بسم الله الرحمن الرحيم

Benha University
Shoubra Faculty of Engineering

Mechanical Department
1st year Mech.

07.04.2019 – Week 9

Impact test

Prof. Farida Sayed Ahmed
Dr. Mahmoud Khedr

Outline

- Introduction.
- Impact testing.
- Izod impact test.
- Charpy impact test.
- Comparison.
- Failure modes.
- Solved example.

Benha University
Shoubra Faculty of Engineering

Mechanical Department
1st year Mech.

07.04.2019 – Week 9

Introduction

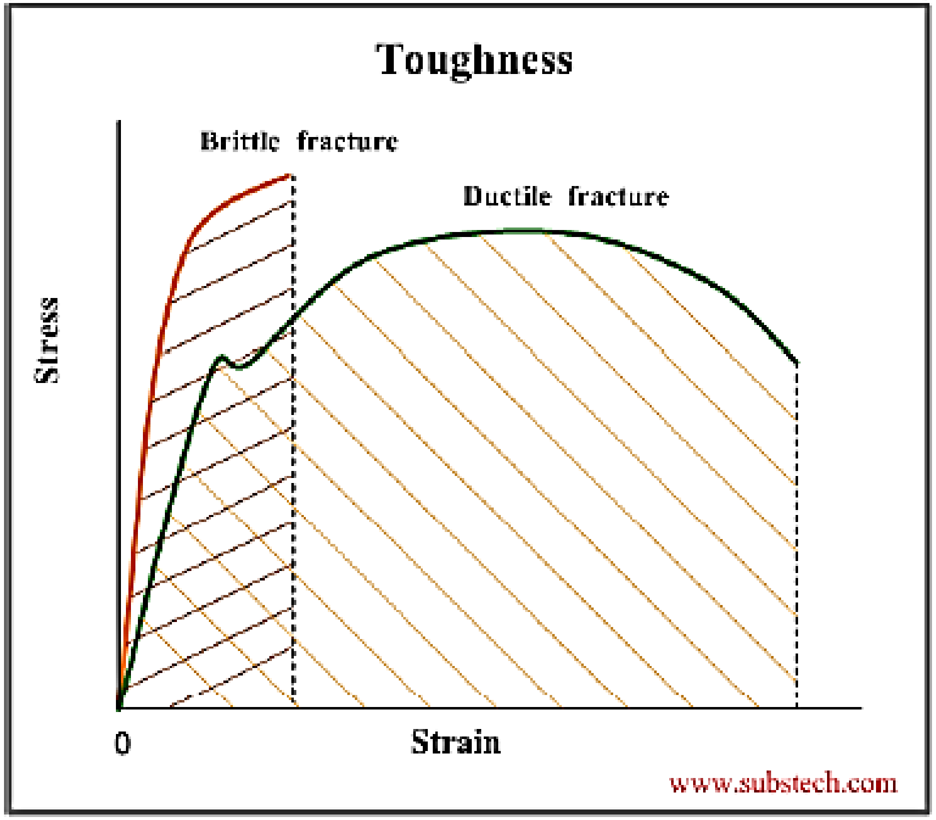
Prof. Farida Sayed Ahmed
Dr. Mahmoud Khedr

Introduction

Toughness is ability of material to resist fracture or to withstand impact. The general factors, affecting the toughness of a material are: temperature, strain rate, relationship between the strength and ductility of the material and presence of stress concentration (**notch**) on the specimen surface.

Fracture toughness is indicated by the area below the curve on stress-strain diagram (see the figure).

Fracture toughness may not represent the true behaviour of metals under impact loads.



Purpose of Impact Testing

- *The purpose of impact testing is to* ***measure*** *an object's* ***ability to resist high-rate loading.***
- *It is usually thought of in terms of two objects striking each other at* ***high relative speeds.***
- *A part, or* ***material's ability to resist impact often is one of the determining factors in the service life*** *of a part, or in the suitability of a designated material for a particular application.*
- *Impact resistance can be one of* ***the most difficult properties to quantify****.*
- *The ability to quantify this property is a great advantage in* ***product liability and safety****.*

Benha University
Shoubra Faculty of Engineering

Mechanical Department
1st year Mech.

07.04.2019 – Week 9

Impact testing

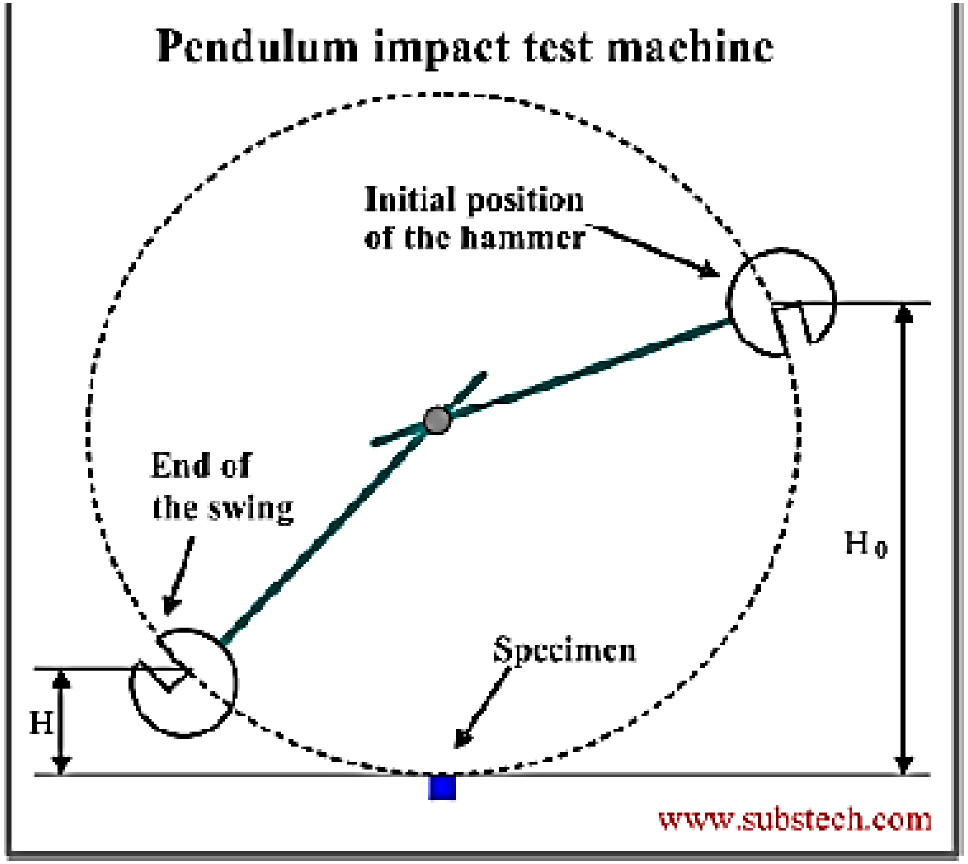
Prof. Farida Sayed Ahmed
Dr. Mahmoud Khedr

