Research Article

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Static testing evaluation of pipe conveyor belt for different tensioning forces

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Abstract: The paper analyzes static tests of pipe conveyors using various statistical indicators and points out the mutual interactions between individual roller stands. Individual measurements were performed on a physical model of a pipe conveyor, while the methodology and procedure were verified by experiments. 15 repetitions of the given series of measurements were selected, which was a compromise between time demands and statistical requirement. Normal contact forces on the individual rollers of three hexagonal roller stands acting on the conveyor belt for different tension forces in the static state (conveyor belt without movement and without transported material) were evaluated. The LabVIEW Signal Express 2010 program from the National Instruments Company was used to record the measured data. The measurements were evaluated by Microsoft Office Excel.

Keywords: Measurement, physical model, pipe conveyor, conveyor belt, contact force, tensioning force, idler roll

1 Introduction

During normal operation, the conveyor belt of the pipe conveyor is exposed to various influences, which cause its static and dynamic wear. Abrasions, cuts and cracks and incorrect operating conditions are the main causes of wear.

Research into the contact forces on the pipe conveyor rollers in terms of durability, reliability and wear on the conveyor belt, is currently an issue which is increasingly at the forefront of researchers, designers, pipe conveyor manufacturers and their users [1–6].

A very effective way of obtaining real values of contact forces between the conveyor belt and the guide rollers in the continuous transport of bulk materials using pipe conveyors is the use of specially designed test equipment. In cooperation between the PHOENIX Conveyor Systems GmbH and the Institute of Transport and Automation Technology (ITA) a research project was realised [7]. The CKIT Company, in cooperation with the Mining University of Leoben, has developed a testing device for pipe conveyors [8]. Further research is known in the field of determining the real values of contact forces between the conveyor belt and the guide rollers of the pipe conveyor [9–14].

This paper analyzes normal contact forces on individual rollers of three hexagonal idler housings acting on conveyor belt for different tension forces in static state - conveyor belt without movement and without conveyed material, pointing out mutual interactions between individual roller stands.

2 Methods

The physical model of the pipe conveyor in Figure 2 was preceded by the creation of its 3D geometric model shown in Figure 1. The physical model is used to measure normal contact forces (CF) on the individual rollers of three hexagonal idler housings acting on the conveyor belt for 5 different tensioning force levels (TF) in static condition - conveyor belt without movement and without transported ma-
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Figure 2: Physical model of a pipe conveyor

Figure 3: Marking the positions of strain gauges on idler housings No.1, No.1, No.3 [12]

Table 1: The characteristics of strain gauges

| Measuring point        | Marking of the measuring point | Type of strain gauge | Number of strain gauges |
|------------------------|---------------------------------|----------------------|-------------------------|
| Idler housings         | ID1 ÷ ID18                      | KDI 500 Single       | 18 pcs                  |
| Tension plate          | ID23, ID24                      | KDI 1.5 kN tens      | 2 pcs                   |

Table 2: Strain gauge sensor parameters

| Type of strain gauge | KDI 500 | KDI 1.5 kN tens |
|----------------------|---------|----------------|
| Capacity [N]         | 800     | 15900          |
| Sensitivity [mV / V] | 1       | 1              |
| Accuracy [%]         | 5       | 5              |

Table 3: Basic characteristics of the conveyor belt and experimental testing equipment

| Type of the conveyor belt | EP500/3 HP 5+3 D |
|---------------------------|------------------|
| Polyester rubber-textile conveyor belt | EP |
| Strength of the belt      | 500 N·mm⁻¹       |
| Pipe shaped belt          | HP               |
| Top cover thickness       | 5 mm             |
| Bottom cover thickness    | 3 mm             |
| Category: transport of materials with the recommended belt surface temperature +150°C |
| Length of the conveyor belt | 8000 mm         |
| Width of the conveyor belt | 800 mm          |
| Thickness of the conveyor belt | 20 mm         |
| Diameter of the pipe shaped conveyor belt | 200 mm |
| Distance between the idler housings | 1000 mm        |
| Diameter of the idler rolls | 76 mm           |

Figure 4: Detail of mounting the end of the conveyor belt

ter material. Both models contain three identical hexagonal idler housings No.1, No.2, No.3.

