UNIT - V

1 A 4 pole 220 V d.c shunt motor, lap wound has 960 conductors. The flux per pole is 20 mWb. Determine the torque developed by the armature and the useful torque in Nm when the current drawn by the motor is 28 A. The armature resistance is 0.1 Ω and the shunt field resistance is 125 Ω. The rotational losses of the machine amounts to 800 watts.

Sol:

$P = 4$, $V = 220$, $Z = 960$, $\phi = 20$ mWb, $I_L = 28$ A,

$R_a = 0.1\ \Omega$, $R_{sh} = 125\ \Omega$

$$I_{sh} = \frac{V}{R_{sh}}$$

$$= \frac{220}{125} = 1.76\ A$$

$$I_a = I_L - I_{sh}$$

$$= 28 - 1.76 = 26.24\ A$$

$$E_b = V - I_a R_a$$

$$= 220 - 26.24 \times 0.1 = 217.376\ V$$

$$E_b = \frac{\phi P N Z}{60 A}$$

$$217.376 = \frac{(20\times10^{-3}) \times 4 \times N \times 960}{60 \times 4}$$

$N = 679.3$ r.p.m

T_a = Torque developed = $\frac{P_m}{\omega} = \frac{E_b I_a}{\frac{2\pi N}{60}}$

$$= \frac{217.376 \times 26.24}{\left(\frac{2\pi \times 679.3}{60}\right)}$$

$= 80.183$ Nm

T_{sh} = useful torque $= T_a - T_{lost}$

$$T_{lost} = \frac{\text{Rotational losses}}{\left(\frac{2\pi N}{60}\right)}$$

$$= \frac{800}{\left(\frac{2\pi \times 679.3}{60}\right)}$$

$= 11.246$ Nm

$T_{sh} = 80.183 - 11.246$

$T_{sh} = 68.9369$ Nm

2. Determine developed torque and shaft torque of 220 V, 4 pole series motor with 800 conductors wave connected supplying and load of 8.2 kW by taking 45 A from the mains. Flux per pole is 25 mWb and its armature circuit resistance is 0.6 Ω

Sol $V = 220,\ P = 4,\ Z = 800.$

$P_{out} = 8.2\ kW \qquad \phi = 25\ mWb$

$I_L = I_a = 45\ A \qquad R_a = 0.6\ \Omega$

$$T_a = \frac{1}{2\pi} \times \frac{\phi Z I_a P}{A}$$

$$E_b = \frac{\phi P N Z}{60 A}$$

$$V = E_b + I_a R_a$$

$$220 = E_b + 45 \times 0.6$$

$$E_b = 193\ V$$

$$193 = \frac{(25 \times 10^{-3}) \times 800 \times N \times 4}{60 \times 2}$$

$N = 289.5$ r.p.m.

$$T_a = \frac{1}{2\pi} \times \frac{25\times10^{-3}\times800\times45\times4}{2}$$

$$= 286.47 \text{ Nm}$$

$$T_{sh} = \frac{P_{out}}{\omega} = \frac{P_{out}}{\left(\frac{2\pi N}{60}\right)}$$

$$= \frac{8.2\times10^3\times60}{2\pi\times289.5}$$

$$\boxed{T_{sh} = 270.48 \text{ Nm.}}$$

3. A 60 kW, 400 V d.c shunt motor has 4 poles and a wave connected armature of 450 conductors. The flux per pole is 45 mwb. $R_a = 0.1\,\Omega$ and $R_{sh} = 200\,\Omega$. If the full load efficiency is 90.5%. find the 1) speed 2) Armature 3) useful torque.

Sol

$P_{out} = 60$ kW, $V = 400$ V, $P = 4$ $\eta_{FL} = 9.5\%$.

