Example 2 : For example 1 determine input current, input power, power factor, developed torque, output shaft power, shaft torque, efficiency of the motor, airgap power, rotor cupper losses, stator cupper losses, if the motor is running at rated speed

solution 1/4 h.p., 4P, 120 V, 60 Hz, 1730 rpm, $R_1 = 2.9\,\Omega$, $R_2 = 2.7$, $X_m = 55.72\,\Omega$
$X_1 = X_2 = 3.26\,\Omega$

$f = 60$ Hz, $P = 4$, $n_s = 60 f / P_p = 60 \times \frac{60}{2} = 1800$ rpm

$$S = \frac{n_s - n_r}{n_s} = \frac{1800 - 1730}{1800} = 0.0389$$

$$Z_f = j0.5(55.72) \,//\, \left(0.5 \cdot \frac{2.7}{0.0389} + j0.5(3.26)\right)$$

$$= j27.86 \,//\, (34.7 + j1.63)$$

$$= 12.988 + j16.822 \ \Omega$$

$$Z_b = j27.86 \,//\, \left(0.5 \cdot \frac{2.7}{2 - 0.0389} + j1.63\right)$$

$$= j27.86 \,//\, (0.688 + j1.63)$$

$$= 0.6137 + j1.554 \ \Omega$$

$$Z_i = R_1 + jX_1 + R_f + jX_f + R_b + jX_b$$

$$= 2.9 + j3.26 + 12.988 + j16.822 + 0.6137 + j1.554$$

$$= 16.5 + j21.636 \ \Omega$$

$$= 27.21 \angle 52.67^\circ$$

$$I_1 = \frac{V_1}{Z_i} = \frac{120}{27.21 \angle 52.67} = 4.41 \angle -52.67^\circ \ A$$

$$p.f = \cos 52.67 = 0.606 \text{ lagging}$$

$$P_i = V_1 I_1 \cos\theta = 120 \times 4.41 \times 0.606 = 320.7 \ W$$

$$\text{developed torque} = T = \frac{1}{\omega_s}(P_{gf} - P_{gb})$$

$$P_{gf} = I_1^2 R_f = (4.41)^2 \times 12.988 = 252.83 \ W$$

$$P_{gb} = I_1^2 R_b = (4.41)^2 \times 0.6137 = 11.94 \ W$$

$$\therefore T = \frac{1}{2\pi \times \frac{1800}{60}}(252.83 - 11.94) = 1.28 \ N.m$$

$$\text{mechanical developed power} = P_m = (1-s)(P_{gf} - P_{gb})$$

$$\therefore P_m = (1-0.0389)(252.83 - 11.94) = 0.9611 \times 240.89$$

$$= 231.52 \ W$$

or $P_m = T.\omega_r = 1.28 \times 2\pi \times 1730/60$

$$\text{output shaft power} = P_o = P_m - P_{rot}$$

$$\therefore P_o = (231.52 - 72.94) = 158.58 \ W$$

$$\text{shaft torque} = T_o = P_o / \omega_r = \frac{158.58}{2\pi \times 1730/60}$$

$$= 0.875 \ N.m$$

$$\text{Efficiency} = \frac{P_o}{P_i} \times 100\% = \frac{158.58}{320.7} \times 100\% = 49.45\%$$

airgap power $= P_{sr} = P_{gf} + P_{gb} = 252.83 + 11.94 = 264.77$ W

Rotor cuppor losses $= RCL = sP_{gf} + (2-s)P_{gb}$

$\therefore \quad RCL = 0.0389 \times 252.83 + (2-0.0389) \times 11.94 = 33.25$ W

note that :-

$P_{sr} = P_m + RCL = 231.52 + 33.25 = 264.77$

$SCL = I_1^2 R_1 = 4.41^2 (2.9) = 56.4$ W

$P_i = SCL + P_{sr}$

$= 56.4 + 264.77$ W

Example 3 ; (reference : baghdad university midyear exams 1993)

The no-load losses at 1/6 hp , 4 pole , 110 V , 60 Hz , single phase I.M are 25 W. At full load slip of 6% the rotor capper losses are 50 W. Neglecting stator copper losses calculate the efficiency of the motor & copper losses caused by forward field at full-load.

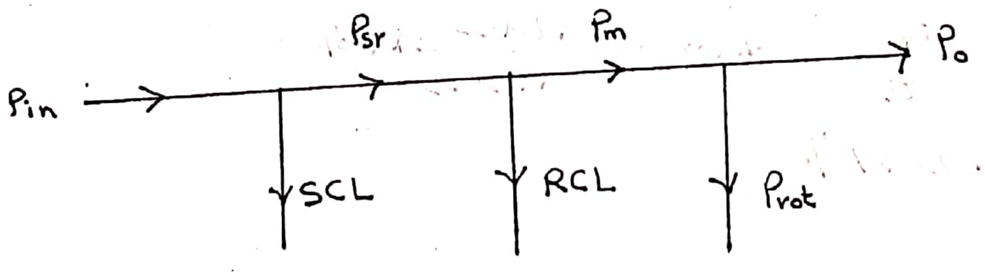
Solution

$P_o = \frac{1}{6} \times 746 = 124.33$ Watt

« since it is at full load »
$P_{NL} = I_1^2 (R_1 + 0.5R_2 + R_{rot})$
$= I_1^2 R_{rot}$
$= P_{rot}$

$P_o = P_m - P_{rot}$

$\therefore P_m = P_o + P_{rot} = 124.33 + 25 = 149.33$ W



$$P_m = (1-S)(P_{gf} - P_{gb})$$
$$= 0.94\,P_{gf} - 0.94\,P_{gb}.$$
$$\therefore\ 149.33 = 0.94\,P_{gf} - 0.94\,P_{gb} \quad \text{--- (1)}$$

$$RCL = RCL_f + RCL_b$$
$$= S P_{gf} + (2-S) P_{gb}$$
$$\therefore\ 50 = 0.06\,P_{gf} + 1.94\,P_{gb} \quad \text{--- (2)}$$

$$P_{gf} = \frac{\begin{vmatrix} 149.33 & -0.94 \\ 50 & 1.94 \end{vmatrix}}{\begin{vmatrix} 0.94 & -0.94 \\ 0.06 & 1.94 \end{vmatrix}} = \frac{149.33 \times 1.94 + 0.94 \times 50}{0.94 \times 1.94 + 0.94 \times 0.06}$$

$$= \frac{336.7}{1.88} = 179.1 \text{ Watt}$$

$$RCL_f = S.P_{gf} = 0.06 * 179.1 = 10.746 \text{ W}$$

$$P_{sr} = P_m + RCL$$
$$= 149.33 + 50 = 199.33 \text{ W}$$

$$P_i = SCL + P_{sr}$$
$$= \text{zero} + P_{sr}$$
$$= P_{sr} = 199.33 \text{ W}$$

$$\eta = \frac{P_o}{P_i} \times 100 = \frac{124.33}{199.33} \times 100\%$$
$$= 62.37\ \%$$