ELECTRICAL ENGINEERING MATERIALS

Unit IV : Magnetic Materials

Topic: Magnetic Materials: Types, Hysteresis and Core Losses

Important Questions with Answers (3rd Semester, Electrical Engg.)

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Short Answer Questions

Q.1 Explain the types of magnetic materials (diamagnetic, paramagnetic, ferromagnetic and ferrimagnetic).

Ans. On the basis of their behaviour in a magnetic field, materials are of four types.

Type	Behaviour	Relative permeability	Examples
Diamagnetic	Weakly repelled by a magnet	Slightly less than 1	Copper, bismuth, zinc
Paramagnetic	Weakly attracted by a magnet	Slightly more than 1	Aluminium, platinum
Ferromagnetic	Strongly attracted; can be made into magnets	Very high	Iron, nickel, cobalt
Ferrimagnetic	Strongly attracted but weaker; very high resistivity	High	Ferrites

Remember: Iron is a ferromagnetic material. Only ferromagnetic and ferrimagnetic materials are useful as engineering magnetic materials.

Q.2 List the desirable properties of good magnetic materials.

Ans. For cores of transformers, motors and relays (soft materials):

1. High permeability.
2. Low retentivity and low coercivity.
3. Narrow hysteresis loop (small hysteresis loss).
4. High electrical resistivity (small eddy current loss).
5. High saturation flux density.
6. Good mechanical strength and easy to roll into thin sheets.

For permanent magnets (hard materials):

1. High retentivity.
2. High coercivity.
3. Wide loop and high energy product.
4. Stable magnetism with time, temperature and vibration.

Q.3 Define hysteresis losses and discuss the factors on which hysteresis loss depends.

Ans. Hysteresis loss is the energy lost as heat in a magnetic material when it is magnetised and demagnetised again and again. The energy lost per cycle is proportional to the area of

the hysteresis loop. It occurs because the magnetic domains have to turn against internal friction every time the field reverses.

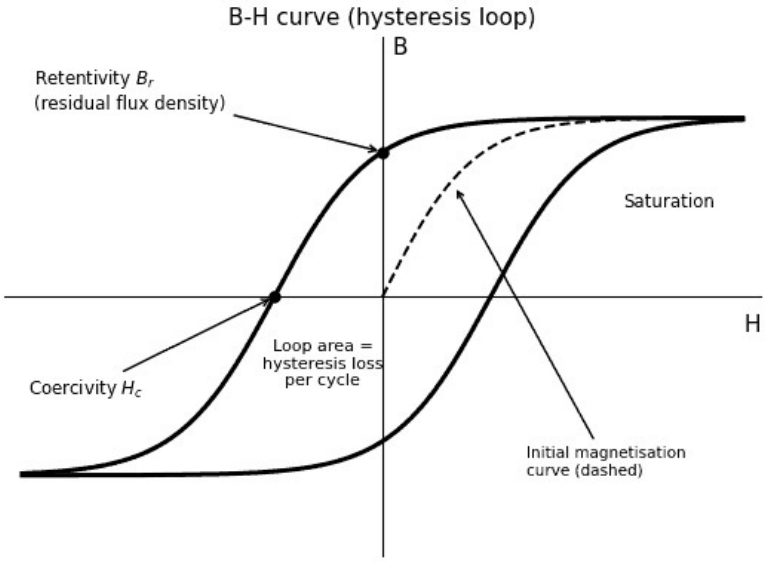


Fig. 1 B-H curve (hysteresis loop)

Hysteresis loss = η × Bmax^1.6 × f × V watts (Steinmetz formula, approximate), where η is the Steinmetz coefficient, Bmax is the maximum flux density, f is the frequency and V is the volume of the core.

Factors:

1. Maximum flux density (more Bmax, more loss).
2. Frequency (loss is directly proportional to frequency).
3. Volume of the core.
4. Quality of the material (a wide-loop material has more loss).

To reduce it:

Use soft materials with a narrow loop such as silicon steel, C.R.G.O. or ferrites.

Q.4 What is eddy current loss? How is it reduced?

Ans. When the flux in a core changes, a voltage is induced in the core itself. It drives small circulating currents called eddy currents, which produce heat. This heat is the eddy current loss. It is proportional to Bmax^2 × f^2 × t^2 × V (approximate), where t is the thickness of the sheet.

