Design of Railway Exceptional Dimension Cargo Reinforcement Scheme System

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Abstract. The reinforcement of exceptional dimension cargo has always been a task of high technical difficulty and strong security demand in railway transportation production. Based on the rules and regulations related to the exceptional dimension cargo loading and reinforcement scheme, this paper uses vb.net to design a system that can formulate exceptional dimension cargo reinforcement schemes by computer. The reinforcement program is the main content, including the exceptional dimension cargo loading program subsystem. A reasonable cargo loading plan is generated based on the relevant parameters of the goods provided, and a speed limit requirement is provided for the operation of the cargo train. This paper calculates the various forces and cargo stability factors that will be encountered when transporting goods, and generates a reasonable reinforcement plan based on the selected reinforcement materials and gives a sketch of the cargo loading reinforcement. The complete cargo reinforcement scheme system simplifies the work of cargo forwarders and quickly obtains reinforcement schemes for simple and exceptional dimension cargo.

1. Introduction
The loading and reinforcement of railway cargo is an important part of the organization of railway transportation. In order to ensure the safety of goods and driving and increase the competitiveness of railway cargo transportation, it is necessary to ensure the safety and economy of loading and reinforcement, which means that the optimization of the loading reinforcement scheme must be reasonable. Before the exceptional dimension cargo is transported, no matter whether the shape of the cargo is complicated or not, it is necessary to formulate a loading and reinforcement scheme for the cargo. This ensures the safety of the cargo transportation process, but it takes a lot of time and effort for the cargo personnel.

In view of this, in order to reduce the workload of cargo personnel and ensure the accuracy of the loading reinforcement scheme, this paper designs a system that automatically generates simple and exceptional dimension cargo reinforcement schemes, including the input of cargo specification, the optimal selection of loading scheme, the speed limit condition of curve part, the force analysis of cargo, the selection of cargo reinforcement material, the optimal selection of cargo reinforcement scheme and the simple loading and reinforcement diagram.
2. Subsystem of cargo parameter

The input of the cargo parameter table is the basis for the successful operation of the system. The user must carefully input all the data such as the product name and the length of the cargo into the table to ensure that the subsequent load consolidation scheme subsystem can be successfully implemented.

The basic parameters of cargo transportation include the loading and unloading station of the goods, the arrival and arrival stations, name, weight, length, high center of gravity, the position of the center of gravity and other dimensions of the goods. Among these parameters, except for the item name, other parameters can only enter numbers and limit the range of each parameter. Considering that the load of an ordinary flat car is basically around 60t, the weight range is limited to 0-58t. Because it takes into account the horizontal reinforcement and reinforcement materials used in the load reinforcement, it needs to occupy a certain load of the car, so the maximum cargo weight is 58t instead of 60t.

In order to ensure safe driving, buildings and equipment along the railway must be kept at a certain distance from the line to prevent collisions between the rolling stock (including the loading or cargo on the vehicle) and adjacent buildings or other equipment, resulting in an accident. Therefore, a non-intrusive contour line must be specified for buildings and equipment, and a contour line for the rolling stock must not be exceeded. This contour line is collectively referred to as the railway clearances [2]. When the parameters are input, the height of the cargo center shall not exceed 3300mm, and the maximum half width of the cargo shall be less than 1700mm.

The relevant dimensions of the goods themselves need to be measured before loading. In addition to the maximum length of the cargo, it is mainly expressed in the height of the center of the cargo and the height of the center, and the width of the first, second and third sides and the side height. The center height is the maximum height from the cargo load surface. Side height refers to the height at different widths on both sides of the cargo below the center height. When the goods have several different side heights, they are measured from top to bottom, and are sequentially numbered as the first side height, the second side height, and the third side height. These parameters can determine whether the goods are cuboid or cylinder-like, and have a detailed description of the shape of the goods. At the same time, through these data, the system can determine which height of the cargo has the largest width, which provides a clear goal for the selection of reinforcement points in subsequent reinforcement schemes.

After the goods parameters have been entered, the user needs to select whether the goods are cylinders. This is to determine whether a horizontal or steel frame is placed between the cargo and the floor of the loading scheme. If a horizontal pad is placed, a rubber pad is required between the cargo and the steel frame to increase the friction between the cargo and the steel frame to prevent the cargo from moving and rolling during transportation.

3. Subsystem of cargo loading

The loading of the goods is essential before the goods are reinforced. Exceptional dimension cargo is generally transported by flat car, and depending on the length of the cargo, the length of the car floor, the allowable offset of the cargo, etc., whether it is necessary to add a cruiser in the case of a car load, or two cars and above installed. This system is limited to flat cars on trucks used for loading large cargo.

