Failure Analysis of Escalator Step

Facai Ren[1], Yu Song[1] and Xiao Liang[1]

[1]Shanghai Institute of Special Equipment Inspection and Technical Research, Shanghai 200062, China

Corresponding author e-mail: caifaren@163.com

Abstract. The escalator step fractured during applications. The cause for escalator step fracture was investigated by means of scanning electron microscope, macroscopic fractography and optical microscope. The results indicate that some porosity defects distributed in the escalator step support. The fracture mode of escalator step is overload fracture.

1. Introduction

Escalators are widely used in public places such as subway, supermarkets and shopping malls. In recent years, with the widely use of escalators, the casualties and property losses caused by escalator are rising year by year [1]. Thus, the safe operation of the escalator is getting widespread attention in the society [2, 3]. In the past years, many researchers have studied the escalator step. Wang [4] designed an escalator step protection device to stop further injury after clamping on an escalator based on the mechanical principle and design theories, with the help of SolidWorks and CAD. This device can reduce the injury degree effectively. Liang et al. [5] analyzed the reasons of an accident caused by the lack of escalator steps from two aspects of human unsafe behavior and equipment unsafe state. The preventive measures from two levels of technical regulations and risk prevention were put forward to avoid the occurrence of similar accidents.

During runtime of the escalator in a shopping mall, about ten steps were arched upward and damaged due to the collision. After preliminary scene investigation, the main reason is that the support draft hole fractured. In this paper, the cause of fracture of support draft hole was analyzed using macro, scanning electron microscope and optical microscope.

2. Fracture Specimen and Analysis Method

The failure escalator step is shown in Fig. 1. The length and width of the escalator step are 1000mm and 400mm, respectively. It can be seen that the support draft holes and part of the step have been fractured. The transmission shaft, which is assembled to the support draft hole of escalator step, has serious plastic deformation.

The fracture of escalator step was analyzed by the scanning electron microscope (SEM) referring to JB/T 6842-1993 <Test methods of scanning electron microscope>. The microstructure of support draft hole was analyzed after etching by the mixed acid solution referring to GB/T 13298-2015 <Metal-inspection method of microstructure >.

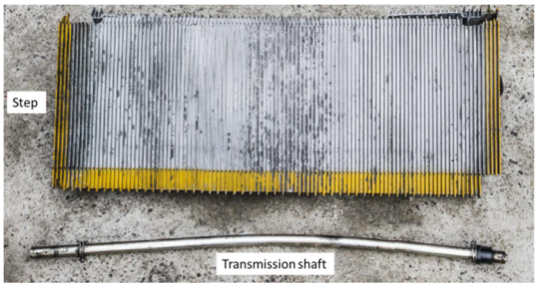

Figure 1. Step and transmission shaft.

3. Results and Discussions

3.1. Macroscopic Fractography

Macroscopic fractography of the escalator step is shown in Fig. 2. It can be seen that the step supports of both sides have fractured. Judged from the step deformation situation, the fracture of support close to the auxiliary wheel was caused by squeeze. The fractures of both sides are almost the same. It can be seen there is a herringbone pattern in the upper side of the fracture. There are lots of pit defects on the fracture surface of both sides. Referring to the drive direction of axis hole and transmission shaft, the bottom side fractured due to the squeeze with transmission shaft and the upper side fractured due to the squeeze with step.

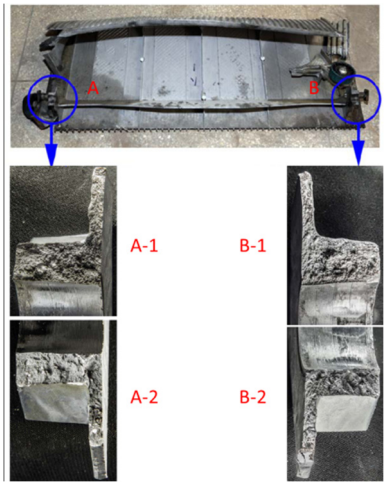

Figure 2. Macroscopic fractography of the escalator step support.

3.2. SEM Analysis of Fracture

The fractography of the fracture initiation region under low magnification is shown in Fig. 3. It can be seen that the fracture surface is relatively rough. Some deeper pits distributed in local region. After further observation, some flat regions with different size were found in the fracture initiation region. The largest length is about 1.7mm. The flat regions belong to cold lap defect.

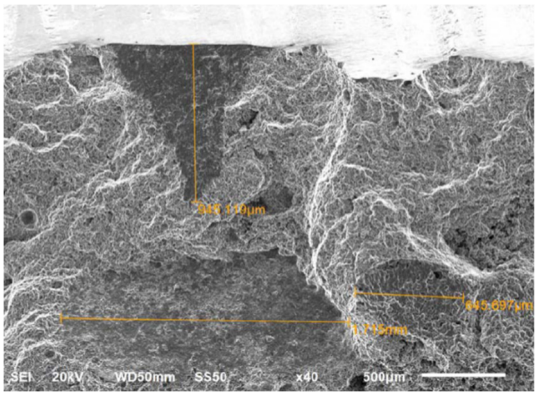

Figure 3. Fractography of the fracture initiation region.

The fractography of the fracture propagation region under low magnification is shown in Fig. 4. It can be seen that more porosity defects distributed in this region. The length and width of the largest porosity defect are about 5.5mm and 1.8mm, respectively. The fractography of the porosity defect under high magnification is shown in Fig. 5. The surface shows the free surface character.

