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THEORETICAL STUDIES OF SOME NONLINEAR ASPECTS OF HYPERSONIC PANEL FLUTTER

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PROJECT STATUS

Effects of Aerodynamic Nonlinearities:

The study of the effects of nonlinear aerodynamic loading on the stability of a two-dimensional panel on hinged supports has been described through 1 September 1969 in Ref. 1. The basic idea has been to look for any changes brought about in the linear stability boundary as a result of an initial disturbance of constant energy. Figure 1 presents a comparison between the linear and nonlinear stability boundaries in the $\lambda - N_x$ plane for a constant dimensionless initial energy of 1750. This energy is roughly comparable to total panel energies that are found for flutter motion near the linear stability boundary. The first two initial modal amplitudes were assumed to be equal and of opposite sign, and the remaining modal amplitudes and time derivatives were assumed to be zero. Note in Fig. 1 that the greatest percentage reduction in the critical value of λ is found for zero or slightly negative (tensile) values of N_x. It can be shown that the key parameter governing this behavior is the ratio of two other parameters - Mh/a, governing the nonlinear aerodynamic effects and the square root of α, the in-plane restraint parameter. Parametric studies are now under way to determine the changes in the stability boundary of Fig. 1 due to changes in the level of the initial energy, in the modal content of the initial energy, in the aerodynamic damping μ/M, and in the interaction parameter $Mh/a(\alpha)^{\frac{1}{2}}$.

Results obtained to date are being presented as part of a paper (Ref. 2) to be given at the AIAA/ASME Structures, Structural Dynamics, and Materials Conference in Denver on 22 April.

Unsteady Boundary-Layer Effects:

The results of the first year's study on this aspect of the project have been described in detail in a report prepared during this time period (Ref. 1). A general formulation of the problem was attempted in which the boundary layer adjacent to an oscillating panel and the external inviscid flow are to be determined simultaneously. The surface pressure obtained from such an analysis would indicate the fact that the viscous and inviscid flows are allowed to interact. This differs from the assumptions of classical boundary layer theory where the pressure is assumed to be a priori

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known from the inviscid flow calculations. This intended formulation has been successfully realized by previous authors for steady flow, an example being the recent paper by Klineberg and Lees (Ref. 2); however, for the case of unsteady flow, a simultaneous formulation of the unsteady boundary layer and the external inviscid flow has not been successfully posed. As a result of these difficulties, an alternate formulation has been attempted along more classical lines.

The alternate formulation follows the basic idea of classical boundary layer theory with some modifications due to the fact that the flow is unsteady. The boundary layer is analyzed by the method of integral equations using as an input the known inviscid solution for the flow past the oscillating panel. The integral analysis is designed to yield the unsteady displacement thickness as the significant parameter in estimating viscous effects. The next step in this scheme is to compute an inviscid flow past an unsteady displacement surface whose position is known once the details of the unsteady boundary layer are known. This method has been applied to the steady incompressible flow past a wavy wall. Currently the method is being applied to the incompressible flow past a flat plate oscillating perpendicular to its own plane for the purpose of gaining some familiarity with an unsteady flow. The next example to be analyzed will be the incompressible flow past an oscillating panel, and ultimately the compressible flow past an oscillating panel will be studied.

REFERENCES

1. McIntosh, S.C. and Lerner, J.I., "Theoretical Considerations of Some Nonlinear Aspects of Hypersonic Panel Flutter," Fourth Annual Report, NASA Grant NGR 05-020-102, 1 September 1968 to 31 August 1969, Department of Aeronautics and Astronautics, Stanford Univ., Stanford, Calif.

2. Eastep, F.E. and McIntosh, S.C., "Analysis of Nonlinear Panel Flutter and Response Under Random Excitation or Nonlinear Aerodynamic Loading," to be presented at AIAA/ASME 11th Structures, Structural Dynamics, and Materials Conference, 22-24 April 1970.

3. Klineberg, J.M. and Lees, L., "Theory of Laminar Viscous-Inviscid Interactions in Supersonic Flow," AIAA Journal, Vol. 7, No. 12, December 1969, pp. 2211-2221.

