces for an AGARD wing-tail configuration in quasi-steady and oscillatory flow in comparison with existing methods.

Further results, such as the fully unsteady aerodynamic analysis of the AGARD wing-tail configuration and other complex configuration (with control surfaces) will be included in the proposed paper.

In conclusion, whereas only simple configuration results are presented, (in order to assess the accuracy).It is the objective of the proposed paper to emphasize the generality, flexibility, efficiency of the present method. Last, but not least the present method provides a unified approach to cover the whole linearized potential flow spectrum and very limited human intervention is required in using the computer code SOUSSA.

CONCLUSIONS

There exists several methods to analyze the problem of wing-body, wing-tail interactions. However, it is apparent that the present method, embedded in the computer program SOUSSA, is unique in the following aspects:

1. It provides a unified approach for steady, oscillatory and fully unsteady, subsonic and supersonic aerodynamic flows.
2. It can be applied to arbitrarily-complex configurations. Wing-body-tail configurations with control surface have been analyzed. (No existing result is available for comparisons. However, simple wing with control surface results shows that the present method is in good agreement with existing ones.)
3. It is computationally extremely general, flexible, efficient and above all, accurate. The elimination of diaphragms in supersonic flow improved considerably the simplicity and efficiency of the code.
4. SOUSSA is the only existing program that can analyze fully unsteady complex-configuration potential aerodynamics in subsonic or supersonic regimes. It is also the only program capable of handling oscillatory supersonic aerodynamics for complex configurations.
5. In contrast to existing methods, which in many instances requires extensive user's background in aerodynamics and familiarity with the specific method, the present

code requires very limited human itervention and is extremely easy to use.

6. Flutter, and optimal design analyses requires evaluation of the aerodynamic influence coefficients for several frequencies and mode shapes. With the unique features mentioned above, the computer time that normally would have been required is dramatically reduced. This is to be added to the fact that preliminary versions of the program already required less computer time than other existing programs (Ref. 4).

7. Applications to flutter indicate good agreement with existing results.

References

1. Morino, L. "Unsteady Compressible Potential Flow around Lifting Bodies Having Arbitrary Shapes and Motions", Beston University, College of Engineering, Dept. of Aerospace Engineering, TR-72-01, June 1972. Superseded by "A General Theory of Unsteady Compressible Potential Aerodynamics", NASA CR-2464. December 1974

2. Morino, L."Unsteady Compressible Potential Flow Around Lifting Bodies - General Theory". AIAA Paper No. 73-196, January 1973.

3. Morino, L. and Kuo, C.C. "Subsonic Potential Aerodynamics for Complex Configurations: A General Theory". AIAA J., Val. 12, No. 2, February 1974, pp. 191-197.

4. Morino, L., Chen, L.T. and Suciu, E.O. "Steady and Oscillatory, Subsonic and Supersonic Aerodynamics Around Complex Configurations" AIAA J., Vol. 13, No. 3, March 1975, pp. 368-374

5. Morino, L. "Subsonic and Supersonic Indicial Aerodynamics and Aerodynamic Transfer Function for Complex Configurations" Boston University, ENG-TN-74-01, September 1974.

6. Tseng, K.D., Chen, L.T. and Morino, L. "SOUSSA : Steady,Oscillatory and Unsteady, Subsonic and Supersonic Aerodynamics for Aerospace Complex Transportation System; A User's Manual" Boston University, ENG-TR-75-03

7. Laschka, B. "Zur Theorie der Harmonisch Schwingenden Tragenden Flache bei Unterschallenstromung", Zeitschrift fur Flugwissenschaften, 11 (1963), Heft 7, pp. 265-292.

8. Labrujire, T.E., Loeve, W. and Sloff, J.W. "An Approximate method for the Calculation of the Pressure Distribution on Wing-Body Combinations at Subcritical Speeds", AGARD Specialist Meeting on Aerodynamic Interference, Silver Springs, Md., Sept. 1970, AGARD Conf. Proc. No. 71

9. Lessing, H.C., Troutman, J.C. and Menees,G.P. "Experimental Determination of the Pressure Distribution on a Rectangular Wing Oscillating in the First Bending Mode for Mach numbers From 0.24 to 1.30", NASA-TN-D-344, 1960.

10. Tijdeman, H. and Zwaan, K.J. "Unsteady Aerodynamics For Wings with Control Surfaces" No. 12, AGARD Symposium on Unsteady Aerodynamics for Aeroelastic Analyses of Interfering Surfaces, AGARD-CP-80-71, 1970

11. Huttsell, L.J., Pollock, S.J. "Unsteady Aerodynamic Loads for the AGARD Interfering Lifting Surfaces" AFFDL paper, 1974.

12. Rodden, W.P., Giesing, J.P. and Kalman, T.P. "New Developments and Applications of the Subsonic Doublet-Lattice Method for Nonplanar Configurations" Paper No. 4, AGARD Symposium on Unsteady Aerodynamics for Aeroelastic Analyses of Interfacing Surfaces, AGARD-CP-80-71, 1970.

13. Schmid, H. and Bechen, J. "Contribution to the AGARD Program on Unsteady Aerodynamics for Interfering Lifting Surfaces." MBB Paper, 1973.

14. Mykytow, W.J., Olsen, J.J. and Pollock, S.J. "Application of AFFDL Unsteady Cord Prediction Methods to Interfering Surfaces", Paper No. 7, AGARD Symposium in Unsteady Aerodynamics for Aeroelastic Analyses of Interfacing Surfaces, AGARD-CP-80-71, 1970.

15. Davies, D.E. "Applications of Unsteady Airforce Calculation Methods to AGARD Interfering Surfaces" AGARD-CP-80-71, 1970.

16. Pollock, S.J. and Huttsell, L.J. "Applications of three Unsteady Aerodynamic Land Prediction Methods" AFFDL TR-73-147, May 1974.

17. Appa, K. "Integrated Potential Formulation of Unsteady Supersonic Aerodynamics for Interacting Wings" NASA CR-132547, Oct. 1974.

18. Appa, K. and Jones, W.P. "Integrated Potential Formulation of Unsteady Aerodynamics for Interacting Wings" AIAA paper No. 75-762.

19. Hammond A.D. and Keffer, B.M. "The effect at high subsonic speeds of a flap-type aileron on the chordwise pressure distribution near mid-semispan of a tapered 35° swept back wing of aspect ratio 4 having NACA 65A006 airfoil section", NACA RM L53C23.

20. Bisplinghoff, R.L. Ashley, H. and Halfman, R.L. "Aeroelasticity", Addison-Wesley, Reading, Mass., 1955

21. Davies, D.E. "Calculation of Generalized Airforces on Two Parallel Lifting Surfaces Oscillating Harmonically in Subsonic Flow, RAE Technical Report 72180, 1973.

