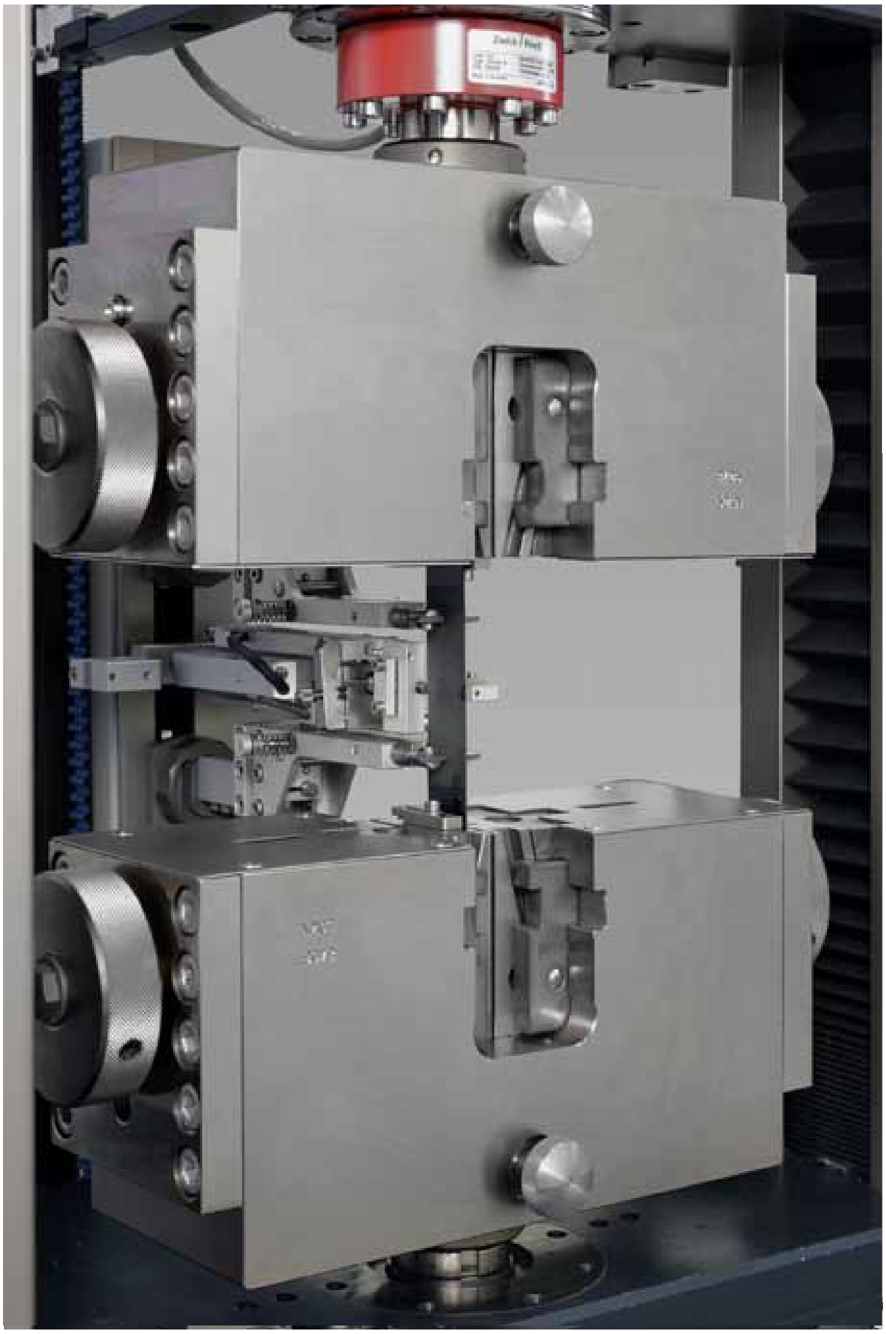
Zwick / Roell

Testing systems

Testing Machines and Systems for Composites

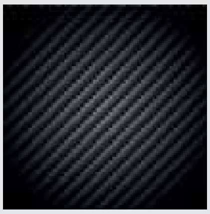


FP 824.2.10.12

Intelligent Testing

Zwick Roell

The Zwick Roell Group



Fiber-reinforced Composites

Products and Services for Composites Testing

Overview of Standards

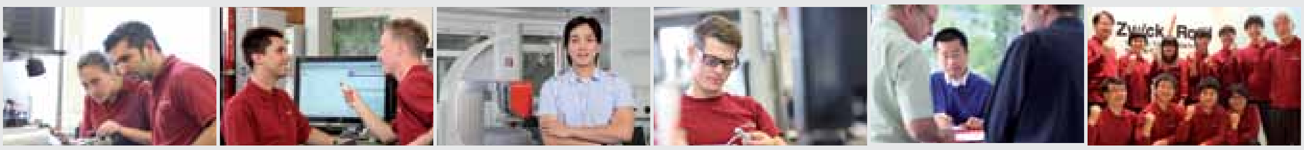
Zwick Roell – with passion and expertise

