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ON THE POSSIBILITIES OF EVALUATING BREAKDOWN CONVEYER BELT TESTS AND MEASUREMENT PROCESS METHODOLOGY OPTIMIZATION

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ABSTRACT:
Manufacturers and customers of conveyor belts are mostly interested in a very important property of belts, which is the resistance against breakdowns. Belt impairment through breakdowns leads to its gradual destruction and thereby to significant economic losses. Therefore, it is in manufacturers interest to produce and customer`s interest to buy conveyor belts, with as high as possible resistance against breakdowns. In this paper, we suggest a methodology, which may be used for conveyor belt testing with regard to the evaluation of its resistance against breakdowns. Further on, the proposed methodology may be used for evaluation of possible associations between parameters important for conveyor belt breakdowns. Not least, we propose an optimization methodology of the measurement process, with regard to the minimalization of costs.

KEYWORDS:
conveyor belt, breakdown, testing, optimization, approximation

1. INTRODUCTION

One of the methods for testing is an impact test on laboratory instruments. Performing these tests in laboratory environment provides large amount of important information also useful for practice.

Few years ago a testing device for impact tests of conveyor breakdowns was designed and constructed on the Department of logistics and production systems of the Technical University in Košice. The device proceeded throught several innovations. Currently the testing board is equipped with a hydraulic system for fastening a sample of a belt and another hydraulic system is responsible for tightening the sample during tests (see figure 1).

FIGURE 1. Testing board with a hydraulic system

The hydraulics allows better grip and tension of the sample belt, which leads to more relevant results from tests. The construction of the testing equipment is in line with current requirements based on present research as well as on conveyor belt manufacturer`s requirements.

Planned tests are performed using this testing equipment, while measured data are independently processed and evaluated. The evaluation of data is an independent process, which in this paper will be shortly outlined.

FIGURE 2. Spherical head of a ram

2. THE PROCEDURE OF TESTING CONVEYOR BELTS AGAINST BREAKDOWNS

Before conducting tests against breakdowns, following parameters are chosen:

- weight of the ram m – it can be changed in an interval from 50 kg to 100 kg,
- head of the ram – sphere (Fig. 2), pyramid or a cone,
- height of the impact by the ram h – may be changed up to the height 2,6 m,
- the type of the conveyor belt.

The test is used for determination of the conveyors belt resistant against breakdowns. The test may be realized without using bulkhead system, a savoir without roller bench or with roller bench. By using the different heads mentioned above, we can simulate various types of impinging materials. From the conveyer belt a sample is engraved with a length of 1,2 m - 1,4 m and a width in an interval of 0,4 m - 0,6 m.

Testing procedure:

- The conveyor belt is hardened on the both ends into hydraulically operated jaws.
- By the means of hydraulic equipment we stretch the belt to the strength of 1/10 of its maximum firmness defined by its manufacturer.
- The ram with a defined weight is raised using a tackle on a desired height, from which it is released as a free-fall right onto the conveyor belt.

FIGURE3. Modul MCP3

During testing the stretching and impact forces are measured by the means of two strain-gauge sensors and a module MCP3 (Fig. 3). A cycle lasts for 10 s and it is possible to acquire almost 20 000 values for the stretching and impact forces in k_N. The output of a software, which is processing the recorded data is a text file, which contains the serial number of the record in the frame of the before mentioned 10 seconds and the magnitude of both forces. In the measurement module MCP3 some filters are available, using which we can set up the number of records per 1 second. At the end of the test the ram is lifted up and assured against possible free-falls, and then the evaluation or manipulation with the conveyor belt is done.

Test results:

The evaluation for possible breakdowns of a conveyor belt rests in a visual control of the conveyor belt. While from the records it is possible to state, what is stretch force F_N and impact force F_R when the breakdown occurred. When a mathematical – physical model is build, the recorded data is processed into tables and graphs (Fig. 4), where the output consists of all interested associations affecting testing results. From the recorded data it is possible to find maximum of attained impact force and the length of the impact measured in milliseconds.

Preliminary results processed by the means of software like Excel and Matlab show a strong correlation between stretch force F_N impact force F_R (Fig.5). Correlation between these two forces may be expressed with an equation:

$$corr\left(F_N, F_R\right) = corr\left(x, y\right) = \frac{k_{xy}}{s_x s_y} \tag{1}$$

while to covariance k_{xy} between variables x, y is expressed as:

$$k_{xy} = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right) \tag{2}$$

and sample standard deviations s_x and s_y are:

$$s_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \tag{3}$$

and

$$s_y = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2}\ , \tag{4}$$

where $\bar{x}$ and $\bar{y}$ are arithmetical means of these variables.

Correlation values for forces F_N a F_R are in interval ⟨0,9891; 0,9915⟩, which suggests linear relationship between both of them. This implies the methodology for valuing results from a mathematical-statistical processing of measured data, from which a functional relationship f may be derived for only impact force or a stretch force F_N as a function of all involved parameters.

