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Failure analysis of rubber composites under dynamic impact loading by logistic regression

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ABSTRACT

During a belt conveyor operation, conveyor belts (rubber composites) are subjected to various stresses inducing the wear and damage processes. The most frequent damage types are caused by the dynamic stress incurred when the conveyed material falls onto a conveyor belt.

The main objective of the present article is the monitoring of damage to rubber composite materials, particularly in the process of impact loading. Test samples were extracted from conveyor belts of the same type (the same structure) and characterised four various phases of the conveyor belt life cycle (new, stored, worn, renovated). Other input parameters were also changed in laboratory conditions: a drop height and a type of material falling onto a test sample, represented by various impactors of a falling drop hammer. The analysis of the test samples damage significance was carried out while applying the logistic regression method. The result is the estimate of the odds ratio of significant damage to a test sample for individual input variables.

1. Introduction

A belt conveyor system belongs to promising continuous conveyor systems in various industries (mechanical engineering, metallurgy, mining industry, building industry, etc.) characterised with high productivity, economic efficiency, and minimal environmental impact of the transportation of various types of materials and in various conditions of utilisation thereof [1]. Belt conveyors play an important role in the transportation of materials. In general, they are continuously working equipments aimed at ensuring an uninterrupted, smooth material flow.

The most important part of a belt conveyor is a conveyor belt [1]. Each conveyor belt has a time-limited service life determined by the wear of cover layers, a number of punctures, and the level or the extent of other types of damage, deformations, and the loss of functional properties [2]. According to Zur [3], a conveyor belt is the component with the highest probability of failures. These failures are caused by a large number of activities within the manufacture, storage, manipulation, and operation performed during the conveyor belt life cycle.

The experience gained in the operation shows that the consumption of conveyor belts is largely caused particularly by the wear and damage process; it is therefore necessary to understand the regularities occurring in this process. According to [4,5], it is very important to describe the wear process for very intensively stressed rubber products, such as tyres and conveyor belts.

In terms of material modelling of rubber-textile conveyor belts, it is a rubber composite [6,7]. Dobrota and Amza examined the resistance of composite materials extracted from various types of conveyor belts with textile plies [8]. Aramid fibres may serves as a

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bumper in a conveyor belt. Their impact on mechanical properties of composites is examined by Hintze et al. [9]. Dushi et al. deals with the fire-resistant rubber properties of conveyor belts [10].

One of the possible approaches to gaining the knowledge of the damage process is testing in laboratory conditions. The first authors who were dealing with conveyor belt wear in laboratory conditions include [11,12,13]. Non-destructive testing of conveyor belt components was dealt with in papers by several authors [14]. Fedorko et al. [15] investigate the applicability of Metrotomography for conveyor belt analysis and condition monitoring.

The research of belt conveyor systems may be carried out while using a wide range of procedures based on simulation or experimental methods. Sarkar et al. [16] make studies on adhesion between the rubber and the fabric and between the rubber and the rubber in a heat-resistant conveyor belt. Mazurkiewicz [17,18] presents the results of the laboratory tests of the physical elongation and strength of typical adhesive-sealed joints of conveyor belts. Gondek et al. [19] deals with the impact bars that significantly increase the resistance of the conveyor belts againts puncture.

Conveyor belt damage was also dealt with by [11,17,18,20,21,22,23,24]. The methodology of testing conveyor belts, especially their service life affected by the wear of cover layers, is discussed by authors [13,25,26]. The analysis of the conveyor belt wear in terms of impact loading in the interaction between a support system and a conveyor belt was described in papers by [12,25,27].

Conveyor belt damage has far-reaching consequences for users. One of the potential approaches of gaining the knowledge of the damage process is testing in laboratory conditions. This article presents the results of the rubber-textile conveyor belt damage occurrence; the evaluation of the experimental research results was carried out while applying mathematical and statistical methods.

2. Material and methods

2.1. Conveyor belt as a rubber composite

A conveyor belt is a closed component circulating around terminal drums; when circulating, it conveys materials or persons along the conveyance length and also serves as a pulling component and transfers all resistances incurring when the belt moves. The most frequently used conveyor belts include rubber-textile conveyor belts.

In terms of the material modelling of the rubber-textile conveyor belts, it is a rubber composite (Fig. 1); the main structural components thereof is a carcass (textile, steel) and cover layers, the thickness of which is also affected by the properties of the transported material.

A carcass serves for the transfer of traction forces from a pulley to a conveyor belt. A carcass ensures that a conveyor belt has the necessary strength and puncture resistance and serves also for the transfer of forces. It may be defined as a multi-component part of a conveyor belt joined with elastic material that joins individual components and distributes the energy when a conveyor belt is in the operation. A carcass may be made of textile or steel. A carcass of a rubber-textile conveyor belt consists of one or more textile plies, i.e. impregnated fabrics of required strength parameters.

A top cover layer and the edge protect the carcass against mechanical damage caused by the conveyed material, against moisture, chemical and thermal conditions affecting a conveyor belt. A bottom cover layer protects the carcass against negative effects of pulleys and idlers with which it comes into contact. Some conveyor belts have a bumper to increase the puncture resistance.

2.2. Experiment execution

The experiment was carried out using the testing equipment intended (Fig. 2, Fig.3), facilitating the simulation of a material fall onto the conveyor belt. This equipment developed at the Logistics Institute at the Technical University in Kosice. The place where the material impacts the belt was supported by an idler set.

The experiment was carried out using the samples from the same manufacturer and with the same conveyor belt structure. The samples were extracted from a new, stored, worn, and renovated rubber-textile conveyor belts P 2500/4 with the strengths of 2500 $N\cdot m^{-1}$ and four component textile-polyamide plies.

- A new conveyor belt has never been used in the operation; it was taken directly from the plant.
- A stored conveyor belt has never been used in the operation, but it was stored for the period of 24 months. The storage was carried out while respecting the applicable standards.

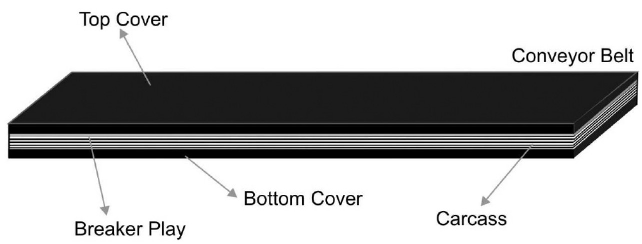

Fig. 1. Rubber composite (conveyor belt).

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