Methods to reduce it:

1. Make the core from thin sheets (laminations) insulated from each other by varnish or oxide.
2. Add silicon to steel, which raises its resistivity.
3. Use ferrites at high frequency, which have very high resistivity.

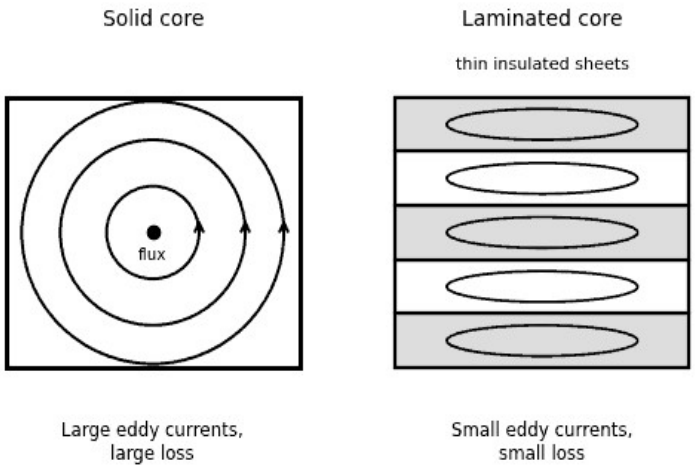


Fig. 2 Eddy currents in a solid core and in a laminated core

Remember: Laminating the stator core of an induction motor reduces eddy current losses.

Q.5 Classify the ferromagnetic material.

Ans. Ferromagnetic materials are of two types.

1. **Soft magnetic materials:** easy to magnetise and demagnetise; narrow loop; used for cores. Examples: iron, silicon steel, C.R.G.O., nickel-iron, Mu metal, soft ferrites.
2. **Hard magnetic materials:** difficult to magnetise and demagnetise; wide loop; used for permanent magnets. Examples: tungsten steel, chromium steel, cobalt steel, Alnico, hard ferrites.

Q.6 Distinguish between soft magnetic materials and hard magnetic materials.

Ans. The difference is given below.

Basis	**Soft magnetic materials**	**Hard magnetic materials**
Magnetisation	Magnetised and demagnetised easily	Magnetised with difficulty; hold the magnetism
Hysteresis loop	Narrow, small area	Wide, large area
Coercivity	Low	High
Retentivity	Low	High
Permeability	High	Lower
Hysteresis loss	Small	Large
Examples	Iron, silicon steel, Mu metal, soft ferrites	Tungsten steel, cobalt steel, Alnico, hard ferrites
Uses	Cores of transformers, motors, relays	Permanent magnets

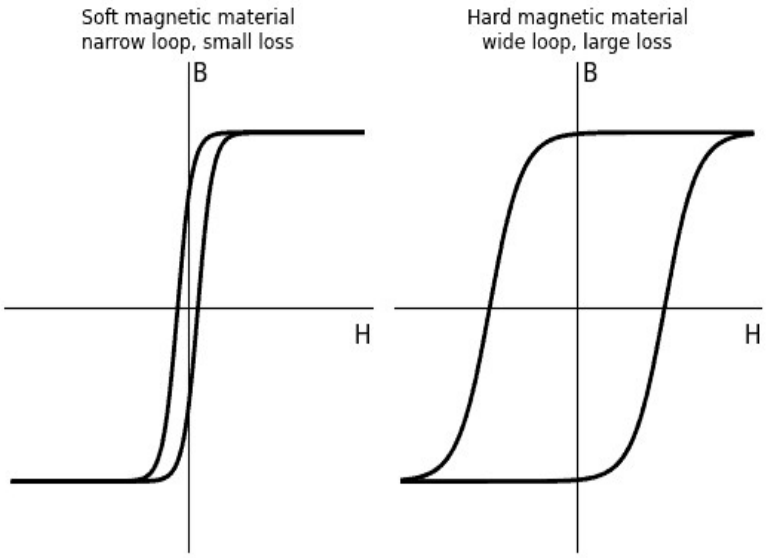


Fig. 3 Hysteresis loops of soft and hard magnetic materials

Q.7 Define retentivity, coercivity and Curie temperature.

