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Spring-Hydraulic Brake Effectiveness When Overhead Crane Braking

Key words: *spring-hydraulic brake, overhead crane, dynamic loads.*

Annotation: *the article exposes the spring-hydraulic brake structural design and describes its operation principle. Such spring-hydraulic brake compared to the classic friction brakes its operation efficiency is analyzed with the assessment of dynamic loads acting on the crane at braking with the suggested type of brake.*

Scientific problem statement

Considerable attention is paid to the issues of improving the hoisting cranes efficiency and reliability. An important element contributing to the crane service security, durability and efficiency is these cranes braking system and the brake device structure immediately. When operation, the "classic" normally-closed crane brake designs *(1)* (shoe, disc-shoe, disc brakes) cause significant dynamic loads in their drives and the crane metal structures.

In addition, when braking by friction brakes, a significant portion of heat is released, and in a friction pair complex processes occur that affect the reliability and durability of the braking device, and therefore the crane.

The analysis of mechanical braking methods and friction brake designs, used to implement these methods, demonstrates the following disadvantages appropriate to these ones *(2)*:
- insufficiently reliable braking due to the friction linings overheating;
- friction pads wear and, accordingly, the need for these pads frequent replacement;
- complicated adjustment of some designs brakes.

Such disadvantages can be avoided by using a new method of braking the overhead crane mechanism movement, consisting in that the braking torque is created not by the braking device friction forces, but by the spring compression one, due to the fact that namely the spring receives the crane movement kinetic energy in the braking device. With this braking method, the friction brakes' disadvantages are eliminated and implemented is a smooth increase in the braking force.

Recent researches analysis

Many scientists and manufacturers *(3, 4, 5, 6, 7)* were engaged in research and creation of new braking devices and constructive improvement of their existing structures.

All studies in the brakes design field can be divided by several areas:
- brake devices friction materials improvement in order to ensure the stability of friction properties in a large temperature range;

- development of friction brakes new designs at improved conditions for removing heat from the contact spot and maintaining the device components' acceptable temperatures range;
- development of combined braking devices and self-reinforcing brakes;
- improvement of the braking device control systems and the brake system drive in order to obtain complex characteristics of the braking torque, its value tracking, etc.;
- development of brakes and braking systems for stepless braking.

Purpose and objectives

This study is purposed to describe the operation of newly designed spring-hydraulic brake design and to analyze the operating efficiency influence when braking the overhead crane.

Main research material

To implement a smooth, friction-free braking of mechanisms actuating movement of cranes and load trolleys, a new spring-hydraulic brake design is proposed *(3)*. At crane braking the spring-hydraulic brake (fig. 1.) dampens the crane kinetic energy transforming it into potential energy of the compressed spring (springs package). Here the spring is used as an elastic element, creating a braking force that occurs when the crane stops. Additionally, to the effort generated by the spring, part of the braking force is created by the resistance of the fluid flowing from one cylinder's chamber to another. In addition, controlling the hydraulic resistance we can control the braking force change law.

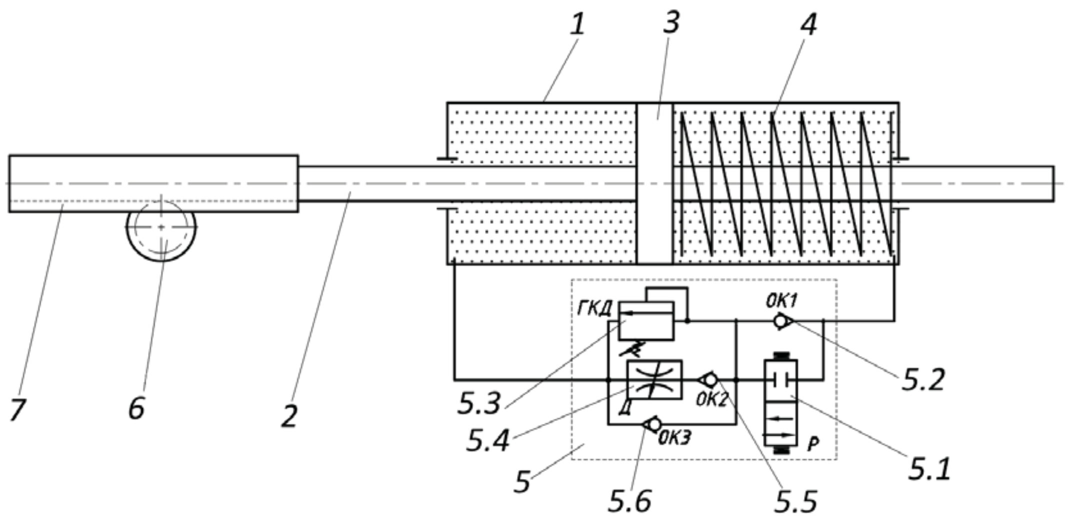


Figure - 1. Schematic diagram of the spring-hydraulic brake

The proposed brake structure allows ensure when braking, a smooth increase of the braking force from the minimum value of F_{tmin} to the nominal F_t one at which the crane or the trolley is completely stopped. The spring-hydraulic brake consists of a cylinder 1 which body locates a piston 3 with a rod 2. The piston is sealed and hermetically separates the right and left cylinder chambers. The cylindric chamber contains the power spring 4, which creates a braking force on the piston rod 2. Depending on the braking force value and the stopping distance length, the spring can be cylindrical, conical, can be a package of different stiffness disc springs, and it is possible to combine several cylindrical springs of different sizes installed in series or in parallel. In addition, the spring-hydraulic brake includes a hydraulic mechanism 5 and contains the fluid that bear the controlling function at this device.

