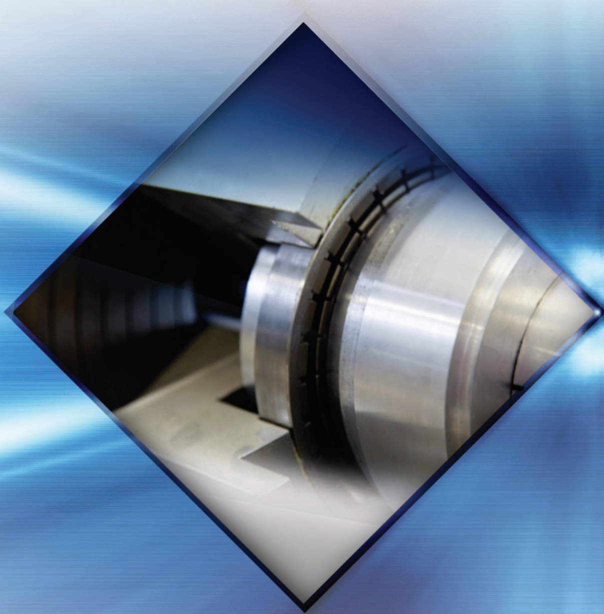
Application Brief

# Improved Efficiency & Performance with Shaped Field Magnets



## Summary

*Shaped field magnets (SFMs), relative newcomers to the permanent magnet arena, have sparked interest among designers of rotating equipment and sensors. Having shown significant gains in efficiency and performance in several machine and sensor applications, SFM devices appear to represent a breakthrough technology development for permanent magnet users.*

*Arnold's proprietary SFM technology makes shaped-field magnetism a reality and offers opportunity for improvements in energy efficiency, cost/performance, and equipment reliability. This brief describes new developments in SFM technology and shows why this advancement holds such promise for rotating machine and sensor applications.*

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## Limitations of Traditional Magnets

Permanent magnets have traditionally been designed to provide a magnetic field of consistent shape, with the anisotropy within and surrounding the magnet as uniform as possible. The classic "iron filings" images show flux field vectors emanating with mirrored curvatures from the N and S poles of the magnet. This time-proven, conventional magnetic field arrangement is suitable for many permanent magnet uses.

However, with the advent of magnetic torque transfer technology and the growing use of rare earth permanent magnets in rotating machinery, the conventional magnetic field distribution presents some limitations. A portion of the magnetic field is wasted or can actually hinder performance. Similarly, with the increasing use of Hall effect sensors in applications ranging from automotive device sensing to industrial systems, the familiar magnetic field shape can inhibit accurate motion detection.

### What Do We Mean By "Shaped Field"?

Unlike a traditional magnet, the shaped field magnet has a field with a deliberate divergence from the anisotropic model. Figures 1 and 2 compare the conventional magnetic field with an SFM field arrangement. In the SFM configuration, the magnetic field is shifted toward one side of the magnet.

Some of the advantages of the shaped field magnet include:

- Higher field strength in the working zone for the mass and size of the magnet
- Substitution of higher-temperature, lower-remanence materials
- Increased design freedom, with less concern for handling stray field effects
- Reduction of overall system weight for equipment using the SFM

Arnold's patent-pending process for SFM fabrication shapes the magnetic field as part of the magnet manufacturing process. The desired field shape is carefully plotted out beforehand so that the various stages of compression, sintering, and field alignment work together to provide the desired field characteristic.