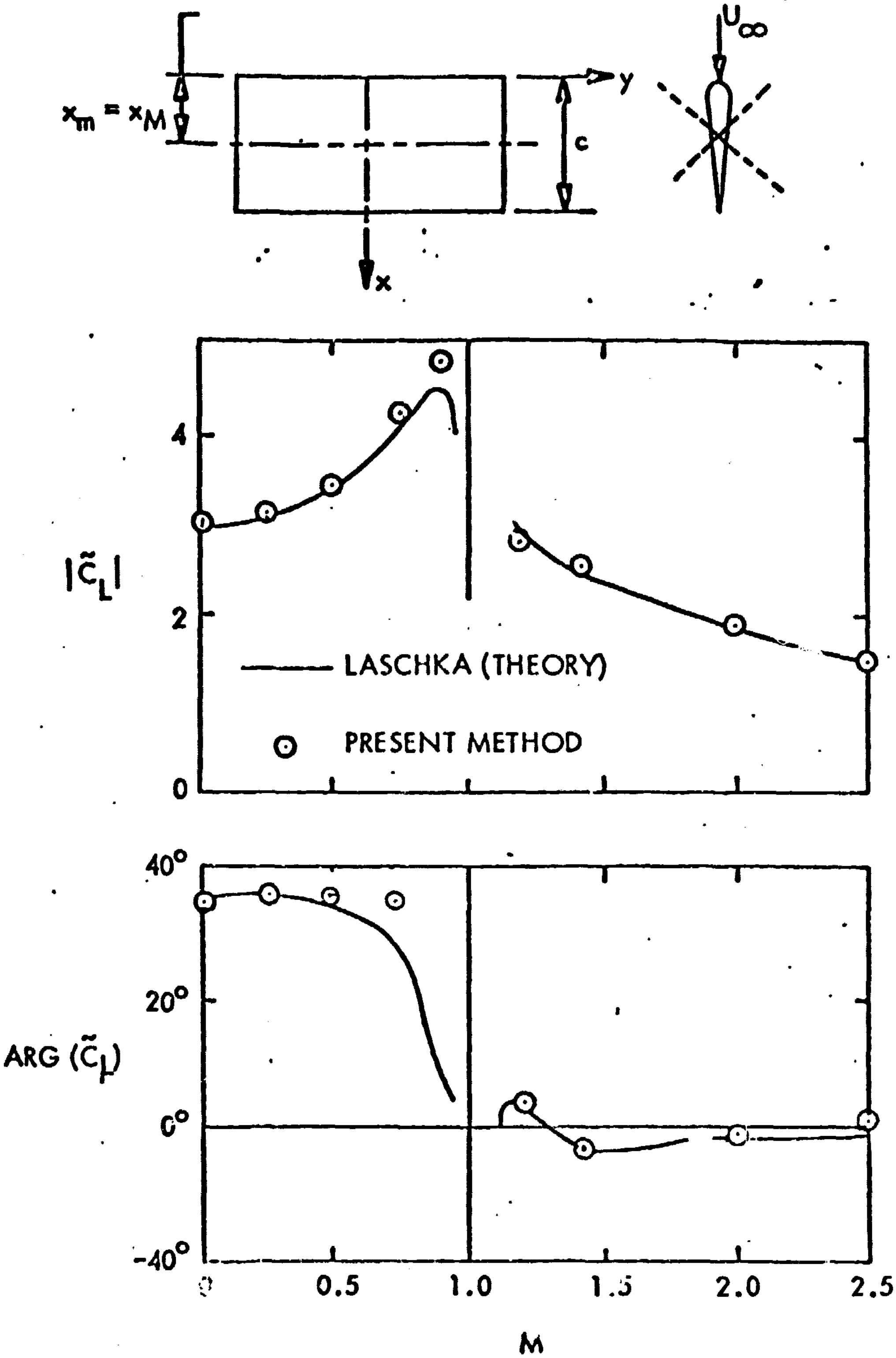

Fig. 1 Lift Coefficient, C_L, Versus M, for Rectangular Wing Oscillating in Pitch, With AR=2, τ=0.001, k=1, N_x=7, N_y=7, N_w=20, L_w/c=2. Comparison with results of reference 11.

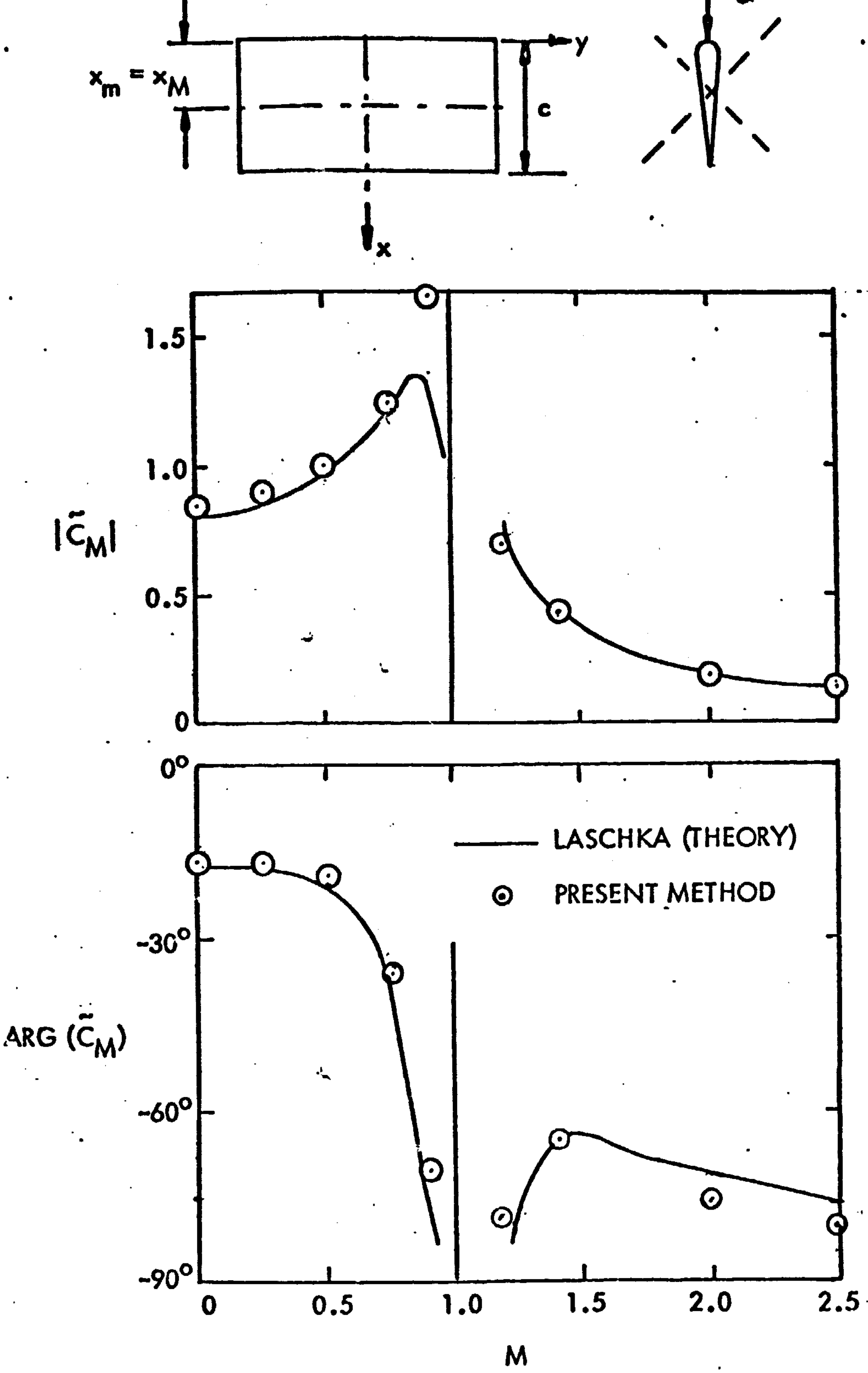

Fig. 2 Moment Coefficient, C_M, Versus M, for Rectangular Wing Oscillating in Pitch, for AR=2, τ=0.001, k=1, N_x=7, N_y=7, N_w=20, L_w/c=2, Comparison with results of reference 11.