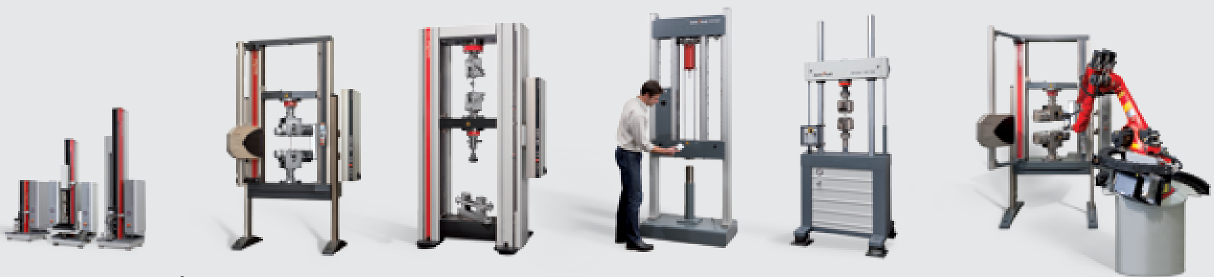
‚Passion in customer orientation!' Ask what our company philosophy is and that is our reply. Proof that these are not just empty words can be found in the fact that over a third of our employees are engaged in service and support.

As a family-run company with a tradition going back 150 years we attach great importance to honesty and fairness. Over the years a spirit of close collaboration based on mutual trust has developed between our customers, partners, suppliers and employees - something we all value highly.

Fig. 1: „Global loops" center square at Zwick headquarters in Ulm, Germany

The foundation for a successful partnership: innovative employees, innovative products!





Always at your service

Our headquarters in Ulm alone have over seven hundred employees, many having been there for years or even decades. Their knowledge, skills and commitment are the reason behind the Zwick/Roell Group's worldwide success.

More than 30% of our staff work in service and support. When our customers need us, we are there - in over 50 countries around the world.

The right solution

We can supply the right solution – for both static materials testing and for the various forms of fatigue testing. We have solutions for hardness testing, for impact testing and for melt index determination.

And if a solution turns out not to be right, our experts will find one that is, from the smallest adaptation to a fully automated testing system.

Zwick Roell – your dependable partner for composites testing

System-based testing solutions
The last few years have seen the evolution of the world's most comprehensive composites testing system here at Zwick – the product of experience and commitment to the task in hand. Despite the complexity of the subject, the modular design of the testing equipment combines ease of operation with a wide range of reconfiguration options to cater for different types of test. This enables reliable, perfectly accurate results which can be used with confidence.

A useful by-product of this modular approach is that our testing machines can easily be retrofitted for new types of test years into the future.

Specialists & standards
Around 100 employees in Zwick's development departments design testing machines, instruments and software packages in line with the requirements of current standards.

Specialists in our Applications Test Laboratories test new products and carry out tests for our customers to verify the suitablility of the equipment for the types of test it is required to perform.

Zwick is closely involved in the development of standards at national and international level through the ten or so Zwick employees who serve on various standards committees, covering areas such as testing machines, aviation, plastics and fiber-reinforced composites.

