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INVESTIGATION OF MINE HOIST WITH MULTI-LAYERED COILING OF HOISTING ROPE

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ABSTRACT
Pros and cons are shown for the mine hoist systems with multilayer coiling of a rope using annular and spiral grooves of a cylinder roll. Main parameters are set for hoist machine and conditions of resonance of hoisting rope by its multilayer coiling according to a scheme with annular grooves.

INTRODUCTION

Exhausting of technical resource for safe and effective work of a great part of the mining hoist systems is one of the main factors for non-profitability of underground mining of minerals in Bulgaria. That is why reasoning and selection of effective decisions for updating and reconstruction of MHS in mining seems to be a task of the day. The decision for updating and reconstruction of MHS at “Capitalna” shaft, Gorubso – Madan by supplying of a new cylinder roll with a multilayer coiling of the hoist rope was proved (Karcelin, 1998).

In the Republic of Bulgaria vertical MHS with a multi-layer coiling of the rope have not been. In the valid rules for occupational safety (Guidelines for Safety…, 1969) too limited position is allotted to this matter. These circumstances set the task for preliminary research of a series of questions from the theory of MHS with a multi-layered coiling of a hoisting rope aiming an application of results to design of final development decisions. Some of these results are shown in the present article.

1. Main point of the multi-layered coiling of a hoist rope.

Decisions with a multi-layered coiling of a hoist rope may also be applied for increasing the height of uplift under definite conditions. There are two different kinds of two-way multi-layered coiling: with stating of the hoist rope from the first layer in a spiral groove and with stating of the hoist rope in a annular groove.

In the second case (fig.1) many annular grooves, situated one by the other are formed on the roll surface, instead of a spiral grooves. However, there is a smooth stripe on the roll, without rims on it, and displaced at an angle β from roll axis.

The multi-layered coiling with a first spiral situated layer has the following advantages:

- simple and technologically accessible working out of the spiral groove by metal-sawing machines in manufacturing conditions;
- easily appliable for transition from one-layer to two-layer coiling in the process of penetrating in depth of the shaft.

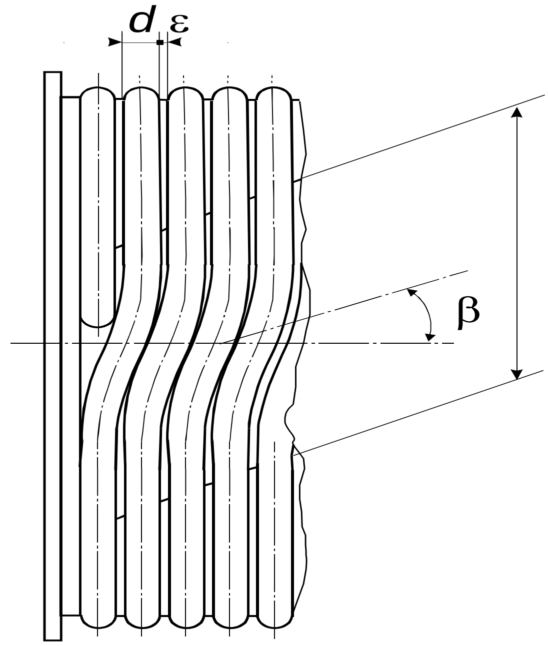

Figure 1.

Disadvantages:

- wedging of rope by the passing from layer to layer between roll rim and the last coil of previous layer;
- the odd layer is located on a spiral groove and the even layer performs a double shifting by transition from coil to coil on every revolution of the roll and consequent dynamic efforts in the rope;

- the compulsory working out of a filling wedge with a complex configuration and its situating in the transition from layer to layer (fig. 2).

The multilayer coiling with positioning of first layer in annular grooves has the following advantages:
- the rope performs a single shifting from coil to coil for every revolution of the roll ;
- the wedging of rope between roll rim and the last coil is almost totally missing.

Disadvantages:
- difficult manufacture of annular grooves with presence of a smooth shifting part;
- appropriate scheme for new machines for manufacture.

