UNIVERZITET U ZENICI
Mašinski fakultet

katedra za Automatizaciju i Metrologiju

PART III:

Testing adhesives and adhesively bonded joints

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TESTING PRODUCT CHARACTERISTICS

About adhesives and adhesively bonded joints*

***Adhesive* – a polymeric material which, when applied to the surfaces of materials, can join them together and resist separation.**

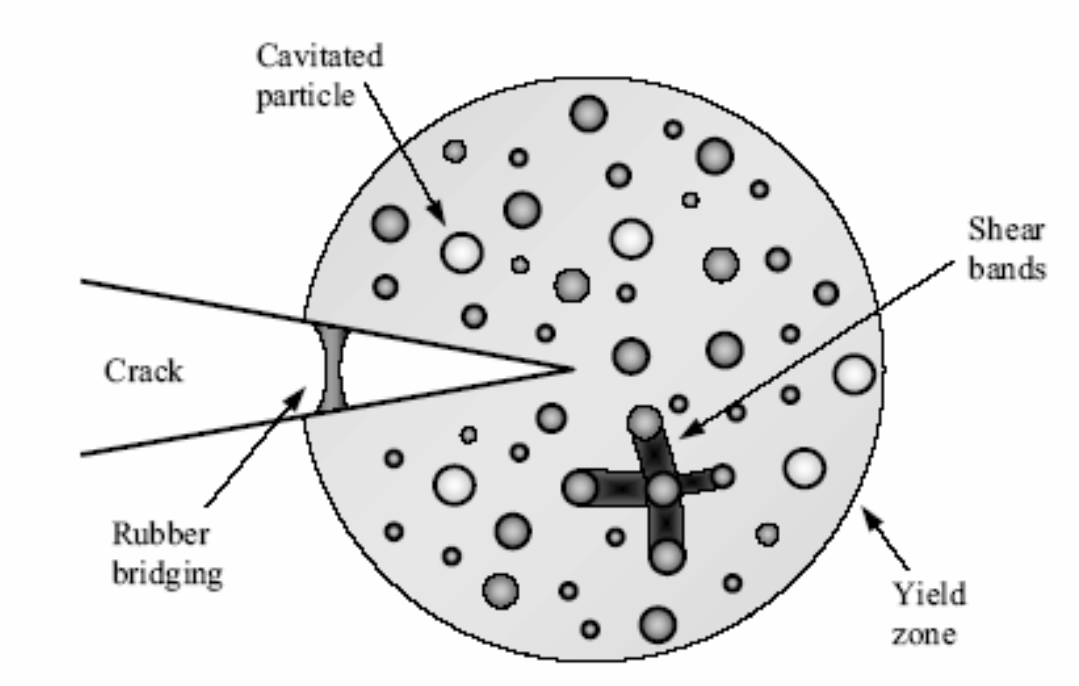
***Structural adhesive* – an adhesive that, once it is hardened, has a modulus and strength sufficiently high so that load-bearing joints may be constructed (epoxy).**

i) *single-part* adhesives, which require heat-curing at elevated temperatures, and

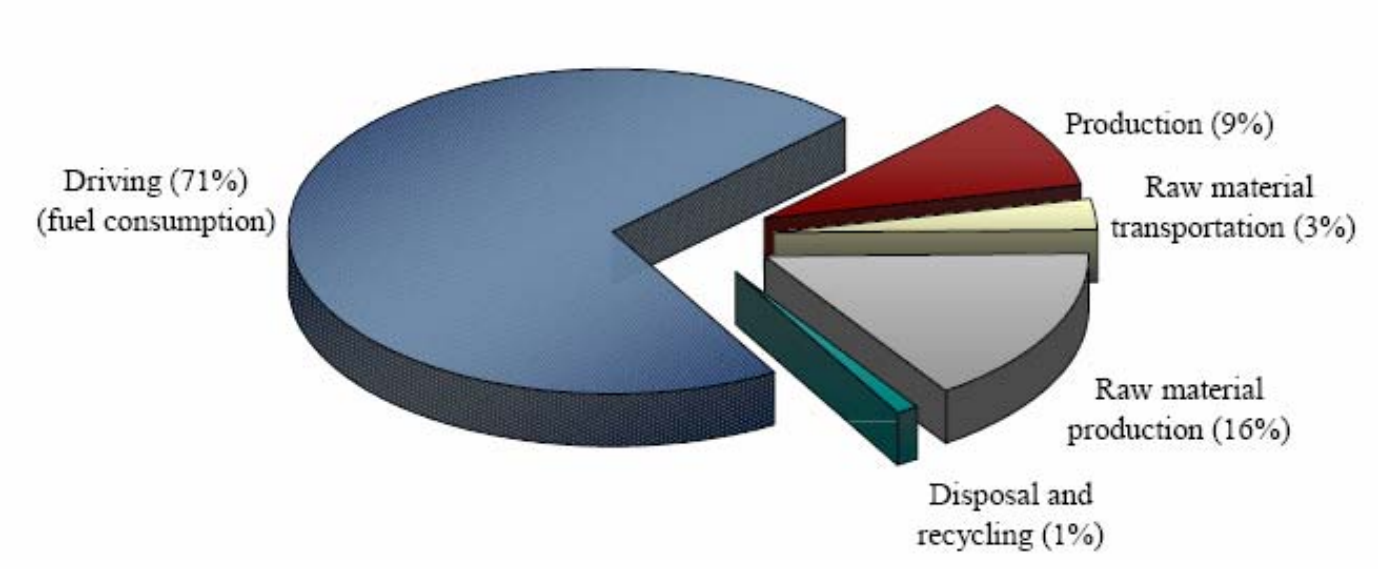
ii) *two-part* adhesives, that can cure at room temperature.

* Georgiu I., The Fracture of Adhesively-Bonded Aluminium Joints for Automotive Structures PhD, 2003

Rubber- toughened epoxies



Adhesives in automotive industry



Energy consumed during the life cycle of a vehicle

Adhesives in automotive industry

BMW ‘X5’ with a steel monocoque body structure

Audi ‘A2’ with an all aluminium-alloy space-frame body structure

Main advantages

• Adhesive bonding offers the possibility to join dissimilar materials; *e.g.* metals, plastics, fibre-composites, wood, *etc.* Dissimilar metals can be joined in this way, since the adhesive prevents intimate contact, which could otherwise lead to galvanic corrosion.

• Adhesives have the ability to join thin sheet-material efficiently.

• A good joint design will be energy-absorbing, and tend to have good noise and vibration damping properties.

• The adhesive may essentially have a dual purpose since, as well as providing mechanical strength, the adhesive may seal the joint against moisture and debris ingress.

• The smooth appearance of the joints produced using adhesives results in lower stress concentrations at the joint edges. Thus, the load is more evenly distributed and stress concentrations are minimised. As a result, a more effective dynamic-fatigue resistance of the component or structure can be obtained.

• Adhesive bonding is often a convenient and cost-effective technique. Process automation by robot minimises the necessity of any human interaction and, with the increased development of flexible manufacturing systems, adhesive bonding may be an integrated part of the assembly line.

Main limitations

• The surface pre-treatment of the substrates to be joined have a major effect on the strength of the joint, in particular under severe environmental conditions.

• Adhesive bonding has a limited service temperature range compared with the other fastening techniques.

• The strength and toughness of adhesives are typically relatively low compared to metals, and therefore their use is limited to only joining thin sheet metals.

• Commercial techniques for non-destructive testing of adhesively-bonded joints are relatively limited compared to those used with other fastening methods.

• Adhesive joints are inherently weak in peel; and vehicle designs need to take account of this, particularly with regard to crashworthiness.

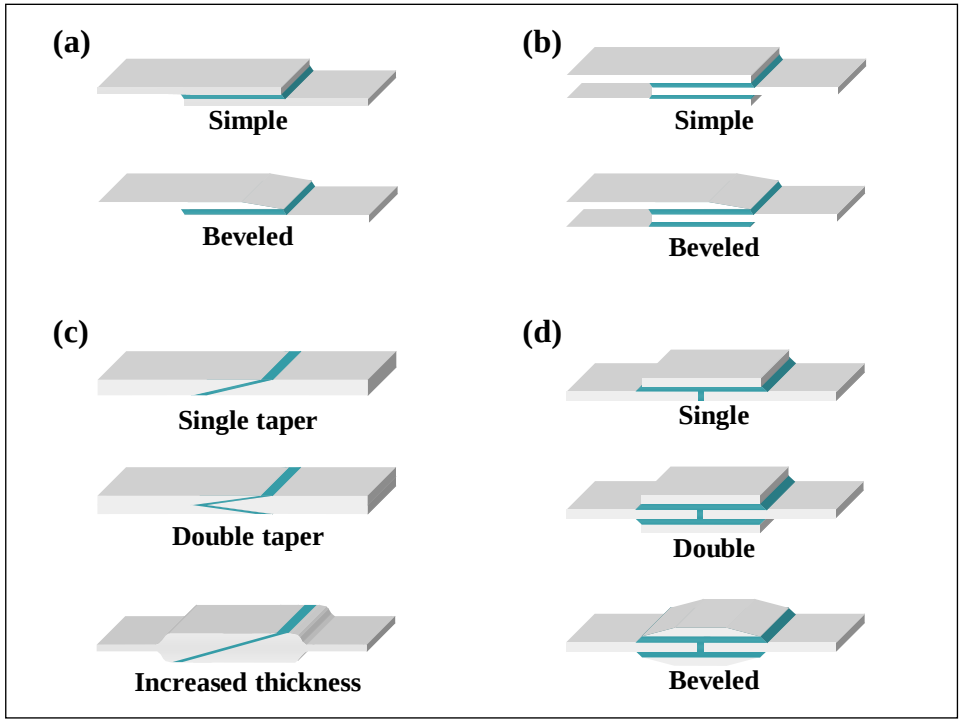
• There is a lack of information and knowledge concerning the potential failure of bonded joints under impact conditions.

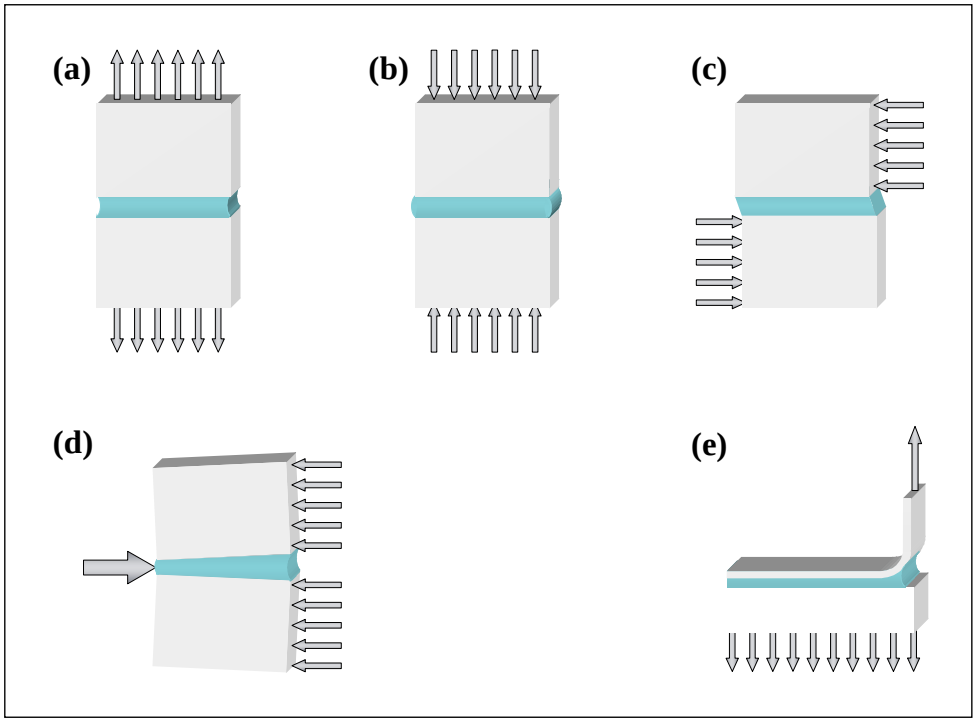
Adhesives in use

Volvo vehicle joined using adhesives. A Volvo vehicle is joined by adhesives using a proportional adhesive dispenser

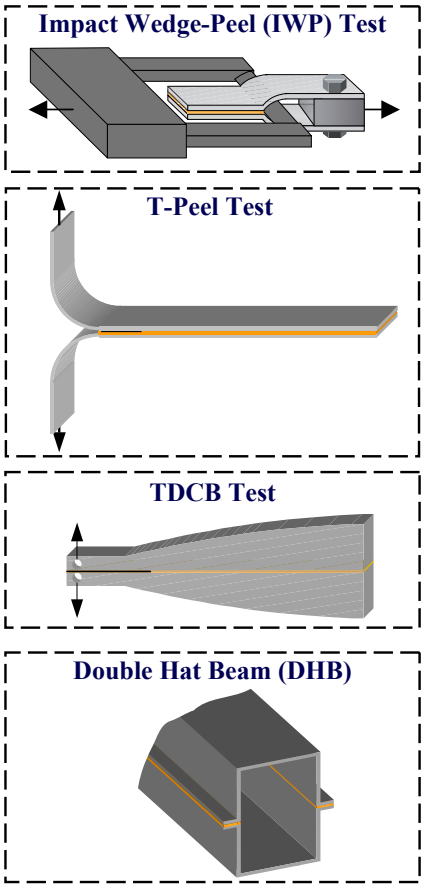
Vehicle manufacture using an epoxy adhesive. Here, vehicle - robotically delivered single-part heat-curable epoxy adhesive

