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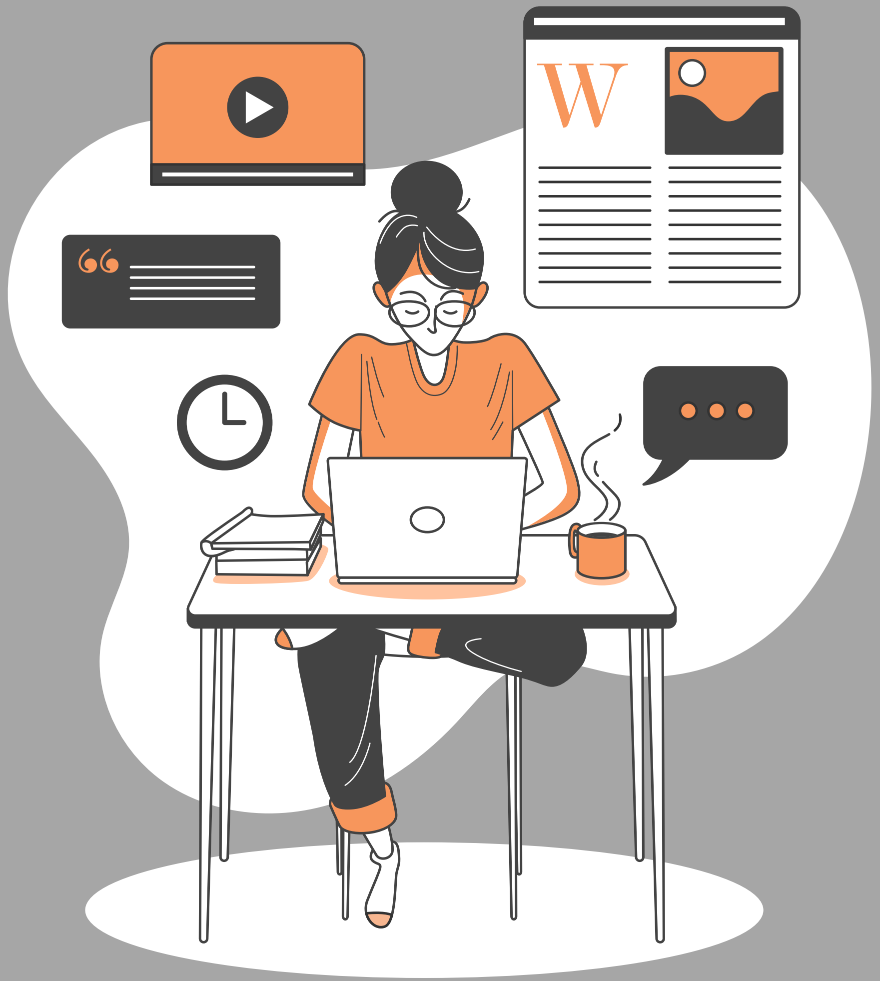

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

III YEAR / VI SEMESTER

EE8002- DESIGN OF ELECTRICAL APPARATUS

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UNIT 01 – Design of Field System and Armature

“Imagination is more important than knowledge.”

—ALBERT EINSTEIN

01. MATERIALS FOR ELECTRICAL APPARATUS

Major Consideration & Electrical Property

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Electrical Engineering Materials

The basic components of all electromagnetic apparatus are the field and armature windings supported by dielectric or insulation, cooling system and mechanical parts.

Major considerations in Electrical Machine Design

Magnetic circuit or the flux path:

Electric circuit or windings

Insulation

Cooling system or Ventilation system

Machine Parts

Design

The factors, apart from the above, that requires consideration are

a. Limitation in design (saturation, current density, insulation,temperature rise etc.,)

b. Customer’s needs

c. National and international standards

d. Convenience in production line and transportation

e. Maintenance and repairs

f. Environmental conditions etc.

Materials for Electrical Machines

The main material characteristics of relevance to electrical machines are those associated with conductors for electric circuit, the insulation system necessary to isolate the circuits, and with the specialized steels and permanent magnets used for the magnetic circuit.

Conducting materials

- Commonly used conducting materials are copper and aluminum.
- Some of the desirable properties a good conductor should possess are listed below.
  - Low value of resistivity or high conductivity
  - Low value of temperature coefficient of resistance
  - High tensile strength
  - High melting point
  - High resistance to corrosion

Materials for Electrical Machines

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Materials for Electrical Machines

For the same resistance and length, cross-sectional area of aluminum is 61% larger than that of the copper conductor and almost 50% lighter than copper. Though the aluminum reduces the cost of small capacity transformers, it increases the size and cost of large capacity transformers. Aluminum is being much used now a day's only because copper is expensive and not easily available. Aluminum is almost 50% cheaper than Copper and not much superior to copper.

