46th Annual Review of Progress
in Quantitative Nondestructive Evaluation
QNDE2019
July 14-19, 2019, Portland, OR, USA

QNDE2019-6946

EFFECT OF CONICAL PROFILE ON THE TRANSMISSION OF ELASTIC WAVES FROM CYLINDRICAL WAVEGUIDE TO BULK

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ABSTRACT

This paper studies the transmission of elastic waves into test specimens for cylindrical waveguide based ultrasonic transducers. However, in order to achieve better mode focusing, topographical waveguides with conical profile were studied. Finite element simulations were used to study wave propagation and transmission into specimen samples using such 'transmission horns'. Fundamental Longitudinal mode L(0,1) was generated in cylindrical rods. Results show that a 50° conical transition profile help achieve better transmission and beam directionality into the specimen and also better reception of the back wall reflections at the waveguide as compared to a simple cylindrical rod waveguide.

Keywords: *Elastic wave focussing, beam width control, longitudinal mode, conical transmission horns.*

NOMENCLATURE

E	Young's modulus
μ	Poisson Ratio
ρ	Density
FE	Finite Element
WG	Waveguide
L(0,1)	Fundamental longitudinal mode

1. INTRODUCTION

When an Ultrasonic Waveguide Transducer [1, 2] is used for transmitting elastic waves into test structures, it is preferred to generate narrow beam width pulses with preferred polarization into the test structure. However the beam spread for fundamental longitudinal mode L(0,1) generated in cylindrical waveguide is more and at a wide angle.

Nicholson, N. C., *et al* [3] studied different horns shapes for reducing transmission losses and concluded significant amount of the energy are lost at waveguide transducer interface. Cegla, F. B., et al [4] designed a SH waveguide for Structural Health Monitoring. Kwon, Y. E., et al [5] using a waveguide with a tapered region was able to induce directionality in the propagated waves into the bulk. Riichi Murayama et al [6] used waveguide with acoustic horn for ultrasonic inspection of high temperature structures.

In this study, we examine different transitional regions between cylindrical waveguide and the test structure for effective transmission and how changes in it affects the beam spread for L(0,1) mode. In order to achieve better mode focusing, we explore waveguides attached with conical profile as the transitioning region between the waveguide and bulk. Finite element (FE) simulations were used to study wave propagation and transmission using such 'transmission horns'.

2. MATERIALS AND METHODS

FE studies were performed for cylindrical waveguide. Simulations were performed for aluminum rod. 2D axis-symmetric modeling was done by using explicit solver of ABAQUS [7]. The diameter of rod was taken as 2mm and the frequency used was 1MHz such as to generate only fundamental longitudinal mode L(0,1). The load was applied axially at the free end of the waveguide.

The properties of aluminum:

E=70GPa, μ= 0.33, ρ= 2700 kg/cm^3

Dispersion curve for such a rod is shown in figure 1 below.

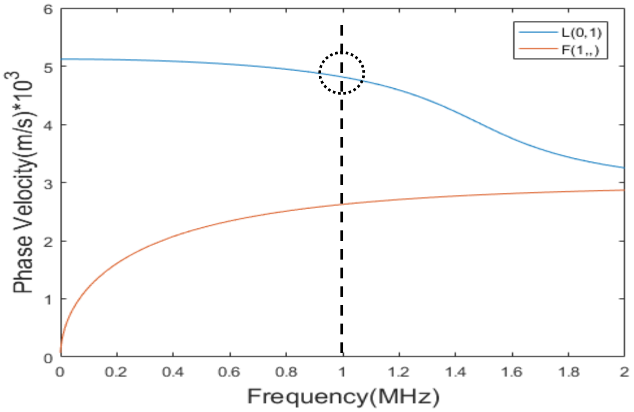

FIGURE 1: The phase velocity curve for 2mm aluminum rod was plotted using DISPERSE[8].

The fundamental longitudinal guide wave mode L(0,1) can be considered as a normal circular source with maximum intensity at center and gradually reducing with increasing distance from radius as shown in figure 2.

