COMPUTER AIDED ELECTRIC MACHINE DESIGN

Section-A lecture-1

- Topics covered
- Basic Concepts of Design
- General feature and limitation of electrical machine design.
- Types of enclosures
- Heat dissipation
- Temperature rise heating and cooling cycles.
- Ratings of machine machines.
- Cooling media used

Cont…..

- BASIC DESIGN PRINCIPLES:
- Output equation and output coefficient,
- Specific electric and magnetic loading.
- Effect of size and ventilation

Basic concept of machine design:

Introduction:-

- Design defined as a creative physical realization of theoretical concepts.
- Engineering design is application of science , technology and invention to produce machines to perform specified tasks with optimum economy and efficiency.
- Engineering is the economical application of scientific principles to practical design problems.

The major considerations to evolve a good design:

- Cost .
- Durability.

- In designing -any system, accuracy of prediction, economy, quality and delivery period playa vital role.
- Basically, a design involves calculating the dimensions of various components and parts of the machine, weights, material specifications, output parameters and performance in accordance with specified international standards.

Various Objective Parameters/or Optimization in an Electrical Machine:

- Rating of the machine (KW/KVA)
- Rated Voltage
- Rated Frequency (for AC only)
- Rated Speed (RPM)
- Type of Connection of Phases (Star/Delta) for 3 ph AC only
- Type of Winding (Lap/Wave)
- Number of Parallel Paths

Conti…..

- Shunt/Compound in case of DC Machine
- Squirrel Cage/Slip Ring type for 3-ph Induction Motor
- Rated Slip /Rotor speed for Induction Motor
- Salient Pole/Round rotor type for 3-ph Alternators
- Rated power factor for 3-ph Alternators
- Core/Shell type for Transformers
- Ratings of HV /L V for Transformers

Applicable curves :

- B/H for magnetic materials used for Core, Poles,
- Loss Curves for magnetic materials
- Hysteresis loss vs. frequency
- Carters coefficients for slots and vent ducts
- Apparent Flux density
- Leakage Coefficient of slots
- HP vs output coefficient for I-ph Induction Motor

Lecture-3

Electrical Materials :

- Materials used in Electrical machines are classified into three types:
- I. Conducting; 2. Insulating and 3. Magnetic
- Design of electrical machines depends mainly on quality of materials used. If low quality materials are used, the machine will be less efficient, more bulky, higher weight and higher cost. Operational running cost will also be higher.

Conti…

- A designer should have perfect knowledge of properties and cost of these materials so that the design can be both efficient and cost-effective.
- Conducting Materials
- Conducting materials are of two categories
- I. Material of low conductivity (high resistivity): Used for heating devices, thermo couples, resistance etc.
- Material of high possible conductivity (low resistance): Used for windings of electrical machines and equipment's.
- Material with lowest resistance should be selected so that it contributes lowest Ohmic losses to enhance efficiency and to reduce Temp-rise.

Requirements of high conductive materials:

(a) Highest Possible conductivity (least Resistance)

(b) Least possible temperature coefficient of resistance

(c) Adequate resistance to corrosion

(d) Adequate mechanical strength and high tensile strength

(e) Suitable for jointing by brazing/soldering/welding so that the joints are highly reliable contributing lowest resistance.

(f) Suitable for rollability, drawability, so that conductors of required shape (wire/strip) are easily manufactured.

Super conducting materials:

- Materials whose resistivity sharply decreases to practically zero value when the temperature is brought down below transition temperature are called super conductors. Due to practically zero resistance, copper losses will be almost zero.
- Hence, machines with these conductors can be designed with very high value of current density reducing drastically the size of the machine. However, these machines are not in commercial use due to practical limitations

Insulating Materials

- Insulating materials are used to provide an electrical insulation between parts at different potential.

Required properties of good insulating materials:

(a) High Insulation Resistance

(b) High Dielectric strength

(c) Low Dielectric Losses and Low Dielectric Loss angle(tan 0)

(d) No moisture absorption

(e) Capable of withstanding without deterioration a repeated heat cycle

(f) Good heat conductivity

Conti…

(g) Good mechanical strength to withstand vibrations and bending

(h) Solid material should have a high melting point

(i) Liquid materials should not evaporate or volatilize.

- Insulation for Conductor Covering
- Copper conductors used in electrical machines are covered with some type of insulating material (usually in the form of tapes) based on thermal grading, dielectric stresses and economy.