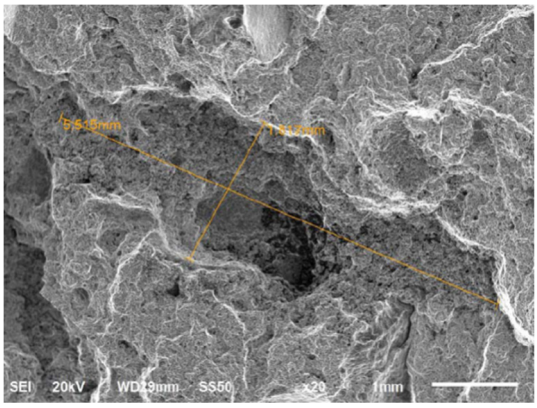

Figure 4. Fractography of the fracture propagation region.

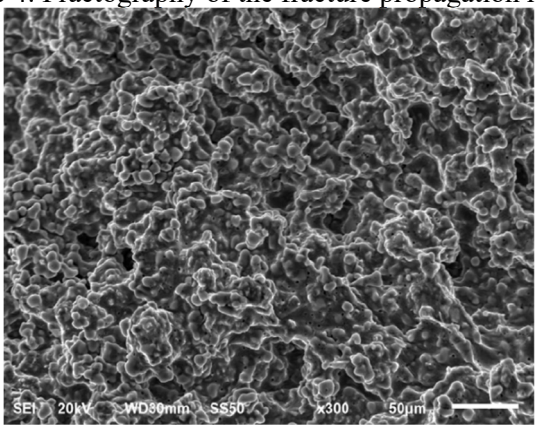

Figure 5. Fractography of the porosity defect.

3.3. Microstructure Analysis

The optical microstructure of the fracture surface region is shown in Fig. 6. It can be seen that there is no obvious plastic deformation and the surface is not very smooth. There are lots of porosity defects distributed in the fracture region. The matrixes are α (Al) phase and eutectic silicon phase. The optical

microstructure of the region away from fracture is shown in Fig. 7. There are also some porosity defects with different size. The matrixes of this region are also α (Al) phase and eutectic silicon phase.

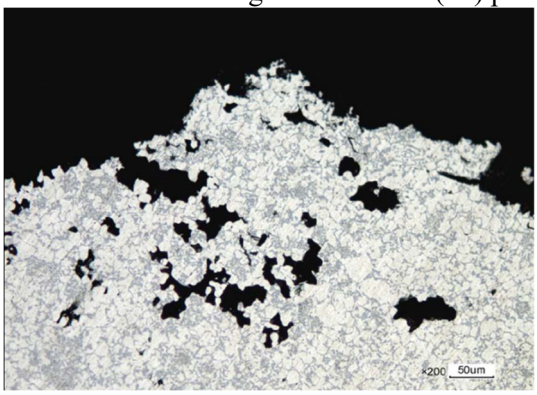

Figure 6. Macroscopic fractography of the escalator step and comb plate.

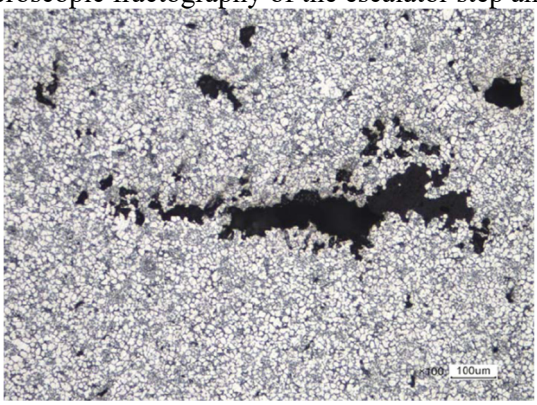

Figure 7. Macroscopic fractography of the escalator step and comb plate.

3.4. Chemical Composition Analysis

The chemical composition of the escalator step is shown in Table 1. Refer to GB/T 15115-2009 <Die casting aluminum alloys>, the chemical composition match to the technical requirement of YL102.

Table 1. Chemical composition of escalator step (wt.%).

Element	Si	Cu	Mn	Mg	Fe	Zn	Al
Escalator step	11.92	0.28	0.07	0.19	0.83	0.25	bal.
YL102	10.0~13.0	≤1.0	≤0.35	≤0.1	≤1.0	≤0.4	bal.

4. Conclusion

Based on the above analysis results, the fracture mode of escalator step investigated in this paper is overload fracture. The support draft hole bears the largest stress in service. At the same time, the escalator step supports have some porosity defects, which can reduce the strength of support. This also increases the probability of overload fracture under impact load.

References

[1] S.H. Ha, S.Z. Ren, C.X. Ma, Analysis on escalator driving chain fracture, Heat Treatment, 4 (2014) 58-61. (in Chinese)
[2] O. Bardyshev, V. Popov, P. Druzhinin, A. Bardyshev, Expert Review of Metro Escalators Safety, Transportation Research Procedia 20 (2017) 31-35.
[3] Y.Y. Xing, S. Dissanayake, J. Lu, S.J. Long, Y.X. Lou, An analysis of escalator-related injuries in metro stations in China, 2013–2015, Accident Analysis & Prevention (2017).

[4] J. Wang, Design and research on a safety protection device for reducing the accident damage of escalator, China Special Equipment Safety 34 (2018) 20-22.
[5] X. Liang, H.J. Shi, W.H. Huang, A case of injury caused by the lack of escalator steps, China Special Equipment Safety 33 (2017) 81-83.