Motherlodes, Silver Bullets and Recycling: What's Left?

Since about 2010, research on permanent magnets seems to focus on three distinct areas:

- Finding a new major untapped rare earth resource
- Developing a new permanent magnet that addresses most or all the issues of existing materials
- Recycling end of life magnets and grinding sludge

Clearly, a major breakthrough in any one of these areas would impact the market in a very positive way. But this three-pronged approach is being promoted indirectly as the complete solution, implying there are no other potentially fruitful places to look. The premise of this article is to point out two potentially fruitful areas that have been substantially disregarded: material selection during the design process and new application development in the rare earth industry.

First, let me say a bit about the three focus areas.

Finding a new rare earth resource could be helpful. The ideal deposit should have all of the following characteristics:

- A high-quality deposit with good geology that lends itself to easy processing
- An accessible location, outside China, with a well-developed infrastructure
- A good distribution of heavy rare earths
- Better environmental oversight

Note that finding a new rare earth resource cannot change the underlying market pressures which are driven by demand and not by supply. Today the rare earth processing business is run primarily to recover Nd, Pr and Dy. A new resource won't change these fundamentals. The best we can hope for is a more favorable situation, based on hitting all or some of the points mentioned above.

As someone who was involved in the formation of what is now called the Critical Materials Institute (CMI), I saw firsthand the formulation of the initial research thrusts and have listened to the presentations about some of the new materials and technologies being developed. Of course this activity is happening worldwide, not just through the CMI. There are some interesting new developments out there. Some are commercially viable, like the grain boundary diffusion technology developed by several Japanese magnet companies to reduce the Dy levels and light rare earth substitutions (Ce and/or La) for Nd, which have been broadly researched. These are solid achievements, yet they have not been as warmly embraced by the marketplace as one might expect. This is most likely because any change in process or composition requires acceptance by the ultimate customer, a lengthy and expensive process called qualification. Consequently, the motivation for changing materials remains on the back burner while rare earth prices remain relatively low. Interest in doing the work of qualifying new materials will appear as soon as rare earth prices go up.

One humble suggestion for people doing this type of research - please plan to provide a complete set of properties for any new material or process. Presenting the $(BH)_{max}$ and H_{cJ} values are a fine way to introduce a material to your stakeholders, but we need all the other properties, too, such as irreversible loss and corrosion characteristics. As engineers, we are trained to look at both the positive and negative characteristics of any material, and to design with all properties in mind. Please give us all the information about the materials you are developing, *good and bad*, so we can make better material selection choices and share this information with the ultimate customers. Look at the datasheets published by magnet companies to describe their materials to get an idea of the information we need, or simply ask me.

The story with recycling is a bit more upbeat than the last two topics. Successful recycling brings material back into the marketplace and tends to tamp down demand for Nd, Pr and Dy directly from the mines. Recycling is strategic in that it represents a source of supply outside China and tends to partially fend off price spikes. From what I have learned, the economics are decent but not spectacular at this point in time. If people keep working on it, I think the economics will improve and recycling will develop into a viable business. There are several different business models in use by the several groups active in this area. Which model or models will emerge as a successful way to operate is still an open question in my mind. But I wish them all well.

Now to the two areas I believe have been largely disregarded. In terms of rare earth availability, one of the most important decisions is a seemingly simple one. It is the grade and dimensions of magnet that an engineer choses as he or she designs a new product. These choices fix the amount of rare earths that need to be processed to make this device, and like any product, these choices become more profound as the scale increases.

A few years ago, I spoke to a company considering making direct drive wind turbines. They sent me a spreadsheet showing their projections of how much materials they would require over the next 10 years. Looking over the spreadsheet, I realized that they were projecting to use more than 10% of the world's supply of Dy in the final year of their projection. I pushed back on this last point, asking if it concerned them to be using so much dysprosium. They said no. I said that I would be concerned if I used 10% of any single material in the world. It is a huge vulnerability to take on, especially if it may not even be necessary. A small change in grade and/or dimensions when the magnet was designed might have reduced or even eliminated this risk.

Understandably, there is not much public information about the magnet material selection process since the details of most designs are usually considered confidential. We need to get over this reticence. My observation is that sometimes magnet design is done very well and other time rather poorly. As I have written about earlier, some of these poorer choices came to light when rare earth prices spiked.

How might we gain some insight into this area? My suggestion is to start collecting and publicizing case studies, something I do for my Magnetics Bootcamp. They would be examples of particularly good or bad designs. Sharing these examples would be a way to show engineers things they should either emulate or avoid.

My guess is that sharing case studies would have a beneficial impact on raw materials comparable in magnitude to any of the three focus areas mentioned at the beginning of this article. However, we don't know quantitatively if this is true, at least not today. To add some rigor to the process, we need a fairly comprehensive benchmarking program to go along with the case studies. That way we will be able to see the true impact of the material selection process in a measurable way.

And the final fruitful area to explore is the development of new applications of rare earths outside the area of magnets. If you use any rare earth today, you owe the availability your material to two significant developments that happened over a half-century ago. First was the technology developed during the Manhattan Project to separate rare earths, this made rare earths available for the first time in commercial quantities as isolated elements. The second was that people in many industries independently made a concerted effort over several decades to identify and develop a wide variety of applications on a significant scale for these rare earths. These two steps made the rare earth business possible.

In recent decades, new application development activity has languished in the rare earth industry on a scale required to keep the business balanced. Few new large-scale applications have been developed and there doesn't seem to be much in the pipeline. At the same time, several big applications have all but disappeared. We don't polish glass with cerium like we used to, nor do we use europium in CRT TV's. However, the disappearance of applications is natural as technologies evolve. What isn't natural is the low-level of activity in developing new business. This short-sighted strategy has dire consequences down the road. As someone who spends some time riding a bicycle, I can tell you that it is possible to move without pedaling for a while, but you won't get very far this way. This is a time for the rare earth industry to pedal, not to coast.

For Magnetics Business & Technology Magazine
March 2019

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Spontaneous Materials