New Calculation Method for Railway Freight Over-limit Judgement

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Abstract: In order to solve the demand for gradual increase of vehicles and cargoes in railway freight transportation. It is necessary to change the current over-limit level determination standard that uses short cars as calculation vehicles to long cars as calculation vehicles. Using a long vehicle as calculation vehicle will cause a series of problems. For example, the original calculation formula for width calculating is no longer applicable, and corresponding changes need to be made to adapt long vehicle based on the original calculation formula. In this paper, the relevant calculation methods for long vehicles are changed based on the original formula.

1. Introduction

The current "Rules for the Transport of Railway Over-limit and Over-weight Cargoes" uses a calculation vehicle with body length of 13.22m and center distance of the bogie of 9.35m[1]. A calculation vehicle with body length of 26m and bogie center distance of 18m should be used to fully investigate and analyze the actual building boundaries. In order to ensure the safety of over-limit cargo transportation, the change of the proposed standard and the clearance of the running part of the vehicle and the lateral vibration offset of the vehicle should be considered to determine the width limitation standard that should be adopted for the undersized cargo[2,3].

2. Calculation Half-Width on Straight Line

Calculation point is the point on goods where excess level needs to be calculated. The factors affect maximum horizontal footprint of calculation point are the measured half-width, the amount of deviation and the additional deviation amount. Through analysis and calculation of the three influencing factors, calculation formula of the maximum horizontal occupy space of calculation point can be obtained, and the result is calculation half width. Determining whether goods over-limit on straight line use the 26 meters length, pin distance 18 meters ordinary wagon, with locomotive vehicle contour size (called calculated vehicle) to run on the same straight line occupies maximum space for judgment.

2.1. The Check Section is Located Between Two Vehicle Bogies

When a railway freight vehicle stays or moves on straight line, the maximum space required for goods and vehicles shall be discussed in two cases. When the calculation point of the cargo and vehicle is located between two bogies, the maximum deviation caused by the departure of steering gear center pin from line center is g_{in}, and the maximum possible distance of steering gear center pin from line center is e:

$$g_{in} = e = 75 \qquad (1)$$

Set measure disteded half-width of the goods is B when the check section is located between two vehicle bogies, and the space required for goods on flat straight road is B_{sin}, then:

$$B_{sin} = B + g_{in} + y' = B + 75 + y' \qquad (2)$$

The vehicle with a limit profile has a half-width B_{sc} of the space required on flat straight road, it is calculated as:

$$B_{sc} = B_v + \frac{L_c}{l_c} \times 75 = B_v + \frac{26}{18} \times 75 = B_v + 108 \qquad (3)$$

L_c - The length of calculated vehicle.

l_c - The pin distance of calculated vehicle.

B_v - The half wide of locomotives profile limit.

It can be seen from the calculation that when check section is located between two vehicle bogies, the maximum widen value caused by the departure of steering gear center pin from line center is less than the maximum widen value of the calculated vehicle. When the check section is located between two vehicle bogies, the maximum space required to calculate the cargo on a flat straight road is half width X_{sin}:

$$X_{sin} = B_{sin} = B\text{-}33 + y' \qquad (4)$$

2.2. The Check Section is Located on the Outside of Two Vehicle Bogies

When the calculation point of the cargo or vehicle is located on the outside of vehicle's two bogies, the maximum deviation caused by the departure of steering gear center pin from line center is g_{out}, and the maximum possible distance of steering gear center pin from line center is e,

$$g_{out} = \frac{2x}{l} \cdot e = \frac{2x}{l} \times 75 \qquad (5)$$

When the check section is located between two bogies, the space required for goods on flat straight road is half-width as B_{sout}, then:

$$B_{sout} = B + \frac{2x}{l} \times 75 + y' \qquad (6)$$

The verification section is located on the outside of two vehicle bogies, and the cargo calculated half-width of maximum space on flat straight road can be expressed:

$$X_{sout} = B + \left(\frac{2x}{l} - 1.44 \right) \times 75 + y' \qquad (7)$$

3. Calculation Half-width on Curve Line

When the vehicle runs on a curve, its longitudinal centerline is not on the same vertical plane as the line centerline. Therefore, compared with on a straight line, the space required for cargo on a curve line is larger. The increase is related to the distance between the longitudinal centerline of the vehicle and the vertical curved surface where the centerline of the line is located. The amount of deviation is determined by vehicle length, pin distance, and curve radius. Determining whether goods over-limit on straight line use the 26 meters length, pin distance 18 meters ordinary wagon, with locomotive vehicle contour size (called calculated vehicle) to run on the same curve line occupies maximum space for judgment.