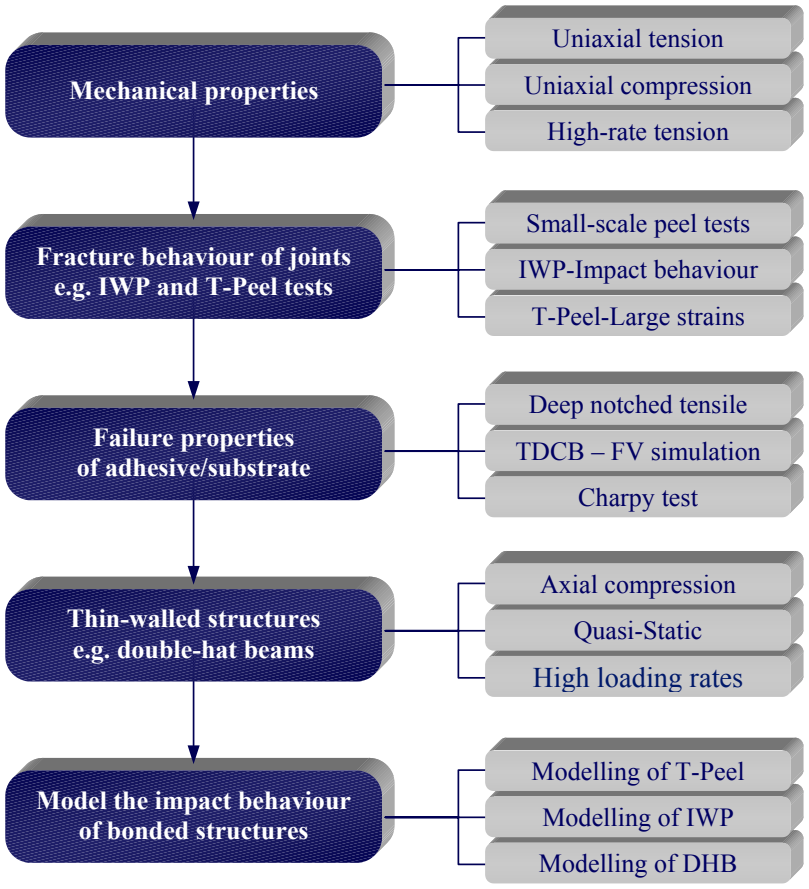
Adhesively bonded joints



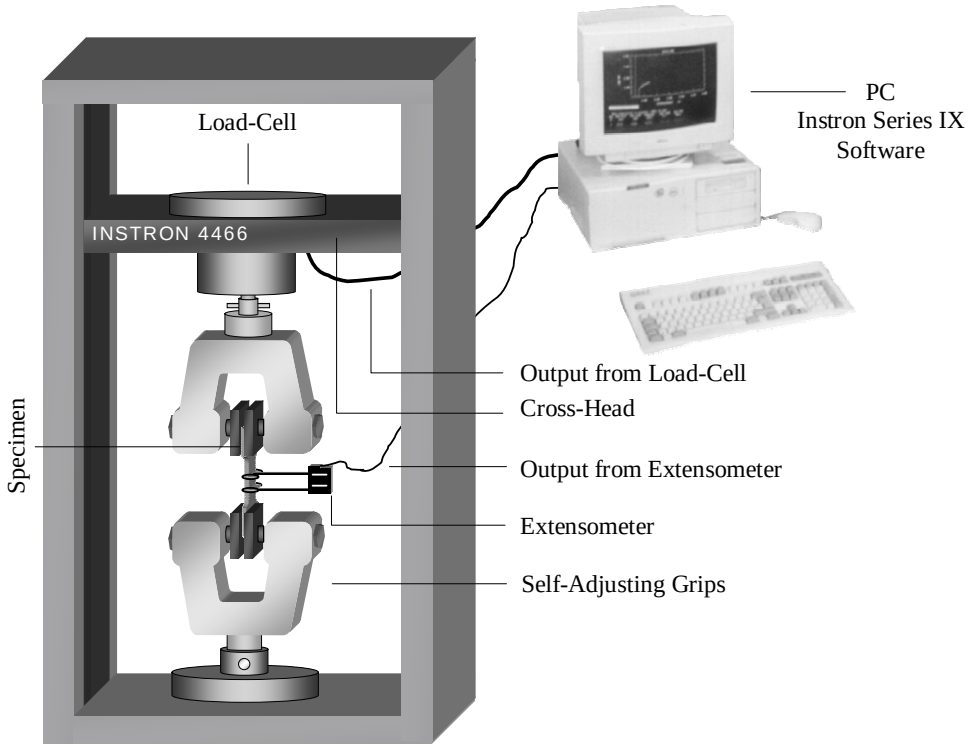


Testing of adhesives and adhesively bonded joints

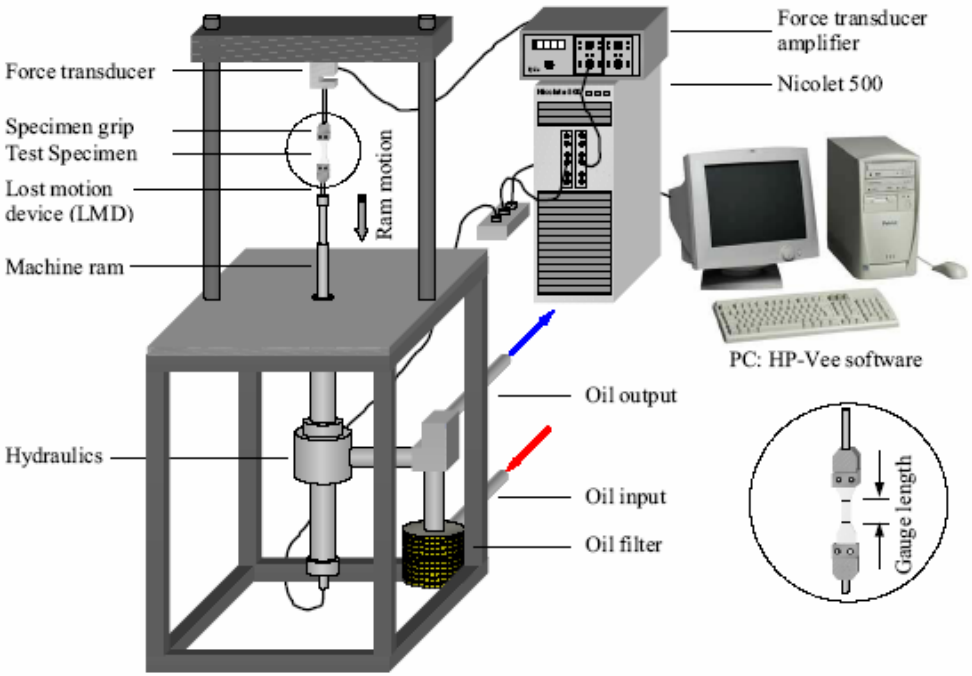




Uniaxial tensile tests

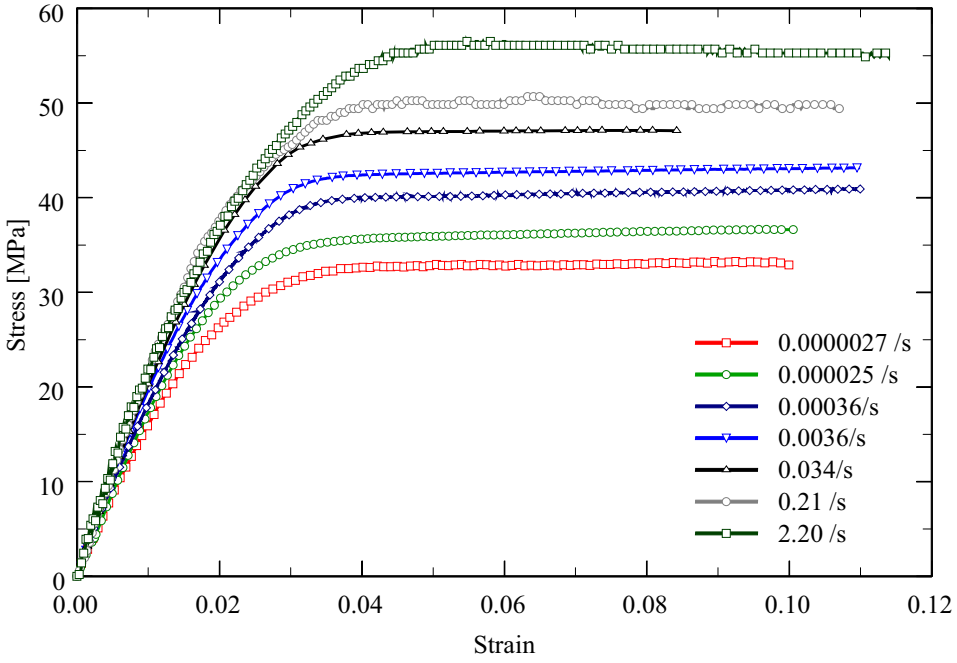


Low-rate tests

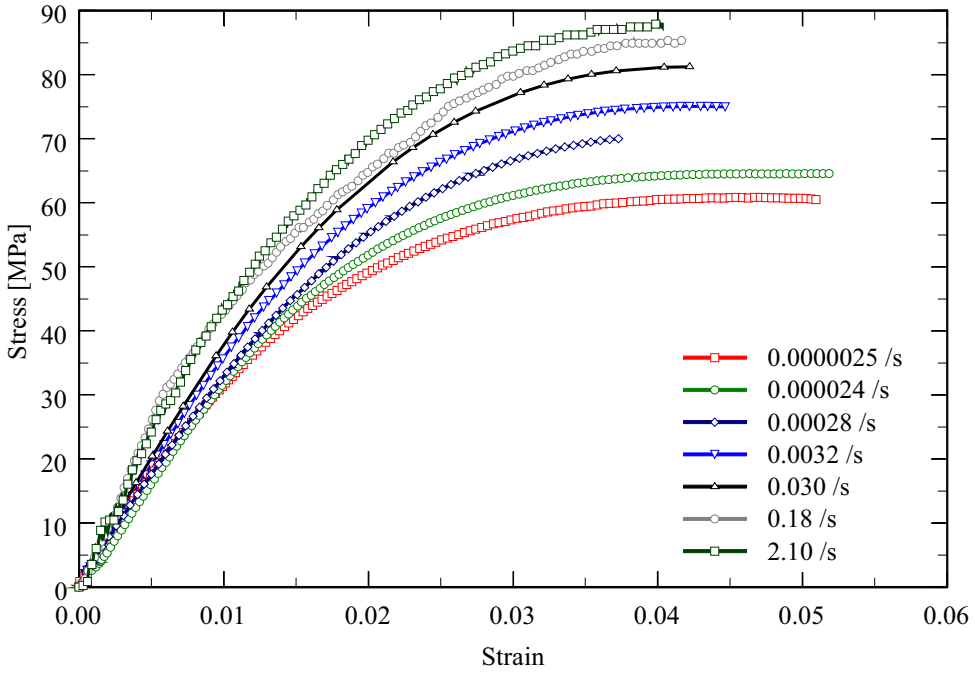


high-rate tests

Uniaxial tensile tests

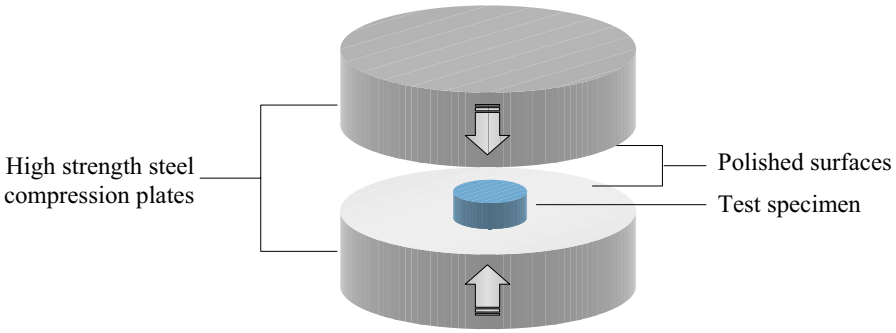


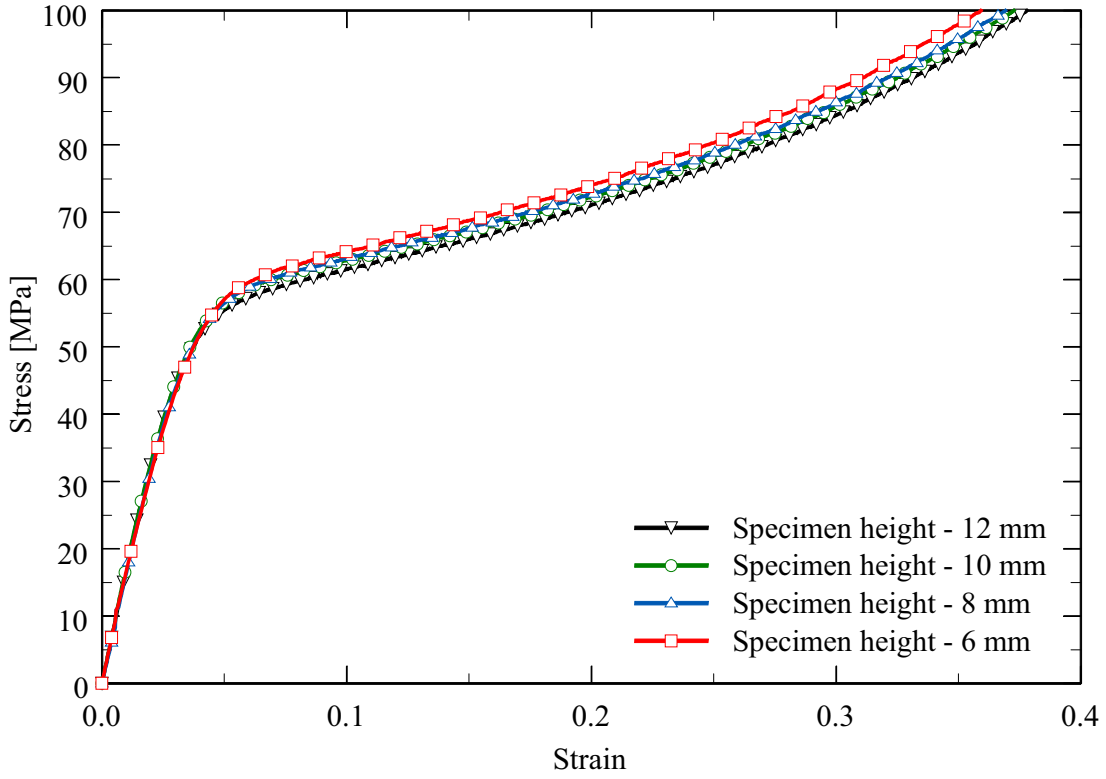
HD 1493



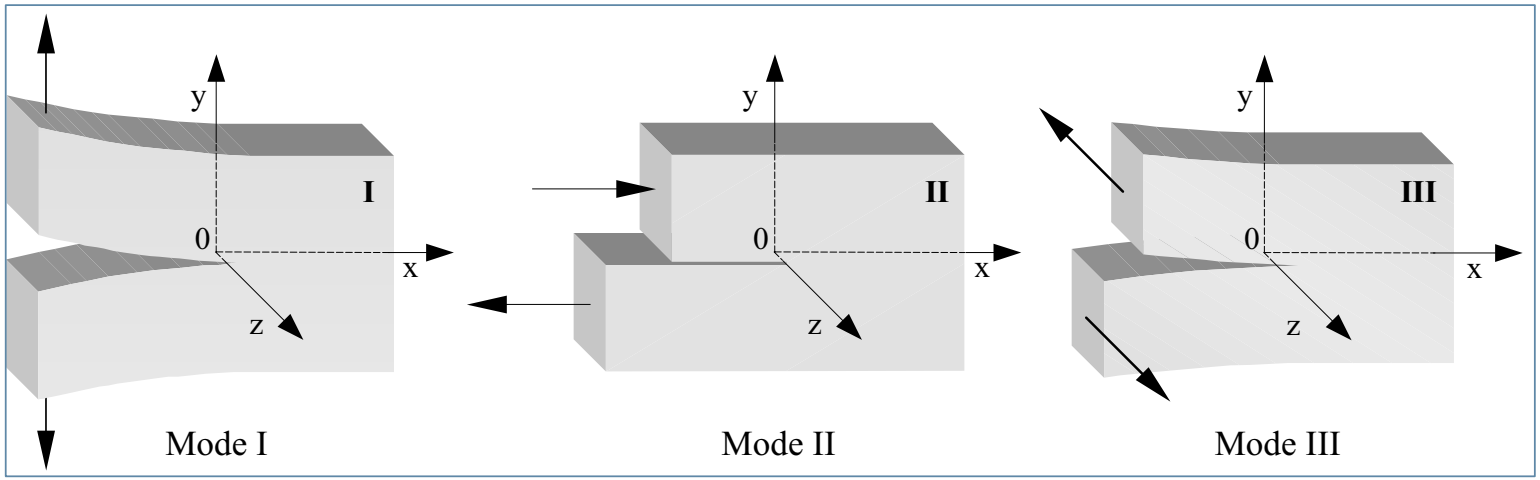
