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Monitoring System for Belt Conveyors

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Abstract Belt misalignment is often a major problem during operation of belt conveyors for bulk materials. There are various belt guiding systems on the market, which are aimed to steer the belt back into the centre of the carrying or return idlers. Those training idlers are used for belt misalignment suppression and can be equipped with a monitoring function.

Such a new monitoring system was developed in cooperation with an industrial partner at the University of Leoben. This movable idler performs an automatic angular adjustment of the axis of rotation in conveying direction and orthogonal to the belt surface. It was equipped with sensors, which measure the movement and the rotational speed of the idler. The extent of the movement is dependent on the intensity of the belt misalignment to be corrected. With training idlers, it is possible to compensate the belt misalignment up to a certain level. When this level is exceeded, the belt runs off the idlers.

The new system can be used for two different purposes. The first application is a simple belt misalignment warning system, which sets an alarm, if a critical belt movement occurs. The second application is a teachable conveyor error identification. With this function a conveyor malfunction, which could lead to a belt misalignment, can be identified after recurrence. In this publication the new monitoring system is introduced and the functions are explained on the basis of trials.

1. INTRODUCTION

Belt conveyors for bulk materials are very energy-efficient and generally reliable systems for the continuous transport of very high, but also low mass flows. Despite the general operational safety, system components can fail for a wide variety of reasons. Typical damages are, for example, the failure of idlers due to bearing damage, belt failure due to surface wear or worn belt cleaners. A problem that should not be underestimated is the belt misalignment, which can be caused by system components failures, among other reasons. Belt misalignment means that the conveyor belt runs off sideways 90° to the conveying direction. This misalignment can have different causes like eccentric belt loading, poorly executed belt splices, belt damages, defective idlers, system contamination, forces occurring orthogonally to the conveying direction caused by the bulk material feed, the routing, etc. A wide variety of systems are used to counteract possible belt misalignment. Often the outer load idlers are inclined by a certain angle to the conveying direction. This readjusting creates a force in the direction of the idler bracket centre, which guides the belt back to its ideal position. In addition to this static belt guidance, various dynamic methods or devices are used, which are also based on the readjusting of idlers. Examples are the Tru-Trainer by ASgCO [1], the PT Smart™ Belt Trainer by FLEXCO [2], the Martin®-Tracker™ system by Martin Engineering [3] etc. Also used for belt centring are convex pulleys or V-shaped moulded return idler brackets, which are pressed onto the belt running side.

Another belt tracking system is the so-called PrimeTracker, which is marketed by the company ScrapeTec Trading GmbH [4]. This system is also based on the principle of twisted idlers or pulleys for belt steering. In cooperation between the Chair of Mining Engineering and Mineral Economics – Conveying Technology and Design Methods and the company ScrapTec, the function of the PrimeTracker was extended by a monitoring function.
This contribution is an updated and extended version of [5] and [7].

2. PRIMETRACKER

The PrimeTracker consists of a rotating roller which is connected to a fixed axle via two ball bearings and a tube with a central rubber bearing. The central rubber bearing allows an axial tilt of the roller rotation axis to the fixed axis. The tilted position of the roller moves the belt back to its original position when a belt misalignment occurs. The system and the principle of operation are shown in Fig. 1.

