obsolete equipment still in use, exist to varying degrees. In the scope of management, there are various kinds of goods, the conditions for loading and unloading them are different, and the workload varies considerably. For some kind of goods there may be several kinds of machines suitable for handling operation, various configuration schemes of handling machines may be adopted. Thus it would be necessary to compare and select various possible types and quantity schemes of handling machines in conjunction with the freight transport practices of Kunming Railway Bureau, especially with the requirements to promote logistics center construction and the ratio targets of mechanization and equipment integrity, so as to determine the optimal configuration scheme of handling machines for the freight transport of Kunming Railway Bureau.

2 Analysis on the present handling operations of freight transport in KRB

Kunming Railway Bureau administrates the railways distributed in Yunnan, Sichuan and Guizhou provinces. The railways includes three kinds of tracks with standard gauge (1435 mm), metre gauge (1000 mm) and cun gauge (a Chinese unit of length, 600 mm). The cun gauge tracks ceased operations in 1990, so Kunming Railway Bureau becomes the unique one with standard gauge and meter tracks in operation at the same time. The operating station layout of freight transport in Kunming Railway Bureau is as shown in Figure 1.

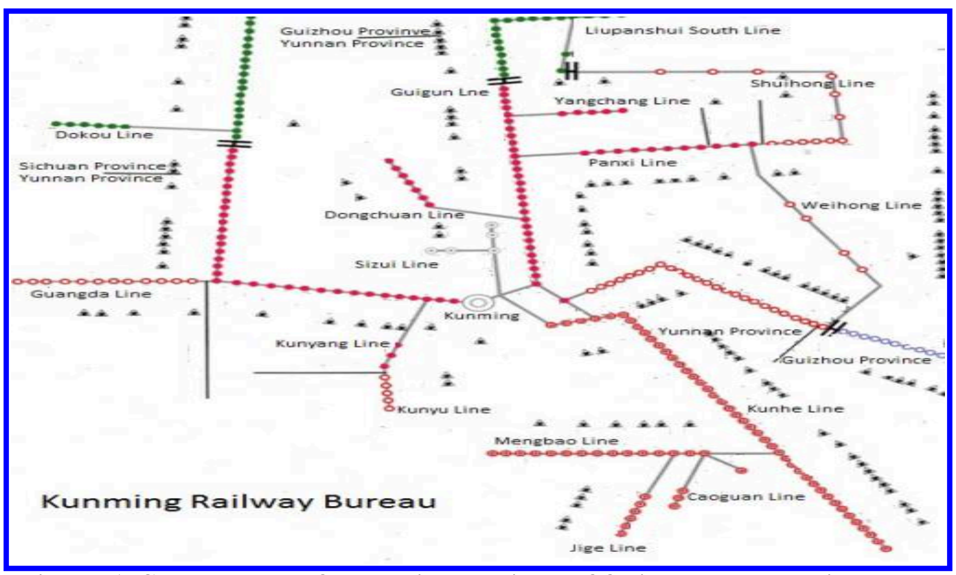

Figure 1. Sketch map of operating stations of freight transport in KRB

With the development of Yunnan Province and its association with surrounding countries, as well as Southeast Asia and South Asia becoming more open, the regional geographic environment and the location of environmental economy of Yunnan are unique and significant. The problem of insufficient for the external passage, especially international railway passage becomes more serious. The transport volume trends of major goods in KRB are represented as Figure 2 (Kunming Railway Bureau and Southwest Jiaotong University, 2014).