Impact test

Impact test is used for measuring toughness of materials and their capacity of resisting impact loads "shock".

In this test the pendulum is swing up to its starting position (height **Ho**) and then it is allowed to strike the notched specimen, fixed in a vice.

The pendulum fractures the specimen, spending a part of its energy. After the fracture the pendulum swings up to a height **H**.



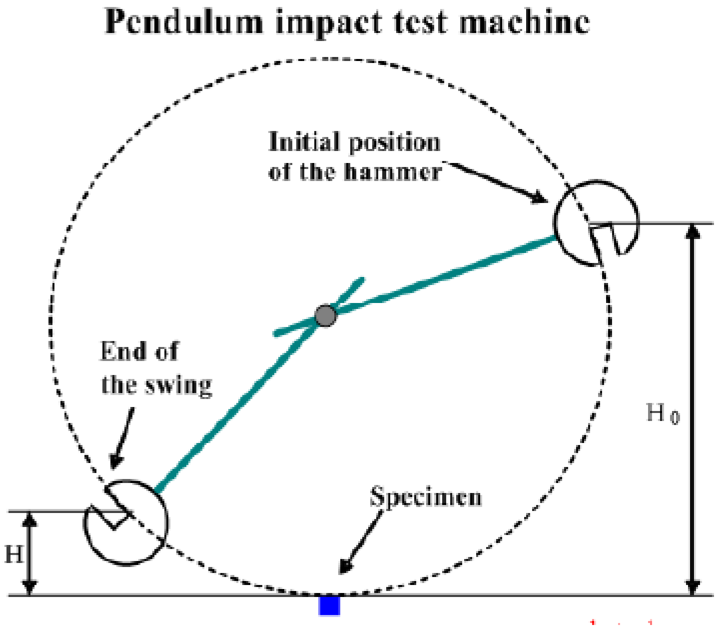
Impact test

The **impact toughness** of the specimen is calculated by the formula:

- **Q = U / A**

Where

- **Q**-impact toughness,
- **U** – the work, required for breaking the specimen
- **$U = M*g*H_0 – M*g*H$**
- **M:** the pendulum mass,
- **A:** cross-section area of the specimen at the notch.



Standard Impact Tests

The impact toughness of a material can be determined with:

1. Izod Standard Impact Test, or
2. Charpy Standard Impact Test.

These tests are named after their inventors and were developed in the early 1900's before fracture mechanics theory was available.

Impact properties are not directly used in fracture mechanics calculations, but the economical impact tests continue to be used as a quality control method to assess notch sensitivity and for comparing the relative toughness of engineering materials.

These impact tests allow designers to ***compare*** the relative impact resistance under *controlled laboratory conditions* and, consequently, are often used for ***material selection*** or quality control.

However, these tests generally don't translate into explicit design parameters.

