Study on the Overlong Cargo's Allowable Loading Weight of NX_{70A} Flat Wagon

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Abstract. As the use of NX_{70A} flat wagon is becoming more and more widely, it is necessary to study the overlong cargo allowable loading weight of NX_{70A} flat wagon. This paper firstly designs several adverse vehicle operating conditions, then builds the dynamics model of NX_{70A} flat wagon and making simulation calculation by SIMPACK to find the most unfavorable condition. Finally, in this condition, this paper finds the allowable loading weight by compare different overlong degree and different weight of the cargo's pressure with the allowable pressure.

Introduction

As the railway freight containerization and the trend of heavy haul is obvious, the use of 70t flat wagon is becoming more and more widely, and the NX_{70A} is one of the most mainstream type. So it will replace 60t flat wagon and become more important in the future.

China's current "railway freight loading and reinforcement rules" (Rail Transport No. [2006]161) rule that loading a 60t,61t flat wagon with the overlong cargo equally prominent at both ends should be under the corresponding loading weight limit which is shown in table 1 [1].

Table 1 the Load Weight Limit for Different Prominent Lengths

Prominent length/mm	L ＜ 1500	1500 ≤L ＜ 2000	2000 ≤L ＜ 2500	2500 ≤L ＜ 3000	3000 ≤L ＜ 3500	3500 ≤L ＜ 4000	4000 ≤L ＜ 4500	4500≤L ≤ 5000
Maximum weight/t	58	57	56	56	55	54	53	52

At present, China lacks the relevant provisions of the NX70A flat wagon. When there are overlong cargo loaded on the wagons, the overlong cargo can't be load without the relevant allowable loading weight rules. If still loading, there will be dangerous when transporting overlong cargo. So, it is necessary to study the overlong cargo allowable loading weight of NX70A flat wagon.

The wheel/Rail railway module in SIMPACK can be used to facilitate the simulation of railway vehicles. It can compute dynamic force between cargo and vehicle in different vehicle operating conditions. By simulation calculation in SIMPACK, this paper determines the most unfavorable operating condition of vehicles and makes a table between the prominent length and maximum allowable loading weight in this operating condition.

The Design of Operating Condition

Vehicle Operation Condition. When the actual vehicle is running, the force between the cargo and the vehicle is influenced by the railway classification, the radius of track curve, the superelevation of outer rail and the vehicle operating speed. Therefore, this paper will design the operating conditions of the vehicle according to the four aspects.

The operating conditions of the vehicle are influenced by the curve radius and the classifications of rail. The railway of high classification can withstand higher speed, so its curve radius is larger. And the increase of speed will aggravate the vibration of the vehicle on the track. Therefore, when determining the radius of the curve, the impact of the curve radius and the vehicle operating speed should be taken into reason. "Code for Design of Railway line" can provide a reference for the radius of the orbit curve.

"Code for Design of Railway line" has been revised and improved in the past 40 years. The 2006 edition is mainly applicable to the railway lines which are built or improved after 2006. Although the current railway construction is based on the 2006 edition, most lines of the existing railway network are built or improved according to the 1999 edition. So, this paper designs the vehicle operation condition according to the 1999 edition of "Code for Design of Railway line" [2].

Chinese railway lines are divided into three grades, the difference of three grades is the degree of track irregularity. The grade Ⅰ is the best and the grade Ⅲ is the worst. Because the highest speed of freight train on the track of grade Ⅰ and the track of grade Ⅲ is usually 120km/h and 70km/h, the curve radius of grade Ⅰ should be 1200m and the curve radius of grade Ⅲ should be 400m.

Knowing curve radius and vehicle speed, the balanced superelevation of outer rail can be calculated using the following formula [3]:

$$h = \frac{11.8v^2}{R} \tag{1}$$

h ——Superelevation of outer rail, mm;

v ——Vehicle speed, km/h;

R ——Curve radius, m;

Under the condition of grade Ⅰ, the superelevation of the outer rail is 140mm. Under the condition of grade Ⅲ, the speed should be 70km/h, but the freight train usually run by 60km/h, so the superelevation of the outer rail is 100mm.

There are two operating conditions of vehicle for the simulation experiment.

