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Experimental Evaluation of The Inclined Double Notch Shear Test and Three Other Interlaminar Shear Tests

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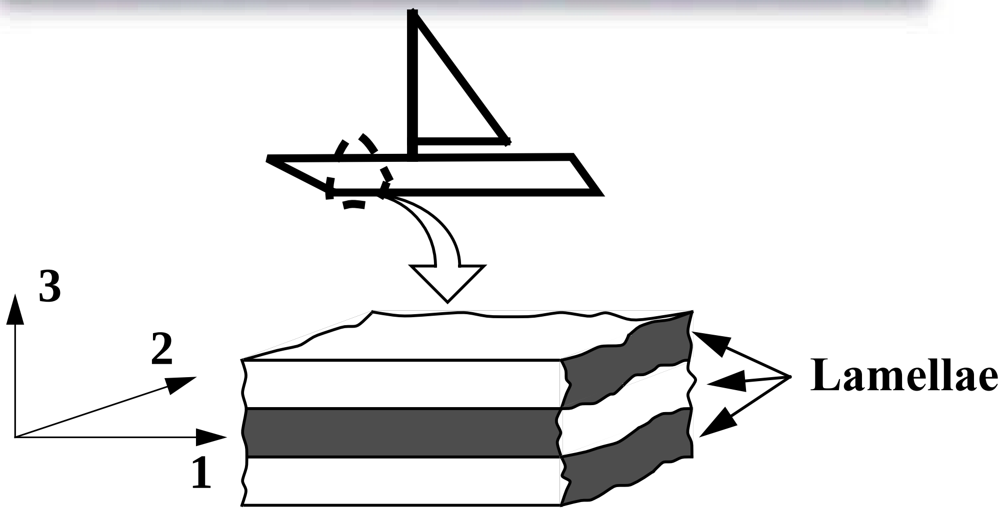

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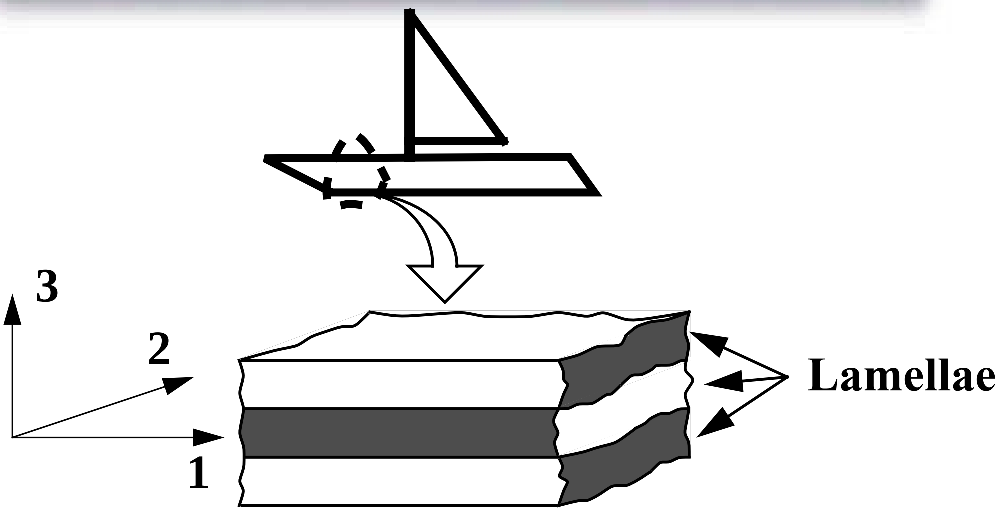

Out-of-plane shear (ILS) = τ_{13} (τ_{23})

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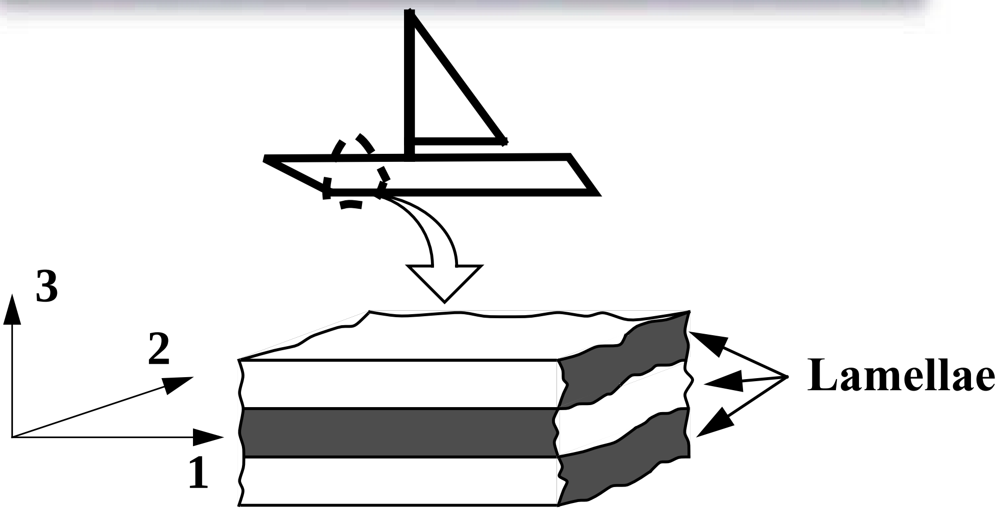
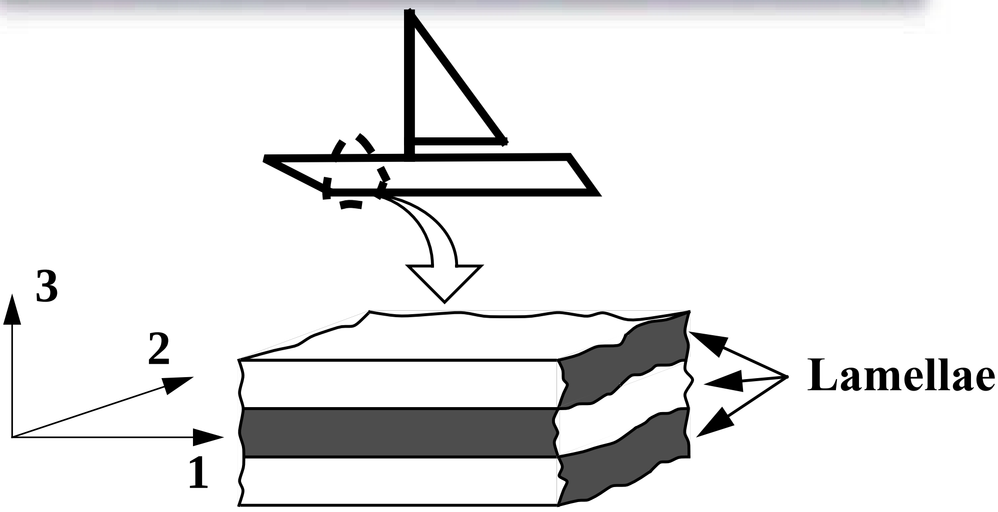


Out-of-plane shear (ILS) = τ_{13} (τ_{23})

In-plane shear = τ_{12}



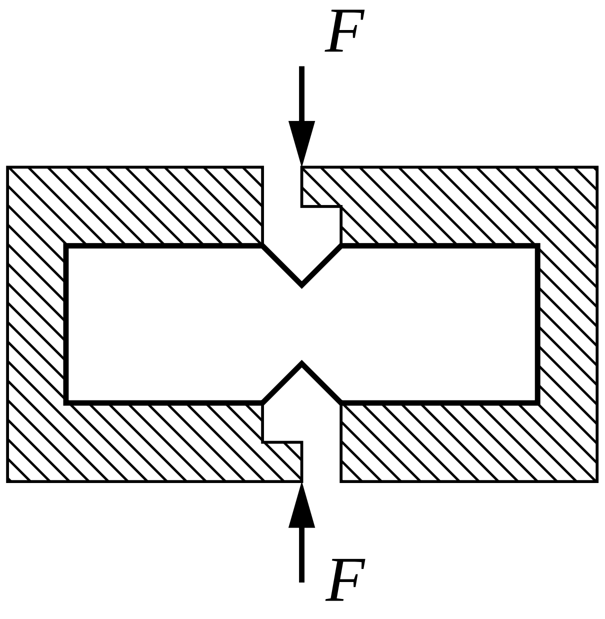
Out-of-plane shear (ILS) = τ_{13} (τ_{23})

In-plane shear = τ_{12}

Material- and engineering-parameters such as G_{ij} or ILSS

Test methods

Iosipescu



$$\bar{\tau}_{12} = F / A$$

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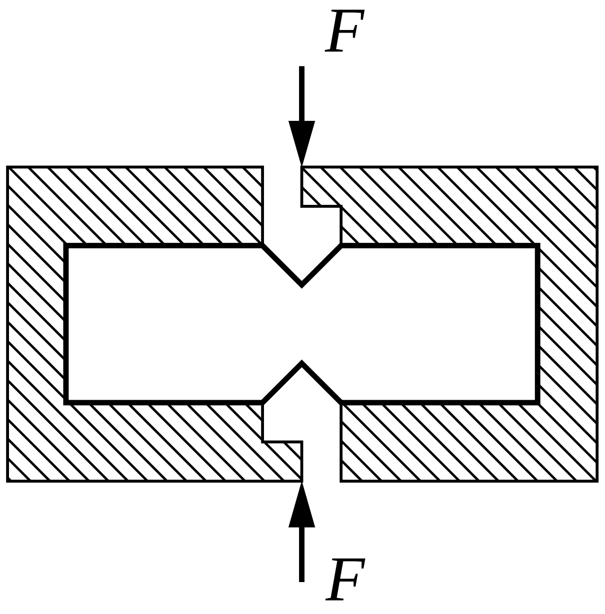
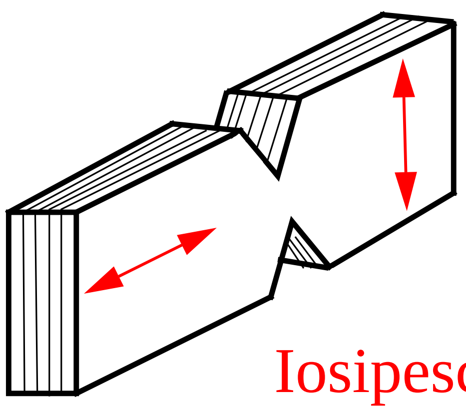
Test methods

