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Leakage Analysis of 15CrMo Cladding Wall Pipe Used in 660MW Supercritical Unit

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Abstract: The cause of leakage of the 15CrMo steel cladding wall tube of a 660MW supercritical unit of a power plant is analyzed by macro analysis, hardness measurement, and metallographic organization observation. The results show that the two sides of the weld are the original old pipe and the new pipe. The old pipe side, after the long-term operation and re-welding of the organization of the aging, is serious after analysis of the first leakage point is located in the old pipe fusion line; the first leakage point is located in the old pipe fusion line, the existence of multiple cracks in the inner wall of the pipe and the presence of oxide skin inside the cracks indicate that the cracks have existed for a long time, and at the same time, due to the severe aging of the old pipe organization, the ability to withstand external forces becomes weaker, which contributes to the expansion of the cracks in the process of operation, which leads to the leakage of the pipe. As a result, the wall cladding pipe was pulled apart after being subjected to external forces.

Keywords: 660MW supercritical unit; 15CrMo; wall cladding pipe; leakage

1. Test Methods and Results

1.1 Macro-Morphological Analysis

The macroscopic morphology of the package wall pipe on the left side of the horizontal flue sent for inspection is shown in Fig. 1. Since the package wall leakage pipe was leaked and replaced in 2018, the two sides of the weld are the original old pipe and the new pipe, respectively. There is a lateral leakage position of the leakage pipe, as shown in position a in the figure, after analyzing this is the initial leakage point, which is cracked along the fusion line of the old pipe side, and there are two other blowout leakage points, as shown in b and c in the figure respectively. Cut 1# and 2# specimens for inspection.

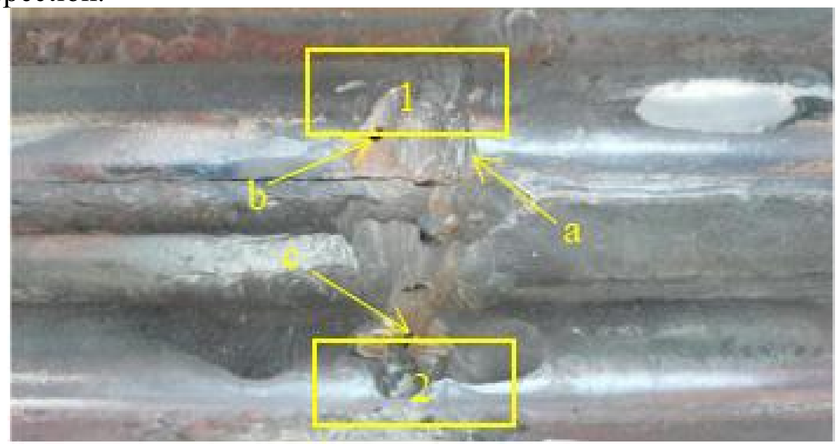

Fig. 1 Macro photo of wall-packed pipe and sampling location

1.2 Hardness Analysis

Use desktop Brinell hardness tester to test the hardness of 2# specimen blowout leakage location on the opposite side of the test results are shown in Table 1.According to the standard DL/T438-2016 on the relevant provisions of the 15CrMo, the material 15CrMo pipe fittings hardness should be 130-197HB, from the results of the test, it can be seen that the hardness value of the examined parts of the packaged wall pipe are in line with the requirements of the standard.

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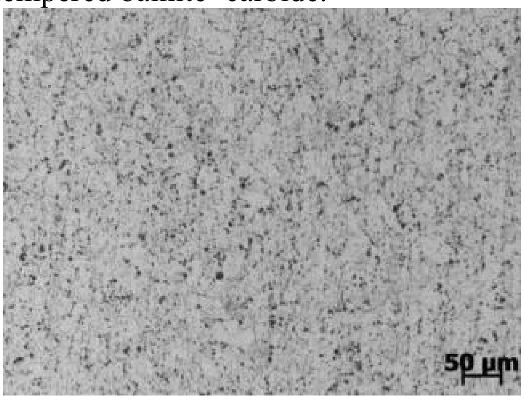
Table 1 Brinell hardness test results

