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EXPERIMENTAL STUDY OF VIBRATION RESPONSE DISPERSION BETWEEN STRUCTURES

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1. INTRODUCTION

Industrial manufacturers are currently concerned by the high levels of dispersion of acoustic and vibrational behaviour of mass-produced products. Quality control during the manufacturing process does not appear to be sufficient to reduce this dispersion [1–5]. This subject is currently being invesigated in many research laboratories. The results presented in this article provide an indication of whether or not such dispersion is due to a problem in the reproducibility of experimental measurements, or to intrinsic differences between structures that are supposed to be identical.

2. EXPERIMENTAL SET-UP

The structure chosen for this study was made from a steel plate of dimensions $1500 \times 200 \times 3$ mm bent by an industrial folding machine to obtain a series of ten identical plates. There is no material discontinuity and each plate element of dimensions $150 \times 200 \times 3$ mm is oriented at an angle of 4° to its neighbour (see Figure 1). This choice follows the work of Rebillard and Guyader on the hypersensitivity of coupled plates [6] where this angle of connection (4°) was demonstrated to introduce extreme sensitivity to small variations.

The typical experimental configuration is the structure previously described, freely suspended with care being taken to maintain it perfectly vertical. The environmental conditions (temperature) were not controlled, but there were very similar conditions between the different tests. The mechanical excitation of the structure was accomplished by using a 10N Brüel and Kjaer (B&K) 4810 electrodynamic shaker. An impedance head (B&K 8001) was used to measure the injected mechanical force. A stinger was placed between the electrodynamic shaker and the impedance head in order to inject only the normal component of the force.

The mobility $Y_{i,j}(\omega)$ is defined, for an angular frequency ω, as the ratio of the complex amplitude of transverse vibrating velocity at point i of the structure to the complex amplitude of force applied at point j:

$$Y_{i,j}(\omega) = V_i(\omega)/F_j(\omega).$$

In references [1], [2] and [6], the mobility of the structure has been shown to be a sensitive quantity, both in terms of its amplitude and phase. It has been chosen, in this paper, as

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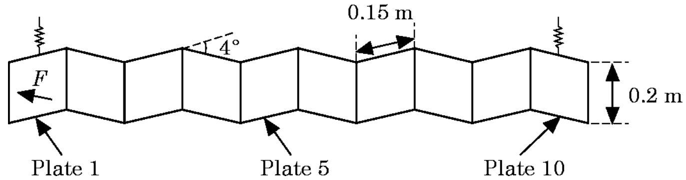

Figure 1. Experimental set-up and a typical structure.

For more details on mobility, see references [7, 8]. In what follows the force is always applied at the mid-point of plate 1, and the transverse vibrating velocities are measured at the mid-point of plates 1, 5 and 10 (see Figure 1).

3. MEASUREMENT PROCEDURE AND RESULTS OBTAINED

Two types of test have been carried out in order to determine the cause of a possible dispersion observed in the vibrating response of the structures that are assumed to be identical. Sequential measurements were carried out on one particular structure after its complete assembly and disassembly with the measurement and excitation devices in order to determine whether or not it is the measurement itself that causes these differences; and identical measurements were carried out on a set of structures manufactured in series in order to determine whether or not the dispersion is intrinsic to the structures.

