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School of Automotive Engineering

Laboratory 6

Bending testing

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Contents

1. Objectives:

1. Students are required to understand the principles of bending testing, and the influence of materials type and cross-section form on bending strength.

2. Introduction:

Material testing allows determining the strength of a material, verifying its properties and establishing its behavior under external influences.

The shape and dimensions of a body, specific weight and density, humidity content, etc. are generally determined with physical tests, whereas strength, elasticity and plasticity, ductility, tenacity and fragility, etc. are determined with mechanical tests.

3. Equipment description:

a. Description

Universal unit consists of a didactic benchtop universal unit. It is distinguished by its rigid construction, accurate control and a precise hydraulic system to apply loads of up to 23 kN., which enables demonstrations of phenomena undetectable under smaller loads.

With this unit the student can perform these material tests:

- Brinell hardness test
- Tensile test
- Compression test
- Bending test
- Shear test
- Deep draw test
- Disc and helical spring tests.

It allows to achieve testing forces up to 23 kN with very little physical effort. Because of this it can be used even by physically weak students.

The unit can be manually operated; it generates the test force through a hydraulic system and performs the measurements through an indicating instrument with pointer, then data can be registered and evaluated through the computer.

b. Specifications

- Main metallic elements made of stainless steel.
- Base unit with feet.
- Upper crosspiece.
- Lower crosspiece.
- Frame pillars.
- Test load is generated using a hand operated hydraulic system.
- Force sensor.
- Deformation displacement sensor.
- Maximum stroke: 45mm.
- Maximum test force: 20kN.
- Dynamometer: 0-20kN., graduations: 0.5kN.
- Elongation gauge: 0-10mm, graduations: 0.01mm.
- Data acquisition system for the computer (PC).

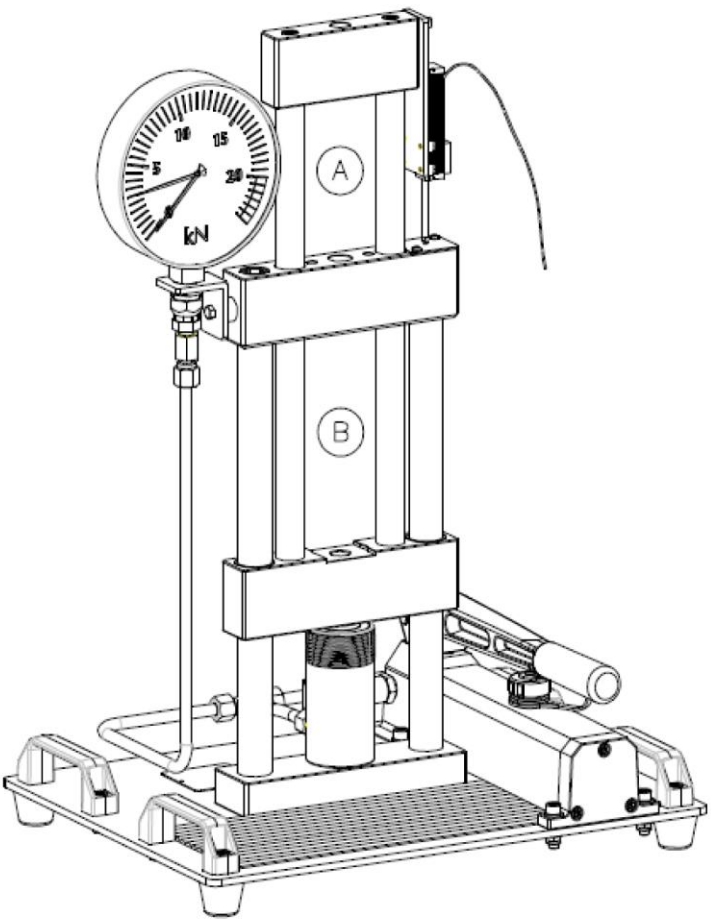


Fig. 6.1 Main unit

Tensile and shear tests are performed in the space between the upper crossbar and the lower support bar (A).

