The International Journal of
TRANSPORT & *LOGISTICS*
Medzinárodný časopis
DOPRAVA A LOGISTIKA

ISSN 1451-107X

APLICATION THE DOE METHOD ON CONVEYOR BELT TENSION BY DYNAMIC IMPACT LOADING

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Abstract: *The paper presents aplication the DOE (Design of Experiments) method on conveyor belt tension by dynamic impact loading. Factors that significantly affect the value of the tension load were identified. Interaction between the dynamic impact loading and the value of tension load influence the impact height as well as the using of a support system. It was examined an increase in the allowable load, which the belt is tensioned during testing.*

Key words: *DOE method, conveyor belt, dynamic impact loading*

1 INTRODUCTION

The conveyor belt transport systems have taken on a new significance in recent years. The application of new developed solutions leads to considerable reduction in operational costs of transport systems, while ensuring their high reliability and service life [1]. Conveyor belts are used in practically every industry where large quantities of goods are moved [2], they are widely used to transport granular matter in bulk [3].

Conveyor belts (CB) of special importance are used for equipping large capacity conveyors or those working under heavy conditions (sharp slope, high speed, with big lengths to transport), where is requesting a very good breaking strength, special flexibility and high reliability [4]. These CB must have high mechanical properties, so CB have in structure different insertions (textile, metallic) and their properties are based on adhesions rubber-insertion [5].

The primary mechanical function of the belt is to bear the transported bulk material during conveyance [6]. In order to stop the conveyor belt sagging between the support rollers it must be kept under tension [7], while the axial load in the belt corresponds to 1/10 of the belt tensile strength. The critical energy, which belt is able to absorb by the deformation work, is proportional to the belt tensile strength [8]. The value of critical energy depends, among other things, on the head shape, method of belt support, strength of belt tension, head weight and height of its fall [9].

The objective of the article is the analysis of the tension load in the conveyor belt, which is developed in real conditions at the material's impact on the belt, particularly on the chutes.

2 MATERIAL AND METHODS

Conveyor belts type P 2000/4, 8+4 were used for experiments. These CB are the fabric belts with a 4-component textile-polyamide skeleton, with the strength of 2000 N/mm. Experiments were realized on test equipment which is available at the Institute of Logistics on Technical University of Košice. The methodology of testing the impact resistance using this testing equipment is described in [10] and determination of impact resistance on the basis of experimental measurements, with the results evaluation using the regression analysis, is described in [11].

Test samples with dimensions of 150 x 1200 mm were attached at both ends to hydraulic grips and tensioned with load of 30 kN, which corresponds to 1/10 of the belt tensile strength. Ram weight is 50 kg and for individual measurements it can vary in the range of 50 – 100 kg with an increase of 10 kg. The impact height gradually can be increased from 0.2 m to max. 2.6 m. Tests have been carried with pyramid impactor (Fig. 1) and they can be carried out with a support system or without this system, in other words without steel idler rolls.

Fig.1 *Tensioned conveyor belt with a support system and a pyramid impactor*

Using the DOE method [12, 13] were identified the effects of factors and their interactions, which greatly affect the value of the tension load and which operates at 1st ram impact on CB. In work [14] was used DOE method in the examining stress conveyor belts in relation to their resistance to breakdown.

3 RESULTS

In this work were observed following input factors with their lower and upper levels (Tab. 1): ram weight (factor A), impact height (factor B), and support system (factor C). The goal was to determine which of factors or their interactions significantly affects the response i.e. the value of the tension load F_t [kN] varied when the ram falls on the conveyor belt. During the experiments the CB breakdown did not occur.

Tab. 1 *List of input factors and their levels*

	Factors	**Low level (-1)**	**High level (+1)**
A	Ram weight [kg]	90	100
B	Impact height [m]	0.2	1.4
C	Support system [-]	- SS	+ SS

Special design was made as complete three-factor experiment with two levels without repeating, along with interactions, the number of possible attempts is 2^3, i.e. 8 experimental runs. Graphical representation of the experiment using a cube is shown in Fig. 2, whereas the cube corners contain the response values.

