FEA UTILIZATION FOR STUDY OF THE CONVEYOR BELTS PROPERTIES IN THE CONTEXT OF INTERNAL LOGISTICS SYSTEMS

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Abstract

Belt conveyors are used in numerous in-house logistics systems. It is necessary to know properties of these conveyor belts for their effective functioning. This work is focused on research forces applied in conveyor belt during contact with rollers and reversing drum according to the different material properties of conveyor belt. For this purpose was created simulation computational model by Abaqus. Effects of the material properties on the forces in the longitudinal and transverse directions were studied by this model. In the model were observed correlation between material properties of the conveyor belt and its tension-strain states in place of the first and second roller stool, at the site of reverse drum and places of troughing transformation of conveyor belt.

Keywords: Conveyor belt, troughing distance, tension, deformation, trough

1. INTRODUCTION

Bulk material transportation requirements are pressed to carry higher tonnages over longer distances and more diverse routes. The major equipments for high tonnages bulk material transportation are trough belt conveyors [1]. For these conveyors it occur largest tension forces at the head end and tail end of belt conveyors. Therefore it is important to understand the dynamics of conveyor belt in this area and the tools that are used today for their design [2]. In this paper you can see model of belt conveyor tail end used to simulate tension and deformation forces related to different material properties of conveyor belt by finite element method. There were created correlations between conveyor belt material prosperities and tension forces in selected areas. Knowledge of these correlations enables detailed design of conveyor systems in the optimization of logistics systems.

2. TAIL END OF BELT CONVEYOR

Pulley at tail end of belt conveyor can by located at the site of the embankment or discharge station. To ensure the tension they are stored in the sliding axle boxes. At discharge station can by use more than one pulley. Snub or bend pulleys can by add to ensure bigger wrap angel. Recommended pulley diameters for tail end or head end are indicated by manufacturers of certain conveyor belts. If pulley diameter is too small proof strength of the external fiber can be exceeded and lead to the fold of these fibers. At the same time it can also compress the inner fiber and cause severe separation of several layers (**Fig. 1**) [3], [4].

AT the discharging station there is an extraction of the trough-shaped conveyor belt into a horizontal form, followed by rotation of the belt in the cross direction by reversing pulley. At the same place it discharges material that creates pressure on conveyor belt. The size of this pressure is determined by the weight of the transported material. Under the influence of these movements and pressure occur reaction forces, that conveyor belt strain on the traction, compression and bending at the same time, so there are changes in tension and deformation state of the conveyor belt. These reaction forces are captured by belt carcass that represents his head and functionally the most important part. It also is the most expensive part of the conveyor therefore is protected rubberized protective layer. The mere belt carcass is made up by textile fabric or steel cords. Belt carcass should have a structure in which it reliably torque reaction forces in the direction of the axis of the belt because it is in this respect most active force. A force in a horizontal plane perpendicular to the conveyor is below one third of main reaction forces. Textile plies strength in the conveyor belt has the same ratio. Flexibility and belt deformation is significantly reflected in the long-distance belt transport and are caused by a transmission of operational forces [5].

The belt edges are stretched during belt transformation from trough shape to horizontal shape, which increases the tension on these edges. If tension at the edge exceeds the elastic limit frame, the belt edges is stretched and permanently cause difficulties with conveyor belt behaviour. On other hand if this tension isn´t big enough may occur spills of material before it reaches reversing pulley. When designing conveyor systems is therefore important to use software support and FEA simulation for predicting these stress-deformation forces, which can help to implement a conveyor belt system with optimal material properties [4], [6,7,8,9].

