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Research and development and application of subway wheel stopper

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Abstract: This paper aims at the problems existing in the transportation of subway cars, light rail cars, urban trains, high-speed trains and other vehicles produced by the company for domestic and foreign countries to their destinations after completion. How to fix the vehicles during transportation is the main topic of this study. We have set up a joint research group. After investigation, analysis and demonstration, we designed a subway wheel stopper, which not only improves production efficiency but also reduces investment costs, thereby achieving the purpose of shock absorption and noise reduction, and ensuring the safe transportation of vehicles.

1. Introduction

Transmission and motion control are important parts of mechanical design. They improve the usability and safety of products. There is still more research and innovation in the field of mechanical design to promote the development of the industry.

The company produces various vehicles for domestic and foreign countries, such as subway cars, light rail cars, urban trains, high-speed trains, etc. When they are sent to the destination after completion, the vehicles are transported by rail in the past. Due to various reasons, the time for the vehicles to be delivered to the designated city is not fixed, and the transportation efficiency is reduced. In recent years, vehicles are usually transported to domestic or foreign countries by various modes of transportation, such as rail, road, sea, and air. That is, rail transportation uses internal combustion locomotives to pull vehicles, road transportation uses special flatbed trucks, sea transportation uses multi-layer freight ships, and air transportation uses large transport aircraft. When using road, sea, and air transportation, three types of equipment are required: (1) vehicle-specific slings; (2) binding ropes; and (3) wheel stoppers (iron shoes). Therefore, wheel stoppers (iron shoes) are an indispensable and important link.

2. Origin and Analysis of the Problem

2.1 Problems with traditional transportation methods

Traditional transportation mode: Railway transportation, that is, a whole train (a normal subway train consists of six cars) is pulled by a diesel locomotive. Because the track gauge of the subway wheelset is the same as that of the railway, both are 1435mm wide, so the subway train can be transported on the railway track (as shown in Figure 1). Due to the slow train pulling, there are many reasons such as waiting for cars in various cities and the depots in the city (that is, the place where subway cars are parked, repaired, and overnight) that lead to the arrival time at the destination being uncertain, the transportation efficiency is reduced, and the subway train is increasingly affected by external factors during transportation (as shown in Figure 2).

Figure 1: Railway transportation, related to subway

Figure 2: Waiting for vehicles and depots in cities

2.2 Problems with the traditional stopper “iron shoe”

The subway vehicles produced by the company are parked on the railway vehicle professional line one after another, and the vehicles are fixed front and back with "iron shoes" and shipped as a whole after batches are completed (as shown in Figure 3). This kind of "iron shoe" can only fix vehicles on the railway line, and is not suitable for fixing vehicles during road, ship, and airplane transportation.(as shown in Figure 3a).

Figure 3: Traditional stopper “iron shoe”

Figure 3a: Vehicles stored on a railway dedicated line are fixed with "iron shoes"

2.3 It is necessary to design a new type of subway wheel stopper for various modes of transportation such as road, sea and air transportation

After the subways produced by the company are completed, they need to be transported to the destination by road, sea, air, etc. In the past, iron chains and ropes were used to fix the subways, which caused many unsafe risks. As a research team, we brainstormed and designed a device to fix the wheels of the subways to ensure that the transportation process is firm, safe and reliable.[1]

3. Design scheme and principle

3.1 Design ideas

To improve product performance and efficiency, the team conducted a stress analysis on the wooden blocks of the wheel chocks (iron shoes) and studied the material properties. Material selection and structural optimization are key steps. Suitable materials can meet design requirements and maintain stable performance during the service life. Structural optimization can improve product performance and efficiency, reduce production costs and energy consumption, and reduce weight and increase stiffness and strength while meeting design requirements.