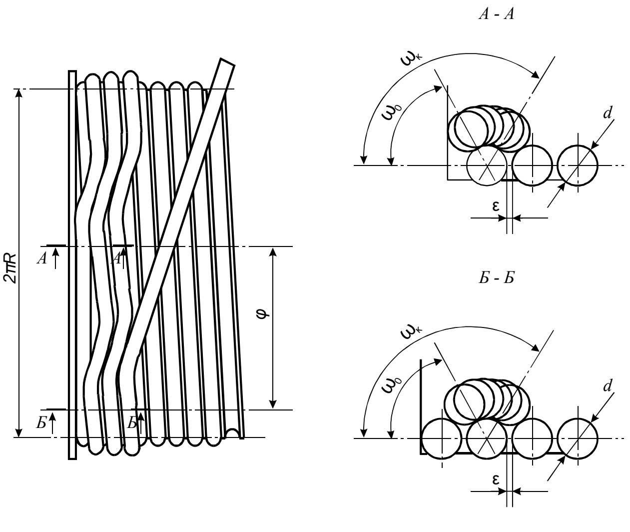

Figure 2.

2. Selection of rational parameters of the hoist machine by the multilayer coiling of hoisting rope according to the scheme with annular grooves.

The angle of slope β (fig.1) of the roll smooth part towards the roll axis and the length of smooth part φ, rad is specified by the expressions (Dimashko etc. 1969):

$$tg\beta = \frac{1}{2\left(1+\frac{\varepsilon}{d}\right)}\sqrt{\frac{D}{d}}\;F(\beta) \qquad (1)$$

$$\varphi = 2\sqrt{\frac{d}{D}}\;F(\varphi) \qquad (2)$$

$$F(\beta) = \int_{\frac{\Pi}{2}-\arcsin\frac{\varepsilon}{2d}}^{\frac{\Pi}{2}+\arcsin\frac{\varepsilon}{2d}} \frac{dx}{\phi(x)} \qquad (3)$$

$$F(\varphi) = \int_{\arccos\frac{d+\varepsilon}{2d}}^{\frac{\Pi}{2}} \frac{dx}{\phi(x)} \qquad (4)$$

$$[\phi(x)]^2 = \frac{\sin x - 2f\cos x}{1+4f^2} - \frac{1}{2} + \exp\left[2f\left(\arccos\frac{d+\varepsilon}{2d} - x\right)\right]\times$$

$$\times\left[\frac{1}{2} - \frac{\sqrt{4d^2-(d+\varepsilon)^2}+2f(d+\varepsilon)}{2d(1+4f^2)}\right] \qquad (5)$$

d - is the rope diameter;
D – roll diameter;
ε - distance between the coils;
f – coefficient of friction “Rope to rope” depending on lubrication (0,1 - 0,14);

However, complex analytic expressions for values of F(β) and F(φ) involve determination by the diagram in fig. 3. (Dimashko etc., 1969). That enables β and φ to be set.

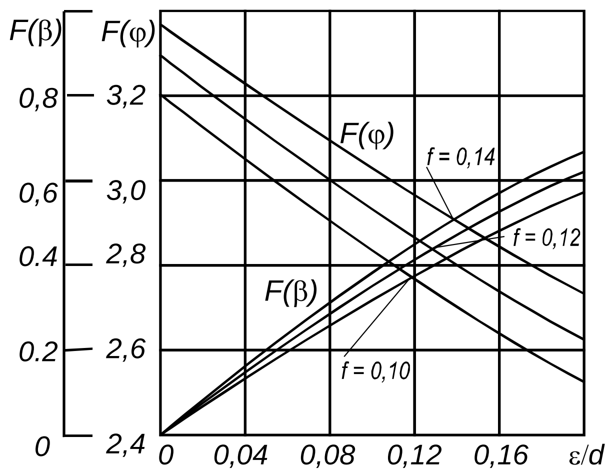

Figure 3.

The parallel coiling of rope to the rim and in the layers happens according to the scheme in fig.4. As roll width B and rope diameter d are preset, the only values that may be changed are ε and n – number of the coils in the first layer that must be integers, specified by the following expressions for the satisfying the given scheme for coiling of hoist rope

$$n = \frac{2B - d - \varepsilon}{2(d+\varepsilon)} \qquad (6)$$

$$\varepsilon = \frac{2B - d(2n+1)}{2n-1} \qquad (7)$$

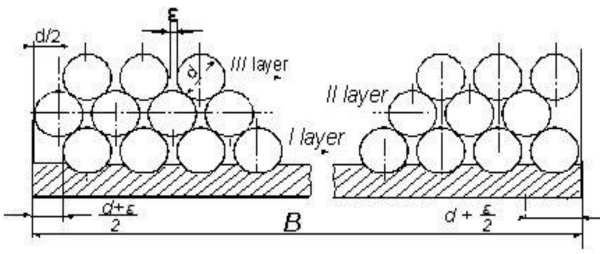

Figure 4.

