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EXPERIMENTAL DETERMINATION OF DYNAMIC CHARACTERISTICS OF ELECTRIC WIRE ROPE HOIST

Abstract:
Experiments are performed using realized testing facilities. The empiric equation of the hardness factor of the "rope – electrical hoist – metal structure" system depending on the rope length with rated load capacity of the hook, is received. A value of logarithmic decrement of fading of oscillations in rope and a dependency of the damper factor depending on the rope length for lifting device of electrical hoist are received experimentally.

Keywords:
Lifting device, dynamic characteristics, dynamic processes

INTRODUCTION

The electric hoist is a compact machine that features simple construction and simple service. In order to investigate the dynamic processes and increasing the reliability of operation of the electric hoist, a thorough analysis of the transition processes is required, not only for the motor but also for the system of driving and driven elements as a whole. In order to investigate the influence of the vertical oscillations of the load on the dynamic load of lifting devices the mechanical mathematical models are established [4]. Dependencies are received for the influence of the ratio of the acceleration time and the duration of the fading oscillations of the load after the completion of the acceleration process, on the minimum and maximum values of the acceleration amplitudes and dynamic force [4]. The using of mechanical mathematical models for investigation of dynamic load of electric hoist is possible with some dynamic characteristics of the lifting device. Most of these characteristics are given in the technical data for the actual electric hoist but the hardness factor c and damper factor d of elastic system of the lifting devise may be received only experimentally.

The kinematical schemes of the lifting devices contain elastic elements and the flexible element of these has the highest elasticity value. The hardness of the flexible element is not a constant value and depends on its length that varies with lifting and lowering of the load [2]. The variable hardness influences on the characteristic oscillations of the load which results in change of the ratio of the start time and the half-cycle of the fading oscillations of the load that is decisive for the dynamic load of the elements of the lifting device [1].

The subject of the investigation is to determine experimentally the hardness factor in vertical moving direction and the damper factor for elastic system of lifting device of electric wire rope hoist.

EXPOSITION

Experimental determination of the hardness factor c and damper factor d is performed for lifting device of electrical wire rope hoist of TT II

10226 type with rated load capacity Q = 500 kg, lifting height 9 m, lifting speed 8 m/min and gear ratio of the tackle u_p=2. A experimental facility shown on Fig. 1 is realized with a possibility to create static load of the hook with force F and measuring of the caused vertical movement of the roller block and longitudinal deformations of the rope.

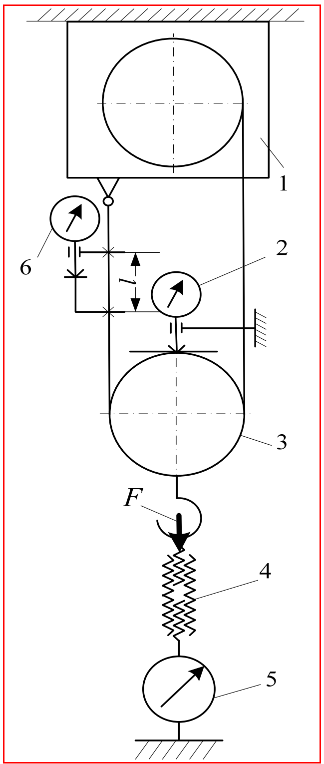

Figure 1. *Scheme of the facility for measurement of the movements of the roller block and the elongations of the rope with various loads of the hook*

The determination of the c factor for hardness of the rope – electrical hoist – metal structure system is made using the measurement of vertical movement of the movable roller block with various load of the hook.

The movement of the roller block 3 (Fig. 1) of the electrical hoist 1 is measured by indicator gauge 2 with a value per division of 0.01 mm with stand fixed to the fixed support. The hardness c_r of the rope is determined by reading its longitudinal deformation with various loading and the elongation Δl of a section with a length of l (Fig. 1) is measured through indicator gauge 6 with a division value of 0.001 mm.

The hook load is made through screw device 4 and the force value is measured by spring loaded dynamometer 5 with a sensitivity 100 N per division and range of 10000 N. 10 tests are made with seven repetitions with loading of the hood with force F up to 5000 N with a step of 500 N and following unloading.

After statistical processing of the experimental data, dependences for the deformation δ_r of the rope and the deformation δ of the whole system "rope – electrical hoist – metal structure" by the loading force F.

The rope deformation is calculated according to the following dependency:

$$\delta_r = \frac{\Delta l}{l} L, \qquad (1)$$

where L is the rope length, m.

The graphical interpretation of the dependencies received $\delta = \delta(F)$ and $\delta_r = \delta_r(F)$, with length L = 4,535 m are shown on Figure 2 a) and Fig. 2 b), respectively. Position 1 represents the changes in the loading deformation, and position 2 represents the unloading deformation, and position 3 represents average values of these.

