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THE EFFECT OF THE LONGITUDINAL WELDED SUPPORT ON THE PIPE FOR GUIDED WAVE PROPAGATION

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Abstract

The torsional mode T(0,1) of guided wave is generated to detect the defects in pipeline. However, since many pipes of interest are supported with longitudinal welded supports for the necessary of manufacturing process in refinery and petro-chemical industrials. The effect of the longitudinal support welded on a 6 inch bore diameter pipe for guided wave propagation is investigated by both simulative and experimental method. Experimentally, the amplitude of the reflected signals from the longitudinal welded support is so large that the signal reflected from the features after the support would be distorted. This phenomenon is also observed when the finite element simulation is adopted. Not only the signal peak lagged behind the actual position of the support but also the enduring signal of the welded support covered up the signal of the defect beyond the support. The echoes from the longitudinal welded support were simulated and mode conversion was discussed. Moreover, the received signals are separated into single-mode waveforms with a mode extraction technique. A good agreement was found between FEM results and experimental results.

1. Introduction

The refinery, gas, chemical and petro-chemical industries operate widely the pipeline systems which usually carry high pressure, high temperature or even highly corrosive fluids. In recent years, guided wave inspection having a lot of superiorities over conventional ultrasonic inspection has been paid attention to. Low cost, long inspection range and time efficiency are the main advantages of guided waves. Lots of researches have used guided wave for defect inspection in pipes [1-3]. When axis-symmetric guided wave modes propagate on the pipe, such as T(0,1) mode, they will be reflected if they impinge onto a discontinuous in its path. The longitudinal welded support is one of the common examples of the discontinuous in pipes. The pipe supports are used to line the pipelines and integrate the manufacturing process for refinery, chemical and petro-chemical industrials.

This study presents the effect of the longitudinal welded support on the reflection of the axis-symmetric T(0,1) mode. A FEM simulation accompanied with experiments was used to understand the phenomenon of guided wave propagation through pipes with the longitudinal welded support. It has been found that the signal reflected from a longitudinal welded support delays for tens of centimeters.

2. Propagation of T(0,1) mode guided wave through a welded support

2.1.1. Dispersion curves

The theoretical prediction of the group velocity (the velocity at which a wave packet propagates along the pipe) dispersion curves for a 6 in. schedule 40 steel pipe was calculated using the software DISPERSE [4]. The only axis-symmetric torsional mode T(0,1) used in this study is shown in Figure 1.

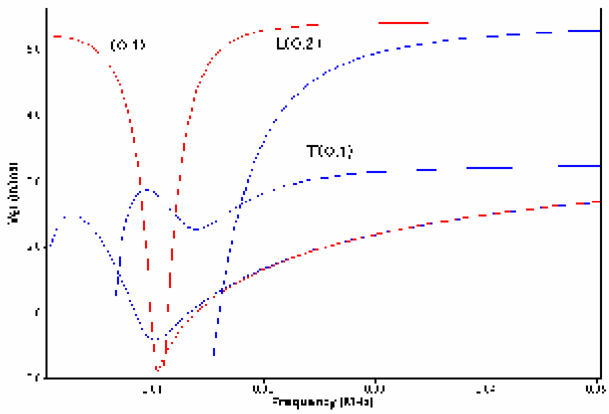


Figure 1: *Group velocity dispersion curve of 6 inch pipe*

The group velocity of T(0,1) is 3260 m/s and one corresponding flexural mode F(1,2) with group velocity 3155 m/s is similar to T(0,1) mode over the frequency range above 20 kHz.

2.1.2. Finite element study

A commercial FE program ANSYS was adopted to simulate the propagation of guided wave in pipes. The FE models produced to investigate the propagation of T(0,1) mode through the welded support were excited at the end A of the pipe shown in Figure 2.