Iosipescu



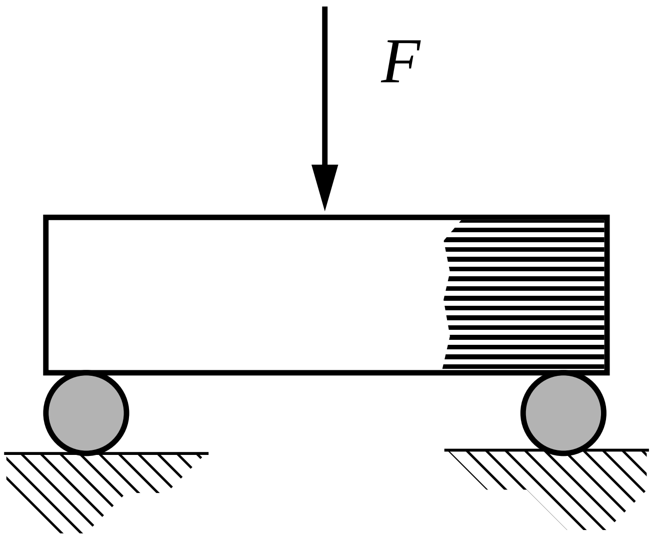
$$\bar{\tau}_{12} = F / A$$

Fiber directions



Test methods

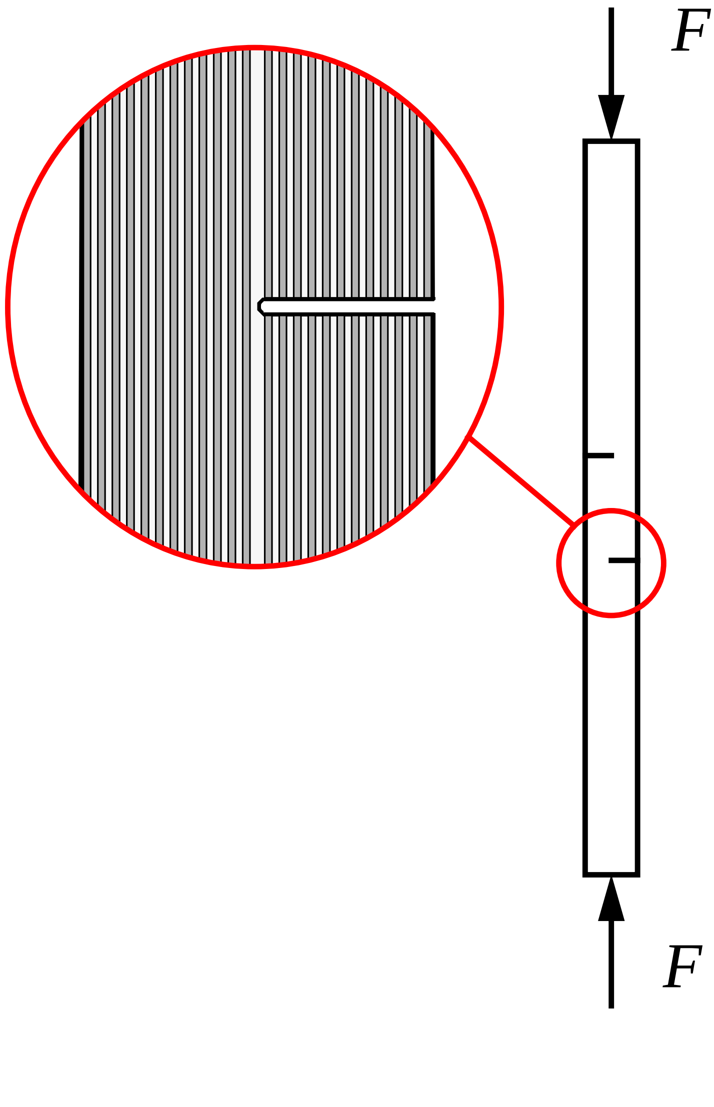
Short three point bending (S3PB)



$$\hat{\tau}_{13} = \frac{3}{2}\bar{\tau}_{13}$$

Test methods

Double notch compression (DNC)



$$\bar{\tau}_{13} = F\,/\,A$$

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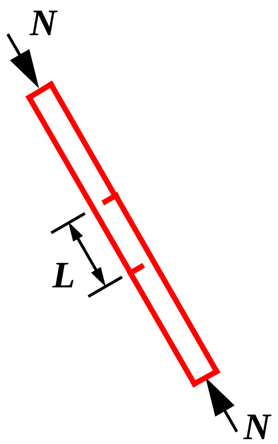
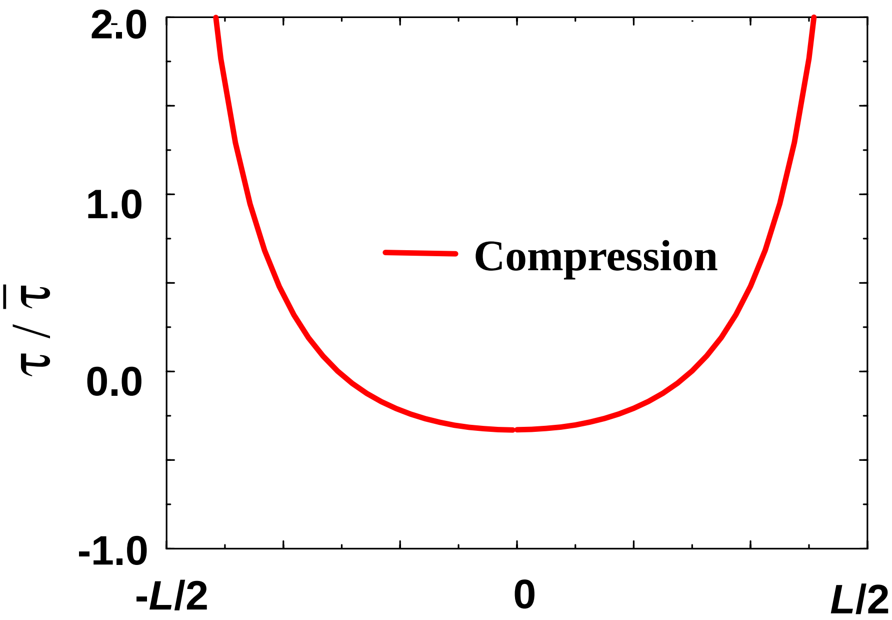
Test methods

IDNS

Compression (*N*)

$(\bar{\tau}_{13} = N/A)$





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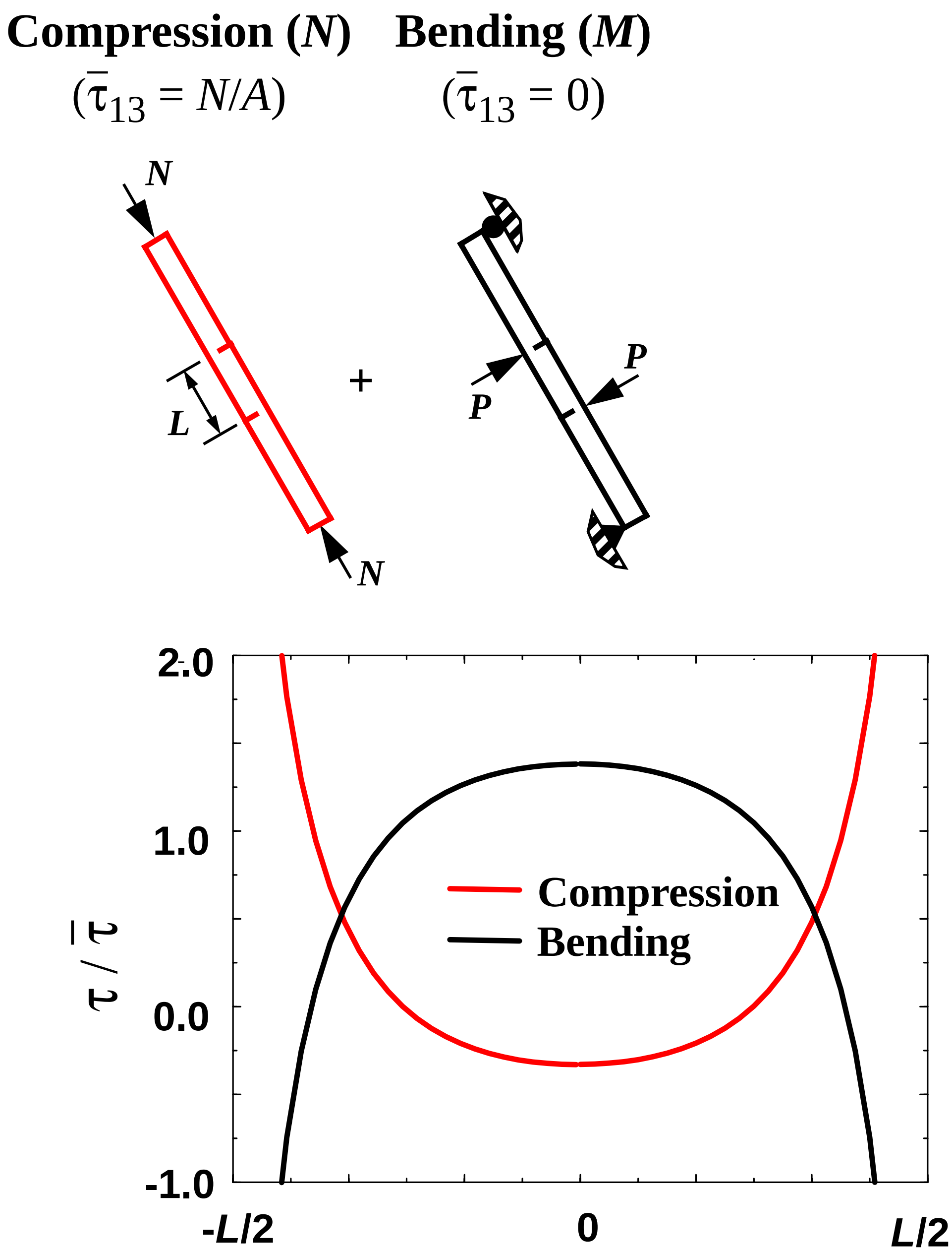
Test methods

