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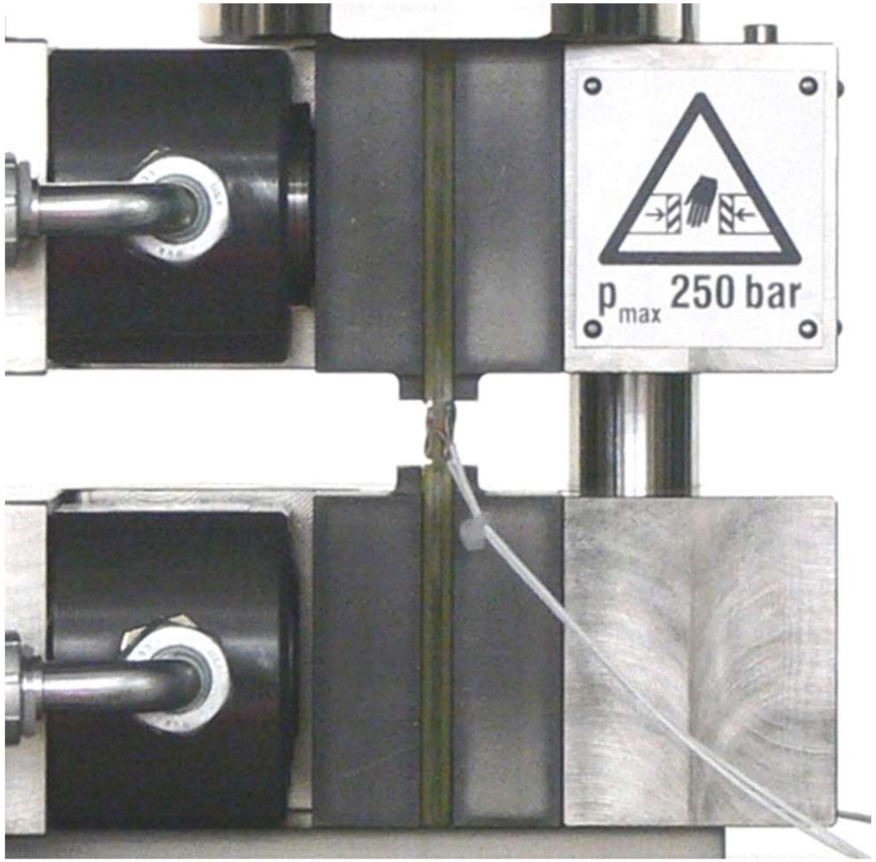
Intelligent testing



Compression Testing of Fiber-Reinforced Polymer Matrix Composites

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Industry Manager Composites

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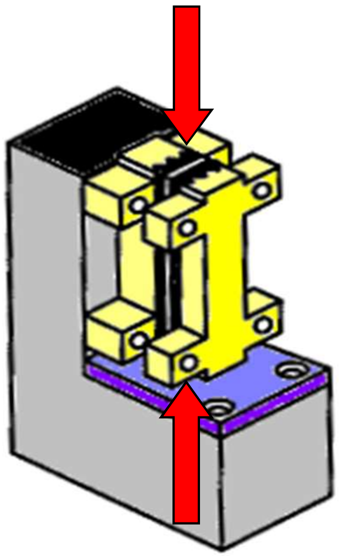
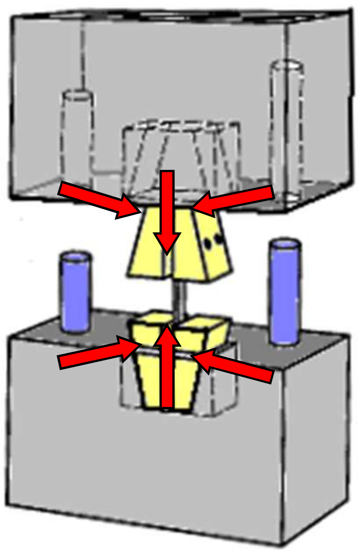
Plain compression test methods

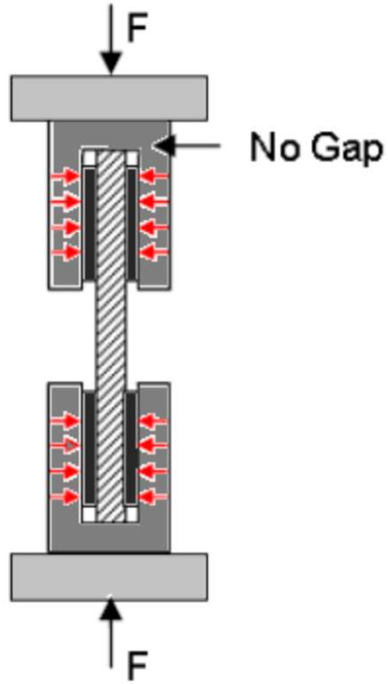
The methods can be distinguished by the type of loading



End Loading configuration



Shear Loading configuration

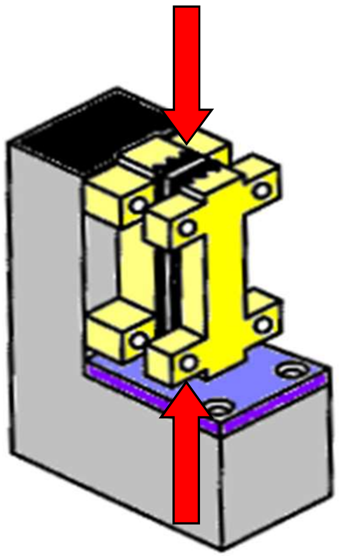


Combined Loading configuration

ISO 14126	*ISO 604*	*ASTM D 3410*	*ASTM D 695*	*ASTM D 6641*	*DIN 65375*	*JIS K 7076*
prEN 2850	*AITM 1-0008*	*Boeing BSS 7260 - type III and IV*	*SACMA SRM 1R-94*	*RAE-TR 88012 CRAG Method 400*	*RAE-TR 88012 CRAG Method 401*	

Plain compression test methods

The methods can be distinguished by the type of loading



End loading configuration

Shear Loading configuration

Combined Loading configuration

ISO 14126	***ISO 604***	***ASTM D 3410***	***ASTM D 695***	***ASTM D 6641***	***DIN 65375***	***JIS K 7076***
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End loading compression

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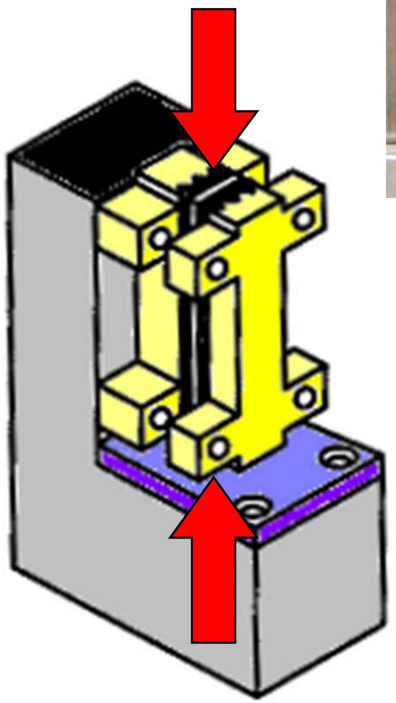
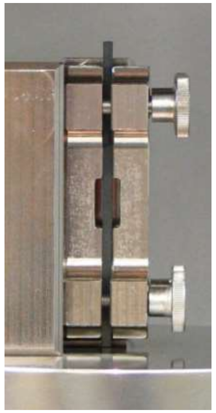
The end loading configuration is adapted for modulus and ultimate strength measurements





modulus

strength

End Loading configuration

Sample preparation

- Needs very careful preparation of specimen ends for ultimate strength measurement
- Two specimen per test
  - Untabbed for compression modulus measurements
  - Tabbed specimen ends for ultimate strength

Advantage

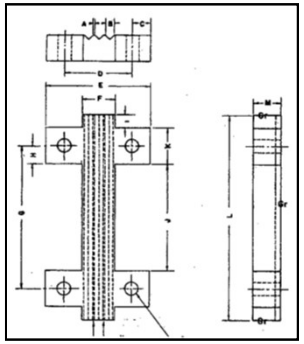
- Quite simple test fixture
- Strain measurement by strain gages or by extensometer possible

Disadvantage

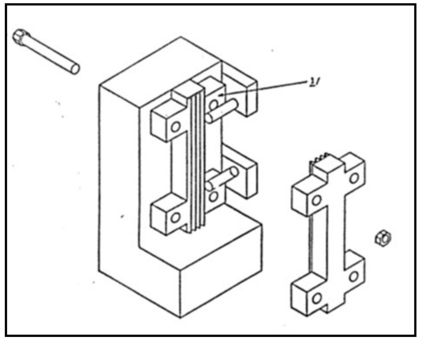
- Method tends to provide low ultimate strength results
- Small gage area

End loading compression

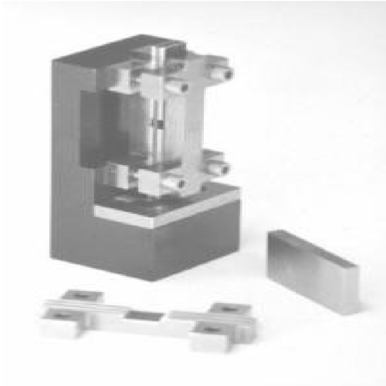
End-loading compression tools are variants of the ASTM D 695 tool, initially developed for plastics testing.



