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The Effect of Design Peculiarities of the Elastic Liner of a Hoisting Machine on the Durability of Rope and Liner

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ABSTRACT: This paper presents a comprehensive approach to the study of rope and liner. The basic principles of liner material selection and the main geometric dimensions of the liner were worked out on the basis of investigations conducted on the stress-strain state of the liner. Using the modern concepts of interaction of bodies with a movable contact point, the mechanism of stress accumulation and the reasons for the increased wear of the liner were determined. On the basis of these investigations, the principles for calculating the dimensions of the liner material along the drum generatrix were established. As a result of these studies, recommendations for material selection as well as for the calculation of geometric characteristics of the drum liner of the hoisting machine are made.

1 INTRODUCTION

The interaction of the rope of a hoisting machine with the drum surface is accompanied by wear of both the rope and the liner. The wear of the rope and the liner is dependent upon many factors, such as the value and the character of the forces of interaction of the contacting surfaces, as well as their relative displacements (Franchufc & Franchuk, 2000).

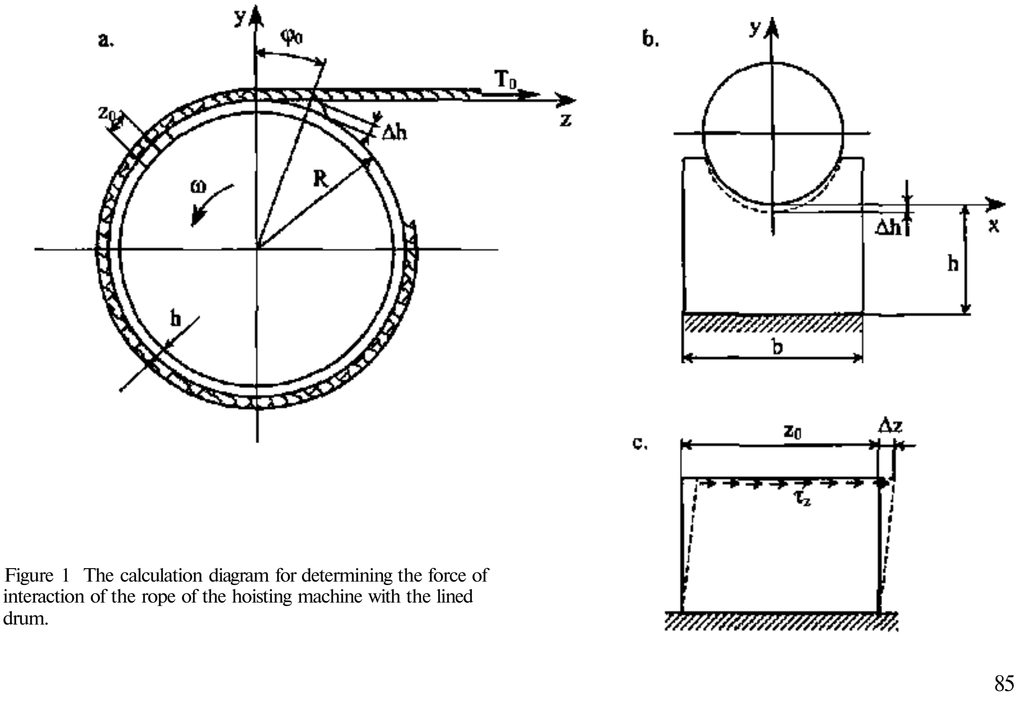

Figure 1 The calculation diagram for determining the force of interaction of the rope of the hoisting machine with the lined drum.

2 VALIDATION PROCEDURE

The most intensive slip of the rope on the liner surface occurs in the zone adjacent to die point of the running-on of the rope over the drum This displacement takes place due to longitudinal elongation and torsion of the rope the angle of deviation. The value of these displacements depends on the rope characteristics, the design and the elastic parameters of the drum liner. If the liner is elastic enough, the slip of die rope on the liner surface decreases. At the same time, if the liner material has a sufficiently large Poisson coefficient, the high give of the liner results in the formation of some convexity on the liner surface, which can be called the "deformation wave" (or "deformation roll"). At the beginning of the motion of the hoisting machine drum, growth in the deformation wave (in front of the rope running-on point) takes place. When this wave reaches a certain value, further growth stops. The accumulation of material in die deformation wave is balanced out with die slip of the surface of the rope and the liner. Thus, there is intensive wear of the rope surface and the liner surface.

The aim of this paper is to investigate the nature of the rope-liner interaction. The present investigation should result in the design selection and calculation of die elastic liner of me hoisting drum.