IDNS



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Test methods

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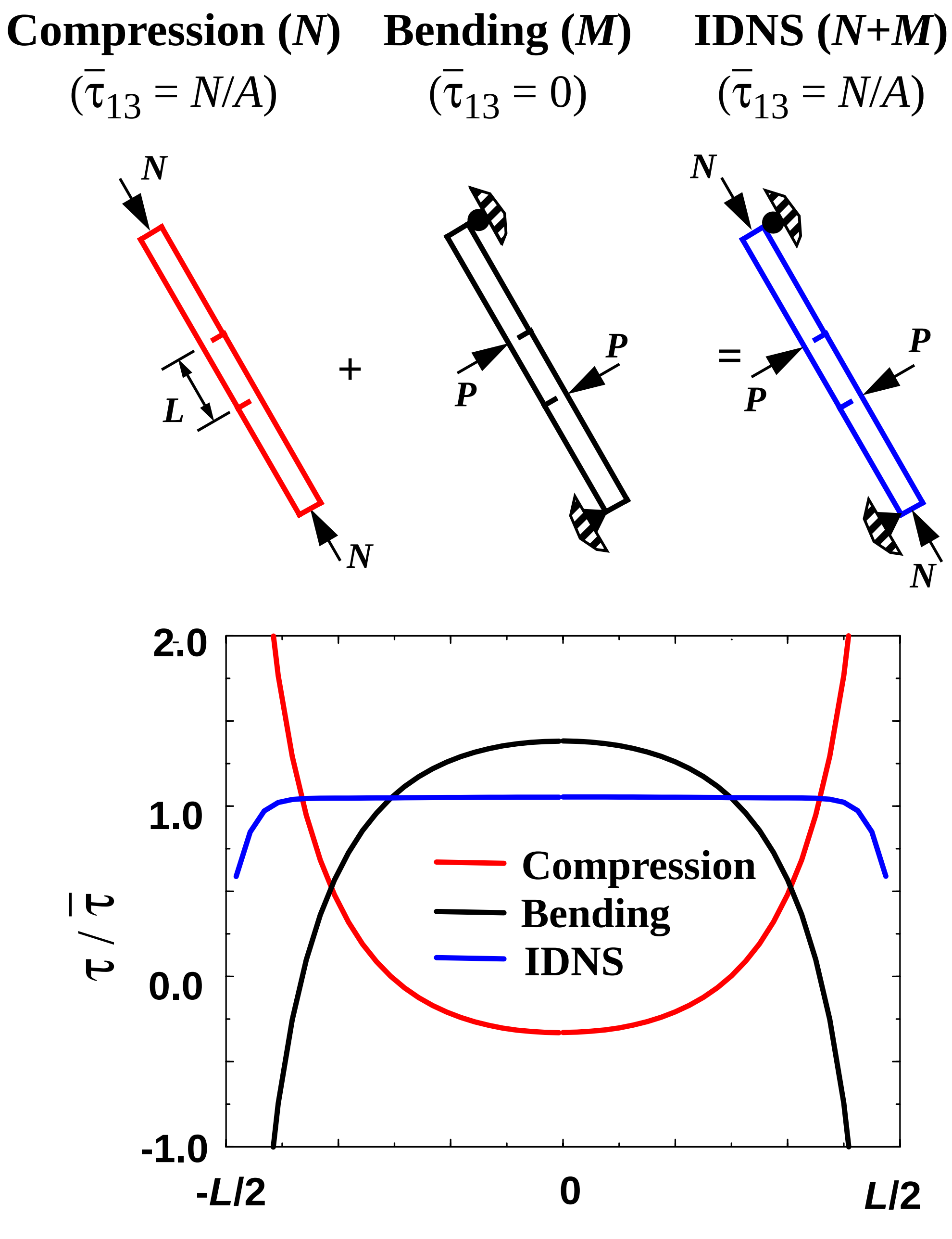

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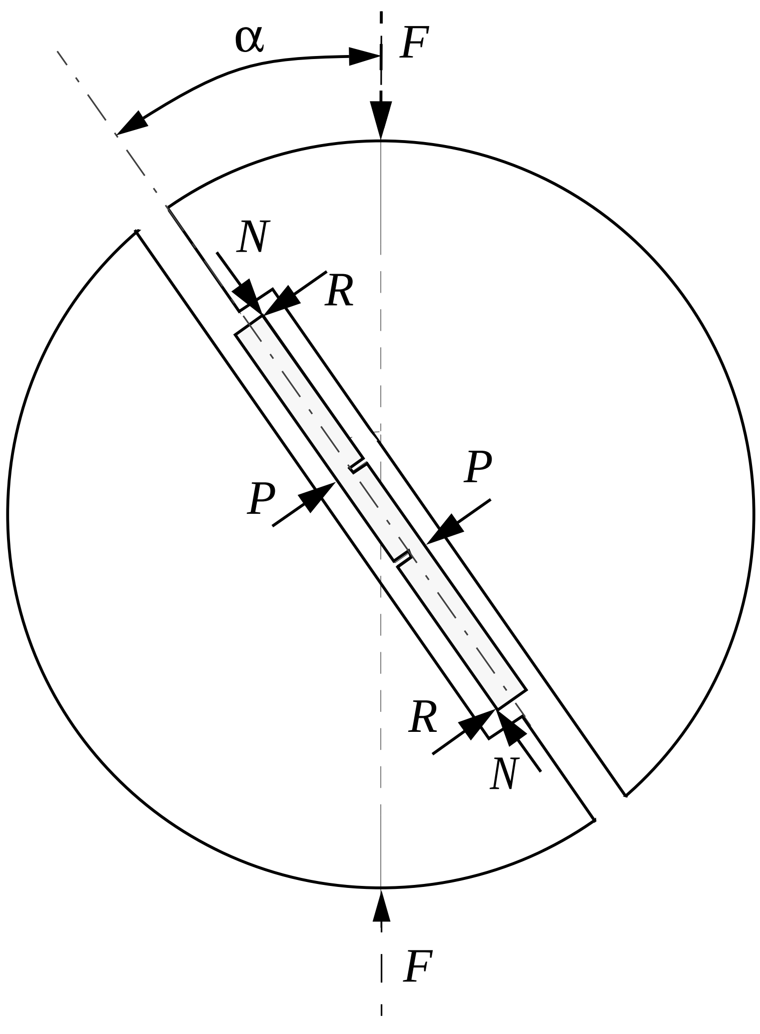
Test methods

IDNS



$$\bar{\tau}_{13} = N / A$$

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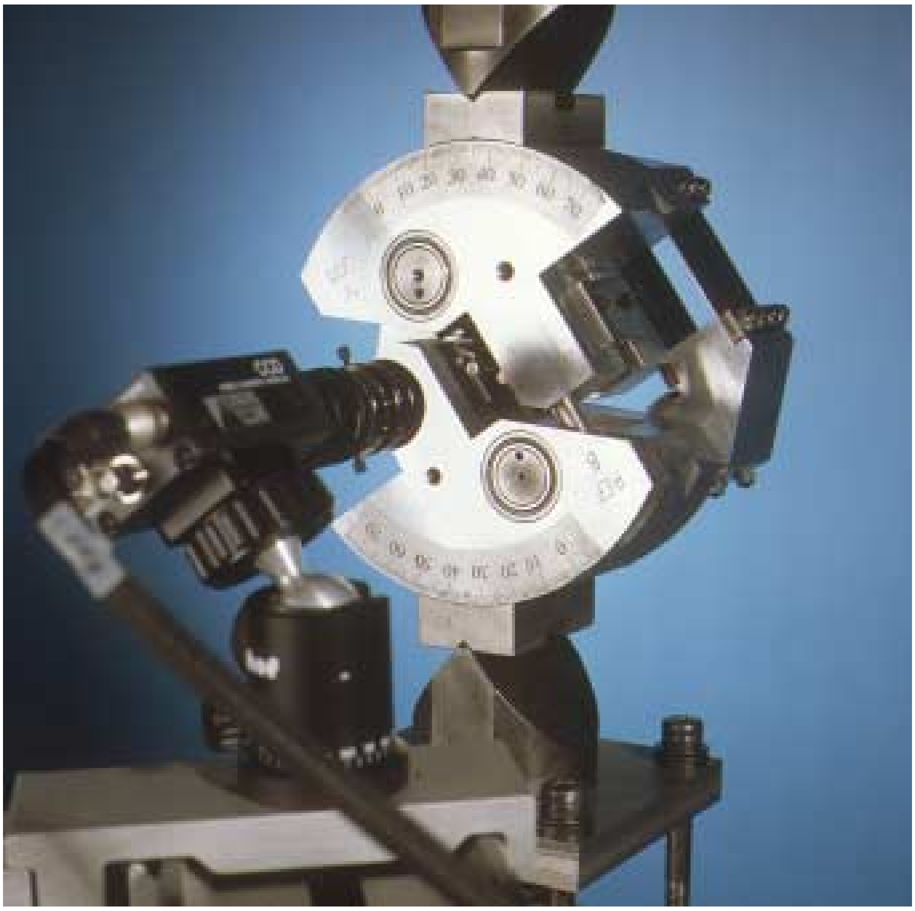
The IDNS-test fixture



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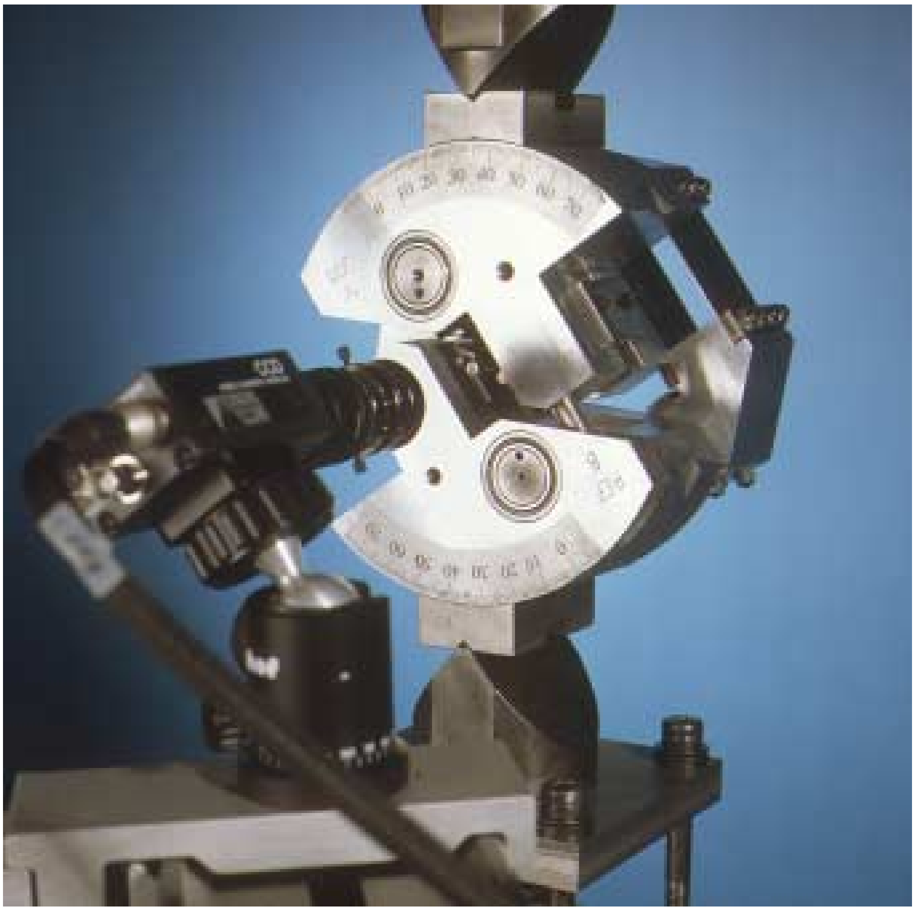
The IDNS-test fixture



- Statically determined loading of the specimen (α)

