Analysis of rope based mechanism for movement of telescopic conveyor segments

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Abstract. The subject of analysis in this paper are rope based mechanisms for the movement of the telescopic conveyors substructure. Experimental test of ropes in conjunction with pulleys on 2 telescopic conveyors were performed in order to assess the real cause of damage and cracking of ropes in a full sense, which occurred in the real application of the conveyor at the site. These are examples of two conveyors with the same characteristics on which combinations of ropes with characteristics of construction of cross section 7x19 and construction of cross section 19x7 are placed, as well as combinations of pulleys with two kinds of grooves. Some specific tests are performed that showed the best combination of construction driving system elements.

1. Introduction
Fig. 1 shows the basics of the telescopic belt conveyor construction analyzed. Dimensions and all the necessary details for the purpose of planning the experimental determination of forces in the ropes and other accompanying analyzes are not presented in the paper because of the professional regulations. Fig. 2 shows some sub-construction segments.

Figure 1. Telescopic belt conveyor.
In the analysis of the mechanism, two rope constructions type 7x19 and rope construction type 19x7 are used. During the industry use there were some damages appeared related to the construction of ropes and its relation to the trolley pulleys, Fig. 3.

2. Experimental research program

There was a need to make a general plan to execute an appropriate experimental tests in the manner of accepting all combinations of constructive elements for making the conclusion what was the optimum combination of the system elements, [1,2].

2.1. General description of the procedure for experimental tests

In this part of the expertise, the aim was to investigate the reasons for the damage of ropes and their cracking in the application on the construction of a telescopic conveyor.

After a detailed consideration of the conveyor assembly and determining all the prerequisites for testing the forces in the ropes, it was found that no sensors can be used to directly measure the force, and since the ropes are mounted in a system with hydraulically pressed ends with screws, and for connection to the connection points on the structures of each of the 4 parts of the mobile segments.

Also, the very small spatial conditions available for the installation of the sensor were very complex, and modifications of the connecting links had to be performed, [3]. Therefore, 4 special sensors were made using strain gages, which were mounted on both sides in the selected section of the conveyor, at the points of connecting joints in the structures, on the second section of the conveyor, i.e. the first mobile.

For testing, 2 conveyors of the same characteristics were used, in which different combinations of pulleys and types of ropes were used for the purpose of testing.

The tests were performed without the presence of a conveyor belt and without loads on the conveyors, i.e. only load simulations were performed due to the change in the length and inclination of the conveyor.

Measuring equipment used: acquisition measuring system Spider 8, as well as created 4 force sensors with strain gages 6 LY-11 120 of manufacturer HBM Germany (Sensor 4; h=8,9 mm; P4 = 73,71 mm², Sensor 3; h=8,9 mm; P3 = 73,71 mm², Sensor 5; h=9,2 mm; P5 = 75,60 mm², Sensor 2; h=9,1 mm; P2 = 75,04 mm²).
2.2. Experimental tests related to conveyor 1 and 2

The initial installation of measuring sensors on both sides of the conveyor 1 was performed, and the test conditions are shown in Fig. 4 and Fig. 5.

The sensor placement methodology was symmetrical placement of the sensors on both sides of the second section, in order to monitor the behavior of the symmetry and the different combinations of pulley types and type of ropes.

![Image](image1.png)

**Figure 4.** Telescopic conveyor construction and measurement acquisition equipment used.

![Image](image2.png)

**Figure 5.** Experimental measuring sensors used – experiment 1.

Complete simulation of changes in the state of the conveyor 1 were performed in 6 phases, but in the Tab. 1 only 4 are presented because of professional relation conditions.

| Phase | Description | Time (s) | CH0 – F2 19x7 (kN) | CH1 – F5 19x7 (kN) | CH2 – F3 7x19 (kN) | CH3 – F4 19x7 (kN) |
|-------|-------------|----------|------------------|--------------------|--------------------|--------------------|
| 0     | Conveyor 1 fully extended and maximally raised | - | - | - | - | - |
| 2     | Conveyor 1 retracted, hydraulics lowered | 185 - 375 | 6.06 | -0.72 | -1.41 | 0.22 |
| 4     | Raised hydraulics, conveyor 1 extraction | 520 - 620 | -a | -1.36 | -1.56 | -1.12 |
| 6     | Conveyor 1 extracted, hydraulic lift | 865 - 950 | -a | -1.65 | -1.6 | -1.4 |

Note: the measuring connection cable 2 – CH0 broke.

Based on all the values (but not all presented in the paper), it is noted:
• in general, low values of working forces at all stages,
• in general, there was a redistribution of forces in the ropes, and unloading (except for rope 2),
• when ropes 2 and 4 are compared, a significant difference in forces is noticed, although the same constructions are 19x7,
• when compare ropes 3 and 5, a slightly higher force relief is noticed in the construction 7x19 in the first three phases of the simulation, and slightly less in the last three phases.

Some examples of test diagrams are showed in Fig. 6.

![Diagram](image)

**Figure 6.** Some experimental diagram examples of conveyor 1 testing: a) Phase 1, b) Phase 4.

Force investigations and installation of measuring sensors on both sides of the conveyor 2 were performed, completely identical to the procedure on the conveyor 1, Fig. 7.