At present, there exist some problems in the configuration or allocation of handling machines for the freight transport in KRB as the following:

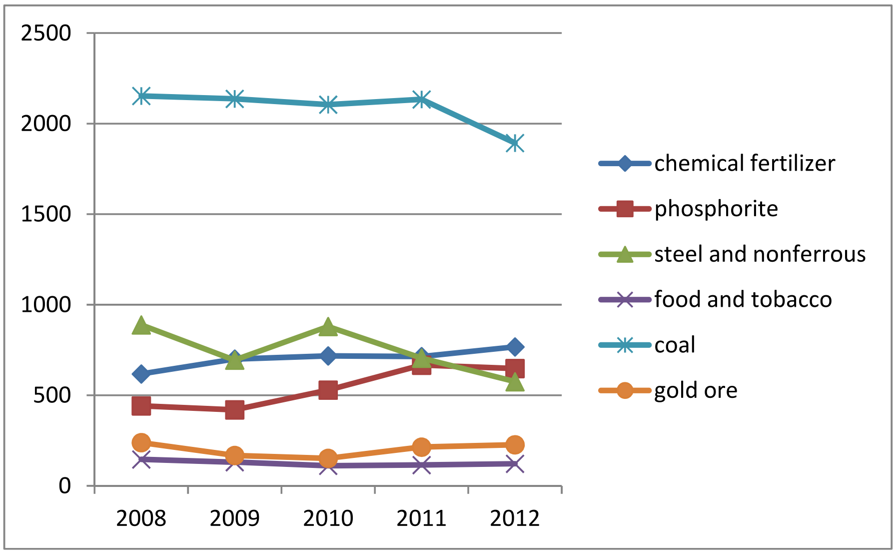

Figure 2. Transport volume trends of major goods in KRB

(1) The equipments are in overtime service, the degree of aging becomes more and more and the performance has been degrading. For example, the 20T gantry in Qujing Station has been in service since 1988.

(2) Because of the repeated installation of handling resources in some areas it is difficult for the scale effect to come true, such as Baita Village station and nearby small stations.

(3) The equipment quantity is insufficient, the loading and unloading are carried out fundamentally by manual labor in some public freight yards, such as Yuanmou station.

(4) Special equipments and universal ones are mixed use, the configuration or allocation of handling machines does not adapted to goods category and yard capacity.

(5) In the model selection there is either blindly novelty seeking, or yield to the temptation of low prices. So scientific criteria are absent and model selection is improper.

3 Model selection method of handling machinery

Aimed at the freight handling practices in KRB, the "Three Phase Method" for the choice of handling machinery types in KRB as the following:

Phase 1——Preliminary Filtering

The basic principles in this stage are:

(1) Based on the characteristics of freight category.

(2) Adapting to the operation property of railway freight yard.

(3) Considering time requirements.

(4) The equipments selected have smooth functioning and work cooperatively.

(5) Various rigging could be adopted to extend the operation scope for a kind of handling machinery.

(6) Standardization, energy conservation and environment protection.

Phase 2——Property Matching

By means of analyzing respective characteristics of handling equipments and tasks (e.g. works of train loading and unloading area, horizontal transport and goods stacking area respectively.), the matching among the handling equipment, goods and conditions can be achieved to determine reasonable handling equipment.

Phase 3——Comprehensive Comparing and Selecting

Through the above two phases the model selection of handling machinery have mainly finished for the great majority of railway freight yards. For some loading and unloading equipments whose operation characteristics are similar and each performance has its own merits, the choice is difficult, so it is necessary to make further comparison and selection in consideration of technical performance, utilization of yard and handling cost so as to make a explicit and scientific decision.

4 Quantity optimization of handling machinery

As the loading and unloading operations in railway yards requires multiple machines working cooperatively, the problem of handling equipment allocation ratio emerges.

4.1 Ratio control

Select 3 kinds of loading and unloading machine commonly used in container center stations as the research object: rail-mounted gantry cranes, front-handling mobile cranes (reach stacker, positive hanging) and container trucks. And suppose the following hypotheses:

(1) The rail-mounted gantry cranes and reach stackers work in uniform motion.

(2) The waiting time cost is ignored.