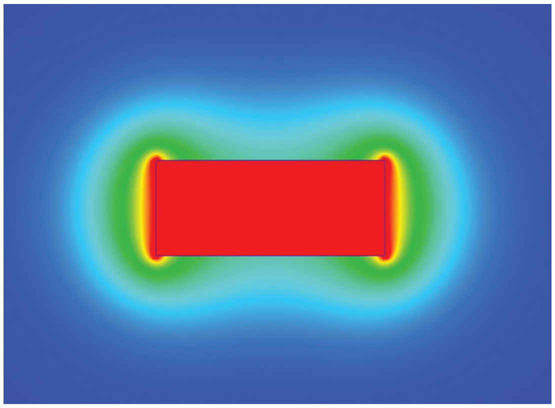

**Figure 1.** Traditional magnet, with symmetric flux fields

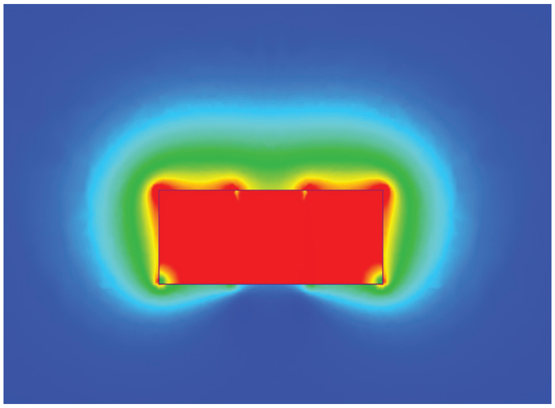

**Figure 2.** Shaped field magnet, with notable asymmetry

## A Look At Torque Transfer Coupling

Magnetic drive couplings can be useful in industrial and utility environments, helping to reduce or eliminate various factors that contribute to machine wear and premature breakdown. However, magnetic couplings have some inherent inefficiencies.

Torque transfer coupling design using magnetic drive couplings relies on inner and outer alternating-pole rings to transfer torque without contact. Each ring has a heavy steel backing for mechanical support and to serve as a yoke for the magnetic circuit. Figure 3 shows a 3-D representation of a contactless magnetic torque transfer coupling. The drive motor is mechanically coupled to either the inner or outer ring; the pump, fan, or other rotating machinery is mechanically coupled to the other ring.

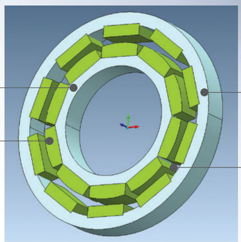


**Figure 3.** Magnetic torque transfer coupling

Figure 4 shows a modeled representation of magnetic field intensity for the conventional magnetic coupling. The close-up view shows field fringing that occurs between neighboring magnets on the same ring. Here, some of the magnetic field vectors between neighboring magnets interfere with each other, wasting some of the potential magnetic force.

*Fringe effects generate unwanted interference. Energy is wasted between neighbors instead of transferring torque.*

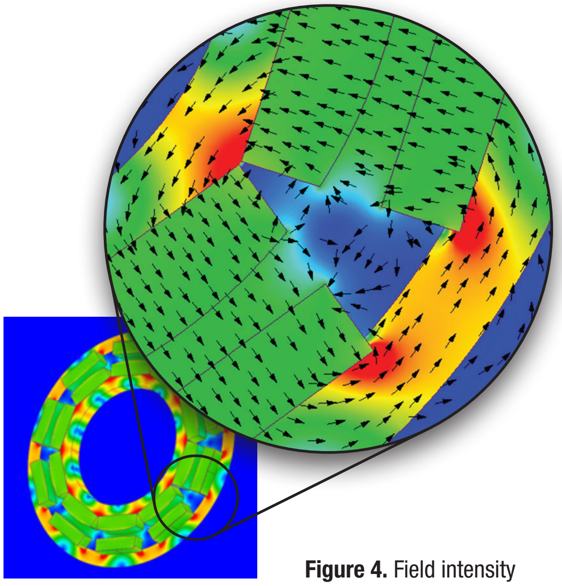

**Figure 4.** Field intensity modeling for standard magnetic torque transfer coupling

One way to address this interference problem is with the Halbach array, in which the magnetic orientation of successive magnets is rotated so that the resulting magnetic field is shifted to one side of the ring. The rotation redirects and concentrates the magnetic flux asymmetrically to the “working” zone of the coupling. (The familiar “refrigerator” magnet is actually a composite magnet designed using the same Halbach array principle.) While the Halbach array offers a workable solution, it can be relatively costly to fabricate, requiring more parts and added weight, and it is complex to assemble on a large scale.

In effect, the shaped field magnet embodies the same flux re-distribution principles as the Halbach arrangement, but executed in a simpler way. Instead of requiring successive magnets with mutually orthogonal field orientations, SFM technology redirects the magnetic field within the magnet material itself. Each individual magnet acts as a repeating unit, as in a Halbach array. Fewer magnets are needed, and the field fringing effects are greatly reduced or eliminated at a cost that is more comparable to the conventional coupling design.