$Z = 450$, $\phi = 45$ mwb, $R_a = 0.1\,\Omega$

$R_{sh} = 200\,\Omega$

$$P_{in} = \frac{P_{out}}{\eta} = \frac{60 \times 10^3}{0.905}$$

$$= 66.298 \times 10^3 \text{ W}$$

$$P_{in} = V \times I_L$$

$$I_L = \frac{V}{P_{in}} = \frac{400}{66.298 \times 10^3}$$

$$I_L = 165.745 \text{ A}$$

$$I_L = I_a + I_{sh}$$

$$I_{sh} = \frac{V}{R_{sh}} = 2 \text{ A}$$

$$I_a = 165.745 - 2$$

$$I_a = 163.745 \text{ A}$$

$$E_b = V - I_a R_a$$

$$= 400 - 163.745 \times 0.1$$

$$E_b = 383.6255 \text{ V}.$$

$$E_b = \frac{\phi P N Z}{60 A}$$

$$383.6255 = \frac{45 \times 10^{-3} \times 4 \times N \times 450}{60 \times 2}$$

$N = 568.334$ r.p.m

$$T_a = \frac{E_b I_a}{\omega} = \frac{E_b I_a}{\frac{2\pi N}{60}}$$

$$= \frac{383.6255 \times 163.745}{\frac{2\pi \times 568.334}{60}}$$

$$= 1055.4636 \text{ Nm}$$

Alternatively

$$T_a = \frac{1}{2\pi} \phi I_a \times \frac{PZ}{A}$$

$$= \frac{1}{2\pi} \times 45 \times 10^{-3} \times 163.745 \times \frac{4 \times 450}{2}$$

$$= 1055.4636 \text{ Nm}$$

$$T_{sh} = \frac{P_{out}}{\omega}$$

$$= \frac{60 \times 10^3}{\left(\frac{2\pi \times 568.334}{60}\right)}$$

$$\boxed{T_{sh} = 1008.1357 \text{ Nm}}$$

4. A 4-pole elc motor is lop wound with 400 Conductors. The pole-shoe is 20cm long and the average flux density over one-pitch is 0.4T, the armature diameter being 30 cm. Find the torque and gross-mechanical power develped when the motor is drawing 25A A and running at 1500 rpm.

B = 0.4T over one pole pitch

$$\text{Pole pitch} = \frac{\pi \times \text{Bore diameter}}{P}$$

$$= \frac{\pi \times 30 \times 10^{-2}}{4}$$

$$= 0.2356 \text{ m}$$

Pole shoe = 20 cm

$$\phi/\text{pole} = \text{pole pitch} \times \text{pole shoe} \times B$$

$$= 0.2356 \times 20 \times 10^{-2} \times 0.4$$

$$= 0.0188 \text{ Wb}$$

$$E_b = \frac{\phi P N Z}{60 A}$$

$$= \frac{0.0188 \times 4 \times 1500 \times 400}{60 \times 4}$$

$E_b = 188\ V$

Gross mechnical power $= E_b I_a$

$= 188 \times 25$

$= 4700\ W$

$$T_a = \frac{E_b I_a}{\omega} = \frac{E_b I_a}{\left(\frac{2\pi N}{60}\right)}$$

$$= \frac{4700 \times 60}{2\pi \times 1500}$$

$$\boxed{T_a = 29.921\ Nm}$$

5. The back e.m.f of a shunt motor is 230 V, the field resistance is 160 Ω and field current is 1.5 A. If the line current is 37 A, find the armature resistance. Also find the armature current when the motor is stationary.

Sol

$E_b = 230\ V$, $R_{sh} = 160\ \Omega$ $I_{sh} = 1.5\ A$.

$I_L = 37\ A$

$I_L = I_a + I_{sh}$

$= 37 - 1.5 = 35.5\ A$

$I_{sh} = \frac{V}{R_{sh}}$

$V = 1.5 \times 160 = 240\,V$

$E_b = V - I_a R_a$

$R_a = \frac{240 - 230}{32.5} = 0.2817\,\Omega$

$N = 0$ r.p.m

$E_b \alpha N$ and $E_b = 0\,V$

$V - I_a R_a = 0$

$I_a = \frac{V}{R_a}$

$I_a = \frac{240}{0.2817} = 851.97\,A$

6. A 4 pole, 250 V, d.c. series motor has a wave connected armature with 200 conductors. The flux per pole is 25 mwb when motor is drawing 60 A from the supply. Armature resistance is 0.15 Ω while series field winding resistance is 0.2 Ω. Calculate the speed under this condition

