2P2-2

Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 231-232
3-5 December, 2014

Polygonal Buffer Rods Having Irregular Cross-Sectional Shapes for Improving the SNR in Ultrasonic Pulse-Echo Measurements

Farhana Mohd Foudzi[1‡]and Ikuo Ihara[2] ([1]Graduate School of Nagaoka Univ. of Tech., Nagaoka 940-2188, Japan, [2]Dept. of Mech. Eng., Nagaoka Univ. of Tech., Nagaoka 940-2188, Japan)

1. Introduction

Although so-called ultrasonic buffer rod method is rather classical, it is still an attractive approach from the viewpoints of its simplicity, convenience, robustness and low cost. However, due to the interference of the mode converted waves, dispersion and diffraction within a long rod of finite diameter, trailing echoes are formed and deteriorates the signal-to-noise ratio (SNR) of the main echo.[1-4)] To overcome such a problem, polygonal buffer rods having regular cross-sectional shapes is developed and their effectiveness for reducing trailing echoes is successfully demonstrated.[5)] Although it is reported that the formation of trailing echoes is restricted and the SNR is improved for odd polygonal buffer rods rather than the even polygonal buffer rods due to no parallel sides on the cross-sectional shape, however, it has been found that even a regular triangle has the tendency to create pairs of parallel interference waves as the pulse-echo waves propagating through the rod. The pairs of parallel interference waves will interfere with each other and generate trailing echoes. In order to eliminate the influence of parallel sides on the cross-sectional shapes and improvement of the SNR, it will be quite useful to discuss the irregular cross-sectional shapes on the pulse-echo measurements with the polygonal buffer rods. In this work, the irregular polygon is defined as a cross-sectional shape that has no parallel sides and all the internal angles are not equal. Square and triangle polygonal buffer rods with such regular and irregular cross-sectional shapes effect on the SNR is examined through 3D numerical simulations.

2. Numerical Experiments and Discussions

2.1 Regular cross-sectional shapes

Three dimensional finite difference analyses are performed on square and triangle buffer rods having 5 mm diameter and 25 mm length with a 5 MHz longitudinal ultrasonic transducer (UT) in pulse-echo mode. The UT is placed at the center of gravity for each cross-sectional shape. Wave3000 from CyberLogic, Inc. is used for the 3D simulations. To obtain accurate results, a grit size of 0.03 mm with the resolutions of 10voxel/mm is employed in the simulations. **Figure 1** shows the captured images of interference waves on the cross-sectional shapes for (a) regular square and (b) regular triangle as the pulse-echo waves propagating through the rod, respectively. The arrows in each shape indicate the direction of wave progress. For a regular square shown in **Fig. 1(a)**, since there are two pairs of parallel sides, two pairs of parallel interference waves depicted as (A1, A2) and (B1, B2) are formed. These two pairs will interfere with each other as depicted by (A1+A2) and (B1+B2) and such interference results in generating trailing echoes. Meanwhile for a regular triangle shown in **Fig. 1(b)**, a wave is propagating from each side of the triangle depicted as A1, B1 and C1, respectively. As each wave reaches the other side of the triangle, it reflects and creates a pair of parallel interference waves. Therefore, for a regular triangle, there are three pairs of parallel interference waves depicted as (A1, A2), (B1, B2) and (C1, C2).

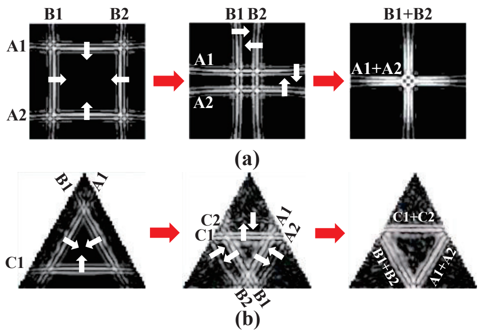

Fig. 1 Captured images of interference waves on the cross-sectional shapes for (a) regular square and (b) regular triangle

2.2 Irregular cross-sectional shapes

Based on the results shown above, irregular cross-sectional shapes are defined for square and triangle buffer rods with the aspect ratio is 0.9 to 1.10 as shown in **Fig. 2**. Irregular shapes for (a) and (c) are symmetry while irregular shapes for (b) and

