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Factors Analysis of Affecting Loading and Reinforcing Scheme of Large Goods in Railway

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Abstract

Large goods transported in railway are kinds of special goods and they are very important in national construction. In order to transport safely, loading and reinforcing schemes must be made first. How to design a reasonable scheme will be affected by many factors. This paper presents the characteristic of the large goods, summarizes the process of designing a loading and reinforcing scheme of large good, then probes the factors of affecting the loading and reinforcing scheme and gives a detail analysis. It's considered that those out-of-gauge and overweight degree of goods, center-of-gravity height of a loaded wagon, position of center-of-gravity of goods, type of wagon for using, reinforcement material and reinforcement method, transport expense and transport organization could affect a scheme in the aspects of safety, economy, rapidity and convenience. This conclusion will instruct and help to make a good scheme.

Keywords

Loading and Reinforcing Scheme, Out-of-Gauge Goods, Overweight Goods, Rail Freight Transportation, Effecting Factor

1. Introduction

1.1. Background and Significance of Study

In China railway, such goods as electricity power, chemical industry and the engineering equipments are generally called large goods. The large goods contain out-of-gauge, overweight, overlength goods and concentrated weight goods. About the concepts of these goods, railway relative department gives the explanation [1]. Out-of-gauge goods have two meanings. Firstly, after a goods being loaded on a wagon, when the wagon

stop over a horizontal line and the longitudinal central line of vehicle lies on the same vertical plan with the central line of track, if any parts of the goods exceed the clearance of the locomotive or vehicle or loading of specific sector, it will be called out-of-gauge goods. Secondly, after a goods being loaded on a wagon, when the wagon is running along the curve with a 300 meters radius, if the caculative widths of any parts of the goods exceed the clearance, it also can be an out-of-gauge goods.

Overweight goods means those goods, after a goods being loaded on a wagon, which live load effect of total weight of loaded vehicle exceeds that of the standard for bridge design (China railway standard loading). Overlength goods indicate those goods, when they are loaded, they will exceed the wagon floor length and need use a runner wagon or straddle transport [2]. Besides, there is a kind of large goods which has a heavy weight within a short bearing surface, which is called concentrated weight goods. For this kind of large goods, concentrated loading should be avoided.

Because out-of-gauge and overweight goods are more complex when transported, this paper will mainly discuss these two goods.

In practical work, before transporting large goods, a loading and reinforcing scheme must be designed. Different schemes will produce different results in regard to safety, transport time, transport cost and organization difficulty. In order to make the scheme better, some influence factors should be considered before and during designing the scheme. This paper aims to probe and analyse these factors.

1.2. Literature

Some scholars have done some relative research work.

Li *et al.* (1997) [3] and Wang (1999) [4] gave some loading measures aimed at a specific out-of-gauge goods, which could gain a better loading scheme. Li (1999) [5] first pointed out that it was necessary to evaluate a loading and reinforcing scheme and gave a discussion, this paper did research mainly for the ordinary goods. Gai (2002) [6] analysed the effect factors to the grade of out-of-gauge goods and presented some methods to decrease the out-of-gauge degree. Wang (2002) [7] put forward the technical condition for loading overlength goods and gave the factors reasonably loaded, including transport charge, out-of-gauge grade and concentrated weight. Li *et al.* (2008) [8] analysed factors influencing loading scheme security of exceptional dimension freight. Lv *et al.* (2014) [9] analysed the factors about oversize goods safety transportation and indicated that loading and reinforcing scheme should be considered. Li (2014) [10] analysed the factors with respect to overweight goods transport.

Above all, these research work concentrated in the aspects of loading scheme evaluation, loading basic technical conditions, effect factors of goods transport safely. It included ordinary goods and some kind of large goods. This is helpful to have some ideas about affecting factors of large goods transportation. However, either the research laid emphasis on the algorithm and only simply considered the factors, or just discussed a kind of freight, or merely studied the loading scheme and no reinforcing scheme. Thus, they are separate in different aspect. This paper will lay emphasis on the large goods

and their factors of affecting loading and reinforcing scheme, then give a detail analysis from goods feature, designing scheme process and influence to the scheme.

