ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 09, Issue, 09, pp. 29915-29917, September, 2019

REVIEW ARTICLE OPEN ACCESS

RESEARCH ON PIPELINE SHAFT GUIDED WAVE DETECTION TECHNOLOGY

***Yang XU and Shang-kun REN**

Key Laboratory of Nondestructive Testing of Education, Nanchang Hangkong University, Nanchang, China 330063

ARTICLE INFO

Article History:
Received 3rd June, 2019
Received in revised form
17th July, 2019
Accepted 06th August, 2019
Published online 30th September, 2019

Key Words:
Pipeline testing;
Axial guided wave;
EMAT; probe design.

ABSTRACT

The application of electromagnetic ultrasonic guided wave detection technology in cylindrical pipe detection was studied and analyzed.The basic theoretical relations of axial guided wave are analyzed and deduced. The dispersion characteristics of axial guided wave are analyzed emphatically. The non-dispersion characteristics of torsional guided wave are of great significance in detection.The basic principle and design method of axial guided wave excited by electromagnetic ultrasonic sensor in recent years are discussed emphatically.The existing problems and development direction of pipeline shaft guided wave nondestructive testing technology are put forward.

Citation: Yang XU and Shang-kun REN. 2019. "Research on pipeline shaft guided wave detection technology", *International Journal of Development Research*, 09, (09), 29915-29917.

INTRODUCTION

Steel pipe is an important steel product that is widely used. The economic benefits of steel pipe application related industries and the life safety of personnel are closely related to the quality of steel pipes (Zhang, 2002). In order to prevent the occurrence of malignant accidents caused by corrosion perforation, leakage, pipeline explosion, etc., it is very important to carry out rapid and effective non-destructive testing of pipelines (Ashigwuike, 2015). Guided wave is a kind of ultrasonic wave that can propagate for a long distance along the longitudinal direction of waveguide (tubular or plate structure waveguide) (Dong, 2006). In addition to aboveground and underground environment, ultrasonic guided wave detection of Marine pipelines has made substantial progress, and ultrasonic guided wave detection technology is receiving more and more attention (Guan, 2017 and Mitra, 2016). Different from the transverse and longitudinal waves in ordinary ultrasonic waves, ultrasonic guided waves are formed when the ultrasonic waves repeatedly reflect and overlap at the discontinuous boundary of the medium (Peng, 2017). When ultrasonic guided waves are generated by cylindrical or tubular waveguides, there are three modes of ultrasonic guided waves, namely, torsional mode guided waves, longitudinal mode guided waves and curved mode guided waves (Rose, 1999 and Yamasaki, 2001). Nishino H *et al* (Nishino, 2001) theoretically and experimentally studied the dispersion characteristics of the guided wave in the hollow cylinder, and found that the ratio of tube thickness to diameter (t/d) had a great influence on the dispersion of the guided wave. When t/d was very small, the longitudinal mode and torsional mode guided wave generated in the tube could correspond to Lamb wave and SH wave respectively in the plate. Ogi H *et al*. (Nurmalia, 2013), used electromagnetic acoustic transducer (EMAT) to excite the torsion conduction wave in the aluminum pipe during the detection of pipe wall thickness reduction, and measured the thickness reduction of the pipe wall through measuring the change in the velocity of the torsion conduction wave group caused by the mode conversion. Huang S L*et al* (Huang, 2018), summarized the characteristics of different mode guided wave sensors by comparing the guided wave of plate and tube structure, analyzed the interaction between guided wave and pipeline defects, and verified the application of guided wave in the localization, size quantification and imaging of pipeline defects. He C F*et al* (HeC, 2007 and Li, 2018), simulated the torsional mode guided wave and were able to detect and locate the defects by establishing the finite element model of the pipeline with longitudinal defects. In this paper, the application of axial guided wave detection in

****Corresponding author:*** **Yang XU,**
Key Laboratory of Nondestructive Testing of Education, Nanchang Hangkong University, Nanchang, China 330063

pipeline is reviewed.Firstly, the theoretical basis of axial wizard wave generation is discussed.Secondly, the sensing technology of axial guide wave in recent years is emphatically discussed, and how to excite and receive axial guide wave in pipeline is discussed.Finally, the pipeline axis guided wave nondestructive testing technology is summarized and forecasted.

The theoretical basis of axial guided wave: Under the condition of no stress boundary, the cylindrical guided wave propagating along the pipe axial direction can be divided into three modes as shown in Fig 1 due to the vibration phenomenon.These three modes can be written as L(0, m), T(0, m) and F(n, m), where n (n =0,1,2,3,4...,n=0 corresponds to the axisymmetric mode,n= 1,2,3...is the circumferential modal parameter;m is the radial mode parameter, indicating the vibration shape of the guided wave mode in the axial direction of the pipe (m= 1,2,3...) (Gazis, 1959). Meitzler (Meitzler, 1961) andZemanek (Zemanek, 1972), classified all the high order modes on the circumference as F modes, that is, the T-mode only has the circumscribed base mode (n=0), and the torsional mode, like the longitudinal mode, is designated as axisymmetric mode while the F-mode is designated as non-axisymmetric mode. In the research direction of guided wave, the generation and propagation mechanism of guided wave in plate plane has been achieved systematically.Silk M G*et al*. (Silk, 1979), proved that the mode of ultrasonic guided wave in the pipeline corresponds to Lamb wave.When the pipe is a thin-walled pipe (the diameter of the pipe is much larger than the thickness of the pipe wall), the pipe can be approximated to the expanded plate plane. In this case, the longitudinal mode guided wave and torsional mode guided wave in the pipe correspond to SH wave and Lamb wave respectively in the plate.