Benha University
Shoubra Faculty of Engineering

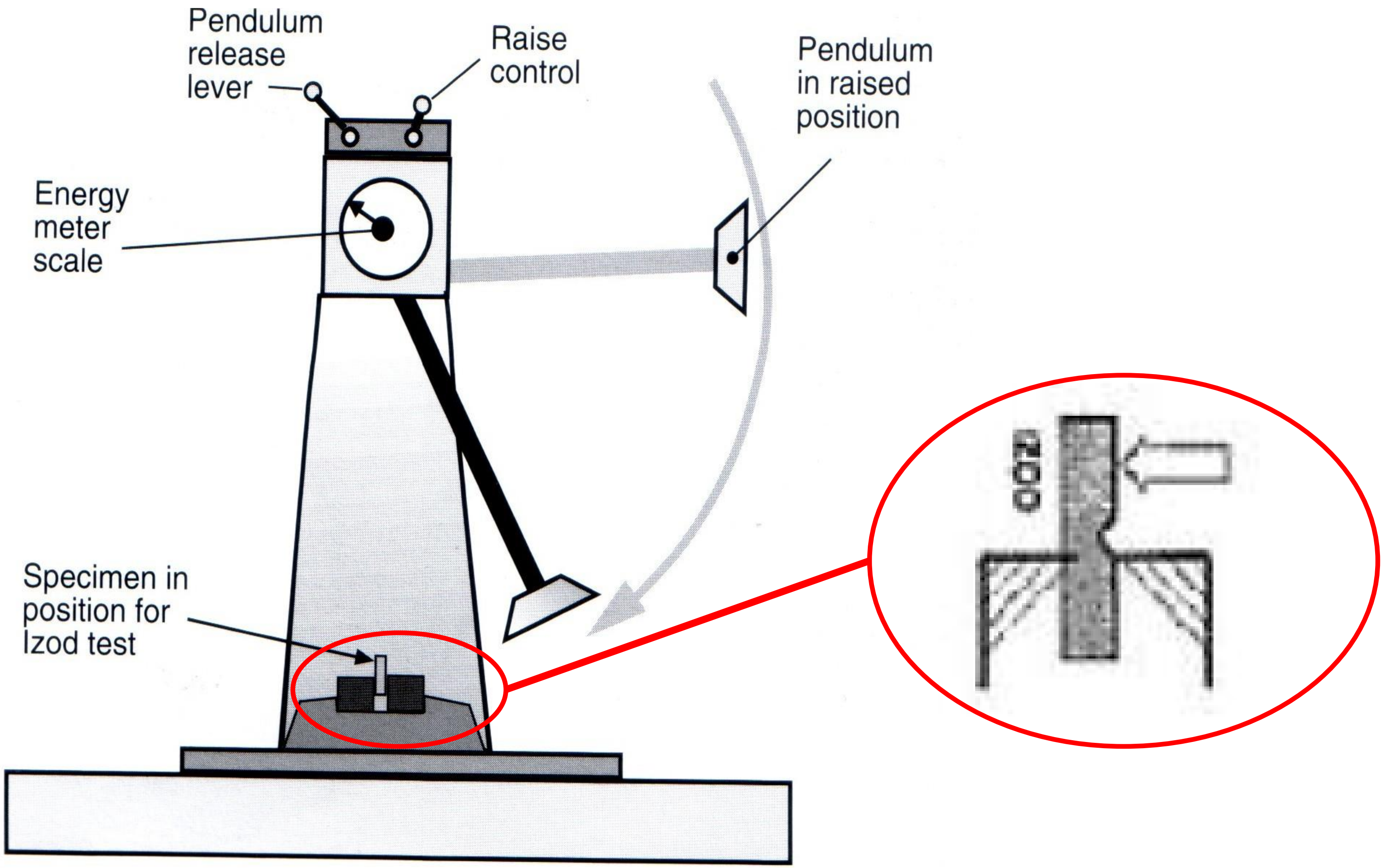
Mechanical Department
1st year Mech.

07.04.2019 – Week 9

Izod test

Prof. Farida Sayed Ahmed
Dr. Mahmoud Khedr

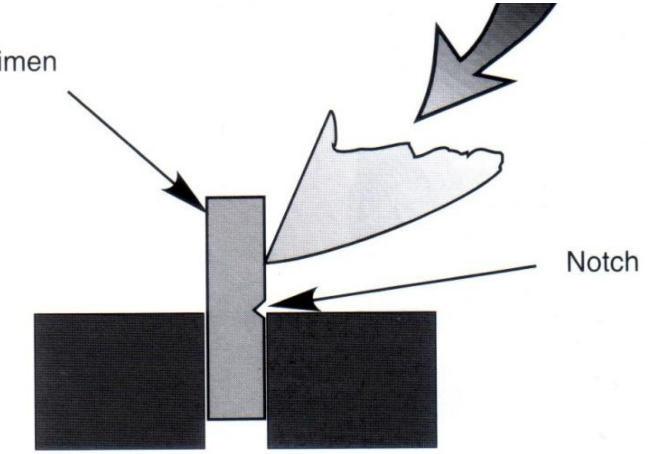
Izod ***Impact Test***



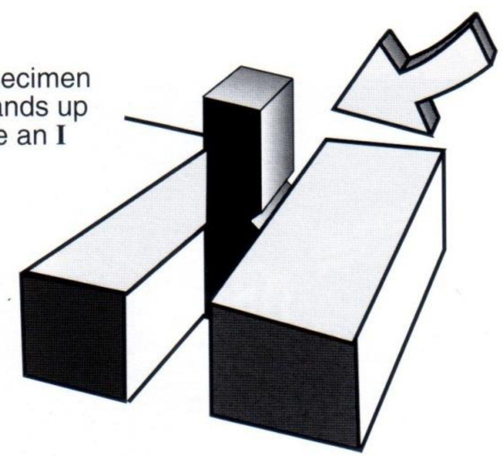
A different striker is fitted for Charpy testing and the specimen is held in a horizontal position with the notch facing away from the pendulum

<u>Izod</u> *Impact Test*

- Strikes at 167 Joules.
- Test specimen is held vertically.
- Notch faces striker.



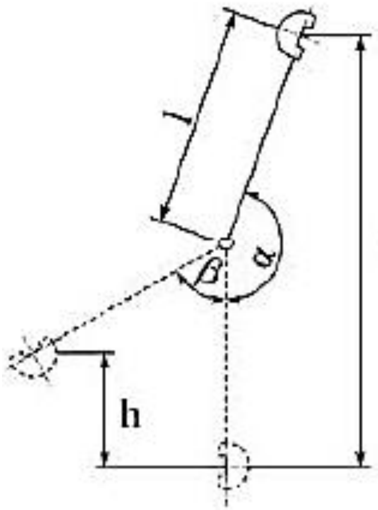
This is how a specimen is held for carrying out an Izod test