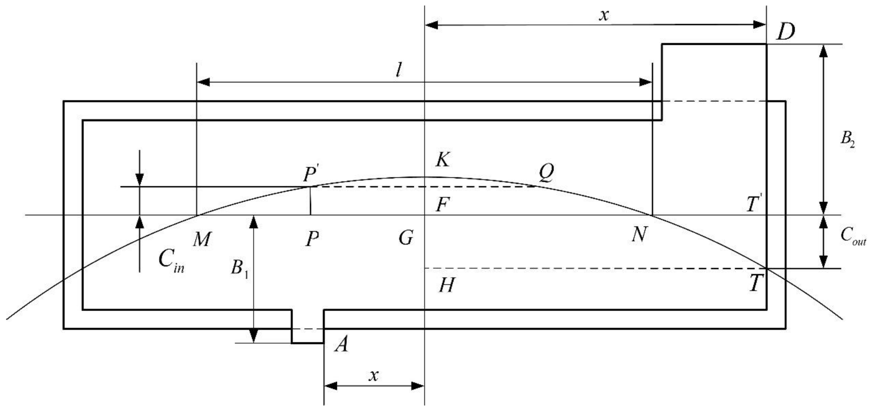

Figure 1: The picture of inside and outside deviation.

As shown in Figure 1, MN is the vehicle pin distance, and is represented by l. G is the focus of the vehicle's vertical and horizontal centerline. $P'Q$ is parallel to the vehicle's longitudinal centerline and intersects with the vehicle's horizontal centerline at F. Set x be the distance from the cargo to the intersection of the vehicle's horizontal and vertical centerline. Therefore, the internal deviation of the cargo is:

$$C_{in} = PP' = KG - KF \qquad (8)$$

The centerline of a curved line with a radius R is part of the circumference of a circle with a diameter of 2R. The pin distance l can be regarded as a string of the circle. If KG is extended to intersect the circle, it is another string. This string must pass the center of circle and the string length is $2R$. According to the intersecting string theorem:

$$\begin{aligned} KG(2R-KG) &= \left(\frac{l}{2}\right)^2 \\ KG &= \frac{(l/2)^2}{2R-KG} \end{aligned} \tag{9}$$

According to $KG \quad 2R$, can get:

$$KG = \frac{l^2}{8R} \tag{10}$$

$P^{'}Q$ is the other string of circle, string length is $2x$, and intersects diameter at F, can get:

$$KF = \frac{(2x)^2}{8R} \tag{11}$$

From above, the formula for calculating internal deviation can be obtained, and the unit of the calculation result is converted to mm:

$$C_{in} = \frac{l^2-(2x)^2}{8R} \times 1000 \tag{12}$$

The section at point D in the figure is outside the center pin of the vehicle bogie. In this section, the deviation is:

$$C_{out} = TT^{'} = KH - KG \tag{13}$$

According to the intersecting string theorem:

$$KH = \frac{(2x)^2}{8R} \tag{14}$$

From above, the formula for calculating external deviation can be obtained, and the unit of the calculation result is converted to mm:

$$C_{out} = \frac{(2x)^2-l^2}{8R} \times 1000 \tag{15}$$

3.1. The Verification Section is Between the Center Pins of Two Vehicle Bogies

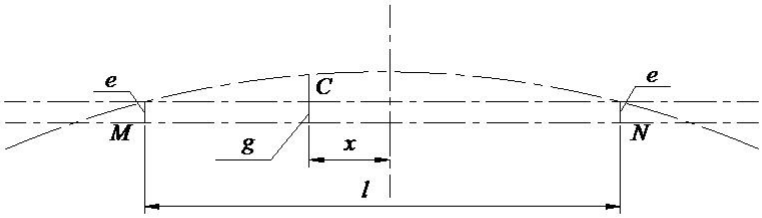

Figure 2: The verification section is between the center pins of two vehicle bogies.