2. The Characteristic of the Large Goods

Large goods are kinds of specific goods, which own some features:

1) Each of large goods has a large, heavy body and complex structure. This feature leads to a special requirement when a vehicle is selected, and increases difficulty when they are loaded and reinforced. Generally, the vehicle should have a higher loading capacity and a low center-of-gravity height, the goods must be reinforced by using some special material and methods.

2) Large goods are not only expensive but also very important equipments. For example, those power unit, transformer and urea synthesizer generally are mostly out-of-gauge and overweight goods. They value often over millions RMB and play important roles in national economy development. This feature makes demands on carriers that they must be very careful to avoid any fault in case there will be great loss.

In sum, large goods are apparently different from original goods. They need more techonology methods and complex organization measures. When organizing the transport of large goods, many departments such as vehicle, locomotive, maintenance, electric service, transport and research institute will involved in. Thus, when designing a loading and reinforcing scheme, various kinds of factors should be considered.

3. Factors Analysis of Affecting Loading and Reinforcing Scheme of Large Goods

3.1. General Process of Designing Loading and Reinforcing Scheme of Large Goods

For railway freight transportation, loading and reinforcing indicate the methods to put the goods on and fix to the wagon. Considering the characteristic of large goods, to design the loading and reinforcing scheme is complicated, some railway regulations [1] [11] [12] must be obeyed and also special attention should be payed to keep safety of freight, loaded wagons and infrastructure. Generally, there are several steps when designing the loading and reinforcing scheme.

1) To know the goods peculiarity and transport requirements

This step is to have knowledge of all the technical data of the goods which will be based on when designing a scheme, such as weight, structure, shape size, center-of-gravity position, supporting flat dimensions, reinforcing point position and etc. Some goods have special requirement when transported. For example, the position of supporting point of a prestressed concrete bridge shouldn't be randomly changed, the goods bearing precision instrument often couldn't endure too much shake. All these must be known ahead so that it can be noticed when designing the loading and reinforcing scheme.

2) To design the loading scheme

First, a suitable wagon should be selected. Then, the reasonable goods position on the

wagon should be decided. When selecting the wagon and deciding the loading position, the out-of-gauge grade and the overweight grade of the goods as well as the center-of-gravity height of a loaded wagon should be reduced as far as possible. In the meantime, concentrated loading should be avoided. When these are paid attention, the further step is to compute the grade of the out-of-gauge, the grade of overweight of the goods and the center-of-gravity height of a loaded wagon.

3) To design the reinforcing scheme

To design the reinforcing scheme mainly includes such work as calculating the forces acting on goods, calculating the forces that should be borne by reinforcement material or reinforcement equipment, determining rational reinforcement method and reinforcement strength as well as determining the specifications and numbers of reinforcement material or reinforcement equipment.

4) To select a final scheme

For one goods, there often have several loading methods and reinforcing methods. So, it's necessary to select a best one. Generally, the loading scheme which has a higher usage of vehicle load capacity, lower out-of-gauge grade and the overweight grade of the goods, lower center-of-gravity height of a loaded wagon as well as lesser interference to the transport, and the reinforcing scheme which is simple and convenient to operate as well as economic in material usage, are the optimal ones.

3.2. Factors and Analysis of Affecting Loading and Reinforcing Scheme of Large Goods

Different loading and reinforcing schemes can show different features. In order to know the pros and cons in different schemes, the affecting factors should be considered. It's considered that there are several main factors as follows.

1) Out-of-gauge and overweight degree of goods

The out-of-gauge and overweight degree of loaded goods is expressed by out-of-gauge grade and the overweight grade of the goods. Each of them has four grades: no exceed gauge, level 1 out-of-gauge, level 2 out-of-gauge, super out-of-gauge and no exceed weight, level 1 overweight, level 2 overweight, super overweight. The higher the out-of-gauge grade and the overweight grade, the lower the safety and the more expense for transport. Moreover, the speed of out-of-gauge or overweight wagon will be limited when operating, and those out-of-gauge or overweight wagons with a limited operation are prohibited to be incorporated into nonstop and transit trains. It is thus clear that, once one goods is out-of-gauge or overweight, the delivery speed of the goods will be serious affected. Therefore, when all of the other indexes are the same, the lower the out-of-gauge grade and the overweight grade of the goods, the better it should be. Referring to literature [1] [12] and [13], relative regulations are summarized in the **Table 1** and **Table 2**.

