Cracking Failure Analysis on 316L Stainless Steel Elbow

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Abstract—The 316L stainless steel elbow used in the pulse soot blower cracked during service, and the cracking occurred at the maximum bending radius of the elbow. There is no obvious plastic deformation at crack and there is much rust deposit on the inner elbow wall of cracked elbow. In order to avoid similar accidents, the methods such as chemical composition analysis, microstructure analysis and crack pattern scanning are adopted to analyze crack reason. The results show that stress corrosion is the main reason to cause crack of 316L stainless steel elbow.

1. INTRODUCTION

Pulse soot blower is a machine which uses the huge sound energy and high temperature and high speed gas produced by the shock wave of deflagration of appropriate mixture such as hydrogen, acetylene and natural gas to vibrate, impact and wash the boiler surface, and blow away the accumulated ash on the boiler surface.

The material of the straight blasting elbow is 316L stainless steel. Lots of cracks occur on the elbow after about half a year the ash blower put to use. This paper analyzes the causes of crack. It is very meaningful to reduce the economic losses and helpful to find a new method to resolve the trouble.

2. MACROSCOPIC EXAMINATION

The crack occurs on the position of maximum bending radius where there is no obvious plastic deformation and the crack is brittle fracture which is shown in Fig. 1(a). There is lots of rust adhered to the inner wall of elbow. The rust distributes near the cracks and the maximum thickness of the rust is 2mm, which is shown in Fig. 1(b). The thickness of the elbow is about 6mm, and the uniformity of the thickness is well.
3. CHEMICAL ANALYSIS
Take a chemical analysis test on the sample from the elbow using Q8 MAGELLAN System spectrum analyzer, and the result is in accordance with the requirements ruled by GB/T20878-2007. The result is shown in Table 1.

| Element | Result | Requirement of GB/T20878-2007 |
|---------|--------|-------------------------------|
| C       | 0.018  | ≤0.030                        |
| Si      | 0.406  | ≤1.00                         |
| Mn      | 1.116  | ≤2.00                         |
| S       | 0.0020 | ≤0.030                        |
| P       | 0.017  | ≤0.045                        |
| Cr      | 16.88  | 16.00～18.00                  |
| Ni      | 10.50  | 10.00～14.00                  |
| Mo      | 2.175  | 2.00～3.00                    |

4. MECHANICAL ANALYSIS
Do tensile test by making test samples at the non-broken places, and the test results are shown in Table 2.
TABLE 2. TENSILE TEST RESULT

| Items | Requirements by Standard GB/T14976-2012 | Sample a | Sample b |
|-------|----------------------------------------|----------|----------|
| Rp0.2 | ≥175MPa                                | 256MPa   | 254MPa   |
| R     | ≥480MPa                                | 504MPa   | 506MPa   |
| A     | ≥35%                                   | 40%      | 41%      |

5. METALLOGRAPHIC ANALYSIS
Take a metallographic analysis on the sample from the crack place using Imager.A1M microscope and the corrosive agent is aqua regia. Fig. 2(a) shows that the microstructure is γ+δ. The crack extends to the inner gradually with arborization and the crack emerges transgranular behavior which are the typical features of stainless steel stress corrosion in the Cl- environments [1, 2] which is shown in Fig. 2(b).

6. FRACTURE MORPHOLOGY ANALYSIS
Take a examination on the fracture and it shows metallic luster from 1mm distance away from the surface from which we could make a prediction that the crack emerges and extends from the inner of the elbow. As shown in Fig. 3, the fracture appearance shows muddy flower pattern. which is the typical pattern of stress corrosion [3, 4]. Energy spectrum shows that element Cl and S exist in both the surface of the fracture and the wall of the elbow as shown in Fig. 4.

![Microstructure](image_url)

Figure 2. Microstructure of crack area.

![Fracture Morphology](image_url)

Figure 3. Fracture appearance shows muddy flower pattern.
Figure 3. Microstructure of fracture.
7. DISCUSSION
The test result shows that the crack originated from the inner of the elbow. The chemical composition of the elbow and mechanical property are in accordance with the product standard. The matrix is \( \gamma + \delta \) and the grain is fine and uniformity. The elbow worked in the environment of high temperature 600~700°C and a large number of Cl- and S2- which are the sensitive medium ion causing stainless stress corrosion crack [5, 6]. At the same time, the ash blower worked by controlling of pulse. So there would be a pulse tensile stress produced at the inner of bending place of the elbow. The stress corrosion crack originated from the inner of the stainless elbow under the both effect by sensitive ion and tensile stress seeing Fig. 5.

8. SUGGESTION
316L stainless steel could show excellent property in corrosive environment, but its advantage will be hard to show under the comprehensive function with high temperature, tensile stress and corrosion. To avoid stress corrosion, we suggest using furnace tube material HP40 eg.
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