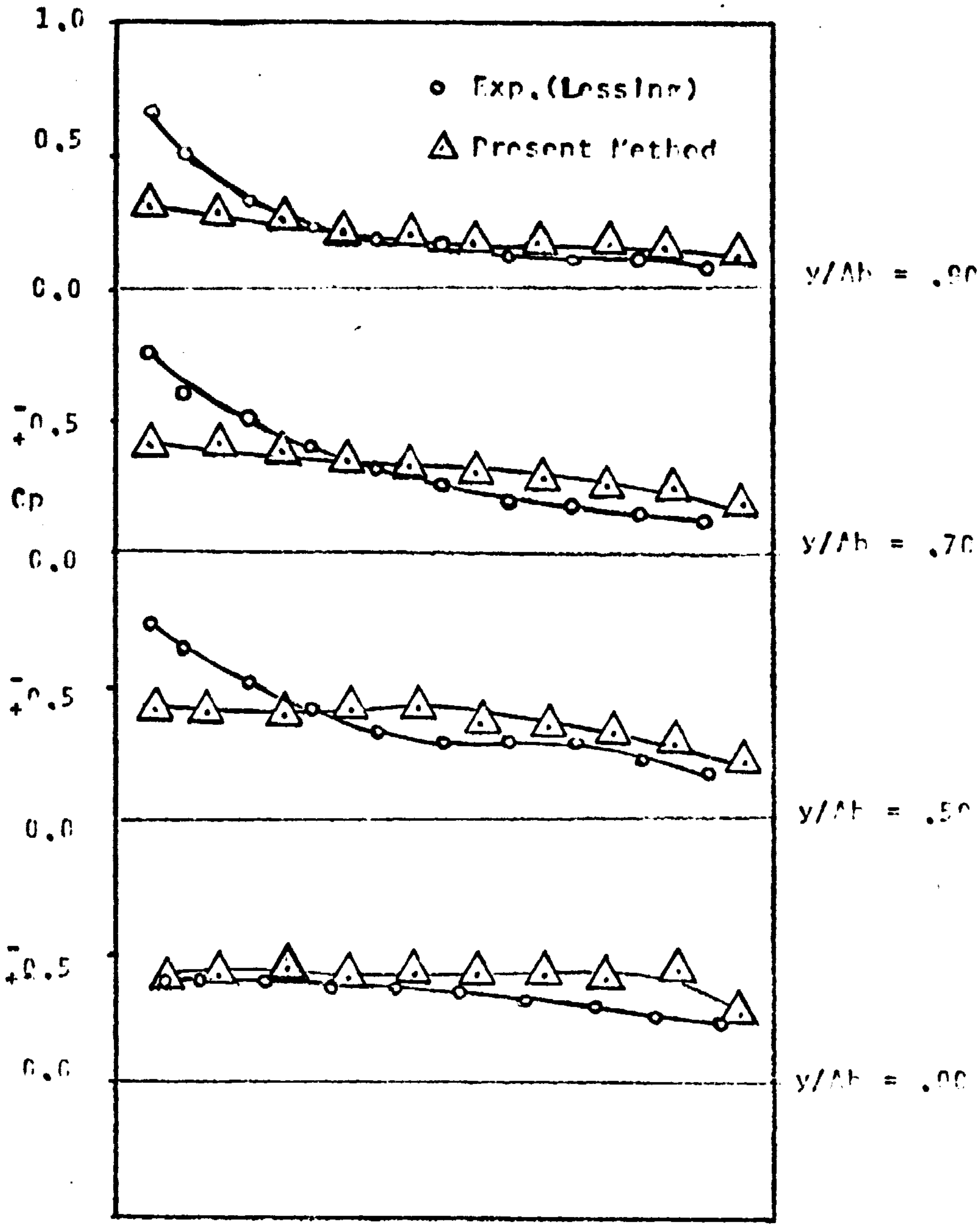

Fig. 3 Lifting pressures ; M = 1.30 , $\alpha = 5^\circ$

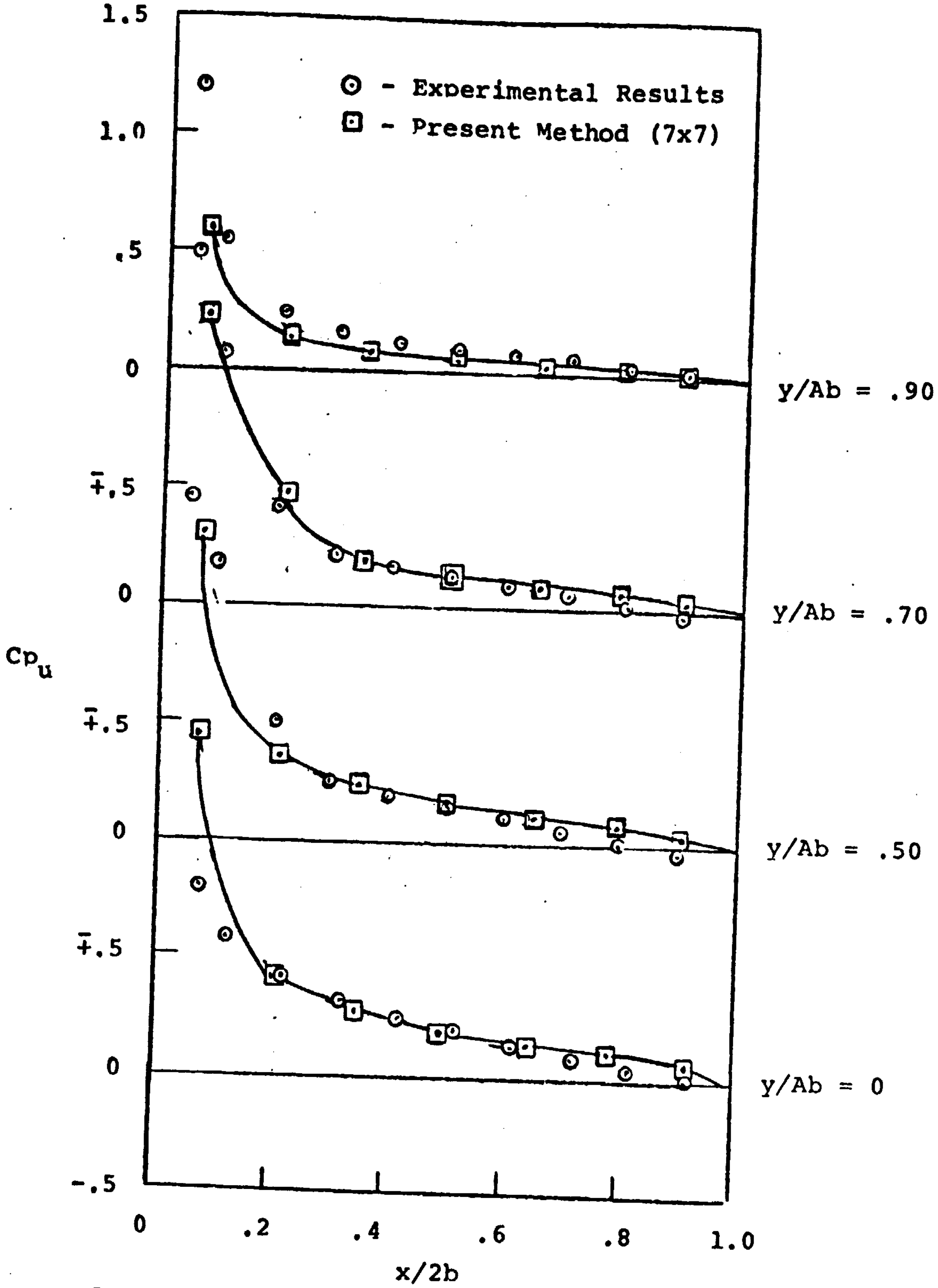

Fig. 4 Lifting pressures; M = 0.70 , α = 5°

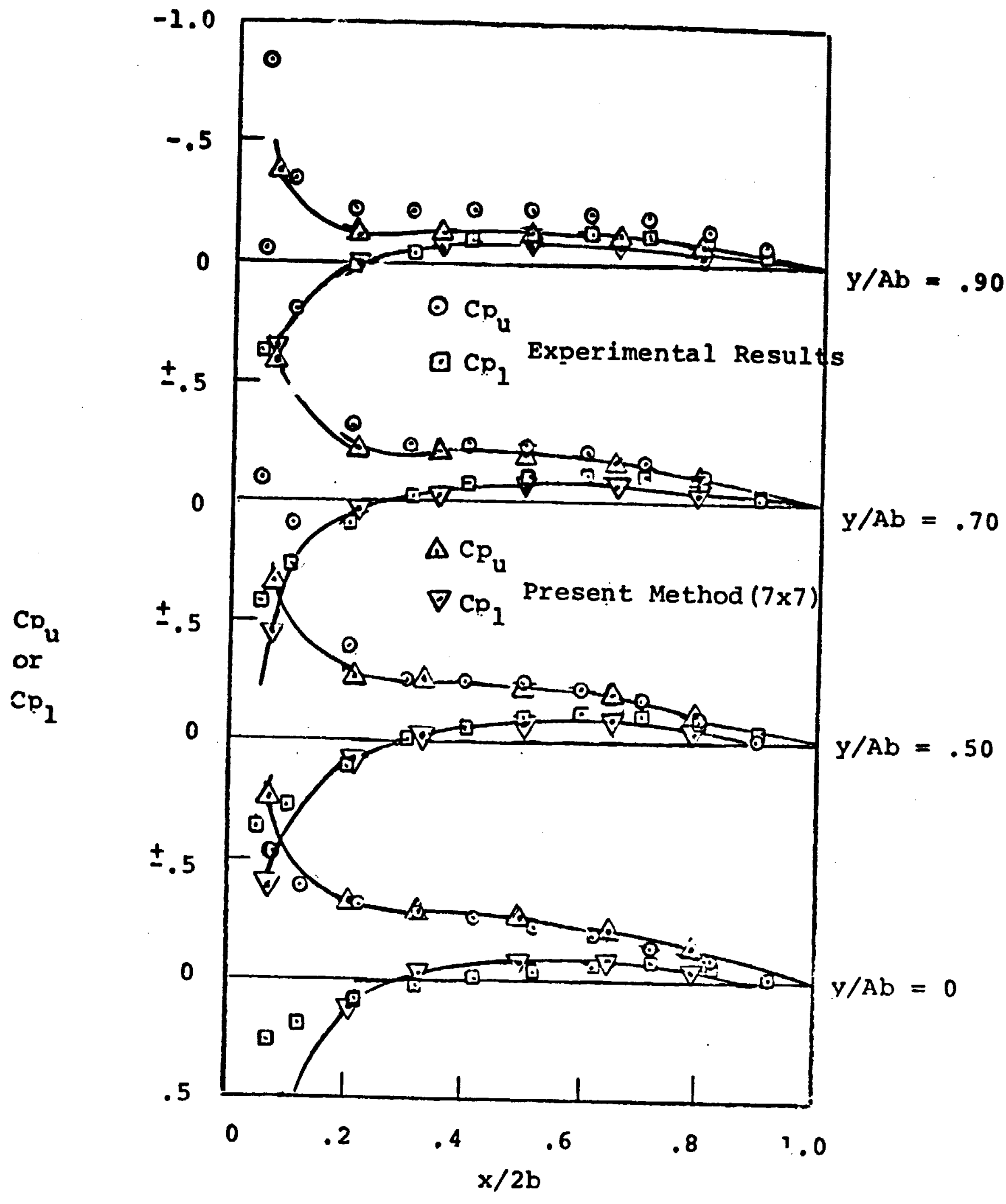