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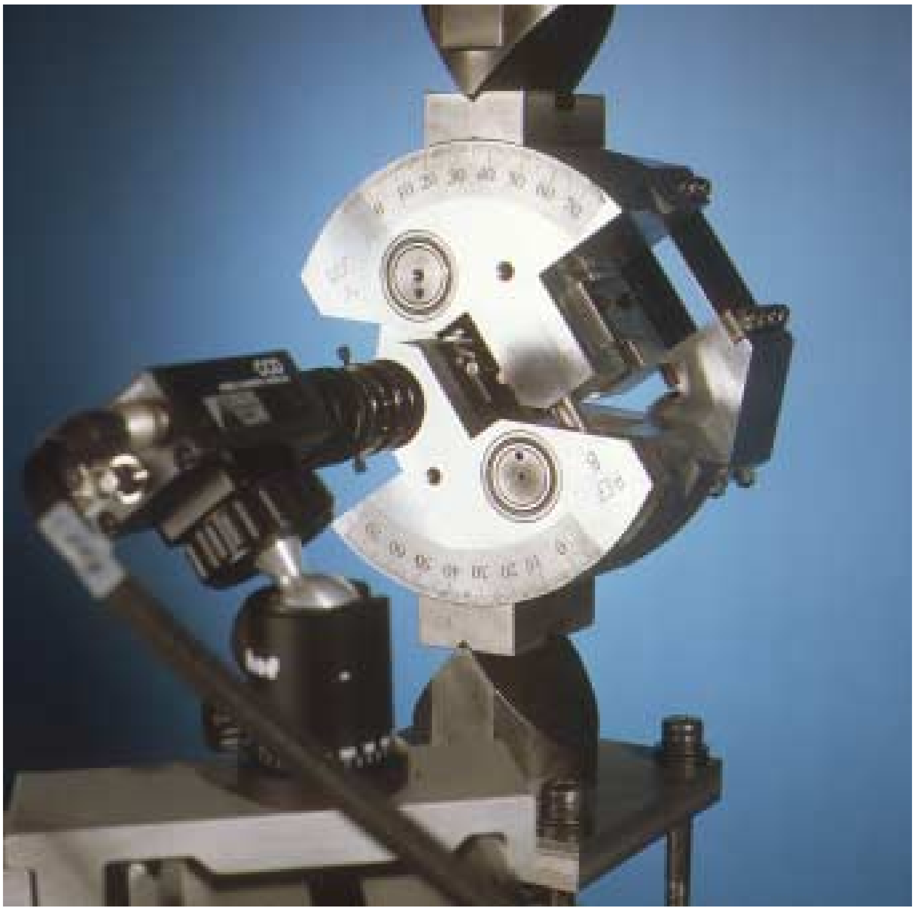
The IDNS-test fixture



- Statically determined loading of the specimen (α)
- Vertical translation and mutually equal rotation of fixture halves allowed.

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Experimental comparisons

Experimental comparisons

- Homogeneity of the shear strain distribution (DSP)

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- Interlaminar shear strength values (ILSS)

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- Homogeneity of the shear strain distribution (DSP)
- Interlaminar shear strength values (ILSS)
- Fraction of shear-separated fracture surface (shear cusps)

Material

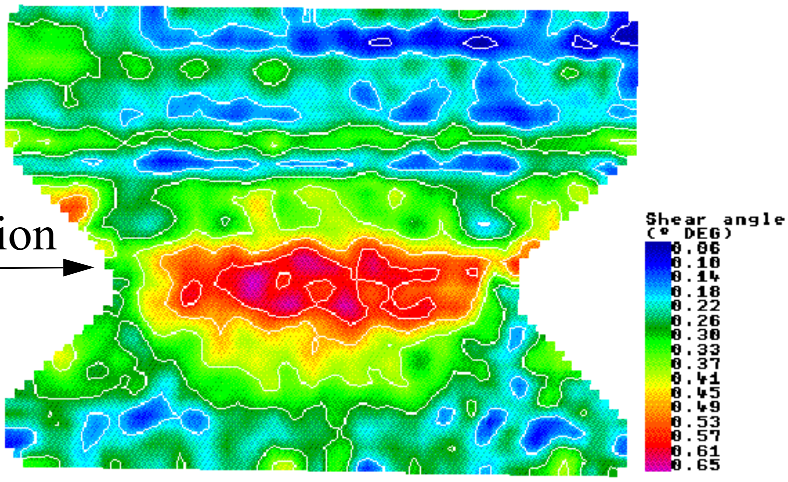
- Uniaxial carbon fiber/epoxy with 32 plies of Ciba-Geigy HTA/6376C
- Panel thickness 4.1 mm
- Nominal fiber fraction 65%
- Elastic constants for the panel

Young's moduli [GPa]	**Shear moduli [GPa]**	**Poison's ratios**
E_1 = 140	G_{12} = 5.2	ν_{12} = 0.30, ν_{21} = 0.021
E_2 = 10.0	G_{23} = 3.8	ν_{23} = 0.50, ν_{32} = 0.50
E_3 = 10.0	G_{13} = 5.2	ν_{31} = 0.021, ν_{13} = 0.30

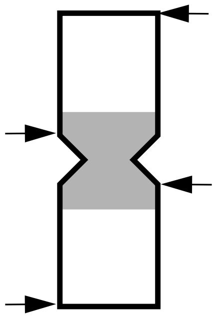
- Strongly anisotropic (E_3/E_1= 0.07)

