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A H NAYFEH ET AL. 30 APR 87 AFOSR-TR-87-0712
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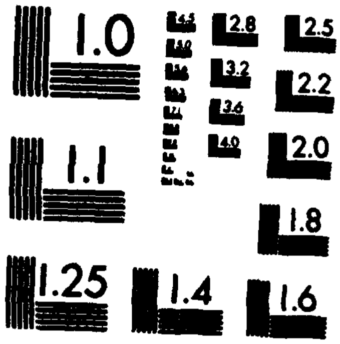

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Experimental-theoretical studies have been conducted on the influence of nonlinearities on flexible structures in the presence of either an external or a parametric excitation.

A single-degree-of-freedom system with quadratic and cubic nonlinearities under the influence of a harmonic parametric excitation was studied using the method of multiple scales and digital- and analog-computer simulations. A global bifurcation diagram was obtained showing the different possible attractors (point, limit cycle, chaotic attractors For small excitation amplitudes, the perturbation results are in excellent agreement with the digital- and analog-computer simulations. For moderate to large excitation amplitudes the accuracy of the perturbation solution is questionable and only digital- and analog-computer simulations were used. The results are in full agreement.

Experiments were conducted on a two-degree-of-freedom mechanical model consisting of two light beams and two concentrated masses to ascertain the influence of autoparametric

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ANNUAL TECHNICAL REPORT

THE EFFECT OF NONLINEARITIES ON FLEXIBLE STRUCTURES

APRIL 1, 1987 TO MARCH 31, 1989

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I. Summary

Experimental-theoretical studies have been conducted on the influence of nonlinearities on flexible structures in the presence of either an external or a parametric excitation.

A single-degree-of-freedom system with quadratic and cubic nonlinearities under the influence of a harmonic parametric excitation was studied using the method of multiple scales and digital- and analog-computer simulations. A global bifurcation diagram was obtained showing the different possible attractors (point, limit cycle, chaotic attractors). For small excitation amplitudes, the perturbation results are in excellent agreement with the digital- and analog-computer simulations. For moderate to large excitation amplitudes, the accuracy of the perturbation solution is questionable and only digital- and analog-computer simulations were used. The results are in full agreement.

Experiments were conducted on a two-degree-of-freedom mechanical model consisting of two light beams and two concentrated masses to ascertain the influence of autoparametric (internal) resonances. The positions of the masses of the model were adjusted so that its natural frequencies were in the ratio of two-to-one. When the lower mode was excited by a primary excitation, ranges of the excitation frequency were

found for which steady-state periodic responses do not exist. Instead, the responses were amplitude- and phase-modulated motions, which can be chaotic, in agreement with the theory.

II. Research Objectives

The proposed study is a theoretical and experimental investigation into the influence of nonlinearities on flexible structures in the presence of multifrequency parametric and external excitations having independent frequencies and phases and arbitrary amplitudes. The nonlinearites and excitations may appear in the governing equations, or the boundary conditions, or both. The study will focus on resonance conditions that may produce large and possibly damaging motions. Special attention will be given to modal coupling and exchanges of energy. We will classify the important resonances and their interactions, devise experiments illustrating the phenomena, and suggest controls for reducing large-amplitude responses.

III. Status of the Research

The vibration research laboratory has been upgraded to conduct both analog and mechanical experiments for ascertaining the influence of nonlinearities on the response of flexible structures to single-and-multi-frequency external and parametric excitations. Mechanical models have been built and tested.

The analog-computer setup proved indispensible for determining the various attractors and their domains of attraction. Experiments have already been conducted to determine the influence of quadratic nonlinearities on the response of single-degree-of-freedom systems to parametric excitations. The quadratic nonlinearity has been found to increase the number and complexity of the possible attractors. Systems with quadratic nonlinearities have been found to be more susceptible to chaos than systems with cubic nonlinearities. Systems with two degrees of freedom will be studied.