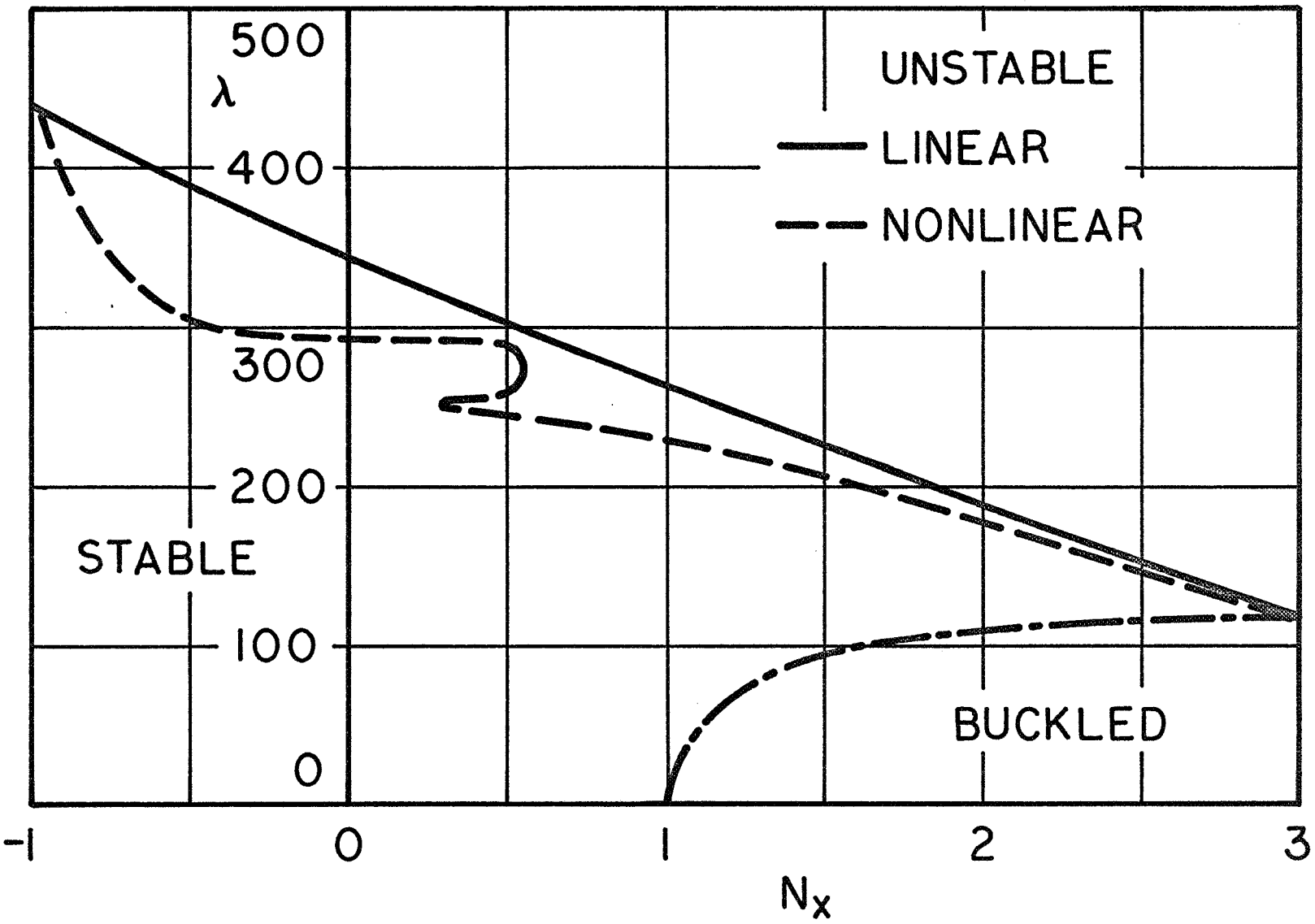

Figure 1. Comparison between stability boundaries obtained with linear or nonlinear aerodynamic loading. Ordinate is dimensionless dynamic pressure, abscissa is dimensionless applied in-plane load. Six assumed modes, $\mu/M=0.01$, $Mh/a=0.05$, $\lambda=0.1$, initial energy = .1750.