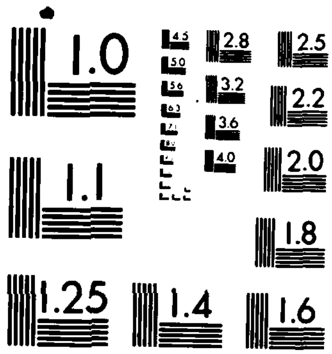

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Several problems concerning the vibration control of helicopters were studied. Methodology for introducing structural modifications leading to vibration reduction has been developed. In particular, a formulation for attaching appendages to continuous structural members was completed and applied to a two-beam helicopter model.

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Limiting Performance of Nonlinear Systems with Applications to Helicopter Vibration Control

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I. STATEMENT OF PROBLEM STUDIED

Several problems concerning the vibration control of helicopters were studied. Methodology for introducing structural modifications leading to vibration reduction has been developed. In particular, a formulation for attaching appendages to continuous structural members was completed and applied to a two-beam helicopter model. A procedure for the optimal placement and subsequent tuning of vibration suspension devices has been devised. The placement and tuning is based on the existence of "fixed" points in the displacement-frequency response curves. The distance of these fixed points from the resonant frequencies to be controlled are an indication of the goodness of placement. Furthermore, a new theory for spreading two natural frequencies of a helicopter model was developed.

II. SUMMARY OF THE MOST IMPORTANT RESULTS

1. Eigenvalue Reanalysis of Locally Modified Structures Using Generalized Rayleigh's Method

Approximate eigenvalue reanalysis methods for locally modified structures have been developed based on the generalized Rayleigh's quotients. For simple modifications such as adding springs, masses, or changing truss member cross-sectional areas, closed form formulas have been derived. The methods have been applied to several examples with good results.

2. Generalized Dunkerley's Estimates for Eigenvalues for Conservative Linear Systems

A. Lower Bound Estimates for Higher Modes

Based on the relationship between the eigenvalues of a linear conservative system and the coefficients of the characteristic polynomial, lower bounds for eigenvalues are computed. The bound on the first eigenvalue is the classical Dunkerley bound. This is a lower bound. The estimated bounds for higher modes do not enjoy this guarantee. Test cases show that we can get the lower bound for up to the third mode. Danilevsky's method was used to generate the characterisitic polynomial.

B. Improved Estimates of Fundamental Modes

In the literature it has been shown that improved lower bounds can be obtained by taking traces of matrices that are powers of the dynamical matrix. This is numerically inefficient since it involves multiplications of matrices. Based on the Newton's identity, the traces of powers of the dynamical matrix can be computed recursively from the coefficients of the characteristic equations. No matrix multiplication is involved. From these traces, upper bound estimates can also be computed.

3. Reshaping the Frequency Spectrum of a Structure

Some of the significant results of this period deal with the reshaping of the spectrum of structures by the selective modification of element properties. The problem is that of shifting natural frequencies away from a particular level, such as that of a driving force frequency. In particular, the goal is to spread two frequencies, i.e., decrease one frequency and simultaneously increase the other frequency, by structural modifications. Normally this involves a two step process, whereby each frequency is shifted separately to achieve the desired changes. However, a new method has been formulated which will (1) identify the best structural elements for modification in order to spread two frequencies and (2) find the optimum magnitude of the modifications to the element stiffness matrices to effect the desired changes. The formulation is based on the use of a 2nd order expansion of the frequencies with respect to the changes in element stiffnesses. The first order terms are used in the identification of appropriate elements to be modified and the full second order expansion is used to optimize the amount of change. A 108 element helicopter (tail boom) model was used to demonstrate the success of the method in spreading two frequencies.

4. Modal Formulation for the Limiting Performance of a Helicopter Mode

The limiting performance problem has been formulated in terms of the modal characteristics of a helicopter. The mode shapes can be obtained experimentally or can be generated computationally.

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IV. PARTICIPATING SCIENTIFIC PERSONNEL

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