Research on Railway Transportation and Loading Reinforcement of the Special Purpose Vehicle

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Abstract. To effectively solve the loading reinforcement problem of overloaded vehicles and equipment when troops use railway transportation, this paper takes the field rushing car of Dongfeng as example. Makes calculations from gravity center stability of heavier cars, force in conveying process, stability and reinforce the strength, analysis its mechanical structure and then calculates, designs its loading reinforcement project. This paper also sets up the whole model and applies software of Ansys to simulated experiment, verifiers the safety and practicality of the loading reinforcement scheme and provides theoretical guidance and technical support for the force railway transport station tasks.

Introduction

With the characteristic of large conveying capacity, less restricted conditions, high flexibility, railway transportation is an important mode of transportation. When facing with sudden task or duty, overrun vehicles and equipment are usually transported by railway. Basing on the reality of overrun vehicles and equipment, increasingly mission requirements, the problem of making army overrun vehicles and equipment quickly be loaded is particularly important. In this paper, certain Dongfeng field application car is selected to be studied about its loading and reinforcement, to determine a reasonable loading and reinforcement scheme, so as to guide the troop practical operation and supply reference for other overrun vehicle equipment loading and reinforcement.

In field condition, the certain Dongfeng field application car is an important vehicle for the use of troop commanding, transportation, communication, equipment maintenance, health care etc. This car can completely satisfy all needs of field operator. This car is consists of transportation chassis truck and shelter. After measuring, the vehicle achieves the first level of overrun standard. When transported, it should be dealt with first level of overrun standard.

Mechanics Analysis and Calculation

The flatcar always making complex vibration due to the roads, crosswind etc. during the process of transportation. The following content is mechanics analysis and calculation after overrun vehicle loaded.

Length-Ways Inertial Force Calculation. As the railway flatcar makes stretching vibration in the condition of acceleration, braking, shunting and humping etc. This stretching vibration is exactly the efficient cause of the length-ways inertial force. The length-ways inertial force is

$$T = t_0 \times Q_{all}$$

In the equation t_0 the length-ways inertial force caused by per ton of loaded car, Q_{all} is the weight of loaded car.

For shelter, if adopt the informal reinforcing equipment, it usually takes No.8 galvanized iron wire etc. to pull and reinforce. This way is belong to flexible reinforcement. So take

$$t_0 = 0.0012Q_{all}^2 - 0.32Q_{all} + 29.85$$

in the equation, Q_{all} is the total weight of the loading car.

Crosswise Inertial Force Calculation. The shaking vibration, swing vibration and rolling vibration caused during the process of flatcar moving always cause the crosswise inertial force of loaded car[1]. The shaking vibration and swing vibration are caused by the factors of railway track bend, crosswind, in-balanced loading etc. Rolling vibration is caused by road quality, crossroad etc. The crosswise inertial force N is

$$N = n_0 \times Q_{all}, \quad n_0 = 2.82 + 2.2\, a/l$$

In the equation n_0 is the crosswise inertial force caused by per ton of loaded vehicle, a is the distance of loaded vehicle center gravity diverge the vehicle horizontal, I is the center distance of loading car bogie.2.3.

Vertical Inertial Force Calculation. During the flatcar moving process, it will cause up and down vibration, shaking vibration and rolling vibration. These three kinds of vibration cause vertical inertial force. The vertical inertial force $Q_{vertical}$ is

$$Q_{vertical} = q_{vertical} \times Q_{car}$$

$$q_{vertical} = 3.54 + 3.78\, a/l$$

In the equation, $q_{vertical}$ is the vertical inertial force caused by per ton of loaded car, the value of *a* and *1* are the same with the value of crosswise inertial force equation.

Wind Powder Calculation. During the process of railway transportation, it always affected by wind, and mostly it's the loaded car affected by the horizontal wind. When there's strong side wind, the car mostly likely suffering major overturning accident on super-giant bridge, high embankment or wind gap [2]. Because of the wind, speed limiting action should be taken in the above road segment. The wind powder W is

$$W = q \cdot F$$

in the equation, *q* is calculated wind pressure inside direction, *F* is the projection area in side direction windward side.