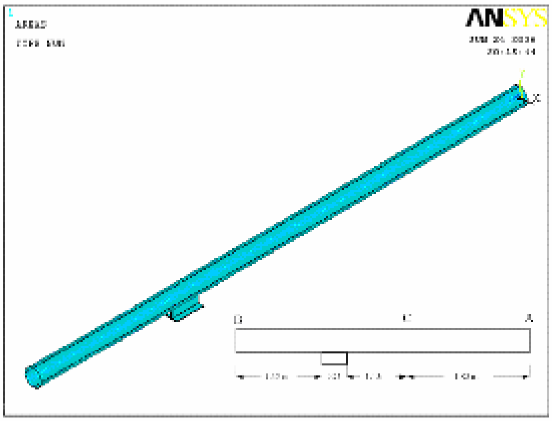


Figure 2: *FEM model of pipe with welded support only*

The excitation signal and reflected signal from the support are monitored at the line C. The distance between the end A and line C is 1.85 m. The whole length of the pipe model is 4.5 m and we use SHELL 63 elements with 5 mm axial length for membrane modeling. There are also 72 elements around the circumferential section of the pipe. One support located 3 m away from the end A was modeled by SOLID 45 elements with 5 mm axial length. As shown in Figure 3, another case was also modeled the same as the abovementioned case but a defect located 4.05 m away from the end A. The circumferential length of the defect is 5 % of the full circumference of the pipe.

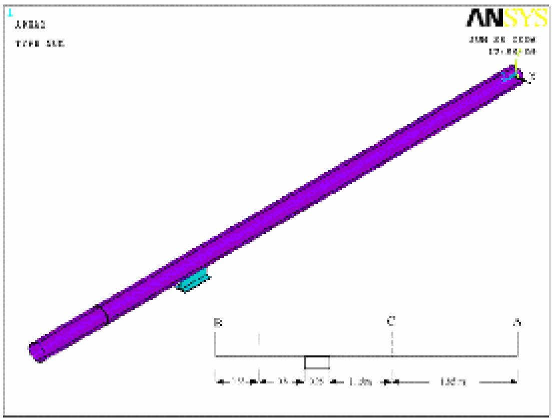
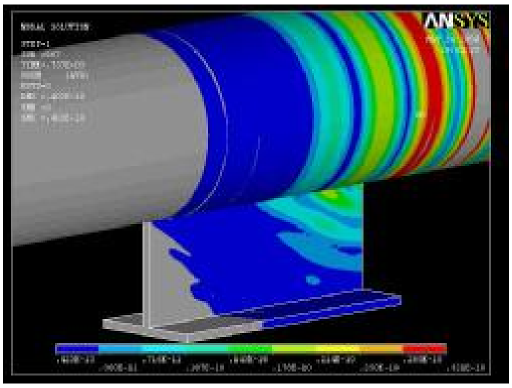


Figure 3: *FEM model of pipe with welded support and defect*

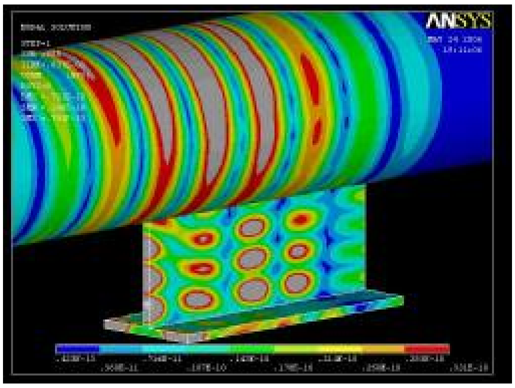
We use a 6 cycles Hanning-window tone burst of 32 kHz as the input. The tone burst was applied as a sequence of prescribed tangential displacement of the pipe. The excitation of T(0,1) mode was achieved by applied the same sequence at all of the nodes around the circumference of the end A. The received signals at line C are separated into single-mode waveforms with a mode extraction technique [5].

