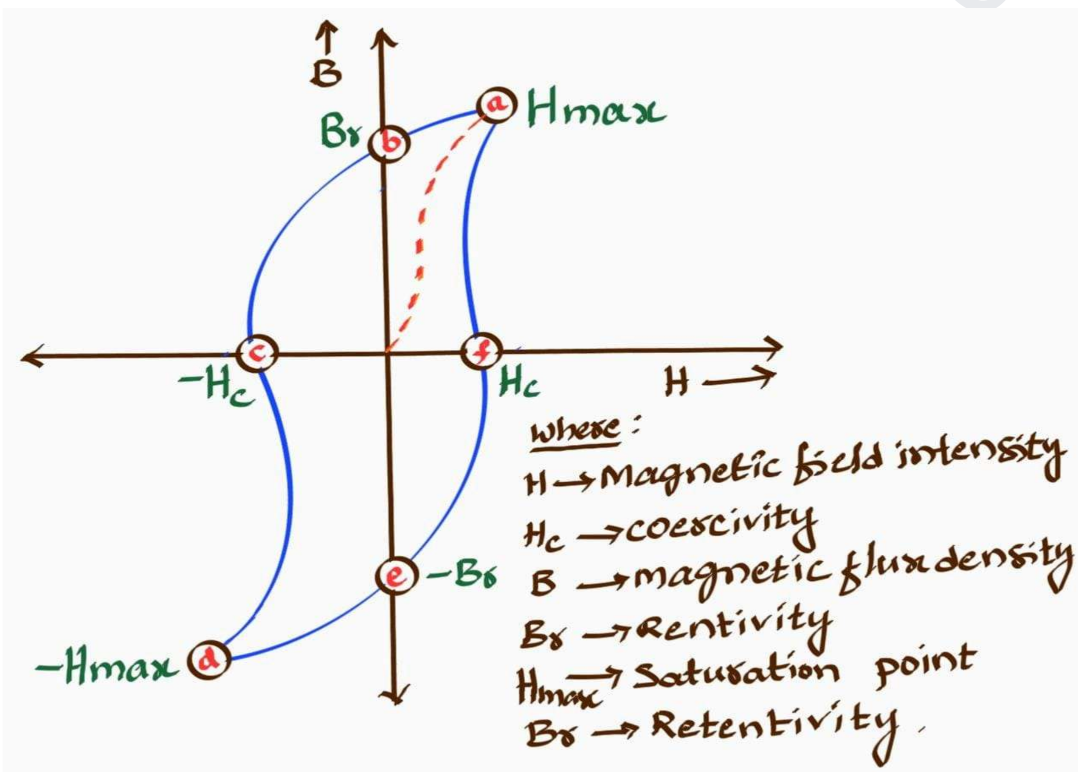
★ Hysteresis (or) Hysteresis in Ferromagnetic Materials

★ Definition:

★ When a magnetic material undergoes a complete cycle of magnetization, the variation of magnetic flux density (B) with respect to magnetic field intensity (H) is represented by a closed curve called a hysteresis loop and the lagging of 'B' behind 'H' is referred to as hysteresis.

★ Explanation:

★ When a specimen of ferromagnetic material is placed in an external magnetic field, it becomes magnetized by induction.



★ The magnetization increases rapidly with the applied field until it reaches a certain value, after which it remains constant. This point is known as the saturation point (H_{max}).

★ When the external field is reduced to zero, the magnetic induction of the material does not return to zero. This remaining magnetic induction is called residual magnetism or retentivity(Br).

★ When a sufficient negative field is applied, the residual magnetization becomes zero.The magnitude of this negative magnetic field intensity is called the coercive field or coercivity(-Hc).

- ★ If the negative field is further increased, the magnetization in the negative direction increases, reaching a maximum value and then remaining constant. This is called negative saturation or saturation in the opposite direction($-H_{max}$).
- ★ As the negative field is decreased back to zero, the negative saturation of magnetization does not follow the initial path. Instead, it creates a new path and reaches a point called negative residual magnetization or negative retentivity (-Br).
- ★ The amount of magnetic field required to bring the residual magnetization back to zero from the negative side is also known as the coercive field (Hc).
- ★ Furthermore, with an increase in the positive magnetic field, the magnetization again reaches the saturation point, thus completing a full hysteresis cycle.
- ★ At points where the magnetic field intensity is zero (i.e., at Br and -Br), the specimen remains magnetized even in the absence of an external magnetic field. This characteristic allows the material to act as a permanent magnet.
- ★ Therefore, it is observed that the magnetic flux density (B) always lags behind the magnetic field intensity (H); this lagging of 'B' behind 'H' is what defines hysteresis.
- ★ Hysteresis is an irreversible property, meaning that when the external field is removed, the specimen does not fully return to its original magnetic state.
- ★ Consequently, the energy supplied to the specimen during magnetization is not fully recovered. The remaining energy is lost in the form of heat, and this energy loss is termed "Hysteresis loss."
- ★ This loss is represented by the area enclosed by the hysteresis loop (e.g., abcdefa).

