

The Case for Replacing Ferrite with Bonded NdFeB



Much has been written in recent years to put the case for replacing ferrite with bonded neodymium-iron-boron (Neo) in permanent magnet motors, mostly by those of us who have an interest in selling Neo. And yet, ferrite still dominates the magnet market, accounting for more than 90 percent of the annual tonnage produced, while bonded Neo is less than 1 percent. Much of the market for bonded Neo has been in applications

where its advantage of higher energy density compared to sintered ferrite has been an enabler for product miniaturization, as in spindle motors for smaller computer hard disc drives. But significant future growth for bonded Neo will rely on finding significant new applications, which is why the scale of the automotive market has become an intriguing opportunity. Bonded Neo would likely not be creating a new motor application for the automobile, but rather would be looking to replace ceramic ferrite in some of the many existing electric motors employed in vehicles today. So what is the case to be made for such replacement?

Finite element analysis is a powerful analytical tool which is commonly used to support design comparisons, but being an electrical engineer, I have always favored using data from actual prototype motors when it is available. I designed and built my first permanent magnet motor more than 35 years ago, but things only started to get really interesting with the invention of Neo magnets in 1983 and their rapid commercialization for use in motors. Over the years, two basic principals have become evident that would govern the selection of a new magnet material. First, when a magnet's technology is the enabler of a new product, the magnet's price is only of secondary importance. In my example of the hard disc drive spindle motor, the average weight of its bonded Neo magnet is now only around 2 grams, clearly too little to be too sensitive to the raw materials pricing issues I have written about recently. However, when a magnet's technology is not a product enabler as with the proposed replacement of ferrite in automotive motors, it must offer not only some technical advantage but also should not cause the motor as a whole to cost more than at present. In this last respect, a bonded Neo magnet (particularly injection-molded) may allow a bonded sub-assembly to be made at a lower cost than an assembly of discrete parts incorporating ceramic ferrite.

Secondly, any given magnet type will be more effective if it is anisotropic rather than isotropic and if it is made to higher densification of its constituent magnetic material. When neodymium-iron-boron is processed as anisotropic powder, its remanence and maximum energy product, $(BH)_{max}$, are almost twice and four times those of its isotropic powder respectively. And while sintered magnets are fully dense, Neo powder is compression-molded and injection-molded at volume fractions of about 80 percent and 65 percent respectively, comparably diluting the powder's remanence to lower values for the

bonded magnets. Higher remanence means that higher flux is available for torque production, which the motor design may exploit as lower weight, higher efficiency, or combination of the two. A year ago in this column I introduced the concept of "price performance" as a fair means of comparing different permanent magnet materials, defining it as a magnet's price per $(BH)_{max}$ (\$/kg/MGOe). The magnetic properties of Neo materials have been matured for some time now, but much has changed over the past year with regard to their pricing. With their inherent magnetic orientation, the price performance of anisotropic bonded Neo magnets is now comparable to that of sintered Neo and much better than isotropic bonded Neo, though still about double (worse than) that of anisotropic ceramic ferrite. But anisotropic bonded Neo is now available with $(BH)_{max}$ up to 25 MGOe, more than five times that of ceramic ferrite, which makes it a most interesting alternative for small motors.

At the 2005 and 2007 Magnetics Conferences, I described case studies of a 40 mm diameter motor which would have automotive use in applications such as power seats or windows, showing improvements in motor weight by replacing its ferrite magnets with isotropic compression-molded Neo. Another study was published in 2003

(Hayashi et al, IEEE Transactions on Magnetics, vol. 39, pp 2893-5, Sept. 2003) describing a motor that had been built for the same purpose, but showing even greater improvements by using anisotropic compression-molded Neo. In both cases, finite element analysis suggested that weight reduction would be optimized by molding the Neo magnets as complete rings and by using four poles rather than two, but the practical matter of preventing demagnetization at stall in this type of application would dictate the minimum magnet thickness to be used. While anisotropic bonded Neo enjoys significant advantages over its isotropic counterpart in terms of price performance and a $(BH)_{max}$ which is about 2.5 times greater, the benefit to motor weight is more modest. But, if it is of value for the existing motor's weight to be reduced (see chart), then there is a strong case for it to be redesigned with its ceramic ferrite magnets replaced with bonded Neo. And in accordance with the second principal explained above, this bonded Neo magnet is clearly most effective if it is compression-molded and made using anisotropic powder, thus providing a 50 percent reduction in motor weight.

For more on this and related topics, I will be holding a workshop March 1, 2009 in Orlando on "The selection and design of permanent magnet materials in today's economic climate," in conjunction with the 2009 Motor, Drive and Automation Systems Conference sponsored by Webcom Communications.

Dr. Peter Campbell has been a consultant to permanent magnet producers and users for more than 30 years. He has been a professor at the University of Cambridge and at the University of Southern California, and has worked with Magnequench Inc. as its head of Technology and head of Sales. Please contact him at drpeterc@earthlink.net, or visit www.magnetweb.com.

