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Using logistic regression in tracing the significance of rubber–textile conveyor belt damage

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ABSTRACT

The main purpose of this work is to investigate different levels of damage that occur on rubber–textile conveyor belts. The conveyor belt damage depends on the heterogeneity of the transported material, transporting conditions and on attributes of the conveyor belt itself. The conveyor belts that are used in this study were divided into three categories: new, worn and renovated. In total, 67 test specimens were examined. The logistic regression method was selected in order to analyze individual levels of conveyor belt damage. Using this method, two differently shaped impact drop hammer tips (spherical and pyramidal) were applied and analyzed. Impact height of the drop hammer and the type of conveyor belt were treated as the independent variables. The output variable was selected as the one that best differentiated between significant and insignificant belt damage. The result of the work enables to estimate the odds of formation of the significant conveyor belt damage for the individual variables. A *surprising result*, which is obtained from the performed tests and model analyses, is a fact that application of a new, unused conveyor belt, leads actually to increased odds of the belt's significant damage.

1. Introduction

Transportation of material by means of belt conveyors is a typical transport method applied in various technological processes that are typical for mining and processing of mineral raw materials. The belt conveyors are exposed to the various impacts that are causing a process of their damage and degradation. Lihua [1] analyzes two typical failure forms of rollers and belt at the belt conveyor and he describes the maintenance methods for a prevention and elimination of failures in order to ensure a normal operation of a belt conveyor. Jurdziak et al. [2] proposed an automatic multi-channel system of data acquisition and data processing for damage detection in belts. Gurjar [3] describes typical failure of the belt conveyor applied in a coal handling system in thermal power plant.

The belt transport is analysed in various publications. Aldrich et al. [4] dealt with an online analysis of coal transporting conveyor belt using a machine vision and Kernel methods. Hou and Meng [5] described experiments designed in order to establish the dynamic properties of the conveyor belt material. There were measured dynamic elastic modulus, viscous damping and rheological constants of the belt. One of the most important areas of bulk solids handling is an efficient flow of materials at transfer points within the system. Bulk material transfer points are found in a wide range of industries, including mining, mineral processing, chemical processing, thermal power plants and many others that are dealing with bulk solids [6]. Methodology for computing of dynamic stress distributions on the large conveyor belts, considering a viscous-damping model, elaborated Pascual et al. [7]. An optimal control of operational efficiency of the belt conveyor systems studied Zhang and Xia [8]. Li et al. [9] elaborated a study of online monitoring and fault diagnosis system for the belt conveyors based on wavelet packet decomposition and support vector machine. Li et al. [10] created an intelligent detection system for mine belt tearing based on machine vision. This paper described first the overall composition of the system and introduced also the methods of belt image pre-processing, image segmentation and feature extraction, which are used in the detection system [10]. Zimroz and Król [11] dealt with failure analysis of the belt conveyor systems for condition monitoring purposes. Application of the GISs, in order to support belt conveyor maintenance management, was presented by Górnia-Zimroz et al. [12].

It is possible to apply a large scale of methods based on simulation or experimental methods. Otrebski [13] realized the

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finite element modelling of mechanical joint and solid woven belt. Sarkar et al. [14] studied an adhesion between rubber and fabric and rubber and rubber in heat resistant conveyor belt. Mazurkiewicz [15] presents the results of the laboratory tests conducted on the physical elongation and strength of typical adhesive sealed joints of conveyor belts. The tests were aimed at examination of the strength parameters of the joints in order to define some guidelines for a monitoring system, which was designed for prevention of unpredicted belt ruptures in the area of each joint occurring throughout the belt conveyor route [15]. Zheng et al. [16] dealt with the design, computer simulation and experimental evaluation of a new optical tomography instrumentation system that has been developed recently for the measurement of concentration profile and mass flow rate of particles in a gravity chute convey pipeline.

A very effective method, specified for investigation of the belt conveyors, is application of the non-destructive testing (NDT). The non-destructive testing of conveyor belting has become a common practice throughout the world. Langebrake et al. [17] dealt with non-destructive testing of the steel–cord conveyor belts. Fedorko et al. [18] investigated the applicability of metrotomography for a conveyor belt analysis and for condition monitoring. Similar to the well-known computer tomography, this technology creates a three dimensional representation of a belt sample, which allows to take a look inside the belt without destroying it.