Vehicle Carry Condition. In order to ensure when the flat wagons which are loaded with overlong cargo pass through the hump or knick point, the cargo wouldn't touch the flat wagon floor, there usually are wood pads between them. The height of wood pads which are used to transport overlong cargo is calculated by the following formula [4][5]:

$$h = 0.031a + h_{\Delta} + f + 80\text{mm} \tag{2}$$

h ——Height of wood pads, mm;

a ——Distance from the cargo jags to the vertical plane of the nearest wheel of the loaded wagon, mm;

h_{Δ} ——Height difference between the floor of the runner wagon and the loaded wagon, mm;

f ——Deflection of the outstanding side of the cargo, mm;

80mm ——Sum of the loaded wagon floor empty height difference (30mm) and security distance (50mm).

Consulting the rule of table 1, this paper provides for over long cargo at most at both ends of the long 5000mm, so the maximal value of a is 1085mm+5000mm=6085mm. And in this paper, the value of h_{Δ} and f is 0. After calculation, the height of the wood pad should be 270mm. Based on the idea of the control variable, all of wood pads are 270mm high and located on the vehicle bridges.

The Size of Cargo and the Position of Computing Force

In general, the cargo that are loaded by one car, outstand the car side, and need to use one car or more to load, is called exceptional length freight, namely overlong cargo [6]. For reducing the interference, the cargo shouldn't be out of gauge. And when the length is between 13m and 23m, according to "railway transfinite overweight cargo transportation rules", the width should be 2.7m, the height should be 2.432m.

Consider the nod, shake, up and down vibration of vehicle and cargo, there are two measuring forces about central line symmetry on the wood pad, and the height of four forces is same as the bottom surface of cargo. The position of the four measuring forces is shown in figure 1.

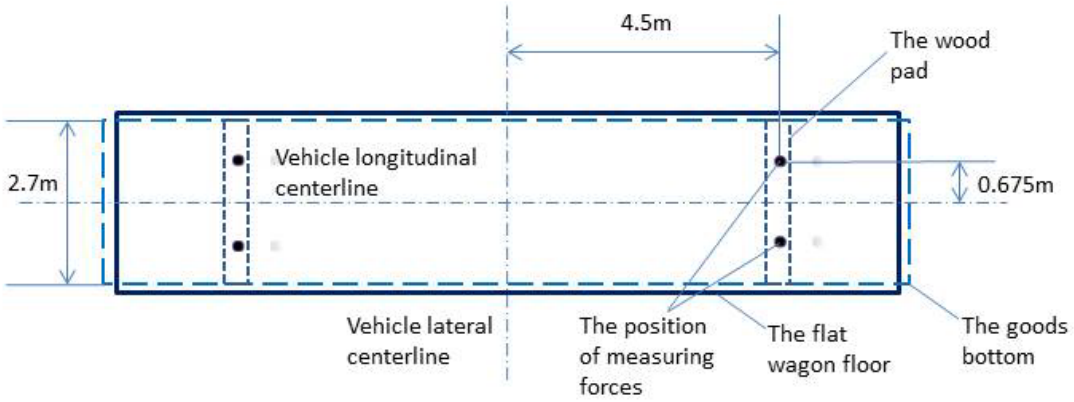


Fig. 1 The position of the measuring forces

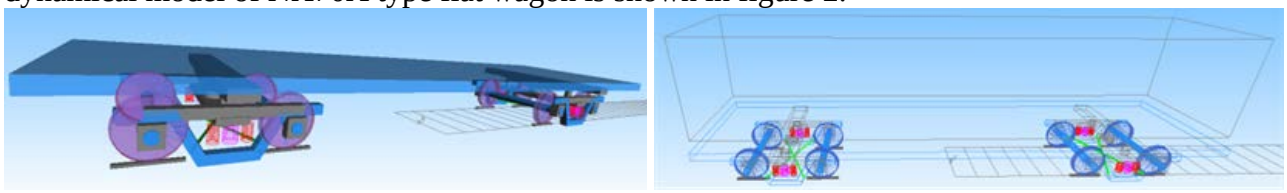
Determining the Most Unfavorable Operating Condition of Vehicle

According to "TB/T 1335-1996 - strength design and test appraisal regulations for railway cars", when carrying out the vehicle design and strength test, the cargo shouldn't be longer than the flat wagon. And when the weight of cargo arrive the limit of loading, the stress on the vehicle's body should be less than the maximum allowable value of the vehicle design standard under any allowable operating conditions [7].