HD 4600

Uniaxial compression





Fracture properties

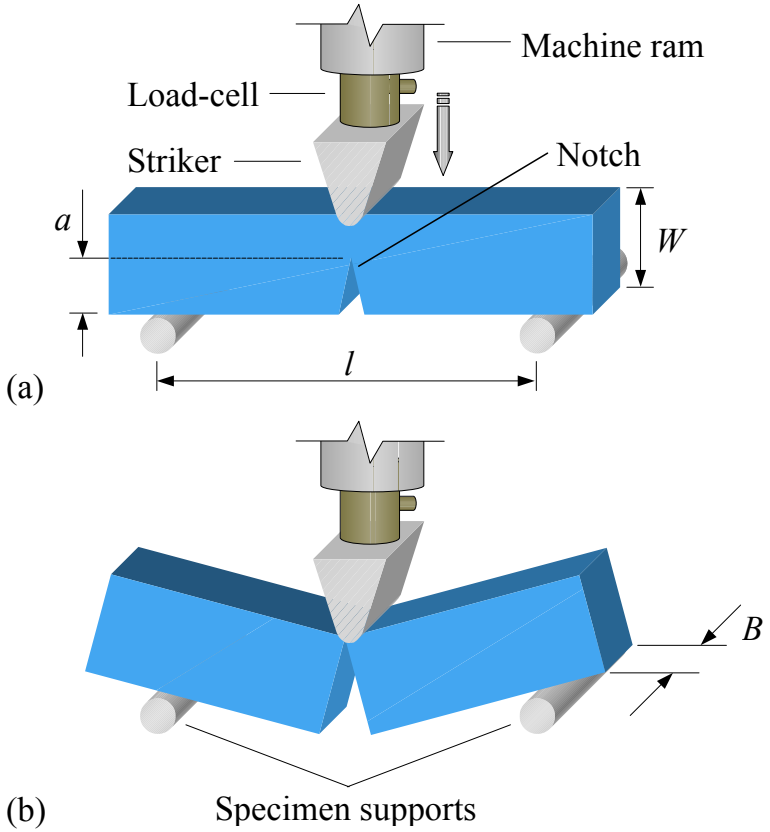


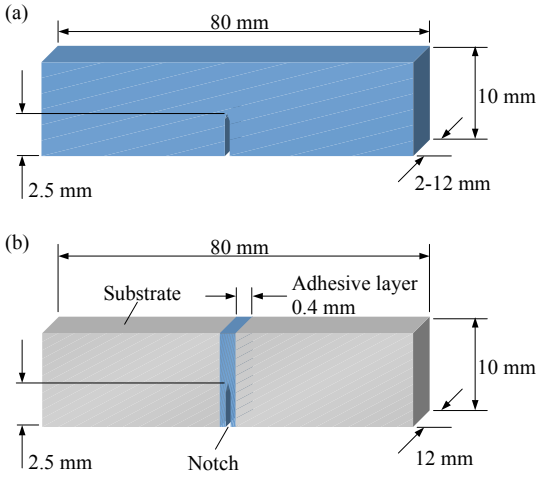
Mode I – tensile opening mode

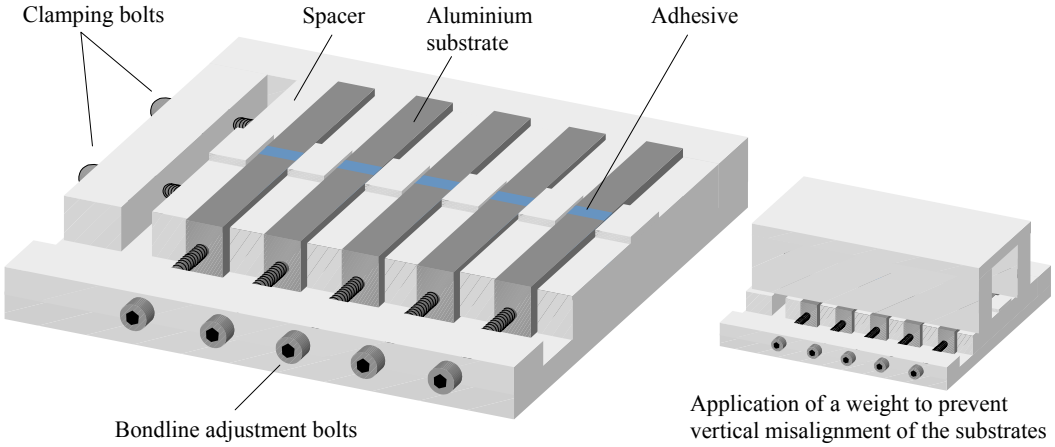
Mode II – in-plane shear

Mode III – anti-plane shear

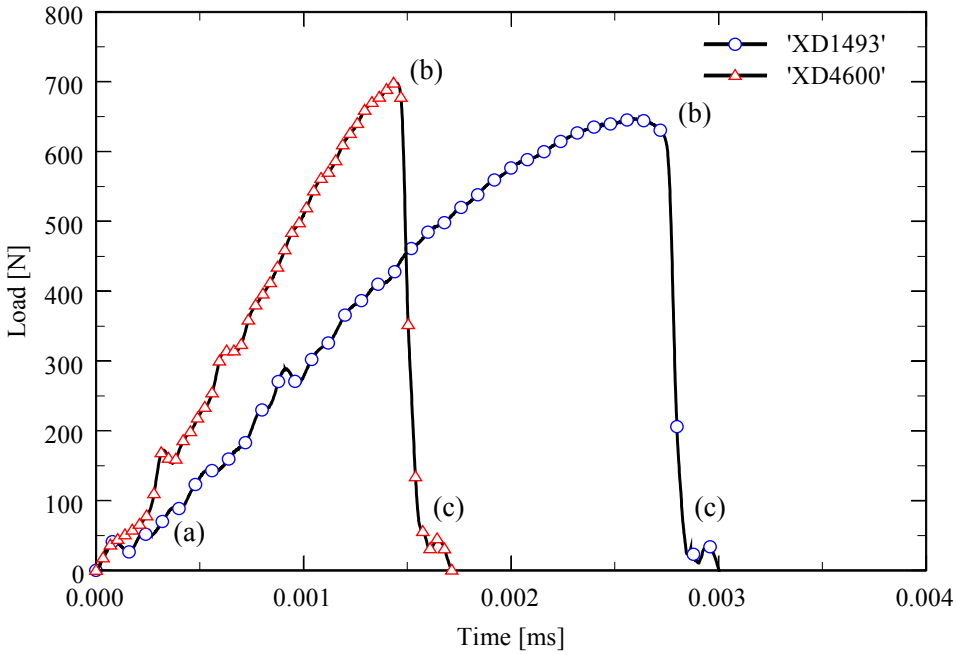
Charpy tests



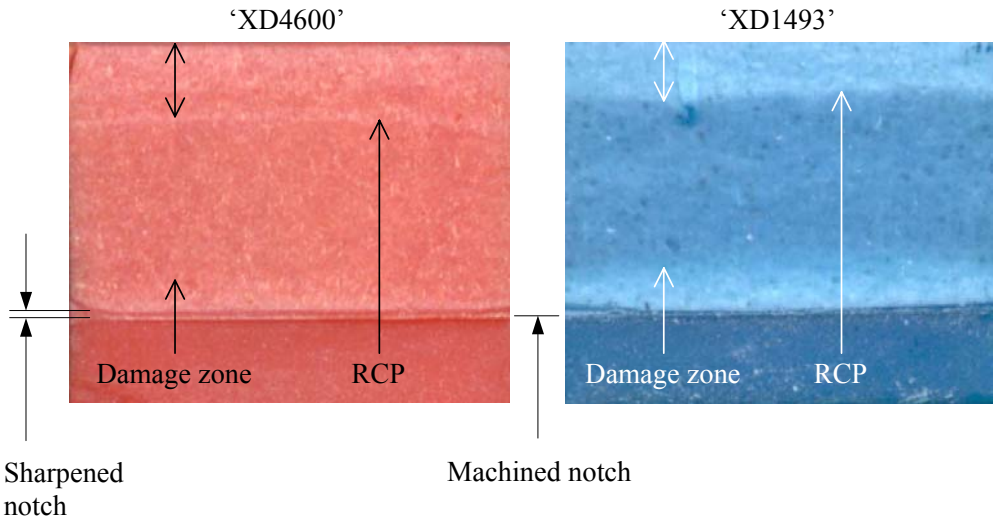




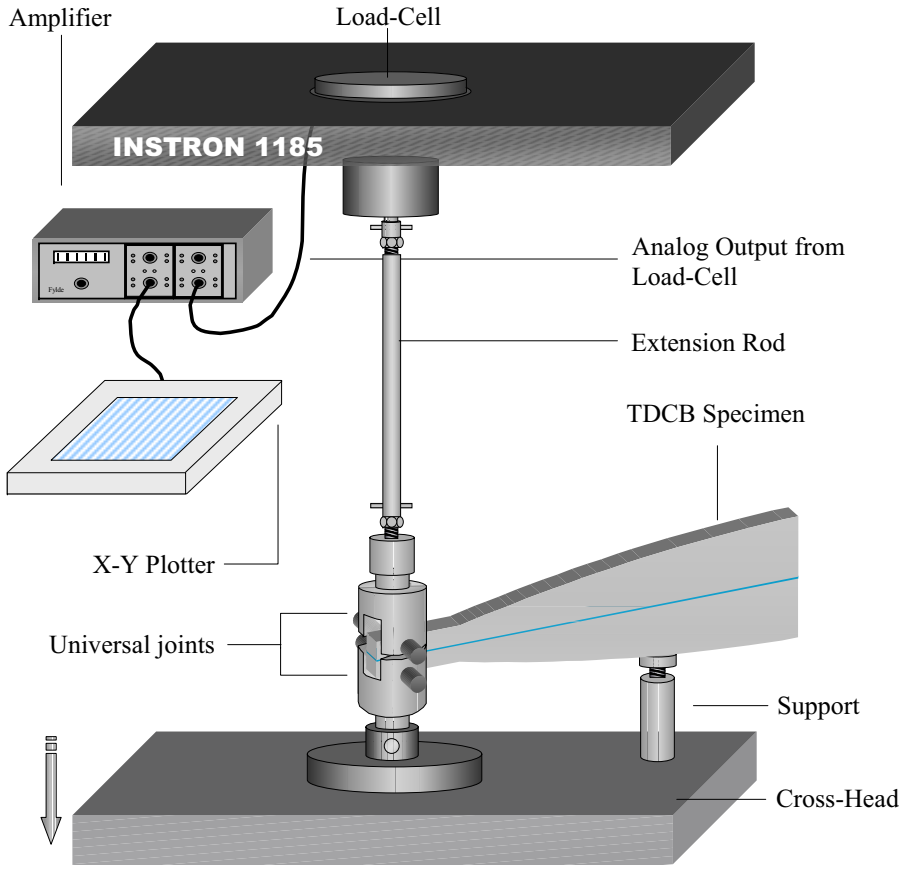
Charpy tests



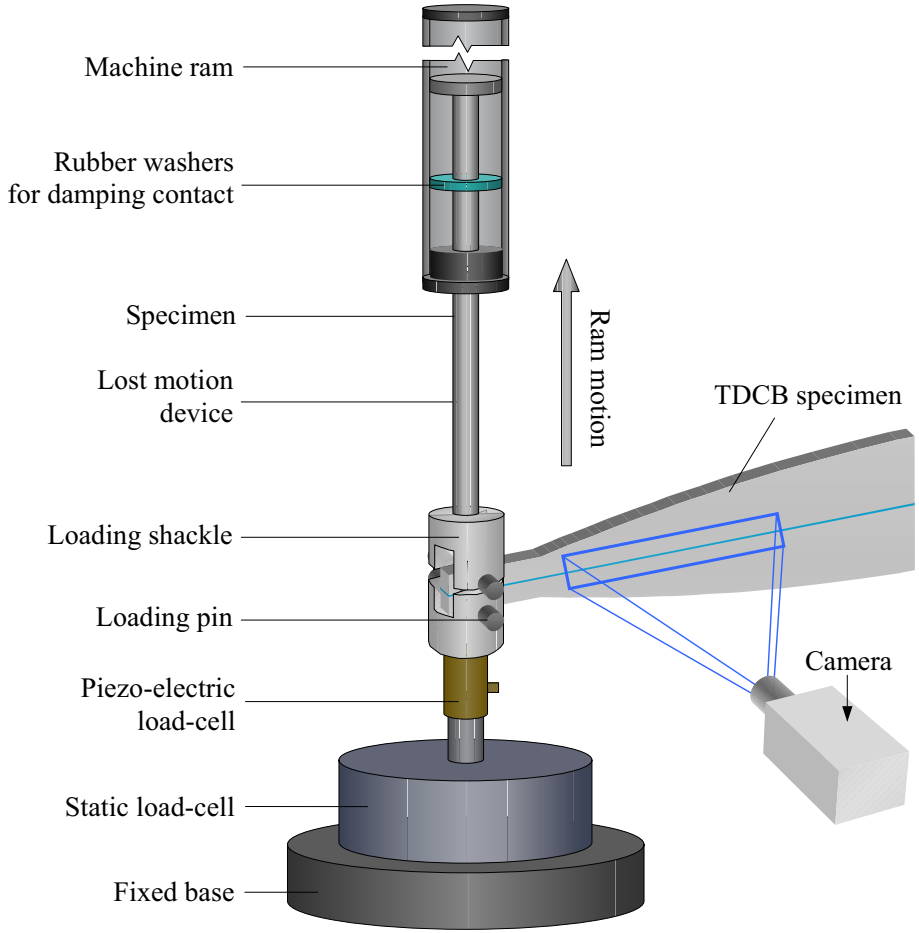
‘XD4600’ ‘XD1493’



