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Stiffness and Failure behaviour of folded sandwich cores under combined transverse shear and compression

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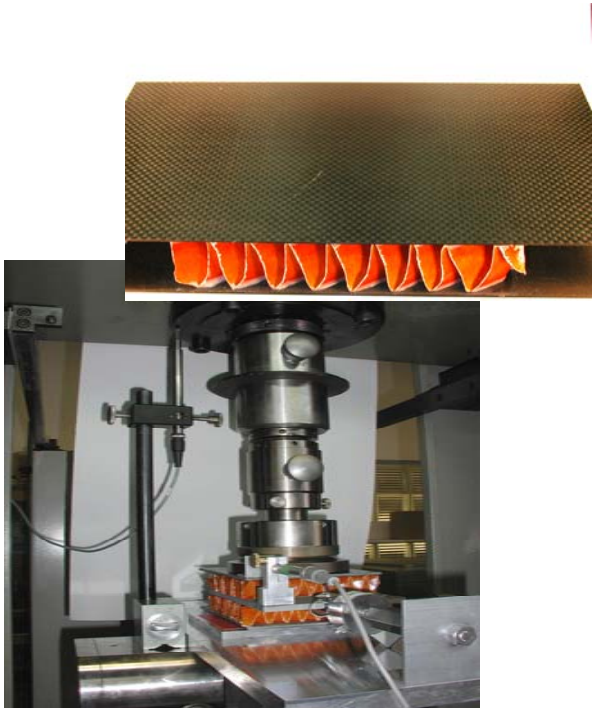
Contents

- Folded core material description
- Test setup and configuration
- Test results by single and combined shear and compressive loads
- Evaluation of a failure criteria
- Conclusion

Overview

- High performance sandwich structures consist of a lightweight sandwich core and stiff face sheets.
- The Folded Core seems to be a interesting core for sandwich structures
- This presentation provide an experimental method to determine the material behaviour of sandwich structures under single and combined loadings of sandwich structures.

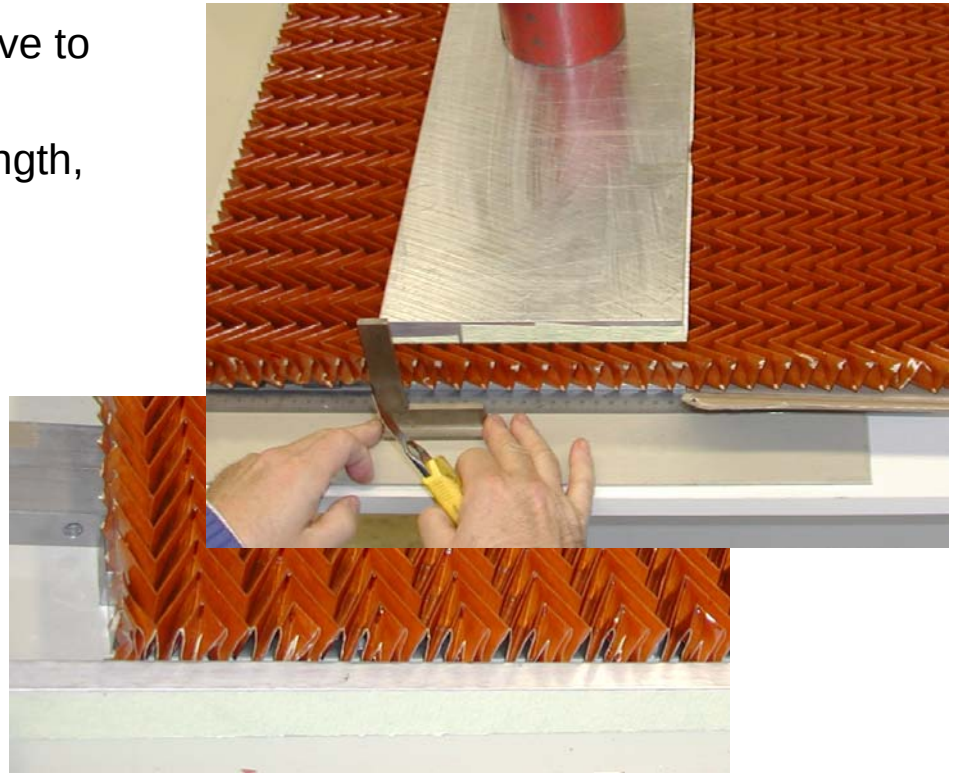


Folded sandwich core

High performance sandwich structures have to provide certain requirements:

