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ANALYTICAL STUDY FOR GEOMETRICAL CHARACTERISTICS OF WIRE ROPES

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ABSTRACT
The paper presents an analytical study of the curvature of straight strand and a strand over a sheave and also an analytical calculation of the curvature of a straight rope and a wire rope over a sheave. The obtained results are used to estimate the lifetime of wire ropes considered as them real lifetime.

KEYWORDS:
strand, curvature, lifetime, parametric equations, wire ropes

1. INTRODUCTION

Wrapping up the steel wires around the one mineral, synthetic or steel core makes wire ropes. They are an important element in function of mining installations, cranes, etc.

In order to perform a stress calculus between the rope's wires there is necessary to know the curvature radius, by considering the wire as a *helix curve,* first being necessary the wire rope's equation.

If we know the parametrical equations of the curve:

$$x = f_1(\lambda);\ y = f_2(\lambda);\quad z = f_3(\lambda),$$

the helix radius will be of the form:

$$\rho = \frac{dx^2 + dy^2 + dz^2}{\sqrt{\left(d^2x\right)^2 + \left(d^2y\right)^2 + \left(d^2z\right)^2}} \tag{1}$$

By meaning of the relation (1) we can obtained the curvature radius of the wire within a straight strand, respectively within a wire rope.

2. ANALYSIS OF A WIRE WITHIN A STRAIGHT STRAND

If the cylinder radius is **r**, the helix angle in a rope strand is ω_1 and the angle parameter is α (Fig.1), the helix curve parametric equations are:

$$x = r\cos\alpha;$$
$$y = r\sin\alpha;$$
$$z = r\,\alpha\,\mathrm{ctg}\,\omega_1.$$

By meaning of the relation (1) we can obtained the well-known curvature radius:

$$\rho = \frac{r}{\sin^2 \omega_1} \tag{2}$$

The **r**'s value depends on the position of wire in the strand, the maximum value is:

$$\rho_{max} = \frac{d_1 - \delta}{2 \sin^2 \omega_1} \tag{3}$$

3. ANALYSIS OF A WIRE WITHIN A ROPE BENT OVER A SHEAVE

Wire ropes are typically subjected not only to axial loads but also to additional bending loads that are induced when the rope is passed over a sheave. In this paper, the assumption is made that the stresses in the individual wires of an axially loaded rope bent around the sheave consist of the stresses that would exist in the same axially loaded rope if it were straight, plus the bending stress that would be induced in the individual preformed wires, each in the shape of a double helix, bent elastically into the rope-centerline curvature that is imposed by the sheave.

The assumption is realistic only for well-lubricated wire rope in which neighboring wires are free to slide relative to each other.

Now, the $\mathbf{r_1}$'s cylinder become a drum with **R** radius, this is meaning that the strand is bent over a cylinder with **R** radius. The wire shape is now a double helix one. The equation for this curve will be of the form:

$$x = (R + r_1 \cos \alpha) \cos\beta$$
$$y = r_1 \sin \alpha$$
$$z = (R + r_1 \cos \alpha) \sin\beta,$$

where: $R = D/2$; D – the sheave diameter.

For the parameters α and β calculus, the value of a step by the central angle β_0 will be considered equal to the one of the wrapping wire within a strand by ω_1 angle:

$$\beta_0 \cdot R = 2 \cdot \pi \cdot r_1 \cdot \mathrm{ctg}\omega_1$$

Also, we write the similarity between the angle parameters for one value and the step's values:

$$\frac{\alpha}{\beta} = \frac{2\pi}{\beta_0}$$

If we write: $i_0 = \frac{r_1}{R_0}$ and $\frac{2\pi}{\beta_0} = p = \frac{\mathrm{tg}\omega_1}{i_0}$, we obtain: $\alpha = p\beta$.

Parametrical equations of helix curve become:

$$x = R(1 + i_0 \cos p\beta)\cos\beta$$
$$y = R\, i_0 \sin p\beta$$
$$z = R\, i_0\, (1 + i_0 \cos p\beta)\sin\beta.$$

By using the (1) equation we obtain the wire curvature radius within a strand over a sheave:

$$\rho_t = R \frac{(1 + i_0 \cos\alpha)^2 + i_0^2 \cdot p^2}{\sqrt{\left[1 + i_0 (1 + p^2)\cos^2\alpha + i_0^2 \cdot p^2 (4 + p^2)\sin^2\alpha\right]}} \tag{4}$$

The curvature radius maximum value will be obtained for $\alpha = 0$:

$$\rho_{t\max} = R \frac{(1 + i_0)^2 + i_0^2 \cdot p^2}{\sqrt{1 + i_0 (1 + p^2)}} \tag{5}$$

and the minimum value for $\alpha = \pi$:

$$\rho_{t\min} = R \frac{(1 - i_0)^2 + i_0^2 \cdot p^2}{\sqrt{1 - i_0 (1 + p^2)}} \tag{6}$$

