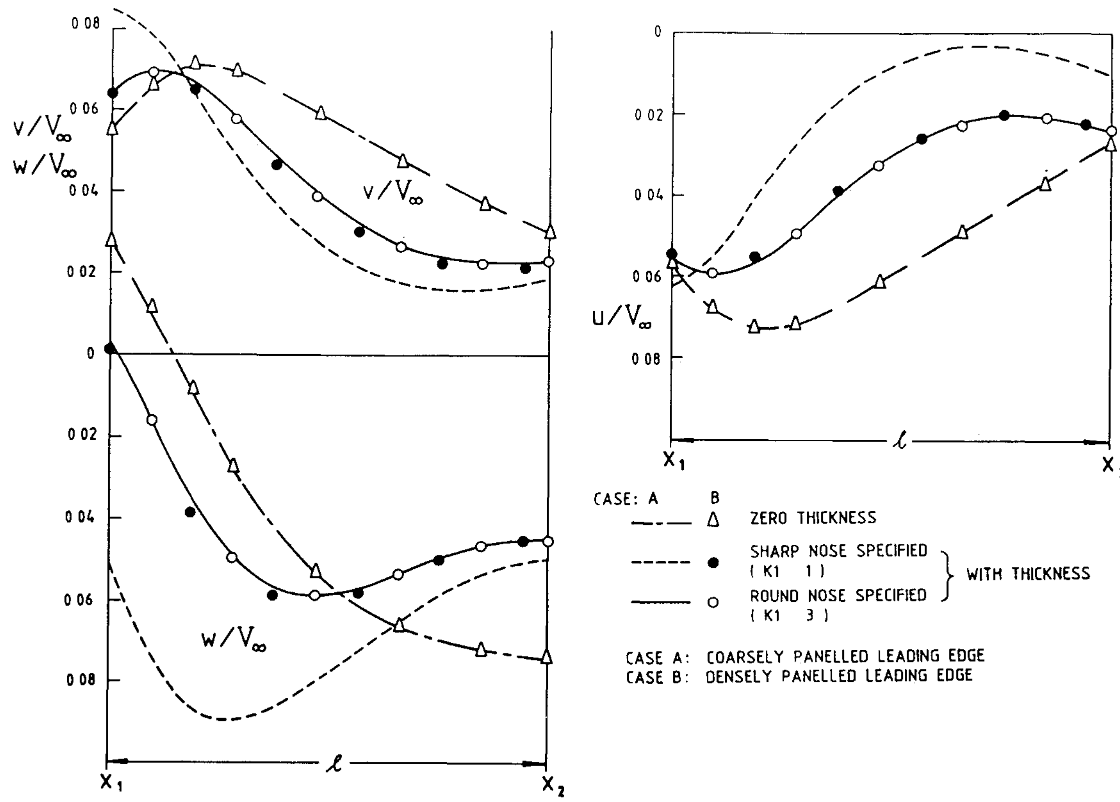

Fig 3 Perturbation flow field along line ℓ (planar boundary condition approximation); $M_\infty = 0\ 4$, $\alpha = 6$ deg

thickness case, the results for Cases A and B match closely Thus, no dense wing leading-edge paneling is required as far as the lift induced flow field is concerned The effect of the wing leading edge paneling on the thickness induced flow field is determined by comparing Cases A and B for the data obtained with thickness taken into account As Fig 3 shows that the influence of the wing thickness on the flow field is severe, particular attention is required Figure 3 demonstrates the trivial result that the differences in the perturbation velocities obtained with $K1 = 3$ (round nose) and $K1 = 1$ (sharp nose) are small if the leading edge region is paneled more densely (Case B) However, for a coarse leading edge paneling (Case A), these differences become very significant, the correct leading edge definition ($K1 = 3$) yielding correct results, whereas the $K1 = 1$ results are totally unacceptable Thus, as far as the thickness induced flow field is concerned no dense wing leading edge paneling is required provided that the roundness of the leading edge is taken into account properly

Conclusions

As to the modeling of carrier aircraft wings in external store load calculations using the panel method, it was demonstrated for a particular wing with round leading edge that:

1) The planar boundary condition approximation may be applied to the aircraft wing

2) Wing thickness may not be ignored

3) Using the planar b c approximation, a coarse paneling of the aircraft wing leading edge region is allowed, provided the leading edge roundness is incorporated properly in the source strengths representing the aircraft wing thickness

Although these conclusions have been demonstrated using particular codes (USSAERO, USTORE), they should have a much more general validity

References

[1]Cenko, A Tinoco E N Dyer, R D and DeJongh J PAN AIR Applications to Weapons Carriage and Separation *Journal of Aircraft* Vol 18 Feb 1981 pp 128 134

