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MATHEMATICAL MODELING OF THE BEGINNING OF DELAMINATION AT RUBBER CONVEYOR BELTS

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Abstract

Nowadays, conveyor belt has become an irreplaceable part in almost all areas in both light and heavy industry. Qualitative and reliable conveyor allows continuous operation of the conveyor system and increases the efficiency of the entire production process. Rubber conveyor belts may contain a steel core (steel cables) or multiple layers of rubber and canvas (carcass). One of the most common causes of failure and main issues in the use and maintenance of rubber conveyor belts with carcass is delamination. In this paper mathematical model for prediction of time until delamination begins was presented. Model was developed based on the exploitation data. Developed model as input parameters uses the length of the conveyor belt and the number of layers.

Keywords*: rubber conveyor belt, delamination, prediction, mathematical modeling.*

1 INTRODUCTION

Material handling is an important sector of industry, which is consuming a considerable proportion of the total power supply. Belt conveyors are being employed to form the most important parts of material handling systems because of their high efficiency of transportation. It is significant to reduce the energy consumption or energy cost of material handling sector [1].A belt conveyor has become an irreplaceable part in almost all areas in both light and heavy industry (cement, brick, foundry, coke plant, chemical industry, mines, quarries, glass factories, sugar, salt pans, silos, plants for waste recycling, etc.) and it is almost impossible to imagine the production process without them. Qualitative and reliable belt conveyor allows continuous operation of the conveyor system and increases the efficiency of the entire production process.

The overall design of a belt is determined by driving unit requirements and the requirements imposed by the nature and volume of material to be carried. In realising an adequate design, there are a number of parameters which have to be considered and satisfied [2]:

- adequate tensile strength and modulus to transmit the power and to carry the material,
- low elongation at working tension to give minimum take-up requirement,
- good load support and sufficient width to carry the type and volume of load,
- flexibility, both directions, to flex round the pulleys, and transversely, for satisfactory troughing,
- dimensional stability to run straight and not to grow too much in service (low permanent elongation),
- good adhesion between all components to avoid delamination,
- good tear resistance to withstand damage,
- ability to be joined (mechanically or chemically) and be close in loop.

Bulk material transportation requirements have continued to press the belt conveyor industry to carry higher tonnages over longer distances and more diverse routes. In order keep up, significant technology advances have been required in the field of system design, analysis and numerical simulation. The application of traditional components in non-traditional applications requiring horizontal curves and intermediate drives have changed and expanded belt conveyor possibilities [3].

In the literature can be found the various research that are use numerical methods for examination of influence the various factors that affect the conveyor lifetime, and also, to insure reliability and availability of the conveyor belts. Some authors [4] examined the adhesion strength between topping rubber and fabric (nylon 66 and polyester-nylon 66) and cover rubber and topping rubber of heat resistant conveyor belt based on SBR and chlorobutyl rubbers.Komander et al. [5] developed a new method for determining the critical energy and the method of determining the average impact energy takinginto account selected range of belt damages, which more reliably characterize their impact resistance. Other authors [6] conduced the experiments designed to establish the dynamic properties of belting material.Barburski [7] examenedthe effect offabric structure on the mechanical properties of the products of these three productionstages. Also, some authors [1] developed the model based optimization approach to improve the efficiency of belt conveyors at the operationallevel.

Further, failure analyses have been performed as a support tool for identification of conveyor belt damage. Some authors [8] analyzed two typical failure forms of roller and conveyor at the belt conveyor, and described themaintenance methods of prevention and elimination failures to ensure the normal operation of belt conveyor. Other [9] performed failure analysis of belt conveyor damage caused by the fallingmaterial with an application of computer metrotomography.

In this paper, a mathematical model for prediction of time until delamination begins was presented. Model was developed based on the exploitation data. Developed model as input parameters uses the length of the conveyor belt and the number of layers.

2 RUBBER CONVEYOR BELTS WITH CARCASS

Conveyor belts are a commonly used equipment of continuous transport.They have a high efficiency andlarge conveying capacity, simpler construction,small amount of maintenance. Can be achieved at differentdistances, different materials transportation. They are widely used in mining, coal handling system in thermalpower plant and other projects [8].