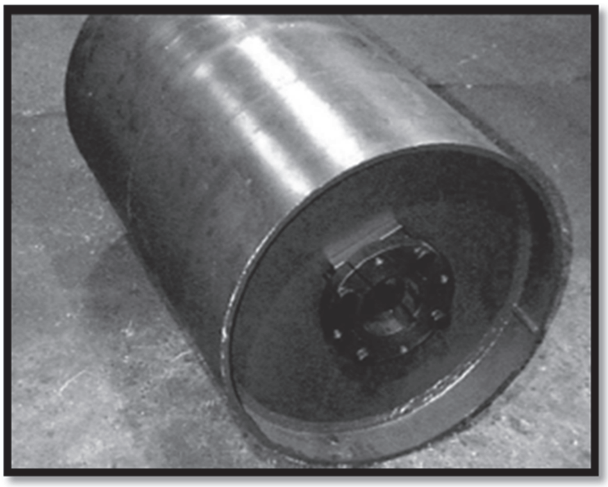

Fig. 1 Drum pulley for belt conveyor [4]

3. CREATION OF CALCULATION MODEL

Calculation model was created to realize FEA simulation of the above-mentioned stress-deformation states. Based on capacity and strength calculation was chosen a conveyor belt with the following parameters:
Belt width B=1000mm,
tensile strength 400 N.mm^{-1}.
belt thickness 4.4 mm,
Weigh 5.3 kg.m^{-1},
tension force T_N = 5301.04 N,
inclination of side idlers 30°,
idler diameter 108 mm
idler length 380 mm
idler spacing (upper limb / lower limb) 1200 mm / 3000 mm.

Abaqus model was then created from the corresponding parameters of a three-roller seat in the upper roller arm, the one roller seats in the lower run, the conveyor belt and the reversing drum (**Fig. 2**).

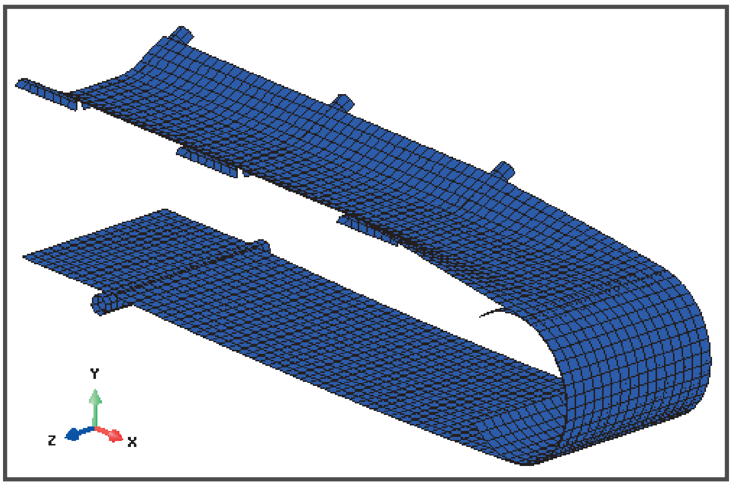

Fig. 2 Final assembly of the conveyor model

4. TENSION AND STRAIN STATES IN MODELED CONVEYOR BELT

In the proposed model were observed correlation between material properties of the conveyor belt and its tension-strain states at the tail end of belt conveyor. The changes in the material properties of the conveyor belt were aimed to density of the conveyor belt, the Young's modulus of elasticity in the longitudinal and transverse directions. Monitored elastic modulus in the longitudinal direction was in the range from E1 = 382 MPa to E1 = 427 MPa and in the transverse direction was defined from E2 = 4.9 MPa to E2 = 8.4 MPa. Range of monitored density was from ρ = 1019 kg.m^{-3} to ρ = 1179 kg.m^{-3}.

4.1. Baseline material prosperities and defining the monitored row

Baseline density for conveyor belt was ρ = 1099 kg.m^{-3}, elastic modulus in the longitudinal direction was E1 = 397 MPa and in the transverse direction E2 = 5.4 MPa. For this baseline model were monitored changes of tension forces on the conveyor belt in the run-up to the return pulley. The progress of these forces and monitored area can be seen at **Fig. 3**. At the **Fig. 3** we can see 20 rows of 20 mm distance from each other. From these rows were gained data that shows tension forces in the area of 400 mm long.