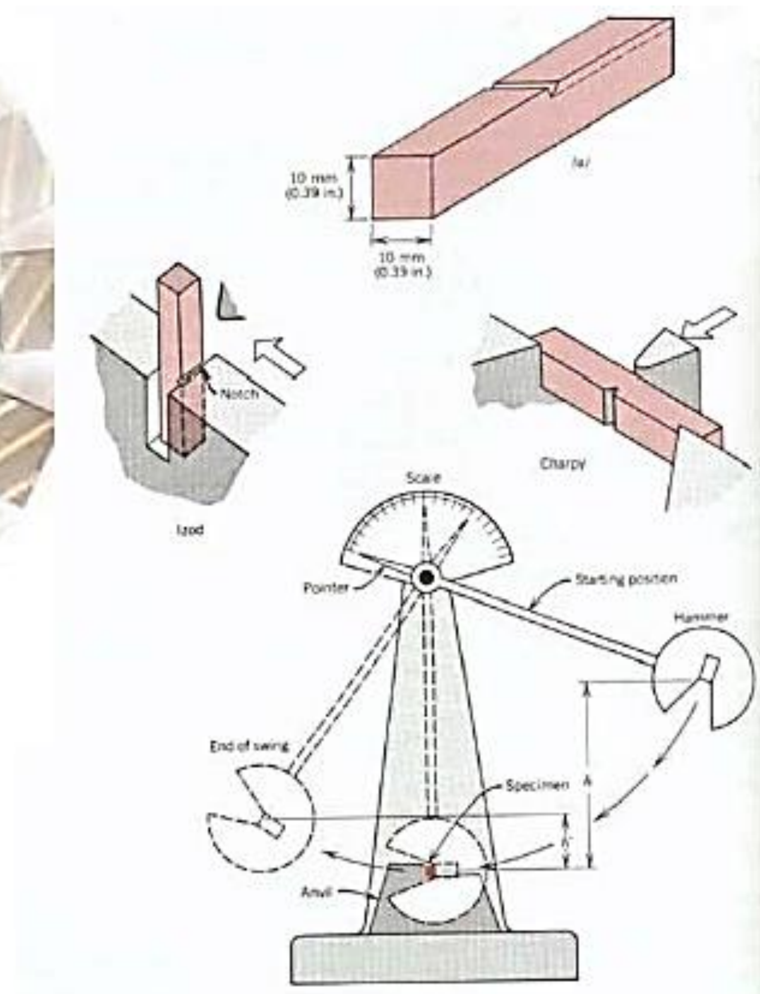


Izod impact test

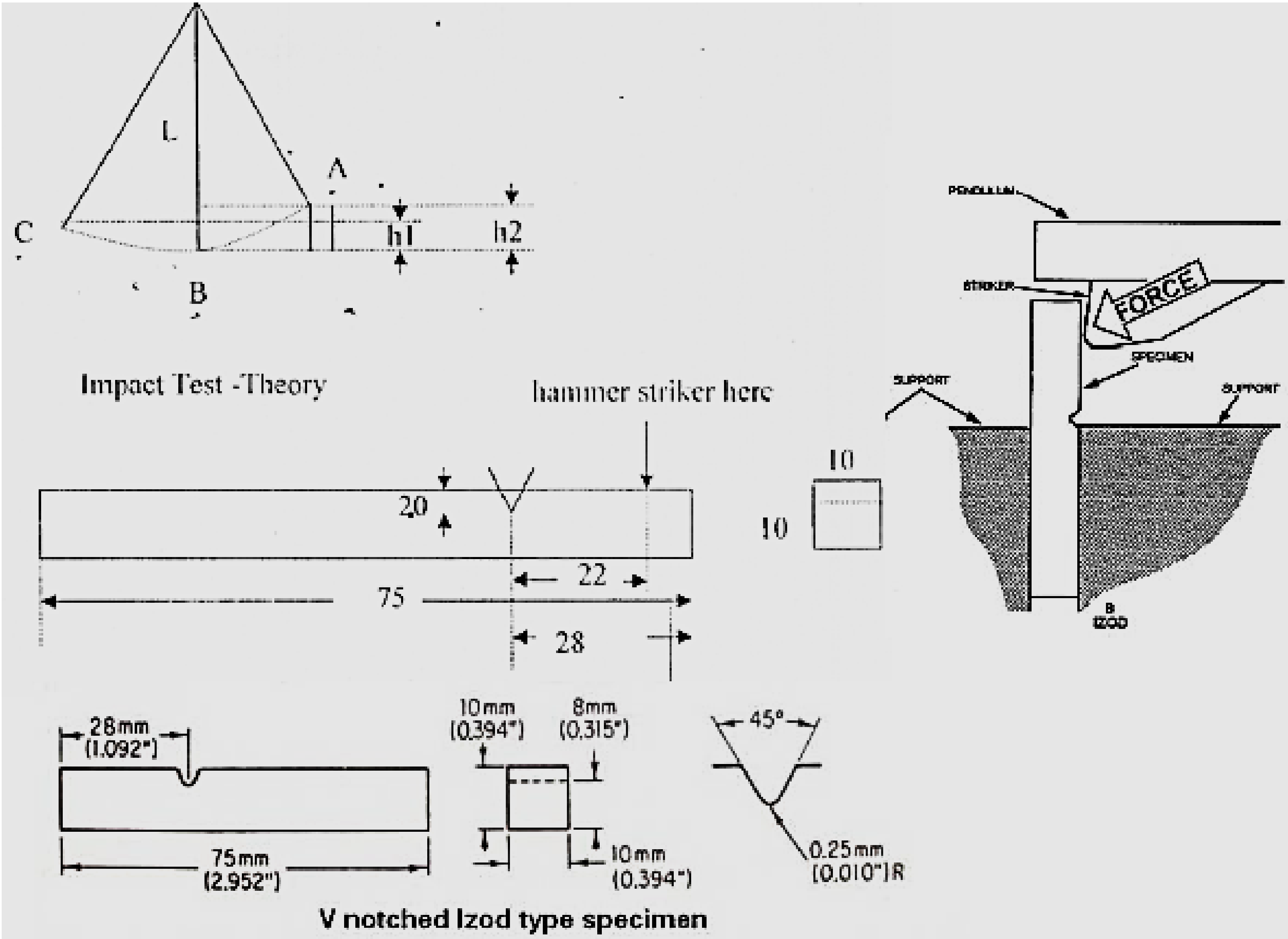
- The Izod impact test is the most common test in North America. **ASTM D256** and **ISO 180**.
- *A pendulum swings on its track and strikes a notched,* ***cantilevered*** *plastic sample.*
- *The energy lost (required to break the sample) as the pendulum continues on its path is measured from the distance of its follow through.*
- *Sample thickness is usually 1/8 in. (3.2 mm) but may be up to 1/2 in. (12.7 mm).*
- The result of the Izod test is reported in energy lost per unit cross-sectional area at the notch (J/m^2).

