PIPE CONVEYOR WITH A COMPLETELY NEW BELT GUIDANCE

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1. INTRODUCTION

Nowadays, the diversity of the various processes of mining, transportation, loading and unloading, and storage continually increases the requirements of the conveying technology. The continuous efforts of the facility designers, to make transport procedures more economical through organized operating guidelines, opened up new fields of operation with higher requirements and a stronger specialization to the conveying technology.

The bulk material conveying technology, a powerful and highly specialized field of the conveying technology, is characterized by its distinctive technical variety. At the present time, the development of conveyors for bulk materials concentrates on reaching - as well as a higher operational reliability and economic efficiency - environmental requirements.

1.1. GENERAL MECHANISM OF PIPE CONVEYORS

In contrast to the common troughed belt conveyor, which just arches the belt on its sides up to a certain trough angle, in the pipe conveyor – as the name implies - the belt totally encompasses the bulk material. Thus, the cross-section can be designed either round or oval. To achieve those cross-sectional shapes, the idler assembly is – apart from some exceptions – arranged hexagonally. Figure 1 shows a schematic comparison of the cross-sections of the troughed belt conveyor and the pipe conveyor (also “closed belt conveyor”).

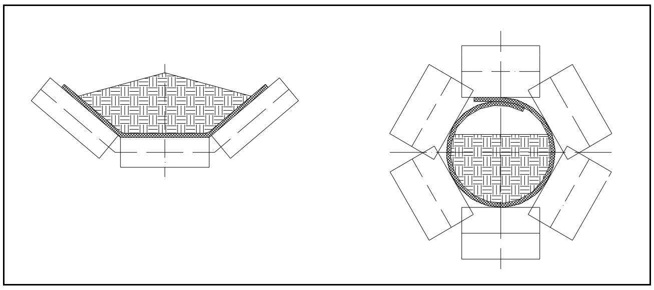

Figure 1: Schematic comparison of the troughed-belt conveyor and the pipe conveyor

Most pipe conveyors use flatly-manufactured belts. They are trough-shaped conventionally in the roll-in section of the conveyor and then closed to a pipe by the ring-shaped idler assembly, which is held in this shape over the whole distance by the idler stations. In the rolling-out section of the conveyor, the belt opens automatically, due to the inner forces, back to the flat belt shape. The return travel of the belt beneath the charging section is performed in the same way. Figure 2 shows the general mechanism of a conventional pipe conveyor.

Advantages of the pipe conveyor in comparison to the troughed-belt conveyor:

- Suitable for transporting “difficult” bulk materials (dusty, muddy, or contaminated)
- Weather condition protection for the various bulk materials
- No losses of material conveyed
- Flexible transport routing under tricky topographical conditions
- Steep-slope conveyance possible
- Curve radius up to 45 m – depending on the closed belt diameter
- Steadier run
- No problems during winter operation

Disadvantages of the pipe conveyor in comparison to the troughed-belt conveyor:

- Higher energy consumption due to the higher drag of the closed belt
- 1,6 times the normal belt width for the same mass flow and for the same belt speed of a trough-shaped belt conveyor with a trough angle of 30°
- Sensitive against overload and oversize
- More difficult repair and dismantling of the belt
- The facility requires more frequent maintenance and safety checks
- Backed-up heat in the closed belt when conveying hot bulk material

The enumeration of advantages and disadvantages shows that the pipe conveyor is - in comparison to the troughed-belt conveyor - superior in many ways. This is especially true for the transport of difficult materials and the protection of these materials during the transport from A to B. A further benefit of the pipe conveyor is the capability of managing transport routing under tricky topographical conditions. This is possible due to the ability to cope with essentially smaller-radius curves and steeper slopes.

