Research on the strength of 25 meter long rail transport using special bogie with six fulcrum points

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Keywords: Railway Transportation; Bogie; unbalanced weight, simulation analysis

Abstract: With the rapid development of China's railway industry, the annual demand for railway transportation is very huge, which occupies a large proportion of 25 meters of rail transport. At present, China's 25 meter rail transport mainly uses two cars straddle transport with six fulcrum points bogie. This mode of transport in the actual operation often occur unbalanced weight problem. This paper established finite element model according to current 25 meters rail transportation loading and reinforcement scheme of the rail, then simulated the fulcrum force, calculated the fulcrum bearing weight, using statics moment balance theory and calculates the vehicle bogie bearing size and weight. By changing the 2, 5 fulcrum position, reducing the weight of 3, 4 fulcrum position to find the right solution. In this solution, the force of the 2nd and 5th fulcrums is increased, so the bogie strength verification is performed to verify the safety of railway transportation.

1. Introduction

With the development of the economy, China's railway industry has also entered the peak period of development. At present, the fixed length of China's rails is mainly 25 meters and 100 meters. The 25 meter rail is mainly used for the transformation and maintenance of the existing line. The 25 meter rail transportation has become an important part of railway cargo transportation.

Russia, Japan, Austria and other countries have special flat cars for 25 meter rail transport, Russia has 25 meter rail transport special flat cars, while Japan mainly uses Kiya87-type rail trucks to transport 25 meter rails, and Austria uses a 22.4 meter flat car [1]. China's 25 meter rail transport has gradually evolved from the first two fulcrums point loading and transportation scheme to the current six fulcrums point dedicated bogie loading and transportation scheme.

The advantage of the six fulcrums point bogie is that the weight of the rail is shared to the six fulcrum of cargo bogies, which effectively solves the problem of concentrated weight of the 25 meter rail transported by the two fulcrums point bogie. The prominent problem is unbalanced weight for six-point bogie. Changing the position and height of the fulcrum is also a solution to solve the problem.

2. Research Status

Scholars have applied data envelopment analysis to study 25 meter rail unbalanced weight and simulation problem.

Han Mei (2016) used Solidworks to establish entity model of 25 meter rail. Two improvement solutions were put forward including change of the height of fulcrums and change of the longitudinal position of fulcrums on the vehicle, and finite simulation analysis are used. According to the results, adjustment of the longitudinal position of fulcrums may avoid weight unbalancing [2].

Zhao Yong (2011) analyzes the causes of the unbalanced weight problem in the 25 meter long rail straddle transportation process, and discusses the solution to solve the unbalanced weight problem [3].

Yin Tao (2009) used the finite element software to simulate and calculate the main structural strength of the cargo bogie when subjected to vertical load, determine the distribution of stress extreme value, improve the accuracy of the inspection position of the cargo bogie, and improve the

  DOI: 10.25236/iwmecs.2019.105

test accuracy of the two cargo bogies.

Yang Guangquan (2012) used the loading and reinforcement scheme of a 100m long rail transported by a common flat car with a length of 1.5 as an example, ANSYS software is used to establish a vehicle-bearing simulation model considering the vehicle center suspension and the adjacent vehicle height difference. The results showed that the vehicle's various load-bearing indicators meet the technical requirements.

Zhao Jianming (1992) introduced three methods for calculating the strength of the frame. The various tests and the latest methods for the dynamic performance analysis of the railways by foreign railways, as well as the research on the fatigue strength and fatigue life of the frame and the methods for reliability evaluation are introduced.

According to the above research, using SolidWorks, HyperMesh and Ansys to study 25 meter rail unbalanced weight and simulation problem is feasibility.

3. Simulation

3.1. Simulation Software

SolidWorks software is the 3D CAD system based on Windows development. Its powerful features, easy to learn and use and technological innovation make it as a leading and mainstream 3D CAD solution. This paper established rails and bogies models using solidworks software.

HyperMesh is a high-performance finite element pre-processor and post-processor. This paper uses Hypermesh software to mesh the rails and bogies to form a finite element model of the bogie.

Ansys software is a large-scale general finite element analysis software that integrates structure, fluid, electric field, magnetic field and sound field analysis. This paper used the ANSYS software to simulate the force and bogie strength of each fulcrum point of the six fulcrum point bogie.

