The Influence Of and The Identification Of Nonlinearity In Flexible Structures

by

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All structures exhibit nonlinear dynamic behavior to some degree; for some it is quite small and in these cases linear models are adequate. For other structures it is appreciable, and for a few, the nonlinear behavior dominates the dynamic response. Nonlinear behavior may be due to material properties (nonlinear constitutive law), geometrical asymmetry, mid-plane stretching, nonlinear damping, large amplitude vibration, or any combination of these and other sources. In most cases, the nonlinearity causes a deviation from linear behavior, but for others it introduces new and unique phenomena--such as subharmonic, superharmonic, combination and internal resonances, parametric resonances and autoparametric interaction, jumps, saturation, self-excited oscillations, bifurcations, chaos, and nonexistence of periodic oscillation--that have no counterparts in linear theory. Hence, a linear mathematical model is in general the least precise model because it can always be improved by including nonlinear terms to do three things: (1) to increase the accuracy of the predicted response, (2) to extend the range of useable solutions, say of larger displacements, and (3) to explain or predict new phenomena that have no counterparts in linear theory.

Several models were built at NASA Langley and used to demonstrate the following nonlinear behavior: internal resonance in a free response, principal parametric resonance and subcritical instability in a cantilever beam-lumped mass structure, combination resonance in a parametrically excited flexible beam, autoparametric interaction in a two-degree-of-freedom system, instability of the linear solution, saturation of the excited mode, subharmonic bifurcation, modulation of excited modes in the "steady-state" response, and chaotic responses. A video tape documenting these phenomena was made.

An attempt to identify a "simple structure" consisting of two light-weight beams and two lumped masses using the Eigensystem Realization Algorithm showed the inherent difficulty of using a linear based theory to identify a particular nonlinearity. Preliminary results show the technique requires novel interpretation, and hence may not be useful for structural modes that are coupled by a quadratic nonlinearity. For example, an identification based on three cycles of free response (0.3 seconds) predicted divergence after nine cycles (1.0 seconds) when the actual response consisted of most of the energy having been transferred to the second mode.

A literature survey was also completed on recent work in parametrically excited nonlinear systems.

In summary, nonlinear systems may possess unique behaviors that require nonlinear identification techniques based on an understanding of how nonlinearity affects the dynamic response of structures. In this way, the unique behaviors of nonlinear systems may be properly identified. Moreover, more accurate quantifiable estimates can be made once the qualitative model has been determined.