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DEFLECTION AND SAFETY FACTOR OF THE SHAFT DEPENDING ON THE POSITIONS OF THE PACKAGES AT OPTIMIZED WINCH HAULAGE

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ABSTRACT
Positioning of two drums in the rotating shaft of Winch Haulage is very important because of the deformations and safety, especially when taking into the account the loads during the exploitation.
Therefore, in this paper is analysed deflection, slope angle and safety factor of the rotating shaft depending on the position of the drum at the optimised Winch Haulage.
The mathematic model of the rotating shaft is elaborated in detail, taking into consideration the dimensions after optimization of the Winch Haulage.
The results for the adopted model, for the dimensions before and after optimization, are satisfactory and present a good starting point for modification in the design of the Winch Haulage.
Key Words: Winch Haulage, Rotating Shaft, Deflection, Drum, Safety Factor

1. INTRODUCTION

Constructive parameters of shaft that must be fulfilled in order to complete the working criteria are: shaft size, rotation moment, safety coefficient, slope angle, displacement of shaft and critical number of rotation.
The selection of the optimum shaft model should also fulfill constraints in order that: the shaft must be in function of winch haulage, and its installation must provide needed functions.
Shaft as a part of winch haulage should also execute technical conditions towards: the other parts of winch haulage, coefficient of exploitation and the safety factor.
Methodology of shaft optimization is presented in four stages were also calculated [1].
The analysis of the formation model of shaft optimization will be explained through Winch Haulages’s shaft model shown in fig.1.1.
Comparison of the results for the adopted model for the dimensions before and after optimization, are satisfactory and present a good starting point for modification in the design of the Winch Haulage.

2. MODEL SHAFT OPTIMIZATION

The Winch Haulage as an engineering system or machine is described by set of quantities some of which are usually fixed and called parameters. All the other quantities are treated as variables in the design process. Its mathematical model formulates relations between the specified quantities - parameters and diameters of shaft adopted as variables.
Based on the shaft dimensions an optimization model to find optimal diameters for minimal value of the shaft’s volume as subject to certain equality and inequality constraints has been elaborated in [1]. Values of the current and optimal diameters and their graphic presentation are given in Figure 2.3.4.and 5. The difference between the values of the model, the optimal values and absorption values of the Winch Haulage shaft are presented at the end of this paper on Table .1.

Table 1. Current/optimal diameters, lengths, safety factor, slope angle, and displacement of the shaft

Values of	D_1	D_2	D_3	D_4	l_2	S	φ	f	Objective function – volume
model	280	360	280	240	3787.5	1.866794	0.007934	17.57546	471365190.1
optimal	279.65	334.639	279.654	240.274	3729.867	1.499404	0.008841	13.11552	413880335.4

The adopted geometrical model for the rotating shaft with Winch Haulage package on it is given in fig. 1, where the position of the Winch Haulage package is changeable within limits allowed by length l_2.
The different quantities influencing in the shaft design either are adopted from tables or are calculated during the creation of mathematical model for the adopted geometrical model of the rotating shaft with Winch Haulage package.