Izod impact test





Izod impact test



Benha University
Shoubra Faculty of Engineering

Mechanical Department
1st year Mech.

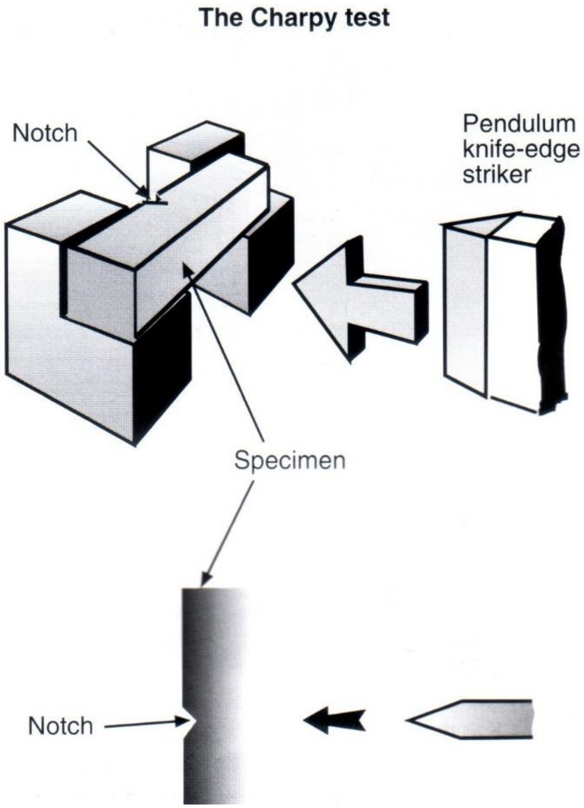
07.04.2019 – Week 9

Charpy test

Prof. Farida Sayed Ahmed
Dr. Mahmoud Khedr

Charpy impact test

- Strikes form higher position with 300 Joules.
- Test specimen is held horizontally.
- Notch faces away from striker.



Charpy impact test

The **Charpy impact test**, also known as the **Charpy v-notch test**, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture.

This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition.

It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. But a major disadvantage is that all results are only comparative.

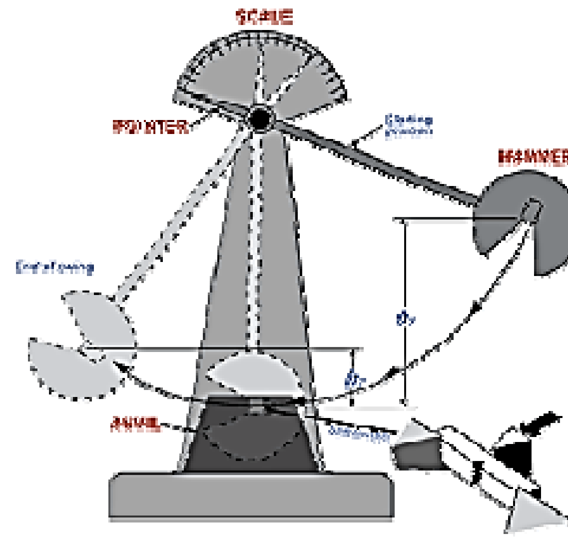
Charpy impact test

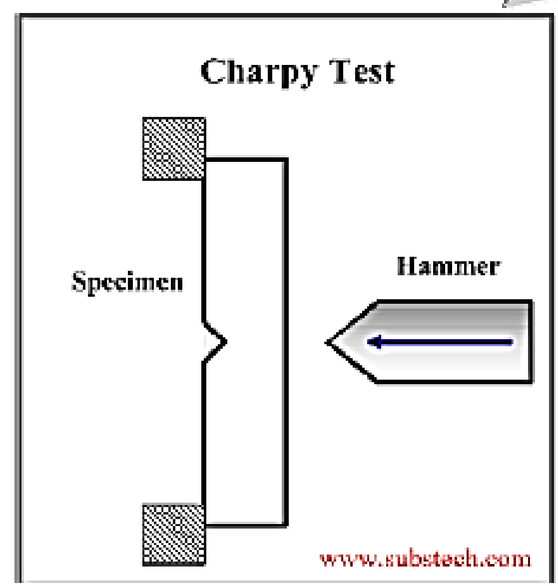
The apparatus consists of a pendulum axe swinging at a notched sample of material.

The energy transferred to the material can be inferred by comparing the difference in the height of the hammer before and after a big fracture.

