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Design of Socket-type Adjustable Support Device for Large Components of Harbin Metro Car Body

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ABSTRACT

This article focuses on the problem that when CRRC Changchun Railway Vehicles Co., Ltd. produces Harbin subway car body steel structures, the roof, chassis, side walls, end walls and other large components need to be finely processed after welding. If traditional horse stools are used for support, it will not only be bulky and the height cannot be adjusted, but also the operator comfort is not high and the work efficiency is reduced. In order to solve this problem, improve production efficiency and save manpower and time costs. We set up a joint research team. After investigation, analysis and demonstration, we developed a plug-in adjustable support device for large subway components. The device can be adjusted in height and width, and the device is light and easy to move and store, with obvious noise reduction and shock absorption effects. It meets the safe production of various types of subway car body steel structures.

KEYWORDS

Large Subway Components; Support Device; Universal and Adjustable; Quality Research; Ergonomics.

1. PREFACE

In the current development of society, our country's economic construction has made great progress and achieved great achievements. In particular, our country's manufacturing industry is also developing rapidly. However, the pillar of economic development is the industrial economy, and in the development of industrial competition, the mechanical engineering economy plays an extremely important role, occupies a very important position, and is also an important part of promoting the rapid development of our country's industrial economy, leading the my country's economic development has entered a relatively advanced stage of development. The innovative development and application of current mechanical engineering technology has become an important part of research and development in the mechanical engineering industry.

The Harbin Metro car body produced by the company adopts an integral load-bearing fully welded structure (the chassis, side walls, end walls, and roof all bear loads) (as shown in Figure 1). The chassis is welded by chassis side beams, chassis end beams, floors, pillow beams, and buffer traction beams. The roof adopts a continuous closed fully welded structure, all of which are made of extruded profiles. The roof is welded by roof side beams, arc top plates, etc. The deflection of Harbin Metro is 16mm, and each train consists of 6 cars. The train formation is: +Tc-Mp-MM-Mp-Tc+.

Harbin Metro is a digital transformation project of the company, which has important historical significance. At the same time, Harbin Metro is also an important model that uses the "subway large component socket-type adjustable support device", which verifies the advancement and practicality

of the new process equipment. It provides a reliable guarantee for the promotion of new technologies and the application of other models.

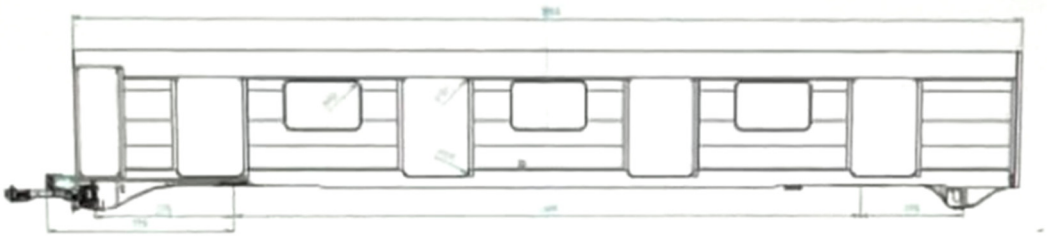


Figure 1. Harbin Metro Steel Structure

2. CAUSE ANALYSIS

2.1. Problems with Traditional Support Devices

The traditional support device (stool) is an integral structure that cannot be disassembled, is bulky, takes up space, and requires a crane to move it to the next process, which reduces the safety factor. When the new production does not need the device, it cannot be changed and is idle (occupying space for storage), wasting costs and becoming a major problem in the steel structure production line. (As shown in Figure 2)

Figure 2. Traditional support device

3. DESIGN IDEAS AND PRINCIPLES

3.1. Achieve Height Adjustment

When producing subway car body steel structures, large parts such as the roof, chassis, side walls, and end walls need to be finely processed after welding. In the past, large parts were placed on traditional support devices (stools) for operation, and workers needed to finely process them again, such as welding small parts on the roof, grinding, and checking for welding leaks. Since the height of traditional support devices cannot be adjusted and cannot be coordinated with the height and arms of operators, operators cannot find a comfortable and safe angle to work, and the operation is time-consuming and laborious. Therefore, when designing the new device, we considered height adjustment, designed sockets for the inner and outer columns, and fixed the position with pins to achieve height adjustment (as shown in Figure 3).

