Research on Pure Mechanical Lifting Pedal Applied to Rail Transit Vehicles

Yingyong Zhang, Zhaozhan Hou, Xiangli Lin, Changkai Xia, Dongjun Yang, Jianwei Song
CRRC Qingdao Sifang Rolling Stock Research Institute Co., Ltd.
No.6 Herong Road, Chengyang District, Qingdao, Shandong Province, China
zyysfsdq@163.com

Abstract. With the continuous development of rail transit industry, the comfort level of drivers and the flexibility requirements of customers for the different vehicle of console are continuously improved. At present, the lifting pedal has been widely used in the industry, which are hydraulic and electric type. Pure mechanical lifting pedal has not been applied in the rail transit vehicles. Considering the service life and reliability of the products, many customers, especially foreign customers, require the pure mechanical structure to meet the requirements of different vehicle models and meet the requirements of different drivers for the console. This paper proposes a kind of pure mechanical lifting pedal applied to rail transit vehicles, which can meet the adaptability of the console to different vehicle bodies and drivers, and greatly improve the universality and reliability of the application.

1. Introduction
At present, pedals are widely used in the console of rail transit vehicles, mainly to improve the driver’s comfort level. The adjustable property of pedal which can adapt to different height of the drivers is widely favored by customers. But now the main application in rail transit is electric lift pedal with low reliability.

There are only two kinds of pedals which are electric and hydraulic pedals in rail transit console. The development of pure mechanical lifting pedal will broaden the market demand and increase the reliability and comfort of pedal products. The structure design of the foot pedal is inspired by the lifting function of the car seat. Zhang Kun et al., put forward the component layout design method for automotive seat skeleton.[1] Zhao Bo did development and application of height adjusting mechanism of automobile seat.[2]

According to the market demand, the lifting mechanism applied to the console pedal. Completing the multi-stage lifting of the pure mechanical lifting pedal can meet the requirements of owners and drivers for man-machine comfort and vision. In addition, avoid the discomfort caused by different drivers' height and work habits. This pedal design scheme refers to the functional mode of car seat. Combining with the foot pedal application in the rail transit industry, the new pure mechanical structure design is adopted to realize the multi-step lifting function. Ergonomic analysis, ultimate load test and fatigue test were carried out to verify the practicability of the pedal.
2. Composition of pedal

2.1. Pedal Function
When stepping on the Elevating button, the Elevating button(5) drives the Lifting frame assembly(3) to realize the lifting of the pedal. The lifting range of the pedal surface is 90-140mm, and the limit block at the top of the guide rail can ensure the forced braking of the pedal plane at the limit position.

![Figure 1. Whole view and range of pedal surface movement.](image1)

2.2. The main structure of pedal
The pedal is composed of eight main parts, including Baseplate, Telescopic cover, Lifting frame assembly, Footboard, Elevating button, Diamond plate, Dust cover and Hairbrush, as shown in Figure 2. The connection type of these parts also be shown in Figure 2.

Hairbrush is installed on both sides of the pedal, which can effectively prevent particles over 1mm from entering. The bottom of the pedal is equipped with anti-leakage board device, which can prevent water and snow from entering the body through both sides of the pedal. Diamond plate in contact with the safety boots is made of stainless steel and passivated, with excellent anti-corrosion properties. The key parts of the pedal are installed in the inside of Dust cover and Telescopic cover. The dust cover is made of aluminum alloy. Telescopic cover is made of PVC.

![Figure 2. Main structure of pedal](image2)

1.Baseplate   2.Telescopic cover   3.Lifting frame assembly   4.Footboard   5.Elevating button   6.Diamond plate   7.Dust cover   Hairbrush
2.3. Structure of Elevating Button

The Elevating button is a part of human-machine interaction with the foot pedal. It is a direct control part that controls the lifting of the foot pedal and transfers the operating force to the lifting frame assembly.

The structure and composition of the Elevating button are shown in Figure 3.

In order to prevent the water, snow, salt, calcium chloride and other things causing corrosion to pedal, Guide pillar of button in contact with the safety boots are made of stainless steel.

![Figure 3. The structure and composition of the Elevating button](image)

1. Elevating button plate 2. Guide bush of button 3. Guide pillar of button 4. Deflector plate 5. Guide sleeve 6. V-wheel fork 7. V-pin roll 8. V-wheel

Figure 4. Waterproof structure of Elevating Button

![Figure 4. Waterproof structure of Elevating Button](image)

1. Rider ring 2. Scraper seal 3. O-ring

Through analysis, it can be found that the only way that sundries can enter into the inside of the pedal is through the button part. So the protection of the button part is especially strict. The buttons are sealed with rubber ring and o-ring. Double layer protection can effectively prevent sundries from entering into the inside of the pedal. Meanwhile, O-ring and rubber ring are both mechanical industry standard parts with a service life of more than 80,000 times lifting process. Material itself has the advantage of corrosion resistance, playing an effective role in the protection for water, snow, salt, calcium chloride.

2.4. Structure of Lifting Frame Assembly

The components and structure of the pedal are shown in Figure 5. Lifting frame assembly is the main part of the pedal to realize the lifting function.

The main structure of the Lifting frame assembly is made of aluminum alloy. The main reason for using aluminum alloy is to reduce weight, and the performance of aluminum alloy is also excellent. Gears, Rack rails and Gear shafts are made of 45# steel and springs are made of spring steel. According to the simulation calculation of gear life and strength, the calculation results show: Contact strength, fatigue strength and fatigue bending strength of gear and rack all meet the application requirements. The service life of the button is also tested and verified, and the button still meets the service requirements after 80,000 lifting times.

