DC Machine Design

OUTPUT EQUATION: -

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

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

Where

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

$¤ = \bar{B} \times ²_P \times L = \bar{B} \times \dfrac{\Pi D}{P} \times L$ = 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

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

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

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

$$Q = \left(1.64 \times 10^{-5}\, \bar{B}\, \bar{ac}\right) D^2 LN \quad KW$$

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

Where

$C = Output\ Co-efficient = 1.64 \times 10^{-5}\, \bar{B}\ \ \bar{ac}$

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

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

Where $C = Output\ Co-efficient = 1.64 \times 10^{-5}\, \bar{B}\ \bar{ac}$

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

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

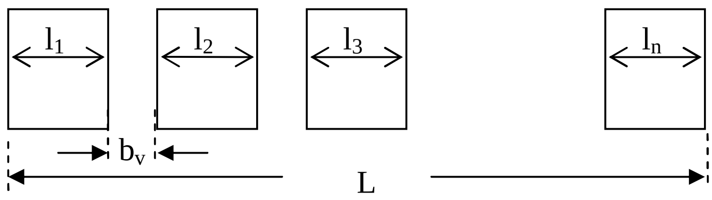
$$\text{¢} = (4 \rightarrow 5)\frac{D}{P}$$

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 $b_v' = b_v \dfrac{5}{5 + \dfrac{b_v}{\text{¢}}}$ =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

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

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

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