Design of Adjustable Width Train Bogie
and Structure Finite Element Analysis

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Keyword: Process bogie, Adjustable, Frame; Strength, Stiffness, Analysis.

Abstract. According to the actual maintenance needs, designed a new bullet train process bogie. Using the software ANSYS to establish finite element model of truck frame, and the frame strength and rigidity is analyzed. Referring to the "Bullet train bogie frame strength test method" (TB/T2368-2005) and the Ministry of Railways standard "Railway vehicles strength design and test standard" (TB/T1335-1996), the frame strength is assessed. The analysis results are consistent with the practical application, and process bogie meets the requirement.

Introduction

Bullet train process bogie is specially designed for motor train unit, used in car body, traction movement of special equipment. Its role is in CRH each model the motor train unit overhaul car body and the bogie support after separation of traction motor car body, make the body to move in the maintenance of the rolls and in libraries. At present our country has a CRH1, CRH2, CRH3, CRH5, four types of train, body width and bogie position caused the maintenance equipment cannot be compatible with a variety of different models. Based on this ,we have designed a kind of adjustable width process can meet the needs of various models of motor car bogie, and by using finite element analysis software of main component architecture to build the finite element model ,analyses the strength stiffness and tested through experiments.

The Technology of Bogie Structure Design

Overall Structure

Train process bogie structure as shown in figure 1, it is mainly composed of structure, beams, supporting device, driving device, master-slave pulley for, explosion-proof battery box, electric control system composition and so on. Equipment bearing mesa height 800 mm; bearing mesa bearing 28t; equipment maximum width 3160mm; maximum length 3080mm; equipment total weight 5t; journal center track spacing is 1956mm to 1435mm.

Stage

Bogie work platform use the fixed two vertical and a horizontal beam structure, the upper beam installation support device; longitudinal beam bottom wheel axle box to installation, simple structure, large bearing capacity, and the derive power supply, power plant has good matching installation. Architecture is one of key components in the process of bogie, but not frame work surface, and to carry and transmit the vertical load, lateral load, and the skew symmetric load, its fatigue strength directly affect the safety of the entire process of bogie performance, reliability and economy on the safety of railway locomotive vehicle maintenance and repair of is essential, therefore the need for strength test.
Support Device

II type lots support unit is the main body of bogie structure, support device by the support column head, floor, dowel, top and bottom friction plate, internal cellular localization logo and shores rectangular rubber spring, etc.

To process in the design of bogie is adjusted by rail and curve function, instead of on both sides of the disc at the center of the traditional structure sliding friction disc structure (as shown in figure 1), makes the main structure is simple and practical. Floor at the bottom of the supporting device, through the grinding of bearing surface contact with the beam on the taper pin will be located in the beam, different models by changing the support device and the relative position of working platform, a total of four working position on the width direction for choice, meet CRH1, respectively, the width of 2, 3, 5 type car requirements, location is determined by cone pin lock position.

Two adjustable side bearing installed at the bottom of the beam, through longitudinal stud and nut screw transmission can adjust is left the vehicle vertical clearance between the beam and side bearing, through transverse socket head cap screw adjusting side bearing and lateral clearance racks, thus ensuring the vehicle side bearing and frame has enough clearance, avoid the side pressure die, meet the needs of the shunting in each process.

II type lots support device in addition to the complete car body support function was also body through a switch and the function of the curve. Support in the design use a flexible support, head lower install cellular rubber spring. Hold head is carried by vehicle, vehicle under static load produced by the gravity and operation process of a certain amount of dynamic load, the load according to hold head, the order of the beam, frame, axle box, eventually evenly distributed to each wheel. Car body hold head mounted on the friction plate, support the device on the plane for grinding processing, forming the friction plate. Friction plate and the sliding friction plate formed on the friction pair, make the body hold head relative support device of the longitudinal and transverse all have certain slip, to meet the process bogie load state of the switch, the requirements of the curve.

Body when head on straight line, through cellular rubber spring to restore it to the center of the supporting device, the effect of rubber spring, there are two: one is to provide the reduction reaction of head, 2 is to provide slip resistance, reduce the car body through the serpentine movement when the switch. At the same time the body holds head around their rotating shaft deflection angle, in order to provide the relative angular displacement between bogie and car body (figure 2).
Figure 2. Hold head through the translation of switch and mobile. Figure 3. Frame finite element model.

Structure Strength Analysis

Building the Frame Finite Element Model

Based on the discrete structure characteristics, divide it into entity class units. Architecture was divided into 553064 nodes, a total of 275280 units. In the model, the X-axis represents the transverse direction, Y axis vertical direction, the direction of Z axis vehicles. Frame finite element entity model and load model shown in figure 3.

Frame Finite Element Calculation of Load

According to the design requirements, for each bogie frame under vertical load is:

\[ F = 38.884 \times 9.81/2 = 190.73 \text{KN} \]  \hspace{1cm} (1)

Bogie frame under lateral load is:

\[ F_y = 0.5( F_z + 0.5m/g) \]  \hspace{1cm} (2)

Which \( m \) for bogie self-respect, here off for 5t, \( F_z \) operating vertical load, the value of \( F/2=95.36 \text{KN} \), counting operation of frame transverse load is 59.94KN, the transverse loading plate carrying on heart.

