Calculating Losses due to Reverse Applied Fields

The first step in calculating the losses associated with reverse applied fields on a permanent magnet is to determine the permeance coefficient (load line) of the magnet in question. This may be accomplished with reference to any of numerous texts or by using web-based programs such as those located in the reference section of the Arnold website. If the geometry is complex or involves adjacent ferromagnetic material or is an assembly, then the easiest and most accurate way to make this calculation is with Finite Element Analysis (FEA) software.

Calculating the permeance coefficient with FEA involves creating a plane on the neutral zone of the magnet that is equal in area to the neutral zone of the magnet. If there is a problem identifying where the neutral zone is in a more complex geometrical situation, one can utilize an age-old rule that all flux is in the direction of magnetization at the neutral zone (i.e. no flux exits or enters the magnet at this cross-sectional position).

Once this surface is created at the neutral zone, the permeance coefficient can be found by integrating, or averaging, the B field and H field on this surface. In the CGS system, the permeance coefficient is:

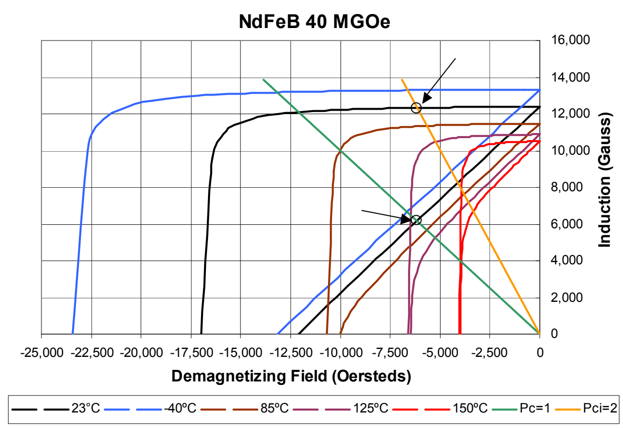
$$Pc = \frac{Bfield}{Hfield}$$

In the SI system (Tesla and kA/m), the permeance coefficient is:

$$P.C. = \frac{Bfield}{\mu_O \times Hfield} / 10000$$

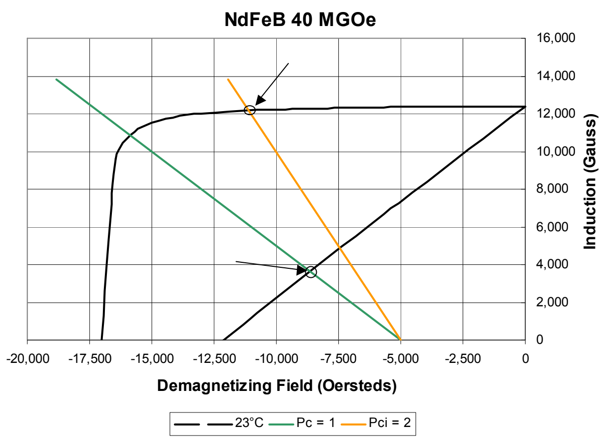
This permeance coefficient is also known as the "normal" permeance coefficient because it provides the slope for a line that originates at the origin and intersects the normal demag curve at the operating point (Bd, Hd) of the magnet.

While this is a very important point in the operating condition of the magnet, it does not provide the intersection with the "intrinsic" curve. To find the intrinsic operating point (Bdi, Hd), the intrinsic permeance coefficient (Pci) is calculated by subtracting 1 from the Pc value, i.e. Pci = Pc – 1, and then plotting a line with this slope and noting its intersection with the intrinsic curve which is at the intrinsic operating point of the magnet. Remember when doing the arithmetic that the slopes are negative in sign - though we often ignore the sign when communicating the values or displaying them on charts. Below is an example of the Pc and Pci plotted for a standard NdFeB magnet. Pc and Pci are defined as slopes of B/H where B is expressed in gauss and H in oersted. If using charts with SI units (Tesla and kA/m), it is often easier to first convert to cgs units.



When there is no reverse applied field, the Pc and Pci lines intersect the normal and the intrinsic curves respectively and have the same Hd value. This condition is only true when there is no reverse applied field.

