Materials Testing

BSSM Workshop on Experimental Mechanics

9th March 2018 - Peter Fuller

Objectives

Understand the fundamentals of materials testing

Topics covered today:

- Materials Testing – why?
- Popular types of machines used for materials testing
  Electro-Mechanical / Servo- Hydraulic / Servo Electric
- Common Test Types & Gripping
- Strain – Definition and Measurement
- Modulus
- Load/Extension vs. Stress/Strain
- Yield Strength
- Load Cells & Alignment
- Extensometers
- Test Conditions
- References

Materials testing

- Why Test?
- Determine the reasons for failure
- Predicting behaviour of materials under different conditions
- Develop new processes and materials
- Find more cost effective materials
- Maintain quality
- Safely reduce amount and/or cost of materials used
- Select materials to match application
- Analyse what went wrong

Tensile testing

Why Tensile testing

- - Most fundamental type of mechanical test
- Simple
- Relatively inexpensive
- Repeatable
- Discover its strength and how much it will elongate

- Other simple test types:
- Hardness – relationship to tensile strength
- Flexure
- Compression

Tensile testing

- Electro Mechanical
  Rotary electric motor, via toothed belt drive
  Typically <500kN

- Servo-Hydraulic
  High pressure oil & Servo Valve
  High Capacity

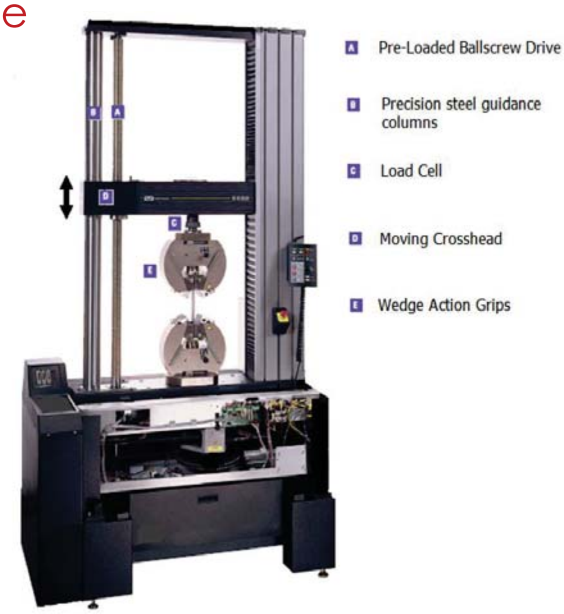
- Electro Dynamic
  Linear electric motor (Newer Technology)
  <10kN

All of these can perform Quasi-static tests. Servo Hydraulic & Electro Dynamic can also perform higher speed dynamic tests to accelerate failure

Classic Tensile Testing Machine

Typical 100kN Tensile Testing machine (Cutaway view of an Instron 5500 series Electromechanical machine)

- Applies force in compression or tension at a constant rate: Either in mm/min, % strain/min, or N/min
- Used for quasi-static unidirectional, or slow cyclic tests
- Records data throughout the test to produce a typical stress/strain curve



Fatigue Testing Machine

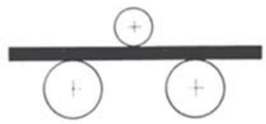
- Applies cyclic loading to the specimen
- Applies force in compression or tension at a constant rate:
  Either in mm/min, % strain/min, or N/min.
- Some systems can also apply simultaneous torsional loads
- By varying the frequency and amplitude of the test, you can determine how the material behaves in repetitive cyclic situations and predict failure

Typical 100kN Fatigue Testing machine
(Instron 8801 Servo Hydraulic)

