Use of flexible polymers (adhesives) in the design of aerospace applications

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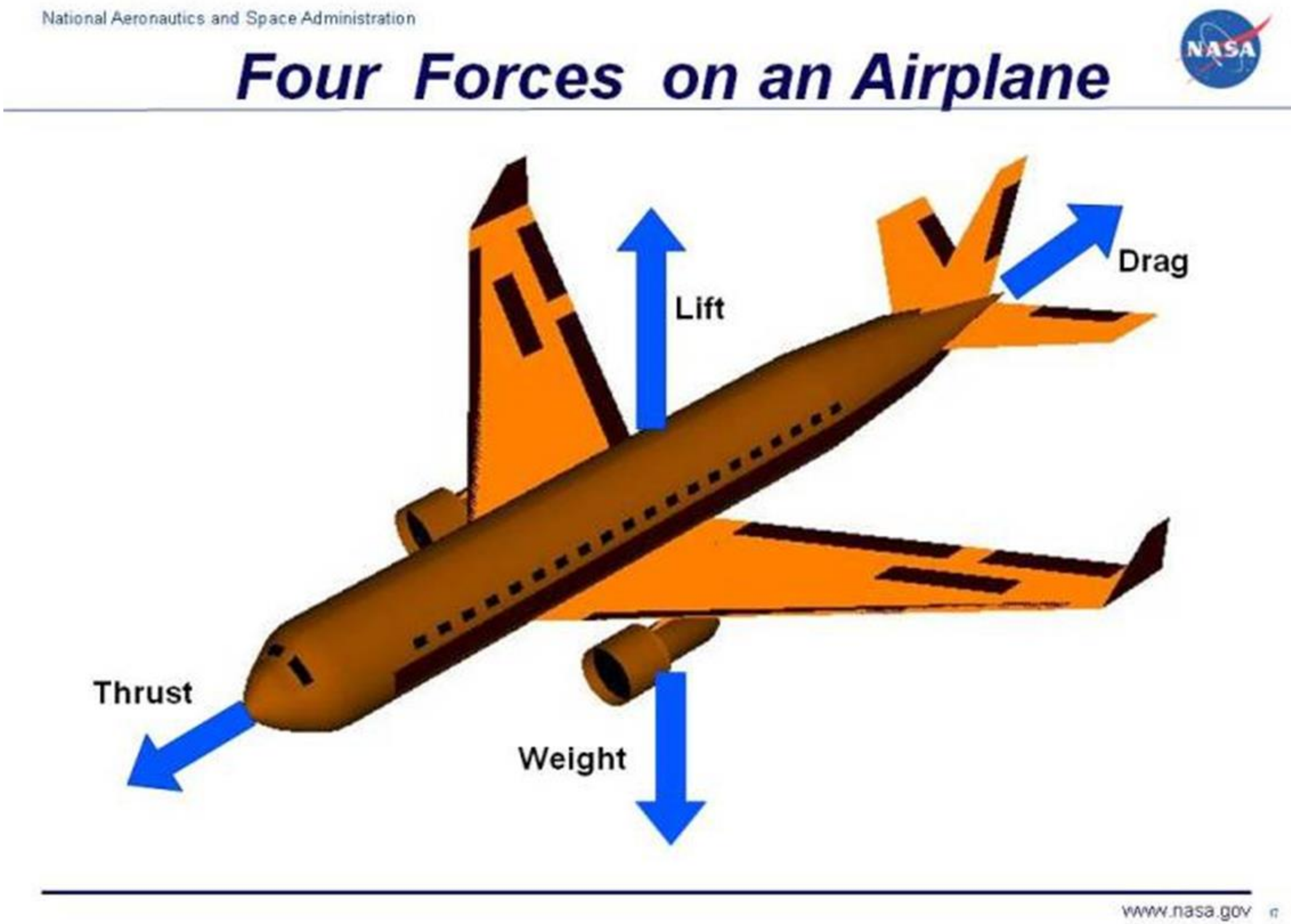
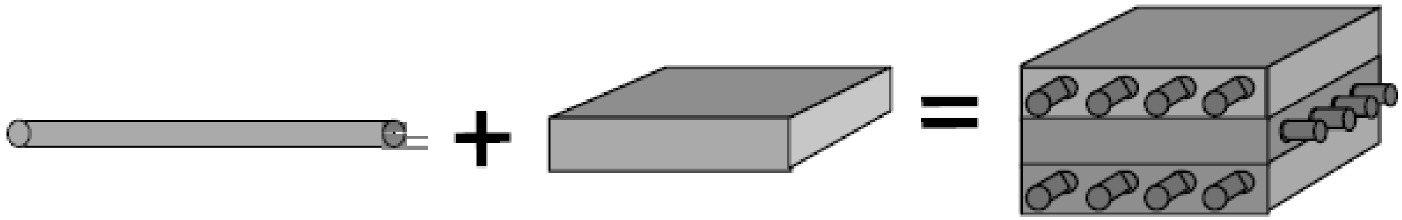
Frame of the presentation

- Why polymer matrix composite materials?
- Some basic information about adhesives & adhesive joints
- Two examples

Why polymer matrix composite materials?





Fiber/Filament Reinforcement

- High strength
- High stiffness
- Low density

Matrix

- Good shear properties
- Low density

Composite

- High strength
- High stiffness
- Good shear properties
- Low density

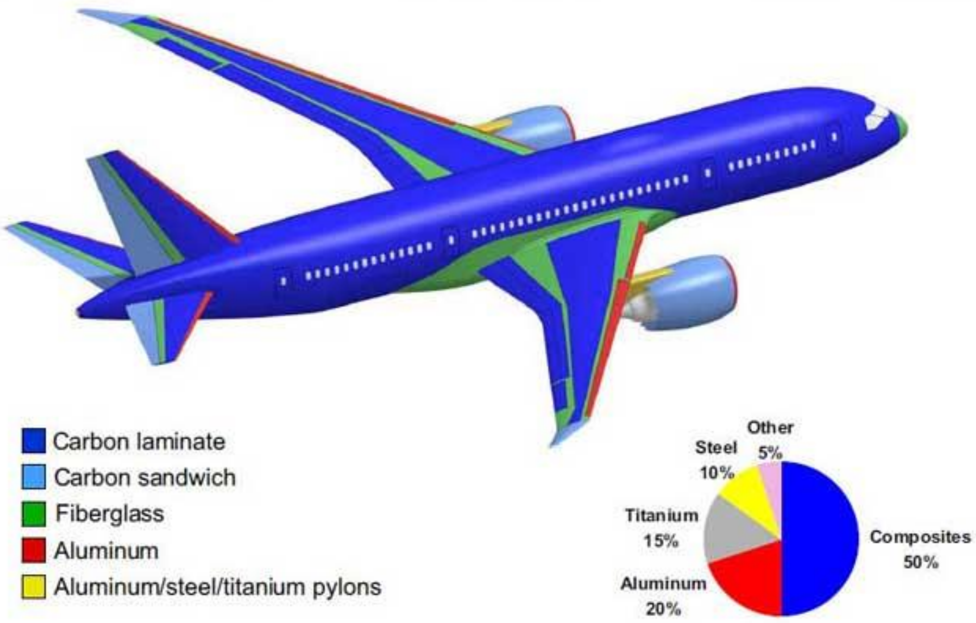
Polymer Matrix Composite Materials

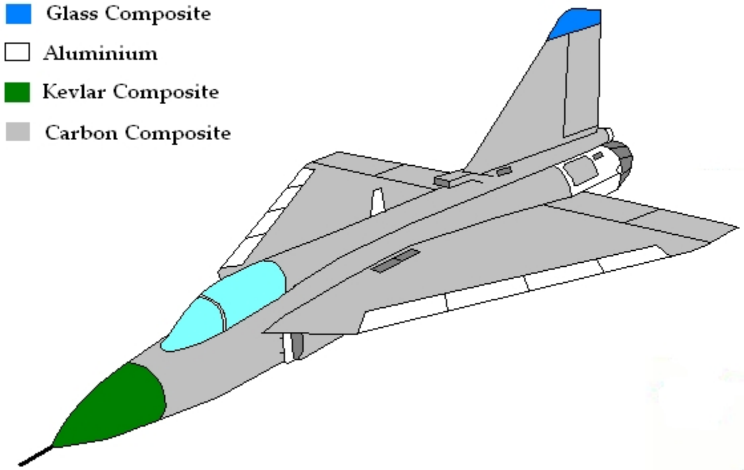
- Composites can be very strong and stiff, yet very light in weight, so ratios of strength-to-weight and stiffness-to-weight are several times greater than steel or aluminum
- Fatigue properties are generally better than for common engineering metals
- Toughness is often greater too
- Composites can be designed that do not corrode like steel
- Possible to achieve combinations of properties not attainable with metals, ceramics, or polymers alone