Compression, bending, deep draw, Brinell hardness and disc and helical spring tests are performed in the space between the upper support bar and the lower support bar (B).

c. Accessories provided:

- Set of two compression plates with fastening elements.
- Specimens for compression tests made of steel, brass, aluminum and copper.
- Jaws for tensile tests with flat and round specimens (2 units).
- Specimens for tensile tests made of steel, brass, aluminum and copper.
- Rods for tensile tests made of steel, brass, aluminum and copper.
- Devices for tensile tests with standard specimens (2 units).
- Standard specimens for tensile tests made of steel, brass, aluminum and copper.

- Device for shear tests.
- Specimens for shear tests made of steel, brass, aluminum and copper.
- Device for Brinell tests. Penetrating ball: 10mm.
- Set of Brinell specimens made of steel, brass, aluminum and copper.
- Device for bending tests.
- Set of specimens for bending tests made of steel, brass, aluminum and copper.
- Device for deep draw tests.
- Specimens for deep draw tests made of steel, brass, aluminum and copper
- Disc springs (2 units).
- Helical springs (2 units).
- Fastening elements for accessories.
- PMMA protection element.

Fig. 6.2 Accessories provided

d. Practical possibilities

- Learning how to use the instrumentation required to perform the main tests on materials.
- Study and familiarization with universal material testing machines.
- Tensile strength tests.
- Compressive strength tests.
- Brinell hardness tests.
- Bending tests.
- Shear tests.
- Deep draw tests.
- Tests with disc springs.
- Tests with helical springs arranged either in series or in parallel.
- Recording stress-strain diagrams.

- Using the data acquisition system.

e. Particularities of the unit software

After the software is installed and run an initial screen, where the test to be performed must be chosen, will appear.

Fig. 6.3 Software Startup screen

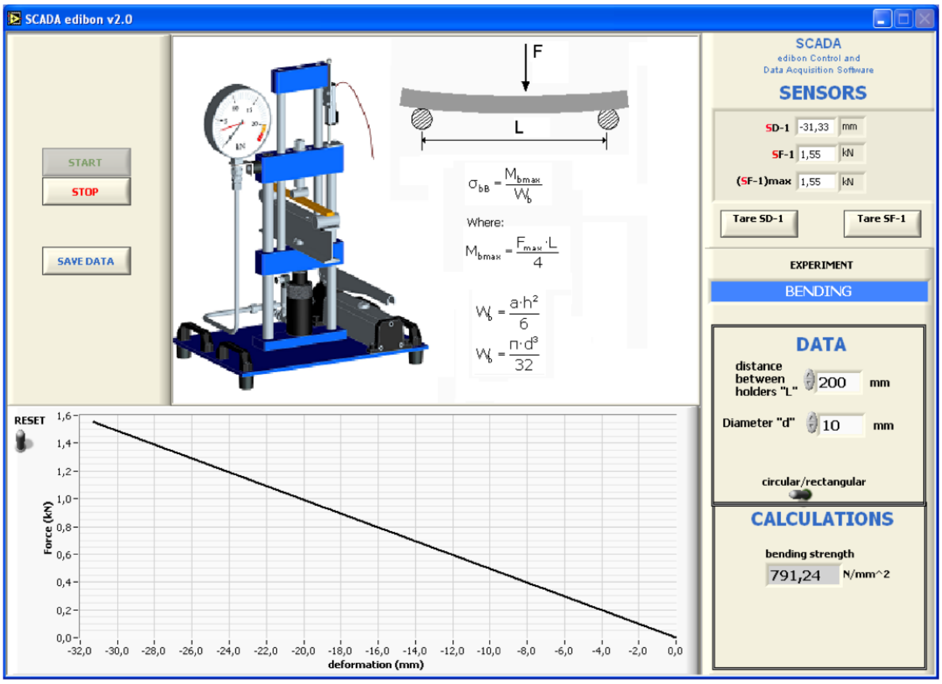


Fig. 6.4 Bending screen

The main result of each test and the formulae and variables required to obtain them can be found when clicking on each test. The software shows a default value for those variables that depend on the test pieces to be studied (for example, diameter of the test piece). That value can be modified by the user in function of the test pieces.

