BOSTON UNIVERSITY

DEPARTMENT OF AEROSPACE ENGINEERING
COLLEGE OF ENGINEERING
BOSTON, MASSACHUSETTS

DEPARTMENT OF AEROSPACE ENGINEERING

BOSTON UNIVERSITY

COLLEGE OF ENGINEERING

BOSTON, MASS. 02215

A NEW UNIFIED APPROACH TO ANALYZE WING-BODY-TAIL CONFIGURATIONS WITH CONTROL SURFACES IN STEADY, OSCILLATORY AND FULLY UNSTEADY, SUBSONIC AND SUPERSONIC FLOWS

Kadin Tseng

and

Luigi Morino

Work supported by NASA Grant NGR 22-004-030

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

INTRODUCTION

A general formulation for the analysis of steady and unsteady, subsonic and supersonic potential aerodynamics for arbitrary complex geometries is presented here. The proposed paper includes the theoretical formulation, the numerical procedure and numerical results. In particular, generalized forces for fully unsteady (complex frequency) aerodynamics for an AGARD coplanar wing-tail interfering configuration in both subsonic and supersonic flows 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 a much more general formulation is considered. First, 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).

In addition, no diaphragm is required in supersonic flow, so that the subsonic and supersonic formulations have been unified. Also the formulation has been extended to allow for the analysis of the problem of the wing-wake intersecting the tail. Additional features are described in details in the section entitled "Assessment of Method".

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 normalwash. 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 normalwash at the centroids of N elements.

For the sake of generality and flexibility, in particular, for structural analysis, the normalwash 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 hence 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.

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 the results are in very good agreement with the ones of Ref. 9. 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 in order to demonstrate the capability of the present method of analyzing fully unsteady flows. 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 wing-body-tail configurations (with control surfaces) will be included in the proposed paper.

ASSESSMENT OF METHOD

An assessment of the method is briefly outlined here. In particular, unique features of the methodology (with existing methods) are stressed and progress with Ref. 4 is emphasized.

1. It provides a unified approach for steady, oscillatory and fully unsteady subsonic and supersonic aerodynamic flows.
2. To the authors' knowledge, this is the only existing program which can handle fully unsteady (complex frequency) aerodynamics for complex configurations (e.g., wing-body-tail combination) in both subsonic and supersonic regimes. No other program can handle even oscillatory supersonic flow problems for complex configurations.
3. It can be applied to arbitrarily-complex configurations. Wing-body-tail configurations with control surface have been analyzed. (No existing results are available for comparison. However, results for a simple wing with control surface shows that the present method is in good agreement with existing ones.)
4. It is a unique feature of the present method in that it is capable of analyzing influence of actual wake geometry on aircraft surfaces. In particular, it can analyze wing-tail configurations with the wake generated by the wing intercepting the tail and merging with the tail generated wake when it leaves the tail trailing edge. This feature has been added very recently to the program and improves considerably the range of applicability of the code. Results are in good agreement with existing ones.

5. The program 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. (Ref. 4 requires the use of diaphragm and hence is limited to simple geometries).
6. In contrast to existing methods, which in many instances require extensive user's background in aerodynamics and familiarity with the specific method, the present code requires limited human itervention and is very easy to use.
7. The evaluation of pressure is performed using the finite-element method. (Ref. 4 used finite-difference and was limited to thin wings)
8. The generalized forces are evaluated for arbitrary geometry and arbitrary three dimensional mode shapes.
9. 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, is expressed as a combination of complex frequency-independent coefficients* with simple frequency-dependent coefficients: the advantage is that every additional frequency analysis other than the first one requires only a minimal amount of CPU time

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

10. 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 (for the normalwash and for the evaluation of the generalized forces) are mode dependent but very simple, while the second one (relating pressure distribution to normalwash 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.
11. Evaluation of the normalwash for complex configurations from prescribed three dimensional mode shapes (Ref. 4 was limited to thin wings with vertical displacements.) is available. Downwash due to turbulence is also included.
12. Applications to flutter have been considered. The results (see next section) are in good agreement with existing ones.

In conclusion, the proposed paper will 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 with very limited human intervention required in using the computer code SOUSSA.

References

1. Morino, L. "Unsteady Compressible Potential Flow around Lifting Bodies Having Arbitrary Shapes and Motions", Boston 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.