One-third containers in the trains are transported to auxiliary container yards, so there must be some intervals for the container trucks to reach the handling tracks. The rail-mounted gantry cranes, reach stacker and container trucks work cooperatively to accomplish the handling and transporting tasks of the containers. That is

$$\frac{NT_G}{Z_G} = \frac{N_J T_J}{Z_J} = \frac{N_Z T_Z}{Z_Z} \tag{1}$$

where N , N_J and N_Z is the handling volume of container trains (TEU), transporting volume of trucks (TEU) and handling volume of reach stackers (TEU) respectively, Z_G , Z_J and Z_Z is the quantity of rail-mounted gantry cranes, container trucks and reach stackers respectively, T_G , T_J and T_Z is the average cycle working time of rail-mounted gantry cranes, container trucks and reach stackers respectively.

This model objective is to minimize the waiting and spare time in the process of loading and unloading in which the containers are loaded or unloaded to/from trains and transported from/to the origins/destinations, that is, the quantity ratio among the rail-mounted gantry cranes, container trucks and reach stackers is to be optimized.

4.2 Reasonable amount determination

Relative researches indicate that there is a certain relationship among the handling machinery amount, attendance number and serviceability rate in a railway freight yard. Suppose there is a freight station equipped with n handling machines whose serviceability rate is α. When m handling machines are required to be on duty, they must be selected from n ones, and each choice has two results: in good condition or not. So the number on duty, express as x, is binomial distribution (Chen Chuanshi and Li Deyuan, 1988) on n and α, which can be written as

$$P\{x = m\} = C_n^m \alpha^m (1-\alpha)^{n-m} \qquad (m = 0,1,2,\ldots,n;\ \ 0 < \alpha < 1) \tag{2}$$

Then let $P_k (0 < k \le n)$ stand for the attendance rate of guarantee that means the probability of k machines can be selected at least from n ones. Thus there is

$$P_k = \sum_{m=k}^{n} P_n(m) = \sum_{m=k}^{n} C_n^m \alpha^m (1-\alpha)^{n-m} \qquad (k = 0,1,2,\ldots,n) \tag{3}$$

And the mathematical expectation of the rate (A_k) can be obtained by multiplying the number on duty and the attendance rate of guarantee of handling machines, that is,

$$A_k = k \cdot P_k = k \sum_{m=k}^{n} C_n^m \alpha^m (1-\alpha)^{n-m} \tag{4}$$

In response to different k, there will be a series of P_k and A_k , the most A_k of which corresponds to the optimum number on duty k^* . In this way there will also be a series of n, α and k^* corresponding each other, which can be transformed into a table. Given α and k^* the reasonable amount of handling machines in possession n can be looked up in the table.

5 Application of Kunming Railway East Station

Kunming Railway East Station (KRES) equips with various types of loading and unloading machines, the problem of reasonable amount determination is discussed in the case of forklifts in the public freight yard of KRES as follows.

There are 40 forklifts distributed in the south, east and west public yards. Their serviceability rate is 95%. According to statistical data, the numbers of forklifts on duty and its frequency in the public yard of Kunming Railway East Station are listed in Table 1 and their cumulative frequency distribution is shown as Figure 3.

Table 1. Numbers of forklifts on duty and its frequency

Number on duty	Occurrence number	Frequency
12	8	0.022
25	16	0.044
28	25	0.069
29	30	0.082
30	38	0.104
32	52	0.142
33	69	0.189
34	78	0.214
35	43	0.118
36	4	0.011
38	2	0.005