Torsional guided wave sensing technology: Most of the traditional guided wave detection systems adopt piezoelectric sensor (PZT) design.The traditional piezoelectric ultrasonic guided wave sensor has obvious advantages such as high detection efficiency, stability, and skilled operation of the worker. However, the traditional piezoelectric ultrasonic guided wave sensor requires high surface condition of the workpiece to be inspected.The high-viscosity coupling agent and the inability to detect at high temperature or low temperature also make the electromagnetic ultrasonic guided wave sensor attract the research of many scholars and have achieved rapid development.Electromagnetic ultrasonic sensor (EMAT) is a sensor for non-contact ultrasonic excitation and reception without any coupling device.Each EMAT can be designed to operate in multiple channels and has piezoelectric sensor capabilities.Compared with traditional sensors, EMAT has many advantages, such as simplicity, high temperature resistance and economy.In addition, EMAT is a suitable driver for generating L, T, and F guided waves, which provides advantages for on-site inspection and on-line monitoring of actual plants. Murayama R *et al*. (Murayama, 2015) developed a new EMAT detection system that can alternate between the three modes. As shown in Fig 2, three different modes of ultrasonic guided waves of L, T, F can be excited by changing the direction of the coil.This eddy current can be generated by a rectangular coil or an elliptical coil. The EMAT placed on the metal material can be rotated in any direction to produce a transverse wave in any direction of vibration. And through the EMAT system, it can be determined that these three modal guided waves can be detected sufficiently strong.

The EMAT guided wave detection system has been tested under different driving conditions and obtained good reception signals.As shown in Fig 3, the EMAT guided wave detection system can obtain relatively more stable signals at the driving frequency of 100 kHz. An aluminum tube with a diameter of 60mm and a thickness of 2mm was selected. The relationship between the driving frequency of the guided wave and the velocity of the guided wave group is shown in Fig 4.When 100 KHz driving frequency is used, L(0,2) is 5230m/s、T(0,1) is 3130 m/s、F (0,1) is 2780 m/s. The adjusted received signal is shown in Fig 5, in which the T(0,1) mode receives the best signal. Torsional guided wave has some special advantages in guided waves for pipeline detection.It only consists of circumferential polarization motion, which is less affected by coating and liquid load, so it can shorten the detection time.Torsional wave has no dispersion and has the same velocity in the range of frequency and thickness. Even for higher modes, the dispersion curve of torsional wave is relatively simple.However, compared with other guided waves, the generation of torsion wave with single mode is quite difficult. Nurmalia, Nakamura N*et al* (Huang, 2018), designed an experiment to study the torsional guided wave group velocity variation caused by mode transformation in the detection of pipe wall thickness reduction.

Torsional modes are generated and detected using EMAT, each EMAT being configured with a special periodic permanent magnet (PPM-EMAT).It consists of a set of permanent magnets arranged in such a way as to provide a periodically biased magnetic field perpendicular to the surface of the specimen.These magnets are located on top of the elongated spiral coils, which are connected to each other in a meandering flow to form an alternating current source that provides eddy currents in the axial direction. Two magnetic fields near the conductive material interact with each other to produce a circumferential lorentz force near the material's surface, thus generating polarized shear waves.The periodicity of the axial alignment of the magnets determines the wavelength of the wave produced.The designed EMAT generates torsional waves with a wavelength of 5.22mm. Each transmit and receive EMAT consists of four ppm-emats surrounding the pipeline.Fig 6 shows a cross-sectional view of their arrangement. The dashed line is added to distinguish each PPM-EMAT in the arrangement.The EMAT is driven by a total of 8 cycles of audio pulses. Depending on the drive frequency and wavelength, the corresponding torsional mode is selectively generated in the test piece. The EMAT receiving part selectively receives the propagation mode, and after amplification, the received signal is transmitted to the signal processing unit.

Fig 7 is the torsional mode group velocity dispersion curve propagated in the pipeline with thickness/outer diameter ratio of 3/25, and broken line indicating a cutoff thickness of a corresponding mode guided wave. Except for the T (0,1) mode, the group velocity of each high mode is highly dependent on the frequency of the waveguide multiplied by the thickness, especially in the low-frequency range. When the frequency is fixed, the group velocity decreases with the thickness. Fig 8 shows the comparison between the actual dispersion curve and the theoretical dispersion curve. The solid line represents the theoretical dispersion curve, and the point represents the actual dispersion curve.When the thickness changes, the T(0,1) guided wave has no obvious change, which confirms the non-dispersive nature of the T(0,1) mode, and the group velocity is independent of the thickness and frequency.