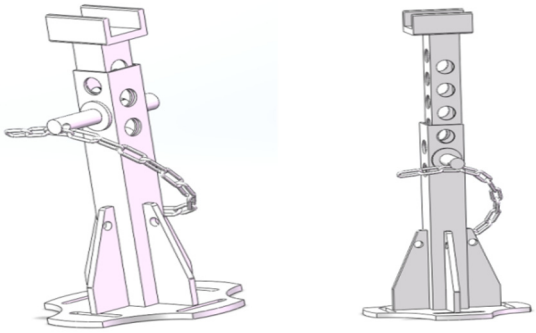


Figure 3. The support device is height-adjustable

3.2. Achieve Adjustable Width

The traditional support device (stool) has a fixed length (as shown in Figure 2). When producing or storing large car body steel structures, the device can be adapted to the steel structure. However, when producing small parts, such as the fine processing or storage of end walls, traction beams and other small parts, the original stool with non-adjustable length will have a part of the tooling waste on one or both sides. This greatly increases the economic cost. In this design, we also made clever improvements to solve this problem. We designed an oblong hole on the chassis of the support seat, and matched it with the pre-buried I-beam installation groove of the production line (as shown in Figure 4). The quick installation and tightening process can achieve left and right adjustment. The longest length on both sides can reach 2800MM, and the shortest can meet the processing and storage of various small parts. The width is adjustable. (As shown in Figure 5)

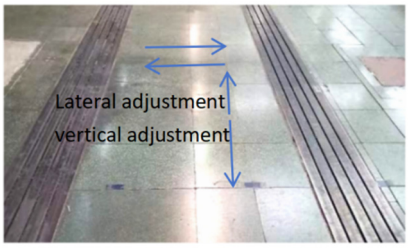


Figure 4. Pre-buried I-beam assembly

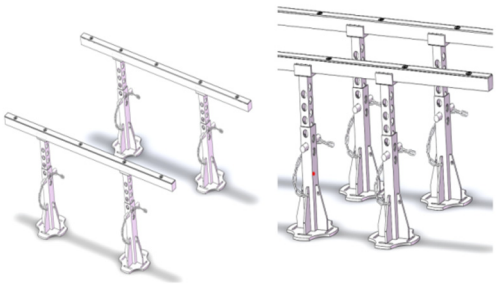


Figure 5. Support device with adjustable width

3.3. Generalized Design Scheme

Since the height and width are adjustable, the device can be freely extended and retracted. The device is lighter than before and can be moved manually without overhead crane lifting, ensuring production safety. When the device is not needed for production, it can be dismantled and dumped out of the site. This is convenient for the production of the next process. Or the width can be adjusted at will, and the original height-adjustable support device can be immediately transformed into a subway component storage rack. One device has multiple uses, adopts a universal chemical equipment design,

saves materials, reduces economic costs, uses the site efficiently, optimizes the process layout, saves manpower, and promotes stable production with high efficiency and high safety assurance in the factory.

3.4. Ergonomics

The design of the adjustable support device for large parts of the subway car body introduces the theory of ergonomics to study the coordination relationship between humans and tooling systems. By studying various factors that affect the human-machine relationship, such as human activity, behavioral characteristics, motivation and reaction, the best human-machine coordination relationship is found. Based on this, the best tooling structure is designed to maximize the interaction between human and tooling system factors to ensure the realization of process goals, meet operability, and ensure safety, efficiency and optimal performance in the use of tooling. (As shown in Figure 6)

Figure 6. Ergonomics

4. STRUCTURAL DESIGN

This device generally uses 3-5 devices as a group to support the subway car body steel structure. The structure of a single support device is as follows (as shown in Figure 7)

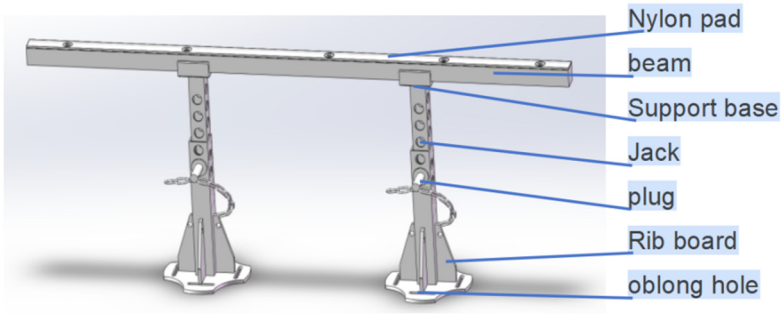


Figure 7. Adjustable support device solidworks

4.1. Name and Function of Each Structure:

1. Bottom plate: The bottom plate plane can not only be fixed to the I-beam embedded in the ground, but also can be placed on the flat ground to make the device stable.

