ADVANCED NDT TECHNIQUES FOR PLASTIC PIPELINE INSPECTION

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Abstract

The use of plastic pipes has increased considerably in the last years. However, plastics are relatively new structural materials, which pose an increasing challenge for non-destructive examination. This has restricted the use of welded plastic pipes in more critical applications like the nuclear industry. Nevertheless plastic pipes are used in other important industries, such as gas and water distribution. The TestPEP project aim is to develop an ultrasonic system, rugged and easy to operate, to solve the problems of ultrasound inspection in plastics. Another important outcome from this project is determining the significance of flaw types and sizes in relation to service requirements. The development of a more effective Non-Destructive Testing (NDT) technique and acceptance criteria for welded plastic pipes will allow a broader use of them in a greater number of industries, guaranteeing a longer service life and lower leakage rates, which will result in reduced risk of serious accidents and pollution.
1. INTRODUCTION

Plastic pipes are currently used to transport gas, water and chemicals. The main reason behind the use of plastic pipes over metal or concrete pipes is related to good chemical resistance, low weight, low cost and the longer predicted service life that these types of pipe present. In particular, polyethylene (PE) pipes have been used for gas and water pipework for decades, and have also been incorporated into non-safety piping systems in nuclear facilities. Due to the material being immune to water corrosion and highly resistant to fouling, it is also being considered as a replacement for stainless steel in safety-critical applications in nuclear power stations [1]. However, the regulatory bodies require the welded joints to be inspected volumetrically and currently such a system is not available. Consequently, there is a need for a reliable Non-Destructive Testing (NDT) approach for the inspection of different PE pipe joints in various material grades and pipe sizes. NDT is commonly used in areas more related to steel structures. The applications of NDT go from the inspection of ships and tankers without taking the vessel out of the water [2] to the inspection of welds in large wind energy towers [3]. However, plastics are relatively new structural materials and ultrasonic NDT inspection in plastic is a challenge due to relatively high attenuation [4, 5]. There have been several studies in developing NDT for plastic pipes. These studies used conventional ultrasonic transducers; including pulse-echo, tandem, creeping waves, and time-of-flight diffraction (TOFD) [6, 7].

This paper is based on a European funded project, TestPEP, which aims to develop and validate the use of an automated NDT approach for testing welded plastic pipe joints. The project will develop phased array ultrasonic NDT procedures, techniques and equipment for the volumetric examination of welded joints in PE pipes. Initially, the technical problem, industry needs and the proposed approach to the solution have been stated [8], and a determination of the ultrasonic properties has been made [9]. The final outcomes of this project will be a flexible scanner with probe holder incorporated, that can be adapted for a variety of pipe joint configurations, and an instrument capable of performing the advanced procedures required for these materials.

This paper shows the development carried out in the TestPEP project in inspection techniques for electrofusion (EF) and butt fusion (BF) joints. Also the scanner system for different pipe sizes, developed in this project, is presented. Detection results from some pipe samples and initial evaluation of the capability of the inspection techniques are presented.
2. TESTPEP PROJECT

The TestPEP project is a European (FP7) funded project that is headed by TWI and involves 15 organizations from seven European countries, with the objective of developing phased array ultrasonic NDT procedures, techniques and equipment for the inspection of welded joints in PE pipes and fittings of diameters between 90 and 1000mm.

The idea behind the use of phased array probes is that they facilitate the collection of ultrasound data to be accomplished very rapidly, which allows the inspection to be performed in a single pass. This simplified mechanical concept will solve many of the requirements, not only economical but also ergonomical. Parallel to the development of the necessary NDE equipment the significance of flaw size and quantity will be established in relation to service requirements. This will be done by carrying out long-term mechanical testing of joints containing flaws and comparing results with tests on joints with no flaws.

The main objectives of the TestPEP project are:

- To develop ultrasonic phased array NDT techniques for the inspection of both BF and EF joints in PE pipes with wall thicknesses up to 45 mm.
- To determine the limits of detection for the above techniques/pipe sizes.
- To determine critical defects sizes and contamination levels for the above pipe sizes.
- To develop defect recognition and automatic defect sentencing software to allow the equipment to provide a pass/fail indication.
- To produce a prototype ultrasonic NDT system that can inspect both BF and EF joints in pipe sizes up to 1m diameter.
The structure of the TestPEP project is shown in Figure 1.

![Figure 1 - TestPEP project flow diagram](image)

### 3. EXPERIMENTAL SET-UP

The two welding techniques used in this study are very dissimilar. In BF, Figure 2 (a), the joining areas of the plastic pipes are pressed against an accordingly heated up element until enough material is melted. The heating element is then removed and the plasticized surfaces of the plastic pipes are pressed together. The pipes cool down under pressure until the melt is re-solidified. On the other hand in EF, Figure 2 (b), an EF fitting is used to heat the exterior surface of the pipes, along with the interior surface of the fitting and join the two plastic pipes.

