Flux Density Enhancement

Using Shaped Field Magnets

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Shaped Field Magnets (SFM)

Shaping the field redirects the magnet’s force to where it is needed.

Advantages:
- Higher applied fields than previously possible
- Field shape is optimized for the application
- Higher-Temp lower remanence materials become competitive
- Increased design freedom around magnets
- Reduced overall system weight

Patent applied for process imparts a domain orientation pattern into the structure of the magnet.
Imparting the Shaped Field - example

Challenges

- Substantially more complex tooling.
- Orienting fields change during compaction.
Sensor Magnets

Possible configurations

uniform diametric

axial 2-pole

Shaped Field
Sensor Magnet - In-plane

- SFMs improve the in-plane case (Bx)
  - For in-plane sensors, field strength is increased 20%

- Increased strength
  - More reliable signals
  - Greater standoff distance
  - More freedom of design
Sensor Magnets - In-plane

Experimental result

Cylinder dia 6.5 x 2.5, Sm2Co17

B on axis [mT] vs Distance [mm]

- Diametric, calculated
- SFM, model calculation
- Measured sample

"In-plane"
The through-plane case

**Less costly approach**

- Array of through-plane sensors, offset from the center of the sensor chip assembly
- SFM improves the through-plane case:
  - For through-plane sensors, field strength can be 50% greater

Note: Coloration reflects field in normal (Bz, vertical) direction.
Sensor Magnets – through plane

Experimental result

Cylinder dia 6.5 x 2.5, Sm2Co17
axial field at r = 1.1 mm

"Through-plane"
Sensor Improvements Using SFMs

…it’s for real

Better-than-expected improvements measured in field trials, with angle errors less than 1°

Arnold is in an approval process for a new automotive application

Planned production in the coming year for >1.2 million pieces
A Classic Case – Torque Transfer Coupling

Especially useful for pumping hazardous (hot, toxic, bio-hazard) liquids or gases


A Classic Case – Torque Transfer Coupling

- **Traditional coupling**: a pair of alternating-pole rings transfer torque without contact
- Steel backing provides mechanical support and a magnetic yoke for the magnets
- The system has certain **inherent inefficiencies**:
  - **Back iron bulk** for magnetic stability
  - **Field fringing** between neighbors on the same ring
By using magnets with rotating orientation, many aspects are improved by concentrating the field in the working zone.

But – this introduces several new disadvantages:
- Cost
- Complexity
- More magnets
- Increased weight

...a complex solution for most torque transfer applications
A Better Solution – Shaped Field Magnets

- With SFMs, the Halbach pattern is imparted into the magnet material itself
- **Direct substitution** of SFMs: coupling with 20% more torque than original design
- **Design from the ground up** with SFMs:
  - Gain torque in a fixed volume
  - Reduce coupling size and keep constant torque
  - Reduce cost by using a smaller system
  - Reduce overall mass, extending bearing life
Coupling Forces (Torque)

- Conventional "up / down"
- "Halbach" array
- Shaped field magnets

Graph showing:
- F / Magn.-Vol. "up/down"
- F / Magn.-Vol. "Halbach"
- F / Magn.-Vol. "shaped field"
- F / A "up/down"
- F / A "Halbach"
- F / A "shaped field"
Enhancements in torque in a commercial coupling for chemical pumps.

Design optimized for shaped field magnets; same overall package size but with reduced steel allowing use of larger magnets.
Results for Torque Transfer

- Proof-of-concept SFM prototypes yielded an average of 19% increased torque.
- Arnold is currently working with a customer to deploy SFMs across their entire suite of products.

... increased efficiency for next-generation performance
Arnold Shaped Field Magnets - Summary

- Field permanently shifted to focused flux for optimum performance
- It is a structural change, not just a difference in magnetizing
- Can be applied to Neo, SmCo, Ferrite magnets
- Design possibilities include
  - Through-plane sensor application sees up to 50% improvement in flux density which allows greater stand-off distance and stronger, more reliable signals
  - Torque coupled drives: 20% or more improvement in coupling with overall lighter design using less back iron and down-sized pole pieces
The science of doing more with less.