Graphical representation of the main effects of all factors is shown in Fig. 3. The growing direction of the lines indicates that the transition from the lower to the upper levels of factors means increasing of effect factors.

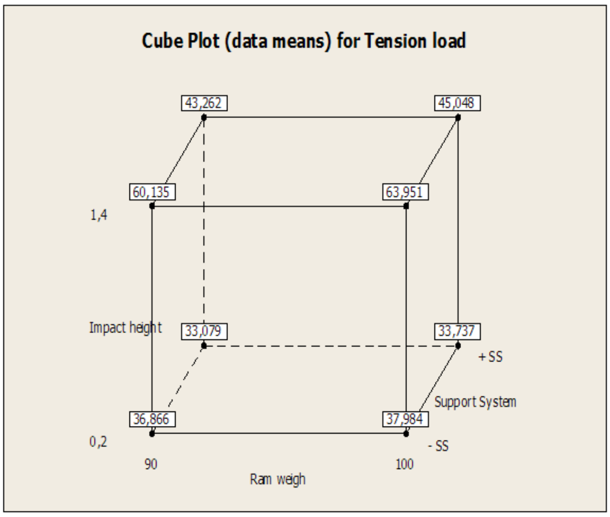


Fig.2 *Graphical representation using cube plot*

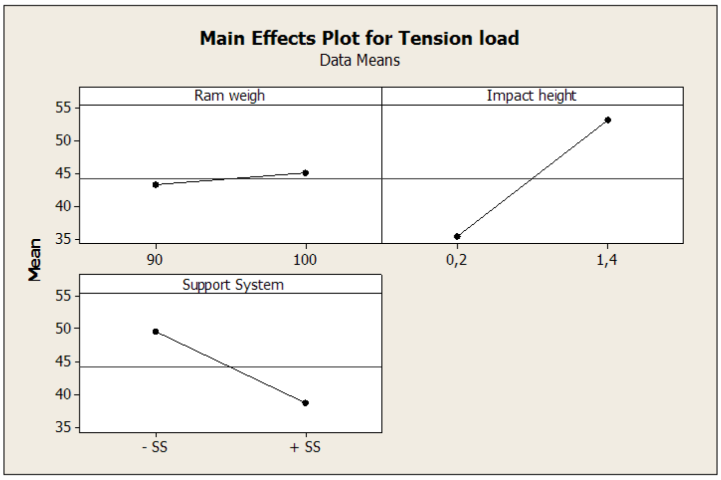


Fig.3 *Graphical representation of main effects*

Tab. 2 clearly indicates that the strongest effect on the monitored response is with factor B (impact height) and factor C (support system). Negligible effect was observed for factor A (ram weight). Significance of individual effects of factors or interactions is tested using the t-test and by the p-value determination. The analysis indicates that the only main factors B and C have a statistically significant effect on the tension load.

Tab. 2 *The main effects of factors*

	Factor A	**Factor B**	**Factor C**
Effect of factors	1.84	17.68	-10.95

Significance of the effects can be assessed graphically, while this type of assessment of the significance of effects and their interactions is most frequently made using the Pareto chart (Fig. 4) and the normal probability plot (Fig. 5). The Pareto chart (Fig. 4) reveals which factors and interactions have statistically significant relationship with the tension load on the significance level of α=0.05.

Factors and interactions that do not have any influence are located near the drawn line (Fig. 5). Factors and interactions located out of the drawn line are regarded as significant. The plots (Figs. 4 and 5) indicate that the statistically significant effect on the response is present only for the impact height (factor B), support system (factor C) and their interaction.

