Laboratoire des sciences de l’ingénieur, de l’informatique et de l’imagerie

EVALUATION OF A NEW EXPERIMENTAL DEVICE FOR SHEAR MODULUS MEASUREMENT

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Introduction

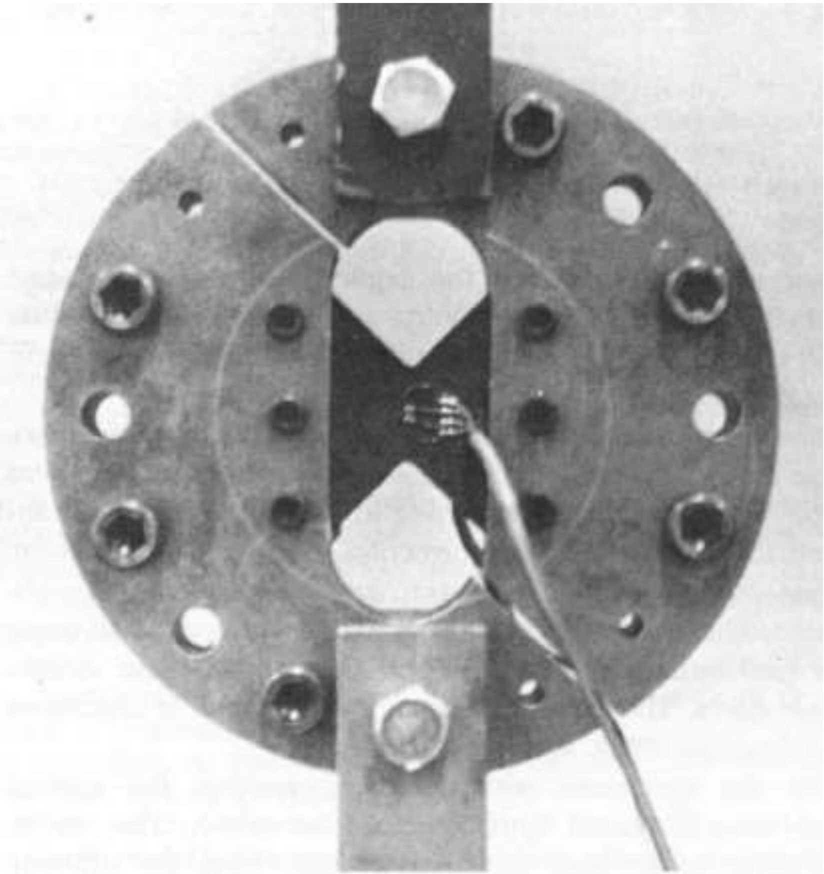
- Isotropic / Orthotropic and homogeneous material
- Purely elastic behaviour

Outline :

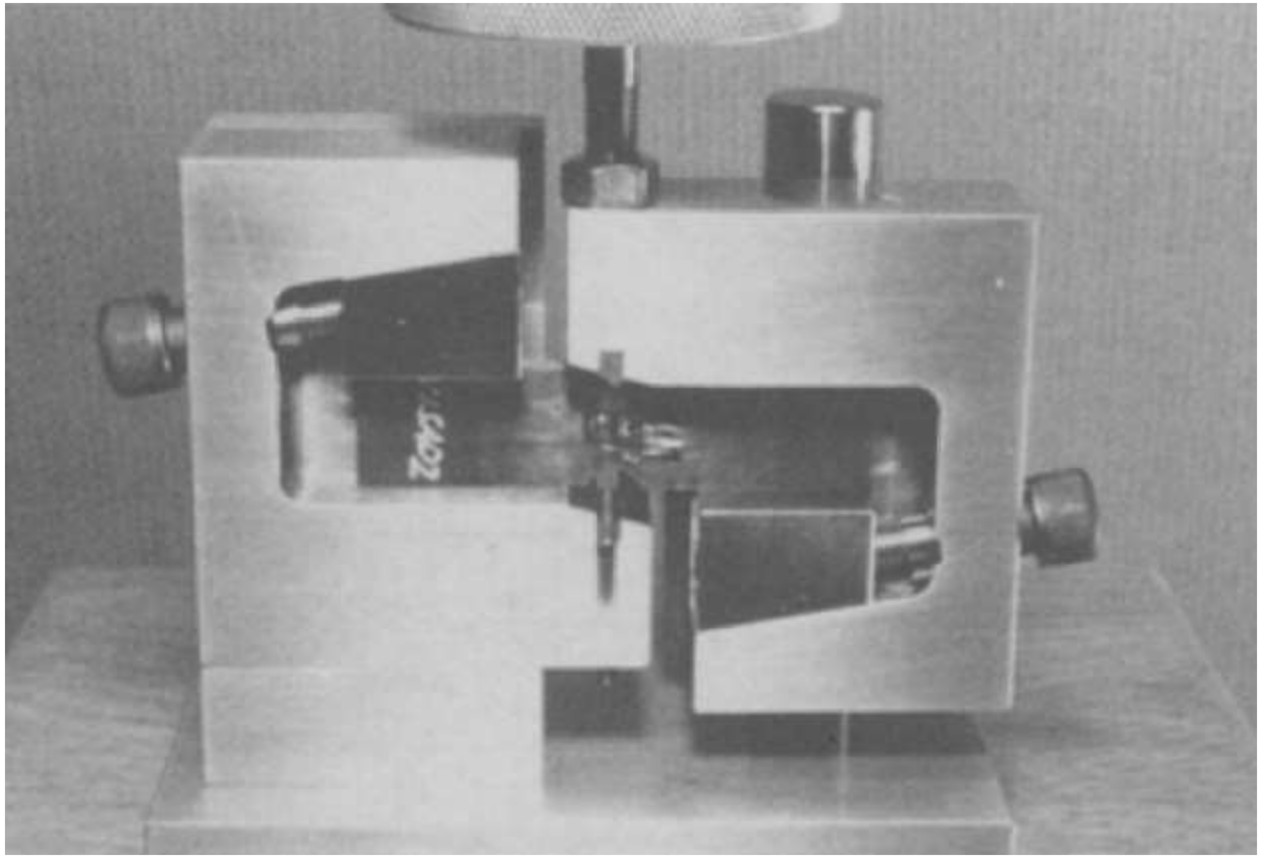
1. Proposal of a new shear device
2. Optimisation of the device on an isotropic material
3. Application to an orthotropic material and comparison with results obtained using conventional methods

