Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2012-13 (2.0 hours)

EEE6022 Motion Control and Servo Drives 6

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. **a.** Figure 1 shows the schematic of a tape drive using a hollow capstan with outer radius R. The inertia of the capstan J_c is given by:

$$J_c = kR^3$$

where k is a constant. Show that the required torque rating of the motor will be a minimum when the capstan radius R is equal to the cubic root of the motor inertia J_m divided by $2k$, if the friction and other inertia in the system are negligible, i.e.

$$R = \sqrt[3]{\frac{J_m}{2k}}$$ **(7)**

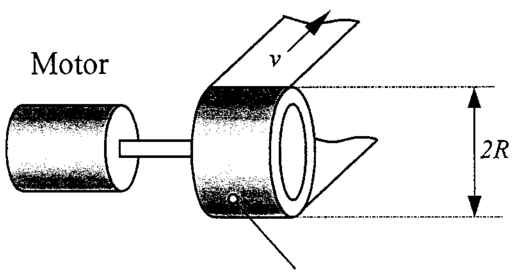

Fig. 1

b. If the motor inertia is 1.2×10^{-3} kgm^2, determine the inertia of the capstan at the optimal condition **(2)**

c. If the torque constant and armature resistance of the motor are 0.9 Nm/A and 0.5 Ω, respectively, and the tape drive is to accelerate from standstill to 1 m/s in ten milliseconds, calculate the voltage and current requirements of the drive, given that the capstan radius is 0.1m. **(5)**

d. The same drive is required to move 0.02 m in every 0.015 s via a trapezoidal velocity profile, determine the peak voltage and current ratings of the drive. Would the motor overheat if its rms torque rating is 6.0 Nm? Justify you answer. **(6)**

2. A permanent-magnet dc servomotor with the following parameters

rated torque = 5Nm
rated current = 10A
armature resistance $R_a = 0.40\Omega$
armature inductance $L_a = 3.2$ mH
moment of inertia $J_m = 4.0\text{x}10^{-3}$ kgm^2
viscous friction coefficient $B \approx 0.0$

is connected to a mechanical payload with an moment of inertia of $2.5\text{x}10^{-3}$ kgm^2 via a 2:1 reduction gearbox.

a. Calculated the motor terminal voltage v_t in steady state for a payload torque of 5 Nm at a speed of 1500 rpm. If the payload torque is increased to 10 Nm, what is the additional voltage required in steady state in order to maintain the same payload speed at 1500rpm? **(4)**

b. If the motor is connected to a 200V dc supply via an H-bridge converter operating in the unipolar mode at 20 kHz switching frequency, calculate the duty ratio of the pulse width modulation and the current ripple in steady state for a payload torque of 5 Nm at a speed of 1500 rpm. **(6)**

c. Sketch the transfer function block diagram between the motor voltage, $v_t(s)$, and the payload speed, $\omega(s)$, and calculated the electrical and mechanical time constants of the drive system. **(5)**

d. If the gain of the H-bridge converter is 20, design a PI current controller to yield a first order closed-loop response with a time constant of 1.0 ms. **(5)**

3. A sinusoidal waveform permanent magnet servomotor has the following parameters

Number of pole pairs = 2

Phase resistance = 4.2 Ω
Phase inductance = 4.8 mH

Voltage constant (the ratio of rms phase voltage induced to the speed of rotation) = 25 V/krpm

Moment of inertia = 0.005kgm^2

a. Calculate the no-load peak flux linkage of a phase winding, and the torque constant of the motor. **(2)**

b. Sketch the per phase equivalent circuit diagram of the motor, and show that the electromagnetic torque of the motor is given by:

$$T_{em} = \frac{3p\Psi_m}{\sqrt{2}} I sin\delta$$

where p is the number of pole-pairs, Ψ_m is the no-load peak flux linkage, I is the rms phase current and δ is the angle between the current and the flux linkage.

Suggest how the motor should be controlled for high efficiency operation. **(6)**

c. Sketch the d-q axis transfer function block diagram of the motor, and specify the parameters of each block. **(4)**

d. Design d-q axis proportional and integral (PI) current controllers with decoupling compensation to yield a first order response with a time constant of 1.0 ms. **(8)**

4. A three-phase, 4-pole star-connected induction motor has a rated speed of 1450 rpm, when operating from a 415V, 50Hz supply. The machine has the following parameters measured at 50Hz and referred to the stator:

Magnetising reactance	= 48.6 Ω
Stator resistance	= 0.35 Ω
Rotor resistance	= 0.55 Ω
Stator leakage reactance	= 1.20 Ω
Rotor leakage reactance	= 0.95 Ω

a. Sketch the per phase equivalent circuit diagram of the motor. **(3)**

b. Describe the principle of operation for scalar speed control in which the ratio of the phase voltage V_s to the supply frequency f is maintained constant, i.e., $V_s/f =$ constant, and explain why the motor torque capability with such a control scheme deteriorates at low speeds. **(8)**

b. If the motor operates at 50% rated torque, calculate the rotor speed, stator current, power factor, air-gap flux linkage, and efficiency. **(9)**

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