About the value of *q* , in the Ministry of Railways of the People's Republic of China. Railway Cargo Loading Reinforcement Rules [1] q is 0.49kN/m^2. But this value does not considering after speed up, there's additional wind loading when two vehicle meet [3]. So when calculating, the value of *q* can be 0.712kN/m^2, this value is more reasonable for calculation result [2][3].

Friction. As the loaded field application shelter car is belong to wheeled vehicle, the touching way is the rubber tire meet the vehicle floor, select the right friction coefficient μ according to the Ministry of Railways of the People's Republic of China. Railway Cargo Loading Reinforcement Rules, the μ is 0.63 [4], and calculate the friction. The friction $f_{vertical}$ and $f_{crosswise}$ is

$$f_{lengthways} = 9.8\mu \times Q_{car}$$

$$f_{crosswise} = \mu\left(9.8Q_{car} - Q_{vertical}\right)$$

Determine the Loading Reinforcement Scheme for Vehicle Equipment

Make a reasonable reinforcement scheme to guide loading operation. It will save time and guarantee railway transport.

Gravity Center Height Calculation. Before determine the loading reinforcement scheme for vehicle equipment, the must to do work is calculating the gravity center height H [5] of heavy vehicle. According to the Ministry of Railways of the People's Republic of China. Railway Cargo Loading Reinforcement Rules, the heavy vehicle gravity center height should not pass 2000mm, or should to balance weight. The heavy vehicle gravity center height *H* is

$$H = \frac{Q_{flatcar} h_{flatcar} + Q_{car} h_{car}}{Q_{flatcar} + Q_{car}}$$

In the equation, $Q_{flatcar}$ is the weight of flatcar, Q_{car} is the weight of shelter, $h_{flatcar}$ is the hight of gravity center to track surface when flatcar empty running, $h_{flatcar}$ is the hight of gravity center to track surface when shelter is loaded.

Overturning Stability Coefficient.

$$\eta_{lengthways} = \frac{9.8Qa_1}{Th}$$

$$\eta_{crosswise} = \frac{9.8Qb_1}{Nh + Wh_{wind}}$$

In the equation, a_1, b_1 are the distance between the lateral or longitudinal plane which loaded vehicle gravity center on to cargo overturning point, h is the height of loaded vehicle gravity center from the lateral plane which the overturning point on, h_{wind} is the height of wind point from the lateral plane which the overturning point on. If the overturning stability coefficient is 1.25, then reinforcement measures should be taken, usually take the method of pulling and reinforcing.

By calculating, it shows the vehicle may overturn, so reinforcement measures should be taken.

If the longitudinal friction force of loaded vehicle is little than longitudinal inertial force of loaded vehicle, or lateral friction force is small than the 1.25 times of the sum of lateral inertial force and wind, reinforcement measures should be taken to prevent it from moving.

The Stability of Movement. The longitudinal stability of movement ΔT is

$$\Delta T = T - f_{lengthways}$$

The lateral movement stability ΔN is

$$\Delta N = 1.25(N + W) - f_{crosswise}$$

Rolling Stability Coefficient. For wheeled vehicles and equipment, rolling stability coefficient should be calculated. The rolling stability coefficient can be divided into longitudinal stability coefficient and lateral stability coefficient, they are $\eta_{lengthways}$ and $\eta_{crosswise}$ their value is

$$\eta_{lengthways} = \frac{9.8Qa_2}{T(R - h_{cover})}$$

$$\eta_{crosswise} = \frac{9.8Qb_2}{(N + W)(R - h_{cover})}$$

In the equation, a_2, b_2 are the distance of lateral or longitudinal vertical plane which loaded vehicle gravity center on to triangular baffle and wheel contact point, R is wheel radius，h_{cover} is the height of triangular baffle and wheel contact point to the lowest point of the wheel on [7].