The hydraulic control equipment 5 consists of: distributor 5.1, controlling the brake operation; check valve 5.2; adjustable hydraulic pressure valve 5.3 allowing to create additional resistance to the fluid flow from one chamber to another and thereby increasing the braking force change law value; check valves 5.5 and 5.6 and an adjustable throttle 5.4 allowing smooth return of the brake rod to its initial position.

The spring-hydraulic brake (Fig. 1) functions as follows: when the crane is braked, gear 6 starts rotation, this gear is connected to the crane wheel axis, and moves the toothed rail 7. The rail is attached to the rod 2, the rod with piston 3 moves, compressing the spring 4 and pushes the hydraulic fluid in the spring-less rod chamber. When the brake activated, the hydraulic fluid passes through the check valve 5.1 and the adjustable hydraulic pressure valve 5.5, that allows creating the additional hydraulic resistance, while the valve 5.1 and the check valves 5.5 and 5.6 are closed. Check valve 5.1. passes the fluid in one direction (during spring compression all the fluid flow passes through this valve) and securely holds the brake in the locked state. If we need to release the brake, the distributor 5.1 opens, the spring extends and the piston moves in the opposite direction, therefore the hydraulic fluid passes through the adjustable throttle 5.4 and the check valve 5.5. Line pressure increasing the check valve 5.6 opens, thus protecting the system from overpressure.

Consequently, when using spring-hydraulic brakes with different stiffness springs and varying hydraulic resistance degrees, the actuator braking force P_t brought to the crane forward movement and providing various methods for increasing the braking force can be written as:

$$P_t = \begin{cases} P_{t1}(\tilde{z}) = P_{tpr}(\tilde{z}_1) + P_{tg}(\tilde{z}_2) & at\ t < t_T \\ P_{t2} = const & at\ t \geq t_T \end{cases} \tag{1}$$

where $P_{t1}(\tilde{z})$ is the braking force change in the process of braking the crane;

P_{tpr} is the braking force value which depends on the spring (spring set) power characteristics in the spring-hydraulic brake;

P_{tg} is the braking force value which depends on the hydraulic resistance in the spring-hydraulic brake;

$\tilde{z}_1$, $\tilde{z}_2$, $\tilde{z}$ are variables that define the braking characteristics type of the crane movement driving mechanism.

P_{t2} is the braking force value at a full stop of the crane (the parking braking force value to hold the crane).

When the spring and hydraulic resistance operated together, differential equations system describing the bridge crane movement will take the form:

$$\begin{cases} m_{np}\cdot\ddot{x}_{np}+c_{np}\cdot(x_{np}-x_k)=-\begin{cases} P_{t1}(\tilde{z})=P_{tpr}(\tilde{z}_1)+P_{tg}(\tilde{z}_2) & npu\ t<t_T \\ P_{t2}=const & npu\ t\geq t_T \end{cases} \\ m_k\cdot\ddot{x}_k-c_{np}\cdot(x_{np}-x_k)+c_m\cdot(x_k-x_m)=-P_w \\ m_m\cdot\ddot{x}_m-c_m\cdot(x_k-x_m)=0 \end{cases}, \quad (2)$$

where m_{np} is the drive rotating parts mass applied to the driving wheels, *kg*;

m_k is the bridge mass, applied to the end beams displacement, *kg*;

m_m is the bridge middle parts mass applied to the mid-span, *kg*;

P_w is the static resistance to the crane movement, *H*;

C_{np} is the movement mechanism drive stiffness coefficient, applied to the driving wheels, *N/m*;

