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CS/M.TECH(ME)/SEM-2/ME-201/2010

2010

MECHATRONIC SYSTEM DESIGN

Time Allotted : 3 Hours Full Marks : 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Answer any *five* questions taking at least *one* question from each Part.

PART - A

1. a) State the factors which affect the cylinder piston acceleration. 3

   b) Distinguish between 'repeatable error' and 'tracking error'. 2

   c) Calculate the tube thickness of a hyraulic cylinder having dimensions as given below :

   Tensile strength of cylinder material = 7300 kgf / cm ^{2} .

   Cylinder bore = 50 mm

   System pressure = 200 kgf /cm ^{2}

   Factor of safety = 4. 4

d) Determine the safe load for a double acting hydraulic cylinder with two ends pivoted and guided and piston diameter = 140 mm, rod diameter = 70 mm, equivalent length = 1000 mm, factor of safety = 4, modulus of elasticity = 24×10^5 N/cm^2 . 5

2. a) Draw and explain the working principle of a ladder diagram for a dual cylinder sequencing circuit with two limit switches. 6

b) Draw a hydraulic circuit which has been designed to crush a car body into a bale size. For supply of emergency pressurized fluid an accumulator may be incorporated. In that circuit take a 160 mm diameter hydraulic cylinder which is to extend 3·0 m during a period of 20 secs. The time between crushing strokes is 8 minutes.

The following accumulator gas absorb pressures are given :

P_1 = Gas charge pressure = 90 bars

P_2 = Gas charge pressure when pump is turned on = 180 bar abs pressure relief valve setting.

P_3 = Minimum pressure required to actuate load = 100 bars abs.

i) Calculate the required size of the accumulator.

ii) What are the pump hydraulic kW power and flow required with or without an accumulator. 8

PART - B

3. a) Write the general statement for constant optimization problem. 4

b) Minimize $f = -4x_1 - 5x_2$

subject to

$$-x_1 + x_2 \leq 4$$

$$x_1 + x_2 \leq 6$$

$$x_1 \geq 0, x_2 \geq 0.$$

Use simplex method to solve the problem. 10

4. a) State the optimality criterion for gradient based search method. 4

b) Minimize $f(x_1, x_2) = 12{\cdot}09\, x_1^2 + 21{\cdot}504\, x_2^2 - 1{\cdot}732\, x_1 - x_2$

starting from the point $\bar{X} = \begin{Bmatrix} 1 \\ 1 \end{Bmatrix}$

Show two iterations. 10

PART - C

5. a) Consider a 4-bar linkage with its shortest link of 3 cm length. The link opposite to the shortest one is 10 cm long. The links adjacent to the shortest one are 12 cm and 8 cm long. Find all the inversions of the chain. 7

b) If a flat belt is being driven by a flat pulley, prove that $\frac{T_1}{T_2} = e^{\mu\theta}$,

where T_1 and T_2 are the tensions in belt in the tight and loose side, θ is the angle of wrap and μ is the coefficient of friction between belt and pulley. 7

6. a) What is the inherent problem in a chain-sprocket drive and how is the problem kept under control ? 3

b) Draw the profile of a cam operating a knife-edge follower having a lift of 30 mm. The cam raises the follower with SHM for 150° of the rotation followed by a period of dwell of 60°. The follower descends for the next 100° rotation of the cam with uniform velocity, again followed by a dwell period. The cam rotates at a uniform angular velocity of 60 rpm and has a least radius of 30 mm. What will be the maximum acceleration of the follower during the lift and descent ? 11

PART - D

7. a) State the iff conditions for internal stability of LTI system. 3

b) Check the internal stability of the following system :

i) Nominal plant model $G(s) = \frac{s-2}{s}$

ii) Cascade compensator $C(s) = \frac{1}{s-2}$

iii) Feedback compensator $F(s) = 1$. 4

c) Consider

$$A(s)D(s) + B(s)N(s) = s^2 + 2s + 2$$

where $D(s)$ and $N(s)$ are given polynomials.

Do solutions $A(s)$ and $B(s)$ exist in the equation when $D(s) = s^2 - 1$ and $N(s) = s - 2$. 3

d)

Fig.

In the unity feedback configuration as shown;

$G(s) = \frac{N(s)}{D(s)}$ and $T(s) = \frac{s(s)}{R(s)}$.

i) Show that the closed loop transfer function $G_o(s)$ is implementable if and only if $G_o(s)$ and $T(s)$ are proper and stable. 2

ii) For $G(s) = \frac{(s+2)(s-1)}{s(s^2 - 2s + 2)}$ and

$$G_o(s) = \frac{(s-1)}{(s+3)(s+1)}$$

Check whether $G_o(s)$ is implementable. 2

8. A unity feedback system has an open loop transfer function

$$G(s) = \frac{k}{s(s+1)(s+5)} .$$

a) Draw the root-locus plot. 3

b) Determine the value of k to give a damping ratio of 0·3.

Now a network of transfer function

$$\frac{10(1+10s)}{(1+100s)}$$

is introduced in tandem. 3

c) Find new value of k which gives the same damping ratio for the closed loop response. 4

d) Compare the velocity error constant and settling time of the original and the compensated system. 4