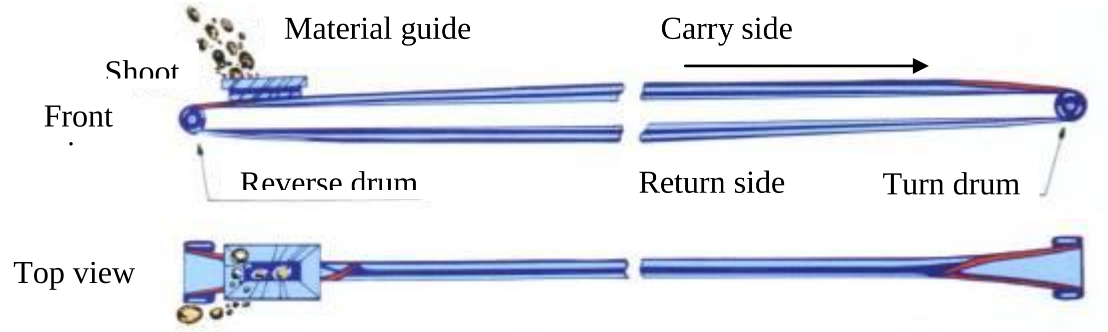

Figure 2: General mechanism of conventional pipe conveyors

2. NEWLY-DEVELOPED PIPE CONVEYOR

2.1. PRESENTATION OF THE NEW SYSTEM

Due to the great number of idlers required for creating the pipe in conventional belt conveyors (12 idlers per idler station), the sum of the kinetic resistances increases along the transport route and results in a large amount of power needed for the drive motor(s). Furthermore, the large number of idlers causes excessive noise, which can exceed the permissible limits - especially in the neighborhood of villages or cities - and, often, expensive acoustically absorbing housing of the entire conveying path has to be provided.

Starting with the initial intention of reducing the number of idlers as well as the noise along the travel path, a new kind of belt guidance was developed at the Department for Conveying Technology and Design Methods, Mining University of Leoben, and subsequently patented (Austrian patent registration No. 1126/99) [1, 2]. Hereby the returning belt is not – as usual – executed as closed belt but is turned round by additional idlers on both ends of the travel path, so that the return strand rests on the already existing idlers of the charging strand. They support and guide the belt – as demonstrated in Figure 3.
In comparison to the conventional pipe conveyors, the two upper idlers on each side are longer to support the belt over its entire width. The finger idlers (the blue ones in Fig. 3), which are situated in certain distances near the extended upper idlers, are necessary to guarantee a steady belt run in curves. They support the belt and prevent it from slipping off.

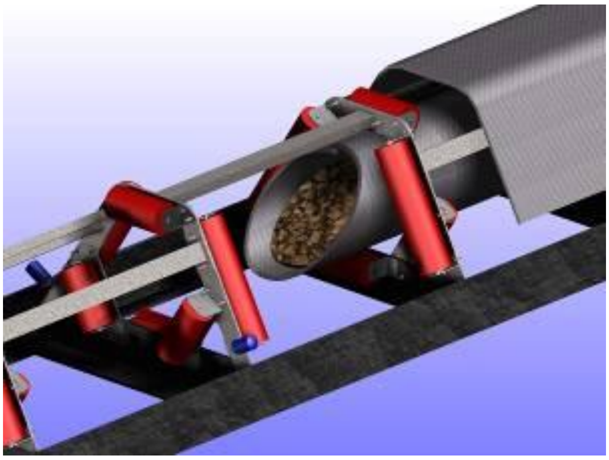

Figure 3: Newly-developed belt guidance for the pipe conveyor

To allow this new kind of system to operate properly, the return stations had to be completely redesigned. Especially the assembly of the deflection idlers and the design of the charging and discharging station had to be changed. In Figure 4 and Figure 5, the suitable constructive measures for this new type of pipe conveyor at the return stations are displayed.

