MECH ENG 4H03 Practice Problem Set 2

1. A single rod pneumatic cylinder will be used to move a mass horizontally in both directions at a speed of 1.5 m/s. The cylinder must overcome a friction force of 300 N during its motion. The inertia force is relatively small and can be neglected. The rod diameter is 12 mm, the supply pressure is 5×10^5 Pa gauge and the air temperature is 20°C. If a pressure drop of 6×10^4 Pa across the valve is desired, determine:
   (a) The minimum bore diameter required.
   (b) The minimum valve flow coefficient required.

   Assume that the pressure drop across the valve is the same for the return flow as for the intake flow and that the air is returned to the atmosphere.

2. You are designing a machine for translating a 40 kg mass horizontally. The mass slides on a linear bearing with a coefficient of friction of 0.02. Its operating cycle should be as follows: accelerate (starting from rest) until it reaches a velocity of 0.6 m/s, then decelerate to a stop, and remain idle for 2 s. The total displacement of the mass should be 0.3 m. The durations of the acceleration and deceleration periods should be the same. The linear motion of the mass will be obtained by coupling the motor to a gearbox that drives a pulley and a timing belt. The pulley has a 0.075 m pitch diameter. The inertias of the belt, gearbox and pulleys may be neglected. The ambient temperature is 25 ^{o}C. You may assume the torque ratings are independent of the speed and that the friction of the motor, gears and timing belt may be neglected.

   a) Find the acceleration and acceleration duration required for the given operating cycle.

   b) For Motor B given in the table below, determine the best gear ratio for this application using the method of section 3.4.3. The available gear ratios are 2, 4, 6, etc. Check that the resulting motor speed, torques and temperature are within their rated values.

	Motor A	**Motor B**
Moment of inertia (kgm^2)	1.34×10^{-5}	1.31×10^{-4}
Max. speed (rpm)	7000	3400
Max. torque (Nm)	2.5	15.5
Max. continuous torque (Nm)	0.2	0.8
Torque constant (Nm/A)	0.06	0.2
Temperature limit (^{o}C)	150	150
Resistance at temperature limit (ohm)	1.68	1.33
Total thermal resistance (^{o}C/W)	6.6	3.15

3. A 20 kg mass is to be translated vertically. It is subject to a10 N friction force. Its operating cycle should be as follows: accelerate (starting from rest) to a velocity of 0.35 m/s in 0.05 s, move at 0.35 m/s for 1.15 s, decelerate to a stop in 0.05 s, remain idle for 0.5 s, accelerate to -0.7 m/s in 0.1 s, move at -0.7 m/s for 0.5 s, decelerate to a stop in 0.1 s, and remain idle for 0.2 s. A positive velocity indicates upwards motion. The linear motion of the mass will be obtained by coupling a DC motor to a gearbox that drives a ball screw with a 0.02 m lead. The moment of inertia of the screw is $1.0\times10^{-4}\ \mathrm{kgm}^2$. The inertia of the gearbox may be neglected. The ambient temperature is 30 ^{o}C. You may assume the torque ratings are independent of the speed and that the friction of the motor, gears and ball screw may be neglected.

   a) If a 500 pulse/rev incremental encoder and quadrature counting are used, what is the linear resolution of the actuator in mm?

   b) Calculate and plot the desired velocity and acceleration profiles.

   c) For Motor A from the table on page 1, determine the best gear ratio for this application using the method of section 3.4.3. The available gear ratios are 0.5, 1, 1.5, etc. Check that the resulting motor speed, torques and temperature are within their rated values.

   d) If Motor A is not suitable then repeat part (d) for Motor B from the table.

   e) The machine is to be redesigned. The ball screw should be replaced with a rack and pinion, where the pitch diameter of the pinion is 0.05 m. You may assume that the friction and inertias of the rack and pinion are negligible. For Motor B, determine the best gear ratio for this application using the method of section 3.4.3. The available gear ratios are 0.5, 1, 1.5, etc. Check that the resulting motor speed, torques and temperature are within their rated values.

   f) Could part (e) be solved by using a different pinion pitch diameter without a gearbox between the motor and pinion? Justify your answer.

4. An actuator consists of a stepper motor and a ball screw with a 5 mm/rev lead. The stepper motors has a resolution of 150 full steps/rev. Calculate the linear resolution of the actuator in mm for:

   a) Full stepping, b) Half stepping and c) Microstepping.

   d) If the ball screw has a repeatability of $\pm$0.002 mm, comment on the meaningfulness of your three answers (a, b and c) for resolution.

5. A machine should translate a mass horizontally using a double rod hydraulic cylinder. Using piecewise constant acceleration, the mass should be moved as fast as possible from one fixed location to another. The bore diameter is 35 mm, the rod diameter is 25 mm, the supply pressure is 1.1×10^7 Pa absolute and the density of the oil is 900 kg/m^3. The mass is 800 kg and the desired acceleration magnitude is 3 m/s^2. Assume that the pressure drop across the valve is the same for the return flow as for the intake flow and that the sump is open to the atmosphere.

   Determine:

   (a) The minimum valve flow coefficient required if the motion range (or stroke) equals 2.5 m.

   (b) The minimum movement time for this 2.5 m stroke.

6. A rodless pneumatic cylinder will be used to move a 5 kg mass vertically. The bore diameter is 30 mm, the supply pressure is 5×10^5 Pa absolute and the air temperature is 20°C. Assume that the pressure drop across the valve is the same for the return flow as for the intake flow and that the air is returned to the atmosphere.

   If the flow coefficient for the valve is 0.15, determine:

   (a) The maximum speed when moving upwards (assuming the stroke is not the limiting factor).

   (b) The maximum speed when moving downwards (assuming the stroke is not the limiting factor).

Hint: The maximum speed will be reached when the sum of the forces acting on the mass equals zero.