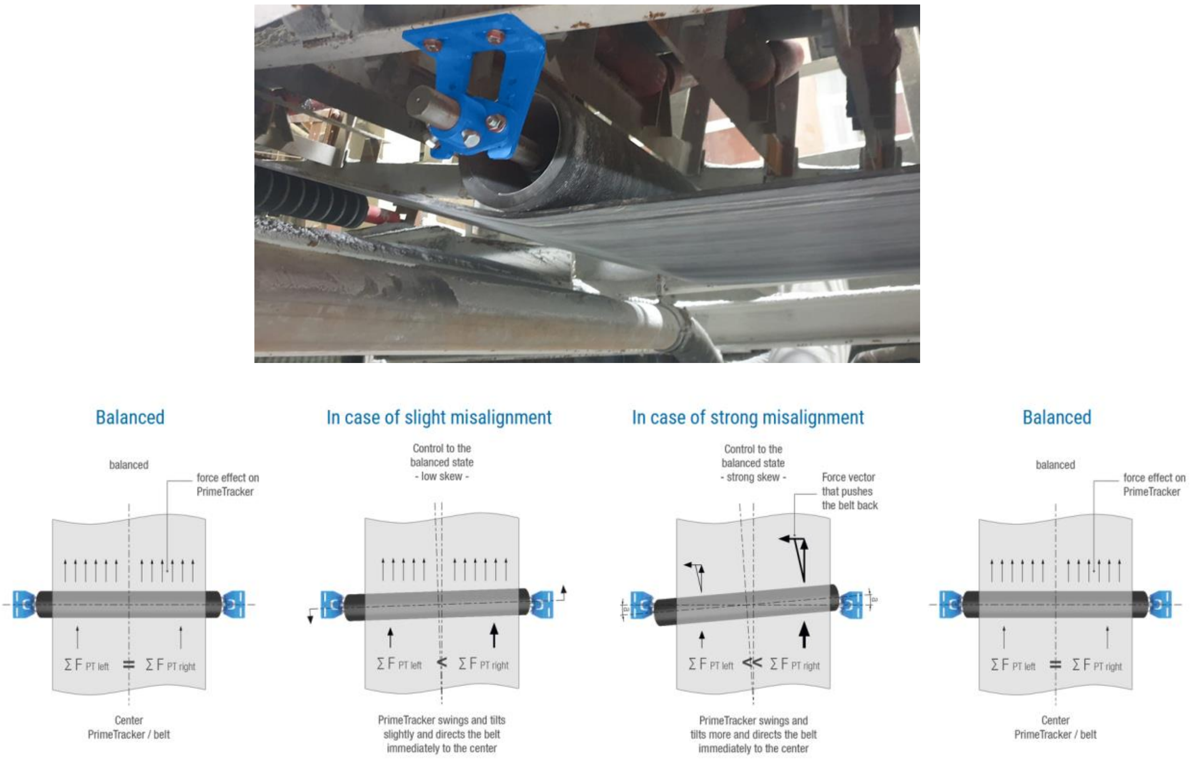


Figure 1 Operational principle of the PrimeTracker [4]

The tilting of the rotation axis in relation to the fixed axis can be used for monitoring tasks, as the readjusting or the movement sequence can be linked to occurring system failure. In order to allow measurement of the movement of the rotation axis in relation to the fixed axis, the system was equipped with two ultrasonic distance sensors. One sensor measures the distance in the conveying direction and the other one the distance 90° to the conveying direction. For the laboratory tests, additional sensors were also implemented in the belt conveyor.

3. MONITORING SYSTEM – TEST SETUP

The PrimeTracker with the monitoring system respectively measuring equipment was installed in one of the four conveyors of the chair's own conveyor circuit. Each belt conveyor has a length of 5m - (see Fig. 2).

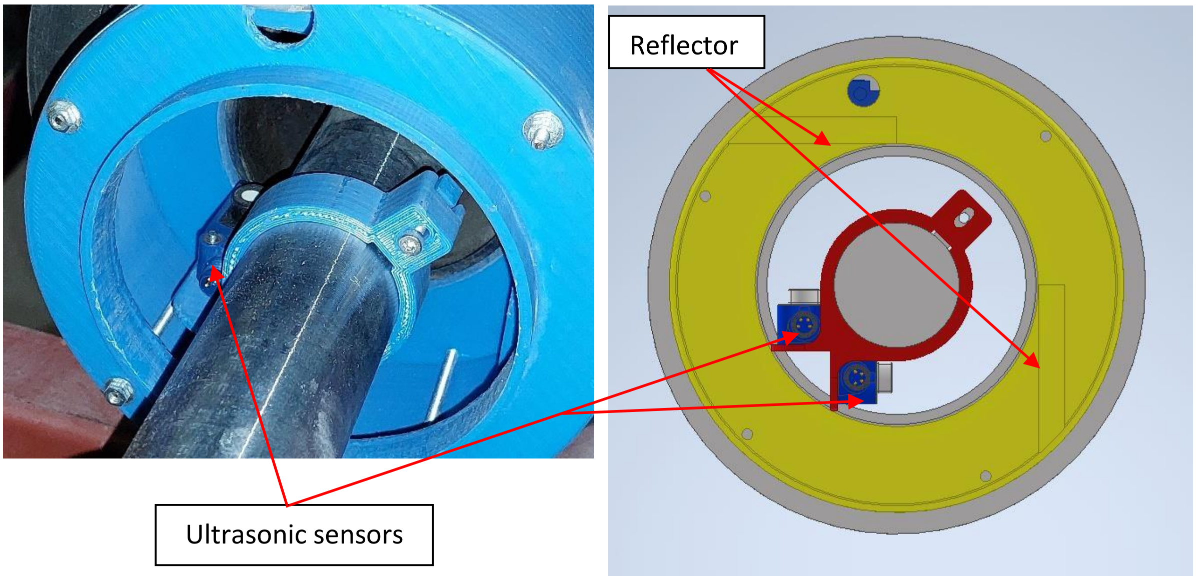
Figure 2 Conveyor circuit with the PrimeTracker installed in one of the four belt conveyors