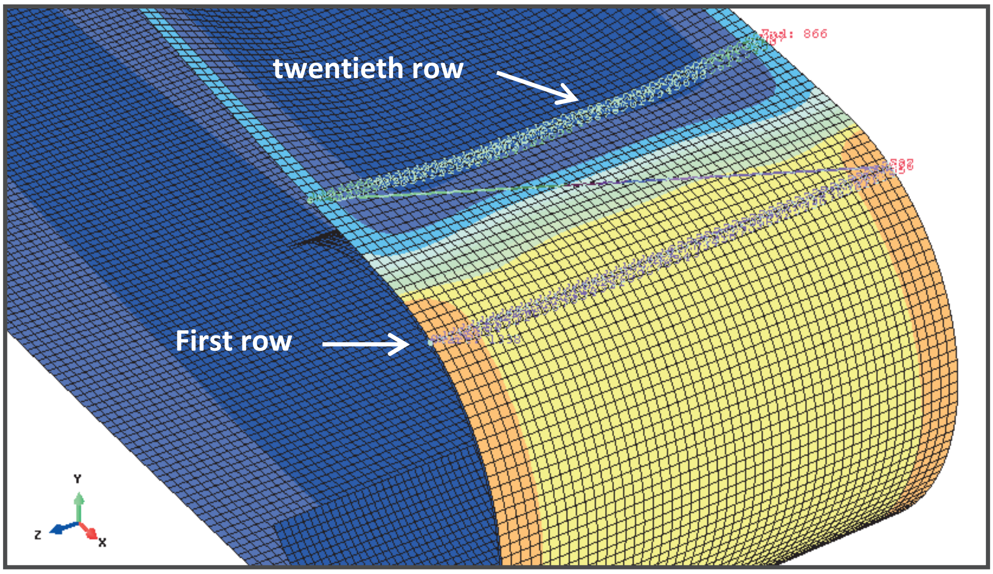

Fig. 3 Monitored area in the belt run-up to the return pulley

In monitored area were biggest tension gained in first row where it is in full contact with return pulley. This force is placed at the edge of this row and is equal 4.1271MPa. Because of that first row was chosen to comparing of different material properties of conveyor belt.

4.2. First row in the belt run-up to the return pulley

First comparison was focused on Young´s modulus in X axis (E1). Range of this modulus were from E1 = 397 MPa to E1 = 427 MPa. Young´s modulus in Y axis was E2 = 5.4 MPa and density ρ = 1099 kg.m^{-3}. The record indicates that with increasing modulus also increases tension in the conveyor belt (**Fig. 4**). The largest values were therefore determined at the biggest monitored young´s modulus E1 = 427 MPa with value 4.399 MPa at the edge of the belt. You can see linear dependence in the correlation graph (**Fig. 5**).

Second comparison was focused on Young´s modulus in Y axis (E2). Range of this modulus were from E2 = 4.9 MPa to E2 = 8.4 MPa. Young´s modulus in X axis was E1 = 397 MPa and density ρ = 1099 kg.m^{-3}. Graph in the Fig. 6 shows growing fluctuations of tension in conveyor belt. The occurrence of these tension fluctuations increases with increasing Young´s modulus in Y axis.

