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Research on Defect Detection and Failure Fuzzy Discrimination of PE Gas Pipe

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Abstract

Based on the research on the detection and evaluation methods of PE gas pipe defects, ultrasonic detection of defects was adopted to make holes with different widths, different directions and different diameters inside PE pipe. The experimental results show that ultrasonic flaw detector can detect different types of defects and judge the type and size of defects. For small defects, fuzzy comprehensive evaluation method is used to determine the degree of pipeline damage, so as to make corresponding measures in time.

Keywords

Ultrasonic Detection; PE Gas Pipeline; The Defect; Fuzzy Comprehensive Evaluation.

1. Introduction

Polyethylene (PE) pipe is loved by people because of its wide use and excellent material properties. It is mainly used for the development of plastic pipelines for municipal gas and water transportation [1]. Nowadays, the development of gas pipelines is very rapid, and the usage increases rapidly. The annual usage is more than 300,000 tons, and the market is short of supply [2]. The detection of defects of PE pipe in the wide use process has become the key to the life evaluation of pipe. The development of accurate and efficient detection technology and evaluation methods not only contributes to the development of science but also can bring huge economic value and good social benefits.

In recent years, many scholars at home and abroad have carried out similar research and achieved relevant achievements. At present, there is no specific ultrasonic testing standard for PE pipes in China. Shanghai Special Inspection Institute has provided ultrasonic testing method for hot melt welded joints of polyethylene pipes and evaluation standard for cavity, inclusion and non-fusion, which can provide a basis for safety evaluation [3]. Hou Huaishu et al. explored the classification identification of defects in butt weld defects of metal pipelines by using ultrasonic detection technology, and identified four defect types of butt weld defects of metal pipelines [4]. AbbasiW et al. [5] proposed a weld imaging data processing method based on multi-scan mode for defects of pipeline weld in different directions, and realized the processing of detection data. Yuan Peng et al. [6] used pulse technology to detect and study different types of defects and welds of pipelines with cladding. Through numerical simulation and experimental verification, the pipe defects and weld seams under the coating are detected. Liao Kexi et al. [7] adopted the non-contact magnetic force detection technology to detect defects in the whole line of pipelines, and used qualitative analysis of magnetic memory detection technology and quantitative analysis of ultrasonic thickness measurement to detect excavated pipelines to verify the results of non-contact magnetic force detection, forming a set of fast and efficient defect detection method system for buried pipelines.

So this article in view of the PE gas pipeline defects that may occur and the position of the defects in related experiments, using ultrasonic flaw detector to detect the different positions of the same defect, the same location of different defects and then by analyzing the related data from actual testing results, finally the fuzzy comprehensive evaluation to judge the risk level of the related defects, and then take preventive measures, Prevent accidents from happening.

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2. PE Pipe Fuzzy Discrimination Method

As an advanced evaluation method, fuzzy comprehensive evaluation method is widely used in various fields. It mainly uses mathematical methods to obtain an accurate and clear result for things controlled by multiple factors, which solves many things that are difficult to accurately express their degree with specific numbers [8,9]. The steps of fuzzy discrimination are as follows:

(1) Hierarchical construction: clarify various conditions and factors of evaluation and provide an overall framework for evaluation.

(2) Establishment of factor set: The set composed of various factors affecting the evaluation object is called factor set U=(U1,U2,U3).

In this paper, it is necessary to evaluate the influence of porosity, slag inclusion and crack on PE gas pipe. For each defect, the corresponding characteristics are selected as the factor set: porosity U=(diameter, depth, position and height); Crack U=(direction, length, depth, width, position); Slag U= (depth, length, position).

(3) Establishment of evaluation set: Evaluation set is a set of all kinds of general evaluation results that judges may make on the evaluation object, which is represented by V. In this article,V =(V1,V2,V3,V4) is (mild, moderate, severe, critical).

(4) The establishment of the weight set: the proportion of each factor to reflect the importance degree, A1 + A2 + A3 +.... + An = 1.

(5) Determine the fuzzy comprehensive evaluation matrix Ri and R.

(6) Fuzzy comprehensive evaluation B=A·R; B = (b1, b2, b3, b4).

(7) Obtain the evaluation results.

3. Experimental Instruments and Schemes

3.1 Experimental Instruments

SDR11 series polyethylene pipe with 110mm nominal diameter was selected in the experiment. HS620 digital ultrasonic flaw detector is used.