Skew symmetric load is a kind of right and reverse symmetrical frame two symmetric axis force, vertical effect on the structure, the calculation of \( F_{xie} = 14.72 \text{KN} \).

The Working Condition of Frame Finite Element Calculation

Reference TB/T2368-2005, specification for normal operation condition takes 0.10\( \alpha \) roll coefficient, coefficient of ups and downs take 0.20\( \beta \), the only considered in the calculation of the car body of ups and downs, so take the ups and downs coefficient \( \beta = 0.20 \). Architecture’s operating load condition calculation uses six combination conditions as shown in the table 1.

Table 1. Operating the main load working condition of load combination table (unit:KN).

<table>
<thead>
<tr>
<th>Working condition</th>
<th>Vertical load</th>
<th>Lateral load</th>
<th>Skew-symmetric loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( F )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>((1 + \beta)F)</td>
<td>( F_y )</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>((1 + \beta)F)</td>
<td>( -F_y )</td>
<td>( F_{xie} )</td>
</tr>
<tr>
<td>4</td>
<td>((1 + \beta)F)</td>
<td>( -F_y )</td>
<td>( -F_{xie} )</td>
</tr>
<tr>
<td>5</td>
<td>((1 + \beta)F)</td>
<td>( F_y )</td>
<td>( F_{xie} )</td>
</tr>
<tr>
<td>6</td>
<td>((1 + \beta)F)</td>
<td>( -F_y )</td>
<td>( -F_{xie} )</td>
</tr>
</tbody>
</table>
The Structure Calculation of Allowable Stress

The allowable stress of material uses quotient of the material yield limit $\sigma_s$ and safety coefficient $S$ to compute. Architecture in the design of the main choose ordinary steel welding structure (Q235), the material yield limit is 235Mpa.

TB/T1335-1996, for complex mechanical structure, need to calculate the equivalent stress, the stress may not exceed the allowable stress. This calculation stress results are all using equivalent stress. The calculating formula for equivalent stress is:

$$\sigma_e = \sqrt{0.5[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]}$$

(Eq.3)

Which: $\sigma_e$ as the equivalent stress, Mpa $\sigma_i$ as the main stress (i=1,2,3), Mpa

Frame Stiffness Calculation

As shown in figure 4 for the architecture in the integral deformation condition 1, red area in the figure represents the maximum deformation zone, appear in the frame of center plate bearing surface, the deformation of 4.247mm; dark blue represents the minimum deformation zone, appear in the frame of axle box location, the deformation is 1.935mm. Architecture center plate bearing faces for the displacement of the axle box position is 2.312mm, form the point of actual structure and the deformation effect, mainly for the vertical deformation, relative displacement of 2.312mm is more ideal, therefore enough stiffness of the fabric. Figure 4 and figure 5 show the frame under the working condition of the first and second deformation nephogram.

![Figure 4. Working condition 1 of frame deformation nephogram.](image1)

![Figure 5. Working condition 2 of frame deformation nephogram.](image2)

Calculation results from table 2 shows that under the condition of operating load, frame produces the maximum equivalent stress 116.719 Mpa in condition of 4. Figure 6 shows that the maximum equivalent stress area appears red in the beam and side beam thru and the rest of the working condition is the same position.

![Figure 6. Architecture operating condition 4 stress nephogram.](image3)
Table 2. The maximum equivalent stress calculation results.

<table>
<thead>
<tr>
<th>Working condition</th>
<th>the maximum equivalent stress (MPa)</th>
<th>occur position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>86.101</td>
<td>The frame beam and side beam thru</td>
</tr>
<tr>
<td>2</td>
<td>103.321</td>
<td>The frame beam and side beam thru</td>
</tr>
<tr>
<td>3</td>
<td>103.476</td>
<td>The frame beam and side beam thru</td>
</tr>
<tr>
<td>4</td>
<td>116.719</td>
<td>The frame beam and side beam thru</td>
</tr>
<tr>
<td>5</td>
<td>105.666</td>
<td>The frame beam and side beam thru</td>
</tr>
<tr>
<td>6</td>
<td>114.356</td>
<td>The frame beam and side beam thru</td>
</tr>
</tbody>
</table>

**Conclusion**

By analyzing the strength of the bogie frame of bullet train technology and field verification, conclusions are as follows:

1) Under static loading, the maximum relative displacement of the frame in 2.312mm, the results are ideal, frame rigidity is enough.

2) In the calculation conditions stipulated in the TBT/2368-2005, structure under operating conditions the maximum equivalent stress is 116.719 Mpa, did not exceed allowable stress under operating conditions of Q235 steel standard of 142 Mpa, stiffness meet the requirements of the architecture.

3) Field experiment results show that the technology of bogie conform to relevant national standards and user requirements.

**Acknowledgement**

Project of Hebei province department, Item no. 16211925, It is supported by the provincial experimental teaching demonstration center of Mechanical and Electrical Engineering Department, Hangshan College.

**References**