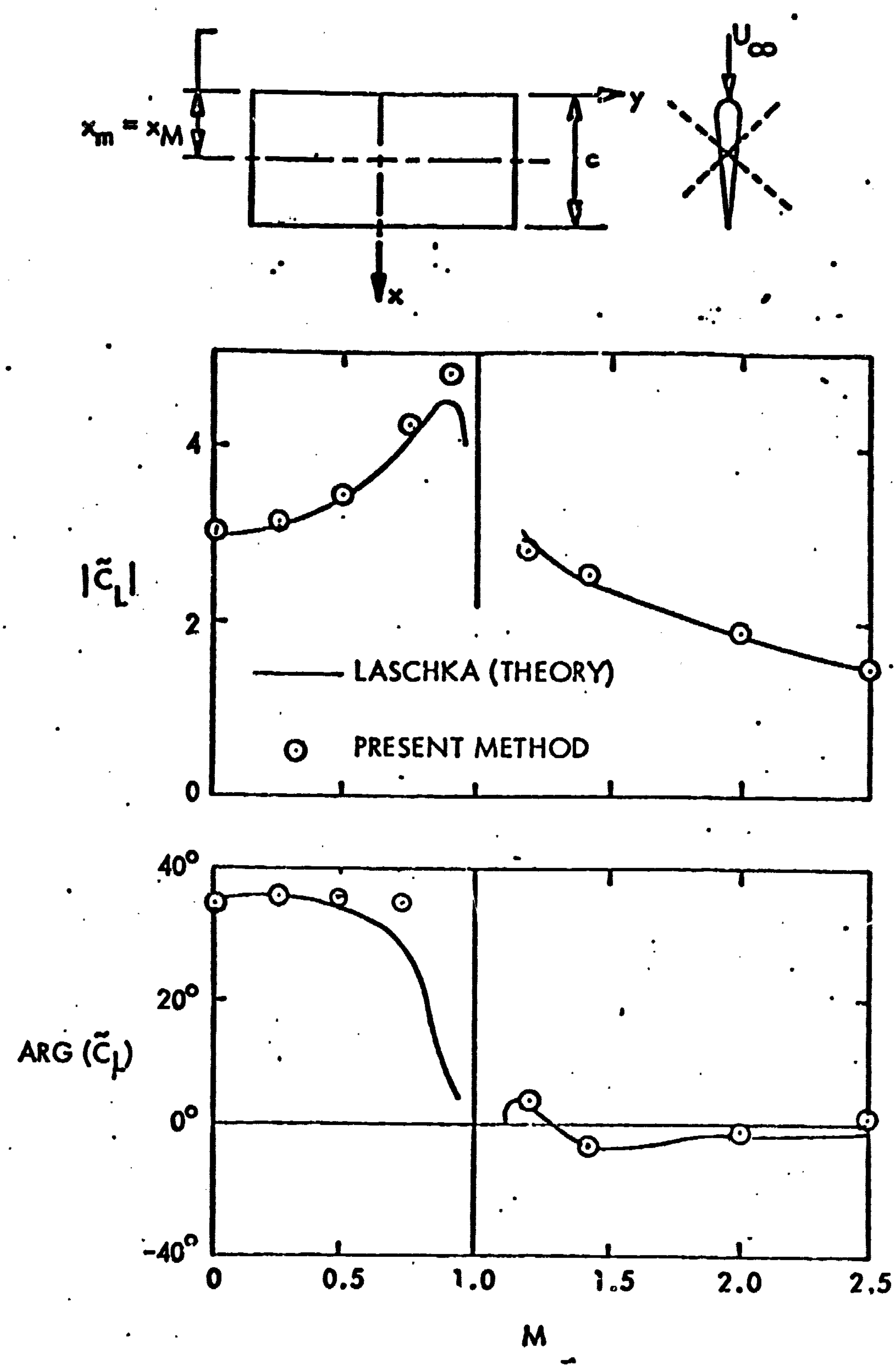

Fig. 1 Lift Coefficient, C_L, Versus M, for Rectangular Wing Oscillating in Pitch, With AR=2, τ=0.001, k=1, N_x=7, N_y=7, N_w=20, L_w/c=2. Comparison with results of reference 11.

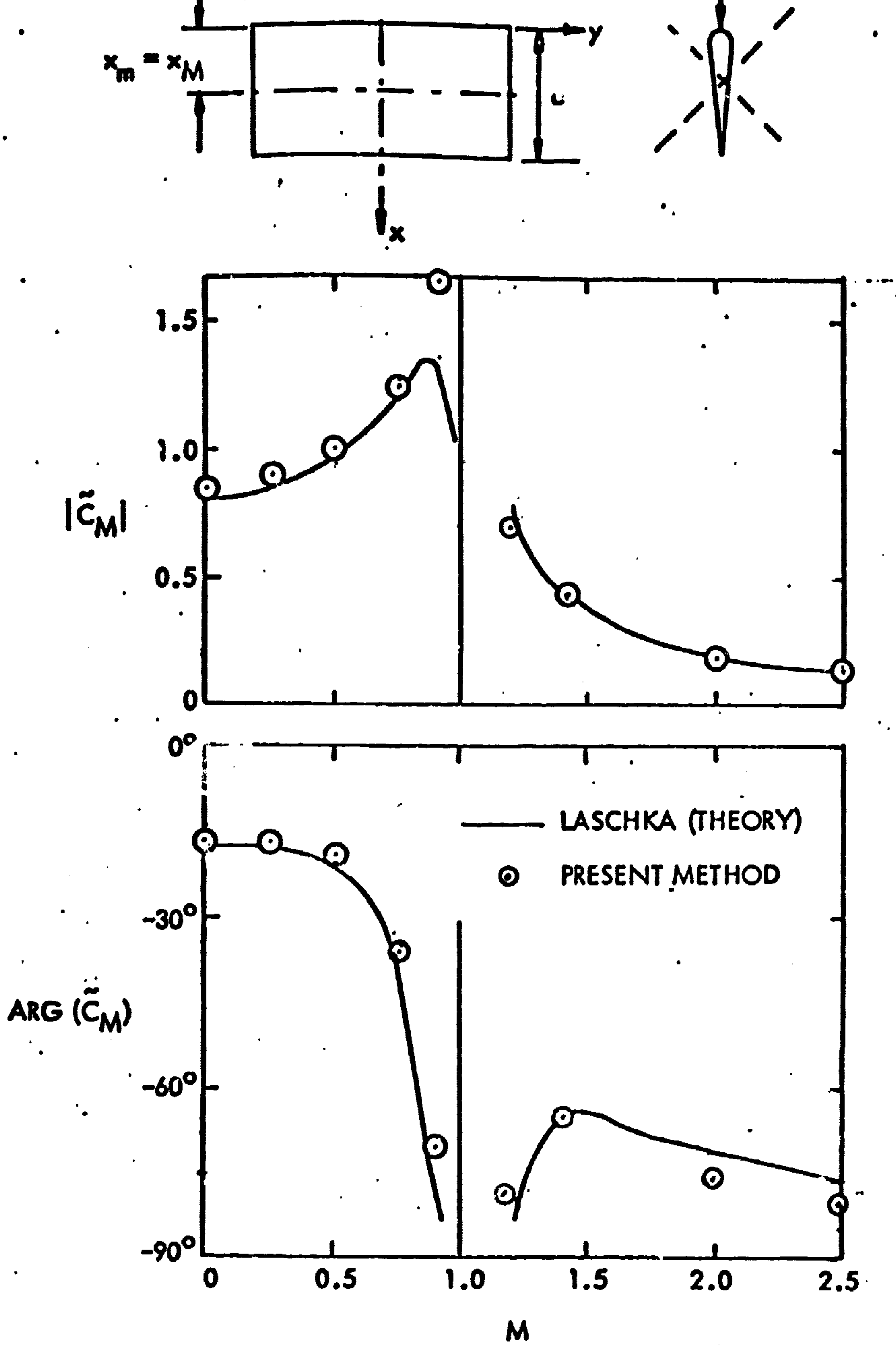

Fig. 2 Moment Coefficient, C_M, Versus M, for Rectangular Wing Oscillating in Pitch, for AR=2, τ=0.001, k=1, N_x=7, N_y=7, N_w=20, L_w/c=2, Comparison with results of reference 11.