Conti…

- In electrical machines of small ratings, insulation materials of class A and E can be used to reduce cost.
- But for larger machines they are not suitable since volume and weight of the machine will be higher and efficiency lower. Techno-economical study proved that Class-B and Class-F insulations are most appropriate for machines of medium and large ratings respectively for commercial use.
- The latest trend is to design large machines with Class-F insulation and utilize for Class B temp-rises.
- Advantages of Class-F insulation is that it possesses excellent propel1ies as indicated above and gives a reliable performance for a longer life.

Conti…

- Insulating Resin and Varnish In electrical machines, resins and varnishes are used for impregnation, coaling and adhesion.
- These resins and varnishes have the following additional insulating properties.

(a) Quick drying properties

(b) Chemical stability even under strong oxidizing influence

(c) Should not attack the base insulating material or the copper conductor

(d) Should set hard and good surface.

Lecture-4

Magnetic Materials

- Magnetic materials playa vital role in electrical machines,,.,since magnetic circuit is created by these materials.
- A good magnetic material should possess the following qualities.

(a) High magnetic permeability so that for required flux density it draws minimum no. of amp turns

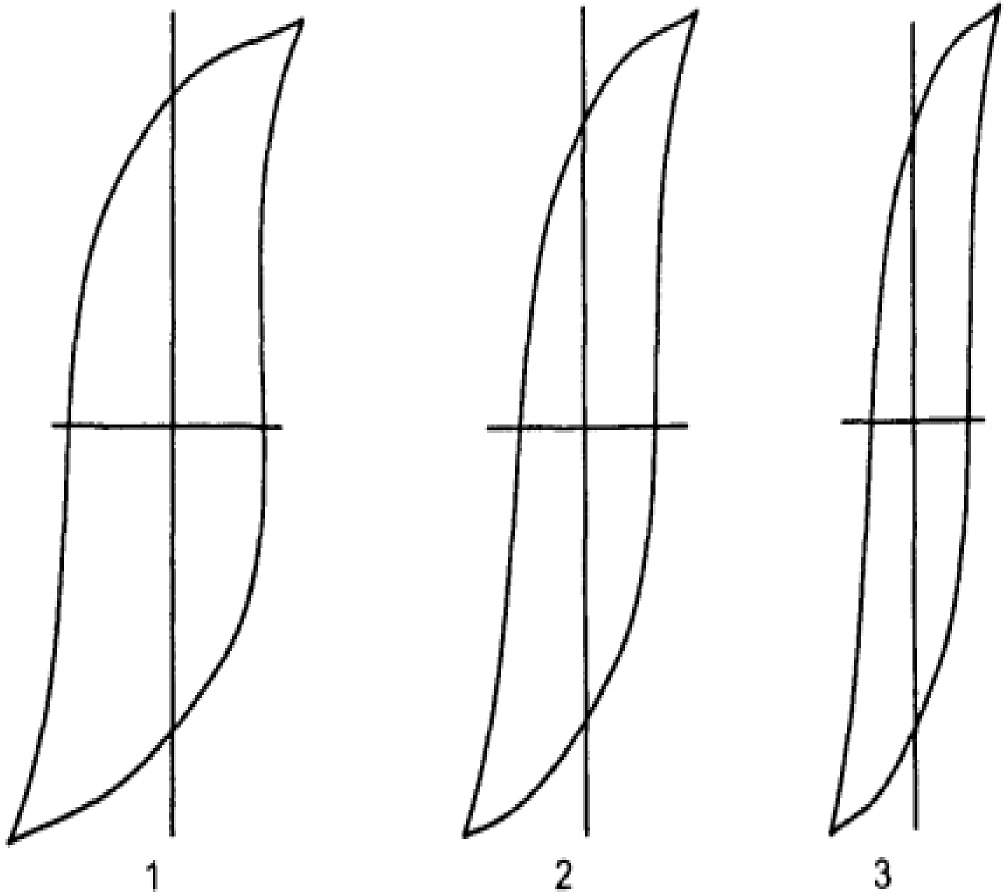
(b) High electrical resistivity to reduce the eddy current losses .

(c) Hysteresis loop should be narrow to reduce hysteresis loss.

