Linear Control Design II - Group Work Problem Module 3

Description

This exercise is based on the work carried out in the Group Work Problem Module 2. For the electro-mechanical system illustrated in Figure 1 and described in Group Work Problem Module 2 the goals for this assignment is: a) linearize the electromagnetic force resulted from the change in current and change in displacement. I.e. Ki and Ks; b) derive the SISO state space model ($\mathbf{A}$, $\mathbf{B}$, $\mathbf{C}$ & $\mathbf{D}$) for the electro-mechanical system using the state parameters

$$\mathbf{x} = \left[q_1, q_2, q_3, q_4, q_5, q_6, q_7\right]^T = \left[i, x_1, \dot{x}_1, x_2, \dot{x}_2, x_3, \dot{x}_3\right]^T$$

where

$$\dot{x} = \mathbf{A}x + \mathbf{B}u$$
$$y = \mathbf{C}x + \mathbf{D}u$$

c) investigate the vibrations of the structure when different initial conditions and inputs are present;

d) compare the obtained results from Group Work Module 2 with the results from this Group Work Module.

Figure 1 : Electro − mechanical system composed of three masses interconnected by flexible beams (mechanical parts) and a pair of electromagnets (electrical parts).

The parameters needed for the assignment are given below.

```
% Parameters
m1 = 0.712;          % [kg] mass of platform 1
m2 = 0.428;          % [kg] mass of platform 1
m3 = 0.428;          % [kg] mass of platform 1

l = 24e-3; % mm, small
r = 14e-3 / 2;
A = pi*r^2;
```

```matlab
R = 148.2;
L = 800e-3; % [H]
iMax = 0.14; % measured at 24v


gam = 0.5;              % bias ratio - normally chosen between 0.2-0.5
ib = iMax*gam;          % Bias current
mu = 4*pi*1e-7;         % Permeability of free space (vacuum)
x0 = 2e-3;              % displacement operation point


b = 0.025;             % [m] beam width
h = 1.0e-3;            % [m] beam thickness
N = sqrt(L*2*x0 / (mu*A)); % estimate number of windings based on above formular
E = 2.0e11;           % [N/m2] elasticity modulus of steel
Iz = (b*h^3)/12;      % [m4] area moment of inertia


L1= 0.145;             % [m] length of beam 1
L2= 0.134;             % [m] length of beam 2
L3= 0.229;             % [m] length of beam 3


% Force constants obtained from the linearisation

k1 = 2*12*E*Iz/L1^3;    % [N/m] stiffness of beam 1
k2 = 2*12*E*Iz/L2^3;    % [N/m] stiffness of beam 2
k3 = 2*12*E*Iz/L3^3;    % [N/m] stiffness of beam 3
```

Problem 1

Linearize the electromagnetic force resulted from the change in current and change in displacement.

Define Ki and Ks

```matlab
% Your solution goes here
% Ki
% Ks
```

Problem 2

Derive the SISO state space model ($\mathbf{A}$, $\mathbf{B}$, $\mathbf{C}$ & $\mathbf{D}$) for the electro-mechanical system using the state parameters

$$\mathbf{x} = \left[q_1, q_2, q_3, q_4, q_5, q_6, q_7\right]^T = \left[i, x_1, \dot{x}_1, x_2, \dot{x}_2, x_3, \dot{x}_3\right]^T$$

where

$$\dot{x} = \mathbf{A}x + \mathbf{B}u$$
$$y = \mathbf{C}x + \mathbf{D}u$$

```matlab
% Your solution goes here:
% Upload a picture or fill in your code
```

Problem 3

The goal of the problem is to investigate how the structure behaves when s_0 (air gap) is varied

from 5 mm to 1 mm. The initial conditions of lateral displacements $x_2(0)$, $x_3(0)$ and velocities $\dot{x}_1(0)$, $\dot{x}_2(0)$, $\dot{x}_3(0)$ are zero and kept for all simulation cases. Only the lateral displacement of the lowest mass $x_1(0)$ is offset by 1 mm from center. Simulate three different values of s_0=5 mm, s_0=3 mm, s_0=1 mm. Explain the simulation results.

```
% Your solution goes here:
```

Problem 4

What is the maximum lateral displacement experienced by the three masses when an initial condition of velocity of 5 mm/s acts on mass 3, assuming s_0=2 mm?

```
% Your solution goes here:
```

Problem 5

A step function $u(t)$=10 V is send to the electromagnets, assuming all initial conditions of lateral displacement, velocity and current nill. How will the three masses vibrate and how will the current change, i.e. amplitudes and frequencies.

```
% Your solution goes here:
```

Problem 6

Compare the obtained results from Group Work Module 2 (problems 4, 5 and 6) with the results from this Group Work Module (problems 3, 4 and 5).

```
% Your solution goes here:
```