CMR INSTITUTE OF TECHNOLOGY	USN										

Internal Assesment Test II – Nov 2022 Set A

Sub:	Electrical Machine Design							Code:	18EE55
Date:	13/11/2022	Duration:	90 mins	Max Marks:	50	Sem:	V	Section:	A & B

Note: Answer any **five FULL** Questions

		Marks	OBE CO	OBE RBT
1.	Mention the factors to be considered during the choice of number of slots.	[10]	CO2	L1
2.	Mention the factors to be considered during the choice of specific loadings.	[10]	CO2	L1
3.	Mention the factors to be considered during the choice of number of poles	[10]	CO2	L1
4..	Explain the factors to be considered during the choice of air gap of a DC machine.	[10]	CO2	L2
5.	Determine the main dimensions, number of poles and length of air gap of a 600KW, 500V, 900rpm generator. Assume average gap density as 0.6 Wb/m^2 and ampere conductors per meter as 35000. The ratio of pole arc to pole pitch is 0.75 and the efficiency is 91%. The following are the design constraints: i) Peripheral speed should not exceed 40m/s ii) Frequency of flux reversals should not exceed 50Hz. iii) Current per brush arm should not exceed 400A iv) Armature mmf per pole should not exceed 7500AT The MMF required for the air gap is 50 percent of armature MMF and gap contraction factor is 1.15.	[10]	CO2	L4
6.	What are the advantages and disadvantages of number of poles in a DC machine?	[10]	CO2	L1
7.	A 4 pole, 25hp, 500V, 600 rpm series crane motor has an efficiency of 82%. The pole faces are square and ratio of pole arc to pole pitch is 0.67. Assume Bav=0.55 Wb/m^2, ac=17000 ac/m. Determine the main dimensions and particulars of suitable armature winding.	[10]	CO2	L4

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1.Mention the factors to be considered during the choice of number of slots.

(iv) Number of Armature Slots:-

Factors to be considered,

a) Mechanical Difficulties:

Slot pitch $Y_s = \frac{\pi D}{S}$ (or) $Y_s = W_s + W_t$

where S - total no. of slots.
W_s - slot width
W_t - tooth width.

Slots $\uparrow^{ses}$ → $Y_s \downarrow^{ses}$; $W_t \downarrow^{ses}$ → reduction in mechanical strength.

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b) Cooling of Armature conductors:

Slots $\uparrow^{ses}$ → lesser no. of conductors/slot are used.
↓
cooling is better.

c) Flux pulsations:-

Flux pulsations, changes in the air gap flux due to slotting → gives rise to eddy current losses in the pole faces
→ produces magnetic noise.

Flux pulsations are $\downarrow^{ed}$ by increasing no. of armature slots.

⇒ In actual design,
No. of slots/pole arc should be integer with slots/pole equal to an integer plus $\frac{1}{2}$.

d) Commutation:-

Sparkless commutator → pulsations and oscillations of the flux under the interpole must be avoided.

From Commutation point of view:
↳ larger no. of slots and smaller number of conductors per slot are better.

⇒ No. of slots per pole should be atleast 9.

(e) Cost :-

Slots ↑ses ⇒ cost of punching slots in Stampings ↑ses.

Slots ↓ses ⇒ reduction in insulation cost.

2.Mention the factors to be considered during the choice of specific loadings.

Choice of Specific Electric loading (or) Ampere Conductors per metre (ac)

→ depends up on

(i) Temp. rise

(ii) Speed of machine

(iii) Voltage.

(iv) Size of machine

(v) Armature reaction

(vi) Commutation.

(i) Temp. rise :

higher value of ac → armature conductors ↑

↓

heat dissipation also ↑

high value of ac ⇒ insulation material used in the m/c can withstand temp. rise

Choice of ac → types of enclosure and cooling techniques of a m/c.

~~ac ↑ → Semi enclosed m/c's~~

higher value of ac"

(ii) Speed of machine:
→ ventillation of m/c is better
↓
m/c rotates at high speed
→ dissipation of heat is better.

high speed m/c – use of high value ac.

(iii) Voltage:
ac value depends on no. of armature conductors.

HV m/c – thickness of insulation is large.
↓
less space for conductors
→ low value of ac

(iv) Size of m/c:
Large size m/c's → more space required for accomodating the conducts.
→ high value ac is possible.

(v) Armature Reaction:
high value of ac → armature reaction will be severe.
field should be made stronger.
↓
mmf required for field ↑ → to prevent in decrease of main flux.
cost of the m/c ↑.

(vi) Commutation:

Sp. Electric loading ∝ armature conductors / armature diameter

$$ac \uparrow \propto \frac{Z \uparrow}{D \downarrow}$$

High value ac ↑

ac ∝ reactance voltage in a coil
∝ inductance in the coil.

High value of ac ⇒ increase the reactance voltage ↑
⇓
delay in commutation

ac ⇒ 15000 to 50000 ac/m.

3.Mention the factors to be considered during the choice of number of poles

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Selection of Number of poles:

→ Factors affecting

(i) Frequency (ii) Weight of iron parts
(iii) Wt. of Cu (iv) Length of Commutator.
(v) Labour charges
(vi) Flashover b/w brushes
(vii) Distortion of field form.

