CMR INSTITUTE OF TECHNOLOGY	USN											

Internal Assesment Test I – Nov 2022

Sub:	Electrical Machine Design						Code:	18EE55
Date:	05/11/2021	Duration:	90 mins	Max Marks:	50	Sem: V	Section:	A & B

Note: Answer any **five FULL** Questions

		Marks	OBE CO	RBT
1.	What are the limitations in the design of electric machines? Explain.	[10]	CO1	L1
2.	Write a note on insulating material and temperature rise? Classify the insulating materials based on thermal considerations and also give examples for each type.	[10]	CO1	L1
3.	i) Define specific magnetic and electric loadings. ii) A 350KW, 500V, 450rpm, 6pole dc generator is built with an armature diameter 0.87 m and core length of 0.32m. The lap wound armature has 660 conductors. Calculate the specific magnetic loadings, electric loadings and pole pitch.	[4+6]	CO2	L2
4..	Derive output equation of DC Machine.	[10]	CO2	L2
5.	What are the modern trends in the design of electric machines?	[10]	CO1	L1
6.	List and explain the desirable properties of insulating materials.	[10]	CO1	L1
7.	What are the major considerations for good design of electrical machine?	[10]	CO1	L1

CI CCI HOD

1.What are the limitations in the design of electric machines? Explain.

Limitations in Design:

Following considerations impose limitation on design:

1. **Saturation:**

m/c – use of ferromagnetic materials.

⇒ max. allowable flux density to be used is determined by the saturation level of the ferromagnetic material is used.

2. **Temp. rise:**

Max. operating life m/c depends
↓
on insulation materials.
↓
life of insulation material – temp. decides.

Y - 90°, C - above 180°

⇒ Proper cooling and ventillation techniques
↳ maintain the temp. at specified values. (within safe limits).

3. **Insulation:**

↳ materials should withstand electrical, mechanical and thermal stresses which are produced in the m/c.

Tfr → mechanical strength is important.
→ large axial and radial forces are produced when secondary wdg of Tfr is s/c with primary ON.

⇒ insulation should have the capability to withstand for large amount of mechanical stresses.

=> Type of insulation → decides max. op. temp. of the m/c.

=> Size of insulation → decides not only for voltage stress & also for mechanical stress.

For ex, Same operating voltage, thicker insulation has to be used for large sized conductors than smaller size zones.

4. Efficiency:
   └ always to be high to reduced operating cost.

=> In order to design a higher efficiency m/c, the magnetic and electric loading should be small
   ↓
   this requires large amt. of material (iron & conductors). cu/Al.

=> capital cost ↑, but running cost ↓.

5. Mechanical Parts:
   ↳ Simple and economically good.
   ↳ recent technological techniques
      ↓
      which ensures performance, reliability and durability.

For. ex. high speed m/c - turbo alternator.

rotor slot dimensions should selected, the stress on bottom of teeth should not ~~go~~ exceed the allowable limit.

2. Write a note on insulating material and temperature rise? Classify the insulating materials based on thermal considerations and also give examples for each type.

Temperature rise and Insulating materials

→ Losses in machines occur in many forms

→ losses are occuring because machines are Power converters (mechanical ⇄ Electrical).

→ lose wastage in energy occurs in electric circuits, magnetic circuit in machine parts due to friction.

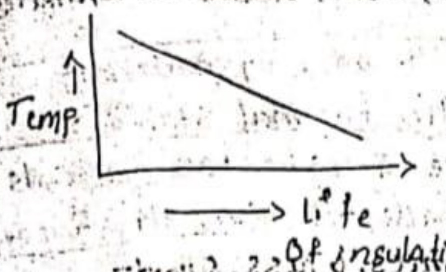
→ As the losses occur in active parts in the form of heat, for reliable operation of machine & to protect windings we use insulating materials to isolate them from iron parts

→ Insulating materials have a safe temperature beyond which it looses its effectiveness, this temperature rise depends on losses which in turn depends on output. this determi the maximum alloable load.

$$T_{life} = 72\times10^{3}\exp(-0.090)$$

life of insulating material.