The rational values of deviation angles providing the parallel coiling are attached in table.1.

Table 1

D/d	60	70	80	100	120	140
$\alpha \geq$	1° 30′	1° 20′	1° 15′	1° 00′	0° 50′	0° 40′

The angle of deviation must be within: $1^0 \leq \alpha \leq 1{,}30^0$ (Guidelines for Safety…, 1969)

That calculation enables the parameters of the multi-layered coiling with annular grooves to be specified accurately enough.

3. Conditions for arising of resonance in rope string.

It was mentioned above that in the scheme of multilayer coiling with a spirally positioned first layer the rope performs a double shift on every revolution of the roll at every even layer. This means that every revolution of the roll brings to two impact pulses.

For certain conditions, frequency of those impact pulses may coincide with frequency of own transverse vibration of a part of the rope, situated between the roll and the guiding wheels.

This effect is called resonance and may cause strong transverse motions of rope string, resulting in rope springing out from rims of guiding wheel, which is already an accident.

Frequency of the forced oscillation caused by impact-pulses in the transition of rope from coil to coil is as follows (Dimashko etc., 1969).

$$P_n = \frac{2\pi}{\varphi} n \text{ , cycles/min.} \quad (8)$$

n – number of revolutions of the roll per minute;

φ - the angle between the double impact pulse, set on the basis of the expression (Dimashko etc., 1969) (fig.2);

$$\tau_2 = \tau\left[1 - \frac{d}{2(d+\varepsilon)}\left(\sqrt{3}.\sin\omega_0 - \cos\omega_0\right)\right] \text{, s} \quad (9)$$

τ_2 is a time interval between first impact pulse and second impact pulse;

τ -time interval corresponding to one revolution of the roll;

ω_0 – angle of passage (coordinating angle), fig. 2.

The angle ω_0 is specified according to the diagram in fig.5 (Dimashko etc., 1969) depending on angle of deviation.

The natural frequency of the transverse vibrations is set according to the expression (Alexeev, 1975):

$$P_c = \frac{\varepsilon_0}{L}\sqrt{\frac{Qg}{q}} = 94\frac{\varepsilon_0}{L}\sqrt{\frac{Q}{q}} \text{ , cycles/min} \quad (10)$$

L is the distance between vertical axes of body for coiling and guiding wheels;

Q – final load including the weight of rope;

ε_0 – dimension of the resonance - 1,2,3…;

q – linear weight of rope;

α - angle of deviation.

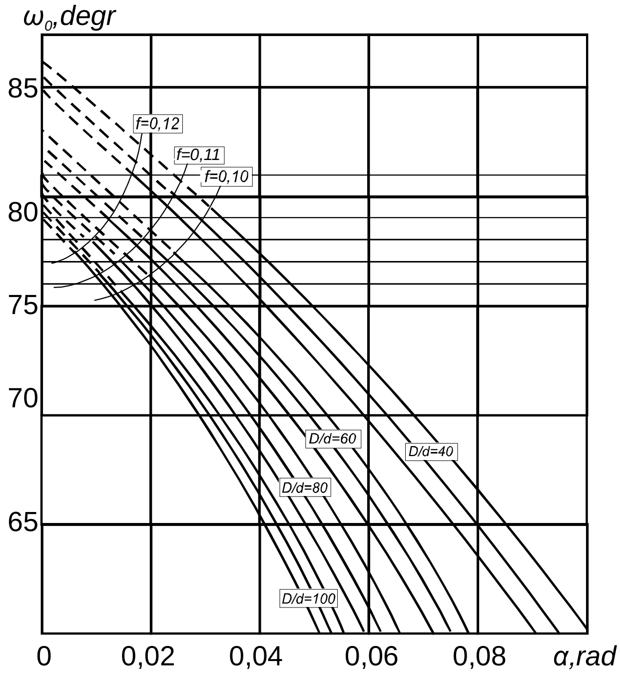

Figure 5.

To avoid the resonance the following condition must be satisfied:

$$P_n \neq P_c \quad (11)$$

The parameters Q, L, α, q, D/d of the hoist machine may cbe changed to fulfil this condition:

CONCLUSION

The above results are applied to development of design decisions for updating and reconstruction of MHS at Capitalna shaft Capitalna, Gorubso, Madan.

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