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Dynamic Damage of Rubber-Textile Belts in Pipe Conveyor Application

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Rubber-textile conveyor belts and steel-cord conveyor belts are exposed to impacts of various negative factors occurring during the standard operation of belt conveyors, whereas these factors are causing gradual wear of the conveyor belts. The wear-out process of the conveyor belt is a limiting condition, which has a decisive impact on operational life of the conveyor belt with regard to keeping the required operational characteristics within the framework of the given transport equipment operability.

Introduction

Wearing of a conveyor belt is an irreversible process without any possibility to avoid it within the operation of a belt conveyor, i.e. during transport of material using the belt conveyors. In general, it is possible to say that the irreversible changes, arising inside of the conveyor belt, are caused by physical, chemical, and biological influences.

A simultaneous acting of these three factors causes aging of the upper and bottom cover of the conveyor belt. Degradation of the conveyor belt rubber parts due to chemical or physical-chemical acting is called corrosion. The corrosion process can be accelerated in consequence of sunshine or temperature.

Undesirable modification of chemical characteristics in some of conveyor belt parts is another negative process, which is called degradation.

The matter of conveyor belt wear is a specific research area, which is interesting both for producers and users of the conveyor belts. The conveyor belt manufacturers are applying various procedures in order to increase the conveyor belt durability [1]. There are applied special additives that are able to eliminate or to slow down significantly the individual undesirable processes. The applied additives are, for example, the antioxidants, antiozonants, UV-absorbers, stabilizers etc. The users of conveyor belts are trying to minimise the conveyor belt wearing by a maintenance system.

The main task of such maintenance system is to provide operational conditions that are able to keep the wear-out process on an acceptable level [2,3]. However, it is necessary to dispose of a large amount of information in order to apply an efficient maintenance system. The required sum of information is necessary for evaluation of the conveyor belt operational conditions or for warning against initialisation of possible undesirable processes [4].In this way, the conveyor belt operator will be able to undertake adequate measures in order to stop or to reduce development of the undesirable processes up to the acceptable level [5].

The above-mentioned questions are relevant for all types of conveyor belts, regardless of the conveyor belt construction, kind of the transported material or operational life [6,7]. However, there are possible also specific unfavourable operational states, which are occurring only in the case of a certain type of the belt conveyor and for other types of the belt conveyors they are almost negligible. A specific wear-out process is typical for a modern and innovative kind of the continuous conveying systems, namely for the pipe conveyors.

Conveyor Belts in Pipe Conveyors

The rubber-textile conveyor belts are used for installation in the pipe conveyors much more than steel-cord conveyor belts. The rubber-textile conveyor belts are suitable for most of the pipe conveyor installations with regard to the strength conditions during the pipe conveyor operation as well as with regard to other circumstances. The conveyor belts installed in pipe conveyors are subjected not only to an influence of the transported material, but they are also exposed to a specific loading, which is caused by a cyclic process of the conveyor belt closing into the piped shape and following opening of it into the flat shape. Important factors are also influences of the operational conditions, quality of maintenance, etc. All these facts are able to cause various damage of the conveyor belt gradually (Fig. 1).

Fig. 1. Example of damage on edge of the pipe conveyor belt. (Pictures: © Technical University of Košice)

Another possible negative phenomenon, which is occurring within the pipe conveyor operation, is such situation when the rubber-textile conveyor belt does not have a full or stable contact with all six idler rolls situated in the hexagonal idler housing (Fig. 2). This unfavourable situation is occurring in the straight sections of the pipe conveyor trajectory as well as in the sections curved horizontally and vertically. The negative result of this situation is a deformed shape of the conveyor belt cross-section, i.e. the flattened or even flat shape of the belt cross-section what means that the conveyor belt does not have the required dynamic properties and is damaged dynamically. The final result of this undesirable situation is a local increasing of intensity of the conveyor belt wear-out process, which causes a damage of the belt cover layers, higher motional resistances and a possibility of material spillage along the conveying trajectory, as well. All these facts are resulting in undesirable technical and economical consequences for pipe conveyor operator or user.

Fig. 2. Example of situation when the conveyor belt does not have a contact with all idler rolls in the hexagonal idler housing.

A special analysis was elaborated within the framework of the given investigation process in order to describe the above-mentioned undesirable behaviour of the conveyor belt and to observe changes occurring in the belt internal construction.