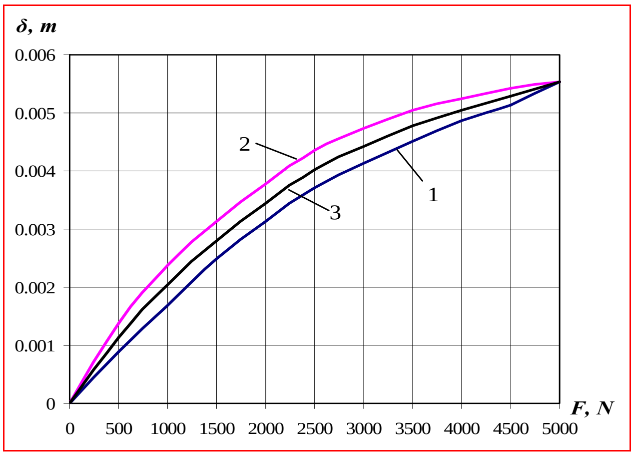

Figure 2.a *Graphical relationships:* $\delta = \delta(F)$

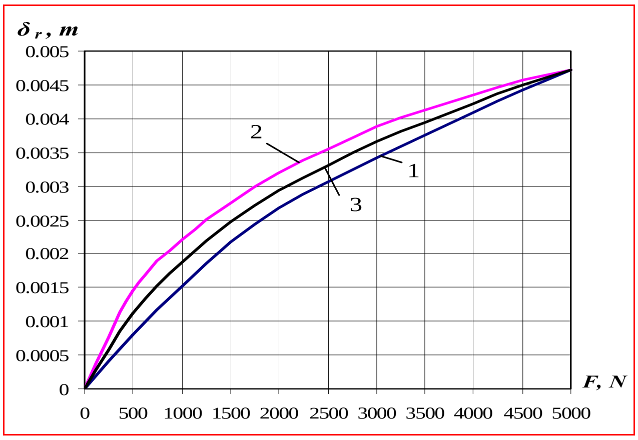

Figure 2.b. *Graphical relationships:* $\delta_r = \delta_r(F)$

From the graphs drawn is clear that the decreasing of the force F causes the deformation values of the system to be close to these for the rope. When compare the force F with the load capacity O of the electrical hoist, a conclusion may be made that in case of loads below 0.2 Q, the deformation of the rope is decisive for the hardness of the whole system.

Because the dynamic loads will be investigated with rated load with the experimental date with maximum load for the hardness factor of the rope c_r, a value of c_r=5,296 . 10^5 N/m, and for the hardness factor of the system c, c =9,042.10^5 N/m, respectively, are received from the following equations:

$$c_r = \frac{F_{\max}}{\delta_r}; \qquad (2)$$

$$c = \frac{F_{\max}}{\delta}, \qquad (3)$$

where

F_{max} = 5000 N is the maximum loading force;

δ_r and δ – the deformation of the rope, respectively the system, with maximum load, m.

Considering the gear ratio of the tackle and using the dependency

$$\frac{1}{c} = \frac{1}{c_s} + \frac{1}{2c_r}, \qquad (4)$$

for the c_s factor of hardness of the "electrical hoist – metal structure" system is received a value of c_s = 6,179 . 10^6 N/m.

Because of the fact that the deformation of the rope depends on its total length, using the equations (1), (2) and (4), values of the hardness factor c of the system in relation with the rope length L with rated load. Using the values received and MS Excel software the empirical equation is calculated $c = f(L)$

$$c = 3243797,403\, L^{-0,832} \qquad (5)$$

with a precision factor $R^2 = 0,995$.

On Fig. 3 is shown the graphical interpretation of the function (5) with the continuous line (pos. 1) and dotted line (pos. 2) represents the regression function c = f(L). From the graph received is clear that the decreasing of the rope length L from 18 to 7 m causes the hardness factor c to be slowly increasing function and in case of L lower than 7 m, the system hardness increases considerably.

In order to determine the damper factor d, the following function shall be used [2]:

$$d = 2\sqrt{\frac{cm}{1+\left(\frac{2\pi}{\nu}\right)^2}}, \text{ kg/s}, \qquad (6)$$

where m is the weight of lifted load, kg;

ν – logarithmic decrement of damping of the rope oscillations.

The logarithmic decrement of the damping of the rope oscillations is determined experimentally using the designated test facility on a base of the investigated electrical hoist shown on Fig. 4.

