What is a demagnetization curve?

Ferromagnetic materials such as iron, cobalt, nickel, and many alloys, including permanent magnets, show a **magnetic hysteresis** phenomenon. The hysteresis loop is generated by measuring the magnetization **M**, while changing the applied external magnetic field **H** (see green curve in ***Fig. 1***).

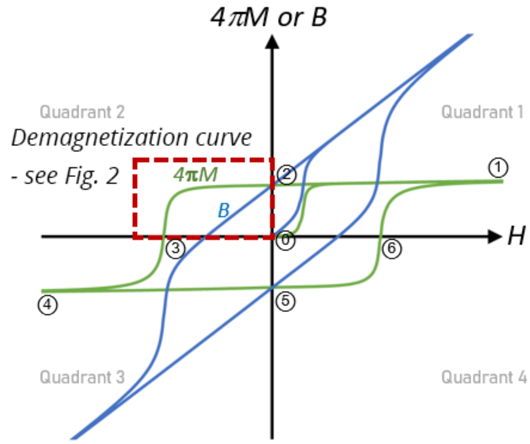

Fig. 1 Magnetic hysteresis loop

The magnetization in a ferromagnetic material increases from 0 or 'virgin' state (point ⓪ as show in ***Fig. 1***) due to an increasing applied magnetic field, to a maximum--the point where the magnetization does not increase anymore, called magnetic saturation (point ①). Upon reducing the magnetic field back to 0, permanent magnets still retain a high value of magnetization (point ②) also known as B_r. The magnetization will eventually decrease to 0 (point ③) by applying a magnetic field in the opposite direction. The magnetic saturation in the opposite direction will occur (point ④) with increasing magnetic field in that direction. Then, decreasing the applied field to 0, the magnet material again retains a high value of magnetization(point ⑤), and increasing the applied field in the positive direction will close the loop through point ⑥, to the saturation at point ①. The magnetic hysteresis loops can be divided into 4 quadrants and the 2nd quadrant is called the **demagnetization curve** as shown in ***Fig. 2***.

Besides magnetization **M**, the magnetic state of a ferromagnetic material can also be described by the magnetic induction **B**. The relation between magnetization **M**, magnetic induction **B** and external magnetic field **H** is given by the following formula:

$\mathbf{B} = 4\pi\mathbf{M} + \mathbf{H}$ (CGS units)

$\mathbf{B} = \mu_0\mathbf{M} + \mu_0\mathbf{H} = \mathbf{J} + \mu_0\mathbf{H}$ (SI units)

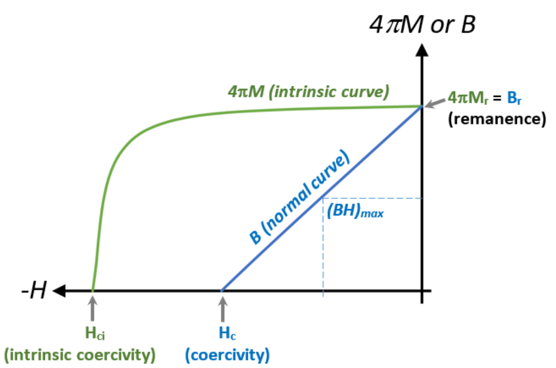

Fig. 2 Demagnetization curve (or 2nd quadrant of the magnetic hysteresis loop in Fig. 1)

Where μ_0 is a constant called the permeability of free space, and **J** is the magnetic polarization.

In order to keep the same unit as magnetic induction **B** in CGS system, **4πM** is commonly used instead of **M** for hysteresis loops or demagnetization curves as shown in ***Fig. 1*** and ***Fig. 2***.

In the 2nd quadrant of the hysteresis loop (***Fig. 2***), the magnetization (4π**M**) vs magnetic field (**H**) plot is called ***intrinsic demagnetization curve*** while the magnetic induction (**B**) vs magnetic field (**H**) plot is called ***normal demagnetization curve***.

