Report of Experiment no. 3

Stress, Strain, and Fracture

For the course

MEC404 Integrated Mechanical Laboratory – II

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Executive summary

The understanding of the concepts of stress, strain and fracture is fundamental in the context of mechanical engineering. They provide valuable insights into the mechanical behaviour of various materials under different loading conditions.

In this experiment, we explored the intricate relationship between applied forces and resulting deformations. Taking the readings of a strain guage under different loading conditions, we were able to determine how the load affects the mechanical properties of these materials. Through these observations, we can form relations between these quantities, which are useful for practical applications. We used a cantilever beam fixed at one end to calculate the deflection of the beam. This was repeated for several masses and measured by a load cell and a strain gauge.

The graphs between the deflection and the load show the relationship between the different loading conditions and their effect on the material's mechanical properties, such as stress and strain(may change this). The fracture of different materials provides necessary information on how different materials fracture under what loading conditions, which has real-life implications in the context of civil engineering and proper structure formation.

Keywords — stress, strain, fracture, mechanical properties, deflection, load

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1. Introduction

The understanding of how objects change under different loading conditions needs to be studied to make long-lasting structures and experimental equipment which contribute to society. This understanding comes in the form of the mechanical properties of various materials characterised by the notion of stress and strain of different materials. The understanding of stress, strain, and fracture can be used in various real-life situations, such as building structures, weighing scales, weighing machines, thermal expansion and contraction of railway tracks. These can also be understood for the manufacturing of various parts related to aircraft components, the automobile industry, glass products, etc. Some issues pertaining to this can be understood through the failure of these machines and components.

2. Practical applications study

2.1 Application studied

A practical application study of stress, strain and fracture was performed by studying the fracture in scenarios such as wire fatigue and thread failure. This was done to understand the mechanical properties of these materials under different loading conditions

2.2 Observations and findings

The wire was subjected to different loads applied manually using hand and observed for fatigue. As observed when a low force is applied, the wire is broken in 8-9 turns, whereas when a medium force is applied the wire breaks in 6-7 turns. When maximum force is applied the wire breaks instantly. On the other hand for thread failure a mild steel bolt was continuously inserted and removed using different forces by a cork wrench and the thread failure was observed. It was observed that the thread fails more quickly if a stronger force is applied.

3. Theoretical and conceptual basics

3.1 Theoretical basis

- Deformation

  Deformation is the change of shape of a material due to applied forces. This deformation can be either temporary, in which the material comes back to its original shape after some time, which is known as plastic deformation, or the material is permanently deformed even after the forces are removed, which is known as plastic deformation. The different examples of deformation can be given as follows:

  (1) Temporary Deformation – Bouncing a rubber ball. The ball deforms when it hits the ground but regains its original shape when it bounces back.

  (2) Permanent Deformation – Bending a plastic rule. The ruler retains its bent shape even after the bending force is removed.

- Stress

  Stress is the force applied per unit area of the material. The different types of stress found in materials are

  (1) Tensile Stress – Pulling forces elongate the material.

  (2) Compressive Stress – Pushing forces compress the material.

  (3) Shear Stress – Parallel forces cause deformation of the material by sliding one part of the material over the other.

- Terms Related to Material Properties

  The various terms related to material properties are defined as follows:

  (1) Ductility – Ability to deform under tensile stress.

  (2) Brittleness – Tendency to fracture when subjected to stress without appreciable deformation.

  (3) Toughness – Ability to absorb energy and deform plastically before fracture.

Hardness – Resistance to deformation, particularly to permanent indentation or scratching.

(4) Mallebility – Ability to deform under compressive stress.

(5) Strength - Ability to withstand an applied force without failing or fracturing.

- Impact and Restitution

  (1) Impact – Impact refers to the collision between two objects or a single object and a surface. It can cause deformation, fractures, or other changes in shape.