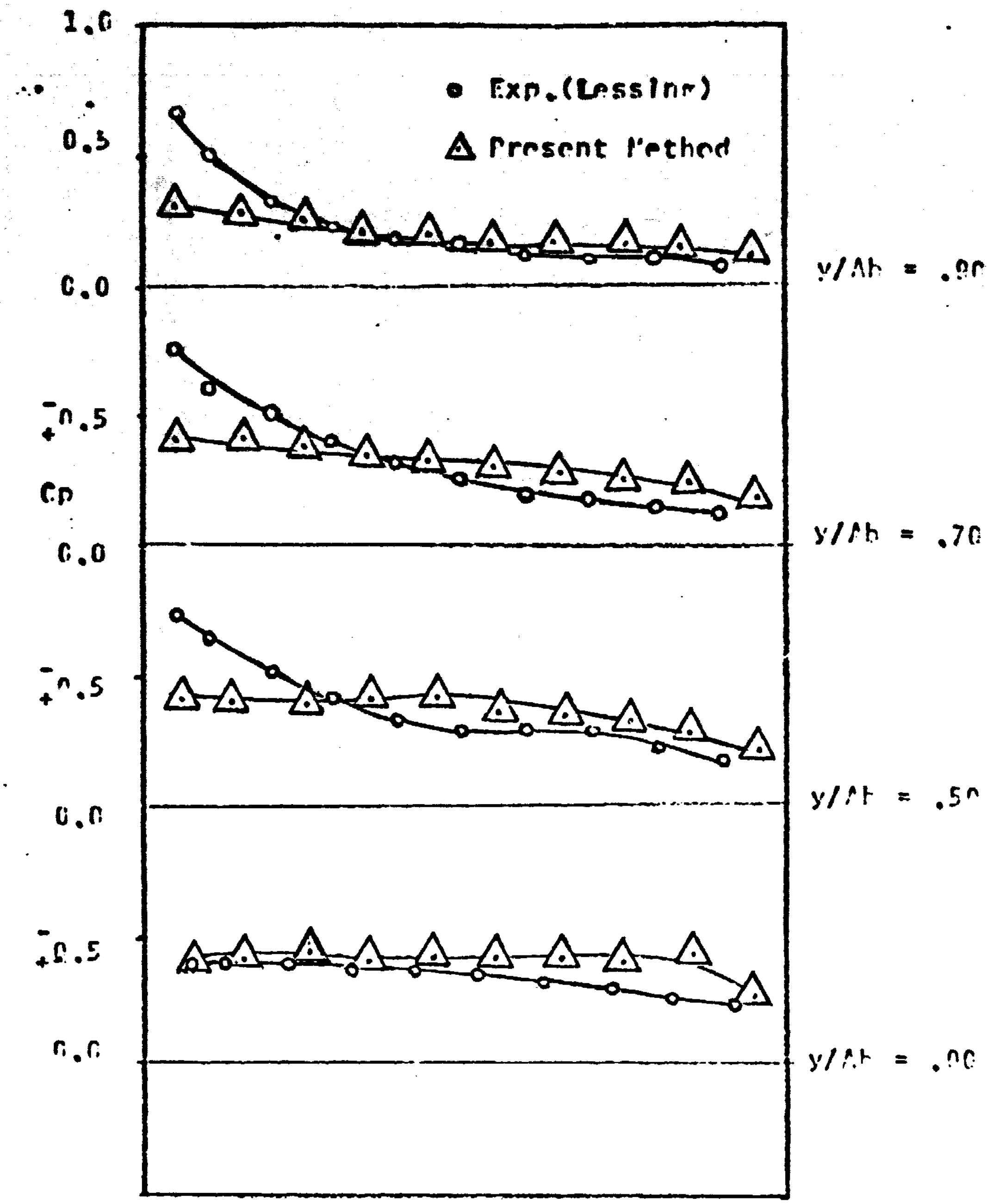

Fig.3 Lifting pressures ; M = 1.30 , $\alpha = 5^{\circ}$

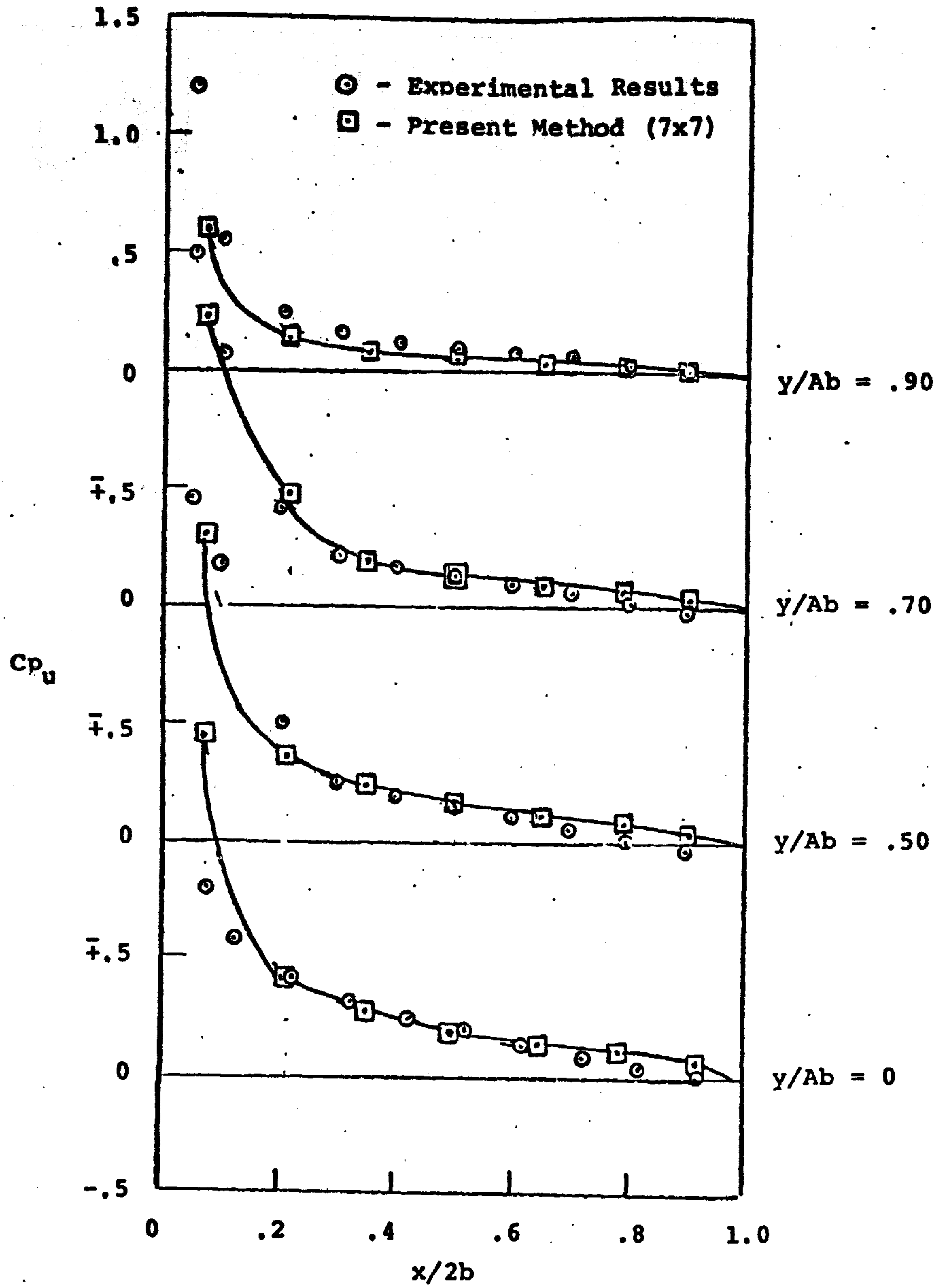

Fig. 4 Lifting pressures; M = 0.70 , α = 5°

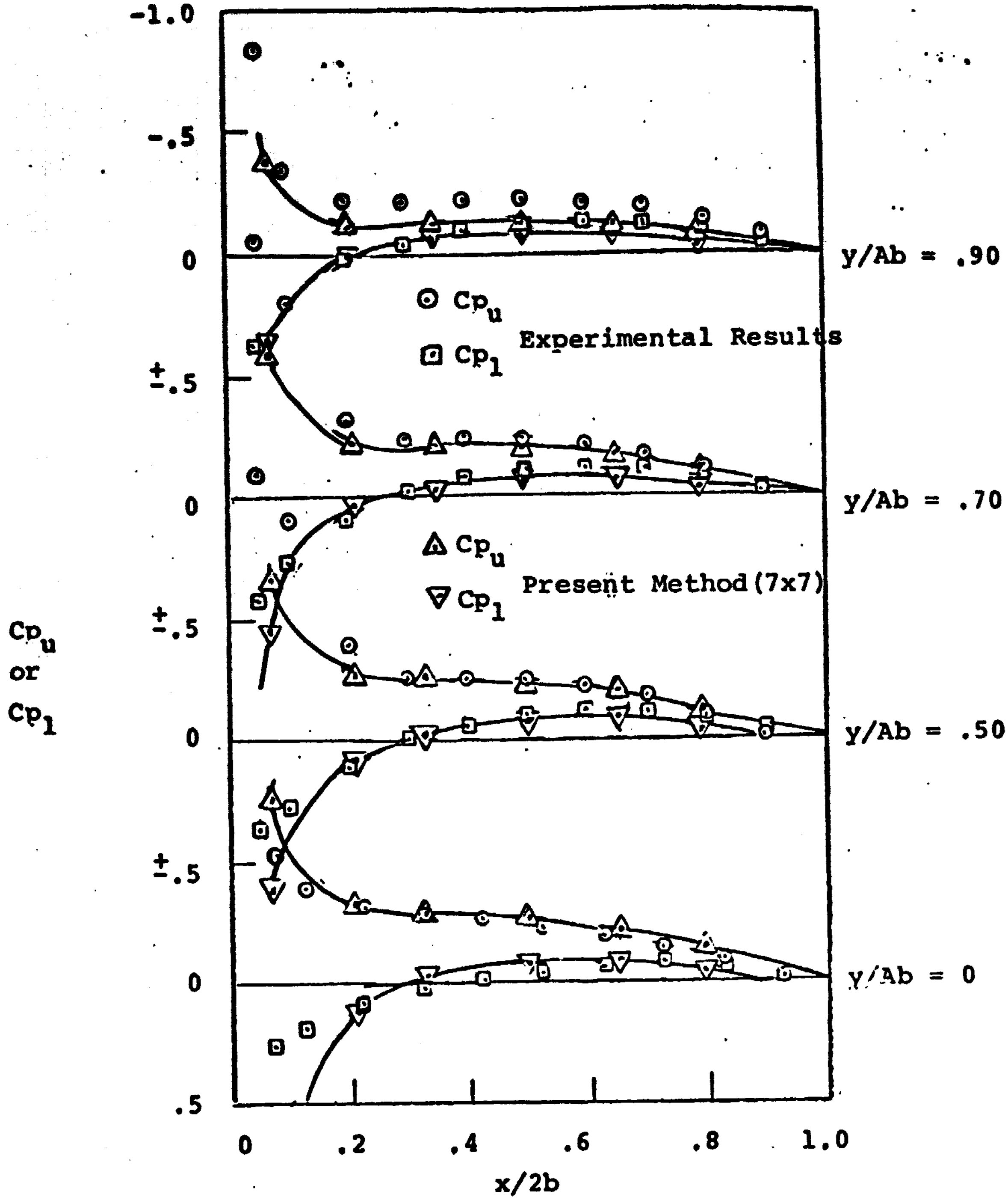

