Research on Anti-swing Mechanism of Crane

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Abstract. With the development of container transport, the crane improves the capacity of loading and unloading containers. But also raises the new question about the swing amplitude of container. The anti-swing technology has become one of the key technologies to improve the loading and unloading efficiency of crane. In this paper, a kind of anti-rolling device for crane is studied, which could use the weight as the power. It could reduce the swing strength of hoisting containers while ensuring the efficiency of energy saving. The strength of the anti-swing mechanism units has excellent safety and reliability, which could meet the requirements of the relevant standard.

1. Introduction

With the development of container transport, the crane improves the capacity of loading and unloading containers, which improves the specification parameters, such as the speed of equipment and crane carriage, the acceleration and deceleration of the equipment and the height of the device[1]. However, it raises the new question on the swing amplitude of container. The anti-swing technology has become one of the key technologies to improve the loading and unloading efficiency of crane. It also could help drivers reduce the working intensity, and improve working comfort.

It was systematically studied about the anti-rolling technology of cranes[2-7]. When the crane carriage is accelerating or braking deceleration, the slings of the crane have a certain inertia due to the non-rigidity of the lifting rope, which is shown as an inertial link in the control equation, which could cause the swing of hoisting tools relative to crane carriage. The easiest way to suppress this swing is to make speed very slight during the movement of the crane carriage, so that the pendulum angle could be always very close to zero[8]. But this kind of anti-rolling theory has little practical value due to extreme inefficiency. It is another effective way to add some mechanical measures in the whole system between crane carriage and hoisting tools. When the crane carriage stops, the swing angle of the hoisting tools could not be reduced to zero at the same time, but it could be reduced to zero by various means[9]. In order to suppress the swing of the hoisting tools, the acceleration of the crane carriage needs to be decreased, and the reasonable vibration reduction methods are adopted. It could greatly reduce the time of swing attenuation when the crane carriage stops. Therefore, it greatly improves the efficiency of loading and unloading, and also has some improvement in stability.

At present, there is no such product to achieve the anti-swing effect and energy saving balance. It is mainly introduced a new kind of anti-swing mechanism of crane, which is mainly studied from system composition, operating principle and strength check. It is useful to the application and promotion of the anti-swing mechanism.

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2. Anti-swing Mechanism

2.1. Structure

The anti-swing mechanism of crane use the weight as the power, which acts on the lifting rope and pulley to achieve the stabilization. The anti-swing mechanism includes at least two sets of anti-swing units, which are set between the crane carriage and the sling. Each unit should consist of two sets of hoisting tools with overlapping and overlapping lifting ropes. The end of the lifting rope is connected with the additional weight, the other one is fixed through the pulley. The main components of the system are shown in Figure 1.

2.2. Working Principle

The device is equipped with two sets of swinging units, which could be used to lift the container, and the horizontal direction of the hoisting device could be stressed simultaneously. Because the intersection is symmetrical, the horizontal force is the same, which could be effective to restrain the fore-and-aft shake of container when hoisting the container. As the hoisting tools swings forward, the second set of anti-swing units passing the after-bracket of crane carriage and pulley bracket of hoisting tool produces a larger backward horizontal component than the forward component of first one producing, so that it could reduce the swing strength of the hoisting container more obviously.

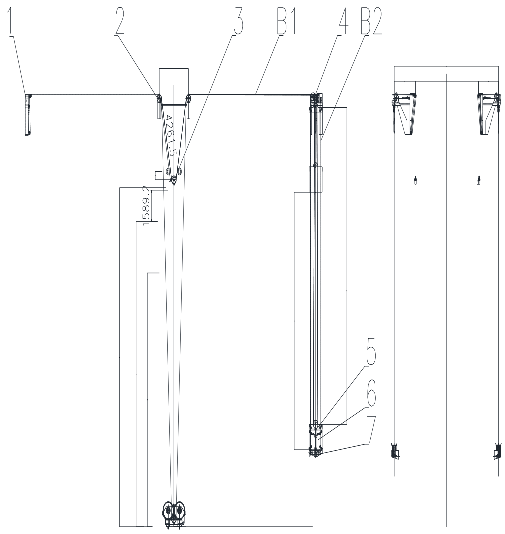

Figure 1 Main Components of System: 1. Front bracket 2. Crane carriage bracket 3. Pulley bracket of hoisting tools 4. After-bracket 5. Balancing weight upper bracket 6. Balancing weight 7. Lower bracket B1. Lifting rope B2. Guide rope

3. Strength Assessment

3.1. Basic Parameter

The engineering sample is taken as an example per GB3811-2008[10]. The basic design parameters of the prototype are shown in Table 1.