2.1.3. In a pipe with longitudinal welded support

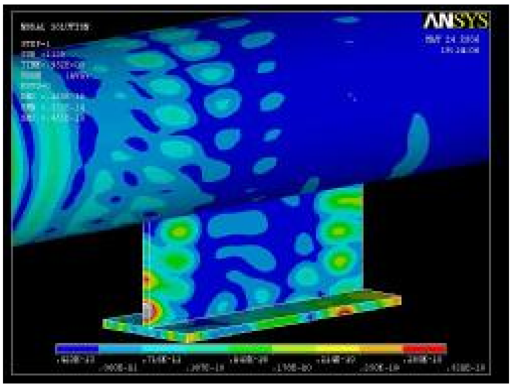
Figure 4 shows the visualization results of T(0,1) mode propagation in a pipe through the longitudinal welded support.



(a) t = 737 μs



(b) t = 837 μs



(c) t = 952 μs

Figure 4: *Snapshots of T(0,1) mode propagation in a pipe with welded support*

From Figure 4(a) we can see that when the T(0,1) mode impinges onto the support it will leakage energy into the support. Some plate modes of guided waves were induced and propagate in the support at the same time as shown in Figure 4(b). After the plate modes reflecting from the boundaries, they leakage into the pipe again and T(0,1) and flexural modes were induced in pipes. In Figure 5, the reflection signals of axis-symmetric mode from the support were received at line C.

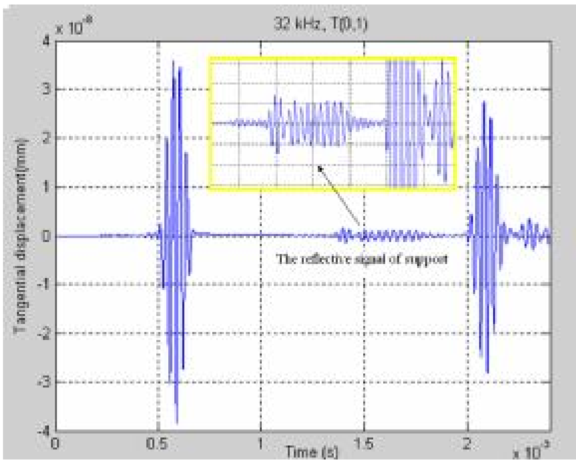


Figure 5: *The time history of T(0,1) mode at monitored line C*

Before the support, the first biggest wave packet was identified as the incident T(0,1) mode and the second biggest wave packet was the reflected T(0,1) mode from the end B in Figure 2. There is still a group of wave packets between the prescribed two big packets. As for FEM model in Figure 2, the welded support is the only feature between the end A and B. Therefore, the group of wave packets was identified as being the reflection of the longitudinal welded support. By calculating the time of flight of the signal and knowing the group velocity of T(0,1) mode, the calculated distance between the support and the end A can be obtained. The distance in FEM model is 3 m, but the calculated distance of the reflection signal from the support is 3.363 m when the excitation frequency is 32 kHz. Not only the signal peak lagged behind the actual position of the support but also the signal persisted for 1.1 m. It will cause the detection of the defect beyond the support more difficult.

Owing to the support is an asymmetric feature in pipes, mode conversion phenomenon is inevitable. From Figure 6 we can get the converted order 1 flexural modes, such as F(1,2) and F(1,3), by adding signals of each node with phase delay around the circumference.

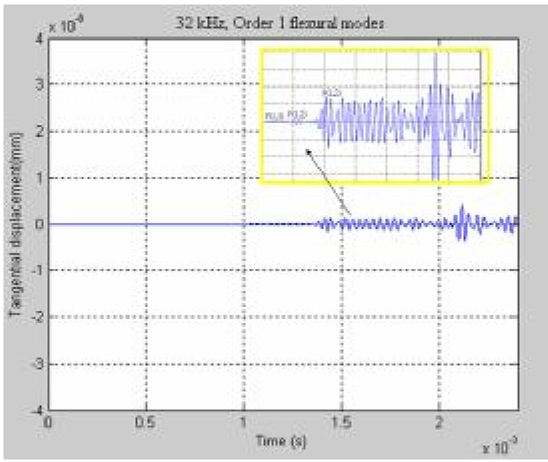


Figure 6: *The time history of order 1 flexural modes at monitored line C*

To present the results of the snapshots and the time histories, the effects of the longitudinal welded support for T(0,1) propagation are signal delay, drag and mode conversion.

