

Investigation on cause of the elevator turbine wear

J Zhang¹, W P Ouyang² and J A Xue²

¹ Fengxian District Special Equipment Inspection Institute of Shanghai Supervision, Shanghai, No. 89 Jianghai South Road, China

² Shanghai Institute of Special Equipment Inspection and Technical Research, Shanghai, No. 915, Jinshajiang Road, China

ouyangweipingvi@163.com

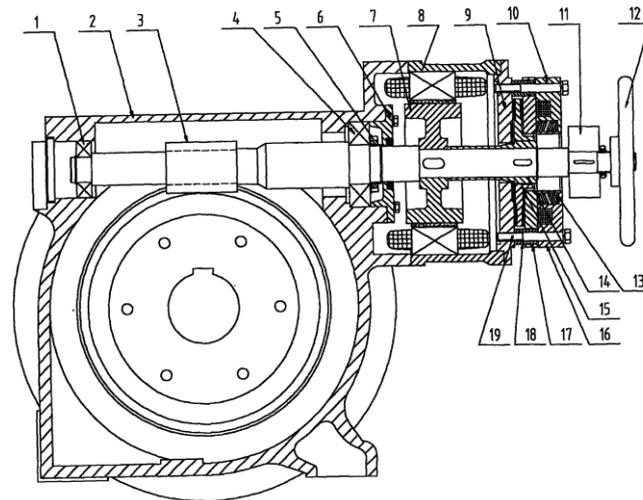
Abstract. Elevator traction turbine is often worn for various reasons, causing serious safety hazard. It is explained the main causes of traction wheel wear in detail in combination with a large number of engineering experience. The effect of turbine wear on the actual operation of the elevator is verified by contrast experiment, which is helpful to identify risks early. It is put forward on some reasonable suggestions for elevator inspection, maintenance and management.

1. Introduction

Elevator tractors, also known as elevator mainframe, are the power equipment of the elevator, which is used to convey and transmit power to make the elevator run. According to the deceleration mode, it could consist of gear tractor and the gearless tractor^[1-3]. The gear tractor has a set of parts that decelerate the transmission by the worm and gear. It has the advantages of large transmission ratio, smaller noise, more stable transmission and so on. When the worm is driven by worm gear, its efficiency is low with the ability of self-locking. It could be increased the safety of the elevator due to better brake torque of the elevator. With the advent of gearless PMSM, the drive way of traditional elevator tractor has been changed, which may possibly replace the traditional gear tractors in the future^[3]. But the gear tractor is still widely used in elevator areas due to its advantages and low maintenance, especially in special occasions such as large weight, low speed and so on.

It is obviously seen that the most important part of gear tractor with worm and gear for decelerating transmission is the worm gear transmission pair besides motor, as shown in Fig.1. It not only transfers kinetic energy of the motor, but also plays a role in reducing speed and increasing torque. In practice, the tractor turbine is often worn for various reasons, which is not easy to find out. It could lead to serious accidents if not handled in time. Therefore, it is necessary to study the cause of wear and its effect on the tractor turbine. It is useful to find the hidden danger in time to reduce the accident risk^[4-7]. It is mainly studied on the phenomenon and cause of the elevator traction turbine wear, and a diagnostic method for judging the wear of elevator turbines is proposed based on the phenomenon caused by the wear of elevator turbines.





1、4	Worm bearing	7	Motor coil	13	Rubber sealing ring
2	Tractor shell	8	Motor shell	14	Rubber washer
3	Worm	9	Motor cover	15	Fan
5	Check ring	11	Rotary encoder	16	Motor shell
6	End cover	12	Hand wheel	17	Set collar
18	Bolt	19	Bolt		

Figure 1. Gear tractor with worm and gear for decelerate transmission

2. Effect of worm gear wear

Worm and gear are the main mechanical transmission structure, and the national standard GB10089-1988 gives a detailed description of its precision. It is shown that the serious wear of the worm wheel causes the tooth profile error and the tooth thickness deviation, which directly leads to the worm pair's backlash enlargement.

The national standard GB/T31821-2015 stipulates technical conditions for the scrap of main parts of elevators. It is noted that the gear teeth appear serious failure, such as plastic deformation, fracture, crack, pitting, gluing and wear, which can be used as scrap condition. Therefore, worm pairs are also essential for the safe operation of elevators.

As shown in Figure 2, two worm wheels A and B come from two completely identical tractors, which have the same brand model and working environment. However, its contour and surface are still smooth, and there are no any signs of wear and pitting, and gear oil is also viscous. But B not only has a serious uneven surface, but also compared with the original thickness size has resulted in serious wear thinning. Even in the addendum, there have been defects, and worm shape is no longer smooth. At the same time, the gear oil produces foam and becomes muddy. So the problem of worm wheel B is very serious.



