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Internal Assesment Test –I

Sub:	Electric Machine Design (EMD)							Code:	15EE64
Date:	07/ 03/ 2019	Duration:	90 mins	Max Marks:	50	Sem:	6^{th}	Branch:	EEE

Question 5 and 6 are compulsory. Answer any 3 questions from remaining.
Sketch figures wherever necessary.

		Marks	OBE	
			CO	Level
Q1(a)	What are the limitations in the design of electric machines? Explain	[06]	CO1	L1
Q1(b)	For a constant total volume of conductors in transformer. Show that for a minimum copper loss, current densities in the windings must be equal.	[04]	CO4	L3
Q2 (a)	List the desirable properties of insulating materials	[04]	CO1	L1
Q2(b)	Explain classification of insulating materials based on thermalconsiderations with two examples each.	[06]	CO1	L2

Q3	Derive the output equation of transformer of a 1-φ and 3-φ core type transformer	[10]	CO2	L2
Q4 (a)	Explain about modern manufacturing techniques in machine design	[06]	CO1	L2
Q4 (b)	List the properties of conducting materials	[04]	CO1	L1
5.	Find the main dimensions of a core and window for a 500kVA, 6600/400V, 50Hz,1-φ, core type transformer. Assume the flux density as 1.2 Wb/m^2 and current density of 2.75 A/mm^2, window space factor K_w=0.32, volt/turn is 16.8 volts. Use cruciform core. Height of window is 3 times its width.	[10]	CO4	L3
6.	A 3-φ, 50 Hz, oil cooled core type transformer has following dimensions. Distance between core Centers 0.2 m, height of window is 0.24 m. Diameter of circumscribing circle is 0.14 m. Flux density in the core is 1.25 Wb/m^2 and the current density in the conductor is 2.5 A/mm^2. Estimate KVA rating. Assume window space factor of 0.2 and a core area factor of 0.56. Also mention no, of steps in core.	[10]	CO4	L3

******All the Best*****

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Solution

Q1 (a)

Limitations in Design

Inspite of availability of material, transportation etc there are many other limitations like listed below

1. Saturation:- As we are Concerned about Electromagnetic machines, we need to use ferro-magnetic materials To get more flux we need increased excitation which will increase the cost, But this increase in excitation also has certain limit beyond which there is no more flux is induced such a point is called saturation.

2. Temperature Rise:- Proper Cooling & Ventillation has to be provided for a machine, the coolant flows throughout the confined path in machine, it collects all the heat & liberates it outer to the machine thus avoiding temperature rise inside the machine The reason for controlling the machine's temperature rise is to increase the life of insulation used in system. Because life of machine depends on the life of Insulation.

3. Insulation:-

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4) Efficiency :- The machine to operate at high efficiency magnetic & electric loadings are to be less, So we need to use more material., so the Capital cost of machine will ~~reduce~~ increase. while reducing Operating cost.

5) Mechanical parts:- Considering the type of machine whether a rotating / Stationary machine, whether operated vertically / horizontally the mechanical parts has to be designed economically with less labour.

Eg:- Size of shaft depends on ~~size~~ rotor speed.

6. Commutation:- Commutation will limit the max. output of the El machine., due to many Commutation problems.

7. Power factor:- lower the power factor higher is current drawn ~~from~~ by the system for the same power. if the current drawn is more size also will increase which will increase the cost.

8. Consumer's Specification:- The Specifications laid by the Consumer are to be met with the the economic constrains mentioned by the manufacturer.

9. Standard Specification:- These cannot be neglected both consumer & manufacturer has to satisfy both.

Q1(b)

$a_p = I_p/\delta_p$

$a_s = I_s/\delta_s$

Usually current density on both primary & secondary is taken same in order to have min. cu loss.

Take U_p & U_s as volume of conductors

I^2R in primary $= (a_p \delta_p)^2 * \frac{\rho L}{a_p}$

$= \rho \, \delta_p^2 \, \underbrace{a_p * L}_{U_p}$

$= \rho \, \delta_p^2 \, U_p$

similarly I^2R loss in secondary $= \rho \, \delta_s^2 \, U_s$

Total I^2R loss $= \rho \, \delta_p^2 U_p + \rho \, \delta_s^2 \, U_s$ $\quad \because U_t = U_p + U_s$

$= \rho \, \delta_p^2 U_p + \rho \, \delta_s^2 (U_t - U_p)$

$\frac{dP_c}{dU_p} = \delta_p^2 \rho - \rho \, \delta_s^2$

$0 = \rho \, (\delta_p^2 - \delta_s^2)$

$\delta_p^2 = \delta_s^2$

$\boxed{\delta_p = \delta_s}$

$\therefore$ for minimum I^2R loss current density should be equal.