Common Test Types

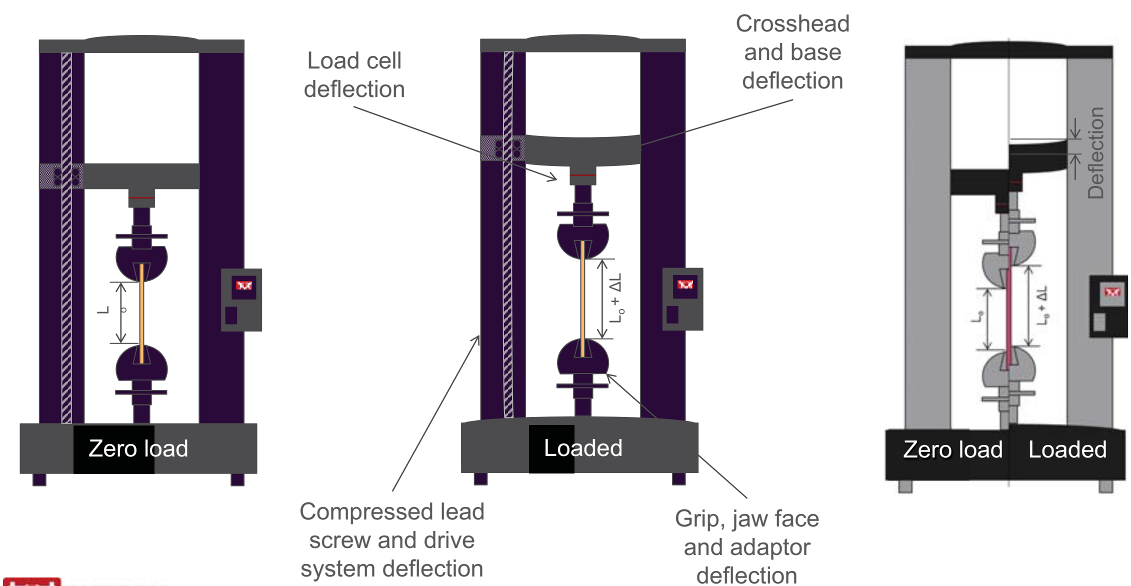
Tensile

Compression



Flexure

System Compliance

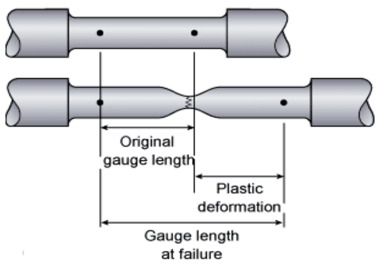


Strain

- Strain is the Ratio of change in extension per unit length (%)
- Elastic region – Hooke's law states:
  'Within the elastic limit, the extension of a material is proportional to the applied force'
- Extensometers: Used to measure strain accurately
  Axial; Transverse; Dual Averaging; Clip-on; Non-Contact; LVDT (linear Variable Displacement Transducer); Bonded strain gauges
- What is strain rate?
  - Change in Specimen Length/Original Cross Sectional Area/Time
  - Change in strain per unit of time
    (in/in/min, mm/mm/s, %/s, s^{-1})
  - Typically measured with an extensometer

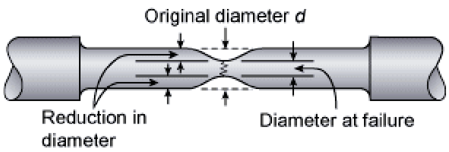
Strain

Axial Strain: Ratio of change in extension per unit length. (gauge) length



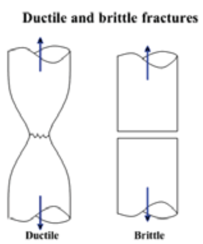
Transverse Strain:

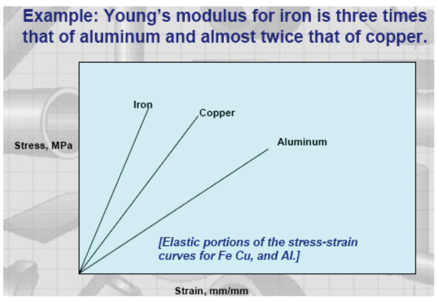
Ratio of change in specimen width/diameter



Modulus

- The modulus of elasticity is a measure of the stiffness of the material – Hooke's Law

