The effect of rib resonances on the vibration and wave scattering of a ribbed cylindrical shell

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Abstract: In this paper, the individual rib resonances of stiffened shells are identified to help explain the resonance bands that are seen in both experiments and numerical computations. For these resonances, periodicity is relatively unimportant in computing the frequencies of resonances on the shell. However, lack of periodicity in rib spacing and size affects the width and strength of these resonance bands.

INTRODUCTION

In this paper, computations of a radial point force on a ribbed cylindrical shell show the normal surface velocities broken into frequency passbands and stopbands. Two passbands correspond to individual rib resonances. The details of the ribs alone are sufficient to determine the passband frequencies. Rib nonuniformity affects the passband width and strength.

SHELL BENDING WAVE

The shell has a bending wave whose behavior excluding ribs can be approximated from in vacuo plate theory as

\[ k = (2\pi f)^{\nu}(E/\rho)^{\mu}(h'/12)^{\nu} \]

which is derived from Cremer (1). \( k \) is the wavenumber, \( f \) is the frequency, \( E \) is the Young's modulus, \( \rho \) is the mass density, and \( h \) is the thickness. Such behavior contributes a response at every frequency, but this is only true for the unribbed shell.

RIB RESONANCES AND APERIODICITY

With the inclusion of ribs, resonances occur that are the consequence of the ribs alone. Since the ribs are welded, there is a resonance corresponding to this boundary condition (2) which is quite different from being cantilevered. Welded ribs allow rotation at the shell. Above this resonance and the first stopband, the bending wave of equation (1) resumes at a sufficiently long wavelength such that there is virtually no rotation. In this case, the boundary condition is effectively cantilevered. For low circumferential modes, this resonance can be approximated with (3)

\[ f = \frac{3.52}{2\pi} \left( \frac{Et'}{12\rho d'} \right)^{\frac{1}{\nu}} \]

where \( t \) is the rib thickness and \( d \) is the rib height. At the lower end of this resonance, the ribs displace radially together. At the higher end, the ribs alternate in their radial displacement.

Finite element computations reveal the shell normal velocities for a broad band of frequencies in Fig. 1. This method shows good agreement with data (4), but has the advantage of having velocities available virtually everywhere. A spatial FFT of the velocities reveals the axial waves in Fig. 2. The top of the first passband has a horizontal stripe indicative of a single frequency resonance. The second passband occurs at low, but changing, wavenumbers. The third passband shows the outer curves as roughly consistent with equation (1).

Although the first two passbands result from individual rib resonances, when the ribs have slight differences from each other, the passbands are affected. When the ribs vary in thickness by a standard deviation of 2.15\% of the mean, their resonances vary, producing a larger (in frequency) passband. This effect is seen more easily at high
circumferential modes. Fig. 3 shows normal shell velocities for mode 20 in which the first passband is broad in terms of frequency, but tapers off at the ends of the cylindrical section. In contrast, when the ribs vary in spacing, the second passband is affected. Fig. 4 shows normal shell velocities in which the spacing varies by 6.55% of the mean, while previous plots have a variation of only 1.64%. Fig. 4 shows the second passband tapered at the ends, with the first passband unaffected.

FIGURE 1. Surface normal velocities for circumferential mode 0.

FIGURE 2. Axial wavenumber of velocity for circumferential mode 0.

FIGURE 3. Surface normal velocities for shell with non-uniform rib thickness, circumferential mode 20.

FIGURE 4. Surface normal velocities for shell with non-uniform frame spacing, circumferential mode 20.

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REFERENCES