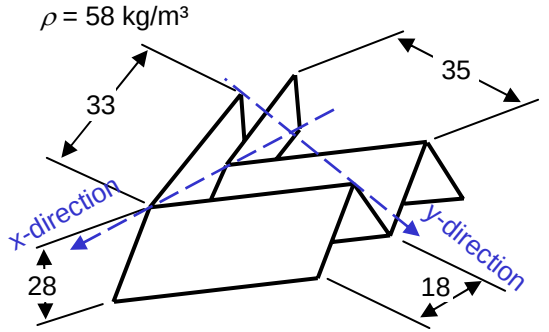
- High transversal shear stiffness / strength,
- High compressive stiffness / strength,
- A low Material density,
- Acoustic and thermal isolation,
- An adequate impact behaviour,
- Good ventilation

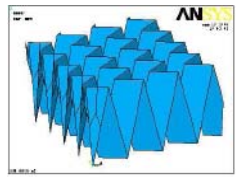
The Folded Core seems to be capable of this requirements and is the objective of the sandwich core material evaluation in this presentation.

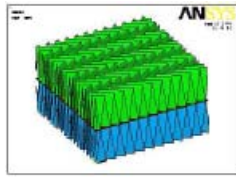


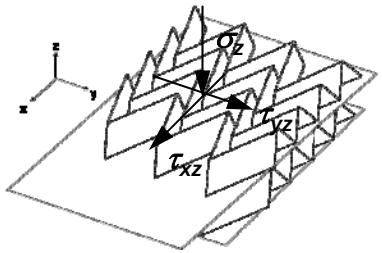
Folded Core geometry

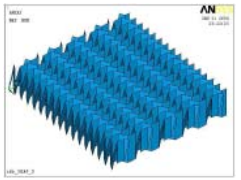
- Nomex material
- Evaporated with resin (not saturated as it is used for honeycombs)
- Relatively high Density 58 kg/m³
- Different geometries, coatings are producible
- In this context the core is used to evaluate the test setup and procedure