Tapered Double-Cantilever Beam (TDCB) Tests



Low-rate tests

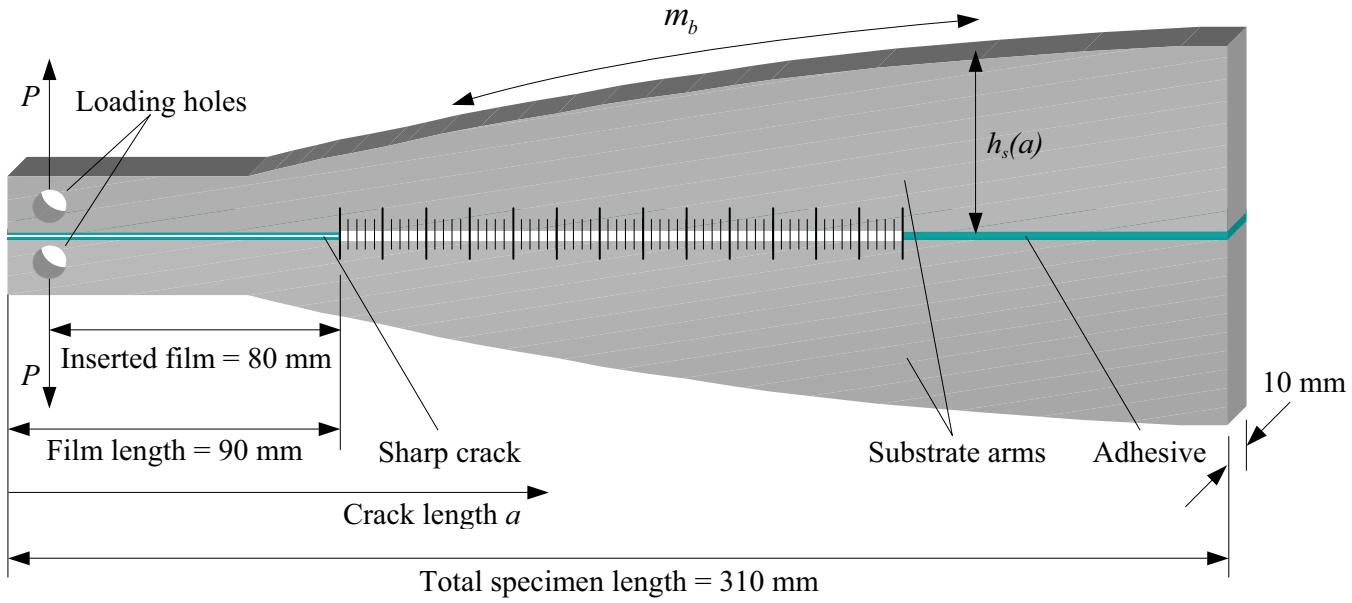


high-rate tests

Tapered Double-Cantilever Beam (TDCB) Tests

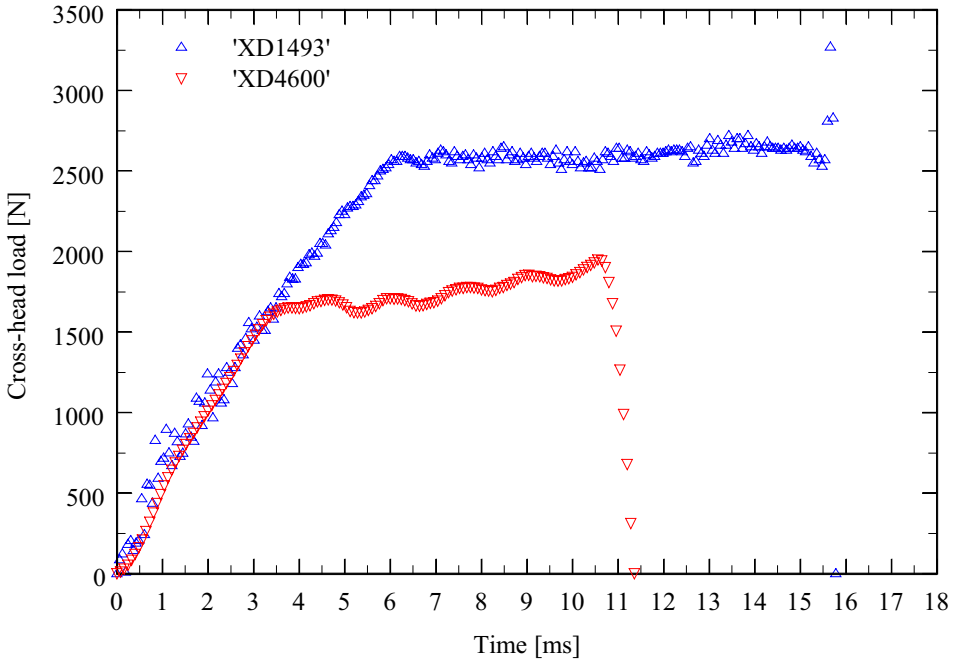
$$G_{Ic} = \frac{4P^2}{E_s B^2} m_b \left[1 + 0.43 \left(\frac{3}{m_b\, a}\right)^{\frac{1}{3}}\right]$$

$$m_b = \left(\frac{3a^2}{h_s^3} + \frac{1}{h_s}\right)$$



Tapered Double-Cantilever Beam (TDCB) Tests

(a)



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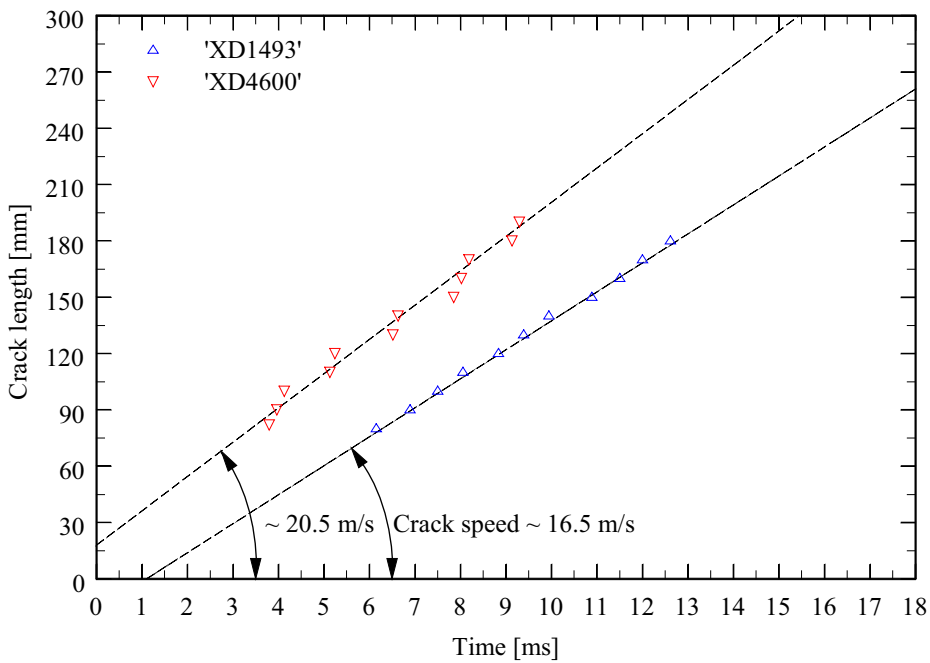
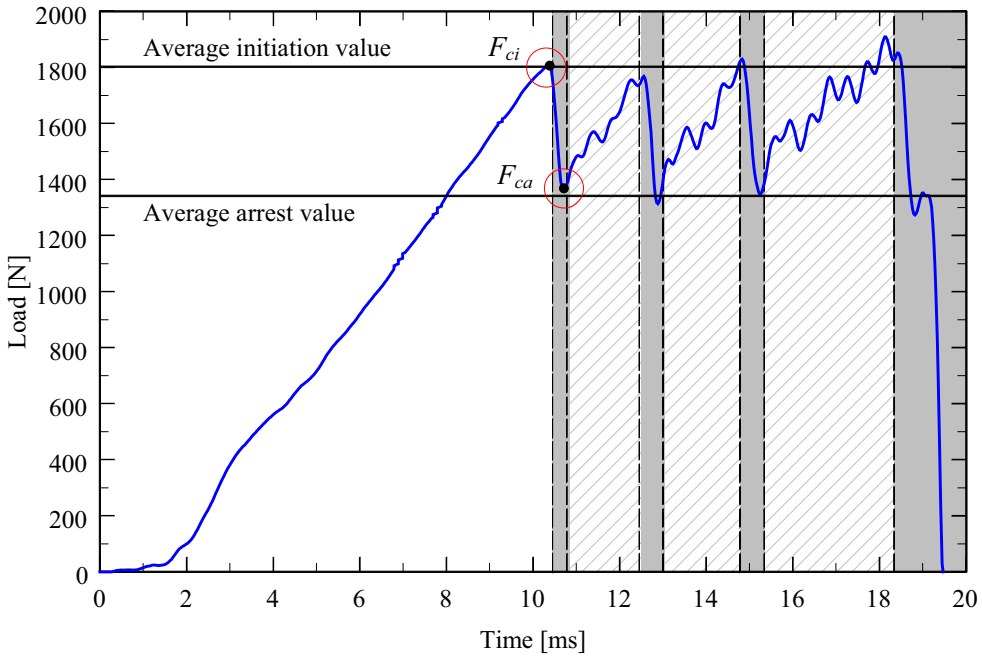


Tapered Double-Cantilever Beam (TDCB) Tests

(a)



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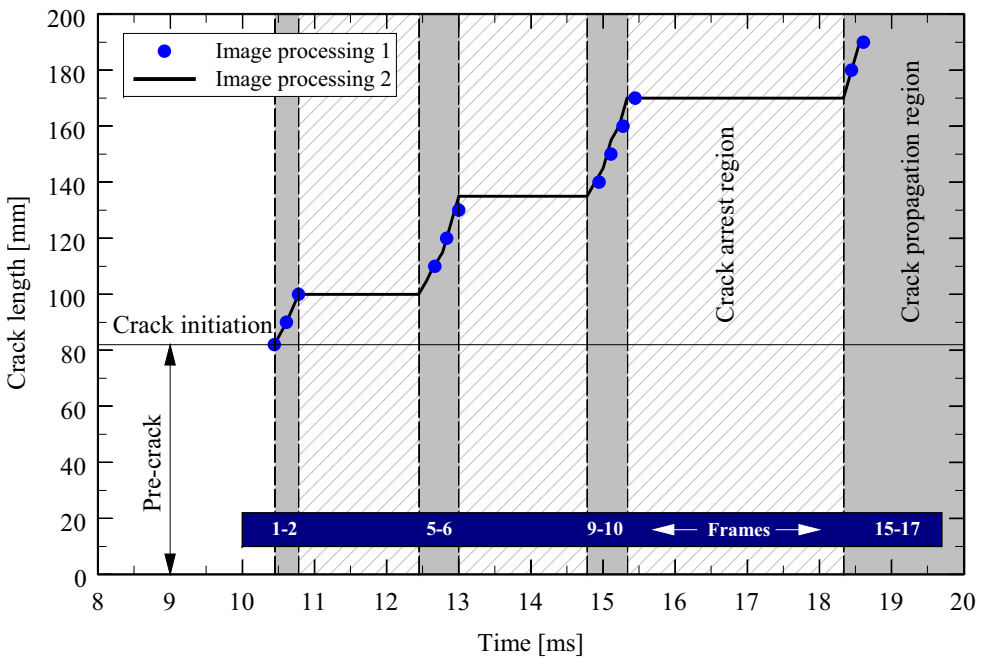
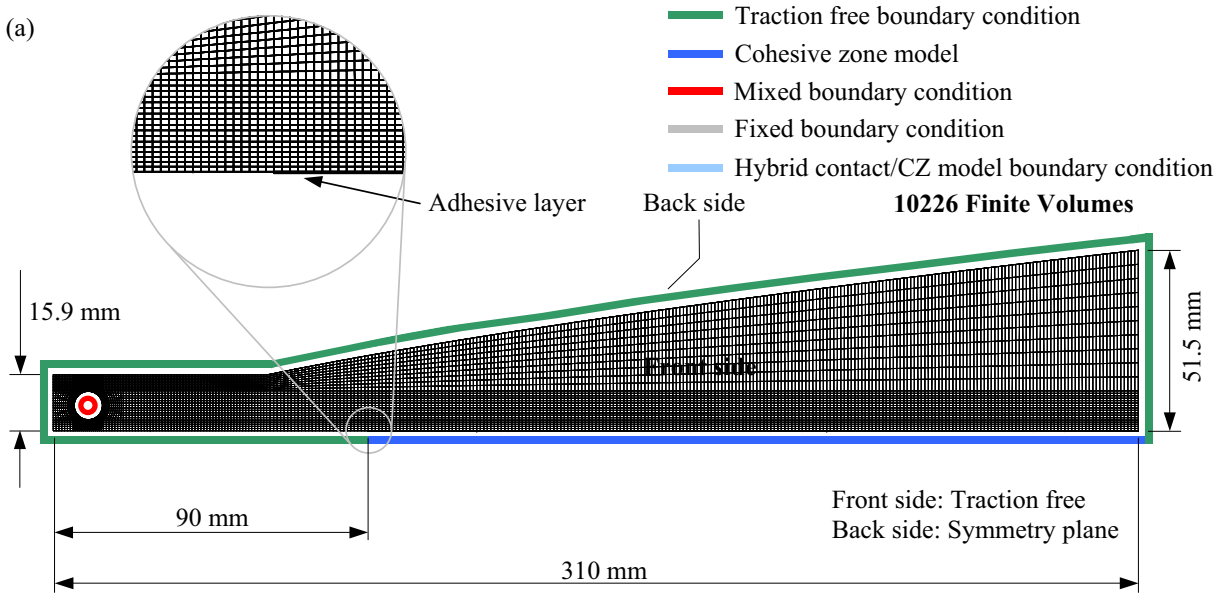
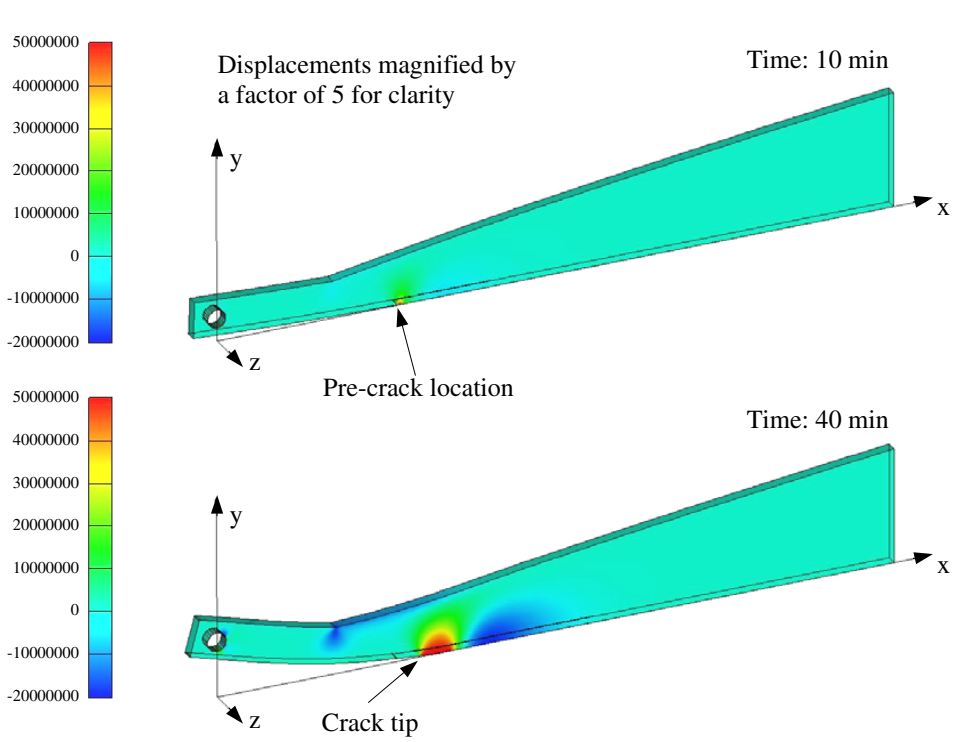


