

## EEE202 – Answers 2012/2013 Resit

Qu 1.

a.) m.m.f = Reluctance  $\times$  flux, Therefore:  $N.I = \text{Reluctance of airgap} \times \phi$

$$\therefore N.I = \frac{x}{\mu_o dh} \times \phi$$

Therefore

$$\phi = \frac{N.I}{\frac{x}{\mu_o A}} = \frac{NI\mu_o dh}{x}$$

Hence, inductance,

$$L = \frac{\phi}{I} = \frac{N\phi}{I}$$

so:

$$L = \frac{N^2 \mu_o dh}{x}$$

and the force on the iron core is given from:

$$F = \frac{1}{2} I^2 \frac{dL}{dx}$$
$$\therefore F = \frac{1}{2} I^2 \left( -\frac{N^2 \mu_o dh}{x^2} \right)$$

As requested:

$$\therefore F = -\frac{1}{2} \cdot \frac{I^2 N^2 \mu_o dh}{x^2}.$$

b) When locked,  $X=6\text{mm}$ , therefore current at this point, given the force needs to overcome a constant 2Nm torque, is: 3.4A

When Unlocked,  $X=3\text{mm}$ , therefore the current at this position is: 1.7A

c). The advantage of having different current levels to lock and unlock the system is that there will be some hysteresis in the current required to operate the system. Once the system starts to lock, for example, the current requirement will drop and the system will continue to lock, the current then has to be reduced significantly before the system then unlocks. There is therefore no uncertainty in the state of the lock.

Qu 2.

a) Examining the profile given, and assuming the application of paint has just finished at time  $t=0$ , the system then accelerates the component from standstill to  $0.5\text{ms}^{-1}$  in 1 second, covering 0.25m of distance, and from  $t=1$  to  $t=1.5$  a further 0.25m of distance is covered leading to the component exiting the machine at position C. At the same time another component enters the machine at position A (at  $t=1.5\text{sec}$ ) This component is then transported 0.25m at the same speed (0.5sec) until  $t=2\text{sec}$ , then the component is decelerated to standstill in a further second (covering a further 0.25m). This leaves the component at position B where it remains for 1 sec whilst it is painted. The cycle then repeats.

b) Total inertia of motor and load =  $0.32\text{kgm}^2$   
Acceleration from  $t=0$  to  $t=1$  is  $0.5\text{ms}^{-2}$ , and  $T=J.a$

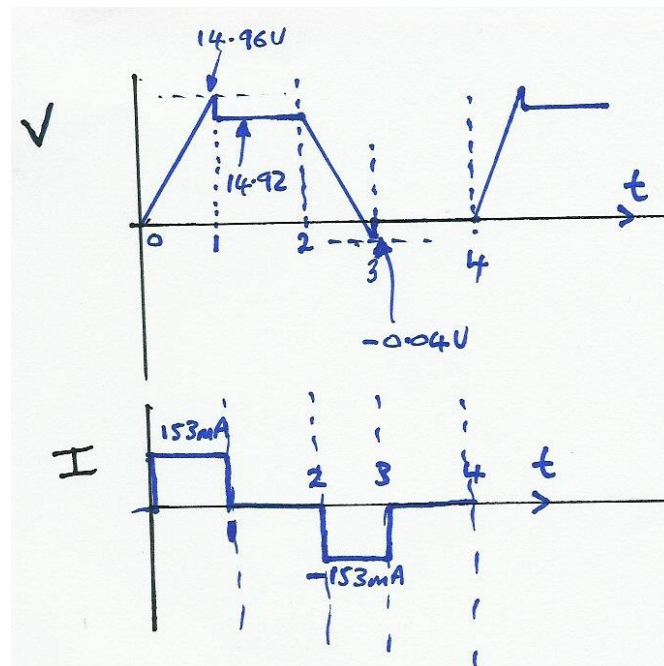
Therefore Torque required =  $0.16\text{Nm}$

$K_m = 100\text{V} / 1000\text{rpm} = 0.955\text{V/rad}$  or  $0.955\text{Nm/A}$

This gives a current requirement of  $0.16 \times 0.955 = 152.8\text{mA}$ .