Proposal for a new shear device

Methods conventionally used to characterise shear moduli



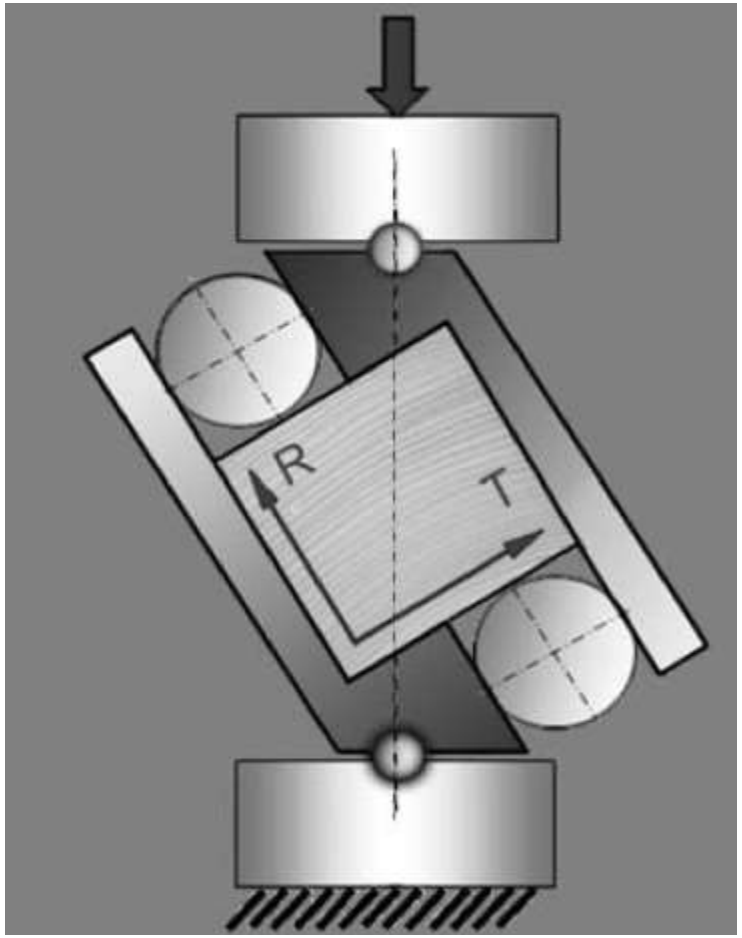
[Yen 2008] Arcan Shear Test Method



[Adams 1987] Iosipescu Shear Test Method

Alternative Solution

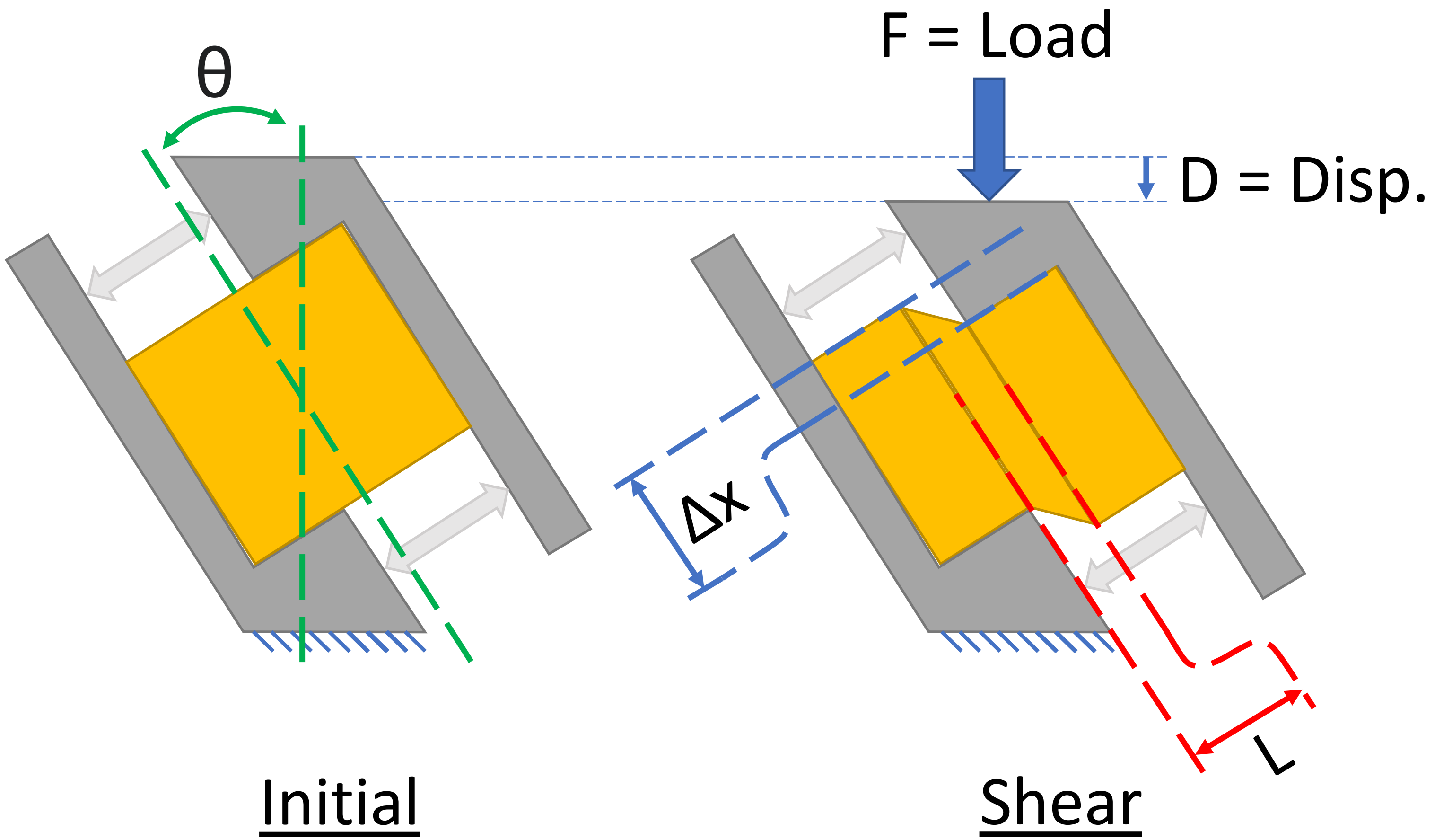
- Previously designed for wood (E_R=1200MPa, E_T=800MPa, ν_{RT}=0.35, G_{RT}=60.8MPa)
- Simple sample shape
- 1 geometry to characterise all directions
- Simplified processing of results



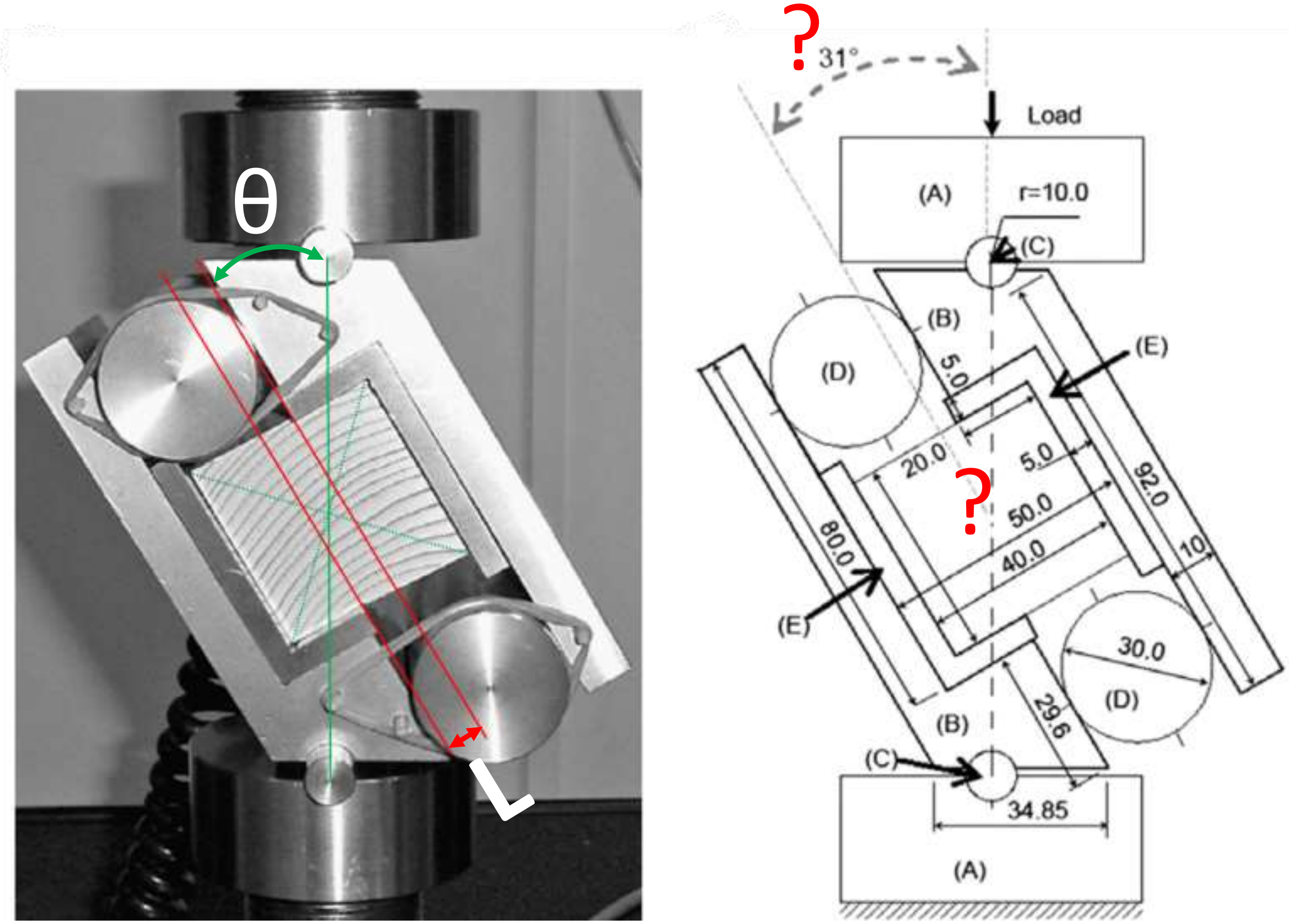
[Hassel 2008] Single Cube Appartus Shear Test Method

How it works

- θ = Angle between the direction of application of the force and the direction of the shear load
- Δx = lateral displacement
- L = thickness
- A = sheared area
- G = shear modulus
- $\Delta_x = \dfrac{D}{\cos(\theta)}$
- $G = \dfrac{\mathrm{F}\cdot L}{A\Delta_x} = \dfrac{\tau}{\gamma}$