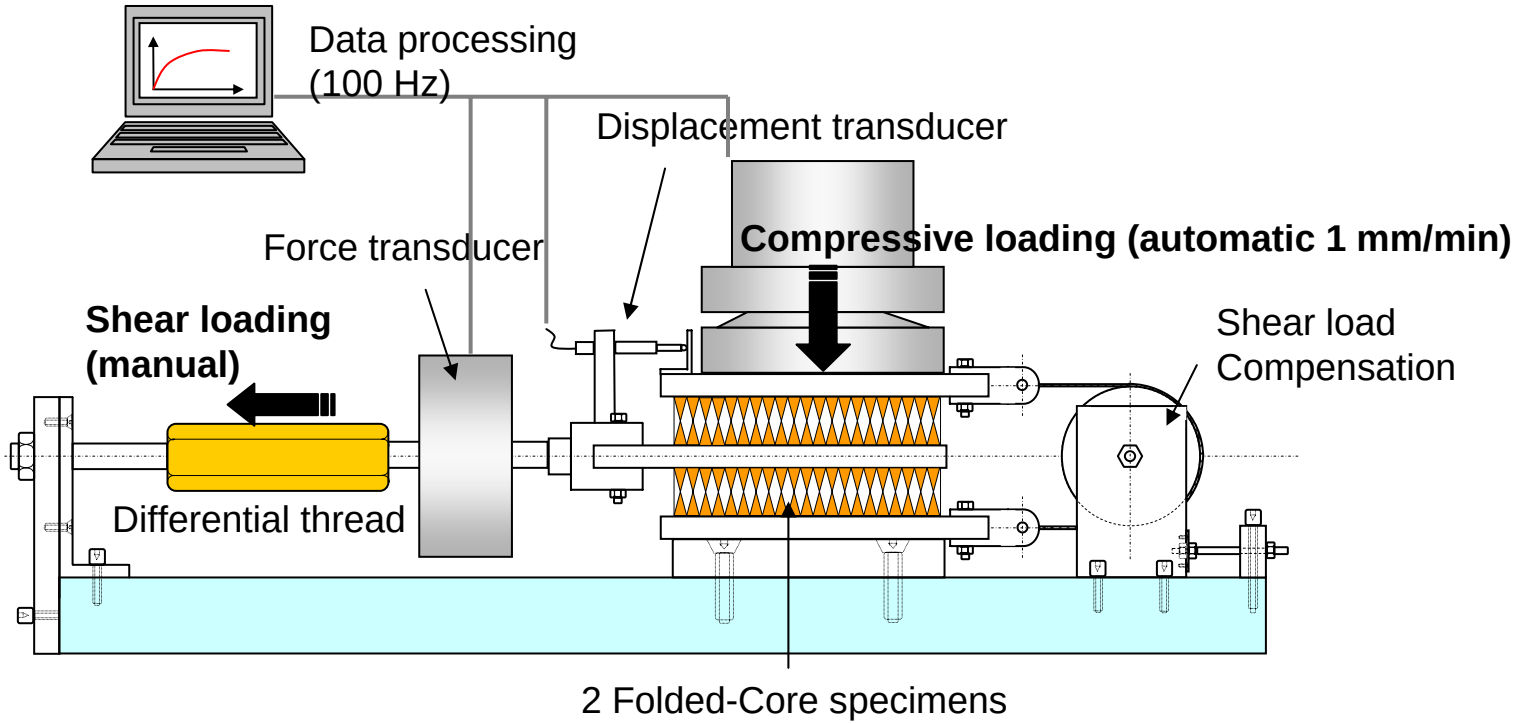




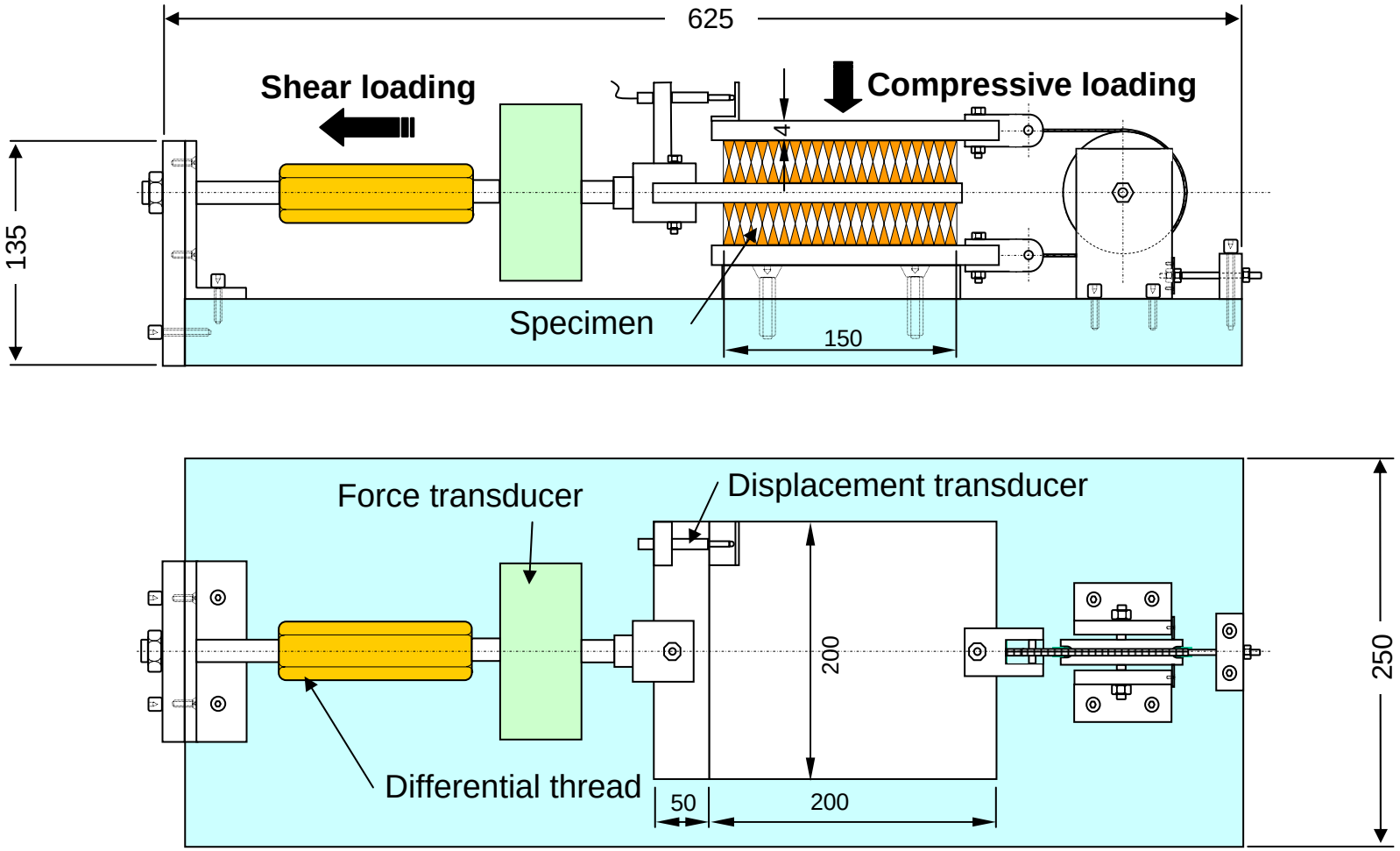
Material characterisation of sandwich cores:

- The material behaviour of characteristic **single loads** of sandwich cores,
- Evaluation of the macro-mechanical material behaviour under **combined loadings.**