2) Center-of-gravity height of a loaded wagon

When the wagon along with the loaded goods is regarded as a whole after a goods is loaded, the whole height of combination center-of-gravity starting from the rail surface

Table 1. Relative regulation to out-of-gauge goods transport.

Items	Explanation
Mark-up expense	Different out-of-gauge degree has different mark-up expense, separately 50% for level 1, 100% for level 2, 150% for super out-of-gauge
Running speed limit	When the out-of-gauge car meets an adjacent line train or close to an infrastructure within a specified distance, the running speed will be limited separately not more than 30, 25 and 15 km/h.
Other expense	If a runner wagon is used, a runner wagon transport fee will be charged. If there is a running speed limit, a mark-up expense of 150% will be charged.

Table 2. Relative regulation to overweight goods transport.

Items	Explanation
Running speed limit	When the overweight car passes through a bridge, there will be a speed limit; For a special flatcar is used, there is a slower design speed limit than ordinary car.
Other expense	If there is a running speed limit, a mark-up expense of 150% will be charged. When an isolated vehicle is used, it will be charged.

is called center-of-gravity height of a loaded wagon. The center-of-gravity height of a loaded wagon is a basic technical standard, and also one of the main factors affecting loaded wagon running stability. It's regulated [11] that center-of-gravity height of a loaded wagon generally may not exceed 2 meters. If exceeds, there must be a speed limit as **Table 3** when running. It is thus clear that, the higher the center-of-gravity height of a loaded wagon, the worse the safety, the slower the operating speed and the longer the transport time. Therefore, when designing a scheme, it should try every means to lower down the center-of-gravity height of loaded wagon and give preference to the scheme with relatively lower center-of-gravity height of loaded wagon.

3) Position of center-of-gravity of goods

Position of center-of-gravity of goods includes lateral and longitudinal one. Generally, when loading one goods, the goods center-of-gravity or the overall goods center-of-gravity should be projected in the center of a vehicle loading plane. In this case, the running stability of a loaded wagon is in a best state. However, sometimes in reality, the goods center-of-gravity or the overall goods center-of-gravity has to deviate from lateral and longitudinal vehicle center lines in order to save runner wagons or lower out-of-gauge grade. The larger the offset values of goods center-of-gravity is, the worse the safety will be when the goods is being transported. When the goods center-of-gravity is offset from lateral direction, it probably causes derail and seriously impacts the transport safety. But, when the goods center-of-gravity is offset from longitudinal direction within the prescribed scope, it only causes little impact on the safety. Therefore, when making a comparison among schemes, it should pay attention mainly to the lateral position of center-of-gravity of goods. The smaller the lateral offset value is, the better it will be for the safety of a loaded wagon.

Table 3. Limited speed for loaded wagon.

Center-of-gravity height range of a loaded wagon (mm)	Limited speed in section (km/h)	Limited speed through the turnout in side direction (km/h)
(2000, 2400]	50	15
(2400, 2800]	40	15
(2800, 3000]	30	15

4) Type of wagon

For large goods transport, several vehicle types will be used, which contain gondola car, ordinary flatcar and special type flatcar or heavy duty car. Different type of wagon has a different carrying capacity, design speed, center-of-gravity height of empty car, vehicle availability and transport cost. The comparison among them is shown as **Table 4**.

The loading capacity of vehicle is related with vehicle loading capacity utilization rate, which indicates the ratio of goods weight loaded occupying marked loading capacity of vehicle. Under the condition of no overload, when the loading capacity utilization rate is higher, the vehicle will load larger goods weight, which will make lower transportation cost for transportation product apportioned to per ton kilometer. Thus, it's clear that the vehicle loading capacity utilization rate is an important factor of evaluating the economy of a feasible scheme.

The design speed will affect the deliver time of goods. The special type flatcar is the slowest of all. The center-of-gravity height of empty car will influence the center-of-gravity height of loaded car. When it is higher, it's running speed will probably be limited.