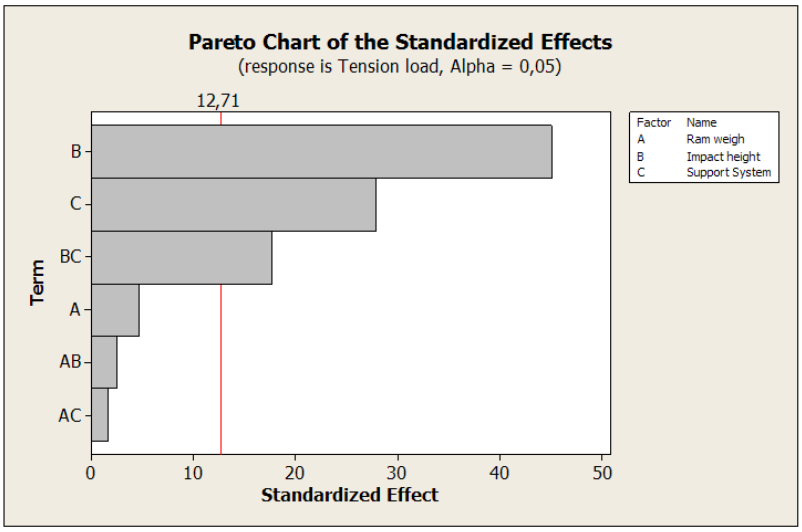


Fig.4 *The Pareto chart of the significance of factors and interactions*

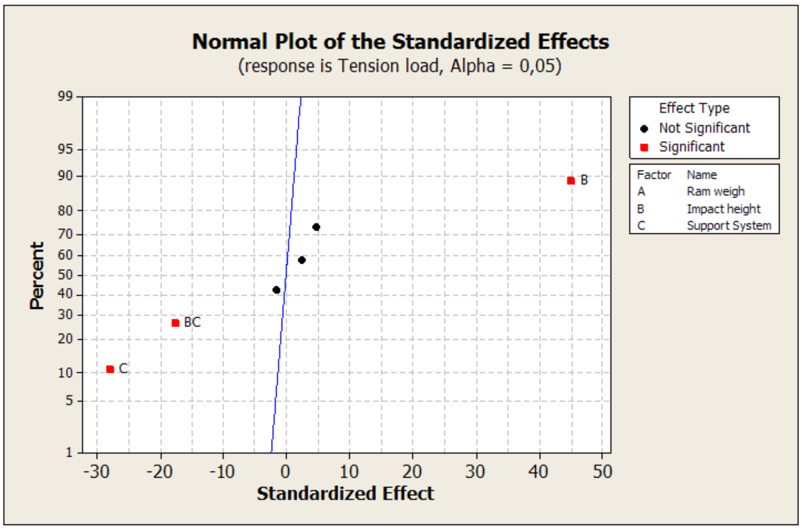


Fig.5 *Normal probability plot of the significance of factors and interactions*

From interaction plot (Fig. 6) can reveal important interactions between factors. If shown lines are parallel, the interaction between factors does not exist or is insignificant. The greater the angle mentioned lines contain, the greater is the interaction between studied factors. Among the factors B and C interaction is significant and between the factors A and B too between A and C the interaction is not significant.

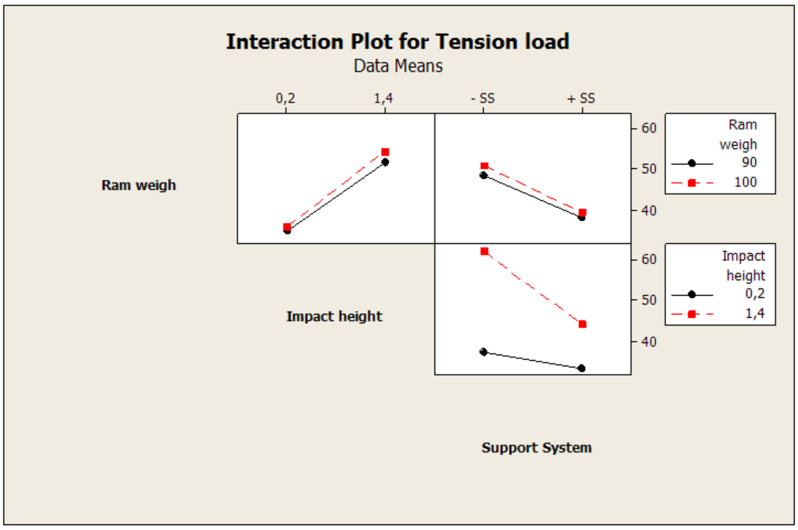


Fig.6 *Interaction plot of main effects*

The model of a full three-factors experiment containing the main factors and all two-factors interactions is determined by [13]:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 \tag{1}$$