There are two different installation options for the PrimeTracker. The system basically steers the belt by the return strand, whereby the PrimeTracker interacts either via the carrying side or the running side of the belt. In Fig. 2 and Fig. 3 the PrimeTracker has been installed in a way that the roller is pressed onto the carrying side of the belt. The alternative installation option with the roller pressed against the running side of the belt is shown in Fig. 1. The investigations described in the following refer to the belt guidance via the carrying side, since a more stable belt run could be set with the small belt width of 400mm used in this case. Six measuring points were implemented for the tests carried out (see Fig. 4).

Figure 3 PrimeTracker pressed onto the carrying side

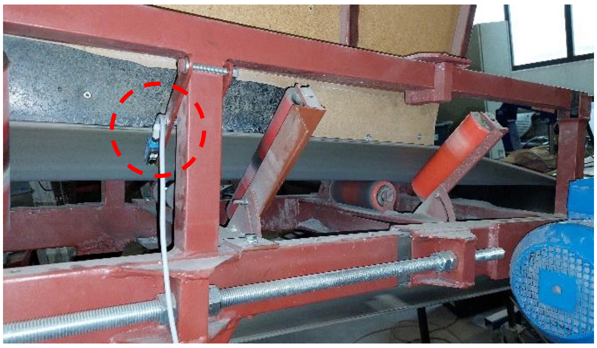
The ultrasonic sensors and the rotational speed sensor were installed into the PrimeTracker, whereby the ultrasonic sensors are intended as the actual monitoring system. The laser sensor for measuring the belt position on the drive pulley is only needed for laboratory operation to measure and monitor the system's reset behaviour. The contrast sensor is also needed for laboratory operation to synchronise the belt circulation position with events. The measurement of the circulating position can also be useful for industrial applications. Depending on the application, it is possible to replace the ultrasonic sensors by Hall-effect sensors.
For the implementation of the ultrasonic sensors and the rotational speed sensor, the PrimeTracker must be equipped with additional components. This requires a mounting device for the ultrasonic sensors, which must be installed on the stationary axis of the system. In order to reflect the ultrasonic signals, additional reflection surfaces that move with the roller movement are necessary. These surfaces do not rotate with the roller. They only move with the tilted position of the roller rotation axis. The additional components are shown in Fig. 4. The rotational speed sensor is also connected to the reflection device.

Fig. 4 also shows a wheel that can be pressed eccentrically onto the belt to simulate eccentric belt loading. The contact force is recorded by a load sensor.



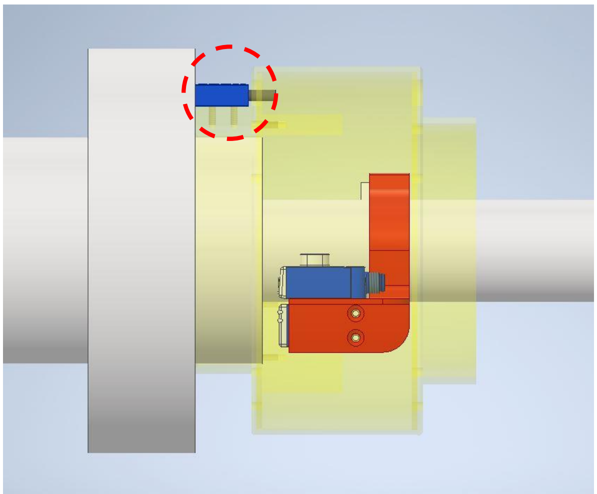
Ultrasonic sensors for measuring the movement of the rotational axes

Laser sensor for measuring the belt position at the drive pulley



Contrast sensor for measuring the belt rotation position

Measuring the contact force of the wheel onto the belt



Rotational speed sensor

Figure 4 Measuring points set up [5]

4. MEASUREMENTS CARRIED OUT

In order to be able to check the function of the steering device in combination with the implemented monitoring system, predefined failures are initialized in the belt conveyor. Before a specific failure is implemented, a calibration run must be carried out in order to subsequently document and evaluate the deviations from the initial measurement. Fig. 5 shows the calibration measurement for the laser sensor, the ultrasonic sensors and the contrast sensor.