1. Hexagonal idler housing No.1 – characterizes the state of closing the conveyor belt,
2. Hexagonal idler housing No.2 - characterizes the normal operation of the conveyor belt,
3. Hexagonal idler housing No.3 - characterizes the state of fixation of the conveyor belt by means of clamping screws.

The physical model of the pipe conveyor (Figure 2) contains 18 strain gauges at positions ID1-ID18 on three hexagonal idler housings and 2 strain gauges at positions ID23, ID24 on the tensioning plate (Figure 1). The 5 different levels of TF are derived by the sum of the tensioning forces at
Table 1 contains the characteristics of strain gauges on the physical model of pipe conveyor, in Table 2 are their parameters.

In the physical model, an older conveyor belt already in operation (Figure 4) with the parameters displayed in Table 3 was used.

### 2.1 The measurement chain and description of automated measurement of TF and CF

On the physical model of pipe conveyor, the National Instruments LabVIEW Signal Express 2010 measuring apparatus was installed, which sequentially records data from individual strain gauges and exports it to Microsoft Office Excel for further processing and mutual comparison. Figure 5 shows the connection of an automated measurement measuring chain that sequentially records CF and TF values from individual sensing sites using strain gauges.

The results were processed in the form of tables and graphs [15]. Figure 6 shows a set of A/D converters from the National Instruments.

The course of 15 automated repeated measurements and their evaluation was carried out according to a pre-planned procedure. At first, the verification of strain gauge sensors was performed using calibration curves. Measurement time courses were recorded for both 5-level stretching and release at once, as shown in Figure 7.

The measurement procedure according to Figure 7:

1. Waiting time approximately 30s
2. Gradual stretching to a given value in [N]
3. Waiting time approximately 120s
4. Gradual stretching to a given value in [N]
5. Waiting time approximately 120s
6. Gradual stretching to a given value in [N]
7. Waiting time approximately 120s

positions ID23 and ID24. The position of strain gauges on all three idler housings is shown in Figure 3.
8. Gradual stretching to a given value in [N]
9. Waiting time approximately 120s
10. Gradual stretching to a given value in [N]
11. Waiting time approximately 120s
12. Gradual stretching to a given value in [N]
13. Waiting time approximately 120s
14. Gradual stretching to a given value in [N]
15. Waiting time approximately 120s
16. Gradual stretching to a given value in [N]
17. Waiting time approximately 120s
18. Gradual stretching to a given value in [N]
19. Waiting time approximately 120s
20. Gradual complete release of the conveyor belt.

3 Results

Figure 8 shows the CF progression for a hexagonal roller stand No.1 using a spatial surface graph. On the x-axis, the positions of the strain gauges ID1 ÷ ID6 belonging to hexagonal idler housing No.1 for 5 TF levels are shown. On the Y axis, the resulting CF values for the strain gauges ID1 ÷ ID6 positions are shown. The position of each strain gauge is displayed above each CF course.

The course of CF shown in Figure 9 shows the course of the hexagonal roller stand No.2 using a spatial surface graph. On the x-axis there are the positions of the strain gauges ID7 ÷ ID12 belonging to hexagonal idler housing No.2 for 5 TF levels. On the Y axis, the resulting CF values for the positions of the strain gauges ID7 ÷ ID12 are shown. The position of each strain gauge is displayed above each CF course.

Figure 10 shows the course of CF for the hexagonal roller stand No.3 using a spatial surface graph. On the x-axis, there are the positions of the strain gauges ID13 ÷ ID18 that belong to the hexagonal idler housing No.3 for 5 TF levels. On the Y axis, the resulting CF values for the positions of the strain gauges ID13 ÷ ID18 are shown. The
position of each strain gauge is displayed above each CF course.