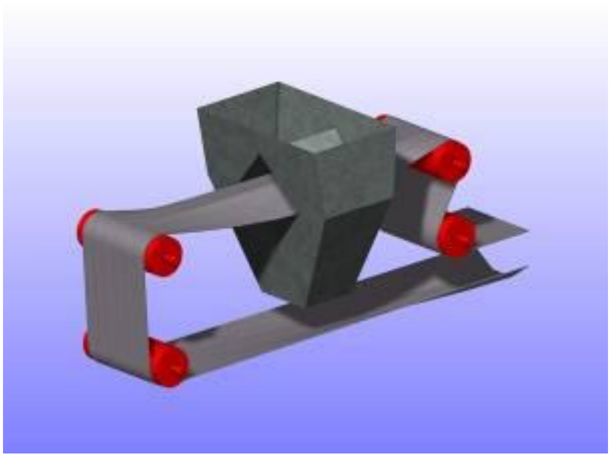

Figure 4: The new pipe conveyor charging station

These figures illustrate that the return station – at the charging station as well as at the discharging station – has to be more complex than in conventional pipe conveyors. Consequently, the use of this new system only becomes more economical than the conventional one above a certain transport length.

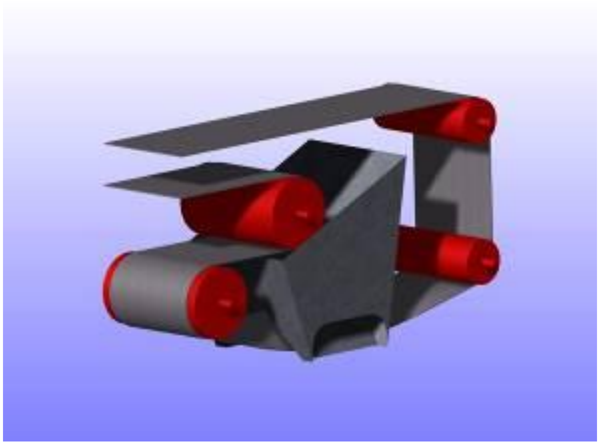

Figure 5: The new pipe conveyor discharging station

2.2. COMPARISON OF THE NEWLY-DEVELOPED SYSTEM WITH CONVENTIONAL PIPE CONVEYORS

Advantages of the newly-developed system:

- No idler assemblies for the belt return
- Reduction of the power by minimizing resistance during belt return
- Decreasing belt tensile forces due to reduced kinetic resistance
- Due to the lower belt tensile forces, less expensive belts can be used
- No support constructions for belt return; consequently a reduction in total weight of the construction
- Very compact design – minimum space required
- Noise reduction as the returning belt covers the complete closed belt strand and its stations
- Weather protection of the idlers

Disadvantages:

- More complex charging and discharging stations

The advantages of this newly-developed system listed exceed the originally expected disadvantages by far. The return of the belt (especially the design of the idler assembly) is a challenge, which has yet to be met.

3. TEST FACILITY

3.1. PLANNING OF THE TEST FACILITY

The goal was to plan, execute, and put on line a test facility. The test facility should be capable of determining the kinetic resistance of the closed belt and its return strand for a wide range of belt widths.

Check list of all targets for the planning and development of the test facility:

- Use of the test facility with a closed belt cross-section up to 500 mm
- Maximum bulk load of the belt with gravel
- Apply preload forces up to 50 kN
- Design with variable idler-station distance - up to 2 m
- Simulation of a belt speed of up to 5 m/s
- Simulation of curves radius – up to 50 m
- Determining the necessary number of finger idlers for the belt return in curves
- Determining the optimum closed belt shape during straight sections and curves
- Determining the optimum layout of the idlers for the belt return

The test facility should deliver, on one hand, results close to reality and, on the other, it should be cheap and require little space. Consequently, the test facility had to be designed in a compact way, allowing for the high and varying demands, which must be met to achieve the required results. The concept of the test facility is designed to simulate the movement of the closed belt by simply moving the idler assemblies, which are mounted on a trolley.