Specimen number	test location	Test results (HB)
2# - opposite side of blowout	New tube side parent material M1	165
	New pipe side heat affected zone R1	207
	Weld H	228
	Old pipe side heat affected zone R2	186
	Old pipe side M2	141

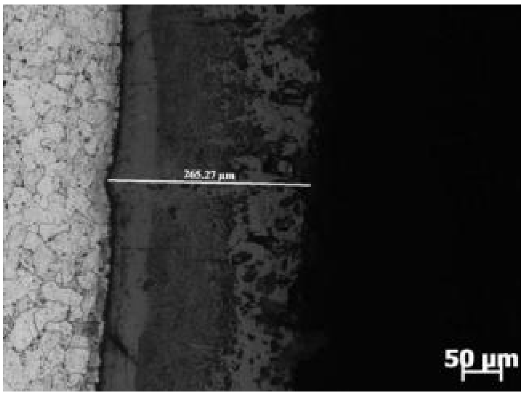
1.3 Metallographic Organization Analysis

The metallographic organization of 1# and 2# specimens was examined, as shown in Figs. 2-5.

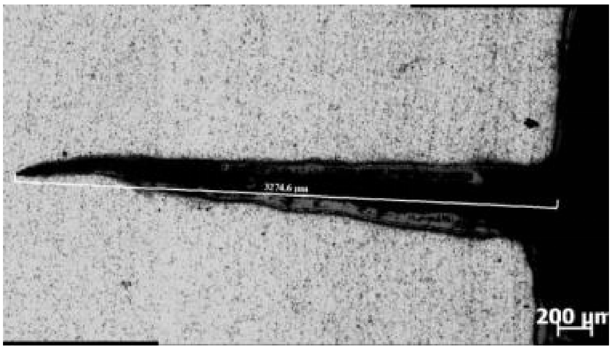
After inspection, as shown in Figure 2, 1 # specimen burst side of the old pipe base material metallurgical organization for ferrite + carbide, spheroidization level of 4, the thickness of the inner wall of the oxide skin of 265.27 μm, the existence of two cracks on the inner wall, one is located in the base material, the length of 3274.6 μm, the other is located in the weld fusion line, the length of 2700.57 μm, the existence of a small number of cracks in the inner skin of the oxide, the existence of the outer wall of a crack, located in the base material, length of 4917.62 μm. One crack is located in the base material with a length of 4917.62 μm, the metallurgical organization of the new pipe base material is ferrite+pearlitic+carbide, the spheroidization level is 2.5, and the thickness of the oxide skin on the inner wall is 120.01 μm; the metallurgical organization of the weld is ferrite+tempered bainite+carbide.