f. Hydraulic system

The force required for testing is produced by the hydraulic system. It allows to obtain testing forces up to 23kN with very little physical effort. Because of this it can be used by physically weaker students

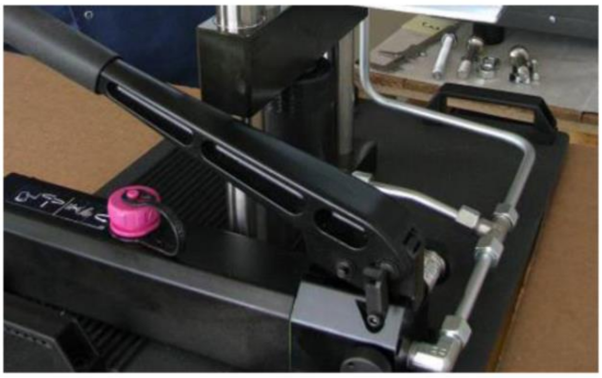
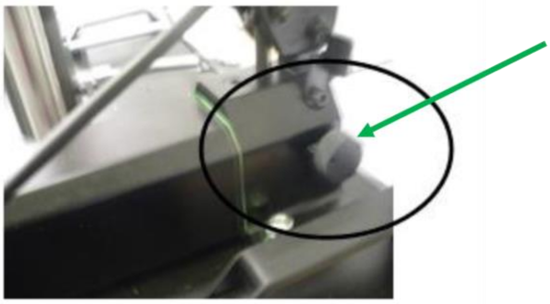


Fig. 6.5 hydraulic system

Pressure is produced with the handle of the hydraulic hand pump and transferred to the hydraulic cylinder. The return valve of the pump must be closed.



The wheel must be totally rotated clockwise to exert the force, whereas it must be totally rotated anticlockwise to release the force.

Fig. 6.6 Return Valve

g. Force measurement

The mechanic gauge for force measurement is calibrated in units of force (kN). The measurement range is 0 - 20kN and the accuracy is ±0.1kN. The smallest scale tile is 0.5kN.

The gauge has a red pointer that indicates the largest force used during the test. Set the red pointer into initial position with the knob (screw).

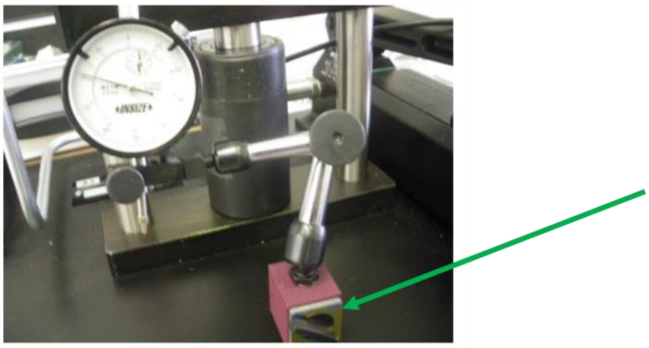
Fig. 6.7 Mechanic force gauge

h. Deformation measurement

Deformation is measured using a portable potentiometer which allows a measurement accuracy of ±0,01mm. While preparing for the experiment, position the potentiometer as shown in Fig. 6.8.

The electronic deformation sensor is fixed to the unit by means of a support.

The “0” of the dial gauge can be set where required depending on the test to be performed. Turn the black wheel for that purpose.



It can be located with a magnet where the measurement wants to be performed. It must be set in ON position to be fixed and in OFF position to be released.

Fig. 6.8 Measure deformation using a portable potentiometer

4. Safety Instructions

ATTENTION

ATTENTION

Read the instructions manual thoroughly before using this unit in order to learn the testing procedure and safety measures and prevent any damage to the unit itself or the user.

ATTENTION

ATTENTION
It is forbidden to dismantle or modify without prior permission any electronic component or switch, as well as their fixed positions.

ATTENTION

ATTENTION
Disconnect the unit from the power supply after use.