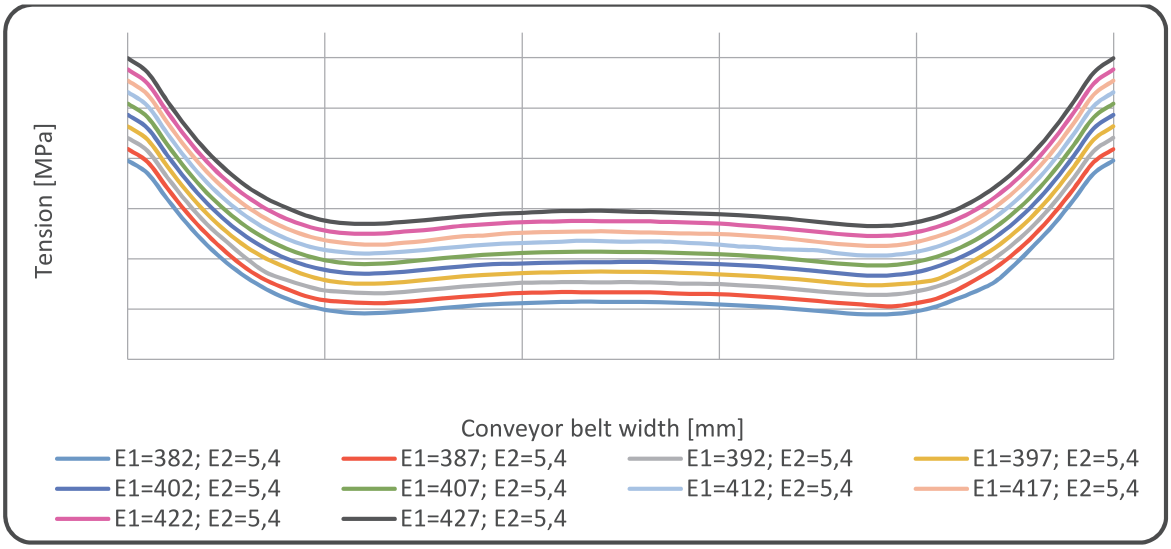

Fig. 4 Tension in the conveyor belt during changes in Young´s modulus in X axis

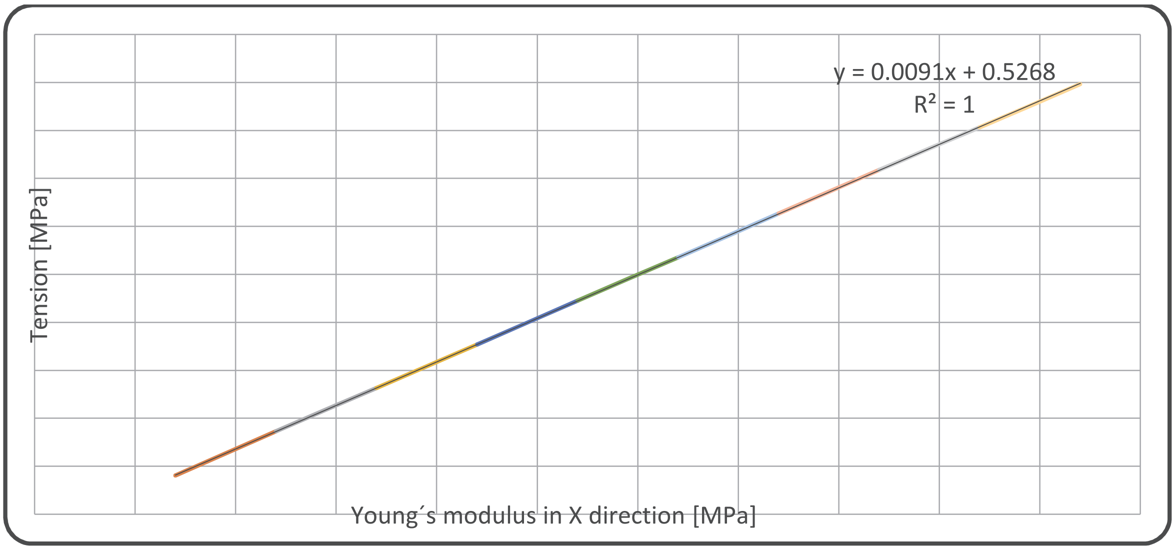

Fig. 5 Correlation graph between Young´s modulus in X axis and tension forces

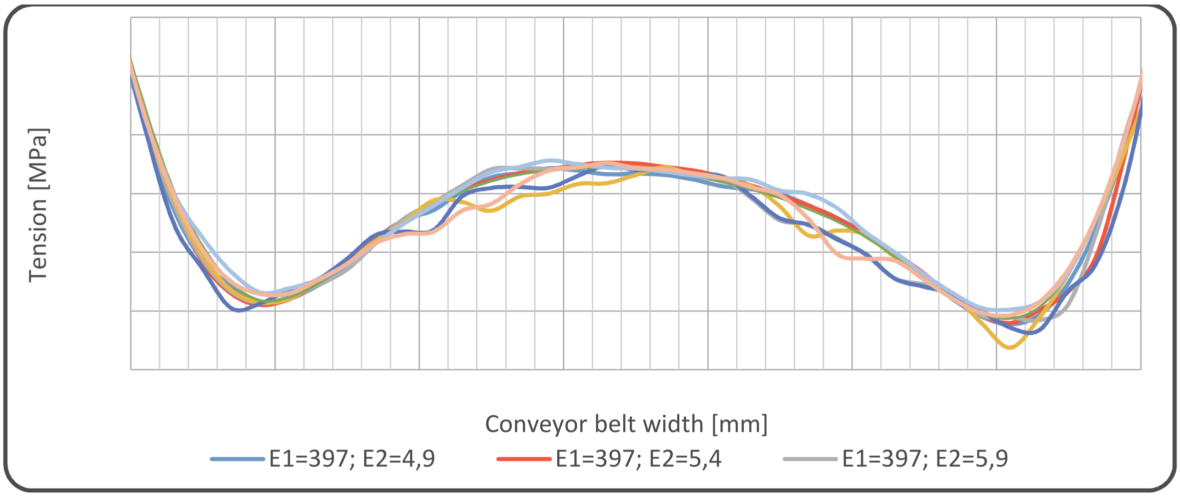

Fig. 6 Growing fluctuations of tension in conveyor belt

In changes of density, the maximum tension value was 4.1281 MPa, noted in the lowest monitored density ρ = 1019 kg.m^{-3} at the edge of belt. Difference of tensions between monitored densities from the edge of the belt toward its center decreases until it hits about 200 mm distance from the edge. At this point are tension values very similar for every monitored density. From this point toward belt center is order of the biggest tension inverted. This finding shows that the biggest and smallest observed tension value is at the belt with same density ρ = 1019 kg.m^{-3}. The biggest one was observed at the very edge of conveyor belt and the smallest was at 240 mm distance from the edge. At these points were created correlation graphs. Correlation graph between tension forces and belt density at the edge of belt shows that with increasing density values, the pressure is reduced in a linear value of 0.00025 MPa by every change in density by 20 kg.m^{-3} (**Fig. 7**). Next correlation graph shows inverted dependence, that tension forces are reduces by 0.00024 MPa in every change in density by 20 kg.m^{-3} (**Fig. 8**).

