

Byrne

University of Wales Trinity Saint David

HNC / HND in Electrical and Electronic Engineering

Dynamics

Dynamics Control and Instrumentation

Ethan Byrne

BYR19852790

2023

Results 21.5
Structure 33

54.5 %

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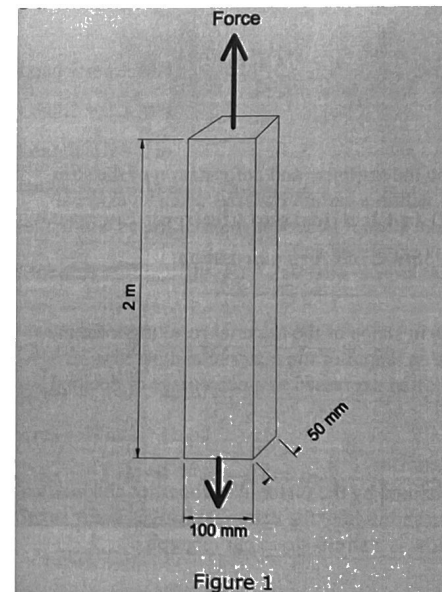
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Introduction

The aim of this report is to solve, analyse and simulate the behaviour of dynamic mechanical systems using traditional analytical techniques and computer-based simulation. The report will also demonstrate the ability to apply instrumentation and control system methodologies to dynamical systems and analyse the behaviour and response of the system and how it can be controlled.

Task 1(a)

It is required to determine the stress in a load bearing strut as depicted in Figure 1:

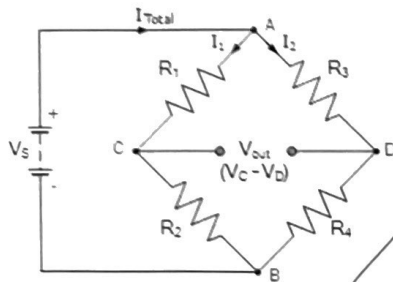


To measure the strain experienced by the load-bearing strut, a common and effective method is to use strain gages. Strain gages are devices that detect and measure the strain in an object when subjected to an external force (DEWESoft, 2022).

In order to utilise a strain gage, the gage needs to be attached to the strut at locations where the strain is expected to appear and aligned in the direction of the anticipated strain. These locations are typically the areas experiencing the highest concentration of stress. The strain gage should connect to a Wheatstone Bridge circuit configuration.

A Wheatstone bridge is a circuit of four resistors connected as two series-parallel arrangements in the shape of a diamond between a voltage supply and ground producing zero

voltage difference between the two parallel branches when balanced. The Wheatstone Bridge was created by Charles Wheatstone as a means to accurately measure unknown resistance values (Electronics Tutorials, 2023). The below diagram is an example of a Wheatstone Bridge circuit.



(Electronics Tutorials, 2023)

Stress and Strain

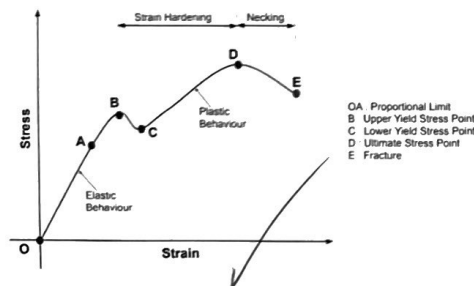
Stress and strain are two concepts that describe the response and deformation of the strut. Stress refers to the internal force per unit area within a certain material when an external force is applied to it. When a load is applied to a strut, it generates internal forces within the material that oppose the applied force. Stress is expressed as:

$$\text{Stress} = \text{Force} / \text{Area}$$

Strain, on the other hand, describes the change in shape of the material resulting from the applied stress. It represents the relative change in length of the material compared to its original length. Strain is dimensionless and is often expressed as a percentage or decimal. Strain is calculated as:

$$\text{Strain} = \Delta \text{Length} / \text{Length}$$

The relationship between stress and strain is defined by the material's properties and is often represented by a stress-strain curve. This curve shows how the material changes under different levels of stress (Tutoroot, 2022). Below is a stress-strain curve graph.



(Tutoroot, 2022)

To maximize the accuracy of the measurements, special arrangements are needed, such as temperature compensation techniques / circuits to minimize the influence of temperature changes on strain measurements (Omega, 2023).

Task 1(b)

Demonstrate the performance of the system when loads of 1.5MN and 2.5MN are applied. Assume the strut is of steel construction to the dimensions shown in figure 1, with a Modulus of Elasticity (E) of 210GPa.

Calculations

Load 1 = 1.5 MN

Load 2 = 2.5 MN

Length (L) = 2 m

Width (b) = 100 mm = 0.1 m

Depth (h) = 50 mm = 0.05 m

Modulus of Elasticity (E) = 210 GPa = 210,000 MPa = 210,000,000,000 N/m²

Load 1: Load of 1.5 MN

Stress = Load / Area

Area = Width * Depth

Area = 0.1 m * 0.05 m = 0.005 m²

Stress = 1.5 MN / 0.005 m²

= 300,000,000 N / 0.005 m²

= 60,000,000,000 N/m²

= 60 GPa

Strain = Stress / E

Strain = 60 GPa / 210 GPa

≈ 0.2857

Load 2: Load of 2.5 MN

Stress = 2.5 MN / 0.005 m²

$$\frac{1.5 \times 10^6}{0.005} = 300 \text{ MPa}$$

$$\frac{300 \times 10^6}{210 \times 10^9} = 0.00143$$

$$\Delta x = \frac{\Delta L}{L}$$

$$\Delta L = 2.86 \text{ mm}$$

$$\begin{aligned}
 &= 500,000,000 \text{ N} / 0.005 \text{ m}^2 \\
 &= 100,000,000,000 \text{ N/m}^2 \\
 &= 100 \text{ GPa} \\
 \text{Strain} &= 100 \text{ GPa} / 210 \text{ GPa} \\
 &\approx 0.4762
 \end{aligned}$$

$\approx 4.76 \text{ mm}$
 4
 APPROX TO BRIDGE?