The working principle of the new wheel stopper (iron shoe) is developed to adapt to various modes of transportation such as road, sea and air transportation. When the vehicle is shipped, the iron shoe must be correctly placed on the exact position of the vehicle wheel. The staff used a special lifting device (as shown in Figure 4) to slowly align the vehicle with the iron shoe, and the wheel landed accurately on the wooden block of the iron shoe (as shown in Figure 5), stopped smoothly, and the wheel was in a fixed state. Finally, a special rope was used to tighten it tightly without any looseness to prevent slipping accidents.[2]

Figure 4: Special lifting equipment is used to lift the vehicle into the iron shoe of a flatbed truck

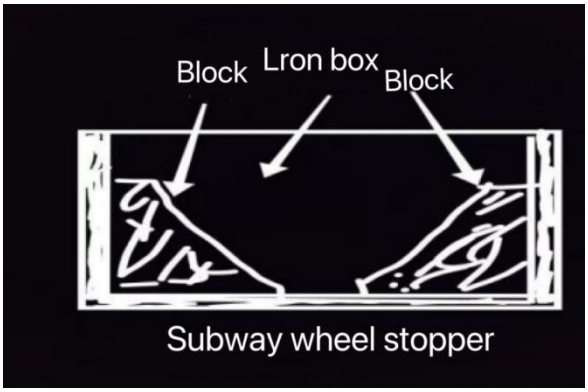

Figure 5: Wheel chocks (wooden blocks)

3.2 Scheme design

1) The wood block is made of red pine, and the iron box is made of Q235A steel plate.

2) In order to be suitable for a variety of vehicle models, a preliminary design is made to determine the working principle and basic form of the machine (as shown in Figure 5).

3) The design team members carried out motion design and structural design according to the new wheel diameter of 840mm, and drew a preliminary general drawing and pre-examination (as shown in Figure 6a,6b); the limited wheel diameter is 770 mm; that is, the curvature of the wooden block is 385 mm.

4) The designer drilled a hole (5 mm in diameter) at the bottom of the iron box and fixed the iron box to the wooden block with wood screws.

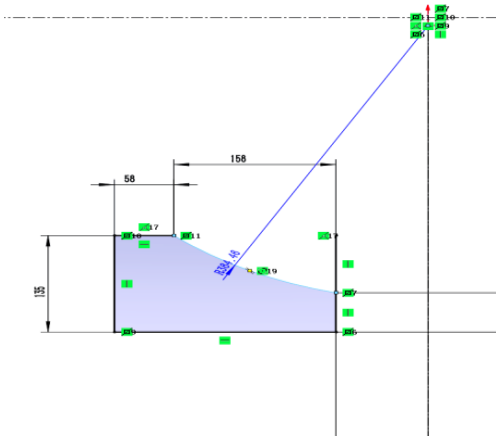

Figure 6a: Block Sketch Figure

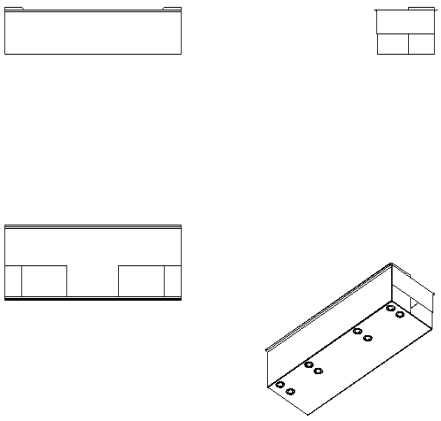

Figure 6b: Stopper Sketch CAD

3.3 Working principle

The wooden block is placed inside the iron box and fixed to the iron box with wooden screws to prevent the wooden block from sliding and the wheel from slipping. The bogie wheel is placed on a wooden block of a size that matches the bogie wheel, so that the bogie wheel fits the wooden block, and the wooden block fits and fixes the iron box to keep it relatively still. The bulge on the front side of the wooden block can prevent the bogie wheel from moving forward and backward.

3.4 Calculation of wheel stopper support force and pressure resistance

The wheel stopper is made of Q235A steel plate on the outside and red pine wood blocks on the inside. Red pine wood: small deformation, uniform wood fiber, good resilience, good anti-corrosion and oil-containing corrosion resistance. Red pine wood is a wood with high compressive strength and durability. It can effectively support the weight of the subway car body and maintain stability. Red pine wood has excellent material quality, straight texture, strong pressure resistance, rich in resin, strong corrosion resistance and not easy to deform.

1) A certain type of subway A car (a normal subway train consists of six cars), the middle car (one) weighs 32 tons, is transported using iron shoes, and the contact wood blocks are pine. Calculate the support force of the iron shoe wood blocks? Calculate the pressure resistance of the wood blocks?