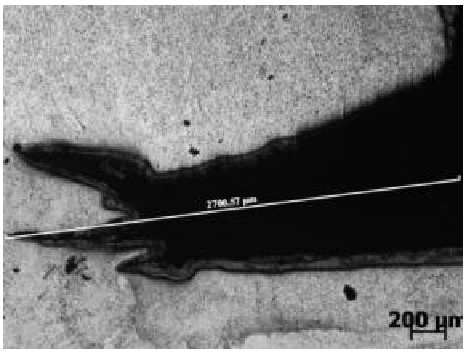
(a) Base metal of old pipe



(b) Inside wall of old pipe



(c) Crack of base metal



(d) Crack of weld fusion line

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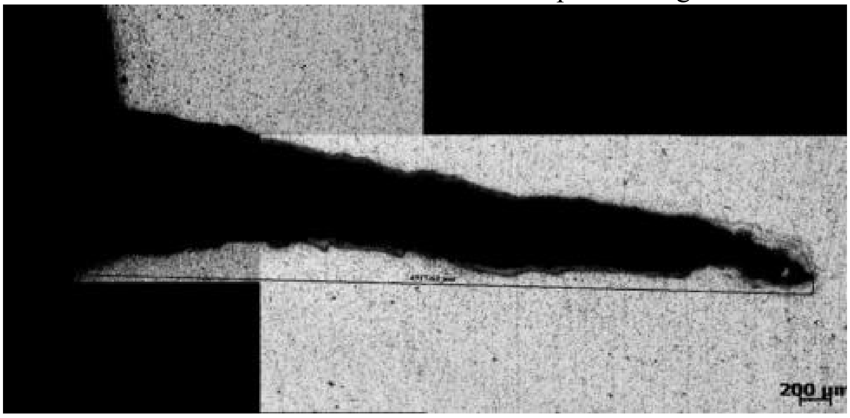
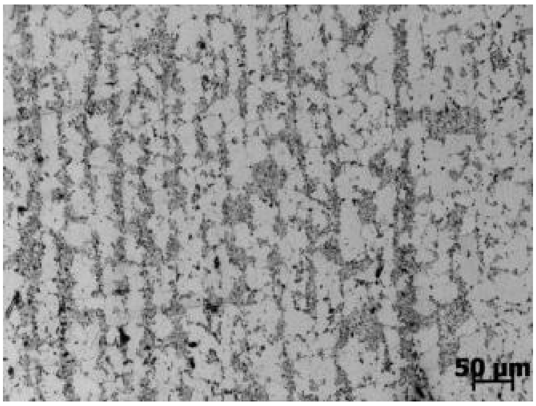
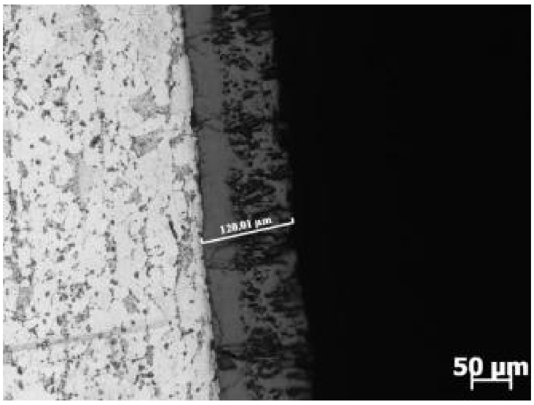
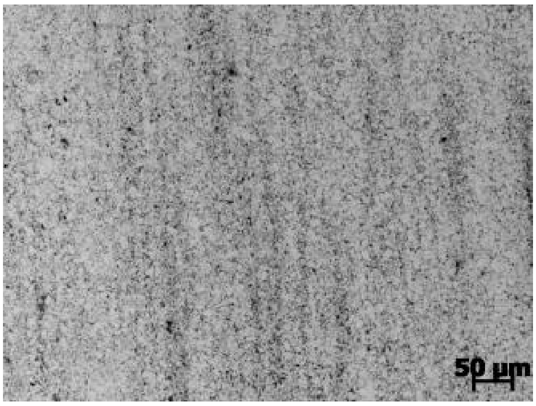