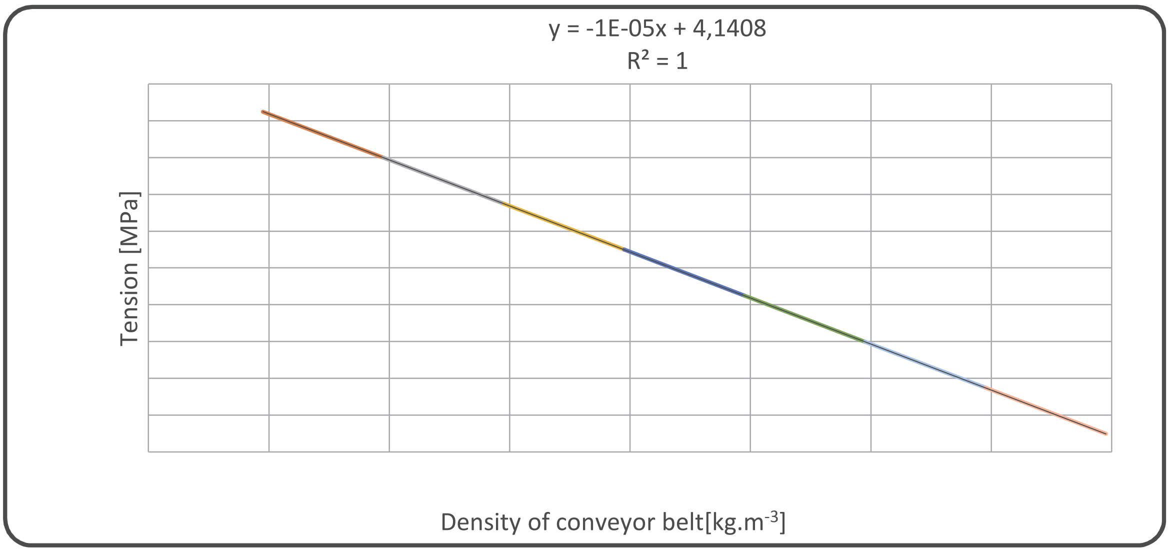

Fig. 7 Correlation between tension forces and belt density at the edge of belt

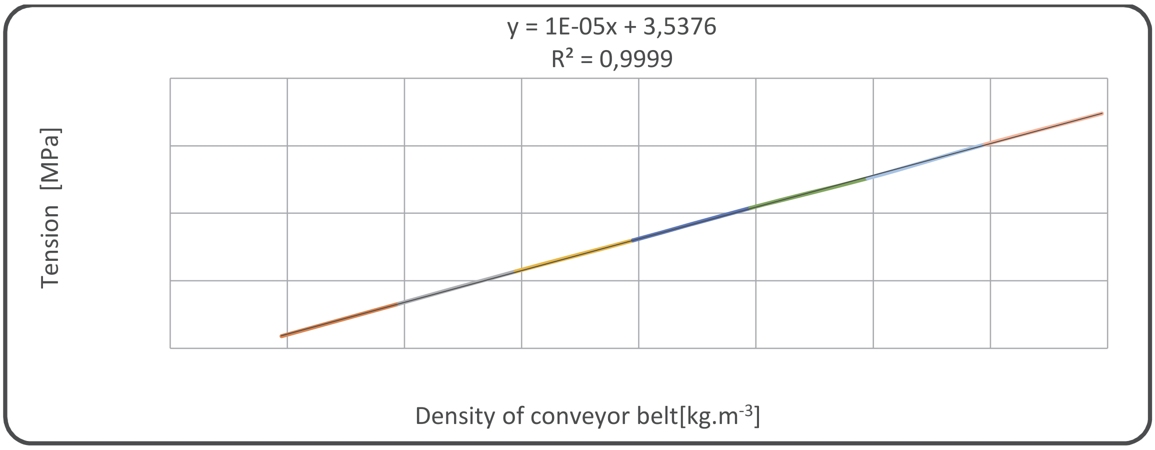

Fig. 8 Correlation between tension forces and belt density at the belt center

With belt density changes the length of conveyor belt is also changed. With the increasing of conveyor belt density, extension is reduced. At the graph cannot be seen linear dependence due to insufficient amount of data (**Fig. 9**). From Pearson's coefficient ρ = -0.91 and detailed comparison of longitudinal deformation is visible relationship between density and longitudinal deformation of the conveyor belt (**Fig. 10**).