In this calibration measurement the belt edge performs a periodic movement. In Fig. 5 this is shown by the second measurement curve from the top for the laser distance sensor. The cause of the recorded fluctuations is due to manufacturing inaccuracies, which are based on both a varying belt width and an inexact belt splice. After a short run-in period, a periodic oscillation occurs, whereby a peak can be observed shortly before the curve maximum. The peak is caused by the belt splice. This peak can also be seen on the measurement curve of the contrast sensor (first curve from the top in Fig. 5). For pulse generation, a coloured marker was applied to the belt on the running side, but this only provided a low voltage pulse. A much higher impulse is caused by the belt splice due to a different belt surface structure. The small peak in the first measurement curve from above, in Fig. 5, is located shortly after the maximum of the second measurement curve from above. The largest peak of the contrast sensor measurement curve is found shortly after the short peak of the second curve from the top. These peaks are caused by the belt splice, whereby the contrast sensor deflects somewhat later due to the offset position (see Fig. 4). Looking at the measurement curve of the ultrasonic sensor for the "vertical" position of the rotation axis (third curve from the top in Fig. 5), this event can also be identified and assigned on the basis of a short-term maximum. The event is marked in Fig. 5 by the dashed line for one period. The measurement curve for the "horizontal" position of the axis of rotation (fourth curve from the top in Fig. 5) provides a regular course without any distinctive short-term peaks. [5]