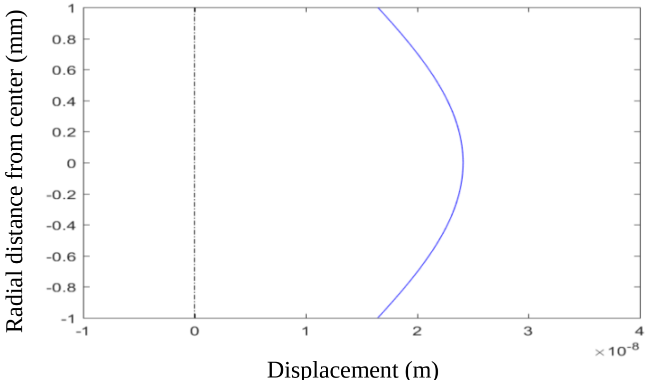

FIGURE 2: Mode Shape (Axial) of L(0,1) for 2mm aluminum rod at frequency of 1MHz using DISPERSE[8].

3. RESULTS AND DISCUSSION

FE simulations were performed for a bulk of 50mm thickness and a waveguide of 200mm length and 2mm diameter. The material for both the waveguide and the bulk was Aluminum. The wave guide was loaded axially at the free end. Infinite elements were attached axially at the free end of the waveguide to reduce undesired reflections.

Case 1: Waveguide (Ø2mm) connected directly to bulk (50mm)

The receiving node was taken at 30mm before the interface when waveguide is connected directly to the bulk.

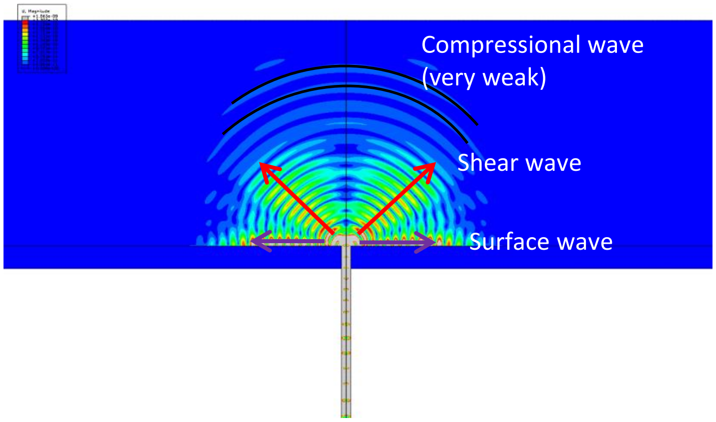

FIGURE 3: Snapshot of FE simulation shows L(0,1) guided wave mode being converted to different modes in bulk**.**

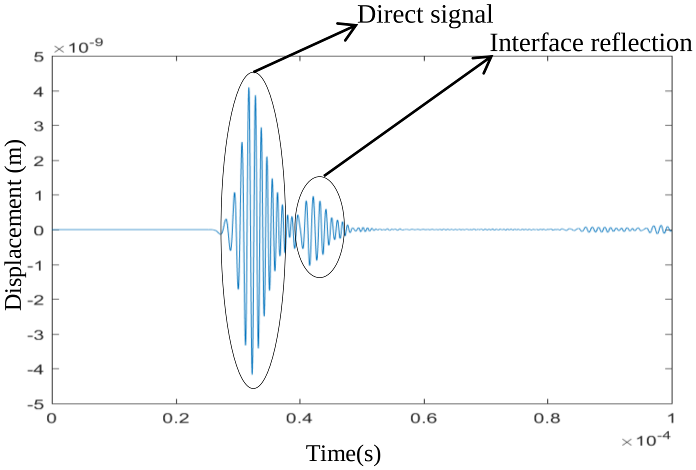

FIGURE 4: Time scan of signal received at the receiving node 30mm from the interface.