2.1.4. In a pipe with longitudinal welded support and a defect

The effect of the support on the detection of the defect beyond the support was discussed using the FEM model in Figure 3. Similarly, we add each signal of the 72 nodes around the circumference at monitored line C and the time history can be obtained in Figure 7. By comparing with Figure 5, only a part of the group wave packets between the two big signals become larger due to the existence of the defect. It was clear that the signal of the defect mixed with a series of reflection from the support. The detection of the defect beyond the support is more difficult to achieve than the case of pure defects in pipes.

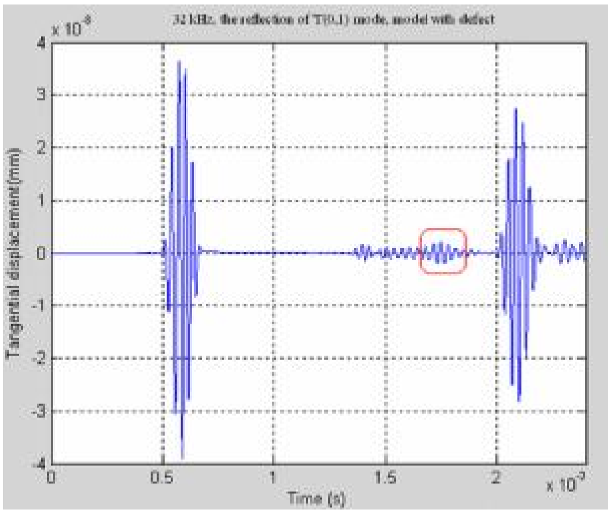


Figure 7: *The time history of T(0,1) mode at monitored line C, defect model*

The converted order 1 flexural modes, F(1,2) and F(1,3), from the support and the defect were shown in the below Figure 8.

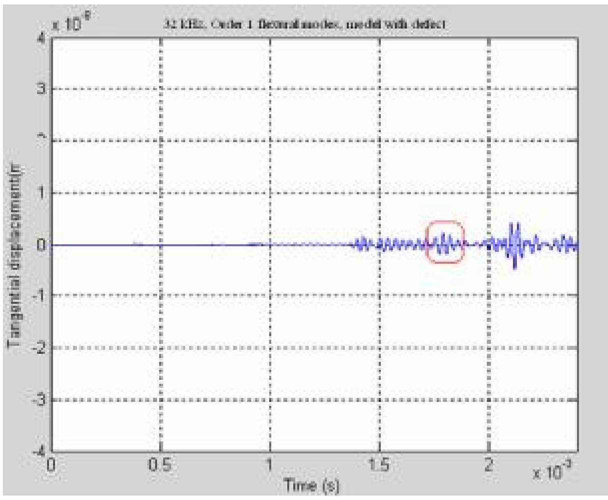


Figure 8: *The time history of order 1 flexural modes at monitored line C, defect model*

When time of flight equals 1.8 ms the signals are composed of the leakage from the support and the reflection of the defect. As for the defect beyond the support within 1 m, the signal of the defect was covered with the reflection of the support no mater what modes we analyzed.

2.1.5. Wave structure and mode conversion in the welded support

The interaction of the T(0,1) mode with the longitudinal welded support has been investigated. Some energy of the T(0,1) mode will leakage into the support. Because the nodes of the same circumference act in the tangential direction simultaneously, the nodes of the support plate were disturbed in the thickness direction(x-direction). As we can see from Figure 10, the dispersion curves of 7 mm steel plate, only A0 and S0 exist in the plate within the frequency range 18 kHz to 32 kHz; moreover, the wave structure of the A0 mode shown in Figure 11 shows the out-of-plane displacement is almost constant across the thickness of the plate. In contrast, the in-plane displacement, which is close to zero on the center of the plate, becomes dominate on the outside surface. As a result of the match for the tangential disturbance in pipes and the wave structure of the support plate, the T(0,1) mode was incident on the support and the A0 mode was generated in the support. After reflection of the A0 mode in the support, the F(1,2) and F(1,3) modes were received in reflection in pipes.