Sol

$P = 4, \quad Z = 200$

$\phi = 25 \times 10^{-3}$ Wb

$I_a = I_L = 60$ A

$R_a = 0.2\,\Omega$

$V = E_b + I_a R_a + I_a R_{se}$

$E_b = 250 + 60(0.15 + 0.2)$

$E_b = 229$ V

$$E_b = \frac{\phi P N Z}{60 Z}$$

$$N = \frac{25 \times 10^{-3} \times 4 \times 229 \times 200}{60 \times 2}$$

$$\boxed{N = 1374 \text{ r.p.m.}}$$

7. A 4 pole series motor has 944 wave-connected armature conductors. At a certain load the flux per pole is 34.6 mWb and the total mechanical torque developed is 209 Nm. Calculate the line current taken by the motor and the speed at which it will run with an applied voltage of 500 V. Total motor resistance is 3 Ω.

sol

P = 4, Z = 944, ϕ = 34.6 mWb, Ta = 207 Nm

V = 500 V and Ra + Rse = 3 Ω

$$T_a = 0.159\, \phi\, I_a \frac{PZ}{A}$$

$$209 = 0.159 \times 34.6 \times 10^{-3} \times I_a\, 4 \times \frac{944}{2}$$

$$I_a = 20.122 \text{ A}$$

$$E_b = V - I_a (R_a + R_{se})$$

$$= 500 - 20.122 \times 3$$

$$= 439.634 \text{ V}$$

$$E_b = \frac{\phi P N Z}{60 A}$$

$$N = \frac{34.6 \times 10^{-3} \times 4 \times 439.634 \times 944}{60 \times 2}$$

$$\boxed{N = 403.798 \text{ r.p.m}}$$

8. A 220 V, 7.5 kW Series motor is mechanically coupled to a fan. When running at 400 r.p.m the motor draws 30 A from the main (220 A). The torque required by the fan is proportional to the squares of speed Ra = 0.6 Ω, Rse = 0.4 Ω

Neglect armature reaction and rotational loss. Also assume the magnetization characteristics of the motor to be linear.

1) Determine the power delivered to the fan and torque develped by the motor.

2) calculate the external loss. Also the magnetization resistance to be added in series to the armature circuit to reduce the fan speed to 200 r.p.m.

Sol

$T \alpha N^2$ $R_a = 0.6\,\Omega$ $R_{se} = 0.4\,\Omega$, $V = 220\,V$

$N = 400$ r.p.m $I_a = 30\,A$

$$E_b = V - I_a(R_a + R_{se})$$

$$= 220 - 30(0.6 + 0.4)$$

$$E_b = 190\,V$$

$$T = \frac{E_b I_a}{\omega} = \frac{E_b I_a}{\left(\frac{2\pi N}{60}\right)}$$

$$= \frac{5700}{\left(\frac{2\pi \times 400}{60}\right)} = 136.077\,Nm$$

$N_2 = 200$ r.p.m

$N_1 = 400$ r.p.m

$I_{a1} = 30A$

Series motor $T \alpha I_a^2$ and $T \alpha N^2$.

$$N^2 \alpha I_a^2$$

$$\left(\frac{N_1}{N_2}\right)^2 = \left(\frac{I_{a1}}{I_{a2}}\right)^2$$

$$\left(\frac{400}{200}\right)^2 = \left(\frac{30}{I_{a2}}\right)^2$$

$$I_2 = 15\ A$$

$$E_{b2} = V - I_{a2}(R_a + R_{se} + R_x)$$

$$= 200 - 15(1 + R_x)$$

Series motor, $\phi \alpha I_a$

$$N \alpha \frac{E_b}{\phi}$$

$$\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{I_{a2}}{I_{a1}}$$

$$E_{b1} = 190\ V$$

$$\frac{400}{200} = \frac{190}{[220-15(1+R_x)]} \times \frac{15}{30}$$

$$\boxed{R_x = 10.5\ \Omega}$$

9. A 15 kW, 250V, 1200 r.p.m shunt motor has 4 poles, 4 parallel armature path and 900 armature conductor. Assume $R_a = 0.2\ \Omega$. At rated speed and rated output the armature current is 75 A and $I_f = 1.5$ A. Calculate i) The flux/pole ii) The torque develped iii) Rotational losses iv) efficiency (v) The shaft load (vi) If shaft load remains fixed but the field flux is reduced to 70% of its value by field control determine the new operating speed.