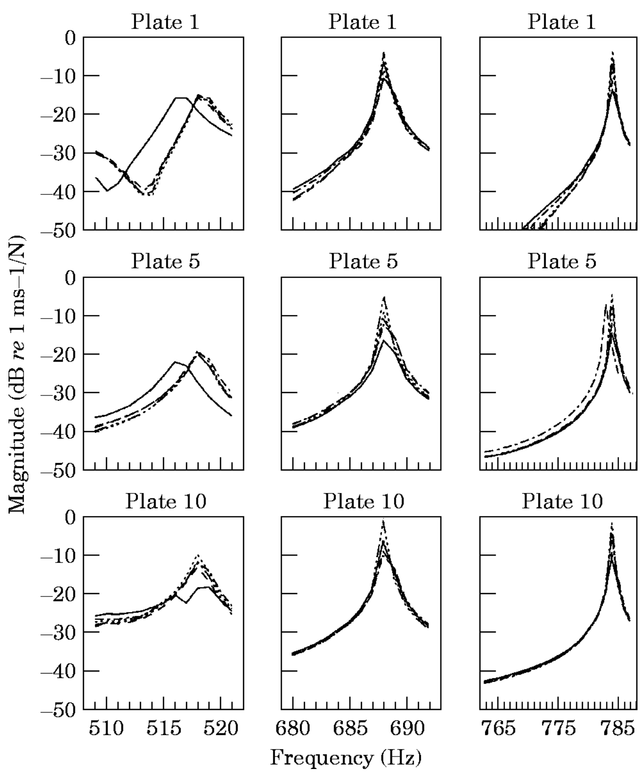

Figure 2. Amplitude (in dB, *re* 1 ms-1/N) of the mobility obtained for a same structure in the case of five different assemblies. Point and transfer mobilities are measured at the centres of plates 1, 5 and 10 and around three frequencies bands of 12 Hz centred at 515, 686 and 775 Hz. ——, Assembly 1; · · · ·, assembly 2; – – –, assembly 3; –·–·–, assembly 4; –· · ·–, assembly 5.

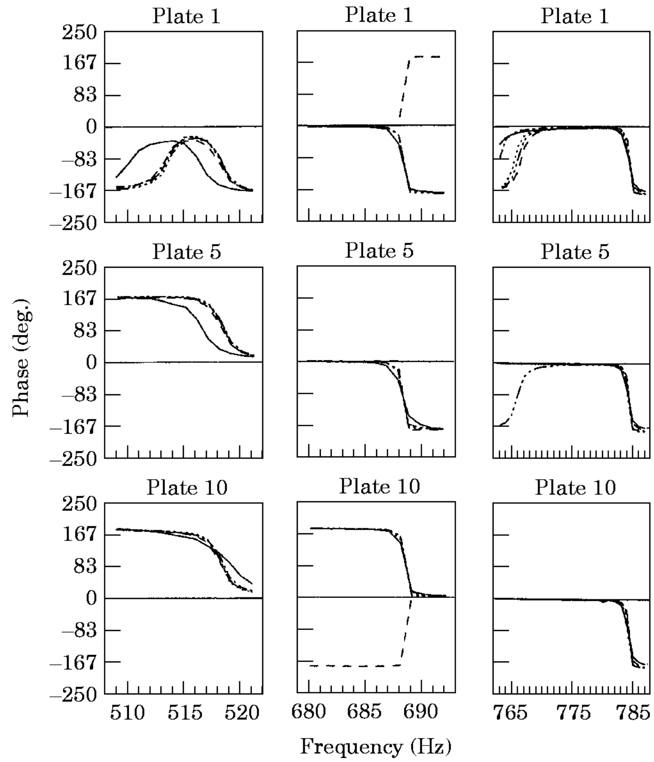

Figure 3. Phase of the mobility obtained for a same structure in the case of five different assemblies. Point and transfer mobilities are measured at the centres of the plates 1, 5 and 10 and around three frequency bands of 12 Hz centred at 515, 686 and 775 Hz. Key as Figure 2.

3.1. *Sequential measurements on a single structure*

Five measurements were carried out on the same structure. The structure and the system used to generate the mechanical excitation were entirely assembled and disassembled between tests. An initial analysis of the vibrating response to a wide band random signal allowed the authors to identify and concentrate on three peaks at 515, 686, and 775 Hz. The structure was then excited by a pure tone signal over a range of 12 Hz in 1 Hz steps around each of these three frequencies. The magnitude and the phase of the point and transfer mobilities are shown in Figures 2 and 3 respectively. The five curves are very close in each figure. A maximum difference of 2 Hz is observed between the peaks of two successive measurements in the frequency band centered at 515 Hz. This difference is simply due to our frequency step of 1 Hz; decreasing this step will then decrease the difference. In conclusion, assembly and dissembly of the structure and its excitation bring very small variations between sequential measurement.

3.2. *Measurements on several "identical" structures*

Four "identical" structures were realized from the same steel sheet and by using the same preparatory steps (cutting and bending). Each structure was excited by using a pure tone signal at frequencies spaced at 1 Hz over a 12 Hz band centred at the three frequencies noted above (515, 686, 775 Hz). The amplitude and the phase of the point and transfer mobilities are shown in Figures 4 and 5 respectively. It can be seen that there are significant differences between curves; in particular some peaks are shifted by more than 10 Hz from the frequency bands centred at 515 and 775 Hz. The magnitude and phase of the mobility