3.2. Establishment of rail and bogie models

In SolidWorks, the cross-sectional view of the rail is drawn according to the actual cross-section of the 60kg/m rail. The bogie model is drawn according to the actual size of the bogie under frame, the bogie length is 3120mm, the width is 1090mm and the height is 120mm. The steel is connected in N-shape with a distance of 625 mm. The thickness of steel plate is 4.5mm, as shown in Figure 1.

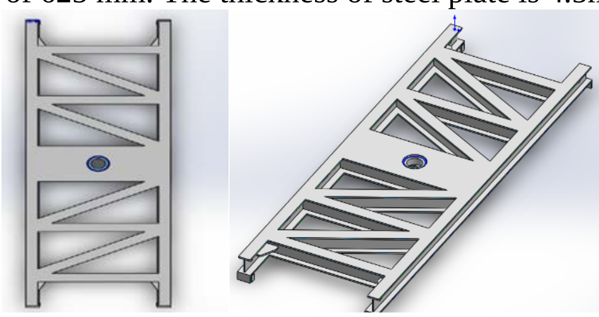

Figure 1 Bogie model.

3.3. Mesh division of rails and bogies

After introducing HyperMesh into the rail model, Automesh is used to mesh the rail section. The mesh size is 10 mm. Then the rail is meshed, the mesh size is 150 mm. The meshed rail model is shown in Figure 2.

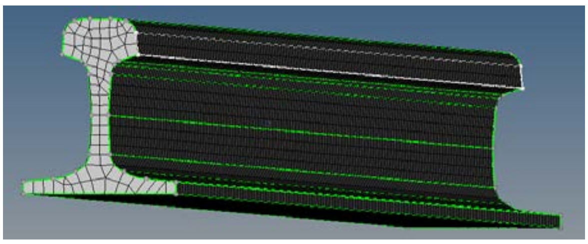

Figure 2 Rail model.

The bogie with six fulcrum points consists of a movable under frame, a fixed under frame, two upper frame, and four movable rams. The four movable rams are placed on the centerline of the four bogies of the two vehicles, namely 1, 3, 4, and 6 fulcrums. The two cargo bogies consisting of the upper and lower frames are placed on the horizontal and vertical centerline of the vehicle. That is 2, 5 two points. The height of the 2 and 5 fulcrums of the six fulcrum point bogie is 35 mm higher than the height of the 1, 3, 4, and 6 fulcrums.

In order to fix the position of rails, according to the loading and strengthening scheme of rails, the constraints are set in Analysis, which are X1, X2, X3, X4, X5 and X6 (Xi represents the distance between i fulcrum and the left end of rails), as shown in Figure 3. The distance between each fulcrum and the left end of the rail is shown in Table 1.

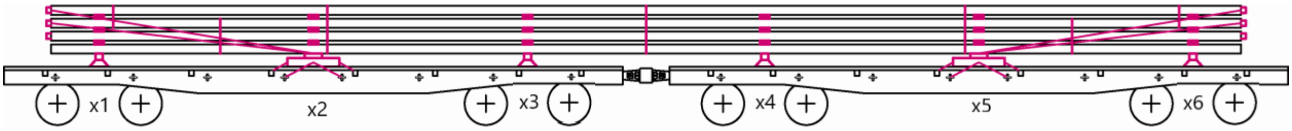

Figure 3 The position of each fulcrum relative to the left end of the rail.

Table 1 The position of each fulcrum relative to the left end of the rail.

Fulcrum	x1	x2	x3	x4	x5	x6
Distance from the left end of the rail (mm)	1031	5531	10031	14969	19469	23949

The bogie model is imported, and the bogie frame is meshed with Automesh. The size of the mesh is 10mm. The set of constraint points and the set of applied force points are shown in Figure 4. The white point in the figure is the set of applied force points.

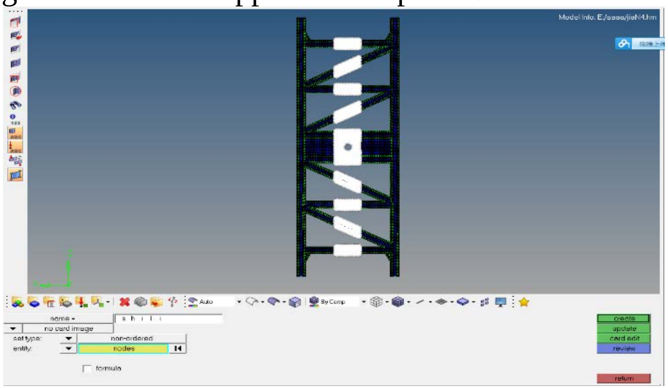

Figure 4 Bogie force point set

3.4. Simulation on bogie force and strength

3.4.1. Simulation on bogie force

The six fulcrum point bogie is in the form of a layered load when loading a 25-meter rail. Each layer of rails is placed in a forward and reverse phase. Simulation was performed by using ANSYS. Firstly, introduce the finite element model of the rail, and then analyze the force of the rail to determine the force of each fulcrum of the bogie under static load, as shown in Figure 5.

