No Substitutions

In a famous scene from the movie “Five Easy Pieces,” Jack Nicholson demonstrates how frustrated someone can become with seemingly unreasonable requests. In this case it was the phrase “no substitutions” on the menu in a diner.[1] While not frustrating in quite the same way, there is a move afoot among some U.S. policy makers to find substitutes for the rare earths used in permanent magnets. I guess the underlying idea is that we can resolve the rare earth shortage by making magnets with the same properties as samarium cobalt and neodymium iron boron, just without the samarium, neodymium and dysprosium.

On some level, this idea makes sense. However, my feeling is that this approach is well-intentioned but misguided. Let me explain why.

While there is no theoretical reason precluding a permanent magnet with exceptional properties and without rare earths, the overwhelming weight of history suggests that such a discovery is indeed unlikely. My friends who make alnico and ferrite magnets would remind me that their magnets have exceptional properties and contain no rare earths,[2] and that rare earth magnets have only existed for about 40 years. They are quite correct. But does all this experience mean that we shouldn’t look? Not at all, it is clearly worth a try. I like the way that Bill McCallum from Ames Labs describes the situation. He says, "The people who have worked on non-rare earth magnets in the past were really smart. We don't pretend to be smarter than they were but we have knowledge and research tools which were not available to them. Only by using these tools, can we hope to find something earlier researchers did not see.” So let’s look, even if the odds are against us, much like buying a lottery ticket and hoping to win a jackpot.

But this raises an obvious question. Are there other cost-saving areas we should explore? Let me describe two of them, with a reminder about the importance of applying resources to areas with a higher probability of success.

Not too long ago, when rare earths were a little less expensive, it was common practice for design engineers to use a bit more magnet than they really needed. A larger magnet makes the design more robust, even though it is a bit more expensive.

In addition to bulkier magnets, another common wasteful practice is overdoing dysprosium additions in NdFeB magnets. While it is satisfying to have more resistance to demagnetization, adding extra Dy carries a double penalty. Not only is dysprosium always more expensive than the neodymium it replaces, but less magnetic flux is available as the dysprosium level increases.

Unfortunately many people do not use design tools like finite element analysis to optimize designs as much as they should, relying instead on bigger magnets and extra Dy for protection. My informal poll of industry application experts suggests that at

[1] http://www.youtube.com/watch?v=6wtfNE4z6a8

[2] A few grades of ferrite contain small amounts of La_2O_3, a rare earth oxide, but most grades of ferrite contain no rare earths.

least 10% of all magnet applications are flawed, meaning that they routinely see designs using the wrong grade of material, incorrect dimensions, or some other significant design flaw. The key point is that flawed designs waste material and increase the magnet cost, both unnecessarily. The cost differential of a wasteful design used to be insignificant, but that may no longer be true and is worthy of review. It is something we need to be smarter about today. How much rare earth could we save by better designs? That is difficult to quantify. But there is an urgent need to focus attention on making large magnets in high-volume applications as efficient as possible.

We also need a much more active program in recycling. One of the costs people frequently overlook in the price of a magnet is the cost of energy. The reduction of a rare earth oxide to a metal consumes a large amount of electricity. Since this cost is buried among all the other costs of a magnet, it is not usually considered but it is significant. In some ways, this is similar to aluminum. After several decades of work, the U.S. aluminum industry manages to recycle nearly 60 % of the aluminum cans it produces.[3] The main advantage to recycling is that far less energy is required to recycle aluminum compared to primary production. The same principle applies to rare earths. Admittedly, recycling rare earths in the form of magnets is more difficult than recycling an empty beer can, but we should not let the difficulty deter us. We need to set a similar target for the recycling of rare earths.

Will these approaches eliminate the threat of rare earth shortages in the magnet industry? My opinion is that they are important steps in the right direction. We will have to wait and see if they are sufficient.

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3 http://www.aluminum.org/AM/Template.cfm?Section=Recycling1&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=30442