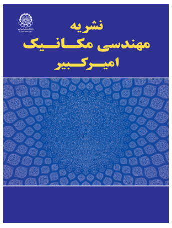

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Ultrasonic Guided Wave-Based Inspection of Straight Seam Welded Pipes

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ABSTRACT: Low-pressure fluid transmission lines are largely manufactured by cold rolling of a plate followed by resistance welding of the two edges of the plate. Consequently, these pipes have a straight weld seam along their length. In this paper, a finite element method is used for simulating the propagation of symmetric guided wave modes L(0,2), L(0,1) and T(0,1) in straight seam welded pipes. A comparison is made between the propagation of these wave modes in seamless and seam welded pipes. Results indicate that the angular amplitude profiles of the L(0,2) and T(0,1) modes do not change much in the presence of the seam weld. However, the presence of the straight seam weld significantly affects the propagation of the L(0,1) mode along the pipe. While the angular displacement profile for the L(0,2) and T(0,1) modes are almost symmetric, for the L(0,1) mode, the angular displacement profile shows high asymmetry. This asymmetric behavior impairs the sensitivity of this mode to the detection of defects in the proximity of the weld line. As a result, the guided wave modes L(0,2) and T(0,1) are considered to be suitable for inspection of straight seam welded pipes but L(0,1) is not recommended for this purpose.

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1- Introduction

Guided wave ultrasonic testing of pipes has received much attention in recent years. Many variables influence the propagation of guided waves in pipes, including the geometry and boundary conditions of the waveguide. According to API 1104 standard, many of the pipes used for fluid transfer are straight seam weld pipes [1]. The straight seam weld makes the geometry of the pipe heterogeneous along with the thickness and affects the sensitivity of the guided wave ultrasonic testing of the pipe.

The inspection of pipes with guided waves dates back to several decades ago. Alleyne and Cawley [2] developed a system to produce an axisymmetric L(0,M) wave mode in a pipe. Zheng et al. [3] used finite element method (FEM) to investigate the propagation of symmetric guided waves and studies the mode conversion of these waves due to interaction with symmetrical grooves. Based on numerous studies, the guided waves are sensitive to geometric variations in the pipe and pipe boundary conditions. In this paper, the effect of straight weld seam on the propagation of three symmetric guided wave modes L(0,2), L(0,1) and T(0,1) is considered.

Table 1. Mechanical properties of a standard steel pipe

Young modulus (GPa)	Poisson's ratio	Density (kg/m^3)
209	0.3	7850

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2- Finite Element Method

A 3-Dimensional (3D) model of a pipe with a diameter of 220 mm and a wall thickness of 4.8 mm is modelled in Abaqus software. The pipe is modelled and evaluated initially as a seamless pipe and then as a pipe with a straight seam weld as shown in Fig. 1. The mechanical properties of the pipe are given in Table 1 [1].

The C3D8 type element is used in Abaqus to decrease the computational time. Furthermore, to mitigate the reflections from two extreme boundaries of the pipe, infinite elements of CIN3D8 are used in boundaries. The sample is then excited

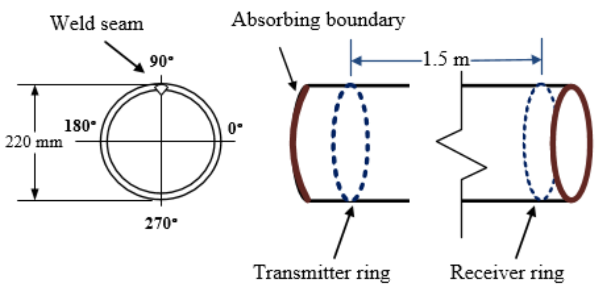

Fig. 1. A schematic of the simulated model in Abaqus software showing a transmitter ring consisting of 24 transducers generating the symmetrical wave modes of L(0,2), L(0,1) and T(0,1).

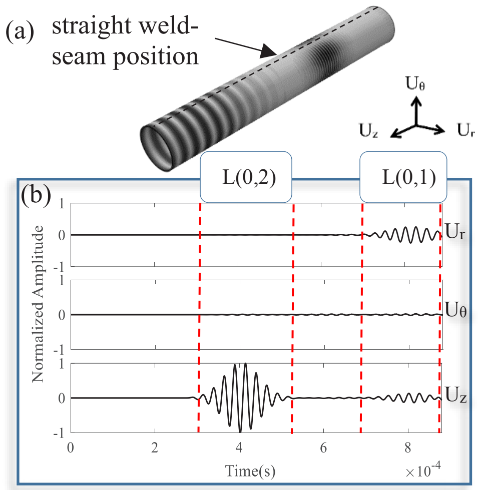

Fig. 2. (a) Propagation of longitudinal mode in the pipe, (b) typical received signal of L(0,2) and L(0,1)

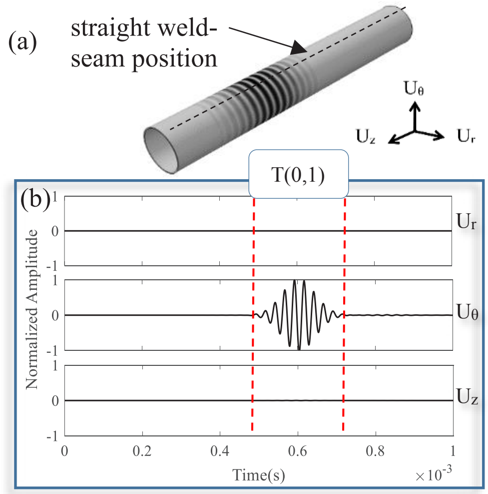

Fig. (a) Propagation of torsional mode in the pipe, (b) typical received signal of T(0,1) mode