Sl.no	Particulars	Copper	Aluminum
1	Resistivity at 20° C	0.0172 ohm / m/ mm2	0.0269 ohm / m/ mm2
2	conductivity at 20° C	58.14 x 106 S/m	37.2 x 106 S/m
3	Density at 20° C	8933kg/m3	2689.9m3
4	Tensile strength	25 to 40 kg / mm2	10 to 18 kg / mm2
5	Melting point	1083° C	660° C

Insulating Materials

- To avoid any electrical activity between parts at different potentials, insulation is used.
- An ideal insulating material should possess the following properties. Should have high dielectric strength.
- Should with stand high temperature.
- Should have good thermal conductivity
- Should not undergo thermal oxidation
- Should not deteriorate due to higher temperature and repeated heat cycle
- Should have high value of resistivity (like 1018 Ωcm)
- Should not consume any power or should have a low dielectric loss angle δ

Insulating Materials

- Should withstand stresses due to centrifugal forces (as in rotating machines), electro dynamic or mechanical forces (as in transformers)
- Should withstand vibration, abrasion, bending
- Should not absorb moisture
- Should be flexible and cheap Liquid insulators
- should not evaporate or volatilize

02. Design of Field & Armature System

Flux, magnetizing Current and winding types

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Design of Magnetic Circuits

- The magnetic circuit of an electrical machine generally consists of ferromagnetic materials and air gaps.
- In an electrical machine, all the windings and possible permanent magnets participate in the magnetizing of the machine.
- It must also be noted that in a multiple-pole system, the magnetic circuit has several magnetic paths.
- Normally, an electrical machine has as many magnetic paths as it has poles.

Design of Magnetic Circuits

- In a two-pole system, the magnetic circuit is symmetrically divided into two paths.
- A possible magnetic anisotropy occurring in the geometry of the magnetic circuit also influences the magnetic state of the machine.
- In the literature, a magnetic circuit belonging to one pole is usually analyzed in the design of a complete magnetic circuit.
- In other words, the amplitude of the fundamental component of the current linkage is acting on half of the magnetic path.
- A complete magnetic path requires two amplitudes.

Magnetization Current

This is the current required to produce flux in the core. It consist of two different current component

1. Magnetization current, required to produced the flux in the transformer core. The following points to be consider about magnetization current.

    a. It is not sinusoidal because of the magnetic saturation in the transformer core

    b. After saturation in the core small change in flux required large amount of current.

    c. The fundamental components of the magnetization current lags the voltage applied to the core by 90 because of purely inductive circuit.

2. The Core Loss current, required to overcome hysteresis and eddy current lossees

    a. core current is non linear because of the non linear effect of hysteresis.

    b. The fundamental component of the core-losses is in the phase of the applied voltage.

Flux Leakage

Magnetic flux leakage (TFI or Transverse Field Inspection technology) is a magnetic method of nondestructive testing that is used to detect corrosion and pitting in steel structures, most commonly pipelines and storage tanks.

The basic principle is that a powerful magnet is used to magnetize the steel. At areas where there is corrosion or missing metal, the magnetic field "leaks" from the steel. In an MFL (or Magnetic Flux Leakage) tool, a magnetic detector is placed between the poles of the magnet to detect the leakage field.

Analysts interpret the chart recording of the leakage field to identify damaged areas and to estimate the depth of metal loss.

Design of Armature

- The armature winding can broadly be classified as concentrated and distributed winding.
- In case of a concentrated winding, all the conductors / pole is housed in one slot.
- Since the conductors / slot is more, quantity of insulation in the slot is more, heat dissipation is less, temperature rise is more and the efficiency of operation will be less.
- Also emf induced in the armature conductors will not be sinusoidal.

Design of Armature

- Also emf induced in the armature conductors will not be sinusoidal.
- Therefore.,
- a. design calculations become complicated (because of the complicated expression of nonsinusoidal wave).
- b. Core loss increases (because of the fundamental and harmonic components of the nonsinusoidal wave) and efficiency reduces.
- c. Communication interference may occur (because of the higher frequency components of the non-sinusoidal wave).
- **Hence no concentrated winding is used in practice for a DC machine armature.**

Design of Armature

- In a distributed winding (used to overcome the disadvantages of the concentrated winding), conductors / pole is distributed in more number of slots.
- The distributed winding can be classified as single layer winding and double layer winding. In a single layer winding, there will be only one coil side in the slot having any number of conductors, odd or even integer depending on the number of turns of the coil.
- In a double layer winding, there will be 2 or multiple of 2 coil sides in the slot arranged in two layers.
- Obviously conductors / slot in a double layer winding must be an even integer.

Design of Armature and Lap Winding

Types of Armature Winding :

According to the way of connecting the conductors, DC armature windings are classified as: **Lap Winding & Wave Winding**

Lap Winding : Lap winding is the winding in which successive coils overlap each other. It is named "Lap" winding because it doubles or laps back with its succeeding coils. • In this winding the finishing end of one coil is connected to one commutator segment and the starting end of the next coil situated under the same pole and connected with same commutator segment.

Simplex Lap Winding: A winding in which the number of parallel path between the brushes is equal to the number of poles is called simplex lap winding.

Duplex Lap Winding: A winding in which the number of parallel path between the brushes is twice the number of poles is called Duplex lap winding.

Design of Armature and Lap Winding

Wave Winding: Wave winding is one type of armature winding. In this winding the end of one coil is connected to the starting of another coil of the same polarity as that of the first coil.

This winding forms a wave with its coil, that's why it is named as wave winding.

It is also called series winding because its coils are connected in series.

Progressive Wave Winding :If after one round of the armature the coil falls in a slot right to its starting slot the winging is called Progressive wave winding.

Retrogressive Wave Winding : If after one round of the armature the coil falls in a slot left to its starting slot the winging is called Retrogressive wave winding.