![Figure 2 – (a) Butt Fusion [10] (b) Electrofusion](image)
PE pipes were used with both welding techniques. Initial tests were carried out on EF joints in pipe diameters between 180mm and 710mm; and on BF joints in pipe diameters between 220mm and 450mm.

4. RESULTS AND DISCUSSION

The results obtained in the development of the NDT techniques are presented for both EF and BF joints. The first results presented are for the electronic scans on the EF fitting itself at one position around the evaluated pipe joints, Figure 3. In the scans it is possible to identify the outer surface of the EF fitting, as well as the inner surface and the wires. However, in some parts of the scan, the bottom surface is hidden by the wires. Figure 3 shows scans carried out on a 180mm and a 710mm pipe fitting. These scans were made using a 7MHz probe on the 180mm fitting and the 5MHz probe on the 710mm fitting. It is possible to identify, in both fittings, the first repetition of the top surface of the fitting in the scans.

![Figure 3](image)

**Figure 3** - (a) Scanning result of a 180mm fitting (b) Scanning result of a 710mm fitting[11]

Figure 4 shows the scanning results on a 180mm outer diameter (OD) welded EF joint. The difference between these scans, Figure 4, and the previous scans, Figure 3, is that now there is a fusion zone. Compared with the previous results there are no reflections under the wires. It is also possible to identify a line above the heating wires indicating the heat affected zone (HAZ), which is more visible in Figure 4(b) than in Figure 4(a). The identification of the position of the HAZ will help in the detection of cold welds.
When evaluating BF joints, circumferential scans were carried out on pipes containing flat bottom holes and slots, simulating possible welding defects.

Figure 4 - (a) Scanning result of a 180mm EF joint (b) same scan, but with +12dB gain[11]

Figure 5 (a) shows the location of the flat bottom holes on 220mm OD pipe. While Figure 5 (b) and Figure 5 (c) show the results obtained using a sector pulse-echo scan system and a tandem scan using different parts of the same phased array probe, one half for transmission and one half for reception. Comparing the results obtained in both scans, the sector pulse-echo scan identified all the flat bottom holes while the tandem scan identified six of the holes. This is to be expected since the tandem scan covers a smaller area of the weld.

Figure 5 - Inspection results on the 220mm OD pipe. (a) Location and size of the flat bottom holes. (b) Sector pulse-echo scan. (c) Tandem scan[11]
Figure 6 shows the results obtained when using a creeping wave scan, Figure 6 (b), and a TOFD scan, Figure 6 (c), in order to detect the slots on a 220mm OD pipe shown in Figure 6 (a).

![Figure 6](image)

**Figure 6** - Inspection results on the 220mm OD pipe. (a) Location and size of the slots. (b) Creeping wave scan. (c) TOFD scan[11].

Circumferential sector pulse-echo scans were also made on a 450mm OD pipe. In this case, four different diameters of flat bottom holes (8mm, 6mm, 4mm and 2mm) were used, Figure 7 (a), positioned at different depths in the pipe. Figure 7 (b) shows the results from the sector pulse-echo scan, it can be seen that most of the defects were identified.

![Figure 7](image)

**Figure 7** - Inspection results on the 450mm OD pipe. (a) FBHs. (b) Sector pulse-echo scan.
Figure 8 - Drawings with the flat bottom holes and inspection results on the 450mm OD pipe.
(a) 8mm (b) 6mm (c) 4mm (d) 2mm

Figure 8 shows a close up of the scan shown in Figure 7, where it can be seen that all the 8mm, 6mm and 4mm flat bottom holes can be identified, Figure 8 (a), Figure 8 (b) and Figure 8 (c). Further trials will be carried out using different frequencies and focal laws to improve the responses from these flaws.

Along with the development and testing of the scanning probes a complete scanning system is also being developed. The system will allow the inspection of pipes with an OD from 90mm to 1m for both BF and EF joints. While the system for EF will have a single probe holder the BF will have two probe holders (Figure 9).

Figure 9 - Scanning system (a) EF probe holder (b) BF probe holders
5. CONCLUSIONS

The main objective of the TestPEP project, development for inspection techniques for both EF and BF joints, is showing some good results. Initial evaluations of detection and sizing capabilities have been conducted. On the smaller BF size, all defects were detected except two FBHs with the tandem technique. However, all defects can be detected by at least one technique. On the larger BF size, the sector pulse-echo technique was evaluated. Not all of the defects were detected, however the use of the tandem technique might prove to be efficient in detecting all the defects.

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7. REFERENCES

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