ATTENTION

ATTENTION
Applied force must don't exceed 20kN

5. Formula Symbols and Units Used

Symbol	Mathematical/physical quantity	Unit
L	Beam length	mm
d	Rode cross-section diameter	m/s
b,h	Rectangular cross-section dimension	m
F	Applied Force	N
$M_{b\max}$	Maximal bending moment	$N.mm$
W_b	Axial moment of inertia	mm^3
σ_b	Bending strength	N/mm^2

6. Basic principles

This test complements the tensile test. It consists on subjecting the specimens, supported by their ends, to a stress applied in the centre or two equal stresses applied to the same distance from the supports.

It is not always done. It is done in pieces and materials that are going to be subjected to bending. It is done with cylindrical, square or rectangular pieces.

To perform the test two rollers must be placed L=20d apart, being d the diameter of the specimen.

Generally, it is a test performed with fragile materials (ceramic and glass), although it is also applicable to metals. Load is vertically applied, on one or two points, resulting in bending tests in 3 or 4 points.

Longitudinal stresses on bending test pieces are tensile stresses on the lower support side and compression stress on the upper load application side.

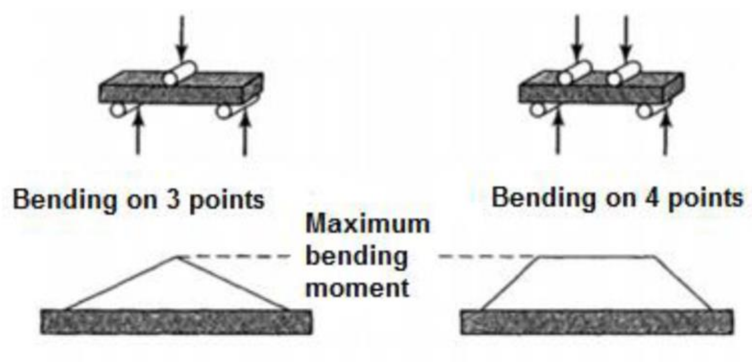
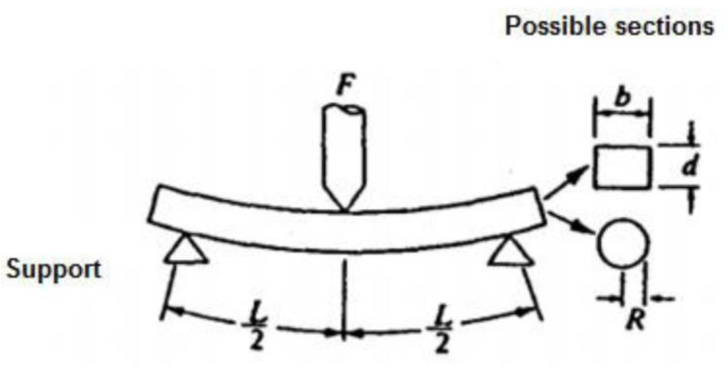


Fig. 6.9 3 and 4 points bending



$$MOR = \frac{3 \cdot F \cdot L}{2 \cdot b \cdot d^2}$$

$$MOR = \frac{F \cdot L}{\pi \cdot R^3}$$

Fig. 6.10 Bending strength

Bending test demonstrates the relationship between the elastic deformation of the sample and a load. The influence of the axial moment of inertia on the size of the elastic deformation can be demonstrated by using samples of various shapes. The test is carried out up to a certain deformation or the material will break up. To determine the bending strength of the material, the maximum force is read on the force gauge "F". With a space between supports "L", the bending strength for a round sample with diameter "d" or rectangular with "$b \times h$"is calculated as:

