Magnetic Power Transmission Technology

By Ken Black, P.E.

In today's tough economic times, the thin margins prevalent in industry are compelling managers to seek new and innovative ways to lower their operating costs. With energy costs continually escalating, reducing consumption is clearly receiving a heightened focus and priority. At the same time, the ability to achieve precise control, improve process efficiencies and lower total life cycle costs of industrial equipment all constitute equally important objectives.

Process control, the ability to regulate the flow of air, fluids and other materials, is critical to both quality control and cost containment in almost all industries. Traditionally, process control has been achieved using throttling devices like control valves, dampers and belt systems. These devices are inherently inefficient because while they throttle down the flow, the pump or fan or other equipment is still being driven at full speed by the motor. This is equivalent to stepping on the gas while simultaneously using the brake to control the speed of an automobile.

The need for energy efficient process control led to the development of adjustable speed drives (ASDs). In industrial pump, fan and blower systems, where loads typically vary over a duty cycle, ASDs provide variable speed (flow) control while reducing the power consumed by the motor. The most widely used ASD is the variable frequency drive (VFD) which, since its introduction in the mid-eighties, has driven market acceptance of ASDs and garnered a dominant share of the ASD market by providing significant energy savings to industry. And VFDs will continue to be an appropriate choice in

Figure 1: *Fully assembled magnetic ASD with magnet rotor assembly.*

many motor applications, notably those of 20 horsepower and below, where they are not only cost effective, but enjoy significant market penetration. However, 85% of industrial motor energy is consumed by motors 20 horsepower or greater. Moreover, this segment has relatively little ASD penetration, and hence can benefit significantly from increased energy efficiency. In these higher horsepower applications, VFDs are not necessarily cost effective, and issues such as complexity, reliability, installation and maintenance costs, harmonic distortion and power quality can quickly wipe out the energy savings achieved.

An efficient alternative to inefficient throttling devices and complex electronic VFDs is a magnetic adjustable speed drive using rare-earth permanent neodymium, iron, boron (NdFeB) magnets to transmit torque across an air gap, so there is no physical connection between the motor and driven equipment. Relative motion between the magnets and a copper conductor creates a magnetic field that transmits torque through the air gap between the components. Varying the width of the air gap changes the coupling force, producing a controlled and continuously variable output speed. This allows precise and efficient speed control for optimum performance, including "soft" starts. And with no direct connection between motor and load, the magnetic drive ASD tolerates misalignment, and virtually eliminates the costly wear-and-tear of vibration.

Figure 2: *Drive showing magnet rotor assembly removed from conductor assembly.*

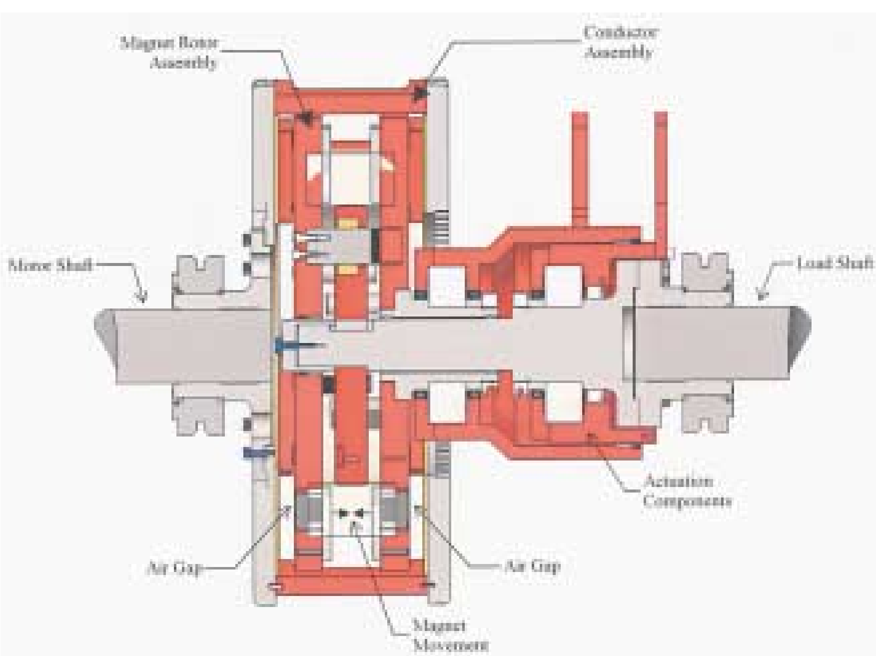

Figure 3: *Cross section of a magnetic ASD showing magnet rotor assembly attached to load shaft and conductor assembly attached to motor shaft.*