2) Each subway car is pulled by 2 sets of bogies. Each set of bogies uses 4 sets of iron shoes for 4 wheels, and each subway car uses 8 sets of iron shoes.

3) When the vehicle weight is 32 tons, that is, W=32000kg, the load of a single wheel is: N= 1/8 W; N= 1/8 ×32000; N=4000kg

4) The standard subway wheel diameter is D=840mm, and the contact angle between the wheel and the iron shoe block is Φ=60 °.

5) The figure shows the force diagram of the wheel shoe. The downward pressure N makes the wooden blocks on both sides bear forces symmetrically. F1 and F2 act on the wooden blocks. N is symmetrical and equal to N/2 for the wooden blocks on both sides, and F1 = F2.

3.5 Support force and pressure resistance

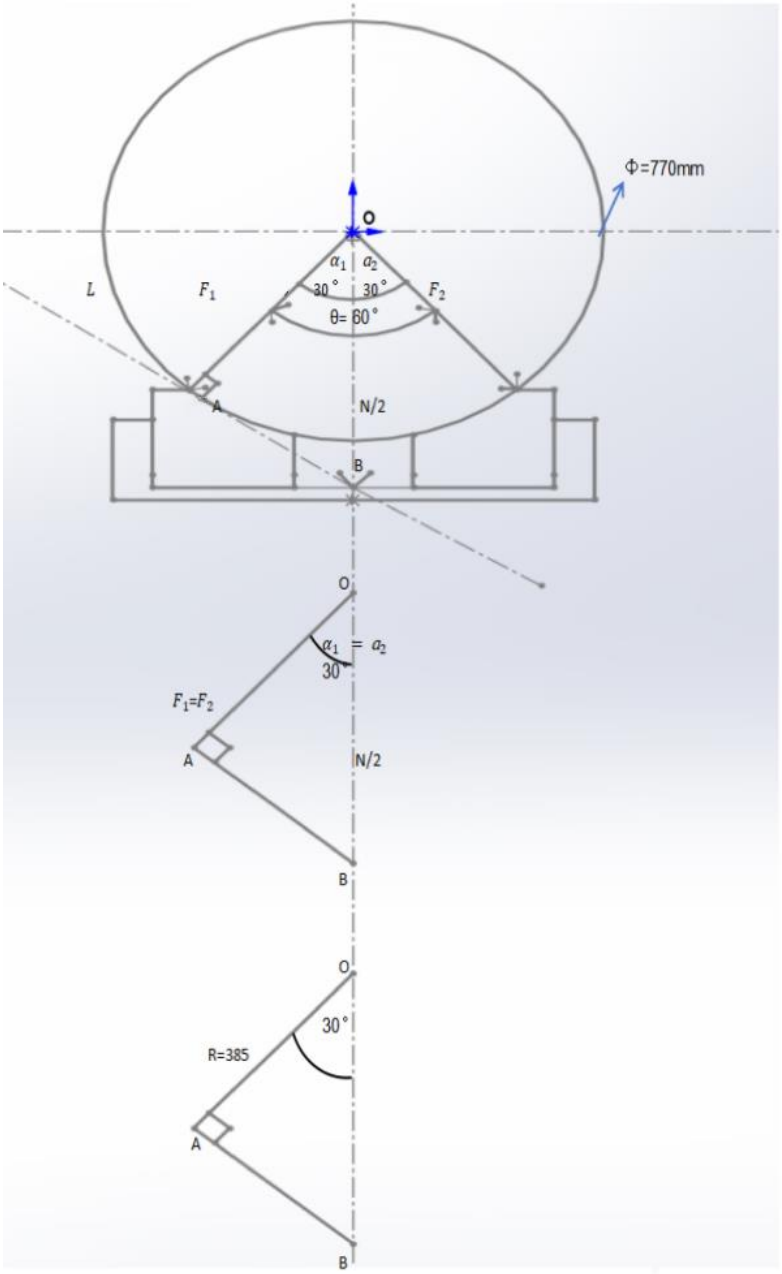

Figure 7: Force analysis

As shown in Figure 7: N is the positive pressure, that is, the downward force of a single wheel; F_1= F_2supporting force, also called support reaction force;

Assume that the point of intersection of the wheel and the arc of the wooden block is A, The designer draws a straight line L through the intersection A, L is perpendicular to OA, and the right triangle OAB is obtained.

