Magnetic Drive Pump Design for Misapplication and Process Upsets

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The distinctions between mag-drive pumps and sealed pumps in real-world applications are blurring. Big time. Here's why.

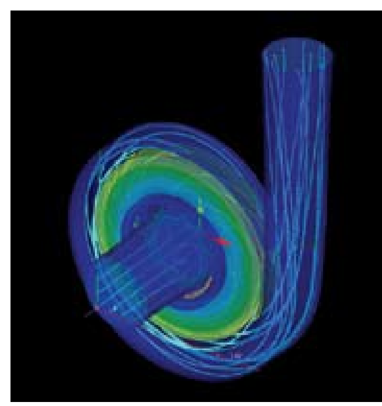
For use in pumping chemicals, magnetic drive pumps have displaced many sealed pump applications. It has been suggested, however, that mag-drive pump designs are less tolerant of misapplication and process upset conditions than "traditional" pumps that utilize mechanical seals.

While application mistakes and upsets will always be injurious to any pump performance, mag-drive pumps are now being optimized through modern design techniques that mitigate the effects of these conditions and blur the distinctions between sealed and mag-drive pumps in real-world applications.

The astronomer Galileo once made this keen observation: "It is a thousand times easier to predict the paths of the stars thousands of miles distant, than to predict the path of a water particle flowing at my feet." 400 years later, the advent of computer-aided design (CAD), finite element and other numerical analysis software is rendering Galileo's observation obsolete.

Finite element analysis (FEA) – analyzing the stress in solid bodies, heat transfer, magnetic flux and fluid dynamics – has changed (and continues to change) the way mag-drive pumps are being designed. These powerful tools literally allow a 'virtual' pump to be tested overnight.

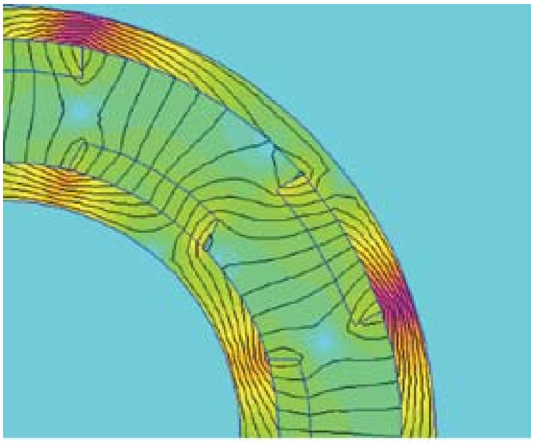
FEA of a typical magnetic drive pump barrier. Note the generous radii and elliptical shape of end for increased rigidity.



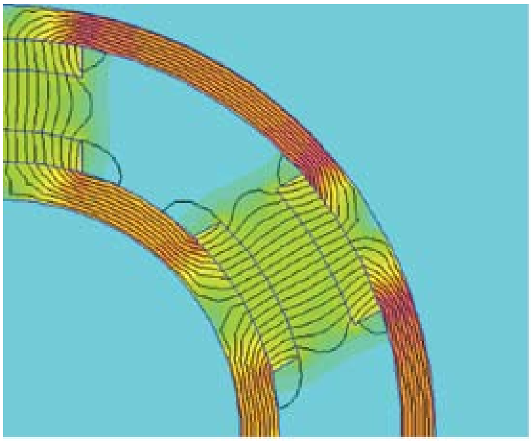
A CFD particle trace of a magnetic drive pump impeller and housing.

Change a vane angle or thickness, adjust the eye diameter, throat area, or any of a hundred other variables, and know the effects to the hydraulic performance within hours. The same is true for the pressure containment and magnetic coupling design details in a mag-drive pump. The outcome is a better design in less time, with a greater ability to integrate the different aspects of that design.

Computational fluid dynamics (CFD) is being used for the hydraulic design of centrifugal and other pump types. From impeller blades to volute shapes, designs can be optimized prior to beginning work on patterns or tools – and



FEA image of the lines of flux and flux density in a 6-pole magnetic coupling at zero torque.



FEA image of the lines of flux and flux density in a 6-pole magnetic coupling at 100% torque.

that capital is better utilized, with less risk. Several brands of CFD use rotating frames of reference that make it possible to analyze impellers dynamically within a stationary housing. Torque values and thrust loads are obtained simultaneously. All of this results in a more efficient and reliable pump.