(i) Frequency:

$$f = \frac{np}{2}$$

n - Speed in rps
p - no. of poles.

Frequency of flux reversal ∝ no. of pole ∝ Iron loss
↑ ↑.

(ii) Wt. of iron parts:-
→ a) Yoke area b) Armature core.

a) Yoke area:

Yoke flux density → same
↓
wt. of iron yoke ↓ if ↑ in poles.

~~b) Armature~~

4.Explain the factors to be considered during the choice of air gap of a DC machine.

Length of Air Gap:-

The length of air gap can be fixed by considering the following:-

(i) Armature Reaction:-

⇒ To prevent excessive distortion of field form by the armature reaction

↳ field mmf made large in comparison with the armature mmf.

⇒ A machine designed with a long air gap requires large field mmf

⇓

Thus the distorting effect of armature reaction can be reduced if the length of air gap is made large.

Field mmf ↑ses ⇒ increase in size & cost of the m/c

(ii) Circulating currents:-

⇒ If gap (l_g) is small (or) slight irregularity in air gap } ⇒ large circulating currents.

(iii) Pole face losses:-

l_g is large → pulsation loss in the pole faces decreases.

(iv) Noise:

l_g is large → quiet noise.

(v) Cooling: l_g is large → better ventillation.

(vi) Mechanical Considerations:-

l_g maintained large – to avoid field distortion before advent of commutating poles.

⇒ By use of commutating poles — brought down the values of airgap length. in order to prevent field distortion form.

But small l_g – makes unbalanced magnetic pull

↓

causing rotor to foul with the stator.

⇒ l_g – maintain proper value.

5.Determine the main dimensions, number of poles and length of air gap of a 600KW, 500V, 900rpm generator. Assume average gap density as 0.6 Wb/m^2 and ampere conductors per meter as 35000. The ratio of pole arc to pole pitch is 0.75 and the efficiency is 91%. The following are the design constraints:

i. Peripheral speed should not exceed 40m/s
ii. Frequency of flux reversals should not exceed 50Hz.
iii. Current per brush arm should not exceed 400A
iv. Armature mmf per pole should not exceed 7500AT
v. The MMF required for the air gap is 50 percent of armature MMF and gap contraction factor is 1.15.

The following are the design constraints:

peripheral speed ≯ 40 m/s

frequency of flux reversals ≯ 50 Hz.

current per brush arm ≯ 400A &

armature mmf per pole ≯ 7500A.

The mmf required for air gap is 50 percent of armature mmf and gap contraction factor is 1.15.

$P_a = C_0 D^2 L n$ in kW.

$C_0 = \pi^2 B_{av}\, ac \times 10^{-3} = \pi^2 \times 0.6 \times 35000 \times 10^{-3} = 207.$

Power developed by armature } $P_a = \frac{600}{0.91} = 660\,kW.$

$n = \frac{900}{60} = 15$ rps.

$$D^2 L = \frac{P_a}{C_0 n} = \frac{660}{207 \times 15} = 0.2126 m^3$$

Number of poles:-

(i) Frequency:

$$\left.\begin{matrix}\text{Frequency of flux} \\ \text{reversals}\end{matrix}\right\} = f = \frac{pn}{2} \text{ Hz}.$$

if $p = 4$, $f = \frac{4 \times 15}{2} = 30 \text{ Hz}$

if $p = 6$, $f = \frac{6 \times 15}{2} = 45 \text{ Hz}$.

if $p = 8$, $f = \frac{8 \times 15}{2} = 60 \text{ Hz}$.

poles 4, & 6, may be used, but we cannot use 8 poles since the frequency exceeds the max. allowable limit of 50Hz.

(ii) Current per brush arm:-

Neglecting the field current,

$I_a = \frac{P}{V}$ $\quad I_a = \frac{600 \times 1000}{500} = 1200 A$.

For lap $\frac{2I_a}{P}$
For wave I_a.

current per brush arm $I_a = \frac{2I_a}{P}$

with $p = 4$, $I_b = \frac{2 \times 1200}{4} = 600 A$. ✗

With $p = 6$, $I_b = \frac{2 \times 1200}{6} = 400 A$. ✓

Current per brush arm should not exceed about 400A. This means that 4 poles cannot be used for this machine.

$\therefore$ Number of poles = 6.

Length of Air gap:

$$B_g = \frac{0.6}{0.75} = 0.8 \ wb/m^2$$

MMF req. at airgap $AT_g = 8,00,000 \times 0.8 \times 1.15 \, l_g$

$= 7,36,000 \, l_g \rightarrow ①$

Also air gap mmf per pole $AT_g = 0.5 \, AT_a = 0.5 \times 7350$

$= 3675 \, AT \rightarrow ②$.

Equating ① & ②, $l_g = \frac{3675}{736000} \simeq 5 \, mm$.

Results:

(i) Main Dimensions

$D = 0.8 m$

$L = 0.33 m$.