Given that θ= 60°; α_1= α_2=θ/2=30°; N/2=4000/2=2000kg;

Find F_1= F_2:

$$F_1= F_2=N/2*\cos\ \alpha= 2000\times\sqrt{3}/2$$

=2000×0.866=1732kg

Ratio and algorithm:

Given $\alpha_1 = \alpha_2 = \theta/2 = 30°$; OA=R=385mm;

Find $F_1 = F_2$:

$$OB = OA/\cos 30° = 385/\sqrt{3}/2$$

$$OB = 385/0.866 = 444.57$$

$$\frac{F_1 = F_2}{N/2} = \frac{OA}{OB}$$

$$F_1 = F_2 = \frac{N/2 \times OA}{OB}$$

$$F_1 = F_2 = \frac{2000 \times 385}{444.57} = 1732kg$$

The feasibility of the support force was confirmed by two calculations.

According to the above calculation, the support force of the iron shoe block is 1732kg.

6) The expanded diagram of the contact surface between the iron shoe block and the wheel is as follows (as shown in Figure 8):

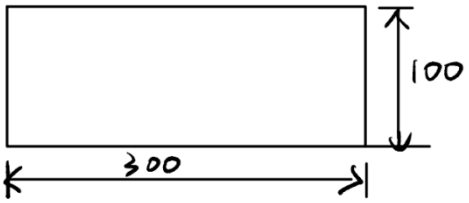

Figure 8: Expanded view of the contact surface of the wheel block

When cm is used as the calculation unit, the contact area S = 30 cm × 10 cm = 300cm^2

7) According to relevant literature and experimental data, the compressive strength of pine wood is between 15 and 28 MPa. That is, the pressure that a square centimeter of iron shoe wood can withstand is 15 to 28 MPa.

When the contact area S=300 cm^2, the iron shoe block can withstand a pressure of

$$Q = S \times (15 \sim 28) = 300 \times (15 \text{ to } 28) = 4500Mpa \sim 8400Mpa.$$

8) Check the pressure resistance of iron shoe wood blocks:

Because (4500MPA～8400MPA)≈(45000kg～84000kg)

Therefore, the compressive strength of the iron shoe wood block is between (45000kg and 84000kg)

That is: Comparison of Q with F1, F2 (45000kg～84000kg)>> 1732kg

Conclusion: Iron shoe wood blocks are safe and reliable.

(Note: The above results are all for a single wooden block)

3.6 The design of the new structure rail wheel stopper has the following characteristics

1) Save space: The device can be quickly installed and dismantled, occupies a small area, and achieves the most optimized process layout.

2) Improve efficiency: Using flatbed trucks for transportation can separate each car compartment for transportation, reduce the length of the vehicle body, and improve transportation safety. Road transportation does not require the vehicle to wait, and can be transported quickly and returned

quickly.

3) Ensure quality: The vehicle body is dropped onto the device and positioned accurately. The bogie wheels will not shift during transportation, thus avoiding damage to the vehicle body due to bumps or other reasons during transportation, preventing slippage and ensuring smooth and safe delivery.

4) Economic benefits: The device uses red pine wood as the basic material. The curvature and size of the wood block can be adjusted at will according to different bogies, reducing economic costs. Road transportation avoids the phenomenon of waiting for other vehicles during railway transportation, saving time costs.

3.7 The wheel stopper achieves the effect of shock absorption and noise reduction

The built-in wood blocks in the iron shoes have a shock-absorbing and noise-reducing effect. This design can play a role in buffering and noise reduction. Wood has a certain elasticity and resilience, which can effectively absorb impact and reduce noise. At the same time, wood can also protect the lower supporting surface from the pressure of the subway wheels, thereby reducing the noise and vibration during transportation to a certain extent, achieving the effect of shock absorption and noise reduction.

Vibration reduction and noise reduction is to reduce noise by reducing vibration. This is an active noise control method that treats both the symptoms and the root causes, and can achieve the dual goals of vibration and noise control. This method is particularly important in the field of rail, and can effectively reduce vibration and noise transmission, and reduce noise and vibration during transportation.