Characteristics of Rubber-Textile Pipe Conveyor Belt with Dynamic Damage

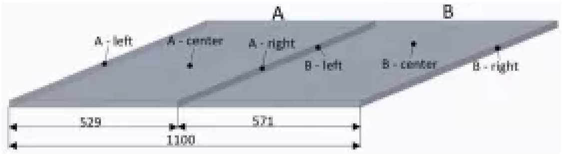

Fig. 3. Designation of the testing sample chosen from the pipe conveyor belt.

In order to investigate the individual mechanical characteristics of the rubber-textile conveyor belt, which was damaged dynamically, a set of measurements was performed within the framework of the investigation process, whereas some of the measured values were compared with a reference sample, i.e. a sample without a dynamic damage. The sample of the analysed conveyor belt was divided into two parts (due to a transport possibility), which are marked A and B (Fig. 3). The first measurement was specified for determination of the belt tensile strength measured in the longitudinal direction (R_m), belt expansibility measured in the longitudinal direction (R_e) and relative elongation at the permissible tension level (σ) according to the standard STN ISO EN 283 – 1.

There were not recorded any relevant differences among the individual parts of the analysed rubber-textile conveyor belt with regard to the obtained values of the above-mentioned measured mechanical characteristics (Table 1).

Table 1: Belt mechanical characteristics

	A Left	**A right**	**B left**	**B right**
R_m [N/mm]	1332	1336	1340	1342
R_e [%]	16	16	16	16
σ [%]	0.8	1.0	0.9	0.8

The second measured set was oriented towards determination of the next mechanical characteristics: the elastic elongation (l_p), plastic (durable) elongation (t_t) and modulus of elasticity ε for individual parts of the investigated conveyor belt (Table 2).

Table 2: Belt next technical characteristics.

	A left	A center	A right	B left	B center	B right
I $_{\mathbf{p}}$ **[%]**	0.5	0.4	0.3	0.4	0.3	0.4
t $_{\mathbf{t}}$ **[%]**	0.7	0.5	0.5	0.6	0.6	0.6
0.6	13889	18519	20000	17241	17857	17241

There are visible, according to the results summarised in Table 2, considerable differences among the individual measured values, in particular among the individual values of the modulus of elasticity measured on the testing specimens separated from the various parts of the analysed conveyor belt sample. From this reason as well as with regard to the requirements of the following analysis there was performed the same set of measurements, but this time using the referential testing specimens, which were separated from a sample of the unused rubber-textile conveyor belt with the identical internal construction. The results from this measurement are summarised in Table 3.

Table 3: Measurement results.

	left	center	right
I $_{\mathbf{p}}$ **[%]**	0.8	0.8	0.8
t $_{\mathbf{t}}$ **[%]**	0.5	0.6	0.5
ε [n/mm]	12820	11905	12195

The results obtained from the comparative measurement confirmed a primary assumption concerning the modulus of elasticity values. The differences among the modulus of elasticity values, which were measured on three testing specimens extracted from margins and from middle of the comparative sample, are negligible. However, the differences among the modulus of elasticity values measured on the testing specimens separated from the sample of rubber-textile conveyor belt, which was damaged dynamically, are considerable.

Another type of test, which was performed first on the analysed sample of the conveyor belt and afterwards on the comparative sample, was the test of conveyor belt troughability (Table 4).

Table 4: Conveyor trough ability test results.

	Sample A	Sample B	Comparative sample
Troughability [-]	0.206	0.235	0.335

The results obtained from the troughability test of the conveyor belt present differences between the analysed and comparative sample of the conveyor belt. However, if there is taken into consideration a fact that the analysed sample was divided into two parts and the comparative part was solid, it is possible to discount these results.

The last set of the performed tests was measuring of adhesive strength among the individual constructional components of the analysed and comparative sample of the conveyor belt. The measured data did not demonstrate any significant contradictions among the compared values obtained from the individual measured samples.

According to the results obtained from the experimental measurements it was elaborated analysis by means of a computational or simulation model using the FEM-procedure based on the Abaqus software tool utilization.

FEM Model of a Dynamically Damaged Conveyor Belt

The experimentally obtained results established a database for the development and application of a computational model in order to realise the FEM-analysis. Geometry of this model is visible in Fig. 4. Realisation of this computational model required application of a pre-processor, which is a basic part of the software Abaqus. Three idler housings with an offset arrangement of the guiding idlers were simulated within the framework of the computational model geometry.

