Development of a Dual Test Rig for the Investigation of Conventional and Driven Rollers

Kriwall, A.; Alshov, A.;Küster, B.

Abstract

Belt conveyor systems are an excellent way to handle bulk material. As loads and distances increase, those systems become bigger and energy efficiency becomes an important factor. The energy consumption of belt conveyor systems is primary determined by the drive power. The drive power is the sum of the main drive power and the power of all intermediate drives, if present. The implementation of driven support rollers allows to reduce the load on the conventional drive based at the head of a conveyor system, by splitting it to multiple driven rollers. The main drive can be build smaller, which leads to a lower energy consumption and therewith to cost savings during the production. Furthermore, driven rollers enable the concept of modular belt conveyor systems, what would be impossible with the conventional head drives. This gives planners more flexibility for engineering new or modifying existing conveyor systems.

Despite the great opportunities and promising characteristics of driven rollers, they yet have not been used in daily operation. Without having sufficient knowledge about the behavior of driven rollers under certain conditions, as heat or cold, and the economic efficiency of them, the benefit is questioned. To bridge the lack of knowledge, investigations and research need to be done. A test rig for driven rollers is indispensable to develop this technology into a marketable commodity. At the same time a test process needs to be implemented.

This paper gives an overview about driven rollers and an accurate insight in the development of a test rig for investigating driven rollers. With this test rig, the use of driven rollers can be simulated under certain climatic conditions. Moreover, different loads and speeds can also be simulated by using state-of-the-art technology.

Keywords: Driven roller, belt conveyor system, energy efficiency, test rig, cost savings

1 INTRODUCTION

From the beginning of the second half of the 20th century, belt conveyer systems became the key technology for the transportation of bulk materials. With belt conveyor systems, a stable and high efficient continuous connection can be set up between a conveyor site and a consumer or transfer point [1]. This can be a connection between a raw material mine and a plant or port. With an increase of the demand for raw materials, belt conveyor systems became bigger. By raising the belt width, drive capacity or speed, more bulk material has been handled.

Beside the belt, the intake, the outtake and a scaffold, a large number of support rollers and the drive are the key parts of a conveyor belt system. The support rollers carry the belt and the transported materials, while the belt is set in motion via the drive.

2 CONVENTIONAL SUPPORT ROLLERS

As conventional support rollers are used in large quantity, they have a simple design. It is a tube mounted on bearings rotating around its own axis. They are mounted below the upper part of the belt to carry and guide the loaded strand and below the lower part to guide the empty strand. Special rollers are designed to clean the lower strand. The running resistance is the main quality criterion of a support roller. It is the circumferential force of the shell over the axis. It is caused by the bearings, seals and the used grease. It varies with different conditions. The running speed, the external force caused by the load and climatic conditions as humidity and temperature also have influence on the running resistance [2]. Other quality criteria are concentricity deviation, breakaway mass, balancing quality and axial relocatability.

The running resistance of the support rollers added to the indentation rolling resistance and other resistances[1] determines the necessary drive power and maximum load of a conveyor belt system [3]. As the running resistance directly counteracts the drive power, a higher running resistance leads to a higher demand of drive power. The drive power determines the energy demand of the entire conveyor system. The running resistance is usually 5% to 15% [4] and can be up to 30% [5] of the total resistance and is therewith a major factor for the total energy consumption of a belt conveyor system.

3 DRIVEN SUPPORT ROLLERS

Instead of support rollers running as idlers, driven support rollers can be used in a conveyor belt system. Driven support rollers are not passive carrying the belt, they act active as a drive. On conventional support rollers, the energy transfer is from the belt to the roller to overcome the rollers running resistance. Using driven support rollers, the energy transfer is from the driven roller to the belt. The driven roller overcomes its own running resistance by itself.

