DC Motor Design

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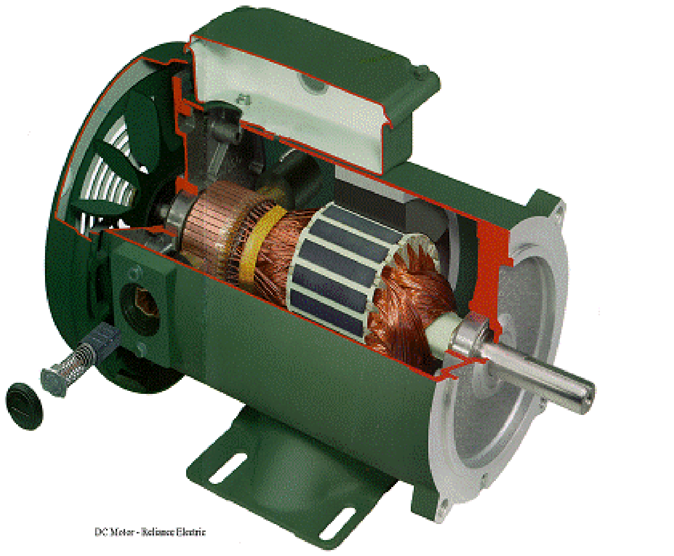

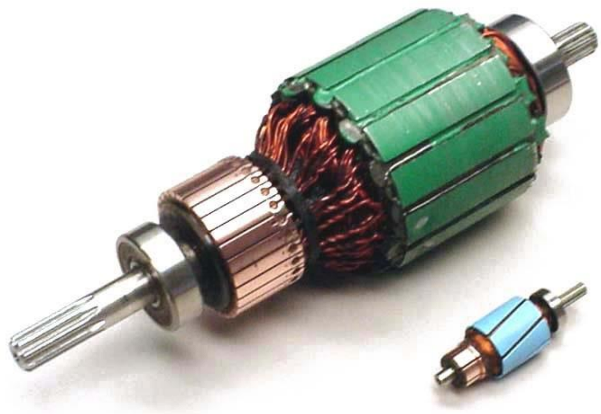

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References:

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DC Machine Design

OUTPUT EQUATION: -

It gives the relationship between electrical rating and physical dimensions (Quantities)
Output of a DC machine

$$Q = E_g \times I_a \times 10^{-3} \qquad KW \qquad ----------------(1)$$

Where

E_g = Generated voltage $= \dfrac{PN\phi Z}{60A}$

$\phi = \bar{B} \times \tau_P \times L = \bar{B} \times \dfrac{\Pi D}{P} \times L$ = Flux per pole

P = No of poles
N = Speed in RPM
Z = Total no of armature conductors
I_a= Armature current

I_Z = Current per conductor $= \dfrac{I_a}{A}$

$Toal\ \ Ampere\ \ Conductors\ \ = Z\, I_Z$

Total Ampere conductors is known as total electric loading

Specific electric loading

It is defined as electric loading per meter of periphery, denoted by $\bar{ac}$.

$$\bar{ac} = \frac{ZI_Z}{\Pi D}$$

Or $\quad ZI_Z = \bar{ac}\ \Pi D$

So put the above values equation (1) can be written as

$$Q = \frac{PN\phi Z}{60A} \times AI_Z \times 10^{-3} \quad KW \quad --------(2)$$

$$Q = \frac{PN}{60A}\phi \times A \times ZI_Z \times 10^{-3} \quad KW$$

$$Q = \frac{PN}{60A}\left(\bar{B} \times \frac{\Pi D}{P} \times L\right) \times A \times \left(\bar{ac}\ \Pi D\right) \times 10^{-3} \quad KW$$

$$Q = \left(16.4 \times 10^{-5}\, \bar{B}\, \bar{ac}\right) D^2 LN \quad KW$$

$$\boxed{Q = C\, D^2 LN \quad KW}$$

Where

$C = Output\ Co-efficient\ = 16.4 \times 10^{-5}\, \bar{B}\ \ \bar{ac}$

D = Inner diameter of stator
L = Length of the IM

$\bar{B}$ = 0.45 to 0.75 T

$\bar{ac}$ = 15000 to 20000 ac/m for 4-20 Kw
= 25000 to 31000 ac/m for 50-200 Kw
= 36000 to 50000 ac/m for >500 Kw

DESIGN PROCEDURE OF DC MACHIN:

1. Estimation of main dimensions (D, L)

We know

$$D^2 L = \frac{Q}{CN} \quad ---------------------- \quad (1)$$

Where $C = Output\ Co-efficient = 16.4 \times 10^{-5} \bar{B}\ \bar{ac}$

$$\left. \begin{cases} \dfrac{L}{\tau_P} = 0.45 \rightarrow 1.1 & : Wide\ range \\ \quad = 1 \rightarrow 1.5 & : Economical\ Design \end{cases} \right\} -------- (2)$$

Note: Selection of no of poles

f = frequency of supply =PN/120= 25-50 Hz, from here calculate the value of no of poles.