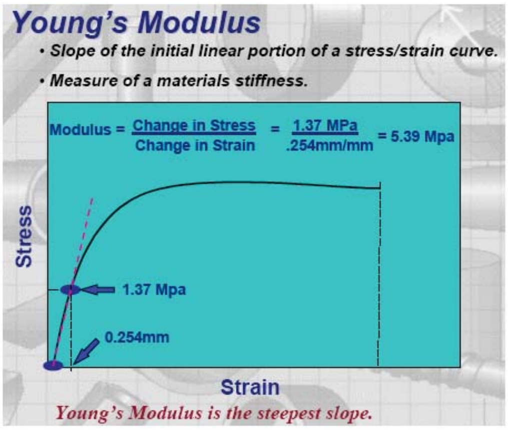


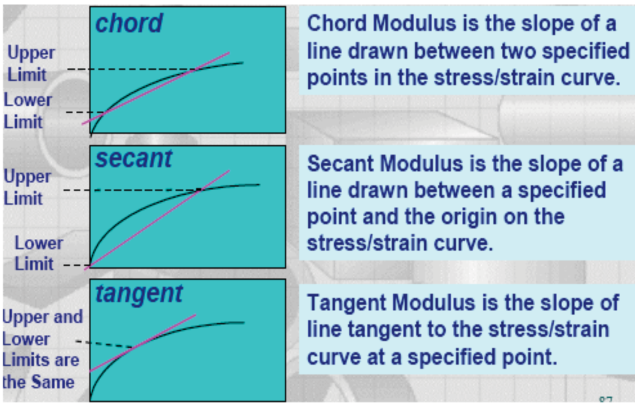


- After 'Yield' the curve is no longer linear and deviates from the straight-line relationship, Hooke's Law no longer applies and some permanent deformation occurs in the specimen
- This point is called the 'elastic', or 'proportional limit'. After this, the material reacts 'plastically' to any further increase in load or stress. It will not return to its original, unstressed condition if the load were removed.

Modulus

Different types of modulus calculation:





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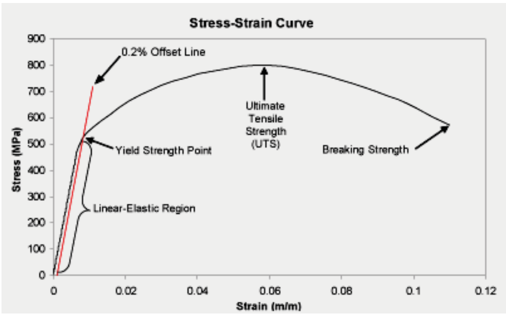
Load vs. Extension & Stress vs. Strain

A 'load' vs. 'extension' graph, has limited use:

If 'Load' is converted into 'Stress' (load per unit cross sectional area) and extension is converted into a percentage of the original specimen length, or 'strain', direct comparisons can be made from the results carried out on different size and shape specimens



NB - The *shape* of the 'load-extension' diagram does not change when converted to a 'stress-strain' diagram

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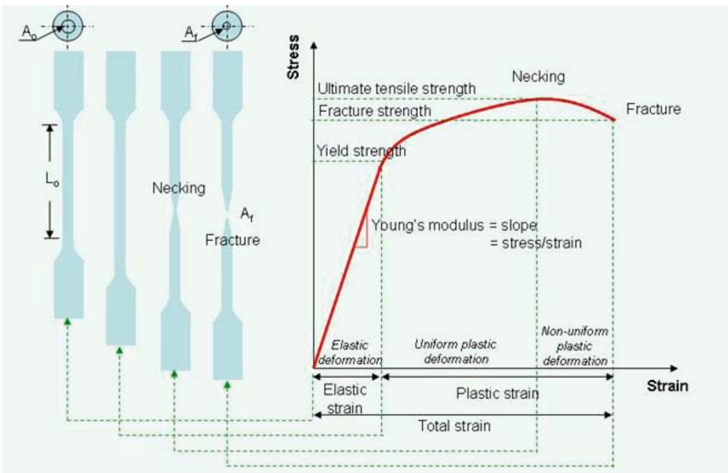
Stress Strain Illustration

For many materials, during the initial portion of the test, the relationship between the applied force, or stress and the elongation, or strain is linear.



