EX/PG/ME/T/114B/2018

M.E. Mechanical Engineering - First Year - First Semester, 2018

Subject: Electro-hydraulic Systems and Control

Time : Three hours **Full Marks: 100**

Answer any FIVE QUESTIONS

1.(a) Draw a schematic of a swash plate type axial piston pump and explain its operation. How can the delivery of such a pump be altered using pressure compensation?

(b) Why are *silencing grooves* provided in delivery and pressure ports of valve plate? [14+6]

2. Explain a hydraulic (tank-filling) system illustrating a simple first-order lag. Write the governing differential equations. Suggest how a *proportional* controller can be implemented for controlling the water level in the tank using a flow control valve. Construct the block diagram representation of the system. Obtain the overall transfer function of the system relating demanded water level and actual water level. Hence obtain an expression for the steady state error. Express the transient response graphically for different possible values of the controller parameter. [20]

3. (a) Explain the terms: frequency response function, loop transfer function and unity feedback system.

(b) Draw the polar plot of the loop transfer function $1/(s+1)$.

(c) Construct *Bode Plot* for the loop transfer function $\frac{4}{(0.4s+1)(s+1)}$. Draw the corner plots and sketch approximately the true profile of the plots on the corner plots. Identify GCF, PCF, GM, PM and comment on the stability of the plant. [3+5+12]

4. (a) State Liapunov's Stability Theorem.

(b) State Sylvester's theorem for a quadratic function Q.

(c) What is meant by the statements "a system is (i) globally asymptotically stable; (ii) locally asymptotically stable; (iii)stable" ?

(d) Consider a nonlinear system expressed by $\ddot{x}+2\dot{x}^3+x=0$. Comment on the stability of the system using a suitable Liapunov function. [3+4+6+7]

5. Consider the case of a 3-landed spool valve driving a symmetric linear actuator. The spool valve ports are rectangular of equivalent width w_p, the discharge coefficient of the ports C_d, the fluid density ρ and the supply and return pressures P_S and P_R respectively. The actuator piston has a mass m and it is connected to a spring of stiffness k and a dashpot of damping coefficient C. The actuator pressure bearing area is A_a. There is no external load acting on the actuator. The fluid is *incompressible*. The spool has a mass m_s, stiffness k_s and damping c_s. It is moved by an electromagnetic motor of coil inductance L, coil resistance R, generator constant K_m, magnetic stiffness K_{mag} and back emf constant K_b. If the voltage across the coils $e(t)$, the displacement to the spool valve is $x(t)$, and the displacement of the actuator is $y(t)$, obtain a non-linear mathematical model for the system.

Show how the above model can be linearised about some operating point and obtain the corresponding transfer function model of the system relating the actuator displacement and the voltage. Assume any symbols required for the problem. Draw the block diagram the system. [20]

6. (a) Use the *Routh-Hurwitz* stability criterion to find out if the following system is stable: $s^4+s^3+4s^2+2s+5 = 0$.

(b) Define the terms – characteristic equation, poles and zeroes.

(c) What are the advantages of a closed loop control systems over open loop control systems? [8+6+6]

7.(a) Sketch the typical phase-plane portraits for a linear second order system, given by $\ddot{x}+2\zeta\omega_n\dot{x}+\omega_n^2x=0$, where ζ and ω_n are the damping coefficient and undamped natural frequency of the system, for an underdamped and an overdamped system.

(b) Consider a simple model of a motor plus load (inertia J, damping B) in a position servo [Fig P7_1] of which the gain of the amplifier varies with system error E as shown in Fig P7_2. For gain K_1, the system is overdamped while for gain K_2 the system is underdamped. Obtain the phase-plane equation of the system for a step input. Using results of Problem 7(a), draw the phase-plane portrait of the non-linear system and comment on the stability.

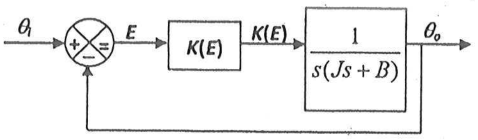

Fig P7_1

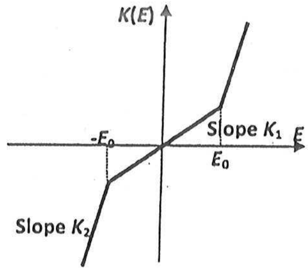

Fig P7_2

[8+12]

8. Write short notes on any FOUR of the following:
   (i) Transient response characteristics of a typical second order system;
   (ii) Simple pressure relief valve;
   (iii) Common nonlinearities encountered in dynamic systems;
   (iv) Over-lapped, under-lapped and critically lapped valves;
   (v) Argand diagram and stability of LTI systems;
   (vi) PID controllers.

[4×5]