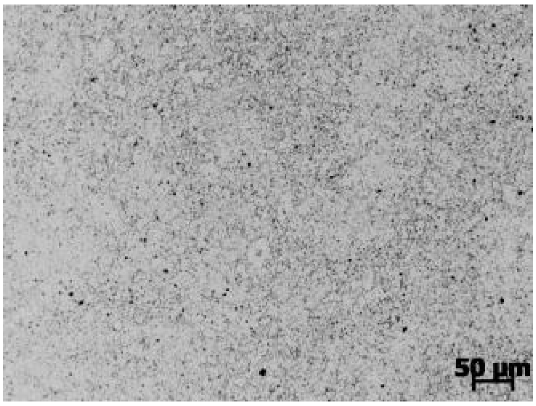
(e) Crack of outer wall of base metal





(f) Base metal of new pipe (g) Inside wall of new pipe





(h) Heat affected zone of new pipe (i) Weld

Fig. 2 Metallographic organization of 1# specimen burst side

As shown in Figure 3, 1 # specimen burst on the opposite side of the old pipe parent material metallurgical organization of ferrite + pearlite + carbide, spheroidization level of 3, the thickness of the inner wall of the oxide skin is 175.79 μm, the thickness of the outer wall of the oxide skin of 92.31 μm; the presence of two cracks in the inner wall, the length of 988.24 μm, 169.69 μm, respectively, the cracks within the presence of the oxide skin. The metallographic organization of the new pipe parent material is ferrite + pearlite + a small amount of carbide, spheroidization level of 2.5, the thickness of the inner wall oxide skin is 173.72μm, 186.54μm, and the thickness of the outer wall oxide skin is 75.17μm; the metallographic organization of the weld is ferrite + tempered bainite + carbide.

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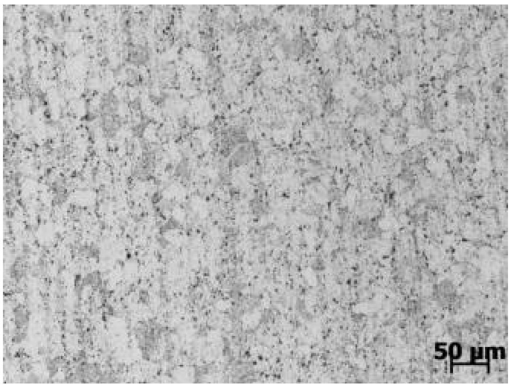
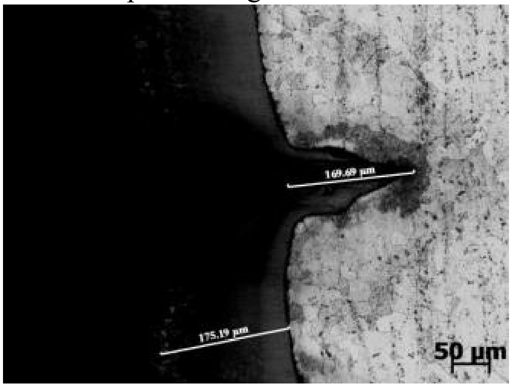
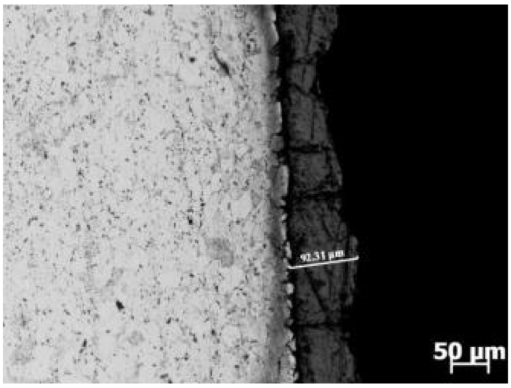


