Attenuation of Structure-Borne Sound in Cross Stiffened Plate

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Introduction

Stiffened plates are widely used in engineering practise to achieve sturdy and lightweight structures. The attachment of parallel stiffeners on plate gives an attenuation of bending waves in a direction perpendicular to the stiffeners. When multiple parallel stiffeners are attached at equal distances, they form a spatial periodic structure and it has specific wave properties. Waves cannot propagate in a periodic stiffened plate at all frequencies. There are frequency zones in which propagation is possible and others in which it is impossible; such frequency zones form pass bands and stop bands of wave propagation respectively [1]. In the first part of this work, the effect of angular incidence of bending waves on stop and pass band is studied.

The effect of cross stiffeners on the attenuation of bending waves in a plate is studied in the second part of this work. The two-dimensional analytic model based on substitution of forces and moments shows that stop and pass bands of wave propagation diminish in case of a cross stiffened plate [2]. This effect is experimentally verified in this work and new observations are put forth in this paper. The crossing stiffeners are placed at equal distances. The measurements are done in order to predict the stop and pass bands.

Experimental Set up of the Cross stiffened Plate:

To analyze the effect of stiffeners, experiments are performed in a progressive manner. In the first step, the infinite plate is modelled by resting its edges on sponge and sand, such that the bending waves at the plate boundaries are absorbed. The plate is excited by point excitation by a shaker with white noise in the frequency band from 50 Hz to 10,000Hz. The set-up is shown in Fig. 1a. The point of excitation is indicated by an inverted cone and response locations are indicated by small dots in Fig. 1.

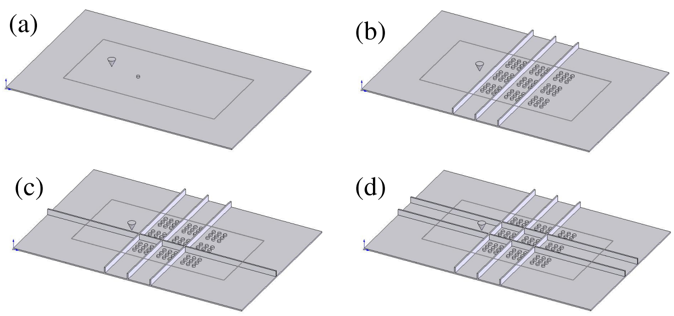

Figure 1: Scheme of experiments: (a) un-stiffened plate; (b) plate with three parallel stiffeners; (c) plate with one crossing stiffener; (d) plate with two crossing stiffeners.

The model of an unstiffened thin plate is satisfactorily accepted, noting that the point mobility of this plate is constant and is equal to the theoretical point mobility as shown in Fig. 3. In the next step, three parallel stiffeners are glued to the plate as shown in Fig. 1b. The transfer mobilities are measured on the plate at various locations. In the next step, one crossing stiffener is glued to the plate as indicated in Fig. 1c. In the final step, two crossing stiffeners are glued to the plate as shown in Fig. 1d and Fig. 2. The transfer mobility is measured at many locations on the plate and total 972 measurements are taken to completely analyze the stiffened plate.

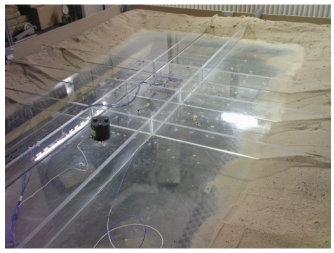

Figure 2: Experimental set up of the cross stiffened plate

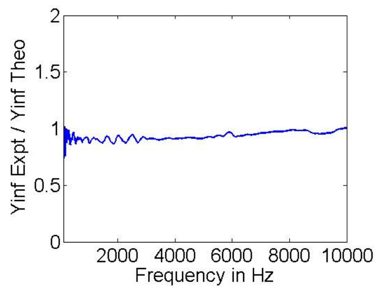

Figure 3: Normalized point mobility of infinite unstiffened plate

Experimental Results:

In the case of a parallel stiffened plate, pass and stop bands of wave propagation are clearly observed in the area after the third parallel stiffener. In the case of oblique wave incidence, the transfer mobilities are similar as for perpendicular incidence in low and mid frequency region up to 4000 Hz. In the high frequency range, the stop and pass bands get shifted to higher frequencies, as shown in Fig. 4.

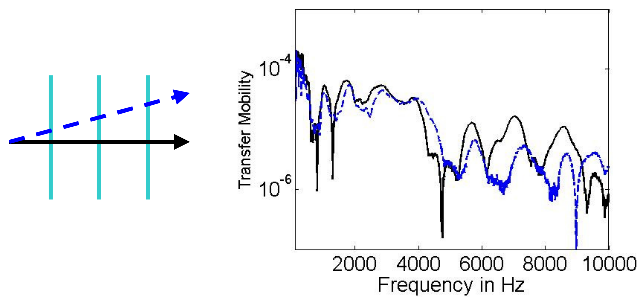

Fig. 4: Pass and stop bands of transfer mobility in parallel stiffened plate: ——— attenuation perpendicular to stiffener; - - - attenuation at 22.5° to stiffener.