2.5. Structure of Rack Rail Platform

The base structure of the rack rail platform is shown in the Figure 6. The rack rail platform is fixed together by fasteners such as bolts, nuts and elastic pads, which serve as the base of the structure. Guide rail provides a stable step length and limiting function for the rise and fall of the pedal surface. Guide rail is arranged on all four sides of the box, which can fully ensure the stability of lifting.
Gear slide platform is equipped with linear slide block to complete up and down sliding cooperating with Guide rail, which plays a certain role in the positioning of the overall structure.

Spring tube has built-in spring to provide elastic force for lifting parts. It can provided a lifting force to effectively overcome the gravity of lifting parts and make the driver feel comfortable when operate the lifting button.

2.6. Structure of Gear Slide Platform

Gear slide platform is used in conjunction with rack rail platform. Rack rail platform is the fixed end of the guide rail. Gear Slide Platform is the moving along the guide rail.

The spring guide rail is divided into spring guide pin and spring tube. The gap between spring tube and guide pin is the space to mount lifting spring. The spring guide pin is connected to the top and the spring tube to the bottom. The structure is designed to overcome the gravity of gear slide platform and constrain the direction of elastic forces.
2.7. Structure of Gear Drive
Brose riser and Gear shaft are the core drive parts. The Gear shaft is fixed on the gear slide platform, and the power output is completed by rotating the gear. Brose riser provides locking function after gear rotation.

Select standard straight teeth gear (2-mode, 17 teeth) to achieve gear drive. Through calculation and verification, the parameters such as the number of teeth and modulus of the gear are determined to ensure the stability and practicability of the overall structure. The practice shows that the double mode gear can complete the design target value well. The reason is that the smaller the modulus, the smaller the meshing surface of the gear, easier to break teeth. When the modulus is too large, it is easy to derail with small number of teeth, resulting pedal cannot rise with gear idling. It has been proved that gear with 2-mode 17-tooth can ensure reasonable unit stroke, stable lifting and smaller structure.

3. Man-machine analysis
Multiple reference 《UIC 651 LAYOUT OF DRIVER’S CABS IN LOCOMOTIVES, RAILCARS, MULTIPLE-UNIT TRAINS AND DRIVING TRAILERS》 in the pedal design process. As for the angle between the pedal plate and the horizontal plane, UIC 651 require that it should be between 15 and 25 degrees. Therefore, in the design, we draw on the experience of other successful projects already in operation. Finally, a 20 degree scheme was adopted. So the current angle between the pedal plate and the horizontal plane is 20 degrees.

Considering the driver wearing safety boots, we conducted man-machine analysis. When the driver adjusts the pedal height, in order to avoid stamping on the two buttons at the same time, the driver can step the button at an inclined angle which is about 12 degrees. If stepping on two buttons at the same time, it will not affect the pedal structure. The pedal surface will lift according to the different forces of the two buttons. At this time, the button with large forces plays a major role.

4. Experiment

4.1. Ultimate Load Test
Aim the sensor at the foot button center. Adjust the angle of the sensor so that it is as centered as possible with the button. Slowly turn the lifting handle. Observe the value of the digital display table. Record the quantitative value when the value is stable. Remove dust cover and other parts to observe the foot deformation in order to have a better vision in the process of experiment.

As the limit measuring force range of the test equipment is 700 N, the test will last until 700 N. According to the test, when the applied force value of the button reaches 700 N, there is no obvious change in the button, pressure bar, height regulator, etc.. But the tread surface has undergone obvious deformation. After applying the force, the tread surface returns to its original shape without plastic deformation.

4.2. Fatigue Test
The test equipment mainly consists of pedal prototype, fixed fixture, cylinder, counter and limit switch, as shown in Figure.11.
According to the test results, the performance of the pedal is good and there is no stuck phenomenon after 80,000 times of lifting. Therefore, the pedal lifetime is up to 80 thousand times.

5. Conclusion

Solidworks software was used to conduct the structural design of the pedal, and gear and rack of the pedal were selected based on the calculation results. Finally, the pedal has applied to the console of rail transit vehicles.

According to UIC651 standard and CATIA software, the pedal ergonomics was analyzed. The result accords with the requirement of ergonomics.

Design test equipment and then carry out ultimate load test and fatigue test on the pedal prototype. The number of pedal lifting can reach more than 80,000 times, meeting the normal service requirements.

References

[1] Zhang Kun, Ding Xiaohong, Ni Weiyu, Wang Haihua. The component layout design method for automotive seat skeleton [J]. Journal of Engineering Design, 2015, (2).
[2] Zhao Bo, Li Bo., Development and application of height adjusting mechanismofautomobileseat[J].Machinery Design & Manufacture, 2012, (4).
[3] Ju Yicheng,. Troubleshooting and countermeasures for DSD foot failure of CRH1 emu [J]. Technology outlook, 2016, (9).
[4] Lao Shengyuan,. Sit-N-Lift Power Seat[J]. Traffic & Transportation, 2006, (6).
[5] Gao Jun, Zhang Na, Liu Zhigang, Bian Yongjun,. Fracture analysis of the foot pedal switch spring [J]. Heat treatment of metals, 2013, (3).
[6] Wang Yu, Meng Shu, Zhu Jiang,. Development of Durability Test Bench for Automobile Seat Adjustment Mechanism[J]. Auto parts, 2015, (8).