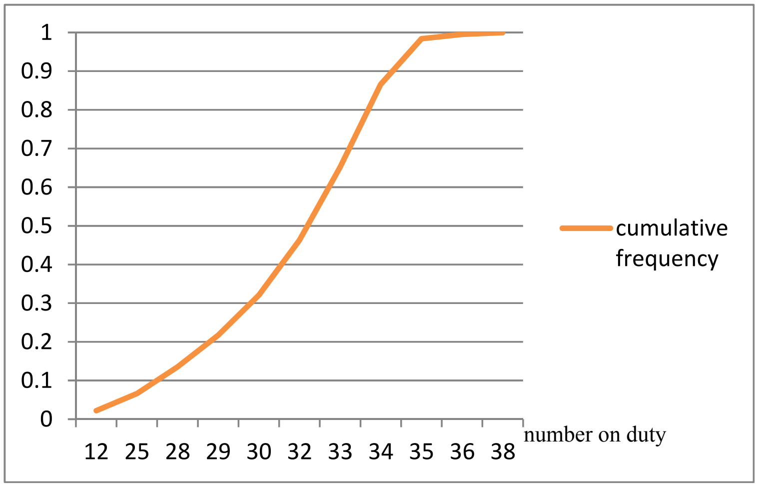

Figure 3. Cumulative frequency distribution of the forklifts on duty

By assigning different values, n and α vary in a certain range. The k^* varying accordingly may be obtained based on the above models with the help of MATLAB compiling and computing. Then a set of n, α and k^* corresponding each other are transformed into the Table 2 as below. The k^* in it stands for practical number of forklifts on duty to ensure normal production, thus n stands for the reasonable number of forklifts in possession.

6 Conclusions

In short, the selection of handling equipment cannot justly distinguish good and bad, but should be combined with practical operational needs, thus the main operation mode and optimal quantity can be determined according to different regions. Finally developing vision problems, along with the changes in the loading and unloading conditions, selected machinery will also change.

Table 2. Query table of reasonable number of forklifts in possession

α / n / k^*	95%	90%	85%	80%
20	17	16	15	14
26	23	21	19	18
30	26	24	23	22
36	32	29	27	25
40	35	33	30	28

46	41	38	35	32
50	44	41	38	35
55	49	45	42	39
60	53	50	46	43

Acknowledgement

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Strength Analysis of Mounting Brackets and Connecting Bolts on an EMU Inner End Door

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Abstract: The strength of the key parts and associated coupling bolts on the high-speed car body, which have direct related to the safe operation, is an important content of vehicle design. Nonlinear static strength analysis of mounting bracket on EMU inner end door was calculated on 8 working conditions with ANSYS software and very part was assessed. Then, sliding coefficients of hanging bracket on the most dangerous condition were analyzed. Results show that contact surface sliding coefficients were less than 1, the hanging bracket is safe and is not prone to sliding. Finally the influence of the sliding coefficient and bolt strength based on different preload was studied. With the preload becoming increasingly, the sliding coefficient became smaller and the bolt stress became larger. Taking the both influence into consideration, a proper range of the preload meeting the design requirements was obtained to provide some technology reference on the structural design and selection of bolts for engineers.

Keywords: Bolt; Contact nonlinear; Strength; Sliding coefficient.

1 Introduction

In order to meet the strength requirements, confirm weakness and provide reference for improvement and determine of the connecting parts on high-speed train, detailed strength analysis is needed. The bolt coupling has been widely used among the key components of high-speed train. Compared to other connections, bolts are easily assembled and repaired. This connection type can increase the preload to prevent loosening and cannot cause a phase change of material component. At present, there are two main calculation methods about bolts strength at home and abroad. One is the traditional theoretical calculation which is generally based on the "Mechanical Design Handbook" or few based on "VDI 2230", the other one is FEA. Taking the mounting bracket on EMU inner end door as object, the 3D model and contact relationship were built with ANSYS software to conduct contact nonlinear strength analysis and sliding coefficients calculation. Under different preload conditions, bolt stress regulation and hanger sliding coefficients change were studied to provide a strong technical support for similar structure design in the EMU.

2 Contact nonlinear finite element method

Overall, the solution method of contact problem can be divided into two categories, one is finite element method, the other is mathematical programming method. Contact force and deformation meet boundary condition through the iterations and the introduction of the penalty function and Lagrange multiplier method etc. In this paper, Lagrange multiplier method is used. Taking the smooth contact for example, the satisfied constraint conditions are:

$$\begin{cases} g_n = U_n - U'_n - \delta^0{}_n \geq 0 \\ (U_n - U'_n - \delta^0{}_n) P_n = 0 \\ P_n \leq 0 \end{cases} \tag{1}$$

U_n、U'_n、$\delta^0{}_n$ are respectively for the normal displacement, initial spacing at any contact point on the boundary objects Ω and Ω'. P_n is the normal force.