3.1. Cargo offset

The projection of the center of gravity is generally located at the intersection of the horizontal and vertical centerlines of the floor. However, in some cases, the goods must be displaced. At this time, the lateral displacement of the goods must not exceed 100 mm. If it exceeds, measures such as counterweights are required. When the center of gravity of the cargo is longitudinally displaced, the weight of the cargo carried by each vehicle bogie shall not exceed 1/2 of the allowable carrying capacity of the permitted car, and the difference between the weight of the two vehicle bogies shall not
exceed 10t. The maximum allowable distance of longitudinal displacement \( a_{\text{permit}} \) can be determined by the following calculation method:

\[
P_{\text{permit}} - Q < 10t : \quad a_{\text{permit}} = \left( \frac{P_{\text{permit}}}{2Q} - 0.5 \right) l \quad (\text{mm})
\]

\[
P_{\text{permit}} - Q \geq 10t : \quad a_{\text{permit}} = \frac{5}{Q} l \quad (\text{mm})
\]

The calculation result of \( a_{\text{permit}} \) is used to judge whether the cargo is a car load, a car load is highlighted, or a car load is prominent at both ends. In order to improve the utilization rate of the vehicle, the priority of the three loading modes is One car weight > One car weight plus one car > One car weight plus two cars. After the user selects the loading mode of the goods, the system also determines the reasonable allowable distance of the longitudinal displacement of the goods to improve the safety.

### 3.2. Calculation of Base

After determining the loading plan, the height of the cross sill and the height of the recess of the steel frame need to be calculated. Since the calculation methods of the two are the same, we take the height of the horizontal pad as an example. The reasonable height \( H_{\text{mat}} \) of the horizontal pad can be calculated according to the formula (3). In the system, since the default load car and the cruiser are the same model, the \( h_d \) is 0 mm. The value of \( f \) is also 0 mm.

\[
H_{\text{mat}} = 0.031a + h_d + f + 80 \quad (\text{mm})
\]

### 3.3. Preliminary load plan generation

After all the various parameters required before loading the goods are calculated, the system can generate a preliminary cargo loading plan. According to the various types of data calculated by the system, and matching the corresponding cad loading sketch, and finally generate a plan.

### 4. Subsystem of car speed limit

When the freight train passes the curve and the turnout, it will be subjected to additional lateral inertial force, vertical inertial force and wind force, and will also be offset by the center of gravity of the heavy vehicle caused by the spring vibration of the car body. Therefore, the center of gravity of heavy vehicles cannot exceed 2000mm from the rail surface [2]. In order to ensure that the heavy truck does not overturn, while retaining a certain safety factor, in addition to taking weight measures to reduce the center of gravity when the center of gravity exceeds 2000mm, the heavy truck needs to operate at the speed limit specified in Table 1.

| Heavy vehicle center of gravity H (mm) | Running speed limit (km/h) | Speed limit through lateral turnout (km/h) |
|---------------------------------------|-----------------------------|------------------------------------------|
| 2000<H≤2400                           | 50                          | 15                                       |
| 2400<H≤2800                           | 40                          | 15                                       |
| 2800<H≤3000                           | 30                          | 15                                       |

### 5. Subsystem of exceptional dimension cargo reinforcement

During the train operation or the shunting operation, the goods loaded on the vehicle may move, roll, tip over, and fall under the influence of various external forces, which may lead to serious railway transportation accidents [2]. In order to ensure the safety of driving and cargo, corresponding reinforcement measures must be taken after the cargo is loaded, so that the cargo is firmly fixed on the floor of the car. The basic requirements for cargo reinforcement are: the reinforcement method to be
adopted must conform to the weight, shape and size of the cargo. The selected reinforcement material must have sufficient strength. After the reinforcement, the cargo can withstand the normal shunting operation and the train operation process. The effects of various external forces generated in the process ensure that the goods do not tip over, roll, move or fall during the whole process of transportation.

5.1. Reinforcement strength
During the transportation of cargo trains, the cargo will be subjected to various external forces, including longitudinal inertial force, vertical inertial force, wind power and friction between the cargo and the floor of the vehicle (speed is not more than 120km/h, the speed of the car is not more than 5km / h). The calculation of each force is as follows.

Longitudinal inertial force:
\[ t_0 = 0.0012Q_t^2 - 0.32Q_t + 29.85 \quad (\text{kN/t}) \]  (4)
\[ T = t_0 \times Q \quad (\text{kN}) \]  (5)

Lateral inertial force:
\[ n_0 = 2.82 + 2.2 \frac{a}{l} \quad (\text{kN/t}) \]  (6)
\[ N = n_0 \times Q \quad (\text{kN}) \]  (7)

Vertical inertial force:
\[ q_v = 3.54 + 3.78 \frac{a}{l} \quad (\text{kN/t}) \]  (8)
\[ Q_v = q_v \times Q \quad (\text{kN}) \]  (9)

Wind force:
\[ W = q \times F \quad (\text{kN}) \]  (10)

Longitudinal friction:
\[ F_{fl} = 9.8 \times \mu \times Q \quad (\text{kN}) \]  (11)

Lateral friction:
\[ F_{fla} = \mu \times (9.8 \times Q - Q_v) \quad (\text{kN}) \]  (12)

During the transportation of freight trains, the longitudinal inertial force, the lateral inertial force, the wind force and the friction force acting on the cargo will cause the cargo to be tipped, moved and rolled in the longitudinal and transverse directions [4]. The condition for measuring whether a cargo will tip over, move and roll is the stability factor. The stability factor is determined by the ratio of the stabilizing moment formed by the gravity of the cargo to the moment formed by all the forces acting on all forces on the cargo. The calculation method is as follows.