So we can conclude that a small rise in the temperature above the limit will adversely effect life of insulating material in turn the machine.



Now other than affecting Insulation temperature rise also affects mechanical parts of machine part

Eg:- soldered joints b/w commutator & windings may open up.

So you may conclude that if machine is properly ~~Op~~ operated under temperature limits the problem mentioned above is solved, but this may lead to expensive machine design.

The heat produced by system depends on loss but by having proper cooling & ventilation system this can be reduced to an extent.

Recently we can obtain higher output with given weight of material using proper ventilation & heat resisting properties of insulating materials.

Class	Temperature	Example
Y	90 °C	Cotton, silk, paper, cellulose, wood. Not suitable for machines
A	105 °C	Class Y materials ~~with~~ impregnated with natural resins, oil etc.
E	120 °C	synthetic resin enamels, cotton, paper laminates with formaldehyde
B	130 °C	mica, glass; fibre, asbestos laminates
F	155 °C	Class B with bonding materials of higher thermal stability
H	180 °C	Glass fibre & asbestos materials, materials made of mica, glass fibre etc
C	>180 °C	mica, ceramics, glass, Quartz without binders / with silicon resins

Class A hass laminated wood, varnished paper.

Young Arya Eats Breakfast as Horlicks & Chocos

3. i) Define specific magnetic and electric loadings.
ii) A 350KW, 500V, 450rpm, 6pole dc generator is built with an armature diameter 0.87 m and core length of 0.32m. The lap wound armature has 660 conductors. Calculate the specific magnetic loadings, electric loadings and pole pitch.

i.

Specific Electric loadings. (ac)

→ $\dfrac{\text{total armature ampere conductors}}{\text{armature pheripheny at airgap}}$

$$ac = \frac{I_z Z}{\pi D}$$

Specific Magnetic loading: B_{av}

→ average flux density over the air gap of a machine

$$B_{av} = \frac{\text{total flux around in the air gap}}{\text{area of the flux path at the air gap.}}$$

$$B_{av} = \frac{P\phi}{\pi D L}$$

ii.

$P = 350\,kW$ $D = 0.87\,m$

$V = 500\,V$ $L = 0.32\,m$

$N = 450\,rpm$ $Z = 660$

$P = 6$ Lap winding

To find :- (i) $B_{av} = ?$

(ii) $ac = ?$

$$B_{av} = \frac{P\phi}{\pi D L}$$

$$\phi = \frac{E_a}{Pn\phi z}$$

$$\phi = \frac{500 \times 6}{6 \times \frac{450}{60} \times 660}$$

$$\boxed{\phi = 0.101\,wb}$$

$$B_{av} = \frac{6 \times 0.101}{\pi \times 0.87 \times 0.32}$$

$$\boxed{B_{av} = 0.692\,wb/m^2}$$

(ii) ac (armature conductors).

$$ac = \frac{I_z \cdot Z}{\pi D}$$

$$I_z = \frac{I_a}{a}$$

$P = VI \times 10^{-3}$ in kW

$$I = \frac{P}{V \times 10^{-3}}$$

$$I = \frac{350}{500 \times 10^{-3}}$$

$$\boxed{I = 700\ amps}$$

$I \approx I_a$ (since I_f is very small)

$$I_z = \frac{I_a}{a} = \frac{700}{6} = 116.66\,A$$

$$ac = \frac{116.66 \times 660}{\pi(0.87)}$$

$$\boxed{ac = 28170.6\ ac/m}$$

Results :- (i) $B_{av} = 0.692\ wb/m^2$

(ii) $ac = 28170.6\ ac/m$

4.Derive output equation of DC Machine.

Output Equation of a DC Machine:

Let

P_a - Power developed by armature in kW.

P_a = Generated emf x armature current $\times 10^{-3}$

$$P_a = E I_a \times 10^{-3} \longrightarrow (1)$$

ϕ - flux per pole in wb.

