MAGNETIC DRIVE TECHNOLOGY WHEN APPLIED TO BELT CONVEYORS

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SYNOPSIS

This paper informs designers and users of the methodology employed in ramping and running belt conveyors when applying magnetic drive technology. Unlike a fluid coupling where the torque is built up as the fluid passes from rest to the working chamber over a period of time, in a fixed magnetic drive, the torque is at its maximum and slips from a high slip value to a zero slip value during ramping until the drive speed and the conveyor speed are eventually equalised. It is thus important that the final overall conveyor loading suits the torque setting of the magnetic coupling which is adjusted accordingly by shimming the air gap. In the adjustable version of the magnetic drive coupling, the air gap can be altered to a higher or lower transmittable torque. This is done by mechanically altering the air gap whilst in motion which can also be modulated by means of a PLC, allowing for the coupling to have a low initial torque which is increased over a period of time as the conveyor accelerates.

This paper discusses magnetic drive technology in theory and goes a step further where case study results are portrayed from actual installations. The advantages and disadvantages of this technology are portrayed and guidance is given as to where this technology is best suited in the conveying industry.

BACKGROUND TO MAGNETIC DRIVE COUPLINGS

Over the past decade, magnetic drive couplings have emerged as a method of accelerating and driving belt conveyors. The torque is transmitted by means of a very strong magnetic field created through permanent magnets restraining the driving element from the driven element. These magnets are rare-earth magnets: neodymium, iron and boron, and have very low magnetic losses, typically 0.09% over a 25 year period.

The magnets are known as 'rare-earth magnets' because the element neodymium is found within the rare earth section of the atomic chart. Rare earth metals such as neodymium were thought to be extremely rare in the earth's crust. NdFeB magnets have the highest energy of all permanent magnets, permitting the small size and high torque transmission capability. NdFeB magnets theoretically retain their magnetic strength and performance for up to 20 000 years, when used continuously within their temperature limits of 120 °C

HOW DOES THE MAGNETIC COUPLING WORK

Magnetic drive couplings operate on the principle of transferring torque from the driving element to the driven element across an air gap. Magnets are bonded into pockets on the driven element and the torque is transferred to the non-drive side across the air gap There is thus no physical connection between the driving and driven elements, with all torque being transmitted across the air gap separating the two elements.

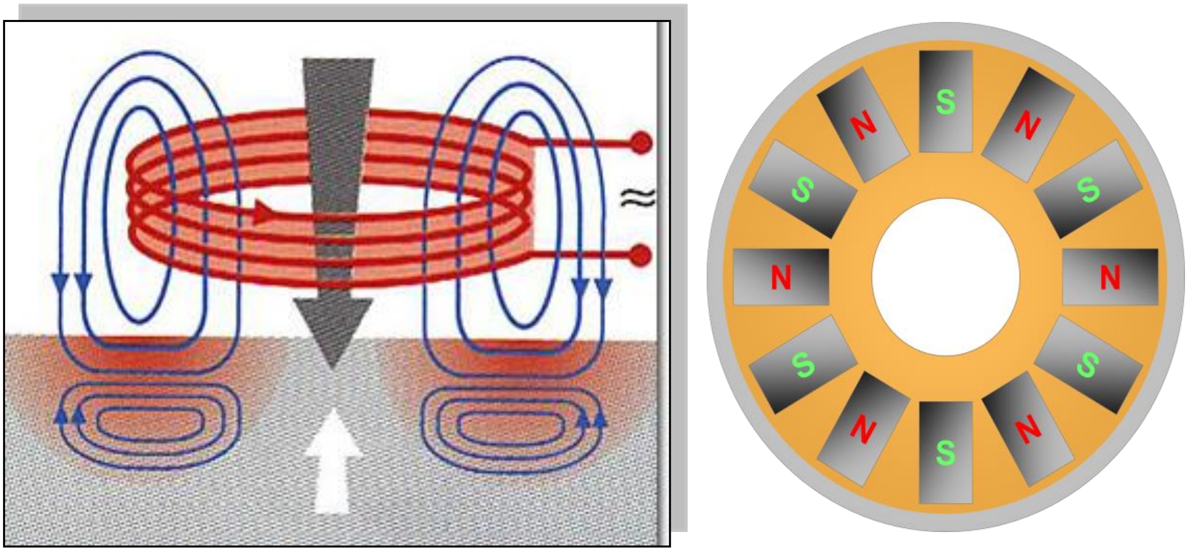

Figure 1. Eddy currents created by fixed magnets

Eddy currents are created when a conductor is moving in relation to a magnetic field.