Therefore, the shock-absorbing and noise-reducing effect of wood blocks is achieved through the density and thickness of its material and by laying sound insulation materials. These factors work together to effectively reduce the propagation and reflection of sound, thereby achieving the purpose of shock-absorbing and noise-reducing.

3.8 The wood blocks can reduce vibration and noise

Sound insulation effect: Wood products have good sound insulation effect and can effectively reduce resonance and noise. This is because the structural characteristics of wood itself can absorb and block the propagation of sound waves.

Noise absorption: Wood products can absorb noise, mainly because wood fibers are porous and can absorb noise.

Shock absorption: The hardness and toughness of wood can remain stable when impacted and is not easy to crack. Wood can withstand long-term use without deformation or damage and has good durability.

Environmental sustainability: Wood is a renewable resource that grows quickly and is much less damaging to the environment than plastic and other materials. Wood products can be recycled after they are discarded, reducing pollution to the environment.

Therefore, the reason why wood blocks can reduce vibration and noise is that their physical properties can effectively absorb and block the propagation of sound waves. At the same time, they have good durability and environmental protection, making wood an ideal shock-absorbing material.[3]

4. The new subway wheel stopper adopts a general chemical equipment design

The device is flexible and light, and can be matched with wooden blocks according to different

types of bogie wheels. It can meet the transportation follow-up requirements. It can minimize the duplication of parts in the design and manufacturing process, and achieve cost reduction, simplified management, shortened cycle and improved professional level.

4.1 Overall design structure

The device consists of two parts: an iron box and a wooden block.
“Metro wheel stopper” drawing number: DKY628-001-00 (as shown in Figure 9).

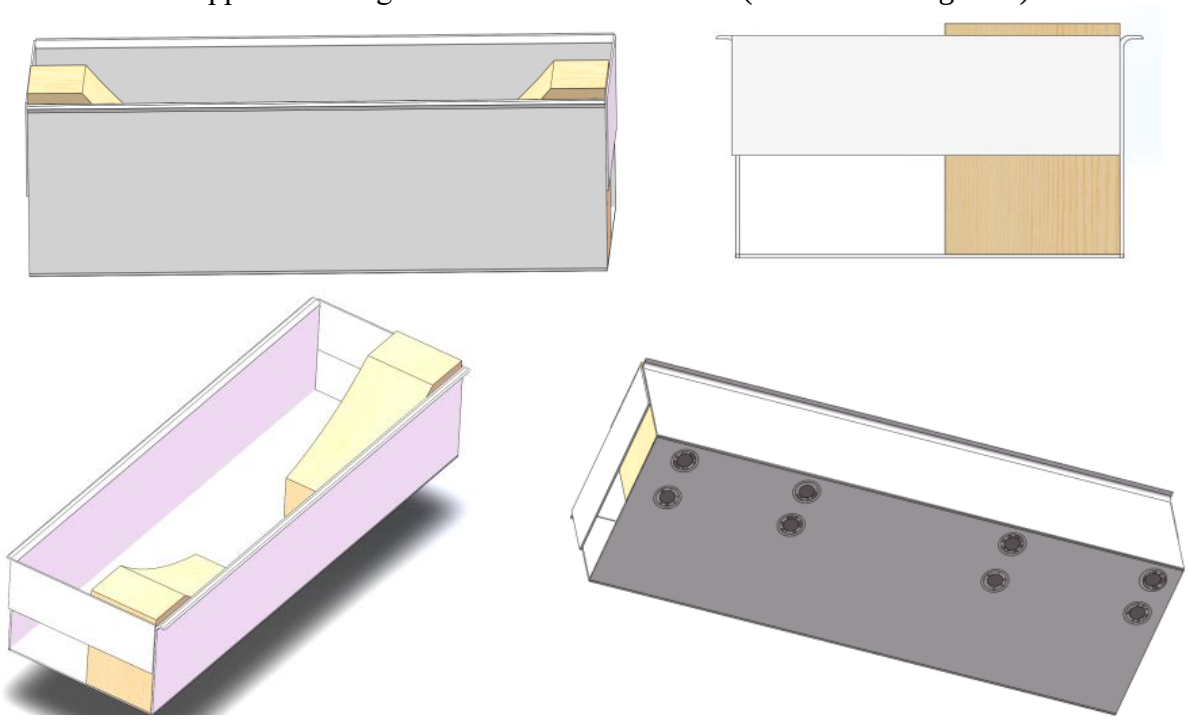

Figure 9: Subway wheel stopper solidworks

4.2 Usage

The subway wheel stopper (commonly known as the iron shoe) is a device used to prevent wheels from sliding. Its correct use can effectively protect the safety of subway vehicle transportation lines and prevent slipping accidents.