When the detection section is located between the center pins of the two truck bogies, the measured half-width of the cargo is B, and the maximum half-width B_{cin} required for calculating the vehicle is in the middle of the vehicle, and x is 0 at this time:

$$\begin{aligned} B_{cin} &= B_c + C_{in} + e \\ &= B_c + \frac{l_c^2 - (2x)^2}{8R} \times 1000 + e \\ &= B_c + \frac{18^2}{8R} \times 1000 + 75 \\ &= B_c + \frac{40500}{R} + 75 \end{aligned} \tag{16}$$

Similarly, when the ordinary vehicle is used to carry the cargo, the half-width of space on curve is set to B_{cuin}, then:

$$\begin{aligned} B_{cuin} &= B + C_{in} + e + y' \\ &= B + \frac{l^2 - (2x)^2}{8R} \times 1000 + 75 + y' \end{aligned} \tag{17}$$

e — The maximum possible distance of bogie center pin from centerline.
l — The length of the cargo vehicle.
x — The distance from vehicle's horizontal centerline to verification section.
R —Curvature radius.

Due to cargo over-limit at $B_{cuin} > B_{cin}$, can get:

$$\begin{aligned} B + \frac{l^2 - (2x)^2}{8R} \times 1000 + 75 + y' &> B_c + \frac{40500}{R} + 75 \\ B + \frac{l^2 - (2x)^2}{8R} \times 1000 - \frac{40500}{R} + y' &> B_c \end{aligned} \tag{18}$$

Because the calculated half-width of cargo exceeds the limit of the vehicle locomotive B_c, it is an over-limit cargo. Then, when the verification section is between center pins of two vehicle bogies, the calculated half-width of the cargo is:

$$X_{cuin} = B + \frac{l^2 - (2x)^2}{8R} \times 1000 - \frac{40500}{R} + y' \quad (19)$$

3.2. The Verification Section is Located Outside of Center Pin of Two Vehicle Bogies

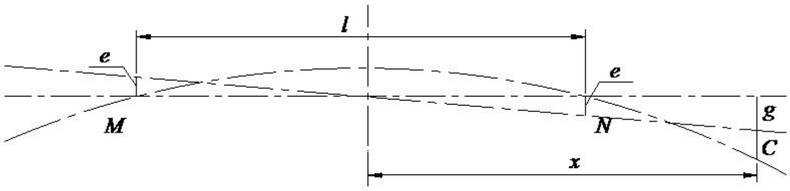

Figure 3: The verification section is located outside of center pin of two vehicle bogies.

When the detection section is located outside of center pin of two bogies, the measured half-width of the cargo is B, and the maximum half-width B_{cout} required for vehicle is calculated as:

$$\begin{aligned} B_{cout} &= B_c + \frac{L_c^2 - l_c^2}{8R} \times 1000 + g \\ &= B_c + \frac{26^2 - 18^2}{8R} \times 1000 + \frac{26}{18} \times 75 \\ &= B_c + \frac{44000}{R} + 108 \end{aligned} \quad (20)$$

Similarly, when the ordinary vehicle is used to carry the cargo, the half-width of space on curve is set to B_{cuout}, then:

$$\begin{aligned} B_{cuout} &= B + C_{out} + g + y' \\ &= B + \frac{(2x)^2 - l^2}{8R} \times 1000 + \frac{2x}{l} \times 75 + y' \end{aligned} \quad (21)$$

e — The maximum possible distance of bogie center pin from centerline.

l — The length of the cargo vehicle.

x — The distance from vehicle's horizontal centerline to verification section.

R —Curvature radius.

Due to cargo over-limit at $B_{cuout} > B_{cout}$, can get:

$$\begin{aligned} &B + \frac{(2x)^2 - l^2}{8R} \times 1000 + \frac{2x}{l} \times 75 + y' > B_c + \frac{44000}{R} + 108 \\ &B + \frac{(2x)^2 - l^2}{8R} \times 1000 + \frac{x}{l} \times 150 - \frac{44000}{R} - 108 + y' > B_c \end{aligned} \quad (22)$$

Because the calculated half-width of cargo exceeds the limit of the vehicle locomotive B_c, it is an over-limit cargo. Then, when verification section is located outside of center pin of two vehicle bogies, the calculated half-width of the cargo is:

$$X_{cuout} = B + \frac{(2x)^2 - l^2}{8R} \times 1000 + \frac{x}{l} \times 150 - \frac{44000}{R} - 108 + y' \tag{23}$$

4. Conclusions

This article re-determines calculation method for judging over-limit cargo based on the use requirements of a long vehicle as calculation vehicle. Calculate whether the cargo and the vehicle exceed the limit by calculating the straight line, the inside of the curve, and the outside of the curve. In the next research, it is necessary to make a comprehensive judgment on over-limit conditions on both straight lines and curves using to make a normalized judgment of the over-limit level.

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