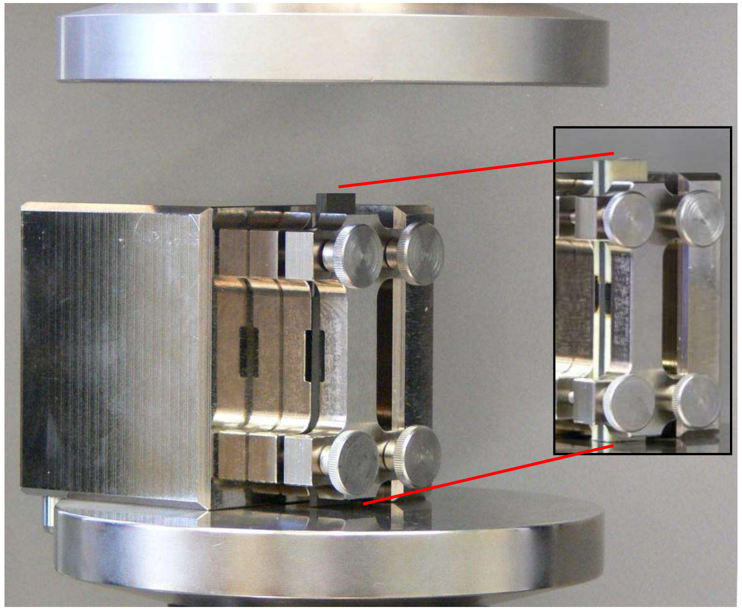
ASTM D 695 tool for plastics. (not used for composites)



The “ASTM D 695 - Boeing modified” tool for composites includes a support and lateral end-stops to place the tool exactly upright and to improve handling.



SACMA introduced this tool with grooves for the strain gages to perform modulus measurements

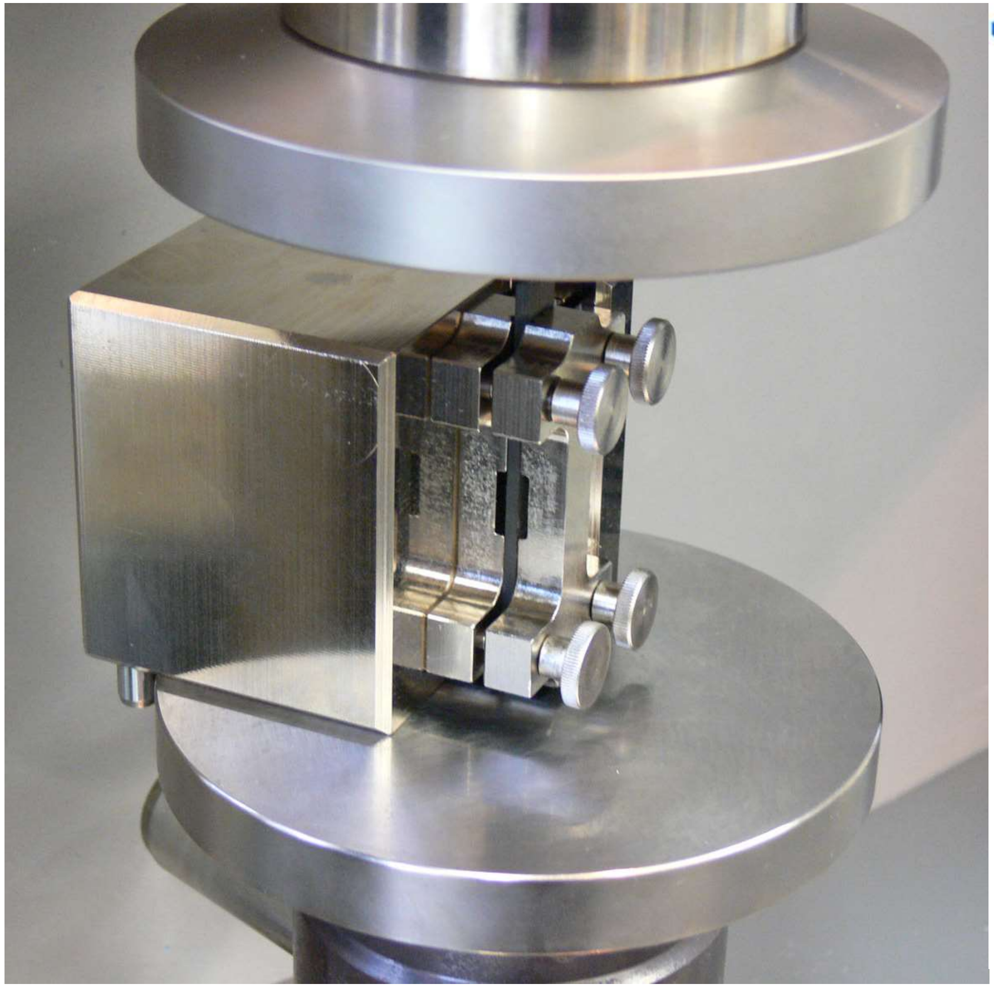


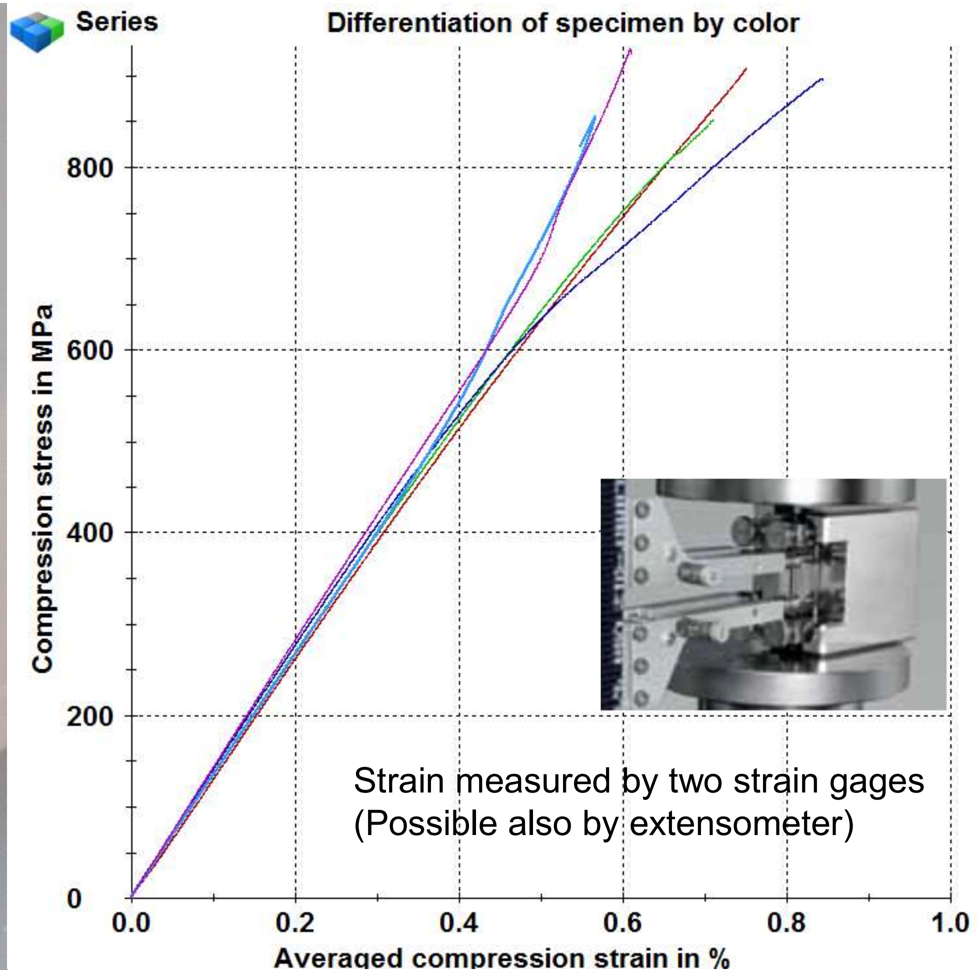
Zwick’s compression tool includes guides for both, Modulus (center) and Ultimate Strength (right) measurement. It is always well centered to the machine.