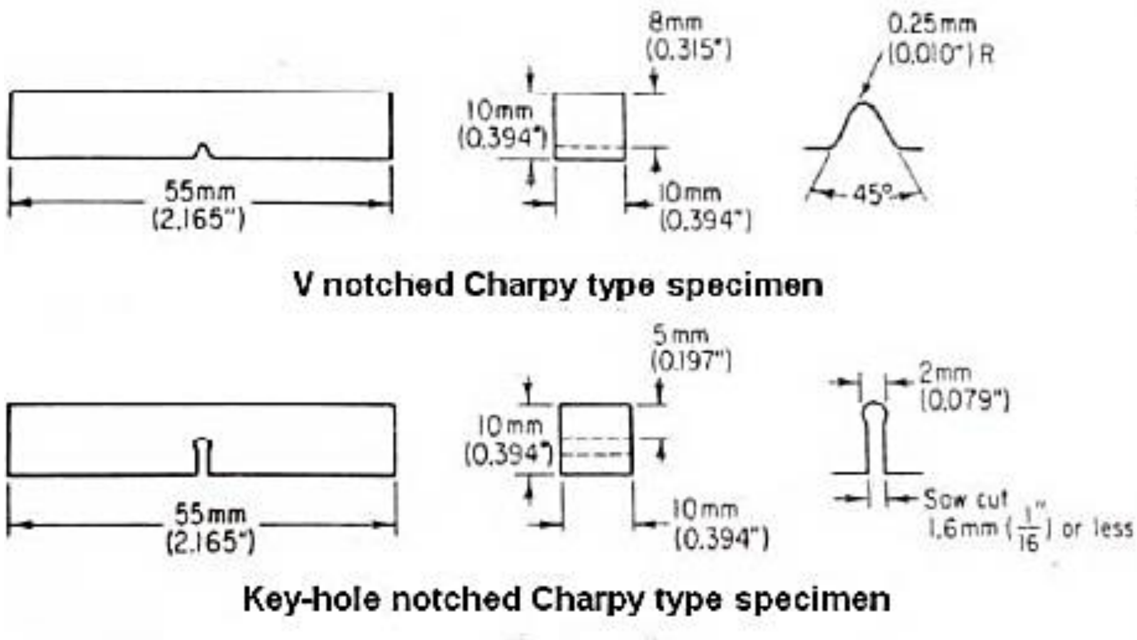
The notch in the sample affects the results of the impact test, thus it is necessary for the notch to be of regular dimensions and geometry.

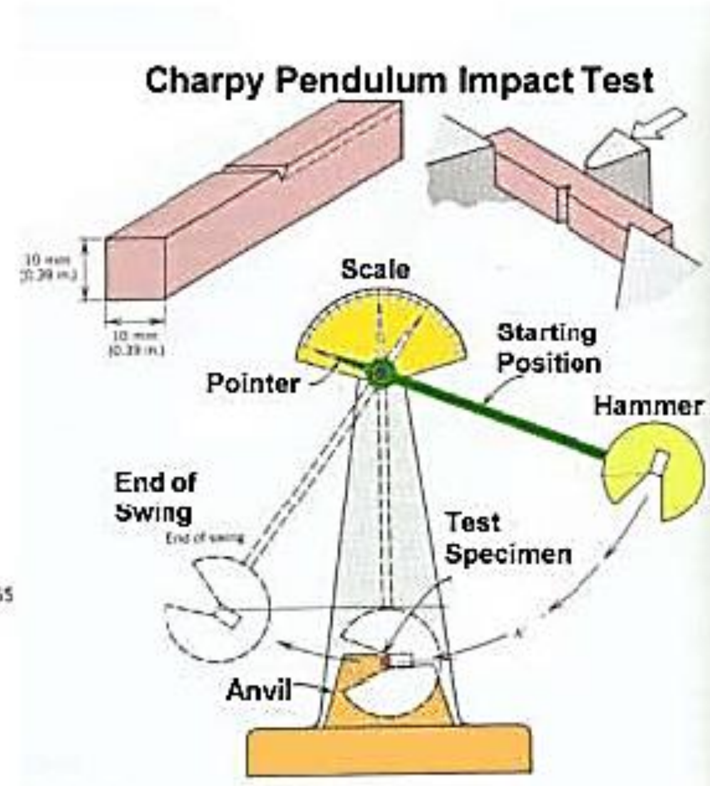
The "Standard methods for Notched Bar Impact Testing of Metallic Materials" can be found in ASTM E23, ISO 148-1 or EN 10045-1, where all the aspects of the test and equipment used are described in detail.