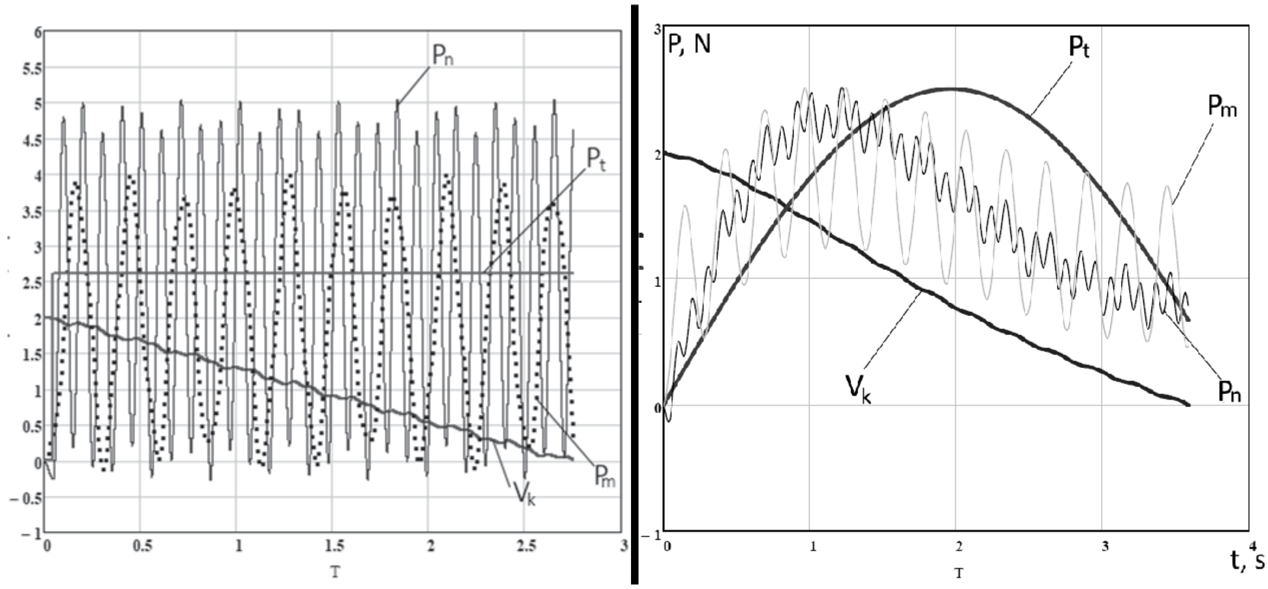
C_m is the crane metal structure stiffness coefficient in the horizontal plane, *N/m*;

x_{np}, x_k, x_m are corresponding masses' displacement values, *m*.

The integration of the differential equations system (2) has been carried out numerically using the Mathcad14 program pack. For each simulated variant of the bridge crane movement braking process using the Runge-Kutta method, a system of differential equations (2) was solved at a constant integration step.

To obtain a "soft" dynamic characteristic, we accept a spring of 3000 *N/m* hardness and the hydraulic resistance (due to the use of automatically controlled hydraulic equipment) creates a variable braking force ranging from 0 to 15,000 *N*, at that the control system provides a sinusoidal law of the hydraulic resistance force variation.

From graphs shown in Fig. 2.a, it can be seen that when the crane is braked with a regular shoe brake, a full stop at a nominal speed of 2 m/s takes 2.75 s, the maximum dynamic loads are: in the drive P_n = 50420 *N*, and in the metalwork P_m = 40100 *N*. When the crane is braked by a spring-hydraulic brake (Fig. 2.b) at spring rigidity c_{pr} = 3000 *N/m* with hydraulic resistance, a full stop at the nominal speed takes 3.5 seconds, the maximum dynamic loads are: in the drive P_n = 25133 *N*, and in metalwork P_m=25010 *H*.



a) б)

Figure - 2. Process of overhead crane braking: a) a shoe brake with a braking torque M = 424 *Nm* (P_t = 26000 *N*); b) spring-hydraulic brake with spring c_{pr} = 3000 N/m and hydraulic resistance (P_{tmax} = 26000 *N*).

The use of spring-hydraulic brakes can significantly reduce the maximum dynamic loads with a slight increase in the braking time and stopping distance to 3.5 *m*.

Conclusions

The carried researches *(8)* showed that the proposed new design of the spring-hydraulic brake allows the following:

1. To carry out frictionless braking of the crane due to the compressible spring energy and the resistance of hydraulic fluid flow from one chamber to another;

2. To eliminate friction elements' wear with respect to such components absence and to simplify the brake adjustment;

3. To get a "soft" dynamic response when crane braking with a spring of low rigidity (3000-5000 *N/m*) and the hydraulic resistance that will increase to a certain limit (from 0 to 12000-15000 *N* to approx. half the braking distance of the crane), and then decrease up to the braking process end. Here the braking force change character is close to half-a-sinusoid. Such specificity of the change in braking force allows reaching the braking time of 3-3,5 seconds, and the dynamic load in the drive and metal of 25000-30000 *N* and 25000-27000 *N* respectively, which is significantly less when braking with normally closed shoe brakes (48000-50000 *N*).

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Role of Technogenic Component in Processes of Groundwater Composition Transformation at Buchak-Kaniv Water Intakes in Eastern Ukraine (on Example of F^- Content)

Key words: *drinking groundwater, pollution, F^-, buchak-kaniv aquifer.*

Annotation: *the geological and ecological factors of F^- increased content in a drinking groundwater of Eastern Ukraine have been considered in the article. The geological base content (GBC) of component at the beginning of active technogenesis period has been determined. The authors have found that the F^- concentrations rises during the process of active exploitation of powerful water intakes. According to the results of correlation analysis, a direct connection between the changes in element content and the value of water withdrawal in the zone of influence of tectonic fault has been established.*

Introduction. The buchak-kaniv aquifer (BKWK) is the one of strategic resources of drinking groundwater within Eastern Ukraine. There is about 50 % of the total volume of water supply which is exactly the water from this aquifer here.