Journal of Sound and Vibration (1997) **204**(2), 377–380

EXPERIMENTAL STUDY OF PERIODIC LATTICE OF PLATES

E. Rebillard

Department of Applied Acoustics, Chalmers University of Technology, S-412 96 Gothenburg, Sweden

T. Loyau

Institut National de Recherche et de Sécurité (INRS), avenue de Bourgogne, B.P. 27., F-54501 Vandoeuvre Cedex, France

and

J. L. Guyader

Laboratoire Vibration Acoustique, INSA de Lyon, Bâtiment 303, F-69621 Villeurbanne Cedex, France

(*Received* 13 *November* 1996, *and in final form* 6 *January* 1997)

1. Introduction

Periodic structures are often found in reality (crystallography, electricity, mechanics) and numerous studies have been devoted to this subject [1]. In the mechanical field, theoretical and experimental approaches have identified basic behaviours for such structures, with the fundamental subsystem considered to be a pendulum, a beam or a plate, respectively [2, 3, 4]. Main phenomena as the pass-band, the stop-band, and less often the amber-band, are now well known and illustrated. Briefly, one can be reminded that for a finite periodic structure, excited by a pure tone excitation, three kinds of frequency band are observable, when considering the vibrational response. These are as follows: a pass-band where the energy is spread all over the structure; a stop-band which corresponds to an energetic confinement in the excited subsystem; in between these (with energetic repartition over the structure, and without consideration of the frequency content) there is an amber-band, observable only for some finite structures. This third particular band is less often seen. Actually it appears at high frequency when the modal density of the structutre increases and when a kind of overlap between less successive pass-bands occurs; the stop-bands then can no longer exist. From an energetic point of view, the energy is spread all over the structure but with a maximum in the excited subsystem and a delay from one subsystem to others. Results and explanations about the amber-band have been given in reference [5].

To the authors' knowledge, no experimental study has been published concerning a periodic lattice of coupled non-coplanar plates. This letter deals with such experimental results in order to check the validity of theoretically predicted behaviour. It is part of a continuation of the theoretical study carried out by Rébillard and Guyader on the vibrational behaviour of a lattice of plates [5].

2. Experimental set-up

The structure under study is made from a long steel plate of dimensions 1500 mm × 200 mm × 3 mm bent (in the direction perpendicular to its length) with successive angles of $+20^\circ$ or -20° each 0·15 m to provide a periodic structure. The

0022–460X/97/270377 + 04 $25.00/0/sv970893

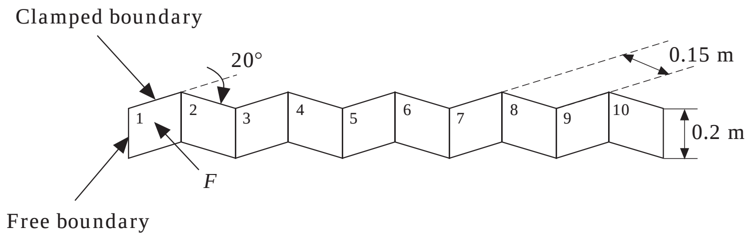

Figure 1. Periodic lattice of 10 identical plates.

boundary conditions are such that the structure is clamped along the length and free at the two perpendicular extremities.

The structure is mechanically excited by a white noise force provided by a Brüel and Kjaer electrodynamic shaker (B&K 4810). An impedance head (B&K 8001) is used to measure the injected mechanical force. A stinger is placed between the electrodynamic shaker and the impedance head in order to inject only the normal component of the force to the structure. The excitation force is located on the first plate of the lattice. The structure is illustrated in Figure 1.

In order to have a global view of the subsystems behaviour, a quantity averaged over space was used instead of a local quantity. The control parameter is the averaged quadratic transverse velocity of each plate divided by the force injected into plate 1, called here the quadratic velocity.