Experimental comparisons - shear strain distributions

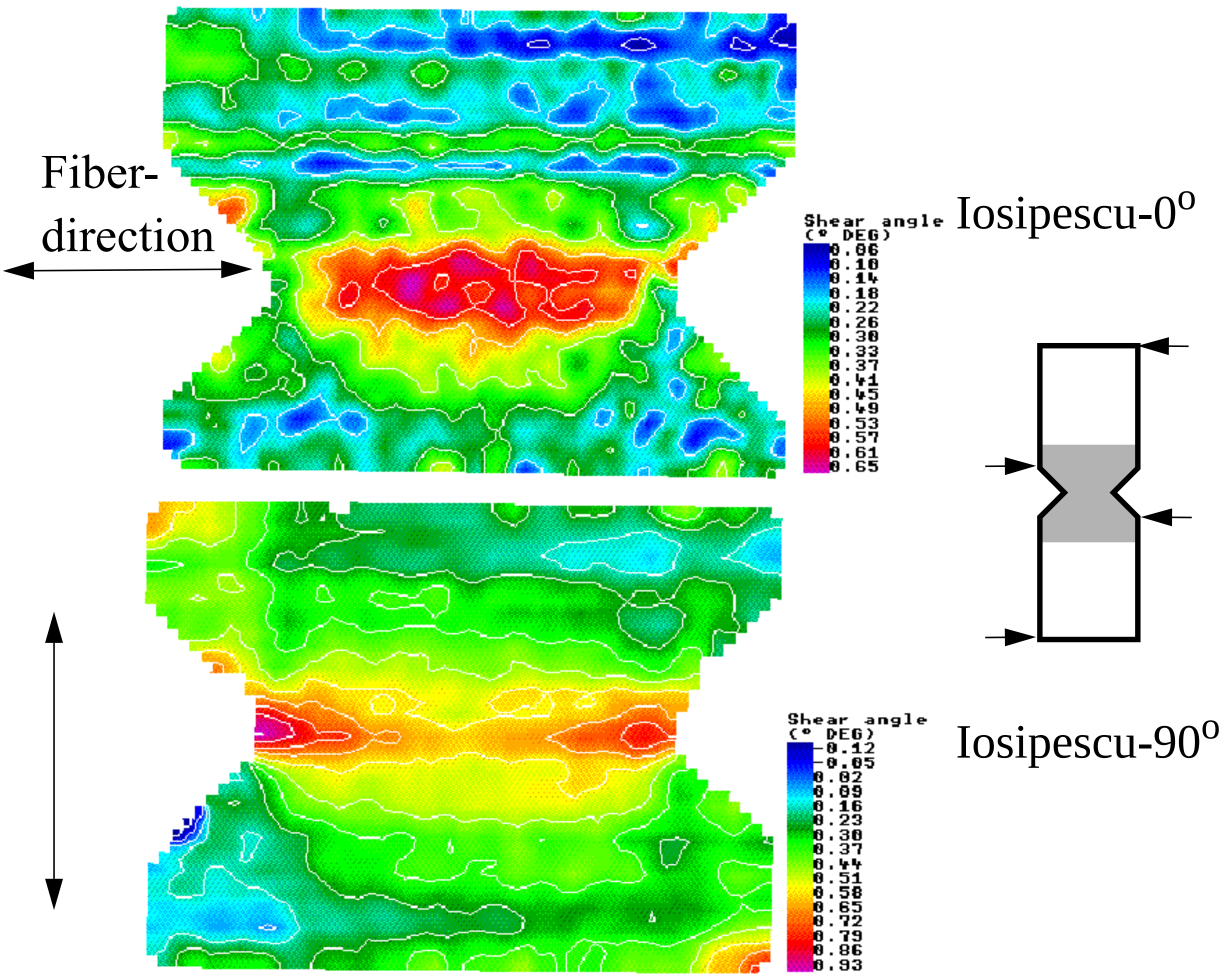
Fiber-direction



Iosipescu-0°



Experimental comparisons - shear strain distributions



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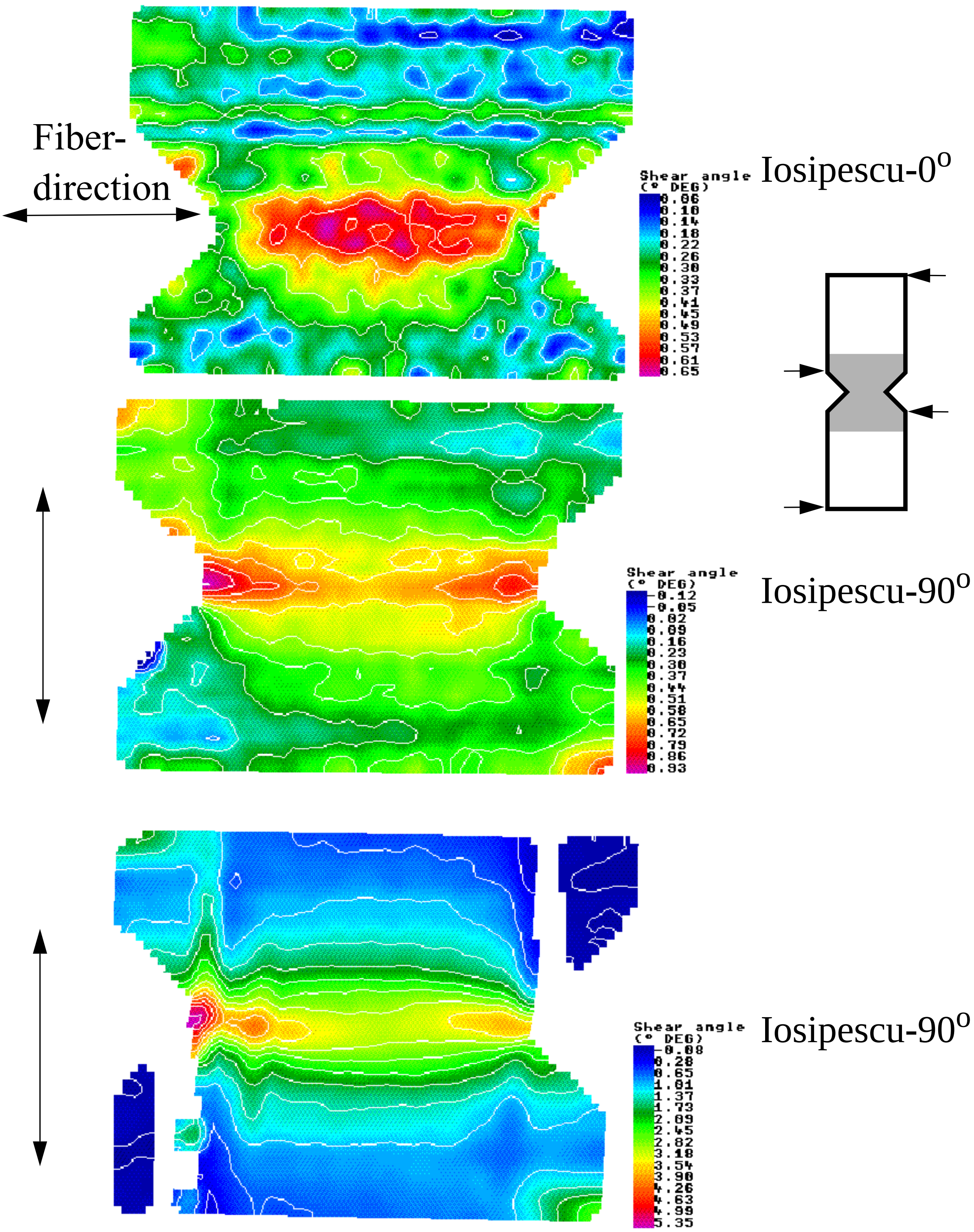

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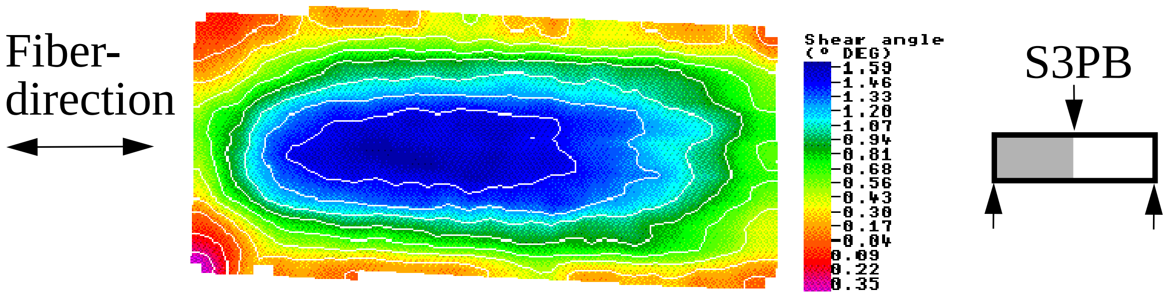

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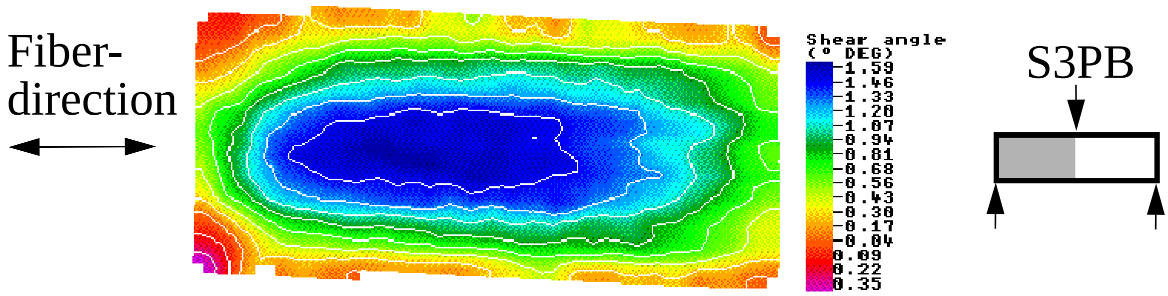
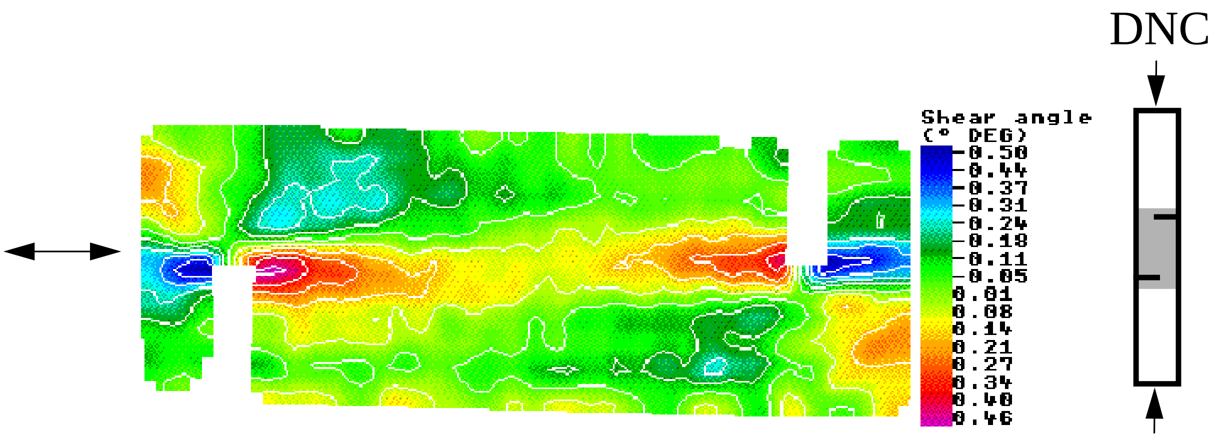
Experimental comparisons - shear strain distributions





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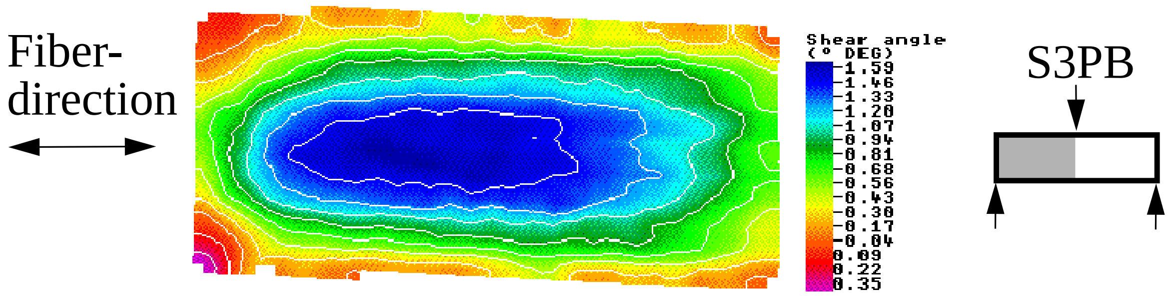
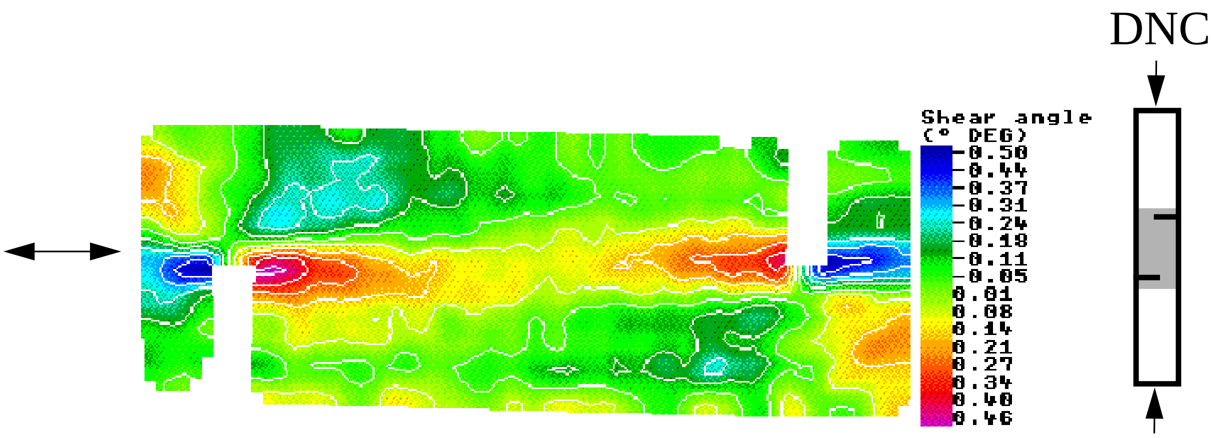
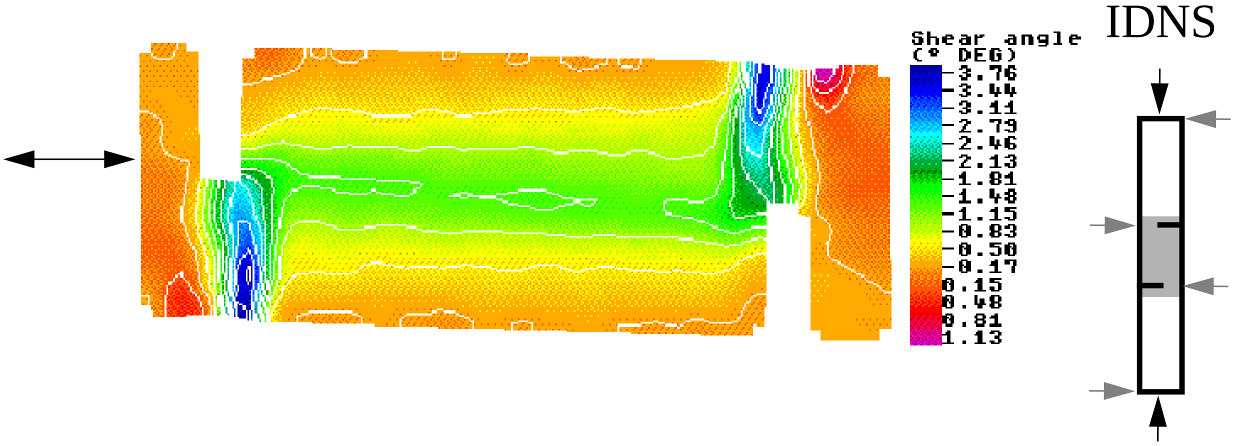
Experimental comparisons - shear strain distributions