[2]Woodward F A USSAERO Computer Program Development Versions B and C NASA CR 3227 April 1980

[3]Van den Broek G J The Use of a Panel Method in the Prediction of External Store Separation *Journal of Aircraft* Vol 21, May 1984 pp 309 315

[4]Woodward, F A , An Improved Method for the Aerodynamic Analysis of Wing Body Tail Configurations in Subsonic and Supersonic Flow Part I Theory and Application Part II Computer Program Description NASA CR 2228 May 1973

A Nonlinear Analysis of the Cushion Stability of Slowly Oscillating ACV's

Hideo Matsuo*
Kumamoto University, Kumamoto, Japan
and
Kensuke Matsuo†
Kumamoto Institute of Technology, Kumamoto, Japan

Introduction

THE main dynamic effects which would appear in the fan duct plenum system of ACV's might be enumerated as: 1) unsteady operating characteristics of the fan 2) unsteady flow in the ducting 3) wave propagation phenomena in the

Received Sept 23 1983; revision received Jan 17 1984

*Professor Faculty of Engineering
†Research Assistant Department of Structural Engineering

ducting and 4) unsteady flow in the cushion The third effect may be generally involved in the second effect but it is separated here for convenience Goldschmied and Wormley,[1] and Hinchy and Sullivan[2] considered effect (1) but in most cases a quasistatic characteristic of the fan has been assumed since with relatively low oscillation frequency as in marine ACV's this effect is not significant [3] On this assumption, Hinchy and Sullivan[4] investigated effects (2) and (3) and reported that the general effect of the air inertia, inertance of the duct flow, was important even for relatively short ducts Durkin and Luehr[5] investigated effect (2) in the volute flow of fans An earlier study by Yano and Nagayama[3] employed a similar method for the analysis of the scavenging system of the diesel engine Goldschmied and Wormley,[1] Sweet, Richardson and Wormley,[6] and at a later time Hinchy and Sullivan[2 4] investigated effect (3) solving one dimensional acoustic equations It is very difficult to rigorously analyze effect (4) In most instances, however, the air in the cushion is in a reservoir condition, thus obviating the need to analyze this effect

In this report an ACV with comparatively low cushion pressure and low oscillation frequency is assumed This is usually the case with conventional marine ACV's Therefore, it may be sufficient here to consider a lumped inertance as the effect (2) The purpose of this report is to extend previous quasisteady analyses[7 8] to a nonlinear analysis of large am plitude oscillation including the effect (2) The compressibility of air is also considered in the quasisteady analysis of the flow in the duct and the cushion but in the present case where the cushion pressure is relatively small (around 10 psf) its effect has proven to be negligible A forced oscillation test of the fan duct plenum model was performed [8] The analytical results have been in good agreement with the experimental results This is noticeable when the inertance in the duct flow is considered The discrepancy (in a frequency range higher than 1 Hz), which appeared in the previous quasisteady analysis,[8] has disappeared The theoretical and experimental results are, therefore, nearly identical

Analysis and Discussion

We assume a quasisteady change except for the flow through the ducting For the continuity of the flow in and out of the cushion we have

$$Sh'/c = Q_f/c - hC_d\sqrt{2P_c/\rho} \tag{1}$$

where P_c is the cushion pressure; Q_f the volume flow rate of the fan; ρ the density of air assumed constant for the present; h the hoverheight; C_d the discharge coefficient; and c the peripheral length of the effective base area S The prime represents a derivative with respect to time t

The quasisteady characteristics of the fan and the powerplant are represented as

$$P_f = P_f(Q_f\ n_f) \tag{2}$$

$$T_f = T_f(Q_f\ n_f) \tag{3}$$

$$T_p = T_p(n_p) \tag{4}$$

where P_f is the total pressure just behind the fan; T_f and T_p the input torque of the fan and the output torque of the powerplant, respectively; and n_f and n_p the rotational speeds of the fan and the powerplant respectively

$$J_f \dot{n}_f = T_{sf} - T_f \tag{5}$$

$$J_p \dot{n}_p = T_p - T_{sp} \tag{6}$$

where T_{sf} and T_{sp} are actual torques affected by the rotary inertia and $J_f/(2\pi)$ and $J_p/(2\pi)$ are the moments of inertia