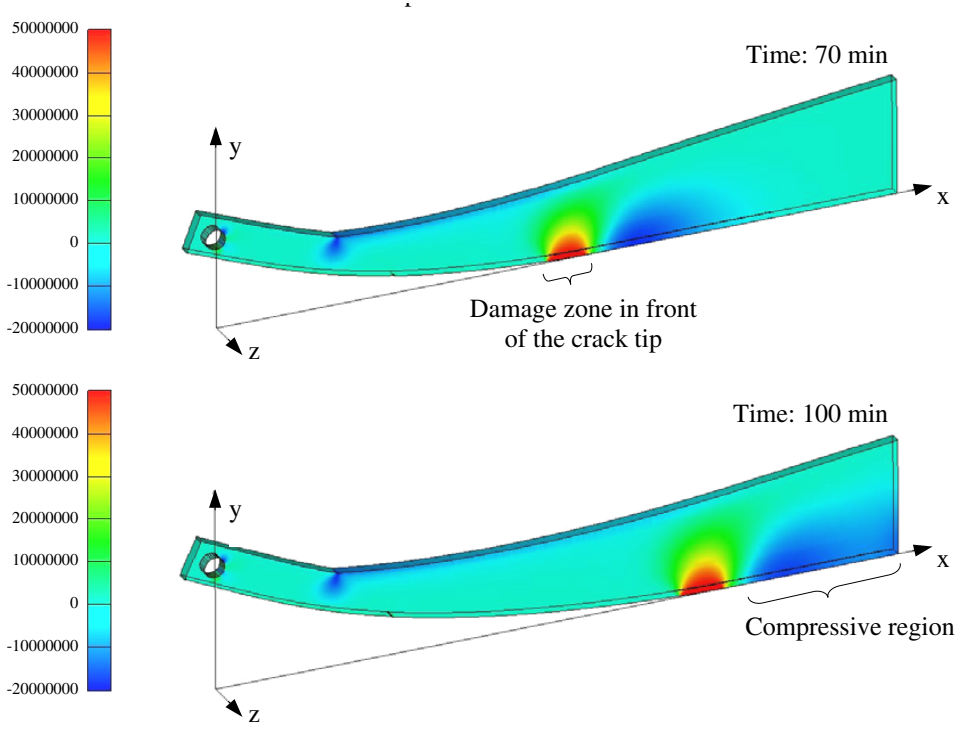
Tapered Double-Cantilever Beam (TDCB) Tests



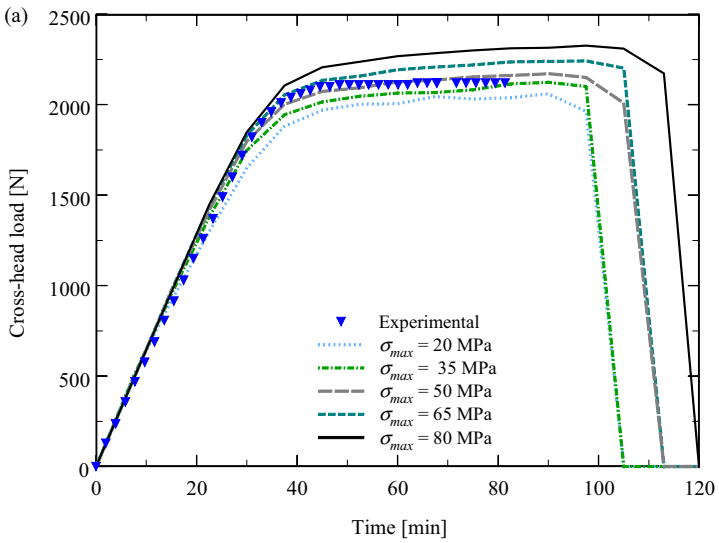
Numerical simulation

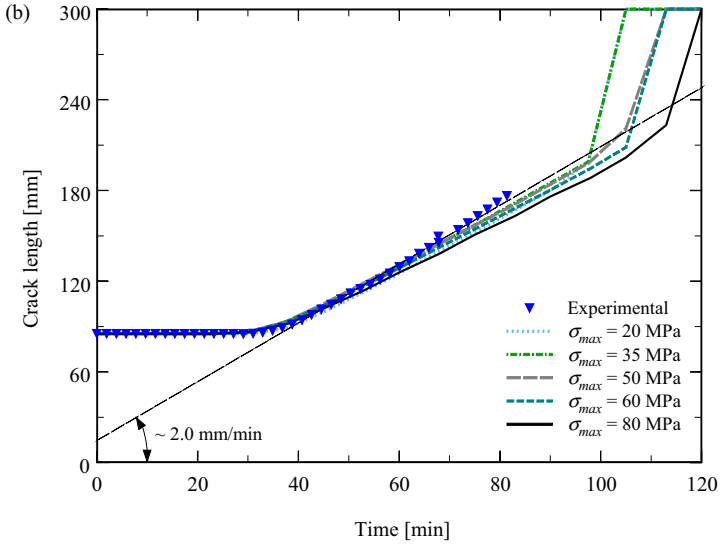
Tapered Double-Cantilever Beam (TDCB) Tests





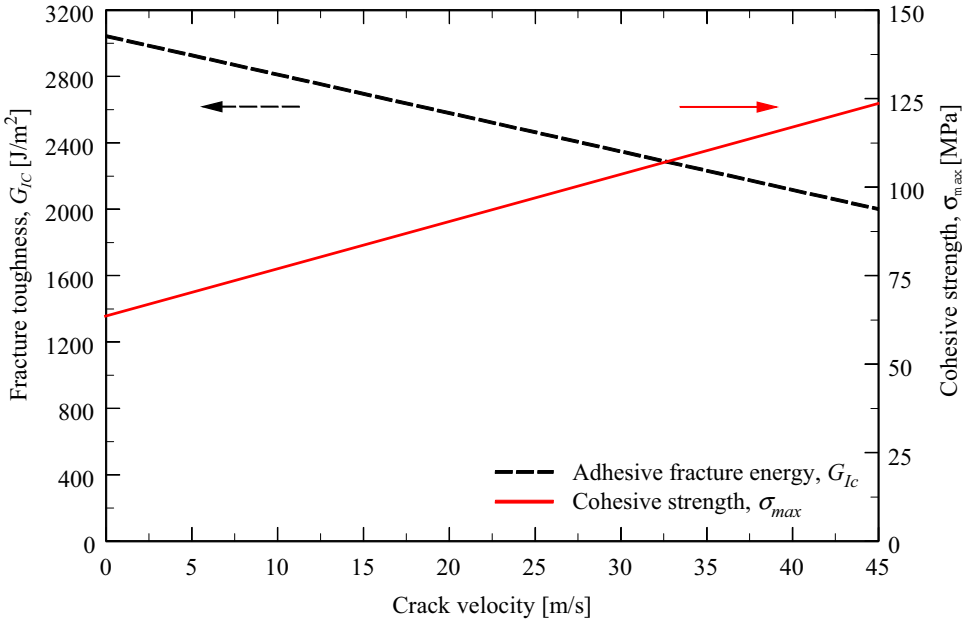
Tapered Double-Cantilever Beam (TDCB) Tests

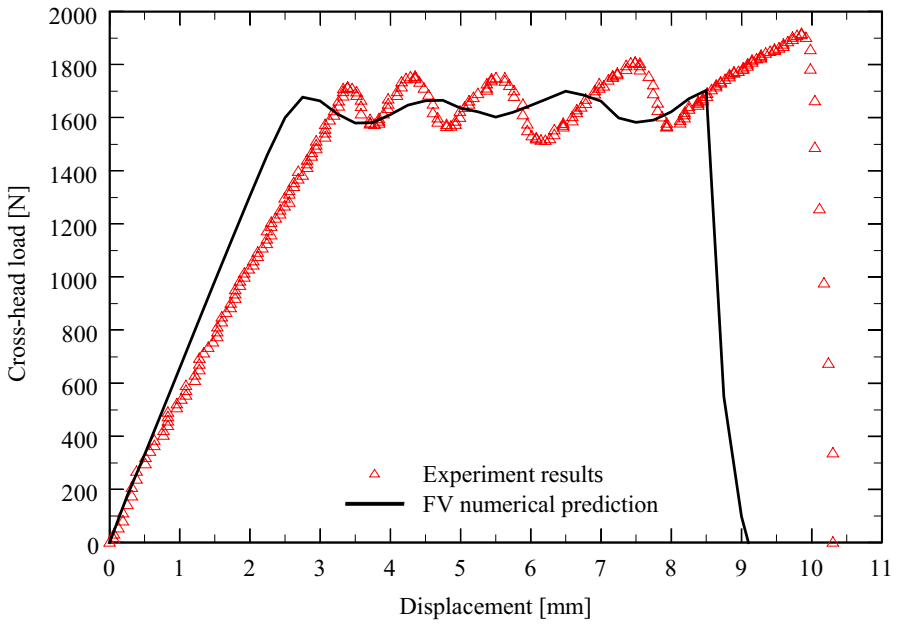




CZM calibration

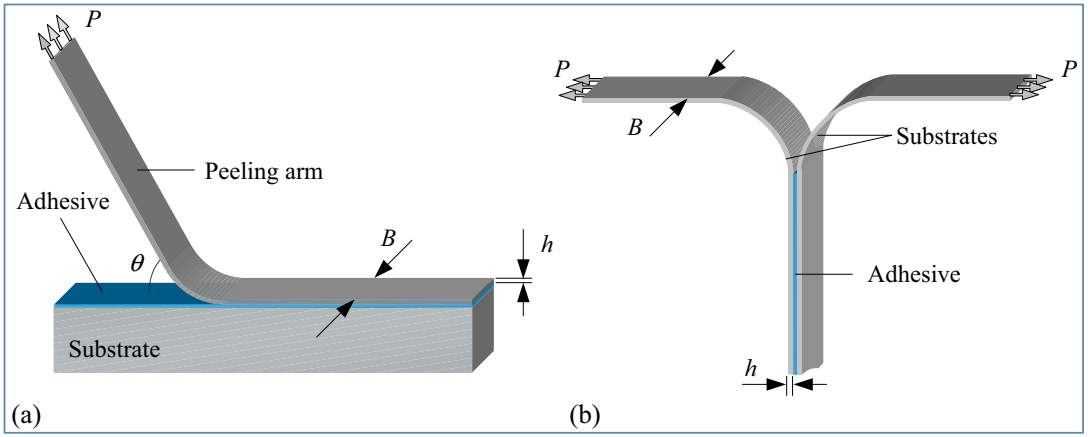
Tapered Double-Cantilever Beam (TDCB) Tests



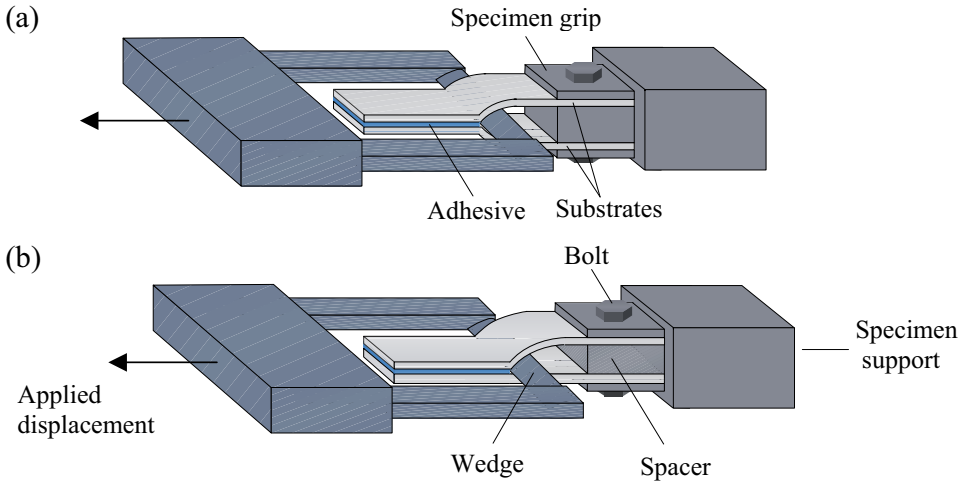


Peel tests

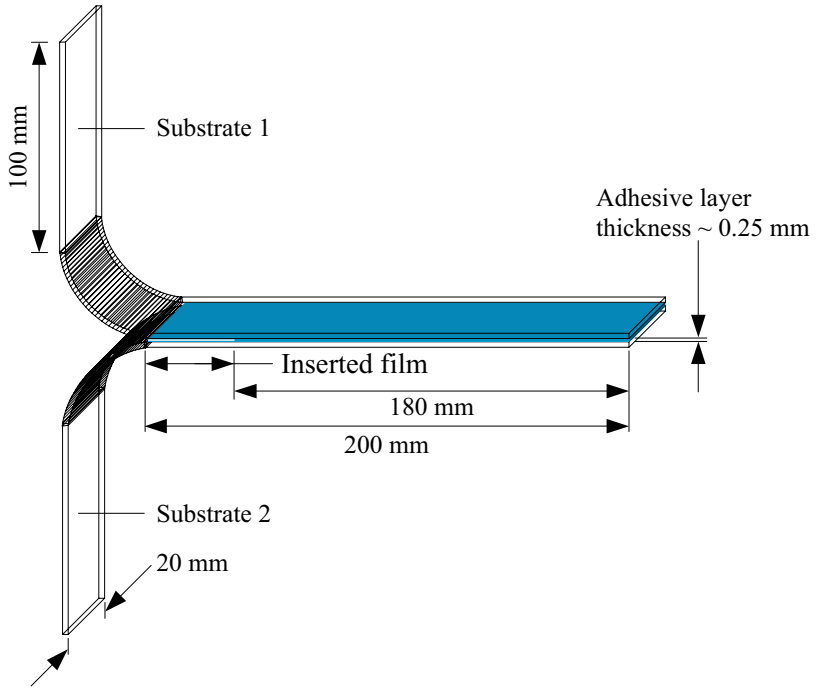
(a) single-arm peel test
(b) T-peel test