Figure 2. Worm wheel surface of two gear tractors

The two charts as shown in Figure 3 and Table 1 are the vibration data measured during the operation of the elevator. It could be seen that the car of the elevator not only exceeds the standard in horizontal and vertical directions, but also has a great noise when the elevator is running based on the Figure 3 and Table 1. It has a great relationship with the wear of the worm wheel. Worm transmission will have sliding friction. The serious wear will result in reduction of contact precision and reverse hysteresis error. If the worm will be still run, the worm tooth surface will be aggravated, the vibration of the car will increase, and the comfort of the car will be reduced. In addition, if the elevator runs in reverse, the tooth thickness will decrease and the worm pair's backlash will increase, which will increase the reverse hysteresis error of the elevator. The whole process will lead to a sudden drop or rise when the elevator starts. If the elevator is utilized under heavy load, it may cause gear teeth to break and the transmission system to fail. The arrester acts on the output side of the motor and it is placed on the same side of the worm. If the car stalls down or rises, it will trigger the speed limit switch and cut off the power supply of the motor and arrester. However, even if the arrester is operated, there is no way to stop the stalled car. If the speed limiter can't operate effectively, then the elevator will become very dangerous and cause grave consequences.

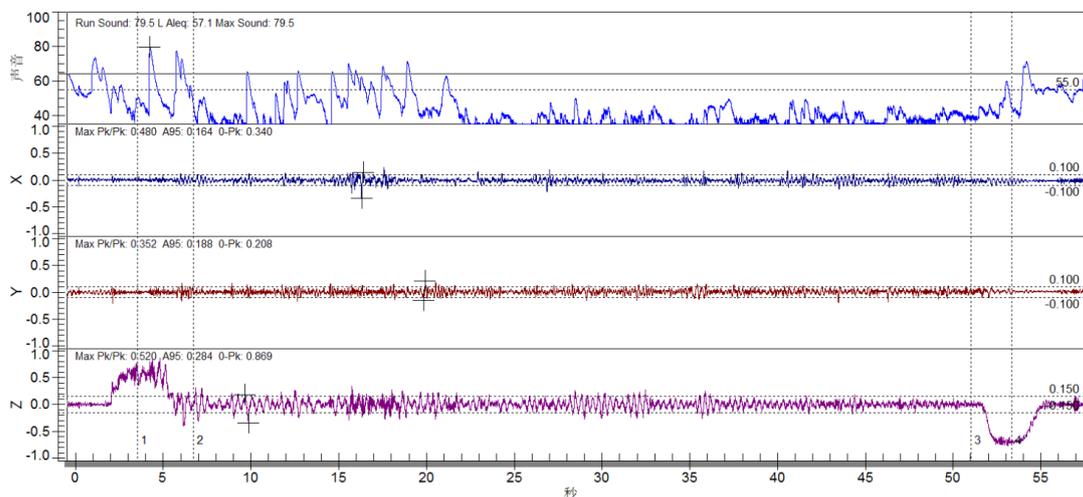


Figure 3. Noise and vibration waveform
Table 1. Comparison of measured data

ISO Ride Quality (m/s^2)	X	Y	Z	Jeck Zone
Max Pk to Pk	0.208	0.160	0.448	0.428
A95	0.084	0.084	0.284	0.008
Sound Level dB(A)	Full Run	Pre-Run	Post-Run	Full Record
Max	79.5	73.6	71.0	79.5
L ALeq	57.1	61.9	59.6	57.9

Raw Data (m/s^2)	X	Y	Z
Max Pk to Pk	0.480	0.352	0.520
A95	0.164	0.188	0.284
Max 0 to Pk	0.340	0.208	0.869
Performance	Max	95	Average
Velocity (m/s)	1.74	1.72	
Jerk (m/s^3)	1.2		
Acceleration (m/s^2)	0.773	0.688	0.546
Deceleration (m/s^2)	0.716	0.704	0.627
Distance Travelled	86.74		

Analysis	Measured	Limit	% Limit
Max horizontal Vib .ISO (m/s ²)	0.208	0.200	104.07
Max Vertical Vib .ISO (m/s ³)	0.448	0.300	149.43
Max Jerk (m/s ³)	1.2	2.5	47.8
Max Velocity (m/s)	1.74	1.60	108.9
Max Acceleration (m/s ²)	0.773	1.500	51.501
Max Sound Level dB(A)	79.5	55.0	+24.5 dB