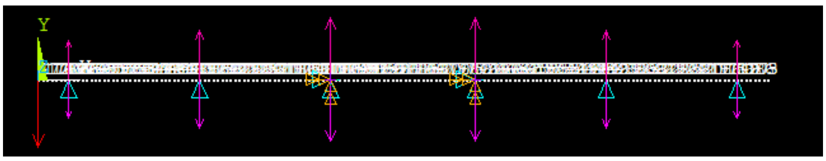

Figure 5 Simulation of rail force on each fulcrum point

The force of a rail on each fulcrum is shown in Table 2.

Table 2 The force of a rail to each fulcrum.

forward X1	forward X2	forward x3	reverse x1	reverse x2	reverse x3	x1 F1	x2 F2	x3 F3
1898N	2413N	3042N	1596N	3376N	2379N	12.5t	20.5t	19.5t

In the static load state, the floor height of the car is the same and the rail does not move. The forces of the 1st and 6th fulcrums are the same, the same as the 2nd and 5th fulcrums, the 3rd and 4th fulcrums. Therefore, it is able to analyze the load on the cargo bogie on a flat car. The force analysis is shown in Figure 6.

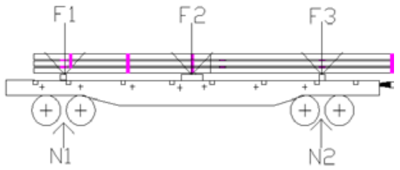

Figure 6 The force analysis of each fulcrum point

Where,

F_1, F_2, F_3: The force of the rail on 1 fulcrum, 2 fulcrum and 3 fulcrum.

N_1, N_2: Load-bearing of vehicle bogie.

Lij: Distance between i fulcrum and j fulcrum.

Let G1, G2, and G3 denote the gravity of the 1 fulcrum slide, the gravity of the 2 fulcrum cargo bogie, and the gravity of the 3 fulcrum movable ram, respectively. The mass of the six fulcrum point dedicated bogie movable ram is 111.4kg, and the bogie corresponding to the 2nd and 5th fulcrum points is 129.7kg for the upper frame and 460.5kg for the lower frame, total is 590.2kg. L_{12}=L_{23}=L_{45}=L_{56}=4500mm, L_{34}=4938mm.

Calculated:

G_1=G_3=111.4kg×9.8N/kg=1091.72N,

G_2=590.2kg×9.8N/kg=5783.96N.

Balance equation based on force arm,

$$N_1 \times L_{13} = (F_1 + G_1) \times L_{13} + (F_2 + G_2) \times L_{23} \quad (1)$$

$$N_2 \times L_{13} = (F_3 + G_3) \times L_{13} + (F_2 + G_2) \times L_{12} \quad (2)$$

Simplify the formula:

$$N_1 = F_1 + G_1 + (F_2 + G_2) \times L_{23} \div L_{13} \quad (3)$$

$$N_2 = F_3 + G_3 + (F_2 + G_2) \times L_{12} \div L_{13} \quad (4)$$

Bring the F value into formula,

N_1=30.1t，N_2=23.2t。

Now, the vehicle is already in a state of unbalanced weight.

3.4.2. Solve the problem of unbalanced weight

The corresponding data is measured by constantly changing the distance that the 2 and 5 fulcrums move to the 3 and 4 fulcrums, as shown in Figure 7.

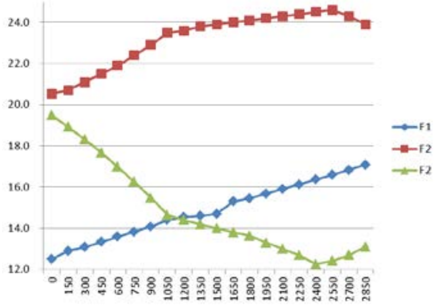

Figure 7 moving distance and forces of 2 and 5 fulcrum

When the 2 and 5 fulcrums are moved to 1050 mm to the 3 and 4 fulcrums respectively, the bearing capacities of the 1, 6 fulcrum and the 3 and 4 fulcrums are basically the same. That is, the positions near the intersection of F1 and F3. The bearing capacity of 2 and 5 fulcrums is 23.5t, the 1,6 fulcrums is 14.4t, the 3rd and 4th fulcrums is 14.6t. The load of the front bogie of the vehicle is 23.8t, and the load of the rear bogie is 29.6. The difference weight between two bogies is less than 10t, and the respective load-bearing capacity does not exceed one-half of the allowable load of the vehicle. Therefore, the solution solves the problem of the vehicle's unbalanced weight.