Common S.I. measuring units used in tensile testing:
Stress (σ): Pascal (Pa) (N/m^2), or more commonly MPa & GPa

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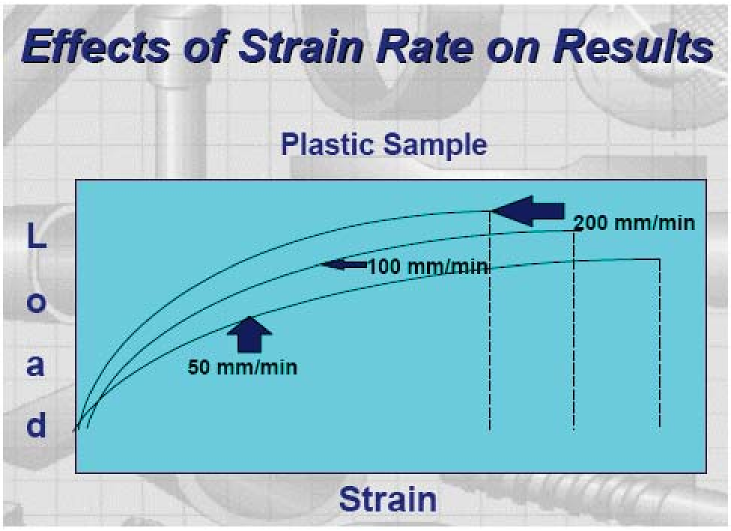
Test Conditions

- The correct and consistent strain rate must be used to ensure consistent results



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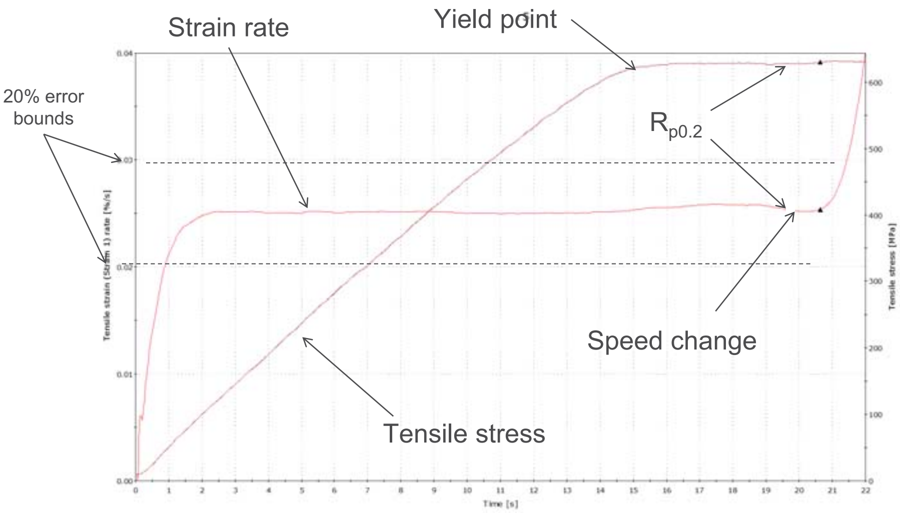
Strain Control Testing (i.e. EN6892-1)



Automatic control

The test system automatically calculates the optimum control parameters dynamically during the test for changing specimen cross-section and stiffness, removing any setup or operator influences.

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Load Cells 1

- Deform elastically under load
- Deformation measured with strain gauges and calibrated as Load or Force
- Accuracy – Typically ±0.5% of reading
- Range - Typically 1 – 100% of capacity

- Potential Errors:
  - Off-axis loading
  - Range
  - Calibration
  - Mass Intertia
  - Overloading
  - Temperature Variation

Common S.I. measuring units used in tensile testing:

Force (or Load): Newtons (N) & (KN)