Suggested points for improvement

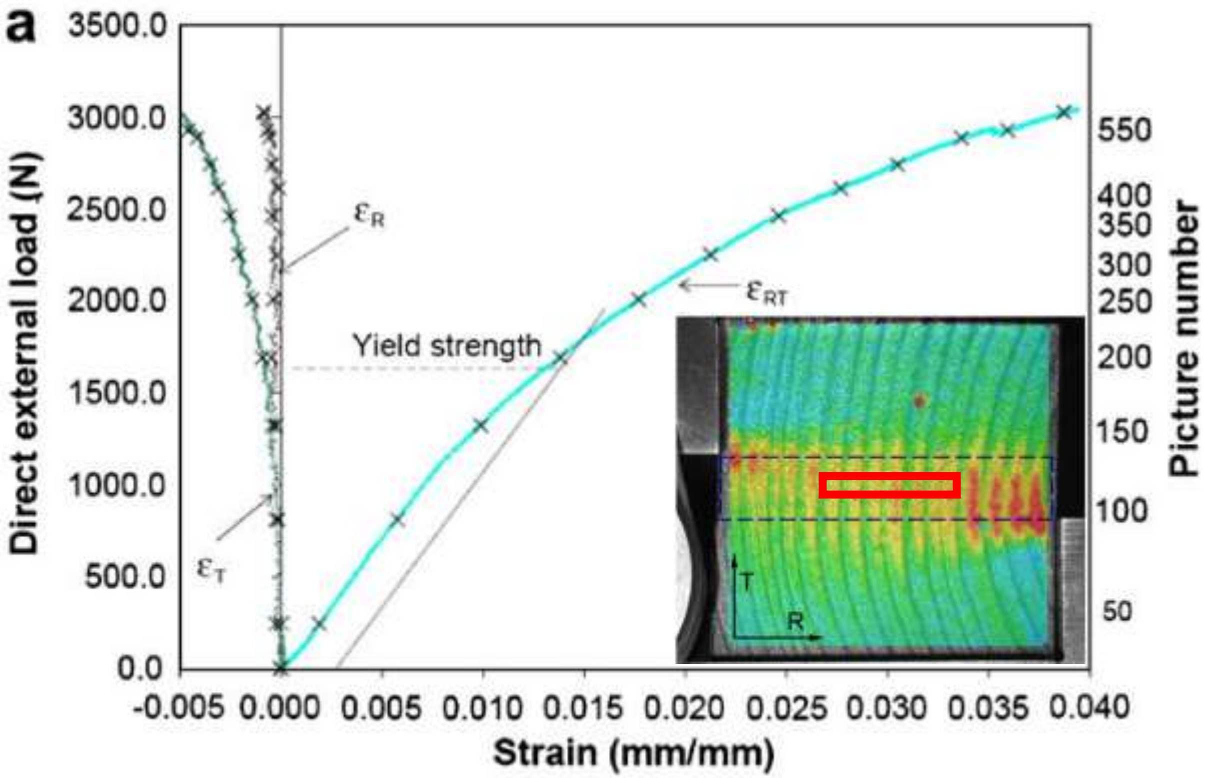


- Reduce the sample size
- Find the optimal value of L
- Find the optimal value of θ

Plan proposed by [Hassel 2009]

Optimisation of the device on an isotropic material

Step 1: Choice of optimisation criteria



[Hassel 2009] Average deformation in the area framed in red

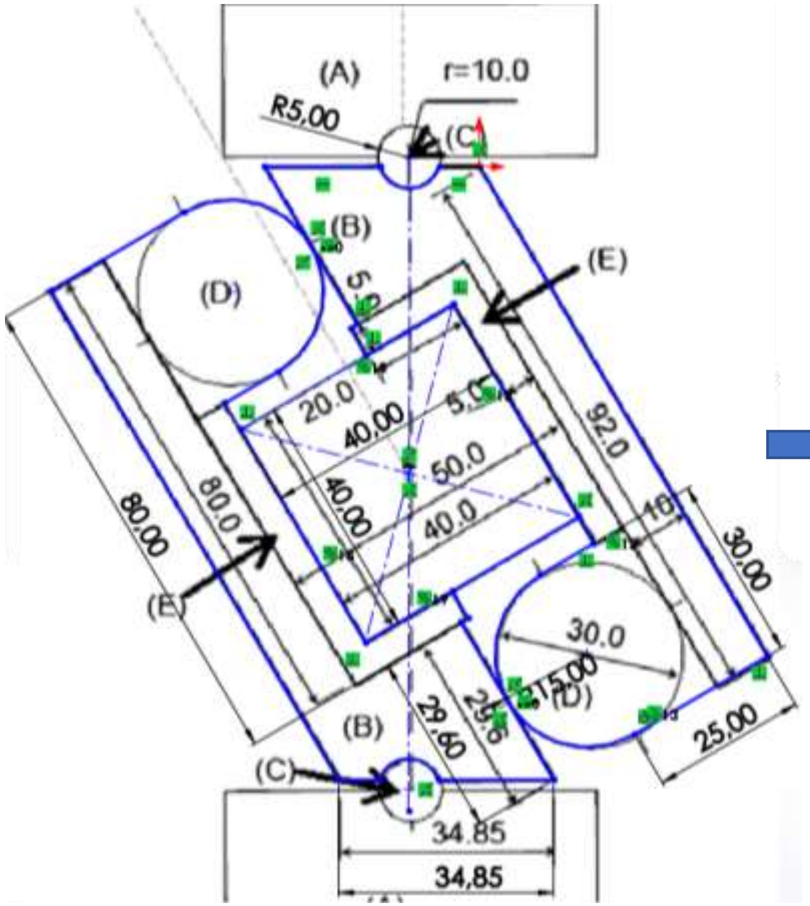
Objective:

- Minimise longitudinal and transverse deformation
- Maximise shear deformation

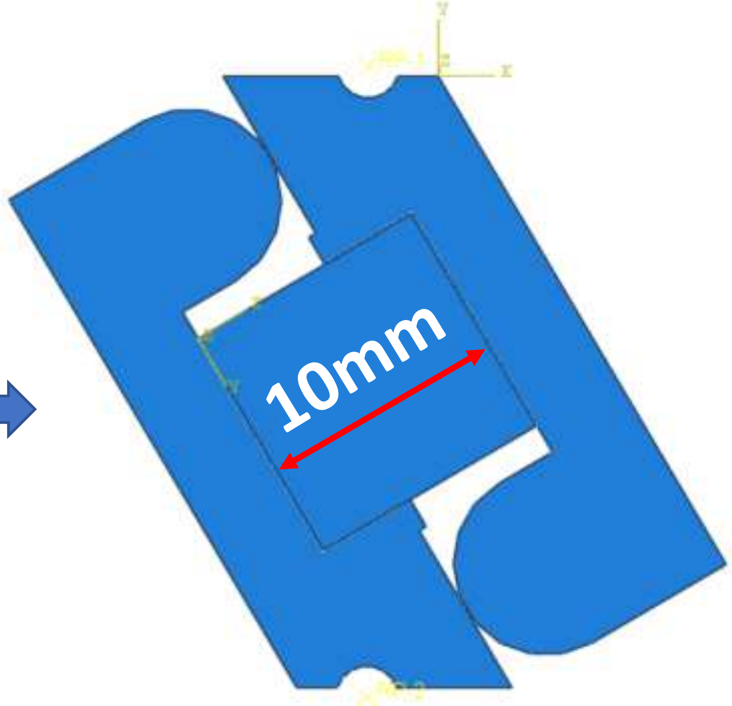
Variables :

- L = distance between jaws ∈ [1-3mm]
- θ = angle between support direction and shear direction ∈ [21-41°]

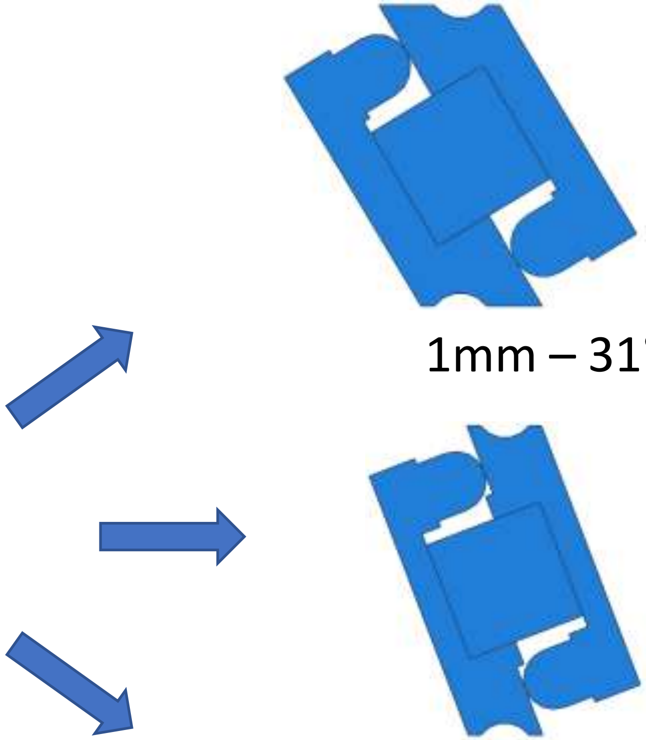
Step 2: Resizing the device and parameterising the geometry



Re-design of SCA on Solidworks (Dassault Systèmes)



Import of different geometries on ABAQUS/CAE (Dassault Systèmes)



