Mechanical Metallurgy

Lecturer

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Assessment

Assignment 20
(homework, quiz, attendance)

Midterm exam 40

Final exam 40

Total 100
Subject of interests

**Part I Mechanical fundamentals**

- Introduction to mechanical metallurgy
- Stress and strain relationships of elastic behaviour
- Elements of the theory of elasticity

**Part II Metallurgical fundamentals**

- Plastic deformation of single crystals
- Dislocation theory
- Strengthening mechanisms
- Fracture
Subject of interests

*Part III Applications to materials testing*

- Tension test
- Hardness test
- Torsion test
- Fracture mechanics
- Brittle fracture and impact testing
- Fatigue of materials
- Creep and stress rupture
Objectives

• *Interaction of stress and strain on materials in elastic and plastic manners will be understood.*

• *Deformation behaviour of metals due to dislocation interaction as well as strengthening mechanisms of metals will be addressed.*

• *Different methods of mechanical testing will be highlighted along with the interpretation of sensible information from the obtained data such that mechanical assessments are appropriately selected for the required applications.*

• *Metallurgical aspects which affect mechanical properties of materials will be discussed.*

• *Finally cause of material failure will be studied and suggested possible solutions will be discussed.*
Main references


Main references


Why failure in materials?

• Seven of the Liberty ships built during the world war II has broken completely in two as a result of brittle fractures.

• Over 1000 of approximately 5000 merchant ships built during World War II had developed cracks of considerable size by 1946.

Failure of Liberty Ships during services in World War II.
Why failure in materials?

- The bridge building industry did not pay particular attention to the possibility of brittle failure until the failure of *Point Pleasant bridge* in 1967.
- The bridge collapsed without warning, costing 46 lives.
Why failure in materials?

- The aircraft was used for inter-island transportation for 19 years before failed.
- Failure has been attributed to multiple-site-damage.

Failed fuselage of the Aloha 737 aircraft in 1988.
Material property assessments

- **Strength**
  - Ductility (elongation, area of reduction)

- **Creep** (elevated-temperature strength)

- **Torsion**

- **Toughness** (resistance to failure)

- **Fatigue**
  - S-N fatigue tests
  - Fatigue crack growth tests

- **Hardness**
  - Micro/Macro hardness tests

- **Tension tests**

- **Creep tests**

- **Torsion tests**

- **Impact tests**
  - Fracture toughness tests
Hardness tests

• **Hardness** is a property which is a measure of a resistance to permanent or plastic deformation.

• Using different indenters, i.e., ball, diamond.

**Parameters:**
• Brinell hardness (BHN)
• Meyer hardness
• Vickers hardness (VHN)
• Rockwell hardness

Macro-microhardness (Vickers) instrument
Tensile tests

- Provide basic design information on the strength of materials.
- Acceptance test for the specification of the materials.

**Parameters:**
- Tensile strength $\sigma_{TS}$
- Yield stress $\sigma_y$
- Young’s Modulus of elasticity $E$
- %Elongation
- Area of reduction

Ture stress-strain curve of a ductile metal under uniaxial tensile loading.

Plate specimens

Round specimens
Torsion test

- Applying *twisting moment* to the specimen and measure the *torque*.
- has not been standardized.

**Parameters:**
- Shear Modulus
- Torsional yield strength
- Modulus of rupture

*Ultimate torsion test results*
Creep test

- **Creep** is high temperature progressive deformation of a material at constant stress.
- A tensile specimen is loaded at a *constant (elevated) temperature*. Strain is measured with time.

**Parameters:**
- Creep strength
- Creep rate

**Typical creep curve**
Impact tests

• Measure toughness of materials in terms of energy absorption.

• Specimen is impacted by a hammer and the energy absorbed during fracture is measured in Joule.

• Easy and practical.

• Establish Ductile to Brittle Transition Temperature (DBTT).

• Not a standard material parameter, should be used in conjunction with other material properties such as strength and fracture toughness for materials determination.

Parameters:

• Impact energy
• Ductile to brittle transition temperature
Fracture mechanics

- Resistance of materials to crack propagation (to failure).
- Crack propagation can be predicted before failure.
- Material will fail when the stress intensity factor $K$ reaches the critical value $K_{IC}$.

**Parameters:**
- Fracture toughness $K_{IC}$
- Crack tip opening displacement $CTOD$
- J-integral $J$

Failed fracture toughness specimens.
Fatigue tests

- Material is subjected to a repetitive or fluctuating stress (cyclic loading) and will fail at a stress level much lower than that causes failure in statistic loading.

- S-N fatigue test and fatigue crack growth resistance.

**Parameters:**
- Fracture life (fatigue strength)
- Fatigue crack growth resistance
- Paris exponent (m)
- Fatigue threshold ($K_{th}$)
To improve properties of metals

WE NEED TO

Understand Metallurgical aspects
- Plastic deformation
- Dislocation theory
- Strengthening mechanisms
- Fracture

Understand mechanical aspects
- Stress and strain relationships of elastic behaviour
- Elements of the theory of plasticity.

Materials assessment

Improvement of materials properties
References

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- www.kockums.se
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