![Sensor Setup](image)

**Figure 7.** Experimental measuring sensors used – experiment 2.

Modifications of the connecting clamps were made in order to be able to insert sensors with strain gages. The implementation of the procedure on conveyor 2 was performed in 6 phase processes, in order to provide the same conditions for comparing the results and observing the mutual influences of the pulleys and ropes, but in the Tab. 2 only 4 are presented because of professional relation conditions.
Table 2. Some of experimental test 2 results.

| Phase | Description                              | Time (s) | CH0 – F2 7x19 (kN) | CH1 – F5 7x19 (kN) | CH2 – F3 7x19 (kN) | CH3 – F4 19x7 (kN) |
|-------|------------------------------------------|----------|---------------------|-------------------|-------------------|-------------------|
| 0     | Conveyor 2 fully extended and maximally raised | -        | -                   | -                 | -                 | -                 |
| 2     | Conveyor 2 retracted, hydraulics lowered | 140 - 200 | -0.73              | 1.65              | -5.6              | 0.56              |
| 4     | Raised hydraulics, conveyor 2 extraction | 305 - 365 | -0.57              | -0.78             | -3.07             | 0.78              |
| 6     | Conveyor 2 extracted, hydraulic lift     | 495 - 540 | -0.64              | -0.76             | -2.87             | 0.77              |

Based on all the values (but not all presented in the paper), it is noted:
- generally, low working forces values at all stages,
- there is a redistribution of forces in the ropes, and unloading in ropes 2 and 3, and 5 in the last three phases,
- in the rope 5 in the first three phases there is an increase in force, and in rope 4 there is an increase in force in the rope in all phases,
- when compare ropes 2 and 4, a difference in the character of forces is noticed, i.e. relief in the construction of 7x19, and an increase in force in the construction of 19x7 ropes,
- when compare ropes 3 and 5, a certain difference in behavior is noticed because in the first three phases with rope 5 there is an increase in force, and then it becomes unloading, while with rope 3 there is a significant relief, so there is asymmetry in behavior.

Some examples of test diagrams are showed in Fig. 8.

![Experimental diagram examples of conveyor 2 testing: a) Phase 1, b) Phase 4.](image)
2.3. Results analysis
Based on the total conducted and meaningful experimental tests, some of the following considerations and conclusions are given:
- The analysis of the values of forces in the ropes shows a better behavior of the rope construction 7x19, compared to the rope 19x7, so the values of forces show a more adequate behavior of the structure 7x19 in contact with the pulleys, with more flexibility,
- The tests were performed without the presence of a conveyor belt and without loads on the conveyors, i.e. only load simulations were performed due to the change in the length and inclination of the conveyor, which means that higher loads are expected in the ropes at the site.
- Rope failure is not caused by tensile loads, because lower values of working forces are generally present, than due to bending dynamic loads. The values of the obtained absolute forces are below the breaking limit (for these test conditions).
- The 19x7 rope is not adequate for this conditions because its structure is different, mainly for more significant tensile loads and lower bending loads, they have less stiffness (which was proven with another experimental testing), and less pronounced elasticity because residual deformations are also present. The fact that Young's modulus of elasticity is smaller is also present.
- The durability of the rope is closely related to the bending radius around the pulleys. It increases with increasing ratio of pulley diameter to rope diameter. The magnitude of the tensile load of the rope is essential for the increase in durability. Industrial practice shows that even with a small D / d ratio, high rope durability can be achieved, but at lower loads. To achieve sufficient durability of the rope, the norms set minimum D / d ratios. This ratio also keeps under control the magnitude of the normal stress in the wires due to the bending of the rope around the pulleys. It would be advantageous to increase the diameter of the pulley radius, if the design allows, in order to achieve more favorable permanent bending strength, [4,5,6].
- It would be good for the project solution, among other things, to prescribe the approximate values of rope prestressing forces in conveyor sections, given the logic that, for example, the prestressing force of the conveyor belt must be calculated and realized as such during installation and before workloads. The recommendation of the prestressing force of the ropes is also important in order to avoid asymmetry in the load of the ropes on both sides of the conveyor.
- After changing the structure of the rope, it is necessary to check the behavior of the system in practice, i.e. to go to meet the recommendations related to the diameters of the reels, if a further need to improve the conveyor structure is determined.

3. Conclusion
The paper presented a specific procedure for investigating the causes of damage to the rope based mechanism for extracting and retracting components of the telescopic conveyor structure.
Experimental research was conducted in very specific circumstances because measuring sensors were specially created only for this research.
Measurements have determined the optimal combinations of rope and pulley construction that ensure further reliability of the system without further damage and interruption in use.
During these studies, somewhat broader experimental trials were applied. The paper presents only a part of the overall procedure and the obtained data.
The significance of the research lies in the fact that modern measuring technology was applied, as well as in the fact that the obtained results indicated an optimal combination of mechanism elements without subjective approaches of researchers in decision making, which solved significant dilemmas of equipment manufacturers.

References
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