The gondola car and ordinary flatcar are the prime type vehicles in railway, the amount are greater and they are easier to be available than special type flatcar. For special type flatcar, it also needs to be transferred and then returned, so railway will charge for use and return. The expense is showed in **Table 5**. This will also have a great impact on the transportation capability and goods delivery speed.

It can be seen that the vehicle selection plays an important role for making the loading and reinforcing scheme. In general condition, the ordinary flatcar should be given preference while the other factors have a relatively small effect.

5) Reinforcement material and means

Reinforcing goods is a kind of effective means to keep the goods to stay in original position on wagon during its whole transportation. The reinforcement material and means are significant factors of measuring convenience and economy of a scheme. **Table 6** shows the operability and expenditure comparison among different reinforcing means. Besides the reinforcement material and means should satisfied with enough amount and strength to assure the stability and safety of goods when transported, good reinforcement means should be easy to operate; reinforcement material (equipment) should be obtained locally or could be repeated use to cut down the cost. Therefore, in

Table 4. Type of wagon and feature comparison.

Type of wagon	Code	Loading capacity	Design speed	Center-of-gravity height of empty car	Availability	Transport cost
Gondola car	C	Low	Medium	Medium	Easy	Low
Ordinary flatcar	N	Medium	High	Low	Mediun	Medium
Special type flatcar	D	High	Low	High	Difficult	High

Table 5. Special type flatcar operation incidental charge.

Charge items	Units	Rates
Charge for use		
indicated weight <180 ton	Yuan/ton kilometer	0.25 - 0.35
indicated weight ≥180 ton	Yuan/ton kilometer	0.30 - 0.60
Charge for return	Yuan/axle	300.00

Table 6. Reinforcement means and feature comparison.

Reinforcing means	Operability	Expenditure
Binding	Ordinary	Medium
Backing	Good	Low
Blocking	Ordinary	Medium
Goods bogie	Difficult	Highest
Reinforcing equipment (bracket)	Difficult	High

the context of keeping transport safety, the smaller the amount of reinforcement material is, the cheaper the cost will be, together with the more convenient reinforcing operation, the better the scheme will be.

6) Total transport cost

Total transport cost here is considered from the angle of customers, which includes transport charges and retention loss fee. Transport charges mean direct charges including freight charge and incidental charges. Considering that some customers care about the transport time, a retention loss fee is put forward and added into the total transport cost. Retention loss fee is an indirect charge, indicating the loss fee to the customer on account of delaying transport to the destination. Total transport cost is a competitive factor, since it could affect which mode of transportation will be chosen by the customer. When schemes are compared, the smaller the total transport cost is, the better the economy of a scheme will be.

7) Transport organization

Although transport organization isn't a factor of affecting the quality of scheme, it could reflect the result. Generally, after a scheme is made, the transport organization

Table 7. Factors of affecting loading and reinforcing scheme and their effects.

Factors of affecting scheme	Effect aspects			
	Safety	Rapidity	Economy	Convenience
Out-of-gauge and overweight degree	×	×	×	×
Center-of-gravity height of loaded wagon	×	×		
Position of center-of-gravity of goods	×			
Type of wagon		×	×	×
Reinforcement material and means			×	×
Ttotal transportation cost			×	
Transport organization		×	×	×

should be done associating to the scheme, such as determining operating speed, operating path and deploying a vehicle, marshalling a train. Different loading and reinforcing schemes will have an influence on difficulty and simplicity. Therefore, when designing the loading and reinforcing scheme of one goods, it should simultaneously consider the convenience of transport organization afterwards.

In summary, the above seven factors will affect the loading and reinforcing scheme in different aspects. **Table 7** shows their effects in these specific aspects.

4. Conclusion

Based on the characteristic of the large goods and the process of making a loading and reinforcing scheme of large goods, this paper analyses the factors of affecting the loading and reinforcing scheme. These factors include out-of-gauge and overweight degree of goods, center-of-gravity height of a loaded wagon, position of center-of-gravity of goods, type of wagon for using, reinforcement material and reinforcement means, total transport cost and transport organization, which will affect the loading and reinforcing scheme in the aspects of safety, rapidity, economy and convenience. Therefore, when designing a loading and reinforcing scheme, considering these factors adequately will contribute to getting a better one and help to make a good decision.

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