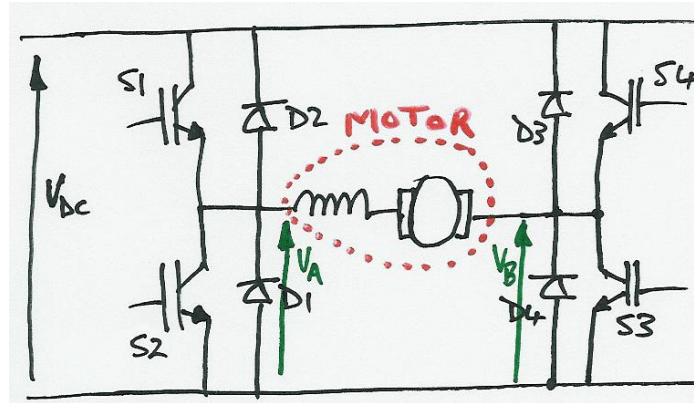
As  $v=r\omega$ ,  $\omega=0.5/0.032 = 15.63 \text{ rad/sec}$ , which gives a back emf of  $14.92\text{V}$ . The applied voltage should therefore be given by  $V=I \times R + E$ , and be  $V=14.92+0.1528 \times 0.25$ , giving a voltage of:  $14.96\text{V}$

c)



The motor specified is adequate, if not a little over-specified.

d) A suitable power electronic servo amplifier would be a 4-quadrant chopper:



e) Continuous stall torque rating is a rating which is determined by the thermal ratings of the motor. The motor is capable of sustaining the losses correspondent to the continuous stall torque continuously. The maximum torque rating of the motor is the maximum short-term torque rating of the motor, and is usually specified by the demagnetisation withstand of the motor design. The motor cannot operate at this level continuously as it would overheat.

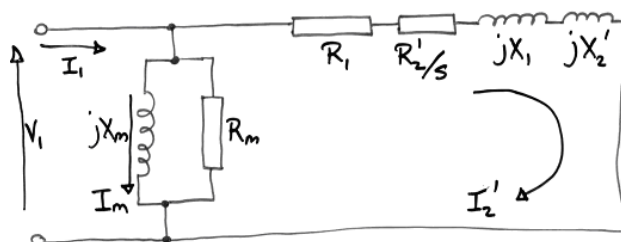
Qu 3.

a) As below:

- $R_1$  = STATOR RESISTANCE PER PHASE
- $R'_2$  = REFERRED ROTOR RESISTANCE /  $\phi$
- $X_1$  = STATOR LEAKAGE REACTANCE /  $\phi$
- $X'_2$  = REFERRED ROTOR LEAKAGE REACTANCE /  $\phi$
- $X_m$  = MAGNETIZING REACTANCE /  $\phi$
- $R_m$  = IRON LOSS RESISTANCE /  $\phi$  (19)
- $V_1$  = RMS SUPPLY PHASE VOLTAGE /  $\phi$
- $E_1$  = INDUCED STATOR PHASE VOLTAGE
- $I'_2$  = REFERRED ROTOR CURRENT
- $I_m$  = MAGNETIZING CURRENT
- $I_1$  = STATOR CURRENT.

#### APPROXIMATE EQUIVALENT CIRCUIT

ASSUME  $E_1 = V_1$  ACCURACY 1-2%  
FOR A TYPICAL MACHINE



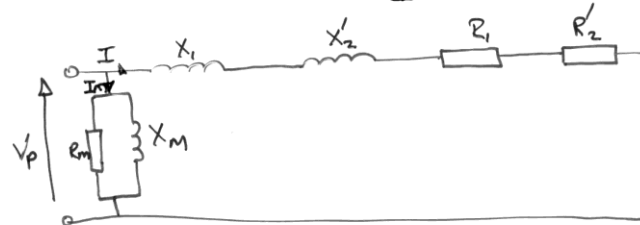
The locked rotor test is:

## LOCKED ROTOR TEST

(12)

REDUCED VOLTAGE APPLIED TO INDUCTION MOTOR WITH ROTOR LOCKED TO PREVENT ROTATION.

