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Gearless drives for medium powered belt conveyors

Getriebelose Antriebe für Gurtbandförderanlagen mittlerer Leistung

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SUMMARY

Recent installations of gearless belt conveyor drive systems have shown the promise of increased reliability, improved system efficiency and reduced maintenance which results in higher productivity, increased revenue and lower operating costs. This contribution examines a method of applying these advantages to conveyor drive systems with power modules in the 600 to 3000 kW range. The new gearless conveyor drive (GCD) with a permanent magnet (PM) motor reduces the failure rate by 50 % and improves energy efficiency. Different mounting variants enable application optimized use in both for new or retrofit of conveyor drives. Gearless drives offer a great potential for the cement industry. ◀

ZUSAMMENFASSUNG

Kürzlich durchgeführte Installationen von getriebelosen Antrieben an Gurtbandförderern haben die Erwartungen nach hoher Verfügbarkeit, verbesserter Effizienz und reduzierter Instandhaltung mit dem Ergebnis einer höheren Produktivität, hoher Wertschöpfung und niedrigeren Betriebskosten erfüllt. Dieser Beitrag stellt die Vorteile eines derartigen Antriebssystems im Einsatz bei Gurtbandförderern für den Leistungsbereich von 600 bis 3000 kW dar. Der neue Band-Direktantrieb (GCD) mit Permanentmagnet-Motor (PM-Motor) verringert die Fehlerrate um mehr als 50 % und erhöht die Energieeffizienz. Verschiedene Möglichkeiten der Verlagerung erlauben die optimale Installation in Alt- und Neuanlagen. Die Einführung des getriebelosen Antriebs in der Zementindustrie verspricht große Möglichkeiten. ◀

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1 Introduction

As cement manufacturers strive to improve their overall operations, new technologies can improve the reliability and efficiency of the transport of bulk materials and packaged product. Conveyors must be durable, keep running and have a high transport capacity. In many industries these requirements translate into wider and longer belts and thus higher torques being transmitted to the pulley shafts. Conventional solutions are limited by the power and torque restriction imposed by the gearbox.

ABB has introduced conveyor drive systems that meet these increased demands, while at the same time delivering radically higher reliability. They are ideal for mining and cement production use. Such installations have been delivered to the mining company Codelco, for the El Teniente and the Chuquicamata projects in Chile.

2 Conveyor classification

In order to gain a clear picture of the available drive solutions related to the actual type of conveyor, ABB established a belt conveyor classification system. Conveyors, in general, can be classified according to several parameters such as: application, length, conveying capacity, lift, type of conveyor, and required drive system power. Looking from the electric drives system perspective, the required power and speed to turn the drive pulley and run the conveyor belt are the most relevant parameters. These parameters directly translate to the dimensioning of the motors, frequency converters, and power transmission equipment. Therefore, ABB has classified mining belt conveyors into low power (< 4 MW), medium power (4 to 10 MW) and high power (>10 MW) segments (Fig. 1).

While low power belt conveyors are found in almost every mining or processing plant, medium powers are common



Figure 2: View of a typical belt conveyor drive with gearbox

in coal and hard rock mining. The highest drive powers are required for belt conveyors transporting copper or iron ore with considerable lift. The need for such high power belt conveyors has driven the recent developments in gearless conveyor drive systems.