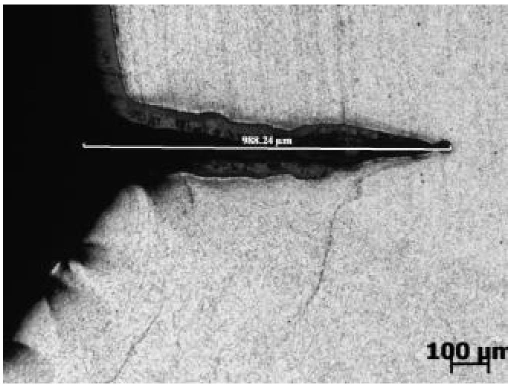
(a) Base metal of old pipe



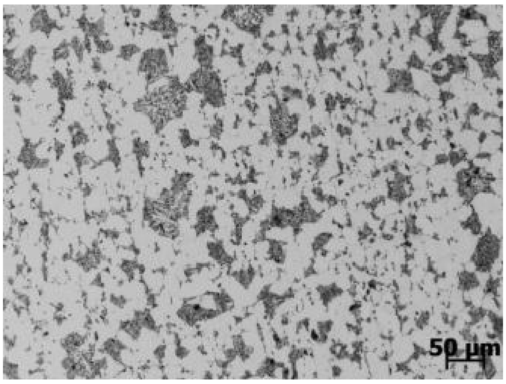
(b) Inside wall of old pipe



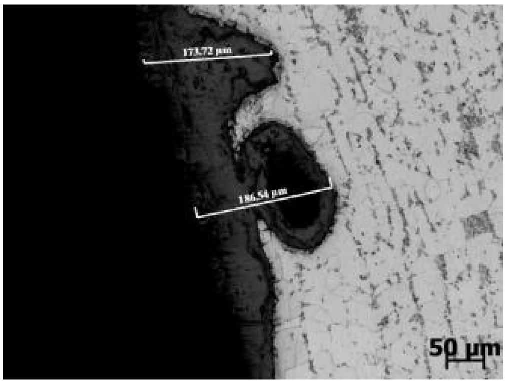
(c) Outer wall of the old pipe



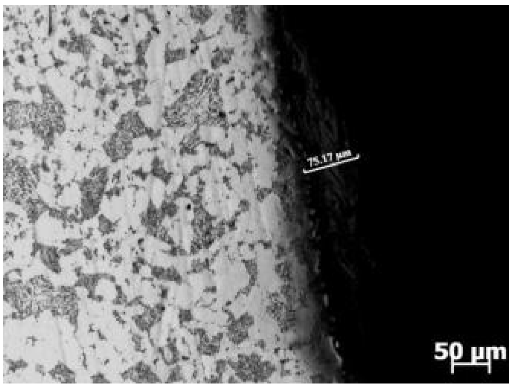
(d) Cracks in the inner wall of the old pipe



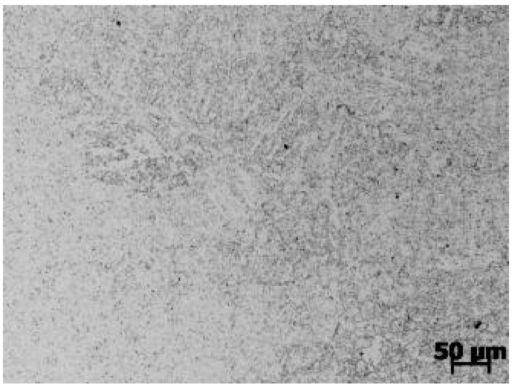
(e) Base metal of new pipe



(f) Inside wall of new pipe



(g) Outer wall of new pipe



(h) Weld

Fig. 3 Metallographic organization of 1# specimen on the opposite side of the bursting hole