3.2 Experimental Scheme

As PE material properties are very different from metal, several key issues need to be considered in ultrasonic detection of defects: probe parameters, pipe joint geometric characteristics and heat affected area, material sound velocity, and scanning range [16].

Since PE pipe is different from traditional metal pipe, it is necessary to make special test blocks, and then use it to measure the relevant parameters and adjust the relevant instruments, and finally make the DAC curve, and then perform the flaw detection experiment on the relevant specimens and record the relevant data.

Specimen: cracks, slag and holes are made inside PE pipe.

(1) Select a piece of pipe and make holes with a diameter of 2.5mm inside. Make two holes with a depth of 5mm and 6mm respectively.

(2) Take the same pipe to make cracks inside the pipe. Make circumferential cracks inside the pipeline: Width: 2mm length: 35mm Depth: 6mm;

(3) Make metal slag at the weld: metal wire with slag depth of 6mm and length of 11mm. (Note: For each group of experiments, the optimal detection value is taken as the final detection result.)

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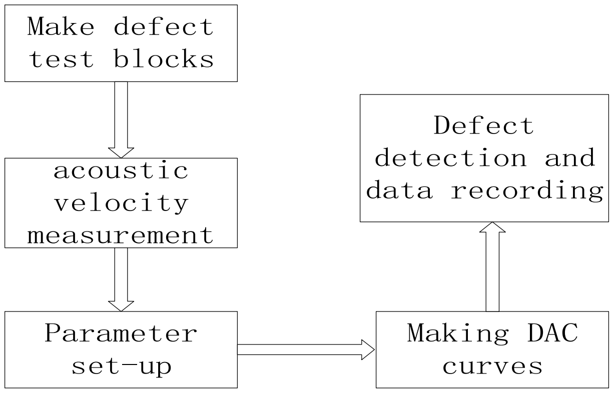

Figure 1. Experimental flow chart

4. Result Analysis

4.1 Analysis of Ultrasonic Detection Effects of Different Defects

As the depth of defects detected in this time is roughly the same, there is no significant difference in the characteristic waveforms [10], so the waveforms are not displayed one by one. Through repeated experiments, the waveforms of all defects were obtained, from which it is not difficult to see that the places where the highest waves of the same defect with similar depth appear are almost the same, and the detection rate is relatively high due to the large defects made this time. By comparing the waveforms, the detection difficulty is obtained [11] : void < inclusion < crack.

According to the different defect types detected by ultrasound, ultrasonic signal waveforms of cavity (defect No. 1) and crack (defect No. 2) are taken as examples.

4.2 Quantitative Analysis of Ultrasonic Detection of Different Defects

Ultrasonic detection is very important for quantitative analysis of different defects, so as to analyze the types of defects and the degree of failure. The specific test results are shown in Table 1 and Table 2:

Table 1. Hole and crack defect detection data table

The probe model	defect id	Diameter (D/mm)	Deviation (mm)	Depth (H/mm)	Deviation (mm)	The amplitude dB
2.5p9 * 9 k2.5 cambered surface	1	2.3	0.2	6.1	0.1	38.4
	2	33	2	6.1	0.1	2.1

Table 2. Inclusion defect detection data table

The probe model	defect id	Length (L/mm)	Deviation (mm)	Depth (H/mm)	Deviation (mm)	The amplitude dB	Deviation from weld center distance ±q/mm
2.5 p9 * 9 k2.5 cambered surface	3	10.5	0.5	6.6	0.3	40	-2
	Note: 1 The actual defect is 11mm in length and 6mm in depth;						

According to the data in Table 1 and 2, the defect detection rate is 100%, and the deeper the depth, the greater the error. For different defects, the depth detection of defects is the most accurate, while the width and length of defects decrease successively, which is greatly related to the operation of the experimenters, the sensitivity of the instrument and the characteristics of the material.

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For the cavity defect, the detection error is small because: compared with other defects, the fabrication of the defect is relatively simple and it is easy to ensure the accuracy of the defect.

For crack defects, the error values of circumferential crack are obviously smaller than that of axial crack, which is caused by the characteristics of inspection surface and probe. In axial crack detection, the arc probe fits closely with the pipe surface, which effectively reduces the scattering of acoustic waves. When the axial crack detection is carried out, if the circumferential detection method is still used, it can only be more accurate for the depth detection, so the probe direction should be constantly moved when detecting, and the fit degree between the probe and the pipeline surface is reduced, which causes a large acoustic loss, and the detection accuracy is decreased.