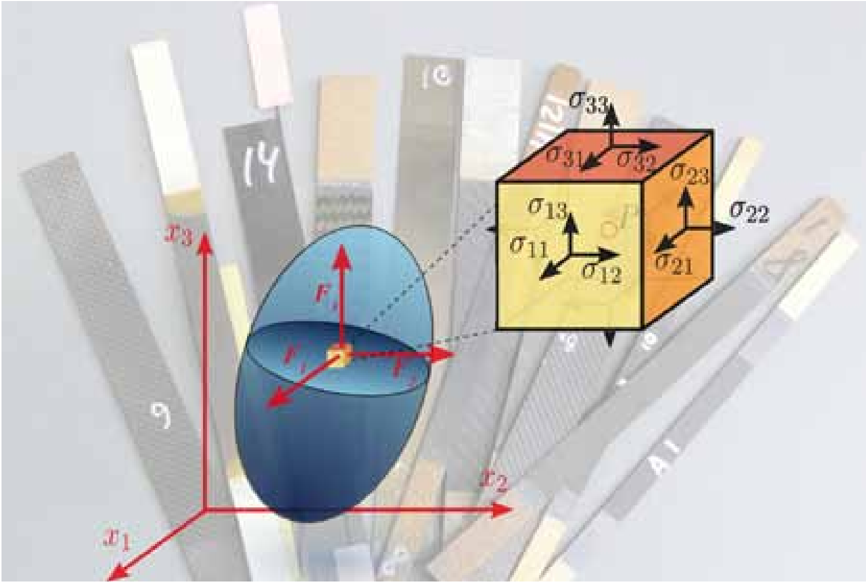


Fig. 1: Zwick products charaterize composite materials in all normal and shear directions.

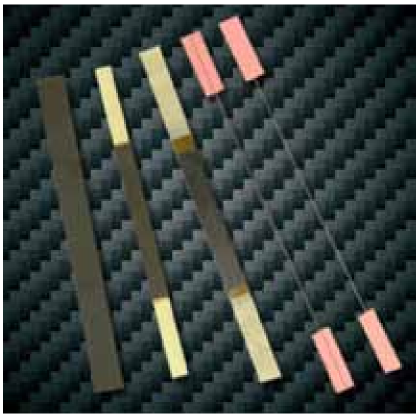
Product quality
Machines used for testing brittle materials are subject to stringent requirements with regard to the quality of drive and guide components, axiality, absence of play and, in the case of compression tests, stiffness.

Modern production methods, experienced staff

Zwick turns out testing machines from a 7000 m² production facility at its Ulm (Germany) site using the latest manufacturing techniques. Modern equipment combined with assembly by an expert and highly experienced workforce ensures consistently high quality. A large number of our employees have been with the company for many years and in some cases are the second or third generation of their family to work at Zwick.

Fig. 2: Zwick´s products are accordant to all established standards.

Calibration and alignment - where it really matters
All testing equipment is calibrated to current ISO standards at Zwick before delivery. This ensures that all sensors measure correctly. In the case of machines which are used to test brittle materials such as unidirectional fiber-reinforced composites, ceramics or brittle metals, an alignment check plus adjustment can additionally be carried out.



Testing fiber-reinforced composite materials

Fiber-reinforced composite materials exhibit orthotrop and in their range of use mainly elastic behavior. Consequently stress-strain behavior is usually measured in all normal and shear directions.

Standardization has produced a range of methods which describe the material in a wide range of loading situations.

Performance of these tests requires precision fixtures and accurate force application with excellent alignment, achieved by means of special alignment fixtures.

The right load frame and fixture for every test: Zwick's extensive range of fixtures covers the whole materials characterization spectrum for composite materials. Two work spaces minimize the need for fixture changements.

Tensile tests on fibers and fiber tows

Tensile tests on unidirectionally reinforced materials such as pultruded rods or resin-impregnated fibre tows require a great deal of experience in the selection of a suitable clamping fixture.

In many cases the specimen must be protected by tabs to avoid premature fiber breakage in the clamped area. However there are solutions which avoid the use of these tabs and the associated extra specimen preparation, achieving genuine efficiency savings.

Zwick has an extremely large range of specimen grips and jaw inserts. In the Zwick Applications Test Laboratory in Ulm can be carried out pre-tests on your specimens to determine the optimum machine configuration.