- The movable unit is equipped with two additional fixed idler stations, which can be moved for the various tests and consequently simulate variable idler station-distances.
- The center idler station is designed for the measuring of the kinetic resistance of the closed belt.
- The movable unit just has to transmit the force and is not designed for determining kinetic resistance.

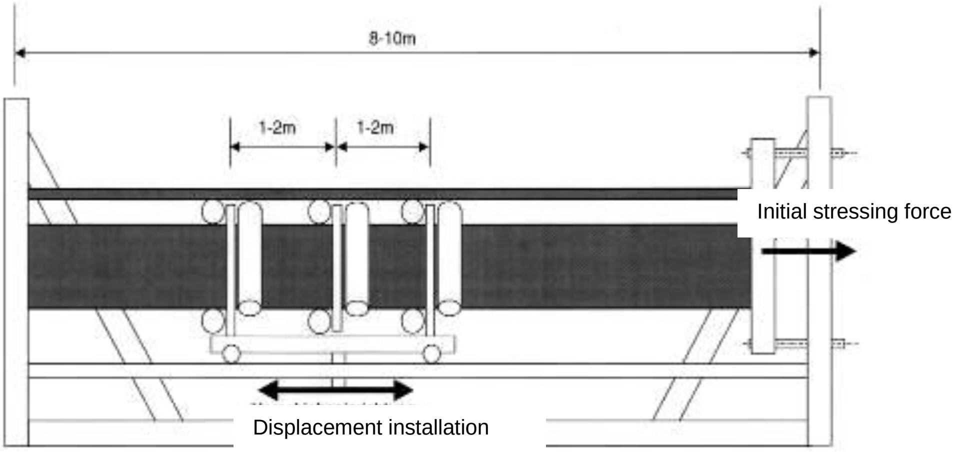

Figure 6: The schematic design of the test facility

Figure 6 shows the schematic design of the test facility. The dark colored surfaces in Figure 6 symbolize the closed belt and the belt return. The belt return is sketched as thick black line, although it actually covers almost all of the upper three idlers.
For test facilities of this kind don't forget that just one of the belts can be fixed and measured or otherwise the idler stations wouldn't be able to move. Another criterion for the design of this test facility was that it should not only be able to measure the movement of the belt and the return belt during straight distances but also simulate curves.

3.2. MEASURING IDLER STATION

The measuring idler station had to be designed to allow the measuring of the occurring kinetic resistance during the moving of the measuring slide and the value of the lateral force during the simulation of a run through a curve without any influence of external friction. Figure 7 shows the measuring idler station, which is positioned according to the directions in between the other two idler stations on the measuring slide.

Figure 7: The measuring idler station on the measuring slide

A column saddle was developed to provide free running of the measuring idler station. It guarantees a very small influence of the own friction as well as absorbing developing static torque without any problems. The column saddle has to allow travel in both directions up to reaching the load sensors.

3.3. MEASURING SLIDE

The function of the measuring slide is to provide the motion of three idler stations in longitudinal direction of the belt. The measuring slide has to be accelerated steadily up to the measuring speed, travel with it over the whole measuring distance, and then be slowed down again until standstill. A rack-and-pinion gear was selected for the transmission of power. The steering rack is mounted on the measuring slide. This permits the back-and-forth movement of the slide, produced by the drive motor and the pinion (Figure 8).

Figure 8: The measuring slide with drive motor and steering rack

3.4. CROSS SLIDE FOR CURVE SIMULATION

The function of the cross slide is to displace the belt and the belt return laterally on a straight travel path to permit simulation of curves. The cross slide travels time-locked to the measuring slide. The cross slide design is illustrated in Figure 9.

