Experimental Determination of Composite In-plane Shear Properties

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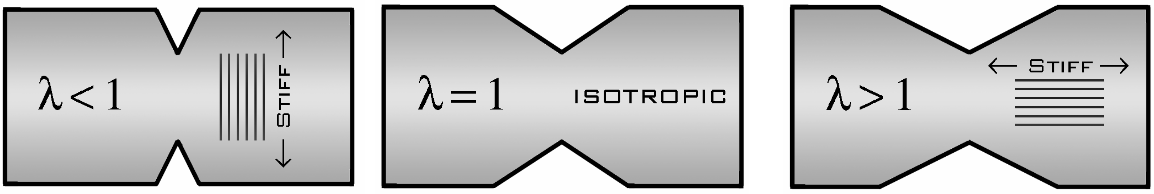
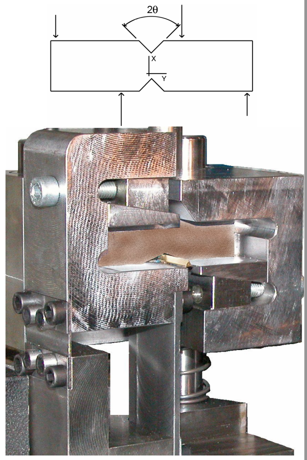
Abstract - The Iosipescu shear test (ASTM standard D-5379) is well established for measuring composite in-plane shear properties. Due to anisotropy of many composites, the arising stress- and strain fields depend on both the material and its orientation. More accurate measuring of bulk shear properties is accomplished by adapting the specimen to the material tested. This is done by rescaling its geometry to recreate the stress and strain fields of an isotropic material. The merits of such a modification were confirmed both numerically and experimentally. A Digital Speckle Photography (DSP-) image correlation technique was used to measure arising strain fields. More accurate shear strengths and moduli are reported. Moreover, shear moduli obtained using standard specimens gave similar results when compensated for strain inhomogeneity based on FE calculated fields.

Objectives:
- Measure true shear moduli
- Measure accurate shear strengths
- Homogenous stress and strain fields
- Accommodate for anisotropy
- Simple specimen modification
- Improved fixture design

How? Rescale the notch opening angle depending on stiffness ratio



2θ = **71°** $2\theta_{iso}$ = **110°** 2θ = **141°**

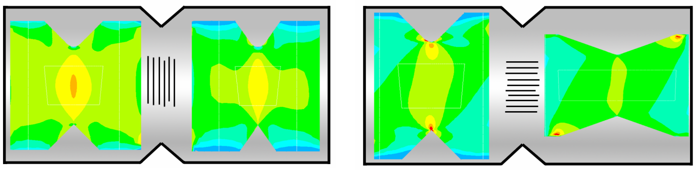


Best isotropic results when $2\theta_{iso}$ = 110°. Similar fields in orthotropic materials if geometry is rescaled lengthwise by a factor of $\lambda^{1/4}$. Thus, modify notch opening angle as:

$$\tan 2\theta = \frac{\tan 2\theta_{iso}}{\sqrt[4]{\lambda}}, \text{ where } \lambda = E_y / E_x$$

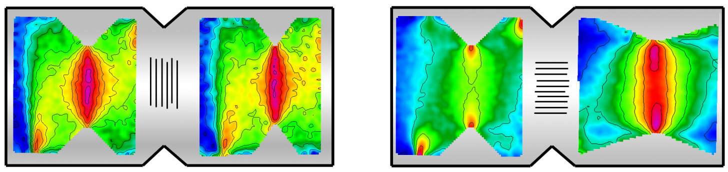
- Simple but accurate
- Relies only on E_x and E_y
- E_x and E_y easily measured
- Confirmed by FE-results and experimental fields

Numerical, FE-calculations



2θ = 90° 71° 90° 141°

Experimental strain fields, DSP technique



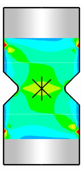
2θ = 90° 71° 90 141°

Measured shear modulus

Fiber orientation	Notch angle	$G_{measured}$ [GPa]	Correction factor	$G_{corrected}$ [GPa]
90°	90°	6.97	.88	6.16
0°	90°	5.67	1.12	6.36
90°	141°	6.66	-	←
0°	71°- s	6.82	-	←

Shear modulus determination using strain gages. Measured strains corrected for inhomogeneity using linear FE results.

Strain gages

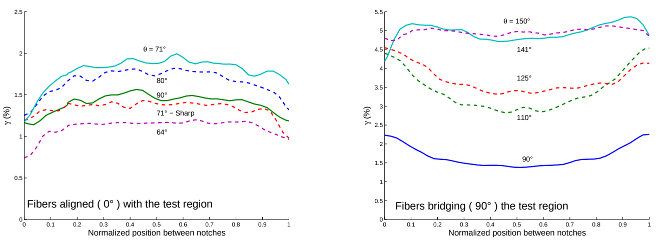


Experimental shear strengths

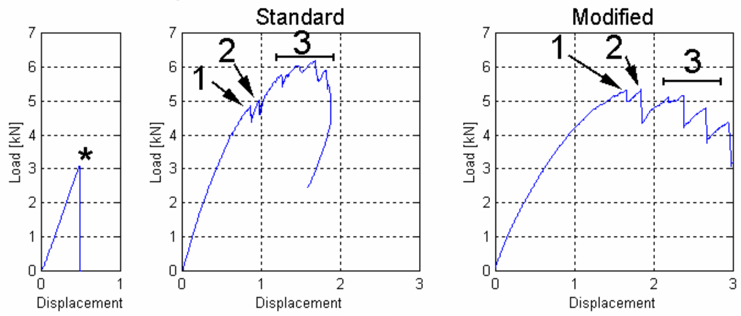
Notch angle	Shear strength [MPa] Ultimate	Notch angle	Shear strength [MPa] 1st	2nd	Ultimate
64°	57.8	90°	76.6	81.8	125.3
71°	61.7	110°	91.4	93.2	116.7
71°	50.3 - s	125°	94.8	91.4	109.5
80°	56.8	141°	103.6	103.7	104.6
90°	60.7	150°	94.6	69.1	105.0

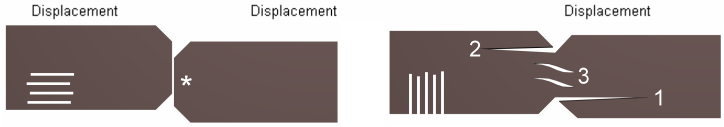
Shear strength values obtained for the laminate. See also below.

Experimental shear strain profiles in test region



Force vs. displacement and failure modes





Catastrophic failure mode.

Gradual failure due to multiple cracking of specimen in test region.

Undesired specimen deformation may be monitored

Specimen twisting at higher loads can be recorded using 3D DSP measurements. Other unwanted deformation modes (out-of-plane or in-plane bending) may also be observed, see Figure.