1mm – 31°

2mm – 21°

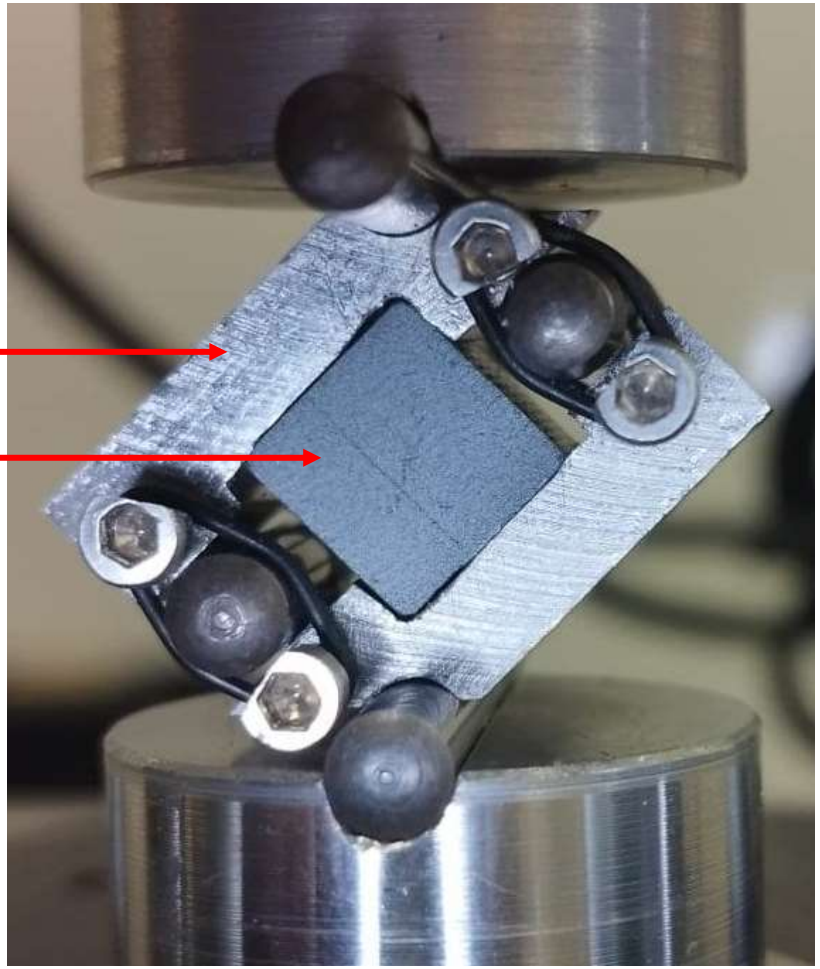
- 2mm-31°
- 2mm-41 °
- 3mm-31 °

Materials

- Manufacturer's data:
- ABS assumed isotropic and homogeneous, purely elastic behaviour
  - Young modulus = E = 2,400MPa
  - Poisson's ratio = ν = 0.41
- Steel assumed isotropic and homogeneous, purely elastic behaviour
  - Young modulus = 210,000MPa
  - Poisson's ratio = 0.3