Figure 9: Design of the cross slide station

3.5. POWER SYSTEM

The criterion for the driving motor and control system selection was the required identical same dip angle of the measuring slide and cross slide. For the driving system a complete package from SIEMENS was selected. It consisted of two servo-motors and two frequency converters for the drivers, combined with an internal control system, which allows any required same dip angle of the motors at a certain stress cycle. The decision for this system was made based on the following requirements:

- Elimination of any external measuring and control technologies
- Substantially less time consumption for the assembly and the start up of the test facility
- Guarantee of reliable and safe functioning of both drivers
- Easy and practical control and operation of both drivers

3.6. BACK-UP STATION

The back-up station serves the purpose of applying the tensile force for the closed belt and for the belt return. It is equipped with a back-up weight to keep the belt tension force constant during the measuring of kinetic resistance (Figure 10). In addition, the back-up station provides the following features:

- A tension-force meter to indicate the actual initial stressing force
- A weight transmission to keep the tension weight low and to assure greater ease of handling during the measuring process
- A tie bar to facilitate installation of the belt and to compensate changes in length
- Height-adjustable rope sheaves for the tensioning devices of closed belt and belt return

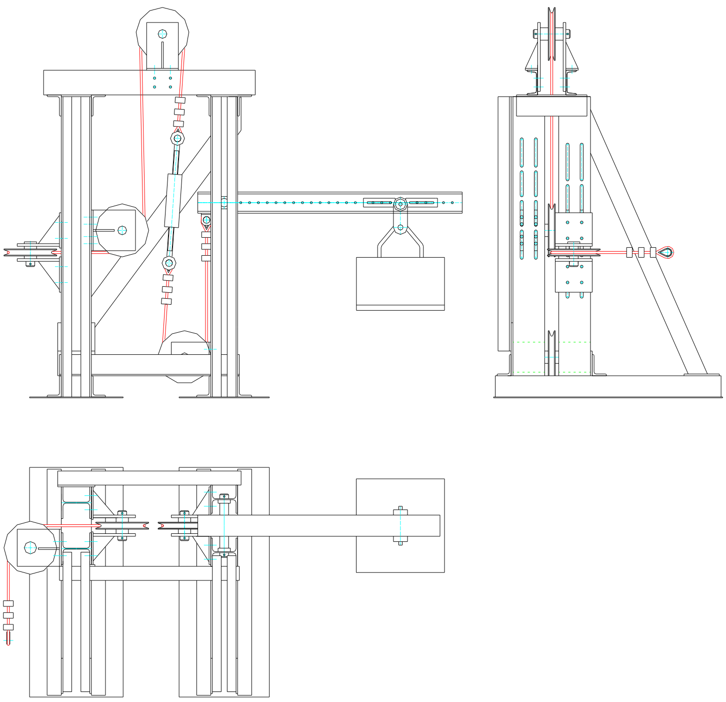

Figure 10: Back-up station design

4. MEASURING

4.1. BELT DATA

For the test series, a belt with the following data was used:

Manufacturer/type:	Semperit/PIPETRANS
Belt width:	800 mm
Total belt thickness:	8.8 mm
Thickness of the carrying surface:	4 mm
Thickness of the running surface:	2 mm
Rupture resistance:	250 N/mm

4.2. BELT RETURN

Figure 11: Belt return with the measuring slide

In the initial test series (Figure 11) various idler arrangements were tested to determine the optimum idler assembly geometry. This optimum is reached at an angle of 50° between the two upper lateral idlers. In Figure 12 the optimum idler layout is shown. Starting at this angle, the entire belt width rests on the lateral idlers.

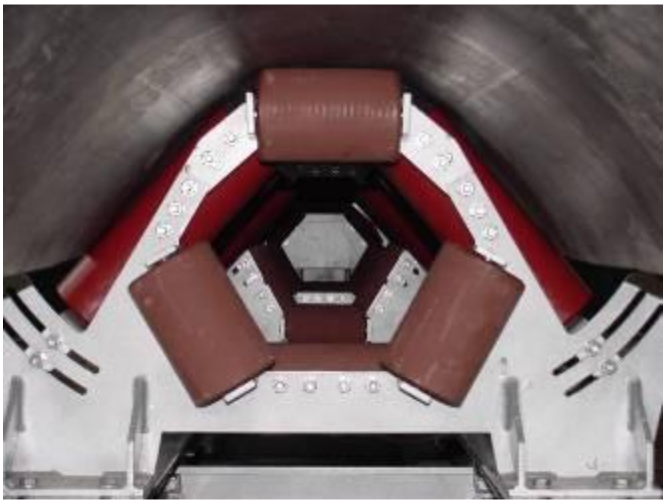

Figure 12: Idler position for an optimum belt return (photo of the test facility)