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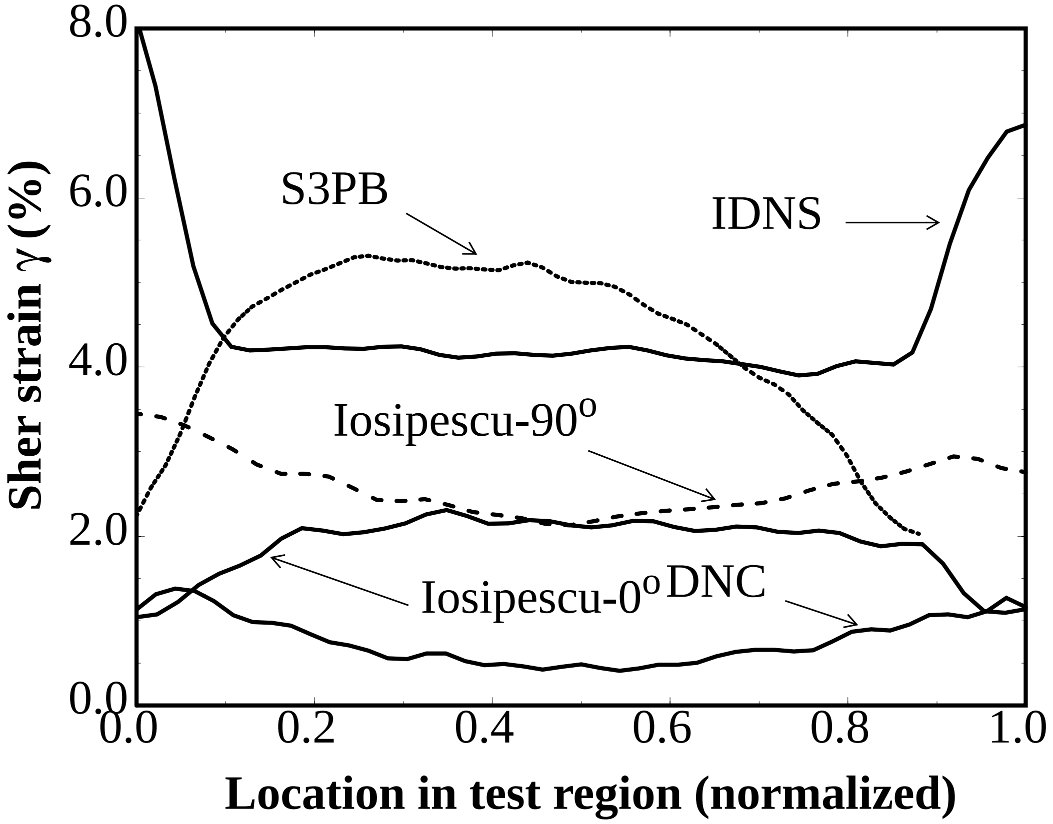
Experimental comparisons - shear strain distributions



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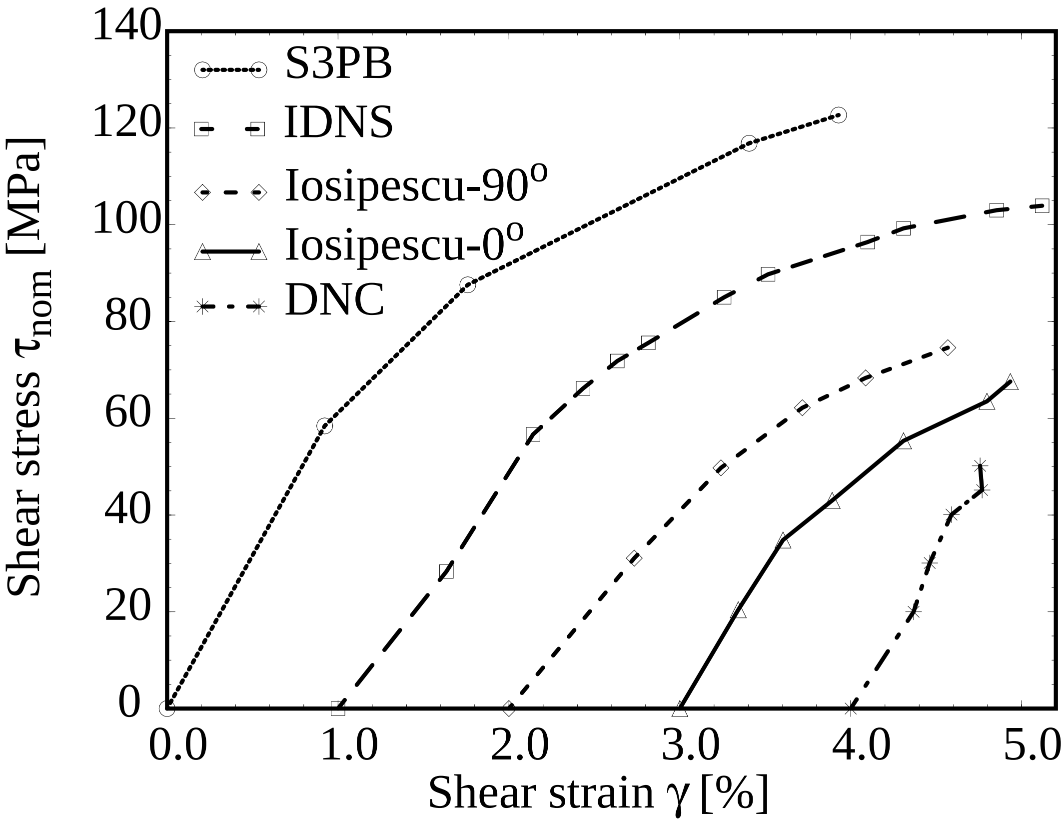
Experimental comparisons -

stress-strain-response in shear



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Experimental comparisons - ILSS-values

Method	Mean $\bar{\tau}$ [MPa]
Iosipescu-0^o	65
Iosipescu-90^o	83* 114
S3PB	133**
DNC	58
IDNS *L*/*b*=1	132
L/*b*=1.5	114
L/*b*=2	111

* At the appearance of the first notch root crack.

**Stresses calculated from linear beam theory.

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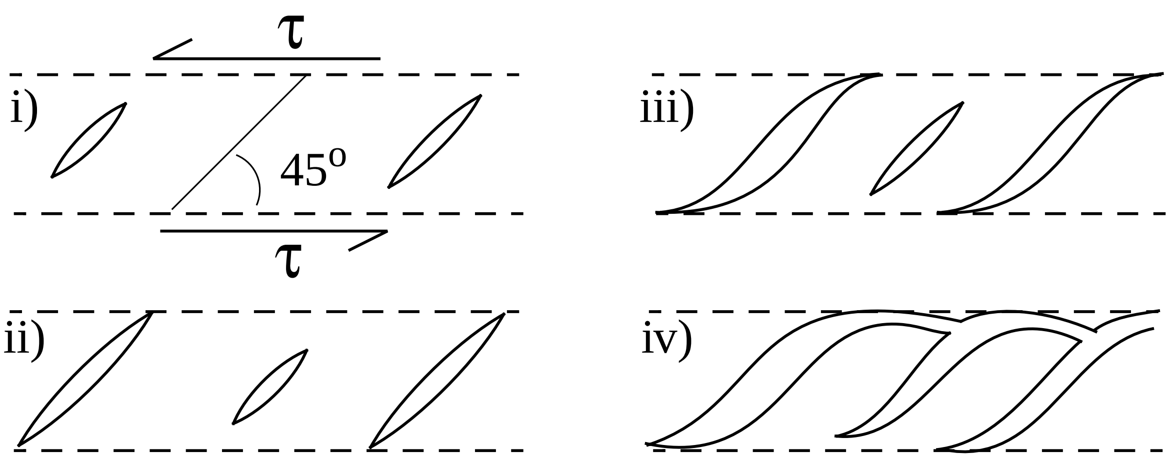
Experimental comparisons - fractography

- Shear separated fracture surface - presence of shear cusps.



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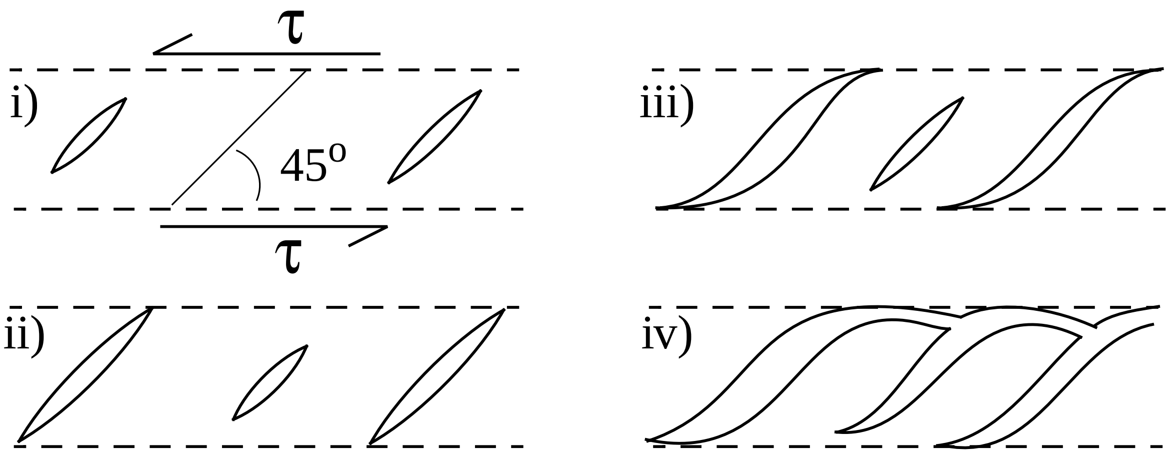
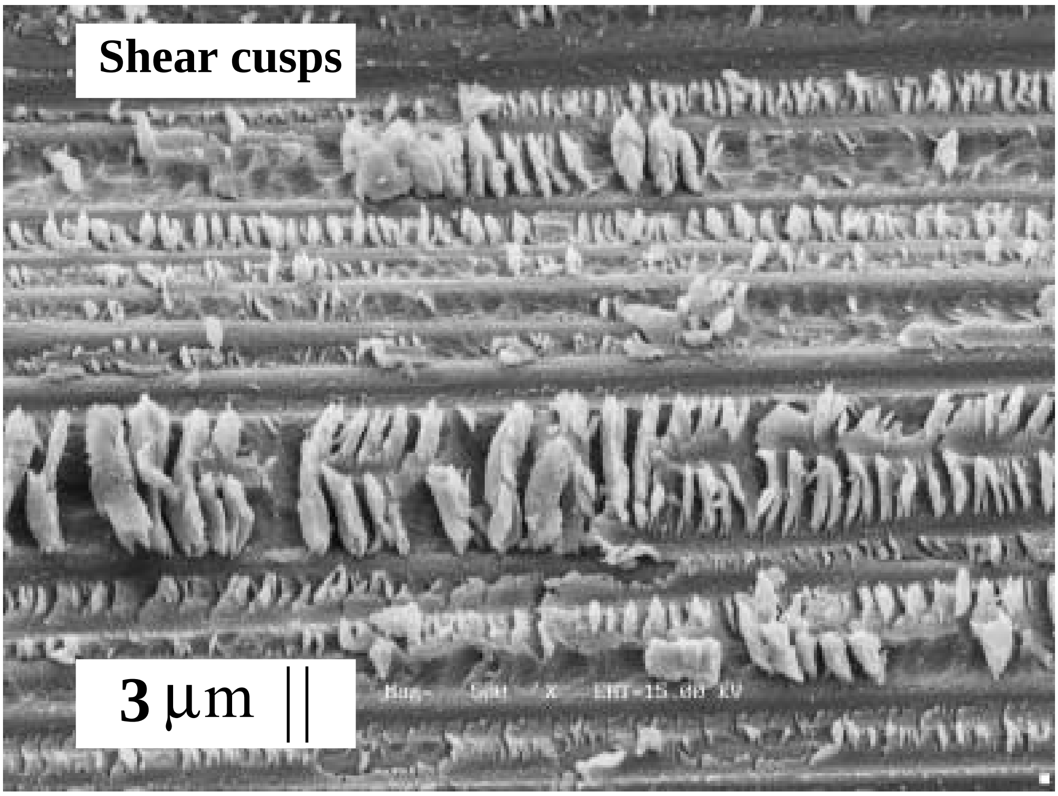