Calculation of Reinforcement Intensity When Pulling. Use n pulling ropes in the same direction[8], then the calculation equation of every rope suffered tension are as following:

$$S_{lengthways\ move} = \frac{\Delta T}{nAC}\sqrt{AC^2 + BO^2 + BC^2}$$

$$S_{corsswise\ move} = \frac{\Delta N}{nBC}\sqrt{AC^2 + BO^2 + BC^2}$$

$$S_{lengthways\ tilt} = \frac{1.25Th - 9.8Qa_2}{n\left(l_{lengthways} + AC\right)BO}\sqrt{AC^2 + BO^2 + BC^2}$$

$$S_{crosswise\ tilt} = \frac{1.25(Nh + Wh_{wind}) - 9.8Qb_2}{n(l_{crosswise} + BC)BO}\sqrt{AC^2 + BO^2 + BC^2}$$

In the equation, $l_{crosswises}$ is the distance of loaded vehicle lateral overturning point to longitudinal vertical plan which the rope bolt point of pull rope on the vehicle, $l_{lengthways}$ is the distance of loaded vehicle longitudinal overturning point to lateral vertical plan which the rope bolt point of pull rope on the vehicle.

Each rope bore force is

$$S \geq \left\{S_{lengthways\ move}, S_{crosswise\ move}, S_{lengthways\ tilt}, S_{crosswise\ tilt}\right\}$$

When the rope is steel wire, the breaking force of the it should be more than 2S. When select the No.8 galvanized rope, then the number n of strand for each pulling rope is

$$n = \frac{S}{0.9P_{permissive}}$$

In the equation, $P_{permissive}$ is the permissive pulling force one strand No.8 galvanized rope, the unit is kN.

According to the structure of certain type Dongfeng field application shelter car, the overturning can be ignored, only calculate the longitudinal and lateral force. When calculating, the value of AC should be considered, as the value of AC affect the calculating result. With the raising of AC value, $S_{lengthways}$ move shows the decreasing trend, $S_{corsswise}$ move shows the increasing trend.

Scheme Determination. For the structure of certain type Dongfeng field application shelter car, according to calculation result, forward loading, and the gravity center projection of vehicle equipment is on the intersection of flatcar longitudinal and lateral central line. Brake after loading and orientation, door and windows should be kept closed, transmission in the initial position, the brake handle fixed with galvanized iron wire. The reinforcement method should be pulling [9], With 16 strands galvanized iron wire respectively pull the front and rear wheels of vehicle equipment into eight shape, tying on the car side T-bar. Use triangular baffle to mask and fasten tightly on the front and back of front and rear wheel of vehicle equipment. The reinforcement wire should be taken wear measure on the edges. The concrete reinforcement plan is shown in Fig. 1.

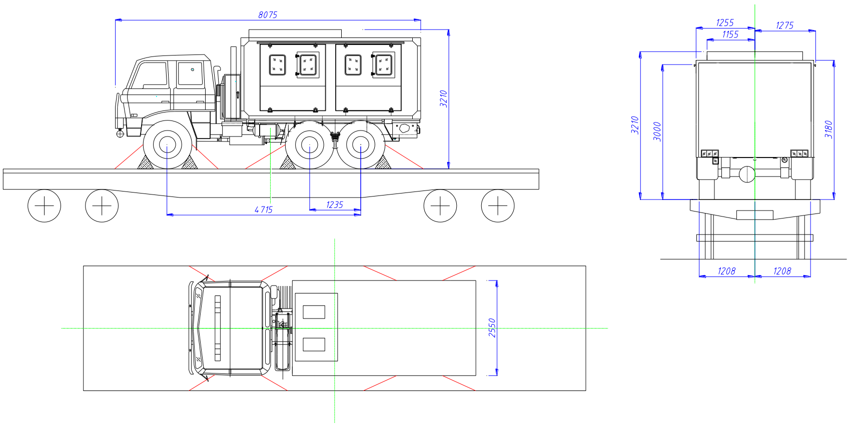

Figure 1. Figure of loading reinforcement scheme

Ansys Simulation Verification

Modeling. Use the Ansys to set a model like Fig. 2, the upper part is car model, the lower part is train flatcar model, the purple part is triangular baffle model. Define the material model, the material elastic modulus of trucks and lower trailer regional is 200 Gpa, the density is 7800 kg/m^3, poisson's ratio is 0.3; the elastic modulus of wood inclined piece is 10 Gpa, density is 800 kg/m^3, poisson's ratio is 0.3. LINK10 unit simulation of galvanized iron wire.