There are two types of driven rollers. On the one hand the driven roller is driven from the outside. A gear mounted on the outside of the roller is connected to the power by a chain or toothed belt. This allows to drive various rollers with one drive. The other type follows a more innovative concept. Each driven roller has a drum motor installed inside (Figure 6). With a gear firmly attached to the shell and the drive connected to the axis, the shell is set in motion. This version only needs an electric connection, what makes the controlling system much simpler.

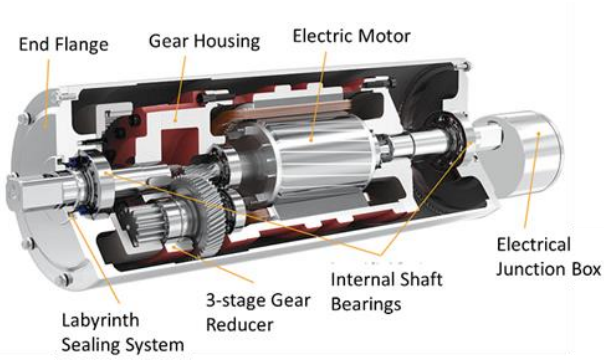

Figure 6: Inside of a driven roller [6]

4 DRIVE AND DRIVEN ROLLERS

Conventional conveyor belt systems have a drive at the head of the conveyor. The running resistance of each support roller must be added to the systems running resistance along the conveyors path. That leads not only to a rising necessary drive power, but also to an increasing belt tensile force [7]. With the drive at the head of the system, the tensile force increases linearly from the rear of the conveyor system to its maximum at the head. The limit of 20.000 N/mm for belts tensile strength restricts the maximum for load and distance for conveyor belt systems [8]. Figure 7 shows the increasing tensile force over the conveyors path and the first approach to reduce the maximum tensile force. With an intermediate drive along the conveyors path, it is possible to decrease the tensile force. A disadvantageous effect on that solution is a deflection of the conveyor belt.

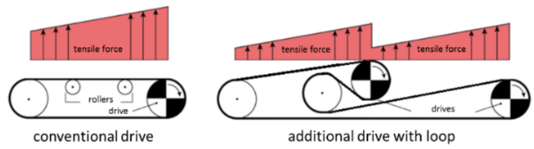

Figure 7: Tensile force of conventional drive and additional drive with loop

As a deflection of the belt leads to an increase of mechanical effort it is less efficient. To avoid this deflection two other concepts have been invented. By using an additional driven belt, the conveyor belt can be powered on its path without any deflection. The construction effort is still huge but allows longer distances and bigger loads. The replacement of conventional support rollers by driven support rollers promises a simpler construction and the advantages of the other concepts by decreasing the tensile force (Figure 8).

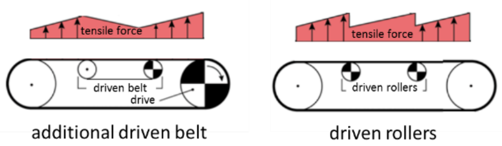

Figure 8: Tensile force of additional driven belt and driven rollers

With the decrease of the tensile force through intermediate drives the requirements of the

[1] Other resistances: Gradient resistances, special resistances, secondary resistances, flexing resistance of the belt, flexing resistance of the bulk material.

head drive decrease and the whole conveyor system can be reduced in size. The more driven rollers are used the smaller the head drive can be. With a sufficient number of driven rollers, the necessary drive power can be pushed to zero and the waiver of a head drive is possible. This leads to a reduction of energy demand and investment costs.

5 OBSTACLES AND POTENTIALS OF DRIVEN ROLLERS

Even if the invention of driven rollers goes back to the 1970s they have not been in operation in daily use since then. So far two obstacles prevent the application of driven rollers.

The first obstacle relates to the contact between the driven roller and the belt. The angle of wrap is small between the roller and the belt, as the belt is a comparative straight part. This is very positive in the application of conventional support rollers, but is an obstacle for driven rollers. For the application of conventional rollers, the smallest possible angle of wrap reduces the friction and therewith the resulting movement resistance [9].