Sol

$V = 250V$, $N = 1200$ r.pm $P = 4$, $Z = 900$, $R_a = 0.2\ \Omega$

$I_a = 75$ A, $I_f = 1.5$ $P_{out} = 15$ kW

i) $E_b = V - I_a R_a$

$= 250 - 75 \times 0.2$

$E_b = 235$ V

$$E_b = \frac{\phi P N Z}{60A}$$

$$\phi = \frac{E_b \times 60A}{PNZ}$$

$$\phi = \frac{235 \times 60 \times 4}{4 \times 1200 \times 900}$$

$$= 0.01305 \text{ wb}$$

(ii) $T_a = \frac{1}{2\pi} \frac{PZ}{A} \phi I_a$

$$= \frac{1}{2\pi} \times \frac{4 \times 900}{4} \times 0.01305 \times 75$$

$$T_a = 140.1956 \text{ Nm}$$

(iii) P_m = Mechanical power developed $= E_b I_a$

$$= 235 \times 75$$

$$P_m = 17625 \text{ W}$$

Rotational losses $= P_m - P_{out}$

$$= 17625 - 15 \times 10^3$$

$$= 2625 \text{ W}$$

(iv) $P_{in} = V \times I_L = V \times (I_a + I_f)$

$$= 250 \times [75 + 1.5]$$

$$P_{in} = 19125 \text{ W}$$

$$\% \eta = \frac{P_{out}}{P_{in}} \times 100$$

$$= \frac{15 \times 10^3}{19125} \times 100 = 78.4313\%$$

v) $\phi_2 = 70\%$ of ϕ_1 $\quad \phi_2 = 0.7\,\phi_1$

$$T \propto \phi I_a$$

$$\frac{T_1}{T_2} = \frac{\phi_1}{\phi_2} \times \frac{I_{a1}}{I_{a2}} = 1$$

$$\frac{1}{0.7} \times \frac{75}{I_{a2}} = 1$$

$$I_{a2} = 75 \times \frac{1}{0.7}$$

$$= 107.1428\ A$$

$$E_{b2} = V - I_{a2} R_a$$

$$= 250 - 107.1408 \times 0.2$$

$$= 228.5714\ V$$

$$N \propto \frac{E_b}{\phi}$$

$$\frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{\phi_1}{\phi_1}$$

$$\frac{1200}{N_2} = \frac{235}{228.5714} \times 0.7$$

$$\boxed{N_2 = 1667.3901\ \text{r.p.m}}$$

10. A 4 pole d.c motor takes a 50 A armature current. The armature has lap connected 480 conductors. The flux pole is 20 mwb. Calculate the gross torque developed by the armature of the motor.

Sol

$P=4 \quad A=4 \quad Z=840, \quad \phi=20\,mwb, \quad I_a\ 50A$

$$T_a = 0.159 \times \phi I_1 \cdot \frac{PZ}{A}$$

$$= 0.159 \times (20 \times 10^{-3}) \times 50 \times \frac{4 \times 480}{4}$$

$$\boxed{T_a = 76.394\ Nm}$$

12. A 4 pole, d.c motor has lap connected armature winding. The flux per pole is 30 mWb. The number of armature conductor is 250. When connected to 230 V d.c supply it draws an armature current of 40 A. Calculate the back emf the speed with which motor is running. Assume armature resistance is 0.6Ω

Sol:

$P=4 \quad V=230V, \quad Z=250 \quad \phi=30\,mWb,$

$I_a = 40A$

$V = E_b + I_a R_a$

$E_b = 230 + 40 \times 0.6$

$E_b = 206\,V$

$E_b = \frac{\phi P N Z}{60 A}$

$N = \frac{30 \times 10^{-3} 4 \times 206 \times 250}{60 \times 4}$

$\boxed{N = 1648 \text{ r.p.m.}}$