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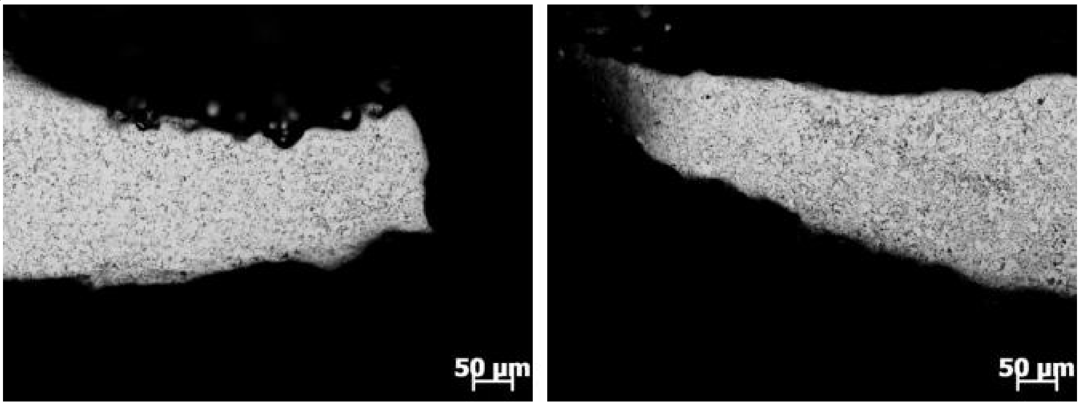
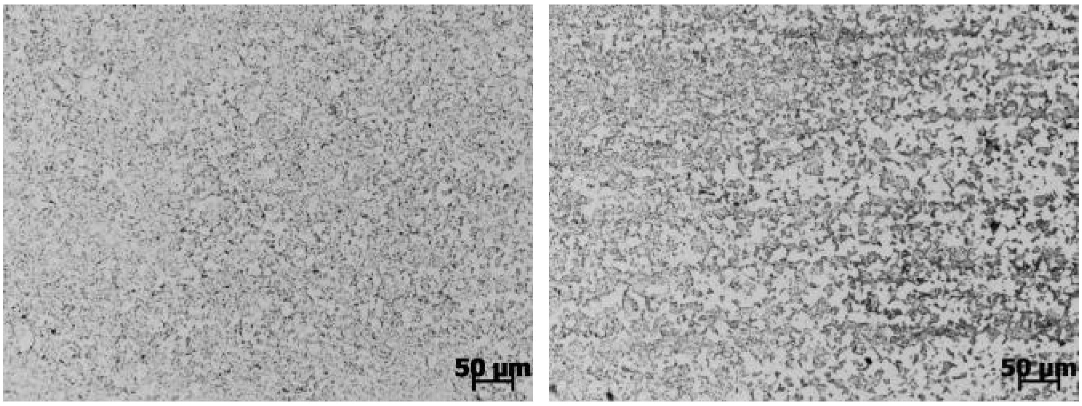
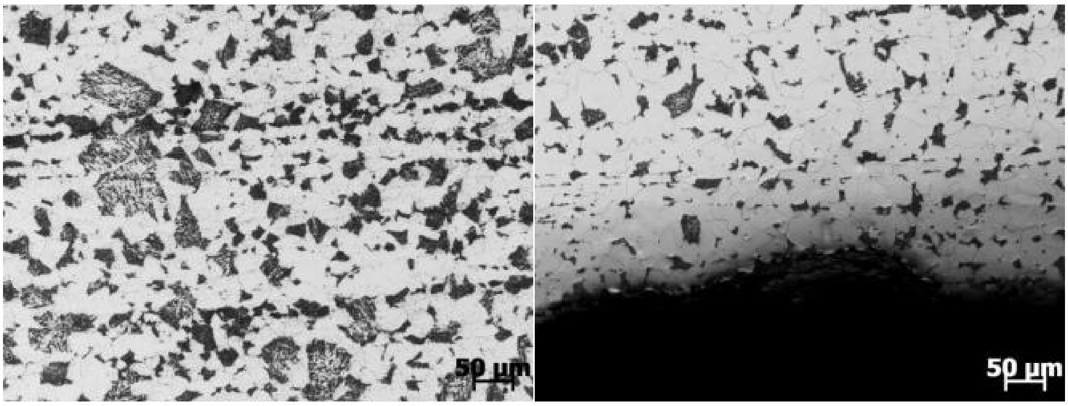
As shown in Figure 4, 2 # specimen blowout location is located in the base material, the metallographic organization of ferrite + a small amount of pearlite + carbide, spheroidization level of 4, the weld metallographic organization of ferrite + tempered bainite + carbide, the heat affected zone organization is ferrite + tempered bainite. The normal position of both sides of the weld is consistent with the organization of the base material, the metallurgical organization is ferrite + pearlite, and there is no obvious oxide skin on the inner wall.



(a) Highest peak of blowout position



(b) Weld (c) Heat affected zone



(d) Base metal of weld (e) Inwall

Fig. 4 Metallographic structure at blown position of sample 2#

As shown in Figure 5, 2 # specimen blowout location opposite side, weld both sides of the base material organization is consistent, the base material metallurgical organization are ferrite + pearlite, spheroidization level of 2.5, weld metallurgical organization for ferrite + tempered bainite, heat affected zone organization for ferrite + tempered bainite. The depth of oxidized skin on the inner wall is 147.25 μ m, and no obvious oxidized skin is seen on the outer wall.