The opposite is the case for driven rollers. The power transmission between the driven rollers and the belt is much lower compared to a head drive with a big angle of wrap. There is a high risk of slip and therefore a larger angle of wrap prevents slip and allows a better power transmission. This dichotomy will be challenging, if conventional and driven support rollers are used in the same system.

The second obstacle is the increase in effort for electronic and controlling. Each driven roller needs cables and only a few driven rollers can be controlled by one frequency converter. This is a huge cost factor for the implementation of driven rollers. But as developments in the electronic-sector make control devices more affordable this cost factor will be reduced.

To overcome those obstacles is part of current research, since the potentials of using driven rollers are magnificent. The reduction of tensile force allows to use lighter and more cost-effective conveyor belts. Lighter conveyor belts are build simpler, which leads to reduced investment costs. Additionally, the usage of lighter conveyor belts results in a lower energy consumption because less mass must be moved. This reduces the costs in operation.

Another major opportunity is the expansion of possibilities in plant design. The maximum flow can be increased due to less tensile force. Currently long conveyor distances are bridged by the connection of several individual belt conveyors in a row. A conveyor belt system based on driven rollers allows to overcome longer distances without any interruptions. One conveyor system can be used to connect producer and consumer over several kilometers of distance. A mining area far away from the coast and a port can be constantly connected with a single conveyor system through a reasonable investment. Figure 9 gives an overview on the potentials and obstacles of driven rollers.

Potentials	Obstacles
Reduced tensile force	Low power transmission
Modular system design	High risk of slip
Longer distances	Expensive cabling
Reduced investment cost for the conveyor belt	Complicated control
Reduced energy costs	

Figure 9: Potentials and Obstacles of driven rollers

6 DEVELOPMENT OF A TEST RIG

The smooth transport of bulk material is vitally important in modern production with its high demands on the availability of resources. To ensure this belt conveyors are used in all parts of the world for the transport of bulk material. Thereby high-quality standards for all components are necessary. For driven rollers no quality standards, test rigs or even test guidelines exist. A condition that must be changed. The Institut für Integrierte Produktion Hannover (IPH) and the Institut für Transport- und Automatisierungstechnik (ITA) develop a dual test rig to ensure that conventional support rollers meet the existing standards and to work out new standards for driven rollers. The test rig allows to run driven rollers under different realistic environmental conditions while the measuring system records characteristic data. This data gives insights into the efficiency and the applicability of driven rollers. Manufacturers and users of driven rollers can rate the usability for certain cases on a comprehensive data basis.

The test rig is based on a frame with a climatic chamber (Figure 10). All testing is within the climatic chamber. Different weather scenarios can be simulated. The temperature within the test chamber can be adjusted from -40 to 60 degrees Celsius. The relative humidity can be adjusted to the desired value.

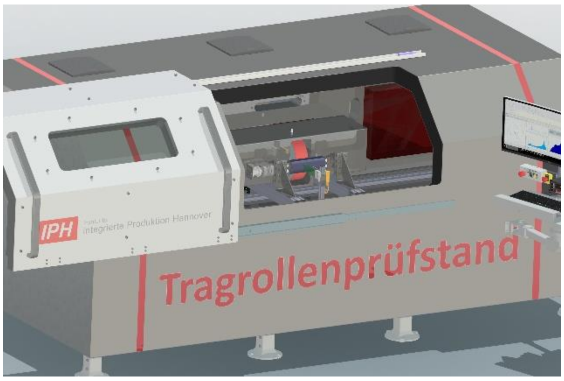

Figure 10: Test rig for rollers

When testing conventional support rollers, the test rig can run all tests according to the German test standard DIN 22112 [10]. This includes the test for running resistance under defined conditions. Additionally, the roller can be tested under more specific conditions. The simulated load can be up to 40 times higher than required by the DIN. Figure 11 gives an overview about the possible values for test parameters compared to DIN values.