The most general form, for all types of conveyor belts and all types of ram heads is:

$$F_R = f\left(m,h\right) \text{or } F_n = f\left(m,h\right). \tag{5}$$

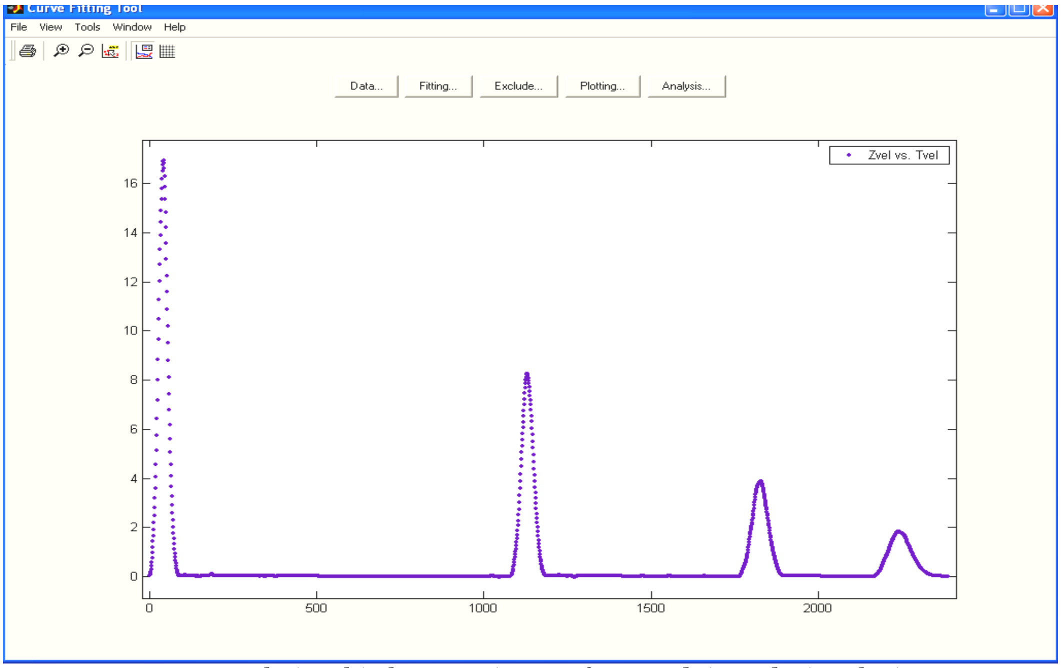

FIGURE4. Relationship between impact force and time, during the impact

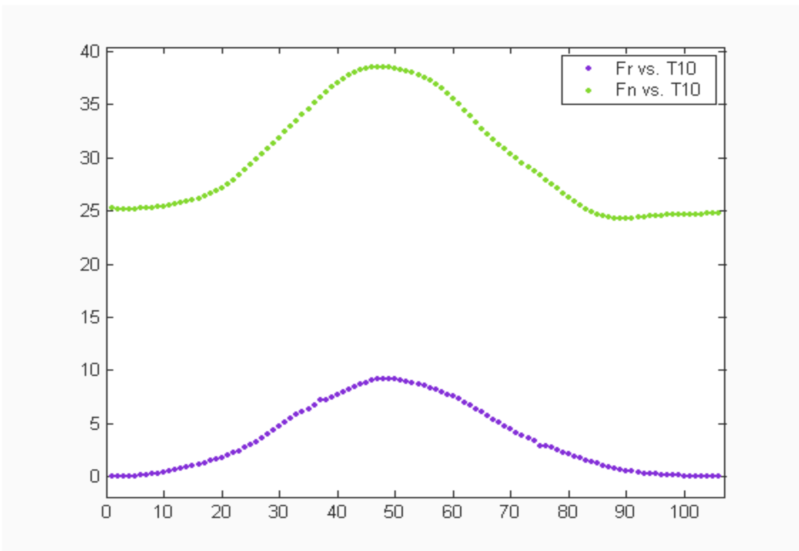

FIGURE 5. Relation between impact force (blue) and stretch force (green) with time

For expressing such a relationship we can use various techniques. One of the easiest techniques is to find a suitable approximation by the means of a regression analysis and testing the validity of this model for a mathematical model. Another technique is to use an iteration progression, which is used in other industries and researches, during which it is possible to use already known practices, which were published in [9, 10, 11, 12].

Other optimization possibilities for measurement process:

By the measurement process pre-test settings on the testing equipment are performed. These setting are coupled with some operations, which from the time consuming perspective can significantly slow down the whole process. Therefore, it is useful to design measurement plans, which will minimize time losses for individual measurements and also which will minimize financial losses, which can originate from material assurance for various measurement procedures for conveyor belts. One of the possibilities is to create a network (graph) of time requirements for various measurements and time transitions between individual settings of the measurement equipment. In this graph, it is very important to create ties (edges) between vertexes (i.e. to define, where the edge will and where won`t be). Then it is important to correctly value each of the edges. Valuing edges may be done according to direct measurements and experience, which had been acquired by the operation of the equipment, or the values may be obtained from a statistical analyses of data, for example using Six Sigma methodology [7].