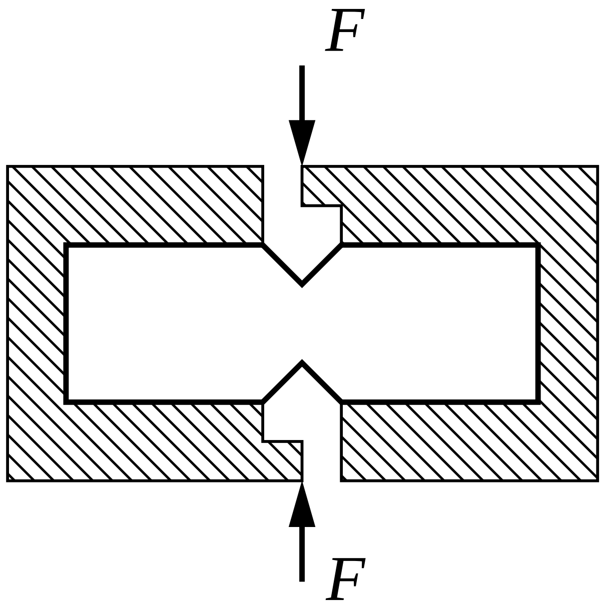
Experimental comparisons - fractography

- Shear separated fracture surface - presence of shear cusps.

Method	Area fraction [%]
Iosipescu-0^o	~50%
Iosipescu-90^o First crack	-
Iosipescu-90^o Maximum	-
S3PB	67 - 72%
DNC	61 - 73%
IDNS	75 - 83%

Conclusions

Iosipescu



$$\bar{\tau}_{12} = F / A$$

Conclusions

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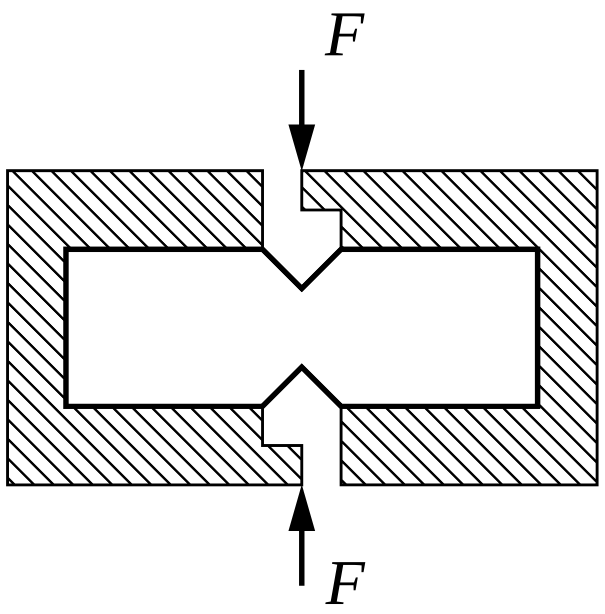

$$\bar{\tau}_{12} = F / A$$

- Not suitable for ILS-measurements.

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Conclusions

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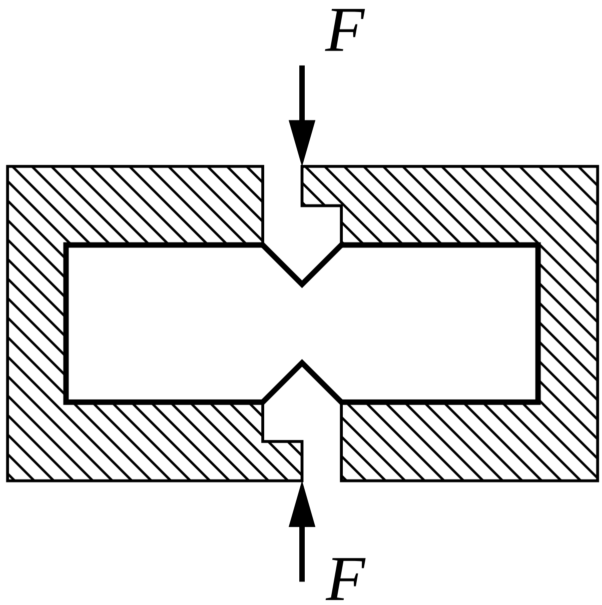
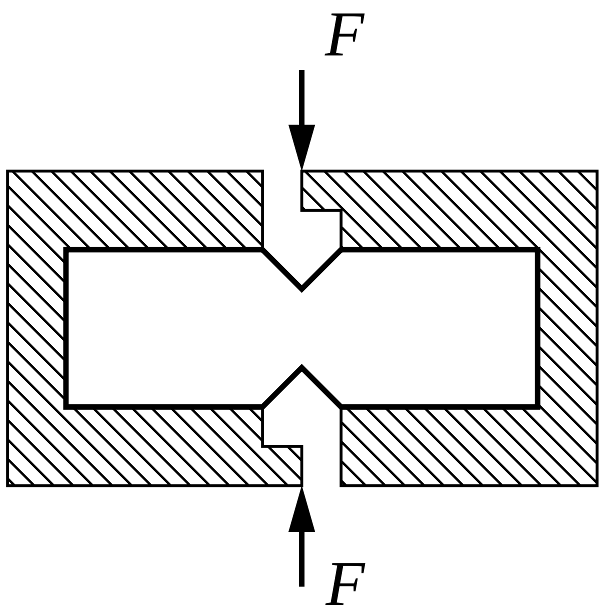


$$\bar{\tau}_{12} = F / A$$

- Not suitable for ILS-measurements.
- Strongly influenced by material anisotropy.

Conclusions

Iosipescu

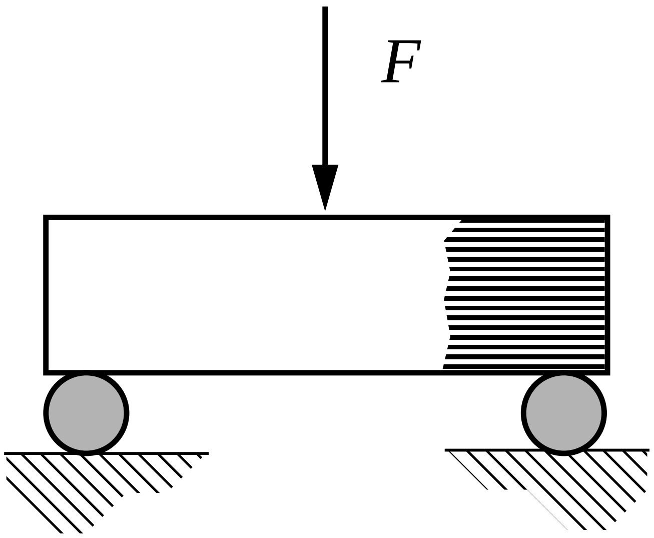


$$\bar{\tau}_{12} = F / A$$

- Not suitable for ILS-measurements.
- Strongly influenced by material anisotropy.
- Fracture initiated in tension.

Conclusions

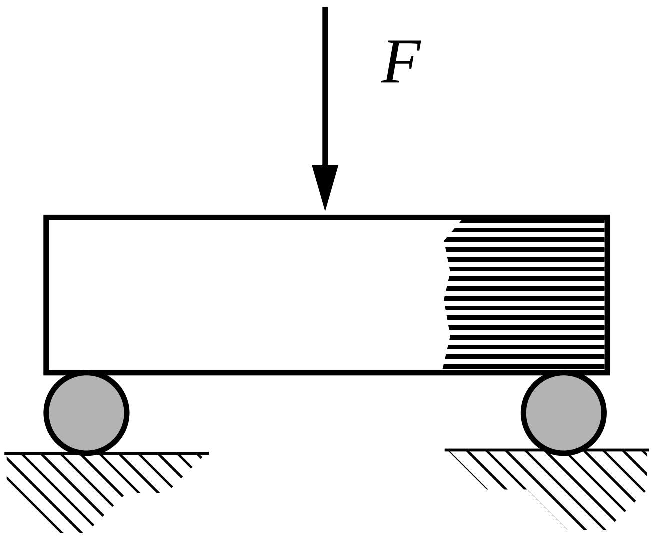
S3PB



$$\hat{\tau}_{13} = \frac{3}{2}\bar{\tau}_{13}$$

Conclusions

S3PB

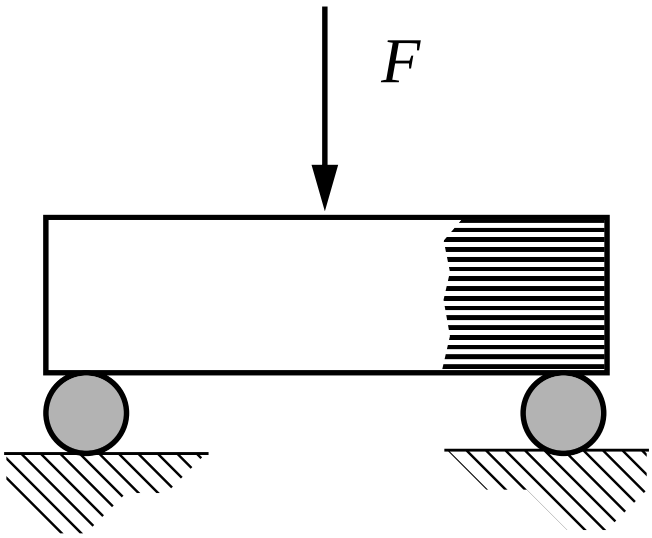


$$\hat{\tau}_{13} = \frac{3}{2}\bar{\tau}_{13}$$

• Measures ILS-properties

Conclusions

S3PB

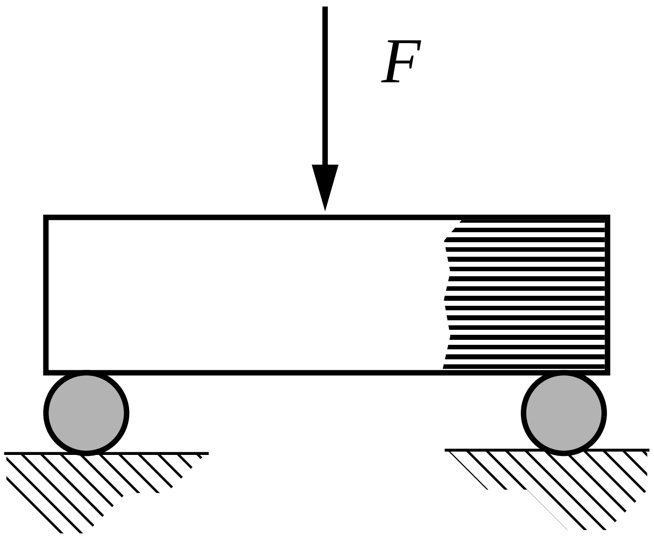


$$\hat{\tau}_{13} = \frac{3}{2}\bar{\tau}_{13}$$

- Measures ILS-properties
- Overestimates true shear-stress levels.

