Study on Performance of Aluminum Alloy Escalator Steps

Xiao Liang*, Facai Ren, Hongjun Shi, Yanbin Zhang and Zheyi Li
Shanghai Institute of Special Equipment Inspection and Technical Research, Shanghai 200062, PR China

*Corresponding author e-mail: liangxiao@ssei.cn
email: caifaren@163.com, hjshi@ssei.cn, zhangyb@ssei.cn, lizy@ssei.cn

Abstract. With the development of lightweight, aluminum alloy escalator steps are more and more widely used. This paper analyzes an escalator accident related to steps. At the same time, different types of aluminum alloy escalator steps are selected for fracture test, and the parameters such as fracture strength and maximum fracture deformation are analyzed. The fracture surface is analyzed by metallography and scanning electron microscope. The results show that most steps have metallurgical defects such as porosity and shrinkage. It is of great significance to scientifically design and manufacture aluminum alloy escalator steps and ensure their safe use.

1. Introduction
In recent years, with the development of urbanization, the application of escalator is becoming more and more common. By the end of 2020, China has about 600000 escalators. At the same time, the cases of escalator failure or accident caused by step damage see an obvious upward trend, which has seriously affected the personal safety of passengers and has attracted everyone's attention. Therefore, it is of great significance to improve the safety of escalator steps by analyzing the failure of escalator steps, testing aluminum alloy steps with different weights and studying the mechanical properties of aluminum alloy steps.

In recent years, many scholars have carried out a series of studies on the safety performance of escalators. Asensio-Lozano et al. [1] studied the role of strontium as modifier and titanium as refiner in aluminum alloy escalator steps processed by hot pressure die casting. Modifiers and refiners are very effective in changing the microstructure parameters such as volume fraction, grain size and shape of proeutectic phase. Wang et al. [2] studied the fatigue properties of 6005A aluminum alloy during friction stir welding. The results show that reducing porosity to reduce crack initiation and grain refinement to delay crack propagation are the main reasons for increasing the fatigue life of friction stir welding. Zhou et al. [3] studied the effect of different mass fraction of Zr on the adaptability/constructability of AA5083 aluminum alloy laser powder layer. Micro zirconium alloying in AA5083 aluminum alloy is an effective method to design corrosion-resistant aluminum alloy suitable for laser powder cladding manufacturing technology. Zhang et al. [4] studied the effects of different texture components on the crimping properties of AA6xxx aluminum alloy sheet. The analysis shows that the advantages of cube and cube texture components contribute to the crimping performance. Wang et al. [5] studied the bending properties of new aluminum alloy gusset plate composite joints through experiments and numerical analysis. The test results show that the flexural stiffness and flexural capacity of FGC joints are higher than those of traditional joints. Zhao et al. [6]...
studied the effects of microstructure, defects and stress distribution on the shear properties of 2219 aluminum alloy T-joint. It is found that the tensile strength of T-joint is better than that of base metal, but the shear strength is only about 40% of that of base metal.

In this paper, the aluminum alloy steps in an escalator accident are analyzed, and different types of aluminum alloy steps are tested and analyzed. The mechanical properties and fracture failure mechanism of aluminum alloy escalator steps are studied.

2. Analysis of aluminum alloy escalator steps in accident

2.1. Macroscopic appearance of escalator step in an accident

During the ascending process of an escalator in a shopping mall, the steps protruded upward and hit the upper comb plate, which blocked the operation of the steps, and then damaged six adjacent steps. The macro morphology of one damaged step is shown in Fig. 1. It can be seen that the main wheel hole, auxiliary wheel hole and both ends of the riser of the step are broken, and a crack is found in the middle of the riser. The length of the crack is about 15mm.

![Figure 1. Damaged escalator step.](image)

2.2. Chemical composition analysis of escalator step

Take samples on the elevator step for chemical analysis. In addition to the main Al element, the analysis results of relevant elements are shown in Table 1. It can be seen from the chemical analysis results that the material of the escalator step is equivalent to YL102 in GB/T 15115-2009 <Die casting aluminum alloys>.

| Element | Si   | Cu   | Fe   | Zn    | Mg    | Mn |
|---------|------|------|------|-------|-------|----|
| Sample  | 11.88| 0.025| 0.85 | <0.005| 0.019 | 0.20|
| YL102 (GB/T 15115-2009) | 10.0-13.0 | ≤1.00 | ≤1.00 | ≤0.40 | ≤0.10 | ≤0.35 |

2.3. SEM analysis of fracture surface

The SEM morphology of the fracture of the auxiliary wheel is shown in Fig. 2. The morphology of the initial area of the section is shown in Fig. 2 (a), which is a quasi cleavage pattern, and no obvious casting defects are found at its edge. However, cold bean flake pores are found in the sub marginal area. The morphology of the extended area is shown in Fig. 2 (b), and the scratch area and loose area can be seen. In the loose area, dendrite particles are accompanied by silicon in the form of micro porosity. Quasi cleavage pattern and massive silicon phase can still be seen under the round scratch area.
3. Performance analysis of aluminum alloy escalator steps

3.1. Material and experimental
In order to study the mechanical properties of aluminum alloy escalator steps, two sizes of steps with width of 1000mm and 800mm are selected for breaking strength test, as shown in Fig. 3. The escalator step is fixed on the inclined plane, and a steel base plate is used to exert a vertical force on the central part of the step tread, increasing the vertical force until the step breaks or fails.

3.2. Analysis of experimental results
The breaking strength test results of aluminum alloy escalator steps with width of 1000mm and 800mm are shown in Table 2. In this experiment, the breaking strength range of aluminum alloy escalator steps is 19.86kN-38.56kN, and the maximum breaking deformation range is 13.70mm-30.80mm. The variation trend of breaking strength and maximum breaking deformation with the weight of escalator steps is shown in Fig. 4. The analysis shows that the breaking strength of escalator steps with a width of 800mm is more dispersed than that with a width of 1000mm. For the maximum breaking deformation, it is just the opposite.
3.3. Fracture mechanism analysis
The results show that the microstructure is mainly α(Al) and eutectic silicon, some samples have a small amount of Fe phase. There are many loose holes in two samples. Through SEM analysis, the section of most samples is rough and brittle cracking, and there are metallurgical defects such as porosity, shrinkage cavity and cold shut on the section.

4. Conclusion
The aluminum alloy escalator steps in the accident have loose defects. Through the experimental analysis of different types of aluminum alloy escalator steps, it is found that most of them have metallurgical defects such as porosity and shrinkage, which have a certain impact on the mechanical properties of the steps.

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