Task 2

Displacement, Velocity and Acceleration

Displacement, velocity, and acceleration are fundamental concepts used to describe the motion of objects in physics.

- Displacement is the change in position of an object from its initial point to its final point. The unit for displacement is metres (m)
- Velocity is a measure of how fast an object is moving and in which direction. It is the rate of change of displacement with respect to time. The unit for velocity is m/s.
- Acceleration describes how the velocity of an object changes over time. It measures the rate at which an object's velocity changes. The unit for acceleration is m/s².

The position coordinate of a particle which is confined to move along a straight line is given by $s = 3t^3 - 24t + 6$, where s is measured in meters from a convenient origin and t is the time in seconds.

Determine:

- (a) The time required for the particle to reach a velocity of 60 m/s from its initial condition at $t=0$.

$$v = ds / dt = 9t^2 - 24$$

$$9t^2 - 24 = 60$$

$$9t^2 = 84$$

$$t^2 = 9.3$$

$$t = 3.05 \text{ s}$$

2

- (b) The acceleration of the particle when $v = 35 \text{ m/s}$.

$$9t^2 - 24 = 35$$

$$9t^2 = 59$$

$$t^2 = 6.56$$

6

$$\begin{aligned}
 t &= 2.56 \text{ s} \\
 a &= dv / dt = 18t \\
 a &= 18 \times 2.56 = 46.08 \text{ m/s}^2
 \end{aligned}$$

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(c) The net displacement of the particle during the interval from $t = 2 \text{ s}$ to $t = 4 \text{ s}$.

$$\begin{aligned}
 s &= (3(4)^3 - 24(4) + 6) - (3(2)^3 - 24(2) + 6) \\
 s &= 102 - 18 = 102 + 18 = 120 \text{ m}
 \end{aligned}$$

- (d) Draw the path of the particle between $0 < t < 5 \text{ s}$.

Task 3

(WattElectronics, 2021) Open loop and closed loop are two types of control systems used in various applications.

In an open loop control system, the control does not rely on feedback from the output. It operates based on a predefined input and does not adjust based on the actual output.

Closed loop control systems use feedback from the output to adjust the control action and maintain the desired output. It continuously monitors the system output and compares it with the desired reference value or setpoint. This control system makes appropriate adjustments to minimize the error and achieve the desired output.

Key differences between the two control systems are as follows:

- Open loop systems are simpler and less complex to design and implement.
- Open loop systems have a fast response since the action is predetermined.
- Closed loop systems are more accurate because they can compensate for disturbances or changes to the system.
- Closed loop systems have very good adaptability in comparison to the open loop systems.

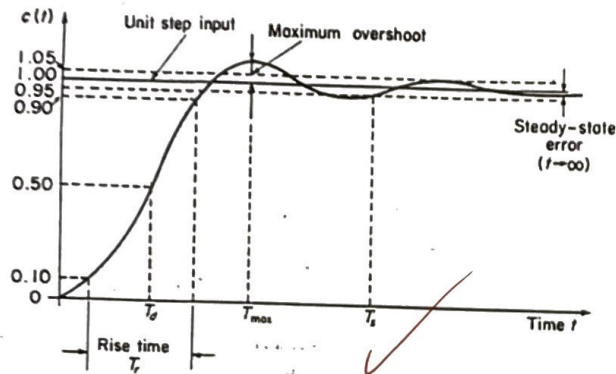
The following terms can be explained as follows:

- Overshoot refers to the phenomenon where the output of a control system exceeds the desired value. Excessive overshoot can lead to instability in the system.
- Non-touching loops are independent loops within a control system that do not share common paths or interact with each other. They are useful in determining the stability and performance of the control system using methods like the Mason's gain formula.
- Plant refers to the system or process being controlled. The plant typically describes the input-output relationship (CircuitBread, 2023).
- Settling time is the time required for the output of a control system to settle and remain within a certain range around the desired value. It is a measure of how quickly the system response settles down after a disturbance or change. Settling time is often within a percentage of about 5% of the desired value.
- Steady state error refers to the difference between the desired value and the actual output value of a control system. Steady state error is typically measured after the transient response has settled down and reached a stable operating condition.
- PID stands for Proportional-Integral-Derivative, which are three types of control actions commonly used in feedback control systems. PID control is a widely used

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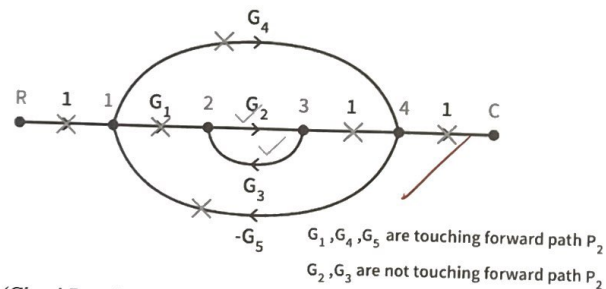
control algorithm that adjusts the control output based on the difference between the desired value and the actual output value. PID controllers are used to stabilize the system and improve response time (Omega, 2023).

The overshoot, settling time and steady state error can be demonstrated using a Step Response Graph like the one shown in the diagram below.



(Hathaway, 2015)

Non-touching loops can be demonstrated with Mason's gain formula signal flow graph diagram like the one shown below.



(CircuitBread, 2020)

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