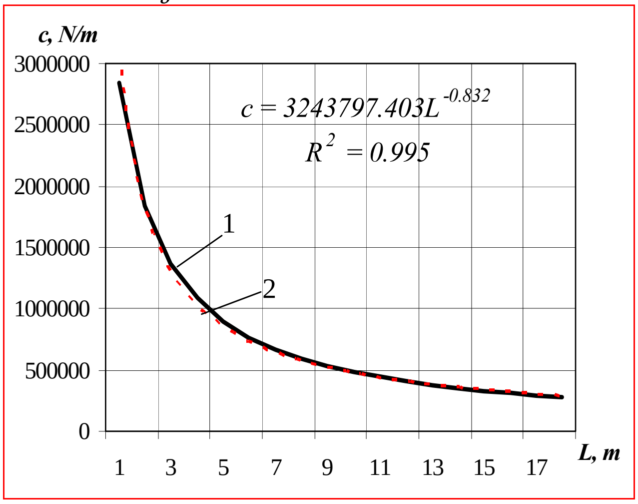

Figure 3. Function $c = f(L)$

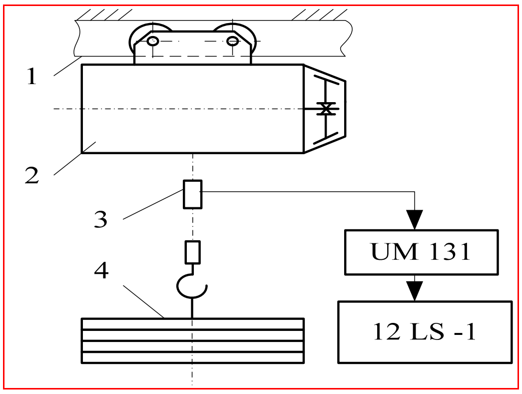

Figure 4. Experimental facility for determination of the logarithmic decrement of damping of the system oscillations

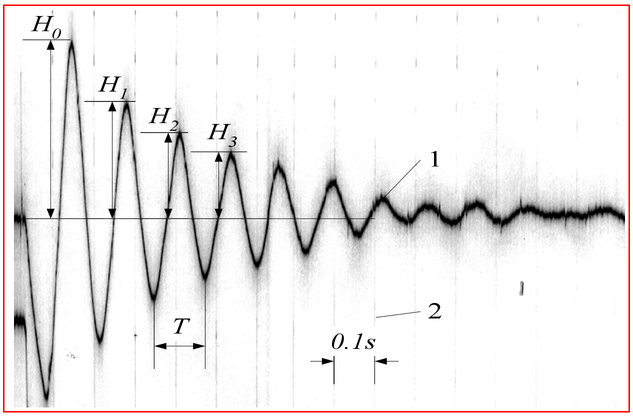

Figure 5. Oscillogram of the rope oscillations in the acceleration process during lowering the load

The electrical wire rope hoist 2 (Fig. 4) is fixed to a monorail track 1 through travel device. A strain-gauge weighting device 3 registers the rope oscillations fixed on the top of the fixed section of the tackle developed by the authors' team [3]. The electrical signal received by the weighting device proportional to the rope force is amplified by the strain-gauge amplifier UM 131 and is recorded by light-beam oscilloscope 12LS-1 using galvanometer with characteristic frequency 1000 Hz.

The experiments are performed with a load with a weight of 500 kg and total rope length 4 to 5 m and the oscillations in the flexible element in transitional processes are recorded. The records for each of the processes of acceleration and decelerating in the directions of lifting and lowering are repeated 4 times.

On Fig. 5 is shown an oscillograph of the rope oscillations during the acceleration in the direction of lowering the load. There are registered the signal 1 from strain-gauge weighting device and vertical marks for time 2 per 0,01 s that are generated by the light-beam oscilloscope. From the record is clear that the rope oscillations are fading with a period T with average value T = 0,1364 s is calculated after processing of the results of 16 oscillograms and using time marks.

The decrement of the damping of the oscillations is determined according to the following equation

$$\nu = \frac{1}{n}\ln\frac{H_0}{H_n}, \qquad (7)$$

where

H_0 is the maximum amplitude for the first deviation from the balanced position, mm;

H_n is the maximum amplitude of n-th successive deviation from the balanced position in the same direction, mm.

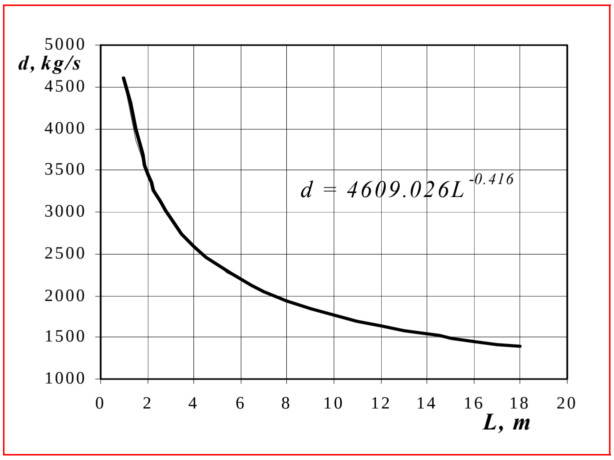

Figure 6. Function $d = f(L)$

Following the statistical processing of the results of the 16 oscillographs, the average values are received for the first four successive amplitudes using which an average value of the damping decrement is received $\nu = 0{,}3593$.

Using equations (5) and (6) with load weight m = 500 kg for the damping factor d and rope length L the following empiric equation is drawn

$$d = 4609{,}026\,L^{-0{,}416} \qquad (8)$$

On Fig. 6 is shown the received function d = f(L) where is clear that in the range of the rope length the value of the damping factor is changed 3 times.

CONCLUSIONS

- Graphical functions for the deformation δ_r of the rope and the deformation δ of the whole system "rope – electrical hoist – metal structure" where it is clear that with hook load with a force up to 0.2 Q the deformation δ_r is decisive for the whole system hardness.
- Empirical functions c = f(L) and d = f(L) are determined that may be used for investigations of the influence of the lifting height on the dynamic loading of the elements of the lifting device with rated loads.

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