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Permanent magnet couplings – the disconnected connection

Industry accepts the fact that good alignment is fundamental to the safe and trouble-free operation of rotating equipment. However, maintenance costs and unscheduled downtime persist as one of the highest budget items for any facility, writes Greg Highfill, MagnaDrive Corp's director of engineering. Regardless of good alignment practices, a variety of system-related conditions can adversely affect equipment operation, causing vibration, accelerated wear and premature failure, he says.

How do maintenance engineers improve equipment reliability when good alignment doesn't alleviate the ramifications of system influences? One approach is to eliminate the mechanical connection between driver and load shafts – to physically disconnect the two shafts. A permanent magnet coupling offers this unique characteristic.

Over the years, continuous improvements in coupling technology have resulted in new products with expanded capabilities. Conventional couplings are capable of operating with some degree of misalignment, yet still transfer forces to the equipment shaft when shafts are not coaxial. Gear-type, metal-disk and elastomer materials are common types of flexible couplings used in industry. The Permanent Magnet Coupling (PMC) manufactured by MagnaDrive as an alternative to conventional couplings, is one that does not rely on flexing of the coupling element to compensate for shaft misalignment.

Figure 1. Permanent Magnet Coupling.

This development of power transmission devices, based on the principle of magnetic induction is the latest breakthrough in coupling technology available to the rotating equipment industry. A PMC transmits torque through an air gap. By design, the air gap creates a 'disconnected connection' which isolates vibration between motor and load, handles misalignment, protects equipment from shock loads, and provides a cushioned start for rotating equipment. The inclusion of a PMC (Figures 1 and 2) will deliver positive results that increase equipment reliability.

Technology overview

The technology uses proprietary, high-energy permanent magnets to transmit torque across an air gap, allowing the input and output members to be mechanically independent. The coupling has two primary components (Figure 3). First, the magnet rotor assembly contains an aluminum rotor populated with permanent magnets and is connected to the load (output) shaft. Second, the conductor rotor assembly comprises copper disks mounted to steel plates and connected to the driver (input) shaft, to rotate at constant driver speed.

The magnet rotor revolves freely within the conductor rotor. When the conductor rotor rotates, relative to the magnet rotor, the magnetic flux from the magnet poles bridges the air gap and creates eddy currents in the copper conductor disks. The eddy currents create poles in the disks that interact with the magnet poles. The magnetic flux develops a tangential force tending to turn the magnet rotor in the same direction as the rotating conductor. The net result is a torque, available at the output shaft, for driving a load.

A PMC is a constant torque device that operates on the slip principle. The device must slip in order to transmit torque; hence the difference in power is called 'slip loss' and is in the form of generated heat. There are also 'windage' and 'frictional losses', but these are small enough to be neglected. Common values of slip for a centrifugal pump or fan application range from 1 to 4%. Slip heat is dissipated into the surrounding air by convection.

Permanent magnet couplings

A PMC accomplishes the primary purpose of any coupling, that is, to

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transmit rotary motion and torque from one piece of equipment to another. In addition, they offer a distinct feature to accommodate unavoidable misalignment between shafts – the driver and load shafts are mechanically independent. This enables the permanent magnet coupling to handle parallel offset, angular misalignment, and thermal expansion without transfer of forces/moments to the equipment shaft.

The basic PMC is factory assembled and balanced. It may be installed indoor or outdoor, without special provisions and can be installed and maintained by millwrights. The PMC mounts directly to the driver and load shafts using keyed or shrink-disc coupling hubs, similar to a conventional coupling. General application and service conditions for PMCs are:

- To 5,000 hp and speeds to 3,600 rpm as standard.
- Ambient operating temperature: -22°F to 130°F (-30°C to 55°C).
- Humidity: 0 to 95% relative.
- Altitude: does not limit performance.

Transmitting torque across an air gap eliminates coupling resistance that can damage bearings, seals and shafts, when operated misaligned. The PMC has advantages that can extend equipment life, reduce maintenance costs, and increase reliability of motor-driven systems. A variety of benefits, each with the potential to enhance the lifetime of one or more components in a motor-driven system, make the technology attractive for use with all types of rotating equipment.

Technology benefits

Vibration isolation

The PMC provides no mechanical path to transmit vibration from load to motor. Reducing equipment vibration will extend bearing and seal life, and lower maintenance and downtime costs.

Shock Load tolerance

Some types of loads are subject to sudden and drastic changes in torque requirements. For direct-coupled equipment, shock loads can increase bearing wear, damage shafts and motor mounts, or cause the driver to lock up and potentially overheat. The PMC accommodates additional torque requirements of a shock load by a temporary increase in slip between the input and output members, without affecting driver operation.

Misalignment tolerance

Despite parallel offset and angular misalignment, the PMC can operate satisfactorily. Elimination of the mechanical connection allows installations subject to thermal expansion, soft foot, system fluctuations and pipe strain to perform properly.

Figure 2. Installation of a PMC between a motor and pump.

