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MONITORING AND ANALYSIS OF THE INFLUENCE OF THE SELECTED PARAMETERS TO THE CONVEYOR BELT DAMAGES

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ABSTRACT: Belt conveyance belongs to the continual transport systems characteristic with high-level conveying performances. The fundamental and the most expensive component of belt conveyors is the conveyor belt. The aim of this paper is to investigate different levels of damage that occur on rubber-textile conveyor belts. The logistic regression method was selected in order to analyse individual levels of the conveyor belt damage. The result of the paper enables to estimate the odds of formation of the significant conveyor belt damage for the individual parameters.
Keywords: conveyor belt, damage, logistic regression

1. INTRODUCTION

Belt transport is a high performance transport system, which has a wide application in praxis. By Kulinovski, [1], for belt conveyors, the transport task can be defined as a process whose purpose is to transport the set quantity of handled material within a defined time between the set loading and offloading locations. From the point of belt conveyor operation the most important construction element is the conveyor belt. The belt conveyor is a limited range, continuously moving transport facility that carries material on the belt surface, between two belts or inside a belt [2, 3].

The belt conveyors are exposed to the various impacts that are causing a process of their damage and degradation. Such serious damage is visible on the upper cover of the belt predominately in the form of transversal and longitudinal grooves, punctures or cracks that are able to cause damage to the belt inner structure, as well. The conveyor belt damage process is discussed in papers [4, 5, 6].

The aim of this paper is to analyse possibilities of a significant damage occurrence in the case of various conveyor belt samples as a result of material impact in the bulk material transfer points.

2. MATERIAL AND METHODS

The experiment was realised by means of the testing equipment, which is illustrated in Figure 1. The test equipment has a hydraulic system for clamping strip samples and other hydraulic system for tensioning the sample during the test. During the experiment it is possible to change the impact height of the drop hammer, the type of conveyor belt and the type and weight of impactor shapes [7].

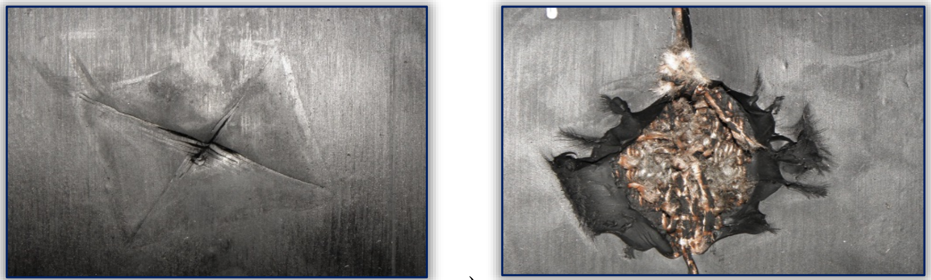
Figure 1. The test device with the drop hammer and impactor details

Two types of impactors were applied during the tests: one impactor with a pyramidal shape and the second with a spherical shape (Figure 2).

Figure 2. The applied impactor shapes

All the conveyor belt samples were from the same manufacturer and they had the same inner construction of the belt. The worn conveyor belt was used in operation during the period 30 months. The renovated conveyor belt was operated during a long period and then it was excluded from operation. Afterwards the upper cover of the belt was renovated, what is allowing further operational usage of it. The impact height was changed from 0.8 m up to the maximum level 2.6 m. The height was changed with the difference from 0.1 to 0.2 m according to the degree of damage. In the case of significant damage, the test was repeated.

The individual types of damage of the conveyor belt were divided into two categories:
- ≡ insignificant damage: puncture on the upper cover, convexity, partial damage of the bottom cover or upper cover without relevant damage of the conveyor belt (Figure 3a),
- ≡ significant damage: partial or total damage of the bottom cover or upper cover, total puncture of the conveyor belt (Figure 3b).



a) b)

Figure 3. Examples of possible damage of the conveyor belt specimens

Logistic regression is a special type of regression where a dependent variable is a categorical variable which acquires limited number of values. In the simplest case we have a dependent variable which is dichotomous with two values 0 and 1. When a monitored event occurred, then Y=1, otherwise Y=0. $P(Y=1)$ means probability of the fact that an event occurred (variable Y acquires category 1). The odds of the event occurrence (Y=1) is defined as a ratio between the probability of the event occurrence and the probability of no-occurrence, thus [8]:

$$odds = \frac{P(Y=1)}{1-P(Y=1)}. \tag{1}$$

Logarithm of this odds is called logit, whereas it is valid

$$\text{logit}(Y) = \ln(odds) = \ln\left(\frac{P(Y=1)}{1-P(Y=1)}\right). \tag{2}$$

The model with k explanatory variables X_i (continuous or dichotomous), where $i = 1, 2, \ldots, k$, can be written in the form:

$$\text{logit}(Y) = \ln\left(\frac{P(Y=1)}{1-P(Y=1)}\right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k, \tag{3}$$

where α is the Y intercept, β_1, β_2,..., β_k are the regression parameters.

3. RESULTS

The experiment was implemented on 56 belt conveyor samples. The occurrence of the damage of the conveyor belt is in the Table 1.