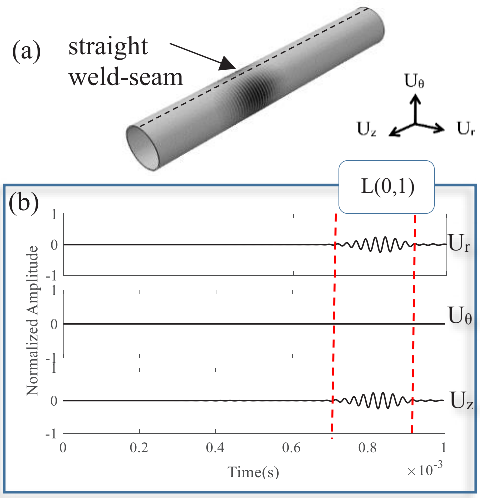

Fig. 3. (a) Propagation of longitudinal mode in the pipe, (b) typical received signal of L(0,1).

with a 10 cycles sine tone burst with a frequency of 40 kHz. To alleviate the generation of flexural modes, the number of transducers in a transmitter ring should be greater than the highest rank of flexural mode at that frequency. Therefore, the sample was symmetrically excited in 24 points around the pipe. Fig. 1 shows a schematic image of the simulated model in the software. The direction of loading for generating the L(0,2), L(0,1) and T(0.1) wave modes has been taken from [4, 5].

3- Results and Discussion

Both the geometry and material properties of a seam weld can affect the propagation of guided waves in a pipe. Figures 2, 3 and 4, respectively, show how each of the modes L(0,2), L(0,1) and T(0,1) propagate in a seam-welded pipe along with their corresponding signals. Note that all signals are measured at a distance of 1.5 meters from the transmitter ring. For further analysis and better understanding of how these modes propagate in a pipe, it is necessary to plot the angular displacement profile of each mode separately.

Symmetric modes have symmetric displacement profiles around the pipe which is a favorable characteristic of these

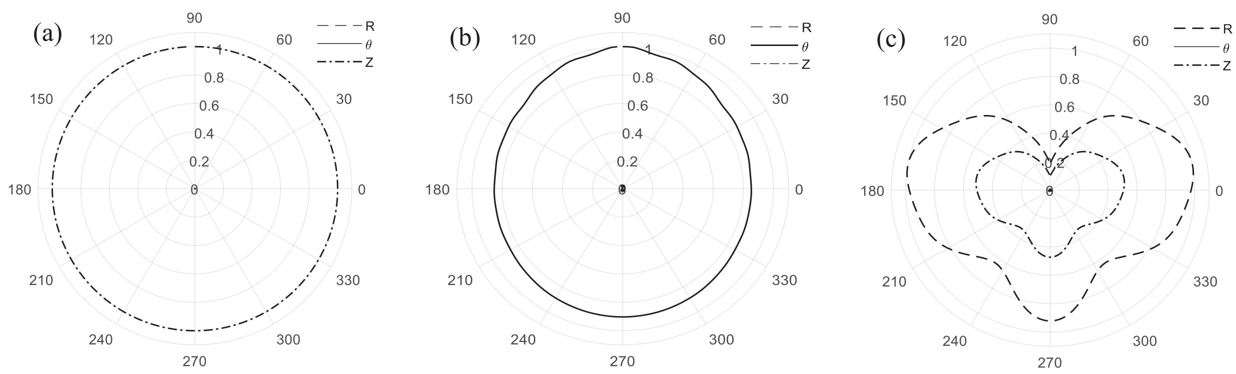

Fig. 5. Angular amplitude profile of (a) L(0,2) mode, (b) T(0,1) Mode and (c) L(0,1) Mode in a straight seam welded pipe. The weld line is at 90 degrees

modes [6]. Fig. 5a shows the angular profile of L(0,2) mode in a pipe with longitudinal seam weld. As seen in Fig. 5a, the existence of the weld seam does not affect the symmetry of this mode around the pipe and the distribution of wave amplitude around the pipe is uniform at all points. The angular profile of T(0,1) is shown in Fig. 5b around a seam welded pipe. The seam does not significantly affect the symmetry of angular distribution of this mode. For the L(0,1) mode, while the angular profile is symmetric around a seamless pipe, it loses its symmetry in the presence of a weld seam as shown in Fig. 5c. Consequently, the distribution of both U_r and U_z around the pipe is not symmetric anymore. The amplitudes of both U_r and U_z displacement components reach a minimum at the position of 90 degrees around the pipe.

4- Conclusions

In this paper, the effect of a weld seam line on the propagation of three guided wave modes in a seam welded pipe at a frequency of 40 kHz was investigated by finite element modeling. The angular profile of displacements around pipes with and without a seam weld was plotted. It was observed that the presence of the seam weld does not affect the displacement profile of the L(0,2) and T(0,1) modes. However, for the L(0,1) mode, the displacement profile is highly affected such that the displacement profile for both displacement components U_r and U_z become non-symmetric around the pipe. For this mode, the displacement amplitude at the seam weld significantly drops and this affects the sensitivity of defect detection at the weld. It can be concluded that the wave modes L(0,2) and T(0,1) are suitable for inspection of pipes having longitudinal weld seams.

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