Fig 5 Pressures on upper and lower surfaces
$M = 0.70$, $\alpha = 5°$

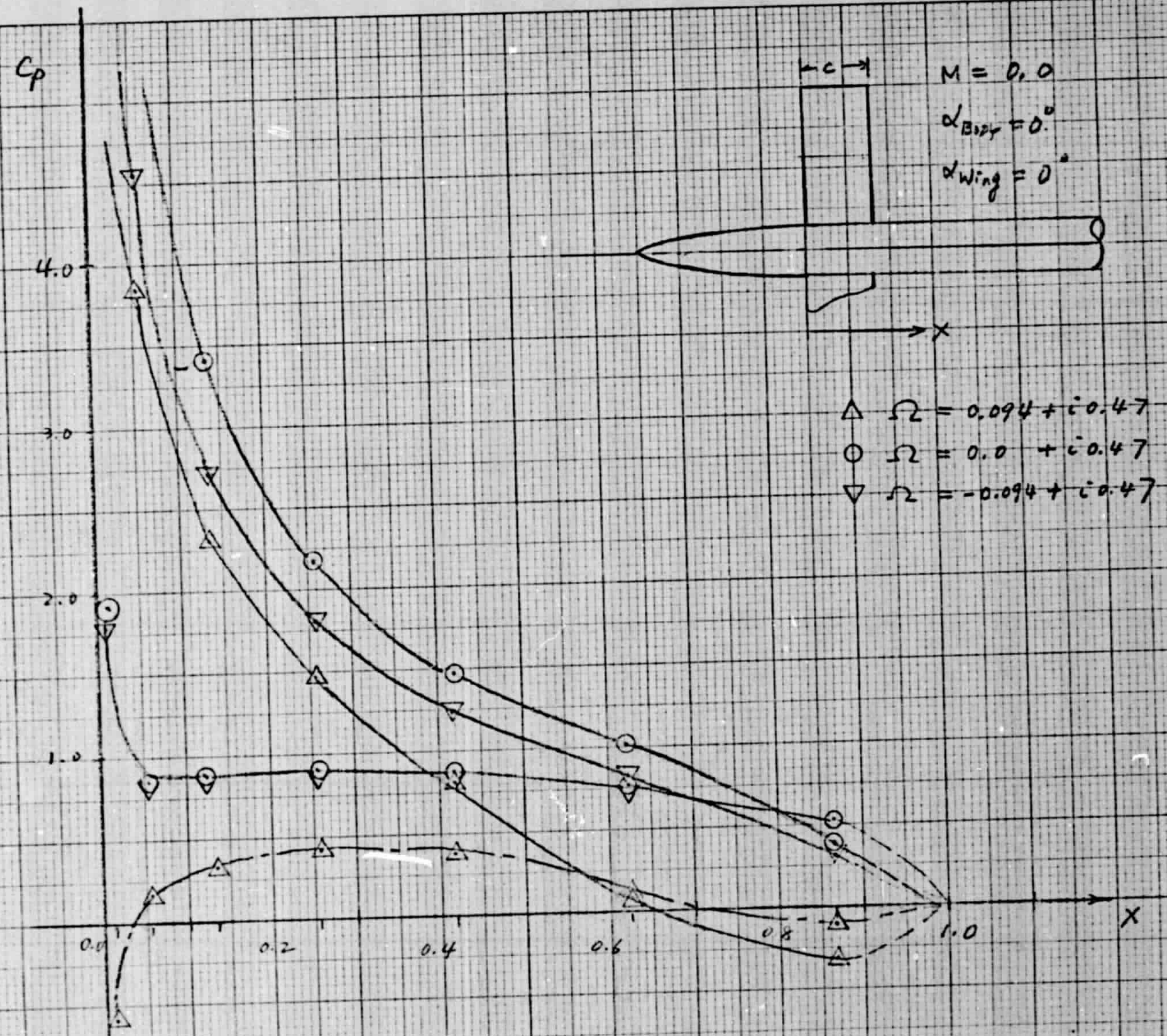

Fig. 6 Pressure distribution at mid semi-span of a wing-body configuration in fully unsteady flow for three different frequencies Ω