2. Rib plate: Strengthen the rib plate to strengthen the connection between the fixed base plate and the support seat.

3. External panel: It connects the beam and the base plate and is an important part for adjusting the height of the device.

4. Plug: After adjusting the height of the device, use the plug to fix the height of the device.

5. Inner column: The inner column cooperates with the outer plate to adjust the height of the device.

6. Bracket: Fixed on the inner column to support the beam.

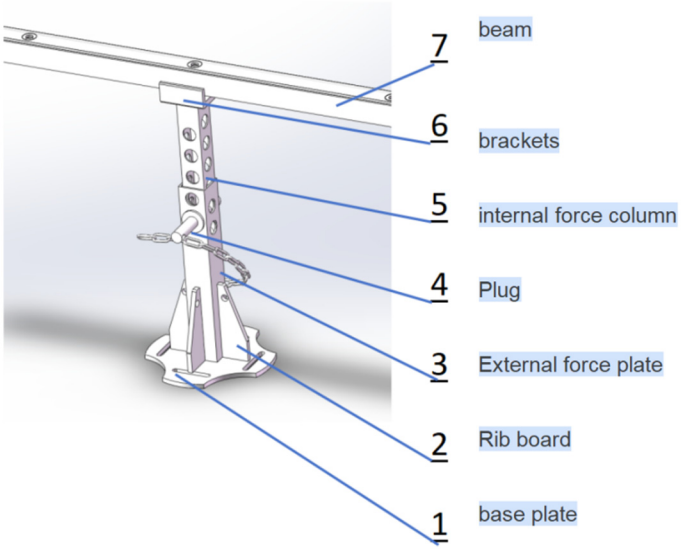


Figure 8. Socket-type adjustable support device

7. Cross beam: The steel structural parts of the vehicle body are placed on the cross beam, which distributes their weight.

* ***Nylon pad:** Fix the nylon pad on the crossbeam to protect the device and the steel structure of the vehicle body (as shown in Figure 7).

The function of nylon pad is:

1）**Wear resistance: Nylon pads have good wear resistance, reducing friction and damage between large vehicle parts and devices (preventing scratches on the vehicle body).**

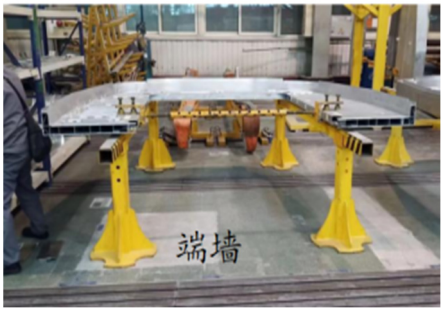
2）**Shock-absorbing effect: The nylon pad is used as a shock-absorbing pad to relieve the operator from vibration and impact during grinding and welding on large vehicle parts (underframe) (as shown in Figure 9), thereby protecting the stability and safety of large vehicle parts and devices.**

3）**Noise reduction effect: Nylon pads are used as sound insulation pads, which can effectively reduce the sound and noise of the car body falling onto the device, providing a quiet working and production environment.**

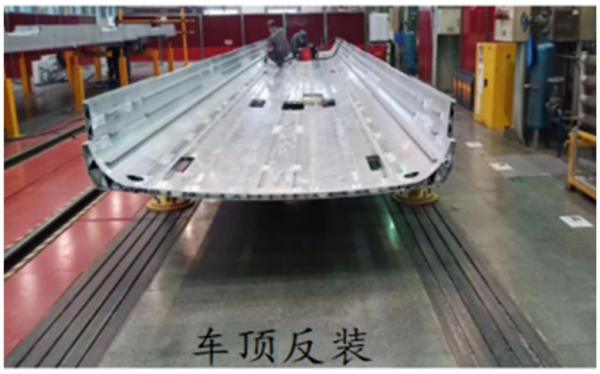
***Oval hole on the bottom plate: Use T-bolts to fix the position between the oblong hole and the I-beam embedded in the ground to fix the device.**

The device consists of a bottom plate, an outer column, an inner column, a latch and a crossbeam. The bottom plate 1 and the rib plate 2 are welded to the lower end of the outer column 3 to increase the strength of the outer column and the stability of placement. The inner column 5 and the outer column 3 form a double-layer telescopic structure. The two are connected into one by a latch 4. The upper part of the inner column 5 is fixed with a bracket 6 to support the crossbeam 7. The bottom of the bracket is provided with a top screw, and the crossbeam can be fine-tuned to ensure the flatness tolerance. When the inner column of an independent unit is adjusted to the required height, a latch connection method is used to achieve mutual fixation of the outer column and the inner column. (As shown in Figure 8) Two groups of unit bodies can store large components such as end walls, chassis ends, and bogies.

