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MEASUREMENT OF VIBRATION INTENSITY IN U-SHAPED SHELL

N Kojima (1), H Zhou (1), M Endo (2) & M Saito (3)

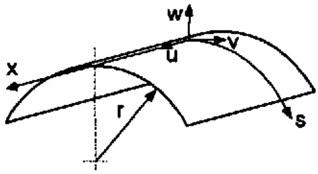
(1) Department of Mechanical Engineering, Yamaguchi University, (2) Graduate School of Yamaguchi University, (3) Mechanical Engineering Laboratory, Daikin Industries Ltd

1. INTRODUCTION

Vibration intensity techniques have been used to find vibration transmission paths and determine the exiting sources[1]. The flexural vibration intensity in plates and beams can be obtained by measuring out-of-plane vibration at several points near the aimed point. Shells are widely used in engineering structures such as pipes and ships. Bourget and Fahy[2] presented a method to measure vibrational power flow along a thin cylindrical pipe. Zhang and White[3] studied vibrational power transmission into a cylindrical shell due to point force excitation. Zhou et al.[4] measured vibration intensity on a cylindrical casing of a compressor using three accelerometers. Pavic[5] presented formulas of vibration intensity in shells based on Kirchhoff's theory. The formulas of vibration intensity in shells are more complex than plates and beams. To obtain the vibration intensity in shells, it is necessary to measure both, out-of-plane and in-plane vibrations. In this paper, measurement of vibration intensity in U-shaped shell is described. Out-of-plane and in-plane vibrations near the aimed point are measured using accelerometers. The experimental results are discussed and compared with numerical results obtained through finite element analysis.

2. EXPERIMENTAL FORMULATION

Vibration power flow in shells is transmitted by flexural waves and longitudinal waves. In this paper only the flexural component is considered. For a cylindrical shell, vibration intensity can be expressed in terms of two components: the axial component and the circumferential component.



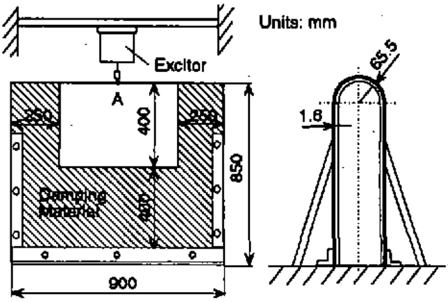


Fig.1 Cylindrical shell coordinates   Fig.2 Testing setup of U-shaped shell

Using the coordinates system shown in Fig.1, the axial component is given by

$$I_{vx} = I_{vxf} + I_{vxc} \tag{1}$$

$$I_{vxf} = D\left[\left(\frac{\partial^3 w}{\partial x^3} + \frac{\partial^3 w}{\partial x \partial s^2}\right) w - \left(\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial s^2}\right)\frac{\partial^2 w}{\partial x \partial t} - (1-\nu)\frac{\partial^2 w}{\partial x \partial s}\frac{\partial^2 w}{\partial s \partial t}\right] \tag{2}$$

$$I_{vxc} = D\left[-\frac{\nu}{r}\frac{\partial^2 v}{\partial x \partial s}\frac{\partial w}{\partial t} + \frac{\nu}{r}\frac{\partial v}{\partial s}\frac{\partial^2 w}{\partial x \partial t} + \frac{(1-\nu)}{r}\frac{\partial^2 w}{\partial x \partial s}\frac{\partial v}{\partial t}\right] \tag{3}$$

where D is the bending stiffness, ν is Poisson's ratio. The term I_{vxf} does not depend on the shell radius and is specific to the vibration intensity for the plate, hence we call it flat term. The term I_{vxc} goes to zero as 1/r for increasing r, therefore we call it curved term.