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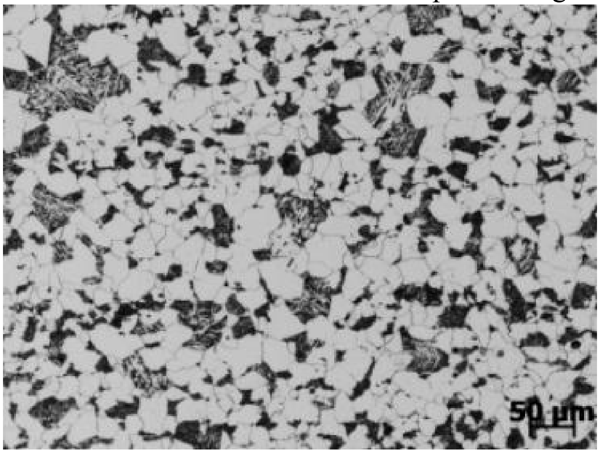
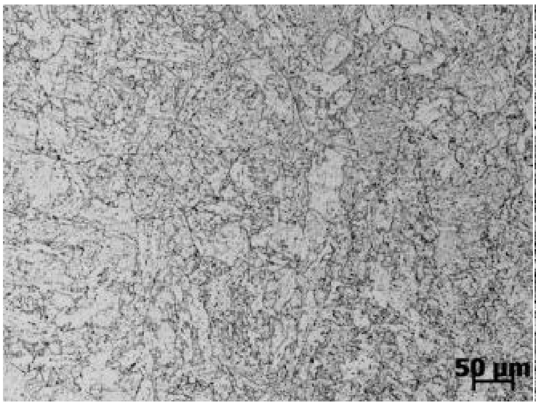
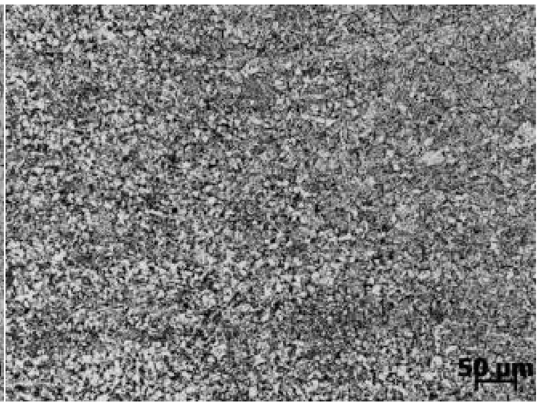
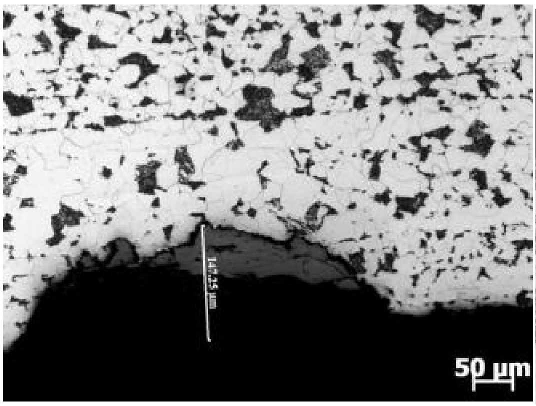


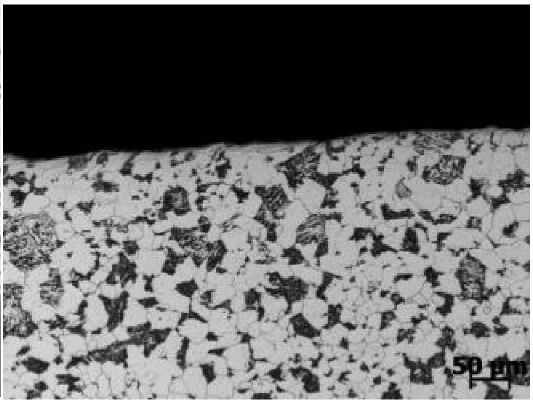
(a) The blown position of sample 2# is opposite





(b) Blow position opposite weld (c) Opposite of heat affected zone





(d) Opposite of the inner wall (e) Opposite of the outer wall

Fig. 5 Metallographic structure on the opposite of the blown position of sample 2#

1.4 Scanning Electron Microscope Analysis

Using EVO-18 scanning electron microscope to analyze the 1# specimen, scanning electron microscope photos shown in Figure 6. From the scanning electron microscope crack photographs, it can be seen that there is an oxide skin inside the crack; from the specimen parent material scanning electron microscope photographs, it can be seen that the burst of the old tube side of the parent material metallurgical organization of ferrite + carbide, do not see the obvious pearlitic organization.