Test setup

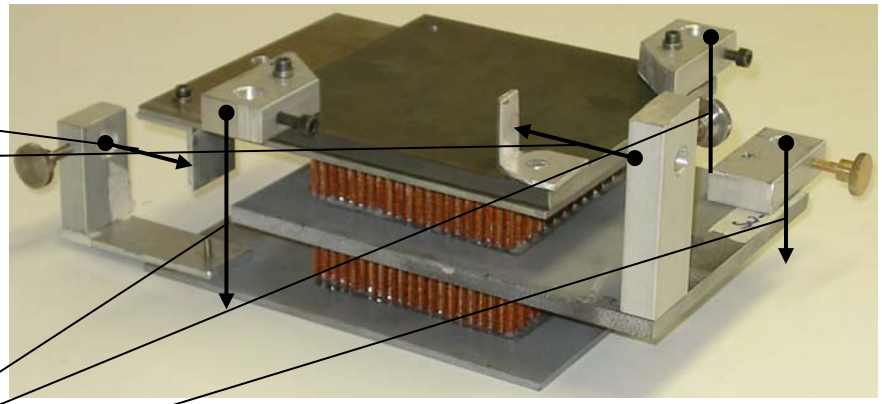

Data processing
(100 Hz)
Displacement transducer
Force transducer
Compressive loading (automatic 1 mm/min)
Shear loading
(manual)
Shear load
Compensation
Differential thread
2 Folded-Core specimens

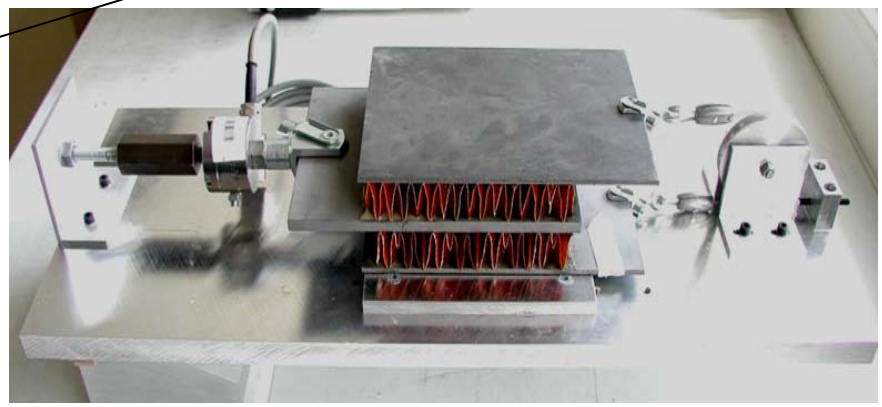
Test setup - overview



Preparation of the specimen

- Horizontal displacement measurement
  - Overall deformation
  - Deformation of the upper face sheets
  - Provide the information of the shear deformation for each core.
- Vertical displacement measurement
  - Deformation of the upper face sheet
  - Deformation of the lower core
  - Provide information of the compressive deformation of each core
  - Detectability of horizontal deviation



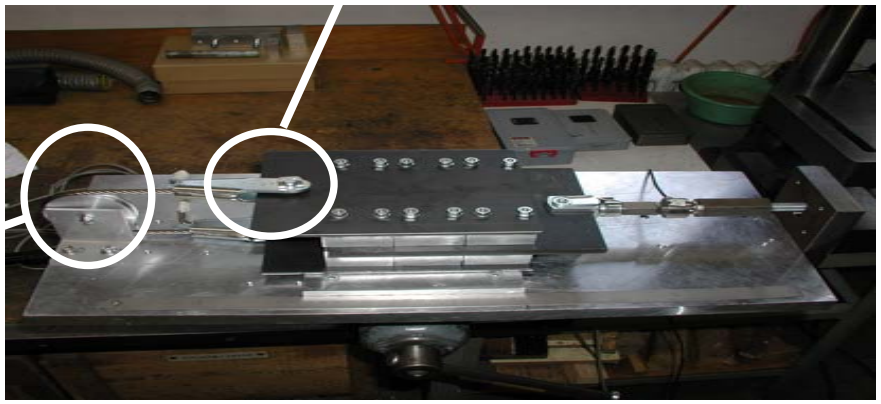


Problems and improvements of the test setup

- A dummy-specimen was used to determine the deformation of the experimental setup.
- Two major problems occurred

1. Failure of the wire due to inappropriate dimension of the wire and the wire mounting device
   - A 6 mm steel wire provides accurate results

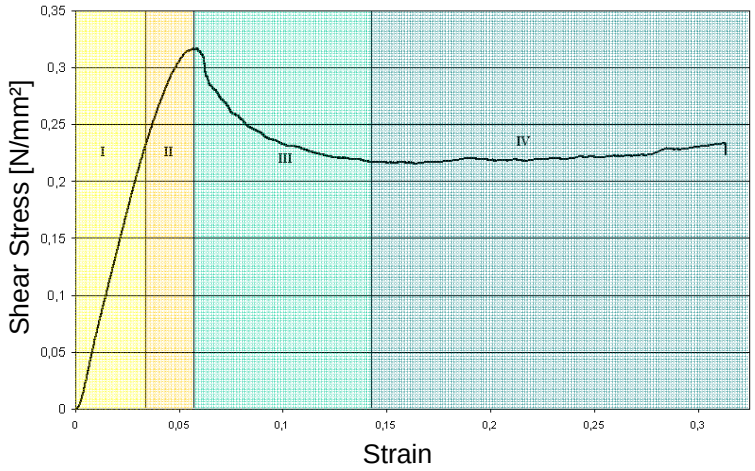
2. Failure of the wheel balancing the shear loads
   - Reinforced wheel mounting