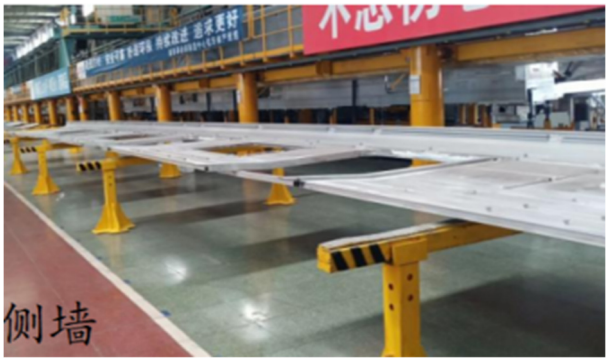
3-4 sets of unit bodies (this device) can be fixed on the I-beam or placed on the flat ground to support the welding of the roof, side walls, end walls, chassis and other components (as shown in Figure 9).

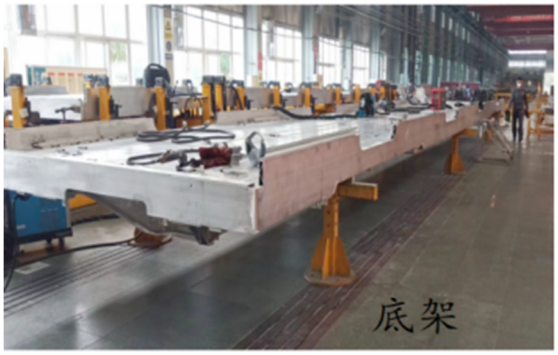


9-a: The device is placed on the ground to support the end wall welding parts



9- b: The device is placed on the I-beam and fixed to support the reverse welding parts on the roof
9-c: The device is placed on the ground to support the normal welding parts on the roof





9-d: The device is placed on the ground to support the side wall welding parts 9-e: The device is placed on the I-beam to support the bottom frame welding parts

Figure 9. Application in the aluminum body production line process

4.2. Top Screw:

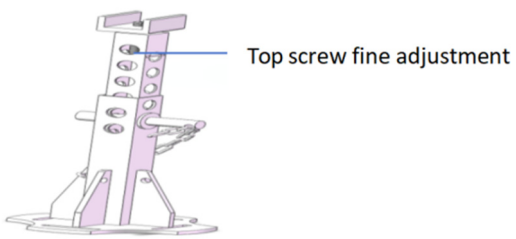


Figure 10. Top screw

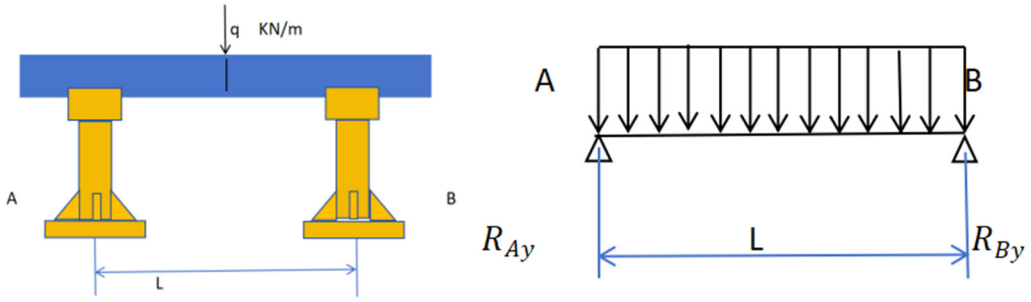
There is a top screw at the bottom of the bracket, which can be used to fine-tune the beam to ensure the overall flatness of the beam (as shown in Figure 10). When using the device, first put a level ruler on the middle of the beam to measure the flatness of the device. If one side of the beam is bottom, you can use the top screw to rotate upwards for fine-tuning (to support the beam).