★ Classification of Ferromagnetic Materials

- ★ Based on the area of their hysteresis loop, ferromagnetic materials can be classified into two main types:

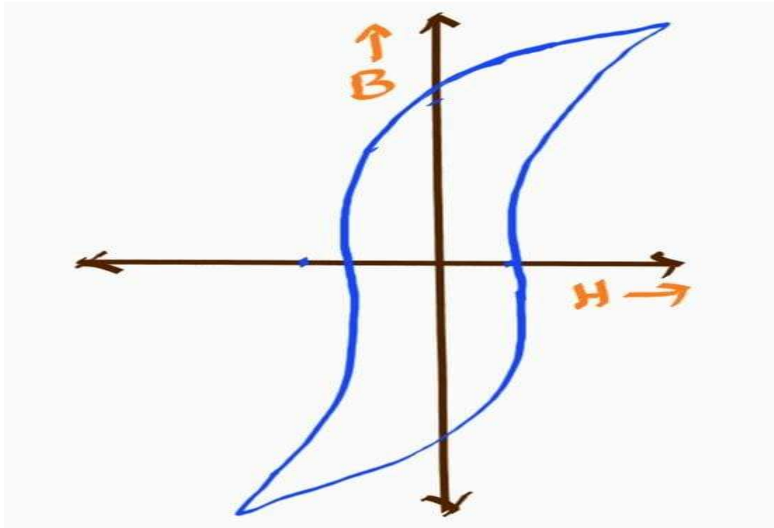
  1.Soft ferromagnetic materials

  2.Hard ferromagnetic materials

★ 1.Soft Ferromagnetic Materials:

★ Definition:

- ★ These are magnetic materials that can be easily magnetized and demagnetized but cannot be permanently magnetized.



★ Characteristics:

★ They exhibit low hysteresis loss.

★ Their retentivity and coercivity are small.

★ They are easily magnetized and demagnetized.

★ Their magnetostatic energy is small.

★ They possess large values of magnetic susceptibility and permeability.

★ They cannot be permanently magnetized.

★ They are commonly used to make electromagnets.

★ These materials are relatively free from irregularities like strains and impurities.

★ Domain wall movement within them is easy.

★ They lose their magnetism readily after the removal of the external magnetic field.

★ Examples:

★ Al-Ni-Co Alloy

★ Iron-Silicon Alloys

★ Ferrous-Nickel Alloys

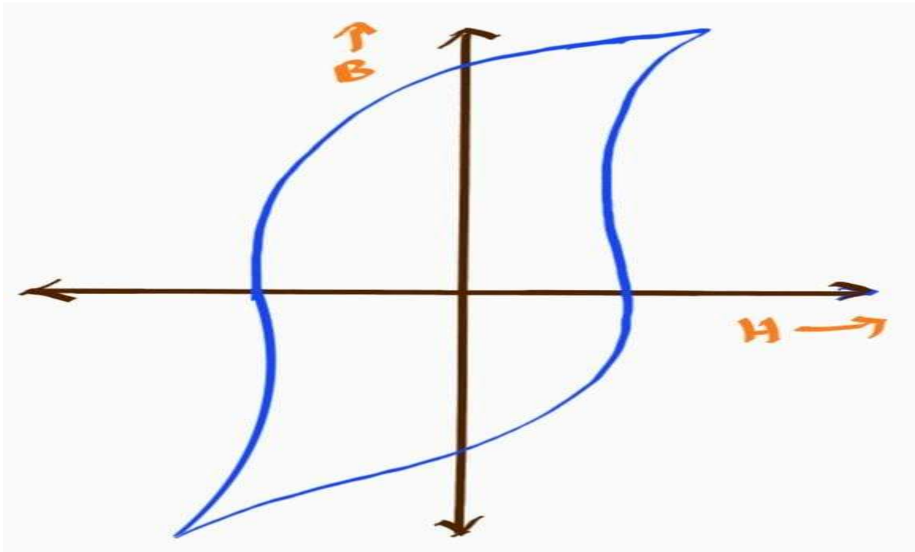
★ Ferrites (some types)

★ Garnets (some types)

★ Hard Ferromagnetic Materials:

★ Definition:

★ These are magnetic materials that are difficult to magnetize and demagnetize but can be permanently magnetized.



★ **Characteristics:**

★ They exhibit large hysteresis loss.

★ Their retentivity and coercivity are large.

★ They are difficult to magnetize and demagnetize.

★ Their magnetostatic energy is large.

★ They possess small values of magnetic susceptibility and permeability.

★ They can be permanently magnetized.

★ They are used to make permanent magnets.

★ These materials tend to have more irregularities, such as strains or impurities.

★ Domain wall movement within them is difficult.

★ They retain their magnetism even after the removal of the external magnetic field.

★ **Examples:**

★ Iron-Nickel-Aluminum alloys (e.g., Alnico)

★ Copper-Nickel-Iron alloys

★ Copper-Nickel-Cobalt alloys

★ Aluminum-Nickel-Cobalt alloys (Alnico types)

★ Cobalt steel

★ (Note: While Al-Ni-Co alloys can be hard magnets, specific compositions or applications can make them behave as soft magnets in certain contexts, though this is less common than them being hard magnets. Iron-Silicon is a more typical example of soft magnetic alloys.)