Scientific Research

Special Pallet Structure Design for Block Stacking

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Abstract：The logistics difficulties about pallet are encountered in China at present. And the resolving is through the second moving and recycling pallet artificially in enterprises. In order to improve logistics efficiency and decrease workers' labor intensity, a special pulled-back pallet is designed for block stacking. People can one through stove the cargo from the special pallet to truck or other container not by manpower but by fork-lift directly. It can solve the problem of the second moving efficiently. This paper introduced the design of the special pallet, and illustrated with the structure drawing, besides calculated the intensity of some major components. The special pallet will be applied in many enterprises.

Key words：block stacking, pallet, pulled-back Pallet, Containerization

Introduction

Containerization is widely used in the products' storage and transport, which attributes to its high efficiency, low labor intensity, being easy to manage and many other features. The containerization means that many single-objects through certain technical measures are combined into large standardization assembly which are in the same size and similar weight. The common containerization tools are pallet, containers, and container vessels [1]. As the smallest container unit, pallet is widely used. The international community has formed the basic concept of the pallet logistics. Ideal pallet logistics is using pallet as container vessels to stacking, cargo, and during the logistics, to load the pallet into the larger standard container vessels, such as container, so as to increase the efficiency of loading and accelerate the speed of logistics. This advantage has been well known and accepted by public.

1. The structure scheme of the special block stacking pallet

1.1 Application status of the pallet logistics in China

With the rapid development of China's economy and the trend of economic globalization, the logistics industry in China should conform to the global ideology and the mainstream trend of pallet logistics as soon as possible. Traditional pallet should be loaded into container or vehicle and enter the logistics circulation together with the cargo.

Although the world of this industry in our country has generally accepted the concept of pallet logistics, but the process of an overall promotion still faces many obstacles. At least, there are three major ones [2] [3] [4]. Firstly, the pallets could not be turned over rapidly on a

large scale, mostly the pallets" left without return". Each shipment will lose pallets and increase the cost of goods. Secondly, the pallets occupy transportation space thus add the cost of transport and goods. Thirdly, among the international trade exchanges, there are many "non-trade barriers" directed against pallets, such as the one for wide use of wooden pallets. Many countries have established extremely harsh fumigation requirement, hampering the internationalization circulation of pallets. Due to involving kinds of core interests of various interest groups, such as different countries and enterprises, this kind of problem is hard to improve efficiently in short time. Based on the mentioned problems, currently, the status quo of many Chinese enterprises is using pallets to store goods in their enterprises and using manpower to stack the cargo to the vehicle and taking the pallets back when goods are sold especially exported. This will not only greatly raise the labor intensity of workers, but also reduce the efficiency. In fact, the pallets are merely the tool used in the enterprises and hasn't really participated in social logistics, that may change the original intention of the design of pallet logistics, however has no alternative.

Whether there is an approach for above items? We propose a new concept named "special pulled-back pallet" (patent No. 201020295195.4) to be the solution. This proposal changes the thought that the traditional pallet merely used for single container. This special pallet may be used as a store tool at normal and a loading tool aided to a special forklift which could stack the all cargo on the pallet to goods stacks on the vehicle when in need of loading, practicing well to improve the efficiency of loading and reduce the labor intensity of workers.

1.2 Structure of special pulled-back pallet

1.2.1. The basic thought of the special pulled-back pallet
The pallet surface of traditional tray is fixed in parallel.

Because of the large friction produced under the gravity work, the pallet couldn't be pulled back under the weight of goods. As a result, the pallet merely can be used as the bearing unit[5].。

In the view of the above situation, we designed the special pulled-back pallet. As the basic thought goes, under the control of a manual hydraulic and mechanical system, the flexible knuckle rod which used to support the pallets could rotation. When the flexible knuckle rod rotates, one side of the pallet can move around the center of fixed knuckle thus makes relative rotation on the other side. So the pallet has two status—of parallel and wedge. As shown in figure 1.
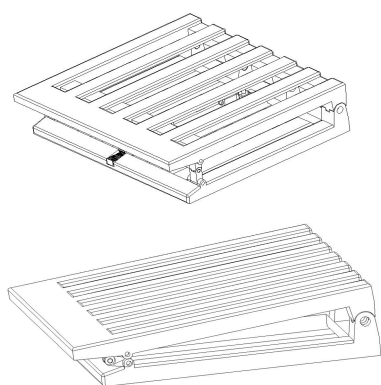