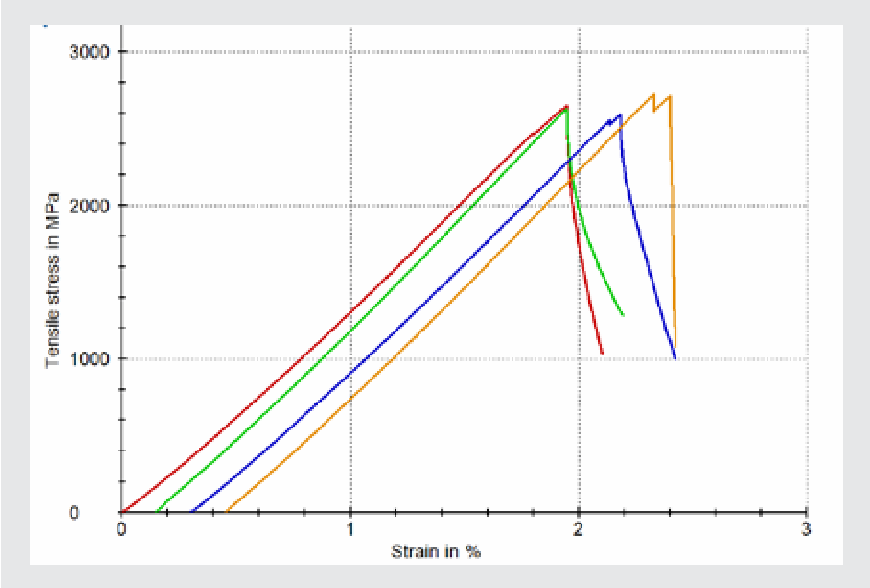


Fig. 2: *testXpert*® II ensures the correct test sequence – completely automatically

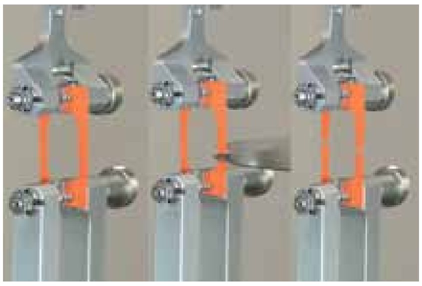


Fig. 3: Single filaments are clamped in a paper mounting

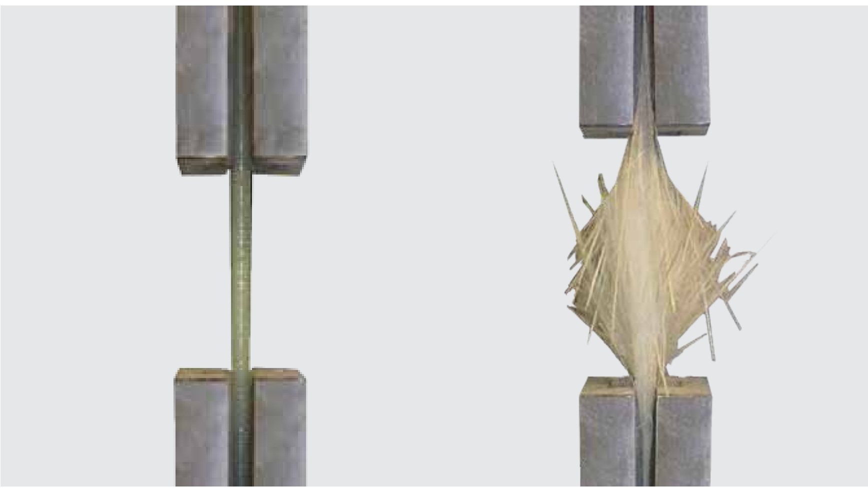


Fig. 1: Valid fiber failures in the free length between grips achieved by soft load application.

Fig. 4: Resin-impregnated carbon fiber tows under test

Plain tensile tests, open and filled-hole tensile tests on laminates, OHT, FHT

Tensile tests on unidirectional laminates require perfect testing machine alignment, the right specimen grips and accurate extension measurement.

Multidirectional laminates are currently tested with specimen of larger cross-sections. These materials are less sensitive to misalignments due to their typical higher plastic deformation.

Zwick provides solutions for many different requirements: simple mechanical wedge grips, or versatile wedge-screw and hydraulic grips with connecting system for compression, flexure and shear test fixtures.

Signal conditioners and electronics for measurements with strain gages, clip-on extensometers and user-friendly, damage-resistant mechanical and optical extensometers figuration are available for strain measurements.