For each plate, a mesh of 36 equal square surfaces is defined. In the middle of each surface, the displacement is measured without contact by using a laser vibrometer, and then the quadratic velocity is derived. One can summarize this mathematically by the formula

$$\langle V_i^2(\omega)\rangle = \frac{1}{S_i}\sum_{j=1}^{36} S_j \frac{|V_j|^2}{|F|^2}.$$

$\langle V_i^2(\omega)\rangle$ is the quadratic velocity of the plate i. S_i is its surface divided into 36 S_j surfaces, in the middle of each of which the amplitude of the vibrating velocity $|V_j|$ is measured at the angular frequency ω.

The laser probe which measures the displacement at several positions, is moved and positioned by using a two axes robot.

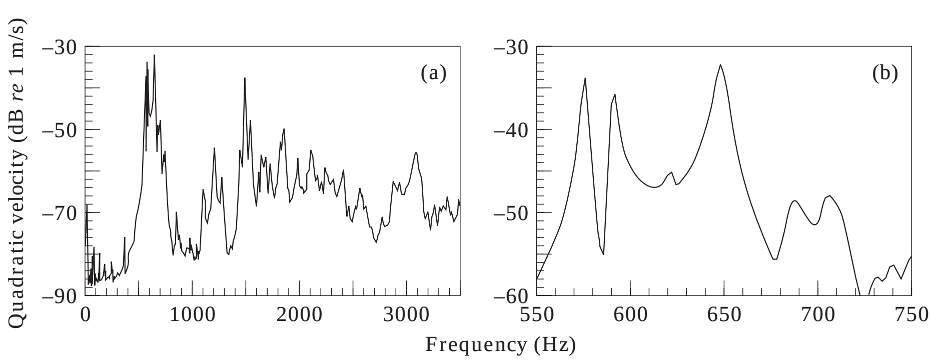

Figure 2. Quadratic velocity (m/s) of plate 4 (a) over the frequency range 0–3500 Hz, and (b) over the frequency range 550–750 Hz (zoom).

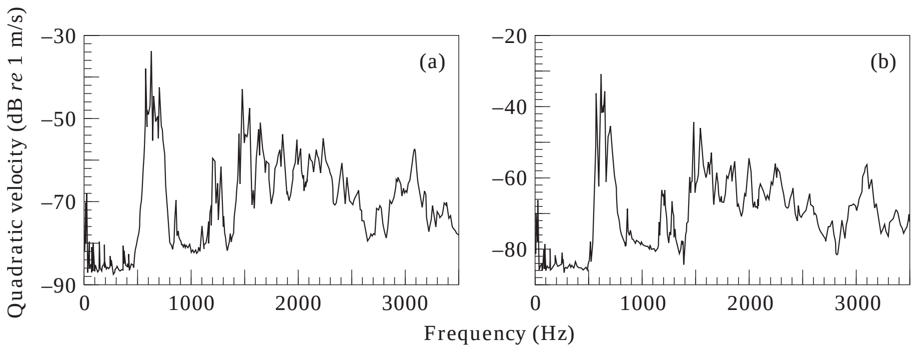

Figure 3. As Figure 2(a) but (a) for plate 5 and (b) for plate 6.

3. MEASUREMENTS AND RESULTS

Results for the quadratic velocity are shown in Figures 2, 3 and 4, respectively for the plates indexed 4, 5 and 6, 7 and 8. It was not possible to make these measurements for the other plates due to the configuration of the experiment. The velocity of vibration is expressed in m/s and the reference used for the logarithmic scale is 1 m/s.

In the results presented, one can observe the three theoretically predicted behaviours: stop-band, pass-band and amber-band. However these phenomena are not so clearly evidenced as in the theoretical results of reference [5]. Considering the figures, one can see the following behaviour as the frequency increases.

(a) Up to 500 Hz, whatever the plate, the level of the quadratic velocity is very low. Clearly, this is a stop-band. For a stop-band, the energy injected into the structure is confined to the excited subsystem, and from one to the next subsystem the level of energy decreases exponentially. This is not verified in these experimental results but one can propose an explanation, namely that the energy level is so low that the signal to noise ratio is not sufficient.

