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PHYSICS

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B-H CURVE, HYSTERESIS LOOP, ENERGY LOSS ASSIGNMENT

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HYSTERESIS

The lag or delay of a magnetic material known commonly as **Magnetic Hysteresis**, relates to the magnetisation properties of a material by which it firstly becomes magnetised and then de-magnetised.

B-H CURVE

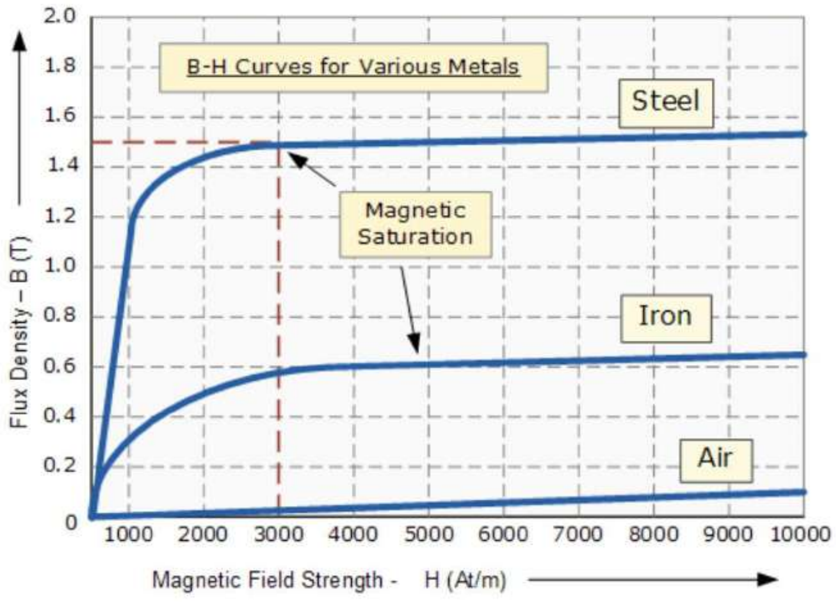
Previously, the relative permeability, symbol μ_r was defined as the ratio of the absolute permeability μ and the permeability of free space μ_o (a vacuum) and this was given as a constant. However, the relationship between the flux density, B and the magnetic field strength, H can be defined by the fact that the relative permeability, μ_r is not a constant but a function of the magnetic field intensity thereby giving magnetic flux density as: $B = \mu H$.

B-H CURVE OF DIFFERENT SUBSTANCES

So for ferromagnetic materials the ratio of flux density to field strength (B/H) is not constant but varies with flux density. However, for air cored coils or any non-magnetic medium core such as woods or plastics, this ratio can be considered as a constant and this constant is known as μ_o, the permeability of free space, ($\mu_o = 4.\pi.10^{-7}$ H/m).

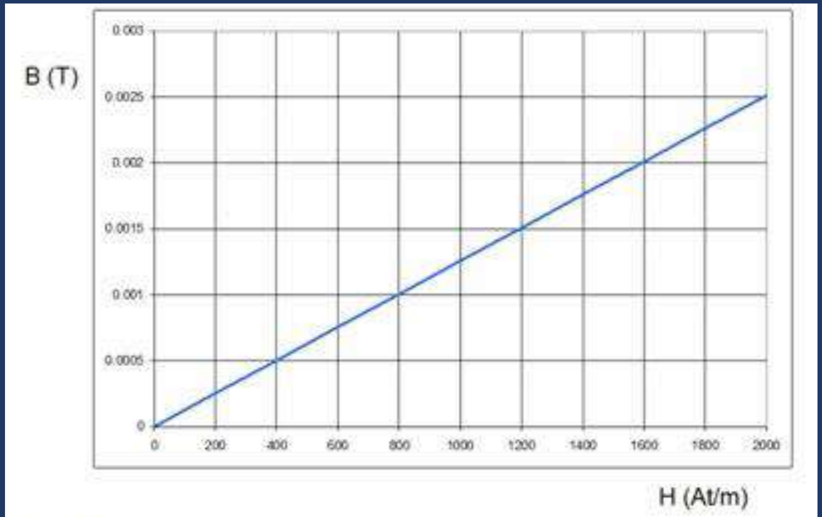
By plotting values of flux density, (B) against the field strength, (H) we can produce a set of curves called **Magnetisation Curves**, **Magnetic Hysteresis Curves** or more commonly **B-H Curves** for each type of core material used as shown below.

Magnetisation or B-H Curve



Is B-H CURVE LINEAR OR NON-LINEAR ???