- Relative motion forms eddy currents, ’swirls’ of current that resist, or oppose, the movement of the conductor.
- If the conductor is being rotated through the field, the opposing force will be in the form of torque.
- If the conductor is moving, and the magnetic field is allowed to move freely, this torque force will cause a rotation of the magnetic field.

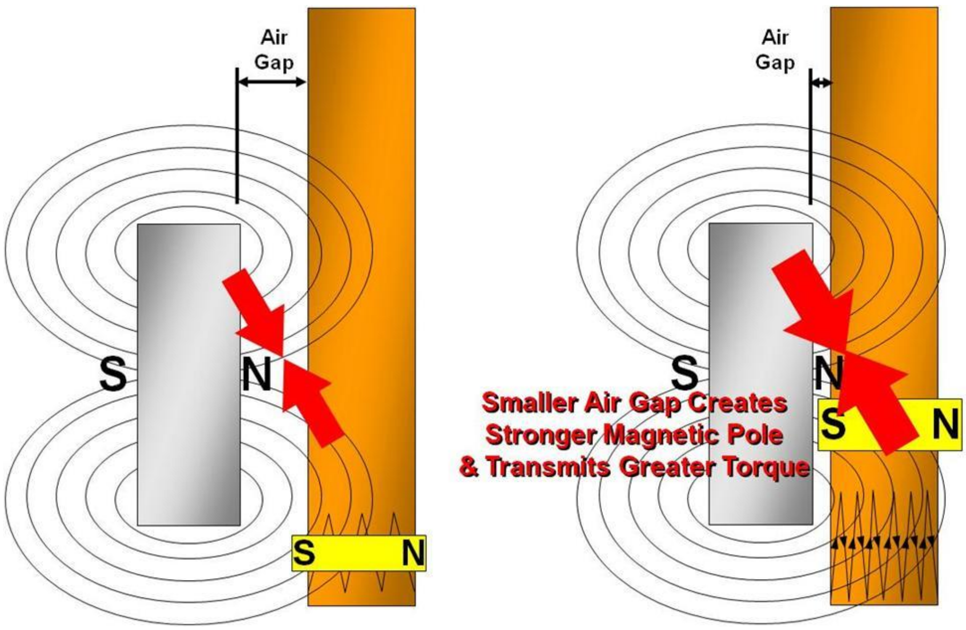

Figure 2. Air gap vs. torque transmitted

ADVANTAGES AND DISADVANTAGES OF MAGNETIC DRIVE COUPLINGS

Advantages:

- Vibration cannot be transmitted across the coupling.
- Due to the transfer of torque being ’vibration free’, the energy saving is considerable when compared to a poorly installed coupling that is consuming energy due to overcoming vibration. It can thus be said that as a result of no apparent misalignment, energy is saved.
- There are no wearing surfaces and thus no oils, greases etc. are required.
- Noise levels are lower than fixed couplings in the case of (DOL) starting.
- Maintenance levels are classified as being LOW.
- The coupling is impervious to shock loading, but heat will build up whilst slipping.
- There are no electro magnets used in the couplings and thus no consumption of external power is required.

Disadvantages:

- Eddy currents generate considerable heat when relative slip is present, particularly during ramping. This heat needs to be dissipated and the coupling must be well ventilated and installed within an acceptable non-gaseous environment. If the coupling stalls due to the load, the heat generated needs to be dissipated or overheating will occur. Coupling selection is thus imperative. When used on conveyors, the full load condition must not allow the coupling to stall as excessive heat build-up will be created.
- The rare earth magnets are set into a machined aluminium rotor which, is restrictive as a result of being a light metal alloy when applied in explosive atmospheres particularly in fiery mining conditions. (The magnesium content of the aluminium needs to be checked for compliance).
- High magnetic fields are present when working with, or in close proximity to, the couplings. These magnetic fields can affect other electronic control systems in close proximity.
- When the load is up to full speed, magnetic slip occurs at between 1% to 3%.