MEASURE  $V_1$  AT  $I_{\text{RATED}}$



USUALLY  $I_m \ll I$  as  $Z_m \gg Z$

$\therefore$  IGNORE THE MAGNETIZING BRANCH

MEASURE INPUT POWER

$$\Rightarrow R_1 + R_2' = \frac{P_{LR}}{3I^2} \quad R_1 \text{ MEASURED}$$

$\therefore R_2'$  CALCULATED

$$\text{ALSO } \frac{V_p}{I} = \sqrt{X_T^2 + R_T^2} \quad \text{WHERE } R_T = (R_1 + R_2')$$

MAY THEN FIND  $X_T'$ , CAN THEN USE GIVEN EQUATIONS TO FIND MAX PULL-OUT TORQUE AT GIVEN VOLTAGE FOR MAX LOAD

b) As  $V_L = 80V$ ,  $I = 20A$ , and  $P = 2kW$  with  $R_1 = 0.4\Omega$ , then:

$$R_2' = 1.27\Omega,$$

$$\text{Also, } X_T = 1.6\Omega$$

From these values, the pull-out torque is

$$T_{\text{PULL-OUT}} = \frac{3p V_1^2}{2\pi f_1} \frac{\sqrt{R_1^2 + (X_1 + X_2')^2}}{(R_1 + \sqrt{R_1^2 + (X_1 + X_2')^2})^2 + (X_1 + X_2')^2}$$

Therefore with a 25% reduction of supply voltage, the line voltage is 311.25V

Giving a pull-out torque of  $T_{\text{Pull out}} = 537Nm$ . If the torque is lower than this, the machine will not pull out under the worst case voltage of a 25% dip in line voltage.

Qu 4

a) Force on a wire in a magnetic field is  $F = B \times I \times L$ , The length of interaction of the coil and the field is  $L = \pi D$ , Thus, the total force is:

$$F = BI\pi DN$$

where N is the number of turns on the coil.

b) As the 'motor' constant is given by  $F = (BN\pi D)I$

$K_e = 10.05\text{Nm/A}$ , and if mechanics are dominated by the mass of coil and diaphragm, then the equivalent capacitance of this is  $C = \frac{M}{K_e^2}$

This gives an equivalent capacitance of  $59.7\mu\text{F}$

The inductance of the winding is given as  $172\text{mH}$ , therefore the resonance of the system is  $49.8\text{Hz}$  or approximately  $50\text{Hz}$ .

c) When the actuator is supplied by a  $12\text{V}_{\text{rms}}$  voltage, then the current is governed in a series resonant circuit by the resistance at resonance, which is given as  $140\Omega$ . This therefore gives a supply input current of  $12/140 = 86\text{mA rms}$ .

d) The back emf of the actuator is the current across the equivalent capacitance in the equivalent circuit. As  $50\text{Hz}$  with  $86\text{mA}$  flowing in it, this is  $E = 4.6\text{V}_{\text{rms}}$  or  $6.5\text{V}_p$

$$\begin{aligned} Dist &= \int_0^{10 \times 10^{-3}} 0.65 \sin(100\pi t) \\ &= \left[ \frac{0.65}{100\pi} \cos(100\pi t) \right]_0^{10 \times 10^{-3}} \end{aligned}$$

Therefore  $\text{Dist} = 4.1\text{mm}$  This is peak to peak displacement of the plunger. Given a plunger diameter of  $50\text{mm}$ , the volume swept out per cycle is  $8.05 \times 10^{-6} \text{ m}^3$  Given  $50$  cycles per second, the total volume of air pumped per cycle becomes  $4 \times 10^{-4} \text{ m}^3$  per second. Given that  $1\text{Litre}$  is  $1000\text{cm}^3$  and the volume pumped is  $4 \times 10^2 \text{ cm}^3$ , the volume of air pumped is  $0.4\text{L} / \text{sec}$  which equates to  $24 \text{ L/min}$ .