When the vehicle is running, the vertical load of the vehicle includes the vertical static load and the vertical dynamic load. If the weight of the cargo was constant, the vertical static load wouldn't change. The more unfavorable operating condition is, the larger vertical dynamic load is. And the overlong cargo will intensify the nod vibration of vehicle and make the vertical dynamic load increased. Therefore, on the most unfavorable operating condition, when the cargo' weight and length arrives the limit, the stress is closest to the maximum allowable value and called standard stress. So, when the flat wagon load the overlong cargo, the allowable loading weight should decrease to make sure that the stress isn't beyond the limit of vehicle.

In order to obtain the allowable loading weight of overlong cargo, the first step is determining the most unfavorable operating condition of vehicle and getting the standard stress.

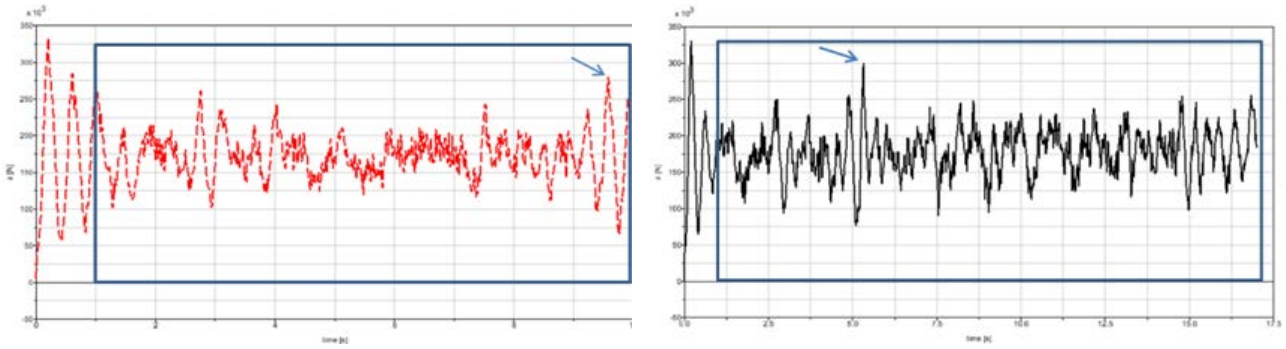
In this paper, the operating condition where the pressure is largest is the most unfavorable condition. The largest one of the four measuring forces is used to represent for the stress in the rest part of this paper. The measuring forces are computed by simulation calculation in SIMPACK and the dynamical model of NX70A type flat wagon is shown in figure 2.



a. the flat wagon without cargo b. the flat wagon with cargo

Fig. 2 the dynamical model of NX70A type flat wagon

After the offline dynamic simulation calculation on the two unfavorable operating condition, the results are shown as the charts including the measuring forces changing with time. The charts of two different conditions are shown in figure 3. After the cargo are put on the flat wagon, there should be 1s to make the vehicle's forces balance in this simulation calculation. The maximum value of the measuring force is the pressure on the 1/4 part of flat wagon where the stress is the largest. The value is shown in table 2.



a. the vehicle is on the rail line of grade Ⅰ b. the vehicle is on the rail line of grade Ⅲ

Fig. 3 the charts of the measuring force in two different conditions

Table 2 the Maximum Value of Pressures on Two Operating Conditions

Operating condition	cargo's pressure on 1/4 vehicle/N
The rail line of grade Ⅰ, the speed is 120km/h, and the radius of the curve is 1200m	280209
The rail line of grade Ⅲ, the speed is 70km/h, and the radius of the curve is 400m	300212

According to the table 2，the second operating condition is the most unfavorable one, and the largest pressure is 300212N as the standard stress.