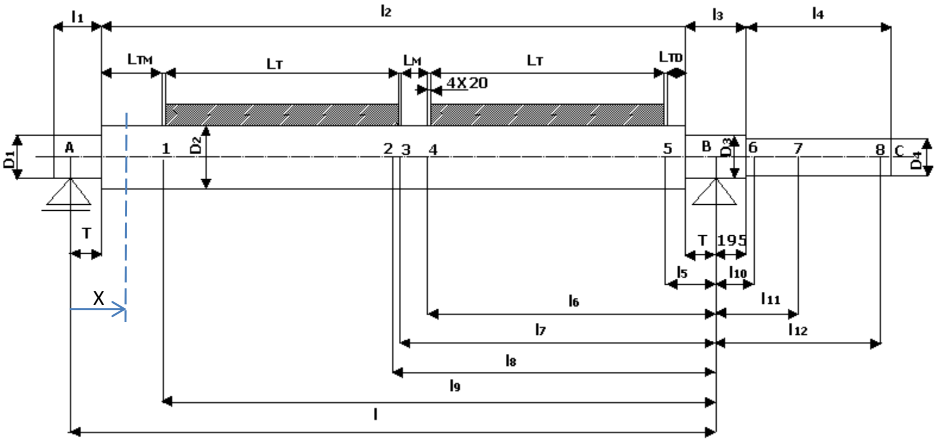

Figure 1. Winch Haulage's shaft model

3. MATHEMATICAL MODEL

Position of the Winch Haulage package assembling on the rotating shaft is given by variable ***X***. Based on the geometrical and constructive constraints the variable domain is:

$$X = 120 \quad \text{to} \quad X = 120 + L_{TM} \tag{1}$$

The behavior of the shaft's model depending on Winch Haulage package position is evaluated calculating three main important quantities:

-the slope angle of shaft:

$$\varphi(X) = \left(\frac{4646477.55728492}{D_1^4} + \frac{X \cdot 14988.6372815643 + 49012843.9107151}{D_2^4} + \frac{5920511.72621788}{D_3^4} + \frac{14059341.7701073}{D_4^4} \right) \tag{2}$$

$$\varphi_{opt}(X) = \left(\frac{4646477.55728492}{D_{opt1}^4} + \frac{X \cdot 14988.6372815643 + 49012843.9107151}{D_{opt2}^4} + \frac{5920511.72621788}{D_{opt3}^4} + \frac{14059341.7701073}{D_{opt4}^4} \right) \tag{3}$$

- the safety factor of shaft:

$$S(X) = \frac{0.000003321343599 \cdot D_2^3 \cdot X + 0.01218933100833 \cdot D_2^3}{\sqrt{31331.3287784646 \cdot X^2 + 89877703.2149337 \cdot X + 65822611386.071}} \tag{4}$$

$$S_{opt}(X)=\frac{0.000003321343599\cdot D_{opt2}^{3}\cdot X+0.01218933100833\cdot D_{opt2}^{3}}{\sqrt{31331.3287784646\cdot X^{2}+89877703.2149337\cdot X+65822611386.071}} \quad (5)$$

- the displacement of shaft

$$f_4(X)=\sqrt{\left[\frac{D_2^4\left(a+bX+cX^2-dX^3\right)+D_1^4\left(eX+fX^2+gX^3+h\right)}{D_1^4\cdot D_4^4\left(X+3670\right)^2}\right]^2+\left[\frac{D_4^4\cdot i+D_3^4\cdot\left(j\cdot X+k\cdot X^2+l\cdot X^3-m\right)+D_2^4\cdot\left(nX+oX^2+pX^3+q\right)}{D_4^8\left(X+3670\right)^2}\right]^2} \quad (6)$$

$$f_{opt\,4}(X)=\sqrt{\left[\frac{D_{opt\,2}^4\left(a+bX+cX^2-dX^3\right)+D_{opt\,1}^4\left(eX+fX^2+gX^3+h\right)}{D_{opt\,1}^4\cdot D_{opt\,4}^4\left(X+3670\right)^2}\right]^2+\left[\frac{D_{opt\,4}^4\cdot i+D_{opt\,3}^4\cdot\left(j\cdot X+k\cdot X^2+l\cdot X^3-m\right)+D_{opt\,2}^4\cdot\left(nX+oX^2+pX^3+q\right)}{D_{opt\,4}^8\left(X+3670\right)^2}\right]^2} \quad (7)$$

Where:

$a=2.7486503647064\cdot 10^{17}$
$b=119359958111152$
$c=28139750379.4768$
$d=10175757.9417071$
$e=32565974075595.1$
$f=28255908586.3345$
$g=7497776.63666374$
$h=1.10486757319858\cdot 10^{16}$
$i=62546002474437.7$
$j=0.00005145319578$
$k=6928927835.62325$
$l=1491252.23002617$
$m=4.54409255638556\cdot 10^{15}$
$n=47961609503330$
$o=49118266476.979$
$p=8821581.03741946$
$q=1.34010171606085\cdot 10^{17}$

The slope angle, safety factor, and displacement of shaft are calculated for both current diameters and optimal ones with MathCad package for the domain of X[120, 500]. The results are graphically presented in fig. 2, fig.3, fig.4 and fig.5.