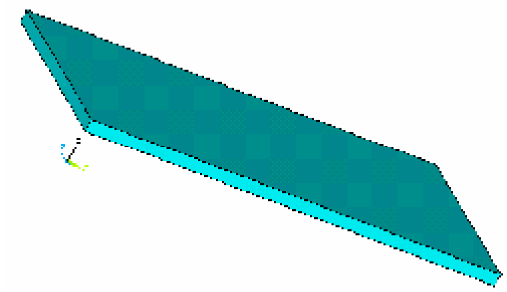


Figure 9: *FEM model of 7 mm thick steel plate*

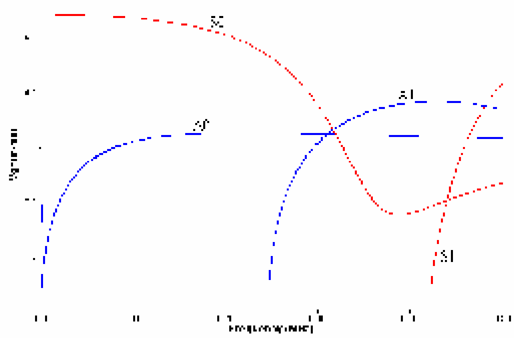


Figure 10: *Group velocity dispersion curve of 7 mm thick steel plate*

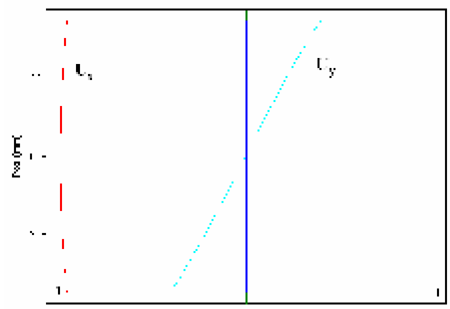


Figure 11: *The wave structure of the A0 mode*

3. Experimental verification of simulation results

The experiments have been performed on a 6 inch schedule 40 steel pipe for measuring the reflected signal of the torsional T(0,1) mode and the relative flexural modes. As shown in Figure 12, the pipe has two flanges, one longitudinal welded support, and one artificial defect on it. Fig.12 shows the positions of various features on the experimental pipe. The transducer is located on the end B and the support is between the transducer and the defect.

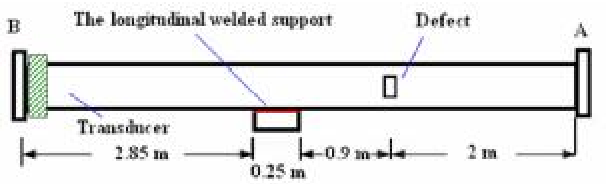


Figure 12: *The diagram of the experiment setup*

A Guided Ultrasonic Ltd Wavemaker 16 Instrument is used to generate a 6 cycles Hanning-window tone burst signal to excite the transducers. As shown in Figure 13, the transducer ring located near the flange about 20 cm, the welded support located 2.65 m away from the transducer and the defect is beyond the support about 0.9 m.

Figure 13: *The picture of the experiment setup*

The frequency of guided wave is excited from 18 kHz increased equally 1 kHz of frequency band to 32 kHz to propagate the torsional T(0,1) mode on the pipe, respectively.

The reflections of T(0,1) from the longitudinal welded support and the defect mixed together when the distance between the support and the defect is less than 1.5 m. A bigger peak of the flexural mode reflection was raised at the position of the defect whether the exciting frequency is 32 kHz in Figure 14 or 28 kHz in Figure 15. The actual position of the support is 2.65 m, but the reflection signals display the peak in 3.07 m when the excitation frequency is 32 kHz or 28 kHz.