4.3. Material Selection:

Ordinary carbon structural steel with a carbon content of less than 0.38% is selected, which is mainly used to make engineering structural parts. This type of steel has a wide range of applications, has medium strength, good plasticity and toughness, and is easy to form and weld. For this reason, rectangular square tubes are selected as the main material for tooling. It has a large moment of inertia and section modulus, has a large bending resistance, can reduce structural weight and reduce costs.

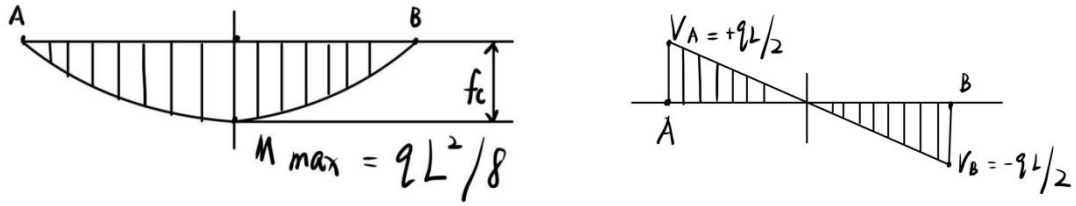
4.4. Bearing Force Analysis

Considering the weight, distribution and dimensions of the large parts of the vehicle body, a force analysis was conducted on a set of unit support devices. The specific force analysis calculation diagram (as shown in Figure 11) is as follows:

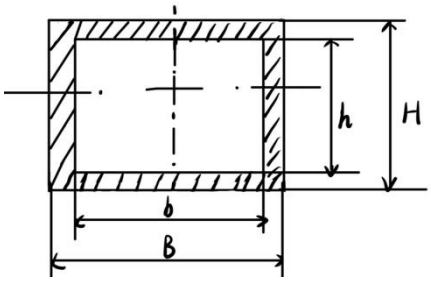


Working diagram (considering uniform load) Calculation diagram

$\sum M_A=0, \sum M_B=0$ $R_{Ay}=$ R_{By}=qL/2



Bending moment diagram shear force diagram



Model cross section

Figure 11. Stress analysis

5. CALCULATION AND ANALYSIS OF DEVICE CARRYING CAPACITY

With universal length L=3500mm, rectangular tube H=120cm

B=80, thickness=5

Calculation results: When q=100kg, deflection fc=1.12mm

When q=1000kg, the deflection fc=11.2mm

In actual use, the gravity q is evenly distributed on several beams, which jointly bear the gravity of large components of the vehicle body, that is the device meets the design requirements.

6. ANALYSIS AND REVIEW

After analysis, review and testing of the plug-in adjustable support device for large parts of subway car bodies by the expert team and the user unit, it is believed that the device meets the production needs.

Economic cost: **Some of the materials used in the design of this device are modified from the scrapped steel plates of the original supporting device (stool), so that the scrapped tooling can be reused.**

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

Quality assurance: **During the production process of the production line, the device can be placed on an I-beam or on a flat ground according to the needs of the site. At the same time, the flatness of the device can be adjusted by fine-tuning with a top screw to make the device stable and ensure the welding quality of large components.**

Improve efficiency: The adjustable design of the device combines ergonomics. The worker's operating comfort is increased. The production efficiency is greatly improved. The flexible design of the device that can be disassembled also improves the efficiency of workers' preparation work. Multiple effects in one.

7. VERIFICATION AND COMMISSIONING

The new structure of the large body parts with a socket-type adjustable support device was carefully processed by the construction unit and completed on-site assembly. After pre-acceptance, it met the design requirements. In the production of Harbin Metro, the tooling verification was carried out to meet the technical requirements (as shown in Figure 12). This device is not only used in the production of Harbin Metro, but also in the production of Changchun Metro Line 3, Chengdu Metro, and Xiamen Metro Line 4.

Figure 12. Tool verification was carried out in the production of Harbin Metro underframe to meet technical requirements

Figure 13. Harbin Metro steel structure rolls off production line

8. CONCLUSION

This article conducted a large amount of research on current problems, analyzed the real dilemma and current situation, made slight changes to the traditional support device, and developed a new support device based on the traditional support method.

This device not only ensures the Harbin Metro steel structure roll-off (Figure 13), but also adapts to the production of various metro models with ideal results. It also solves the problem of storing large parts (small parts welding) and steel structures of the metro body, creating a new situation for technological innovation.

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