Table 1. Classification and frequency of the damage

Type of the conveyor belt	Type of damage		
	Insignificant damage	Significant damage	Total
Worn	22	9	31
Renovated	15	10	25
Total	37	19	56

The aim of the analysis is investigated an occurrence of the conveyor belt significant damage (the variable DAMAGE, signed. Y) in relation to three independent variables: the impact height of the drop hammer (the variable HEIGHT, signed X_1), the type of conveyor belt (the variable CONVEYOR BELT, signed X_2) and the type of impactor shapes (the variable IMPACTOR, signed X_3).

The variable Y is dichotomous variable with two values: 0 and 1. In the case of a conveyor belt significant damage Y=1 and if not, Y=0. The independent continuous value X_1 represents the impact height of the drop hammer (in m). The variable X_2 describes the type of conveyor belt with the two categories: renovated and worn conveyor belt. The variable X_3 describes the type of impactor shapes: pyramidal and spherical impactor. A summary description of the variables is in the Table 2. Analysis of the model is in the Table 3.

Table 2. Summary of variables

Variables	Description
Dependent Variables	
DAMAGE (Y)	1 in case of a significant damage, 0 in case of no significant damage
Independent Variables	
HEIGHT (X_1)	Impact height (meter)
CONVEYOR BELT (X_2)	1 in case of a worn conveyor belt, 0 in other cases
IMPACTOR (X_3)	1 in case of the pyramidal impactor, 0 in other cases

Table 3. Logistic regression analysis

Predictor	df	Estimate	Standard error	p-value
Intercept	1	-11.338	3,172	0.000
HEIGHT (X_1)	1	0,046	0,013	0.001
CONVEYOR BELT (X_2)	1	1,715	0,859	0.046
IMPACTOR (X_3)	1	1,162	0,792	0.143
Goodness of Fit Tests				
Method	df	Chi-Square	p-value	
Pearson	44	26.378	0.984	
Deviance	44	30.889	0.932	
Hosmer-Lemeshow	8	4.306	0.828	

The logistic regression model is in the form

$$\text{logit}(Y) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \ . \quad (4)$$

The result of the model is

$$\text{logit}(Y) = -11.338 + 0.046 X_1 + 1.715 X_2 + 1.162 X_3 \, . \quad (5)$$

The statistical significance of the model was verified by the credibility ratios test. The statistical significance of the estimated parameters was verified by the Wald test (Wald Chi-Square). The results show that the model is a statistically significant. It is possible to say that the parameters β_1 and β_2 are significant statistically with the significance level 0.05 (p-value<0.05) and they are relevant with regard to a possibility of conveyor belt significant damage. Goodness of fit statistics confirms that the model was fit to the data well (p>0.05).

The analysis of the logistic regression show that if the value of the continuous variable X_1 (HEIGHT) is changed by one meter and the values of the other independent variables stay unchanged then the logit will change by coefficient 0.046. If follows that the odds ratio of a significant conveyor belt damage for an increase of 0.1 meter in impact height of drop hammer is exp(0.046*0,1)=1.05. The coefficient of the variable X_2 characterizes a change in logit, if there is compared the worn conveyor belt with the renovated conveyor belt at the same impact height and the same impactor shapes. The odds that in the worn conveyor belt occurs a significant damage is exp(1.715)=5.56-times higher in comparison with the renovated conveyor belts. The coefficient of the variable X_3 characterizes a change in logit, if there is compared the pyramidal impactor with the spherical impactor at the same impact height and the same type of conveyor belt. The odds of a significant damage of the pyramidal impactor after an impact of the drop hammer is exp(1.162)=3.20-times higher in comparison with the spherical impactor.

Table 4. Measures of association

Pairs	Number	Percent	Summary Measures	
Concordant	616	87,6	Somers' D	0.76
Discordant	82	11,7	Goodman-Kruskal Gamma	0.77
Ties	5	0,7	Kendall's Tau-a	0.35
Total	703	100.0		

The Table 4 summarizes a number and percentage of the concordant, discordant and ties couples, as well as measures of association. The classification table confirms that even 87.67% of all cases were classified correctly. The model is quality sufficiently with regard to the measure values.

4. CONCLUSIONS

The analysis of experimental measurements with the pyramidal impactor indicates that the renovated conveyor belt shows the best tests on the resistance to the puncture and to the significant damage compared with the worn conveyor belt. The total damage of the upper cover layer together with a damage of the belt internal structure, occurred in the of the maximum impact height 2.60 m. There was only a puncture in top cover layer up to the height of 1.90 m with worn conveyor belts. In case of the worn conveyor belts were only the insignificant damage on the upper cover up, namely up to the impact height 1.90 m. A total puncture of the worn conveyor belt occurred at the impact height 2.40 m.

The analysis of experimental measurements with the spherical impactor indicates that the significant damage and the puncture of the conveyor belt were only in the maximum impact height. The renovated conveyor belt remained without a damaged upper cover up to the impact height 2.20 m, but after impact of the drop hammer the bottom cover was damaged totally, as well as it was damaged the belt internal structure. It was classified as a significant conveyor belt damage. The result of logistic regression shows that the increase of the impact height increases odds of a significant conveyor belt damage. The using the worn conveyor belt increases markedly odds of a significant conveyor belt damage in a comparison with the renovated conveyor belt. Application of the pyramidal impactor increases markedly odds of a significant conveyor belt damage in a comparison with the spherical impactor.

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