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THE INFLUENCE OF TECHNOLOGICAL PARAMETERS ON MINE HOISTING CAGE IN DYNAMIC CONDITIONS

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ABSTRACT
Modern mining industry imposes lots of requirements on mine hoisting equipment associated with hoisting speed, height and payload. To satisfy these needs hoisting equipment should be designed in a proper manner, which requires reliable information on process parameter values.
This paper presents the results of strain measurements in a mine hoisting cage. The experiment was designed in order to get the dependence of cage strains and technological parameters, i.e. the hoist heigh (rope lenght), cage acceleration and payload. These data can be used for estimation of stresses and coefficients of safety and their comparison to those given in Regulations of Tecnical Normatives in Mines reffering to people and freight hauling, [1].
These results are also useful in validation of mathematical models and realized technical solutions.
Key words: hoisting equipment, stress-strain state, experimental design, dynamic conditions

1. INTRODUCTION

Mine hoisting equipment represents complex intermittent transport machinery with several transporting operations during freight haulage in one transportation cycle. Theoretical analysis of hoisting equipment stress-strain state is based on some assumptions which can produce mathematical models that differ from the real system, especially in transient periods when dynamic forces appear. In that sense experimental measurements are used to capture real values of relevant physical quantities, which can be used for correction of established theoretical models or validation of realized design solutions.
The results of strain measurements of two-storey hoisting cage which were conducted in real conditions (in-sity) are presented in this papaer. The measurements were performed during acceleration and deceleration of the cage when moving up and down. The strain rates and consequent stresses in hoisting equipment components change depending on the cage location in the shaft (height), hoisting speed (acceleration), freight weight, resistance force and so on.

2. DESIGN OF EXPERIMENT

In experimental investigation of stress-strain state multifactorial experimental design was used. The advantages of the multifactorial experimental design are that interactions between different factors affecting the measured quantity can be simultaneously examined and the relative importance of several factors can be assessed, [2, 3, 4].
Measurements were performed on two-storey hoisting cage in the Coal Mine Zenica - ″Raspotočje″, which was designed for people and freight haulage. The cage was designed as welded steel construction (Č.0561) with the following characteristics: mass approx. 7500 kg, ultimate stress σ_m = 550 MPa, and modul of elasticity E = $0{,}21\mathbf{x}10^6$ MPa,

The MATLAB software (version 7.0) and its module *Model-Based Calibration Toolbox* was used for design of experiments i.e. experimental points, [5]. The first order mathematical model i.e. linear regression model was assumed. The three-factorial experimental design was adopted for acquiring the data and the appropriate experimental matrix is given in Table 1.

Table 1. Values of input parameters in three-factorial experimental design

Input parameter	Label	Meaning	Level 1 Lower level	Level 2 Upper level	Degree of freedom
x_1	L (m)	Hoist height	85	330	1
x_2	a (m/s^2)	Cage acceleration	0,5	1	1
x_3	N (kg)	Cage payload	0	8600	1
The interaction of input parameters will also be analysed, i.e: $x_1 \cdot x_2$, $x_1 \cdot x_3$, $x_2 \cdot x_3$, $x_1 \cdot x_2 \cdot x_3$.					

Measurements were performed using two strain-gauges mounted on locations MM1 ana MM2 on hoisting cage construction, Figure 1. Strain-gauges characteristics were: Ohm-type LY 11-10/120, manufacturer HOTTINGER BALDWIN MESSRECHNIK GMBH. The measurement signal was sent to measurement system *Spider 8* HBM.