Conclusions

S3PB

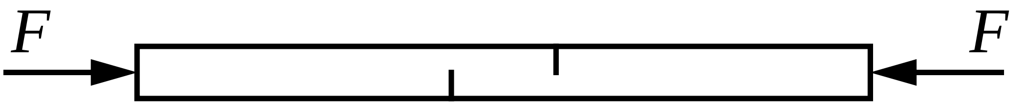


$$\hat{\tau}_{13} = \frac{3}{2}\bar{\tau}_{13}$$

- Measures ILS-properties
- Overestimates true shear-stress levels.
- In-homogenous shear-strain distributions.

Conclusions

DNC



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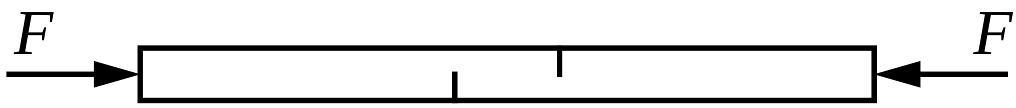
Conclusions

DNC

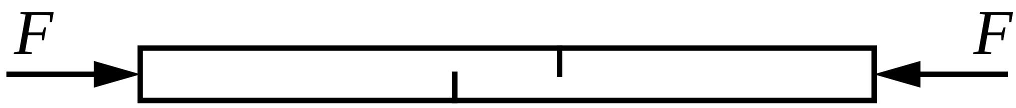


$$\bar{\tau}_{13} = F / A$$

- Measures true ILS-properties (*F*/*A*).

Conclusions

DNC



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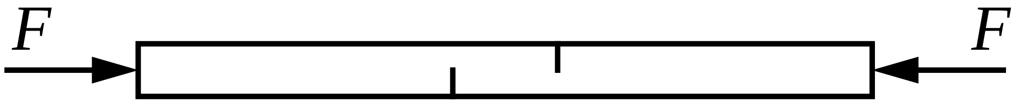
- Measures true ILS-properties (*F*/*A*).
- High stress/strain concentrations in the vicinity of the notches.

Conclusions

DNC

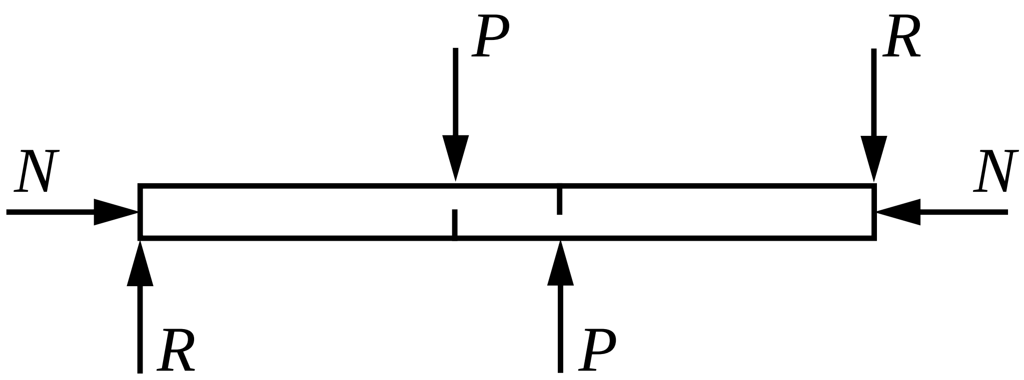


$$\bar{\tau}_{13} = F / A$$

- Measures true ILS-properties (*F*/*A*).
- High stress/strain concentrations in the vicinity of the notches.
- Grossly underestimates ILSS values.

Conclusions

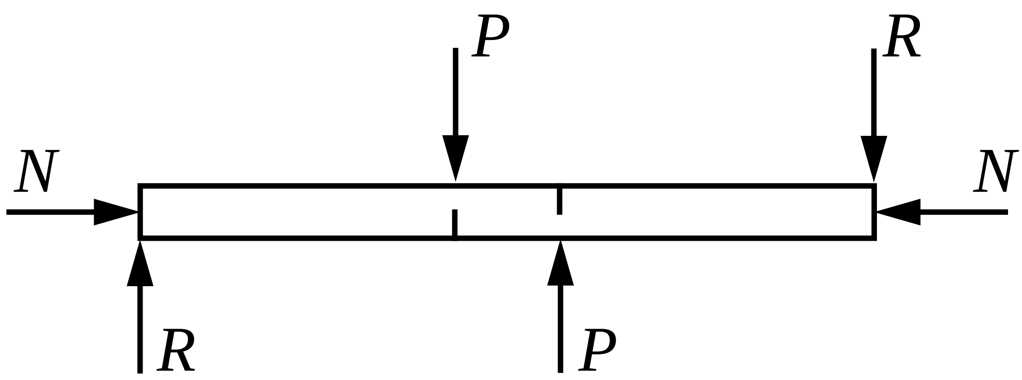
IDNS



$$\bar{\tau}_{13} = N / A$$

Conclusions

IDNS



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Conclusions

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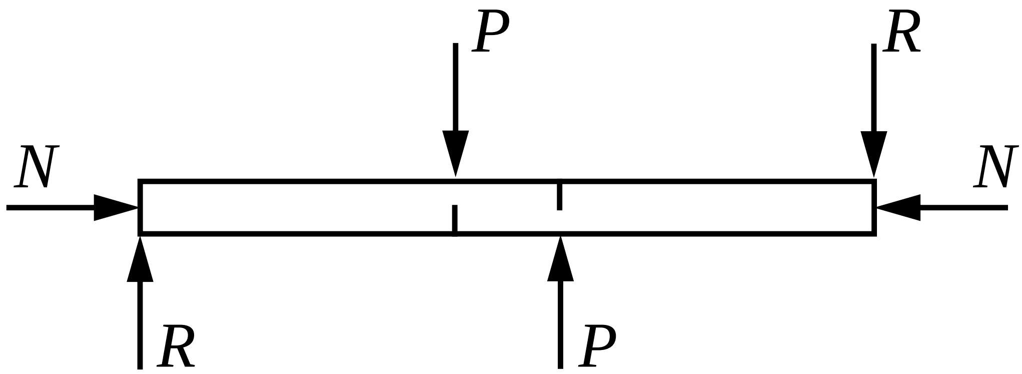
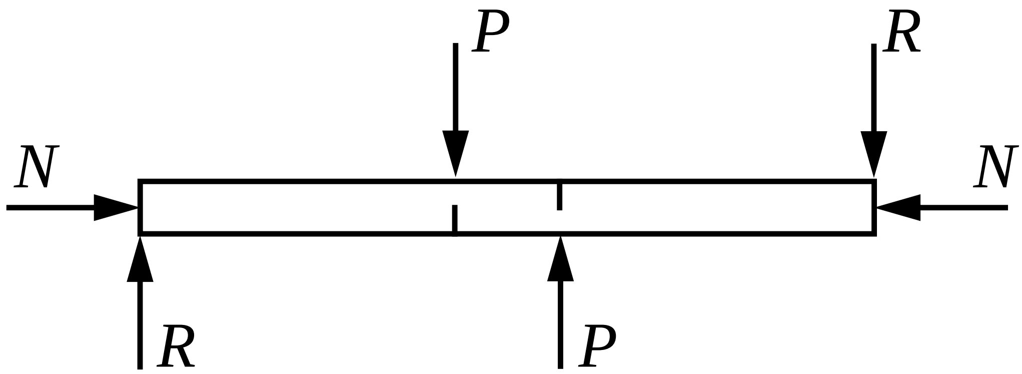


$$\bar{\tau}_{13} = N / A$$

- Measures true ILS-properties (*N*/*A*).
- Insensitive to material anisotropy.

Conclusions

IDNS

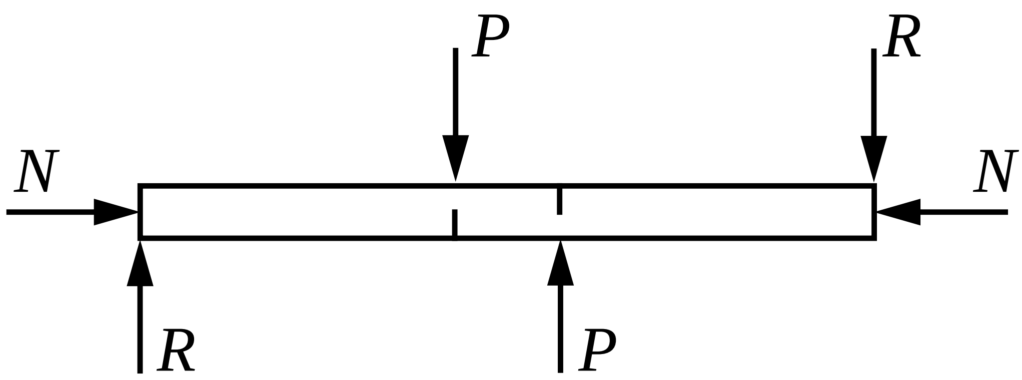


$$\bar{\tau}_{13} = N / A$$

- Measures true ILS-properties (*N*/*A*).
- Insensitive to material anisotropy.
- Homogenous shear strain distribution.

Conclusions

IDNS



$$\bar{\tau}_{13} = N\,/\,A$$

- Measures true ILS-properties (*N*/*A*).
- Insensitive to material anisotropy.
- Homogenous shear strain distribution.
- Further development worthwhile.