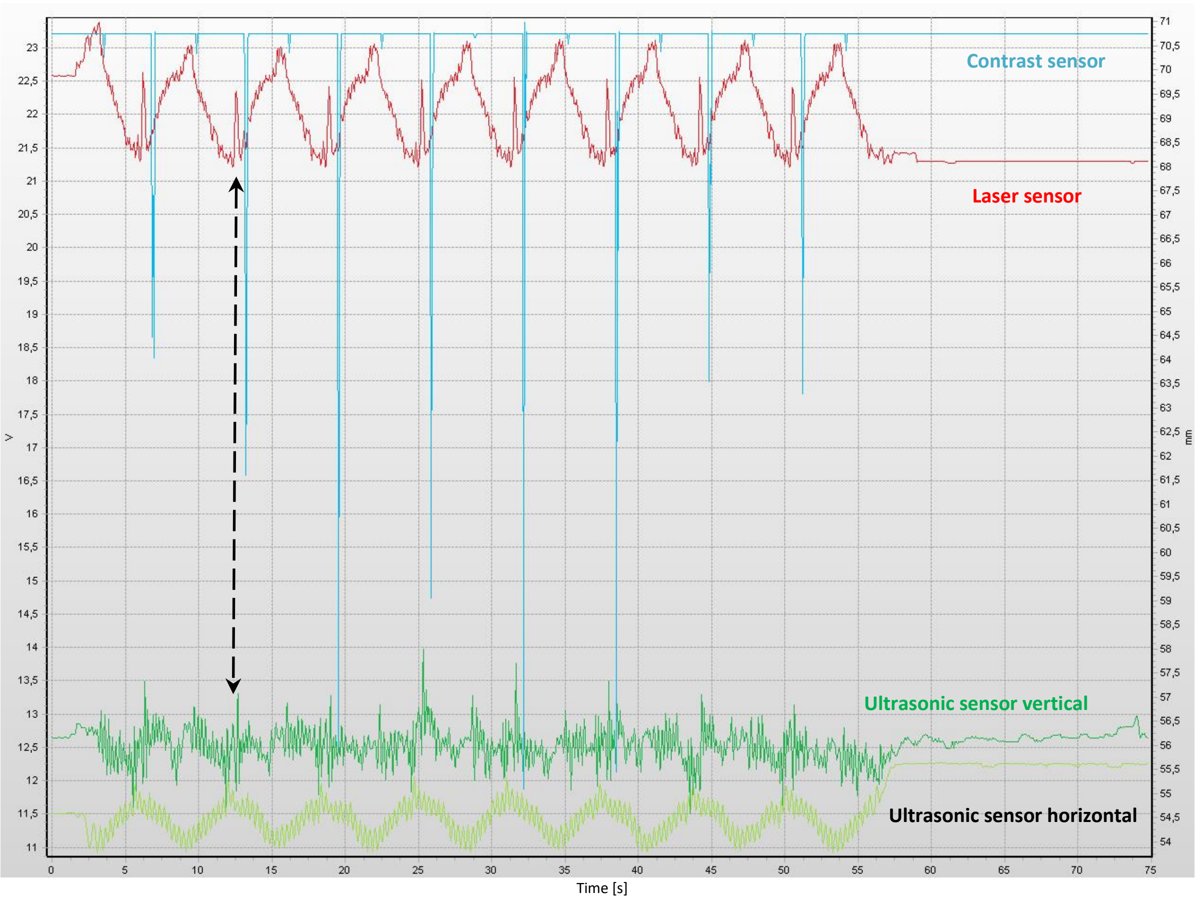


Figure 5 Calibration measurement [5]

4.1. Measurements with Defined Failures

In order to investigate the monitoring possibilities and the functionality of the system, tests were carried out with various failures implemented into the conveyor system.
The following faults were introduced:

- Eccentric belt load by means of a wheel, loaded with 75N, 125N and 200N on the right side of the belt in the conveying direction, as well as 125N and 225N on the left side (see Fig. 4).

- Idlers blocked with screw clamps on the right side in conveying direction

Figure 6 With screw clamps blocked idlers

- Asymmetrically pressed-on belt cleaner, which leads to a gap between belt and scraper on the right side in conveying direction

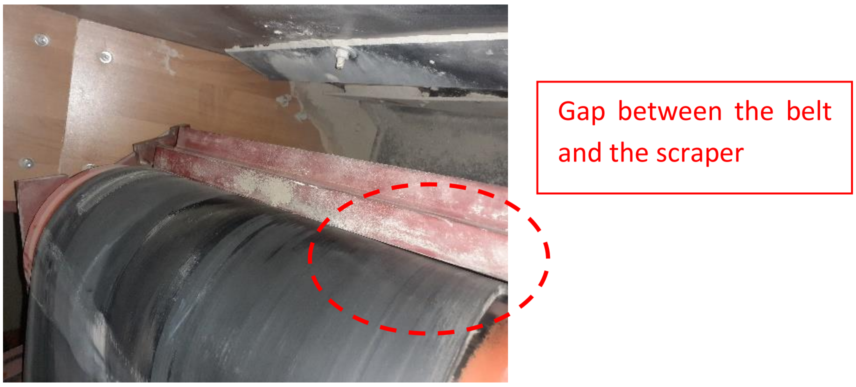


Figure 7 Asymmetrically pressed-on belt cleaner [5]

All tests (except the blocked idlers) result in a displacement of the conveyor belt on the drive pulley as well as a tilt of the roller rotation axis of the PrimeTracker to the stationary axis. The course of the belt displacement is shown in Fig. 8. Further tests with blocked and loaded idlers were carried out which lead to a belt displacement – the results can be seen in [6].