(ii) No. of poles $p = 6$.

(iii) $l_g = 5 \, mm$.

6.What are the advantages and disadvantages of number of poles in a DC machine?

Advantages of large number of poles

↳ Reduction in → weight of armature core and yoke.

→ Cost of armature and field conductors.

→ Overall L and D of machine.

→ Length of Commutator.

→ Distortion of field factor.

Disadvantages of large number of poles

↳ Increase in → frequency of flux reversal.

→ labour charges.

→ Possibility of flash over between brush arm

7.A 4 pole, 25hp, 500V, 600 rpm series crane motor has an efficiency of 82%. The pole faces are square and ratio of pole arc to pole pitch is 0.67. Assume Bav=0.55 Wb/m^2, ac=17000 ac/m. Determine the main dimensions and particulars of suitable armature winding.

Given, $P = 4$ $P = 25hp$ $V = 500V$

$N = 600rpm$ $\eta = 82\%$ $L/b = 1$

$b/\tau = 0.67$ $B_{av} = 0.55 Wb/m^2$ $ac = 17,000\ ac/m$.

To find (i) D & L (ii) Particular of suitable armature winding Z, S_a, Z_s, C, T_c.

i) Main dimensions (D&L)

$$P_a = C_0 D^2 L n$$

$P_a \propto P$

$D = 0.387\ m$

$L = 0.177\ m$

(ii) No of armature conductors, $Z = \frac{Ea}{P\phi n}$

Series motor :- $I_L = I_a$

$P_{in} = VI_L \times 10^{-3}$

$I_L = \frac{P_{in}}{V \times 10^{-3}} = \frac{22.74}{500 \times 10^{-3}}$

$I_L = 45.48A$

$I_a = 45.48\ A$

The armature current for parallel path is less than 200A and wave winding is preffered.

$E \approx V$

$a = 2$ ($\because$ Wave winding)

$B_{av} = \frac{P\phi}{\pi DL}$

$\phi = 0.0257\ Wb$

$Z = \frac{500 \times 2}{4 \times 0.0257 \times 10}$

$Z = 972$ Conductors.

No of armature slots : S_a

$Y_s = 25mm$ to $35mm$

$S_a = \frac{\pi D}{Y_{sa}}$

If $Y_{sa} = 25mm$, $S_a = 42$

$Y_{sa} = 35mm$, $S_a = 30$

No of armature slots varies from 30 to 42.

→ In wave winding slots per pole should not be a multiple of pole pair.

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∴ To reduce flux pulsation the slots per pole should be integer ±1/2

→ For wave winding the no of slots be an odd number the permissible choice of slots are 31, 33, 35, 37, 39, 41.

→ To avoid dummy coil in wave winding better choose even no of slots per pole arc.

$$\text{Slots/pole arc} = \frac{\text{Pole area}}{\text{Pole pitch}} \times \frac{\text{Slots}}{\text{Pole}}$$

$$= \psi \times S_a/P_{ea}$$

$$= 0.67/4 \times P_{ea}.$$

$$\text{Slots/pole arc} = 0.1657\, S_a$$

	slots/pole arc
$S_a = 31$	5.52
$S_a = 33$	5.86
$S_a = 35$	6.19
$S_a = 37$	6.53
$S_a = 39$	6.86

→ Slots/pole arc 8 to 16 is not possible from above calculation let us choose integer as 6 if $S_a = 33$ slots per pole arc nearest to 6. ∴ no of armature slots $S_a = 33$.

$$\text{Armature Conductors/slots} = \frac{\text{Total armature conductors}}{\text{Armature slots}}$$

$$Z_s = \frac{Z}{S_a}$$

$$Z_s = \frac{972}{33}$$

$$Z_s = 29.45$$

$$Z_s \sim 30$$

New value of Z = No. of slots × ~~slots~~ conductors/slots

$$Z = S_a \times Z_s$$

$$Z = 33 \times 30$$

$$Z = 990$$

$$\text{Minimum no of coils} = C_{min} = \frac{EP}{15}$$

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$C_{min} = \frac{500 \times 4}{15} = 133$

let us consider different values of possible coils by using following formula $C = \frac{1}{2} u S_a$ ↳ coil sides/slot

If $u = 2$

$= \frac{1}{2} \times 2 \times 33 = 33$

$u = 4, C = 66$

$u = 6, C = 99$

$u = 8, C = 132$

$u = 10, C = 165$ ✓

Choose the number of coils such that conductor/slot Z_s is divisible coil sides per slot.

To check if Z_s/u is divisible (or) not

	I	II	III	IV	V
Ratio of Z_s/u	$\frac{30}{2}$	$\frac{30}{4}$	$\frac{30}{6}$	$\frac{30}{8}$	$\frac{30}{10}$
Divisible (or) not	✓	×	✓	×	✓

When U is 10 the number of coil is more than required minimum number of coils.

Therefore number of coils, $C = 165$.

No of turns / coils $= \frac{Z}{2C}$

$= \frac{990}{2 \times 165} = 3$

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No of turns/coils = 3

Result :- L = 0.177m Z = 990

D = 0.387m