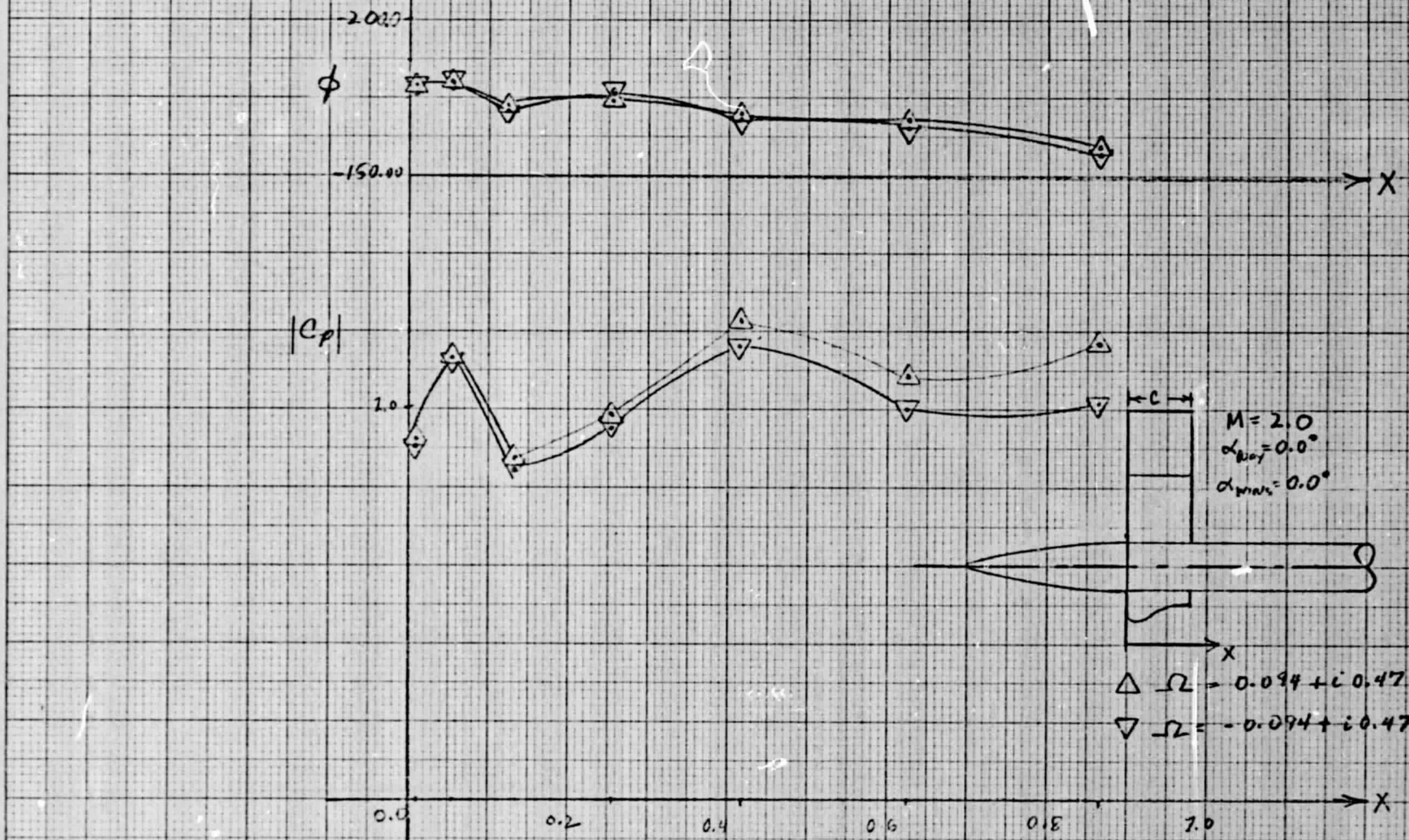

Fig 7 Absolute value and phase angle of pressure distribution at mid semi-span on the upper surface of a wing-body configuration in fully unsteady flow for two frequencies, Ω.

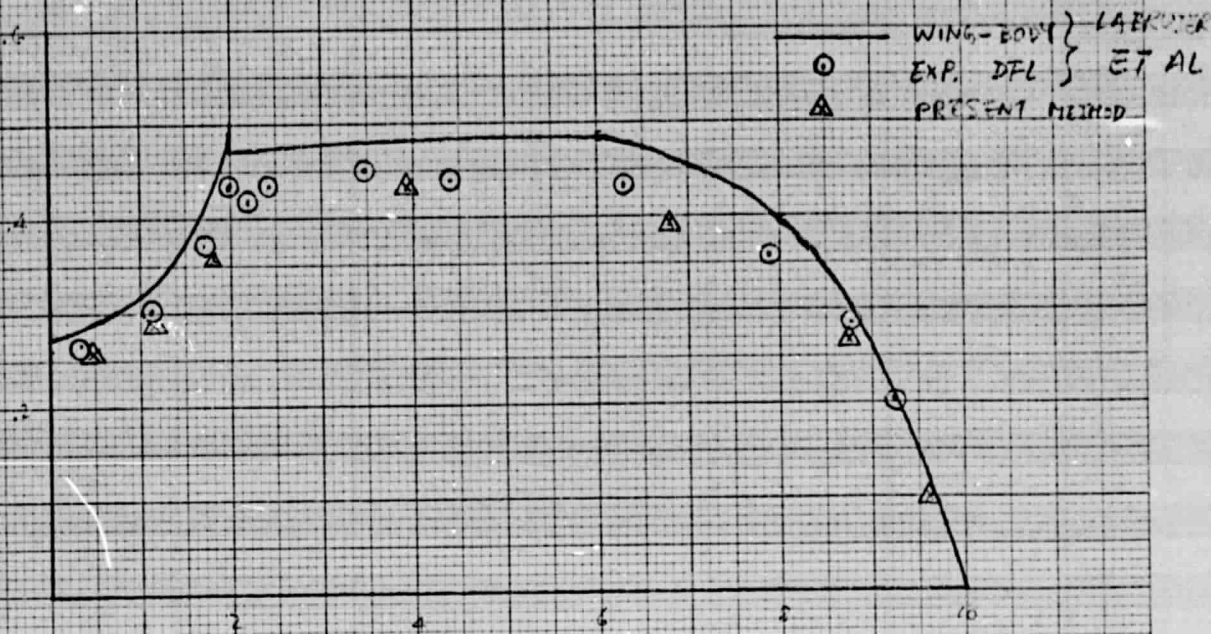

Fig. 8 Sectional lift distributions for a Wing-Body configuration in steady flow with $\alpha_W = 6°$, $\alpha_B = 0°$ and $M = 0$

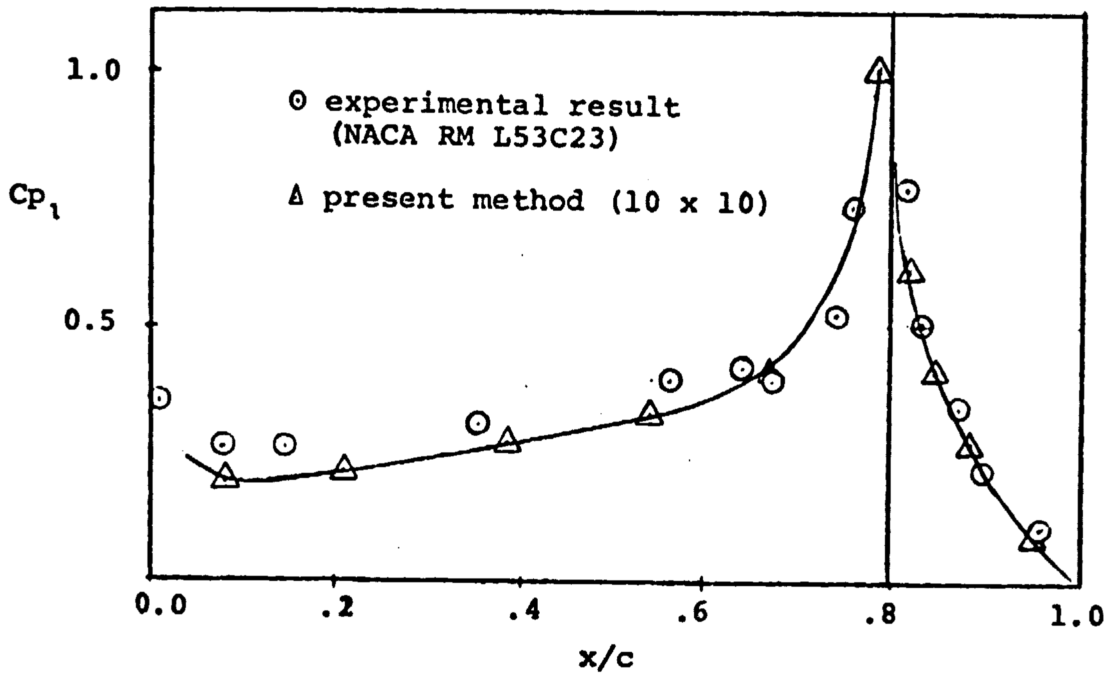

Fig. 9 Chordwise pressure distribution over a 35° swept wing, at the 46-percent-semispan station. $\alpha = 0^\circ$ $\delta = -15^\circ$, $M = 0.6$.