The Six Sigma method is the basis of the method is the cycle of improvement DMAIC (define-measure-analyze-improve-control), by which it is possible to link very effectively more complex statistical tools into one mutually interconnected unit. This way a synergic effect is induced by exact outputs of individual statistical tools. It was practically verified, that simple implementation of basic mathematical statistic does not provide acceptable results in practical conditions. It is therefore necessary to modify individual methods so that they modeled real situation of given process. The Six Sigma employs following tools:

- Process map - describes process from the point of view of quality, costs, time, responsibility and illustrates the information flow through given process.
- DMAIC - method for improvement of processes and reduction of their variability by consecutive steps.
- IPO diagram - describes inputs into the process and controls of the process's outputs.
- CE diagnostics - diagram of cause and effect, solving problems by discovering their causes. Looking for the causes, their sorting into categories, determining their effect on the output and finding out the possibilities for improvement of the processes.
- Histogram - is a suitable tool for visualization of frequency of occurrence of the followed phenomenon in the process. It contains tolerance limits defining process capability.
- Pareto diagram - shows frequency of occurrence of non-numerical data and enables to determine the effect of input factors on the observed parameter.
- Regulation chart - is a process control tool, which helps to distinguish random and extreme causes of variability thus helping to reduce the variability of the whole process.
- Correlation diagram - indicates mutual dependency of two parameters and determines their interrelation - correlation.
- Regression analysis - enables to observe the relations of two or more process parameters and helps to predict behavior of observed quantities.
- FMEA - analysis of possible failure and their effects helps identify, analyze and determine priorities of possible causes of process failure with aim to evaluate risks connected with failure outcome.
- DOE - is design of experiment, which effectively evaluates relation of two or more inputs to one output. Helps identify and quantify results of inputs changes at the output.

- FTA analysis - failure tree analysis enables failure decomposition by which it is possible to observe whole problem.

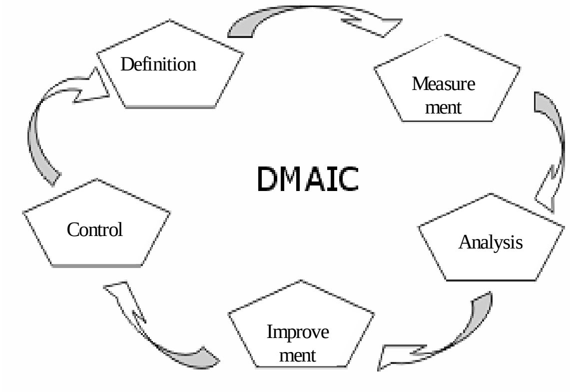

FIGURE 6. Cycle of quality improvement

The concept of the project is based on DMAIC cycle (Fig. 6) by means of which problems of the process are defined in the first place and then objectives to reach during the process are set.

Then value functions are designed, using which we will search an optimum. The most widely used function for this kind of optimization are:

$$S(e) = \sum_{e \in E \cap D} w(e) \text{ or } B(e) = \max_{e \in E \cap D} w(e) \qquad (6)$$

If we would also create categories, which may for example represent stages of the measurement process, than we could use the modified value functions, like for example:

$$L_1(e) = \sum_{i=1}^{p} \max_{e \in S_i \cap D} w(e),$$

$$L_2(e) = \max_{i=1,\dots,p} \sum_{e \in S_i \cap D} w(e)$$

or

$$L_3(e) = \max_{i=1,\dots,p} \sum_{e \in S_i \cap D} w(e) - \min_{i=1,\dots,p} \sum_{e \in S_i \cap D} w(e) \quad (6)$$

The issues, complexity and algorithms for solving these value functions may be found in papers [1, 2]. If we can find an optimum solution, than it serves as an effective plan for measuring process on this equipment. In this paper, it is not our intention to describe the technical details surrounding the construction of this kind of optimization problem, because currently, we have not enough data for determining relevant weight for valuing edges.

3. THE CONCLUSIONS

As of the time of writing this paper, impact tests were already done on the before mentioned testing facility. This was due to the need of building a mathematical – physical model, for which the described methodology was successfully used, as it is written in the 2rd section of this paper. In the future, we anticipate the use of technical diagnostics or materiology when judging the inner subversions of bearing stratum of the belt (skeleton), which is by the simple visual inspection not detectable. One of the possibilities to justify the existence of this effect may be the use of measure of extended sample. Concurrently, the resulting measurements are being processed and in the near future, concrete functional associations for the tested types of conveyor-belts with changing ram heads, will be available.

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