Conclusion

Compared with the research on the guided wave detection technology in plate, the guided wave detection technology in tube is still immature, but it has a great application prospect because of its long-distance detection, wide detection range and high efficiency. In this paper, based on the recent research on the pipeline axis guided wave detection technology, the pipeline axis guided wave technology is reviewed systematically.With the continuous development of pipeline guided wave detection technology, there are still some problems to be solved:

- The theoretical basis of guide wave of pipeline axis is based on the theoretical basis of guide wave in the plate. However, in reality, there are pipes with curved pipes and special shapes, etc. It is necessary to further study the processing method of guide wave generated in the pipe when the above special cases occur.
- When studying the dispersion phenomenon of guide wave in the pipeline, it is found that there are three guide wave modes in total, but the guide wave excited in the pipeline is often not single in mode, which will have a great impact on the test results. Therefore, it needs to be further studied on how to excite a single guide wave in the pipeline.
- The torsional modes of the three modes have no dispersion characteristics, but there are few studies on the torsional mode guided waves, and most of them focus on numerical simulation and simulation analysis. The pipeline guided wave loss based on torsional mode should be further studied.

Acknowledgement

This project is supported by National Natural Science Foundation of China (51865039) and Nanchang Aviation University Graduate Innovation Special Fund Project (YC2018046).

REFERENCES

Ashigwuike E C, Ushie O J , Mackay R , *et al*. A study of the transduction mechanisms of electromagnetic acoustic transducers (EMATs) on pipe steel materials[J]. Sensors and Actuators A: Physical, 2015, 229:154-165.

Dong W R, ShuaiJ. Ultrasonic guided wave detection technology for pipeline [J]. Pipeline technology and equipment, 2006(06):21-23.

Gazis D C. Three-Dimensional Investigation of the Propagation of Waves in Hollow Circular Cylinders. I. Analytical Foundation [J]. *The Journal of the Acoustical Society of America,* 1959, 31(5):568-573.

Guan R, Lu Y, Duan W, *et al*. Guided waves for damage identification in pipeline structures: A review [J]. Structural Control and Health Monitoring, 2017, 24(11):17.

H Nishino, S Takashina, F Uchida, *et al*. Modal Analysis of Hollow Cylindrical Guided Waves and Applications[J]. *Japanese Journal of Applied Physics,* 2001, 40(1):364-370.

HeC F, Li W, Wu bin. Numerical simulation of torsion mode guided wave detection of longitudinal defects in pipelines [J]. *Journal of Beijing university of technology,* 2007, 33(10):1009-1013.

Huang SL, Wang Z, Wang S, Zhao W. Research progress of pipeline electromagnetic ultrasonic guided wave technology and its application [J]. *Chinese journal of instrumentation*, 2018,39(03):1-12.

Li Z M, He C F, Liu Z H *et al*. Research progress and prospect of pipeline weekly guide wave detection technology [J]. *Journal of Beijing university of technology*, 2018, 44(05):641-657.

Meitzler, Allen H . Mode Coupling Occurring in the Propagation of Elastic Pulses in Wires [J]. *The Journal of the Acoustical Society of America,* 1961, 33(4):435.

Mitra M, Gopalakrishnan S. Guided wave based structural health monitoring: A review[J]. Smart Materials and Structures, 2016, 25(5):30.

Murayama R, Jie W, Kobayashi M. Pipe inspection system of a pipe by 3-modes guide wave using polarized-transverse wave EMATs[J]. Proceedings of SPIE-The International Society for Optical Engineering, 2015,9302:6.

Nurmalia, Nakamura N, Ogi H, *et al*. Mode conversion of torsional waves generated by electromagnetic acoustic transducer[C].Japan: AIP Conference Proceedings,2013,1511:909-915

Peng F, Xu B, Chen H, *et al*. Numerical Simulation of Pipeline Defect Detection Based on Piezoelectric Ultrasonic Guided Wave[J]. Piezoelectrics and Acoustooptics, 2017, 39(3):462-466.

Rose J L. Ultrasonic waves in solid Media[M]. United Kingdom: Cambridge University Press,1999:154-162.

Silk M G. The propagation in metal tubing of ultrasonic wave modes equivalent to Lamb waves [J]. Ultrasonics, 1979, 17(1):11-19.

Yamasaki T, Tamai S, Hirao M. Optimum excitation signal for long-range inspection of steel wires by longitudinal waves[J]. NDT&E International, 2001, 34(3):207-212.

Zemanek, Joseph. An Experimental and Theoretical Investigation of Elastic Wave Propagation in a Cylinder[J]. *The Journal of the Acoustical Society of America,* 1972, 51(1B):265.

Zhang G C, Fan H, Jia H M. Reliability analysis of several methods of steel tube flaw detection [J]. Steel, 2002,37(09):56-60.

****