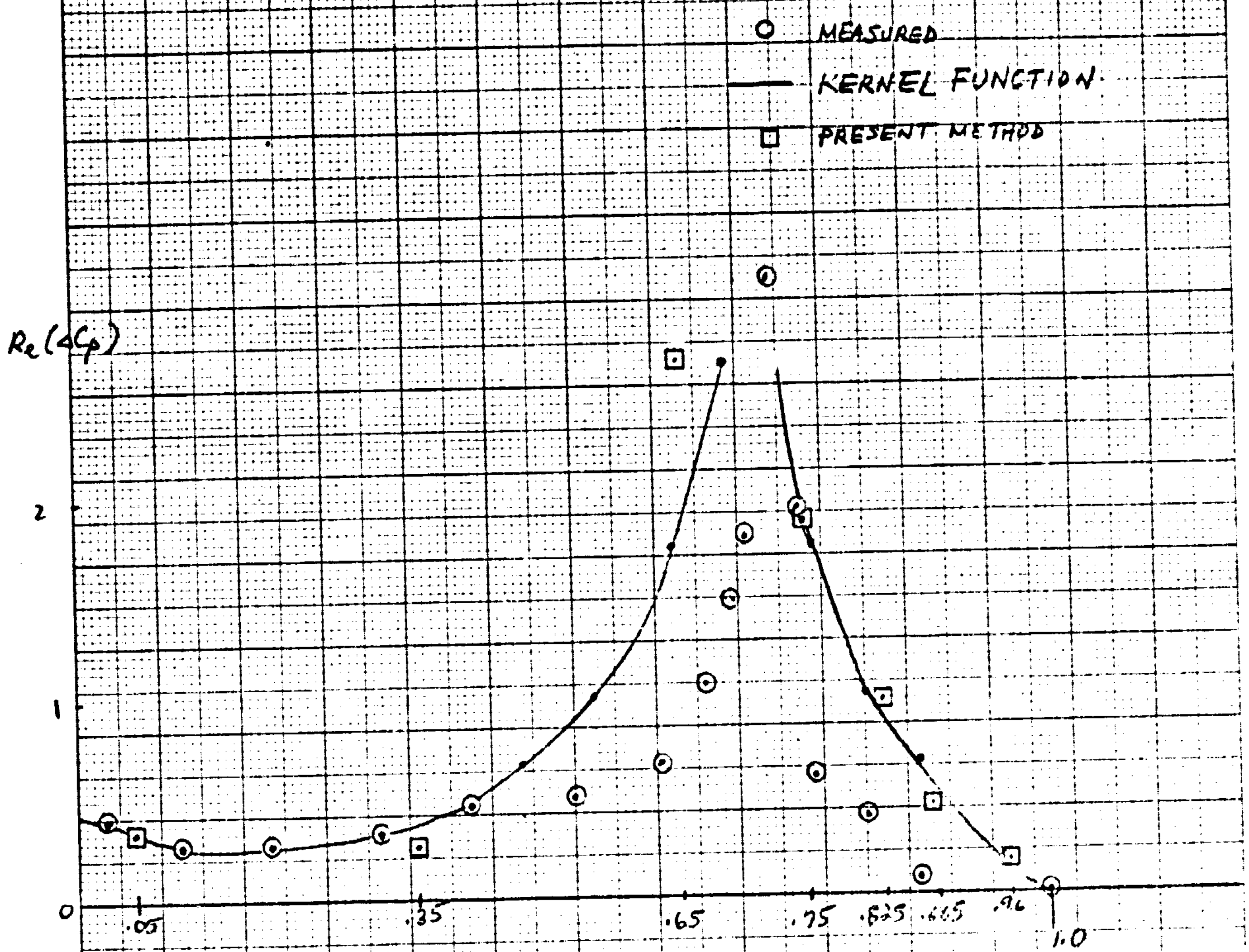

Fig 10. Unsteady pressure distributions on a rectangular wing with full span control surface

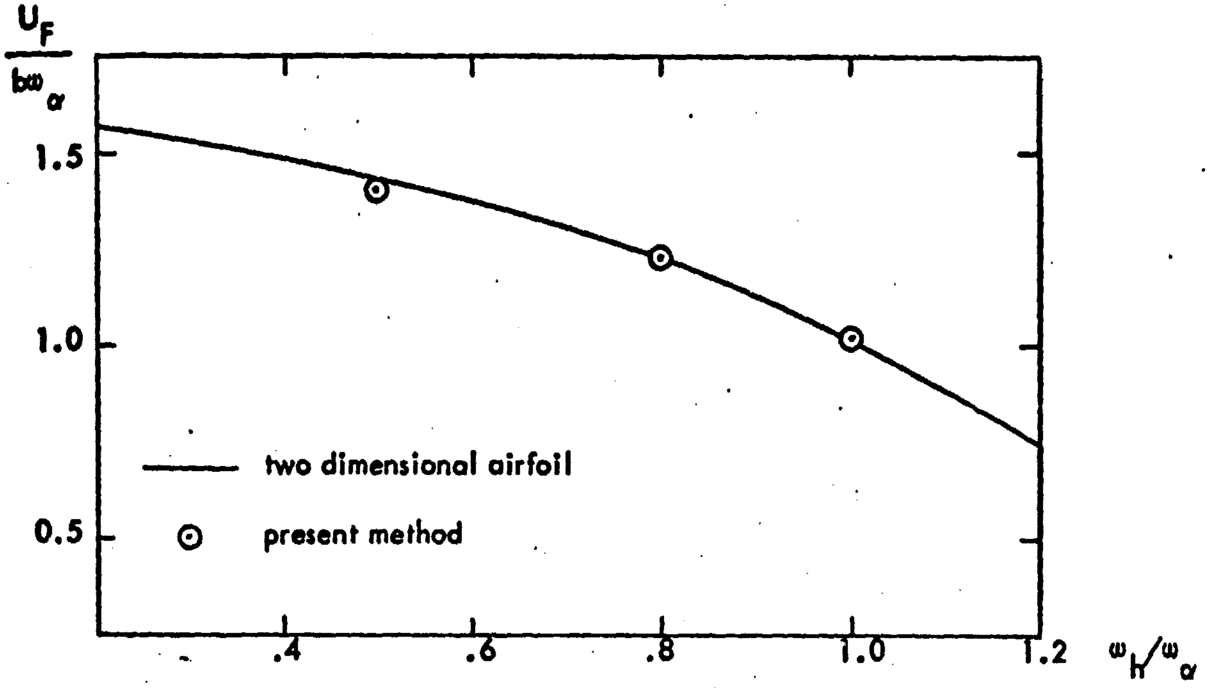

Figure 11a Flutter speed as a function of ω_h/ω_α for a rectangular wing with AR = 16, M = 0, τ = 0.1%, μ = 5, X_α = 0.2, r_α = 0.5, and NX = 8, NY = 10. Results are compared with exact solution given by two dimensional airfoil theory (Ref. 20) (X_{EA} = -0.2C).

