FORMATION OF BAND GAPS IN A THIN PLATE WITH A PERIODIC STUBBED SURFACE

RAVI RANJAN
RESEARCH SCHOLAR
DEPARTMENT OF PHYSICS, J.P. UNIVERSITY, CHAPRA, SARAN
(BIHAR) INDIA

Received: Sept. 04, 2017 Accepted: Oct. 15, 2017

ABSTRACT *We have studied the formation of band gaps in a thin plate with a periodic stubbed surface. We found that the evolution of the band gaps in a thin plate with a periodic stubbed surface gradually increasing with the height of the stubbed cylinders. When the height of the stubs increases, some resonances are formed. This result in slower wave velocity and flatter bands near the edge of the Brillouin zone (i.e., at the X-point). We also found that the dispersion curves are getting flatter and flatter as the stubs on the plate causes the resonance that induces the flat bands because the acoustic energy is trapped by the periodic stubs. We analyze that by increasing the height of the stubs lowers the resonant frequencies and it enhances the mutual repelling of the bands. We also found that by using the laser ultrasonic techniques, it shows that acoustic energies with frequencies in the complete and partial band gaps that correspond to the fact that Lamb waves with frequencies in the gaps attenuate during the propagation.*

Key words: *Periodic stubbed surface, Brillouin zone, Lamb waves, acoustic energy, Propagation.*

INTRODUCTION

Tzung-Chen Wu1 studied numerically and experimentally the wave guiding of Lamb modes in a thin plate with a periodic stubbed surface and proposed a frequency-selection method based on the found complete band gaps of Lamb waves in the periodic structure. Propagation of bulk and surface acoustic waves in the periodic structures called photonic crystals has attracted a lot of interests due to their renewed physical properties2-7. The existence of band gaps, the frequency ranges in which acoustic wave propagation is forbidden, in such periodic structures has led to a variety of potential applications, such as filters. The frequency band structure of acoustic waves propagating in the plates composed of two different kinds of solid constituents periodically arranged have been studied numerically and experimentally8.

METHOD

The evolution of the band gaps in a thin plate with a periodic stubbed surface is studied first by gradually increasing the height of the stubbed cylinders. Consider a thin plate (plate thickness of h1 = mm) with periodic cylindrical stubs on one of the plate surfaces [a unit cell of the structure is shown in Fig. 1(a).

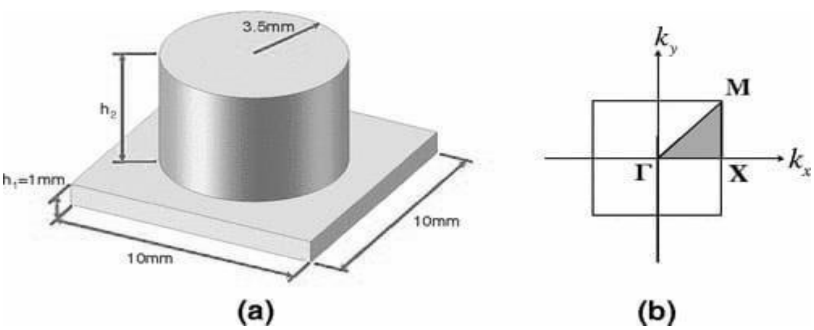

Fig. 1 : (a) Schematic of a unit cell of the PC plate with a periodic stubbed surface and (b) the corresponding first Brillouin zone. Gray area in (b) is the irreducible part of the zone.

The material chosen to constitute the whole structure is aluminum 6061. The cylindrical stubs are arranged in square lattice with a lattice constant a = 10 mm. The diameter of the cylindrical stubs is d = 7 mm and the filling factor defined as F = πd2/4a2 is 0.385. For waves propagating along the Γ – X direction in the first Brillouin zone [referring to Fig. 1 (b)], the calculated dispersion relations are shown in Fig. 2. The height of the stubs increases from one time of the plate thickness (h1) gradually up to 10h1. When the height of the stubs increases, some resonances are formed and thus result in slower wave velocity and flatter bands near the edge of the Brillouin zone (i.e., at the X point). As the stub height is about three times that of the plate thickness, i.e., h2 =3h1 some narrow complete band gaps, the frequency ranges with shaded color in Fig. 2, start forming. From Fig. 2, one can observe that as the stub height increases gradually, many bands originally crisscrossing in the dispersion curves start to separate at their intersections. The repelling of the bands finally results in different individual curves where each curve is composed of several evolved segments of old bands from the case of a uniform thin plate without the stubs. As a result of the repulsions, the mode coupling is resulted. This evolution due to the existence of the stubs on the surface of the thin base plate makes the dispersion curves possess much more complicated vibrating modes.