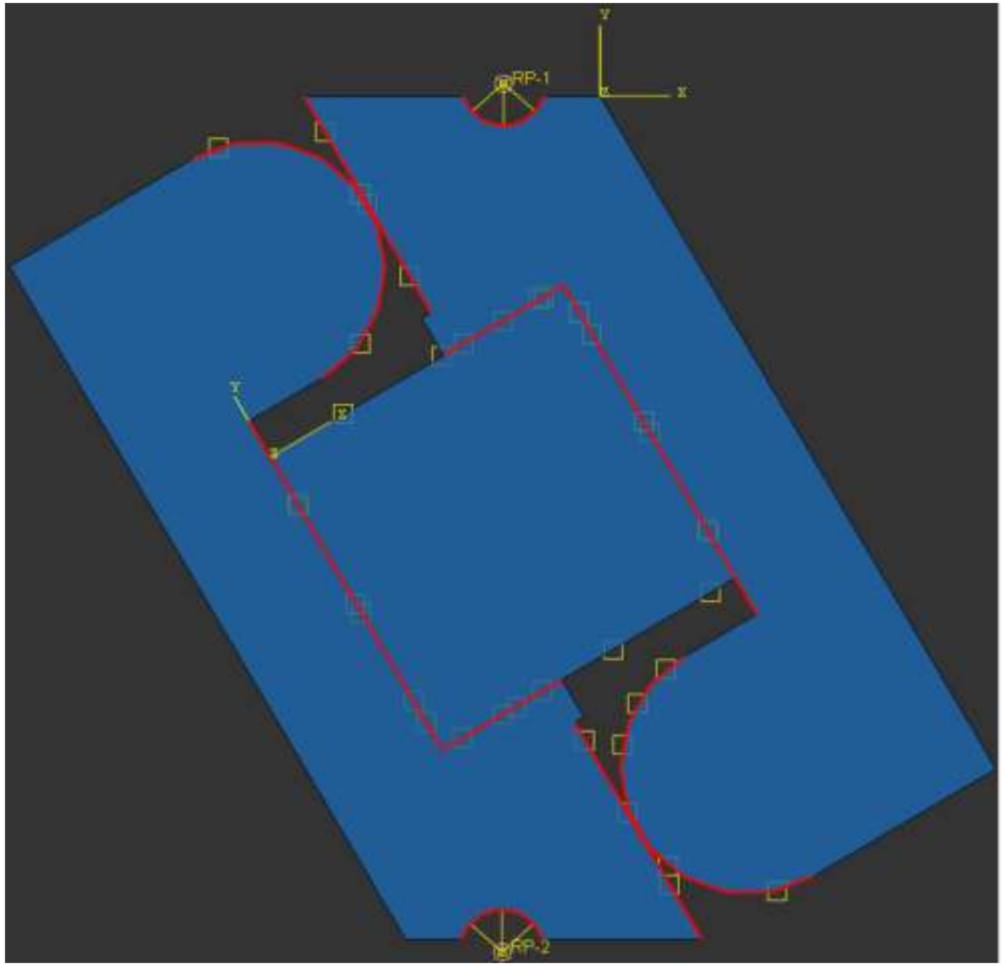
Grip in steel

Cube in ABS

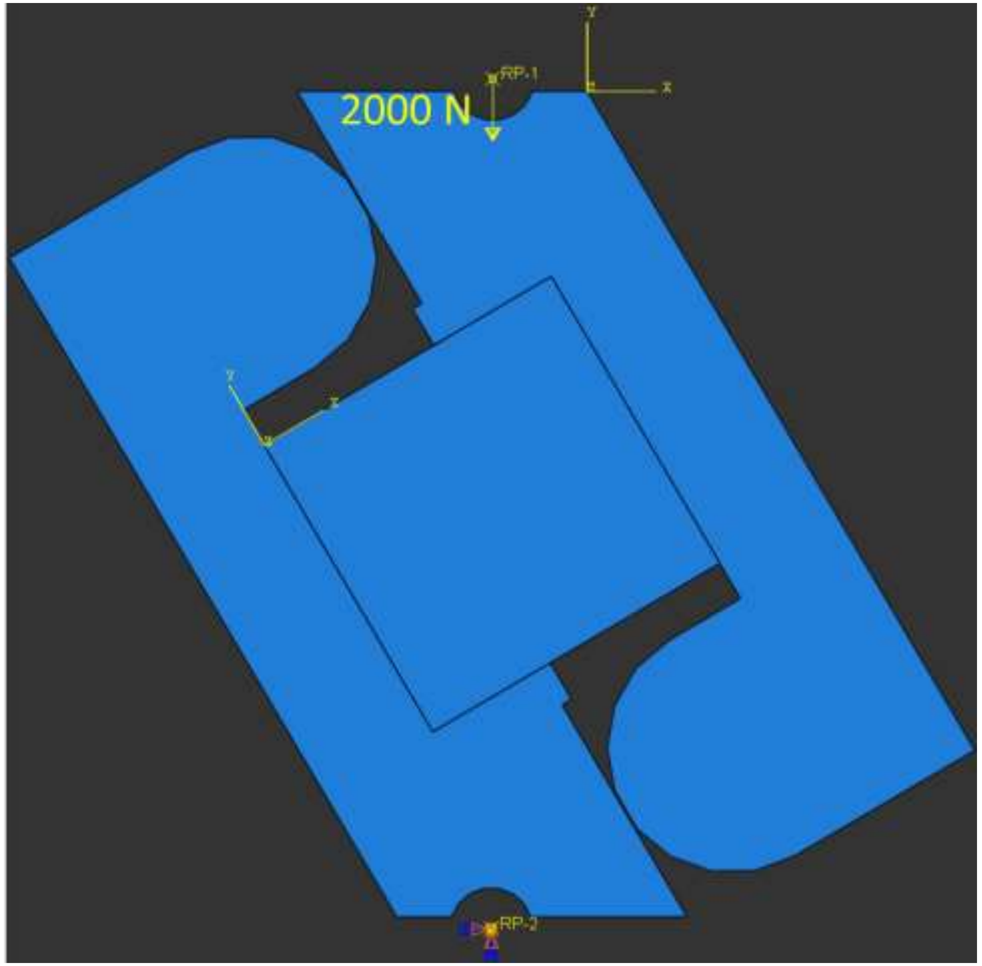


Single cube appartus with a 10mm square ABS sample

Boundary conditions



Contact conditions

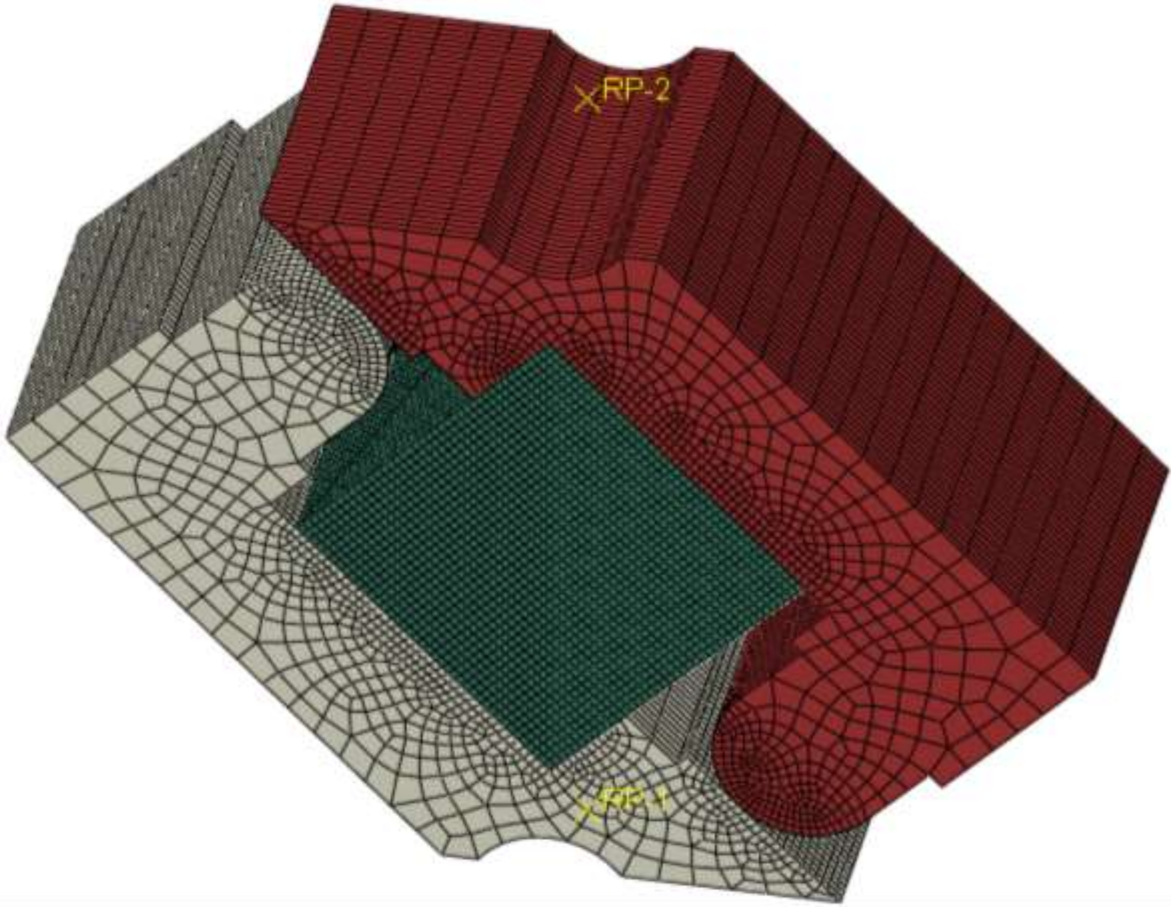


Loading

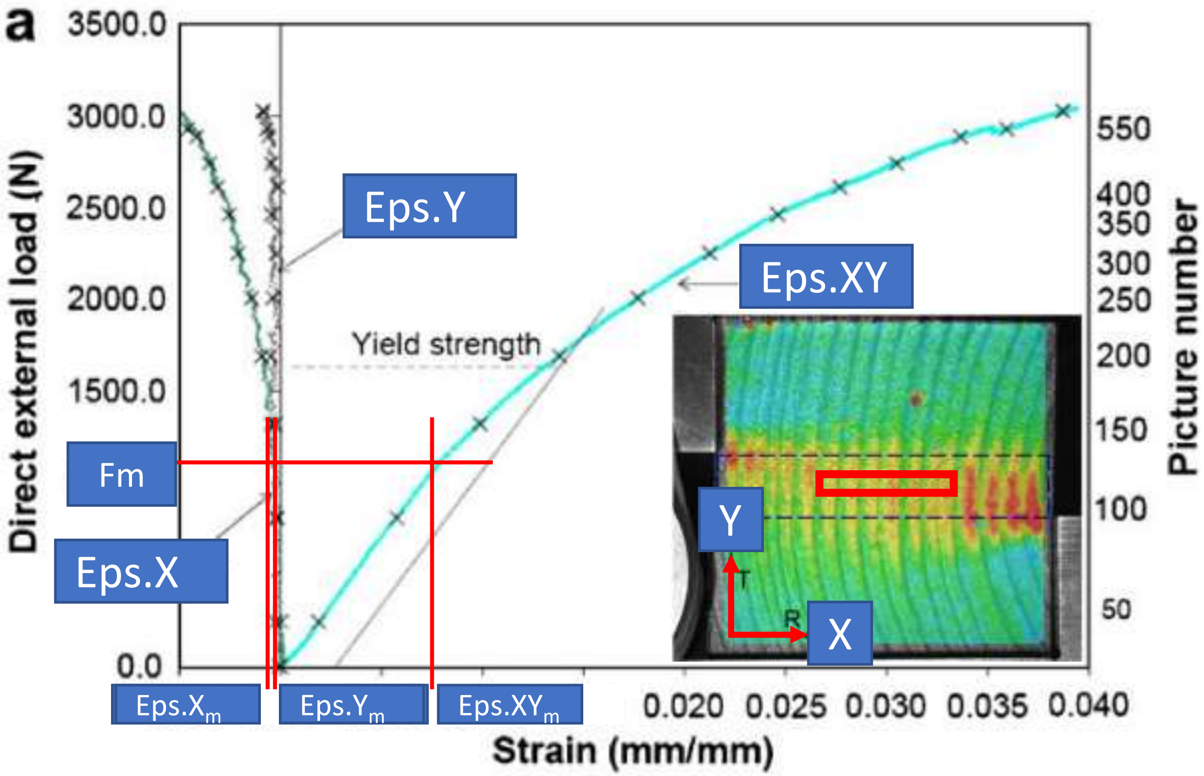
Meshing

- Cube : 64 000 quadratic hexahedral elements (C3D20R)

- Grip : 29 000 quadratic hexahedral elements (C3D20R)