3. Reason of worm gear wear

Causes of worm gear wear referring to the relevant data and combining with previous inspection experience and literatures^[8-11] are mainly attributed to the following aspects:

- It is caused by the quality problem or performance degradation due to the long time service. The material of worm gear is improper or degenerated, whose hardness and strength are not enough.
- The reason may be due to the tractor seal aging, gear oil leakage, resulting in the gearbox oil level drops, the two conjugate tooth profiles surface without oil film protection under high strength condition, and then the temperature rises rapidly. So this series of processes cause severe wear on the surface of the worm wheel.
- The gear oil may be mixed with hard impurities, such as sand, metal chips, etc. When the worm and gear is running, these impurities are formed by cutting and scraping the two conjugate tooth surface, which wear the tooth surfaces. If iron scraps produced by wear could not be cleaned up in time, the gear oil and impurities in the gearbox are not changed. The impurities will be accumulated more and more. So this series of processes cause severe wear on the surface of the worm wheel.
- In order to reduce cost, the gear oil added by the maintenance unit does not match the worm gear, or the new gear oil is not replaced for a long time. For this case, the viscosity of the original gear oil has dropped down, and it may have been deteriorated after mixing air and moisture, so the worm and gear could not be effectively lubricated and cooled. This process causes severe wear on the surface of the worm wheel.
- It may be caused by the failure of the bearing fixed at the two ends of the worm gear, or failure to be effectively fixed, resulting in the axially moving or radial run of the worm gear when running. This situation leads to worm pair, middle plane and axis angle deviation, which makes the worm and motor output shaft could not guarantee accurate concentricity. So it results in increase of vibration and the sliding friction of the gear surface in the running. The entire process resulted in severe wear on the surface of the worm wheel.

4. Preventive measures

Worm gear transmission pair should always keep contact with good accuracy, sufficient and clean lubrication, rated load and speed, suitable temperature, and good cooling conditions, and the kinetic energy output of the motor could stably transmitted to the traction wheel and the wire rope to make the car of elevator run smoothly. When confirming the worm gear surface with serious wear, the use unit and maintenance unit reached the point immediately. In order to protect the residents' safety and avoid unnecessary accidents, the elevator immediately stops using, and replaces the worm wheel in time, and check the related parts comprehensively. The preventive measures are shown below:

- When the elevator is regularly maintained, especially when replacing gear oil, pay attention to ascertain whether there is pitting or abrasion on the surface of the worm wheel. Open the oil tank covers, and check the whole worm surface carefully through maintenance operation;
- According to the elevator's usual environment, use condition, use frequency, maintenance unit needs to replace the suitable gear oil regularly. In addition, by checking the existence of impurities or ablation in the old oil, we can judge the operation and wear of the gearbox;

- During the regular maintenance, maintenance staffs can touch the tractor shell to determine whether there are phenomena of oil temperature rising, trembling vibration, decreasing efficiency and noise increasing when the gearbox is running, so as to judge whether the worm gear meshing is normal;
- When the wear is serious, we can judge whether the tractor runs normally by riding the car to feel its running stability;
- Elevator inspectors should give attention to the wear of worm gear, the quality of gear oil and oil level. If necessary, we can also measure the circumferential backlash of the worm wheel;

5. Conclusion

The elevator is a major vehicle for manned, so we must put the safe operation in the first place. Gearbox is an important part for elevator. Whether part could work normally depends on not only the design and manufacture, but also the daily maintenance. Only the gearbox is working normally, which could make the elevator run safely and smoothly.

References

- [1] Xin M, Wu D J, Liu Z K, Liu Q and Lu L 2016 *Small & Spec. Electr. Mach.* **5** 29.
- [2] Yao Q L 2002 *Chin. Elev.* **7**
- [3] Huang X 2005 *Chin. Elev.* **10** 28
- [4] Guo J Y 2016 *Chin. Spec. Equip. Saf.* **8** 62
- [5] Huang S Y 2015 *Mach. China* **10** 2
- [6] Yu M H 2016 *Eng. Technol.* **9** 00258
- [7] Dai K, Lu Y, Han J J and Li J J 2013 *Chin. Sci. Technol. Achi.* **21** 49
- [8] Jia J H and Ding G L 2014 *Maschinen Markt* **27** 51
- [9] Wang H R 2013 *Lift. Transp. Mach.* **3** 104
- [10] Wang J P and Chen F 2014 *Archit. Eng. Technol. Des.* **34** 27
- [11] Xin H B, Yang H W, Zhao Y C, Chang C and Bian J 2016 *Econ. Manage.* **5** 00161