Performance analysis on an in-service escalator driving chain

Facai Ren¹, Xiaochang Liu¹, Xiao Liang¹ and Xinghua Wu¹

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

Corresponding author e-mail: caifaren@163.com

Abstract. The performances of an in-service escalator driving chain were investigated. The tensile properties were analyzed by conducting tensile tests. The chain plate was investigated based on the optical microscope and scanning electron microscope analysis. The results show that the surface of the outer chain plate has poor and decarbonized phenomena.

1. Introduction

In recent years, escalator backsliding injuries often occur due to the breakage of driving chain, which is often related to improper lubrication and maintenance of driving chain. Therefore, especially for escalators without chain-breaking protection devices (additional brakes), whether the quality of in-service driving chains can be effectively tracked and controlled is directly related to the accident risk of special equipment and the personal safety of passengers.

In the past, some researchers investigated the tensile properties of different materials. Yang et al. [1] measured the tensile properties of subzones in the CrMoV welded joint by miniature specimens. The results show that the fracture occurred at the heat affected zone region close to the base metal for the miniature specimen. Wang et al. [2] investigated the properties of early age strength ultra-high performance concrete made with calcium sulfoaluminate cement. Wu et al. [3] investigated the effect of Ca content on the microstructure and tensile property of AE42 alloy. The results show that the addition of Ca significantly improved the yield strength of AE42 alloy. Ding et al. [4] studied the tensile behaviour of as-received and aged Alloy 709. The results show that the ultimate strength of both materials is strongly influenced by the temperature. Wronski et al. [5] investigated the qualitative and quantitative behavior of titanium T40 during tensile loading. The results show that more frequent subgrain formation and higher orientation spread was observed in the sample deformed along rolling direction. Sen et al. [6] investigated the tensile behavior of three microstructures of a high strength near β titanium alloy.

In this paper, the escalator driving chains serving in the urban rail transit area are sampled and analyzed. This research has important engineering significance and research value for life prediction, maintenance and clear replacement cycle of escalator driving chain.

2. Sample and Experimental

The escalator driving chain sample used for three years is shown in Fig. 1. It can be seen that all of them are dismountable connection chains with open pins. Oil and grease were distributed on the surface of driving chain samples, and no dry oil area and rust were observed, and no obvious damage was observed. Two sections of tension samples were taken from the escalator driving chain sample, each section contains five free chains, and tension tests were carried out respectively. The tensile tests refer to GB/T 1243-2006 Short-pitch transmission precision roller and bush chains, attachments and...
associated chain sprockets. Oil and grease were cleaned on the surface of driving chain samples, and metallographic observation, chemical composition detection and SEM observation were carried out.

Figure 1. Escalator driving chain sample used for three years.

3. Results and Discussions

3.1. Tensile properties

The load-displacement curves of escalator driving chain used for three years are shown in Fig. 2. The tensile strength are 353.92 KN and 352.38 KN, respectively. The results meet the strength requirements of 24A-2 typed driving chain in standard GB/T 1243-2006 Short-pitch transmission precision roller and bush chains, attachments and associated chain sprockets.

Figure 2. The load-displacement curves of escalator driving chain.

The macroscopic fracture morphology of the tensile test specimen is shown in Fig. 3. It can be seen that the outer chain plate and pin axle on both sides fall off; the connecting pin hole of the two inner chains at the same end is cracked, and the cross section is deformed and sheared; the two pin axles at this place are bulging and bending from the middle to both sides.

Figure 3. Macroscopic fracture morphology of the tensile test specimen.
3.2. Metallographic microstructure analysis
The metallographic analysis was carried out on the normal section of the outer chain plate. The microstructure distribution morphology of the wear and non-wear areas is shown in Fig. 4(a). The upper left side of the graph is the wear area and the upper right side is the non-wear area. There is no poor and decarbonization phenomenon on the surface of the wear area, as shown in Fig. 4(b). In the non-wear area, there are poor and decarbonization phenomena on the surface, and the depth is about 0.02 mm (the thickness of chain plate is about 4.80 mm), as shown in Fig. 4(c). The cardiac tissue is sorbite. Poverty and decarbonization can be seen on the outer surface of the outer chain board with a depth of about 0.02 mm, as shown in Fig. 4(d).

![Figure 4. Metallographic microstructure of the outer chain plate.](image)

3.3. SEM analysis
The wear area morphology of the outer chain plate at low magnification is shown in Fig. 5(a). It can be seen that the wear mark distribution is circular. At high magnification as shown in Fig. 5(b), the grooves along the annular distribution can be seen. The grooves are locally deep and show the shape of ‘plough groove’. The morphology of the inner chain plate wear marks at low magnification is shown in Fig. 5(c). It can be seen that the wear marks are circularly distributed. At high magnification, the grooves along the annular distribution can be seen, locally deep, showing a plough groove’ shape, as shown in Fig. 5(d).

![Figure 5. SEM analysis of the outer chain plate.](image)
3.4. Chemical composition analysis

The chemical composition of chain plate is shown in Table 1. The results show that the inner and outer chain plate are both 45Mn steel referring to GB/T 699-1999 < Quality carbon structural steels >.

| Element       | C   | S       | Si    | Mn  | P     | Cr    | Ni  | Mo  | Cu  |
|---------------|-----|---------|-------|-----|-------|-------|-----|-----|-----|
| Outer chain plate | 0.44 | 0.009 | 0.23  | 1.00| 0.02  | 0.10  | 0.04| 0.001| 0.05|
| Inner chain plate | 0.44 | 0.008 | 0.20  | 0.98| 0.03  | 0.10  | 0.04| 0.001| 0.06|
| 45Mn (GB/T 699-1999) | 0.42 | ≤ 0.17 | 0.70  | ≤   | ≤     | ≤     | ≤  | ≤   | ≤   |

4. Conclusion

From the chemical composition analysis results, it can be seen that the material of the outer and inner chain plate is equivalent to 45Mn. The tensile test results show that the tensile strength of the chain meets the relevant technical requirements. From the metallographic analysis results, poor and decarbonized phenomena can be seen on the surface of the outer chain plate. From the distribution and morphology of decarbonization, it can be inferred that decarbonization occurs in the process of heat treatment.

References

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