More Than Just Your Supplier

As a producer of permanent magnet materials for over 50 years, we have a deep understanding of the science behind the materials. This insight separates us from competitors and allows our engineering team to provide best-in-class service to customers. Our applications engineering team works closely with customers to develop magnetic solutions and optimize design performance. In addition to applications engineering, we also provide magnetic circuit design, finite element analysis, and research and development services.

The Hard Stuff

Why is the demagnetization curve important?

Important magnetic properties of permanent magnets, such as residual induction $\mathbf{B}_r$, coercivity $\mathbf{H}_c$, intrinsic coercivity $\mathbf{H}_{ci}$, and maximum energy product $\mathbf{(BH)}_{max}$, can be obtained from demagnetization curves.

$\mathbf{B}_r$ is the residual induction or flux density, which represents the magnetic induction corresponding to zero magnetizing field in a magnetic material after full saturation when measured in a closed magnetic circuit. The unit for magnetic induction **B** and residual induction $\mathbf{B}_r$ is **G**, Gauss (CGS unit) or **T**, Tesla (SI unit).

*Note that 1 **T** = 10,000 Gauss.*

$\mathbf{M}_r$ is the remanent magnetization or remanence, which represents the retained magnetization when the external magnetic field is reduced to zero after full saturation when measured in a closed magnetic circuit.

Note that $4\pi\mathbf{M}_r = \mathbf{B}_r$ *(CGS unit).*

The unit for magnetization $4\pi\mathbf{M}$ and remanent magnetization $4\pi\mathbf{M}_r$ is **G**, Gauss (CGS unit) or **A/m**, Ampere per meter (SI unit).

Related to the $4\pi\mathbf{M}$ magnetization units: $1\ \mathbf{G} = 10^3 / 4\pi\ \mathbf{A/m}$.

$\mathbf{H}_{ci}$ is the intrinsic coercivity, which is equal to the demagnetizing field that reduces magnetization **M** to zero after full saturation. The unit for the magnetic field **H** and intrinsic coercivity $\mathbf{H}_{ci}$ is **Oe**, Oersted (CGS unit) or **A/m**, Ampere per meter (SI unit). $\mathbf{H}_{ci}$ is a good indication of a material's resistance to demagnetization.

Note that $1\ \mathbf{Oe} = 10^3 / 4\pi\ \mathbf{A/m}$.

$\mathbf{H}_c$ is the coercivity or normal coercivity, which is equal to the demagnetizing field at which the magnetic induction **B** is reduced to zero after full saturation. The unit for coercivity is **Oe**, Oersted (CGS unit) or **A/m**, Ampere per meter (SI unit).

$\mathbf{(BH)}_{max}$ is the maximum energy product, or maximum energy that the magnet can store. It is the maximum product of (B x H) that can be obtained on the normal demagnetization curve as shown in ***Fig. 2*** with the dotted rectangular area. The unit for $\mathbf{(BH)}_{max}$ is **MGOe**, Mega•Gauss•Oersted (CGS unit) or **J/m³**, Joule per cubic meter (SI unit).

Related to the max energy units: $1\ \mathbf{MGOe} = 10^5 / 4\pi\ \mathbf{J/m^3}$.

In CGS system, the following relationships are always true:

$\mathbf{H}_c \le \mathbf{B}_r$ --- the upper limit of normal coercivity $\mathbf{H}_c$ is residual induction $\mathbf{B}_r$

$\mathbf{H}_c \le \mathbf{H}_{ci}$ --- normal coercivity $\mathbf{H}_c$ will never be greater than intrinsic coercivity $\mathbf{H}_{ci}$

$\mathbf{(BH)}_{max} \le (\mathbf{B}_r/2)^2$ --- the theoretical upper limit of maximum energy product $\mathbf{(BH)}_{max}$ is $(\mathbf{B}_r/2)^2$

Residual induction $\mathbf{B}_r$, intrinsic coercivity $\mathbf{H}_{ci}$, coercivity $\mathbf{H}_c$, and maximum energy product $\mathbf{(BH)}_{max}$ are the most common specifications required by customers. Demagnetization curves are measured by using a Hysteresigraph, also known as Permeameter. The testing requires a magnet sample with standard dimensions that is representative of the material lot used to manufacture the finished parts for customers.