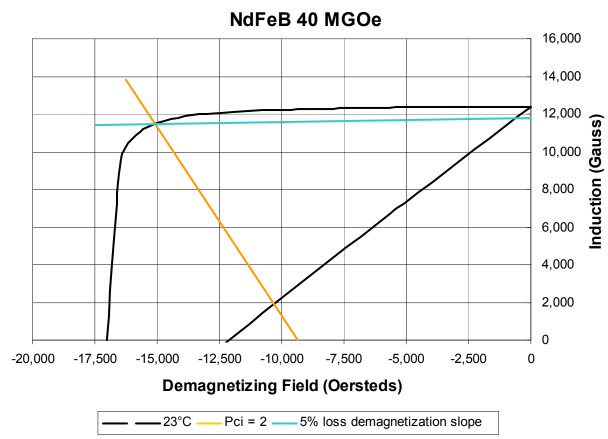
Applying a reverse field (demagnetizing influence) creates a shift in the origin of the Pci slope equal to the applied field. At this time, it is standard practice to discontinue use of the Pc slope because it is no longer directly applicable. In order to demonstrate this, the Pc slope has been left on in the curve below. Note how different the Hd values would be for the appropriate intersections if one looked at the Pc slope instead of the Pci slope.



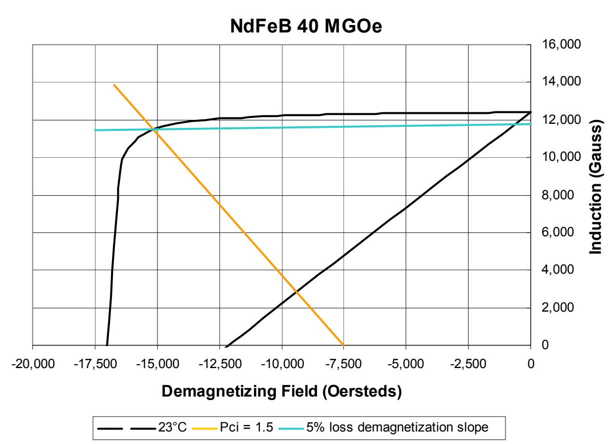
Using the intersection of the intrinsic (magnetization) curve and the Pci slope one obtains the magnetization of the magnet under the reverse applied field. Adding the Bdi and Hd values results in Bd under the influence of the reverse field (Bd = Bdi + Hd; remember Hd is a negative value in the second quadrant).

The recoil permeability for this example material is 1.02 (slope of the normal curve at the intersection with the B axis). To obtain the intrinsic recoil permeability we just need to subtract 1 from the "normal" recoil permeability. This results in a value of 0.02 for the intrinsic recoil permeability (slope of the intrinsic curve). The Bdi value at the intersection of the Pci = 2 and the intrinsic curve is 12,156 Gauss and occurs at Hd = -11,333 Oersteds. Applying the intrinsic recoil slope to the Bdi value will result in a reduced Br' of 12,383 Gauss (12,156G + 0.02 X 11,333 Oe). This is only a 0.15% loss compared to the original Br of 12,400 Gauss.

In order to prevent this demagnetization one may choose to pre-stabilize the magnet by inducing a loss of a few percent prior to use. This can be shown on the following curve. In this case, a pre-stabilization of approximately 5% is sought and may be graphically shown by starting a line at the B axis with a value of 95% of Br and drawing into the second quadrant at a slope equal to the intrinsic recoil permeability (0.02). The intersection with the intrinsic curve will show the intrinsic magnetization of the magnet as long as it does not demagnetize further. The graph below shows the stabilized magnetization curve.



It should be noted that for a Pci = 2 that the reverse applied field required to demagnetize to this extent is ~9,300 Oersteds (740 kA/m). The magnet will operate on this reduced (stabilized) intrinsic magnetization curve as long as the demagnetizing influence for a Pci = 2 does not exceed the stabilizing value of 9,300 Oersteds reverse applied field.



If the Pci is reduced to 1.5 (Pc = 0.5, Pci = 1.5), then the amount of reverse field that may be applied without demagnetization is less. This field strength can be determined by plotting a new Pci line from the intersection of the 5% stabilization curve with the original intrinsic curve but using a slope of –1.5 and noting the intersection of this curve with the H axis. The graph below demonstrates this new determination.

Note the intersection with the H axis now shows a maximum allowable reverse applied field of only 7,500 Oersteds.

Because the normal curve is calculated by the equation Bd = Bdi + Hd, the new normal curve for the stabilized properties may also be determined.

Analysis for any temperature can be completed in the same manner. The methodology is identical: just substitute the demag curves for the desired temperature.

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