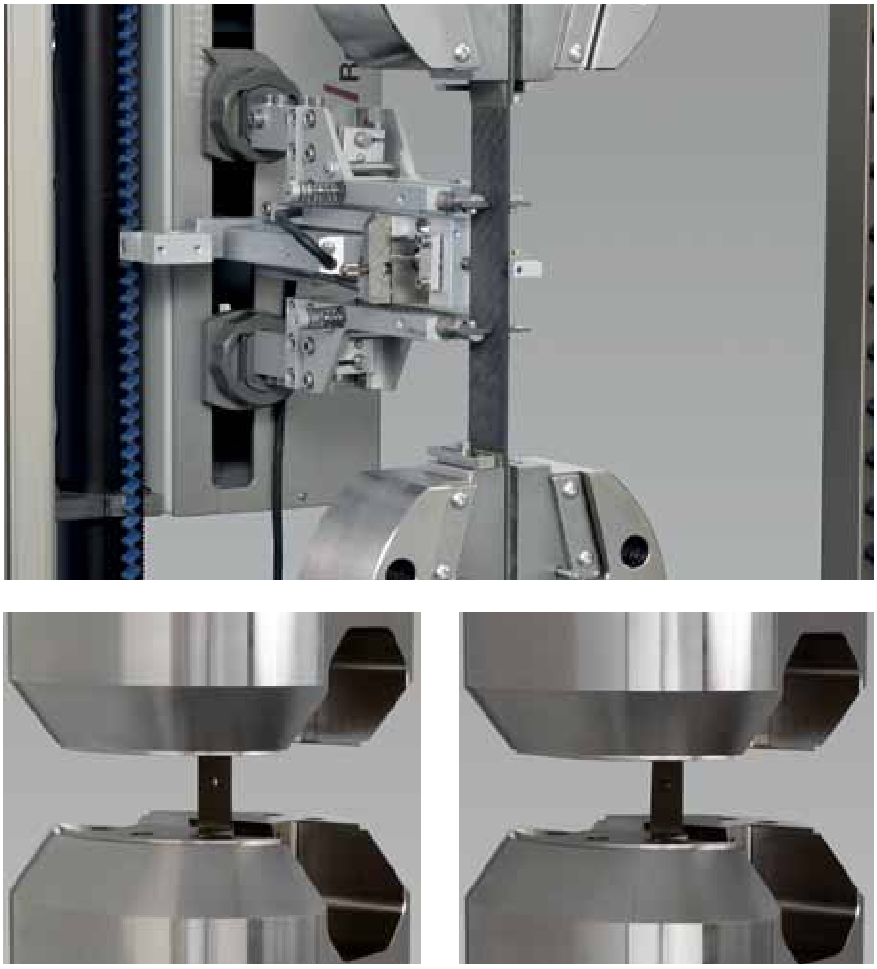


Fig. 2: Tensile tests are performed as plain tensile in fiber direction (0°), perpendicular (90°), and on multi-directional laminates also as open-hole tensile (OHT) or filled-hole tensile (FHT) tests.

Fig. 1: Centrically closing wedge grips, laterally adjustable wedge-screw grips and hydraulic wedge grips with a wide range of jaws are available for testing all kinds of laminates.

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Compression tests, OHC, FHC

Various types of compression test, each with its own specific fixture, have been developed over the last four decades.

These fixtures are usually distingished by the type of compression loading employed.

End loading between two compression platens is simplest as far as the fixture is concerned, but calls for a high level of accuracy in machining the specimen ends. The method delivers reliable compression modulus values but often results in premature failure and therefore in low maximum compressive strengths.

Shear loading is very well suited to measuring higher strengths. Older ASTM standards define the Celanese compression test fixture, which was however extremely sensitive to variations in specimen thickness. The EN standard solved this problem by using flat wedges in place of cones in the grips.

Fig. 2: End-loading compression test fixture to EN 2850 and ASTM D 695 (modified Boeing). The support block is centered to the compression axis by end stops.

The HCCF manufactured by Zwick represents a significant improvement. The parallel hydraulic gripping principle prevents jaw movements during the test, giving a higher proportion of valid tests. The HCCF can be used for shear loading under lower forces and in combined shear/end loading for high forces. It is also suitable for open and filled hole compression tests (OHC, FHC) to the Airbus standard.

In 2011 the HCCF was approved by Airbus for tests to AITM 1.0008.

A mechanical variation of a combined loading fixture is represented by the compression test fixture to ASTM D 6641.

Fig. 1: Celanese compression test fixture to historical ASTM standard

Fig. 3: IITRI compression test fixture to current ASTM standard

Fig. 4: Combined loading compression test fixture to ASTM D 6641 (© Wyoming Test Fixture Inc.)

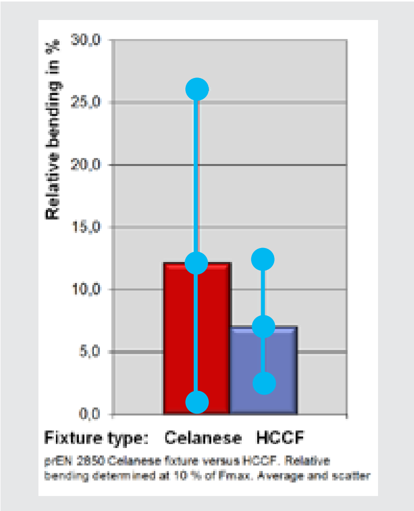

Fig. 1: Significantly improved bending and reduced measured-value scatter with the HCCF

Fig. 3: The HCCF - Hydraulic Composites Compression Fixture - is used for shear loading and combined loading

Open-hole (OHC) and filled-hole (FHC) compression tests to ASTM standards are carried out on long specimens using anti-buckling guides.