In free space (also nonmagnetic materials), the permeability μ_0 is constant so that BH Curve Relationship is linear. This, however, is not the case with ferromagnetic materials used in electric machines, wherein the BH Curve Relationship is strictly nonlinear in two respects saturation and hysteresis.



B-H for Vacuum

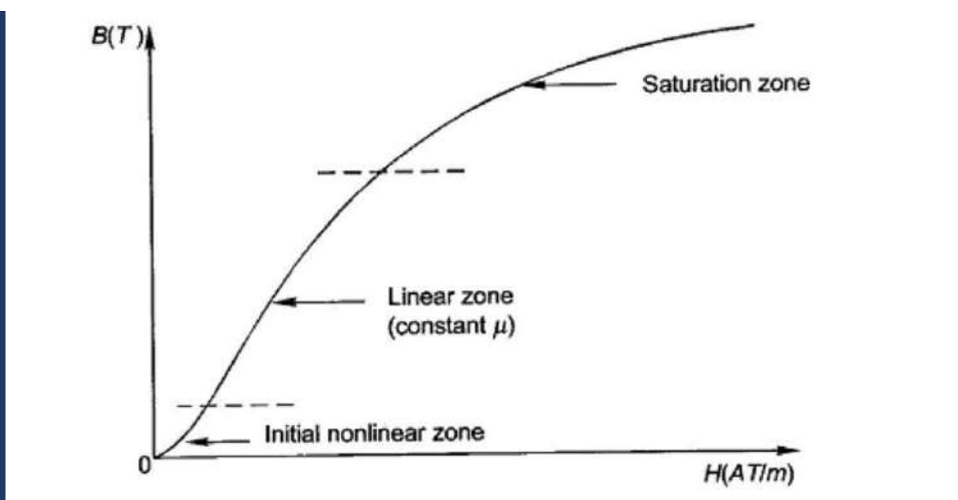


Fig. 2.3 *Typical normal magnetization curve of ferromagnetic material*

HYSTERESIS PHENOMENON

Hysteresis phenomenon occurs when ferromagnetic materials are magnetized in one direction; even when the imposed magnetizing field is removed, ferromagnetic materials will not relax back to zero magnetization. Because the material can only be driven back to zero with a field in the opposite direction, there is a lack of retraceability known as hysteresis.

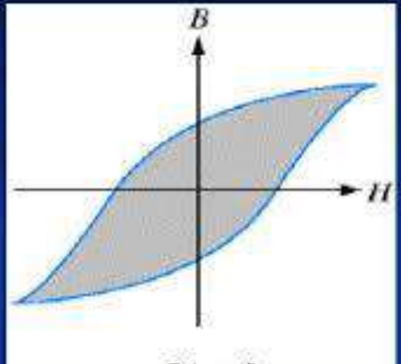
When this occurs, applying an alternating magnetic field will yield a hysteresis loop. Because ferromagnetic materials have this phenomenon occurring predictably, it can be useful as a predictive or stabilizing mechanism. This is because some ferromagnetic materials retain magnetization.

SOME BASIC KNOWLEDGE

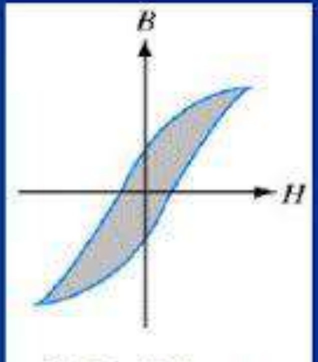
1. **Retentivity** - A measure of the residual flux density corresponding to the saturation induction of a magnetic material. In other words, it is a material's ability to retain a certain amount of residual magnetic field when the magnetizing force is removed after achieving saturation. (The value of **B** at point b on the hysteresis curve.)
2. **Residual Magnetism** or **Residual Flux** - the magnetic flux density that remains in a material when the magnetizing force is zero. Note that residual magnetism and retentivity are the same when the material has been magnetized to the saturation point. However, the level of residual magnetism may be lower than the retentivity value when the magnetizing force did not reach the saturation level.
3. **Coercive Force** - The amount of reverse magnetic field which must be applied to a magnetic material to make the magnetic flux return to zero. (The value of **H** at point c on the hysteresis curve.)
4. **Permeability, m -** A property of a material that describes the ease with which a magnetic flux is established in the component.
5. **Reluctance** - Is the opposition that a ferromagnetic material shows to the establishment of a magnetic field. Reluctance is analogous to the resistance in an electrical circuit.