Other Notes

The value of torque is achieved by setting the distance between the driving element and the driven element. Two different types of couplings are generally used in conveyors, namely the fixed type and the delay type.

Type 1 - Fixed Type Coupling

In this coupling the air gap is fixed and thus the characteristics cannot be easily altered once installed. The slip can however, be changed if the coupling is removed, stripped and the effective gap is reduced to increase the transmitted torque or increased to reduce transmitted torque by means of shimming the distance between the driving and driven elements.

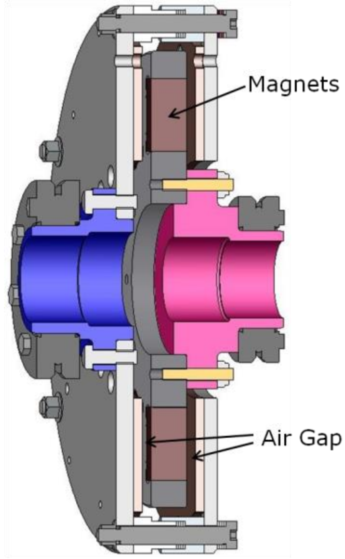

Figure 3. Fixed type coupling

Figure 4. Fixed type cross section

Type 2 - Delay Type Couplings

In some applications a delayed start capability is required in order to extend the ramping time. The delay type couplings have the ability to apply a lower torque to get the belt moving and then apply full torque. The nett effect is extending the ramping time. The delay start coupling is commonly used on conveyors.

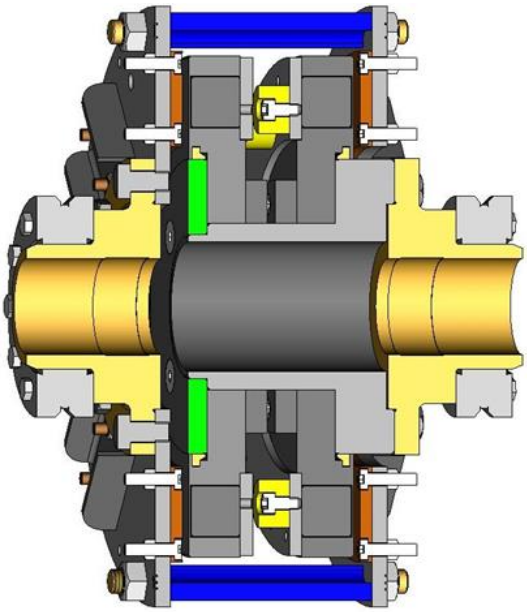

Figure 5. Delay type coupling

Figure 6. Cross section

Delay Coupling							
Operating state	**Motor**	**Load**	**Slip**	**Repelling force**	**Attractive force**	**Air gap**	**Torque**
At rest	Stopped	Stopped	0	0	Normal	Minimum	0
Start up	Fast acceleration	Slower	High	High	Normal	Maximum	Low, increasing
Normal	Normal speed	Normal speed	Low	Low	Normal	Minimum	Rated
Load seizure	Normal speed	Stopped	High	High	Normal	Maximum	Reduced
Shut off	Decelerating	Decelerating	Low	Decreasing	Normal	To minimum	Decreasing

Table 1. Delay coupling

Type 3 - Torque Limiting Coupling

In torque overload situations, the coupling automatically disengages as a result of the loss of output speed relative to input speed, disengaging the drive. When the jam is cleared and the motor is turned off, the coupling automatically resets itself centrifugally to resume operation on the next start command. It thus offers overload torque protection and automatic resetting when the motor is turned off. *Torque limiting couplings are seldom used on conveyors.*