Assuming the reduction ratio κ and the transmission ef ficiency η_t we have

$$n_p = \kappa n_f \tag{7}$$

$$T_{sf} = \kappa\eta_t T_{sp} \tag{8}$$

We assume that the air in the ducting is incompressible and that the flow is one dimensional and unsteady From the conservation law of momentum we have[9]

$$\frac{\mathrm{d}}{\mathrm{d}t}(\rho S_f u \delta x) = -\frac{\partial}{\partial x}(PS_f)\delta x - \pi f D(\rho u^2/2)\delta x \tag{9}$$

where u is the flow velocity and P the fluid pressure; S_f the fan exit area and D the diameter of the duct; and f the wall friction coefficient Integrating Eq (9) over the full length of the duct we have

$$(\rho L/S_f)\dot{Q}_f = P_f - P_c - \zeta(\rho/2)(Q_f/S_f)^2 \tag{10}$$

where L is the duct length and ζ is defined as

$$\zeta = 4fL/D \tag{11}$$

From Eqs (1) (2) and (10) we have the expression

$$G_1(\dot{Q}_f\ Q_f\ n_f;\ h'\ h) = 0 \tag{12}$$

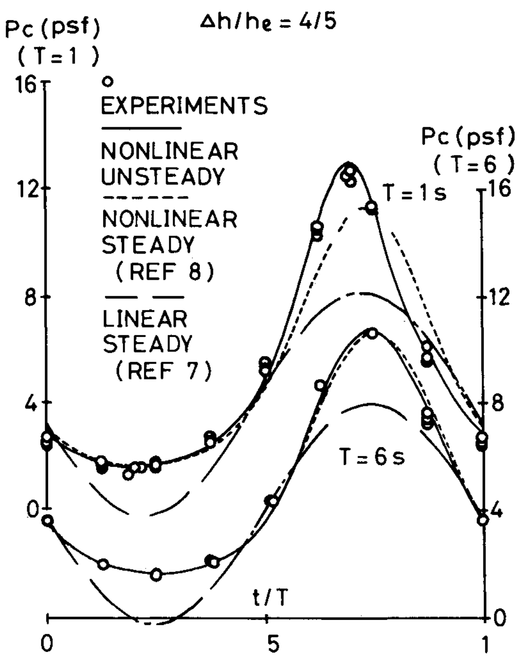

Fig 1 Variation of cushion pressure with time

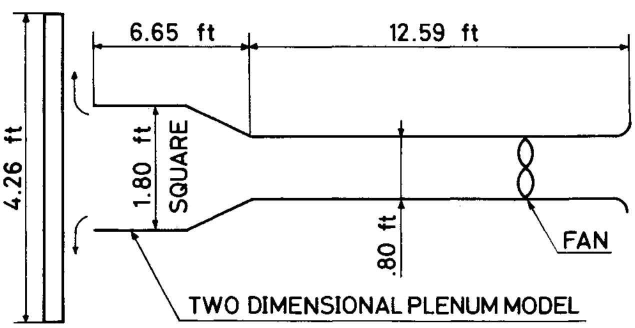

Fig 2 A sketch of experimental setup

while from Eqs (3 8)

$$G_2(Q_f\ \dot{n}_f\ n_f)=0 \tag{13}$$

Equations (12) and (13) form a system of nonlinear dif ferential equations When $h(t)$ is known, it can be numerically integrated with appropriate initial conditions If we only wish to seek the steady state solutions, the initial conditions can be chosen arbitrarily To simplify the procedure, we define nondimensional quantities such as

$$\xi=4Q_f/(\pi^2 d^3 n_f) \tag{14}$$

$$\psi=\psi(\xi)=2P_f/(\rho\pi^2 d^2 n_f^2) \tag{15}$$

$$\lambda_f=\lambda_f(\xi)=16T_f/(\rho\pi^3 d^5 n_f^2) \tag{16}$$

$$\lambda_p=\lambda_p(n_f)=16T_p/(\rho\pi^3 V^{5/3} n_p^2) \tag{17}$$

where V is a characteristic volume of the powerplant and d the diameter of the fan

Substitution of Eqs (14) to (17) into Eqs (12) and (13) leads to

$$g_1(\dot{n}_f\ n_f\ \dot{\xi}\ \xi;\ \dot{h}\ h)=0 \tag{18}$$

$$g_2(\dot{n}_f\ n_f\ \xi)=0 \tag{19}$$

where

$$g_1=\psi-\frac{Ld}{2Sn_f^2}\xi\dot{n}_f-\frac{Ld}{2Sn_f}\dot{\xi}-\left[\frac{\zeta}{2S_f^2}+\frac{1}{2(cC_dh)^2}\right]\frac{\pi^2 d^4}{8}\xi^2+\frac{Sh}{(cC_dh)^2}\frac{d}{2n_f}\xi-\frac{1}{\pi^2 d^2 n_f^2}\left(\frac{S\dot{h}}{cC_dh}\right)^2 \tag{20}$$

$$g_2=\frac{16(J_f+\kappa^2\eta_t J_p)}{\rho\pi^3 d^5}\frac{\dot{n}_f}{n_f^2}-\kappa^3\eta_t\frac{V^{5/3}}{d^5}\lambda_p+\lambda_f \tag{21}$$

