

Magnet Price Performance



In my column in the spring issue earlier this year, I discussed some likely effects from the rise in rare earth prices on the long-term growth of neodymium-iron-boron ("Neo") magnet markets. Unfortunately, the upward trend I indicated for the end of 2006 has continued, raising the price of Neo magnets about 20 percent further over the first half of 2007. This has to be accepted for devices that

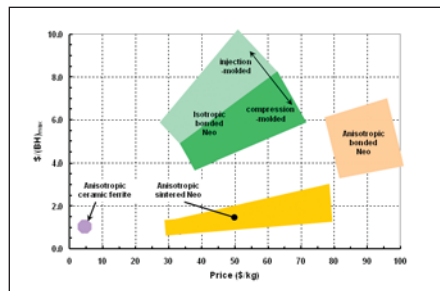
demand a high power density and therefore require the high energy provided by Neo magnets, such as hard disk drives (head actuator and spindle motors) and hybrid electric vehicle drive motors. But if it is not required as an enabler for a successful product, then the sustained uncertainty over the price for Neo leads to the selection of tried and trusted ferrite magnets for new products.

I have often seen a quantity dubbed "flux for bucks" used to measure the relative merits of permanent magnet materials, taking account of their magnetic properties and their price. It typically utilizes remanence as the magnetic parameter, but for relative purposes this alone fails to also account for a magnet's coercivity, which measures its ability to sustain magnetic flux in an air gap. I favor "price performance" as a more suitable means to make this comparison, utilizing maximum energy product rather than remanence. As I mentioned in my previous column, maximum energy product, (BH)_{max}, is the quantity most commonly used to rate a permanent magnet material, providing a measure of the best combination of a magnet's capacity to produce flux and its capacity to deliver it to an air gap. Furthermore, the B x H product is indeed a direct measure of the energy available per unit volume of a magnet, actually being 2x this amount. Using (BH)_{max} works particularly well for comparison purposes when the materials all have high coercivity, which leads to approximately linear demagnetization characteristics through their maximum energy points and below - this is the case with most ferrite and rare earth magnets, whether sintered or bonded.

I believe a fair comparison between permanent magnet materials is to use their price performance, defined as price per (BH)_{max} (\$/kg/MGOe). This can be plotted against any suitable variable, but magnet price (\$/kg) is probably of greatest interest today since the technical properties of most commercial types of the material have been mature for several years now. However, any class of rare earth magnet can be manufactured in a variety of ways to provide a wide selection of properties, resulting in there being many commercial grades of each magnet class. Each of the major classes of Neo magnet is therefore represented by a relatively large area on the price performance diagram, covering all the individual points for each available grade. As you would expect, the costlier grades are the ones which provide some performance enhancement, but this

also means that more economic grades are available for applications with no unusual performance requirements.

What constitutes the price of a rare earth permanent magnet falls into three categories: its manufacturing process, supply of its raw materials and its required performance. Sintered Neo is an anisotropic material whose alignment is imposed during the pressing operation. The predominant method has evolved over the years from use of an axially-oriented aligning field through the die cavity to using a transverse field, which achieves a more complete magnetic orientation, improved magnetic properties and hence better (i.e. lower) price performance. Sintered Neo is also produced



as a radially-oriented ring, but providing this field alignment in a suitable die cavity is a more complex process - these magnets are at the high end of the price band. Because their manufacturing process demands a stable magnetic powder, most bonded Neo magnets are made from isotropic powder which is only magnetized after molding. This leads to a simpler and more economic process, though methods which develop

greater densification consequently produce higher magnetic remanence and hence better price performance. Anisotropic bonded Neo magnets have the highest \$/kg because their fine powder is quite unstable and has to be handled in a batch process, which must also incorporate the magnetic aligning field; but this orientation produces far superior magnetic properties compared to isotropic bonded magnets.

My column in the spring issue has already discussed the effects on price of the supply of raw materials, at least with respect to neodymium. Unfortunately, certain other rare earth elements (such as dysprosium or terbium) are also employed in some grades of Neo to enhance the magnet's ability to withstand more extreme operating or environmental conditions. While used in relatively small quantities, these elements are far less abundant in rare earth ores and therefore have a comparable impact to neodymium on the price of the alloy.

The price performance diagram is a valuable tool with which to compare permanent magnet materials that can easily be adjusted as magnetic properties evolve and prices fluctuate. In simple terms it shows that price performance is improved with greater densification of the magnet material and/or with better orientation of the magnetic powder. While a molded magnet may offer a particular advantage to a specific application, these criteria explain why the very best value in a Neo magnet is provided by the anisotropic sintered class, some economic grades of which can compete very favorably with ceramic ferrite.

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