ISO 14126 meth. 2			*ASTM D 695*		*DIN 65375*	*JIS K 7076*
prEN 2850 type B	*AITM 1-0008*	*Boeing BSS 7260 - type III and IV*	*SACMA SRM 1R-94*			

End loading compression - modulus

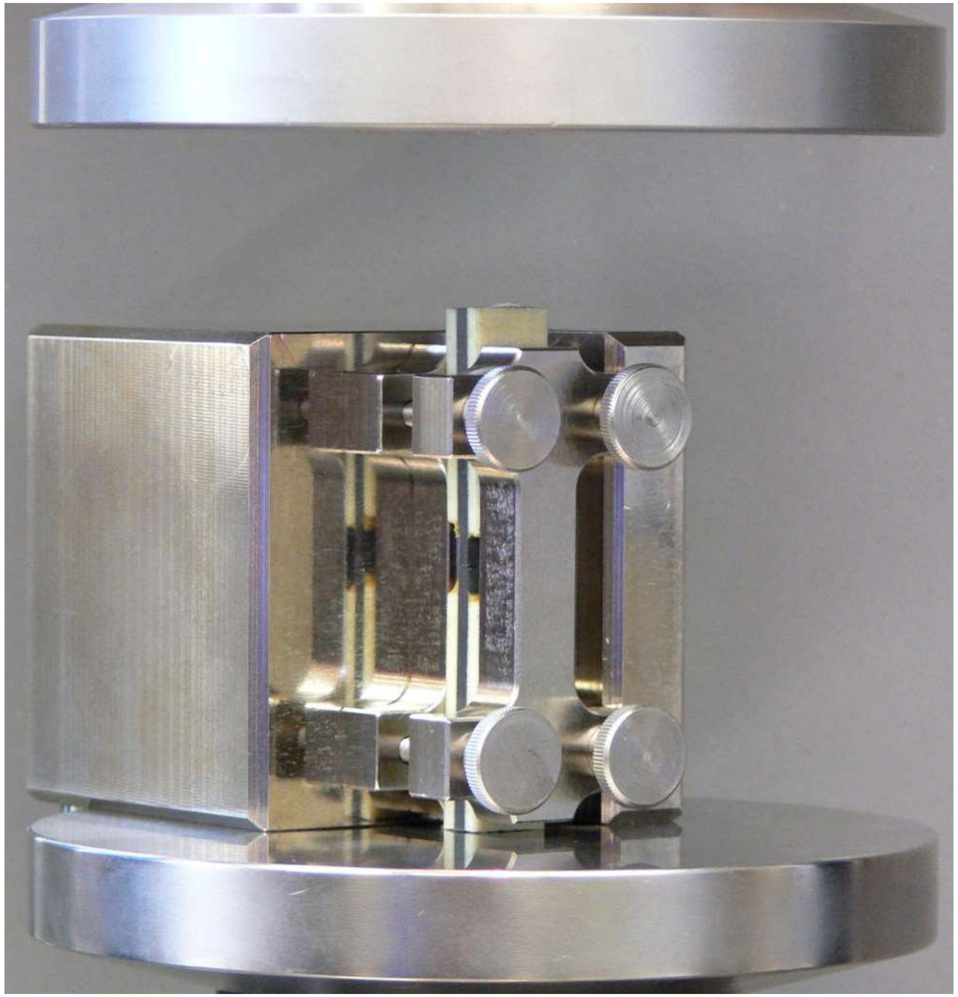
UD 0° samples without tabs show variances below 5% for modulus results, but break early nearby the specimen ends.

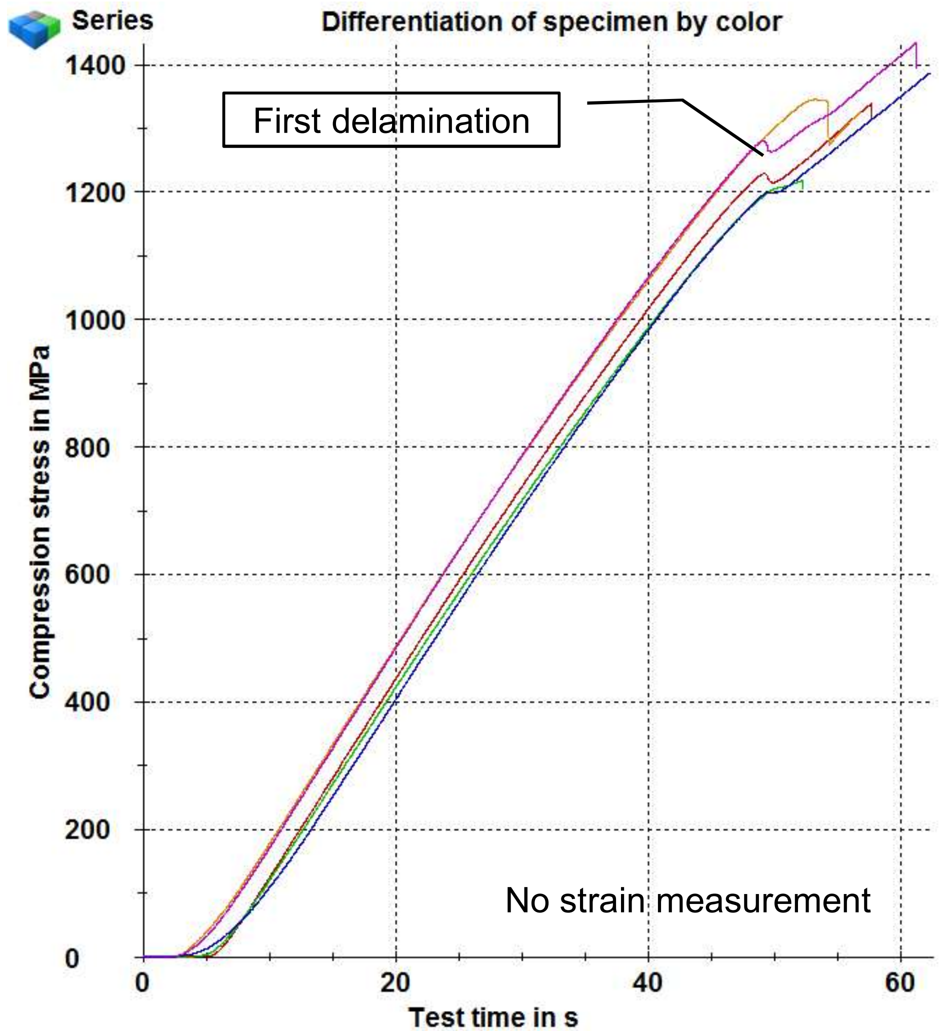




End loading compression - strength

Specimen with tabbed ends must be used for strength measurements. Tabs and ends are to be prepared with great care.

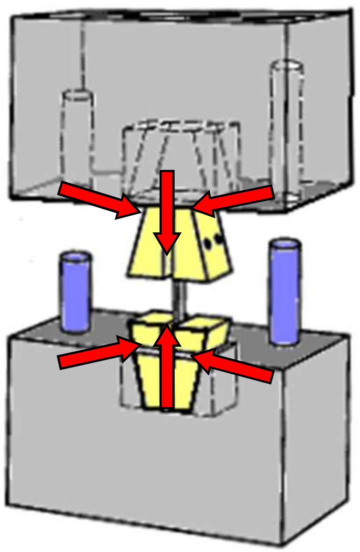




Plain compression test methods

The methods can be distinguished by the type of loading

End loading configuration



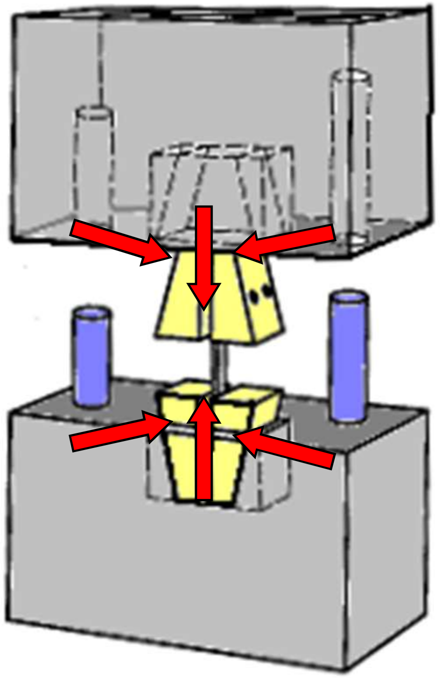
Shear loading configuration

Combined Loading configuration

ISO 14126	***ISO 604***	***ASTM D 3410***	***ASTM D 695***	***ASTM D 6641***	***DIN 65375***	***JIS K 7076***
prEN 2850	***AITM 1-0008***	***Boeing BSS 7260 - type III and IV***	***SACMA SRM 1R-94***	***RAE-TR 88012 CRAG Method 400***	***RAE-TR 88012 CRAG method 401***	

Shear loading compression

Transmitting the force into the laminates via tabs reduces peak forces at the load introduction point.



