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Fracture analysis on fasten bolt of a shaft sleeve of escalator stave

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Abstract. The fasten bolt of a shaft sleeve of escalator stave fractured during applications. The cause for fasten bolt fracture was investigated by means of macroscopic fractography, optical microscope and scanning electron microscope. The results indicate that superficial decarbonization occurred on the bolt screw thread and the depth overstepped the requirements of relevant standards. The fracture mode of fasten bolt of a shaft sleeve is clockwise torsion overload fracture.

1. Introduction

Escalators are widely used in public places such as subway, shopping malls and hotels. In recent years, with the increasing popularity of escalators, the accident caused by escalator is rising year by year as well as improving the quality of service [1]. Thus, how to ensure the safe operation of the escalator is getting widespread attention in the society.

Bolting is one of the most extensive ways of connection between mechanical parts. It is widely used in various fields, such as engineering machinery, automobile, ship, space, chemical, water conservancy and so on. It is also the most used standard part. Bolt failure can influence the use of machine equipment, and even cause a safety accident. The factors affecting the failure of bolts include service load, environmental temperature and medium, and the quality and performance of the bolt. Fracture is most important and dangerous failure mode of bolt. Brittle fracture, in particular, often causes serious personal casualties and huge economic losses.

In the past years, the fracture analysis of bolt has been studied by many researchers [2-5]. Molaei et al. [6] investigated the main reasons of the co-fracture of sixteen connecting bolts. The stress state of bolts has been studied and the failure causes were determined by fractography analysis. The results show that the fatigue mechanism caused the bolts failure. Kong et al. [7] studied the failure mode and cause of the U-shaped bolts by macro and micro observation, hardness and tensile property testing. The results show that the U-shaped bolts were fatigue fracture. Hedayat et al. [8] proposed the appropriate failure criteria for predicting the bolt fracture in shear.

During runtime of the escalator in a square, more than ten steps were arched upward and damaged due to the collision between the stave and the support plate. After preliminary scene investigation, the main reason is that the fasten bolt of a shaft sleeve of this escalator was broken. In this paper, the cause of fracture of fasten bolt was analyzed using macro, scanning electron microscope and optical microscope.

2. Fracture Specimen and Analysis Method

The failure shaft sleeve of escalator is shown in Fig. 1. The shaft sleeve, which is fixed to support arm of stave by fasten bolt, is assembled with driving chain pin. The length and outer diameter of the shaft sleeve are 160mm and 30mm, respectively. The depth and diameter of the axis hole are 37mm and 24.5mm, respectively. The shaft lining is nylon sleeve with the diameter about 20mm. There are two orthogonal fixing screw holes in the shaft lining back-end, which are 50mm and 60mm distant from the end. It can be seen that the fasten bolt of shaft sleeve has been fractured. The fracture surface sunk inside. The axis hole of shaft sleeve has no obviously plastic deformation.

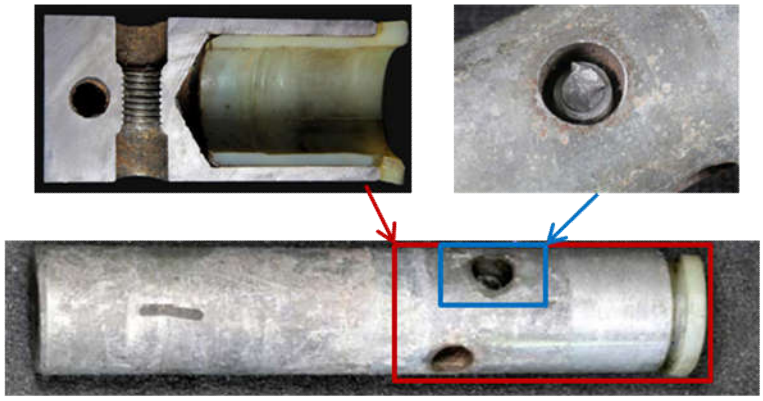

Fig. 1 Shaft sleeve and the damage morphology of fasten bolt.

The fracture of bolt was analyzed by the scanning electron microscope (SEM) referring to JB/T 6842-1993 <Test methods of scanning electron microscope>. The microstructure of longitudinal section near the fracture was analyzed after etching by the 4% nitric acid alcohol solution referring to GB/T 4340.1-2009 <Inspection methods of microstructure for metals>.

3. Results and Discussions

3.1. Macroscopic Fractography

Macroscopic fractography of the fasten bolt of a shaft sleeve of escalator stave is shown in Fig. 2. It can be seen that the fracture surface developed along the screw thread root. The fracture is much rougher in zone ‘A’ which has a step. The fracture of edge is relatively smooth. It is obvious that the pattern is leaning and spinning, which indicates that the fracture mode is torsion overload fracture.

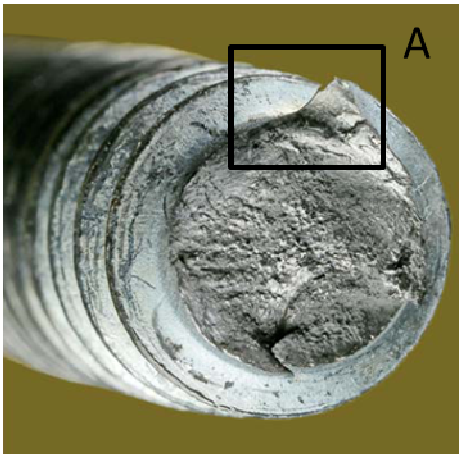

Fig. 2 Macroscopic fractography of the fasten bolt

3.2. SEM Analysis of Fracture

The fractography of fractured bolt under low magnification is shown in Fig. 3. It can be seen that all the fracture edge located at the screw thread root. There is downward sliding bruise at the 3 o'clock position edge. It's still visible that the subsurface is downward. The 6 o'clock position exhibits outside-in oblique fracture shape and has oblique crack step. There is bruise at the 9 o'clock position edge. The fracture surface exhibits bottom-up development. The central zone of fracture presents dimple pattern, which indicates forward overload tension crack type.