The variations in kinetic resistance of the belt return were measured under the following variable conditions:

- Idler station distance
- Conveying speed
- Belt tensile force
- Geometry of the idler positions

4.3. CLOSED BELT

The test series for the belt were performed with the optimum idler arrangement for belt return, which had been determined in the test series for belt return.

Figure 13: Closed belt on the measuring slide

With the idler settings described under 4.2 kinetic resistance of the closed belt (Figure 13) was measured under the following varying conditions:

- Idler station distance
- Conveying speed
- Belt tensile force
- Degree of load (%)

5. RESULTS

5.1. BELT

The test series of the closed belt resulted in kinetic resistances between min. 10 N and max. 70 N. The kinetic resistance increased with variation of the following parameters:

- Increase of the idler station distances
- Increase in belt speed
- Reduction of belt tensile forces
- Increase of load (%)

Belt Return

The series of measurements resulted in kinetic resistances from a minimum of 4 N to a maximum of 10 N for each idler station.
In comparison to conventional closed belt conveyors, the largest differences occurred during the belt return.

The test series of the unloaded belt (conventional closed belt conveyors):

- 10 N (for high belt tension forces, lower belt speed, and smaller idler station distances)
- and 50 N (for small belt tension forces, higher belt speed, and larger idler station distances)

This means that use of the new belt return system - when compared to a conventional pipe conveyor - results in a reduction of the kinetic forces by a factor 2.5 to 5.

6. INVESTIGATION INTO BELT SLIDING DEPENDING ON DIFFERENT BELT-ELONGATIONS OF LOADED PIPE AND RETURN BELT

A fact which has to be investigated is the influence of different belt-elongations in loaded pipe and return belt which are acting on the upper idlers.
Therefore, belt-elongations in upper and lower strand were measured at a conventional belt conveyor. The measurement took place in a short distance to the drive pulley where the difference in elongation is greatest. The measurements were carried out under variation of loading conditions, belt speed and back-up force. The measurement assembly is shown in Figure 14.

Figure 14. Measurement of belt tension in carry side and return side

Depending on loading condition, belt speed and take-up force, the difference in elongation between carry side and return side was 0,21 to 0,92 mm/m.
Due to this difference insignificant sliding effects occur between return side and the idlers.
At the same time drive power is transferred from the faster strand over the idler to the slower strand. This leads to a compensation of belt speeds and elongations. Similar relationships were tested and discussed in [4]. Anyway, due to the low normal forces of the return side on the idlers sliding should not be a problem. Theoretical investigations show pleasant results. The interplay of the idlers with belts on two sides is very complex and has to be established by experimental tests. Therefore, a prototype of the new pipe conveyor is to be built in spring 2003.

CONCLUSION

Currently facilities with pipe conveyors run the charged belt as well as the belt return in a pipe shape produced by six idlers as circular arrangement.
The newly-developed belt return, however, is not as customary with the belt closed. Here, the belt is permitted to resume its original flat shape during the return path traveling on top of the already existing idlers for the loaded strand.
In comparison with conventional pipe conveyors, the charging and discharging stations require a more complex design. On the other hand, there are the various advantages, resulting from the transport path. Because of these advantages, it can be assumed that this new development will be applied in the near future – especially, since these advantages are combined with substantial cost reductions (idlers, belt, noise reduction and drive power) when compared to conventional pipe conveyors.

7. LITERATURE

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