Shear loading configuration

Sample preparation

- Needs very careful sample preparation

Advantages

- Load introduction by the specimen surface
- Better strain distribution compared to end-loading
- Avoidance of peak stresses
- No specific machining of specimen ends needed

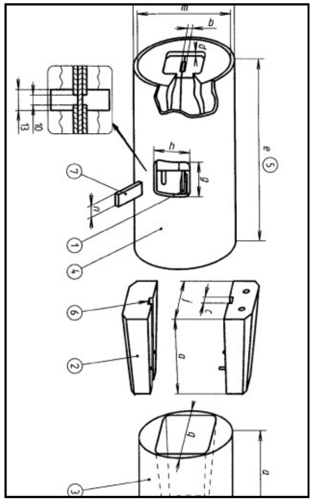
Disadvantages

- More complex test fixture
- Sensitive to tab and glue thickness variations
- Only adapted to quite thin laminates
- Limited in force when using tabs which may shear off

Shear loading compression

Shear loading tools use conventional clamping principles known from tension testing. Several improvements have been applied from the simple early Celanese tool to today's new HCCF fixture.

The former ASTM D 3410 tool was equipped with conical wedges. Therefore is was sensitive to the specimen thickness and to torsion forces.



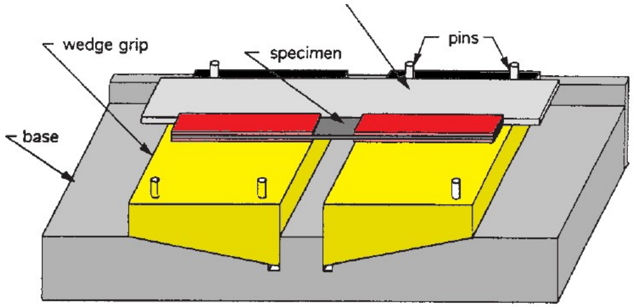
Former DIN 65380 and prEN 2850 proposed modified Celanese tools with flat wedges to solve the problem of specimen thickness (left). The IITRI developed a similar tool with two guides to overcome the torsion problem (right).

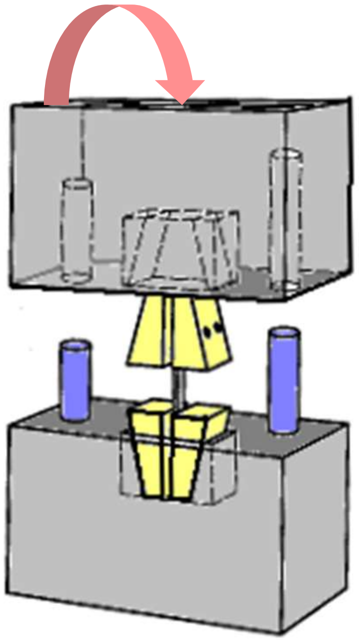
HCCF performs the IITRI function, but with significantly improved handling and stiff parallel clamping.

ISO 14126 meth. 1		***ASTM D 3410***				***JIS K 7076***
prEN 2850 type A	***AITM 1-0008***			***RAE-TR 88012 CRAG Method 400***	***RAE-TR 88012 CRAG method 401***	

The IITRI fixture (ASTM D 3410) is an improvement compared to former Celanese type fixtures, but still is difficult to handle.

Jig for specimen alignment, ASTM D 3410





IITRI fixture described in ASTM D 3410

Function principle of the IITRI fixture

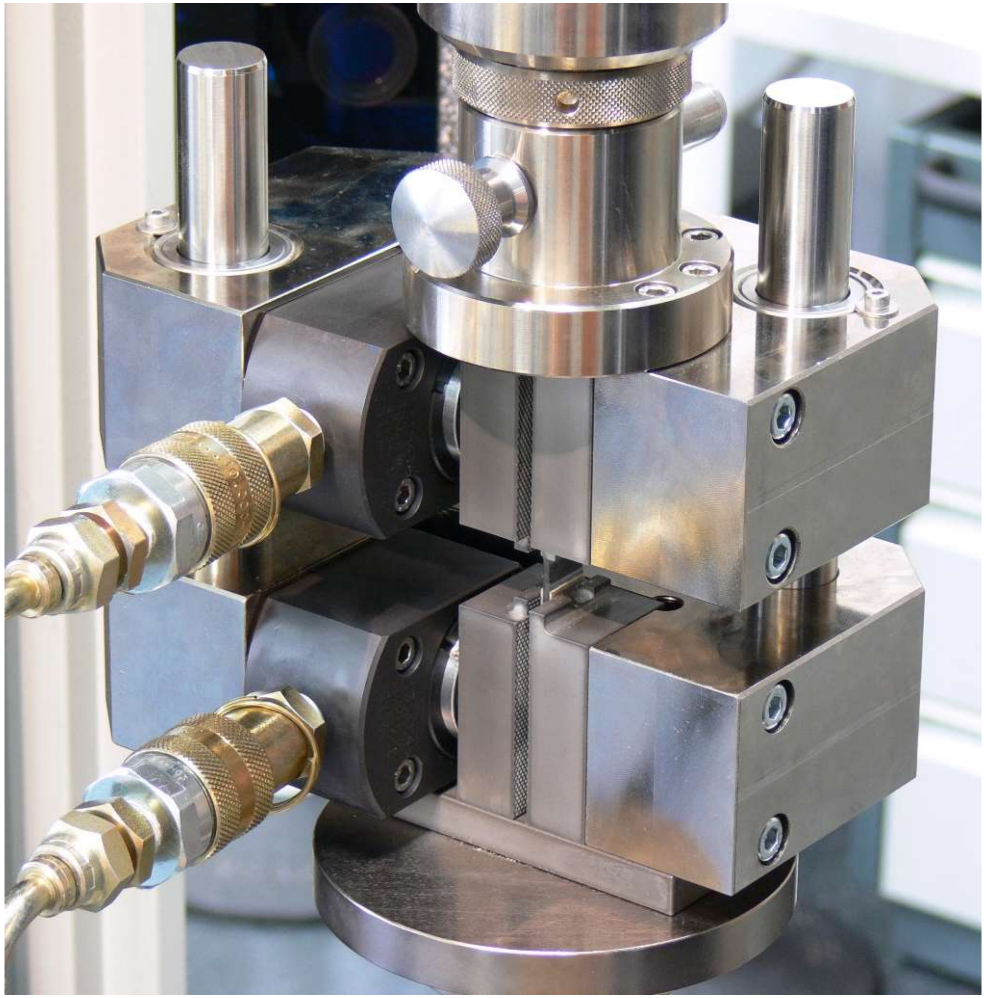
- Specimen has to be aligned to the wedges in a specific jig.
- Upper half of the fixture to be brought in place
- Wedges move into place at first load apply, thus applying misalignments to the laminate
- Wedges move during the whole test and may "amplify" bending or buckling
- No possibility for corrective interventions during the test
- High compression forces can be transmitted, limited only by crushing of the laminate or tabs
- High percentage of non valid tests to be expected.

Compression tests - HCCF

The HCCF with its parallel clamping principle is easy to operate and supplies reliable test results.