Silicon Steel

- Magnetic properties of permeability and resistivity of steel are greatly improved by adding a certain percentage of silicon. But, if the percentage of silicon increases 4%, steel becomes brittle.
- These silicon steels are made into laminations of normal thickness of 0.35mm and 0.5 mm either by cold working or hard working

Hysteresis Loss: 1 → High & 3→ Low



Variation in flux densities in machines and transformer based on size of materials

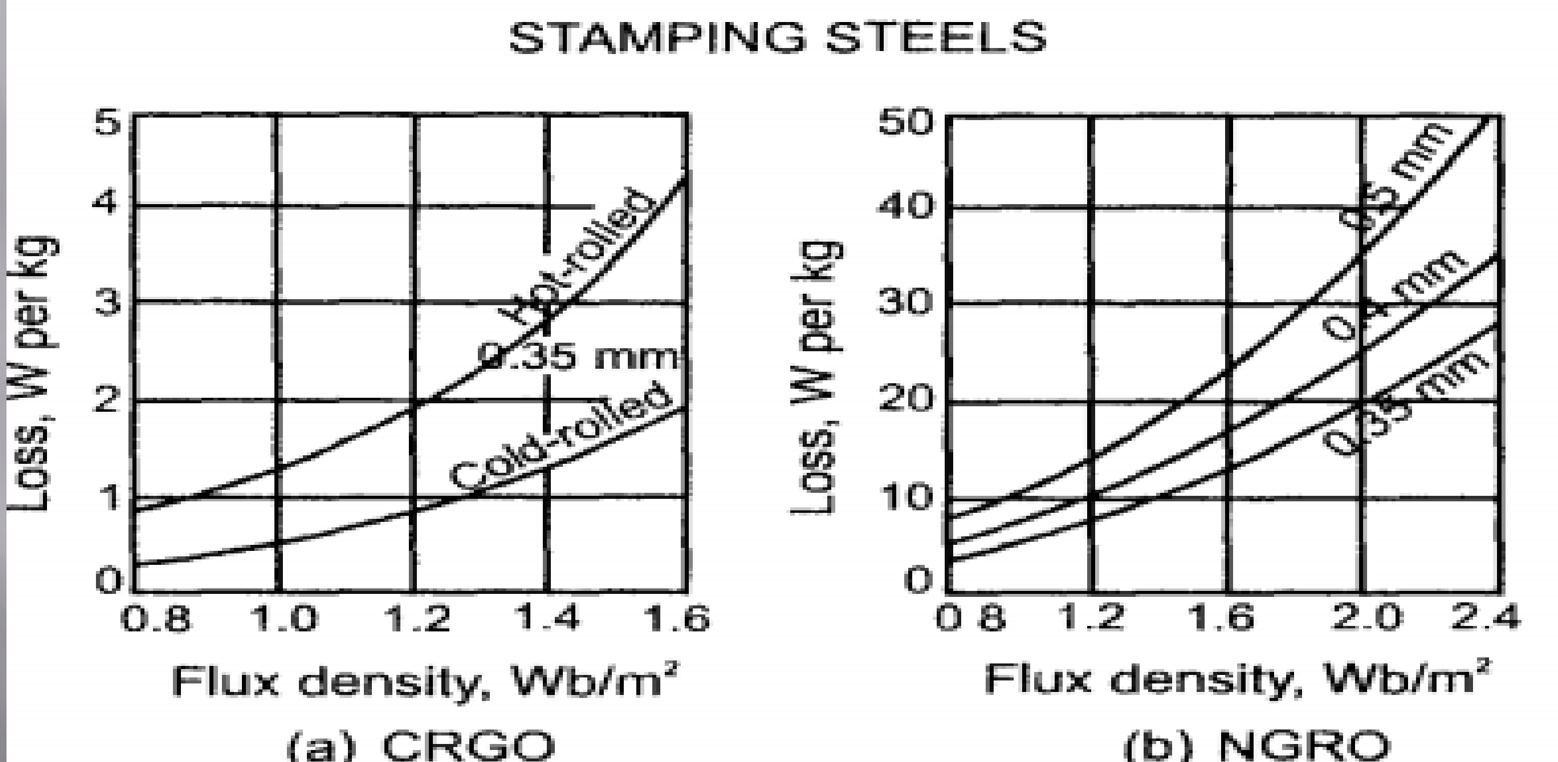


Fig. 2.3 Core loss at 50 c/s.
(a) Transformers (b) Machines

General Procedure for Calculation of Amp-Turns

(a) Flux/pole value is calculated using the formula

(b) Flux density(B) in each part is calculated (B= FluxArea of fluxpath)

(c) From the B-H characteristic of the material used for that part (ref above fig) value of A T/m (H) is read out

(d) Length of the magnetic path (L) in meters of that pat1 is calculated

(e) AT required for that part = H x L (If the cross-section of the path is not uniform ex:-armature tooth), the path is again split into no of sub-parts, B and H values of each sub-part is estimated and average value of H is arrived at

(f)Same way AT required for each part is calculated.

(g) Algebraic sum of AT required for each part gives the total AT required for the Circuit.