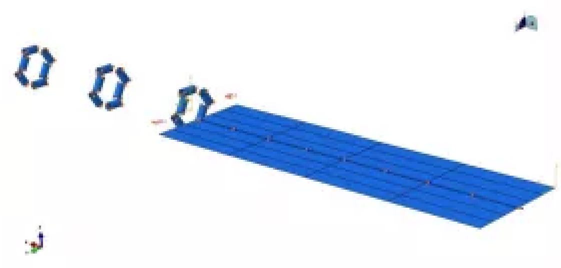

Fig. 4. Geometrical model created using the software CAE Abaqus.

Model of the conveyor belt was divided into the six axial parts taking into consideration the results obtained experimentally from the analysed sample. The six-parts division was selected in order the conveyor belt model could contain six zones with various modulus of elasticity values in accordance with the results obtained from the individual experimental measurements specified for modulus of elasticity determination. The given zones are characterised by the same modulus of elasticity values in transversal direction as well as by the equal material density values, while in longitudinal direction the individual modulus of elasticity values are different in each of zones.

The boundary conditions are defined in such a way that each of the guiding rolls has removed all degrees of freedom. The conveyor belt has removed three degrees of freedom in the middle in all directions except of longitudinal direction. This arrangement enables to do the required shift of the conveyor belt into the correct position in the idler housing within the framework of the calculation process.

Margins of the conveyor belt are bound by means of two referential points and there are situated the auxiliary torques in these referential points in order to form the piped shape of the conveyor belt. Another loading of the conveyor belt represented the gravity force and tensional force. The finite element mesh was assembled using the finite elements of the type Shell with the global contact function defined between the individual contact pairs.

The first part of the computational process was forming of the conveyor belt into the pipe shape by means of the above-mentioned auxiliary torques. Afterwards the pipe-shaped belt was positioned properly into the hexagonal idler housing using the required shifting. Further, the conveyor belt was released after removing of the auxiliary torques so that the belt came into a contact with the forming idlers. Finally, the analysed sample was loaded by the gravity force and tensioning force.

Computational Results

The above-described model was applied for two computational procedures. The first computational process was realised with the different modulus of elasticity values in longitudinal direction in the divided six axial zones. The second computational process used the constant modulus of elasticity values in longitudinal direction in all six zones. All other material constants and boundary conditions remained the same for both computations. The main purpose of this methodology was a comparison of the obtained results in order to discover changes in distribution of the stress-deformation relations in both computational models.

The next figures (Figs. 5, 6) illustrate the calculated distribution of the stress fields in the conveyor belt with a dynamic damage on internal and external side of the pipe conveyor belt in any place of a straight section in conveying trajectory.