Features of the HCCF

- Shear loading up to about 40 kN
- Combined loading up to 200 kN
- Up to 35 mm large specimen possible
- Exact alignment of the jaw faces
- Accurate guiding
- Hydraulic parallel clamping principle
- No movements of the jaw faces during the test
- Initial misalignments due to tab or glue thickness differences are visible at the moment of clamping and can be corrected.
- Adjustable specimen end-stops
- Easy adjustment of the specimen, free access, simple cleaning.
- Covers several standards and load-apply methods



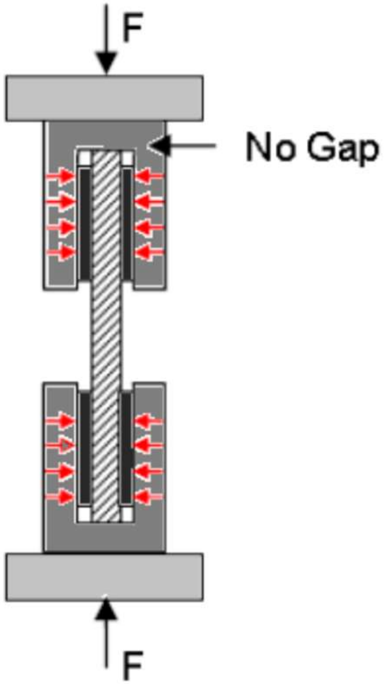
HCCF – Hydraulic Composites Compression Fixture

Plain compression test methods

The methods can be distinguished by the type of loading

End loading configuration

Shear loading configuration

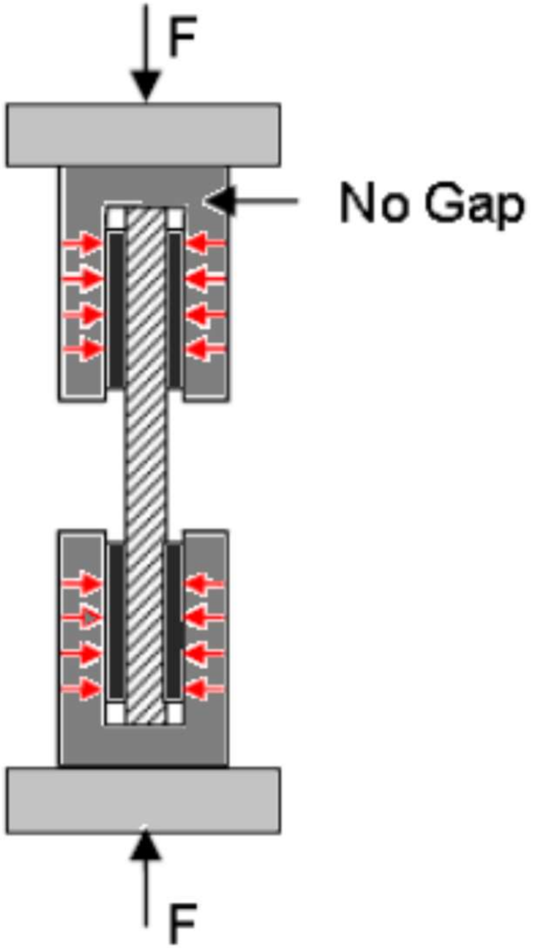


Combined loading configuration

ISO 14126	***ISO 604***	***ASTM D 3410***	***ASTM D 695***	***ASTM D 6641***	***DIN 65375***	***JIS K 7076***
prEN 2850	***AITM 1-0008***	***Boeing BSS 7260 - type III and IV***	***SACMA SRM 1R-94***	***RAE-TR 88012 CRAG Method 400***	***RAE-TR 88012 CRAG method 401***	

Combined loading compression

The combined loading compression methods can be used for most types of polymer matrix fiber reinforced composites.



Combined loading configuration

Sample preparation

- Needs very careful sample preparation including accurate machining of the specimen ends

Advantages

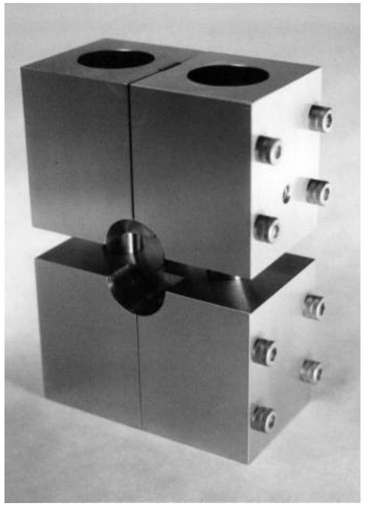
- Load introduction partly by the specimen ends and partly via the surface
- Higher load transmission than in shear loading
- Adapted to most fiber structures, not only laminates
- Adapted to large specimen and thicker structures or laminates
- Adapted to test ductile thermoplastic matrices

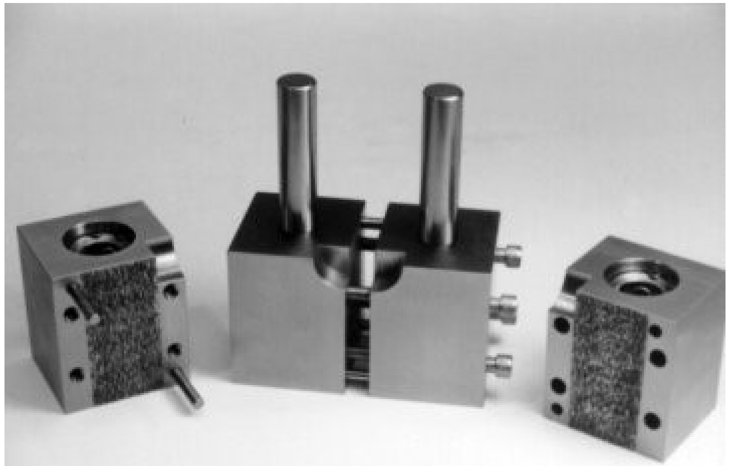
Disadvantages

- Sensitive to tab and glue thickness variations
- Specific machining of specimen ends needed

Combined loading compression

Compression tests at high loads are performed with combined loading.





Picture source: WTF

Mechanical combined loading tools adjust the clamping force by the bolt torque. Stiff column-type guides allow exact axial alignment throughout the test. The gage length can simply be adjusted by the overall specimen length. But the handling remains time consuming and the application of the shear load laborious.

HCCF performs combined loading, but with significantly improved handling.

ISO 14126 meth. 2				***ASTM D 6641***		
	AITM 1-0008					

Contents

Results and validation criteria

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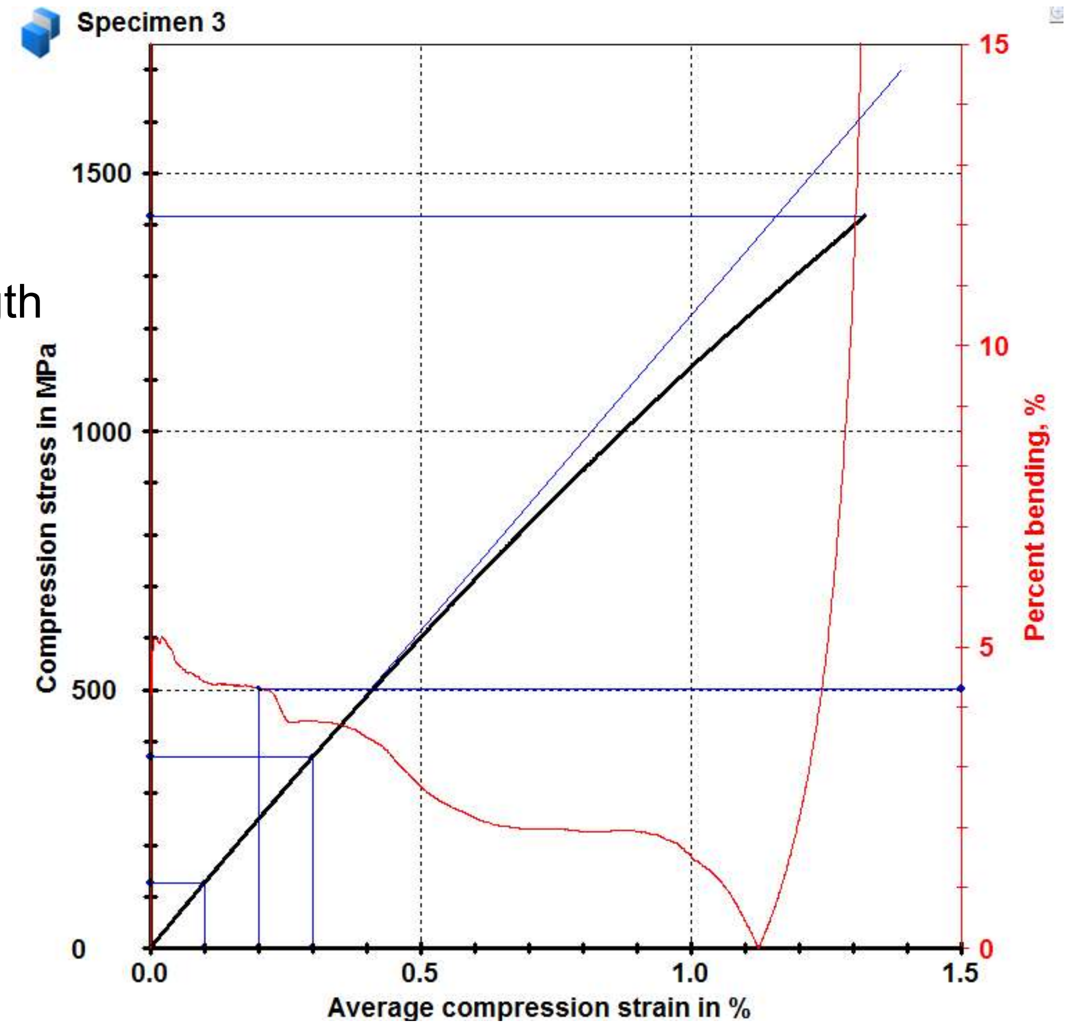
The results and validation criteria defined in different standard are similar.