HYSTERESIS

Hysteresis curve of soft and steel



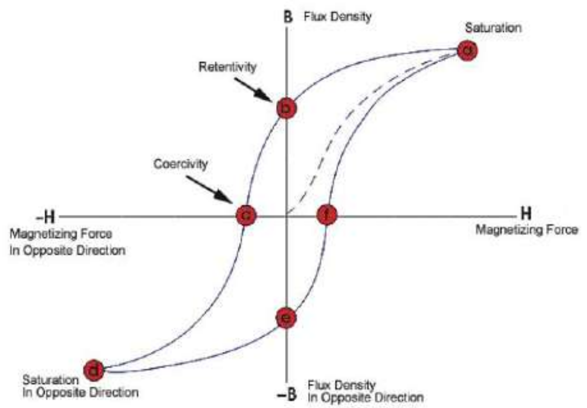
(a) Steel



(b) Soft Iron

- The retentivity of soft iron > retentivity of steel
- Soft iron is more strongly magnetized than steel
- Coercivity of soft iron < Coercivity of steel
- Hence, soft iron loses its magnetism more rapidly than steel does.

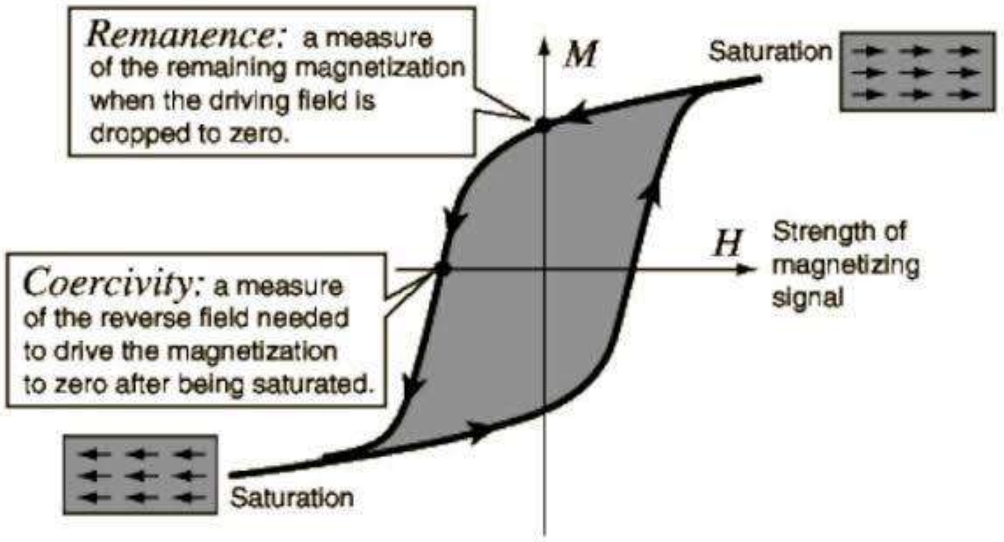
EXPLANATION

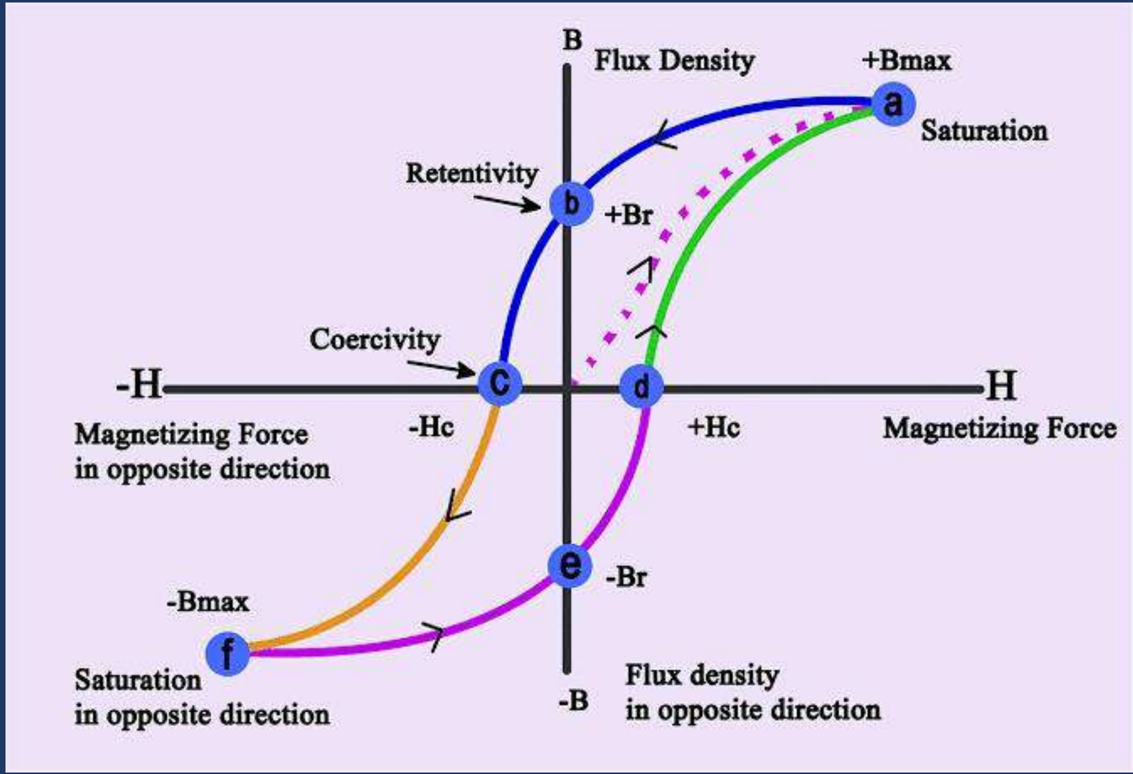


The loop is generated by measuring the magnetic flux of a ferromagnetic material while the magnetizing force is changed. A ferromagnetic material that has never been previously magnetized or has been thoroughly demagnetized will follow the dashed line as **H** is increased. As the line demonstrates, the greater the amount of current applied **(H+)**, the stronger the magnetic field in the component **(B+)**. At point "a" almost all of the magnetic domains are aligned and an additional increase in the magnetizing force will produce very little increase in magnetic flux. The material has reached the point of magnetic saturation. When **H** is reduced to zero, the curve will move from point "a" to point "b." At this point, it can be seen that some magnetic flux remains in the material even though the magnetizing force is zero. This is referred to as the point of retentivity on the graph and indicates the remanence or level of residual magnetism in the material. (Some of the magnetic domains remain aligned but some have lost their alignment.) As the magnetizing force is reversed, the curve moves to point "c", where the flux has been reduced to zero. This is called the point of coercivity on the curve. (The reversed magnetizing force has flipped enough of the domains so that the net flux within the material is zero.) The force required to remove the residual magnetism from the material is called the coercive force or coercivity of the material.

As the magnetizing force is increased in the negative direction, the material will again become magnetically saturated but in the opposite direction (point "d"). Reducing **H** to zero brings the curve to point "e." It will have a level of residual magnetism equal to that achieved in the other direction. Increasing **H** back in the positive direction will return **B** to zero. Notice that the curve did not return to the origin of the graph because some force is required to remove the residual magnetism. The curve will take a different path from point "f" back to the saturation point where it with complete the loop.