1. **Retentivity:** the flux density that remains in a material when the magnetising force is reduced to zero.
2. **Coercivity:** the reverse magnetising force needed to bring the flux density in the material back to zero.
3. **Curie temperature:** the temperature above which a ferromagnetic material loses its magnetic properties and behaves like a paramagnetic material. Approximate values: iron about 770 °C, nickel about 360 °C, cobalt about 1115 °C.

Long Answer Question

Q.8 Explain the hysteresis loop of a magnetic material with a diagram. Discuss hysteresis loss and eddy current loss and the methods of reducing them.

Ans. When the magnetising force H is increased, the flux density B in a ferromagnetic material rises and finally becomes steady at saturation. When H is reduced to zero, B does not fall to zero. When H is taken through a full cycle (positive, negative, positive), B traces a closed loop called the hysteresis loop. The lag of B behind H is called hysteresis.

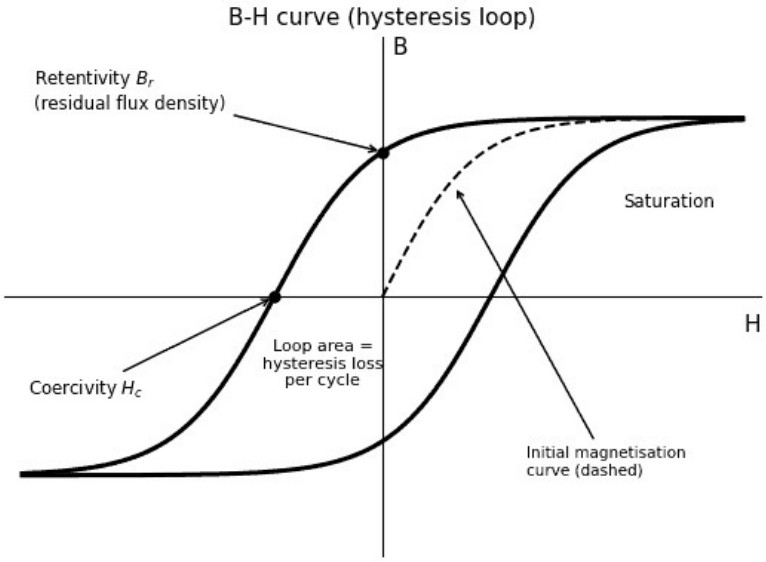


Fig. 4 B-H curve (hysteresis loop)

1. **Retentivity (Br):** flux density left when H = 0.
2. **Coercivity (Hc):** reverse H needed to make B zero.
3. **Saturation:** stage where B no longer rises with H.

Hysteresis loss:

It is the energy lost as heat in each cycle, proportional to the area of the loop. It depends on the maximum flux density, the frequency, the volume of the core and the quality of the material. It is reduced by using soft materials with a narrow loop (silicon steel, C.R.G.O., ferrites).

Eddy current loss:

It is the heat produced by circulating currents induced in the core. It depends on the square of the flux density, frequency and sheet thickness. It is reduced by laminating the core, adding silicon to raise resistivity, and using ferrites at high frequency.

Comparison:

Basis	**Hysteresis loss**	**Eddy current loss**
Cause	Reversal of magnetisation of domains	Induced circulating currents in the core
Depends on	Bmax, frequency, volume, material	Bmax squared, frequency squared, thickness squared
Reduced by	Soft materials with narrow loop	Lamination, silicon, ferrites

Note: The formulas and temperatures are approximate textbook values and are not given in the syllabus.

Points to Remember (for MCQ and True/False)

1. Iron is a ferromagnetic material.
2. Hard magnetic materials are used for making permanent magnets (True).
3. Laminating the stator core reduces eddy current losses.

4. A magnetic material loses its magnetic properties at the Curie temperature.
5. Soft magnetic materials have a narrow hysteresis loop and low hysteresis loss.
6. The area of the hysteresis loop represents energy lost per cycle.
7. Retentivity is the flux left at zero magnetising force; coercivity is the reverse force needed to remove it.
8. Tungsten steel and cobalt steel are hard materials; iron and silicon steel are soft.