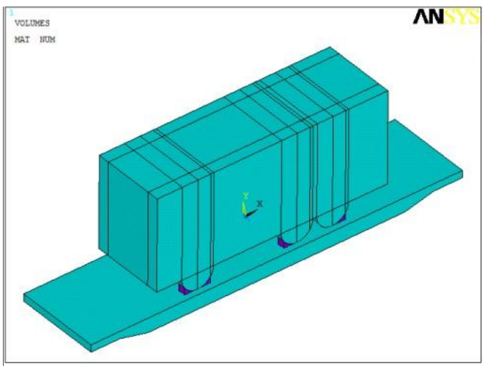

Figure 2. Modeling Chart

Meshing. The mesh is shown in Fig. 3, choose 8 node hexahedron unit SOLID185 points divided into entity grid, LINK10 unit simulation wire rope. The grid model is shown in the chart below. The node number is 29695, unit number is 22802.

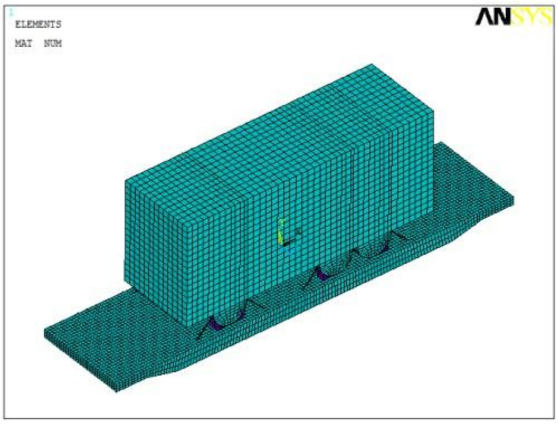

Figure 3. Meshing Chart

Applied Loading. Select each wheel and contour line of bottom contact position, restrain vertical and lateral degree of freedom, as shown in chart 4. Select each inclined piece underside, restrain the vertical degree of freedom. Select steel wire near the side of the truck endpoint, apply fixed displacement restrain. Calculate according to the above: The longitudinal inertial force is 317.4 kN, lateral inertial force is 45.5 kN, vertical inertial force is 57.3 kN, wind is 18.45 kN, longitudinal friction is 98.784 kN, lateral friction is 62.68 kN, impose the loaded forces on the car body.

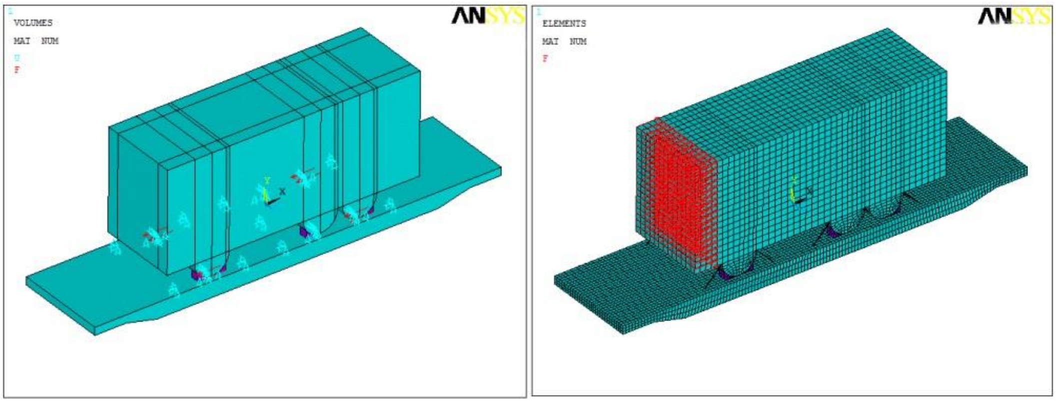

Figure 4. Imposing Loaded Force Chart

The Result Analysis. The simulation result is shown in Fig. 5, 4 mm galvanized iron wire breaking strength is 4.3 kN, then the 16 strand breaking strength is 68.8 kN, take 1.5 times safe coefficient. then the 16 strands of galvanized iron wire allowable breaking strength is 68.8/1.5 = 45.8 kN. 41.956 kN < 45.8 kN, so choose 16 strands of galvanized iron wire is relatively safer.