  (2) Restitution – Restitution is the measure of how much kinetic energy is retained or lost in a collision. Perfectly elastic collisions have a restitution of 1, meaning all kinetic energy is retained. Inelastic collisions have a coefficient of restitution less than 1, indicating some kinetic energy is transformed into other forms of energy like heat and deformation.

- Deformation Under Compression

  Deformation under compression is commonly referred to as compression deformation. It occurs when a material is subjected to forces that compress or shorten it along a particular axis.

- Processes leading to fracture

  1. Fatigue - Repeated loading and unloading can cause microscopic cracks to form, leading to fatigue failure.

     Applications - Aircraft Components

  2. Brittle Fracture - Occurs without significant plastic deformation, often in materials with low toughness.

     Applications - Glass products

  3. Ductile Fracture - Occurs with significant plastic deformation, giving warning signs before a fracture occurs.

     Applications - Automobile parts made of metals

- Methods of Analysis of Fractures

  The methods of analysis of fractures are as follows:

  1. Visual Inspection - Examining the fracture surface visually to determine the pattern and characteristics of the fracture.
  2. Scanning Electron Microscope(SEM) - Provides high-resolution images of the fracture surface for detailed analysis.
  3. X-Ray Diffraction - Helps identify the crystalline structure of fractured materials.

3.2 Equations

Basic Equation for Deformation

Deformation in a material is often described by the strain(ϵ), which represents the relative change in shape or size of a material element. For linear deformation, it is calculated using the formula:

$$\epsilon = \delta L/L \tag{1}$$

Now we will calculate the maximum deflection of the beam given by

$$\delta_{max} = Pa^2(3L - a)/6EI \tag{2}$$

Here L is the length of the beam which is 250mm, I is the moment of inertia of the end of the rectangular cross section, a is the area of the cross section, E is the modulus of elasticity or more commonly known as Young's Modulus which is given by

$$E = ebt^2/6FL \tag{3}$$

where e is the micro strain which is calculated on the basis of guage resistance, b is the thickness of the beam which is 2mm, b is width of the beam which is 31mm, and F is the load on the beam which we have kept in the testing matrix.

3.3 Validation with theory

From the experimental results we will obtain the values of maximum strain, which can be plotted to check the behaviour of the same.

4. Pre-experiment planning

The things performed and kept in mind before performing the experiment are as follows.

4.1 Safety

For the experiment, the beam to be tested was checked for cracks and deformation. The strain gauge used to test the deformation could not be calibrated as there was no manual for the load cell attached to the strain guage and a proper manual could not be procured. So to compensate the error was noted and eliminated in the readinfgs. The loads were carefully collected and placed for measurement with proper safety measures. All dust was cleaned from the table before performing the experiment. The power lines to the load cell and strain gauges were properly checked and suitable caution was maintained.

4.2 Independent and dependent variables

The fixed parameters for the experiment were the length, thickness, width,micro strain and, the material of the beam which was the characteristic of the measuring instrument. The independent variables included the testing loads which were decided by the experimenter.

4.3 Pre-test uncertainty analysis

Parameter	Uncertainty
Mass	1 gram
Length	0.1mm
Width	0.1mm
Thickness	0.1mm

These are all the errors in the measurement of the dependent variables. Since the errors are too small to check for uncertainties therefore a qualitative analysis can help get rid of these uncertainties. The errors were measured based on the least count of the measuring equipment.