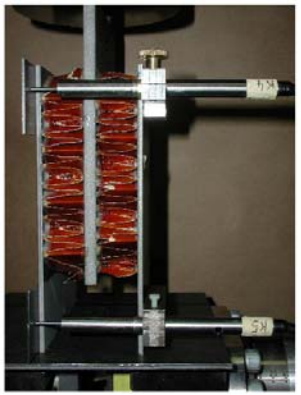


Results of a single shear loading

- Applying of a single shear load by a compression test of two sandwich cores
- The linear deformation provides accurate linear elastic results
- Nonlinear elastic effects result in unsymmetrical deformations of the specimen
- Four characteristic sections are observed in the stress strain curve

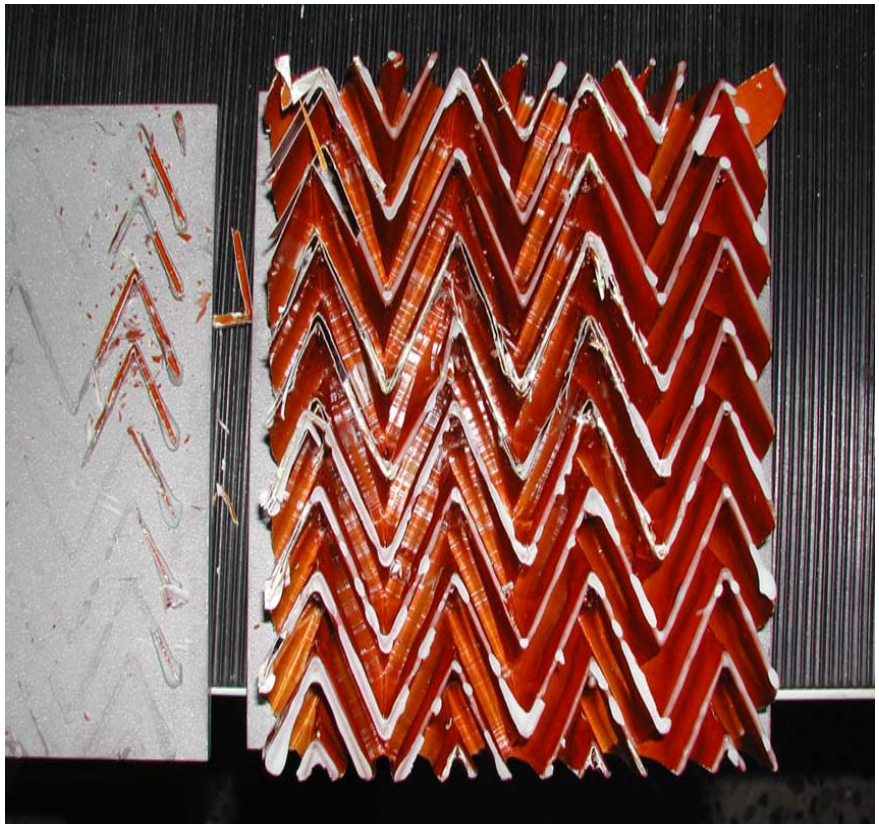
I) The Linear Elastic deformation (up to 3% Strain)
II) The Nonlinear Elastic deformation (3% - 5.5%)
III) Macroscopic failure and degradation (5.5% - 14.5%)
IV) Straining without further degradation (>14.5%)





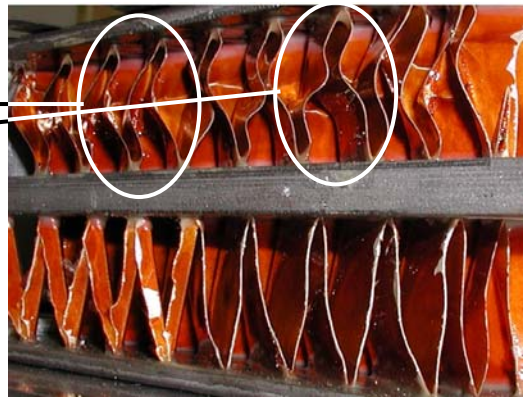
Shear failure results

- The folded core is bonded with a epoxy resin to the face sheets (steel).
- The resin bonding of the face sheet prevents shear failure of the adhesively bonding
- By further monotonically loading buckling phenomena become important for the material failure
- The material quality of the evaluated folded core is low compared with actual produce core materials (advanced properties are expected by a more accurate core geometry)



