Effect of Cross-slot Defect in welded joint on Ultrasonic Test

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Abstract. 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. It is shown that the cross-slot of the weld is different from the cross-slot in the base metal, and the attenuation of the ultrasonic wave in the base metal and the weld is different. The gain compensation is too large, and the automatic welding gain compensation ratio of the upper groove of the weld is lower. The automatic welding gain compensation of the cross-slot is large, and the manual welding gain compensation of the lower cross-slot is higher than that of the automatic welding, and the cross-slot gain compensation of the automatic welding upper surface weld is higher than that of the manual welding.

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 can be safely used at very low temperatures without post-weld stress relief heat treatment. However, due to its structural characteristics, it is extremely difficult to ultrasonic testing[1-5]. 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 The welding process, that is, the acoustic reflection characteristics of the manual and automatic welds are compared with the properties of the base material. This paper focus on the effects of transverse groove defects on ultrasonic propagation characteristics.

2. Slotted test block design
Prepare two blocks of test block 1 and test block 2, and open a groove of 5 mm in length, 2 mm in depth and as small as possible in the middle of the weld toe of one of the test blocks 1 and 2, in another test block. 1 and the test piece 2 in the middle of the weld root opening a slot of the same size, the depth of the t/3 position of the four test blocks from the weld 120mm, respectively, the depth of
1mm, 1.5mm, 2mm, 2.5mm. Technical requirements include: (1) groove line cutting or electric spark, the groove depth of the weld is 2mm, the width is as small as possible. (2) the surface of the base material is ground, the surface roughness is 6.3, due to the deformed weld seam. Both sides of the weld need to be ground separately. (3) The weld is strengthened, and the flat is strengthened. (4) The defects of the base metal are not repeated.

| Defect kind | Welding process | Base metal Defect location | Defect size mm | Weld Defect location | Defect size mm |
|-------------|-----------------|----------------------------|----------------|----------------------|----------------|
| Cross-slot  | Automatic welding | Distance weld 120mm | 1 | Weld upper surface | 2 |
|             | Manual welding   | Distance weld 120mm | 1.5 | Weld upper surface | 2 |
|             | Automatic welding | Distance weld 120mm | 2 | Welded lower surface | 2 |
|             | Manual welding   | Distance weld 120mm | 2.5 | Welded lower surface | 2 |

3. Cross-slot test block test process
Ultrasonic flaw detection was performed on the test block in the third scheme with a probe. Firstly, the defects of the cross-slot depth of the base material were 1mm, 1.5mm, 2mm, and 2.5mm, and the data measured by the test were recorded. Then, the grooves on the upper surface and the lower surface of the weld were respectively inspected, and the measured data was recorded. The weld seams of the hand weld and the automatic weld cross-slot are shown in Figure 1. The detection diagram is shown in Figure 2.

(a) Manually welded weld pattern of cross-slot test block

(b) Surface weld block automatic weld seam diagram

Figure 1 Schematic diagram of cross-slot test block weld
4. Results and discussion

4.1. Cross-slot test block test data

The data measured in the test of the upper and lower cross-slot test pieces in the base metal are shown in Table 2. The measured data of the upper surface and the lower cross-slot test in the weld are shown in Table 3.

| Cross-slot depth (mm) | 1.0 | 1.5 | 2.0 | 2.5 |
|----------------------|-----|-----|-----|-----|
| Gain (cross-slot) / dB | 64.4 | 57.6 | 57.6 | 57.2 |

| Welding process | Direct wave / dB | Automatic welding | Manual welding |
|-----------------|-----------------|-------------------|----------------|
| Upper cross-slot | 78.2            | 73.4              |                |
| Lower surface slot | 74.2          | 75.0             |                |

4.2. Cross-slot test block test data processing and conclusion

The gain compensation data in Tables 4.5 and 4.6 are plotted as a groove depth-gain compensation diagram, the following conclusions can be drawn:

(1) For ultrasonic flaw detection of grooves with different groove depths, the gain compensation decreases with the increase of the groove depth, indicating that the larger the groove depth is, the higher the ultrasonic reflection wave is. However, the gain compensation of the groove depth of 1.5mm and 2.0mm is the same. It may be related to the little difference between the depths of the two grooves, so the difference in gain compensation is not likely to exist.

(2) Compared with the cross-slots in the base metal, the cross-slots in the weld have different attenuation laws in the base metal and the weld. The gain compensation is too large, which means that the ultrasonic attenuation in the weld is too large because of the welding process. Excessive coarse grained structure is generated in the weld joint, which increases the attenuation of the ultrasonic waves, resulting in an increase in the required detection sensitivity.
(3) The automatic welding gain compensation of the upper cross-slot of the weld is larger than the automatic welding gain compensation of the lower cross-slot. It is because the width of the upper surface of the weld is larger than the width of the lower surface during the automatic welding process, so on the upper side. When the cross-slot is flaw-detected, the ultrasonic wave passes through the weld seam more than the lower surface. The ultrasonic reflection wave on the upper surface of the weld is lower than the lower surface, the upper surface attenuation is larger than the lower cross-slot, and the gain compensation is large, so the detection sensitivity of the groove on the upper surface is required to be higher than that of the lower surface.

(4) The manual welding gain compensation of the lower cross-slot is higher than that of the automatic welding. This is because the heat input value of the surface weld under manual welding is larger than that of the automatic welding, resulting in more coarse crystal structure, large attenuation, and large gain. In the case of groove defects on the lower surface of the weld, manual welding requires higher detection sensitivity than automatic welding.

On the contrary, the cross-slot gain compensation of the automatic welding upper surface weld is higher than that of the manual welding, because the heat input value of the automatic welding upper surface is larger than that of the manual welding upper surface, and the automatic welding of the upper surface weld is thick. There are more crystal structures than manual soldering, so the ultrasonic reflection wave of the automatic surface weld is more attenuated than the manual soldering, the natural gain compensation is increased, and the sensitivity of the required detection is improved.

5. Conclusion
In this paper, the influence of 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 the 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 cross-slot of the weld is different from the cross-slot in the base metal, and the attenuation of the ultrasonic wave in the base metal and the weld is different. The gain compensation is too large, and the automatic welding gain compensation ratio of the upper groove of the weld is lower. The automatic welding gain compensation of the cross-slot is large, and the manual welding gain compensation of the lower cross-slot is higher than that of the automatic welding, and the cross-slot gain compensation of the automatic welding upper surface weld is higher than that of the manual welding.

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