Zwick offers reliable strain measurement via strain gages or accurately guided double-sided clip-on extensometers to fit with the HCCF.

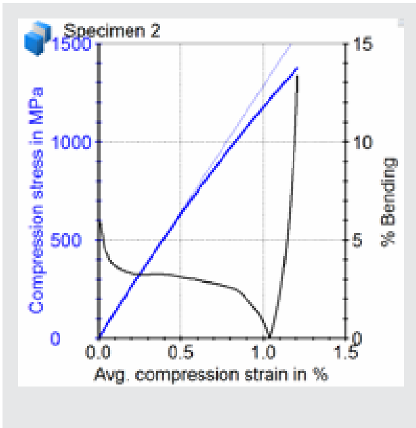

Fig. 4: *testXpert*® II stress-strain diagram with monitoring of relative bending

Fig. 6: Various standards permit strain measurement using clip-on extensometers

Fig. 2: The HCCF is also suitable for open-hole compression tests to Airbus standards

Fig. 5: OHC and FHC compression tests to ASTM require an anti-buckling guide, used both in shear loading with hydraulic grips and in end loading between compression platens

Compression after impact (CAI)

With adjustable drop-height to 1m and integrated speed measurement at the impact point, the HIT230F drop-weight tester is perfectly matched to the requirements for pre-damaging CAI specimens.

The modular weight set enables exact adjustment of impact energy, while a special device prevents multiple impacts. The 16 mm-diameter indenter is instrumented and generates a force-travel diagram via the user-friendly *testXpert*® II testing software, providing information about the damage sequence and the Mode II energy release rate.

Residual compressive strength is determined in a subsequent compression test. For ISO, EN and Airbus standards the specimen is clamped at the upper and lower end. ASTM, DIN and Boeing standards require the specimen to be guided at its four edges only.

Strain gages are applied to monitor bending and buckling.

Significant characteristics obtained from this test are damage resistance and damage tolerance.