- **Results**
  - Compression modulus
  - Ultimate compression strength
  - Compression strain at ultimate strength (only shear and combined loading)
  - Defined, but less common: Compressive Poisson's Ratio
- **Validation criteria**
  - Percent bending (PB)
  - Failure type



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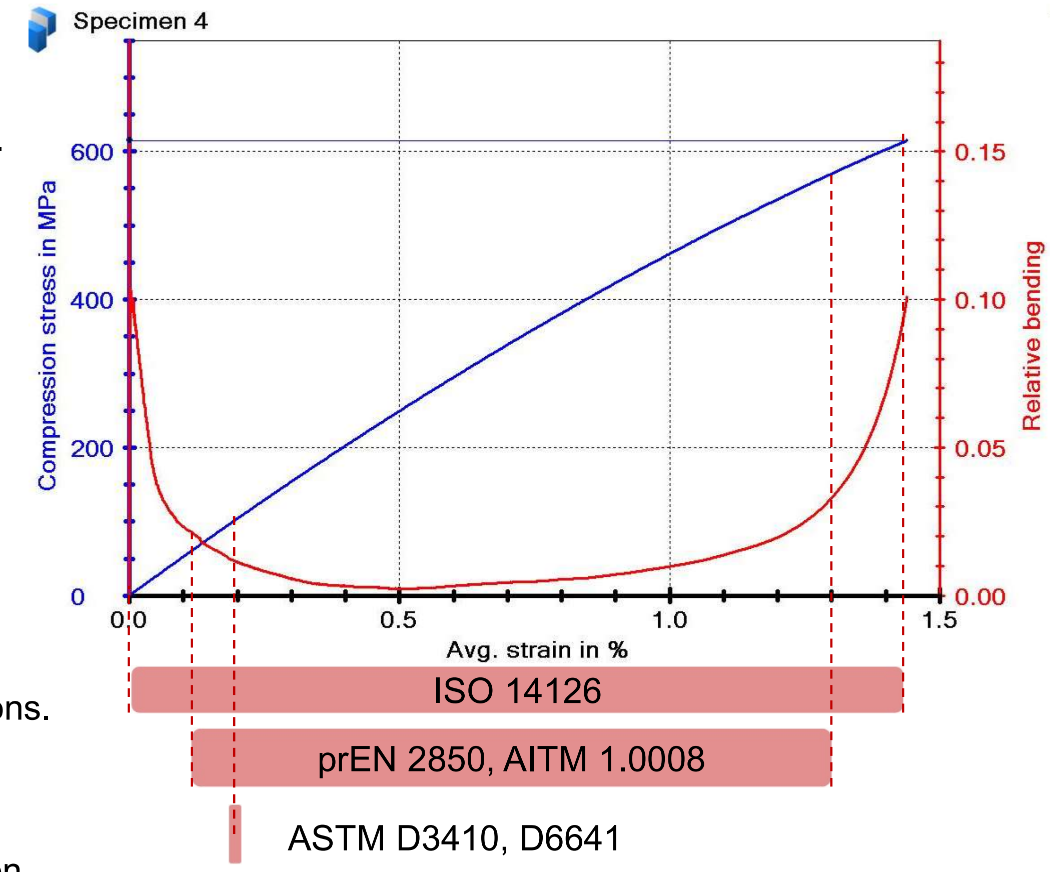
The definitions of validity criteria are different throughout the standards and sometimes very difficult to achieve.

Criteria: Bending, Percent Bending (relative)

- ISO 14126:
  - No supervision directly after clamping
  - PB may not exceed 10 % throughout the whole test. (This condition is nearly impossible to achieve)
- prEN 2850, method A – Shear Loading
  - between 10% and 90% Fmax: ≤ 5%
- AITM 1.0008:
  - Bending after clamping: max. 150 µm/m
  - between 10% and 90% Fmax: ≤ 10%
- ASTM D 3410, D 6641:
  - PB is only considered relevant for elastic deformations.
  - PB ≤ 10% at mid-span of the region used for compression modulus measurement.
  - Statement, that even 30 or 40% bending shows often no effect to the results

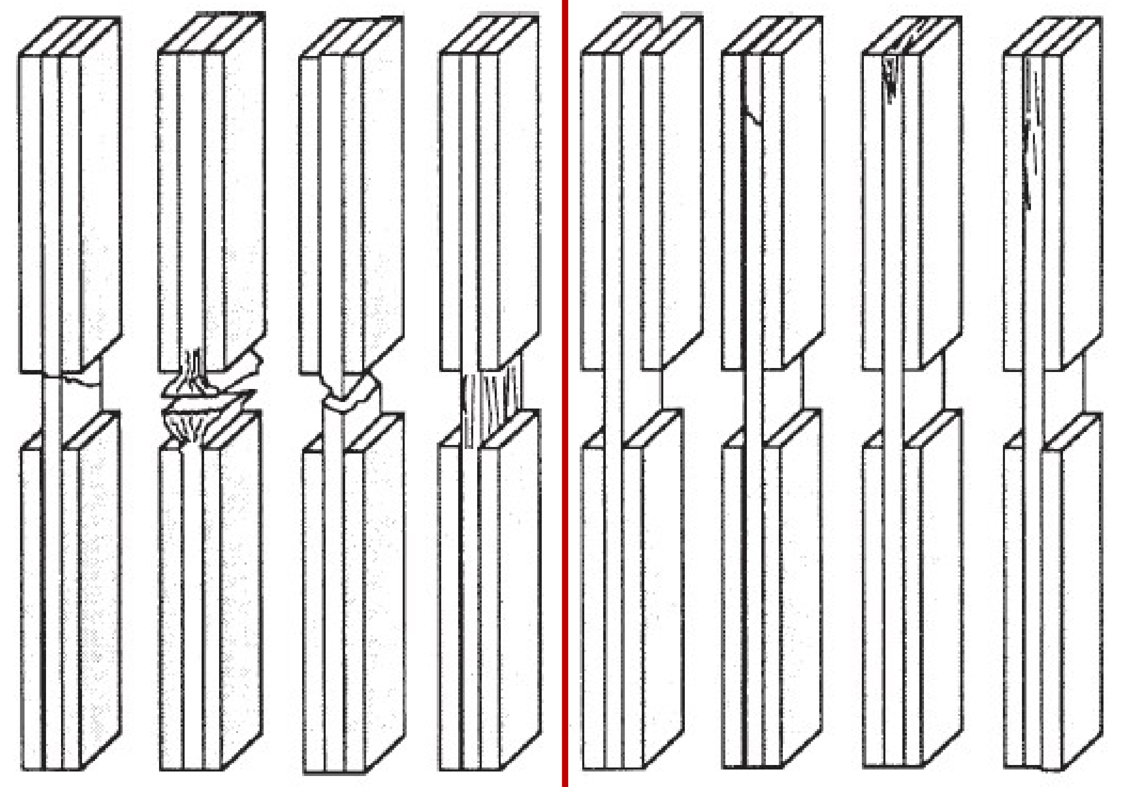


Results and validation criteria

Valid types of break always occur within the free length between grips.

Criteria: Type of break

- ISO 14126:
  - Indicates examples for valid break types
- prEN 2850, method A – Shear Loading
  - A break type is considered as being valid when the break appears within the free part of the specimen.
- AITM 1.0008:
  - Indicates valid and non-valid types of break.
- ASTM D 3410, D 6641:
  - Indicates valid and non-valid types of break and gives a method for classification.



