Failure Analysis of An Elevator Brake Plunger

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Abstract. A failure analysis was performed on an elevator brake plunger. The macroscopic morphology and metallographic microstructure of the elevator brake plunger were investigated based on the optical microscope and scanning electron microscope analysis. The results showed that the material of elevator brake plunger doesn’t meet the technical standard of DT4.

1. Introduction
Elevator brake is one of the most important safety and security parts. In case of emergency, elevator brake can enable the elevator cabin to slow down and stop manner. Thus, the failure analysis of elevator brake plunger is very important to prevent similar accidents from happening again.

Thike et al. [1] proposed a rule-case based hybrid reasoning method for materials failure analysis. The results show that this method can reduce manual failure analysis work of domain experts. Shaalini et al. [2] discussed the difficulties faced with, the failure analysis technique used, the bottleneck of the 14 nm fin-field effect transistor failure analysis by old technology node failure analysis equipment, and the failure analysis findings. Zhang et al. [3] performed a failure analysis on a cracked handhole flange. The results show that liquation crack was caused by the low-melting point annular oxide inclusions and silicate eutectic. Liu et al. [4] analyzed the fracture failure tubing using a series of comprehensive failure analysis methods and proposed the fracture reason, characteristic and mechanism of the fracture tubing. The results show that the formation of pits and occurrence of cracks induce an environmental sensitive cracking. Simões et al. [5] presented a failure analysis of a filling valve from a beer filler, which integrated a packaging line and leaded to the production cadence. Gomes et al. [6] discussed the influence of initial imperfections in the material, as well as the influence of the loadings applied to the crankshaft.

In this paper, the reasons for the failure of elevator brake plunger were investigated. The microstructure, chemical composition and micro-hardness of elevator brake plunger were analyzed.

2. Macroscopic morphology
The macroscopic morphology of elevator brake plunger is shown in Fig. 1. The out diameter and length of elevator brake plunger are 95mm and 107.5mm, respectively. One end of the plunger is fitted with magnetic sleeve and the other is fitted with the supporting shaft. The outer circle of the supporting shaft is riveted with a copper sleeve. There are some fine lines distributed along the circumference on the surface of copper sleeve. These are normal rotating friction traces. No longitudinal trace is found on the surface of copper sleeve, which indicates that no abnormal friction
damage happened in this area. The wear phenomenon is obvious on the mating zone of plunger and magnetic sleeve. The width of mating mark is in the range of 22.2mm~23.2mm. Some wear debris are found adhere to the surface.

![Figure 1. Macroscopic morphology of elevator brake plunger.](image)

3. Results and Discussions

3.1. Metallographic microstructure analysis

The cross-section of wear zone was analyzed by optical microscope. The results show that the microstructures are ferrite and a little pearlite as shown in Fig. 2(a). Sunken rheology is found on the wear surface of the cross-section. The depth is about 0.024mm. The folded sunken crack rheology with the depth of 0.08mm is also found as shown in Fig. 2(b). As shown in Fig. 2(c), there are gray oxides in the crack. The gray oxides are also found embedded into matrix as shown in Fig. 2(d).
3.2. SEM analysis

Some elevator brake plunger samples machined from wear zone were analyzed by scanning electron microscope (SEM). The low multiple SEM image of this zone is shown in Fig. 3(a). It can be seen that there are some discontinuous micro-pits parallel distributed along the motion direction. The high multiple SEM image of this zone is shown in Fig. 3(b). It can be seen that there are rheological and strained phenomena along the motion direction. The detailed tension crack and strained morphology is shown in Fig. 3(c). The embedded rheological morphology by extraneous material is shown in Fig. 3(d). The extraneous material was analyzed by energy dispersive x-ray analysis. The results show that the Fe content is about 75.73%, Zn content is about 6.43% and O content is about 4.84%.

3.3. Chemical composition analysis

The chemical composition of escalator brake plunger is shown in Table 1. The chemical composition of escalator brake plunger is compared with DT4 referring to GB/T 6983-2008 < Soft magnetic iron >. The results show that the C, Si, P and Mn contents are beyond the standard while the Al content is below standard.
Table 1 Chemical composition of elevator brake plunger (wt.%).

| Element | C   | S   | Si  | Mn  | P   | Cr  | Ni  | Al  | Cu  |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Plunger | 0.096 | 0.005 | 0.20 | 0.48 | 0.016 | 0.031 | 0.018 | 0.032 | 0.030 |
| DT4     | ≤0.010 | ≤0.010 | ≤0.1 | ≤0.2 | ≤0.015 | ≤0.10 | ≤0.05 | 0.20~ | ≤0.05 |

3.4. Micro-hardness analysis

The Vickers hardness values of the center for elevator brake plunger are shown in Table 2. The average value of Vickers hardness is about 137.9.

Table 2 Vickers hardness of elevator brake plunger.

| Points | 1    | 2    | 3    | 4    | 5    | Average value |
|--------|------|------|------|------|------|---------------|
| Vickers hardness (HV1) | 136.5 | 138.1 | 139.2 | 137.3 | 138.4 | 137.9          |

4. Conclusion

The material of elevator brake plunger doesn’t meet the technical standard of DT4 referring to GB/T 6983-2008 < Soft magnetic iron >. The microstructures of elevator brake plunger are ferrite and a little pearlite.

References

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