Quantities assessed

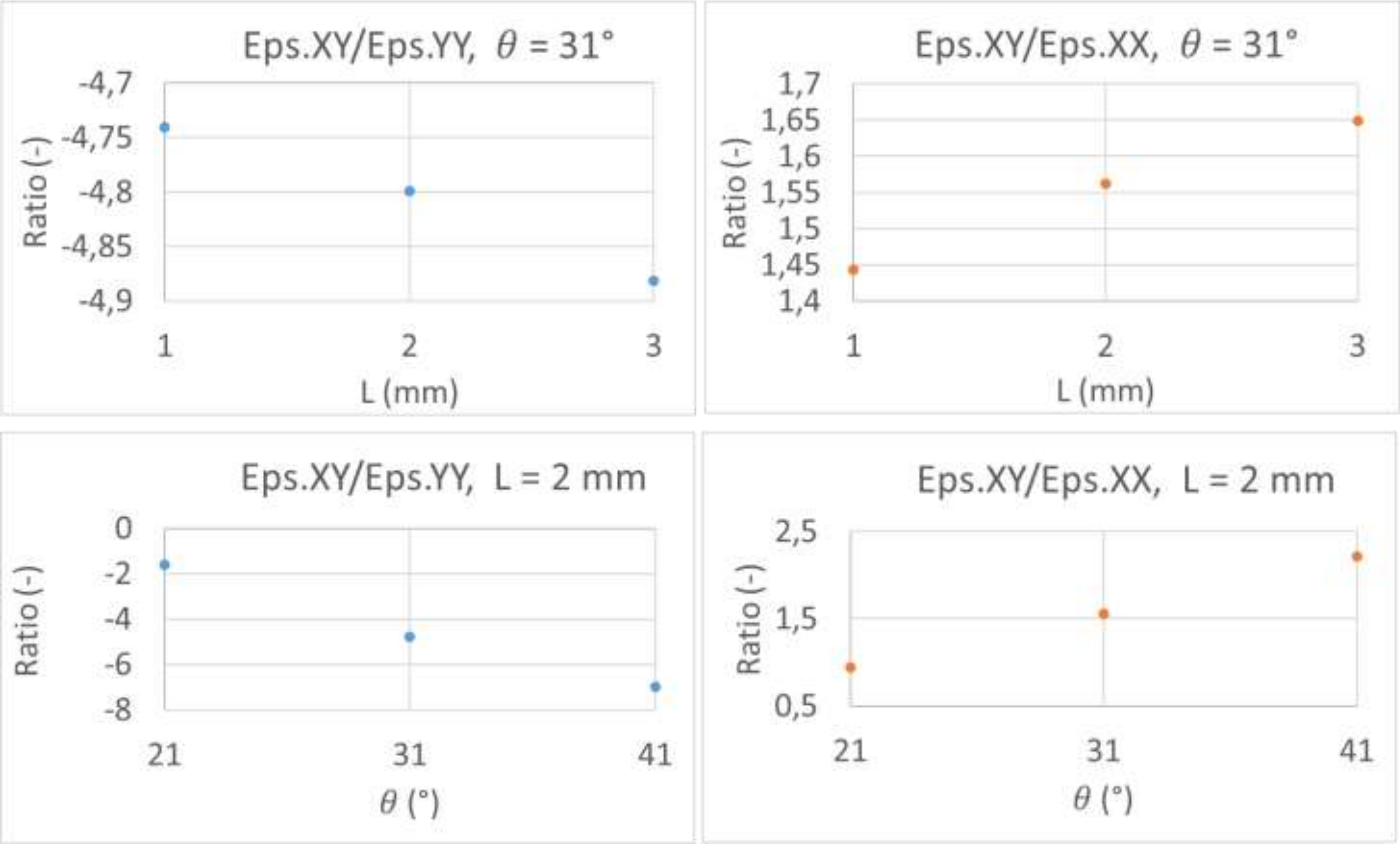


[Hassel 2009] Average deformation in the area framed in red

- Fm = Maximum force in the first linear part of the curve
- Eps.Xm = Average deformation measured in the red zone
- Eps.Ym= Average deformation measured in the red zone
- Eps.XYm= Average deformation measured in the red zone
- Criterion :
- $Eps.XY_m / Eps.X_m$
- $Eps.XY_m / Eps.Y_m$

Results of the parametric study

- If L ↑ then shear dominates
- If θ ↑ then shear becomes dominant
- Proposed configuration 4mm and 45°



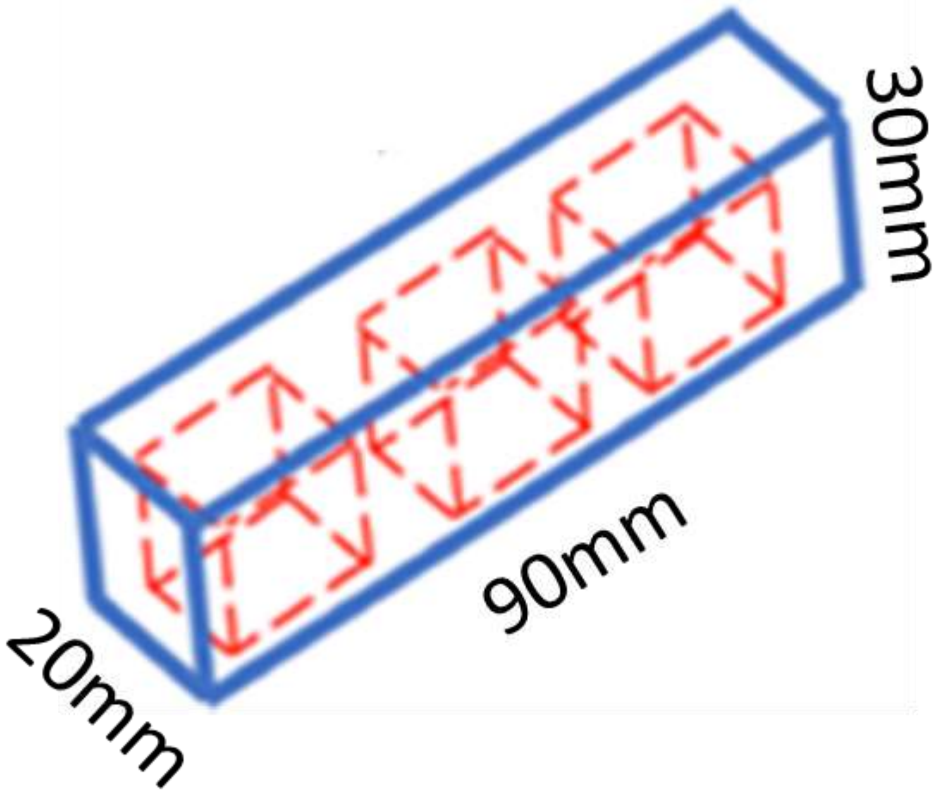
Experimental protocol

Machining of 3 specimens:

- Block 20x30x90mm
- 3-axis milling machine
- Ø 5mm groove milling cutter
- Cutting speed: 300mm/min
- Feed speed: 0.3mm/min
- Manufacture of 3 cubes measuring 10x10x10mm3

Test conditions

- Instron E10000 testing machine
- Crosshead speed 1mm/min
- Maximum force 5000N
- Stopping criterion, force drop of 50N



ABS block before machining the 3 cubic samples

Experimental Protocole

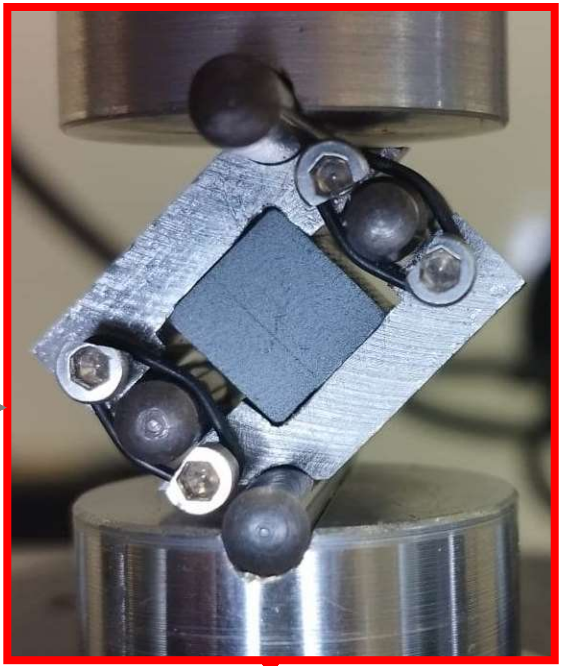
Instrumentation

- 10kN force cell
- Basler acA2500-60um camera, InfiniProbe MS lens and Gom Correlate Pro (Zweiss)

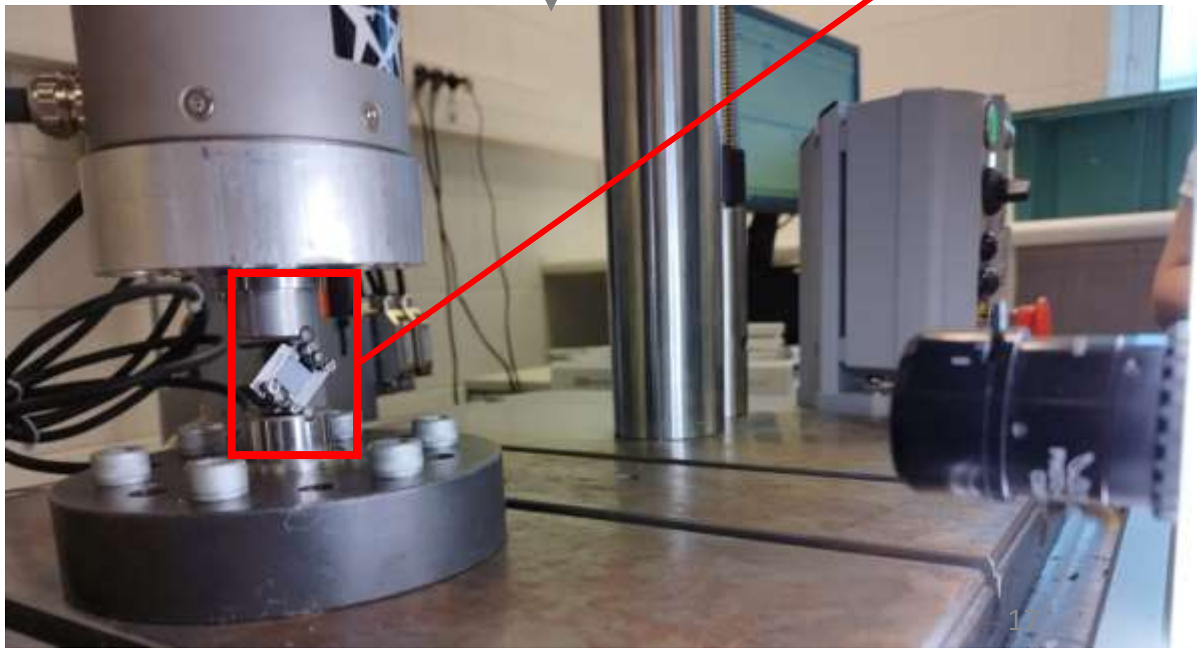
Calculations performed

- Eps.XYm/ Eps.Xm
- Eps.XYm/ Eps.Ym
- Analytical calculation of G for isotropic materials (Gisotrope)
- Calculation of modulus from machine data (Gload)
- Calculation of modulus from force and image correlation (Gcorrelation)