Disadvantages and Limitations of Composite Materials

- Properties of many important composites are anisotropic - the properties differ depending on the direction in which they are measured – this may be an advantage or a disadvantage
- Many of the polymer-based composites are subject to attack by chemicals or solvents, temperature, humidity, just as the polymers themselves are susceptible to attack
- Composite materials are generally expensive
- Manufacturing methods for shaping composite materials are often slow and costly

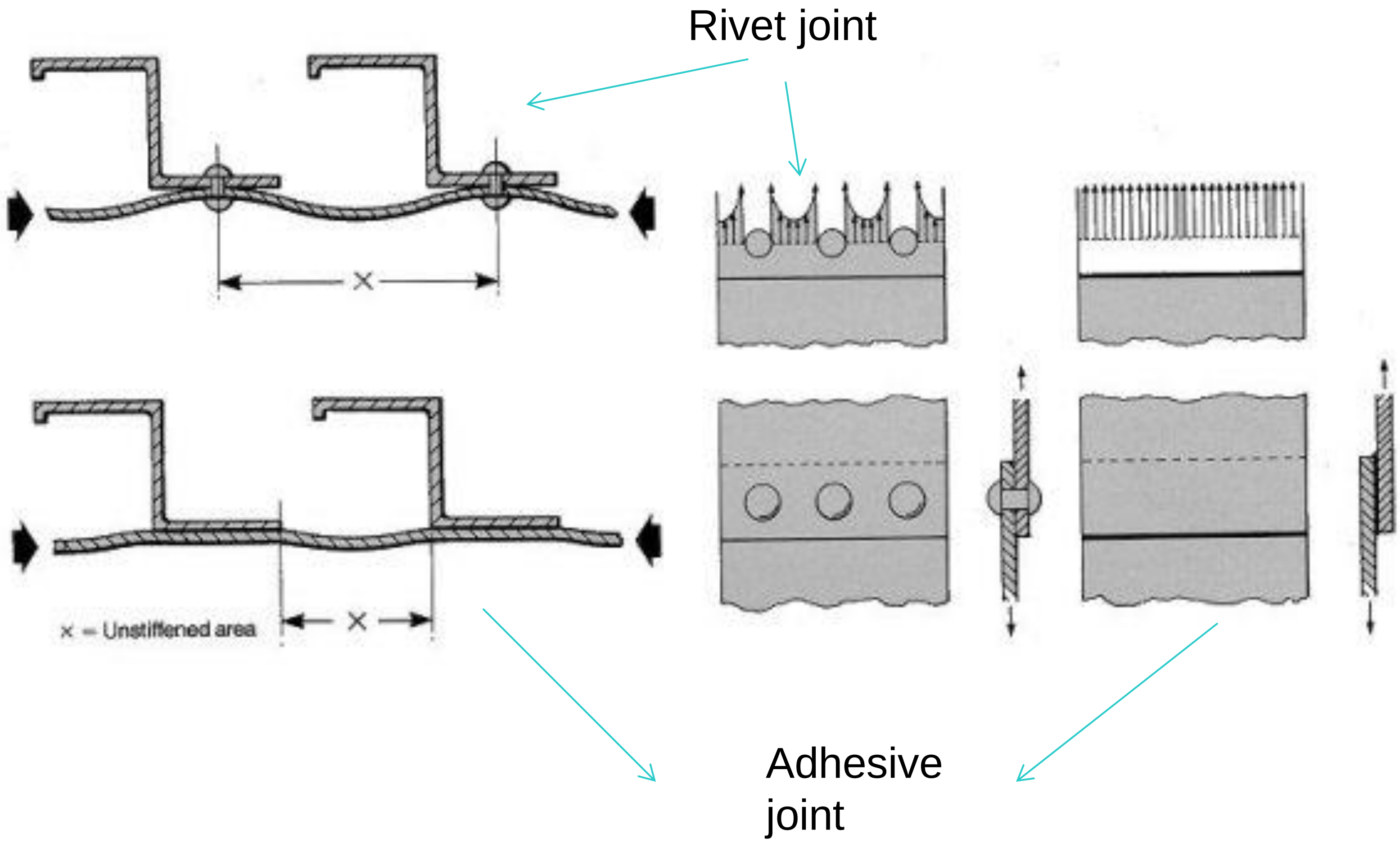
Applications



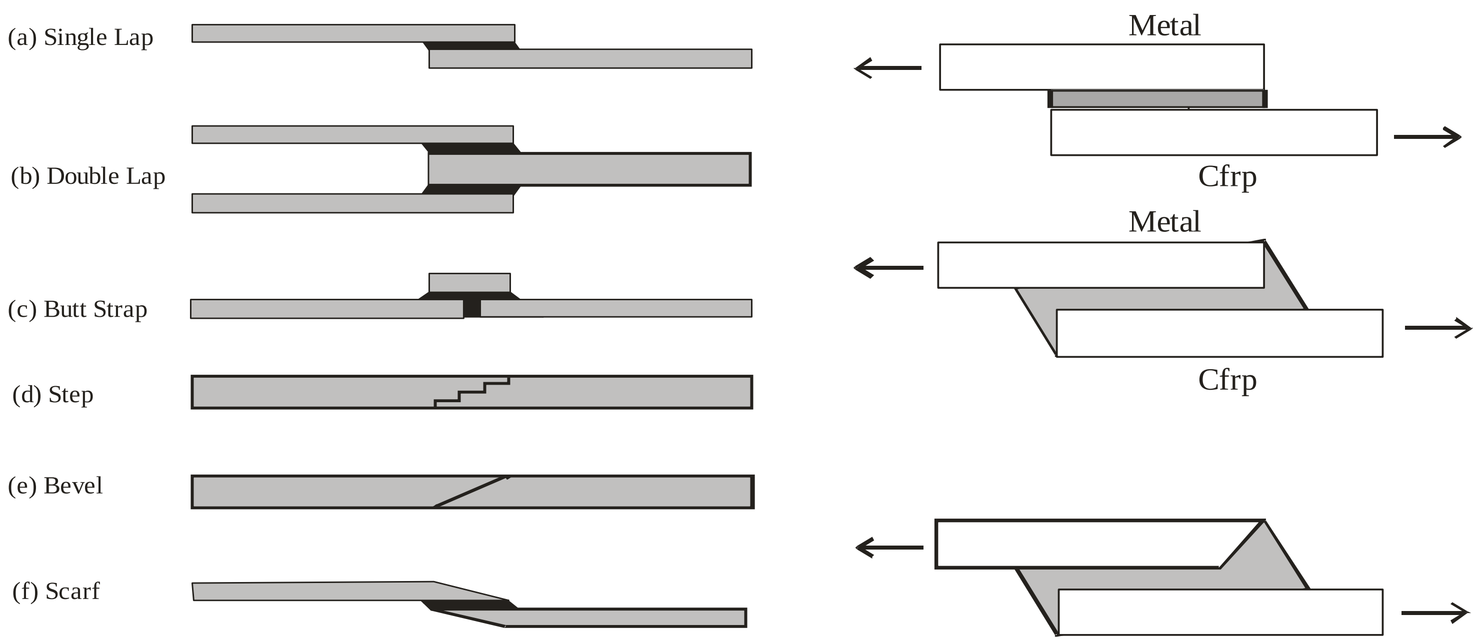


Composites in LCA

Joining techniques of composites



Types of adhesive joints



Definition of an adhesive

- An adhesive is defined as a substance capable of holding materials together by surface attachment.
  - Structural Adhesives: usually reckoned to be those with a high strength (50 MPa and upwards) and (these days), a strain to failure of at least 10% in tension, and which usually have a tensile modulus of 2 GPa or so
  - Flexible Adhesives: significantly less stiff, less strong, but much more ductile

Advantages

- Joining dissimilar materials (dissimilar thin sheets and foils)
- Improvement in the appearance of the finished assembly by the elimination of irregular surface
- the fabrication of complex shapes
- Relatively uniform distributions of stress over the entire bonded area
- Improving fatigue resistance and giving good vibration damping
- ....