Conveyor belts are, in most cases, the most cost-effective solution for handling bulk material mass flows over short and medium conveying distances. The belt is a key component of these conveyors and its dynamic characteristics determine the working performance to a great extent. A wide range of different materials: piece, bulk and raw materials (stone, coal, ore, waste, sand, etc.) could be transported by conveyor system. They can transport materials and up to 20 km distance.In the conveyor, as the conveyor belt is traction components, transmit power and motion, and also iscarrying components, support material load.

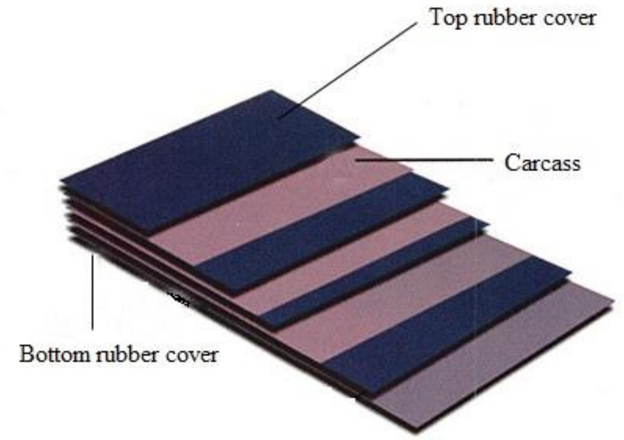

Fig. 1 *Layers in rubber conveyor belt with carcass*

Conveyor belt systems have been significantly developed for decades and are playing a critical role in today's large-scale continuous transport systems. Rubber conveyor belts may contain a steel core or multiple layers of rubber and canvas (carcass) (Fig. 1), while the maximum width of conveyor could be up to 3000 mm. The carcass may consist of several spacers made of synthetic polyamide–polyester fabrics impregnated with a solution of latex that provides an intermediate layer to prevent delamination of the vulcanized composite [7].It is basically a composite material with two distinctly different materials composed orthogonally to achieve both strength in one direction and bending flexibility in the other direction. A number of fabric ply-layers are used in the belt construction [6]. These layers are bonded to the inter-rubber layers and to the covers by a vulcanising process. The fabric material is made up of either polyamide fibers commonly referred to as nylon or polyester.

Rubber conveyor belts are widely used in steel industries for bulk handling of raw materials like coal, coke, iron ore etc., and they need to be highly reliable. Qualitative and reliable conveyor allows continuous operation of the conveyor system and increases the efficiency of the entire production process. Failure of conveyor system can lead to increase the downtime of the plant as well as the maintenance costs.

2.1. Delamination of rubber conveyor belts

Failure of conveyor belt system finds its roots from many causes like poor joints, delamination, weak places in parent belt, belt mis-tracking, idler or pulley wear etc. In most cases, the lifetime of conveyor belt systems is influenced by delamination and wear caused by impact of bulk solid material [9].

Fig. 2 *Edge delamination at rubber conveyor belts*

The delamination is the separation of the rubber covers and the carcass, or the separation of the carcass plies at the edge of the belt (Fig. 2). The rubber covers on the top and bottom of the belt act as the barrier between the heat source and the carcass. The carcass consists of layers of fabric (usually polyester and nylon), bonded together by thin layers of rubber. The effectiveness of the heat-resistant rubber covers is the most crucial factor that determines the length of the belt's working life. If the core temperature of the carcass becomes too high then the belt will start to fall apart. This delamination process also occurs between the covers and the carcass. An increase of only 10˚C in the core temperature of the belt carcass can reduce the life of the belt by as much as 50%. Knowledge of physical, mainly mechanical, properties of conveyor belt rubbers belongs to important preconditions of trouble-free operation of conveyor belt transportation.

3 MATHEMATICAL MODEL FOR PREDICTION OF THE BEGINNING OF DELAMINATION AT RUBBER CONVEYOR BELTS

In order to develope mathematical model for prediction of delamination at rubber conveyor belts, a set of 84 explatation data from mining industry was used. The data set consisted of exploitation data of conveyor belts: length (50, 100 and 200 m) and the number of conveyor belts layers (3 to 7 layers), and the operating time (in months) when the delamination occured.