Z - total no. of armature conductors.

N - Speed in RPM

n - motor speed in rps $\left(n = \frac{N}{60}\right)$

a - no. of parallel paths.

$a = 2$, wave wdg

$a = P$, lap wdg

$$E = \frac{P\phi N Z}{60 a}$$

eqn (1),

$$P_a = \frac{P\phi n Z}{a} \times I_a \times 10^{-3} = \frac{P\phi n Z}{a}$$

Let, current in each conductor $\Big\}$ $I_z = \frac{I_a}{a}$

$$P_a = P\phi \, I_z Z \, n \times 10^{-3} \longrightarrow (2)$$

Sp. Magnetic loading, $B_{av} = \frac{P\phi}{\pi D L}$

Sp. Electric loading, $ac = \frac{I_z Z}{\pi D}$.

$P\phi = B_{av} \pi D L$

$I_z Z = \pi D\, ac$

D - Diameter of armature

L - length of the armature.

$P_a = B_{av} \pi D L \; \pi D\, ac \times n \times 10^{-3}$

$P_a = \pi^2 B_{av}\, ac\, D^2 L\, n \times 10^{-3}$

$$P_a = C_o D^2 L n \text{ in kW}$$

where $C_o = \pi^2 B_{av}\, ac \times 10^{-3}$

↓

output Co-efficient.

(i) Generator:-

Power developed by a Generator } $P_a = \text{i/p} - \text{losses}$ (↑ windage loss, friction loss, iron losses)

$$P_a = \frac{\text{output power}}{\eta} - \text{losses}.$$

$$P_a = \frac{P}{\eta} - \text{losses}.$$

For large generators,

losses are negligible :

$$\boxed{P_a = \frac{P}{\eta}}$$

ii) Motor:-

$P_a = \text{o/p power} + \text{losses}.$

$$\boxed{P_a = P + \text{losses}.}$$

larger motors:

$$\boxed{P_a = P}$$

5.What are the modern trends in the design of electric machines?

Modern Trends in Design of Electrical Machines: (5)

Design of Machine involves both a "science" and an "art."

Science: ⇒ Universally accepted, Basic principles and mathematical equations followed.

Art: knowledge of these principles often insufficient to produce correct and economic design.

⇒ Sometimes machine design mathematical equations are less compared to number of unknowns.

The design of machine involves following steps:

⇒ choice of constructional principle

⇒ cooling & ventilation system

⇒ insulating materials

⇒ conducting materials.

⇒ The design process of machine is majorly divided into three design problems.

1) Electromagnetic design

2) Mechanical design

3) Thermal design.

⇒ These problems are interrelated to each other. So they can be solved separately and results can be inter related later.

⇒ Design of each and every system are independent on each other.

So optimization is required, there comes the idea of iteration.

=> we can used digital computers for the same purpose to

↳ redue time

↳ get results quickly [less computation time]

↳ reduce manpower in calculations.

6. List and explain the desirable properties of insulating materials.

Electrical Properties of Insulating materials.

1. High dielectric strength, at elevated temperatures
2. High resistivity or specific resistance
3. Low dielectric ~~resistanc~~ hysteresis
4. Good thermal Conductivity
5. High thermal stability

Good mechanical properties.

[redacted]

Electrical properties mentioned above can varry due to many factors mentioned below

* Frequency, type of waveform, rms value of output/input voltage (test piece)
* Temperature and moisture content on test piece
* mechanical pressure on test piece
* Dimensions of test piece.

7.What are the major considerations for good design of electrical machine?

Major considerations for Good design:

1. Cost
2. Durability

} conflict to each other.

3. Performance criteria as laid down in Specifications.

=> Most of the cases, its difficult to machine perform all the performance irrespective of cost and durability.

=> Impossible to cheap and also at same durability.

=> M/c long life → high quality materials → cost ↑.

=> A performance meet certain, a compromise b/w : cost and durability can be had.

=> A good design – a m/c life b/w 20 - 30 yrs. and has low initial cost.