Characteristic	Test rig	DIN 22112
Load	Up to 10 kN	250 N
Rotations per minute	Up to 960 min^{-1}	650 min^{-1}
Temperature	-40 °C to 60 °C	18 to 22 °C
Diameter of shell	89 mm to 219 mm	-
Length of axle	Up to 1500 mm	-

Figure 11: Characteristics of the test rig

The roller is clamped into bearings and is driven by a drive wheel. Compared to the use of a belt for driving the roller the drive wheel is a more realistic scenario for driven rollers considering the angle of wrap. Furthermore, the drive wheel is easier to handle in the setup. A special drive wheel is used for the test rig which allows wheel temperatures up to 100 degrees Celsius.

The drive wheel is connected to a servo motor via clutch (Figure 12). The servo motor is controlled by a frequency converter. The driving wheel and the servo motor are mounted moveable. An electromechanical compact cylinder is used to push the drive unit against the roller with a certain adjustable force. The electromechanical compact cylinder is controlled by another frequency converter and the adjusted force by the electromechanical compact cylinder simulates the load. While running on a certain speed and with a certain load a torque sensor, mounted on the rigid roller axle, measures the torque and therefore the running resistance of the support roller.

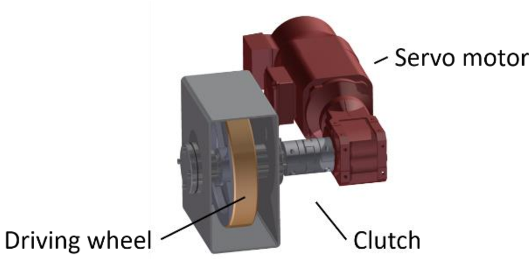

Figure 12: Drive unit

The test scenario of driven rollers is different. The running resistance of a driven roller cannot be measured in the same way as the running resistance of idlers. The internal drum motor of the roller overcomes the running resistance. As the running resistance is not directly measurable the energy consumption under certain conditions can be measured. The drive unit of the test rig acts as a break, when testing driven rollers. The break energy transfers from the drive wheel via the clutch to the servo motor and from there to the frequency converter. The frequency converter transforms the energy to heat outside of the test chamber. With the drive unit a defined braking force can be put on the driven roller. The driven roller is controlled via an extra frequency controller. Thereby the energy consumption of the driven roller can be measured under a specific speed, load and braking force. By varying the parameters and recording the energy consumption of the driven roller its motor characteristic curve can be plotted.

The test rig is controlled via a PC and an independent safety circuit. The safety circuit automatically stops the test and sets the drive unit back to its initial point in case of an emergency. All frequency converters and sensors are connected to the PC. With a touchscreen optimized graphical user interface (Figure 13) a LabVIEW program controls and regulates the test rig. The data from the actuators and sensors is saved for further use.

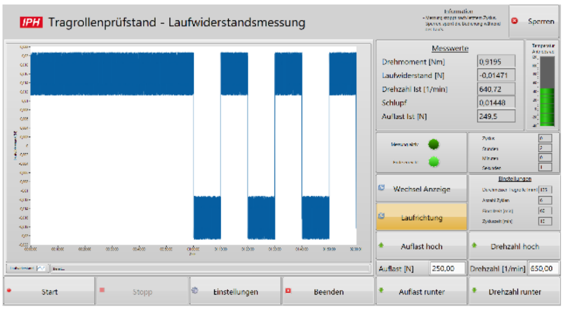

Figure 13: Graphical User Interface

7 CONCLUSION

Due to their enormous potential, driven rollers are expected to become the future standard in belt conveyors systems. The chance to significantly increase the maximum conveyor length and decrease the energy consumption and costs will be indispensable to use. The ability of the implementation of modular conveyor systems opens unforeseen possibilities in the fields of flexibility, scalability and mobility [1,11].

Both, the construction of new modular conveyor systems with driven rollers and the expansion of existing systems to expand the capacity appear to be of great importance. For new systems the research is promising. Upgrading existing conveyor systems with driving rollers is an efficient way to maximize the capacity with low effort.