Principles Of Operation

Figures 1 and 2 illustrate the basic configuration of the magnetic drive ASD. Two discs, steel backed with copper faces, are structurally tied together and rotate with the shaft of the motor. Between these, two axially moveable aluminum discs containing arrays of axially polarized permanent magnets are attached to the load shaft. When the components are rotated, the relative slip induces currents in the discs and enables torque to be transmitted without physical contact. In order to control the amount of torque transfer, it is necessary to adjust the rate of change of magnetic flux linkage of the conducting discs. This is accomplished by changing the width of the air gap between the magnets and conducting discs. The magnet discs are moved along the shaft enabling continuous adjustment of the clearance between magnet discs and conductor discs while the ASD is in operation. When the clearance between the magnet discs and the conductor discs is small, their relative slip is minimized by the strong coupling. The slip increases as the spacing increases, enabling speed control of the load.

The magnetic drive ASD is controlled by an actuator that allows the process control signal to modulate the speed or torque output of the ASD to satisfy process control requirements. Actuators normally use 110 VAC power to control the drive, and accept 4-20 milliamp or other typical control signals.

Figure 4: *Magnetic ASD installation with 125 hp, 1800 rpm motor and centrifugal fan. The ASD saves 155,000 kWh of energy and $15,000 on maintenance costs annually.*

Applications

The magnetic drive ASD is exceptionally well-suited to rotating equipment with variable loads, notably pumps, fans and blowers, in applications from 10 to 1500 horsepower. It is equally well-suited to retrofit and new installations. (It is not recommended for constant torque applications because the large amount of slip generates a significant amount of heat in the ASD).

The ASD can be used in either a direct-drive or belt-driven connection, in both horizontal and vertical applications. For direct-drive systems, where the motor shaft is connected directly to the load, the shaft is disconnected or cut to insert the ASD. The motor is generally moved 12 to 18 inches farther from the load shaft to provide space for the ASD. The conductor assembly is bolted to the motor drive and the magnet rotor assembly is bolted to the load shaft. The ASD can tolerate a significantly greater degree of misalignment than would be appropriate for a hard connection between motor and load. For belt-driven systems, the application can either be converted to a direct-driven system, or a pulley can be added to the output shaft.

Benefits

The fact that motor and load are physically separated in the magnetic drive ASD has a number of advantages. The motor can be started up independently and gradually engage the load in a soft start. This reduces locked rotor current, motor heating, start-up-induced brownouts and peak power demand charges, and can allow for motor downsizing to meet running rather than higher start-up requirements. Figure 6 illustrates this advantage in a 125 horsepower motor and fan application at Ash Grove Cement Company in Durkee, Oregon.

The ASD tolerates gross parallel and angular misalignment, simplifying installation, and virtually eliminating vibration transfer. Bearings and seals last longer, extending equipment life.

In comparison to traditional throttling systems, the magnetic drive ASD saves considerable energy, from 25 to 66% in systems audited. It also eliminates vibration problems caused by turbulent flow, vibration and water hammer that typically occur in throttled systems.

Figure 5: *Daishowa America paper mill in Port Angeles, WA, is a typical ASD installation.*

The magnetic drive ASD can also be an attractive alternative to VFDs, which, though energy efficient, are complex and can be costly to install and support in many applications. Unlike VFDs, magnetic ASDs create no harmful electronic harmonics, and they are unaffected by power quality. Because VFDs require a hard link between motor and load, they do not solve vibration, wear and alignment problems that are virtually eliminated with the magnetic drive ASD. In higher horsepower and/or medium voltage applications, VFDs can be prohibitively expensive to purchase and install. And finally, a typical VFD has a life expectancy of 8 - 10 years compared to over 30 years for the magnetic drive technology..

The elegantly simple technology and its many benefits led IndustryWeek magazine to recognize it as a Technology of the Year for 2001.