When elastic guided waves L(0,1) mode is transmitted from a waveguide directly to a bulk sample, it undergoes mode conversion into different bulk modes, i.e., compressional wave and shear wave as shown in figure 3. A major portion of the energy is also lost as surface wave. The compressional wave generated is very weak in nature and spreads out radially from the interface. However, the shear wave generated is stronger in nature, but they are generated at angle of 40°-60° degrees. So this shear wave is not particularly useful for us. The time scan of signal received at the node in the waveguide 30mm from the interface shows no reflected signal from the back wall as shown in figure 4. The perturbations in the time scan after 85ms is reflections from the free axial end of the waveguide.

Case 2: Waveguide (Ø2mm) connected to bulk (50mm) using a 50 degree solid cone

The receiving node was taken at 30mm away from the starting point of conical profile.

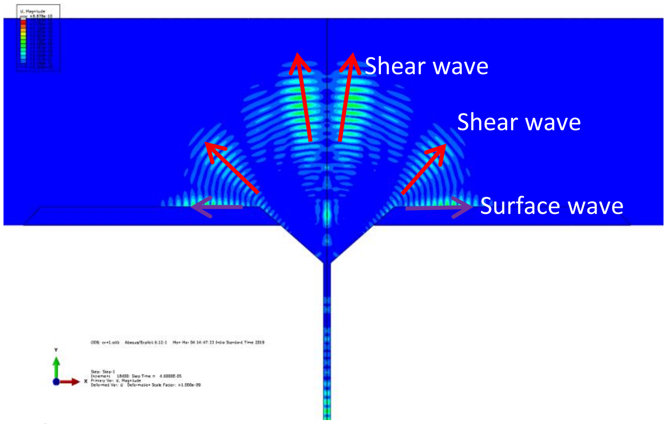

FIGURE 5: Snapshot of FE simulation shows L(0,1) guided wave mode being converted to different modes in bulk when the waveguide is connected to the bulk using 50° cone.

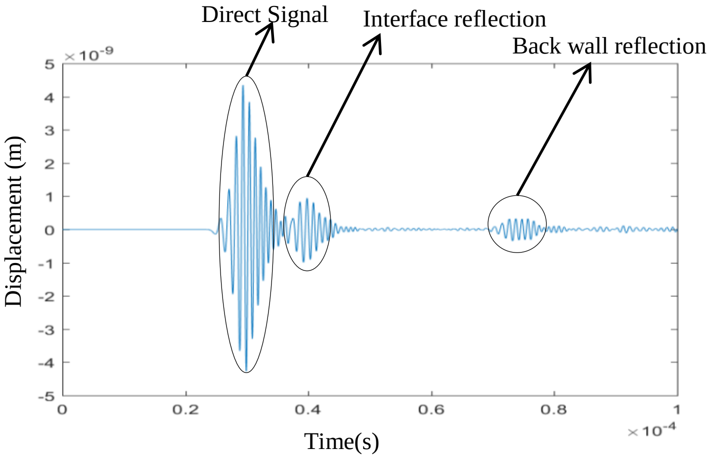

FIGURE 6: Time scan of signal received at the receiving node 30 mm from the start of conical profile.

However it is observed when we use a conical profile, the shear wave generated is at an angle of 10°-15° as shown in figure 5. A possible explanation of this change is due the effect of boundary at the region of mode conversion. The time scan of signal received at the node in the waveguide 30mm away from the start of the conical profile shows strong reflected signal from the back wall as shown in figure 6. The mode converted shear wave reflects from the back wall of the bulk sample and is received at the waveguide. The compressional wave generated is very weak, hence its reflection is not observed in the time scan.

This strongly generated shear wave may be used for ultrasonic inspection of bulk samples. Also the conical profile also acts a larger aperture for receiving the reflected signal.

4. CONCLUSION

This paper proposes the use of conical transmission profile for cylindrical waveguide in order to generate better mode focused and axially directed bulk shear wave. Finite element analysis were performed and the results were compared. The proposed conical profile is observed to have a shear wave directed closer to the axial direction of the waveguide. Time plot of different cases clearly indicates superiority of using conical horn transmission profile. Some of the benefits were also discussed. This work is currently being further investigated and will be reported in near future.

5. REFERENCES

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