Fig 5 Pressures on upper and lower surfaces

$M = 0.70$, $\alpha = 5°$

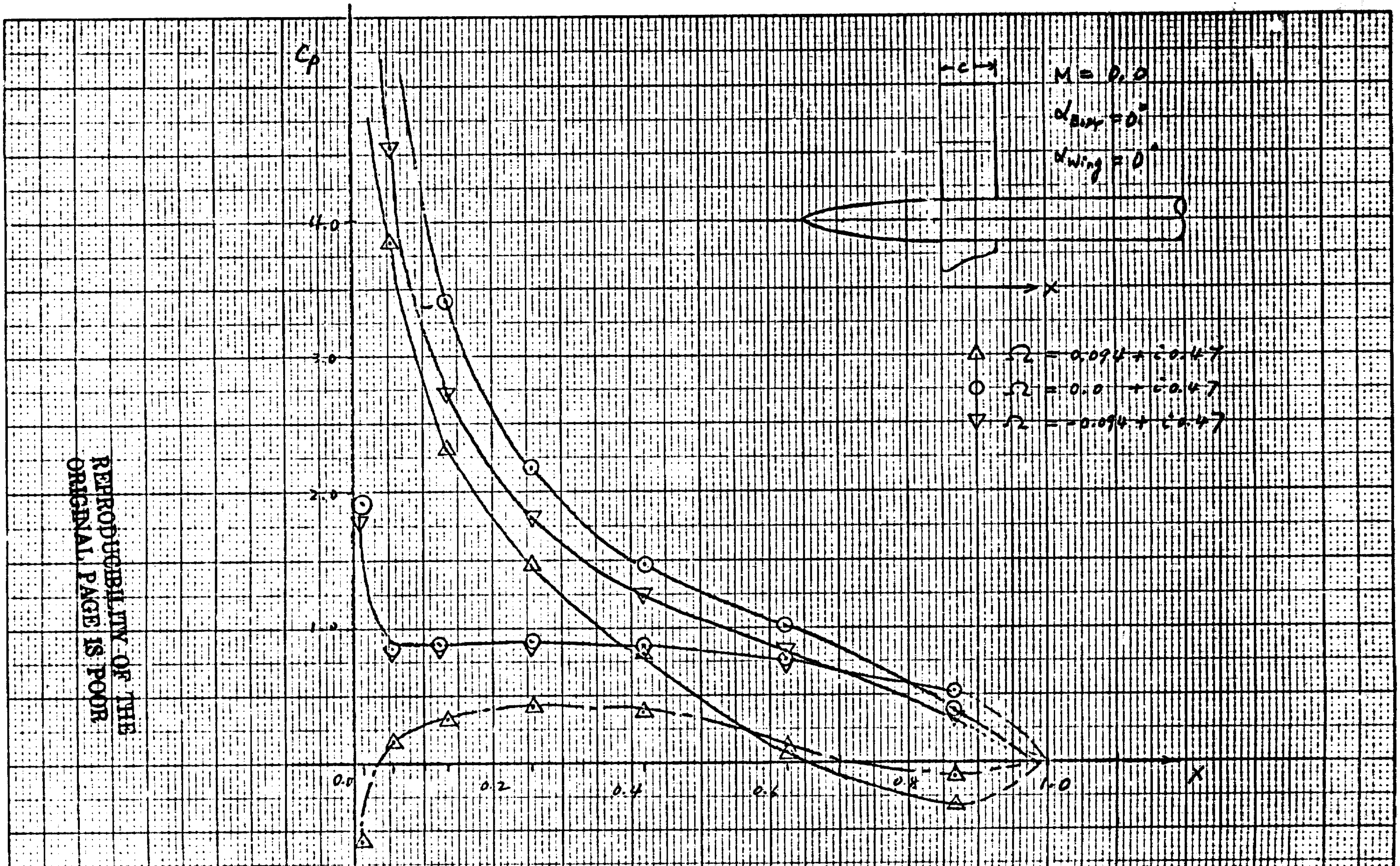

Fig. 6 Pressure distribution at mid semi-span of a wing-body configuration in fully unsteady flow for three different frequencies Ω