Further Details for Calculations

1. For Air-Gap :

Amp turns for Air-Gap (A Tg)

$$= 0.796 \times Bg \times Kg \times Lg * 10^6$$

- Here the additional term "Kg" is the Total Air-Gap Coefficient, where Kg = Kgs x Kgv.

(a) The factor "Kgs" is the gap coefficient for the slot and

Kgs = slot pitch/(slot pitch – slot width* Cg)

where "Cg" is the Carter Gap Coefficient and depends on ratio of slot width to Air gap which is to be read from given curve

Conti…

(b) The factor "Kgv" is the gap coefficient for ducts and

$$Kgv = L/(L - nv*bv*cv)$$

- L =Gross length of Armature
- Nv = No of vent ducts
- bv ~=Width of vent duct
- Cv = Carter's coefftient (read from given curves)

For Armature Tooth:

(a) Flux density at one-third section from the narrow end of the tooth is calculated and corresponding value of"H" is read and therefrom "AT" are calculated.

(b) Flux from air gap entering the armature gets divided into 2 parts: (1) majority through tooth (2) slightly through slot. The flux density obtained with the ratio of total flux to the tooth cross section is the apparent Flux density (Bappt). To get the

value of "H", one has to use the curves drawn for apparent flux density vs. AT/m

- for various values of"Ks" where Ks = SP*GL/(TW*Li)
- SP =Slot pitch
- GL = Gross length of Armature
- TW =Tooth width at Y:J from narrow end of tooth
- Li = Net iron length

Lecture-5

Heating and Cooling

Heating :

- In electrical machines, heating is the main criterion for design. Electrical machines are designed and manufactured with a selected class of insulation which can withstand a certain temperature.
- If overheating occurs, insulation will get weakened and results in short circuits
- leading to the damage of the machine.

In general excess temperatures can change the following insulation properties:

(a) Decrease in Resistance
(b) Decrease in Electrical Strength
(c) Increase in Dielectric Loss angle
(d) Increase in Dielectric losses
(e) Decrease in tensile strength

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- When a machine is loaded at time $t = 0$, and when the temp rise is zero (Temp rise = M/c temp - amb temp), the temp-rise gradually increases exponentially with respect to time and and after certain time it attains the steady state value (θmax) governed by the equation $\theta = \theta max\ (1- e^{(-t/\ \tau)})$

where θ Temperature rise at any time (t) and τ heating time constant of the machine which is calculated from formula

Conti…

τ = GS/(A *lamda)

where

G =Weight of the machine (Kg)

S = Average specific heat (Watt-sec/KgfOC)

A = Area of cooling surface (sq.m)

lamda = Specific heat dissipation from the cooling surface (Watts/m-square/°C)

Cooling :

- When load is removed and the machine is stopped, temperature-rise gradually decreases and cools down exponentially with respect to time, as governed by the formula

$$\theta_c = \theta h - e^{(-1/ \tau c)}$$

where

θh -Temp-rise of the machine just before stopping and load removed

Θ_c Temperature rise at any time(t)

τc -cooling time constant of the machine

Effect frequent healing and cooling of machine :

- If a machine is subjected for loading and un-loading many times in day, thermal expansion
- and contraction of insulation occurs and results in early cracking down of insulation and
- reduction in its life period. Hence, design of such machines needs additional care

Modes of Heat Dissipation :

- Heat is dissipated by three modes:

1. Conduction 2. Convection and 3. Radiation

- Since Transformer is a static device, no rotational losses. Heat produced by core and windings are to be dissipated by tank.
- In most power transformers watt loss per Kg in the iron and the watt loss per Kg in the copper will be nearly equal.
- For small transformers a smooth case readily dissipates the heat as can be seen from the above by Convection and Radiation. But in case of rotating machines, rotational losses exist and heat transfer takes place by Conduction and Convection with negligible radiation.

Types of Enclosures

- Electrical machine is protected by a metallic cover called enclosure against ingress of

moisture, dust, atmospheric impurities and any foreign material.

The degree of protection varies in different environments. If the machine is provided under a roof, it is safe from

certain problems like falling of rain, snow etc. But still protection is required from air born

dust etc.

If the machine is not having a roof, higher degree of protection is required.

- If higher degree of protection is provided, cooling is lower and vice versa.

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- Depending upon the required degree of protection, enclosures are classified into
- following types:
- (a) Open Type: Ends of machine are in contact with atmosphere. Cooling is better. Here
- it is with lowest degree of protection.
- (b) Protected type: End covers are provided with holes for ventilation.
- (c) Screen protected type: A wire mesh to prevent foreign bodies is additionally provided for protected type (b).
- (d) Drip Proof type: In a damp environment hanging bowls are provided, so that
- condensed moisture does not enter the machine