A two-degree-of-freedom mechanical model has been tested by shaking it with a primary excitation. The frequencies of the model were adjusted to be in the ratio of two-to-one. The autoparametric resonance has been found to produce complicated responses, including chaotic motions. Consequently, it appears that autoparametric resonances need to be avoided in the design of flexible structures. Experiments will be conducted using this model by shaking it with the following excitations: (a) primary resonance of the second mode, (b) subharmonic resonance of the second mode, (c) combination resonance of both modes, and (d) parametric resonance of either mode.

IV. Publications

1. Nayfeh, A. H., "Parametric Excitation of Two Internally Resonant Oscillators", Journal of Sound and Vibration, Vol. 119, No. 2, 1987.

2. Zavodney, L D. and Nayfeh, A. H., "The Response of a Single-Degree-of-Freedom System with Quadratic and Cubic Nonlinearities to a Fundamental Parametric Resonance," Journal of Sound and Vibration, Vol. 119, No. 1, 1987.

3. Nayfeh, A. H., Mook, D. T., and Nayfeh, J. F., "Some Aspects of Modal Interactions in the Response of Beams," AIAA Paper No. 87-0777-CP, 1987.

4. Nayfeh, A. H. and Sanchez, N. E., "Global Bifurcations Including Escape for a Softening Duffing Oscillator", submitted for publication, Physical Review Letters.

5. Nayfeh, A. H. and Zavodney, L. D., "Experimental Observation of Amplitude- and Phase-Modulated Responses of Two Internally Coupled Oscillators to a Harmonic Excitation", submitted for publication, Physical Review Letters.

6. Nayfeh, A. H., "Application of the Method of Multiple Scales to Nonlinearly Coupled Oscillators" Chapter for the Lasers, Molecules, and Methods, a Volume in the Advances in Chemical Physics Series, 1987.

V. Professional Personnel

1. A. H. Nayfeh, University Distinguished Professor.
2. D. T. Mook, Professor.
3. L. D. Zavodney, Ph.D. Candidate.
4. N. E. Sanchez, Ph.D. Candidate.
5. J. F. Nayfeh, Ph.D. Candidate.

VI. Interactions

A. Presentations

1. Nayfeh, A. H., "Quenching of One Resonance by Another," Annual Meeting of the Vibration Institute, Las Vegas, NV, June 24-26, 1986.

2. Nayfeh, A. H., "Parametric Excitation of Two Internally Resonant Oscillators," 23rd Annual Meeting of the Society of Engineering Science, Buffalo, NY, August 25-27, 1986.

3. Nayfeh, A. H. and Zavodney, L. D., "Influence of Nonlinearities on Flexible Structures," AFOSR 4th Forum on Large Space Structures, State University of New York at Buffalo, August 28-29, 1986.

4. Nayfeh, A. H., "Forced Response of Nonlinearly Coupled Oscillators," Applied Mechanics Research Seminar # 8, United Technologies Research Center, East Hartford, CN, September 18, 1986.

5. Nayfeh, A. H. and Zavodney, L. D., "The Response of Two-Degree-of-Freedom Systems with Quadratic Nonlinearities to a Combination Parametric Resonance", 57th Shock and Vibration Symposium, New Orleans, LA, October 14-16, 1986.

6. Nayfeh, A. H., "Parametric Excitation of Two Internally Resonant Oscillators", Mathematics Seminar, VPI&SU, February 18, 1987.

7. Nayfeh, A. H., "Perturbation Methods in Nonlinear Dynamics", presented at the AFOSR/ARO Conference on Non-Linear Vibrations, Stability, and Dynamics of Structures and Mechanics, VPI&SU, March 23-25, 1987.

8. Nayfeh, A. H., Mook, D. T., and Nayfeh, J. F., "Some Aspects of Modal Interactions in the Response of Beams", presented at the AIAA/ASME/ASCE/AHS 28th Structures, Structural Dynamics and Materials Conference, Monterey, CA, April 6-8, 1987.

B. AirForce Laboratories

A. H. Nayfeh visited Wright-Patterson Airforce Base and discussed some of the research results with James Olsen and Ken Wenz on November 24, 1986.

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