For the configuration of three parallel stiffeners and one crossing stiffener as indicated in Fig. 1c, the transfer mobilities are plotted in Fig. 5. At a point shielded by the stiffener shown in Fig. 5a, the attenuation is improved at low frequencies. The stop and pass bands are not distinctly observed at high frequencies. At a point away from the cross stiffener, the attenuation is similar as that of the parallel stiffened plate as shown in from Fig. 5b.

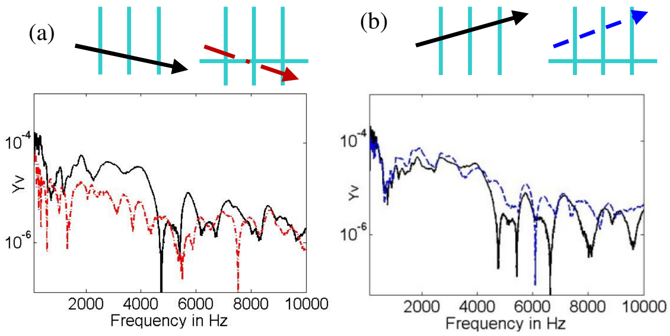

Fig. 5: Transfer mobility of plate with single cross stiffener:
(a) — · — mobility at a point shielded by cross stiffener;
(b) - - - - mobility at a point away from cross stiffener.
—— mobility of parallel stiffened plate at same point.

For the configuration of three parallel stiffeners and two crossing stiffeners as indicated in Fig. 1d, the transfer mobilities are plotted in Fig. 6. At a point in a channel containing the source, the vibration levels are increased at all frequencies as shown in Fig. 6a. Thus a channelling effect is observed with overall increased vibration levels.

At locations in the side boxes, in angular direction, the attenuation is improved at low frequencies up to 3500 Hz as observed in Fig. 6b. At high frequencies, stop and pass band effects are not present.

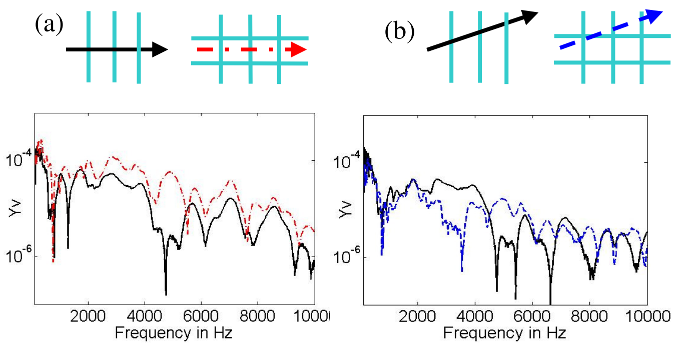

Fig. 6: Transfer mobility of cross stiffened plate:
(a) - · - · mobility at a point in channel;
(b) - - - mobility at a point in angular direction;
—— mobility of parallel stiffened plate at same point.

Comparison of Measurements with Analytical Results:

The analytical solution of Structure-Borne Sound propagation through stiffened plates is obtained by substitution of forces and moments methods [2]. The analytical results are compared with experimental results. The transfer mobility in a cross stiffened plate is plotted in Fig. 7. A similar pattern is observed in analytical results.

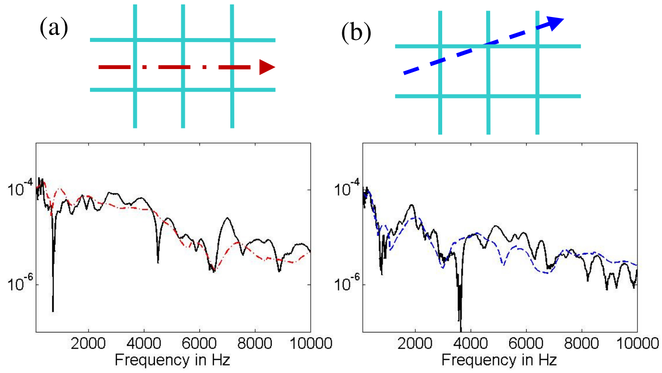

Fig. 7: Comparison between analytical and measured transfer mobilities of a cross stiffened plate. (a) at a point inside the channel; (b) at a point in angular direction; the black lines show experimental results and coloured lines show the analytical results.

Concluding Remarks

Attenuation of structure borne sound can be obtained using parallel and cross stiffeners. In a parallel stiffened plate excited by point source, at oblique wave incidence to stiffener, stop and pass band frequencies increases in high frequency range. In a stiffened plate with one crossing stiffener, attenuation is improved at lower frequencies but stop and pass bands are not distinct at high frequencies. In a cross stiffened plate excited by a point source, channelling of Structure-Borne Sound takes place. In the sidewise blocks, attenuation substantially improves at low frequencies due to the cross stiffeners. However at high frequencies, stop and pass bands disappear.

References

[1] Mead,D.J, *Passive Vibration Control,* John Wiley & Sons Ltd, 1988, pp.183-196.

[2] Tschakert,R., Petersson, B.A.T., *Stop and Pass Bands in cross-stiffened plates, A 2-Dimensional Model of Structure-Borne Sound propagation in stiffened plates,* Proceedings of Noise and Vibration: Emerging Methods (NOVEM) -2009.