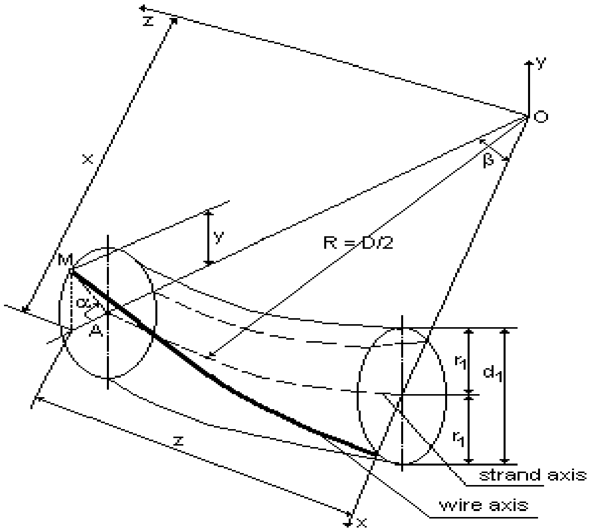

Fig.1. Wire configuration within a rope bent over a sheave

4. ANALYSIS OF A WIRE WITHIN A ROPE COMPOSED BY ROPE STRANDS

The wire curvature radius is determined (Fig. 2) by considering the strand deformed over a circle with **R'** radius:

$$R' = \frac{R}{\sin^2 \omega_2}$$

where:
R' – the strand curvature radius in a determined section;
R – the cylinder radius (the rope radius for the external layers wires)
ω_2 – the strand helix angle in wire rope.

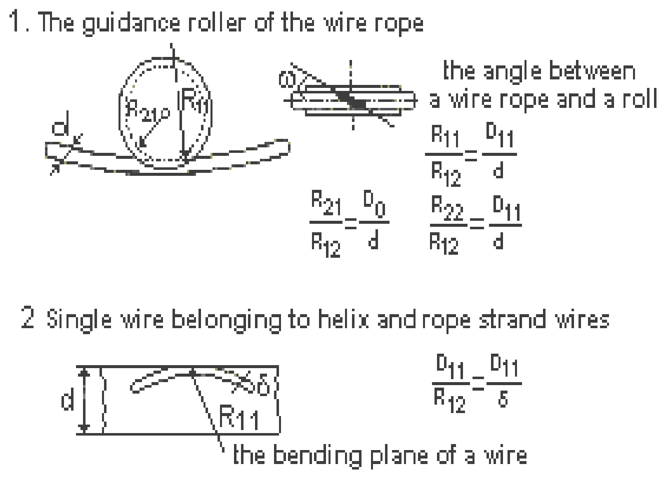

Fig.2. The main curvature radius in the wire - wire, respectively wire – sheave contact areas

By using the (4) equation where R = R'; $i_0 = i = \frac{r}{R'}$ and $p' = \frac{tg\omega_2}{i}$, we obtain the curvature radius of a wire within a straight rope:

$$\rho_s = R' \frac{\left(1 + i\cos\alpha'\right)^2 + i^2 \cdot p'^2}{\sqrt{\left[1 + i\left(1 + p'^2\right)\cos\alpha'\right]^2 + i^2 \cdot p'^2\left(4 + p'^2\right)\sin^2\alpha'}} \quad (7)$$

The curvature radius of a wire within a rope bent over a sheave may be obtained by following the next steps:

- the curvature radius of the strand axis calculus:

$$\rho_{tor} = R \frac{\left(1 + i_1 \cos\alpha^{'}\right)^2 + i_1^2 \cdot p_1^2}{\sqrt{\left[1 + i_1\left(1 + p_1^2\right)\cos\alpha^{'}\right]^2 + i_1^2 \cdot p_1^2\left(4 + p_1^2\right)\sin^2\alpha^{'}}} \quad (8)$$

where: $p_1 = \frac{tg\omega_2}{i_1}$ and $i_1 = \frac{R}{R^{'}}$.

- the curvature radius of the wire axis will be calculated by using (4) equation,

where: $R = \rho_{tor}$ and $i_1 = \frac{r}{\rho_{tor}} = i^{'}$:

$$\rho_s^{'} = \rho_{tor} \frac{\left(1 + i^{'} \cos\alpha\right)^2 + i^2 \cdot p^2}{\sqrt{\left[1 + i\left(1 + p^2\right)\cos\alpha\right]^2 + i^2 \cdot p^{'2}\left(4 + p^{'2}\right)\sin^2\alpha}} \quad (9)$$

5. CONCLUSIONS

The obtained results for geometrical characteristics of wire ropes are used to estimate the lifetime of wire ropes considered as them real lifetime. Expressions for the axial, bending and line-contact loads on individual wires and on the strand that comprise complex wire-rope constructions are developed in another paper for the common loading situation where a rope is pulled axially and simultaneously bent over a sheave or drum.

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