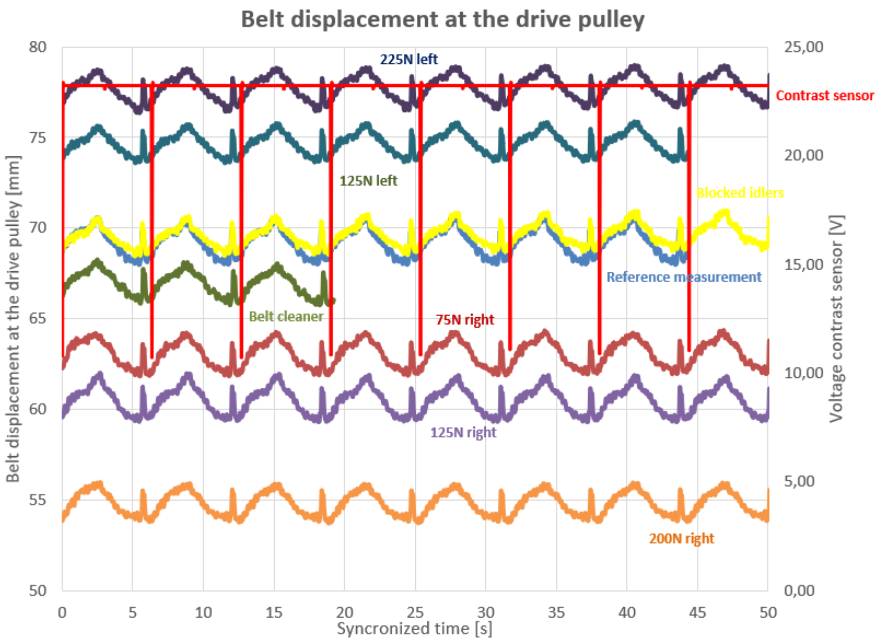


Figure 8 Conveyor belt displacement at the drive pulley [5]

Figure 8 shows that belt misalignment occurred despite the PrimeTracker. The misalignment depends on the load intensity and the location of the failure. The PrimeTracker should actually prevent the belt from shifting on the drive pulley, up to a certain load height. The reason for its limited function can be found in the laboratory conditions. The installed belt with a width of 400mm is outside the specification range (belt width between 500mm and 2000mm) of the PrimeTracker. This means that the steering ability is limited. However, the belt is prevented from running off the drive drum. This restriction did not influence the verification of suitability as a monitoring system, as the PrimeTracker responded measurably to loads or failures implemented in the conveyor system. The behaviour of the PrimeTracker under different additional belt loads can be seen in Fig. 10. The corresponding definition of the directions of movement is shown in Fig. 9.

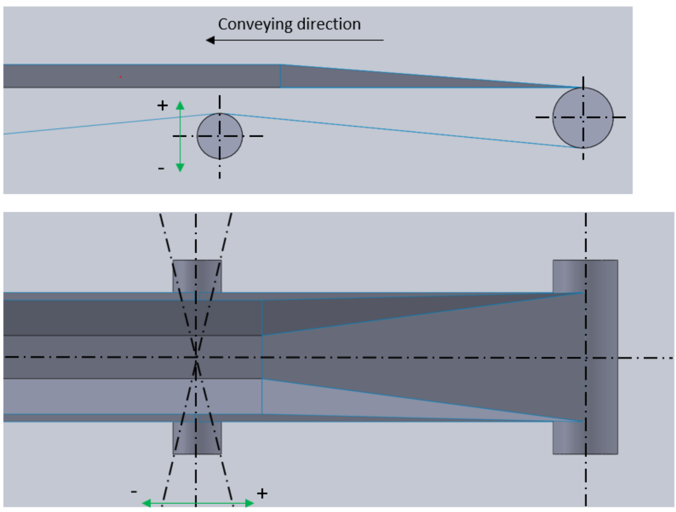


Figure 9 Definition of the direction of movement [5]