3.4.3. Simulation on bogie strength

In the solution, the force of the 2nd and 5th fulcrums is increased from the initial 20.5t to 23.5t, and the bogie load is increased. Therefore, the strength of the bogie needs to be verified to determine whether the bogie strength is met. The ANSYS software was used to verify the strength of the bogie. The bogie was restrained and the load was applied. The load-bearing capacity of the frame under the fixed core was 23.5t, and the simulation result of the actual ratio was obtained, as shown in Figure 8.

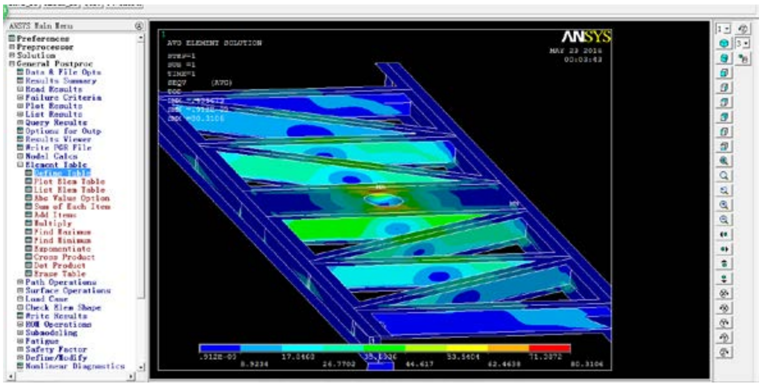

Figure 8 Strength results in the actual ratio

Considering the dynamic load coefficient of 0.4, the maximum vertical load stress on the bottom frame of the hard core can be calculated to be 112.42 Mpa, which is less than the allowable stress (160Mpa) of the bogie material. Therefore, the bogie strength meets the requirements.

4. Conclusion

This paper analyzes the current situation of 25 meter rail transportation in China. At the current stage, the load of the 25 meter rail loading and transportation scheme under the static load condition and the bearing capacity of the vehicle bogie are judged according to the Regulations on Railway Freight Loading and Reinforcement. In order to solve the problem of unbalanced weight, analyze the changes and trends of the force of each fulcrum when the 2 and 5 fulcrums are in different positions of the vehicle. When the 2 and 5 fulcrums are moved to 1050 mm to the 3 and 4 fulcrums respectively, the bearing capacities of the 1, 6 fulcrum and the 3 and 4 fulcrums are basically the same. Due to the change of the position of 2 and 5 fulcrums, the weight of the bogie at 2 and 5 fulcrums is increased. Therefore, it is necessary to verify the strength of the bogies of 2 and 5 fulcrums, the simulation results shows that the bogie strength meets the requirements.

Acknowledgements

National Key Research and Development Program of China (Project No. 2018YFB1201402).

References

[1] Ding Wenying, Li Shanpo, Yin Tao, Ma Yukun, Yang Guangquan. (2010) Introduction of Long Rail Transportation Technology at Home and Abroad. Railway Freight Transport, 10:36-40.

[2] Han Mei, Zheng Hang, Fang Zhe, Yang Nengpu. (2016) Study on Unbalanced Weight Problem

of 25 m Rail Based on Simulation Analysis, Journal of the China Railway Society, 01:8-11.

[3] Zhao Yong, Zhang Zhongping. (2011) Discussion on Unbalanced Weight Problem of 25m Rail by Using Six-point Cargo Bogie. Railway Freight Transport, 01:35-37.

[4] Yin Tao. (2009) Application of Simulation Technology in Testing of Railway Cargo Bogies. Railway Freight Transport, 09: 40-42

[5] Yang Guangquan, Ma Yukun. (2012) Simulation on Vehicle Loading of 100m Long Rails in Normal Flat Cars. Railway Freight Transport, 03:37-42

[6] Zhao Jianming. (1992) Strength Analysis and Reliability Evaluation of Steering Frame. Locomtive & Rolling Stock Technology. 04:1-4