The Application of Permanent Magnets in Magnetic Sensors

Permanent magnets are ubiquitous in modern societies. Devices which use permanent magnets include motors, sensors, actuators and acoustic transducers, just to name a few. These devices are then used in home appliances, speakers, office automation equipment, aerospace, wind turbine generators, medical laboratory diagnostic test equipment, and more. It is estimated, for example, that a typical automobile uses up to 120 permanent magnets in windshield wipers, starter motors, seat adjusters, door lock actuators, fuel pumps, sensors, gauges, etc. Hybrid Electric Vehicle and Electric Vehicle drive technologies has been greatly enhanced by the availability of high performance magnetic materials.

Brief Permanent Magnet History

The historical development of permanent magnet materials based on their magnetic performance ((BH)max) is shown schematically in Figure 1. Of the many permanent magnet materials, four are still in common use: Alnico, ferrite, samarium cobalt (SmCo), and neodymium iron boron (NdFeB). Alnico was invented and commercialized in the early 1940s. Ferrite magnets, also known as ceramic magnets, were first commercialized in 1952. SmCo5 was introduced in 1961 and an improved composition, based on Sm2Co17, was introduced in the early 1970s. The most recently developed material is NdFeB and was first available in 1984. Both the SmCo and NdFeB based materials belong to the family of rare earth magnets. Ferrite magnets, while providing less magnetic strength than rare earth magnets, cost far less. Therefore, they are still widely used wherever product cost is a major consideration over magnetic performance.

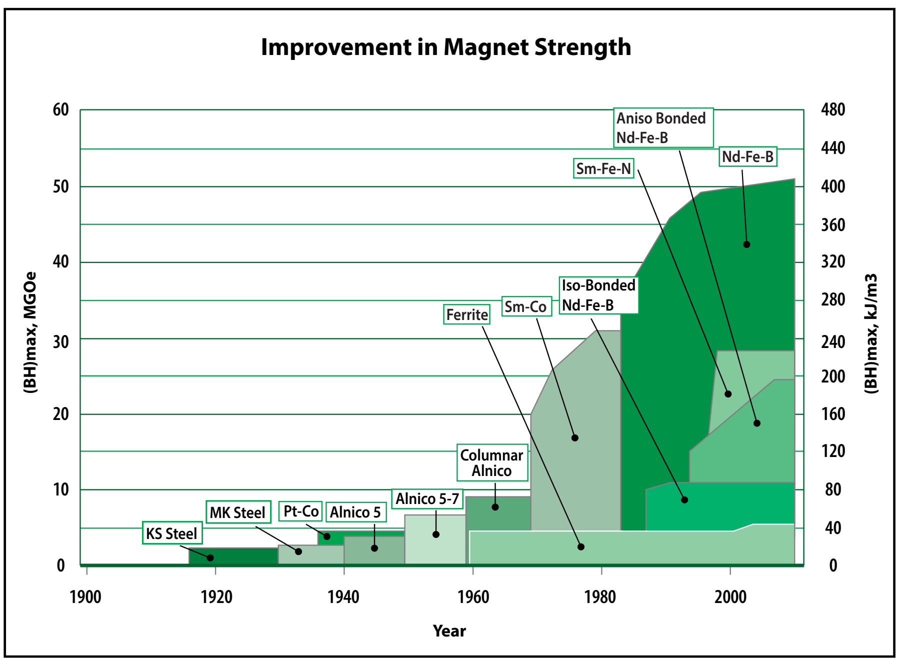

Figure 1

Magnetic Sensors

Today magnetic sensors are vital devices in many applications and industry segments. Their primary function is to interact with a magnetic field and convert mechanical motion or position to an electrical signal. They operate without contact (through an air gap) with no physical wear or tear and can work through sealed barriers with high reliability. Most magnetic sensors use one of the following operating principles:

Hall Effect
Variable Reluctance
Giant Magneto Resistive

Wiegand Effect
Reed Switch
Magnetostrictive

The role of the permanent magnet in a sensor is to provide a magnetic field in an air gap; the field can constant and extremely precise, or vary in magnitude and direction.

In the permanent magnet industry the magnetic parameter, (BH)max, is considered to be the best all-round single indicator of permanent magnet performance and is always included in any list of published magnetic properties. It can be shown from first principals that for a magnetic circuit the energy stored in the field in the air gap is directly proportional to the product of flux density (B) and corresponding field strength (H) at any point on the second quadrant demagnetization normal curve; the product BH is known as the energy product as shown in Figure 2 below. Hence, it follows that the volume of a magnet required to produce a given field in a given gap is minimum when the product of BH is maximum; (BH)max. In other words the

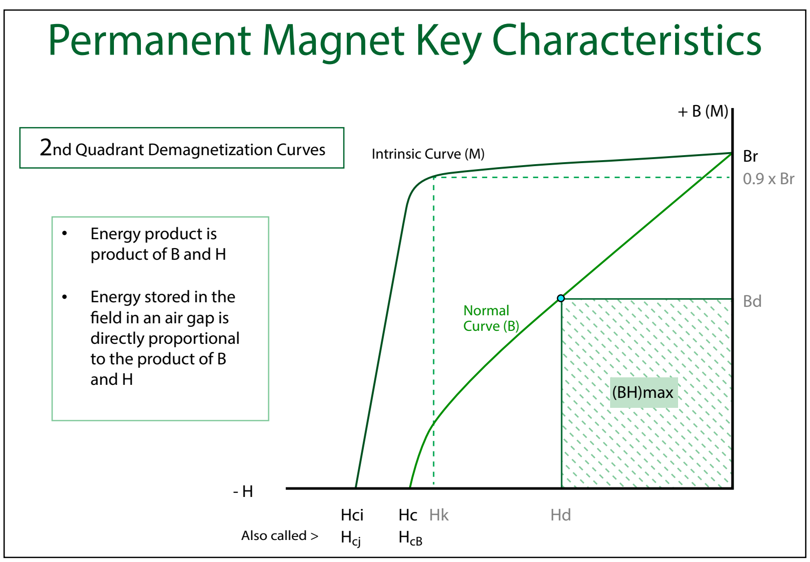

Figure 2

higher the (BH)max the smaller the magnet volume to generate a given flux density.