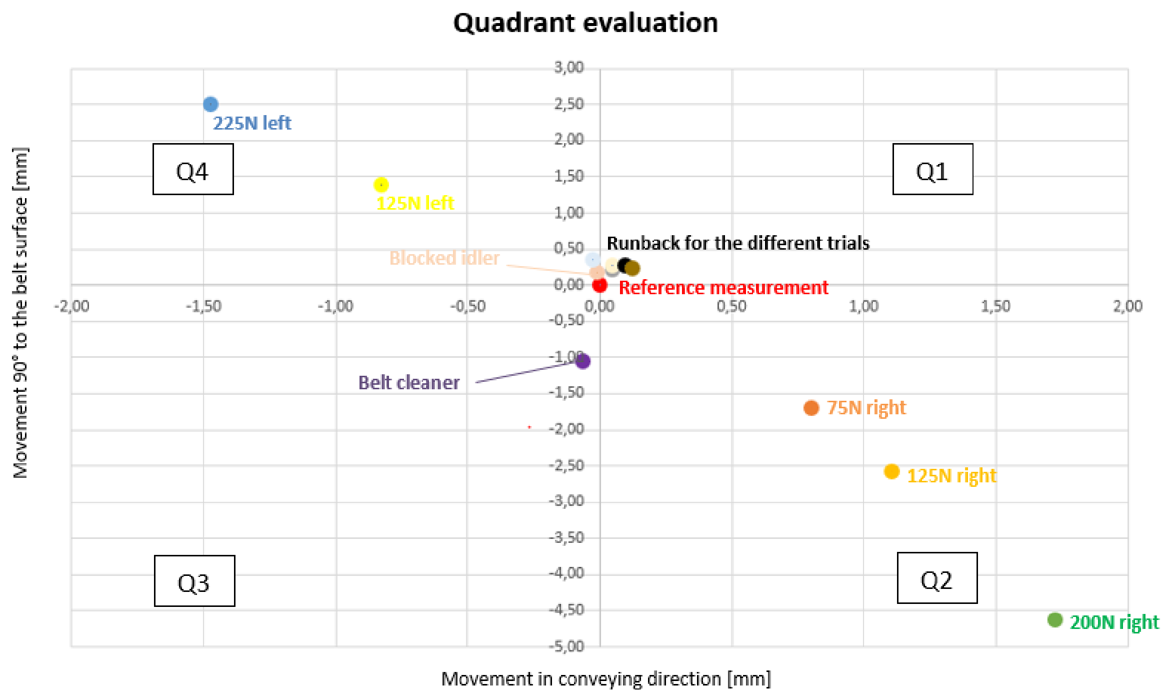


Figure 2 Movement of the “PrimeTracker” with different belt loads [5]

In order to allow assignment of an applied failure to a movement pattern of the PrimeTracker, different approaches can be used. One elaborate and data-intensive option is to analyse the entire periodic oscillation pattern of the two measurement curves, possibly with the inclusion of extreme values. In the evaluation shown in Fig. 10 a simpler path was followed, which also offers the possibility of failure assignment. Here the measurement curves for the movement parallel to the conveying direction and 90° to the conveying direction were each averaged after the run-in phase and entered in the quadrant diagram. This enables a distinct classification by a specific data point for each occurring failure. The calibration measurement was used as zero point (see Fig. 10). For all measurements the average displacement under the applied corresponding loads were determined. In order to determine the runback behaviour of the PrimeTracker after the removal of the applied load, further measurements were carried out with the exception of the belt cleaner. This was always done after the respective measurement with the added failure. Fig. 10 shows the runback points of all load conditions in the close proximity of the starting point. The minor deviations from the zero point are approximately in the range of the measuring tolerance of 0.1mm of the used ultrasonic sensors.

Furthermore, it can be seen that there is no clearly measurable effect due to the blocking of the two idlers (on the right-hand side of the belt in the conveying direction). The measured displacment of the PrimeTracker is within the measurement tolerance and can therefore not be evaluated. In this case, the blocked idlers, which are only loaded by the belt, do not cause any measurable belt misalignment.

The behaviour shown in Fig. 10 is confirmed by measuring the belt run on the drive pulley. The average shift of the belt on the drive pulley, measured with the laser distance sensor is shown in [5]. For example, the shift of the belt on the drive pulley, due to the blocked idlers, is also within the measurement tolerance (+/- 1mm) of the laser sensor. However, all other measurements provide a characteristic value for the respective load. The deviation for the belt runback after the removal of the applied loads is also within the measurement tolerance. It can therefore be assumed that the belt always moves back to its original starting position on the drive pulley after a failure has been removed.

It is important that in both measuring positions (PrimeTracker and drive pulley) it is possible to distinguish whether the failure occurred on the left or right side of the belt. The belt cleaner, which causes an additional load on the

left side of the belt (viewed in conveying direction), shows a different behaviour from the tests with the wheel (see Fig. 10). The failure is now located in the third quadrant (Q3), and not in the fourth quadrant (Q4) as expected. This behaviour cannot be recorded with the method of measuring the position of the belt on the drive pulley. Essential information gets lost by this method. In an industrial application, the shift of the belt on the pulley is avoided up to a certain load anyway. Failure detection is therefore not possible in this case on an industrial scale.
The research carried out so far show that the measurements on the PrimeTracker, in conjunction with the four-quadrant method, provide a promising monitoring method for different failure situations that can occur during the operation of belt conveyors. The adjustment of the PrimeTracker, depending on the occurring system failures, corresponds to the laws of tilted standard idlers which are used to reduce or avoid belt misalignment.