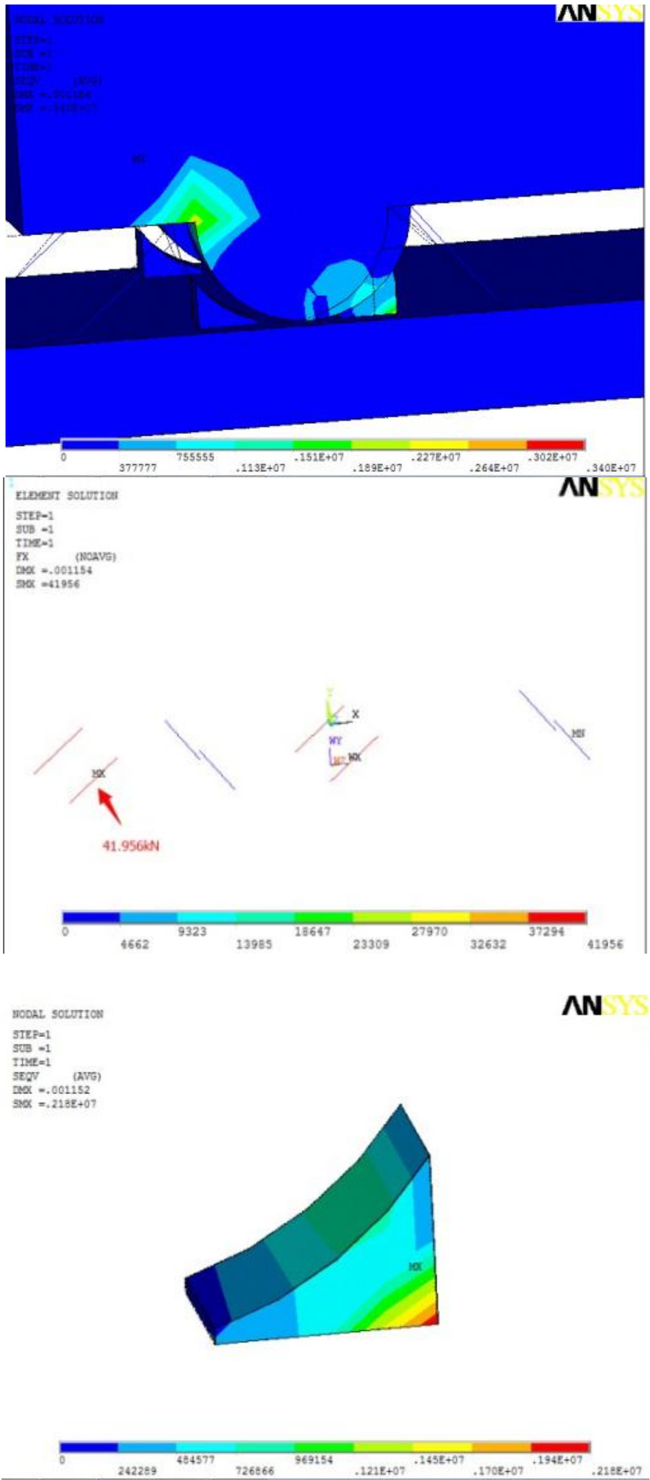

Figure 5. Result Analysis

Conclusion

By the mechanics calculation and numerical analysis of certain type Dongfeng field application shelter car, determine the loading reinforcement scheme, namely using the reinforcement way of pulling, With 16 strands of 4mm galvanized iron wire respectively pull the front and rear wheels of vehicle equipment into eight shape, tying on the car side T-bar. And by Ansys software simulation, verified that the scheme is reasonable and safe, and guide the troop practice well in practice.

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