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The effect of a shaker on the resonance frequencies of a circular plate

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Abstract: This study presents the analysis of the effect of the concentrated mass on the resonance frequencies of a vibrating thin circular plate. The eigenfunction expansion has been used to express the transverse displacement of the plate. The appropriate number of modes is determined approximately to achieve physically correct results. Then highly accurate results are obtained numerically. The mean square vibration velocity used to determine the resonance frequencies of the plate. The introducing of the concentrated mass is justified by modelling the added mass of the moving component of the exciter.

Keywords: added mass, exciter, circular plate, resonance frequencies, modal expansion

1. Introduction

An accurate determination of the resonance frequencies of vibrating structures is of the utmost importance in diagnostics and design both in mechanical engineering and physical systems. So far, a number of studies dealt with such problems. Some examples are the results proposed by Ostachowicz et al. [1] who used a diagnostic method for localization of concentrated masses on a vibrating plate. They used the method of analysing the shifts in the resonance frequencies. Further, Cho et al. [2] examined dynamic responses of stiffened panels with added masses and openings. Wrona et al. [3] applied the added masses for shaping the dynamic responses of rectangular planar panels.

One of the methods of examining the frequency responses of structures is using the electromagnetic exciters. The investigated structure is then excited within the desired frequency range and the normal vibration velocity is measured in selected points on the structure. The exciter needs to have sufficient force over the analyzed frequency interval. Usually the mass of the moving component of the excited is significant compared to mass of the structure. In such cases the effect of the added mass of the exciter on the resonance frequencies of the structures should not be neglected. This paper focuses on this problem. The examined structures is a thin circular plate. The plate is free at its circumferences and mounted at its centre to the excited. This selection motivated by the simplicity of the structure and numerical analysis. The modal expansion of the plates vibrations is used along with the in-vacuo eigenfrequencies of the plate. Applying this expansion requires to carefully determine all the necessary modes of the plate to achieve physically correct results. Therefore the nondimensionalized added mass incrementals are determined to estimate roughly the resonance frequencies. Then some more modes will be taken for calculations to achieve desired numerical accuracy. The proper and accurate determination of the resonance frequencies of structures is an important practical problem. Therefore some sample results are presented herein.

2. Results and Discussion

The equation of motion of the excited plate can be presented as follows (e.g. Rao [4] Eq. (14.200) ora Ostachowicz et al.)

$$D\nabla^4 W - \rho h \omega^2 W - m_c \omega^2 \delta(\vec{r} - \vec{r}\,')W = P \,, \tag{1}$$

where W is the transverse displacement of the plate, D is the plate's stiffness, ∇^4 is the biharmonic operator, ρ is the plate's density, h is its thickness, ω is the angular frequency, m_c is the concentrated mass of the moving component of the exciter, δ is the Dirac delta, $\vec{r}$ is the radius vector on the plate, $\vec{r}\,'$ is the radius vector of the concentrated mass, and P is the external excitation. In this particular study the external excitation is the point excitation at the same point as the concentrated mass of the exciter.

3. Concluding Remarks

The method of modal expansion can be successfully applied for analysis of dynamic responses of a vibrating circular plate given that the following requirements are satisfied. The resonance frequencies are initially predicted using the approximated calculations for a single dominant mode. Then the appropriate number of modes can be determined to obtain physically correct results. Further, the accurate values of resonance frequencies can be determined by finding local maximums of the mean vibration velocity on the plate. As the main disadvantage of the point excitation is that it can point to a nodal line, the dynamic responses of the physical system should be averaged over a number of different excitation points.

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