Fig. 1: HIT 230F drop-weight tester with accessories for CAI pre-damaging

Fig. 3: The CAI specimen is securely held in the drop-weight tester

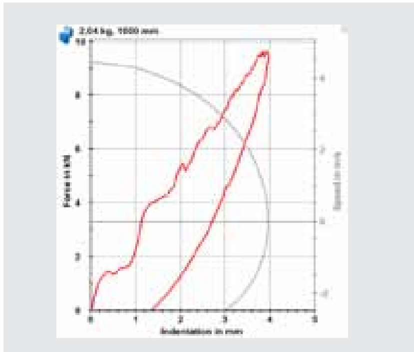

Fig. 4: The instrumentation provides a force-travel-speed diagram

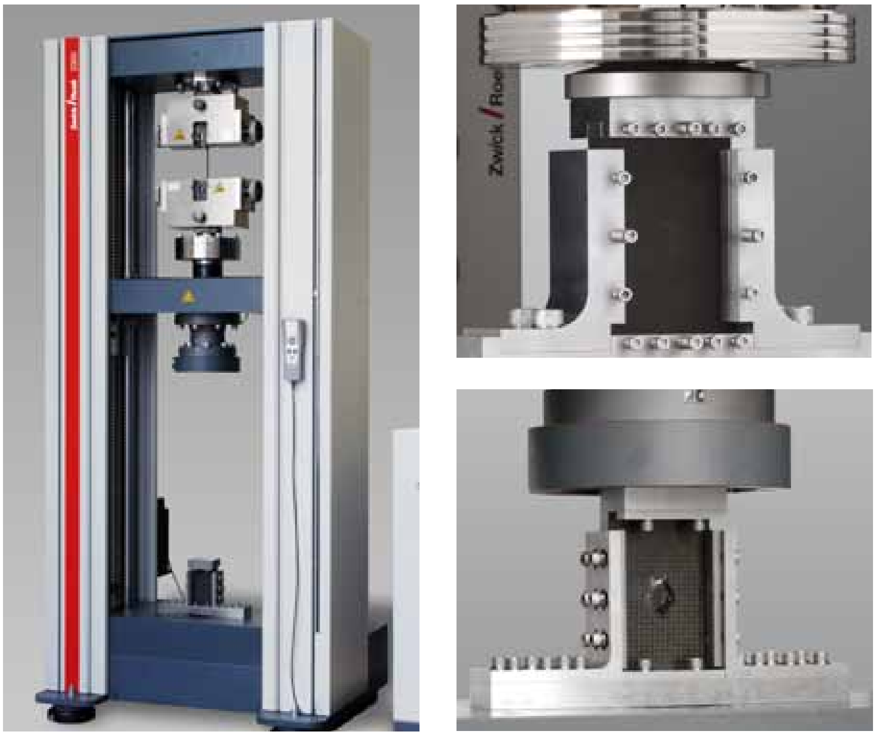

Fig. 2: The residual compressive strength of the specimen as determined in the compression test represents its damage tolerance (lower: compression fixture as per ASTM, DIN, Boeing; upper: compression fixture for ISO, EN, Airbus)

In-plane shear (IPS) by the ± 45° tensile test

This shear test is performed using specimens with a fiber direction at ± 45° to the tensile axis.

This causes the fibers to be disrupted, so that that they slip past each other along their alignment during the tensile test, causing deformation of the matrix.

The shear deformations are determined by measuring longitudinal and transverse strain. Several solutions are available from Zwick for this:

- measurement using two strain gages
- measuring with a biaxial clip-on extensometer
- measuring with makroXtens plus a transverse strain extensometer.

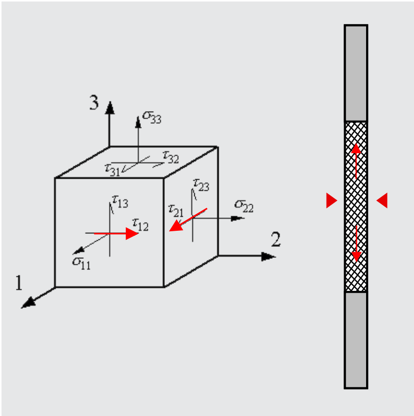

Fig. 2: The ± 45° layup-type of the laminate allows measurement of shear properties.

Fig. 3: Measuring shear strain using strain gages

testXpert® II displays the shear stress/shear strain curve in accordance with the standard and calculates characteristic values including shear modulus (G_{12}) and shear strength (τ_{12}).

Fig. 4: Measuring shear deformation with a biaxial clip-on extensometer

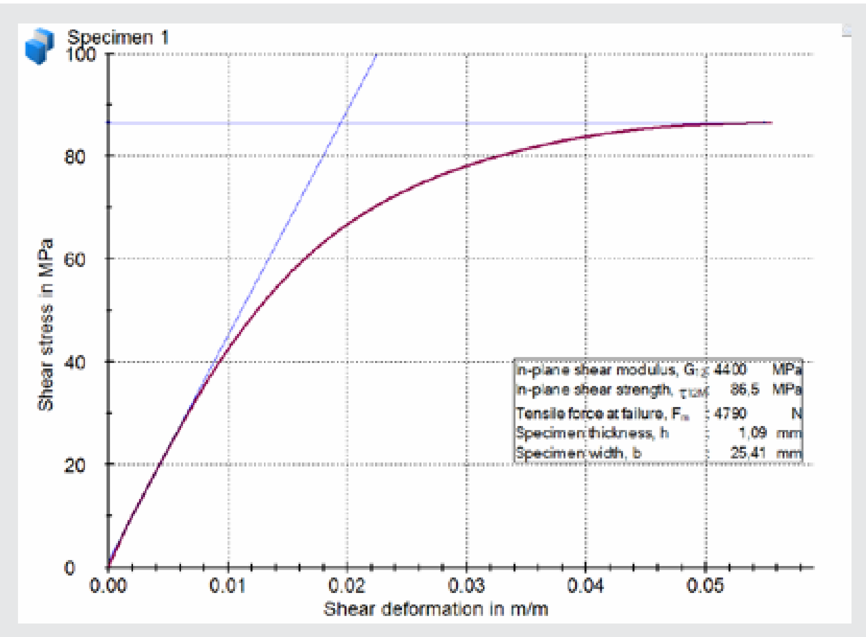

Fig. 1: Shear modulus is determined between two shear deformations, e.g. 0.1 % and 0.5% to ISO 14129 or 0.05% and 0.25% to prEN 6031 and AITM

Fig. 5: Measuring shear deformation in two planes using makroXtens

Lap shear test

This method is normally used for comparative measurements of the shear strength of adhesive joints or the bond between two layers of a laminate.

By using a high-resolution extensometer it is possible to measure shear strain if the thickness of the adhesive layer is known.

Accurate test results are achieved with exactly aligned mechanical, pneumatic or hydraulic grips. Jaws with a lateral adjustment facility are required for simple single lap-shear specimens.