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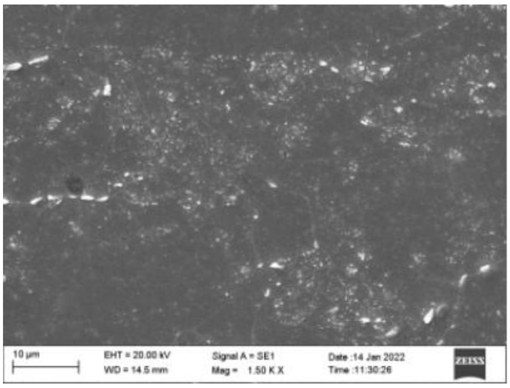
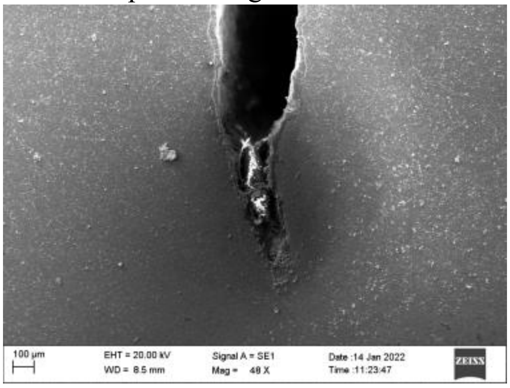
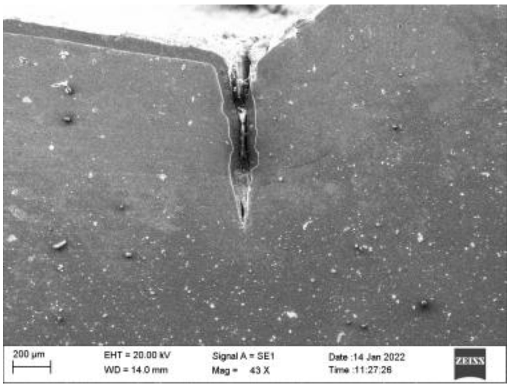


(a) Sample 1# old tube side base material



(b) Crack on the side of the opening of 1# sample



(c) Opposite crack of 1# sample opening

FIG. 6 SEM photos of 1# sample bursting crack and base metal

2. Conclusion

The left side of the horizontal flue wall pipe for macro and micro morphology, hardness, metallurgical organization and other analyses, welds on both sides of the original old pipe and the new pipe, the old pipe after long-term operation and re-welding after serious tissue aging, the analysis of the first leakage point is located in the fusion line of the old pipe, the inner wall of the wall pipe there are a number of cracks and cracks within the presence of oxidation, indicating that the cracks existed for a long time, and at the same time, due to the serious aging of the old pipe, the ability to withstand external forces becomes weaker, leading to the expansion of cracks during operation, which in turn led to the pipe leakage. At the same time, due to the serious aging of the old pipe organization, the ability to withstand external forces becomes weaker, prompting the cracks to expand in the operation process, which in turn leads to pipe leakage. As a result, the wall cladding pipe was cracked after being subjected to external forces.

3. Suggested Improvements

(1) It is recommended that the horizontal flue wall pipe and other long-running pipe sections be expanded and inspected, with emphasis on whether there are cracks and other defects in the inner wall, and be replaced in a timely manner.

(2) It is recommended to carry out organization and performance sampling of the wall-packed pipe, and deal with the pipe sections with serious aging or reduced performance in a timely manner.

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