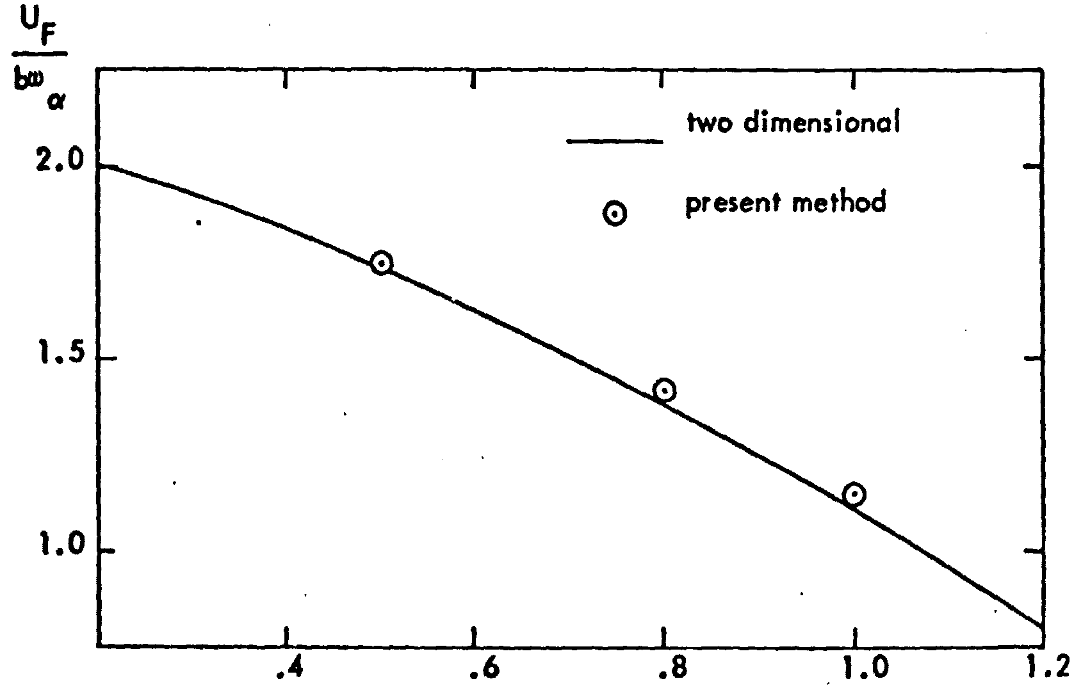

Figure 11b Flutter speed as a function of ω_h/ω_α for a rectangular wing with AR = 16, M = 0, τ = 0.1%, μ = 10, X_α = 0.2, r_α = 0.5 and NX = 8, NY = 10. Results are compared with exact solution given by two dimensional airfoil theory (Ref. 20)(X_{EA} = -0.2C).

TABLE 1

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD WING-TAIL INTERFERENCE $M = 3.0$ $\Delta z/L = 0.0$

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	$k \approx 0.0$		$k = 1.5$		METHOD*
			[illegible]	[illegible]	[illegible]	[illegible]	
WING TWIST	WING TWIST	1, 1	-0.0226	-	0.0966	0.1436	11
			-0.0208	-	0.1002	0.1463	17
			0.0387	-	0.1059	0.1446	18
			0.0189	0.1820	0.1066	0.1345	PRES.
WING BENDING	WING TWIST	2, 1	0.3035	-	0.3846	0.0890	11
			0.3020	-	0.3740	0.0890	17
			0.2661	-	0.2710	0.1207	18
			0.2789	0.1082	0.3238	0.0765	PRES.
TAIL ROLL	WING TWIST	3, 1	-0.2152	-	-0.0394	0.0769	11
			0.2137	-	0.0463	0.0696	17
			-0.2660	-	-0.1200	0.0351	18
			0.2226	-0.1020	0.1438	-0.0612	PRES.
TAIL PITCH	WING TWIST	4, 1	-0.1550	-	-0.0147	0.0559	11
			0.1516	-	0.0171	0.0517	17
			-0.2170	-	-0.1316	-0.0727	18
			-0.0006	0.0416	0.1438	-0.0612	PRES.
WING TWIST	WING BENDING	1, 2	0.0	-	-0.0700	0.0307	11
			0.0	-	-0.0720	0.0327	17
			0.0	-	-0.0294	0.0801	18
			0.0	0.0121	-0.0668	0.0463	PRES.
WING BENDING	WING BENDING	2, 2	0.0	-	-0.0759	0.2363	11
			0.0	-	-0.0730	0.2335	17
			0.0	-	0.0167	0.2464	18
			0.0	0.1794	-0.0530	0.2040	PRES.
TAIL ROLL	WING BENDING	3, 2	0.0	-	-0.1531	0.0230	11
			0.0	-	0.1477	0.0160	17
			0.0	-	-0.1146	-0.0611	18
			0.0	0.1642	0.1701	0.0670	PRES

* NO. IN METHOD-COLUMN IS FOR "REF NO"; PRES. FOR "PRESENT METHOD"

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE 1 (CONT.)

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD WING-TAIL INTERFERENCE $M = 3.0$ $\Delta Z/L = 0.0$ (CONT.)

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	$k \approx 0.0$		$k = 1.5$		METHOD+
			Q'_{ij}	Q''_{ij}	Q'_{ij}	Q''_{ij}	
TAIL PITCH	WING BENDING	4, 2	0.0	–	-0.1033	0.0197	11
			0.0	–	0.0988	0.0167	17
			0.0	–	-0.0930	-0.0857	18
			0.0	0.0198	0.0216	0.0398	PRES.
WING TWIST	TAIL ROLL	1, 3	0.0	–	0.0	0.0	11
			0.0	–	0.0	0.0	18
			0.0	0.0	0.0	0.0	PRES.
WING BENDING	TAIL ROLL	2, 3	0.0	–	0.0	0.0	11
			0.0	–	0.0	0.0	18
			0.0	0.0	0.0	0.0	PRES.
TAIL ROLL	TAIL ROLL	3, 3	0.0	–	0.0168	0.2560	11
			0.0	–	0.0700	0.3171	18
			0.0	0.2348	0.0127	0.2283	PRES.
TAIL PITCH	TAIL ROLL	4, 3	0.0	–	0.0050	0.1786	11
			0.0	–	0.0365	0.2280	18
			0.0	0.1704	0.0008	0.1669	PRES.
WING TWIST	TAIL PITCH	1, 4	0.0	–	0.0	0.0	11
			0.0	–	0.0	0.0	18
			0.0	0.0	0.0	0.0	PRES.
WING BENDING	TAIL PITCH	2, 4	0.0	–	0.0	0.0	11
			0.0	–	0.0	0.0	18
			0.0	0.0	0.0	0.0	PRES.
TAIL ROLL	TAIL PITCH	3, 4	0.4665	–	0.4517	0.1632	11
			0.4638	–	0.4410	0.2168	18
			0.4338	0.1483	0.3859	0.1518	PRES.

TABLE I (CONT.)

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD WING-TAIL INTERFERENCE M = 3.0 $\Delta z/L = 0.0$ (CONT.)

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	k ≈ 0.0		k = 1.5		METHOD *
			[illegible]	[illegible]	[illegible]	[illegible]	
TAIL PITCH	TAIL PITCH	4,4	0.2882	–	0.2965	0.2588	[illegible]
			0.2873	–	0.3162	0.3010	[illegible]
			0.3018	0.1962	0.2578	0.1910	PRES.
WING TWIST AND TAIL ROLL	WING TWIST AND TAIL ROLL	1+3, 1+3	0.2472	0.3125	0.2630	0.3016	PRES.
WING BENDING AND TAIL PITCH	WING TWIST AND TAIL ROLL	2+4, 1+3	0.2830	0.3218	0.3571	0.2646	PRES.
WING TWIST AND TAIL ROLL	WING BENDING AND TAIL PITCH	1+3, 2+4	0.4338	0.3348	0.5244	0.2694	PRES.
WING BENDING AND TAIL PITCH	WING BENDING AND TAIL PITCH	2+4, 2+4	0.3018	0.4057	0.2729	0.4414	PRES.

TABLE 2

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD WING-TAIL INTERFERENCE   M = 3.0 . ΔZ/L = 0.6

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	k = [illegible]		k = [illegible]		[illegible] *
			[illegible]	[illegible]	[illegible]	[illegible]	
WING TWIST	WING TWIST	1, 1			0.0919	0.1462	11
					0.1059	0.1446	18
					0.1172	0.1318	PRES.
WING BENDING	WING TWIST	2, 1			0.3801	0.0890	11
					0.2710	0.1207	18
					0.3387	0.0824	PRES.
TAIL ROLL	WING TWIST	3, 1			0.1053	0.0554	11
					-0.0132	0.1024	18
					-0.1566	-0.0515	PRES.
TAIL PITCH	WING TWIST	4, 1			0.0856	0.0541	11
					-0.0068	0.0817	18
					-0.0876	-0.0406	PRES.
WING TWIST	WING BENDING	1, 2			-0.0746	0.0301	11
					-0.0294	0.0801	18
					-0.0438	0.0596	PRES.
WING BENDING	WING BENDING	2, 2			-0.0729	0.2447	11
					0.0167	0.2464	18
					-0.0248	0.2218	PRES
TAIL ROLL	WING BENDING	3, 2			-0.0491	0.0615	
					-0.0715	-0.0012	
					0.0358	-0.0402	
TAIL PITCH	WING BENDING	4, 2			-0.0406	0.0485	
					-0.0602	0.0104	
					0.0338	-0.0606	

TABLE 2 (CONT.)