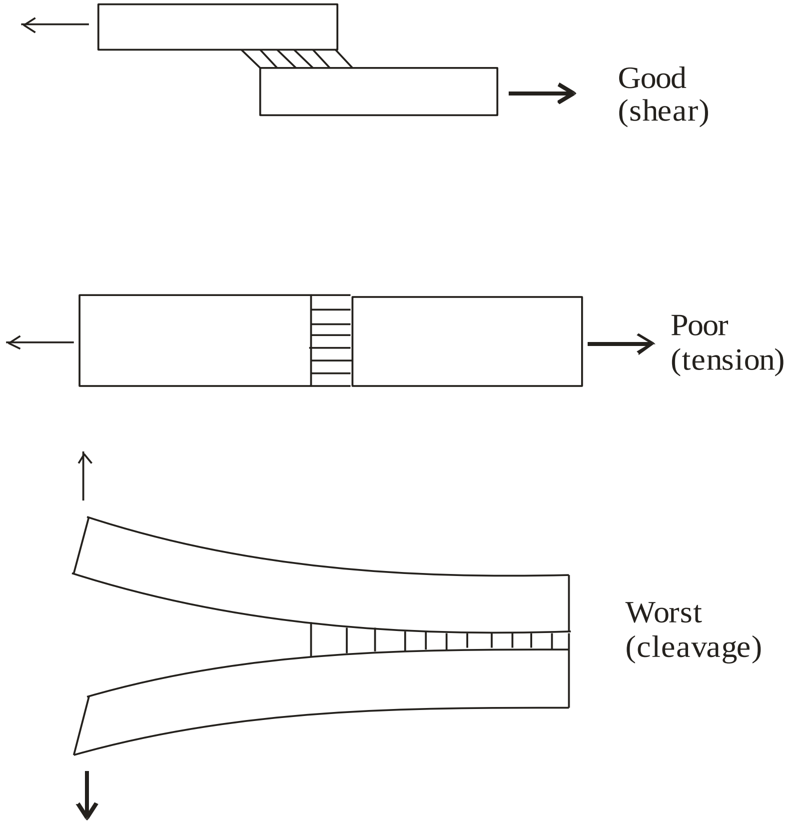
Disadvantages

- residual stresses in bonded joints (different thermal expansion)
- curing requirement
- sensitivity to peel loading, creep etc…
- degradation of the adhesive caused by heat, cold, chemical agents, radiation, and bio-deterioration
- not easily dismantled for repair or salvage
- assessment of bond quality

The most important parameter! Surface pretreatment

- Chemical solutions to clean the surfaces
- Surface modification methods

Loading types



Failure mechanisms

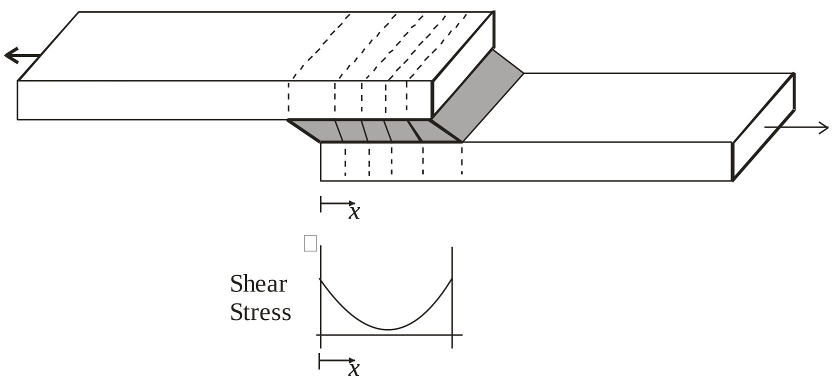
- Adhesive failure
  - Poor surface treatment (failure in adhesive-adherend interlayer)
- Cohesive failure
  - able to get mechanical performance of an adhesive (failure in adhesive or in adherend)
- Adhesive-Cohesive failure
  - usually due to the adherend yielding

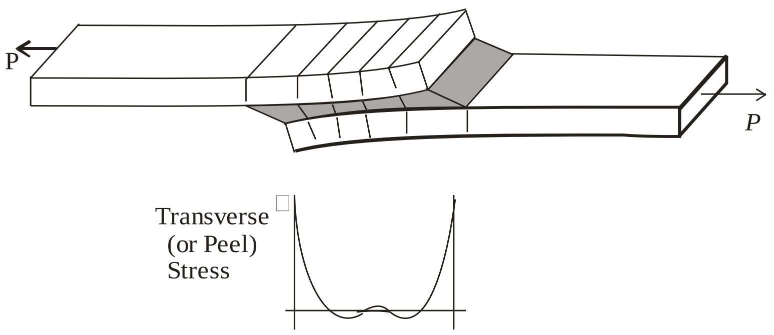
Design- Predictions

- Analytical Analysis
  - Volkersen's elastic adherend model
  - Goland & Reissner bending model
- Numerical Analysis
  - FEM (the most effective tool)

Problems with analytical analysis

- Volkersen's elastic adherend model
- Goland & Reissner bending model

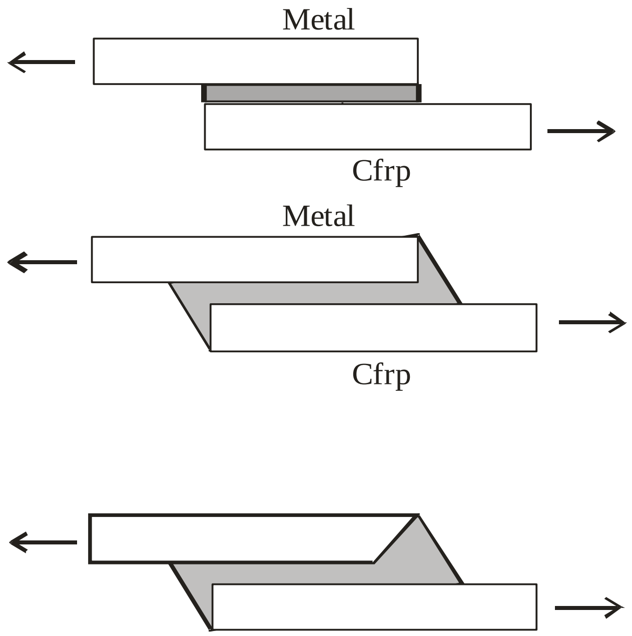




Reality and three-dimensional stress analysis

- differential straining of the adherends causing a shear stress distribution in the adhesive which is a maximum at the ends of the overlap (Volkersen (1938))
- offset loading of the lap joint which causes the loaded adherend to bend adjacent to the overlap region (Goland and Reissner (1944))
- end effects such as the adhesive free surface, spew, and material and geometric discontinuities which all affect the stresses at the overlap ends (Crombe and Adams (1981))
- Poisson’s ratio effects
- adherend plasticity