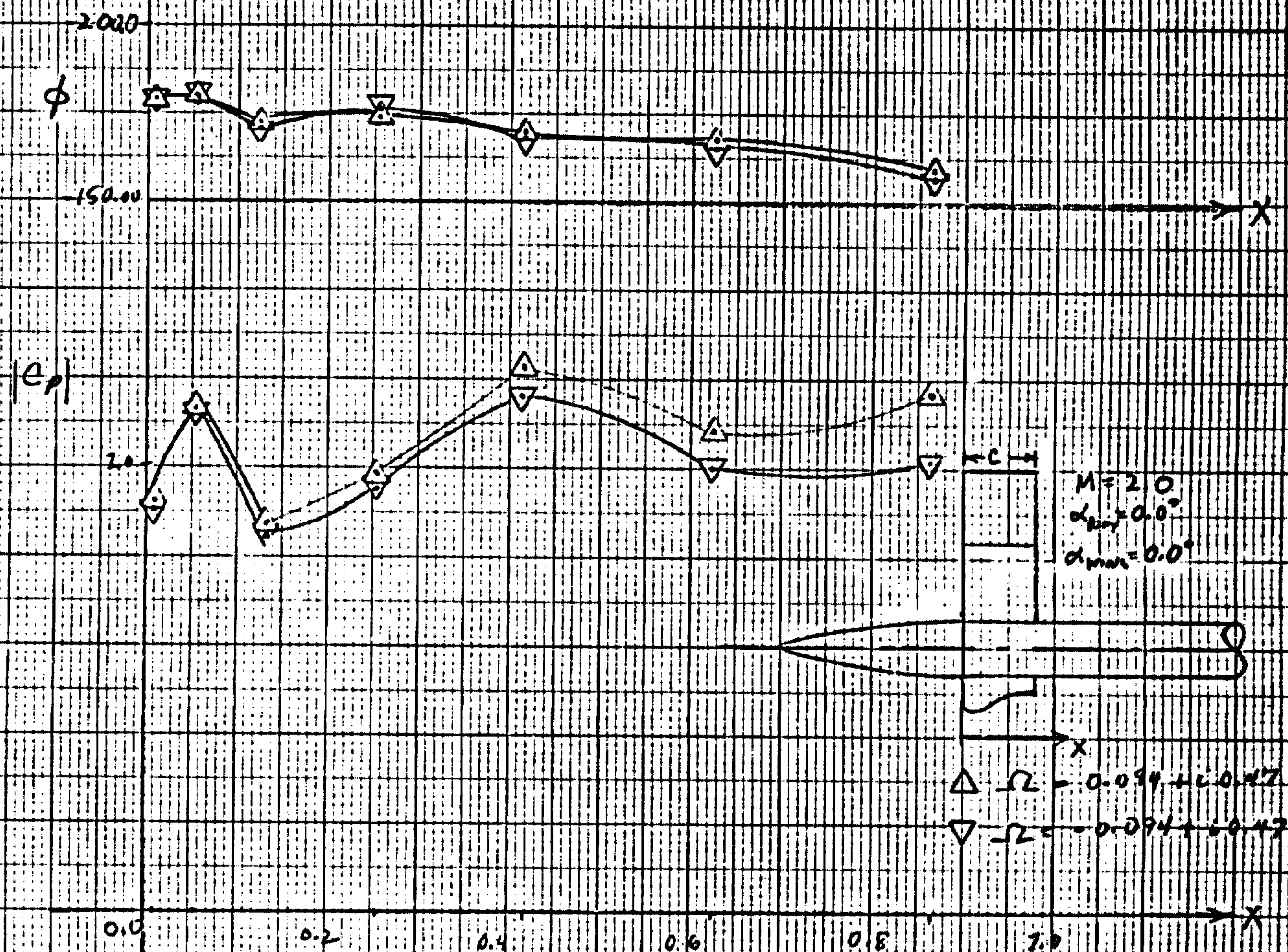

Fig 7 Absolute value and phase angle of pressure distribution at mid semi-span on the upper surface of a wing-body configuration in fully unsteady flow for two frequencies, Ω.