4 Discussion

The results of individual measurements were not always as expected. Some strain gauge sensors showed no results due to deformation of the conveyor belt or if the conveyor belt did not touch the strain gauge sensor, which could have happened due to the inertia of the deformation of the conveyor belt when the conveyor belt was packed between repetitive measurements for several days. In this case, the measured data showed low or even negative values.

Different CF courses for 5 TF levels were obtained from the CF waveforms for strain gauges ID1 ÷ ID6 belonging to idler housing No.1. The maximum CF = 727.8N was at position ID6 at the total value of TF = 28000N. The minimum CF = 108.8N was at position ID2 at the total value of TF = 16000N. Anomalies were observed at the ID4 position, where the course of CF was constant during the 30 sec, 60 sec and 90 sec of settling for the TF amounts monitored, respectively.

From the CF waveforms for strain gauges ID7 ÷ ID12 belonging to idler housing No.2, different CF courses were measured for 5 TF levels. The maximum CF = 229.1N was at position ID10 at the total value of TF = 28000N. The minimum CF = 22.7N was at position ID8 at the total value of TF = 16000N. A variety of CF results could have been observed in tensioning and releasing the conveyor belt after 30 sec, 60 sec, and 90 sec of settling.

From the CF waveforms for strain gauges ID13 ÷ ID18 belonging to idler housing No.3, different CF courses were observed for 5 TF levels. The maximum CF = 144.1N was at position ID13 at the total value of TF = 28000N. The minimum CF = - 44.8N was at position ID16 at the total value of TF = 28000N. It was possible to observe the diversity of CF results in tensioning and releasing the conveyor belt after 30 sec, 60 sec and 90 sec of settling. Anomalies were observed at the ID18 position, where the course of CF after

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Table 4: The order of idler roll loading in each idler housings

| Idler housing | ID | The order of idler roll loading |
|---------------|----|-------------------------------|
| No.1          | ID1| 3.                            |
|               | ID2| 6.                            |
|               | ID3| 4.                            |
|               | ID4| 5.                            |
|               | ID5| 2.                            |
|               | ID6| 1.                            |
| No.2          | ID7| 5.                            |
|               | ID8| 6.                            |
|               | ID9| 4.                            |
|               | ID10| 1.                          |
|               | ID11| 3.                          |
|               | ID12| 2.                          |
| No.3          | ID13| 1.                          |
|               | ID14| 2.                          |
|               | ID15| 3.                          |
|               | ID16| 5.                          |
|               | ID17| 4.                          |
|               | ID18| 6.                          |
30 sec, 60 sec and 90 sec of settling was constant and even negative for the observed TF amounts.

From the course of CF shown in Figures 8, 9, 10, the order of loading of the individual idler rolls in the idler housings was determined - as is displayed in Table 4.

5 Conclusion

Despite frequent use of pipe conveyors, the issue of tracking CF on idler rolls is relatively neglected. Nevertheless, CF significantly influence the performance characteristics of pipe conveyors and represent an important factor in the continuous transport of raw materials. As a result of further research on this issue, a large volume of measured data needs to be processed. Therefore, there are often problems in terms of both time processing and evaluation.

The paper points out a suitable way of evaluating individual CF measurements on a physical model of a pipe conveyor in dependence on TF, while the respective methodology and procedure were verified by experiments. The data obtained from the individual CF measurements from the rollers acting on the conveyor belt for various TFs in a static state (the conveyor belt does not move) were categorized into a whole and then investigated and analyzed from different perspectives separated from measurement errors or eventual operator errors. Data was analyzed by means of statistical characteristics using charts and tables in Microsoft Office Excel. The obtained results will be used in further follow-up research, which will bring useful new knowledge for the theory, practice as well as for the production of conveyor belts.

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References

[1] Barburski M. (2016). Analysis of the pipe conveyor belt pressure on the rollers on its circuit, J. Ind. Text. 45, 1619–1634. doi:10.1177/1528083714567242.