Figure1.Two Work Status of Pallet

Parallel status is the loading phase while the wedge status is pulled-back phase. Under the wedge status, part of the friction may be offset by the effect of making use of the horizontal extrapolation component of goods' gravity, so that the pallet could be easily pulled back from the goods stacking. Therefore, whole goods on the pallet can be stowed to the stacking of goods once through. It improves the efficiency of loading and reduces the labor intensity of workers, arguably to be an available solution to decrease the second manual operation.

1.2.2. Structure and working principle of the Special pulled-back pallet

The figure 2 and figure 3 separately show the structure and the hydraulic system of this special pulled-back pallet. The components' names are as followed:1.Bottom pallet; 2.Pin; 3.Upper pallet; 4.Oil tank; 5.Manual oil pump; 6.Two-positions-four-ways reversing valve; 7.Unidrictional throttle; 8.Piston; 9.Rack; 10.Incomplete gear; 11.Fuel tank; 12.Rod-cavity tubing; 13.Rod-less-cavity tubing; 14.Mamual oil pump tubing; 15.Reversing valve oil return pipe; 16.Underlying active flexible knuckle rod; 17.Underlying driven flexible knuckle rod; 18.Flexible hinged shaft; 19.Upper driven flexible rod; 20.Overflow valve; 21.Check valve; 22.Overflow valve oil return pipe; 23.Upper active

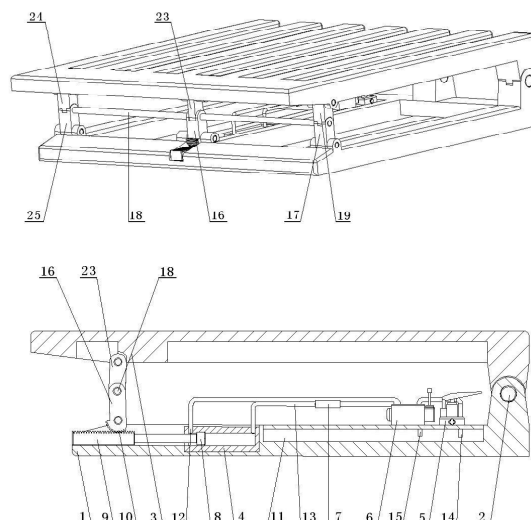flexible knuckle rod; 24.Upper driven flexible knuckle rod; 25.Underlying driven flexible knuckle rod.
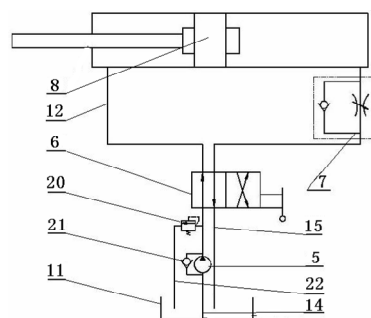

Figure2. Structure of Pallet

Figure3. Hydraulic System of Pallet

As it is shown in the left part of figure 3, when the goods need to be loaded into containers or vehicles，at first the forklift left the pallet in proper place, then manual adjust the two-positions-four-ways reversing valve to the pipe connection status thus manual oil pump will press oil to the rod-cavity and the piston can move to the rod-less-cavity. This will pull the linked rack to the right and drive the incomplete gear which meshes the rack to rotate in counterclockwise. It leads the same directory rotation of underlying flexible knuckle rod. The gravity of the goods on the pallet will produce increasing rotation moment for the underlying flexible knuckle rod when the upper and underlying flexible knuckle rod turn away from the same line and the pallets leave the vertical position. So it will drive the piston moves rapidly to the rod-less-cavity. Meanwhile, without the manually pressing oil with the oil pump, the oil that rod-cavity needs can taken directly from the oil tank by taking use of check valve and the movement of the piston. To stop the rapid rotation of the upper pallet and to prevent the

