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DEMAGNETIZATION CURVE. The demagnetization curve of a magnetic material represents the functional relationship between the magnetic induction, B, and the magnetic field, H, when H is decreased from the saturation state to the point of zero flux. In order to reach the saturated state of ferromagnetism one must apply a sufficiently large magnetic field to compensate for the magnetostatic energy which requires the formation of domains of reverse magnetization and the anisotropy energy which tends to keep the magnetization aligned along certain crystalline axes. When the applied field is decreased the magnetization is similarly decreased by the following processes: (1) The rotation of the magnetization towards crystalline directions of easy magnetization. (2) The formation of domains of reverse magnetization. (3) The growth of domains of reverse magnetization. The experimentally observed demagnetization curve of any material which describes this decrease of magnetization is characterized by three gross features of considerable technological importance, i.e. (a) The remanent magnetic flux, B_r, which is defined as the flux remaining when the magnetic field is zero. (b) The coercive field H_c which is defined as the magnetic field required to reduce the flux to zero. (c) The squareness of the demagnetization curve which roughly specifies the characteristic shape of the magnetization variation between the remanent and the zero flux states.

The general characteristics of the demagnetization curve has been described by theories of Goodenough, Néel, Vittel and others, in which one postulates two magnetic field quantities, namely, H_n which defines the applied field at which a domain of reverse magnetization is nucleated and H_0 as the magnetic field required to move a domain wall over the highest variations in the domain wall surface energy. If H_n is less than zero, the flux at the remanent state is determined entirely by the fact that the magnetizations have rotated only to their "easy" crystalline directions. This combination would generally be associated with a large remanent flux. However, if H_n is greater than zero the remanent state is determined entirely by constraints on the domain wall energy which tend to inhibit the free motion of these walls. In the extreme case of no spatial variations in the domain wall energy the remanent state would be zero. "Squareness" of the curve is determined by the relationship between H_0 and H_n. The first requirement for a square demagnetization curve is a high remanent state — i.e. H_n less than zero. However, if H_n is less than H_0 then the nucleated domain of reverse magnetization can grow to reduce the flux to zero. In this case, the coercive force would be comparable to H_n. On the other hand, if H_n is greater than H_0 there will be a continual decrease in the magnetization from the point of nucleation and the coercive force will be comparable to H_0. In this way the squareness of the hysteresis loop can be varied by controlling the nucleation of domains of reverse magnetization.

The demagnetization curve is often represented by a rectangular hyperbola which passes through the points B_r and H_c.

$$B(1 + (H/H_c)(B_r/B_s)) = B_r\left(1 + \frac{H}{H_c}\right). \qquad (1)$$

where B_s is the flux at saturation. The value at which the product BH is a maximum is extremely important for technological applications of permanent magnets. As two limiting cases in the relationship between B and H we might consider a rectangular curve and a linear decrease. For the rectangular decrease the BH product would be maximum at the coercive field. However, for a linear decrease in the magnetization the maximum value of this product would be at half the coercive field. The maximum product for the rectangular hyperbola is given for the magnetic induction equal to

$$B_s - \sqrt{B_s(B_s - B_r)}. \qquad (2)$$

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ENERGY PRODUCT OF A MAGNETIC MATERIAL. The energy product of a magnetic material is a parameter of considerable importance in the design of permanent magnets which use the given material as a source of magnetomotive force. The importance of the energy product arises through the well-known theorem which states that

$$\tfrac{1}{2}\int_V \mathbf{B}\cdot\mathbf{H}\,\mathrm{d}V = 0$$

where **B** is the magnetic induction and **H** is the magnetic field when integrated over a region which contains no current-carrying elements. The proof of this result follows from the fact that **B** is derivable from a vector potential, **A**, and **H** is derivable from a scalar potential, Φ, since the current density is zero everywhere in the region. If the permanently magnetized media which serve as the sources of **B** and **H** are confined to a finite region, their scalar and vector potentials will vary as $1/r$ at large distances. The surface integral associated with the above volume integral, i.e.

$$\int_V \mathbf{B}\cdot\mathbf{H}\,\mathrm{d}V = \int_s \Phi\nabla x\,\mathbf{A}\,\mathrm{d}s$$

will vanish if the volume is taken sufficiently large. A valuable result is obtained if we divide the volume into two regions so that

$$\tfrac{1}{2}\int_{V_1} \mathbf{B}\cdot\mathbf{H}\,\mathrm{d}V = -\tfrac{1}{2}\int_{V_2} \mathbf{B}\cdot\mathbf{H}\,\mathrm{d}V,$$

where V_1 includes all of the permanently magnetized material and V_2 contains the rest of the space. So that in any permanent magnet structure the left side of the equation would represent the sources of the magnetomotive force and the right side would represent the energy stored in the air gap plus the magnetic energies associated with the magnetic circuit and leakage fields. Therefore, the maximum attainable fields in the air gap will be set by the maximum value of the left side of the equation. In any practical magnet the total volume of permanently magnetized material is limited by either weight or economical considerations. Therefore, one is interested in obtaining the maximum possible value of the product **BH**. The value of the quantity $(\mathbf{BH})_{max}$ is usually taken as a measure of the "quality" of a magnetic material **(Evershed criterion).** The behaviour of the energy product is closely related to the character of the demagnetization curve. In the remanent and zero flux states the product will be clearly zero: however, it must go through its maximum at some intermediate point. For a given remanent flux, $\mathbf{B}_r$, and coercive field $\mathbf{H}_c$, the theoretical maximum of this energy product is given for a rectangular hysteresis characteristic by $\mathbf{B}_r\mathbf{H}_c$. The "fullness factor" of a given material is defined by the ratio $(\mathbf{BH})_{max}/\mathbf{H}_c\mathbf{B}_r$. Energy products of typical common commercial materials are given in the following table.

Material	$\mathbf{B}_r$ (gauss)	$\mathbf{H}_c$ (oersteds)	$(\mathbf{BH})_{max}$ (gauss-oersteds)
Alnico VB-DG	13,300	685	$6{\cdot}5 \times 10^6$
Alnico 2	7300	560	$1{\cdot}7 \times 10^6$
Platinum–cobalt (77:23)	6000	4300	$7{\cdot}5 \times 10^6$
Vicalloy	11,500	200	$1{\cdot}5 \times 10^6$
Alcomax 3	13,200	650	$5{\cdot}0 \times 10^6$
Ferroxdur	4080	1360	$3{\cdot}0 \times 10^6$

See also: Demagnetization curve.

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R. V. Jones