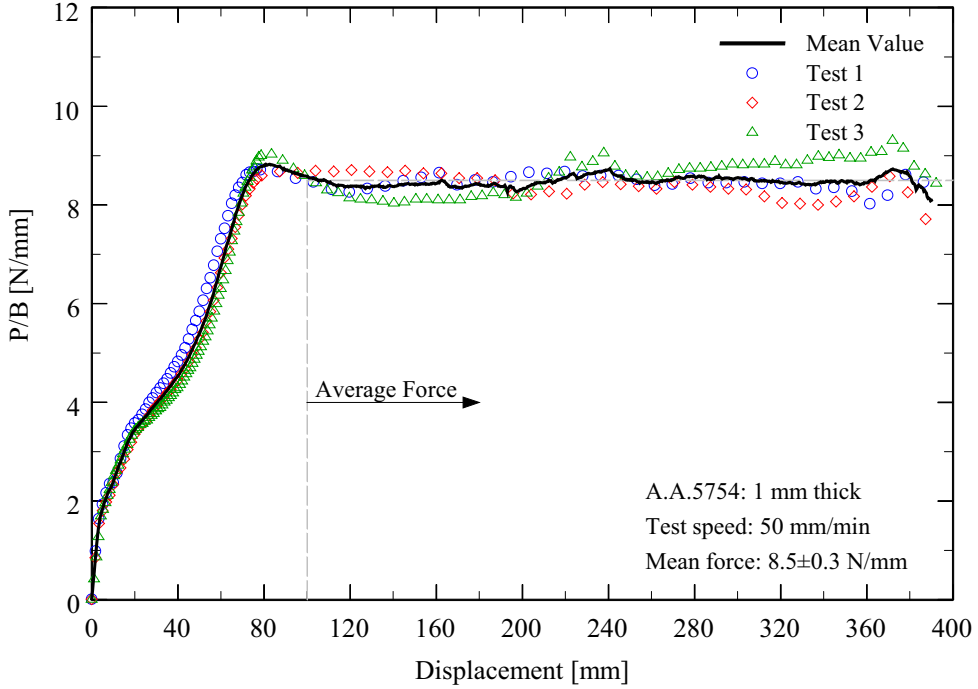


Impact peel test
(a) symmetric
(b) asymmetric



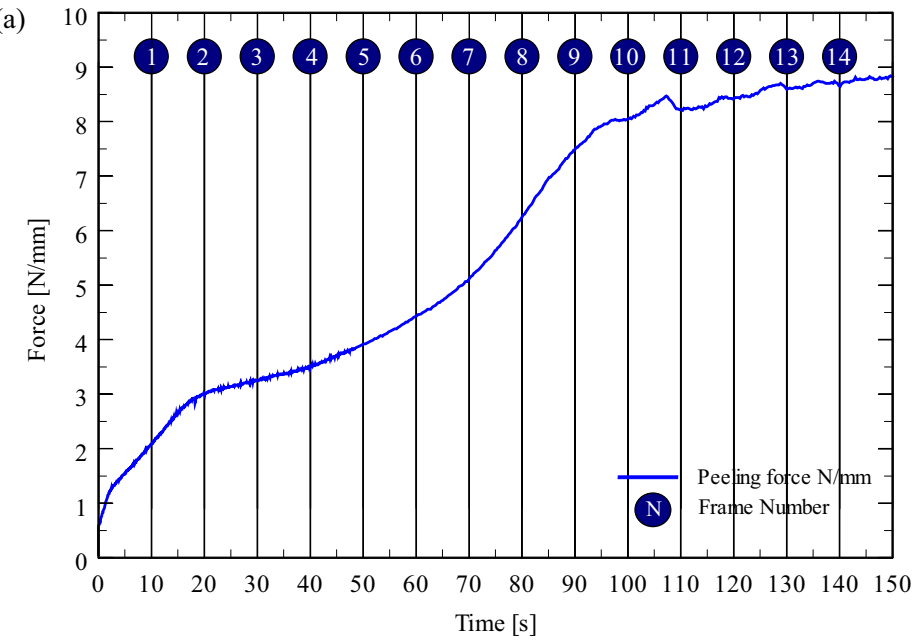
T-peel tests


100 mm
Substrate 1
Adhesive layer
thickness ~ 0.25 mm
Inserted film
180 mm
200 mm
Substrate 2
20 mm

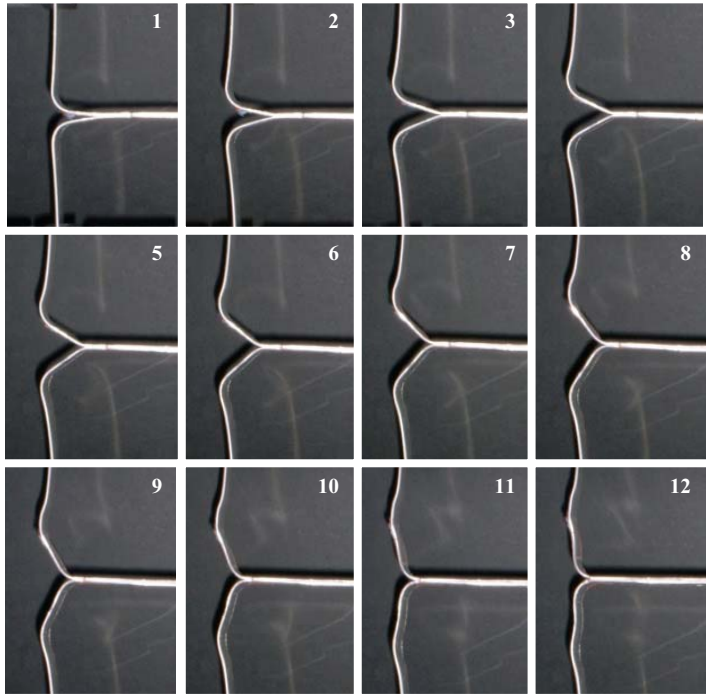

Mean Value
Test 1
Test 2
Test 3
Average Force
A.A.5754: 1 mm thick
Test speed: 50 mm/min
Mean force: 8.5±0.3 N/mm
P/B [N/mm]
Displacement [mm]
0
2
4
6
8
10
12
0
40
80
120
160
200
240
280
320
360
400

T-peel tests

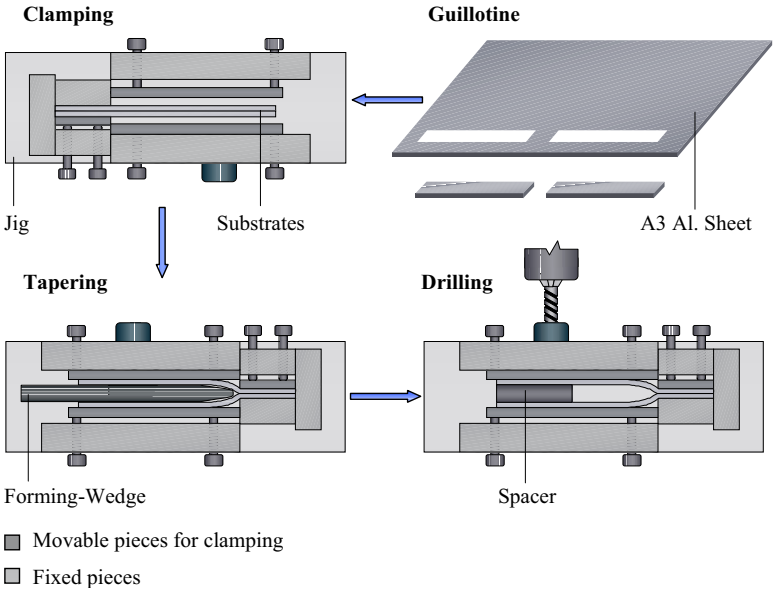
(a)

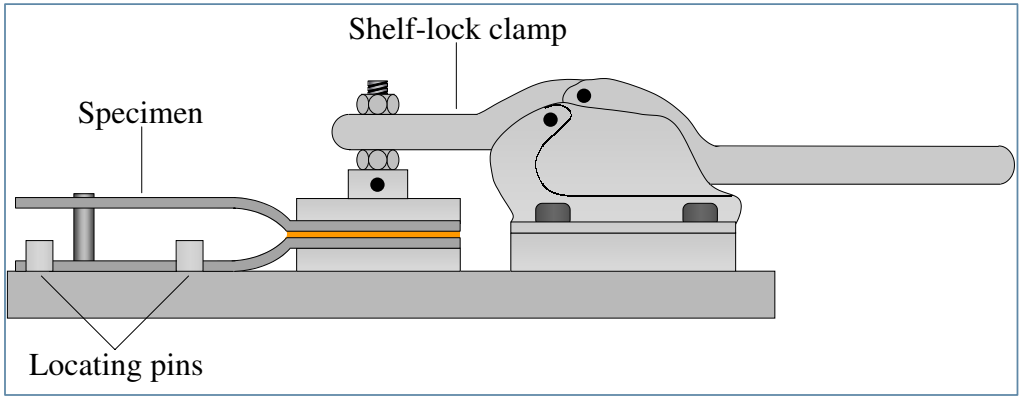


(b)