For the mathematical modeling of the measuring data, an arbitrary function was chosen, as shown in Eq. 1.

$$\tau_{est} = f(j, n), \tag{1}$$

with the length of conveyor l in meters and the number of layers $n$as influential factors, while the unit τ_{est}, is representing the estimated time in months τ until the beginning of delamination.

The input data were first averaged for each category (the number of layers and length) and after the averaging, the fitting was done. The fitting was done on the basis of the Least square method and the following equation was obtained (Eq. 2).

$$\tau = 7.33 l^{0.017+0.185/n} \tag{2}$$

with the R^2 value of 0.7 (Fig. 3). The relatively low value of regression could be explained by the relatively high value of scattering of the input data, which was up to 15% in the respect to the averaged data.

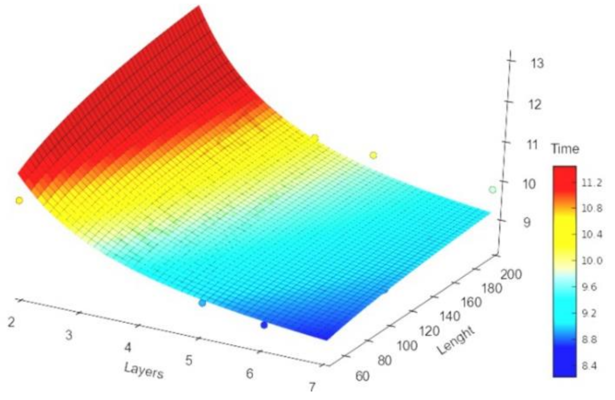

Fig. 3 *The results of fitting*

The error of the model was determined on the basis of comparison between the randomly chosen experimental data and the results of the obtained function. The comparison showed that the largest error (ε) amounts 13.30% and it was adopted as the error of the model (Tab. 1).

Table 1 The validation of the obtained function

n	l	τ	$\tau_{est.}$	ε
4	100	10.5	9.81	6.57%
3	50	11.5	9.97	13.30%
4	50	10.6	9.39	11.42%
7	100	9	9.44	4.89%
2	100	12	12.13	1.08%

4 RESULTS AND DISCUSSION

The results obtained by mathematical modeling show, according to the Eq. 2, that with the number of layers increasing,the time of the delamination asymptotically tends to the value shown in Eq. 3:

$$\tau = 7.33 l^{0.017} \tag{3}$$

On the other hand, the length of the conveyer belts has far less influence on the delamination time, because of the very small value of the power, i.e.

$$0.017 + \frac{0.185}{n} \ll 1 \tag{4}$$

Comparing the data obtained by mathematical model with the available data gives the deviation less than 15%, with most of deviation below 10%, which represents a satisfactory accuracy.

The developed mathematical model showes that the beginning of delamination significantly reduced with the increase of layers numbers, while the length of the conveyor belt has a less influence on the reduction of beginning of delamination.

The negative impact of number of layers to conveyor belt lifetime could be reduced with adhesion strength between rubber and fabric layers enhancement by using of different types of fabric [4].

5 CONCLUSION

Nowdays, conveyor belts are indispensable parts of all modern industry systems. Qualitative and reliable conveyor allows continuous operation of the conveyor system and increases the efficiency of the entire production process. Failure of conveyor system can lead to increase the downtime of the plant as well as the maintenance costs. Failure of conveyor belt system finds its roots from many causes like poor joints, delamination, weak places in parent belt, belt mis-tracking, idler or pulley wear etc.

Mathematical model for prediction of time until delamination begins was developed based on the exploitation data. Developed model as input parameters uses the length of the conveyor belt and the number of layers.

Comparing the data obtained by mathematical model with the available data gives the deviation less than 15%, with most of deviation below 10%, which represents a satisfactory accuracy. Based on the developed mathematical model it can be conclude that the beginning of delamination significantly reduced with the increase of layers numbers, while the length of the conveyor belt has a less influence on the reduction of beginning of delamination.

Thus developed model can be used in the control and maintenance of conveyor belts.

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