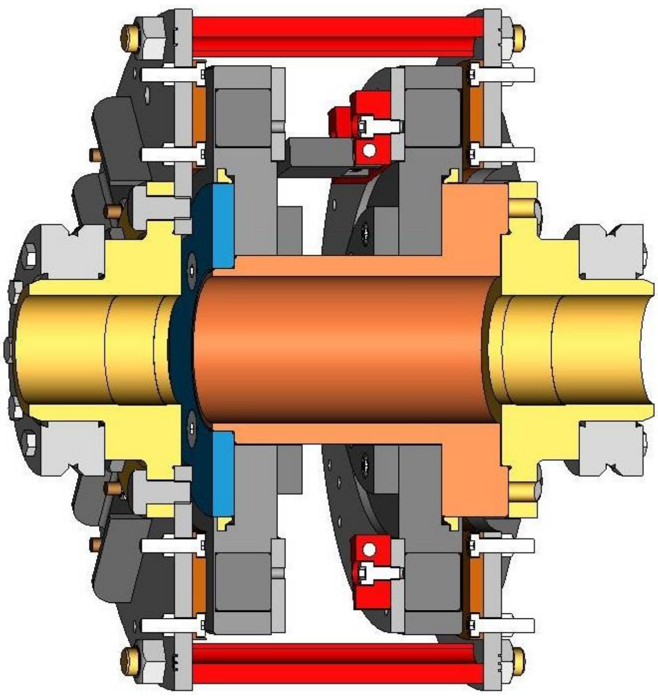

Figure 7. Torque limiting coupling

Torque Limiting Coupling								
Operating state	**Motor**	**Load**	**Slip**	**Repelling force**	**Attractive force**	**Flipper position**	**Air gap**	**Torque**
At rest	Stopped	Stopped	0	0	Normal	Down	Minimum	0
Start up	Fast acceleration	Slower	High	High	Normal	Down	Intermediate	Low, increasing
Normal	Normal speed	Normal speed	Low	Low	Normal	Up	Minimum	Rated
Load seizure	Normal speed	Stopped	High	High	Normal	Up	Maximum	Minimal
Shut off	Decelerating	Decelerating	Low	Decreasing	Normal	Down	To minimum	Minimal to 0

Table 2. Torque limiting coupling

Type 4 - Adjustable Speed Drive (ASD)

Applications currently benefiting include pumps, fans, blowers, centrifuges and bulk handling equipment, although there are very few installations using ASDs on conveyors. Industries served include water and wastewater treatment, pulp and paper manufacturing, power generation, oil and gas processing, cement, mining, chemical and food processing, irrigation, maritime and HVAC systems.