Table 1 Design Work Parameters

Balance weight of single side		Q= 4 t=4000kg
Lifting speed	Rated load	23 m/min
	No-load	52 m/min
Acceleration time	Rated load	2 s
	No-load	5 s
Classification group of mechanisms		Hoisting mechanism L2 T7 M7

Lifting distance	15m
Lift load impact coefficient	$\phi_2 = 1.2$
Load single side calculation load	$P = \phi_2 BW = 1.2 \times 4000 = 4800kg$

3.2 Key Component Strength Assessment

3.2.1 Stress Analysis of Balance Weight

The force diagrams of the balance weight upper bracket and balance weight are shown in Figure 2. The balance weight upper bracket is connected by turning plate consist of two symmetrical layout of the upright tube and the balance weight. Material of upright tube is Q325, ($[\sigma] = 2400\text{kg}/\text{cm}^2$). The strength of upright tube should meet the following requirements:

Tensile stress of upright tube: $\sigma_l = \dfrac{P}{F} \le [\sigma]$

Normal contact stress between upright tube and turning plate: $\sigma_n = \dfrac{P}{F_2} \le [\sigma]$

Tensile stress of upright tube: $\sigma_l = P \div F = 104\text{kg/cm}^2 \le [\sigma]$=2400kg

Where:

The diameter of upright tube D, 7.8 cm,

Sectional area $F = 47\text{cm}^2$

Normal contact stress: $\sigma_n = P \div F_2 = 252\text{kg/cm}^2 \le [\sigma]$=2400kg

Where:

Area contacted with the turning plate, $F_2 = 3.8 \times 2.5 = 9.5\text{cm}^2$

Contact stress $\sigma_n = P \div F_2 = 252\text{kg/cm}^2 \le [\sigma]$=2400kg

The balance weights are composed of multilayer steel plates, and the turning plate plug with the diameter of 4cm is sold with shear force. The shear is 1200kg. So Shear stress

$\sigma_\tau = Q \div F_3 = 96\text{kg/cm}^2 \le [\sigma]$

Contact stress of turning plate：$\sigma_n = P \div F_2 = 252\text{kg/cm}^2 \le [\sigma]$

Above all, the strength of the balance weights meet the strength assessment

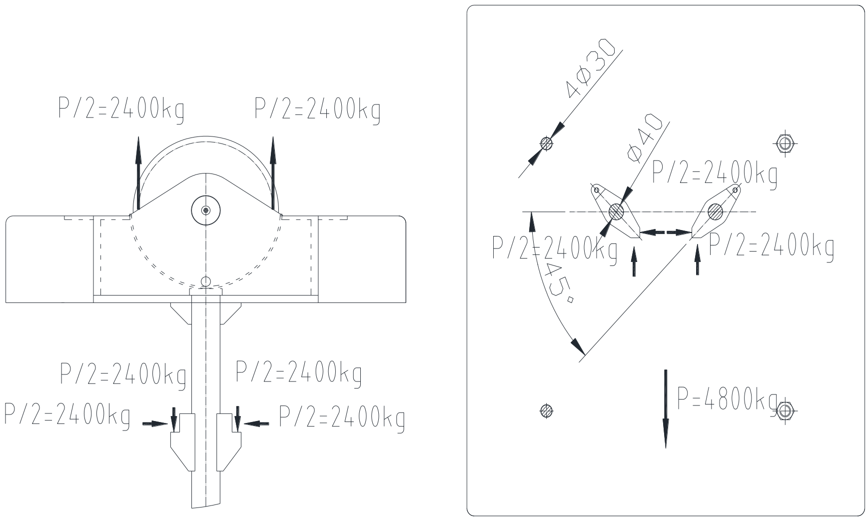

Figure 2 Force Diagram of Balance Weight and Upper Bracket

3.2.2 Stress Analysis of Front bracket

Force diagram of front bracket is shown in Figure 3. Related parameters are shown in Table 2.

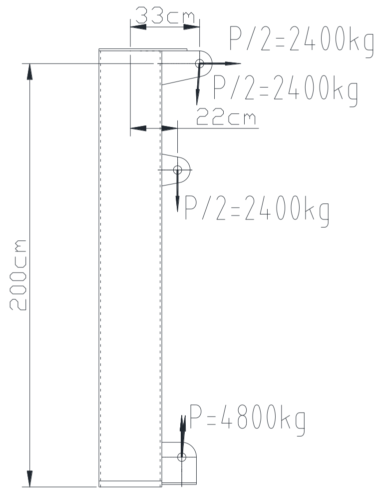

Figure 3 Force Diagram of Balance Weight and Upper Bracket

Table 2 Mechanical Feature Parameters of Front Bracket

Material of Front Bracket	300×150×10 Rectangular Tube
Cross-Sectional Area	$F_3 = 86cm^2$
Section Modulus	$W_Y = 665cm^3$

The root section of the front bracket is a dangerous section, and its strength should meet the following requirements.

$$\sigma_z = \frac{P}{F_3} + \frac{\frac{P}{2}\times(200+33+22)}{W_Y} \le [\sigma]$$

Where:

$[\sigma] = 1600\text{kg}/cm^2$ --------------------- Allowable stress of front bracket

Plug in the relevant data:

$\sigma_z = 976kg/cm^2 \le [\sigma] = 1600kg/cm^2$

Above all, the strength of the front bracket meet the strength assessment.

3.2.3 Stress Analysis of Crane Carriage Bracket

Force diagram of front bracket is shown in Figure 4. Related parameters are shown in Table 3.