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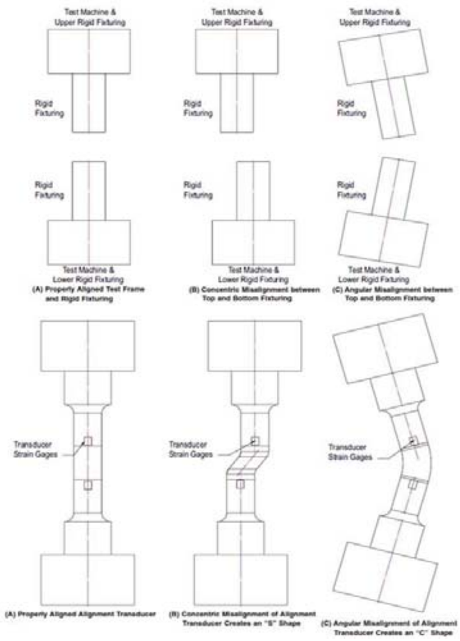
Load Cells & Alignment

- Alignment:
  Angularity & Concentricity

- Why do we need good alignment?
- Compliance to Nadcap is of increasing importance to laboratories around the world
- The purpose of these standards is to ensure that testing in the laboratory is done consistently and to ensure aerospace manufacturers that the materials provided them by suppliers have been tested under the correct test conditions.

Good alignment = good results!



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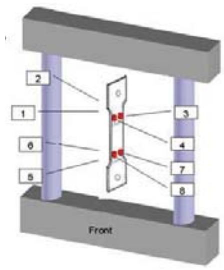
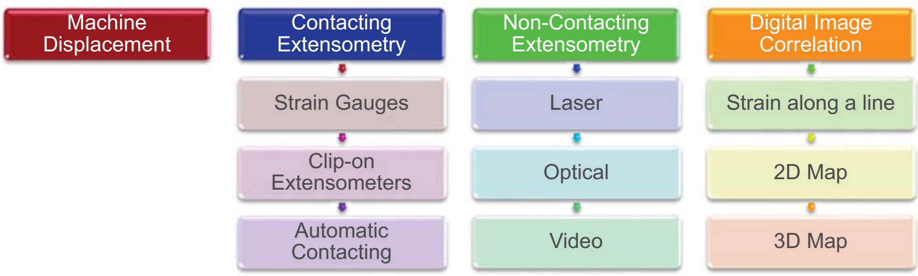
What is Alignment?

Alignment and how to measure and adjust



Strain Measurement

Different methods of measuring strain



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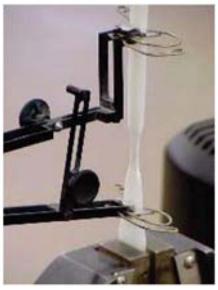
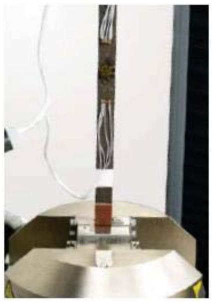
Extensometers - Contacting





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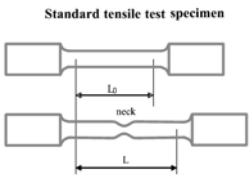
Non-Contact Extensometry

50kN Instron machine shown with non contact (Video) Extensometer



Where ‘Lo’ is the gauge length

Camera tracks marks on the specimen to measure strain

Strain control demo

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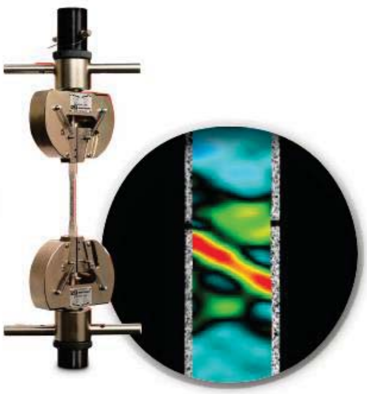
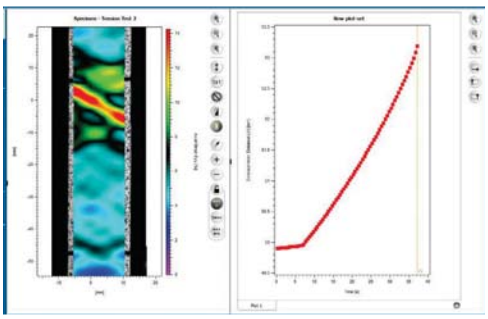
Digital Image Correlation

Instron machine shown with non contact (Video) Extensometer & DIC Replay

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Questions