Static And Dynamic Loads Affecting Load – Gripping Devices (HZP) In Construction

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ABSTRACT

The article describes the device, the principle of operation and scope of load -griping devices designed to overload building goods and installation of structures in construction. The recommendations for the operation, device and selection of the main parameters of rental devices, static and dynamic, loads affecting the loading devices are presented.

Keywords: construction and installation work, installation mechanisms and equipment, cargo, removable lifting devices.

Introduction

With the continuous acceleration of scientific and technological progress, innovative technologies and the use of modern complex high-performance equipment and materials, greater accuracy in the installation of building structures, process equipment, loading and unloading operations and high qualification of installers, the introduction of effective methods for performing installation work using more advanced lifting equipment, contributing to a significant reduction in terms and cost of work [1-3].

Each type of lifting device corresponds to a very specific nature of the application and distribution of the load. During the entire cycle of operation of the load gripping device, the conditions for reliable retention of the load must be observed. Safe operation of the GZP for each type requires taking into account the appropriate safety factors for the forces of holding the load (strength). The values of these coefficients are usually taken taking into account the operating conditions and the possibility of accurate calculation of the load gripping device [4-8].

Research methods

The calculation of HZP links is reduced to determining the normal stresses arising in them from stretching and bending. In links, the tensile strength is determined from the conditionn_p

$$n_p = \frac{\sigma_b}{\sigma_p} \geq 5\,n$$

where, σ_b -temporary tear resistance;

σ_p - tensile stress.

For bending load safety factor $n_{изг}$. determined from the condition

$$n_{изг} = \frac{M_{np}}{M_{изг}} = \frac{\sigma'_m}{\sigma_{изг}} \geq 1,25$$

Where, M_p - ultimate bending moment; $M_{изг}$ – bending moment in the section;

σ'_m – bending yield strength of one of the extreme fibers of the section;

$\sigma_{изг}$ is the bending stress of one of the extreme fibers of the section.

Slings from steel ropes must be made with a safety factor of at least 6 (six times safety factor). In case of angle deviation α from the calculated in the direction of its increase, the safety factor K will decrease sharply [9-10].

An additional load on the elements of the sling load gripper may arise from the uneven distribution of the acting forces due to skew when hanging the load. The redistribution of the load can be caused by the shape of the load made with deviations from the correct geometric dimensions, for example, a building element made of reinforced concrete with incorrectly sealed mounting loops [11].

In conditions when the load gripper holding the load is stationary or moves at a constant speed along a straight path, only a static load acts on it. In the process of moving the load gripper with a variable speed and rotation, in addition to the static load, it also has a dynamic load. Dynamic loads occur during periods of starting and braking of crane mechanisms due to the action of acceleration or deceleration, as well as the result of shocks and shocks. The crane is an elastic system, so the forces of inertia cause the vibration of its elements, which continue for some time after the end of the transient processes [12].

Since the working operations of the crane are often combined (lifting, moving, lowering, turning), it is possible to superimpose oscillations resulting from the action of inertia forces of various assembly units, which can lead to their increase. This is also possible due to a change in the length of the load suspension. Impact forces can occur when the position of the center of the load changes during the lifting process. Although it is possible to calculate the impact force, it causes a number of difficulties due to the variability of the factors that cause this force to arise [13]. Dynamic loads arising during the operation of the lifting mechanism are considered in the literature [14, 15,].

Sources of large dynamic loads are shocks and impacts, which reach great force with large gaps in the gears of mechanisms, faulty railroad junctions, and wear of slewing bearings.

The main dynamic load on the load grip occurs in the process of lifting the load [14], and two options for its occurrence are possible: the first option involves lifting the load “from the weight”, the second - lifting the load “with pickup”. In the second case, the load is located on some base, the ropes sag and, therefore, at this moment the load on the grip is zero.

In the first variant, the load on the load $P_{г.з.}$ will be the sum of the static load Q_c and dynamic $P_{дин}$ which is a function of the excess driving force $P_{изг}$ depending on the nature of its development over time (t) and elasticity of the supporting structure (r), i.e. $P_{дин} = f(t, r)$. Consequently, $P_{г.з.} = Q_c + P_{дин}$

In the second variant of loading, the dynamic load occurs during the period when the hoisting rope moving at nominal speed (V), the load from the weight of the load will be instantly applied. Lifting load $P_{г.з.}$ will also be the sum of the static load Q_c dynamic, $P_{дин}$ in this case, which is a function of the rope speed and the elasticity of the support structure (r), that is $P_{дин}(V, r)$. For both options, the dynamic coefficient will be equal to

$$K_{дин} = \frac{P_{г.з.}}{Q_c} = 1 + \frac{P_{дин}}{Q_c}$$

In general, a crane with a load on the hook is a three-mass system with two elastic links, one of which is the elasticity of the crane itself, and the second is the elasticity of the ropes on which the load gripper is suspended [14-18].

When lifting the load “from the weight”, the dynamic deformation of the crane structure differs little from the static one (Fig. 5). This system can be reduced to a two-mass system by replacing the stiffness of the ropes r_n and rigidity of the crane $r_к$ reduced stiffness r :

$$R = \frac{r_n r_к}{r_n + r_к}.$$

A simplified system can be represented as consisting of two masses: m_p are the masses of the motor rotor and the masses of the lifting mechanism reduced to it, and $m_г$ - the mass of the load, interconnected by an elastic element with reduced stiffness r .