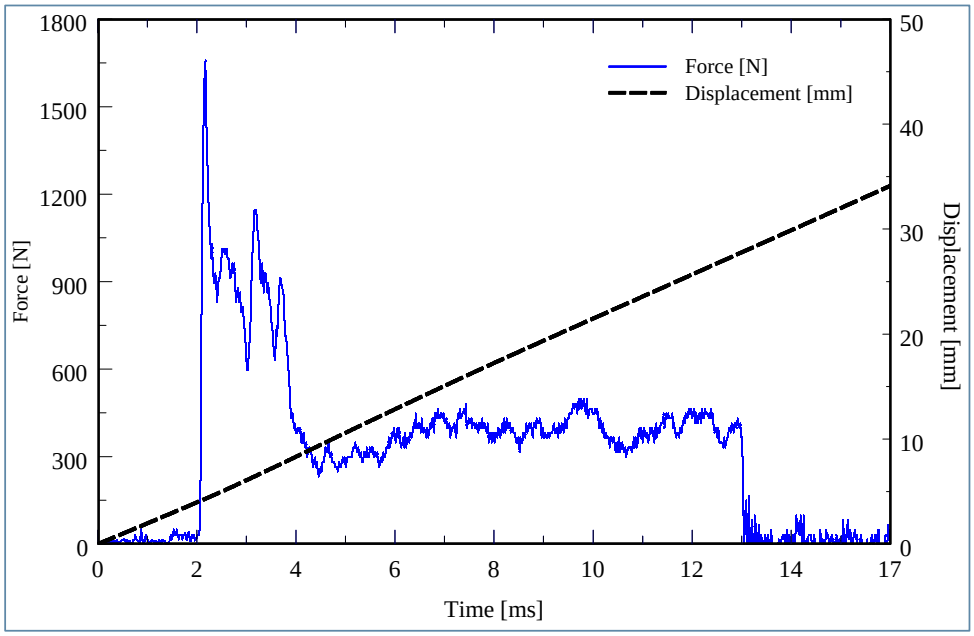
Impact-wedge-peel tests

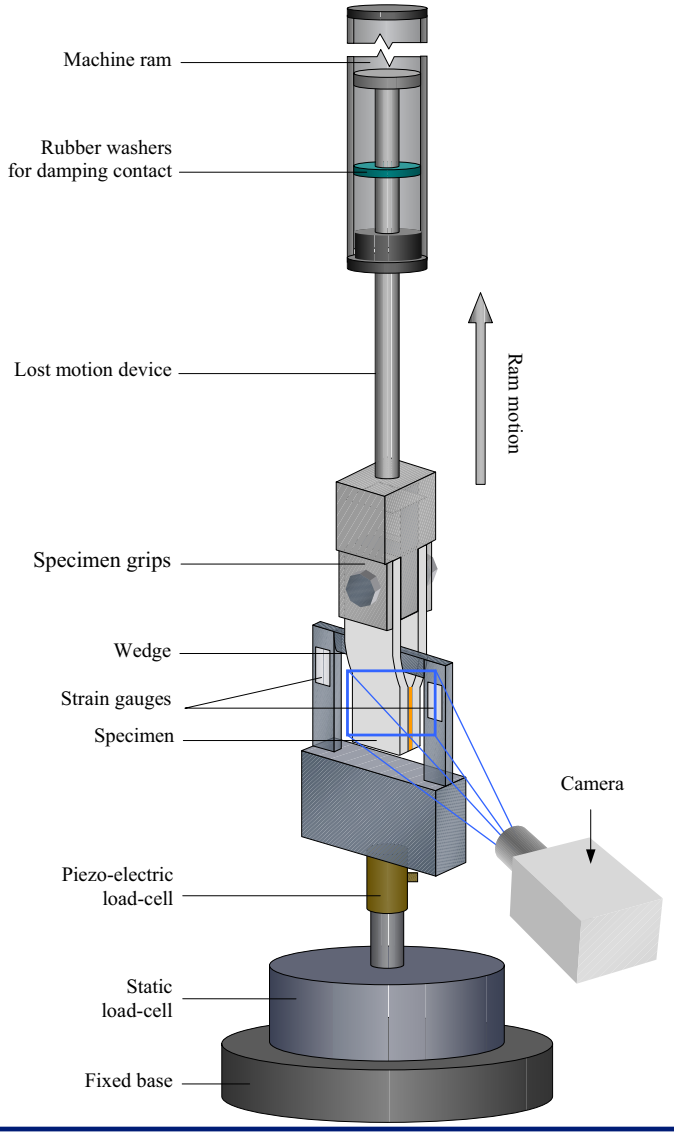




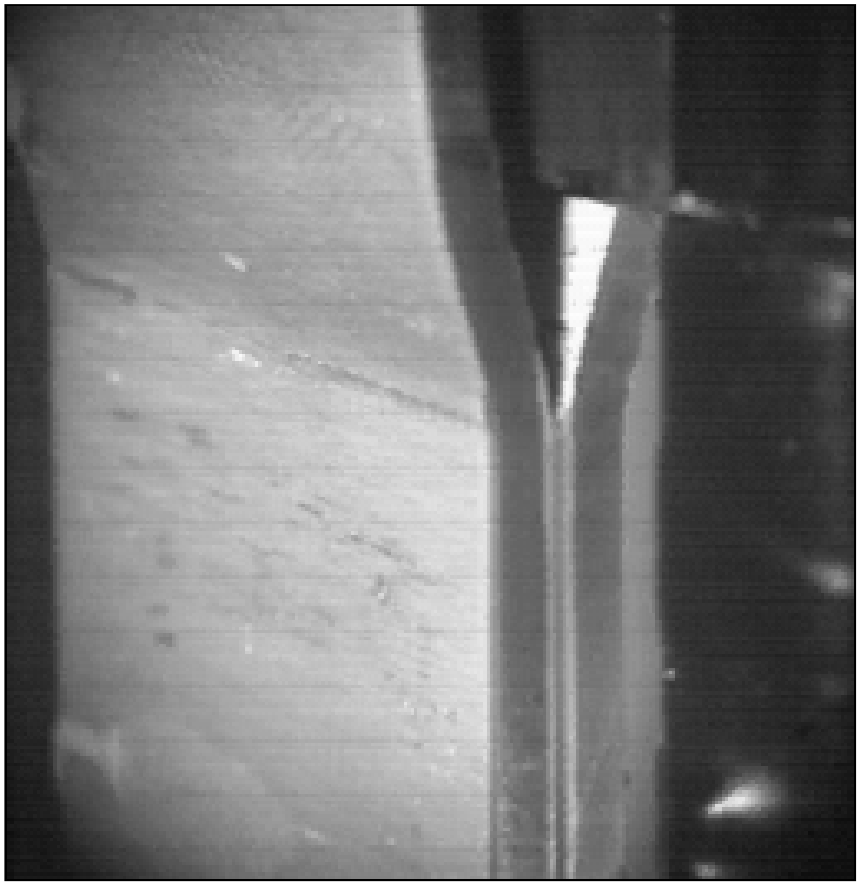
Specimen preparation

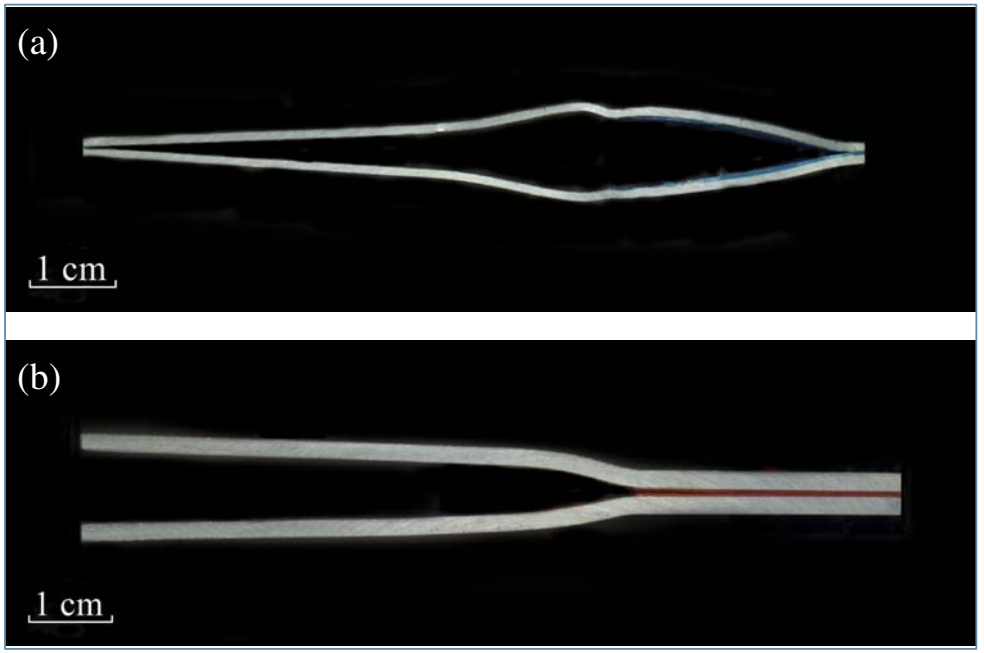
Impact-wedge-peel tests



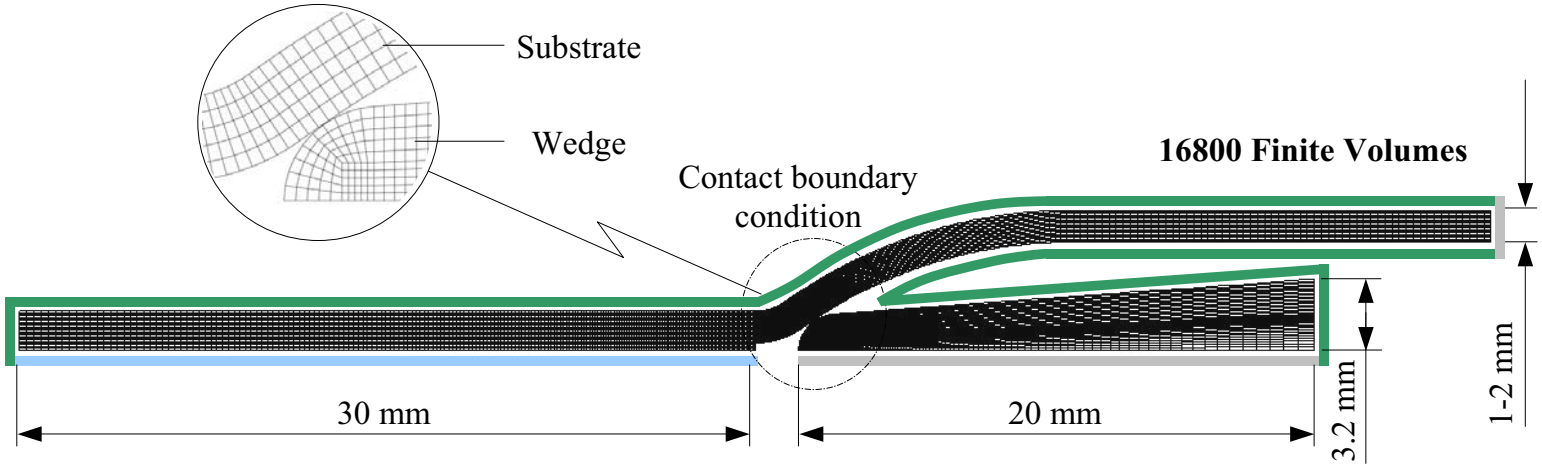


Impact-wedge-peel tests

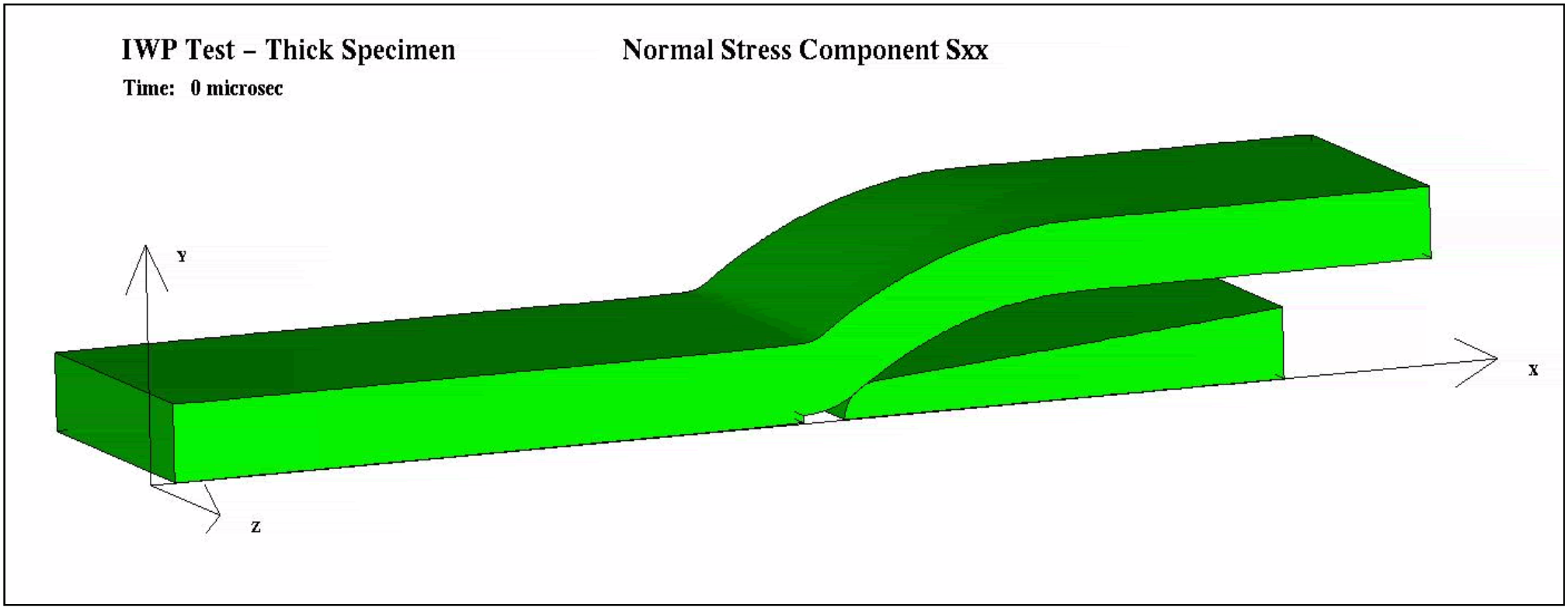




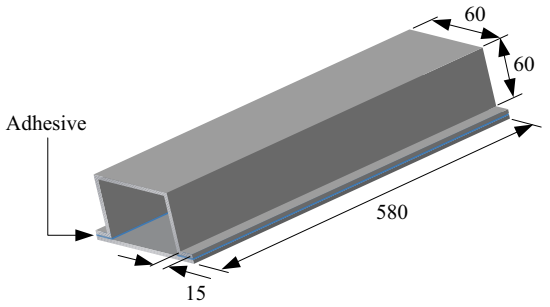
Impact-wedge-peel tests



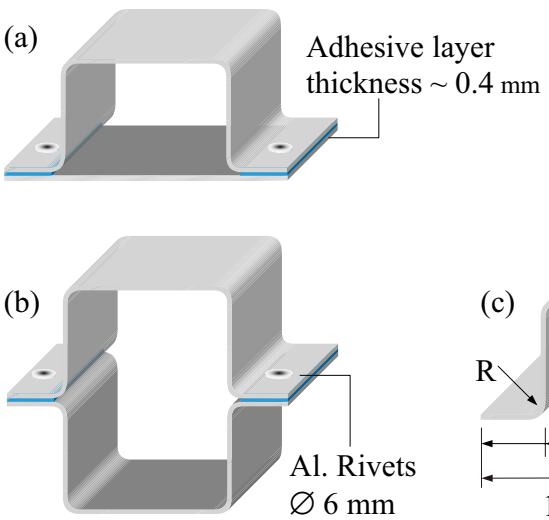
Impact-wedge-peel tests

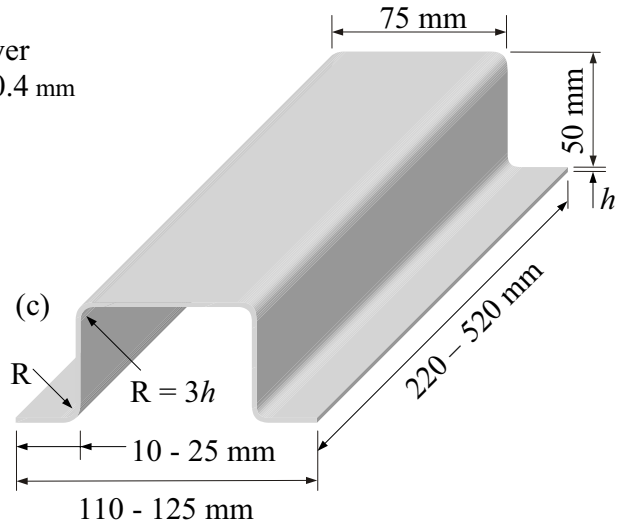


Box-beam components

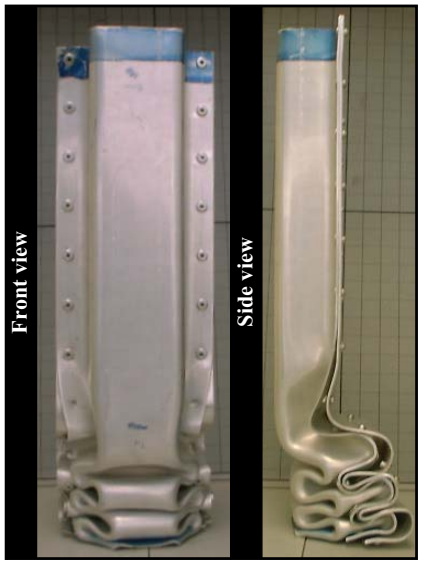


Note: All dimensions in mm

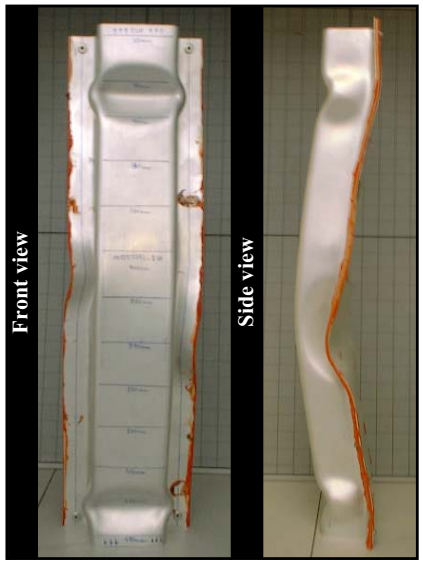




Box-beam components

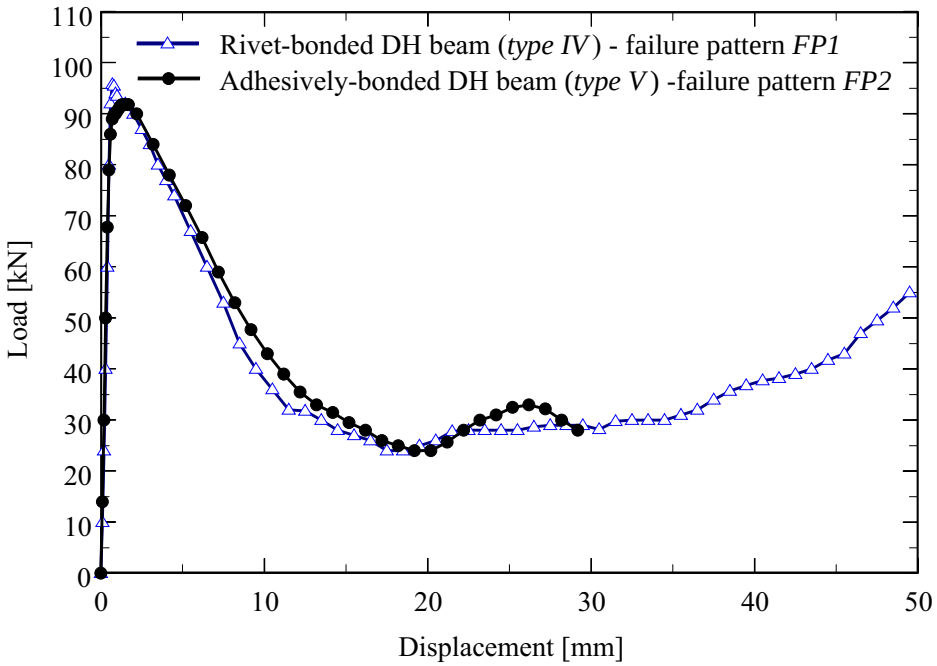


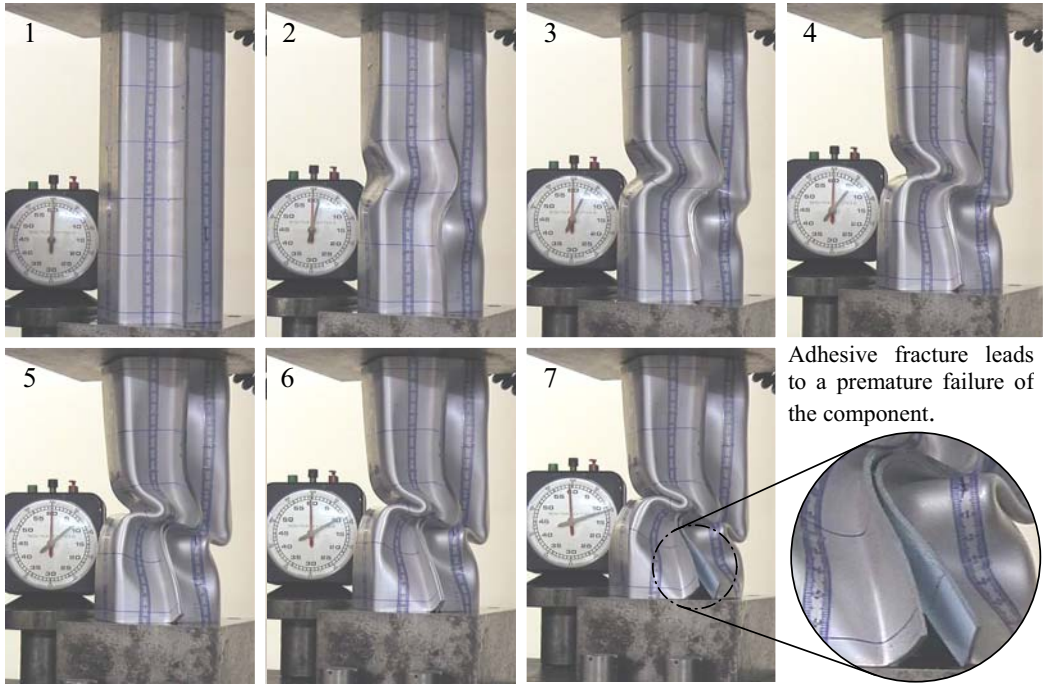
(a) TH beam, riveted at 25 mm pitch - *Type I*.