[2] Michalík P., Molnár V., Fedorko G., Zajac J., Luściński S., Hatala M., Monka P., Simkulev V. & Orlovský I. (2011). Analysis of compressive forces on rolls of a pipe conveyor, In EAN 2011 49th Int. Sci. Conf. Exp. Stress Anal., (pp. 245–250). Brno, Czech republic: Brno Univ. of Technology.

[3] Stehlíková B., Molnár V. & Fedorko G. (2014). Possibilities of Experiments and of Using Experimental Results obtained from the Test Equipment for Measuring Properties of Conveyor Belts Pipe Conveyor, Appl. Mech. Mater. 683, 165–170. doi:10.4028/www.scientific.net/AMM.683.165.

[4] Ramjee S. & Staples P. (2015). Pipe conveyors for infrastructure projects: Innovative solution for conveyor systems, Bulk Solids Handl. 35, 20–25. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84943194359&partnerID=40&md5=e585cb5433761a1c39d23bf0c7562a7.

[5] Marasova D., Fedorko G., Kubin K., Molnar V. & Husaková N. (2010). Analysis model for determination of contact loads between tube-shaped conveyor belt of a pipe conveyor and carrier rolls, Cuprum Czas. Nauk. Górnictwa Rud. 3, 71–76. http://baztech.icm.edu.pl/baztech/cgi-bin/bggetdoc.cgi?AGH1-0023-0174.

[6] Michalik P. & Zajac J. (2012). Using of computer integrated system for static tests of pipe conveyor belts, In Proc. 13th Int. Carpathian Control Conf. ICCC 2012, (pp. 480–484). IEEE. doi:10.1109/CarpathianCC.2012.6228691.

[7] Hötte S., Overmeyer L. & Wennekamp T. (2011). Research on the Form Force Behaviour of a Pipe Conveyor in Different Curve Radii, In Bulk Solids India 2011.

[8] CKIT. Retrieved July 26, 2019, from www.ckit.co.za/right-index/tech-focus/belt-guide/new-belt-guidance.htm.

[9] Molnár V., Fedorko G., Stehlíková B., Kudeláš L. & Husáková N. (2013). Statistical approach for evaluation of pipe conveyor’s belt contact forces on guide idlers, Meas. J. Int. Meas. Confed. 46, 3127–3135. doi:10.1016/j.measurement.2013.06.019.

[10] Molnár V., Fedorko G., Stehlíková B., Michalík P. & Weiszer M. (2013). A regression model for prediction of pipe conveyor belt contact forces on idler rolls, Meas. J. Int. Meas. Confed. 46, 3910–3917. doi:10.1016/j.measurement.2013.07.045.

[11] Molnár V., Fedorko G., Stehlíková B., Michalík P. & Kopas M. (2014). Mathematical models for indirect measurement of contact forces in hexagonal idler housing of pipe conveyor, Meas. J. Int. Meas. Confed. 47, 794–803. doi:10.1016/j.measurement.2013.10.012.

[12] Molnar V., Fedorko G., Stehlikova B. & Paulikova A. (2015). Influence of tension force asymmetry on distribution of contact forces among the conveyor belt and idler rolls in pipe conveyor during transport of particulate solids, Meas. J. Int. Meas. Confed. 63, 120–127. doi:10.1016/j.measurement.2014.12.014.

[13] Fedorko G. & Ivanco V. (2012). Analysis of Force Ratios in Conveyor Belt of Classic Belt Conveyor, Procedia Engineering, 48, 123–128.

[14] Rozbroj J., Nečas J., Gelnar D., Hlosta J. & Zegzulka J. (2017). Validation of movement over a belt conveyor drum, Advances In Science And Technology-Research Journal, 11(2), 118-124. doi:10.12913/22998624/71883

[15] Vlach J., Havlíček J. & Vlach M. (2008). Začínáme s LabVIEW, BEN - technická literatura.