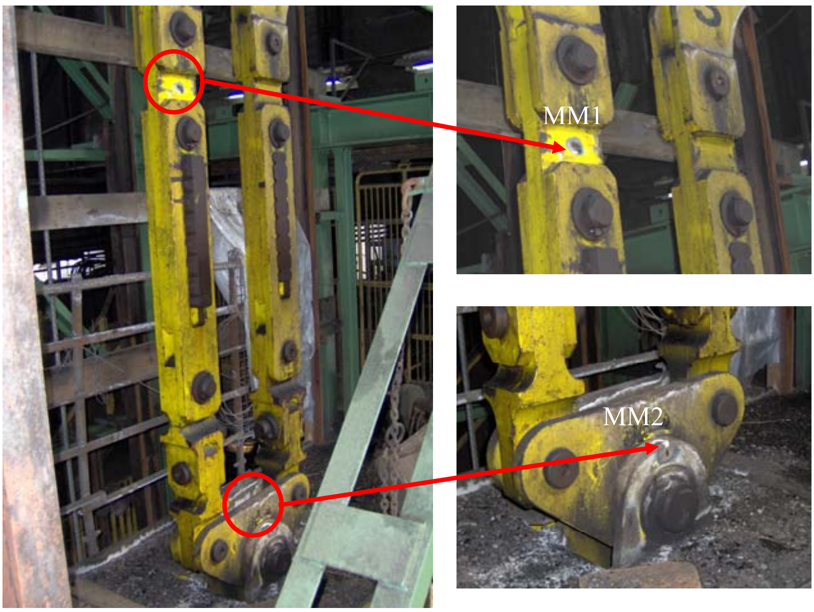


Figure 1. Experimental setup – location of strain-gauges on cage construction

3. ANALYSIS OF EXPERIMENTAL RESULTS

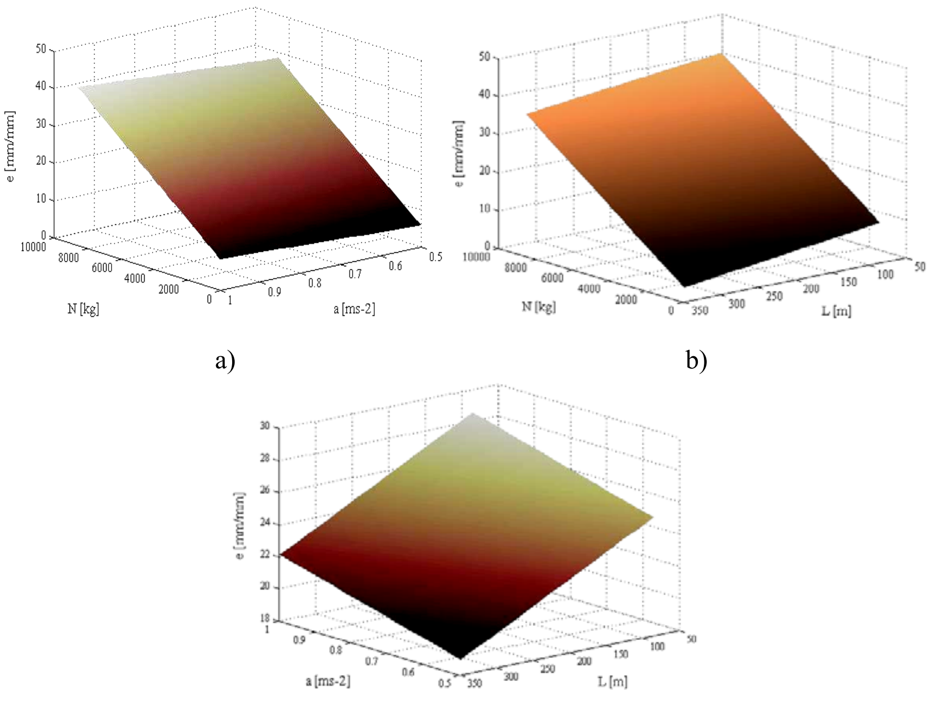
Using the values of strains measured by strain-gauges and mechanical properties of construction material, the stress values in measured points can be calculated. These results are given in Table 2.
Maximal strain values can be used to calculate maximal stresses necessary for static and dynamic analysis. The influence of factors and their interactions on the maximal strain value $\widehat{e}_M$ is evaluated by regression analysis. The obtained regression relation is in the form:

$$\widehat{e}_M = -5{,}08291 + 0{,}0361194 \cdot L + 15{,}82232 \cdot a + 0{,}37825 \cdot N - 0{,}0322466 \cdot a \cdot N \,. \qquad (1)$$

Also, the coefficients of correlation and variation from regression surface are calculated, which shows that the established regression model (1) matches well with the experimental data (coefficient of determination $R^2 = 0,99967$ i coefficient of correlation $R = 0,99984$). The regression surface given by (1) is multidimensional, and consequently it can not be represented by one graph. Therefore independent variables are substituted by their average values and 3D graphs of regression surface for different combinations of independent variables are plotted in the observed ranges, Figure 2.

Table 2. Results of strain-gauge measurements

Randomized order of experiments	Exp. N^o	Influencing factors			Measured strain(μm/μm)		Stress values(MPa)	
					MM 1	MM 2	MM 1	MM 2
		L(m)	**a**(m/s^2)	**N**(kg)	$e_1 \times 10^{-6}$	$e_2 \times 10^{-6}$	σ_1	σ_2
M2	1	330	1	0	4,9	3,2	1,04	0,62
M1	2	330	1	8600	39,5	25,8	8,29	5,42
M5	3	330	0,5	0	2,5	1,6	0,50	0,31
M6	4	330	0,5	8600	35,4	23,1	7,43	4,85
M4	5	85	1	0	11,9	7,8	2,51	1,64
M3	6	85	1	8600	45,0	29,4	9,45	6,18
M8	7	85	0,5	0	9,5	6,1	1,98	1,29
M7	8	85	0,5	8600	42,0	27,3	8,78	5,73
Verification	MV	165	0,5	4300	17,9	13,0	3,76	2,72



a) b)

c)

Figure 2. Strain values in relation to a pair of influencing factors:
a) variation of acceleration and cage load (for average height i.e. rope length);
b) variation of acceleration and height (for average cage load);
c) variation of height and load (for average acceleration)

The results of strain measurement show that the stress value is mostly affected by cage load, then by cage speed (i.e. acceleration). The influence of the rope length i.e. height is negligible for this type of hoisting equipment. The influence of factor interactions can also be neglected.
Similar regression relations for other types of hoisting equipment can also be reproduced by hoist design engineers and mining technologists to compare with maximal stresses allowed by national standards and Regulations of Tecnical Normatives in Mines reffering to people and freight hauling, [1].

4. CONCLUSIONS

The experimental investigation of two-storey hoisting cage of haulage system in Coal Mine Zenica – excavation ″Raspotočje″ during transient and steady-state transport conditions gave the following conclusions:

- the observed influencing factors express different significance on the stress and strain values in hoisting cage. The cage load is the most significant factor for the stress value, while rope length and cage speed (i.e. acceleration) influence is almost negligible for this type (Koepe) of hoisting equipment. The influence of factor interactions can also be neglected.
- dynamic response of the cage in transient regime shows that maximal stresses are far below allowable stress limit i.e. the stress values are approx. 2 % of ultimate stress (safety coefficient is $\psi = 50$);

Since experimental measurements of strain rates give possibility to get more realistic theoretical models, this kind of analysis contribute to the methodology of hoisting equipment design giving chance to get optimal solutions in a relatively fast and cheap way.

5. REFERENCES

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