Failure Analysis of Collecting Pipe Head Used in Ammonia Refrigerating System

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Abstract. The head of a collecting pipe used in ammonia refrigerating system fractured during applications. The cause for head fracture was investigated by means of scanning electron microscope, optical microscope and chemical composition analysis. The results indicate that the welded joint has serious incomplete penetration defect. The fracture mode of collecting pipe head used in ammonia refrigerating system is brittle failure at low temperature.

1. Introduction

The ammonia refrigerating system is widely used in large cold storage, refrigeration station of chemical plants, industrial ice making and large air conditioning system of indirect refrigeration [1]. The accidents occurred in the ammonia refrigerating system usually cause personal injury or death or property damage. Welding is one of the most used ways of connection for pipe and pipe or head. Weld joint failure can influence the life of equipments, and even cause a safety accident [2-4]. Accordingly, how to ensure the safe operation of the ammonia refrigerating system is getting widespread attention. In this paper, the collecting pipe head dropped off during applications was studied by analyzing the macroscopic and microscopic fractography and the chemical composition. The cause of the head fracture was indicated.

2. Fracture Specimen and Analysis Method

The gas collecting pipe and its blind end head-off case is shown in Fig. 1. The elliptical head is connected with the gas collecting pipe by welding. The thickness and outer diameter of the gas collecting pipe are 5mm and 159mm, respectively.

![Image of gas collecting pipe and head-off case](image-url)

Figure 1. The gas collecting pipe and its blind end head-off case.
The fracture of head was analyzed by the scanning electron microscope referring to JB/T 6842-1993 <Test methods of scanning electron microscope>. The microstructure of the head was analyzed after etching referring to GB/T 13298-1991 <Inspection methods of microstructure for metals>.

3. Results and Discussions

3.1. Macroscopic Fractography

Macroscopic fractography of the head of a collecting pipe is shown in Fig. 2. The weld penetration depth and thickness unevenly distributed along the circumference by means of measuring and analyzing. The biggest and smallest effective thicknesses of the weld are 6.7mm and 2.5mm, respectively.

![Figure 2. Enlarged image of the head fracture.](image)

Macro morphology of the head weld fracture is shown in Fig. 3. It can be seen that the fracture trail is fresh and all the fracture color is same. No old fracture trail or fatigue striation is found. There is no obvious plastic deformation on the fracture. It can be inferred that this belongs to overload brittle fracture based on the macro analysis. There are radiation stripes on the fracture surface from inside to outside. Most likely, the micro crack originated from the porosity in the weld and developed very quickly.

![Figure 3. Macro morphology of the head weld fracture.](image)

3.2. SEM Analysis of Fracture

The low multiple SEM image of the incomplete penetration butt weld fracture is shown in Fig. 4. It can be seen that there are obvious weld porosities in the weld. It is found that the similar defects are widespread in the fracture of the whole weld. The low multiple SEM image of the weld porosity with relatively large size on the fracture is shown in Fig. 5. The diameter of the weld porosity is about 1mm. There is a micro crack near the porosity of the fracture, as indicated by the white arrow. The cleavage
step morphology is found in this micro area. The cleavage direction indicates that the micro crack developed from the porosity edge to outside. The high multiple SEM image of the head fracture morphology near the pipe inner surface is shown in Fig. 6. It can be seen that there are typical river-like patterns and lots of micro-zone cleavage planes on the weld fracture. It can be inferred that the fracture happened at the condition of low temperature instantaneously base on the accident.

![Image](image-url)

**Figure 4.** Low multiple SEM image of the incomplete penetration butt weld fracture.

![Image](image-url)

**Figure 5.** Low multiple SEM image of the weld porosity on the fracture.

![Image](image-url)

**Figure 6.** High multiple SEM image of the head fracture morphology near the pipe inner surface.

3.3. Analysis of Microstructure and Chemical Composition of Weld

Metallographical structure of the weld cross-section is shown in Fig. 7. It can be seen that the weld microstructure is the normal welded structure of the low carbon steel. There is a micro crack between the fusion and heat affected zone near the fracture. Micro-structure of micro crack tip in the weld with high power microscope is shown in Fig. 8. It can be determined that the crack tip is the result of crack growth.
The chemical composition of the weld was tested by the Energy Dispersive Spectrometer. The results show that the head material is 15# steel, the pipe material is 20# steel and the weld material conforms to the E4303 electrode composition. E4303 electrode belongs to low carbon steel electrode with excellent plasticity. The electrode composition matches the pipe and head [5].

4. Conclusion
Low carbon steel has comparatively high ductility and strong fracture-resistant ability at room temperature and very low ductility at low temperature. The fracture of the weld exhibits the complete brittle fracture. It can be inferred that the weld fractured at once based on the analysis of fracture. This indicates that the collecting pipe was in low temperature brittle condition. In addition, the failure welded joint has serious incomplete penetration defect. The discontinuous structure of the welded joint leads to the bigger stress concentration, which caused the brittle failure of welded joint at last.

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