Modern permanent magnet materials are very versatile and offer a wide range of characteristics to meet a myriad of application requirements.

The optimum type of permanent magnet for a given sensor design depends on many factors as shown below:

Maximum Energy Product ((BH)max)
Demagnetization Curve Shape
Flux Density (Br)
Recoil Permeability
Resistance to Demagnetization (HcJ)
Corrosion Resistance
Usable Temperature Range
Physical Strength
Magnetizing Field Requirement
Electrical Resistivity
Magnetization Change with Temperature
Available Sizes, Shapes, and
Manufacturability
Raw Material Cost and Availability

The most common types of permanent magnets used in sensors are sintered samarium cobalt, sintered Neodymium Iron Boron and bonded magnets of various types. These are described in more detail below:

Samarium Cobalt

The first generation of commercial rare earth permanent magnets, based on Samarium Cobalt intermetallic compounds, was introduced in the early 1970s. Shortly after the development of SmCo5 permanent magnets, alloys containing copper as well as the rare earths and cobalt emerged. These became known as the precipitation-hardened family of R (Cu, Co) alloys and eventually led to the development of high-energy Sm (Co, Cu, Fe, TM) 7-8 magnets (where TM is Zr, Ti or Hf).

Samarium Cobalt Advantage: Magnets based on Sm and Co offer the combination of highest operating temperature, flux output and thermal stability for the rare earth group of materials..

Samarium Cobalt Disadvantage: The major disadvantages of Samarium Cobalt relate to the lower (BH)max, compared to NdFeB-based magnets.

Also the alloys contain an appreciable amount of cobalt a metal subject to supply limitations and disruptions.

Neodymium Iron Boron

In the early 1980s both Sumitomo Special Metals and General Motors announced a new class of magnetic material based on the ternary compound Nd2Fe14B. Soon after the announcement several permanent magnet manufacturers began commercial production of permanent magnets based on Nd2Fe14B. These materials combine high HcJ, with the highest known (BH)max of any commercially available magnet. The powders produced by the GM process, known as Magnequench, are magnetically isotropic and primarily used in unoriented bonded magnets.

Neodymium Iron Boron Advantage: NdFeB based magnets have two major advantages when compared to SmCo based magnets. These offer a combination of lower costs, primarily driven by lower raw materials, and higher room temperature Br and (BH)max performance.

Neodymium Iron Boron Disadvantage: The major disadvantages of NdFeB magnets are their relatively low maximum operating temperatures and poor corrosion resistance. Increases in operating temperature are primarily addressed by increasing the intrinsic coercivity by substitution of Dy for Nd. Corrosion resistance is addressed by coating the magnets.

Bonded Magnets

Bonded magnets are an important but often overlooked group of products that magnetic circuit and device designers should consider when choosing the optimum permanent magnet type for their specific application need. In their most basic form bonded magnets consist of two components: 1. A hard magnetic powder; and 2. A non-magnetic polymer or rubber binder. The powder may be hard ferrite, NdFeB, SmCo, alnico, or mixtures of two or more magnetic powders known as hybrids. In all cases, the powder properties are optimized through processing and chemistry specifically aimed at utilization in a bonded magnet. The binder that holds the magnetic particles in place can produce either a flexible or rigid magnet. Typical binders for flexible magnets are nitrile rubber and vinyl. Binders for rigid magnets include nylon, PPS, polyester, Teflon™ and thermoset epoxies. The thermoplastic binders may be formed into sheet via a calendaring or extrusion process or formed into various complex shapes using injection molding. Compression bonding almost exclusively combines isotropic NdFeB powders with a thermoset epoxy binder using a uniaxial room temperature pressing process.

Bonded Magnet Advantage: A major advantage of bonded magnet processing is near net shape manufacturing requiring zero or minimal finishing operations compared to powder or cast metallurgical processes. In addition value added assemblies can be economically produced in a single operation.

Bonded Magnet Disadvantage: The major disadvantage of bonded magnets is the dilution of the magnetic component by the binder system resulting in lower (BH)max.

Other Magnet Options

When the operating temperatures exceed around 450 C or extremely high thermal stability is required AlNiCo magnets are the material of choice. Conversely, if weight and volume are not critical and cost is paramount hard ferrite magnets are an option.

About Magnet Applications, Inc. (MAI)

MAI (www.magnetapplications.com) is located in

DuBois, PA and is one of the largest North American manufacturers of injection molded (both ferrite and NdFeB) and compression bonded NdFeB magnets. In addition MAI supplies a full range of permanent magnet products and technical assemblies supported by application and sales engineering throughout North America.

They are part of the Bunting Magnetics Group (www.buntingmagnetics.com). Bunting Magnetics is a family-owned group of companies manufacturing products which serve global markets and include a broad range of magnetic materials and components, magnetic separation systems, material handling equipment, metal detection equipment, magnetic cylinders for the printing industry, bonded magnets, and technical assemblies.

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