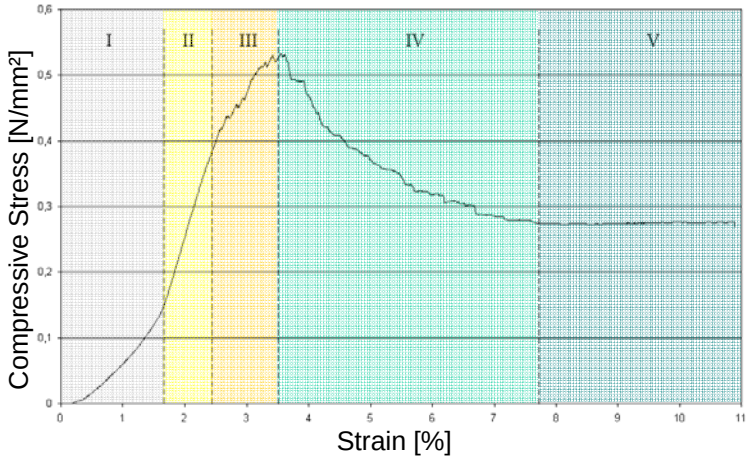
Results of a single compressive loading

- The initial material failure is essentially characterised by buckling phenomena
- Two different buckling modes are observed:
- Symmetric buckling mode
- Asymmetric buckling mode



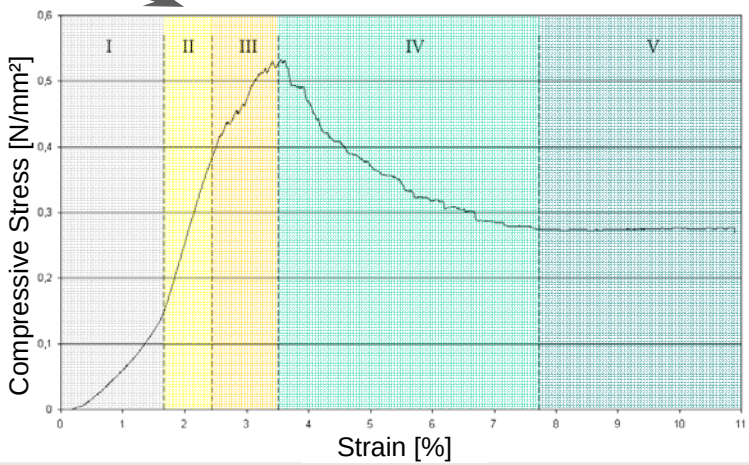
- Characteristic sections of the stress strain curve:

I) Relaxation of the test set up (up to 1.8% Strain)
II) Linear Elastic deformation (1.8 – 2.5% Strain)
III) Nonlinear Elastic deformation (2.5% - 3.5%)
IV) Failure and degradation (3.5% - 7.8%)
V) Straining without further degradation (>7.8%)



Compressive failure results

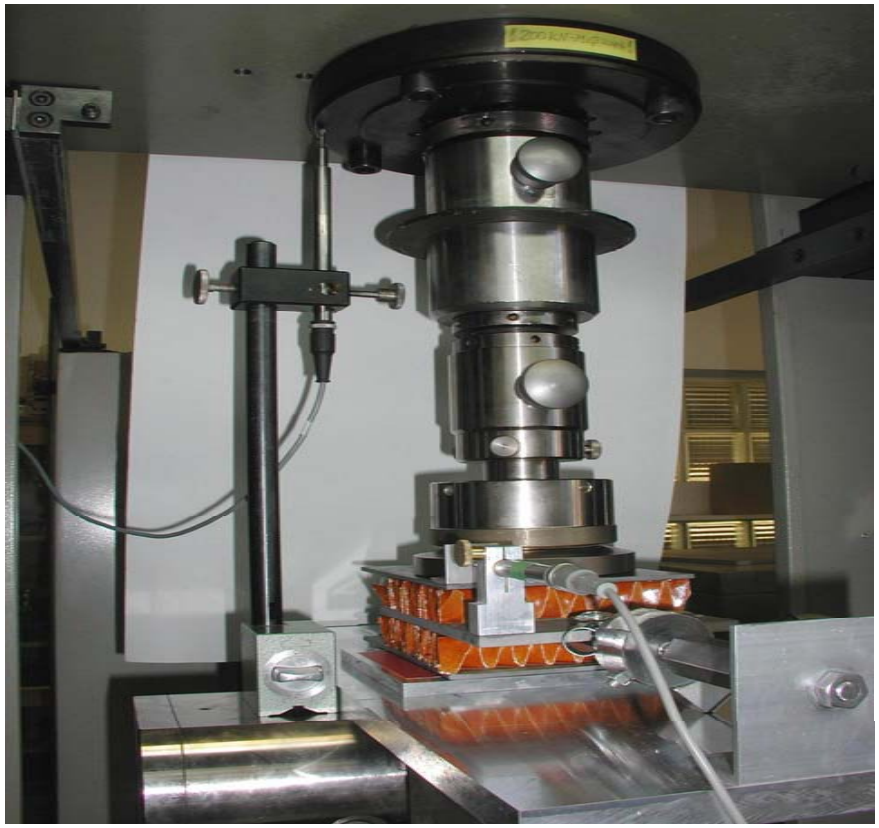
- Failure results from a stability failure of the core.
- The core is able to expand after the test.
- Structural failure is characterised by different failure modes of the folded core.
- The adhesively bonding of the face sheet is unimportant for compressive loadings.
- A linear elastic behaviour is detectable.
- Additional micromechanical effects (resin particle break off, Nomex material failure) characterise the nonlinear material behaviour and failure.
- The nonlinear material behaviour and the stiffness degradation based on highly complex mechanism.



