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Case study

Fracture analysis of U71Mn rail flash-butt welding joint

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ABSTRACT

This paper mainly investigates the fracture problem of U71Mn rail flash-butt welding joint. Fracture surface morphology, microstructure and micro hardness are analyzed by using the scanning electron microscopy (SEM/EDS), the optical microscope (OM) and the micro Vickers hardness tester (Vickers-tester). The analysis results show that the welding joint is fatigue fracture, and the fracture surface morphology is the cleavage fracture characteristics. The metallographic morphology, inclusions and micro-hardness near the fracture surface are all in the normal levels. On the other side, the free solidification microstructure which extended from the outside to inside in the joint of the left side of the rail web and the rail head is the crack source of the rail welding joint fatigue fracture. Under the action of bending stress, the crack firstly generates in this area, and gradually extended to the rail web, to final fracture.

1. Introduction

Because of convenience, high efficiency, large volume and low transport cost, rail transport obtains high attention all over the world and gets very rapid development. Since the 1960s, the rail transport was developed toward the direction of high speed, high efficiency and large-capacity. Because of the high demands for the rail transport, the safety of the rail transport was directly threatened by the rail fracture accidents [1–3]. Since shock and vibration can be reduced effectively by continuously welded rail, which can ensure the safety and stability of the rail transport, it is widely applied at present.

Continuously welded rail is laid by using the seamless welded rail. How to achieve an effective and stability welding is the key to the continuously welded rail laying. Practice shows that the rail welding joint is a weak link in the continuously welded rail, which directly affects the service life of the continuously welded rail. And most of the continuously welded rail fracture comes from the fracture of welding joint [3,4]. For this reason, many researchers paid much attention to the failure fracture causes and preventive measures of the continuously welded rail [5–8]. It can be seen that, improving the mechanical properties of the welding joints, such as strength, toughness and so on, in order to avoid premature failure fracture is of vital significance for modern rail transport.

In this paper, the U71Mn rail which was welded by flash-butt welding, broke at the welding joint after a period of service. The rail fracture surface was studied by analyzing the macroscopic and microscopic morphology and the chemical composition. The cause of the rail fracture was indicated and the preventive measures were proposed.

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2. Experimental results

2.1. Macroscopic inspections

Fig. 1 shows the rail fracture position and the crack propagation shape. As shown in Fig. 1, the rail fracture happens at the flash-butt welding joint, and crack propagation shape is irregular curved.

The macroscopic morphology of the rail fracture surface is shown in Fig. 2. As shown in Fig. 2, firstly, the rail head is slightly sunken, the rail web is rugged, and the rail bottom is relatively flat. Secondly, the fracture surface of the rail is corroded at the different degrees. At the left side of the rail web, there exists a 100 mm $\times$ 10 mm oxidation corrosion area, and a serious crescent-shaped corrosion area is found at the corner of the left side of the rail web and the rail head. And the fracture surface is fresh at the right side of the rail web. Another oxidation corrosion area can be found at the right side of the rail bottom. Thirdly, the fracture surface roughness in the serious corrosion area is smaller than that in the fresh fracture surface area in the rail web. Finally, the herringbone pattern at the both sides of the rail bottom corner points to the rail web and the radiation pattern of the rail head fracture surface also points to the rail web.

2.2. SEM observations and EDS analysis

In order to study the microstructure morphology of the rail fracture surface, the specimen is collected from the fractured rail which is shown in Fig. 2. The specimen is cleaned by ultrasonic wave in anhydrous alcohol, and then is observed by using the Hitachi S-570 scanning electron microscope.

Fig. 3 shows the microstructure morphology and spectral analysis results of the different areas of the rail fracture surface. In Fig. 3(a), the serious corrosion crescent-shaped area (1# specimen) is primarily cleavage fracture microstructure morphology, in which many secondary cracks as well as a small amount of inclusions exist. From the analysis results, it can be seen that the inclusion mainly contains Si, Ca, C and O elements. In Fig. 3(b), at the corner of the left side of the rail web and the rail head (2# specimen) the microstructure morphology of the rail fracture surface have the characteristics of cleavage fracture, and free solidification structure morphology observed in the area extends from the edge welding joint to the internal. The analysis results show that the free solidification structure mainly contains Fe element. In addition, the observations suggest that the flat area (3# specimen) at the left side of the rail web and the instant fracture area (4# specimen) at the right side of the rail web are the cleavage fracture microstructure morphology.

2.3. Metallographic morphology observations and micro-hardness tests

After grounding and polishing, the microstructures closed to the edge of the welding joint fracture surface is observed via ZEISS optical microscope 80-DX (MC80-DX). Fig. 4 shows the metallographic morphology of the rail welding joint and

Fig. 1. Rail fracture position and crack propagation shape.