A selection of the suitable conveyor belt is one of very important conditions for a reliable operation of the belt conveyors. Andrejiová et al. [19] used the AHP method for a determination of the optimal selection criteria of the conveyor belts. Another suitable methodology for application in the research area, which is focused on a durability and damage of the conveyor belts, is a logistic regression method. This method was applied already and presented in various investigative works. The logistic regression model is used for prediction of a binary response variable in terms of a set of explicative ones [20]. Kucharavy and De Guio [21] elaborated a logistic substitution model and technological forecasting. There is discussed in this paper an application of several models based on the logistic growth function (simple logistic, component logistic and logistic substitution models) in the context of technology change forecasting [21]. The logistic regression model, together with response variables subjected to randomized response, was presented by den Hout et al. [22]. Hsieh [23] elaborated a semi-parametric analysis of randomized response data with missing covariates in logistic regression. Logistic regression analysis of randomized response data with missing covariates was studied by Hsieh [24].

Many research problems require analysis and prediction of the output categorical variable or simulation of influence of various input independent variables on the observed output variable. The logistic regression is one of suitable statistical tools, which is specified for estimation of a certain phenomena probability (output variable) according to the known specific facts (input variables) that are able to influence a phenomenon occurrence. There is implemented in this article a logistic regression method as a suitable tool for determination of such model, which describes relation among the severity of conveyor belt damage and the input variables (the type of conveyor belt, the impact height). This method also allows prediction of situations that can be occurred during transport of bulk solids predominately by means of the belt conveyors.

2. Material and methods

2.1. Problem formulation

The resistance of conveyor belts to puncturing is defined as the ability of the conveyor belt to absorb the whole energy of material impact, which is generated in the moment of material striking into the belt, i.e. it is the ability of the conveyor belt to absorb the impact energy by the deformation work of the conveyor belt without the destruction of it. If the impact energy is greater than the absorption ability of the conveyor belt, then a significant damage of the belt is occurring. 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. This fact is referred to rubber–textile and steel–cord conveyor belts.

The main purpose of this research was 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, which are situated within a belt conveyor transport system. The individual conveyor belt samples were extracted from three categories of the same type of conveyor belt: from a new, worn and renovated rubber–textile conveyor belt. The tests of the individual samples were performed by means of experimental testing equipment, which is specified for testing of the conveyor belt resistance to puncturing.

2.2. Realisation of experiment

The experiment was realised by means of the testing equipment, which is illustrated in Fig. 1. This test device enables the simulation of material stroke onto a conveyor belt. The detailed description of the test device is in Fig. 1.

The basic parameters of the experiment are in Table 1.

Two types of impactors were applied during the tests: one impactor was equipped with a pyramidal shape and the second with a spherical shape (Fig. 2). Both types of the applied drop hammer impactor are simulating a kind of material, which is falling onto the conveyor belt, namely the pyramidal impactor represents a material with sharp and hard edges, whereas the spherical impactor simulates an inconsistent, crumbly material.

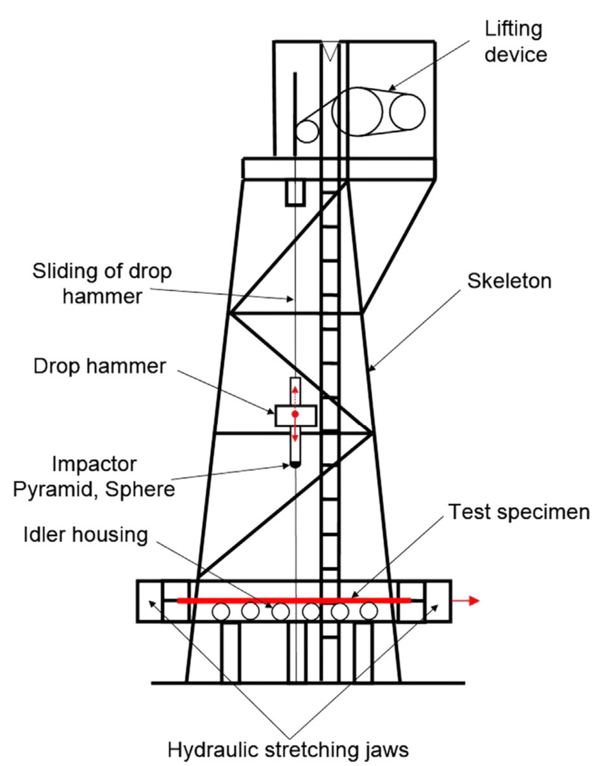

Fig. 1. The test device with the drop hammer and impactor details [25].