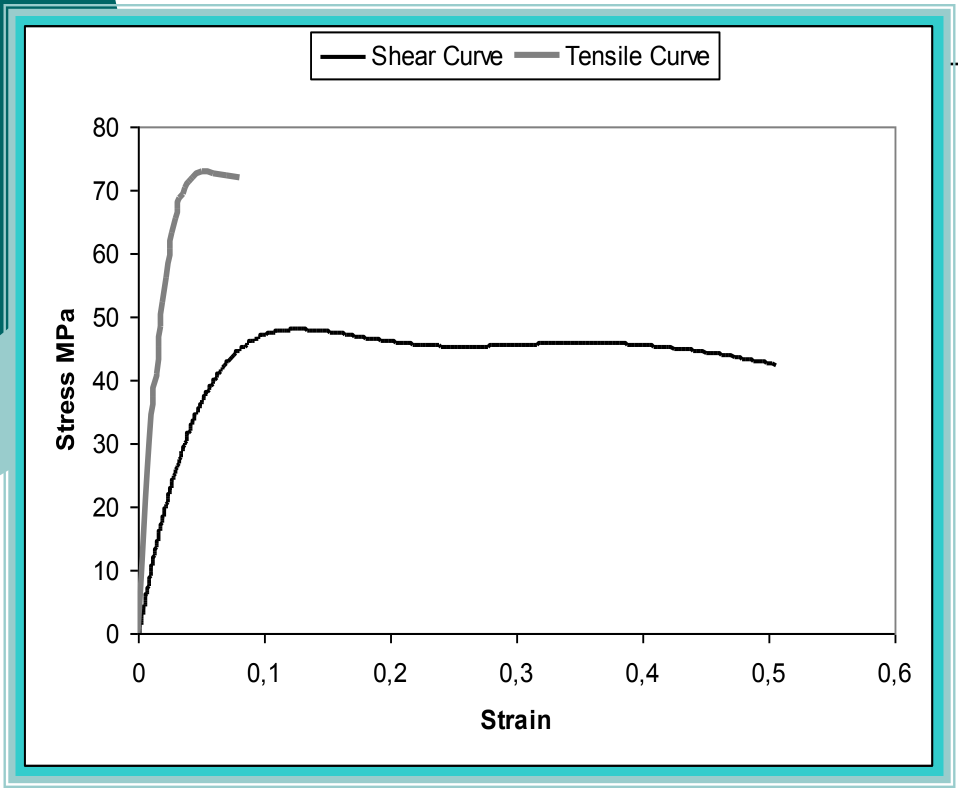
Some precautions to reduce the stress concentrations at the ends



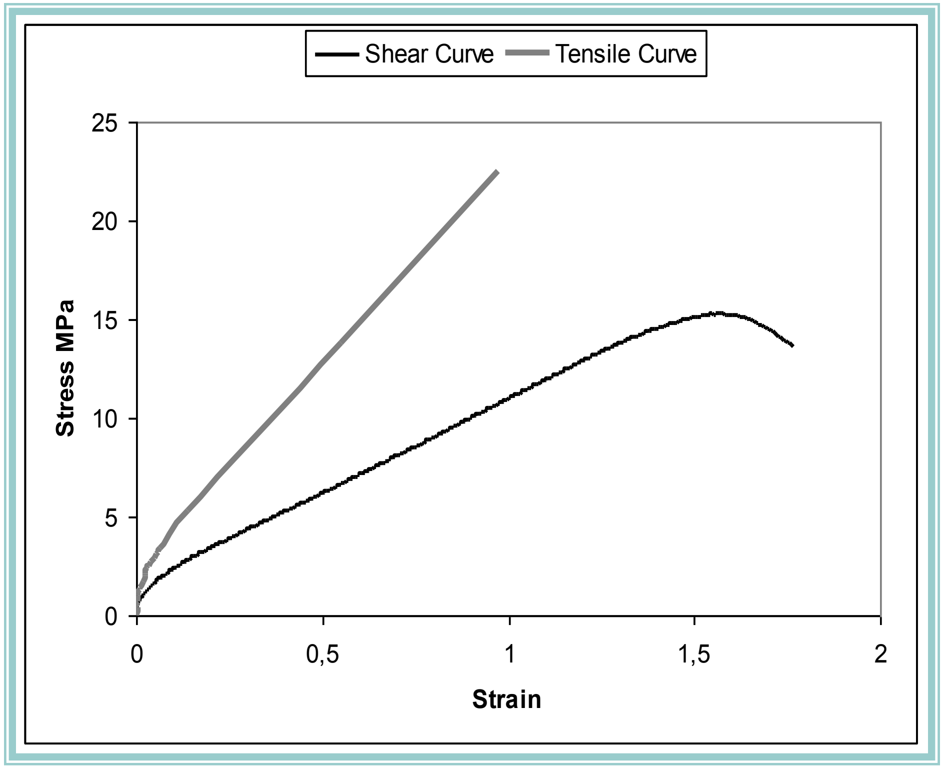
Examples

- **A Structural Adhesive**: AV119, one-part epoxy, manufactured by Ciba Polymers. cured at 120 C for an hour according to manufacturer's instructions.
- **A Flexible Adhesive**: 9245 Structural Bonding Tape (SBT), mixure of acrylic and epoxy, cured at 140 C for 45 minutes according to the manufacturer's instructions.