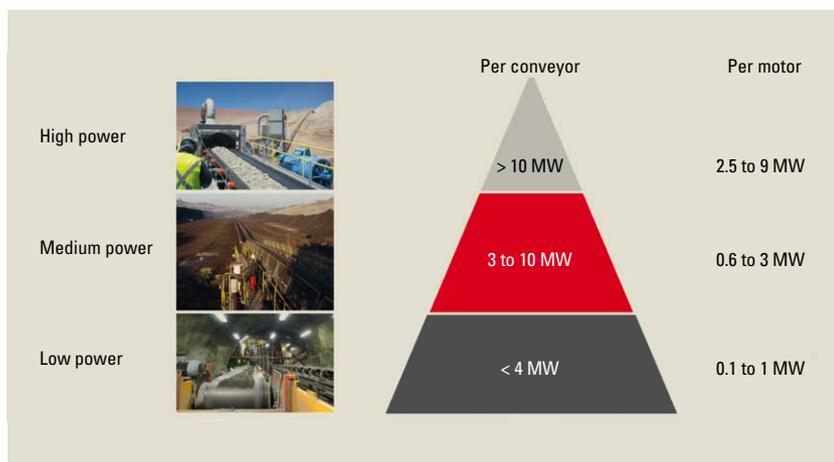


Figure 1: ABB's conveyor classification

3 The gearless drive concept

Conventional belt conveyor transmissions face several limitations. The feasibility of a gear reducer with power ratings above 3.5 MW is very limited. Secondly, gear reducers are maintenance-intensive. The bearings and pinions of the gear reducer, together with the lubrication system, the danger of leaks, oil cooling devices, can turn into a Mean Time Between Failure (MTBF) of as little as three to four years (Fig. 2). Changing bearings is a major overhaul, and failure of the input stage is the most common. Thirdly, the operating life of the gear reducer is comparatively short, about ten years on average. For example, a cement or mine operation that

is expected to last 20 years will require that the gearboxes be exchanged at least once during the life of the plant.

The solution developed with high power drives eliminates maintenance-intensive gearboxes and creates a gearless conveyor drive (GCD). It uses a synchronous motor attached to an adapted pulley shaft specifically designed to support the high torque produced by the electrical machine.

In contrast to a conventional geared solution, the drive train of a gearless drive system is simple and long-lasting. A 6 MW power rating, for example, can be achieved in just one drive system, comprising a single 6 MW synchronous motor. The count of parts exposed to high levels of wear and tear is very low, providing an MTBF of up to 30 years.

This approach has been successfully proven in the field. For example, the gearless belt conveyor drives in the Prosper Haniel coal conveyor in Germany have been in operation since 1985, and still operate today. This illustrates that gearless drives are normally efficient and long lasting drives.

4 The challenge of medium power belt conveyors

ABB began to study direct drives for belt conveyors in 1994. The focus of the investigation during this time was mainly on coal mining and overburden conveyors of 5 to 10 MW drive power and single motors with a power of < 2.5 MW. These conveyors are mobile and the drives are installed in a raised position embedded in a steel structure (▶ Fig. 3).

Because the motors cannot be installed on a concrete foundation, bending forces in the support structure have to be considered along with the total weight of the drive station. Former studies demonstrated that direct drives for such conveyors are technically or commercially not feasible with conventional motor technology. For these reasons, a more compact and lighter motor is needed.

5 The conventional gearless motor

In more recent gearless conveyor drive system installations, a synchronous low speed motor powered by a frequency converter is used. This approach features all the advantages inherent to such a converter, including smooth control, controlled starting torque at very low frequencies, unity power factor, and a variable speed control. The converters can also operate in the regenerative braking mode for downhill belt conveyors. Such "state-of-the-art" motors and converters meet the required power range and have been used in other industries, such as underground mining as well as in the oil and gas industry. They are a perfect fit for high power conveyor drives.

A low speed synchronous motor (▶ Fig. 4) consists mainly of a stator stack with stator winding supported by the stator frame, the rotor with exciter winding, a heat exchanger, stator end-shields and, depending upon the construction, rotor bearings and a rotor shaft.



Figure 3: Typical location of motors in medium power belt conveyors

The magnetic flux between rotor and stator is created by a flow of electrical current through the exciter winding into the rotor. The excitation current causes thermal losses heating up the rotor. The lower the rotor speed, the lower the "self-ventilating" effect of the rotor. Therefore internally forced cooling air, distributed by a heat exchanger along on top of the motor, is required to get the power losses out of the motor. The excitation losses are in the range of 50 to 100 kW for a low speed/ high power motor.

6 Permanent magnet motor – the solution for medium power

Lower weight, compact size and efficient cooling are mandatory for most of the belt conveyor drives in the medium power segment. A conventional electrically excited synchronous motor can hardly fulfill this requirement. Due to the constructive effort for cooling as well as rotor field exciter, weight and size are relatively high. Such motors usually exceed the required dimensions for medium power GCDs.

Higher torque density and more compact motors are gained when the power losses in the rotor circuit are reduced to a minimum. In order to achieve this, there is the option to generate the magnetic flux by permanent magnets rather than the electrical excitation current. Permanent magnets provide magnetic flux without any external energy supply, hence rotor heat losses are negligible.

