Influence of Vertical Hole Defects on Ultrasonic Test

Du Yannan¹,²*, Zhu Xuchen¹, Ouyang Weiping¹, Tang Xiaoying¹,², Xue Xiaolong¹,², Ding Ju¹

¹ Shanghai Inst. of Special Equip. Inspection & Tech. Res., Putuo, Shanghai, 200062, China
² Shanghai engineering research center of pressure pipeline intelligent inspection, Putuo, Shanghai, 200062, China
*Corresponding author’s e-mail: ynduzgz@163.com

Abstract. 9Ni steel has good toughness and high strength. This paper focuses on the influence of vertical hole defects on the ultrasonic propagation characteristics, which are studied from two aspects of the propagation characteristics of the base metal and the ultrasonic waves of the weld, respectively. The acoustic reflection characteristics of the reflector are compared with the acoustic reflection characteristics of the two different welding processes. (manual welding and automatic welding). It is shown that the gain compensation of the weld is larger than the gain of the same diameter and the same position of the vertical hole in the base metal. The gain compensation of the automatic welding is larger than that of the manual welding. The ultrasonic attenuation in the automatic welding is larger than that of the manual welding. The results of the study contribute to improving the application of ultrasonic testing in 9Ni weld joints.

1. Introduction
9Ni steel has good toughness and high strength. Compared with austenitic stainless steel and aluminum alloy, it has small thermal expansion coefficient, good economy and low temperature of -196 °C. It is widely used in the manufacture of large LNG storage tanks. This steel could be safely operated at very low temperature without post-weld stress relief heat treatment. However, due to its structural characteristics, it is extremely difficult for ultrasonic testing. In this paper, the effects of welding process on the ultrasonic propagation characteristics of 9Ni steel are studied. From the perspective of the propagation characteristics of the ultrasonic material of the base metal and the weld, the acoustic reflection characteristics of different reflectors in the base metal are studied, and then two different welding process. The acoustic reflection characteristics of the manual and automatic welds are compared with the properties of the base material.

2. Vertical hole test block design
Prepare one piece of test block 1 and test block 2, and make a vertical hole with a diameter of 1 mm at the middle of the weld bead on the two test blocks, and open the diameter of 1 mm and 1.5 mm respectively at an intermediate position of 120 mm from both sides of the weld. 2mm, 2.5mm vertical hole. Technical requirements are: (1) weld hole diameter is 1mm, weld and base metal are vertical holes; (2) base material surface grinding, surface roughness is 6.3. Due to the deformation of the weld bead, the two sides of the weld need to be separately ground; (3) the weld is strengthened with high
smoothing; (4) the defects of the base metal are not repeated. The defect locations are summarized in Table 1.

| defect kind | Welding process       | Base metal                  | Weld               |
|-------------|-----------------------|-----------------------------|--------------------|
|             |                       | Defect location             | Defect size mm     | Defect location     | Defect size mm |
| Vertical hole | Manual welding        | In the middle of the weld on both sides 120 | Left side 1         | Middle weld        | 1             |
|             |                       |                             | 1.5 on the right   |                    |               |
| Vertical hole | Automatic welding    | In the middle of the weld on both sides 120 | Left side 2        | Middle weld        | 1             |
|             |                       |                             | Right side 2.5     |                    |               |

3. Vertical hole test block test process
Ultrasonic flaw detection was carried out on the test piece by the probe. Firstly, the defects of the vertical hole diameter of the base material were 1mm, 1.5mm, 2mm and 2.5mm, and the direct wave was used. The measured gain data is recorded in Table 2. Then, the probe is used to inspect the weld vertical hole defects of the two test blocks, and the measured data are recorded in Table 3. The vertical hole test block weld is shown in Figure 1. The schematic diagram of vertical hole test block detection is illustrated in Figure 2.
4. Results and discussion

4.1. Vertical hole test block test data

The gain data measured by ultrasonic testing of vertical holes in the base metal are shown in Table 2. The gain data measured for flaw detection in the weld is shown in Table 3.

Table 2 Ultrasonic flaw detection gain data of vertical holes in base metal (direct wave)

| Vertical hole diameter (mm) | 1.0 | 1.5 | 2.0 | 2.5 |
|-----------------------------|-----|-----|-----|-----|
| Gain (vertical hole) / dB   | 78.0| 76.0| 74.2| 72.8|

Table 3 Ultrasonic flaw detection gain data of vertical holes in welds (direct wave)

| Welding process | Automatic welding | Manual welding |
|-----------------|-------------------|----------------|
| Gain (vertical hole) / dB | 81.8              | 81.0           |

4.2. Vertical hole test block test data processing and conclusion

The gain compensation data in Tables 2 and 3 is made into a defect size-gain compensation relationship diagram, the following conclusions could be drawn:

(1) Firstly, the gain compensation of the defects of different diameters of the vertical holes in the base metal is observed. The larger the defect diameter, the higher the ultrasonic reflection wave, the smaller the gain compensation, the smaller the attenuation, and the lower the detection sensitivity required.
(2) For vertical hole defects, the gain compensation of the weld is higher than the same diameter in the base material. The gain compensation of the vertical hole at the same position is large, indicating that the attenuation law in the joint and the base metal is different, due to the welding process in the weld. The influence causes the coarse-grained structure in the weld to cause the ultrasonic wave to attenuate in the weld, so the gain compensation of the defect in the weld is larger than the gain compensation of the defect in the base metal, and the required detection sensitivity is improved.

(3) For the vertical hole defects in the weld, the gain compensation of the automatic welding is larger than that of the manual welding. The ultrasonic attenuation in the automatic welding is larger than that of the manual welding, which is related to the welding process. The heat input value of the automatic welding is better than that of the manual welding. The large heat input value leads to more coarse crystal structure generated in the automatic welding, so that when the ultrasonic wave detects the vertical hole defect of the same position and size, the automatic welding seam makes the attenuation of the ultrasonic wave larger, so the weld inspection in the automatic welding. The sensitivity requirements are higher.

5. Conclusions
In this paper, the influence of the welding process on the ultrasonic propagation characteristics of 9Ni steel is studied. This paper focuses on the influence of vertical hole defects on the ultrasonic propagation characteristics, which are studied from two aspects of the propagation characteristics of the base metal and the ultrasonic waves of the weld, respectively. The acoustic reflection characteristics of the reflector are compared with the acoustic reflection characteristics of the two different welding processes, manual welding and automatic welding, and the properties of the base material. The research shows that the gain compensation of the weld is larger than the gain of the same diameter and the same position of the vertical hole in the base metal. The gain compensation of the automatic welding is larger than that of the manual welding. The ultrasonic attenuation in the automatic welding is larger than that of the manual welding. The results of the study help to improve the application of ultrasonic testing in 9Ni welded joint.

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