Mechanical behavior

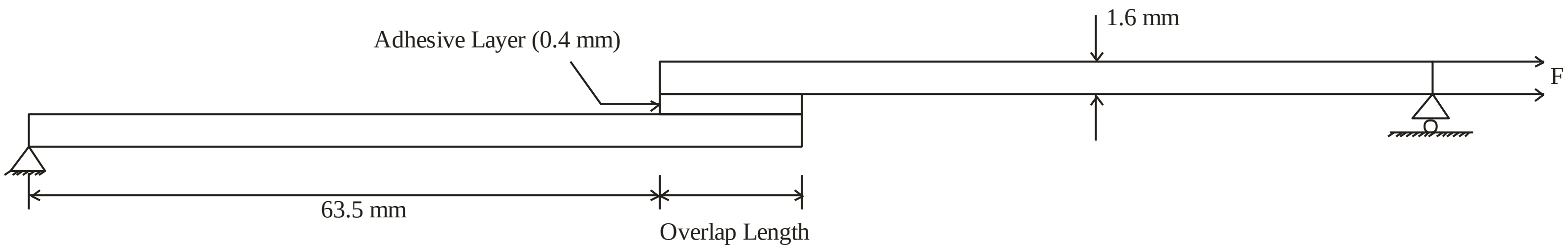


Structural Adhesive AV119



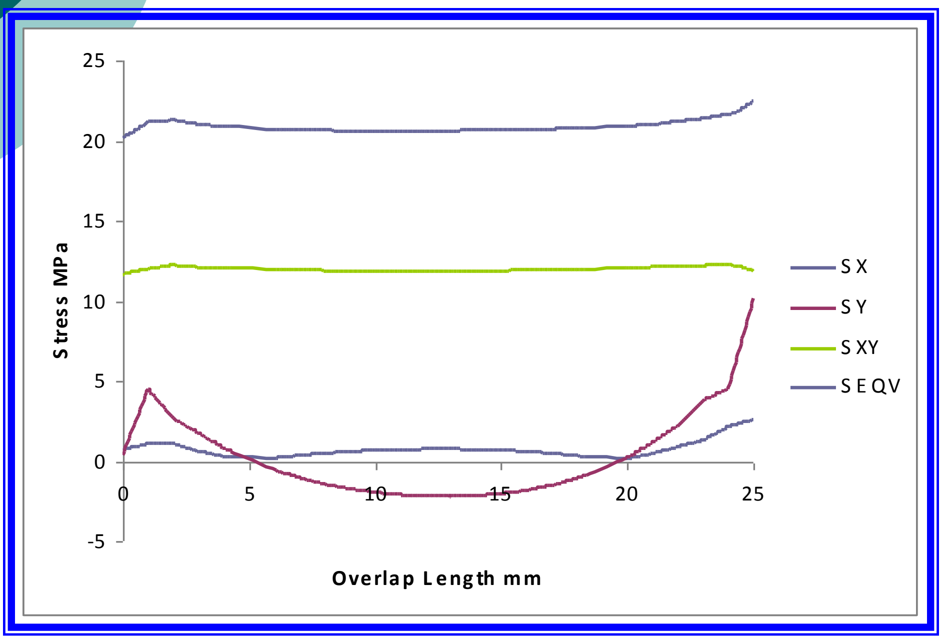
Flexible Adhesive SBT

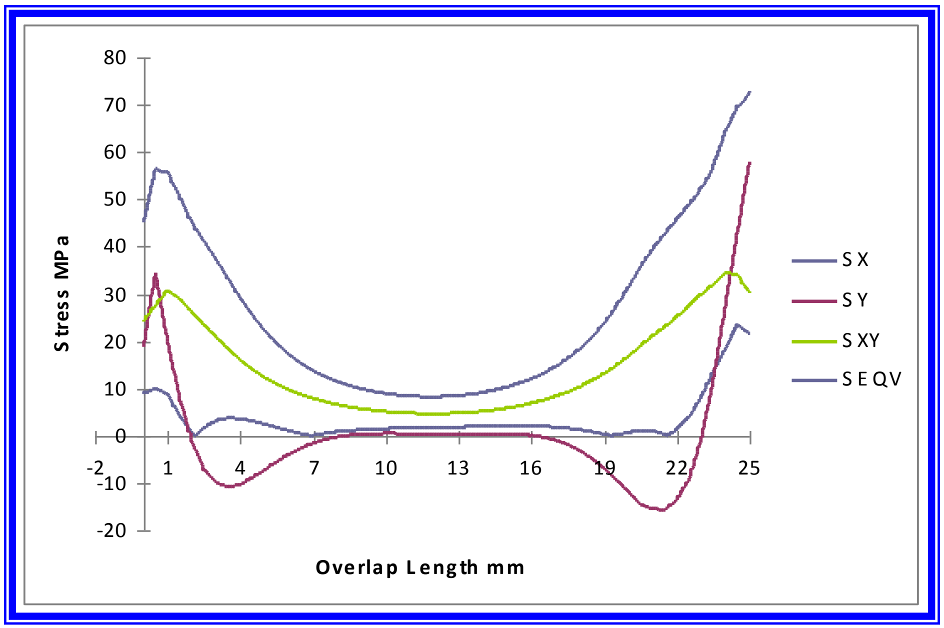
Lap shear performance in quas-static loading under tensile loading



Stress distributions in the adhesive layers under tensile loading

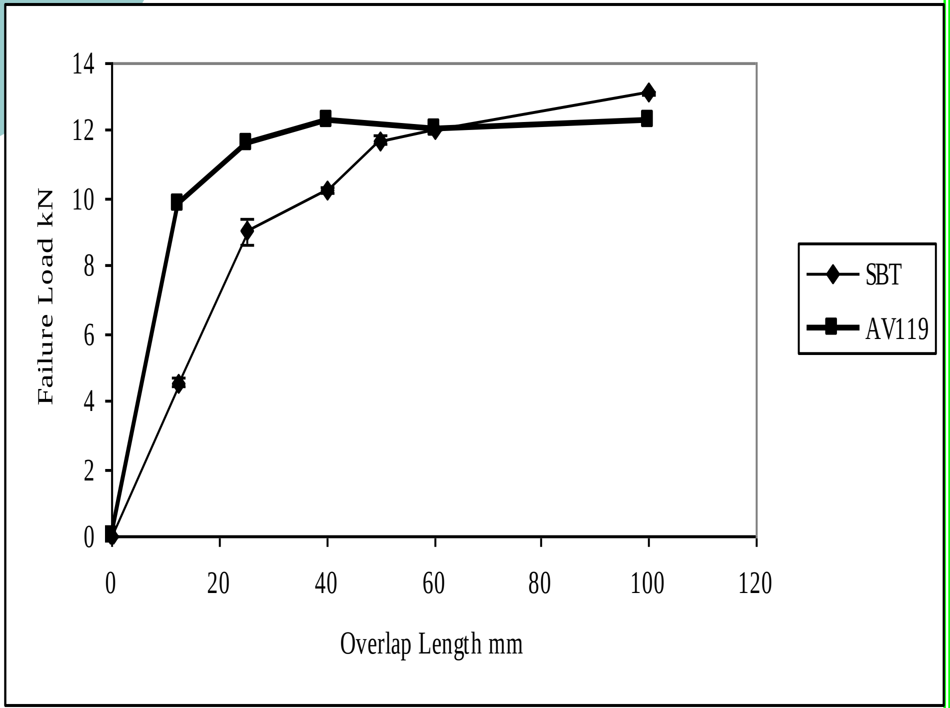
- SBT (Flexible Adhesive)
- AV119 (Structural Adhesive)

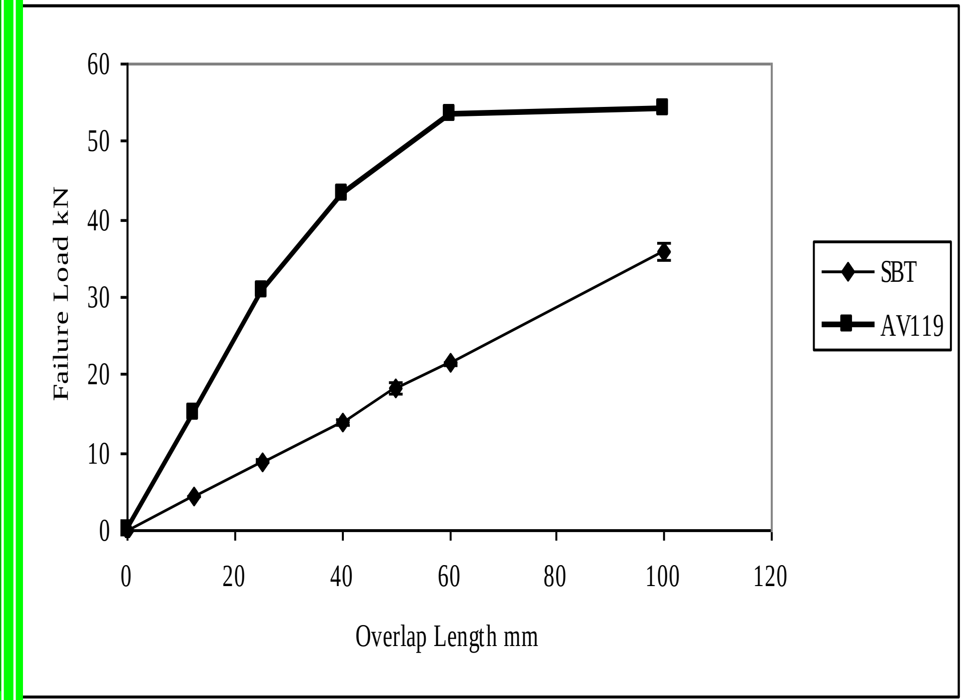




Comparison of results from tensile loading

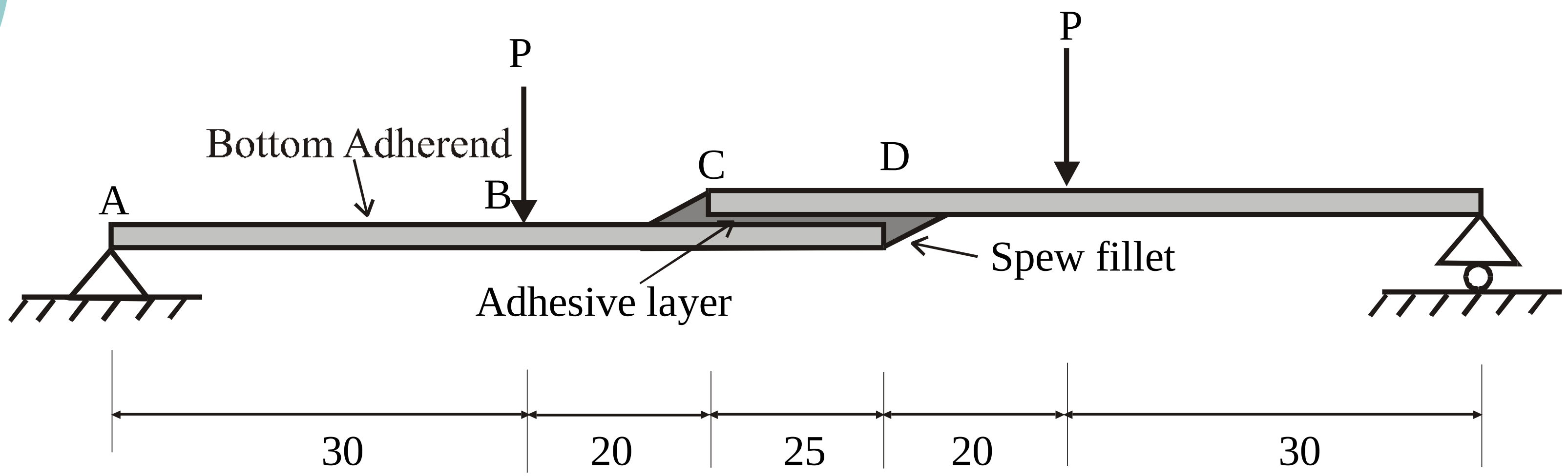
- Mild steel adherends
- Hard steel adherends