Installations

The Daishowa America paper mill in Port Angeles, Washington, is a typical ASD installation. (Photo) Two motors and pumps, both 100 horsepower, 1175 RPM, ran in parallel pumping wastewater from the main pump station sump to a clarifier. The pump station was designed to operate at full speed,

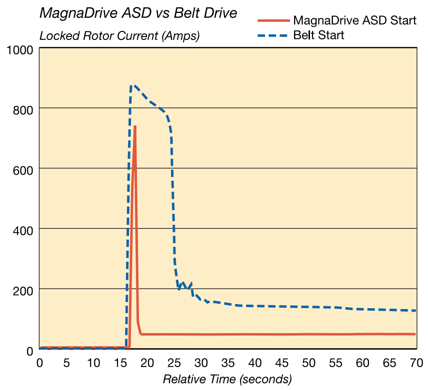

***Figure 6:** Motor start-up locked rotor current over time for a 125 hp motor and fan. The dashed blue line represents a typical hard start with a motor coupled to the fan through belts. The curve shows peak start-up current in excess of 875 amps (equivalent to 975 hp at 480 volts and three phase) for duration of 10 seconds. The solid red line shows that the magnetic ASD reduced the duration of locked rotor current to 1.5 seconds, while reducing no-load running current from 142 to 49 amps, which saves energy when fan is not needed.*

24 hours a day. The system was controlled with a level-control valve downstream from the discharge of the pumps and a bypass valve working in tandem to maintain a level in the sump. Controlling level with these valves wasted energy and caused vibration that created maintenance problems and shortened equipment life. The operators considered installing VFDs on this pumping system, but ruled them out due to limited space and high infrastructure costs. Instead, they installed two magnetic drive ASDs to regulate the speed of the pumps. The ASDs maintain the desired flow to the clarifier while reducing energy demand from 142 to 62 kW, a savings of 80 kW. With continuous operation, this translates to a savings of over 700,000 kWh per year. In addition, the ASDs eliminate damaging vibration and water hammer, resulting in equipment and maintenance cost savings of approximately $15,000 per year. Terry Dotson, Daishowa's Utilities Maintenance Supervisor, said the magnetic drive gave his company incredible energy savings and flow control capabilities. He said, "I think there are a lot of applications throughout the pulp and paper industry that haven't even been thought of yet, and I'm looking for other applications at our mill."

This new technology is now beginning to be actively marketed in Canada. In Waterloo, Ontario, it was recently installed in a booster pumping station at a new industrial complex owned by the Region of Waterloo. The Region operates numerous municipal facilities including sewage and water treatment plants where they have had problems with VFDs, notably having to completely replace 8-year-old VFDs due to unavailability of spare parts. At the new industrial complex, a magnetic drive ASD and a VFD have been installed next to each other on two 30 horsepower, 3600 RPM motors and pumps, with the objective of evaluating suitability of the ASD for installation in other facilities where VFDs have been problematic. While results of the test are not yet available, the operators are very pleased with the magnetic drive performance to date and expect that it will compare very favourably on energy savings, and significantly outperform the VFD on reliability, maintenance and life cycle costs.

The City of Kamloops, British Columbia, is also preparing to install three magnetic drive ASDs in a booster station for the city's domestic water system. The ASDs installed on 200 horsepower, 1800 RPM pumps will allow efficient, flexible speed control through the operation period. The magnetic drive technology was selected over VFDs primarily because of lower maintenance costs over the long term. Other considerations included the electronic harmonics and costly filters associated with VFDs, and difficulty in obtaining spare parts for units only a few years old. The operators expect that enough energy will be saved due to speed control with the magnetic drive ASDs to qualify the installation for BC Hydro Power Smart rate and incentive benefits.

A New Standard For Industrial Couplings

The core magnetic power transfer technology that provides torque transfer while isolating the motor from its load has many applications beyond speed control. It also offers a family of over-torque prevention couplings for constant speed applications from 10 to 1000 horsepower. Examples include conveyors, compressors and many types of manufacturing machinery. These systems typically operate with standard industrial couplings that comprise a hard link between the motor and its load. They suffer from vibration and alignment problems, equipment failure and downtime. Sometimes they even suffer catastrophic events where material in the system causes load seizure, damaging or even destroying the equipment and motor, and creating significant safety hazards. The magnetic system couplings significantly reduce vibration transfer, equipment damage and downtime, and the need for costly and time-consuming laser alignment. Further, they are nearly maintenance free, requiring only an annual inspection that can be performed while the equipment is in operation. Finally, in torque overload situations, for example where material becomes jammed in the system or is too heavy, the magnetic drive couplings automatically disengage, shutting down the system and preventing damage or even destruction of the motor and driven equipment. When the jam is cleared, the coupling automatically resets itself to resume operation.

This new technology also appears to have strong potential in vehicles, including applications as a clutch substitute, a continuously variable transmission, a constant-speed drive to power alternators and superchargers, a variable-speed drive for fan clutches, differentials and accessory drives, and a braking system. Ω

Ken Black, P.E. is Senior Applications Engineer for MagnaDrive Corporation, headquartered in Seattle, Washington.