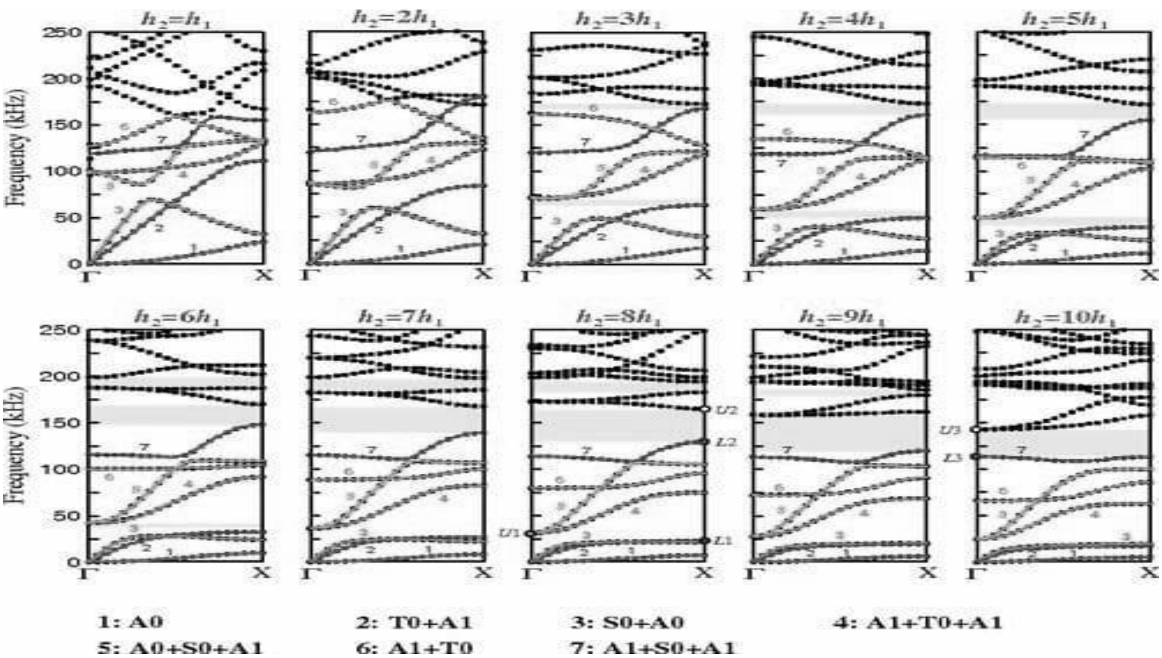

Fig.-2 : Variations in dispersion curves along the Γ-X direction with increasing stub height. The frequency ranges with shade denote the complete band gaps.

Moreover, Fig. 2 also shows that the dispersion curves are getting flatter and flatter as the stub height increases. This effect could be explained by that the growth of the stubs on the plate causes the resonance that induces the flat bands because the acoustic energy is trapped by the periodic stubs. The phenomenon of energy trapping by periodic array of mechanical resonators had been shown in the surface wave propagation. Increasing the height of the stubs lowers the resonant frequencies and enhances the mutual repelling of the bands. As a result, the band gaps are opened up and then widen.

RESULTS AND DISCUSSION

The experimental characterizations of the band gaps for this structure by using the laser ultrasonic techniques showed that acoustic energies with frequencies in the complete and partial band gaps exhibit much lower intensities in the measured spectra which agree well with the numerical result and correspond to the fact that Lamb waves with frequencies in the gaps attenuate during the propagation. In addition, some resonant peaks appearing at some of the band-edge frequencies, such as at 19 (the bottom edge of the first partial band gap), 100, and 109 kHz (the bottom and upper edges of the second partial band gap, respectively), where the slopes of the frequency bands approach zero which associate with high density of states of Lamb modes, were observed.

Moreover, a frequency range (about 66-100 kHz) in the measured spectra corresponding to no band gaps and exhibiting low intensity was also found. The frequency bands in this range are referred to as the deaf bands due to ineffective excitation of the modes by the given source.

CONCLUSION

We have studied the formation of band gaps in a thin plate with a periodic stubbed surface. We found that the evolution of the band gaps in a thin plate with a periodic stubbed surface gradually increasing with the height of the subbed cylinders. Moreover it shows that acoustic energy with frequencies in the band gaps can be separated out. The existence of band gaps in such periodic structures led to a variety of potential application, such as filters, efficient acoustic wave guides, etc.

REFERENCES

1. Tzung-Chen Wu Phys. Rev. B, 79, 104306, (2009).
2. M.S. Kushwaha, P. Halevi, L. Dobrzynski and B. Dyafari-Rouhani, Phys. Rev. Lett. 71, 2022, (1993).
3. R. Scindou, B. Djafari-Rouhani and J.O., Vasseur, Phys. Rev. B, 77, 094304, (2008).
4. F. Meseguer, M. Holgado, D. Caballero, N. Benaches, J. Sanchez-Dehesa, C. Lopez and J. Llinares, Phys. Rev. B, 59, 12169, (1999).
5. J.O. Vasseur, P.A. Deymier, B. Chenni, B. Djafari-Fouhani, L. Dobrzynski and Prevost, Phys. Rev. Lett. 86, 3012, (2001).
6. G. Wang, X. Wen, J. Wenl L. Shao and Y. Liu, Phys. Rev. Lett. 93, 154302, (2004).
7. S. Benchabane, A. Khelif, J.Y. Rauch, L. Robert and L. Laude, Phys. Rev. B, 73, 065601, (2006).
8. F.L. Hasiao, A Khelif, H. Moubehir, A. Choujaa, C. Chen and V. Lande, Phys. Rev. B. 76, 056601, (2007).