$$\sigma_b = \frac{M_{b\max}}{W_b}$$

Where

$$M_{b\max} = \frac{F_{\max}.L}{4}$$

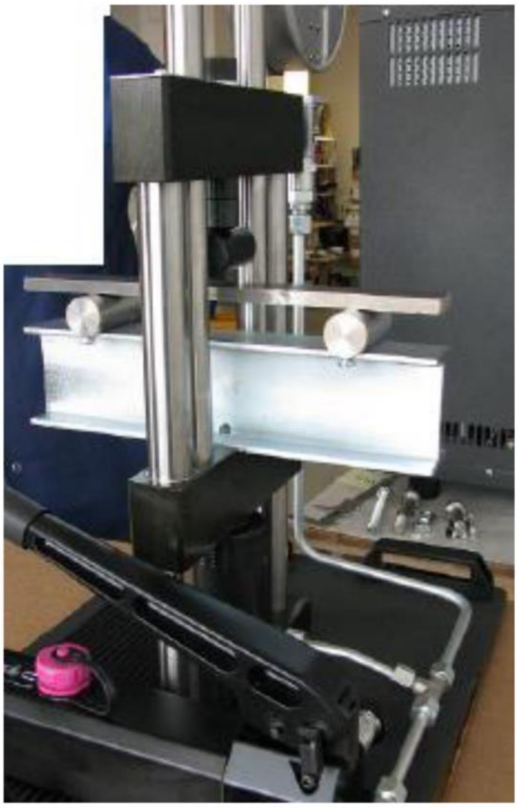
For rectangular cross-section $W_b = \frac{b.h^2}{6}$

For circular cross-section $W_b = \frac{\pi.d^3}{32}$

7. Experimental Procedure

The bending test is carried out in the lower part of the device, between the lower support bar and the upper crossbar. On the lower side of the profile there is a groove to fix it perpendicularly to the lower support bar. The distance between the cylindrical supports can be altered, if needed.

1. Before starting the test, mount the required accessories on the apparatus.
2. Run the software and click on “bending” test.
3. Use the hydraulic system to lift the test piece until the element that applies the force slightly touches the test piece.
4. At that moment, press start and tare the deformation and force measurements if the system was already measuring and apply the load



8. Questions

1- Discuss the obtained experimental results and give your evaluation of the relationship of the bending strength and materials type and cross-section form.

2- Do the experiment as described in paragraph 7 for 7 different beams:

a. Using the unit software, measure the deflection and stress for the bending load from 0 to 3 kN (except aluminum; 2kN) (with increment equal to 0.5 kN).

b. Plot the relationship between deflection and stress for all beams.

c. Discuss the results and give your evaluation of the relationship bending strength - material and cross-section.

d. Calculate the Young modulus E, in the case of 2kN load for all beams:

The deflection is calculated as:

$$\delta_{max} = \frac{F_{max}.L^3}{48.E.I}$$

Where I the second moment of area

For rectangular cross-section $I = \frac{b.h^3}{12}$

For circular cross-section $W_b = \frac{\pi.d^4}{64}$

9. Results

1- Mathematical calculation

Rectangular cross-section beam 1

Material: , $E =$ GPa

Dimension: $b =$ mm , $h =$ mm , $L =$ mm

Load increment	Load applied	deflection	Bending stress
0			
0.5			
1			
1.5			
2			
2.5			
3			

Rectangular cross-section beam 2

Material: , $E =$ GPa

Dimension: $b =$ mm , $h =$ mm , $L =$ mm

Load increment	Load applied	deflection	Bending stress
0			
0.5			
1			
1.5			
2			
2.5			
3			

Rectangular cross-section beam 3

Material: , $E =$ GPa

Dimension: $b =$ mm, $h =$ mm, $L =$ mm

Load increment	Load applied	deflection	Bending stress
0			
0.5			
1			
1.5			
2			
2.5			
3			

Circular cross-section bar 1

Material: , $E =$ GPa

Dimension: $d =$ mm , $L =$ mm

Load increment	Load applied	deflection	Bending stress
0			
0.5			
1			
1.5			
2			
2.5			
3			

Circular cross-section bar 2

Material: , $E =$ GPa

Dimension: $d =$ mm , $L =$ mm

Load increment	Load applied	deflection	Bending stress
0			
0.5			
1			
1.5			
2			
2.5			
3			

Circular cross-section bar 3

Material: , $E =$ GPa

Dimension: $d =$ mm , $L =$ mm

Load increment	Load applied	deflection	Bending stress
0			
0.5			
1			
1.5			
2			
2.5			
3			