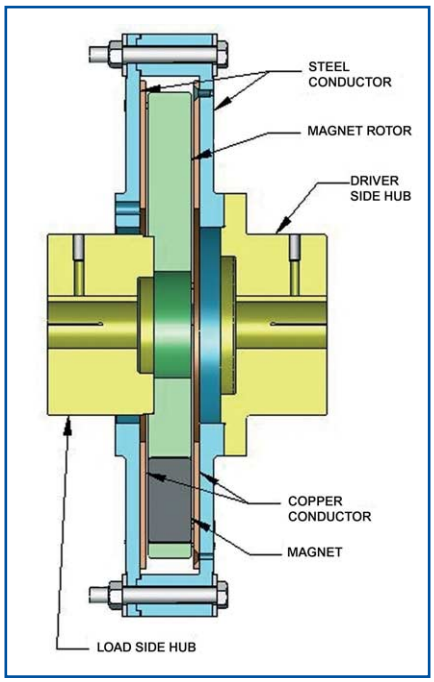

Figure 3. Cutaway of a shaft-mount air-cooled PMC.

Cushioned start

PMCs provide a cushioned start as a result of the slip between input and output members. This reduces fatigue stress in the system, inrush current at start-up, and motor winding heat.

Power quality, harmonics, replacement parts and lubrication

As the PMC is non-energized it is not vulnerable to process shutdown due to voltage sags, power fluctuations, and lightning strikes. It generates no electronic harmonic distortion and no voltage transients detrimental to the power distribution system or disruptive to electronic equipment. With no wear or contacting parts there are savings on part replacements and no requirement for lubrication.

Electromagnetic interference (EMI)

For an assembled unit, electromagnetic interference is not a factor and is less than that typically found in an electric motor. However, for disassembled units, individual magnets and exposed magnet rotors require strict safety precautions and handling procedures.

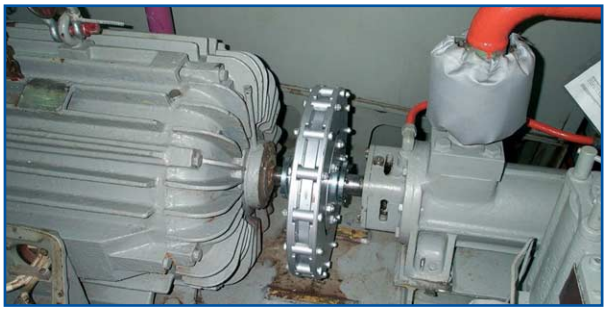

Figure 4. The U.S. Navy applications of PMC's, where reliability is critical to ship operations, includes water circulating pumps, JP5 fueling pumps, hydraulic elevator, catapult water, and boiler-feed water pumps.

The weight, length, and center of gravity should be considered for shaft-mount arrangements to evaluate overhung loads and estimate critical frequencies, especially with long, small diameter shafts. PMCs have limited axial end float capability – as a result of the air gap between rotors. For shaft mount configurations, both pieces of machinery must have bearings that limit total axial end float.

Naval and power plant cases

The US Navy has installed well over a thousand PMCs, making it one of the largest industrial users of this technology (Figure 4). The installations are on front-line operational fighting ships in the fleet covering ten different ship classes (frigates, destroyers, carriers, etc.). Naval analysis showed that sailors used to spend 29 sailor-days per year per pump repairing and replacing mechanical seals, couplings, and bearings, because of coupling alignment difficulties. The old greased couplings required quarterly maintenance, and produced as much as three pounds of hazardous waste each year. Alignments took up to two full days and depending on application, required cold and hot alignment checks. Installation of PMCs eliminated the need for time-consuming alignments and did not change the normal load and wear patterns of bearings and seals, improving reliability.

The Navy tested PMC technology for two years prior to fleet-wide deployment and demonstrated that this could handle 0.25-inch misalignment without performance degradation. The PMCs require no maintenance, create no hazardous waste, and reduced system vibration. The disconnected feature eliminated downtime caused by system lockup and destructive overload torque conditions between the pump and motor (if the pump seizes, the motor is not damaged). Estimated US Navy cost avoidance is US$6.3 million annually.

A North American power plant was experiencing vibration problems on their air preheaters with 30 hp, 1800 rpm motors. In an effort to correct this, they began re-greasing all couplings during every outage. Each re-greasing tied up two maintenance technicians for three days. Unfortunately, the reduction in vibration levels accomplished by re-greasing lasted only a couple of weeks before high vibration levels returned. The couplings were then replaced with PMCs, which require no lubrication. Vibration levels were reduced significantly from 0.71 in/sec to 0.12 in/sec – a level maintained after one year of continuous operation. Annual savings exceeded US$21,600 for each coupling retrofit.

Conclusion

Technology advancements result in the development of innovative products for industry. Challenged to effectively manage plant assets and lower total cost of ownership, the 'disconnected connection' may often be that solution. MagnaDrive Corporation's power transmission products provide the improved performance and longevity of rotating equipment.

Inclusion of a permanent magnet coupling into the drive train has helped users throughout industry maximise existing asset value, increase equipment reliability and up time, reduce maintenance costs, and progress towards a lubrication-free environment. Move beyond good alignment practices to ensure the trouble-free operation of rotating equipment by moving forward with permanent magnet couplings – the disconnected connection. ■

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