(b) Rivet bonded TH beam joint using the `XD4600' adhesive and a pair of end rivets - *Type IV*.

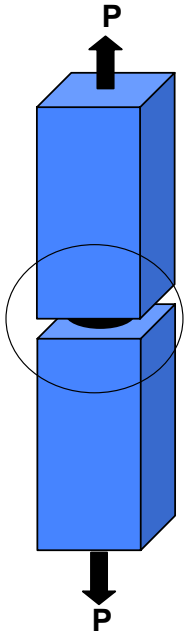
Box-beam components

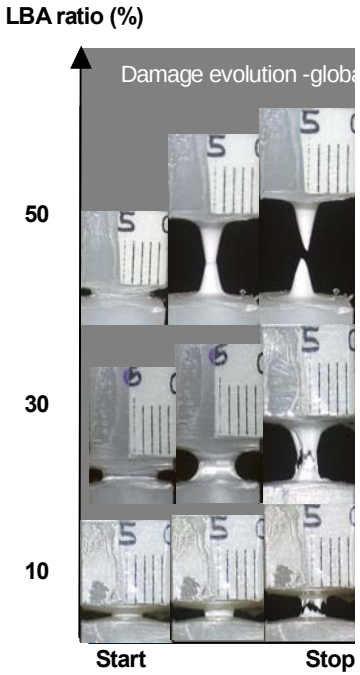


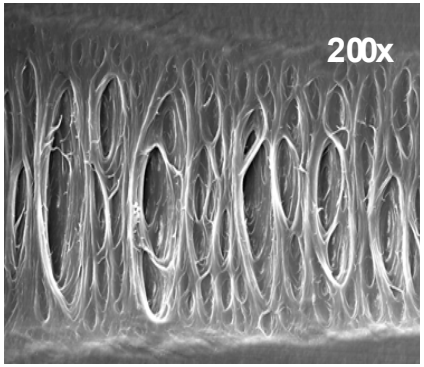


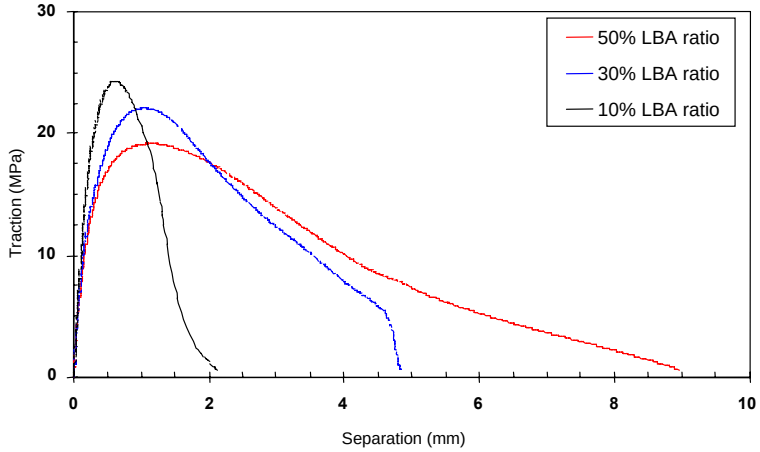
Adhesive fracture leads to a premature failure of the component.

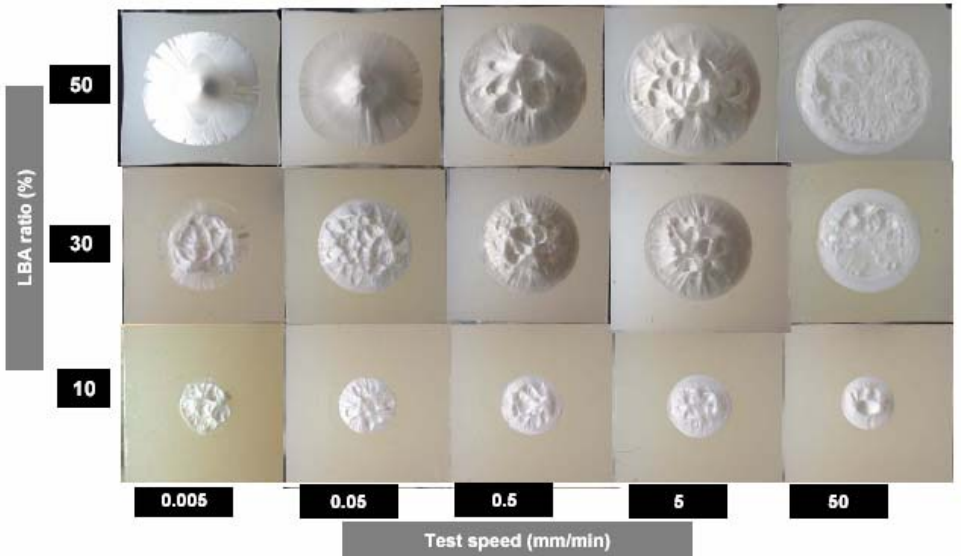
Deep-notched tensile tests



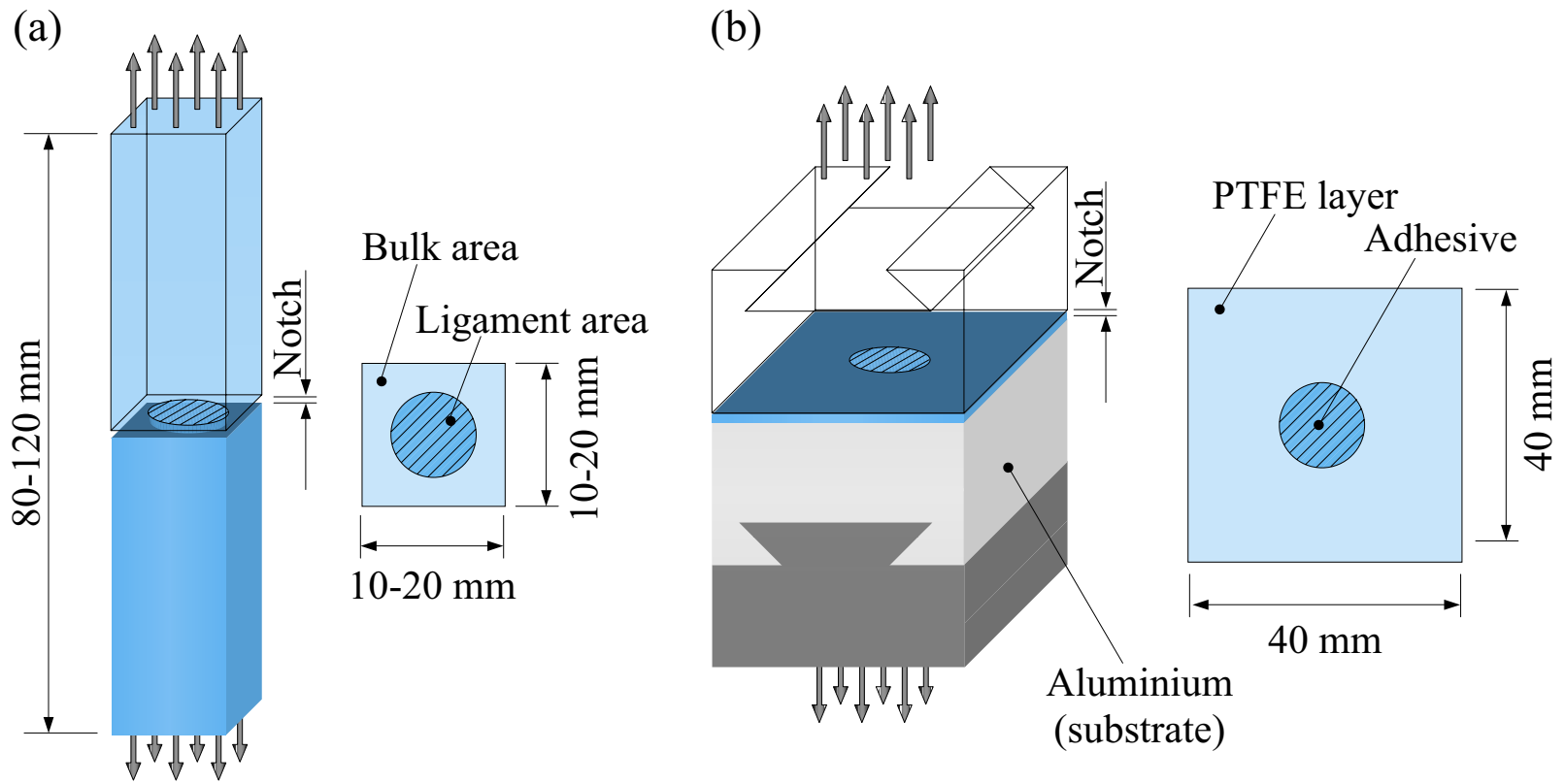






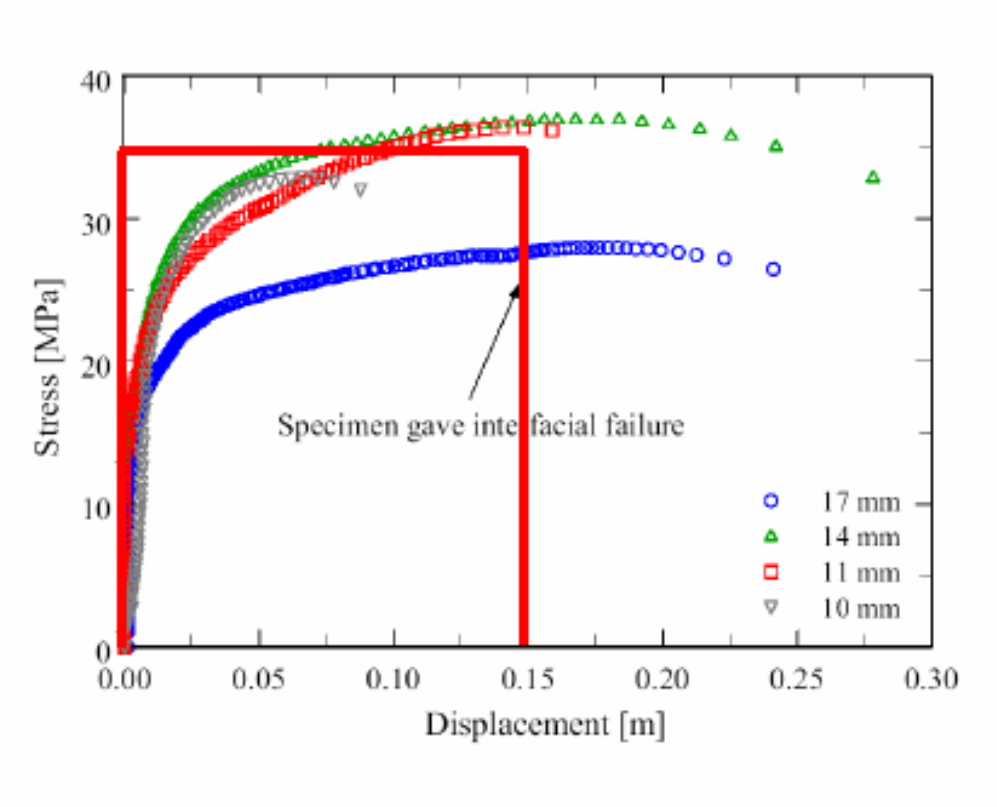


Deep-notched tensile tests

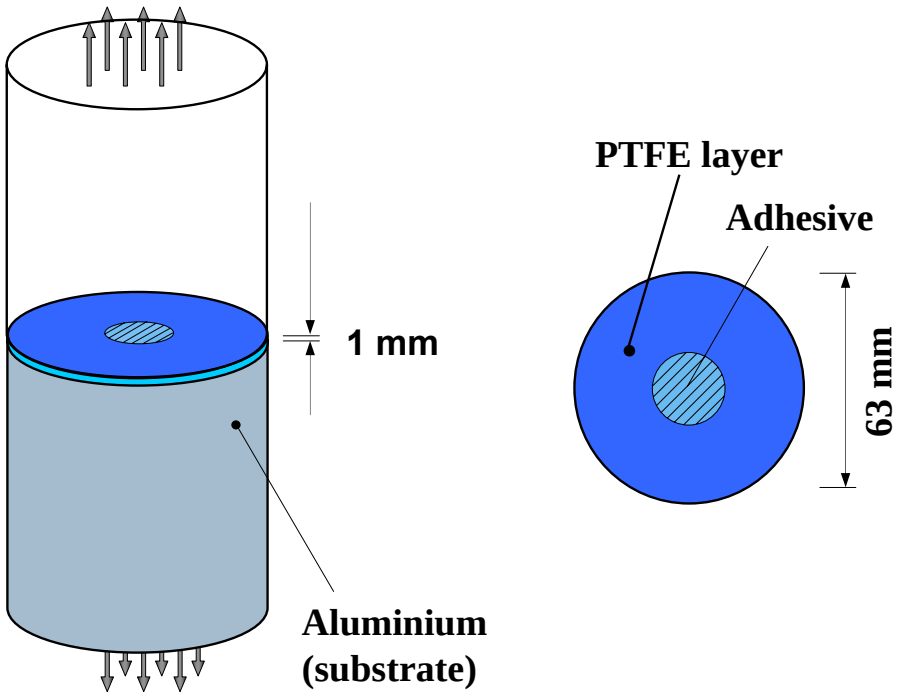


Adhesive DNT specimen; (b) Adhesive/substrate DNT specimen

Deep-notched tensile tests



Deep-notched tensile tests - current



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TESTING PRODUCT CHARACTERISTICS