4.2. Checking the Repeatability of the PrimeTracker Adjustment in Case of Recurring Failures

For such a monitoring system, the repeatability of the measurements is essential in case of recurring identical failures. To confirm the repeatability, further measurements were carried out with eccentric belt loads by a wheel (see Fig. 4). The load induced by the wheel has the advantage that the applied “failure” can be repeated exactly, as the load can be set precisely repeatable by the force sensor used. The belt was always loaded at the same position on the left and right side of the conveyor belt with 50N, 100N, 150N and 200N. Before the reference measurement, the belt was preconditioned, i.e. the conveyor was switched on for a certain time and was loaded with 200N by the wheel. After removing the load, the conveyor was switched on again for a certain time until the belt had moved back to its starting position on the drive pulley. Then the reference measurement and the further measurements with the different loads were carried out. For control purposes, not only the different load levels but also the measurements without loads were repeated. The repetition of the measurement without a load was carried out in each case before the start of the individual load series by the wheel on the left and right side of the belt. The measurement results of the test series can be seen in Fig. 11.

The measurements show that a recurring "failure" always shows the same movement pattern of the PrimeTracker. The deviations of the repeated measurements without a load are also within the range of the measurement tolerance of the sensors (measurement tolerance = 0.1mm - ultrasonic sensors). Failure identification is therefore realistic in the case of recurrence. However, the prerequisite for this is that the corresponding failure pattern was assigned and stored in the evaluation software [7] when it occurred for the first time.

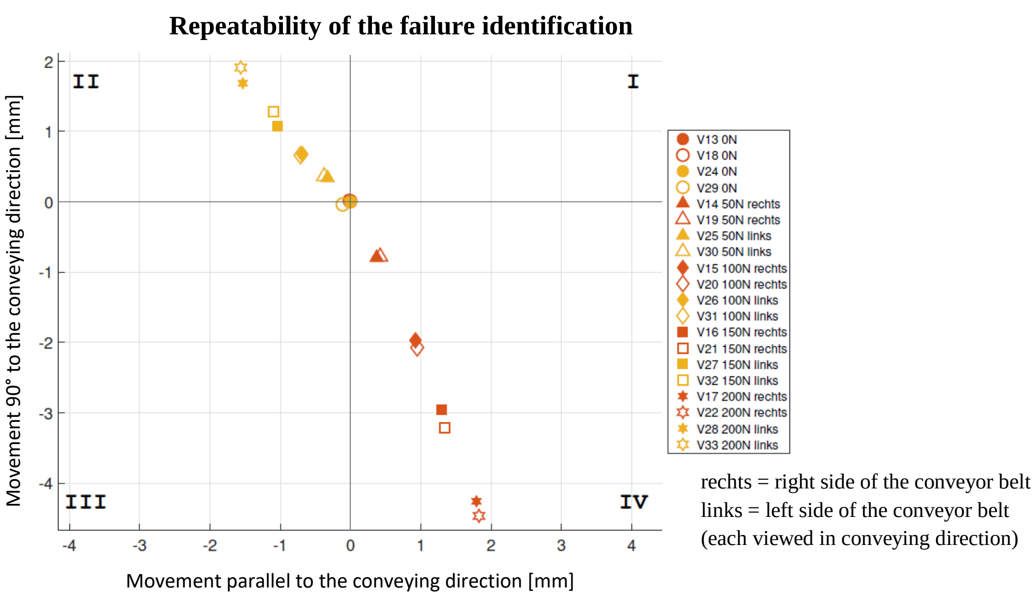


Figure 11 Repeatability of the “PrimeTracker” adjustment in case of recurring failures

5. SUMMARY AMD OUTLOOK

The PrimeTracker is already established on the market as a belt guiding system. The PrimeTracker can be expanded into a monitoring system for belt conveyors by means of a cost-effective, additionally installed measuring system. Initial investigations have confirmed that a simple evaluation process makes it possible to record and also identify system failures that occur. Recording a conveyor malfunction that leads to belt misalignment is possible immediately after the installation and a following calibration of the measuring system. However, failure identification requires a learning process of the system. After a specific failure occurs for the first time, it must be assigned to the evaluation unit by the system operator (corresponds to a point in the quadrant diagram with a defined concentric fluctuation range). If the assigned failure occurs again, it can be identified. Suitable maintenance or failure elimination measures can thus be initiated by the system operator in a failure-specific manner.

Investigations with alternative sensors are currently underway. In addition, further failures are being implemented into the test belt conveyor at the chair and identified and assigned with the new system. After completion of the laboratory tests, the new monitoring system will be verified at an industrial plant. In the future, the measurement results can be provided in different ways depending on the user's requirements. Direct integration into existing systems is possible. "Stand-alone" solutions are also planned. The function of the already developed evaluation software for the stand-alone solution can be seen in [7].

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