And operation steps of subway wheel stopper (iron shoe):

1) The iron shoes should be ready before the subway cars are shipped;

2) Ensure that the iron shoes are manufactured in accordance with standard requirements and have reliability and durability;

3) Check to make sure the iron shoe is well assembled and has no obvious damage;

4) Determine whether the iron shoes are suitable for the terrain and transportation conditions of road, sea, air and other transportation tools:

5) When the subway vehicle is being loaded, the iron shoes must be correctly placed on the exact position of the vehicle wheels;

6) The subway vehicle must be slowly aligned with the iron shoe, the wheels must accurately fall onto the wooden block of the iron shoe, stop steadily and the wheels must be in a fixed state.

5. Analysis and Review

After the analysis, review and testing of the rail car body stopper by the expert team and the user unit, it is believed that the device meets the production needs. (As shown in Figure 10) After the careful processing of the construction unit, the on-site assembly was completed, and after the pre-acceptance, it met the design requirements. It is now put into production (as shown in Figure 11). The device is universal and adjustable, and the device can be adjusted at any time according to the wheel model of different vehicle models. At the same time, the device achieves the purpose of shock reduction and noise reduction.

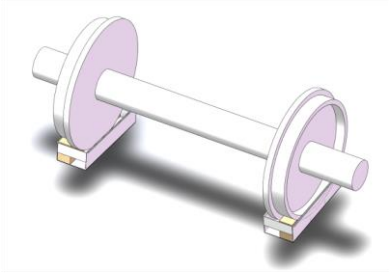

Figure 10: Stopper application simulation

Figure 11: Subway wheel stopper

6. Put into use

Operation steps (as shown in Figure 12): When the company's subway vehicle is being loaded, the subway is lifted from the track by a gantry crane (as shown in Figure 12 - a), and hung above a flatbed truck. The vehicle wheels are slowly aligned with the iron shoes (the iron shoes with pre-determined positions) (as shown in Figure 12 -b), and then the wheels are accurately dropped onto the iron shoe wooden blocks and fixed (as shown in Figure 12 - c). In this way, the subway is firmly fixed on the flatbed truck after lifting, iron shoes, and overall binding ropes (as shown in Figure 12 - d).

a: The gantry hoist lifts the subway from the track

b: It is hoisted above the flatbed truck and aimed at the iron shoe

c: It falls on the iron shoe and is fixed (vertically) (horizontally)

d:is fixed on a flatbed truck through hoisting, iron shoes, and overall binding ropes.

Figure 12: Metro wheel stopper operation steps

The quality assurance of any mode of transportation requires this device. This device covers many fields such as machinery manufacturing, air transportation (as shown in Figure 13a), ship transportation(as shown in Figure 13b), road transportation(as shown in Figure 13c), etc. (as shown in Figure 13a). The industries involved are all technology-intensive, highly related and large-scale industries. Without exception, they have become a step in many links of China's rail transportation industry that is not often mentioned, but is indispensable.

Figure 13a: Air transport uses large transport aircraft

Figure 13b: Sea transport uses multi-layered cargo ships

Figure 13c: Highway- specific flatbed truck

7. Conclusion

This paper conducts a lot of research on existing transportation problems, analyzes the current difficulties and current situation, and slightly changes the traditional transportation mode to establish a new transportation system based on the traditional transportation mode. It has been proved to be a feasible new technology through experiments. The use effect is good, thus achieving the purpose of vibration reduction and noise reduction, and it is suitable for transportation by various vehicles, technological innovation, and promoting the development of tooling design. The process optimization design achieves the innovation goal.

Acknowledgement

This achievement has been applied for a patent of the People's Republic of China.

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