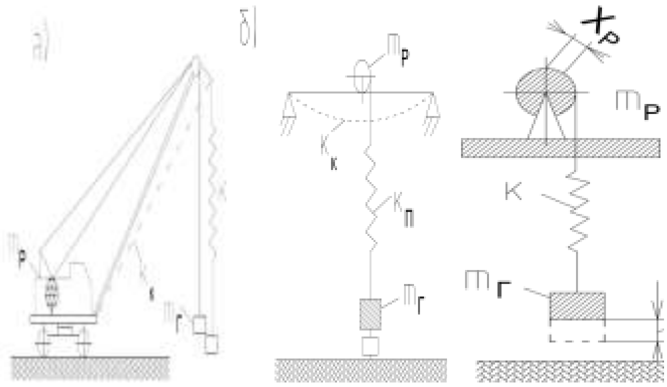

Fig.5. Scheme of dynamic loading of the load grip when lifting the load "from weight", a - on a jib crane; b - on an overhead crane; c - calculation scheme.

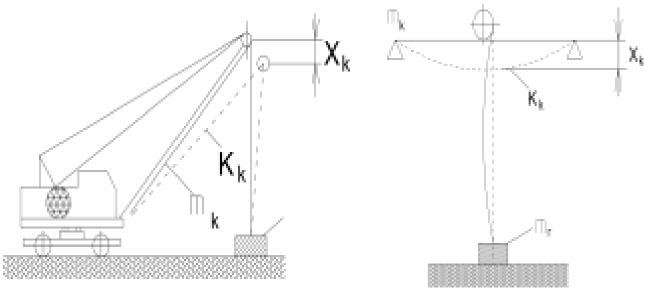

Fig.6. Scheme of dynamic loading of the load grip when lifting the load "with pickup", a - on a jib crane; b - on an overhead crane.

From the solution of the equations of motion for the considered case of lifting the load, the dynamic load is determined by the formula:

$$P_{дин} = 2\varphi Q_c \frac{m_г}{m_г + m_p} = 2\varphi g \frac{m_г^{\ 2}}{m_г + m_p}$$

Where, $\varphi = \frac{T_{изг}}{Q_c}$. The dynamism coefficient is equal to: $K_{дин} = 1 + 2\varphi \frac{m_г}{m_г + m_p}$.

When determining the dynamic loading of the mass m_p and $m_г$ should be attributed to the periphery of the drum, and the mass $m_г$ proportional to the square of the ratio of the number of branches of the cargo chain hoist wound onto the drum to the total number of branches on which the load hangs Q_c.

When braking a descending load $P_{дин}$ dynamic coefficient $K_{дин}$ can be determined by the same formulas, but under $T_{изб}$ the difference between the braking force applied to the load and the weight of the load must be understood.

The calculation of the dynamic loading of the load gripper suspended on four branches of the rope, when lifting a load of 10 tons "from weight" at a speed of 30 m/min with an average crane operation mode, showed that the maximum dynamic coefficient will be equal to:

$$K_{дин} = 1 + 2\varphi \frac{m_г}{m_г + m_p} = 1 + 2 \cdot 1{,}8 \cdot 0{,}093 = 1{,}33$$

When analyzing the dynamics of the oscillatory process that occurs when lifting a load, taking into account the compliance of the crane metal structures, one should generally consider a system consisting of a load mass $m_г$, crane mass $m_к$ and rotor mass m_p , electric motor and elements of the lifting mechanism, interconnected by elastic links with the stiffness of the lifting ropes r_n and steel structures of the crane $r_к$ (Fig. 6).

The process of lifting the load under the accepted assumption proceeds as follows.

At the first stage, the slack of the rope is selected: at the second stage, the process of elastic deformation of all structural elements occurs, which continues until the force P on the load grip, increasing from zero, will not become equal to $Q_c = m_г g$. Only after that, at the third stage, the lifting of the load begins.

From the solution of the equations of motion for the considered case of lifting the load [13], the dynamic load on the load grip is determined from the formula:

$$P_{дин} = -\frac{Q_c}{g} \upsilon \rho \sin \rho t,$$

Where, g - acceleration of gravity;

υ - the steady speed of lifting the load;

t – current time;

$\rho = \sqrt{\frac{r_к}{m_к}}$ is the frequency of circular oscillations;

$$r_к = \frac{Q_c}{y_{cm}};$$

y_{cm} - deflection of the structure from static load.

The maximum value of the dynamic load at $\sin \rho t = -1$ will be

$$P_{дин}^{макс} = Q_c \frac{v}{g} \rho = Q_c \frac{v}{g} \sqrt{\frac{r_к}{m_{кг}}},$$

Where, $r_к$ – rigidity of the crane structure.

The full load on the load grip is determined by the formula:

$$P_{г.з} = Q_c + P_{дин}^{макс} = Q_c \left(1 + \frac{v}{g} \sqrt{\frac{r_к}{m_{кг}}} \right),$$

And the dynamism coefficient will be

$$K_{дин} = \frac{Q_c + P_{дин}^{макс}}{Q_c} = 1 + \frac{v}{g} \sqrt{\frac{r_к}{m_к + m_г}}.$$

The last formula is convenient for practical use and reliable to an acceptable extent, although it takes into account the influence of the second stiffness element present in the system under consideration [13].

For a load that is not associated with a specific crane, it is necessary to determine the extreme value of the possible dynamic coefficient $K_{дин}$.

Conclusion

The calculations performed show that under normal operating conditions, the vertical dynamic effect on the load grip should be taken into account only when the load lifting mechanism is operating. During the operation of the mechanism of movement of the crane and the rotation of its rotary part in normal operating conditions, the dynamic overload does not exceed 5-6% of the static one.

With vertical transportation (lifting) of cargo with its upper grip and existing speeds in the lifting mechanisms of construction cranes up to 20–40 m/min, the drag forces are insignificant compared to the weight of the cargo and other loads on it.

When transporting cargo with a gripper in a vertical position or close to it, especially large-sized flat structures, it is necessary to take into account the wind loads acting on the cargo.

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