A broken adherend from the tensile test

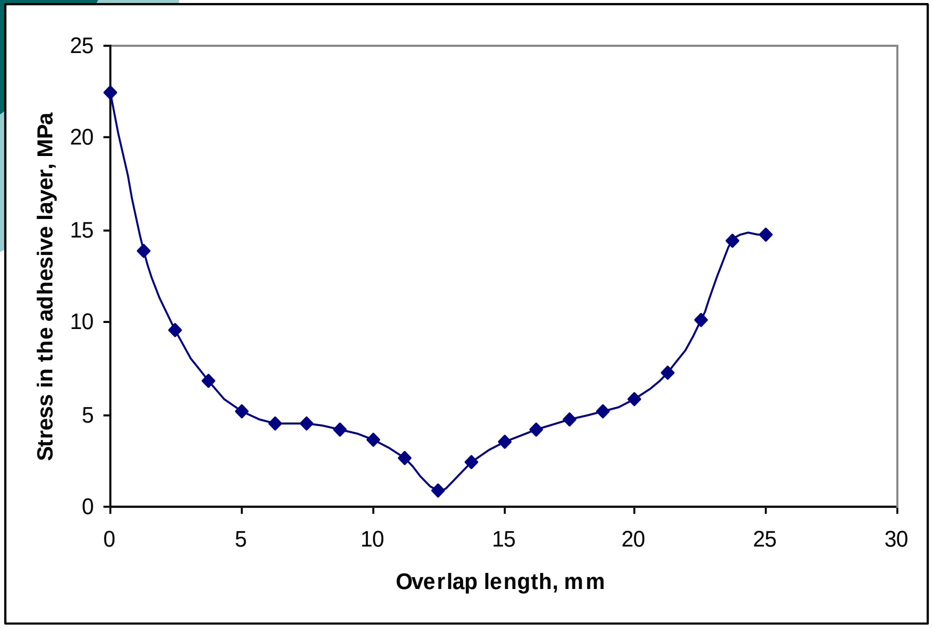
Lap shear performance in quas-static loading under bending loading

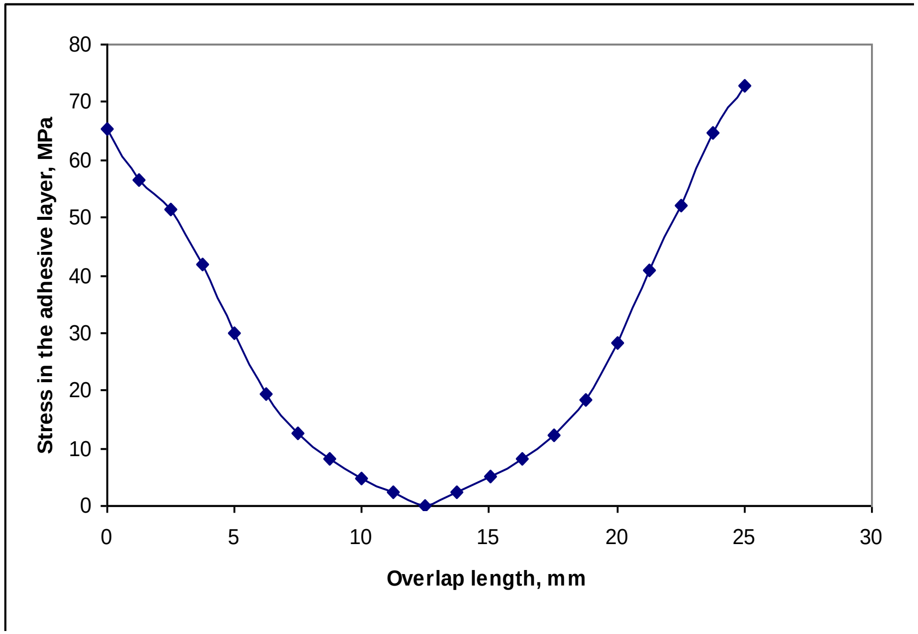


All dimensions in mm

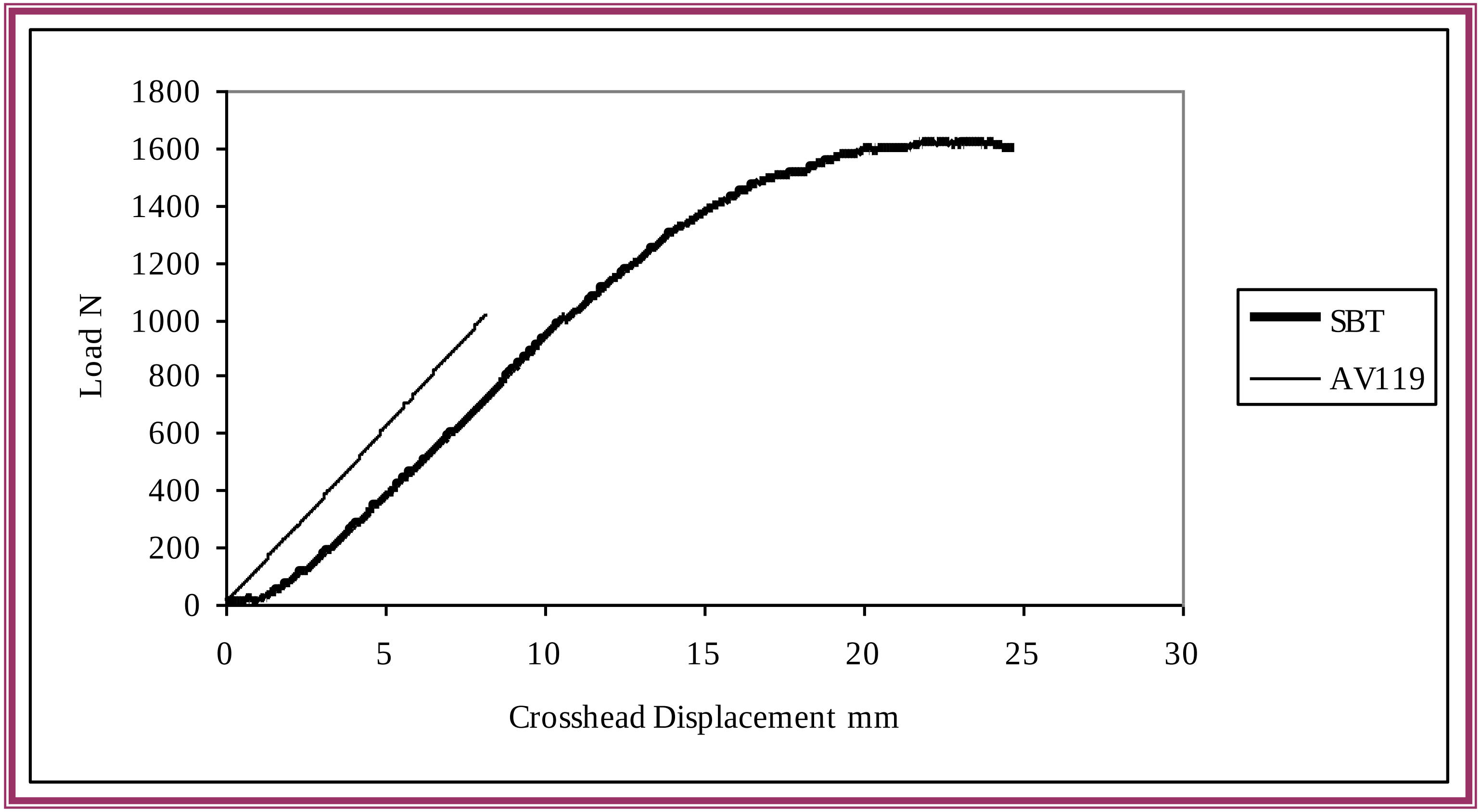
Stress distributions in the adhesive layers under bending loading