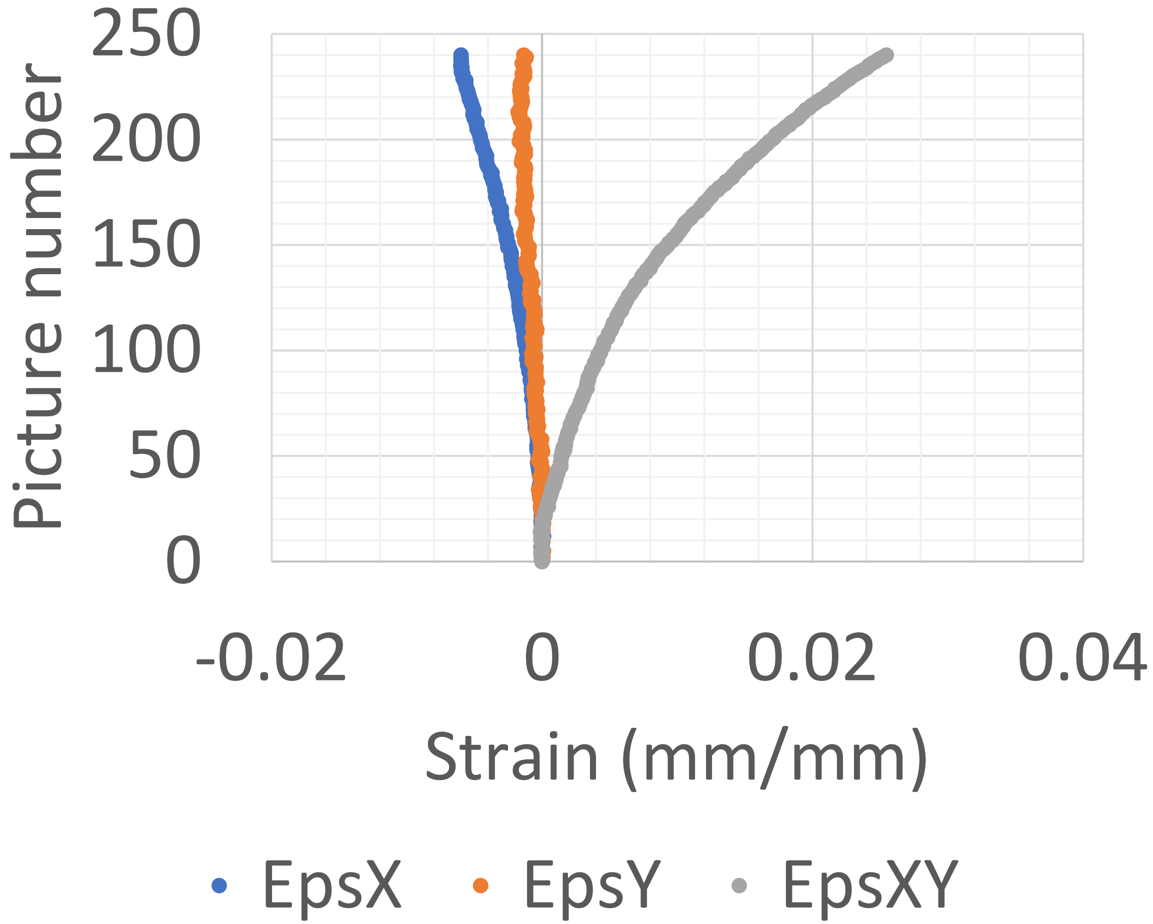
Zoom on the single cube appartus



Complete experimental set-up



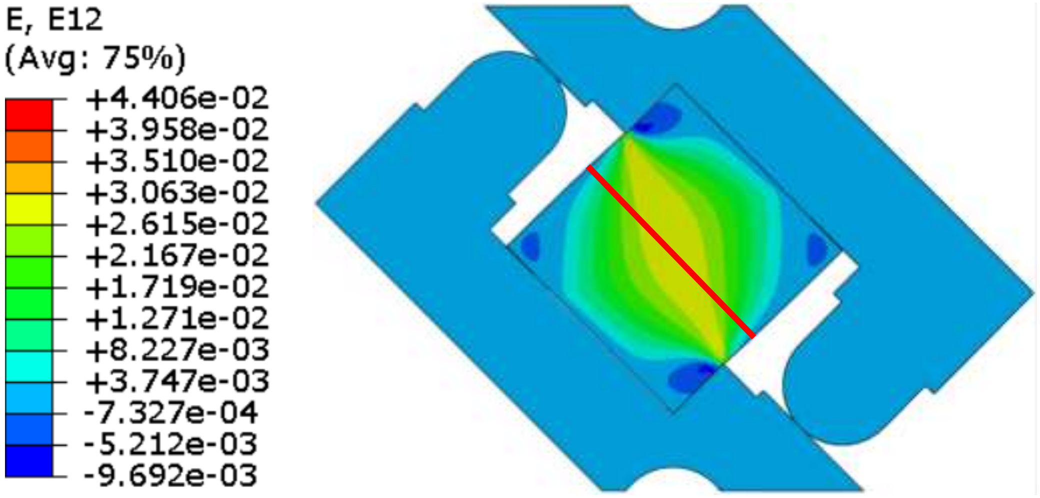
Results

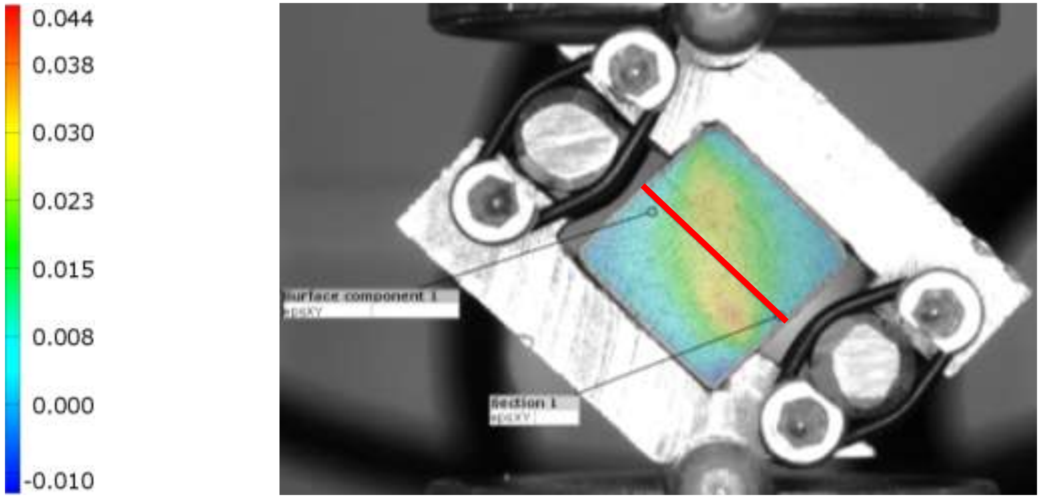


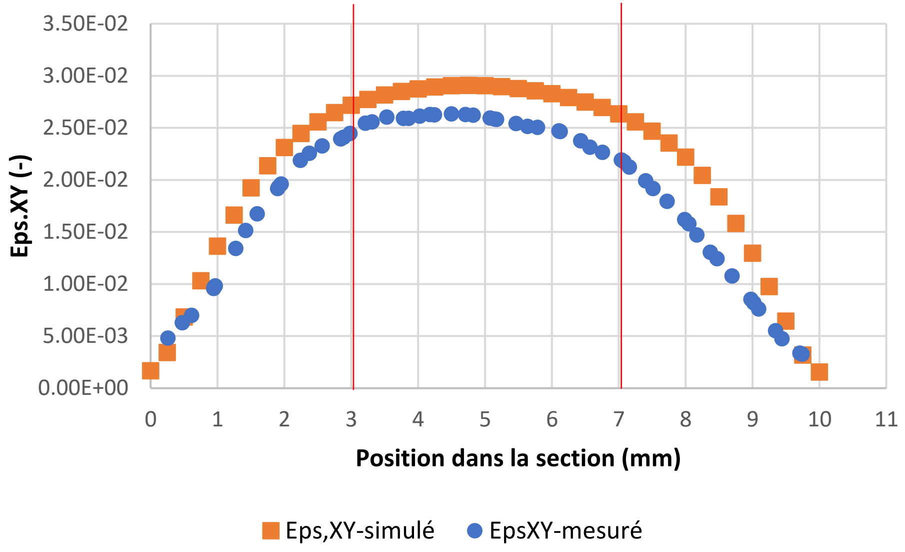
Typical curve obtained using Gom Correlate for shear tests

Dimensions	Values
$G_{isotrope} = E/2(1+\nu)$	851MPa
$G_{Load} = (F \cdot L)/(A\Delta x)$	223 ± 6MPa
$G_{correlation} = \tau/\gamma$	1020 ± 48MPa
$Eps.XY_m / Eps.X_m$	4,15 ± 0,11
$Eps.XY_m / Eps.Y_m$	13,94 ± 4,88