Figure 5 shows a modeled representation of magnetic flux density for a torque transfer coupling using SFMs. The close-up view shows reduced field fringing between neighboring magnets on the same ring. Because the field strength of the SFM is skewed to the working volume and less of the field is wasted in bridging neighboring magnets, torque is increased. The SFM construction also directs less of the magnetic field into the yoke, reducing the magnetic requirements and yoke thickness. This can reduce the overall size and weight of the coupling, resulting in greater efficiency, cost savings, reduced wear, and extended bearing life.

*SFMs provide enhanced field strength, reduced fringing, and more efficient use of magnetic energy. Reduced saturation allows thinner iron yoke.*

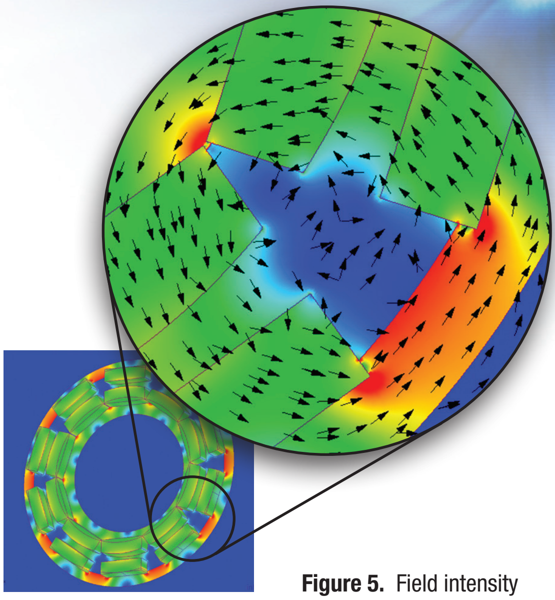

**Figure 5.** Field intensity modeling for magnetic torque transfer coupling using SFMs

## Efficiency Gains For Couplings Using SFM

With their ability to redirect the magnetic field to where it is most useful, SFMs have the capability to boost torque values for existing designs by 20 percent. Substitution of an SFM-based coupling for the traditional magnetic coupling can have immediate benefits for manufacturing and maintaining rotating equipment.

These impressive results from retrofitting SFM-based couplings are only the beginning. Because SFM devices effectively pack more focused flux into less space, they have the potential to dramatically impact machine design on the drawing board. When introduced early in machine design stages, the SFM can provide pronounced benefits in size, cost, reliability, and energy savings, yielding torque increases as high as 75 percent within the same design volume. Consider the opportunity to provide the same torque from a reduced size coupling. This benefit, in turn, relaxes requirements for supporting structures, horsepower for drive motors, bearings, seals, lubricants, and cooling systems. These reduced requirements can have positive impact on performance, reliability, and periodic maintenance.

**The bottom line:** While SFM-based couplings can be a cost-effective retrofit for conventional coupling systems, it can provide more substantial benefits and savings when incorporated earlier in the machine design process.

## Is There An SFM In Your Future?

We've looked at what SFMs are and the advantages they offer in couplings and other rotating machine technologies. While the ability of the SFM to provide a custom-shaped magnetic field is undeniably beneficial, a number of questions can help determine if SFMs provide a practical and affordable solution for specific applications.

Volume is a consideration due to the added cost and greater design and manufacturing time for SFM fabrication. With shaped field capability, two magnets of identical shape can have very different flux field arrangements, each manufactured for a specific purpose. The number of possible flux distributions is theoretically infinite, which is a boon to the designer but presents new challenges for optimization.

System performance can also be an important factor in determining if an SFM is the best choice. Opportunities for reduced weight, increased torque, energy savings, and equipment reliability need to be balanced against factors of cost and overall operational requirements. Lower-volume equipment manufacture might justify the added time and expense for SFM design and delivery.

Arnold has been at the forefront of developing SFMs and related magnetic materials and components. We work with customers large and small to design and provide the magnetics solutions that help them stay competitive and provide the best performance for their own customers' investment. The SFM is just one of our exciting new products that are helping to redefine the nature of magnetics and provide solutions for next-generation machinery, instrumentation, and sensors.

Contact us for more information about what we offer and to explore opportunities for improved performance with shaped field magnets.

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