damage at the goods' bottom, which caused by that over-rapid falling of goods, there is a flow adjusted check valve connected to rod-less-cavity tubing. By controlling the rate of rod-cavity discharge oil to slow down the speed of the piston rightward movement until the tips of the pallets tightly arrived together into the wedge shape as Figure 1. According to the calculation, the wedge angle can reach about 10 degrees. The author's another patent, a forklift with a push slab, which shown as figure 4, is able to hang on the tray's girder and drag the tray to the outside, while using the push slab with same speed of the forklift to push the goods to the inside. The tray can be drawn out, then the goods stacking process finished. Because of wedge angle, gravity will generate a larger outward component to push the pallet, so with the aid of additional slab, the forklift can pull the pallet back without large power.
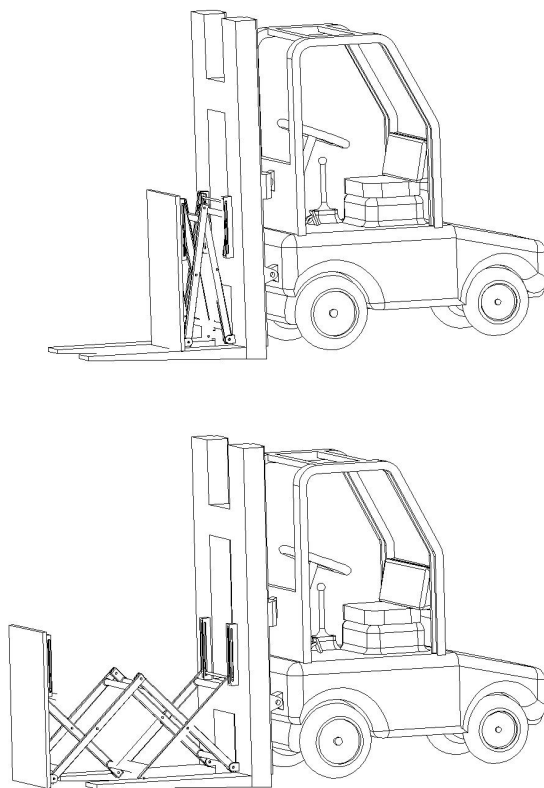

**Figure4. To Status of the Forklift with Push Slab F**

As the pallet has been pulled back, just move the reversing handle to change the two-positions- four-ways reversing valve for another position shown as right part in figure 3. Next, use manual oil pump to press oil to the rod-less-cavity, and then the piston move toward the rod-cavity and lead the upper and underlying flexible knuckle rod to oppositely rotate. Generally the two flexible knuckle rods recover on the same line and the two sides of pallet are in right-angle status. During this process, the piston moves faster because of the check valve on the rod-less-cavity has no throttle effect which caused by the performance of the check valve. To avoid that the manual oil pump keeps pressing oil after the upper flexible knuckle rod has reached the proper position and connected tightly with the upper pallet's edge, we add an overflow valve in the system of hydraulic as the security.

2. Related theoretical calculation

2.1 The drag force of forklift required

In order that the pallet can be pulled back from the stacking of goods, the drag force must be greater than the friction between the goods and the pallet. It needs demonstration through the strict calculation. The mechanical model of the relationship between pallet and gravity (G) is illustrated in Figure 5.
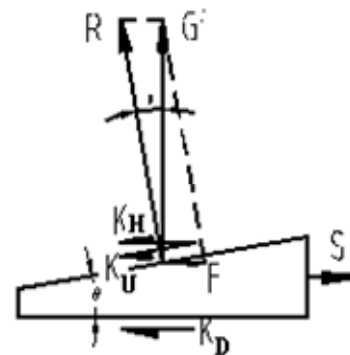
Horizontal force and Positive pressure

$$F = G' * Tan\theta$$

$$R = G' / Cos\theta$$

Given:
G'=25000N
$\theta=10^0$
f=0.15
(f stands for the Friction Coefficient)
F stands for Horizontal Force
R stands for Positive Force

Figure5. Mechanical Model

Other forces:

$$K_D = G' \bullet f = 25000 \times 0.15 = 3750N$$

$$K_U = R \bullet f = 25385 \times 0.15 = 3808N$$

$$K_H = K_U / Cos\theta = 3808 / Cos10 = 3867N$$

In the horizontal is the balance of the Drag Force (stood by S), Friction (stood by K) of the two surface and Horizontal Force (stood by F).

$$S = (K_D + K_H) - F = K - F$$
$$= (3750 + 3867) - 4408 = 3209N$$

In the formulation, K stand for the Horizontal Friction, the results are shown in the table 1.