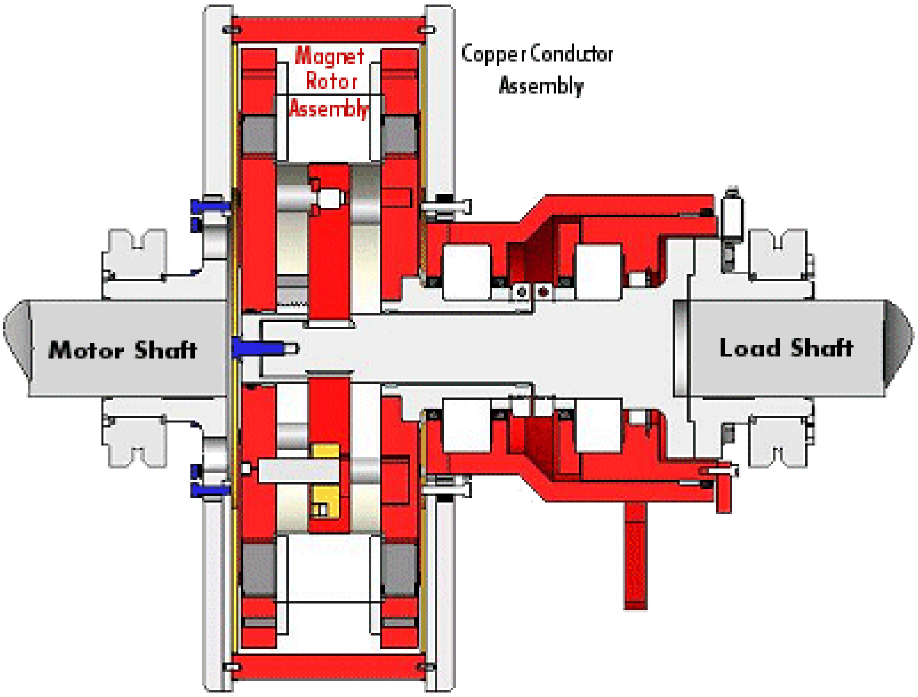

Figure 8. Adjustable speed drive cross section

The principle of magnetic induction requires relative motion between the magnets and the conductors. This means that the output speed is always less than the input speed. The difference in speed is known as slip. Typically, when the coupling is operating at full rated motor speed, the slip is between 1% and 3%.

The output torque is always equal to the input torque. The motor is only required to produce the amount of torque needed by the load. The efficiency of the system is calculated by dividing the output (load) speed by the input (motor) speed.

The ability to transmit power or to control speed is not affected by minor angular or offset alignments between the motor and load. Vibration due to misalignment is virtually eliminated. Transmission of vibration across the drive is also eliminated due to the air gap configuration.

When installed in a system, the coupling is controlled from a process signal. The pressure, flow, level or other process control signal is provided to the coupling actuator. The drive will then modulate the speed of the load to satisfy the control needs.

The coupling is easily retrofitted to existing installations. No modifications to the power supply are necessary, minimizing capital and installation costs. No Electro-Magnetic Interference (EMI) or harmonic distribution is created by the system. The load is operated at its optimum speed, increasing energy efficiency and reducing operating and maintenance costs.

Figure 9. Adjustable speed drive installation with actuator

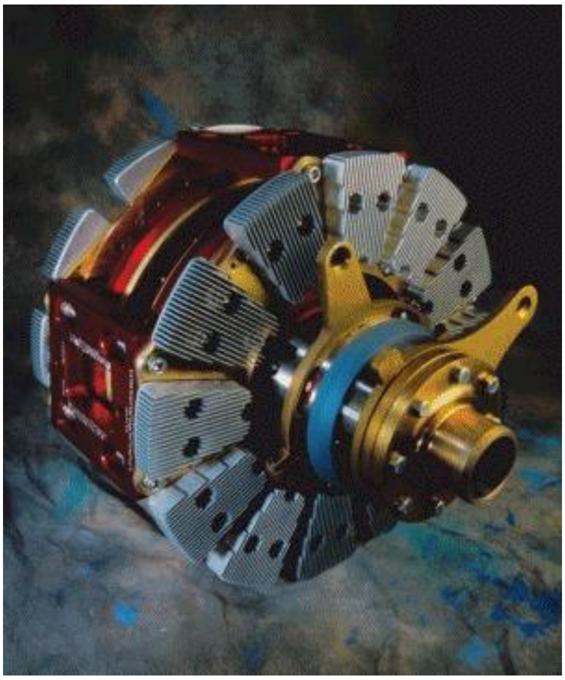

Figure 10. Adjustable speed drive

Cost of ASD vs. VFD

The ASD magnetic drive is cost advantageous when compared to the VFD drive technology up to around 75 kW, then the costing of the two technologies are about equal up to 300 kW.(Source: Steve Tredinnick, Syska Hennessy Group).

Efficiency of ASD

The ASD is not very efficient when operating at lower speeds when the coupling slip is high. At high speed the ASD will obtain greater levels of efficiency. Therefore, the ASD reaches the highest efficiency when the air gap is minimised and slip is between 1% to 3%.

Adjustable Speed Drive Evaluation

Although the ASD can be used to vary the operating speed of the conveyor based on changing the output torque to suit the load, it is not recommended to be used to run a conveyor at various speeds. The strength of the ASD lies in using it as a ramping device in order to take a conveyor up to full operating speed in an acceptable time, such as not to induce a high drive start factor, DSF, which will in turn induce unwanted dynamics into the conveyor. The ramp time needs to be programmed into the control system for the ASD.