Equations (18) and (19) were solved using the fourth order Runge Kutta method with intervals of 0 001 s in t $\psi(\xi)$ and $\lambda_f(\xi)$ were approximated by polynomials of seventh and third order in ξ respectively, using the method of least squares $\lambda_p(n_f)$ was similarly approximated by a polynomial of the third order in n_f A simple harmonic oscillation

$$h=h_e+\Delta h\ \sin(2\pi t/T) \tag{22}$$

is assumed To confirm the independence of the steady state solutions of the initial conditions computation was made for several cases with the same T and $\Delta h/h_e$ but with different initial conditions The results have been compared with the previous linear[7] and nonlinear[8] quasisteady solutions and the experimental results [8] Results are shown in Fig 1 A sketch of the experimental setup is shown in Fig 2 The plenum oscillates horizontally and the instantaneous cushion pressure and the hoverheight are measured electrically The details of the experiment and of the method of analysis are discussed in Ref 8 Experiments were made for $T \gtrsim 1$ s and $\Delta h/h_e \lesssim 0\ 8$ The mean hoverheight h_e was kept at 0 984 in (25 mm) throughout As T decreases (and as $\Delta h/h_e$ increases) the discrepancy between the quasisteady solution and the ex perimental results become noticeable [8] The present nonlinear unsteady solution gives good results A quasisteady con sideration of the compressibility of air was also made using the method employed by Yano and Nagayama [4] In the present study the difference has been so small that it cannot be clearly represented graphically It can almost be concluded that the inertance of air in the duct is the dominant unsteady effect in the present study

References

[1]Goldschmied F R and Wormley D N , Frequency Response of Blower Duct Plenum Systems *Journal of Hydronautics* Vol 11 Jan 1977 pp 18 27

[2]Hinchy M J and Sullivan P A , Duct Effects on the Dynamic Fan Characteristics of Air Cushion Systems *Journal of Hydronautics* Vol 13 Jan 1979 pp. 28 29

[3]Yano R and Nagayama F 'Study of Surging in the Scavenging System of the Diesel Engine *Journal of the Japan Society of Mechanical Engineering*, Part 2 Vol 36 Aug 1970 pp 1374 1384

[4]Hinchy, M J and Sullivan P A Duct Effects on the Heave Stability of Plenum Air Cushions *Journal of Sound and Vibration* Vol 60 Sept 1978 pp 87 99

[5]Durkin J M and Luehr L W H Dynamic Response of Lift Fans Subject to Varying Backpressure AIAA Paper 78 756 April 1978

[6]Sweet L M Richardson H H and Wormley D N , Plenum Air Cushion/Compressor Duct Dynamic Interactions *Journal of Dynamic Systems Measurement and Control* Vol 97 Sept 1975 pp. 283 292

[7]Matsuo H and Matsuo K Effects of Fan Ducting and Powerplant Characteristics on the Cushion Stability of Air Cushion Vehicles *Journal of Aircraft*, Vol 18 May 1981, pp 372 376

[8]Matsuo H and Matsuo K A Nonlinear Analysis of Cushion Stability of ACV s in Vertical Motion *Journal of the Japan Society for Aeronautical and Space Sciences* Vol 31 July 1983, pp 376 384

[9]Shapiro A A *Compressible Fluid Flow*, Vol 2 The Ronald Press Company New York N Y 1954 pp 972-973

An Inverse Solution for Component Positioning Using Homogeneous Coordinate Transformations

D P Raymer,* R A Maier,† and M J Killian‡

Rockwell International, Los Angeles, California

Introduction

HOMOGENEOUS coordinate transformations are used widely in computer graphics and aircraft computer aided conceptual design [1 3] They are used to create or thographic and perspective views and also can be used to allow local axis systems for the separate components which comprise the aircraft three dimensional data base In such an application each component's local axis system is defined by six parameters; i e , x_l y_l z_l (origin offset), and roll, pitch and yaw (axis orientation) Matrix operations are used to transform the points or equations which describe the com ponent into the global axis system These matrix operators are the 3×3 direction cosine relationships which are a subset of the homogeneous coordinate transformations

Presented as Paper 83 2460 at the AIAA Aircraft Design Systems and Technology Meeting, Ft Worth Texas Oct 17 19 1983; received Nov 7 1983; revision received Feb 10 1984

*Project Manager Advanced Concepts North American Aircraft Operations Member AIAA

†Supervisor, Master Dimensions North American Aircraft Operations Member AIAA

‡Member Technical Staff CAD/CAM North American Aircraft Operations