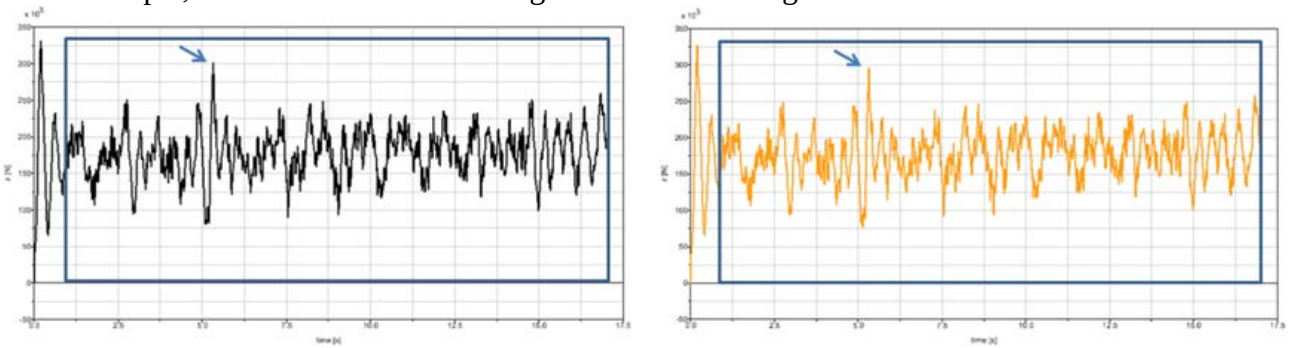
Determining the Allowable Loading Weight of Different Overlong Cargo

Simulation Calculation's Project. In this paper, the overlong cargo's lengths are between 13m and 23m. After each time of simulation calculations, the cargo's length grows 1m, one integer multiple length named one length grade.

According to previous researches, the longer the overlong cargo is, the smaller the allowable weight is. So, the allowable weight of a length grade can be the first trial calculation weigh of the next length grade. In this paper, there is 0.5t varying between different allowable weights at least.

After getting the maximal pressure of the overlong cargo on once trial calculation (hereinafter referred to as the trial pressure), it should be compared with the standard stress. In fact, they can't completely be the same. So, the trial pressure and the standard pressure should be similar as far as possible, and the difference between them shouldn't be more than the 1% of the later. If so, the trial calculation weigh would be the allowable loading weight.

Simulation Calculation's Process and Result. According to the above project, the allowable loading weight can be get from the result charts of simulation calculation. Taking the 14m long cargo as an example, the charts of different weights are shown in figure 4.



a. 70t cargo b. 69.5t cargo

Fig. 4 the charts of measuring forces which is from 14m length and different weights' cargo.

Comparing these two charts, when the cargo is 70t weight, the trial pressure is most similar to the standard stress. So, when the cargo is 14m long, the allowable loading weight is 70t at most.

After analyzing every charts of simulation's results, table 3 is drawn, and include all sets of simulation's data whose trial pressure which is most similar to the standard pressure.

Table 3 the Trial Pressures of Different Lengths and Weights Cargo

Cargo's weight（kg）	70000	70000	69500	69500	69000	67000	66000
Cargo's length（m）	13	14	15	16	17	18	19
Trial pressure（N）	300212	301284	299973	297314	298023	300555	300441
$\frac{F_T - F_S}{F_S} \times 100\%$	0	0.36%	-0.08%	-0.97%	-0.73%	0.11%	0.08%
Cargo's weight（kg）	66000	65000	62500	61500			
Cargo's length（m）	20	21	22	23			
Trial pressure（N）	297988	301360	298713	300744			
$\frac{F_T - F_S}{F_S} \times 100\%$	-0.74%	0.38%	-0.50%	0.18%			

F_T ——Trial pressure, N; F_S ——Standard pressure, N.

In the all sets of data, the difference between the trial pressure and the standard pressure is not more than 1% of the later. So, the accuracy of the simulation's results is high enough.

Summary

This paper establishes a dynamic model of NX70A flat wagon including cargo and track by SIMPACK. Considering the actual situation in transportation, it determines the operation condition of the simulation. After the simulation calculations and the data analysis, this paper get the conclusion of the study.

Loading a NX70A flat wagon with the overlong cargo that were equally prominent at both ends and balance weight should be under the corresponding loading weight limit which is shown in table 4.

Table 4 the Load Weight Limit of NX_{70A} Flat Wagon for Different Prominent Lengths

Prominent length/mm	L＜1500	1500 ≤L＜2000	2000 ≤L＜2500	2500 ≤L＜3000	3000 ≤L＜3500	3500 ≤L＜4000	4000 ≤L＜4500	4500≤L≤5000
Maximum weight/t	69.5	69	67	66	66	65	62.5	61.5

For the further study, it can be overlong cargo allowable weight about other type of 70t flat wagon. And it can make a more complete provision of the 70t flat car's using on the freight transportation.

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