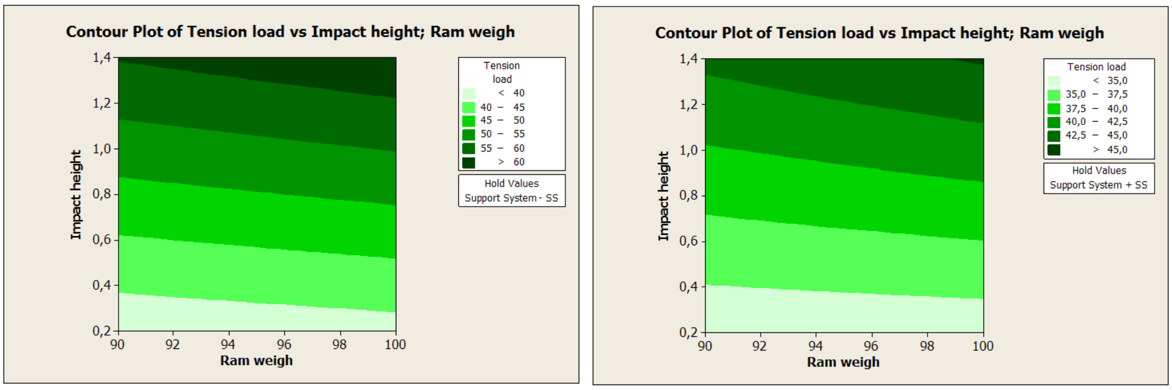
where y is the response, x_1 up to x_3 represent values of factors, interactions between the respective two factors (e.g. x_1x_2 represents the AB interaction) and β_0, β_1 up to β_{23} are estimates of the regression model coefficients that can also be calculated using the effects. The values of all model coefficients are shown in Tab. 3.

Tab. 3 *The coefficients point estimate of the regression model*

Coefficient	β_0	β_1	β_2	β_3	β_{12}	β_{13}	β_{23}
Value	44.258	0.922	8.841	-5.476	0.478	-0.311	-3.468
p-value	0.003	0.133	0.014	0.023	0.248	0.358	0.036

The value of the determination coefficient R^2_{adj} = 99.78 % indicates that the identified regression model explains the experimental results in 99.8 %.

Using contour plots (Fig. 7) helps to visualize the response surface. Plots are useful for establishing desirable response values and operating conditions. This plots show how a response variable relates to two factors (weight and height) based on a model equation. Because plots show only two factors at time, any other factor (support system) is held at a constant level. Thus, plots are only valid for fixed levels. If holding levels are changed, the response surface also changes (Fig. 7 a, b). Therefore, it makes sense to hold support system fixed at its low and high levels and compares the plots. Points of a contour plots that have the same response are connected to produce contour lines of constant responses. The darkest green (i.e. grey) area indicates the contour where the response is the highest. It can be concluded, on the basis of following visualization of values of the monitored response, that in the case of omission of the support system were measured higher tension loads.



a) factor C fixed at its low level *b) factor C fixed at its high level*

Fig.7 *Contour plots*

6 CONCLUSIONS

The DOE method was applied to determine the effect of three input factors (ram weight, impact height and supporting system) on the tension load of the conveyor belt, which has an important role during the dynamic impact loading i.e. the belt operation in real conditions. Negligible effect was observed for the ram weight. Statistically significant effect on the response was observed for the impact height (factor B), supporting system (factor C), and two-factor interaction BC.

Acknowledgement

This article is the result of the Project implementation: **University Science Park TECHNICOM for Innovation Applications Supported by Knowledge Technology**, ITMS: **26220220182**, supported by the Research & Development Operational Programme funded by the ERDF. "We support research activities in Slovakia/This project is being co-financed by the European Union"

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