Valid types of break

Non-valid types of break

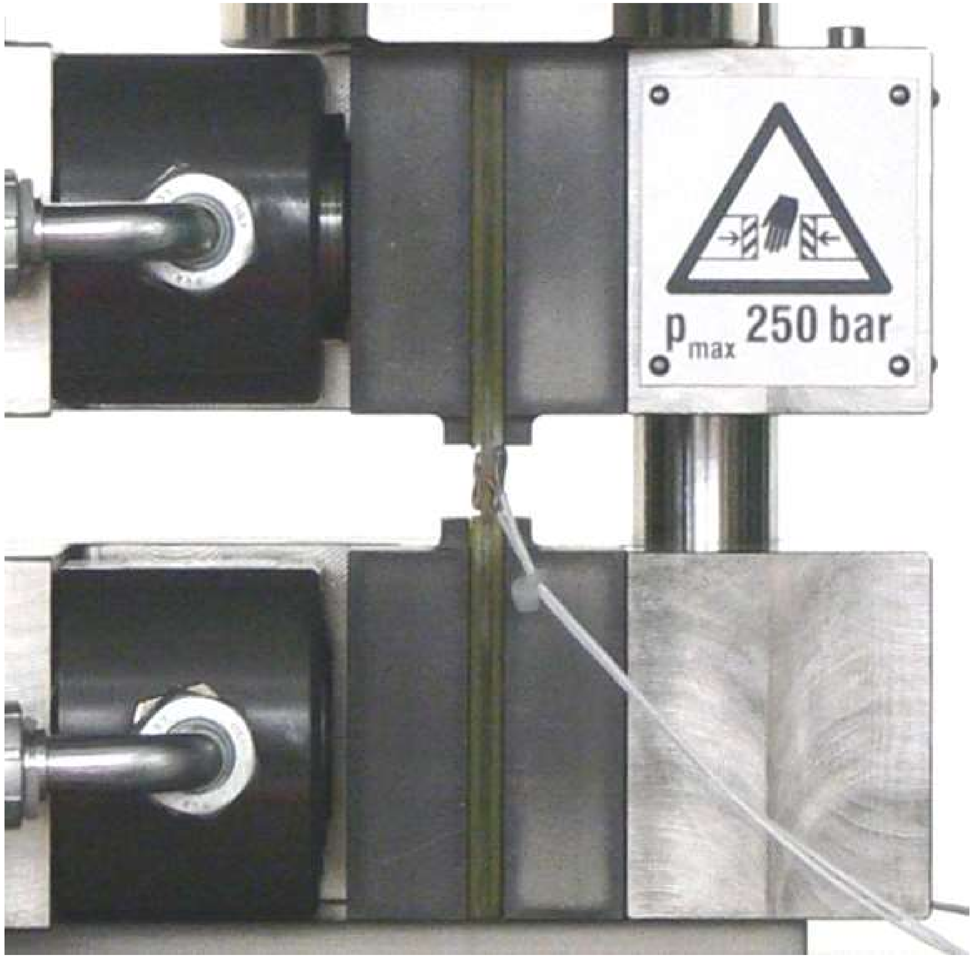
Contents

Electro-mechanic Allround-Line testing machines fit perfectly for compression tests.

- 50 kN is normally sufficient for tests according to ASTM D 3410, ASTM D 6641, ISO 14126, EN 2850 where the specimen width is 12 mm (1/2 in) or even less
- 130 kN may occur when testing multidirectional laminates to ASTM D 3410
- 180 kN may be needed for specimen types A1 according to AITM 1.0008, due to the standard specimen width of 32 mm.
- The test frame shall be well aligned and equipped with loadcell and two measurement channels for strain signals
- The test procedure is completely controlled by testXpert III software.

The strain can either be measured with a clip-on extensometer, or – which is most common – with two strain gages.

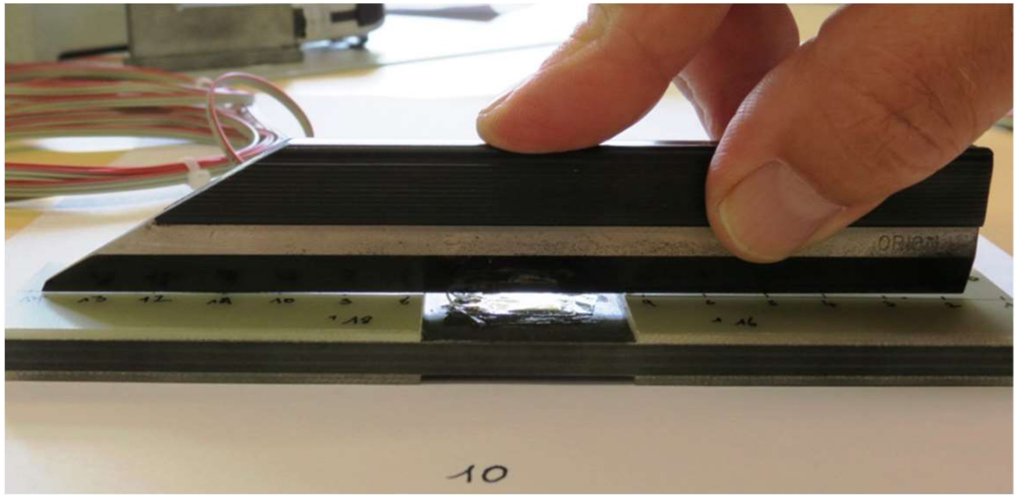
Double sided clip-on extensometer placed on a specific holder



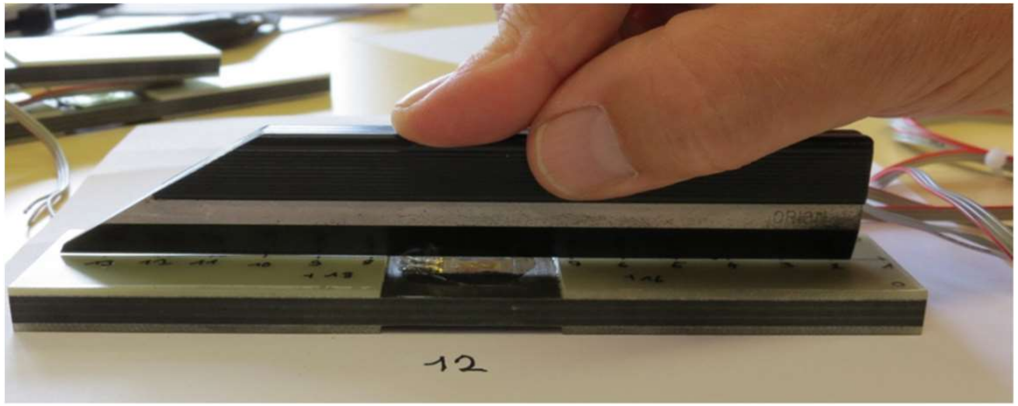
Two quarter-bridge strain gages applied to opposite sides

Compression tests are very sensitive to alignment. Most misalignment problems are due to tab thickness variations.

During the test, alignment can be supervised by the signal difference between the strain gages.



Visible light at the left tab near the center.
Variations up to 200 µm.



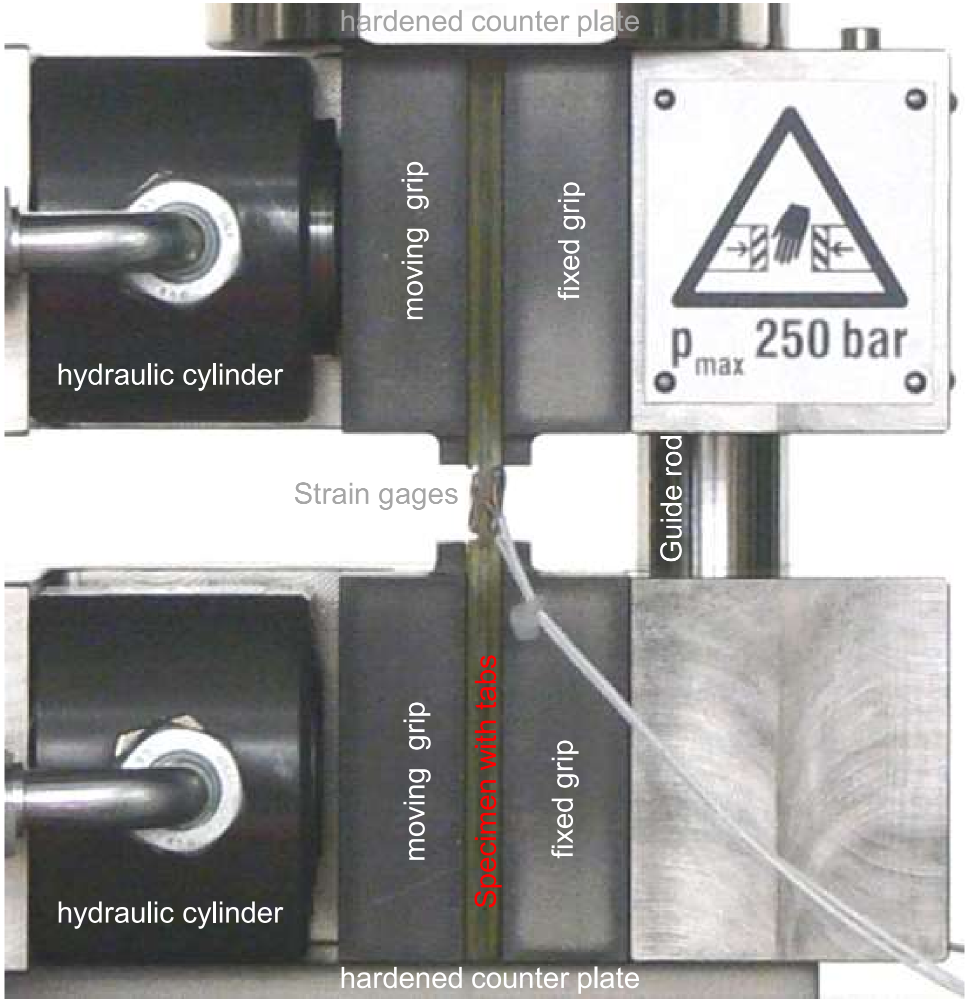
Visible light at the left tab, left side.
Variations up to 227 µm.