Experimental and numerical comparison







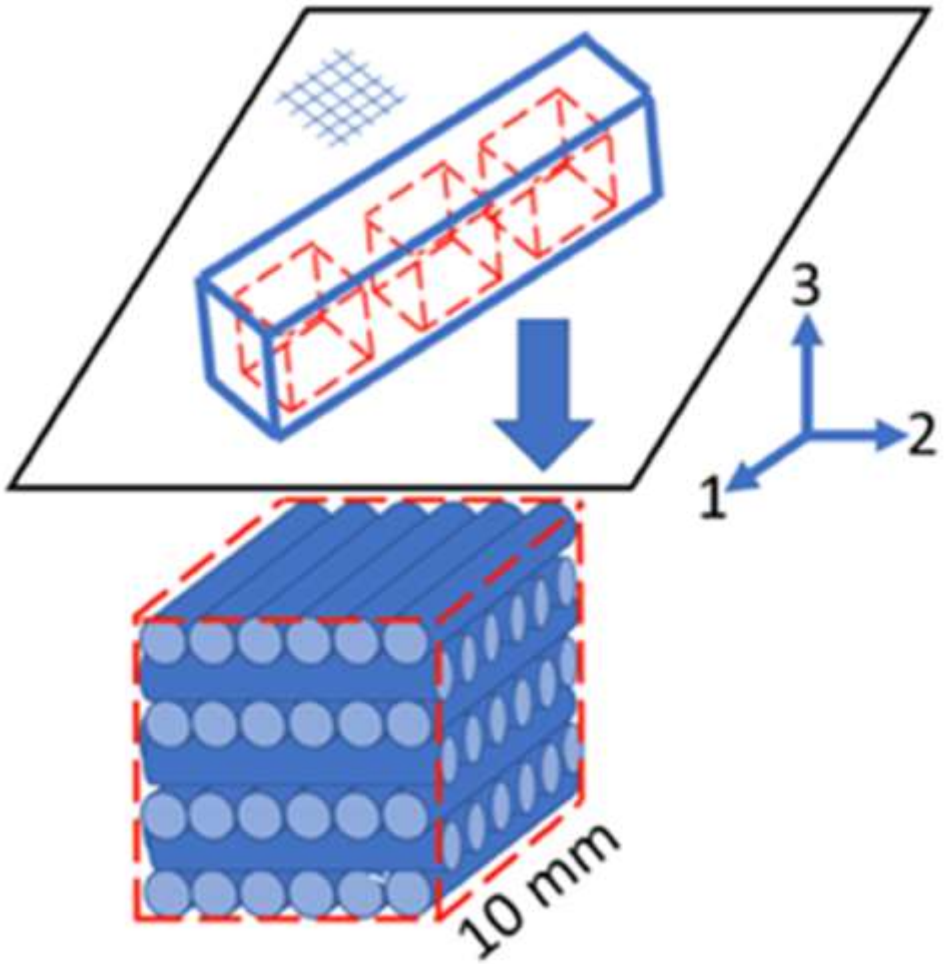
- Same distribution of deformations
- 14% difference on average

Conclusion

- As with the numerical simulation, Eps.XY is larger than Eps.X and Eps.Y. We can therefore consider pure shear at the centre of the specimen.
- Because of the rigidity of the machine, it is important to instrument the specimen.
- The values obtained by image correlation are close to those obtained digitally
- There is a 25% discrepancy between the assumed shear modulus of the ABS and its actual modulus.
- Further tests should be carried out to check the isotropy of the cast material and, if necessary, Young's modulus.

Use for an orthotropic material and comparison with results obtained by conventional methods

Manufacture of 3D printed ABS test tubes



Orientation des fibres et géométrie des cubes imprimés

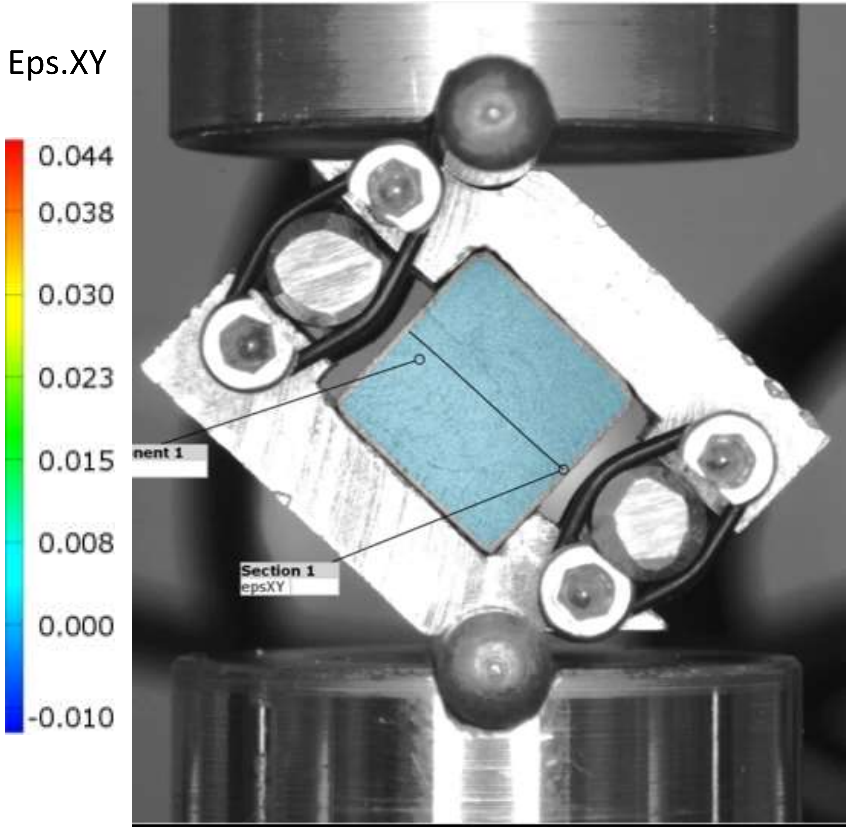
3D printed ABS block :

- Material: White Z-ABS
- Machine: M200plus, Zortrax
- Infill patern : line
- Density : 100%
- Layer thinkness : 0,2mm
- Layer orientation [-45°,+45°]

Test pieces :

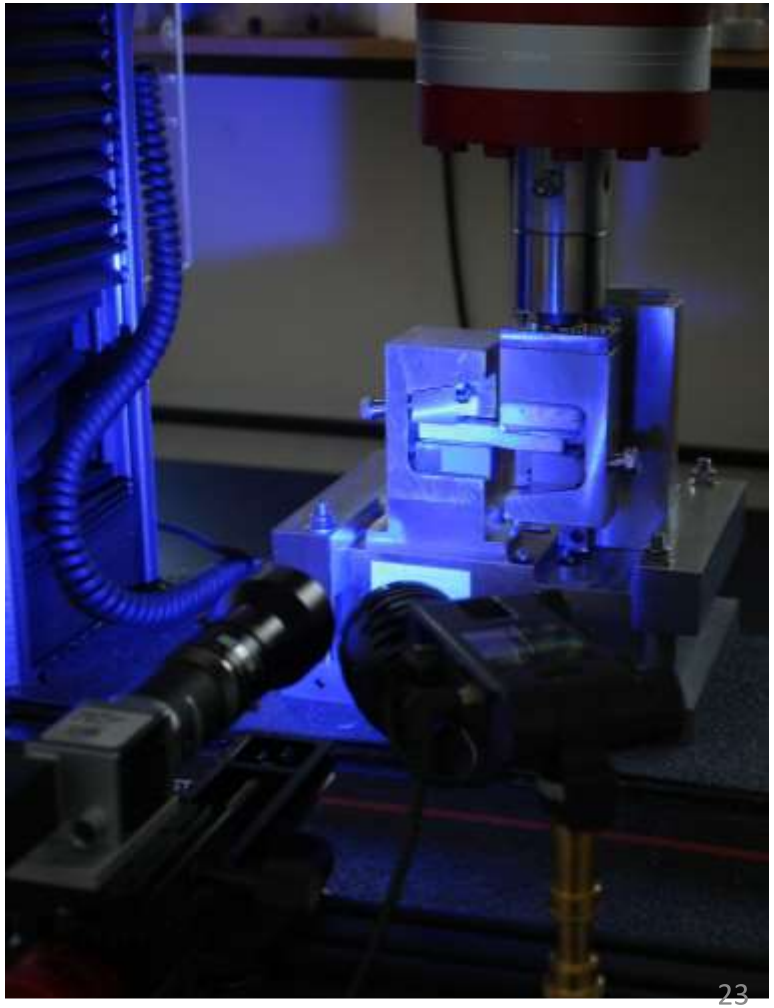
- 9 cubes with sides of 10mm
- 9 prisms with 10mm square base and 80mm length

Experimental protocole



The results of the cube tests are processed according to the protocol described previously and the Iosipescu tests are processed according to ASTM D5379.

MPa	G12	G13	G23
Iosipescu	560 ± 21	448 ± 14	458 ± 21
SCA	548 ± 27	550 ± 53	517 ± 43



Conclusion

- The average error between the two methods is 12.5% with an error include in 3% to 10%.
- Many sources of dispersion that can affect results:
  - Placing the central zone on GOM Correlate (currently freehand)
  - Storage conditions and time taken to perform tests after specimens have been manufactured
  - Treatment of tests iosipescu different from SCA
- Good alternative for minimising the material required for testing, but still requires some improvements

Thank you for your attention

Bibliographie

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