4.4 Test matrix

Serial Number	Weight	Displayed	Error	Error(%)	δ_{max}

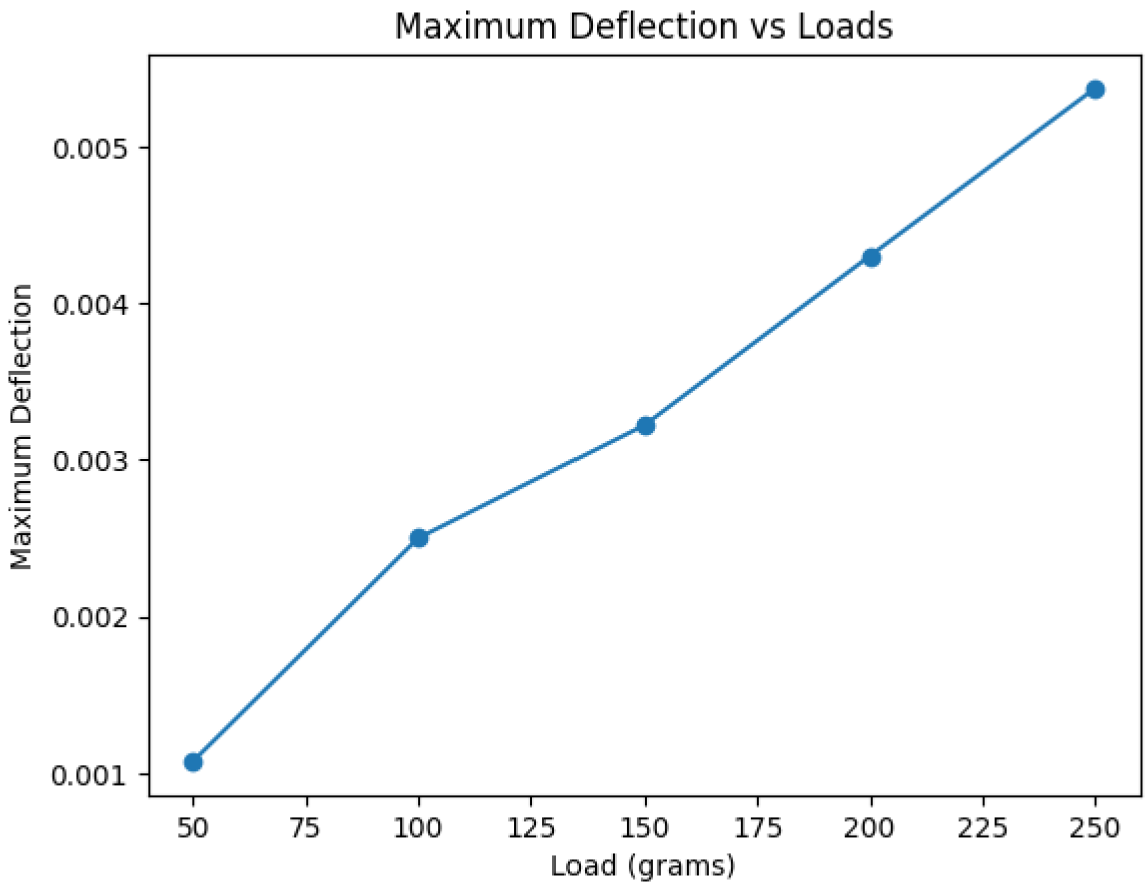
These parameters were noted in the test matrix as they were the most relevant to the experiment. All of these weights were measured three times and the average of three readings was taken and noted down as the final reading.

