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# Study on the detection method of HDPE electro-fusion welding defect based on X-ray technology



# Study on the detection method of HDPE electro-fusion welding defect based on X-ray technology

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**Abstract**: Electro-fusion welding is a common method for high-density polyethylene (HDPE) pipes. It has a high degree of automation and mature technology. However, during the welding process, various buried defects are easily generated. In this paper, HDPE pipes with welding defects were processed, and X-ray technology was used to detect the defects. The results show that: The X-ray detection technology is sensitive to the defects of sockets and ultralight clay-filled holes. But it is difficult to distinguish the size of the holes. Unfilled holes are partially fused during the welding process, which makes them difficult to detect. In addition, the defects of cold-welding and unscratched oxide skin cannot be detected.

## 1. Introduction

HDPE pipelines are widely used in gas transmission. During the laying process, the connection between two pipelines is an important link that affects its structural integrity and lasting strength[1]. Electro-fusion connection refers to the connection method in which the electro-fusion pipe fittings and pipes are melted and combined together by an applied current. This connection method was first introduced into the polyethylene pipe network system by the British pipeline company in 1969. Subsequently, technology developed rapidly in Europe. In the 1990s, Japan and the United States and other countries also adopted this connection method in large numbers. This connection method has been developed for 50 years, and its technology is relatively mature and has a high degree of automation. It is generally used in pipes with a diameter of less than 90 mm. When the pipe diameter increases, the processing of electro-fusion pipe fittings is more complicated[2-5] and the cost rises sharply. Besides, hole defects are prone to occur during the welding process, which has a great safety hazard[6, 7].

In order to ensure the smooth and safe transportation of pipelines, an effective detection method that can be promoted in a large area is urgently needed. The polyethylene material has a large acoustic wave attenuation coefficient, and the wire in the electro-fusion sleeve seriously interferes with the signal, which makes the traditional ultrasonic detection method ineffective. Not applicable for this condition. In this paper, X-ray technology is used to detect HDPE pipes containing various types of welding defects, and the experimental results provide data support for the field of HDPE pipe inspection.

## 2. Experimental

In this paper, HDPE pipes with DN110 and SDR=11 are selected to process a series of defects to simulate possible situations in actual working conditions. The defect processing plan is shown in Table 1.

Table 1. Defect processing scheme.

| Sample number | Defect type | Defect size (mm) | | Illustrate |
|---|---|---|---|---|
| | | Length | Depth | |
| 1# | Flawless | | | Standard process |
| 2# | The socket is not in place | | | Distance between the two pipes is too large |
| 3# | Cold-welding | | | Theoretical cold-welding degree 40% |
| 4# | Cold-welding | | | Theoretical cold-welding degree 50% |
| 5# | hole | φ5 | 3 | No padding |
| 6# | hole | φ5 | 4 | No padding |
| 7# | hole | φ4 | 3 | No padding |
| 8# | hole | φ4 | 4 | No padding |
| 9# | hole | φ5 | 3 | Ultralight Clay Fill |
| 10# | hole | φ5 | 4 | Ultralight Clay Fill |
| 11# | hole | φ4 | 3 | Ultralight Clay Fill |
| 12# | hole | φ4 | 4 | Ultralight Clay Fill |
| 13# | The oxide skin is not scratched | | | Aging of the pipe surface |

The actual hole and its processing are shown in Figure 1, in which Figure 1(a) shows the position of the hole in the plan view of the pipe, and Figure 1(b) shows the position of the hole on the outer wall of the pipe.

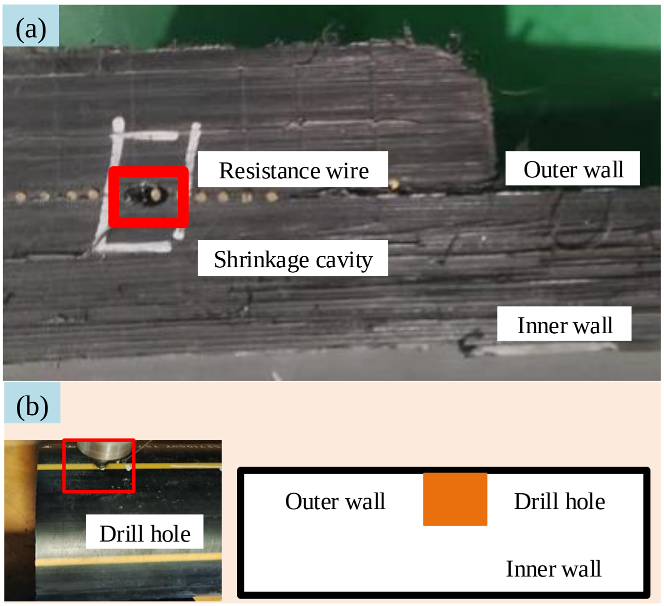



Figure 1. The actual hole and the processing map; (a) Section of electric fusion butt welding, (b) Schematic diagram of hole processing.