Stability of goods overturning:
\[ \eta = \frac{9.8Qa}{Th} \]  (13)
\[ \eta = \frac{9.8Qb}{Nh + Wh_w} \]  (14)

Horizontal stability of goods:
\[ \Delta T = T - F_{fl} \quad (\text{kN}) \]  (15)
\[ \Delta N = 1.25(N + W) - F_{fla} \quad (\text{kN}) \]  (16)

5.2. Design and calculation of reinforcement methods
The reinforcement materials used for large goods are mainly composed of steel and wood. The reinforcement materials used in this procedure are wire rope, wire rod, galvanized iron wire and flat steel strip. The reinforced method of galvanized iron wire, wire rod and steel wire rope is similar, and the goods are reinforced by the “ba zi la qian” method. Assuming that the shape of the cargo is relatively regular, it is reinforced with a symmetrical pull. First, it is necessary to calculate the tensile force that should be taken when pulling the leash to prevent longitudinal movement, lateral movement, longitudinal overturning, and lateral overturning. The calculation method is as follows.
Prevent vertical movement:

\[ S_{vm} \times n = \frac{\Delta T}{AC} \sqrt{AC^2 + BO^2 + BC^2} \quad \text{(kN)} \]  

Prevent lateral movement:

\[ S_{lm} \times n = \frac{\Delta N}{BC} \sqrt{AC^2 + BO^2 + BC^2} \quad \text{(kN)} \]  

Prevent vertical overturning:

\[ S_{vo} \times n = \frac{1.25Th - 9.8Qa}{(l_t + AC)BO} \sqrt{AC^2 + BO^2 + BC^2} \quad \text{(kN)} \]  

Prevent lateral overturning:

\[ S_{lo} \times n = \frac{1.25(Nh + Wh_w)}{(l_t + BC)BO} \sqrt{AC^2 + BO^2 + BC^2} \quad \text{(kN)} \]  

Because the force required to be pulled by each pulling rope during reinforcement is \( S \geq \max\{S_{vm}, S_{lm}, S_{vo}, S_{lo}\} \), and when the wire rope is used for pulling, the wire rope The breaking force requirement must not be less than twice the \( S \). When the wire rod or galvanized iron wire is used to pull the goods, the number of strands required for each pulling rope is \( n = S/(0.9P_a) \).

When the flat steel strip is used for reinforcement, it is indicated that the flat steel strip is used as a waistband to pressurize the goods. Normally we only use a waistband reinforcement for cylindrical goods. Box-type goods can also be reinforced with waistbands, for which we will not consider them for the time being. In order to prevent the longitudinal or lateral movement of the cargo or prevent it from rolling laterally when the cargo is reinforced by the waistband, the force that the waistband should withstand is calculated according to Equation (21) and Equation (22).

Prevent vertical or lateral movement:

\[ P_m = \frac{\max\{\Delta T, \Delta N\}}{2\mu \cos \gamma} \quad \text{(kN)} \]  

Prevent horizontal scrolling:

\[ P_s = \frac{1.25(N + W)(R - h_y - h_a) - 9.8Qb}{2nb \cos \gamma} \quad \text{(kN)} \]  

Each leg cuff needs to withstand the pulling force \( P \geq \max\{P_m, P_s\} \) under the premise of preventing the goods from moving and rolling. Because the flat steel belt waistband, the cross-sectional area of the flat steel strip is \( F \geq \frac{10^6 P}{[\sigma]} \) (cm²), in the formula, \([\sigma]\) is the allowable stress of the flat steel strip, flat steel The allowable stress \([\sigma]\) of ordinary carbon steel with a belt is 140 MPa.

After the system determines the reasonable reinforcement scheme through calculation, the user can also view the sketch of the cargo reinforcement as needed.

6. Conclusion

This paper designs the system to calculate the formulas and parameters that must be involved in the design of the large cargo loading reinforcement scheme, reduces the workload of the relevant personnel, and simulates the optimal loading scheme and reinforcement scheme based on the calculation results. This article takes Railway Loading and Reinforcement Rules as the main reference basis, and carries out step by step analysis and treatment on the reinforcement of large and large cargo in strict accordance with the requirements and steps in the regulations, ensuring the feasibility and rationality of the system.

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