Nonlinear Interaction of Panel Flutter with Harmonic Forcing Excitation

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Theme

THE nonlinear interaction characteristics of panel flutter and harmonic excitation are studied. Both the forcing component and flutter component are included and a wide range of dynamic pressure is covered so that both preflutter and post-flutter responses are studied.

Contents

The interaction of panel flutter and forcing excitation has been studied by some investigators in recent years. Examples are the work by Dowell[1] on the interaction of panel flutter with random excitation and that by Dzygadlo[2] on the interaction of panel flutter with harmonic excitation. However, because of the method (numerical integration) used by the former and because of the small nonlinearity and single-frequency solution employed by the latter, the results do not give the complete picture of the interaction characteristics. Kuo[3] recently did some study on the nonlinear interaction of panel flutter with harmonic forcing excitation. Wide range of dynamic pressure is covered and both flutter frequency and forcing frequency components are considered so complete interaction was investigated. This paper is a condensation of part of his study.

The problem studied here is a two-dimensional simply supported plate subject to both a supersonic airflow and a harmonically varying pressure on one side and stationary air on the other. The length of the plate is finite in the direction of the airflow and is equal to a. Using von Kármán's nonlinear plate theory and piston theory, the equation of motion of the plate can be written as shown in Eq. (4.1) of Ref. 3. This equation is solved by employing Galerkin's technique and harmonic balance method and is checked by numerical integration method. The nondimensional displacement w is approximated by

$$w = \sum_{n=1}^{N} [a_n \sin \omega\tau + b_n \cos \omega\tau + c_n \sin \Omega\tau + d_n \cos \Omega\tau] \sin n\pi\xi \quad (1)$$

where τ and ξ are nondimensional time and coordinate variables and ω and Ω are the frequencies of flutter and forcing excitation, respectively, based on τ. At low dynamic pressure λ, flutter is not possible, so a_n and b_n have to be set to zero. The response is then called pure forced response. At high λ, both flutter components and forced components are possible; one obtains the complete interaction of the two excitations and the resulting response is called flutter-forcing interaction. Over certain range of λ and forcing frequency Ω, both pure forced response and flutter-forcing interaction can be obtained, depending on the initial condition; the solution is then called coexistence.

Results obtained for a two-mode approximation are shown in Figs. 1–4, for different values of λ and forcing frequency Ω and forcing amplitude F_R. R_x, λ_c, and μ/M are the nondimensional membrane force, critical dynamic pressure without forcing

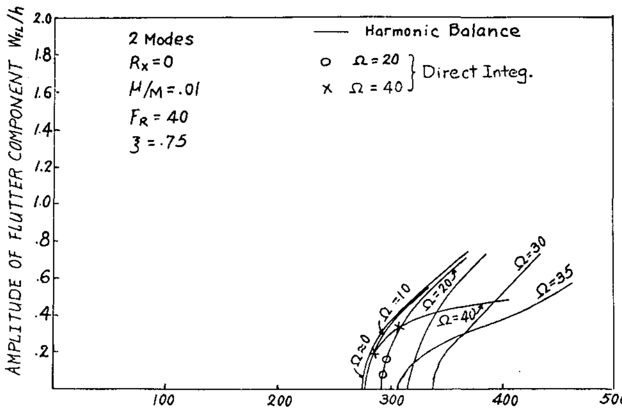

Fig. 1 Flutter-forcing interaction—amplitude of flutter component.

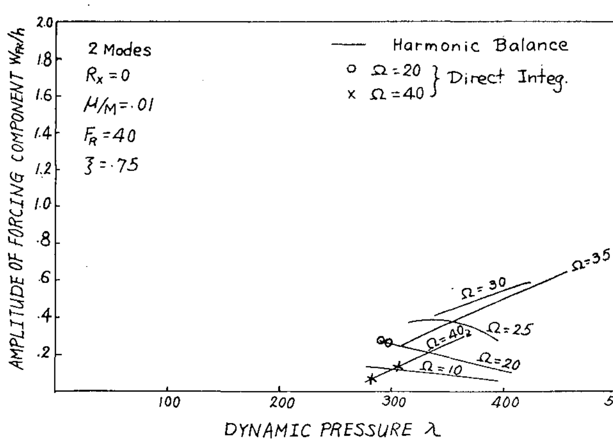

Fig. 2 Flutter-forcing interaction—amplitude of forcing component.

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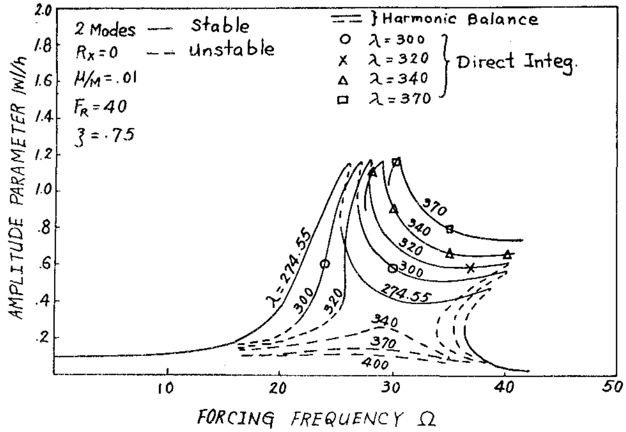

Fig. 3 Nonlinear pure forced response of a panel at $\lambda \geqq \lambda_c$.

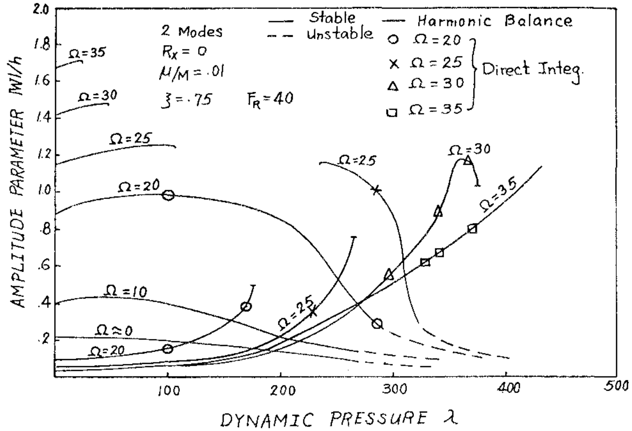

Fig. 4 Nonlinear pure forced response of a panel at different forcing frequencies Ω.

excitation and the mass ratio, respectively. $|W|/h$ is the amplitude of pure forced response and W_{FR}/h and W_{FL}/h are the amplitudes of the forcing and flutter components in the case of flutter-forcing interaction. These results show that, even with nonlinear terms, more realistic than the ones used by Dzygadlo, the interaction between flutter and harmonic excitation cannot be neglected. In addition, the harmonic balance method is a convenient method for this type of problem, since it requires less computer time and gives better physical understanding than the direct integration method.

References

[1] Dowell, E. H., "Noise or Flutter or Both?," *Journal of Sound and Vibration*, Vol. 11, No. 2, 1970, pp. 159–180.

[2] Dzygadlo, A., "Local Analysis of Nonlinear Forced Vibrations of a Plate of Finite Length in Plane Supersonic Flow," *Proceedings of Vibration Problems*, Vol. 11, No. 4, Warsaw, Poland, 1970.

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