For inclusion, the error is large because there is a gap between the size predetermined during sample preparation and the size after successful sample preparation, and the length and depth of inclusion are changed due to extrusion of the melt layer during the fusion of the two ends, which is the main reason for the error.

4.3 Fuzzy Comprehensive Evaluation Method for PE Gas Pipe Defects

The fuzzy evaluation of defects takes hole defects as an example, cracks and slag inclusions are evaluated by the same method. In this paper, the failure degree of no. 1 defect is evaluated.

1) Factors and membership degree determination:

Table 3. Membership degree determination of hole defects

Defect 1 (part)	Defect factors			
	Depth (6.1)	Position (straight pipe)	Aperture (2.3)	Height (3.9)
optimal	0	1	0	0
good	0	0	1	0
center	0	0	0	1
poor	1	0	0	0

2)Factor weight determination:

Table 4. Weight determination of hole defects

Weight of hole defect		membership			
factors	weight	optimal	good	center	poor
The depth of the	X	0	0	0	1
location	Y	1	0	0	0
The aperture	Z	0	1	0	0
highly	W	0	0	1	0

Weight calculation of depth, position, width, aperture and height is carried out successively:

X = (0 X 0.1 + 0 1 X 0.4 * 0.3 + 0.2 + 0)/((0 1 X 0.2 X 0.1 + 0.3 + + 0 X 1 X 0.4) + (1 * 0.2 + 0.1 + 0 0 + 0 X 0.4 X 0.3) + (0 * 0.2 + 0.1 + 1 + 0 0 X 0.3 X 0.4) + (0 * 0.2 + 0.1 + 0 1 x 0.3 + 0 x) = 0.4 0.4).

Y = (+ 0 / + 0 x 0.2 x 0.1 x 0.3 + 0 x 0.4)/((0 1 x 0.2 x 0.1 + 0.3 + + 0 x 1 x 0.4) + (1 * 0.2 + 0.1 + 0 0 + 0 x 0.4 x 0.3) + (0 * 0.2 + 0.1 + 1 + 0 0 x 0.3 x 0.4) + (0 * 0.2 + 0.1 + 0 1 x 0.3 + 0 x) = 0.1 0.4)

Z = (0 1 x 0.2 x 0.1 + 0.3 + + 0 x 0 x 0.4)/((0 1 x 0.2 x 0.1 + 0.3 + + 0 x 1 x 0.4) + (1 * 0.2 + 0.1 + 0 0 + 0 x 0.4 x 0.3) + (0 * 0.2 + 0.1 + 1 + 0 0 x 0.3 x 0.4) + (0 * 0.2 + 0.1 + 0 1 x 0.3 + 0 x) = 0.2 0.4)

W = (0 x 0.1 + 0 1 x 0.3 x 0.2 + + 0 x 0.4)/((0 1 x 0.2 x 0.1 + 0.3 + + 0 x 1 x 0.4) + (1 * 0.2 + 0.1 + 0 0 + 0 x 0.4 x 0.3) + (0 * 0.2 + 0.1 + 1 + 0 0 x 0.3 x 0.4) + (0 * 0.2 + 0.1 + 0 1 x 0.3 + 0 x) = 0.3 0.4)

So: X=0.4, Y=0.1, Z=0.2, W=0.3.

The weight set A=[0.4,0.1,0.2,0.3].

According to the membership relation table, the matrix of each factor can be obtained:

R1 =,0,0,1 [0], R2 =,0,0,0 [1], R3 =,1,0,0 [0], R4 =,0,1,0 [0].

Evaluation matrix R= $\begin{bmatrix} R1 \\ \dots \\ R4 \end{bmatrix}$.

B = A, R = (0.4, 0.1, 0.3, 0.4).

When the same probability occurs, the value of the grade with high damage degree is taken as the result, so the hazard level corresponding to 0.4 is urgent. Therefore, no. 1 defect can be judged as an emergency defect and maintenance measures need to be taken immediately.

5. Summary

Through experimental analysis, the following conclusions are drawn:

(1) The ultrasonic detection method of defects in polymer pipe is not much different from that of traditional metal pipe, but the selection of probe and the setting and adjustment of instrument parameters are different.

(2) For different defects: the same instrument and the same probe can detect slightly different effects: hole > inclusion > crack: the same defect at different positions is also different: straight pipe > elbow > joint > weld.

(3) The evaluation system is quite different from that of metal pipes. Because the attributes of plastic pipes are greatly improved compared with traditional metal pipes in all aspects, the risk level of plastic pipes should be lower than that of metal pipes of the same grade with the same defect and the same quantity.

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