Typical procedure – combined loading

The HCCF allows to check and adapt alignment after first clamping, but before test load apply.

General test procedure with HCCF:

- Connect the strain gages to the test machine
- Zero the strain gages in free hanging position
- Zero the load signal
- Install the specimen into the HCCF, grips are slightly opened
- Approach a small preload to bring the specimen ends into contact with the HCCF's counter platens
- Close the grips by hydraulic pumps
- Supervise the absolute bending, which is the signal difference of the strain gages
- If bending is higher than 150 microstrains, adapt alignment by clamping pressure or re-open the grips and adapt with paper spacers.
- Run the test until break
- Verify percent bending and break type



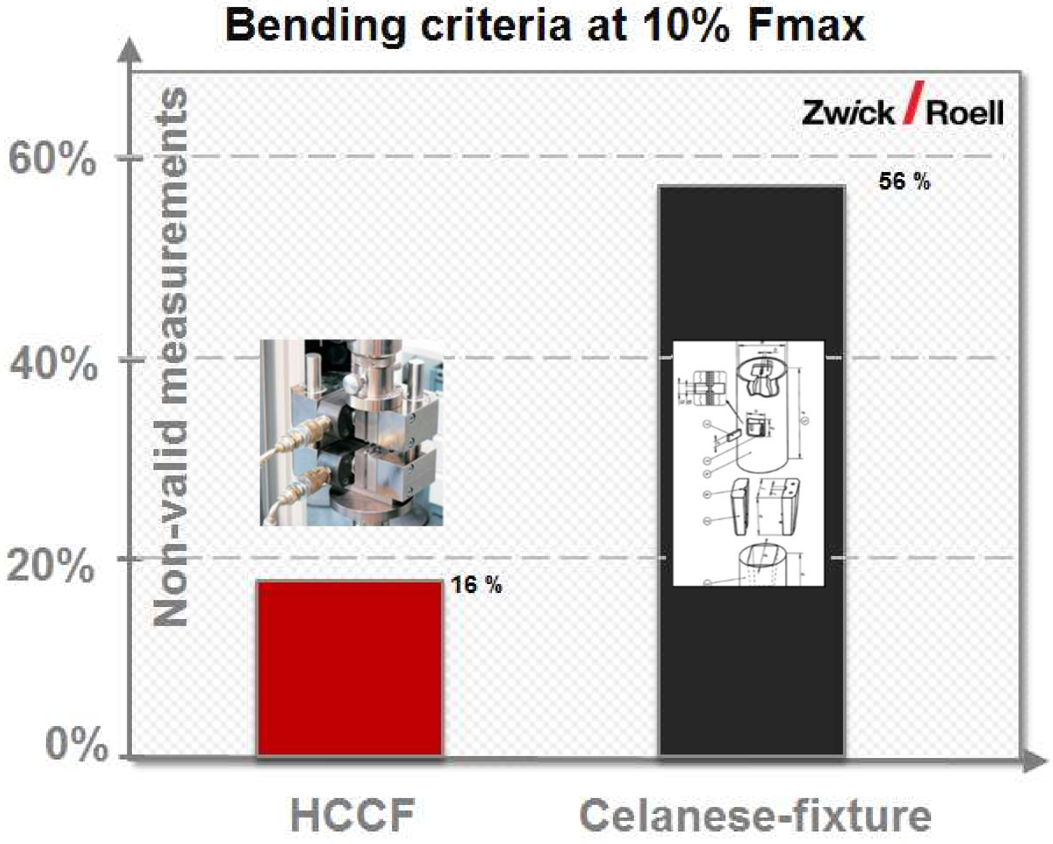
Compression tests, CRC

Case study: The number of valid test was significantly increased by the use of the HCCF compared to a mechanical Celanese-type fixture.

Test conditions

- Test piece according to compression standard prEN 2850
- Geometry A1 (10 x 2 mm)
- 18 measurements per each fixture
- Load introduction by shear loading via the tabs.

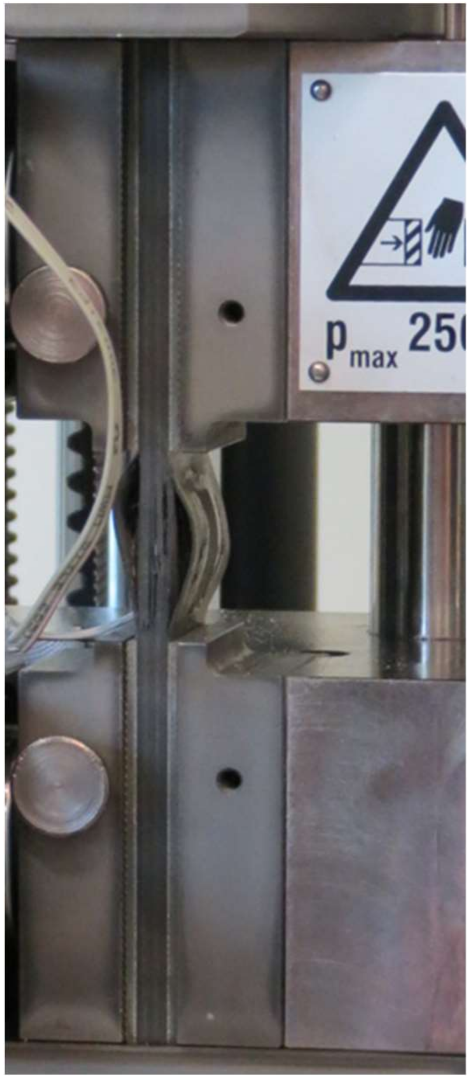
Aim: Assessment of the bending criteria at 10%F_{max}

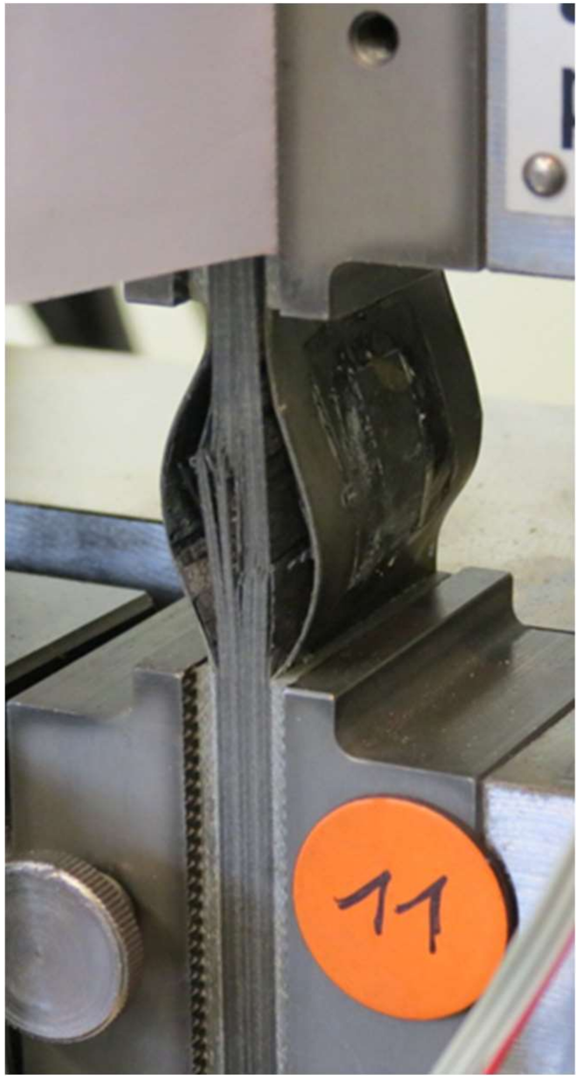


16% of the tests with HCCF were not valid, while 56% of the tests performed with a Celanese wedge-type fixture were not valid.

Examples of obtained break types

Compression tests according to AITM 1.0008





Examples of obtained break types

Compression tests according to ASTM D 6641, CFRP

Examples of obtained break types

Compression tests according to ISO 14126, GFRP

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Thank you !

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Fiber-Reinforced Polymer Matrix Composites