Table 1. Forces of pallet stressed （N）

	R	*F*	*K*	*S*
G=25000N θ=10^0	25385	4408	7617	3209

According to the products sample, the forklift from the typical forklift producers, like Hefei Forklift Factory's A-100 forklift, the drag force can reach 12400N when the fork height less than 1.6m. So using forklifts is more than enough to meet the needs of pulling the pallet back.

2.2. Calculation of gear modulus

In the mechanical system, the mesh strength of the incomplete gear and the rack is crucial, thus the calculation is necessary here. Considering the most dangerous circumstance, say, half of the standard load 25000N works on the one side of the flexible knuckle rod, while the angle of the underlying active flexible knuckle rod is 90^0. At the moment, that work on the rod is: T=12500*L. L stand for the center distance of the two holes on the underlying flexible knuckle rod. Suppose L=90mm.

T=125000*90=1125000=1.125×10^6（N·mm）

According to the Modulus Formulate of Bending Fatigue Strength on the Tooth Root：

$$m \geq \sqrt[3]{\frac{2kT}{\phi_d z_1^2} \cdot \frac{Y_{sa} \cdot Y_{Fa}}{[\sigma_F]}}$$

$$= \sqrt[3]{\frac{2 \times 1.2 \times 1.125 \times 10^6}{0.7 \times 26^2} \times \frac{2.60 \times 1.595}{1290}} = 2.6mm$$

The result indicate that the modulus of this gear-rack shouldn't be less than 3mm under the 25000N standard load of pallet.

According to the reference [7], in the formulation, if Working Condition Coefficient K=1.2, Tooth Width Coefficient Φ_d= 0.7, Gear Number (whole number) Z_1=26, Their equivalent gear-tooth coefficient Y_{sa}=2.6, stress correction coefficient Y_{fa}=1.595

Its Allowable Stress[σ_F] calculate as follows：

$$[\sigma_F] = \frac{K_{FN} \times \sigma_{FE}}{S} = \frac{1.7 \times 910}{1.2} = 1290MPa$$

In the formulation: The gear material use the steel through carburizing hardening treatment with hard surface .Its surface hardness should be more than HRC=60. ,σ_{FE}=910Mpa, Safety Coefficient S=1.2, Lifetime Coefficient according number of work in 100, 000 times, that is N=10^5, K_{FN}=1.7

Because of the constrain of the space, we omit the calculation process of the other hydraulic system which are composed of the standard components.

3. Conclusion

In all, the structure of this special pulled-back pallet is arguable to be regarded as a new trail. It is obviously that taking advantage of this pallet could efficiently reduce workers' working intensity and greatly raise the loading efficiency .Therefore it is an effective tool to increase the productivity.

But from the view of present analysis, there are still some places in this structure that should be improved in the future.

First, due to the mechanical hydraulic mechanism at the intermediate girder, the forklift cartridge can only from one-side in support, unlike the traditional tray can insert a fork from all four sides.

Second, there is a drop height less than 100mm at the moment the goods just left the pallet, which due to the structure constraints and will cause some impact to the goods. So this pallet is applicable to the products with better anti-dropping quality or the ones not with necessary to avoid dropping, like bags, packages etc. With knowledge that such products account for a considerable proportion in the daily logistics, it is believed that this pallet will be perfectly useful.

Third, the bottom of the under-layer products will have frication with the pallet surface, which may even wear the package. Accordingly, it is proposed to lay some corrugated boards on the pallet before loading in order to reduce the wearing capacity of package as well as to maintain the integrity of the goods after be stacked. The defects above still have the space of perfecting. We will continue to make efforts.

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