Q2(a)

Insulating materials:

* They are diverse in thier origin & properties.
* They can be natural / human made (synthetic)
non metallic, organic /inorganic
uniform / heterogeneous.

* Some are in intermediate position b/w
organic & inorganic.

Electrical Properties of Insulating Materials:

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

Good mechanical properties.

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Q2(b)

Examples of various classes of insulating materials are :

Class Y. Cotton, silk, paper, cellulose, wood etc., neither impregnated nor immersed in oil.

Materials of class *Y* are unsuitable for electrical machines and apparatus as they deteriorate rapidly and are extremely hygroscopic.

Class A. Materials of class Y impregnated with natural resins cellulose esters, insulating oils, etc. Also included in this class are laminated wood, varnished paper.

Class E. Synthetic resin enamles, cotton and paper laminates with formaldehyde bonding, etc.

Class B. Mica, glass fibre, asbestos with suitable bonding substances; built up mica, glass fibre, and asbestos laminates.

Class F. Materials of class B with bonding materials of higher thermal stability.

Class H. Glass fibre and asbestos materials and built up mica, with silicon resins.

Class C. Mica, ceramics, glass, quartz without binders or with silicon resins of higher thermal stability.

Class C materials are not directly involved in machine design.

Classification 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 enamles, 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

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Q3.

Transformers

output equation of Transformer

ϕ_m - Main flux Wb. B_m :- flux density. wb/m^2

δ → Current density A/m^2

A_{gi} → Gross Core area (m^2) (apparent area)

A_i → Net core area (m^2) (effective area) → Stacking factor * A_{gi} ↳ (lamination part)

A_c → area of copper in window. (m^2)

A_w → window area (m^2)

D → diameter between centres. (m)

d → diameter of circumscribing Circle (m).

f → frequency (Hz)

E_t → emf per turn (V).

$I_p I_s$ → Current in primary and secondary (A)

$V_p V_s$ → terminal voltage in primary and secondary (V)

$T_p T_s$ → No. of turns in Primary and Secondary.

a_p, a_s → area of conductors in primary in secondary (m^2)

L_{mt} → length of mean turn of transformer winding (m)

l_i → mean length of flux path in iron (m)

G_i → weight of active iron (Kg)

G_c → weight of copper (Kg)

g_i → weight per m^3 of iron (Kg)

g_c → weight per m^3 of copper (Kg)

P_i → loss in iron per kg (W)

P_c → Loss in Cu per Kg (W)

i) Single phase transformer.

Voltage induced in transformer with T turns excited by source of f Hz $\therefore E_t = \frac{E}{T} = 4.44 f \phi_m$ →(1)

Total Copper area in window : A_c = Copper area of Primary wdg + Copper area of Secondary wdg

(In 1 φ transformer window have one primary & one secondary winding)

= Primary turns * area of prim Conductor + Secondary turns * area of sec. Conductor

$= T_p * a_p + T_p * a_s$

Taking density as δ then. $a_p = \frac{I_p}{\delta}$ $a_s = \frac{I_s}{\delta}$

∴ Total Conductor area in window $A_c = T_p * a_p + T_s * a_s$

$= T_p * \frac{I_p}{\delta} + T_s * \frac{I_s}{}$

$= \frac{AT}{\delta} + \frac{AT}{\delta}$

$A_c = \frac{2AT}{\delta}$ →(2)