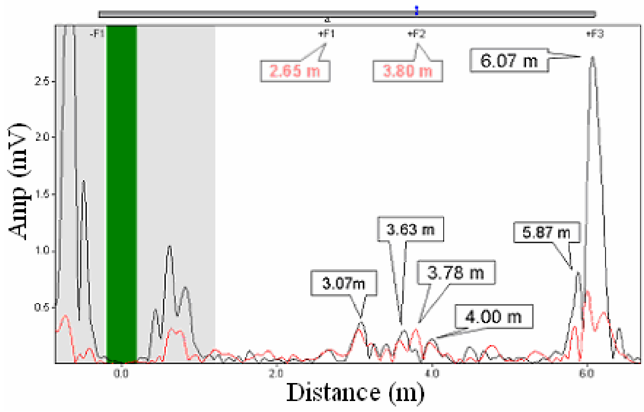


Figure 14: *32 kHz experimental result of a pipe with support and a defect*

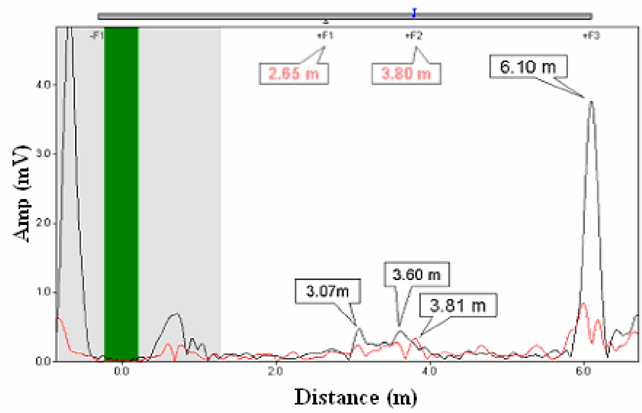


Figure 15: *28 kHz experimental result of a pipe with support and a defect*

By considering the result of Figure 15 and Figure 16, the detection of defect was more difficult when the defect located beyond the longitudinal welded support and the excitation frequency is 28 kHz. Without the support, the signal of the defect showed a good characteristic of the asymmetric feature in pipes. With the support, the signal of the defect covered with the signal of the support.

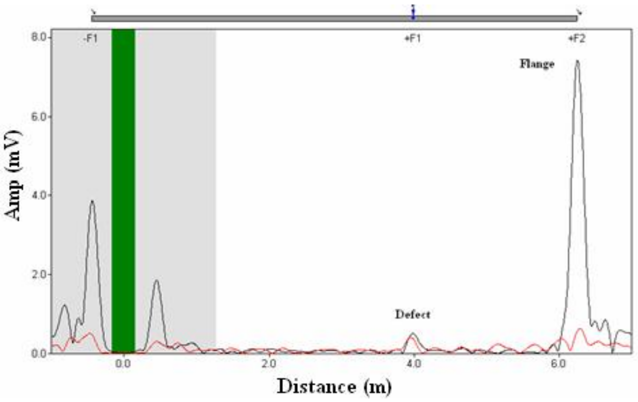


Figure 16: *28 kHz experimental result of a pipe with a defect only*

4. Conclusions

The effect of the longitudinal welded support for T(0,1) propagation has been investigated in this study. A good agreement was found between FEM results and experimental results. The reflections of the T(0,1) mode and the flexural mode from the welded support were measured and extracted. At the same time, the snapshots of simulation showed the whole pictures of the interaction between the T(0,1) mode and the welded support. Also the mode conversion in the welded support was defined by considering the wave structure of the A0 mode in the plate. The delay of the signal in FEM model is 0.36 m and in the experimental result is 0.42 m when the excitation frequency is 32 kHz. The enduring signal of the welded support covered up the signal of the defect beyond the support. It will cause the detection of the defect more difficult.

We can see the effect of the longitudinal welded support, but the problem still exist. More test of different excitation signals may reduce the effect we discussed.

5. References

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