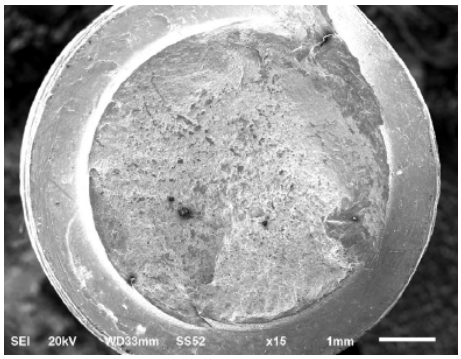

Fig. 3 Fractography of the fasten bolt

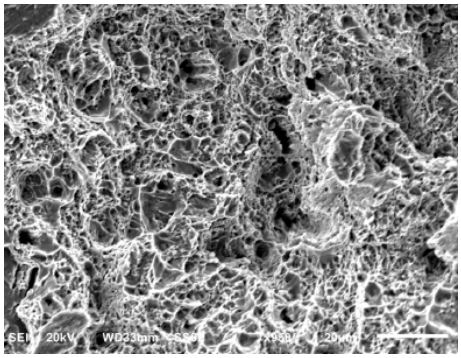

Fig. 4 Dimple morphology of the fracture central zone

3.3. Microstructure Analysis

The optical microstructure of the longitudinal section near the bolt fracture is shown in Fig. 5. It can be seen that the left fracture tends towards diagonal distribution. The diameter of fracture has relatively contract phenomenon which is caused by the deformation before fracture. The edge of the screw thread appears bright white which is related to decarbonisation. The screw thread has obviously deformation phenomenon. It can be seen from the optical microstructure of part A that the surface microstructure of screw thread is ferrite and only tiny amounts of sorbite. There is decarbonization phenomenon and the maximum depth is about 0.08mm. It also can be seen that there is diagonal zigzag micro-crack distributed on the screw thread and the length is about 0.2mm.The matrixes are sorbite and a few ferrite.

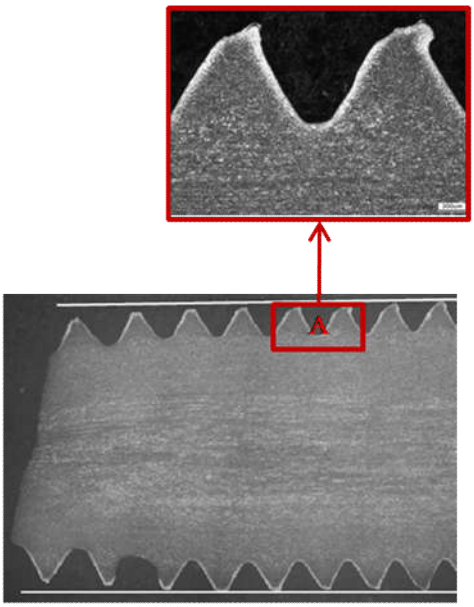

Fig. 5 Microstructure of longitudinal section near the bolt fracture

The microstructure of fracture central zone of the fasten bolt is shown in Fig. 6(a). It can be seen that there is no oxidation phenomenon on the fracture surface. The microstructures of the central zone of fracture are sorbite and undissolved massive ferrite. The microstructure of fracture boundary part of the fasten bolt is shown in Fig. 6(b). The left side is the screw root surface and the upside is the fracture surface. It can be seen that the surface microstructure of screw root is ferrite. There is no oxidation and decarbonization phenomenon on the fracture surface. The microstructures of the boundary part of fracture are sorbite and a few ferrite.

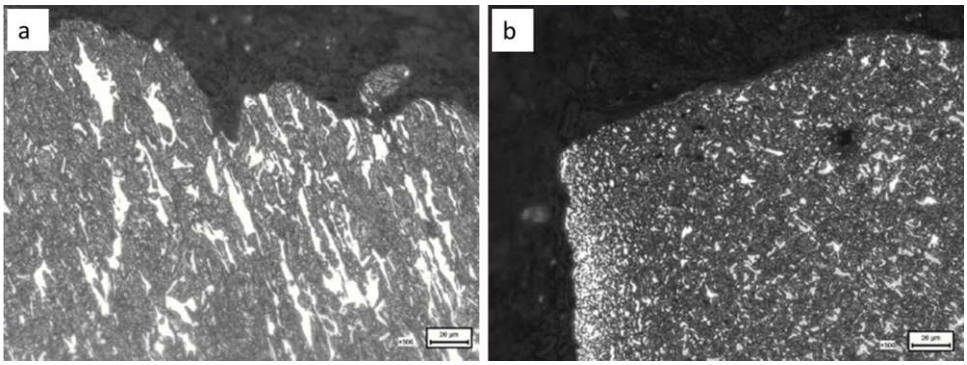

Fig. 6 Microstructure of (a) central zoneand (b) edge zone of the bolt fracture

4. Conclusion

The bolt screw thread has the phenomenon of superficial decarbonisation and the maximum depth is about 0.08mm, which has overstepped the standard requirement (≤0.015mm) of GB/T 3098.1-2010 <Mechanical properties of fasteners-Bolts, screws and studs>. The fracture mode of fasten bolt investigated in this paper is clockwise torsion overload fracture.

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