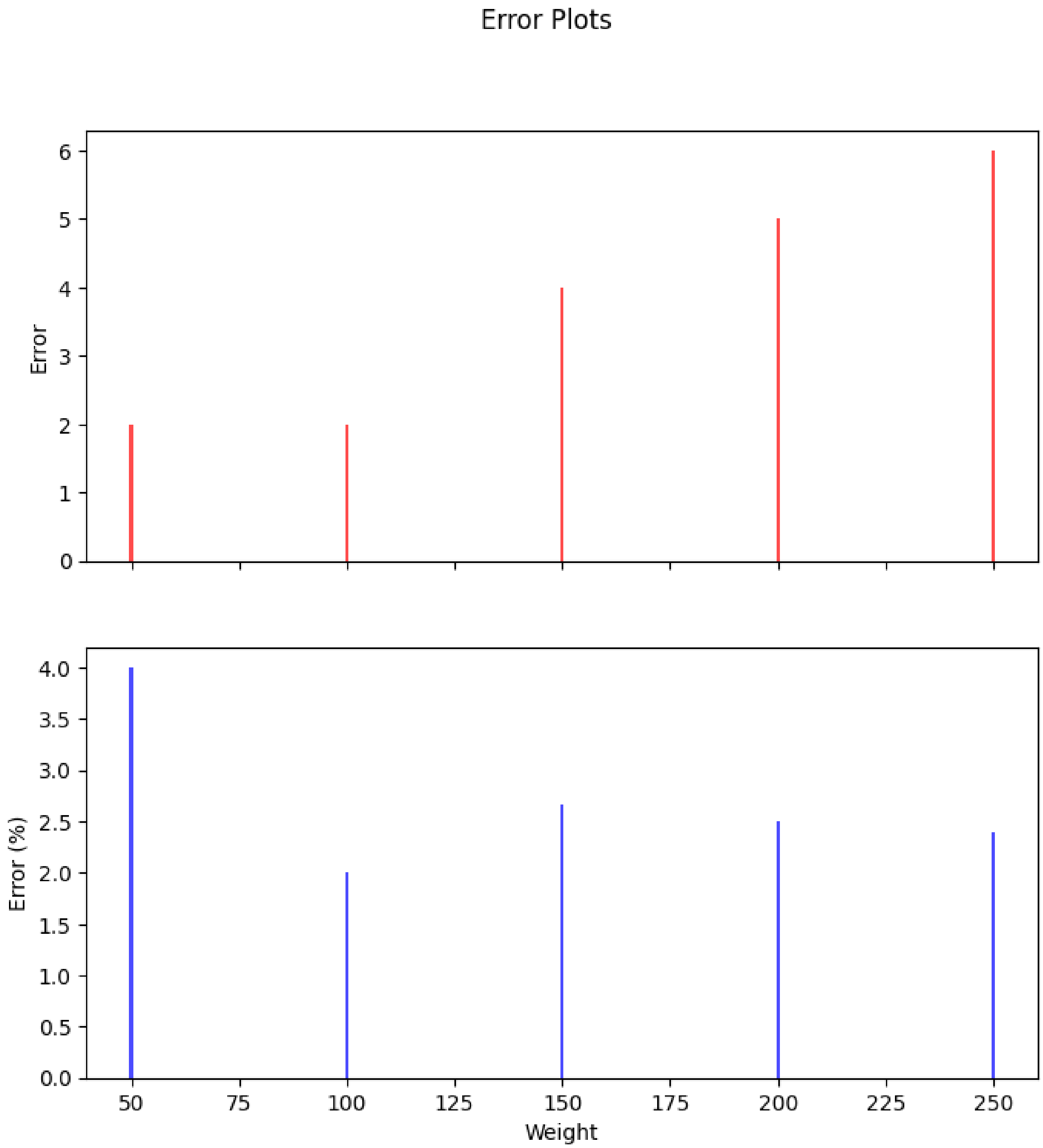
5. Experiment execution

The masses were first measured using a measuring scale and then marked. The experimental setup was then turned on by giving power and the initial reading error was noted as calibration was not possible without the manual for the testing apparatus. Then the readings were collected using the averaged out reading of each mass with three trials. The error in the weight measured was also noted by subtracting the strain guage reading with the reading from the measuring scale.

6. Data analysis and discussion

Serial Number	Weight	Displayed	Error	Error(%)	δ_{max}
1	50	60	2	4%	0.001075
2	100	110	2	2%	0.00250
3	150	162	4	2.66%	0.00322
4	200	213	5	2.5%	0.00430
5	250	266	6	2.4%	0.00537





Therefore we observe an almost linear pattern in the maximum deflection along with some outliers which are quantified by the error plots. These help in quantifying the objectives of the experiment.

7. Conclusions

From the experiment, we saw how we can calculate the strain for different loads for the given testing apparatus and how it affects real life applications. In conclusion, the conducted experiment on stress,strain and fracture provided invaluable insights into the mechanical behaviour of materials under different loading conditions. The experiments showcased the diverse nature of material, each uniquely to varying stresses and strains.

8. References

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