- SBT
- AV119



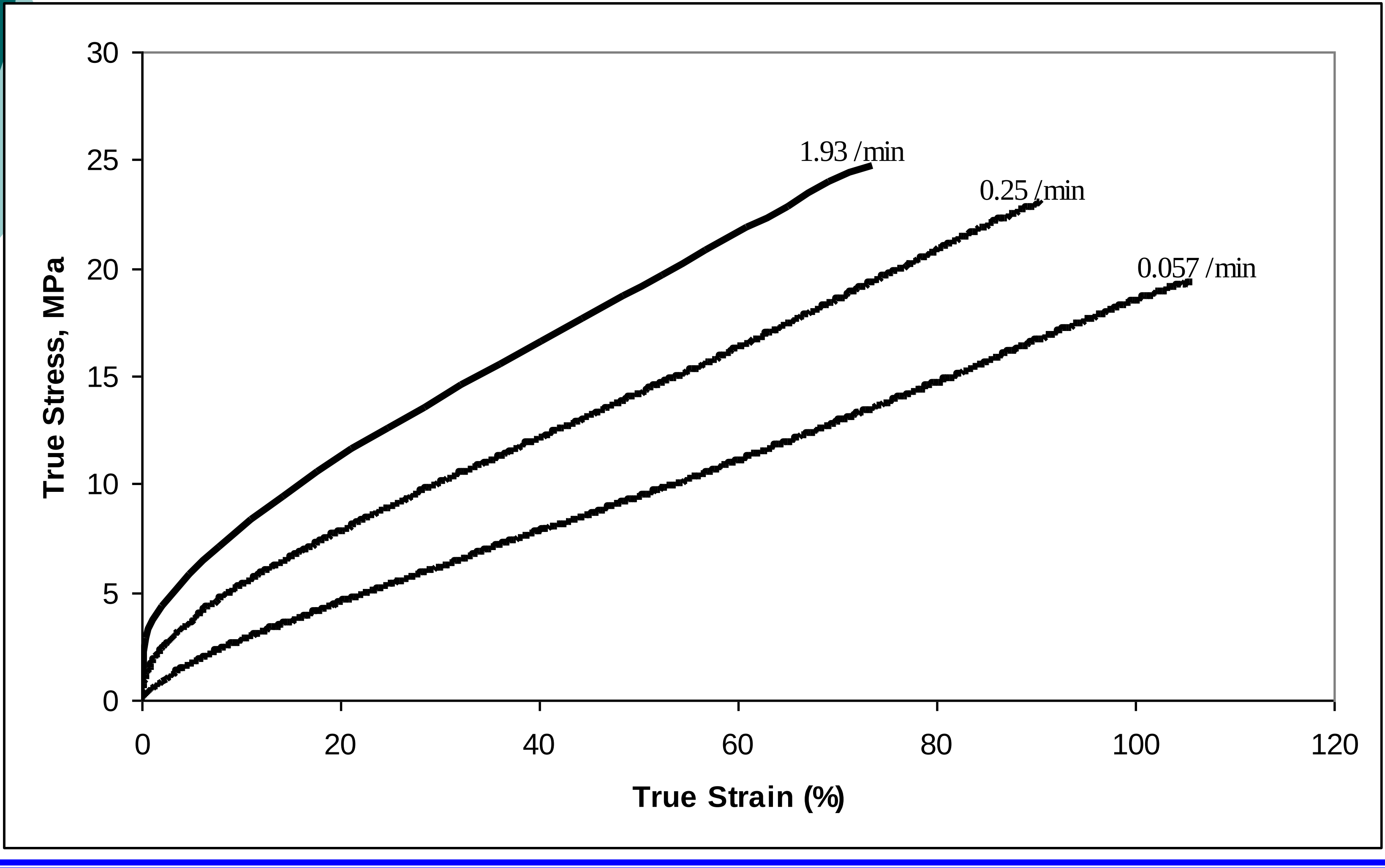


Comparison of curves (results) from bending loading

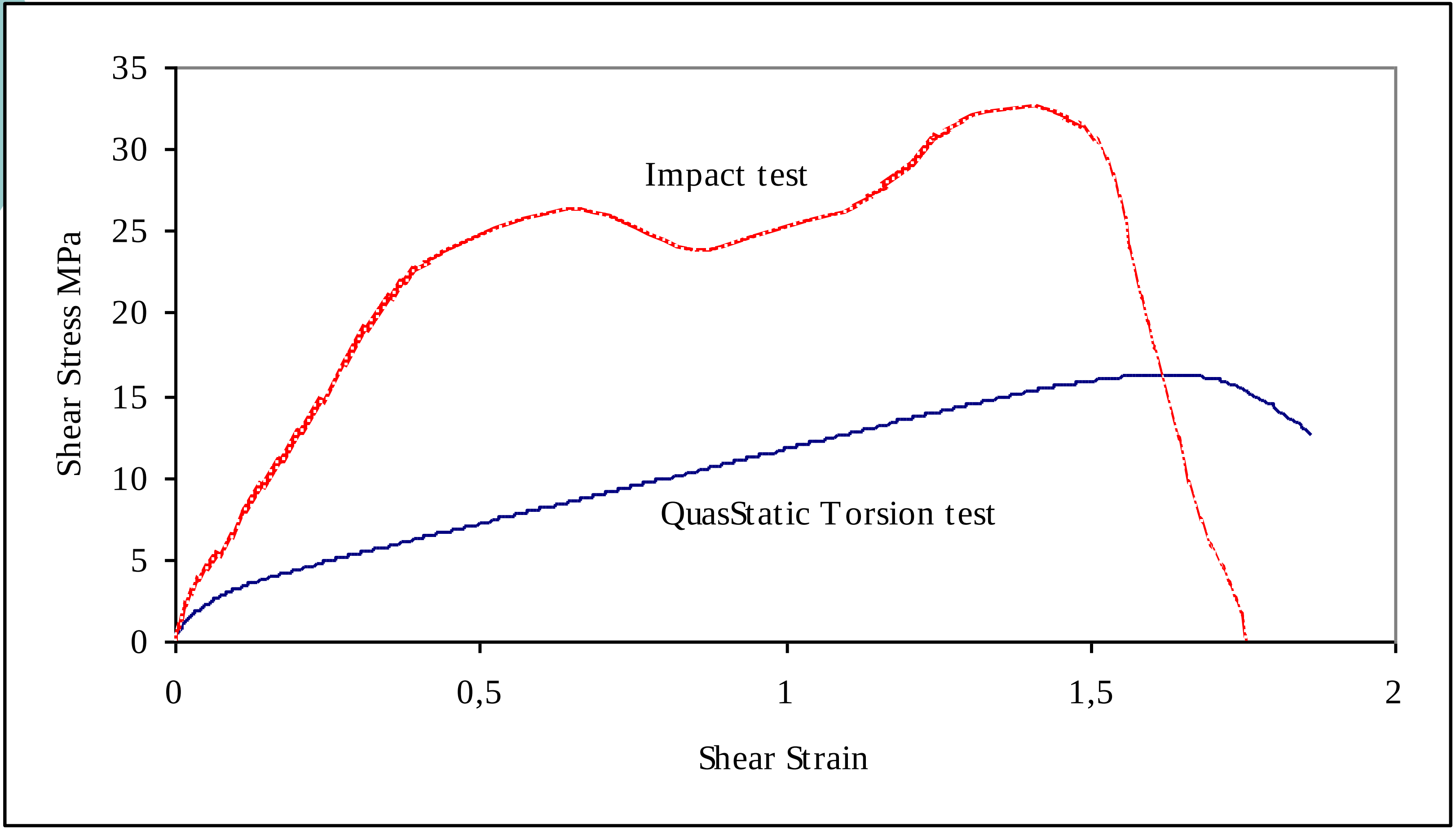


A broken adherend UTS= 2000 MPa

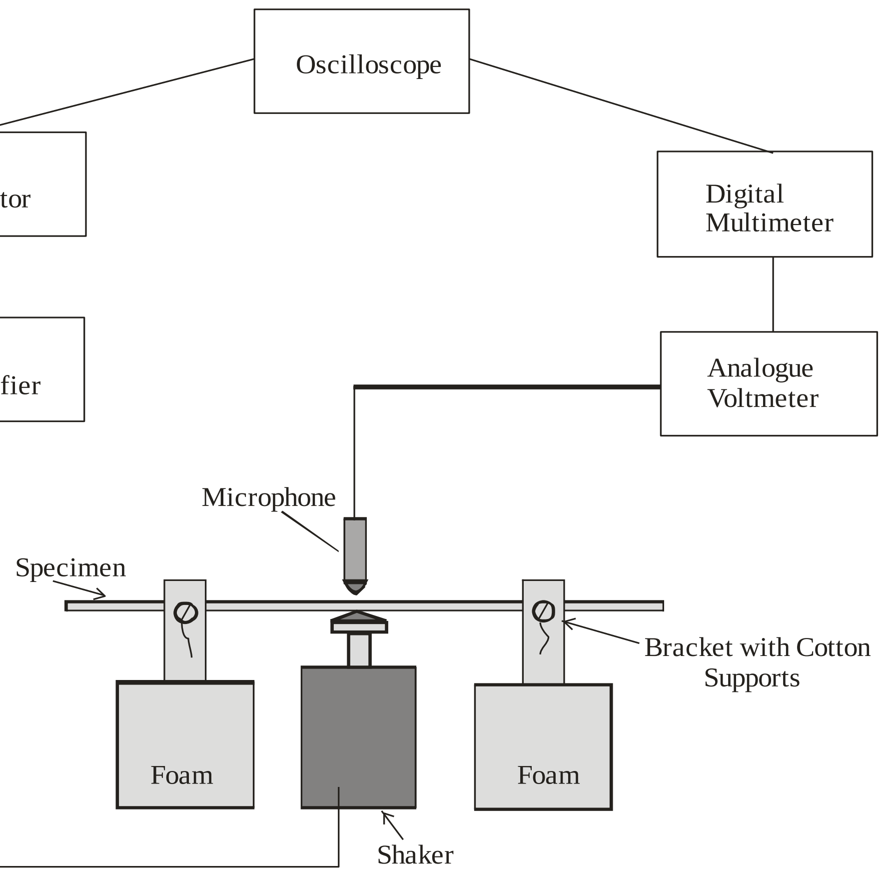
SBT stress-strain variation curve with strain-rate variation at room temperature using a laser extensometer



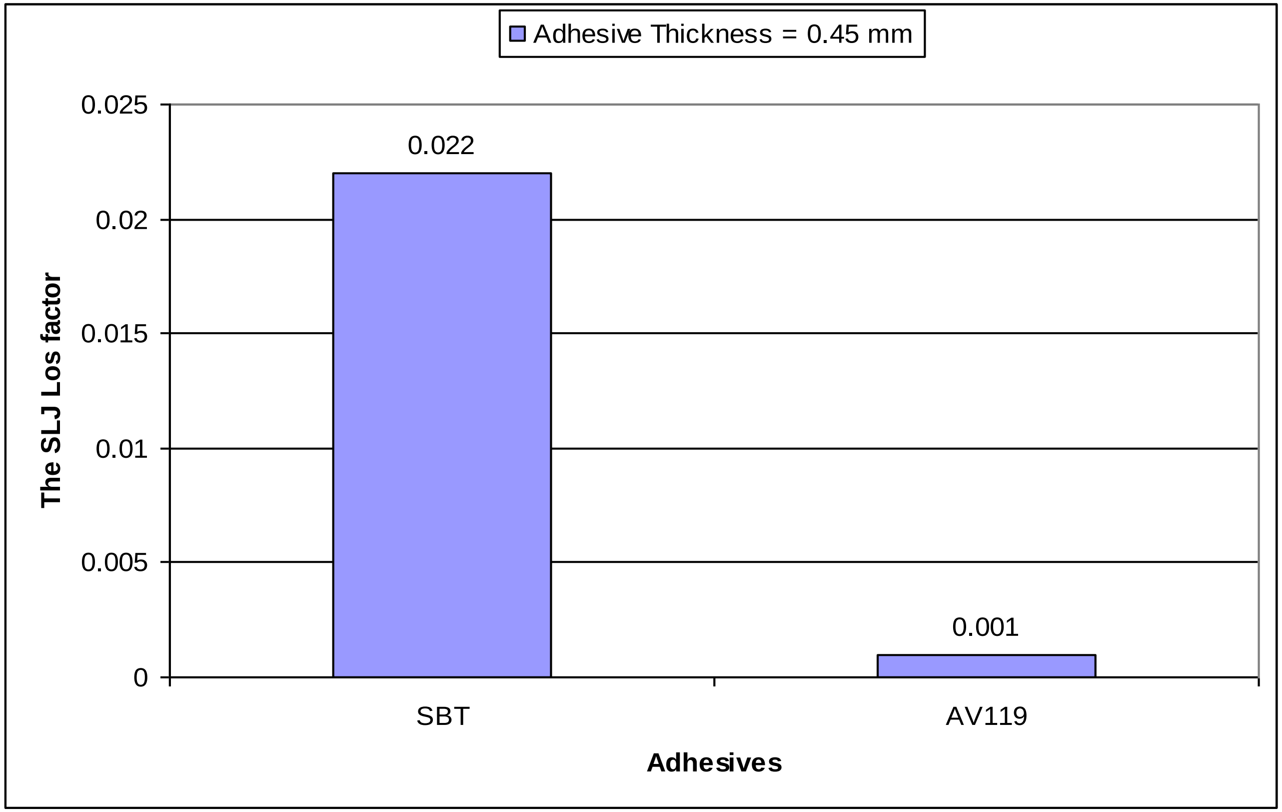
Comparison of quasi-staic and impact test



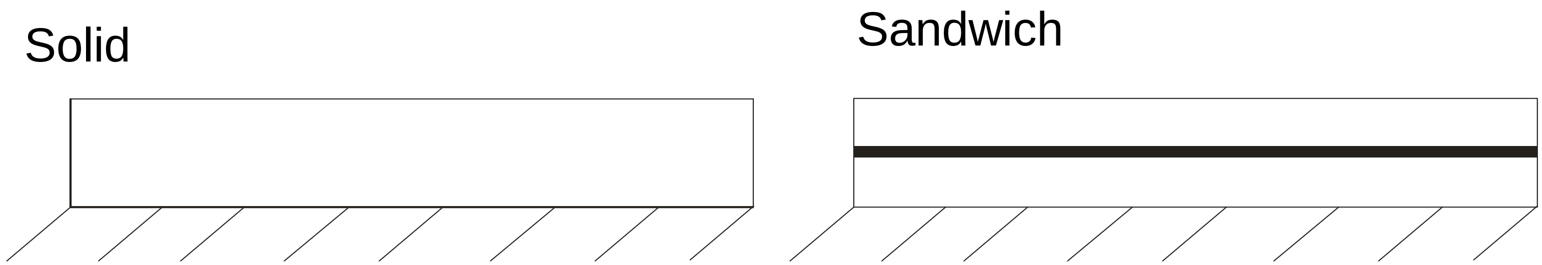
Vibration set-up dynamic properties of materials



Damping performance of the adhesives



Benefiting from damping properties of polymers (Adhesives)



Conclusions

- Mechanical behavior of materials plays an important part in the performance of aerspace structures
- Correct design data are vital for reliable predictions
- Aerospace components require careful design approach
- Sometimes relativesly less strong materials provide much more strong structural systems (SBT, AV119)

Thank you！

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