2.1 *Details of the example problem*

Let us consider the interaction of the steel rope with the drum of the hoisting machine. The drum is lined with elastomer-type elastic material. Figure 1 represents the calculation model for determining the force of interaction of the rope and the drum liner. The drum of the hoisting machine with radius R rotates at an angular velocity co. The hoisting rope Is loaded with force T_0. In order to determine normal loads q acting from the side of the rope on the liner, the pulling force T_0 of the rope becomes a major factor. The value of the tangential load is also influenced by the forces of engagement of the liner material and the rope. The dependence between shear stresses T and normal stresses p on the surface of the interaction of the rope and the liner will assume the form (Novikov et al. 1978):

$$T\hat{}p \quad W+ß_0 x.-a_0 p \qquad (i)$$

where % = —— is the ratio of the relative velocity of

motion of the contacting bodies to the absolute velocity of the rope displacement; 8o, ßo, Xo are the experimental coefficients.

Figure 2 presents the plot of dependence of the shear load T, on the relative velocity of motion of me

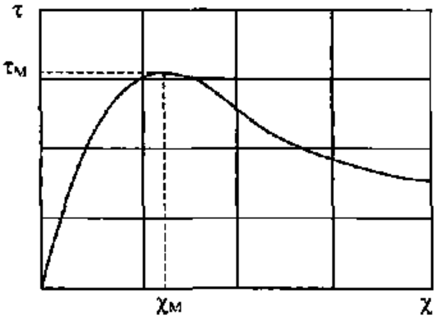

Figure 2 The dependence of the shear load T on the relalive velocity of motion of the drum and the liner *X*-

drum and the liner y̲- The plot has a rising part and a falling part, and the maximal value of engagement force of the rope and die liner is obtained at the relative velocity /„. The value of this force, as well as the corresponding relative velocity V, can be calculated from the expression:

$$\chi_M = \sqrt{\frac{\lambda_0 p}{2\delta_0 V}} \qquad (2)$$

or

$$v_{I:M} = \sqrt{\frac{\lambda_0 p V}{2\delta_0}} \qquad (3)$$

which is obtained by investigation of expression (1) to the extremum.

When the liner is continuous, die running-on of the rape over the drum is accompanied by the presence of the deformation wave (or roll) and the constant slip of the surfaces of the liner and the drum. The velocity of relative motion x('i2) can correspond to the rising or the falling parts of the engagement curve (Figures 2, 3). The relative motion on the rising part of the curve is accompanied by creep and leads to insignificant wear of the surfaces. When the relative velocity is more than $\underline{y}_{\lambda p}$ the slip occurs, which is accompamed by considerable wear of the liner and the rope.

2.2 *Analysis procedure*

The relative velocity of the slip of the rope and the liner In the running-on zone can be determined on the basis of the calculation model shown in Figure 1. Let us assume that element deformation takes place along the plane surface in the direction of the y-axis. The lateral surfaces (in the direction of the x-axis) are free. During rope winding, there is an accumulation of deformation in the direction of the z-axis. At the same time, considering the material anisotropic, we obtain:

$$\varepsilon_y = \frac{\sigma_y}{E}, \quad \varepsilon_x = \nu\varepsilon_y,$$
$$\varepsilon_z = \nu\varepsilon_y, \quad G = \frac{E}{2(1+\nu)} \qquad (4)$$

Here, E and G are modules of elasticity in compression and in shear; £K, £j, e£ are relative deformations in the direction of the corresponding axes; v is the Poisson coefficient

Under constant rope pulling, the liner material having the deformation wave height Ah at the initial moment will move during the rotation of the drum to the angle (po (Figure la), m relation to the rope to the value

$$\Delta z = R\varphi_0\varepsilon_z$$

or, taking into consideration (4):

$$\Delta z = R\varphi_0\nu\varepsilon_y = R\varphi_0\nu\frac{\Delta h}{h} \qquad (5)$$

Then the relative velocity of the slip is:

$$v_{12} = \frac{\Delta z}{\Delta t} \qquad (6)$$

and the time of rotation to the angle (puis:

$$\Delta t = \frac{\varphi_0}{\omega} \qquad (7)$$

where to is the angular velocity of the drum rotation.

From equations (5), (6), (7) we will have:

$$v_{12} = \frac{R\nu\omega\Delta h}{h} \qquad (8)$$

Since

$$\frac{\Delta h}{h} = \varepsilon_z = \frac{\sigma_z}{E} \approx \frac{q}{d_k E} = \frac{T_0}{ERd_k}$$

then from expression (8) we obtain:

$$v_{12} = \frac{T_0\omega\nu}{Ed_k} \qquad (9)$$

where d^ is the rope diameter.

