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Failure analysis of belt conveyor damage caused by the falling material. Part I: Experimental measurements and regression models

Gabriel Fedorko [a,*], Vieroslav Molnar [a], Daniela Marasova [a], Anna Grincova [b], Miroslav Dovica [c], Jozef Zivcak [c], Teodor Toth [c], Nikoleta Husakova [a]

[a] Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Kosice, Park Komenskeho 14, 042 00 Kosice, Slovak Republic
[b] Faculty of Electrical Engineering and Informatics, Technical University of Kosice, Letna 9, 042 00 Kosice, Slovak Republic
[c] Faculty of Mechanical Engineering, Technical University of Kosice, Letna 9, 042 00 Kosice, Slovak Republic

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ABSTRACT

The most common case of conveyor belts damage is their puncture by falling sharp material. One of the ways, how to minimize this type of damage, is using of suitable type of conveyor belt. Therefore, the analysis of conveyor belts on the part of their puncture resistance is an important factor for their use in operation conditions. The aim of the paper is to determine the dependence among the weight of sharp material falling on the conveyor belt, shatter height and force conditions in the conveyor belt on the base of experimental measurements by the help of regression mathematical model and to determine conditions under which the conveyor belt is damaged. The experimental results enable the operator of a conveyor belt to set the shatter height and maximum weight of falling weight below the threshold values in order to prevent conveyor belt damage.

1. Introduction

Belt conveyors are machines for continuous transport [1]. Belt conveyor is a commonly used equipment of continuous transport; it has a high efficiency and large conveying capacity, simpler construction, small amount of maintenance. Can be achieved at different distances, different materials transportation [2]. Belt conveyor is widely used in mine, coal, chemical industry, ports, and power plants [3]. In the belt conveyor, as the conveyor belt is traction components, transmit power and motion, also is carrying components, support material load [2]. One of the main causes of damage and often end the life of conveyor belts is their dynamic stress. Dynamic analysis is the key to decide whether the design is rational in technique, safe and reliable in running, feasible in economy. It is very important to study dynamic properties, improve efficiency and productivity, guarantee conveyor safe, reliable and stable running [4]. The dynamic characteristics of a belt conveyor are determined to a large extent by the properties of the belt [5].

Dynamic stress causes fatigue strength functions in shear loading of fabric conveyor belts. Kozhushko and Kicks [6] dealt with functions fatigue strength in shear loading of fabric conveyor belts. They concluded that the fatigue phenomenon of belts is explained by the decrease of shear strength, which is determined as an ultimate angle initiating the lamination failure of the central rubber layers [6].

* Corresponding author.
E-mail address: gabriel.fedorko@tuke.sk (G. Fedorko).

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Cheng and Du [6] researched force state of belt conveyor during horizontal turning section to improve the design level of belt conveyor with horizontal turning. Kumar [7] presented the review of belt conveyor design modification and latest technologies or methodologies used in different applications to reduce failures, maintenance cost and equipment related fatal accidents occurs during operation.

For dynamic analysis of conveyor belts it has proved use of the finite element method (FEM). Hatala and Maras [9] in their research focused on the application of the FEM numerical modeling stress–strain state in conveyor belts. Pascual et al. [10] presented a methodology to compute dynamic stress distributions on large conveyor belts considering a viscous-damping model.

The next author who dealt with the possibilities of FEM application within the frame of detailed research of the conveyor belts problem was Lodewijks [8,9]. Fedorko and Ivančo [10] researched by FEM the force ratios in conveyor belt of classic belt conveyor. By application of FEM for research of belt conveyors one of the key factor is determination of right material properties of conveyor belts. This problem was solved by the work of Mazurkiewicz [11].

Conveyor belt is very important for belt conveying operator also on the part of economy. For this reason it is necessary to pay increased attention to research of causes which cause its degradation and damage.

Romani [12] dealt with the ability to control the drive acceleration torque providing a smooth soft start while maintaining belt tensions within specified safe limits which are critical for belt conveyors performance. Zimroz and Król [13] deal with failure analysis for condition monitoring. Mazurkiewicz [14] also dealt with the problem of conveyor belts damages.

One of the main reasons for conveyor belt wear is the stress caused by the impact of lumpy material [15].

Impact of material on the conveyor belt is caused in many cases not only wear, but also conveyor belt damage. This problem was solved in the past not only in theory [19–22], but also by testing in laboratory conditions [23–26]. In theory, the effort of authors is oriented to the creation of mathematical models with the aim to describe the properties of conveyor belt. Till now it was described mathematical apparatus for determination of a reliability of belt conveyors using the renewal theory [16,17]. Regression models in the area of conveyor belt breakdowns were solved only marginally [18,19]. The most attention is in mathematical modeling by FEM [20,8–10].

Research of damaged conveyor belts can be realized directly during the operation of belt conveyors, what is often almost impossible or strenuous for realization or it is possible to use special test devices. Aldrich et al. [21] realized online analysis of coal on a conveyor belt by use of machine vision and kernel methods. On the other hand Fiset and Dussault [22], Ballhaus [23,24], Flebbe [25] and Hardygora [26] dealt with analysis of the causes of belt conveyors damages in laboratory conditions.

Damage of conveyor belt leads to its gradual destruction and due this fact we can monitor huge economic losses for users. Therefore the effort of producers is to produce and interest of customers is to buy conveyor belt wit the greatest damage resistance. The part of the article is a methodology, which can be used by conveyor belts tests associated with the assessment of their damage resistance and breakdown creations in extreme cases.

2. Material and methods

2.1. Problem formulation

A conveyor belt changes its shape and size under the thumb of external load what means that it is deformed. Mechanical properties express the relation among the size of acting external force and caused deformation, which include elastic and deformational characteristics characterized by the modulus of elasticity, modulus of deformability and strength properties, for example strength in compression, strength in tensile, strength in shear. Dimensional, functional, physical, mechanical and special test methods are determined for the testing of basic properties of conveyor belts with textile cords and cover layers from rubber.

Shock tests, which are the object of the research in this work, belong to special tests realized for purpose of overall assessment of conveyor belts intended for special use, primarily for bulk material conveying in hard operation conditions in opencast quarries. They are very specific are of testing, and until now unmodified by any standards or regulations. The aim of shock test is to determine the destructive resistance of a conveyor belt with regard to the conditions, in which the belt will work (lumpiness of the conveying material, its shape and so on).

At present, there is no clear way of determining or evaluation of conveyor belts breakdown resistance. In practice, a conveyor belt is often exposed to impact of sharp material on its surface, especially in the place of conveyor filling or on shifting. It occurs to their damage and in some cases conveyor belt is not able to the next operation. Its results are no small economic damages which are related to the necessary of damaged belt exchange and created non-operating states. The paper is aimed at the problem of rubber–textile conveyor belt damage by falling material. The aim is to determine the dependence among a weight of material falling on the conveyor belt, shatter height and force ratios of conveyor belt by regression mathematical model and to determine conditions by which it creates a damage of conveyor belt. For a more detailed study of the conveyor belt after realization of experiments it was applied a method of industrial computed tomography.

2.2. Description of the experiment

Laboratory experiment is an appropriate means of determining the shock and tension forces during material impact on a conveyor belt, i.e. for determination, respectively verification of use properties of investigated object – conveyor belt