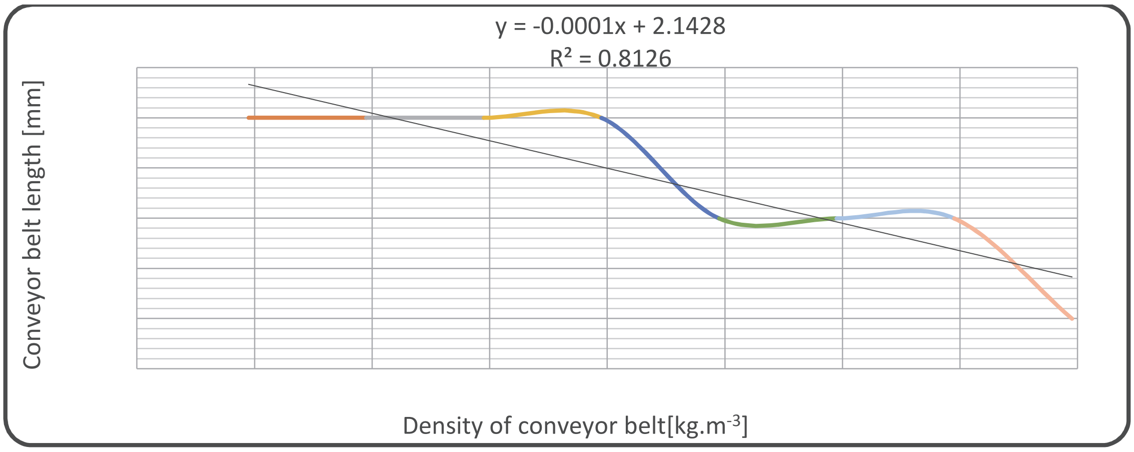

Fig. 9 Correlation between extension and belt density at the center

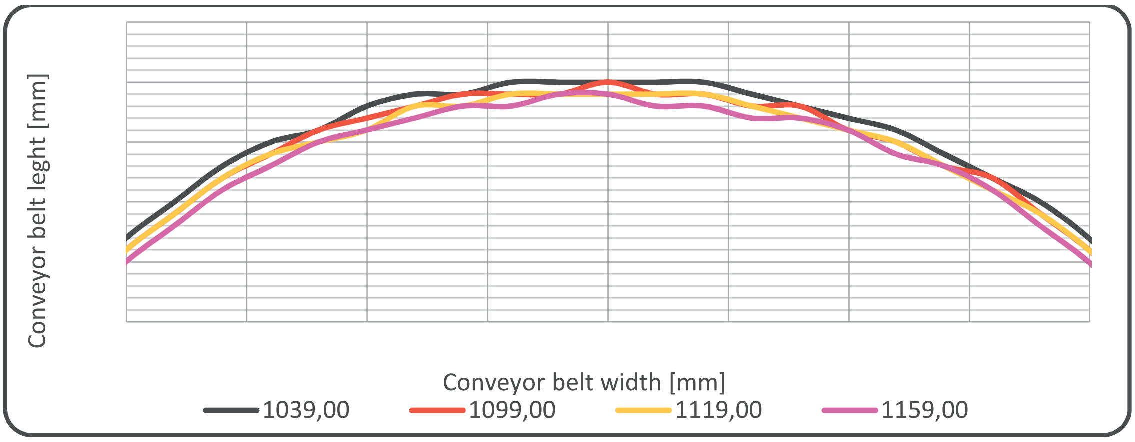

Fig. 10 Longitudinal deformation of conveyor belt

Complete illustration of the tension forces acting on the conveyor belt at the highest density in the observed run-up to return pulley can be seen at **Fig. 11**.

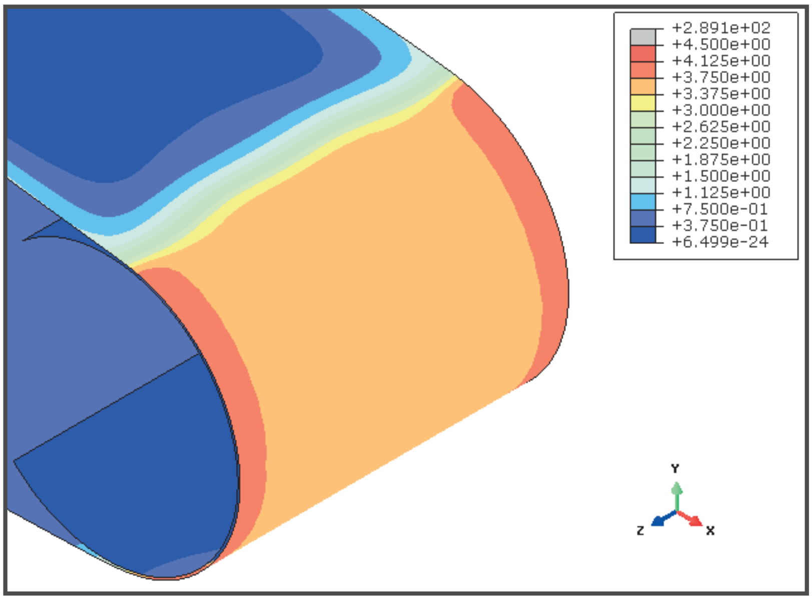

Fig. 11 Tension forces acting on the conveyor belt at density ρ=1019kg.m^{-3}

5. CONCLUSION

The presented work was done to determine the impact of selected material properties (Young's modulus of elasticity in the longitudinal and transverse direction, the density of the material of the conveyor belt) to the observed parameters (tension and deformation forces). Monitored area in this work was tail end of conveyor belt. To this end were created correlation of selected material properties and observed parameters of conveyor belt. These parameters have a significant impact on durability of the conveyor belt so it is important to know these correlations, predict prognosis and calculate its tension-strain states. These are the data which will be used in the development of new types of conveyor belts various designs. These findings will be applicable in the design of conveyor belts with respect to the tune of physical resistance, energy consumption and optimalization of production and distribution systems.

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