MEC108 Coursework 1

Assignment Regulations:

- This is an individual assignment. Every student MUST submit one soft copy of the answer sheet via the ICE before the due date.
- The assignment is **Due at: 18:00, 12 May, 2021.**
- A coversheet can be created in your own way, but the following information MUST be included: your student ID number, full name and email address.
- You can provide your answers by either hand-writing or produce a word document.
- For hand-written answer sheets, you can either scan them or take photos before submission, as long as the answers are clear and easy to read.
- For every problem, you need to provide detailed answer, including schematic diagrams, phasor diagrams, plots of results, etc., if they are necessary.
- For problems which require programming using MATLAB/Simulink (or Octave), you need to present, in your answer sheets, the coding of the programmes and/or Simulink models used with details on relevant settings, e.g. initial conditions, simulation time, time step size, solvers chosen, etc.
- You may refer to textbooks and lecture notes to discover approaches to problems, however, the assignment should be your own group work. Students are reminded to refer and adhere to plagiarism policy and regulations set by XJTLU.
- Assignments may be accepted up to 5 working days after the deadline has passed; a late penalty of 5% will be applied for each working day late without an extension being granted. Submissions over 5 working days late will NOT be marked. Emailed submissions will NOT be accepted without exceptional circumstances.

Analysis and Optimum Design of a Step Direct Acting Solenoid Valve

Consider a cylindrical solenoid valve as shown in the attached engineering drawing. This is a typical example of a step direct acting solenoid valve used in hydraulic systems. The parameters for the electromagnet are given below:

The coil has N turns and the coil resistance is R_c.
The cylindrical plunger has the radius R.
The effective gap length between the plunger and the magnetic core is g.
The plunger moves vertically, so that the gap length δ varies with the movement.
The permeability of the material for plunger and core is considered as infinity.

The plunger is supported by the spring with constant K, and the spring force is

$$f_k = K(\delta_0 - \delta)$$

where δ_0 is the initial gap length (at the bottom of the plunger) at which the spring is unstretched.

During operation of the solenoid magnet, the minimum value of δ is 0.5 mm. The other parameters of the solenoid magnet are given below:

$R = 6.4\,mm$; $h = 1.6\,mm$; $g = 2.0\,mm$; $\delta_0 = 1.5\,mm$; $K = 1.8\,N/mm$; $B = 0.5\,kg/s$; $M_{plunger} = 0.03\,kg$; $N = 550\,turns$; $R_c = 5\,\Omega$.

Assume the fringing effect can be neglected:

(a) Sketch a simplified schematic diagram of the electromagnet, based on your understanding of the drawing, and then answer the following questions:

- Which parts form the magnetic core, what materials are used (e.g.do they have good permeability) for each of the parts? A list of parts is given in Table 1 which also tells the materials used for each part.
- What is actually inside the "air gap, g"?
- What is the plunger material and its nature?
- Draw the loop for applying Ampere's law.

(15 Marks)

(b) Derive the expression of the inductance L as a function of δ. Properly set up the coordinate system.

(10 Marks)

(c) Derive the expression of the magnetic force f_{fld} imposed on the plunger as a function of δ, the magnetic flux linkage λ and the coil current i. Comment on the direction of f_{fld}, i.e. to make δ increase or decrease? Properly set up the coordinate system.

(10 Marks)

(d) Derive the dynamic equations governing the behaviour of the solenoid magnet. Then solve the equations to find the dynamic response with the above provided parameters. Is this response good or not, and, why? Properly set up the coordinate system.

(25 Marks)

(e) Try different values of B and/or K to optimize the dynamic response of the system. Then comment on the comparison of results with different B and/or K.

(20 Marks)

(f) Briefly describe the working principle of a step direct acting solenoid valve. Then, comment on what aspects need be considered for its design and optimization (e.g. stable response, fast response time, large final displacement but within the limit) and reason. Next, comment on how these aspects are accounted for through working on Part (e).

(20 Marks)

Table 1. Parts/components list

Item No.	Title	No. off	Material
1	Valve body	1	Copper alloy, Hpb58-3
2	Diaphragm	1	Rubber, EPDM
3	Pressing plate	1	Copper alloy, Hpb58-3
4	Plunger sleeve	1	Alloy steel, AISI 440c or 42CrMo
5	Coil bobbin	1	Plastic, ABS
6	Plunger	1	Magnetic iron, DT4
7	Coil	1	Red copper
8	Magnetic ring	1	Alloy steel, AISI 440c or 42CrMo
9	Magnetic core	1	Alloy steel, AISI 440c or 42CrMo
10	Washer	1	Spring steel, 65Mn
11	Lock nut	1	Carbon steel, Q235
12	Housing	1	Stainless steel, 304
13	Electrical connection terminal	1	
14	Reset spring	1	Spring steel, 65Mn
15	Valve cover	1	Carbon steel, Q235
16	Sealing ring	1	Nitrile Rubber, NBR