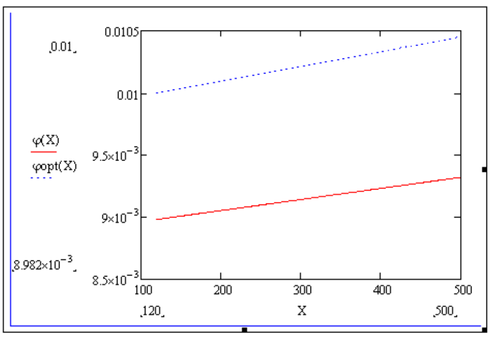

Figure 2. Results for slope angle current/optimal rotating shaft

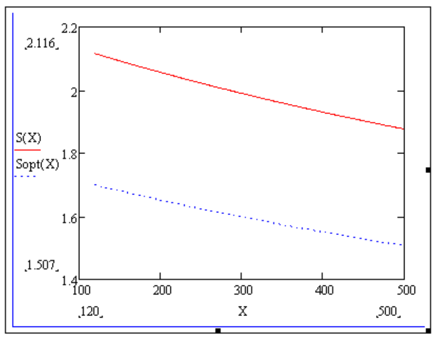

Figure 3. Results for safety factor at current/optimal rotating shaft

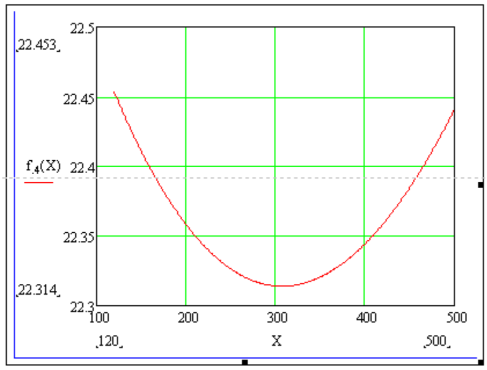

Figure 4. Results for displacement at current rotating shaft

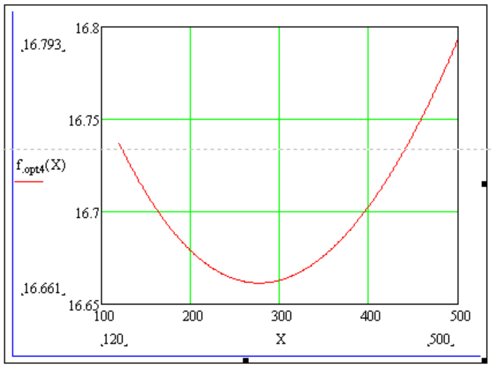

Figure 5. Results for displacement at optimal rotating shaft

4. CONCLUSIONS

Based on the adopted approximation for the move of the Winch Haulage package within domain $X \in [120,500]$, fig.1 it was noticed that:

- Slope angle increases at both models – for current and optimal dimensions, but still is within allowed limits, while values at optimal model are greater than at current model,fig.2;
- Safety factor decreases at both models and values at optimal model are lower than at current model,fig.3;
- Displacement has minimum value at optimal model closer to the left support (minimum at $X<300$), fig. 5 comparing to the current model (minimum at $X>300$), fig.4, and as well values at optimal model are lower than at current model, fig.4 and fig.5.

Therefore it can be concluded that:

- The best position for the Winch Haulage package is to be at $X=280$, fig.5, where the displacement has minimum value $f_{opt4}=16.661$ and as well as the slope angle and the safety factor are within limits; and
- The adopted model, fig.1 is a good base for modification of the current mechanical model, always taking into consideration the functionality and assembling;

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