Labyrinth structure sealing performance on grounding device of railway passenger vehicles

Gang Li¹, Xiangli Lin¹, Yingying Liu¹, Lun Li¹, Qingshan Liu¹, Jishun Guo¹, Zilian Zhao²

¹CRRC Qing Dao Si Fang Rolling Stock Research Institute CO., LTD.  
²Qingdao University of Science & Technology, China

Abstract. In this paper, the function of isolating carbon powder and water in the labyrinth structure on Grounding Device of Railway Passenger Vehicles is studied. The possibility of carbon powder and water entering the bearing through the labyrinth structure under the condition of seal failure of the grounding device is analyzed.

Keywords: Grounding device; Labyrinth groove; Oiling; Sealing.

1. Introduction

Grounding is the main method to solve the problem in the field of EMC [1], which attracts people’s great attention. In the railway industry, grounding device can provide effective protection for bearings, prevent bearing damage caused by working current or system fault current and lightning current passing through bearings [2, 3]. At the same time, the grounding system can also improve the signal-to-noise ratio of communication equipment when working [4]. According to the function, grounding devices are mainly divided into two types: protective grounding and operational grounding [5, 6].

Many literatures have reported the grounding device. Guo Jinyu optimizes the structure of grounding device in view of the current situation that the grounding device does not meet the protection level IP67, so as to avoid the corrosion of parts and bearing failure of grounding device and Bogie Axle Box assembly. Based on three types of vehicles, Yuan Deqiang and others put forward a scheme to improve the proximity of protection grounding [7]. Through field testing and comparative analysis, it is proposed to install protective grounding device on all power bogies [8]. Lin Ping improved the safety and stability of the shaft-end grounding device by analyzing the structural deficiencies of the grounding device of Guangzhou Metro Line 3[9]. Zhong Biyi and Zhu Jun briefly introduced the grounding technology of Metro vehicles. Taking Shanghai Rail Transit Line 4 as an example, the classification and characteristics of the grounding of metro vehicles were introduced. The grounding design principle of metro vehicles was analyzed, but there was no theoretical and practical data support [10,11].

The grounding device axle box cover is provided with a labyrinth structure, and the function of the labyrinth structure to isolate toner and water is rarely reported. Based on this, this paper mainly studies the influence of the labyrinth structure on the carbon and water content of the bearing side oil before and after oil injection.
2. Test method and process
In order to prove that oil injection at axle box labyrinth can better increase the sealing of axle box, the following experiments are designed for only bearing oil injection and simultaneous oil injection at axle box labyrinth. At the same time, the on-the-spot experiments are compared.

(1) In the labyrinth groove of the bearing end, oil is injected 680 g, and there is no refueling in the labyrinth groove of axle box cover. The simulation speed of the axle is 120 km/h. During this period, the observation window of the axle box cover is regularly observed and recorded. After 96 hours of operation, the grounding device was removed to observe the grease status of the labyrinth groove of the axle box cover and axle box cover.

(2) In the case of bearing oil injection 680 g and in labyrinth groove of axle box cover without oil, bearing oil injection 680 g, axle box cover labyrinth oil injection 40 g, etc. (The position of oil coating is shown in the figure 1(a), (b)). In both cases, Put 20g carbon powder into the axle box cover (Carbon powders produced by wearing 4 carbon brushes for 2 mm). After 72 hours of axle test, the axle box cover was removed and the distribution of oil and carbon powder in the bearing, labyrinth and axle box cover were observed.

(3) In these two cases, water is injected into the observation hole shown in Fig. 1 (d) to the lowest point 5 mm away from the labyrinth groove. See Fig. 1 (c). After 72 hours of wheel axle test, the axle box cover is removed to observe the distribution of oil in the bearing, labyrinth and axle box cover, observe the situation of carbon powder and water entering the labyrinth, and take the oil samples on the bearing side for component testing.

![Figure 1. Axis Box Diagram](image)
3. Analysis on experimental results

3.1. Analysis of experimental results
According to test 1, the grounding device was removed after 96 hours of operation, and the maze groove position of axle box cover and axle box cover was observed. There was no grease in the groove, as shown in Fig. 2 (a). Grease accumulates under the axle center line, as shown in Figure 2 (b). This experiment shows that only oil is applied to bearings but not to the labyrinth of axle box cover. Oil at bearings can not enter the labyrinth of axle box cover. Oil at the labyrinth needs to be applied separately.

![Figure 2. (a) There was no grease in the groove, (b) Grease accumulates under the axle center line](image)

3.2. Experimental Analysis of Adding Carbon Powder

3.2.1. Analysis of the results of Experiment 2. Figure 3 is a picture of the experiment after only 20g carbon powder was added to the bearing. It can be seen from the picture that there is no carbon powder in the labyrinth groove in the axle box cover, and there is no obvious color change in the grease in the bearing. It is proved that the labyrinth groove has the ability to prevent carbon powder from entering the bearing. Because the running time of the simulation experiment is relatively short, it can not be proved that the train will not have problems in the running time of the two vehicle inspections. Now the on-the-spot sampling experiment is added to determine more clearly the obstruction effect of the labyrinth groove on carbon powder in the long running process.