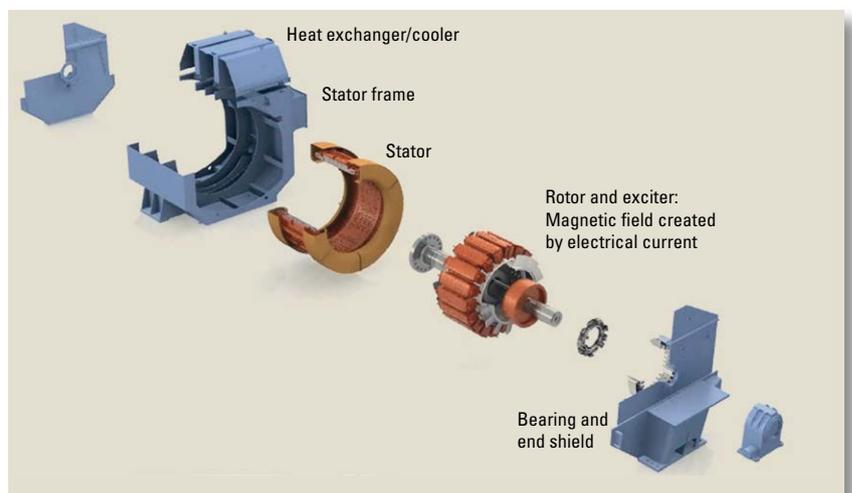


Figure 4: Field excited synchronous motor

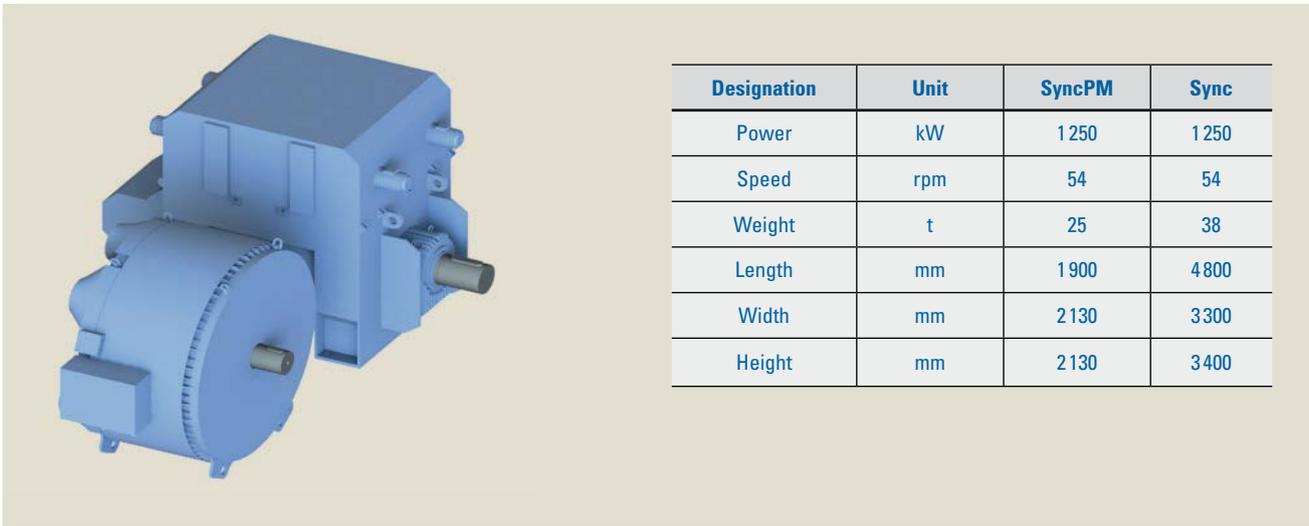


Figure 5: PM motor (left) vs. synchronous motor (right)

Permanent magnet (PM) synchronous motors have found more applications in recent decades by industries and applications where space, weight, and energy efficiency are driving factors. Direct drives with a rated speed of around 300 rpm for paper machines, propulsion drives in marine, electric vehicles or wind generators with rated speeds as low as 10 rpm require efficient motor technologies. Major users have been the marine and the wind power market, where weight and space reduction is mandatory in order to perform competitively. Customized PM motor design and integrated solutions have been developed. ABB made use of learning from these applications and designed a PM motor specifically for implementation into direct conveyor drives. The totally enclosed motor with a high IP rating (IP65) combines the advantages of a rugged surface-cooled high speed motor with the ability of a low speed torque motor. **▶** Fig. 5 illustrates clearly the smaller dimensions and lower weight of a PM motor.

7 Pilot drive installation

To date, ABB is the only supplier on the market engineering and supplying GCD solutions for medium powered belt conveyors. Recently the company installed a pilot drive at a major lignite mining operation in Germany (**▶** Fig. 6). The company applied a PM motor for the retrofit of a 200 kW drive. A GCD offers a > 50 % lower failure rate than conventional driven conveyors, with a > 30 % reduction of energy losses and significant operational cost savings as well as lowest OPEX and lowest cost per ton.