(Primary & secondary ampere turns are considered same as we are neglecting magnetizing mmf)

$$K_w = \frac{\text{Conductor area in window}}{\text{total area of window}} = \frac{A_c}{A_w}$$

$$A_c = K_w A_w \rightarrow (3)$$

Combining (3) & (4)

$$\frac{2AT}{\delta} = K_w A_w$$

$$AT = \frac{K_w A_w \delta}{2} \rightarrow (4)$$

Total rating of 1 ϕ transformer in KVA

$$Q = V_p * I_p * 10^{-3}$$ (consider $V_p \simeq E_p$)

$$= E_p * I_p * 10^{-3}$$

$$= E_t * T_p * I_p * 10^{-3}$$

$$= E_t * AT * 10^{-3}$$

$$= E_t \frac{K_w A_w \delta}{2} * 10^{-3}$$

$$= 4.44 f \phi_m K_w A_w \frac{\delta}{2} * 10^{-3}$$ ($\phi_m = B_m A_i$)

$$Q = 2.22 f B_m A_i K_w A_w \delta * 10^{-3}$$

$$\boxed{Q = 2.22 f B_m \delta A_i A_w K_w * 10^{-3}} \rightarrow (5)$$

This equation holds good for both Shell type and core type. (Both (5) & (6))

ii) Three phase Transformer:- Here each window will have 2 primary & 2 secondary turns.

$$A_c = 2(a_p T_p + a_s T_s)$$

$$= 2\left(\frac{I_p}{\delta} T_p + \frac{I_s}{\delta} T_s\right).$$

$$= 2\left(\frac{I_p T_p + I_s T_s}{\delta}\right)$$

$$A_c = \frac{2 * AT * 2}{\delta} = \frac{4AT}{\delta}$$

$$A_c = K_w A_w$$

$$K_w A_w = \frac{4AT}{\delta}$$

$$AT = \frac{K_w A_w \delta}{4}$$

Rating of 3 ϕ transformer in KVA.

$$Q = 3 V_p I_p * 10^{-3}$$

$$= 3 * E_p I_p * 10^{-3}$$

$$= 3 * E_t * T_p * I_p * 10^{-3}$$

$$= 3 E_t * AT * 10^{-3}$$

$$= 3 E_t \frac{K_w A_w \delta}{4} * 10^{-3}$$

$$= 3 * 4.44 f \phi_m K_w . A_w \frac{\delta}{4} * 10^{-3}$$

$$= 3 * 1.11 f B_m A_i K_w A_w \delta * 10^{-3}$$

$$\boxed{Q = 3.33 f B_m \delta A_i A_w K_w * 10^{-3}} \rightarrow (6)$$

Q4(a)

Modern machine manufacturing techniques.

As the electricity demand is increasing day by day, machines with new technologies; greater efficiencies and outputs are needed. For all these we are following Some modern trends in manufacturing industries. which are listed below:-

① Modern machines are Characterized by wide range of power outputs :- The power output varies from few fraction of watts to several thousands of watts in a single unit. The ratio of power output of smaller machine to the largest machine is $1:10^{10}$.

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As there are wide range of power outputs, there are wide range of rotational speeds also available.

A machine is classified based on the ~~ma~~ constructional features & sub classified based on power output and rotational speed.

Classification of machine based on the range of power outputs is listed below.

Speed

(a) Small size machines:- Power output upto 750 W ($\leq$ 250 rpm)

(b) Medium size machines:- Few kilowatts to 250 kW (2000-2500 rpm)

(c) Large size machines:- 250 kW to 5000 kW, these machines are designed & manufactured as series.

(d) Larger size machines:- manufactured based on ~~consumer~~ customer demand. Power outputs may range from hundreds to megawatt.

* machines with low speed have larger diameter & smallest axial length, while high speed machines have smaller diameter & larger axial length.

(2) To build machines with smaller size:- This will reduce the amount of material used while maintaining efficiency & overload capacity.

Improved power ratings with smaller size machines are possible due to following technical advancements.

(i) Stray load losses are reduced by using new techinques in arranging the conductors and other parts of machine

(ii) Vast developments in cooling & ventilation system for machines. (effective way of heat dessipation

(3) magnetic materials with good mechanical strength less iron loss and high permeability. high permability gives high flux density with less material, hence smaller machine with more power output.

(4) Greater outputs with Good newer insulating materials:- Insulating materials determine the temperature limit of machine, higher the temperature withstanding Capability greater the power output with smaller size of machine.

(5) Modern machine building with higher ~~eletro~~ electro-magnetic loadings for active parts & higher mechanical loadings for construction materials.

(6) To reduce the overall cost of machine, individual parts are constructed using modern techiques.

(7) Environmental conditions:- The machine should be able to withstand wide environmental conditions, so manufacturer has to design it accordingly.

Q4(b)

Requirements of Conducting materials

(1) materials must have highest possible conductivity or least possible resistivity

(2) Temperature co-efficient of resistance must be as low as possible.