![Figure 3. Picture of the experiment after only 20g carbon powder was added to the bearing](image)

For the labyrinth groove oil injection experiment, we can see that there is no carbon powder in the labyrinth groove of axle box cover, the color of bearing grease has no obvious change, and no black phenomenon after carbon powder mixing is observed. At this time, a small amount of oil distribution
can be seen in the labyrinth groove of axle box cover, as shown in Fig. 4 (a). A small amount of red oil enters the labyrinth groove of the axle box cover, as shown in Fig. 4 (b).

Fig 4. (a) A small amount of oil distribution can be seen in the labyrinth groove of axle box cover, (b) A small amount of red oil enters the labyrinth groove of the axle box cover.

3.3. Experimental analysis of water addition in axle box cover

Fig. 5 is about 5 mm from the lowest point of the labyrinth groove. After 72 hours of operation, the plastic film and organic glass at the observation holes on both sides of the axle box cover have obvious water droplets, as shown in Fig. 5 (a), (b). 70 g bearing oil was extracted and the content of water and carbon powder was detected. The test results are shown in Table 2.

Fig 5. About 5 mm from the lowest point of the labyrinth groove

For the axle box labyrinth groove, 40 g oil is applied in the position of bearing pressure plate and axle box cover. After 72 hours of operation, it can be seen. There is more oil accumulation in the lower part of the center line of the shaft, and there is no obvious water stain at the end of the bearing, as shown in Fig. 6 (a). When the bearing oil moves to the labyrinth groove, the distribution of rare red oil can be observed in a small section of the labyrinth groove, as shown in Fig. 6 (b). The moisture content of oil is shown in Table 2.

Fig 6. The axle box labyrinth groove
Table 1. Oil test results

| Serial number                  | Copper content (mg/kg) | Moisture content (mg/kg) |
|--------------------------------|------------------------|--------------------------|
| Bearing oil injection          | <10                    | 822                      |
| Bearings and labyrinth caps are oiled | <10                     | 725                      |

Table 1 shows that the moisture content in oil injected into bearings is significantly higher than that in oil injected into labyrinth grooves. This shows that when oil injected into labyrinth grooves, it can effectively prevent water from entering bearing side in axle box cover. It is very necessary to apply oil in labyrinth grooves of axle box cover.

3.4. Bearing Grease Analysis of On-line Vehicle

According to the overhaul plan of Sifang Vehicle Co., Ltd. of Zhongche Qingdao, 30 grounding devices were selected, the axle box cover was opened to observe and record the distribution of oil in the axle box cover, the sampled oil was detected by the third party in SGS Group, and the contents of water and carbon powder in the oil sampled from the vehicle and the oil sampled from the test were compared and analyzed.

Table 2. Oil test results

| Serial number                  | Copper content (mg/kg) | Moisture content (mg/kg) |
|--------------------------------|------------------------|--------------------------|
| Raw oil                        | <10                    | 693                      |
| Axle End of Ungrounded Device  | <10                    | 495                      |
| Spot sampling                  | 980                    | 640                      |

Table 2 is the result of oil detection in the bearing end cap of a train by selecting some existing vehicles (running 600,000 kilometers). It can be seen from the table that the content of Cu in oil and grease in the end cover of the existing car (carbon brush is composed of carbon and copper) is 980 mg/Kg, which is obviously higher than that of crude oil lipid (<10 mg/Kg). In order to exclude the increase in the content of Cu in oil and grease caused by wear on the inside of the bearing, the oil and grease test experiment of the axle end without grounding device is added. The result shows that wear of carbon brush occurs during The carbon powder and copper powder can enter the inner side of the bearing through the labyrinth groove, which indicates that the labyrinth groove can’t completely block the carbon powder entering, and can be further improved. Therefore, it is suggested that grease be applied to the labyrinth groove of the axle box cover when the grounding device is installed.

4. Summary

(1) When oil is applied inside the labyrinth, no oil flick is observed in the axle box cover after 96 hours of operation. The grounding device is removed and the position of the axle box cover and the labyrinth groove of the axle box cover is observed. There is no oil in the labyrinth groove, which proves that oil can not enter the labyrinth groove only on bearings, and oil needs to be applied in the labyrinth groove alone.

(2) Through the carbon powder experiment, we can see that the labyrinth groove has some hindrance ability to carbon powder, but after a long time operation, carbon powder can still pass through the labyrinth groove, and there is the necessity of oil coating in the labyrinth groove.

(3) The experiment of adding water shows that the labyrinth groove has a poor ability to hinder water. Oiling the labyrinth groove can effectively prevent water from entering the bearing side. Oiling the labyrinth groove can improve the sealing of the labyrinth groove.
In summary, three experimental methods have proved that when the bearing is oiled according to the standard and the axle box cover is oiled in the labyrinth groove, the sealing performance of the axle box cover can be increased, and the powder and liquid can be effectively separated into the bearing end.

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