## 3. Results And Discussion

### *3.1 Sample 1#*

Figure 2 shows the X-ray negative of the normal welding sample. It can be seen that the resistance wires at the welding place are neatly arranged and clearly visible, and there are no obvious defects.


Figure 2. 1# Normal welding.

### *3.2 Sample 2#*

Figure 3 shows the X-ray negative of the socket-insertion defect. It is shown that the resistance wires at the welding place are neatly arranged and clearly visible. The black area in the middle of the picture is larger.

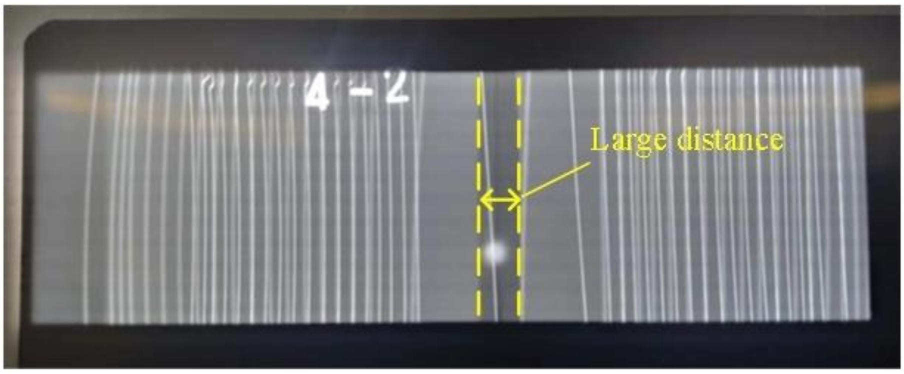
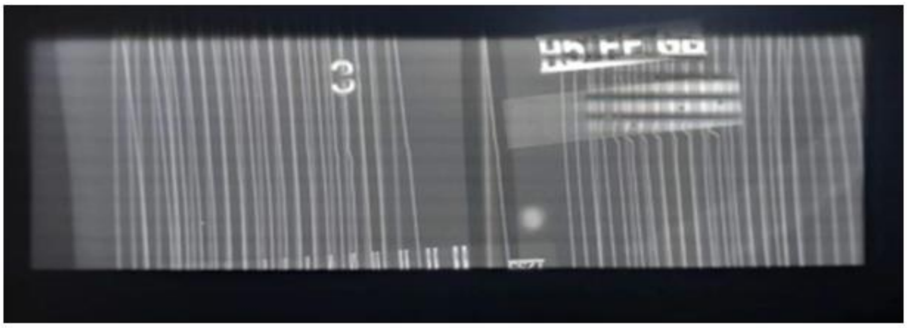



Figure 3. 2# Socket is not in place.

### *3.3 Samples 3# and 4#*
During electro-fusion welding, due to the short energization time or low energization voltage, the welding input heat is insufficient, resulting in a small diffusion range and a low entanglement degree of molecules on the fusion surface. Thus, the connection strength reduces. The standard power on time of the electro-fusion pipe is 240 s and the power on voltage is 29.5 V. During the defect processing, the energizing voltage is not changed, and the energizing time is changed to 144 s and 120 s respectively, corresponding to 40% and 50% of the cold-welding degree. Figure 4 shows X-ray negatives, which can not clearly distinguish the cold-welding.

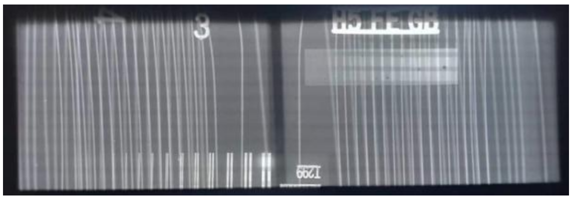


(a) 3# Cold-welding (degree 40%).

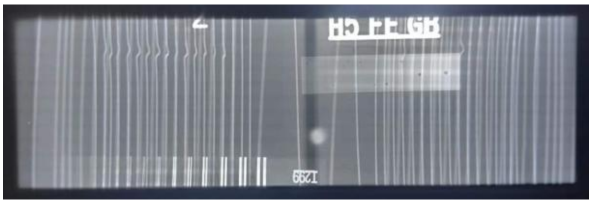
(b) 4# Cold-welding (degree 50%).

Figure 4. 3#, 4# Cold-welding.

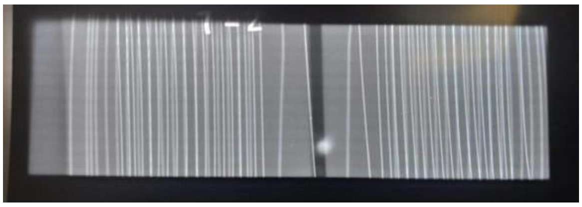
### *3.4 Samples 5–8#*
Figure 5 below shows X-ray inspection negatives with different sizes and unfilled holes. It is difficult to see obvious hole defects in the figure, which indicates that for unfilled holes, molten tubes will flow into the holes and fill them during welding.



