Simulation analysis on fatigue life of escalator main drive chain

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Abstract. This paper analyzes the fatigue life of the main drive chain of escalator in subway station. By analyzing the force of the main drive chain, the maximum and minimum force values of the main drive chain are obtained. The fatigue life of the main drive chain is analyzed based on the stress and fluctuating load, and the fatigue life of the escalator main drive chain in the subway station is obtained.

1. Introduction
Due to the long running time and poor load condition of escalators in metro stations, the risk of main drive chain fracture of escalators in metro stations is relatively high. The main drive chain is the most important part in the power transmission process of escalator. Once the main drive chain breaks, the brake of the drive device will lose the connection with the step. At this time, the ladder will be in the out of control state, and the escalator will slide down under the action of load.

The researchers studied the failure causes of various chains. Mamiya et al. [1] developed an out of plane bending fatigue test device for chain link and studied the fatigue behavior of chain under out of plane bending condition. The results show that stress range, average stress and joint angle have influence on fatigue life. Pantazopoulos et al. [2] analyzed the fracture failure reason of copper tube drawing machine chain. The results show that the fracture failure is caused by the fatigue in the eye area of the chain link. Zhao et al. [3] analyzed the fatigue life of excavator track link and put forward the fatigue life analysis method of key components chain of crawler vehicle. The results show that the fatigue life of the chain is the longest in the horizontal straight line state and the shortest in the fulcrum turning state. Perez et al. [4] proposed a fatigue life prediction method of mooring chain under tensile load. Pantazopoulos et al. [5] analyzed the cause of stainless steel belt fracture failure. The results show that the failure is caused by the bending fatigue from the surface of the strip. Idapalapati et al. [6] studied the failure reason of the broken steel pin of the chain component of the continuous cold drawing machine in service. The results show that the high stress concentration factor and the soft annealed material used in the chain assembly lead to fatigue. Papadopoulou et al. [7] studied the failure reason of the broken steel pin of the chain component of the continuous cold drawing machine in service. The results show that the high stress concentration factor and the soft annealed material used in the chain assembly lead to fatigue. Zarandi et al. [8] studied the failure reason of the broken steel pin of the chain component of the continuous cold drawing machine in service. The results show that the high stress concentration factor and the soft annealed material used in the chain assembly lead to fatigue.

In this paper, the strength and fatigue life of the escalator main drive chain were analyzed.
2. Numerical simulation parameters and model

2.1. Numerical simulation parameters
In this study, the main drive chain of escalator in a subway station is taken as the research object, and
the fatigue life simulation model of the chain is established. The main drive chain of escalator is
shown in Fig. 1. After consulting the technical data of the escalator and combining with the field
measurement, the following data are obtained. The main drive chain plate is made of 45Mn, the sleeve
is made of 20Mn, and the pin shaft is made of 20CrMnMo. The running speed of the escalator is
0.5m/s and the lifting height is 4.7m. The daily operation time of escalator is 17 hours, and the peak
time of carrying (full load) is 4 hours. The lubrication mode of main drive chain is automatic
lubrication, and the frequency is 300s/10h. The time interval of metro trains is 3-4 minutes.

2.2. Numerical simulation model
The numerical simulation model of the main drive chain is shown in Figure 2. Fatigue life can be
estimated by fatigue cumulative damage law and the simplest is linear Miner fatigue rule. According
to this rule, partial fatigue damage can be added linearly, and fracture occurs when the damage value
reaches 1. Combined with the fatigue life test results, when the elongation of the main drive chain
reaches 3%, the main drive chain breaks. The fatigue damage value is 0.21 by fitting calculation.
Therefore, 0.21 is taken as the extreme value of fatigue life in this study.
3. Results and Discussions

3.1. Kinematics simulation analysis
According to the collected data, the rotational speed of the driving wheel is 4.69rad/s, and the torque applied to the driven wheel is 2162.5Nm when the escalator is fully loaded. No. 150 chain link (yellow link as shown in Fig. 2 (a)) is arbitrarily extracted as the monitoring object. The speed curve and force curve of the chain link are shown in Fig. 3 and Fig. 4 respectively. Through the kinematic analysis of the main drive chain, it can be concluded that the tension on the tight side of the chain link is the largest, which is 5800N, and the tension on the loose side is the minimum, which is 400N.

3.2. Strength analysis
One end of the chain is fixed and constrained, and the other end is loaded with the maximum tensile force of 5800N or the minimum tensile force of 400N. The stress results of the chain under the maximum and minimum tension conditions are shown in Fig. 5. When the chain is subjected to the maximum tension, as shown in Fig. 5 (a), the maximum stress occurs outside the inner chain plate, which is 450MPa. When the chain is subjected to the minimum tension, as shown in Fig. 5 (b), the maximum stress occurs outside the inner chain plate, which is 447.6MPa. By comparing the results of the above maximum and minimum tension conditions, it can be found that the maximum stress occurs...
on the outside of the inner chain plate, and the stress on the inner chain plate is mainly caused by the interference fit between the sleeve and the inner chain plate, and the tension has little effect on the stress.

Figure 5. Numerical simulation results of strength.

3.3. Fatigue life analysis
In order to save calculation time, some chain links are selected for fatigue life calculation. The calculation results are shown in Fig. 6. Thus, it can be concluded that the outer chain plate, sleeve and pin shaft of the chain link are infinite life as shown in Fig. 6 (a). The part with the shortest life is the inner chain plate, as shown in Fig. 6 (b), which is 1.338e7 cycles, located outside the inner chain plate.

Figure 6. Numerical simulation results of fatigue life.

The simulation results show that the fatigue life of the main drive chain is 1.338e7 cycles, i.e. 27450h, when the wear elongation of the main drive chain reaches 3% (i.e. the fatigue damage is 0.21). Considering the actual service load condition, that is, the escalator runs for 17h every day, including 4h under full load condition, the fatigue life of the main drive chain under the current service load condition is 116663h. The fatigue life of the main drive chain is about 18.8 years when the escalator runs for 17 hours a day.

4. Conclusion
Through the fatigue life simulation analysis of the main drive chain, the following conclusions can be drawn: the outer chain plate, sleeve and pin shaft parts of the chain link are infinite life, and the part with the shortest life is the inner chain plate. Under the current load condition, the fatigue life of the main drive chain is 18.8 years.
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