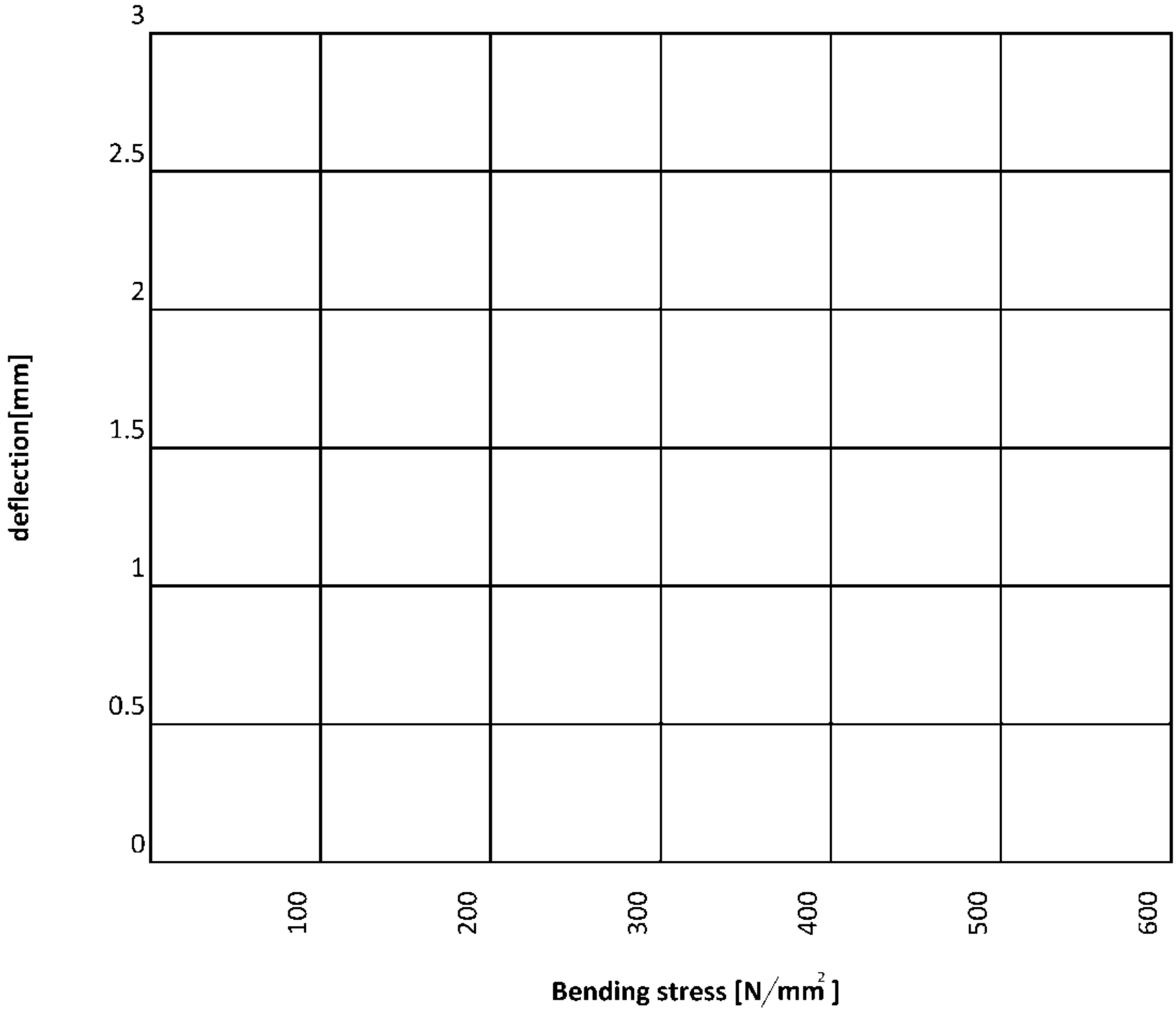
Squair cross-section bar

Material: , $E =$ GPa

Dimension: $a =$ mm , $L =$ mm

Load increment	Load applied	deflection	Bending stress
0			
0.5			
1			
1.5			
2			
2.5			
3			

1- Discussion about the results and conclusion:



Deflection in function of stress for all different beam or bar