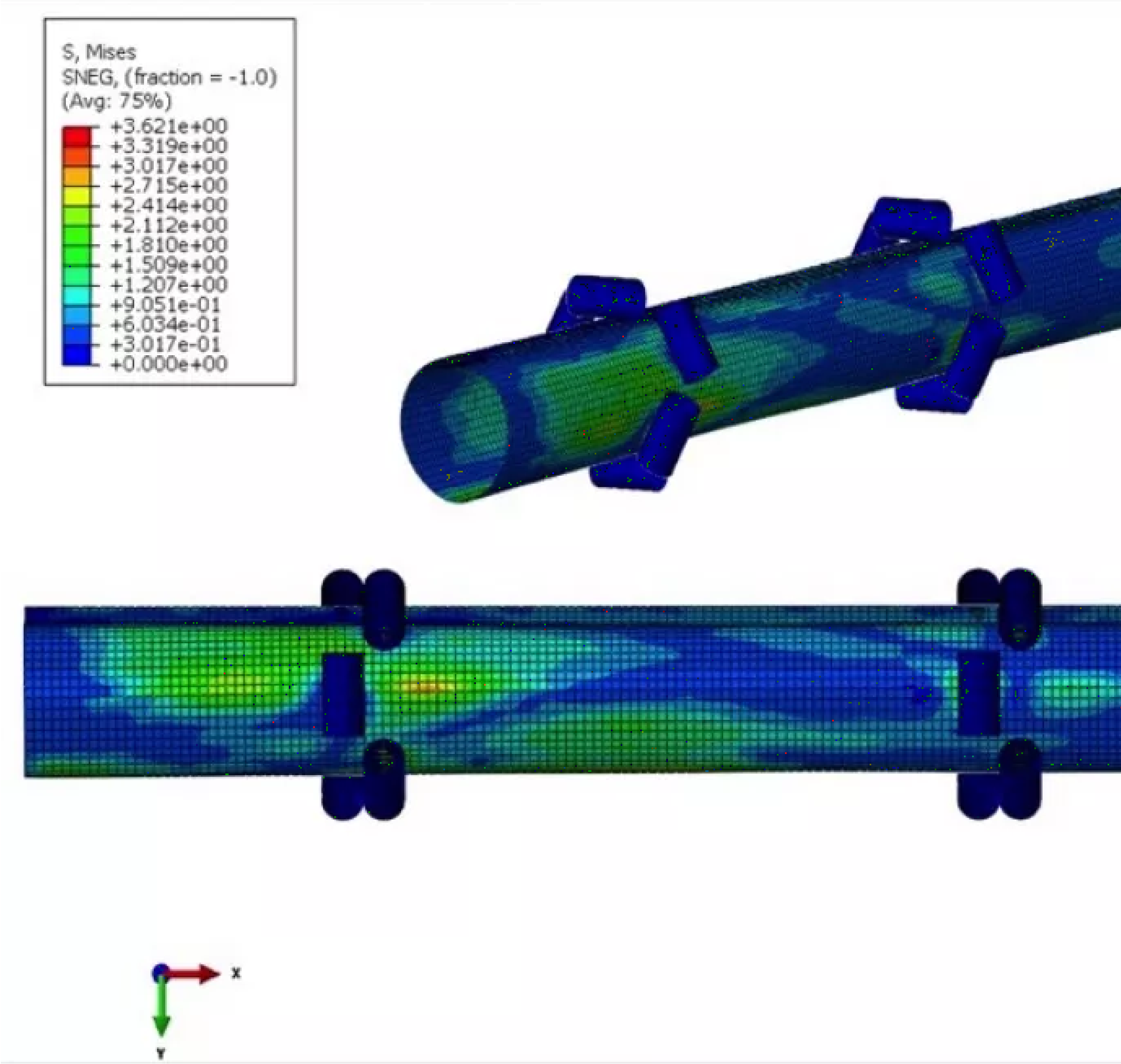

Fig. 5. Distribution of the resulting stress fields in the pipe-shaped conveyor belt.

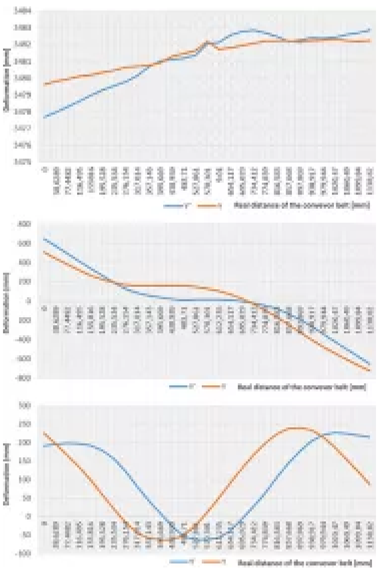

Fig. 7. Graphs of conveyor belt deformations for the belt with the dynamic damage Y and without dynamic damage Y´ in direction of the axes X, Y, Z.

The graphs in Fig. 7 describe the partial values of deformations in the case of pipe-shaped belt in direction of the axes x, y, z. The graphs are recording the values obtained from both computational examples. The graphs show significant differences in the calculated results between the model of conveyor belt, which is damaged dynamically and the model of undamaged conveyor belt. It is possible to say according to the obtained results that if the belt is damaged dynamically, it is formed in the idler housing otherwise than it should be, in comparison with the undamaged belt. The contact points between the belt and forming idlers in the hexagonal idler housing are also different for both types of the conveyor belts.

Conclusion

The results obtained from the experimental measurements and from the FEM computations confirm the primary assumption, which was considered before beginning of the investigative process. The non-standard behaviour of the pipe conveyor belt can be clarified by a divergence of the belt material characteristics and the resulting consequence is a loss of contact between the conveyor belt and guiding rolls in the idler housings as well as flattened shape of the belt. One of the possible undesirable consequences of such situation is a spillage of the transported material along the conveying trajectory. Another operational aspects of the deformed conveyor belt (e.g. motional resistances, wear of belt constructional parts) will be investigated in terms of the next, more detailed research work.

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