Charpy impact test

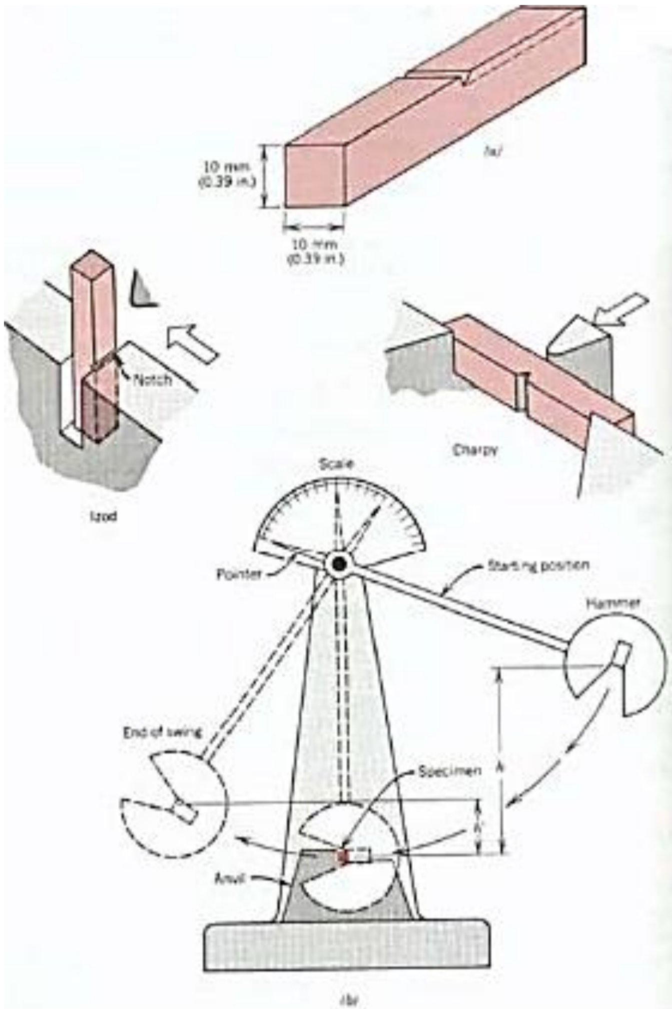


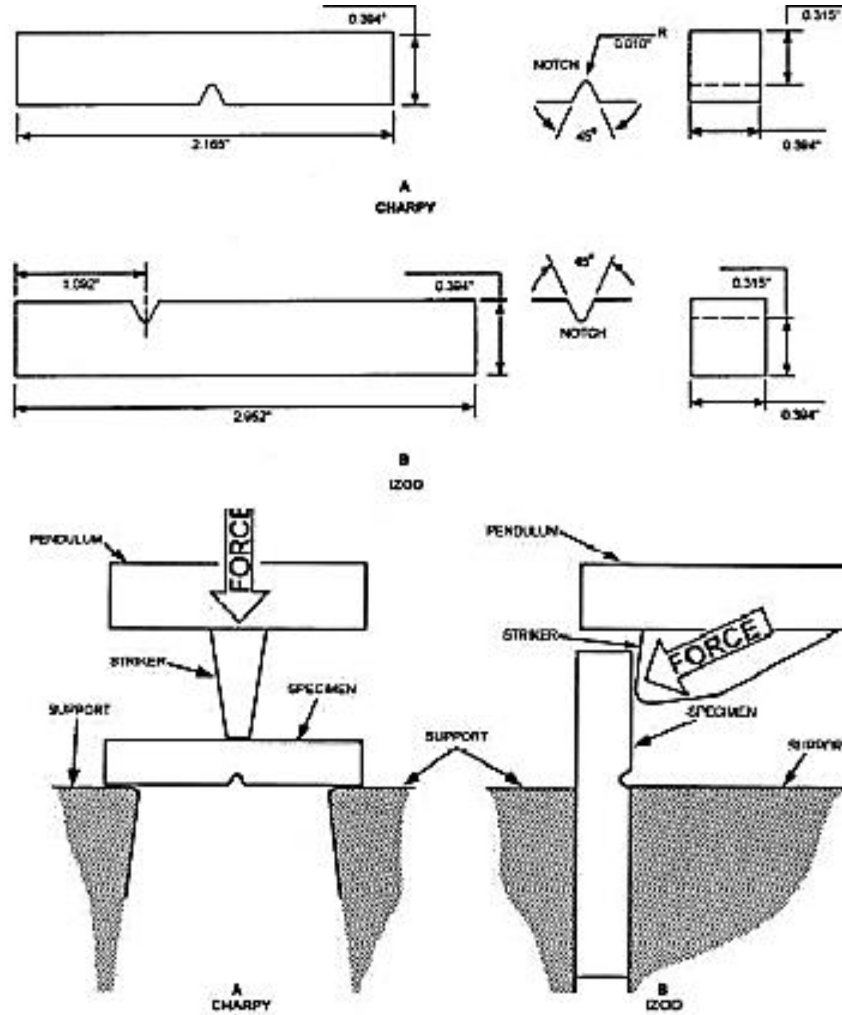


Comparison between Impact Tests

1. The two tests use different specimens and methods of holding the specimens.
2. But both tests make use of a pendulum-testing machine.
3. For both tests, the specimen is broken by a single overload event due to the impact of the pendulum.
4. A stop pointer is used to record how far the pendulum swings back up after fracturing the specimen.
5. The impact toughness of a metal is determined by measuring the energy absorbed in the fracture of the specimen.
6. This is simply obtained by noting the height at which the pendulum is released and the height to which the pendulum swings after it has struck the specimen.
7. The height of the pendulum times the weight of the pendulum produces the potential energy and the difference in potential energy of the pendulum at the start and the end of the test is equal to the absorbed energy.

Comparison between Impact Tests





Benha University
Shoubra Faculty of Engineering

Mechanical Department
1st year Mech.

07.04.2019 – Week 9

Watching the tests

1 Izod

2 Charpy

Prof. Farida Sayed Ahmed
Dr. Mahmoud Khedr

Failure modes

Benha University
Shoubra Faculty of Engineering

Mechanical Department
1st year Mech.