The equation for the circumferential component can also be decomposed into two terms.

$$I_{vs} = I_{vsf} + I_{vsc} \tag{4}$$

The first term in Eq. (4) I_{vsf} can be obtained by exchanging x and s in Eq. (2). The second term in Eq. (4) can be written as

$$I_{vsc} = D\left[-\frac{1}{r}\frac{\partial^2 v}{\partial s^2}\frac{\partial w}{\partial t} + \frac{1}{r}\frac{\partial v}{\partial s}\frac{\partial^2 w}{\partial s \partial t} + \frac{1}{r}\left(\frac{\partial^2 w}{\partial s^2} + \nu\frac{\partial^2 w}{\partial x^2} - \frac{1}{r}\frac{\partial v}{\partial s}\right)\frac{\partial v}{\partial t}\right] \tag{5}$$

To obtain the one direction component of vibration intensity using finite difference method, vibration data at 8 points near aimed point are necessary for two dimensional vibration transmission.

3. EXPERIMENTAL SETUP

The experimental arrangement is shown in Fig.2. In order to prevent reflection of vibrational energy from edges, damping material with thickness of 3mm is set around measuring area In cylindrical shells vibrational energy is transmitted in both directions, axial and circumferential. The circumferential component of energy flow is cyclical, hence, it generates standing waves in the shells. In this study, damping material is set on edges of the U-shaped shell to filter-out the vibrational energy leaving only progressive waves in the shell. The U-shaped shell is excited at the top centre (point A in Fig.2).

The out-of-plane vibrations are measured by one accelerometer. The in-plane vibrations are measured by using two accelerometers, as shown in Fig.3. When the shell has very small out-of-plane motion, the in-plane vibration v_0 can be obtained from the signals v_1, v_2 of the two accelerometers,

$$v_0 = v_1 - \frac{v_2 - v_1}{v_2 - v_1} l_1 \qquad (6)$$

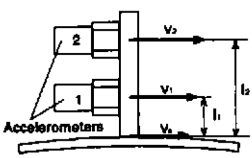
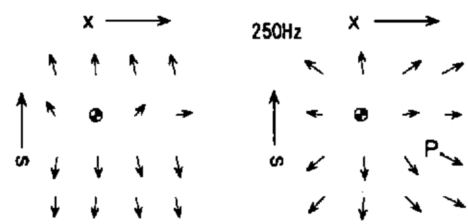


Fig.3 Arrangement of two accelerometers for measuring the in-plane vibrations



(a) Obtained from out-of-plane vibrations

(b) Obtained from out-of-plane and in-plane vibrations

Fig.4 Measured vibration intensity at 250Hz

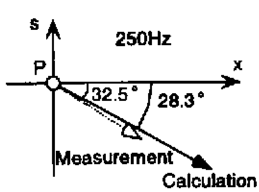
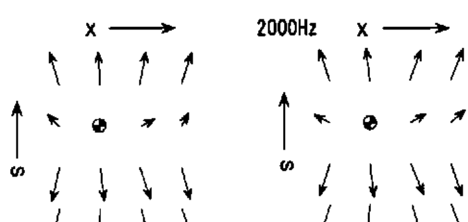


Fig.6 Comparison of measured and calculated vibration intensity at point P



(a) Obtained from out-of-plane vibrations

(b) Obtained from out-of-plane and in-plane vibrations

Fig.5 Measured vibration intensity at 2kHz

4. EXPERIMENTAL RESULTS

Fig.4 shows the measured vibration intensity vectors around the exciting point at frequency 250Hz. (a) is obtained by using the flat term only, and (b) is obtained by using both flat and the curved terms. The vibration intensity vectors in (a) apparently acting in circumferential direction. The vectors in (b) are distributed in a radial pattern.

Fig.5 shows measurement results at 2kHz. At this frequency the vectors for (a) out-of-plane vibrations and (b) in-plane and out-of-plane vibrations are seen to have almost the same pattern. In this case, the vectors at the top of the shell lean to one side. The reason is that the boundary conditions are not identical for the two plane part.

The comparison of measured and calculated results at one point (P in Fig. 4) is shown in Fig.6. Although the computed and measured vectors act in the same direction, they have different magnitude.

5. CONCLUSIONS

In this paper, measured results of vibration intensity in U-shaped shells have been presented. Vibration intensity in U-shaped shell contains a flat part and a curved part that can be measured by out-of-plane and in-plane vibrations at 8 points which are near the aimed point. The in-plane vibration of the shell can be measured with two vibration transducers. In shells, at low frequencies, vibration intensity was shown to strongly depend on the radius. Experimental and computational results are in good agreement.

References

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