(3) materials should not be brittle, should have good mechanical strength

(4) material must have good rollability & drawability & low electrical resistance at joints

(5) Good weldability & solderability

(6) adequate resistance to corrosion.

Q5.

Given

$Q = 500\ KVA$

$V_2/V_1 = 6600/400\ V$

$f = 50\ Hz$

Core type 1ϕ

$B_m = 1.2\ wb/m^2$

$\delta = 2.75\ A/mm^2 \rightarrow 2.75 \times 10^6\ A/m^2$

$K_w = 0.32$

$E_t = 16.8\ V$

Two step

$H_w = 3\ W_w$

$$E_t = 4.44 f B_m A_i$$

$$16.8 = 4.44 * (50) * (1.2) * (A_i)$$

$$A_i = 0.063\ m^2$$

$$Q = 2.22 f B_m A_i A_w K_w \delta \times 10^{-3}$$

$$500 = 2.22 * 50 * 1.2 * 0.063 * A_w * 0.32 * 2.75 \times 10^6 \times 10^{-3}$$

$$A_W = 0.0677\ m^2$$

$$H_W = 3 W_W$$

$$A_W = H_W * W_W$$

$$= 3 W_W * W_W$$

$$0.0677 = 3 W_W^2$$

$$W_W = 0.15\ m$$

$$H_W = 0.45\ m$$

$$A_i = K_i d^2$$

$$0.063 = 0.56\ d^2$$

$$d = 0.335\ m$$

Area of iron core $A_i = 0.063\ m^2$

Area of window $A_w = 0.067\ m^2$

Width of window $W_w = 0.15\ m$

Height of window $H_W = 0.45\ m$

diameter of circumscribing circle $d = 0.335\ m$

Q5

Given

$Q = 500\ KVA$

$V_2/V_1 = 6600/400\ V$

$f = 50\ Hz$

Core type 1ϕ

$B_m = 1.2\ wb/m^2$

$\delta = 2.75\ A/mm^2$ ⟶ $2.75 \times 10^6\ A/m^2$

$K_w = 0.32$

$E_t = 16.8\ V$

Two step

$H_w = 3\ W_w$

$E_t = 4.44\ f\ B_m A_i$

$16.8 = 4.44 * (50) * (1.2) * (A_i)$

$\boxed{A_i = 0.063\ m^2}$

$Q = 2.22\ f\ B_m A_i A_w K_w \delta \times 10^{-3}$

$500 = 2.22 * 50 * 1.2 * 0.063 * A_w * 0.32 * 2.75 \times 10^6 \times 10^{-3}$

$\boxed{A_W = 0.0677\ m^2}$

$H_W = 3 W_W$

$A_W = H_W * W_W$

$= 3 W_W * W_W$

$0.0677 = 3 W_W^2$

$\boxed{W_W = 0.15\ m}$

$\boxed{H_W = 0.45\ m}$

$A_i = K_i d^2$

$0.063 = 0.56\ d^2$

$\boxed{d = 0.335\ m}$

Area of iron core $A_i = 0.063\ m^2$

Area of window $A_w = 0.067\ m^2$

width of window $W_w = 0.15\ m$

Height of window $H_W = 0.45\ m$

diameter of circumscribing circle $d = 0.335\ m$

Q6.

Q6.

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6

Given

~~Q = 500 KVA~~

$D = 0.2\, m$

$d = 0.14\, m$

$B_m = 1.25\, Wb/m^2$

$\delta = 2.5 \times 10^6\, A/m^2$

$K_w = 0.2$

$K_i = 0.56$ - core area factor.

$A_w = H_w \times W_w$

$W_w = D - d$

$= 0.2 - 0.14$

$A_w = 0.24 \times 0.06$

$A_w = 0.0144\, m^2$

$A_i = K_i d^2$

$= (0.56)(0.14)^2$

$A_i = 0.011\, m^2$

$Q = 3.33 f B_m \delta K_w A_w A_i \times 10^{-3}$

$= 3.33 (50)(1.25)(2.5 \times 10^6)(0.2)(0.0144)(0.011) \times 10^{-3}$

$Q = 16.48$ KVA

Area of window $A_w = 0.0144\, m^2$

Area of iron $A_i = 0.011\, m^2$

KVA rating Q is = 16.48 KVA

Core is two step as iron factor is 0.56