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD WING-TAIL INTERFERENCE $M = 3.0$ $\Delta Z/L = 0.6$ (CONT.)

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	k ≈ 0.0		k = 1.5		METHOD*
			R'_{ij}	I'_{ij}	R'_{ij}	I'_{ij}	
WING TWIST	TAIL ROLL	1,3			0.0	0.0	11
					0.0	0.0	18
					0.0	0.0	PRES.
WING BENDING	TAIL ROLL	2,3			0.0	0.0	11
					0.0	0.0	18
					0.0	0.0	PRES
TAIL ROLL	TAIL ROLL	3,3			0.0165	0.2622	11
					0.0700	0.3170	18
					0.0409	0.2898	PRES.
TAIL PITCH	TAIL ROLL	4,3			0.0072	0.1864	11
					0.0355	0.2208	18
					0.0265	0.2240	PRES
WING TWIST	TAIL PITCH	1,4			0.0	0.0	11
					0.0	0.0	18
					0.0	0.0	PRES.
WING BENDING	TAIL PITCH	2,4			0.0	0.0	[illegible]
					0.0	0.0	[illegible]
					0.0	0.0	PRES.
TAIL ROLL	TAIL PITCH	3,4			0.4517	0.[illegible]	[illegible]
					0.4410	0.2168	[illegible]
					0.5000	0.137[illegible]	PRES
TAIL PITCH	TAIL PITCH	4,4			0.2965	[illegible]	11
					0.3162	[illegible]	18
					0.3174	[illegible]	PRES.

TABLE 2 (CONT.)

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD WING-TAIL INTERFERENCE $M = 3.0$ $\Delta Z/L = 0.6$ (CONT.)

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	k ≈ 0.0 B'_{ij}	k ≈ 0.0 B''_{ij}	k = 1.5 B'_{ij}	k = 1.5 B''_{ij}	METHOD
WING TWIST	TAIL ROLL	1,3			0.0	0.0	11
					0.0	0.0	18
					0.0	0.0	PRES.
WING BENDING	TAIL ROLL	2,3			0.0	0.0	11
					0.0	0.0	18
					0.0	0.0	PRES
TAIL ROLL	TAIL ROLL	3,3			0.0165	0.2622	11
					0.0700	0.3170	18
					0.0409	0.2898	PRES.
TAIL PITCH	TAIL ROLL	4,3			0.0072	0.1864	11
					0.0365	0.2208	19
					0.0263	0.2240	PRES
WING TWIST	TAIL PITCH	1,4			0.0	0.0	11
					0.0	0.0	18
					0.0	0.0	PRES.
WING BENDING	TAIL PITCH	2,4			0.0	0.0	11
					0.0	0.0	18
					0.0	0.0	PRES.
TAIL ROLL	TAIL PITCH	3,4			0.4517	0.1632	11
					0.4410	0.2168	18
					0.5000	0.1874	PRES
TAIL PITCH	TAIL PITCH	4,4			0.2965	0.2582	11
					0.3162	0.3010	18
					0.3724	0.2354	PRES.

TABLE 3

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD. WING-TAIL INTERFERENCE $M = 0.8$ $\Delta z / L = 0.6$

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	k = 0.0		k = 1.5		METHOD *
			I	R	I	R	
WING TWIST	WING TWIST	1, 1	-0.0871	0.1726	-0.2035	0.1952	11
			-0.0733	0.1635	-0.1644	0.1782	12
			-0.0600	0.0679	-0.1598	0.1335	PRES
WING BENDING	WING TWIST	2, 1	0.2611	0.3804	0.2147	0.4145	11
			0.2776	0.3788	0.2243	0.3974	12
			0.2272	0.3607	0.1955	0.3684	PRES
TAIL ROLL	WING TWIST	3, 1	-0.0619	0.0042	-0.0615	0.1246	11
			-0.0660	0.0347	-0.0343	0.0432	12
			-0.0556	-0.0045	-0.0489	0.0163	PRES
TAIL PITCH	WING TWIST	4, 1	-0.0206	0.0075	-0.0232	0.0108	11
			-0.0718	0.0371	-0.0406	0.0492	12
			-0.0154	-0.0006	-0.0181	0.0080	PRES
WING TWIST	WING BENDING	1, 2	0.0	-0.0515	-0.1360	-0.0507	11
			0.0	-0.0440	-0.1232	-0.0387	12
			0.0	-0.0362	-0.1163	-0.0391	PRES
WING BENDING	WING BENDING	2, 2	0.0	0.1842	-0.3478	0.2083	11
			0.0	0.1961	-0.3303	0.2147	12
			0.0	0.1588	-0.3317	0.2008	PRES
TAIL ROLL	WING BENDING	3, 2	0.0	-0.0345	-0.0431	-0.0137	11
			0.0	-0.0420	-0.0496	0.0052	12
			0.0	-0.0356	-0.0376	-0.0122	PRES
TAIL PITCH	WING BENDING	4, 2	0.0	-0.0138	-0.0192	-0.0049	11
			0.0	-0.0459	-0.0573	0.0051	12
			0.0	-0.0104	-0.0162	-0.0042	PRES

TABLE 3 (CONT.)

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD WING-TAIL INTERFERENCE $M = 0.8$ $\Delta z/L = 0.6$ (CONT.)

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	k = 0.0		k = 1.5		METHOD*
			[illegible]	[illegible]	[illegible]	[illegible]	
WING TWIST	TAIL ROLL	1, 3			-0.0008	-0.0031	11
					-0.0008	-0.0064	12
					-0.0005	-0.0018	PRES
WING BENDING	TAIL ROLL	2, 3			-0.0026	-0.0052	11
					-0.0015	-0.0006	12
					-0.0032	-0.0036	PRES
TAIL ROLL	TAIL ROLL	3, 3			-0.3156	0.4215	11
					-0.2974	0.4322	12
					-0.3638	0.3877	PRES
TAIL PITCH	TAIL ROLL	4, 3			-0.3115	0.1875	11
					-0.5089	0.4945	12
					-0.2962	0.1454	PRES
WING TWIST	TAIL PITCH	1, 4			-0.0087	-0.0016	11
					-0.0028	-0.0001	12
					-0.0044	-0.0012	PRES
WING BENDING	TAIL PITCH	2, 4			-0.0156	0.0012	11
					-0.0046	0.0007	12
					-0.0120	0.0002	PRES
TAIL ROLL	TAIL PITCH	3, 4			0.5328	0.7713	11
					0.3278	1.0701	12
					0.3916	0.7766	PRES
TAIL PITCH	TAIL PITCH	4, 4			-0.0452	0.6442	11
					-0.0264	1.6094	12
					-0.1496	0.5354	PRES

TABLE 3 (CONT.)

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD WING-TAIL INTERFERENCE $M = 0.8$ $\Delta Z/L = 0.6$ (CONT.)

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	K = 0.0		K = .15		METHOD +
			[illegible]	[illegible]	[illegible]	[illegible]	
WING TWIST AND TAIL ROLL	WING TWIST AND TAIL ROLL	1+3, 1+3	-0.1470 -0.1156	0.5492 0.4254	-0.5713 -0.5661	0.6274 0.5346	21 PRES
WING BENDING AND TAIL PITCH	WING TWIST AND TAIL ROLL	2+4, 1+3	0.2404 0.2117	0.5308 0.4990	-0.1262 -0.1308	0.5989 0.5226	21 PRES
WING TWIST AND TAIL ROLL	WING BENDING AND TAIL PITCH	1+3, 2+4	0.6402 0.6351	0.6181 0.6475	0.3558 0.2332	0.7180 0.7242	21 PRES
WING BENDING AND TAIL PITCH	WING BENDING AND TAIL PITCH	2+4, 2+4	0.1619 0.1694	0.7565 0.6266	-0.4568 -0.5094	0.8729 0.7317	21 PRES