Combined shear and compressive loadings

- **Test setup procedure for the experimental evaluation:**

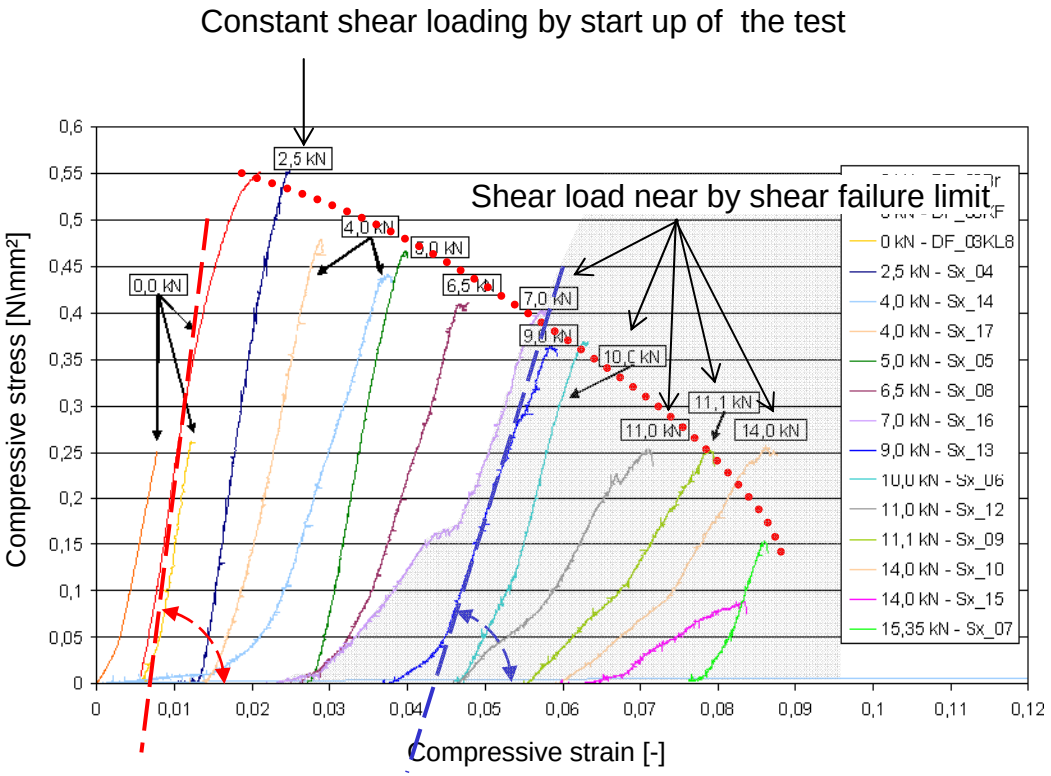
1. Installation of the strain transducer.
2. Compressive loading of the specimen until the compression fixture is in contact with the specimen.
3. Adjustment of the pressure plate in the contact position to the specimen.
4. Unloading of the specimen.
5. Shear loading of the specimen by hand, a constant deformation is provided.
6. Start of the test by monotonically increasing the compressive load.
7. Due to failure processes the constant shear force is decreasing by increasing compressive loads.