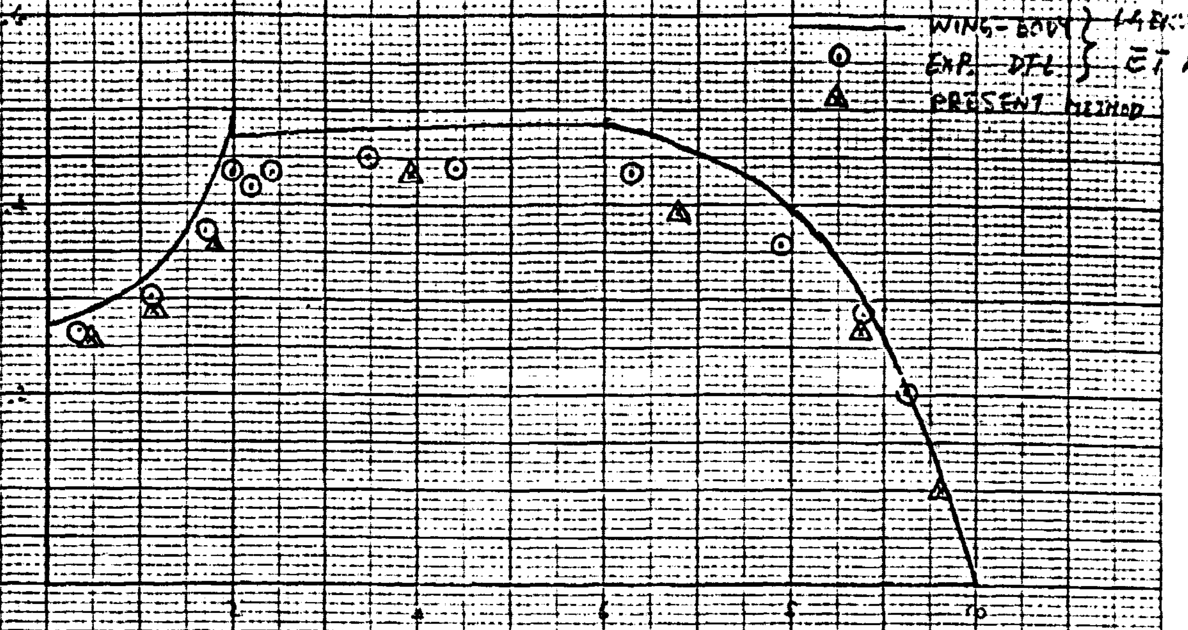

Fig. 8 Sectional lift distributions for a Wing-Body configuration in steady flow with $\alpha_W = 6^\circ$, $\alpha_B = 0^\circ$ and $M = 0$

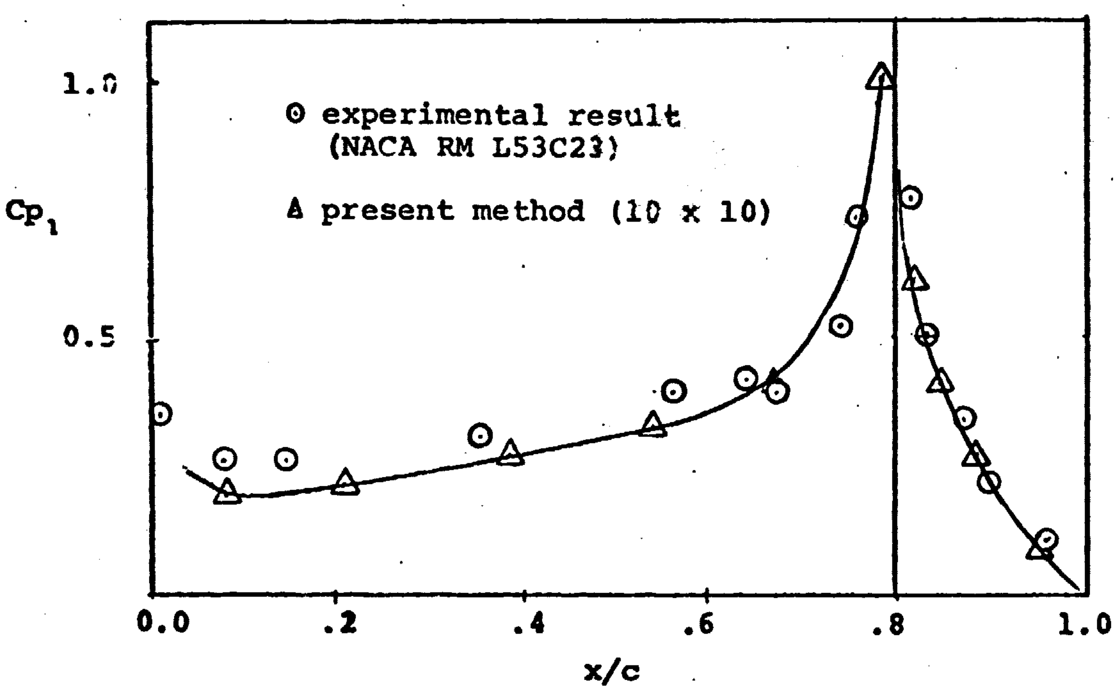

Fig. 9 Chordwise pressure distribution over a 35° swept wing, at the 46-percent-semispan station. $\alpha = 0°$ $\delta = -15°$, $M = 0.6$.