Consider applying finite element analysis to the radial magnetic coupling design. These tools help determine the least amount of magnetic material necessary for a target amount of torque being transferred from a motor to the impeller. A key design variable here is the air gap, or radial distance, from inner to outer magnet in a dipole pair. The smaller the air gap, the less magnetic material is necessary.

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Several things must be included in the air gap, however. For example, a protective skin of metal or thermoplastic is often required over the inner magnets, the thickness of the barrier wall that separates and seals the fluid from the environment, as well as part clearances on both sides of the barrier.

To some users the pump must be applied to high specific gravity fluids so the internal pressure is high, meaning the barrier must be thick and deflection held to a minimum. To others the internal clearance is most important, so that solid particulates can flow through the pump. OEMs require a robust design (able to tolerate relatively large dimensional deviations) so the pump is easy and quick to assemble onto the motor and component cost is minimized.

All of these competing requirements must be balanced to develop the best design, and modern design methods do this concurrently.

These same tools also prevent some of the maladies that have historically caused mag-drive pumps to be considered intolerant of application mishaps and process control problems. Two of these that are directly influenced by the magnetic coupling design are the ability of the pump to run dry and the consequences of decoupling the drive.

The ability for a magnetically-coupled pump to run without fluid to lubricate the internal components is a complex problem of tribology. A solid lubricant must somehow be introduced to reduce the sliding friction and remove heat for a period of time, otherwise the temperatures of these components will rise rapidly and lead to seizures and pump failure.

A combination of carbon and a ceramic, such as alumina or silicon carbide, can be made to run dry for several minutes with graphite or other adjuvant serving as the dry lubricant – when corrosion and wear resistance allow this. With careful attention to other factors such as P-V and internal clearances, some mag-drive pumps (usually 5-hp or smaller) can be made to run dry for hours.

If application conditions demand that all ceramic or other materials, such as metal or PTFE, be used for the sliding components, then either hard facing or other protection (such as a power monitor) must be used to prevent pump damage resulting from a process upset that introduces dry running. Our experience is that roughly 80 percent of mag-drive pump applications perform well with no run dry protection, other than carbon/ceramic material selection.

Unlike eddy-current couplings sometimes used as variable speed devices on pumps, mag-drive pump couplings are zero slip couplings. Decoupling of the type of magnetic coupling used in most larger (above fractional motor frames) mag-drive pumps can cause damage. Careful consideration of the loads to the coupling, both static and dynamic, is necessary to properly size the magnetic coupling and prevent decoupling.

Many smaller mag-drives (fractional and sub-fractional) utilize hard ferrite magnets, while most larger mag-drives utilize rare earth magnets. This often confuses mag-drive pump users.

Ferrite magnet drives must generally be applied in combination with soft start (or reduced starting) torque motors due to the relatively low magnetic strength of the ferrite. Ferrite is a poor conductor of electricity and, as such, generates low levels of eddy currents. If they decouple, the limited amount of magnetic flux and resistance to eddy current generation prevents damage to the pump – indeed, the decoupling is often referred to as a feature to prevent motor overload damage.

Couplings made with rare earth elements (Neodymium or Samarium), however, produce a *much* stronger magnetic field and are good electrical conductors. They are generally capable of starting standard NEMA design B induction motors. Should they decouple, the two strong magnetic fields moving relative to each other will induce high levels of current in the conductors. The resulting heat can cause melting of plastic components and even irreversible demagnetization. Since there is potential for pump damage, rare earth magnetic couplings are not designed to decouple at overload conditions in order to protect the motor.

Thankfully, to a magnetic coupling, normal-starting torque 3-phase induction motors started with full voltage are relatively difficult to couple to the pump rotor, and magnetic couplings must be generously sized for motor starting.

According to EASA, the required torque to accelerate a motor to full speed (a function of the full load, locked rotor and breakdown torques) generally falls between 3 and 4 times the full load torque of the motor. This is the torque that the coupling must be able to transmit dynamically in order to couple the impeller to the applicable motor as it accelerates to operating speed.

As a result, decoupling is rare since few process upsets, specific gravity swings, or flow variations would result in such high torque variations. Armed with intimate knowledge of the pump rotor inertia and the average acceleration torque for a given motor size, the engineer can choose from several good 2-D finite element software programs that will greatly simplify the job of magnetic coupling design.

In conclusion, modern design tools that utilize finite elements are improving mag-drive pump performance, versatility and reliability. Properly applied to coupling and hydraulic design to optimize coupling sizes and minimize loads, these tools contribute to pump designs that are significantly more forgiving of less than ideal process conditions.

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