The common finite element formula is below.

$$[K]\{U\} = \{F\} \tag{2}$$

The equation can be obtained by the energy functional variation.

For example, the potential energy functional of a deformable body can be expressed as:

$$\Pi_p = \frac{1}{2}\{U\}^T [K]\{U\} - \{U\}^T \{F\} \tag{3}$$

According to the principle of minimum potential energy, for the displacement of deformable body satisfying the boundary conditions, the potential energy Π_p is minimum and satisfies the stress boundary conditions. That is:

$$\delta \Pi_p = 0 \tag{4}$$

The functional is written as with Lagrange multiplier method:

$$\Pi_L = \Pi_p + \{\lambda\}^T \{g_n\} \tag{5}$$

$\{\lambda\}$ is the introduced multiplier. The formula (4) can be rewritten as:

$$\delta \Pi_L = 0 \tag{6}$$

In which displacement $\{U\}$ and Lagrange multiplier $\{\lambda\}$ are unknowns. Π_p is the quadratic term of displacement $\{U\}$. After formula (6) variation, the elements of main diagonal corresponding $\{U\}$ are not zero and corresponding the multipliers $\{\lambda\}$ are zero in the total stiffness matrix which cannot be solved due to singularity. For this reason, a perturbation Lagrange multiplier method is created. The formula (6) through $\varepsilon > 0$ introduction is written as:

$$\Pi_c = \Pi_p + \{\lambda\}^T \{g_n\} - \frac{1}{2\varepsilon}\{\lambda\}^T \{\lambda\} \tag{7}$$

Compared with Π_L, Π_c has a quadratic term $\{\lambda\}$. The main diagonal elements are no longer zero corresponding to $\{\lambda\}$ and the total stiffness matrix is no longer singular matrix. When $\varepsilon \to \infty$, the formula (7) is reduced to the equation (6).

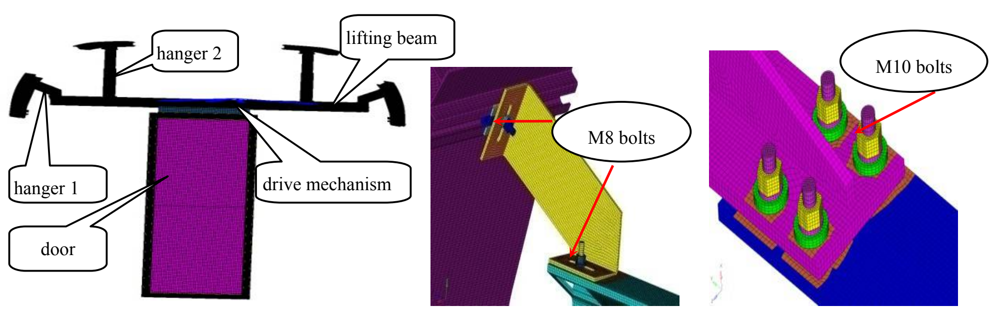
3 The finite element model

3.1 Geometry

The mounting bracket structure was comprised of hanger, lifting beam, bolts, door and drive mechanism etc (as shown in Fig. 1). Hanger 1 was connected with the roof and lifting beam by two M8 bolts respectively. Hanger 2 was connected with itself by eight M10 bolts, with roof by four M10, and with lifting beam by eight M8 bolts. Inner end door weight was about 60 kg and drive mechanism weight was 20 kg.

3.2 Finite Element Model

The finite model was meshed with hexahedral elements (solid 185) and driving mechanism was meshed with mass element (mass 21). According to contact location, the relationships of all parts between bolt, bolt gasket, hanger and lifting beam were defined and there were 104 contact pairs in total. The whole finite element model was 670,664 elements and 922,426 nodes.



(a) overall view (b) local view 1 (c) local view 2

Fig 1. Finite element model

3.3 Calculation Conditions

(1) Preload calculation

There were two types of bolts M10 (tightening torque 36 N•M) and M8 (tightening torque 12 N•M) in the model. The preload was calculated with Eq. 8 in "Mechanical Design Handbook" .