CONCLUSION

Magnetic drive couplings MUST be correctly selected to suit the installed power and the demand power of the conveyor. If undersized they will slip, overheat and not work as is the case with most Correctly sized for small to medium conveyors, these couplings can be found to be reliable and require very little maintenance.

Magnetic drive couplings when applied to high inertia loads such as conveyors, cannot offer low drive start factors. The couplings operate very comfortably at a DSF of 180% and still offer good ramping at a DSF of 160%. Below 160% other available technologies are more suited. The coupling drives at a fixed torque value and if this value is exceeded, then the coupling will slip, generating heat. When used with multiple drives, staggered delay starting is the norm.

The air gap needs to be fine-tuned on commissioning to optimise the ramping. The coupling will not allow for a controlled start and will always ramp more rapidly when empty and slower when loaded. Vertical curves must be considered for the empty condition under a DSF of at least 180%. If at all possible try to design the beltline without vertical curves and if this is not possible make sure that the curve radius is large enough to suit the high empty DSF.

The most popular couplings used in conveyors are of the delay start type. and the ASD type has not been applied widely to conveyors.

These delay type couplings have a niche place in the market for certain conveyors and operate very successfully within given parameters. They cannot offer a controlled start to a conveyor under adversely loaded conditions and are not suited to long ramping times. These constraints limit their use from small to medium conveyors. For longer ramping times and more controlled starting, the ASD coupling controlled via a PLC would need to be considered amongst other technologies.

The torque limiting type of couplings are seldom used on conveyors for the reason that if the coupling disengages due to over loading. Once the motor is turned off the coupling will reset in preparation for the next start.

Provided that the conveyor is not too large and if in the case of an emergency, the coupling can easily be mechanically locked up. This will however, offer no dampening to the start, but will probably get the conveyor underway in the same manner as a DOL start. This could be seen as an advantage over a fluid coupling until such time that the coupling can be changed out.

Additional information for ASD as per report conducted by the Pacific Northwest National Laboratory

Technology Demonstration of Magnetically-Coupled Adjustable Speed Drive Systems

W. D. Chvála, Jr., D. W. Winiarski, M. C. Mulkerin, June 2002
Prepared for the U.S. Department of Energy

What to Avoid

Constant torque systems are a difficult application for MC-ASDs. In these situations, where the same torque is required at high and low speeds, the amount of slip needed to regulate the speed under constant torque conditions generates a significant amount of heat in the coupling. These applications are possible, but facility staff should work closely with the manufacturer to ensure proper sizing and installation of the coupling.

This report will also show that users should avoid situations where the load requires the output shaft speed to be substantially reduced for a large portion of the operating hours. In this situation, the MC-ASD would produce a large amount of slip to produce the desired output speed and would be forced to operate in this inefficient mode for a substantial amount of time. The efficiency of the MC-ASD drives is greatest near full speed and drops substantially when operated below about half speed. If by motor downsizing, changing pulley ratio, or staging a series of motor/pumps the motor will operate a greater portion of the time at higher speeds, this will improve the suitability for the MC-ASD devices. These actions should be considered anytime an MC-ASD is applied to get the smallest motor and MC-ASD coupling possible.

Table 3. Extract: Pacific Northwest National Laboratory

REFERENCES

1. Tredinnick, Steve. Syska Hennessy Group

ABOUT THE AUTHOR

A T Exton

The author of this paper has been involved in the mining industry since 1969 where he commenced his training West Rand Consolidated Mines Ltd as an apprenticed Fitter & Turner. During his Apprenticeship he obtained a National Technical Diploma in Mechanical Design. After 7 years employment in the mines, he joined the private sector in the Mining Division of Dowson & Dobson (Pty) Ltd. as a design engineer. He was involved in the design field of both coal and hard rock mining equipment for various companies until 1990.

In July 1995 Nepean Conveyors (Pty) Ltd. was formed in South Africa and the author was appointed as the founding Managing Director, which position he held until 30 June 2008, for 13 years.

Subsequently the author retired in 2008 and is currently the Managing Director of Accrete Consulting (Pty) Ltd., consulting on conveyors to the Bulk Material Handling industry.

Relevant Affiliations:

A director of companies
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