Figure 6: New ABB medium power GCD on excavator at the LEAG-owned Jaenschwalde lignite mine, close to Cottbus, Germany

The pilot application was commissioned in July 2017, with good results. It is on a bucket chain excavator and is working at the LEAG-owned Jaenschwalde lignite mine close to Cottbus, Germany. The machine handles up to 15000 t/h of overburden (sand with large contained rocks) and is designed for temperatures in the range of -25 to +40 °C, with the ability to withstand harsh shock and vibration parameters. The GCD so far has performed very well under these challenging conditions.

8 Trade off

The development and implementation of gearless belt conveyor drives in the high power range, where the use of gearless drives is the only option, has awakened an interest in gearless systems for medium power belt conveyors to achieve similar benefits. A gearless drive drastically decreases the effort for maintenance, repair and asset management. The major gain is the considerable reduction of downtime of a conveyor system and a subsequent higher productivity.

The only drawback of gearless drive systems is the upfront investment. Gearless drive systems normally cost more than conventional drive systems. For a 1.5 MW gearless drive, the investment for the electric drive is about 10 to 20 % higher than a conventional design. In a new conveyor installation the combined cost of mechanical and electrical equipment will still be around 5 % higher. However, the overall return on investment is less than one year, in terms of gained efficiencies and operational savings (**▶** Fig. 7).

While summing up the investment cost is usually an easy exercise, it is more complex to predict reliable numbers on OPEX. Operational costs depend mostly on the country and region of installation, environmental conditions, quality of design and commissioning.

Considerable OPEX cost reduction can be achieved from higher uptime of the system, plus savings in energy consumption. It should be kept in mind that usually several conveyors are connected in series, with each conveyor being a potential bottleneck. If one conveyor fails, all upstream equipment such as crushers and excavators are down.

The representation (Fig. 7) shows a total cost of ownership (TCO) simulation over 15 years operation time. With a higher

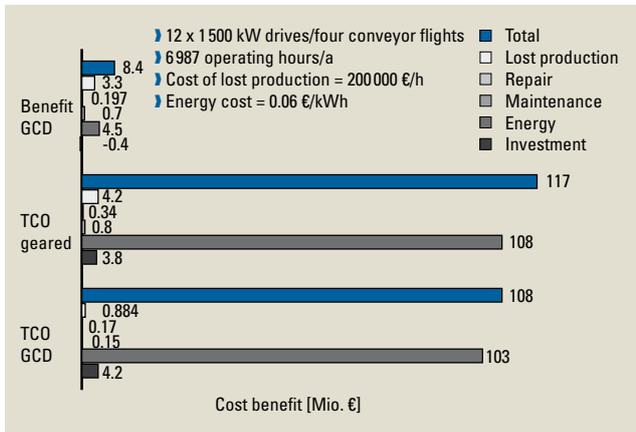


Figure 7: General example of cost benefit after having operated a gearless drive for over 15 years (TCO – Total Cost of Ownership)

initial investment of about 400000 € and annual savings in operation costs of 560000 €, the return on investment is less than a year.

9 Final remarks

The introduction of a feasible gearless conveyor drive (GCD) concept for medium power conveyor drives based on a permanent magnet synchronous motor offers exciting possibilities for cement and mining applications. This new concept allows implementation of a gearless motor into an existing or new medium power conveyor, which had not been feasible with conventional gearless motors up to this point. The new concept has been proven in a pilot project.

The major advantages of gearless compared to geared conveyor drives are:

- Higher reliability (50 % lower failure rate) and less maintenance
- Higher efficiency with lower energy consumption and lower noise emission
- Extended lifecycle (Expected motor lifetime of 25 years is ten years longer than with gearbox.)

Gearless drives are especially beneficial in installations where

- The planned life cycle is longer than ~ten years.
- Gearboxes are trouble makers.
 - High availability is required.
 - No redundant production lines exist
 - Material buffers are small or non-existent (surge bins, stockpiles)
 - Maintenance work is hard to perform (high altitude, high or low temperatures)
 - Maintenance personnel is difficult and expensive to source
 - Harsh ambient conditions

Gearless conveyor drives (GCD) are an efficient, long lasting and reliable solution which helps cement manufacturers to increase production, annual revenue and decrease the specific costs. While the upfront investment is typically higher when compared to a conventional drive, the savings in maintenance, energy cost and downtime lead quickly to a return on investment. ◀