07.04.2019 – Week 9

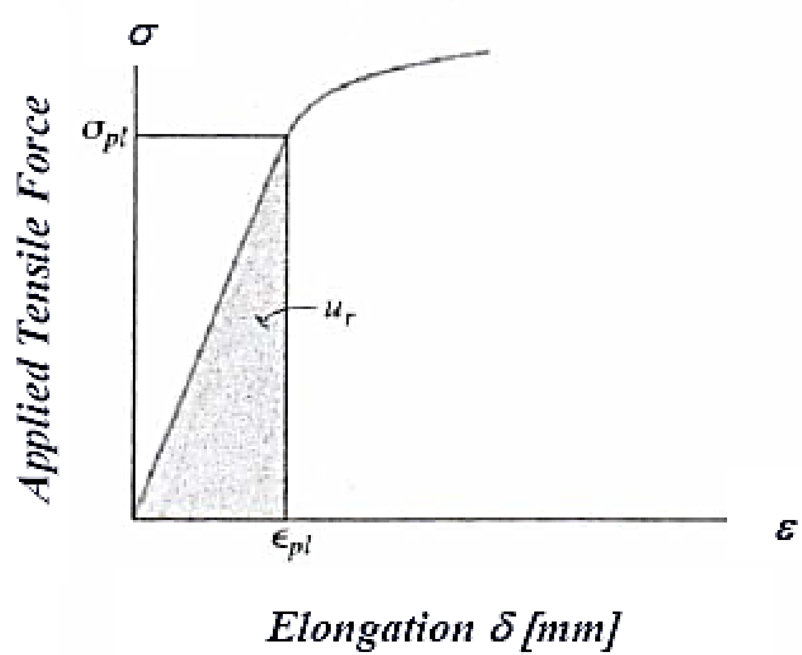
Strain energy

Prof. Farida Sayed Ahmed
Dr. Mahmoud Khedr

Strain Energy under Impact Tension

A material's resilience represents the ability of the material to absorb energy without any permanent damage to the material. In particular, when the load a reaches the proportional limit, the strain-energy density, is calculated by and is referred to as the *modulus of resilience Ur.* Mathematically it is the area under the straight line "elastic region" of the load-deformation curve per unit volume.

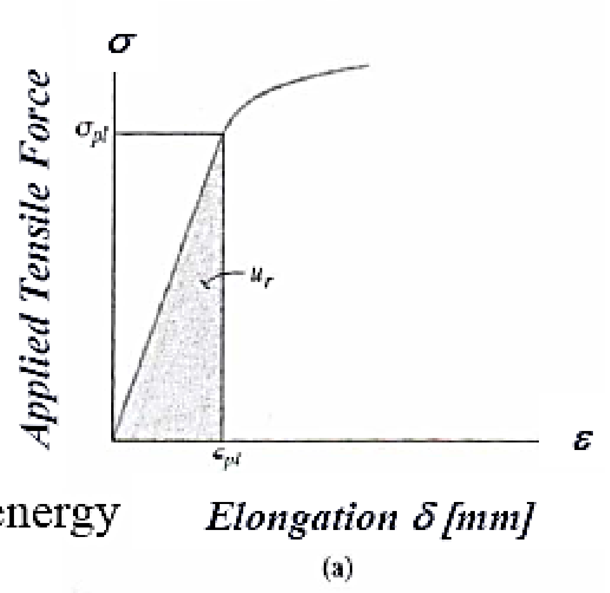
$$U_r = \frac{P_{PL} * \delta_{PL}}{2 * A * L}$$



Internal strain energy

Under uniaxial impact tension, the strain energy U within the elastic zone may be less than the *modulus of resilience Ur*. Mathematically it is the area under the ***PART*** of the straight line in the "elastic region" of the load-deformation curve per unit volume. This ***internal*** strain energy is simply the ***external*** impact energy.

$$U = \frac{P * \delta}{2 * A * L} = \frac{\sigma * \varepsilon}{2} = \frac{\sigma^2}{2 * E} = \frac{E * \varepsilon^2}{2}$$



U is the ***strain energy per unit volume*** of the membe

P is the equivalent static load,

δ is the axial deformation due to the external impact energy

E is the modulus of elasticity,

A is the cross sectional area of the specimen,

L is the length of the specimen.

External strain energy

If a load W is falling from a height H causing uniaxial tension in the member of length L, cross sectional area A and modulus of elasticity E produces an extension d in the member, then the Total ***external*** impact energy is given as

$$\text{External Energy} = W\,(H + \delta)$$

P is the equivalent static load,
δ is the axial deformation due to the external impact energy
E is the modulus of elasticity,
A is the cross sectional area of the specimen,
L is the length of the specimen.

Elastic Impact tension

By equating the Total ***external*** impact energy with the internal strain energy ***strain energy per unit volume*** of the member X the member volume we get

External Energy = Internal Strain Energy

$$W\,(H+\delta) = \tfrac{1}{2}\,P * \delta$$

$$= \tfrac{1}{2}\,\sigma * A * \delta$$

$$= \tfrac{1}{2}\,E * \varepsilon * \delta * A$$

$$W\,(H+\delta) = \tfrac{1}{2}\,E * \delta^2 * A * L$$

P is the equivalent static load,
δ is the axial deformation due to the external impact energy
E is the modulus of elasticity,
A is the cross sectional area of the specimen,
L is the length of the specimen.

Solved example

A falling weight of 65 kN is falling from the top of a 2000 mm aluminum bar. If the aluminum bar has a modulus of elasticity = 70 MPa and 50 mm diameter, then calculate:

(i). The maximum tensile stress in the aluminum bar.

(ii). The maximum distance "measured from the top of the aluminum bar" that the falling weight will reach during falling.

(i). External energy = Internal strain energy

$W (L + \Delta) = \frac{1}{2} \Delta^2 E A / L$

$65 * (2000 + \Delta) = \frac{1}{2} \Delta^2 * 70 * (\pi\, 50^2 / 4) / 2000$

$\frac{1}{2} \Delta^2 * 70 * (\pi\, 50^2 / 4) / 2000 - 65 * \Delta - 130x10^3 = 0$

$34.36\, \Delta^2 - 65 * \Delta - 130x10^3 = 0$

By trial and error: $\Delta = 62.46$ mm

Maximum distance = 2000 + 62.46 = 2062.46 mm below the top of the aluminum bar

(ii). $\sigma = E * \Delta / L$

$= 70 * 62.46 / 2000$

$= 2.18$ MPa.