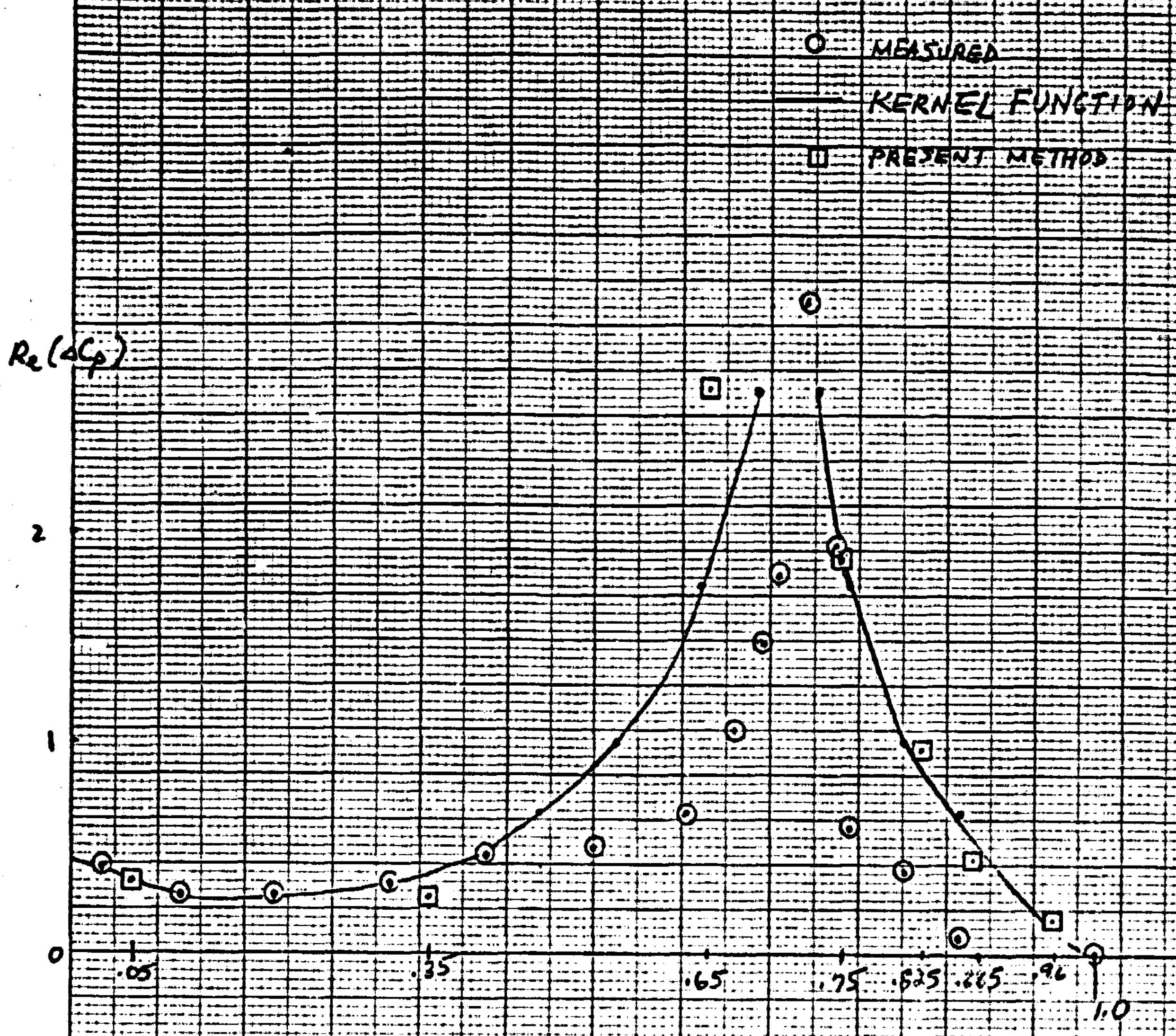

Fig 10. Unsteady pressure distributions on a rectangular wing with full span control surface

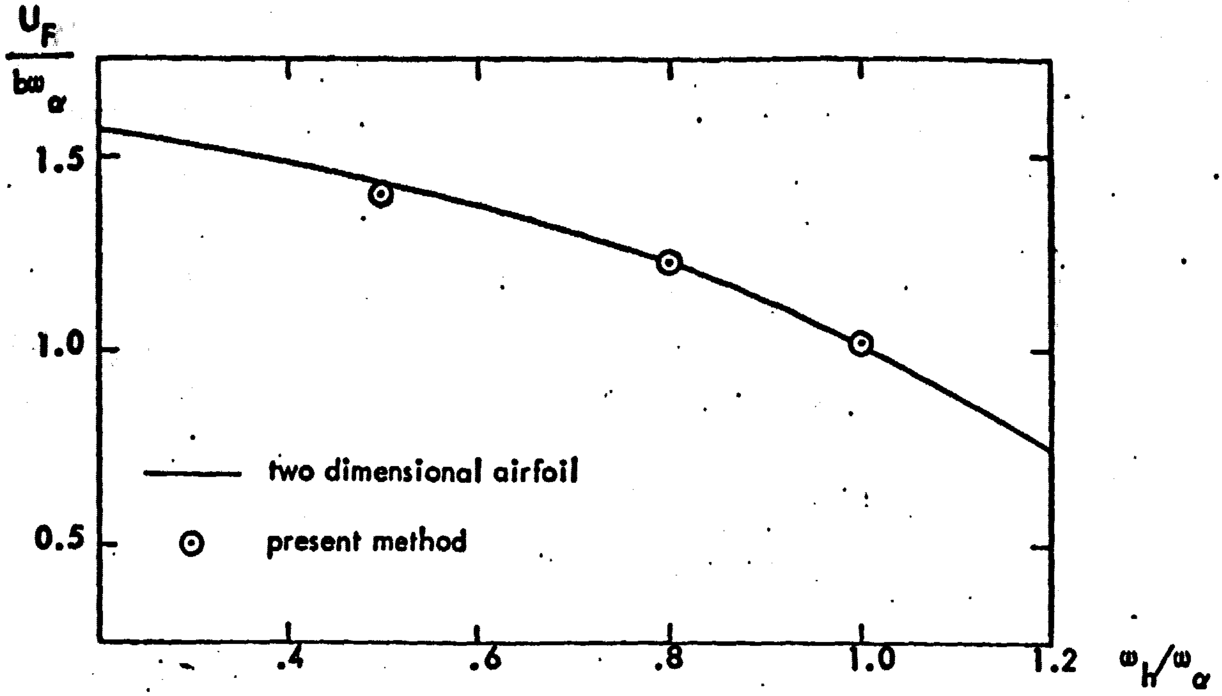

Figure 11a Flutter speed as a function of ω_h/ω_α for a rectangular wing with AR = 16, M = 0, τ = 0.1%, μ = 5, X_α = 0.2, r_α = 0.5, and NX = 8, NY = 10. Results are compared with exact solution given by two dimensional airfoil theory (Ref. 20) (X_{EA} = -0.2C).

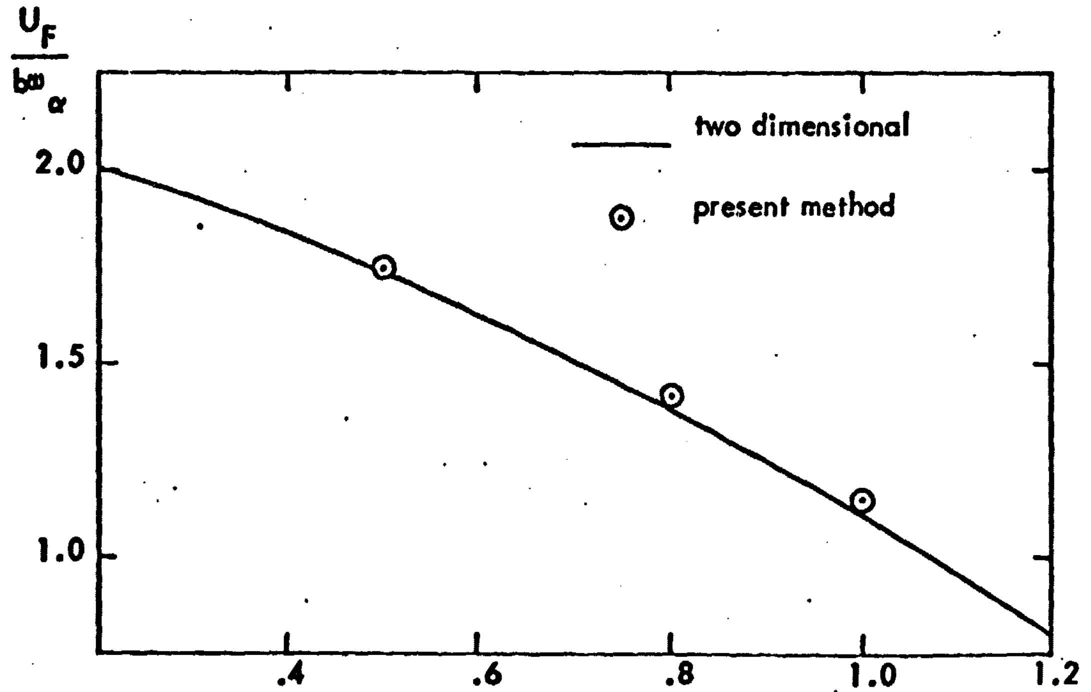

Figure 11b Flutter speed as a function of ω_h/ω_α for a rectangular wing with AR = 16, M = 0, τ = 0.1%, μ = 10, X_α = 0.2, r_α = 0.5 and NX = 8, NY = 10. Results are compa ed with exact solution given by two dimensional airfoil theory (Ref. 20)(X_{EA} = -0.2C).