The test rig developed by IPH and ITA gives the opportunity to gain insights in all fields to reach a market penetration for driven rollers. The energy consumption and the economic conditions will be determined. The applicability of new developed rollers can be validated. With the test rig, the optimum settings for support and driven rollers for different conditions can be identified with little effort.

Due to its construction the test rig can be used for future investigations on conventional and driven rollers. Research in this field can be continued in the next years.

8 ACKNOWLEDGMENT

The work of Ake Hübner, Alexander Alshov and Benjamin Küster within the IGF project 19137 N of the Society for Transport Management and Logistics (GVB) was funded via the German Federation of Industrial Research Associations (AiF) in the programme of Industrial Collective Research (IGF) by the Federal Ministry for Economic Affairs and Energy (BMWi) based on a decision of the German Bundestag.

9 REFERENCES

[1] R. Alles, „Intermediate drive of belt conveyors by means of driven support rollers and linear motors” (in German),. Ph.D. dissertation, Technische Universität Hannover, Hanover Germany, 1976.

[2] A. Kropf-Eilers, L. Overmeyer, T. Wennekamp, „Energy-optimized conveyor belts - development, test methods and operating procedures“ (in German) *in Aufbereitungs Technik, Bauverlag,* vol. 49, no. 9, pp. 25-34, 2008.

[3] DIN Deutsches Institut für Normung e.V.: DIN 22101 Continuous conveyors – Belt conveyors for loose bulk materials – Basis for calculation and dimensioning, English translation of DIN 22101:2011-12 ICS 53.040.20, Normenausschuss Bergbau (FABERG) im DIN, Beuth Verlag GmbH, Berlin, 2011.

[4] F. O. Geesmann, E. Nagy, J. Báti, H. Visonta, „Design of heavy support rollers for the upper run of belt conveyor systems Part III: Operational design of a support roller” (in German), *AT Mineral Processing,* Bauverlag, vol. 04, 2009.

[5] A. Gladysiewicz, „Optimization of support rollers for increasing the efficiency of belt conveyors” (in German), presented at *Fachtagung HdT - Gurtförderer und ihre Elemente,* Essen, Germany, 2013.

[6] BNP Media, “Thinking inside--and outside--the box”, http://www.foodengineeringmag.com/articles/95822-thinking-inside--and-outside--the-box, last access 2017-08-14.

[7] L. Gladysiewicz, J. Bukowski, “New insights of movement resistors of support rollers” (in German), presented at 14. Fachtagung Schüttgutfördertechnik, Magdeburg, Germany, 2009.

[8] H.-P. Lachmann, „Limit data of conveyor belts with steel cables” (in German), *Fördern und Heben*, vol. 23, no.8, pp. 425-428, 1973.

[9] L. Overmeyer, S. Hötte; S. Falkenberg, T. Wennekamp, „Investigations for optimizing wear behaviour of conveyor belts“ (in German), *International Rubber Conference,* Nuremburg, Germany, 2009.

[10] DIN Deutsches Institut für Normung e.V.: DIN 22112-3 Belt conveyors for underground coalmining - Idlers - Part 3: Testing. ICS 53.040.20, Normenausschuss Bergbau (FABERG) im DIN, Normenausschuss Maschinenbau (MAN) im DIN, Beuth Verlag GmbH, Berlin, Germany, 1996.

[11] M. A. Alspaugh, “The Evolution of Intermediate Driven Belt Conveyor Technology”, in *Bulk Solids Handling*, vol. 23, no. 3, pp. 168-173, 2003.

Kriwall, Ake

Leibniz Universität Hannover

Institut für Integrierte Produktion Hannover gGmbH

huebner@iph-hannover.de

Alshov, Alexandr

Leibniz Universität Hannover

Institut für Integrierte Produktion Hannover gGmbH

alshov@iph-hannover.de

Küster, Benjamin

Leibniz Universität Hannover

Institut für Integrierte Produktion Hannover gGmbH

kuester@iph-hannover.de