If we compare the value vu obtained from expression (9) with the value obtained from expression (2), we can determine at what section (rising or falling part) of the engagement curve the *system* works (and, correspondingly, determine the character of engagement and wear). For a liner composed of separate elements placed along the drum surface, die accumulation of deformation occurs only in the direction of the z axis. Then maximal shear stresses (Fig. 1 ,c) will equal:

$$\tau = G\gamma = G\frac{\Delta z}{h} \qquad (10)$$

Taking into account that:

$$\varepsilon_z = \frac{\Delta z}{z_0}$$

and, in turn:

$$\varepsilon_z = \nu\varepsilon_y = \nu\frac{\sigma_y}{E}$$

we obtain:

$$z_0 = \frac{E\tau h}{G\nu\sigma_y}$$

If we take into consideration equation (4), we will have:

$$z_0 = \frac{2(1+\nu)\tau h}{\nu\sigma_y} \qquad (11)$$

In order to decrease friction and wear of the rope and the liner, it is necessary that shear stresses should be less than critical. This will ensure the engagement of the surfaces and ensure that the engagement will not break down.

Assuming:

$$p = p_{mid} = \sigma_y = \frac{T_0}{Rd_k} \qquad (12)$$

and,

$$v = R\omega$$

after transformations, we will have the dependence for determining the ultimate length of the liner material, ensuring relative motion of the surfaces of the liner and rope wimin the creep limits:

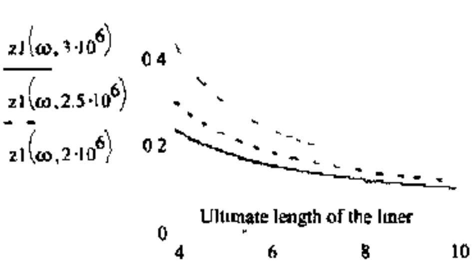

Figure 3. The dependence of the ultimate length of the liner *material on* the angular velocity *of the drum rotation*

$$z_{0f} \leq \frac{2(1+v)}{v} \frac{\sqrt{\frac{\lambda_0 T_0}{2\delta_0 d_k \omega}}}{\frac{3}{2}\lambda_0 \frac{T_0}{d_k} + \beta_0 \sqrt{\frac{\lambda_0 T_0}{2\delta_0 d_k \omega}}} \cdot h \qquad (13)$$

3 RESULTS

Let us analyse the results obtained- Figure 3 demonstrates the plot of dependence of the ultimate length of the liner material on the angular velocity of the drum rotation. If the angular velocity increases, the ultimate length of the liner material somewhat decreases The same phenomenon takes place during the increase of the ratio $\frac{T}{d_k}$. It is clear from equation (13) that the value z,f is proportional to the line thickness and does not depend on the drum diameter.

A combined liner was created and installed (Figures 4, 5) for a one-drum hoisting machine. This liner consists of alternating strips of polyamide elements and rubber strips. The polyamide elements have a groove under the rope. The rubber strips were made of worn-out truck tyres. These strips have no groove under the rope is intermittent.

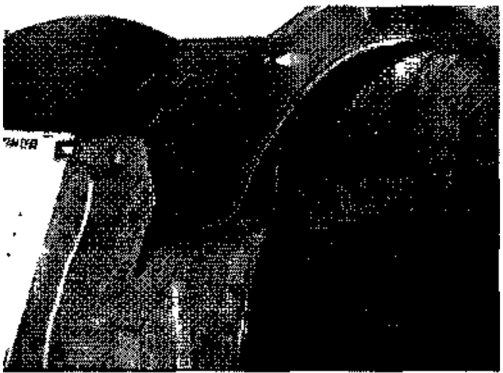

Figure 4. The one-drum hoisting machine with the combined liner.

Mining trials of the liner were earned out. These trials demonstrated that dynamic loads had decreased considerably. The wear of the liner is insignificant. The noise characteristics of the machine operation decreased. All this was achieved due to the elastic relaxation properties of the liner, and the selection and calculation of the optimal dimensions of the liner elements.

4 CONCLUSIONS

The conducted trials show that not only the physical and mechanical properties, but also the geometrical characteristics of the liner of the drum of the hoisting machine have an important effect on the durability of the rope and the liner. The use of the combined liner enables us to increase their durability and to considerably decrease the dynamic and noise characteristics of the machine operation.

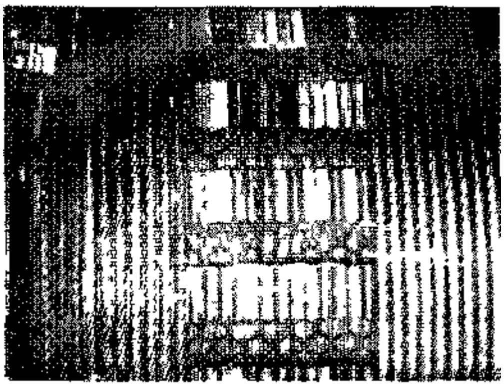

Figure 5. The combined liner for the one-drum hoisting machine

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