TABLE 1

GENERALIZED AERODYNAMIC COEFFICIENT FOR AGARD WING-TAIL INTERFERENCE M = 3.0 Δz/L = 0.0

GENERALIZED FORCE IN	CAUSED BY PRESURE IN	i, j	k ≈ 0.0		k = 1.5		METHOD*
			Q'_{ij}	Q''_{ij}	Q'_{ij}	Q''_{ij}	
WING TWIST	WING TWIST	1, 1	-0.0226	–	0.0966	0.1486	11
			-0.0208	–	0.1002	0.1463	17
			0.0337	–	0.1059	0.1446	18
			0.0189	0.1220	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	0.1433	-0.0612	PRES.
WING TWIST	WING BENDING	1, 2	0.0	–	-0.0700	0.0309	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	0.2264	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"

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+
			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	0.1337	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
			[illegible]	–	0.4410	0.2162	18
			0.4338	0.1283	0.3757	0.1518	PRES.

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 ≈ 0.0		k = 1.5		METHOD *
			Q'_{ij}	Q''_{ij}	Q'_{ij}	Q''_{ij}	
TAIL PITCH	TAIL PITCH	4,4	0.2882	-	0.2965	0.2588	11
			0.2873	-	0.3162	0.3010	18
			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 $M = 2.0$ $\Delta z/L =$ [illegible]

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	k ≈ 0.0		k = 1.5		METHOD*
			Q'_{ij}	Q''_{ij}	Q'_{ij}	Q''_{ij}	
WING TWIST	WING TWIST	1, 1			0.0913	0.1462	11
					0.1059	0.1446	18
					0.1172	[illegible]	PRES.
WING BENDING	WING TWIST	2, 1			0.3391	0.0893	11
					0.2716	0.1207	18
					0.3297	0.0824	PRES.
TAIL ROLL	WING TWIST	3, 1			0.1253	0.0524	11
					-0.0182	0.1024	18
					-0.1566	-0.0315	PRES.
TAIL PITCH	WING TWIST	4, 1			0.1856	0.0541	11
					-0.0003	0.0317	18
					-0.0376	-0.0406	PRES.
WING TWIST	WING BENDING	1, 2			-0.0746	0.0801	11
					-0.0244	0.0801	18
					-0.0435	0.0586	PRES.
WING BENDING	WING BENDING	2, 2			-0.0729	0.0447	11
					0.0167	0.0464	18
					-0.0242	0.0218	PRES.
TAIL ROLL	WING BENDING	3, 2			-0.0291	0.0615	
					-0.0715	-0.0012	
					0.0359	-0.0901	
TAIL PITCH	WING BENDING	4, 2			-0.0401	0.0485	
					-0.0605	0.0104	
					0.0382	-0.0666	

TABLE 2 (CONT.)

GENERALIZED AERODYNAMIC COEFFICIENT FOR PLANAR WING-TAIL INTERFERENCE M = [illegible] ΔZ/L = [illegible] (CONT.)

GENERALIZED FORCE IN	CAUSED BY PRESSURE IN	i, j	k ≈ 0.0		k = 1.5		METHOD
			Q'_{ij}	Q''_{ij}	Q'_{ij}	Q''_{ij}	
WING TWIST	TAIL ROLL	1, 3			0.0	0.0	11
					0.0	0.0	18
					0.0	0.0	PRES.
WING BEND.	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	[illegible]
					0.0700	0.3170	18
					0.0469	0.2898	PRES.
TAIL PITCH	TAIL ROLL	4, 3			0.0072	0.1864	11
					0.0835	0.2[illegible]8	18
					0.0[illegible]5	0.[illegible]40	PRES
WING TWIST	TAIL PITCH	1, 4			0.0	0.0	11
					0.0	0.0	18
					0.0	0.0	PRES.
WING BEND.	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]
					0.4416	0.2167	[illegible]
					0.5000	0.[illegible]	PRES
TAIL PITCH	TAIL PITCH	4, 4			0.[illegible]	[illegible]	[illegible]
					0.[illegible]	[illegible]	18
					[illegible]	[illegible]	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	$k \approx 0.0$ Q'_{ij}	$k \approx 0.0$ Q''_{ij}	$k = 1.5$ Q'_{ij}	$k = 1.5$ Q''_{ij}	METHOD *
WING TWIST	WING TWIST	1, 1	-0.0871	0.1726	-0.2035	0.1952	11
			-0.0733	0.1635	-0.1641	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	0.3474	12
			0.2272	0.3807	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	0.0025	-0.0232	0.0163	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	-0.0367	-0.1163	-0.0391	PRES
WING BENDING	WING BENDING	2, 2	0.0	0.1842	-0.3478	0.2283	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	-0.0395	-0.0431	-0.0137	11
			0.0	-0.0420	-0.0492	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 Q'_{ij}	k ≈ 0.0 Q''_{ij}	k = 1.5 Q'_{ij}	k = 1.5 Q''_{ij}	METHOD*
WING TWIST	TAIL ROLL	1, 3			-0.0008	-0.0031	11
					-0.0003	-0.0004	12
					-0.0005	-0.0013	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	0.1825	11
					-0.5089	0.4945	12
					-0.2962	0.1454	PRES
WING TWIST	TAIL PITCH	1, 4			-0.0037	-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
					-0.0126	0.0002	PRES
TAIL ROLL	TAIL PITCH	3, 4			0.5328	0.7713	11
					0.3276	1.0701	12
					0.3416	0.7766	PRES
TAIL PITCH	TAIL PITCH	4, 4			-0.0452	0.6443	11
					-0.0264	1.6094	12
					-0.1293	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 = 1.5		METHOD*
			Q'_{ij}	Q''_{ij}	Q'_{ij}	Q''_{ij}	
WING TWIST AND TAIL ROLL	WING TWIST AND TAIL ROLL	1+3,	-0.1470	0.5492	-0.5713	0.6274	21
		1+3	-0.1156	0.4254	-0.5661	0.5346	PRES
WING BENDING AND TAIL PITCH	WING TWIST AND TAIL ROLL	2+4,	0.2404	0.5308	-0.1262	0.5939	21
		1+3	0.2117	0.4990	-0.1308	0.5226	PRES
WING TWIST AND TAIL ROLL	WING BENDING AND TAIL PITCH	1+3,	0.6402	0.6131	0.3555	0.7180	21
		2+4	0.6351	0.6475	0.2332	[illegible]	PRES
WING BENDING AND TAIL PITCH	WING BENDING AND TAIL PITCH	2+4,	0.1619	0.7565	-0.4568	0.8729	21
		2+4	0.1694	0.6266	-0.5094	[illegible]	PRES