Solving equation (1) & (2) we can find out D & L.

2. Check for D & L

Peripheral speed

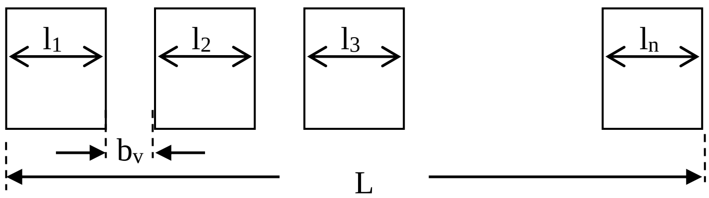
$$V_P = \frac{\Pi DN}{60} < 60\ \ m/\sec$$

3. Length of air gap

$$\delta = (4 \rightarrow 5)\frac{D}{P}$$

4. Find effective length

Ventilating ducts are required when L>12 Cm and for every 7 to 8 Cm, we provide 0.8 cm ventilating duct.



Generally

$l_1 = l_2 = l_3 = \ldots\ldots\ldots = l_n$

Let

n_v =No of ventilating ducts

b_v = Width of one ventilating duct

Gross Iron length

$l = l_1 + l_2 + l_3 + \ldots\ldots\ldots + l_n$

Actual Iron length

$l_i = K_i * l$

Where K_i =Stacking factor

=0.90 to 0.92

Overall length

$L = l + n_v * b_v$

Effective length

$$L_e = L - n_v \times b_v^{'}$$

Where $b_v^{'} = b_v \dfrac{5}{5+\dfrac{b_v}{\delta}}$ =Effective width of ventilating duct (< b_v due to fringing)

5. Design of winding

$$E_g = \frac{PN\phi Z}{60A} \Rightarrow Z = \frac{60A}{PN\phi} E_g$$

$$\phi = \bar{B} \times \tau_P \times L = \bar{B} \times \frac{\Pi D}{P} \times L$$

Armature slots

$$S = \frac{\Pi D}{\tau_{Sg}}$$

$$\tau_{Sg} = Slot\ \ pitch = 15 \rightarrow 20\ \ mm$$

No of conductors per slot

$$N_C = \frac{Z}{S}$$

N_C Must be an integer and divisible by 2 for double layer windings. If not an integer make it integer and hence find the corrected value of N_C that is $N_{C,corrected}$. Also find out the corrected values of followings

$$Z_{corrected}$$

$$\phi_{corrected}$$

$$\bar{B}_{corrected}$$

Armature current

$$I_a = \frac{Q \times 10^3}{E_g}$$

X-sectional area of conductor

$$F_C = \frac{I_a}{\delta (2 \rightarrow 2.5) A / mm^2}$$

6. Design of commutator

No of commutator segments

C= No of coils

No of conductors in parallel path

$$= \frac{Z}{A}$$

No of turns

$$= \frac{1}{2}\frac{Z}{A}$$

$$\text{No of coils} = \frac{\text{Total No of turns in parallel path}}{Tunrs/Coil}$$

Width of each commutator segments

=3 to 4 mm

Mica insulation

=0.8 mm

Dia of commutator

D_C= (0.6 to 0.8) D

The voltage per commutator segment should be between 25 to 30 volts.

7. Find Characteristics

Find out core loss and Cu loss and efficiency

$$\eta = \frac{\text{O/p power}}{\text{O/p power} + \text{Core loss} + \text{Iron loss}}$$

Choice of Pole:

- In ac machines, number of poles are fixed by the relation N=120f/P.
- But in DC machines theoretically any number of poles can be used
- However there is a small range of number of poles which are economically suitable
- Consider that main dimension and specific loading i.e. D, L B_{av}, ac are fixed and that the number of poles may be varied.
- It depends on a number of factors:

1. Frequency: frequency of flux reversal -> should be less
2. Weight of Iron parts of the machine
3. Filed magnets
4. Weight of copper
5. Length of commutator
6. Flash over between brushes
7. Distortion of field from
8. Labour charges