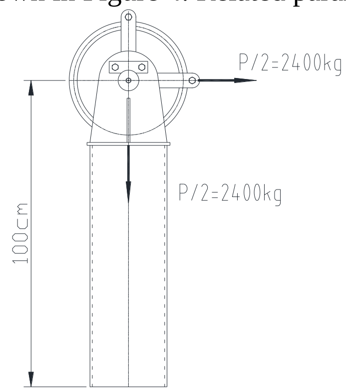

Figure 4 Force Diagram of Crane Carriage Bracket

Table 3 Mechanical Feature Parameters of Crane Carriage Bracket

Material of Crane carriage bracket	300×150×10 Rectangular Tube
Cross-Sectional Area	$F_4 = 86cm^2$
Section Modulus	$W_Y = 665cm^3$

The root section of the crane carriage bracket is a dangerous section, and its strength should meet the following requirements:

$$\sigma_z = \frac{P/2}{F_4} + \frac{\frac{P}{2}\times 100}{W_Y} \le [\sigma]$$

Where:

$[\sigma] = 1600\mathrm{kg}/cm^2$ --------------------- Allowable stress of Crane carriage bracket

Plug in the relevant data:

$$\sigma_z = 389kg/cm^2 \le [\sigma] = 1600kg/cm^2$$

Above all, the strength of the Crane carriage bracket meet the strength assessment.

3.2.4 Stress Analysis of After-bracket

Force diagram of after-bracket is shown in Figure 5. Related parameters are shown in Table 4.

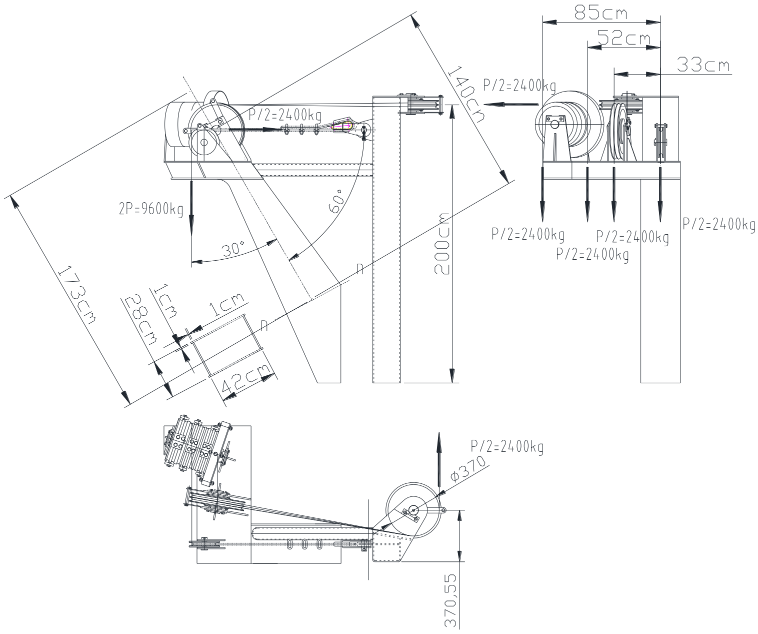

Figure 5 Force Diagram of After-bracket

Table 4 Mechanical Feature Parameters of After-bracket

Material of After-bracket	16Mn variable section groove structure
Cross-Sectional Area	$F_5 = 136cm^2$
Section Modulus	$W_X = 1628cm^3$, $W_Y = 1303cm^3$

The section of the after-bracket n-n is a dangerous section, and its strength should meet the following requirements:

$$\sigma = \sigma_n + \sigma_x + \sigma_y = \frac{N}{F_5} + \frac{M_X}{W_X} + \frac{M_Y}{W_Y}$$

$$= \frac{2P\cos 30^\circ + \frac{p}{2}\sin 30^\circ}{F_5} + \frac{2P\times 173\sin 30^\circ - \frac{P}{2}\times 140\cos 60^\circ}{W_X} + \frac{\frac{P}{2}\times(85+52+33)}{W_Y} \le [\sigma]$$

Where:

$[\sigma] = 2400\,\text{kg}/cm^2$ --------------------- Allowable stress of after-bracket

σ_n --------------------- Compressive stress of posterior bracket section

σ_X --------------------- Bend stress of posterior bracket X-X section

σ_Y --------------------- Bend stress of posterior bracket Y-Y section

M_X --------------------- Bending moment of posterior bracket X-X section

M_Y --------------------- Bending moment of posterior bracket Y-Y section

Plug in the relevant data:

$\sigma = 70 + 406 + 313 = 789kg/cm^2 \leq [\sigma] = 2400kg/cm^2$

Above all, the strength of the After-bracket meet the strength assessment.

4. Conclusion

In this paper, it is introduced that a new type of the anti-swing mechanism could save energy and effectively reduce the swing of container, which could use the weight as the power. The device is equipped with two sets of swinging units. Because the intersection is symmetrical, the horizontal force is the same, which could be effectual to restrain the fore-and-aft shake of container when hoisting the container. The engineering sample could pass all strength assessment to meet the safety requirements, which could be utilized in actual products.

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