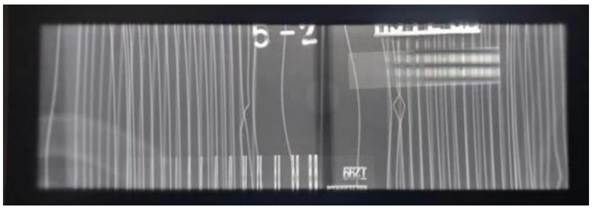
(a) 5#, φ5×3.



(b) 6#, φ5×4.



(c) 7#, φ4×3.

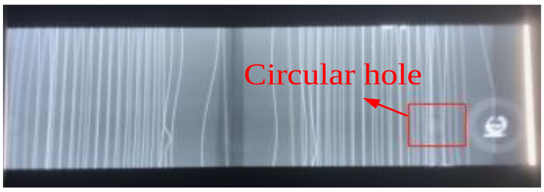


(d) 8#, φ4×4.

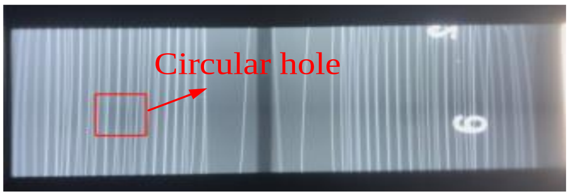
Figure 5. 5–8# Unfilled holes.

### *3.5 Samples 9–12#*

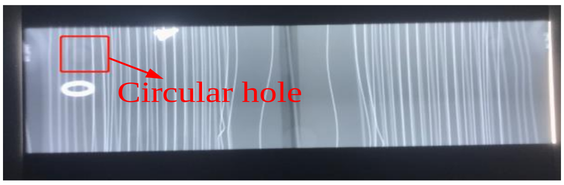
Figure 6 shows the X-ray negatives of the holes filled with ultra-light clay. It is seen that there is a circle shadow at the position of the holes, but there is no obvious difference in the negatives with holes of different sizes. Therefore, X-rays cannot determine the hole size.



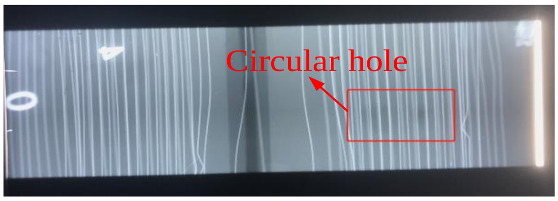

(a) 9#, φ5×3.




(b) 10#, φ5×4.




(c) 11#, φ4×3.




(d) 12#, φ4×4.

Figure 6. 9–12# Ultra-light clay-filled holes.

### *3.6 Sample 13#*

Figure 7 shows the scale unscratched defect. It indicates that the unscratched oxide scale has no obvious shadow in the negative and cannot be detected by X-ray.

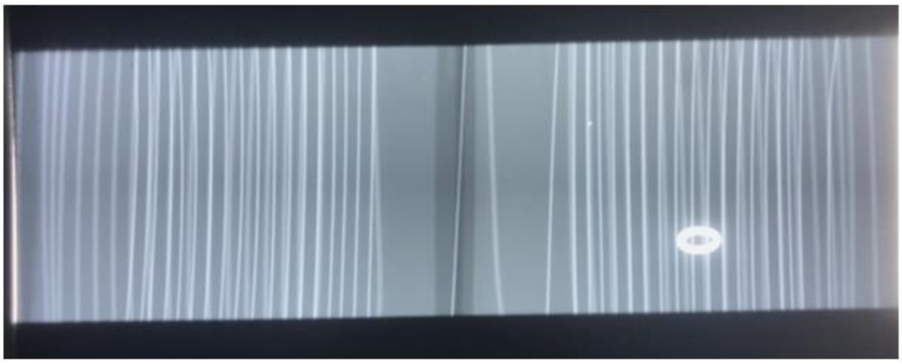


Figure 7. 13# Oxide skin is not scraped.

## 4. Conclusion

X-ray inspection technology is sensitive to the defects of the inadequate socket and filling holes with ultralight clay. When the pipe socket is not in place, the shadow part in the negative is wider. Filled voids will have noticeable shadows in the negative. But it is difficult to distinguish the hole size. However, the unfilled holes are partially fused during the welding process, and the holes are difficult to detect at this time. In addition, the defects of cold-welding and unscratched oxide skin cannot be detected. Now the requirements for pipeline inspection are gradually increasing. For future work, researchers should strengthen the classification and accuracy of X-ray detection.

## Acknowledgment

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