Supply and Demand: Part 2

In Part 1 of this column in the previous issue of *Magnetics Business & Technology* magazine, I showed that we have arrived at a time when the total worldwide demand for rare earth oxide (REO) will be driven by the need for neodymium oxide, specifically for use in neodymium-iron-boron (Neo) magnets. It appears that the demand for neodymium oxide will drive the supply gap for at least the next few years. Now in Part 2, I want to discuss the consequences of equally alarming price trends for a couple of other elements which are critical for many permanent magnet materials.

Neodymium-iron-boron is not usually constituted from just these three elements. If it were, we would not have the wide array of Neo magnet grades that are available today, with equally varied properties. Historically, the application that drove the demand for Neo was the hard disk drive, whose "voice coil" head actuator is designed for maximum response without having to endure any extreme environmental conditions. Neo from an alloy using close to the ternary 2:14:1 composition served this product well by providing a relatively high flux density, but its moderate intrinsic coercivity - the property which quantifies a magnet's ability to retain its magnetization - would not protect it against the strong demagnetizing fields and/or high temperatures that occur in more demanding applications like servomotors. And it is applications such as motors for electric power steering and hybrid electric vehicle drives that are pushing the demand for Neo magnets today.

To meet these demands, the heavy rare earth element dysprosium is substituted for some of the light rare earth neodymium in the composition, since this provides a much improved intrinsic coercivity and hence resistance to demagnetizing fields. Furthermore, cobalt is substituted for some of the iron to provide stability for the magnet at higher temperatures, though with some loss of intrinsic coercivity. Clearly both of these elements, often added together, are critical components of the Neo magnet to enable many major new and existing products.

This is well illustrated by one of the examples I gave in my previous column. A typical drive motor for a hybrid electric vehicle uses about 1,500 gm of sintered Neo magnets, but to significantly raise their intrinsic coercivity for such a demanding application, as much as 6 percent of this alloy may be dysprosium metal (substituted for neodymium). This amounts to more than 100 gm of dysprosium oxide for each motor, which means that hybrid electric vehicles alone will require over 200 mT of dysprosium oxide by 2010, based upon Toyota's projected 2 million units per year. The problem is that the major REO producing regions of the world, both current and forthcoming, and rich in the light rare earths (such as neodymium) and contain negligible dysprosium.

Heavy rare earths are nowhere near as abundant in the earth's crust, and only occur in a few regions, the most productive source today being from ionic clay found in Jianzxi, Southern China. But for the year 2006, the Chinese government imposed a limit of 7,000 mT of REO to be mined in Jianzxi, about 470 mT of which would be dysprosium oxide. Compare this amount to the current estimate of 200 mT needed for the hybrid electric vehicle drive and it is apparent that, even if production of heavy rare earths can rise over the next few years, the requirement for dysprosium from a few very demanding applications such as this will exhaust most of the available supply.

From the REO supply standpoint, it is clearly beneficial for the designs of such products to be critically evaluated on the basis of how much intrinsic coercivity they really need. Any consequent reduction in dysprosium content will also have a cost benefit, because at the end of 2007 the price of dysprosium metal was $123/kg, three and a half times greater than that of neodymium. Likewise, a cost benefit will accrue from a reduction in the cobalt content, since its price rise has been steadily accelerating over the last few months of 2007 to around $86/kg. But even a small amount of cobalt significantly improves corrosion resistance, particularly in bonded Neo magnets where at least about 2 percent is needed for its beneficial effects to be properly realized.

With the demand for neodymium oxide now driving the supply of REO and bearing an increasing share of the refining cost, there is ample supply of some other rare earths at reasonable prices - such as samarium, which ended 2007 at only $15/kg. This has led some to suggest that samarium-cobalt magnets might now be considered to replace Neo in some of its applications, but notice that it is cobalt which dominates the cost of samarium-cobalt, not samarium. Take for example a high coercivity grade rare earth magnet with a 34 to 35 MGOe energy product. In Neo, this might contain around $16.50/kg of rare earths, including about $7.40/kg each for neodymium and dysprosium. In samarium-cobalt, this energy product may be achieved by replacing about one third of the cobalt with iron. Even so, while its samarium content is valued at only about $1.70/kg, the cobalt costs a hefty $46/kg. At least this serves to illustrate why Neo must remain the dominant product for high energy magnet applications, and why designers need to come to terms with the rare earth price situation.

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