Test results with combined loading (elastic part)

Linear elastic material behaviour

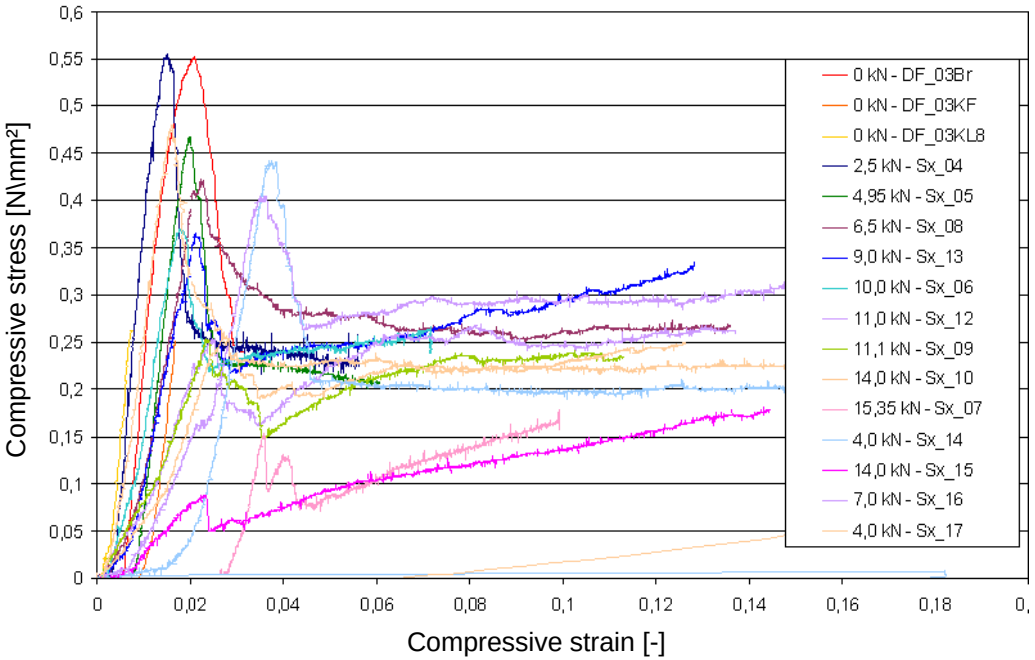
- Data scatter (results from inaccurate geometry, influence of fabrication, etc.).
- More specimen required for an accurate experimental evaluation.
- The strength tends to decrease by increasing shear loading.
- The compressive material stiffness is probably dependent on the shear load.
- Critical elastic behaviour by high shear loads (applied shear load near by the shear failure limit)



Test results with combined loading (inelastic part)

Nonlinear material behaviour

- Quite different material behaviour for combined loadings
- A lot of effects were detected for the macroscopic failure (buckling, micromechanical failure)
- Differences in the stress strain curves portends a macroscopic complex failure behaviour
- Separately individual failure of the upper and lower cores disguise the material behaviour of a single core

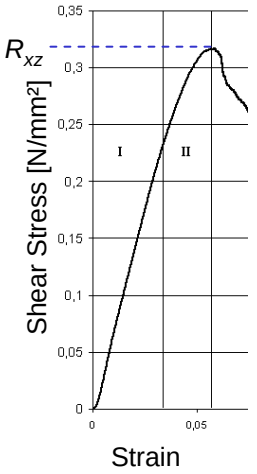


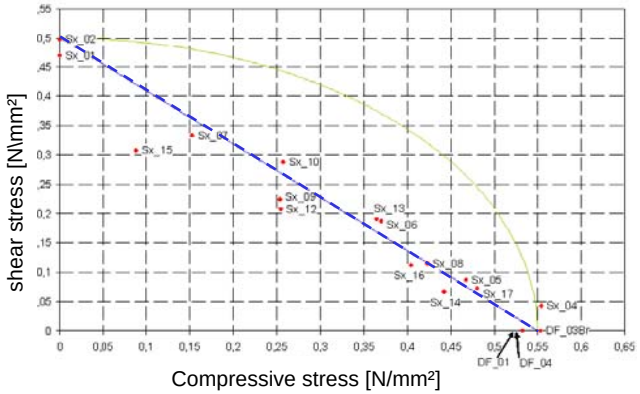
Failure criterion – Test results

- First failure defined at the end of nonlinear elastic deformation (section II)
- Shear strength associated with experimental uncertainties
- Data scatter due to geometric variations and fabrication influence of the folded core
- Approximately linear correlation between shear and compressive stress
- Proposed failure criterion:

$$\frac{\sigma_z}{R_z} + \frac{\tau_{xz}}{R_{xz}} + \frac{\tau_{yz}}{R_{yz}} \leq 1$$

- Suitable for first failure estimation in folded sandwich cores





Conclusion

Advantageous

- It has been shown that this simple test setup provide appropriate results concerning a first failure estimation and material characterisation.
- The test setup provides appropriate results for linear elastic deformation and macroscopic failure.
- Good results achievable for combined loadings up to moderate shear loading (relatively high shear loadings results in failure before relevant compressive loads are applied)

Disadvantageous

- The results dependent of the separated failure behaviour of two folded cores
- The test setup provides only a constant shear loading

Interesting improvements

- Biaxial test machine for monotonic increasing compressive and shear loadings

Acknowledgement

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- The folded sandwich core material was provided by Airbus Germany

Thank you for your attention