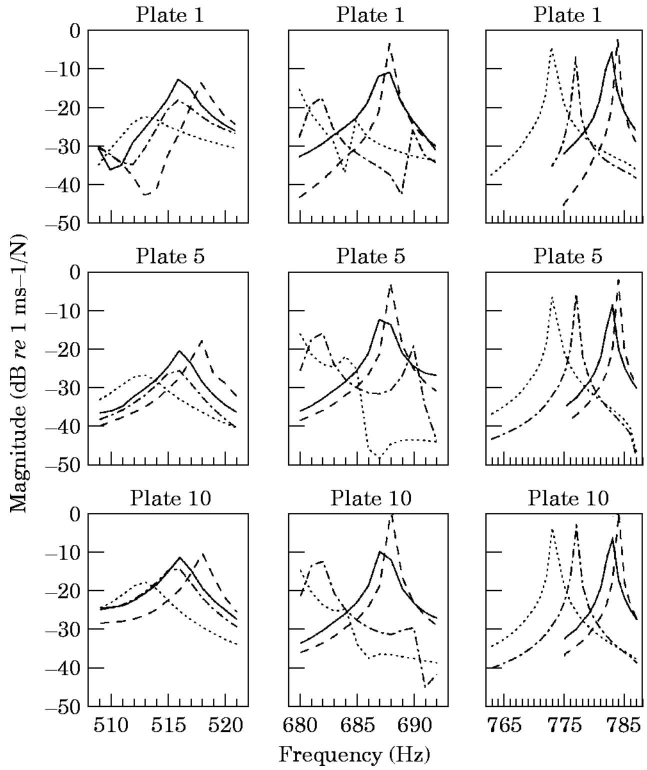

Figure 4. Amplitude (in dB, *re* 1 ms-1/N) of the mobility obtained for four "identical" structures using the same assembly. Point and transfer mobilities are measured at the centres of the plates 1, 5 and 10 and around three frequency bands of 12 Hz centred at 515, 686 and 775 Hz. ——, Structure 1; ·····, structure 2; -----, structure 3; –·–·–, structure 4.

of the band centred at 686 Hz are also significantly different from test to test. In fact, the magnitude of the mobility in this frequency range can vary by more than 30 dB from one structure to another. The existence of intrinsic differences in structures assumed to be identical is clearly demonstrated by these results.

4. CONCLUSION

The measurements presented clearly demonstrate that the dispersion of vibration behaviour is due to sensitivity to small differences in the structures. The uncertainties due to the measurement process of course exist, but are of a lower order of magnitude. The degree of sensitivity however depends on the structures, as was theoretically demonstrated in reference [6].

Small variations of connection angle in coupled plates can have a large effect, or not, on the vibration behaviour of the assemblage, depending on the angle of connection. The sensitivity is very high for a small angle of connection: that is to say for "quasi-flat plates".

One sensitive connection in coupled plates is sufficient to render sensitive the whole assemblage. One can conclude that the probability of complicated "identical" structures having different behaviour, is very high.

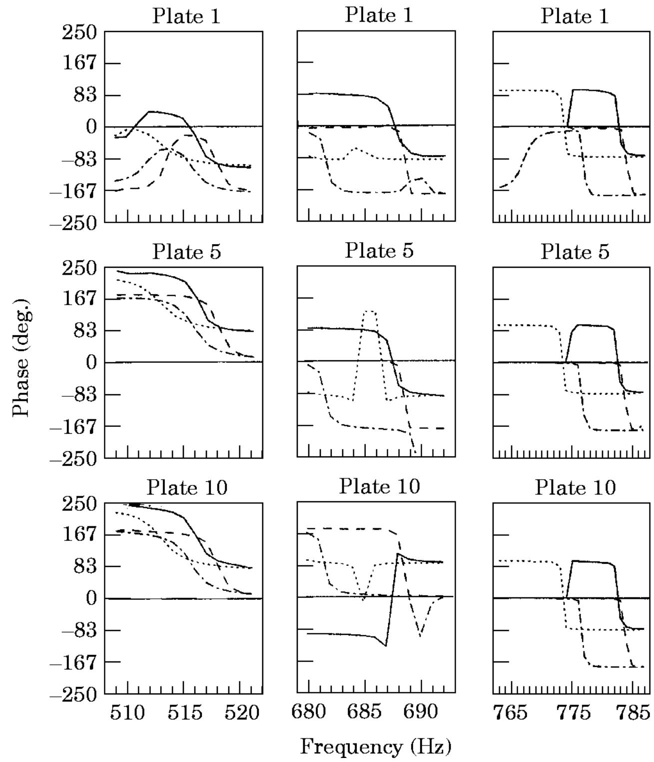

Figure 5. Phase of the mobility obtained for four "identical" structures when using the same assembly. Point and transfer mobilities are measured at the centres of the plates 1, 5 and 10 and around three frequency bands of 12 Hz centred at 515, 686 and 775 Hz. Key as Figure 4.

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