- A good permanent magnet should produce a high magnetic field with a low mass, and should be stable against the influences which would demagnetize it. The desirable properties of such magnets are typically stated in terms of the remanence and coercivity of the magnet materials.





ADVANTAGES OF HYSTERESIS LOOP

1. Smaller hysteresis loop area symbolizes less hysteresis loss.
2. Hysteresis loop provides the value of retentivity and coercivity of a material. Thus the way to choose perfect material to make permanent magnet, core of machines becomes easier.
3. From B-H graph, residual magnetism can be determined and thus choosing of material for electromagnets is easy.

ENERGY LOSS

Definition: The work done by the magnetising force against the internal friction of the molecules of the magnet, produces heat. This energy which is wasted in the form of heat due to hysteresis is called **Hysteresis Loss.**

Hysteresis loss is caused by the magnetization and demagnetization of the core [illegible]. As the magnetizing force (current) increases, the magnetic flux increases. But when the magnetizing force (current) is decreased, the magnetic flux doesn't decrease at the same rate, but less gradually. Therefore, when the magnetizing force reaches zero, the flux density still has a positive value. In order for the flux density to reach zero, the magnetizing force must be applied in the negative direction.

When in the magnetic material, magnetisation force is applied, the molecules of the magnetic material are aligned in one particular direction. And when this magnetic force is reversed in the opposite direction, the internal friction of the molecular magnets opposes the reversal of magnetism resulting in Magnetic Hysteresis.

To wipe out or overcome this internal friction (or in other words, known as residual magnetism), a part of the magnetising force is used. This work, done by the magnetising force produces heat; thereby causing wastage of energy in the form of heat is termed as hysteresis loss.

SEE THE PICTURE AND EXPLAIN HYSTERESIS