---

ihara@mech.nagaokaut.ac.jp

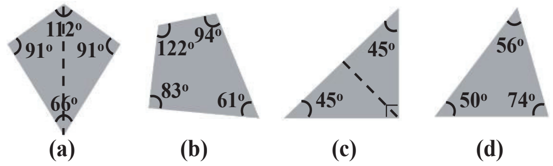

Fig. 2 Irregular cross-sectional shapes for square and triangle buffer rods

(d) are asymmetry. **Figures 3** and **4** show the simulation results for square and triangle buffer rods with regular and irregular cross-sectional shapes, respectively. It is observed that irregular shapes are better in improving the SNR compared to regular shapes due to no parallel sides. However, the improvement of SNR is not significant for the irregular symmetry shapes depicted as (b) in **Figs. 3** and **4** because they still have the tendency to create pairs of parallel interference waves. **Figure 5** shows the captured images of interference waves on the cross-sectional shape for (a) irregular symmetry triangle and (b) irregular asymmetric square, respectively. In **Fig. 5(a)**, the middle figure shows that similar wave propagations occur at both sides of the triangle separated by a dashed symmetry axis. Therefore, a pair of parallel interference waves depicted as (A2, A3) is formed and interferes with each other. Better improvement in SNR is observed for the irregular shape depicted as (c) in **Figs. 3** and **4**, respectively. This is because the irregular shapes are asymmetric and have no parallel sides. **Figure 5(b)** shows that the interference of waves is refrained as the pulse-echo waves propagate through the rod. Therefore, for any polygonal buffer rods having irregular asymmetric cross-sectional shapes, the formation of trailing echoes is reduced and the SNR is improved.

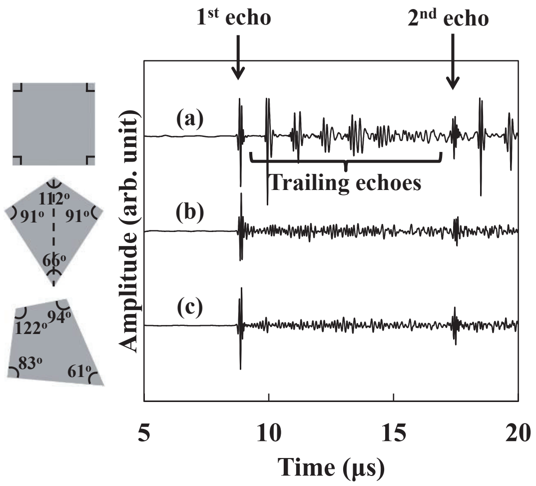

Fig. 3 Simulation results showing pulse-echoes for the square polygonal buffer rods having (a) regular and (b, c) irregular cross-sectional shapes.

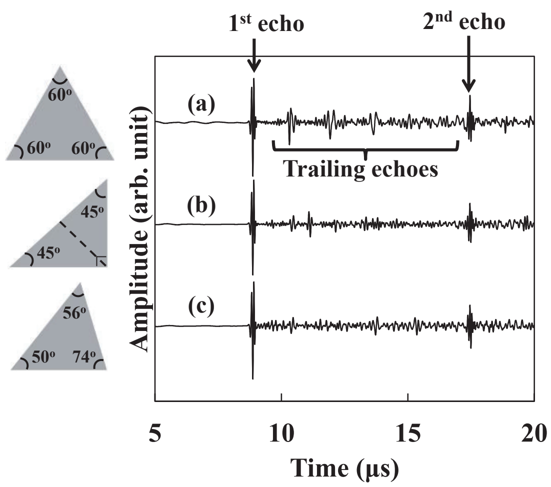

Fig. 4 Simulation results showing pulse-echoes for the triangle polygonal buffer rods having (a) regular and (b, c) irregular cross-sectional shapes.

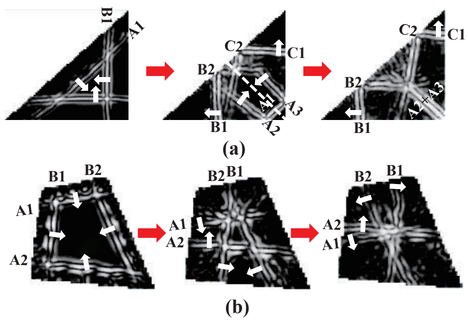

Fig. 5 Captured images of interference waves on the cross-sectional shapes for (a) irregular symmetry triangle and (b) irregular asymmetry square

3. Conclusions

The effect of irregular cross-sectional shape on the formation of trailing echoes of polygonal buffer rods is numerically examined. It has been demonstrated that asymmetric irregular cross-sectional shapes reduce trailing echoes effectively and result in improving the SNR in pulse-echo measurements with buffer rods.

4. Acknowledgment

Support by the Grant-in-Aid for Scientific Research (B) 25289238 from the JSPS is greatly appreciated.

5. References

1. C.-K. Jen, J.-G. Legoux and L. Parent: NDT & E Int. **3** (2000) 145.
2. I. Ihara, C.-K. Jen and D. R. Franca: Jpn. J. Appl. Phys. **39** (2000) 3152.
3. C.-K. Jen, J.-Y. Chen, S.-V. Hoa, K.-T. Nguyen, J.-G. Legoux and H. Hebert: IEEE Ultrason. Symp. (1997) 801.
4. C.-K. Jen, L. Piche and J. F. Bussiere: J. Acoust. Soc. Am. **97** (1990) 23.
5. M. F. Foudzi and I. Ihara: J. Phys.: Conf. Ser. 520 (2014) 012025.