(b) There is a first group of peaks between 550 and 750 Hz. They correspond to a pass-band. Among the different results, one can find eight peaks of quadratic velocity at 576 Hz, 590 Hz, 622 Hz, 648 Hz, 682 Hz, 702 Hz, 740 Hz and 750 Hz. The theory for a lattice predicts that for a finite structure constructed from n equivalent susbsystems, there are in each pass-band n peaks: that is to say ten, in the present case. To explain the fact that two expected peaks are missing in the

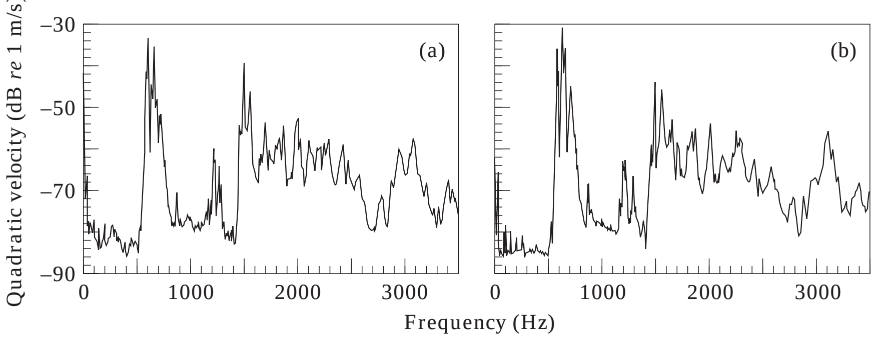

Figure 4. As Figure 2(a) but (a) for plate 7 and (b) for plate 8.

experimental results, one can say that this lattice is not composed of ten identical subsystems. It is made up of ten geometrically identical plates, but the two at the extremities do not have the same boundary conditions as the others. For a pass-band, one can observe that the level of the quadratic velocity is almost the same for each of the plates on which measurements were made; this is consistent with theoretical results for lattices.

(c) From 800 Hz to 1200 Hz, a second stop-band is clearly observable.

(d) A second pass-band, which is not so obvious as the previous one, is also perceptible from 1200 Hz to 1400 Hz.

(e) Above 1500 Hz, stop-bands and pass-bands are no longer perceptible. About this fact, two possible causes, both of which have been theoretically identified, can be responsible. First, one can say that one has reached an amber-band. The modal density of each subsystem increases with frequency, and it is no longer possible to obtain a stop-band, as explained in reference [5]. Second, one can say also that the behaviour is due to the lack of precise periodicity of the structure, which, as explained in reference [6], causes this typical distribution of pass-band/stop-band to disappear. Actually, the observed behaviour is presumably due to be a combination of these two proposed causes.

4. CONCLUSION

The measurements presented have clearly illustrated the typical behaviour for a finite periodic structure, even for a low number of subsystems. The first pass-band and stop-band are obvious, and, due to the modal density of each subsystem, the amber-band appears early.

However some deviations from the predicted lattice behaviours appear (eight peaks instead of ten in the pass-band) due to imperfections in the experimental set-up; these imperfections can also contribute to the vanishing of alternate pass-band/stop-band behaviour.

REFERENCES

1. L. BRILLOUIN and M. PARODI 1956 *Propagation des ondes dans les milieux périodiques*. New York: Masson et Cie.
2. C. H. HODGES and J. WOODHOUSE 1983 *Journal of the Acoustical Society of America* **74**, 894–905. Vibration isolation from irregularity in a nearly periodic structure: theory and measurements.
3. J. M. CUSCHIERI 1990 *Journal of Sound and Vibration* **143**, 65–74. Vibration transmission through periodic structures using a mobility power flow approach.
4. G. MAIDANIK and J. DICKEY 1993 *Journal of the Acoustical Society of America* **94**, 1435–1444. Quadratic and energy estimates of the partial response of ribbed panels.
5. E. REBILLARD and J. L. GUYADER 1997 *Journal of Sound and Vibration*. Vibrational behaviour of lattices of plates: basic behaviour and hypersensitivity. (in press).
6. A. J. KEANE and W. G. PRICE 1989 *Journal of Sound and Vibration* **128**, 423–450. On the vibration of mono-coupled periodic and near periodic structures.