Rail-shear test

ASTM includes additional methods for in-plane shear testing on unidirectional laminates and woven fabrics. These involve attaching test panels to rails.

The test measures shear stresses and strengths, shear strains (determined using strain gages) as well as shear modulus.

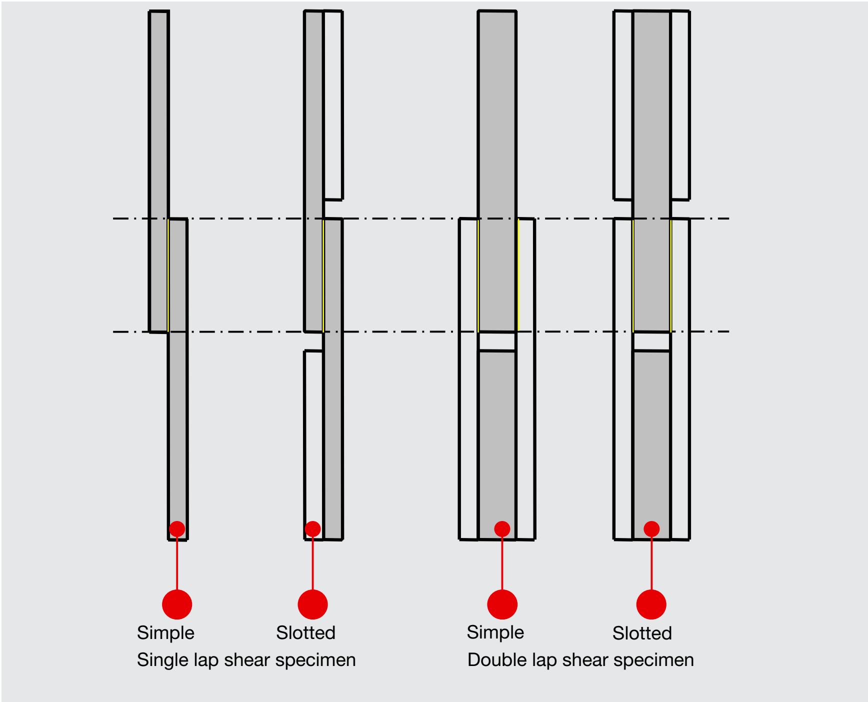

Fig. 1: Lap-shear tests are carried out on simple or slotted single or double-lap specimens.

Fig. 2: Specimen grips must have lateral adjustment capability for testing simple single-lap shear specimens (left). Right: slotted douple lap-shear specimen.

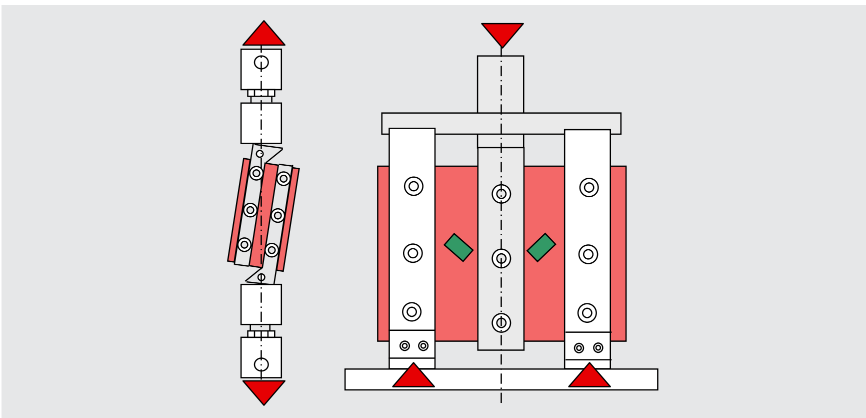

Fig. 3: Rail-shear method to ASTM D 4255. Left: two-rail shear for tensile test; right: three-rail shear for tensile or compression test

V-notch shear test

Shear properties of laminates made of unidirectional laminated or woven fabrics can be determined by means of the v-notch shear test.

There are two methods differing with regard to the size of the specimen and the type of load application. Specimens used in the v-notch rail shear test are larger and are clamped, whereas the Iosipescu method features loading applied to the specimen edges.

The notch ensures concentration of the shear stresses in the smallest cross-section. Shear strain is measured on this shear plane, using for example strain gages with short grid lengths.

The Iosipescu method includes axial guidance of the specimen holders, providing a shear plane virtually free of bending moments.

Fig. 2: V-notch rail shear test: exact alignment of fixture and specimen (left)

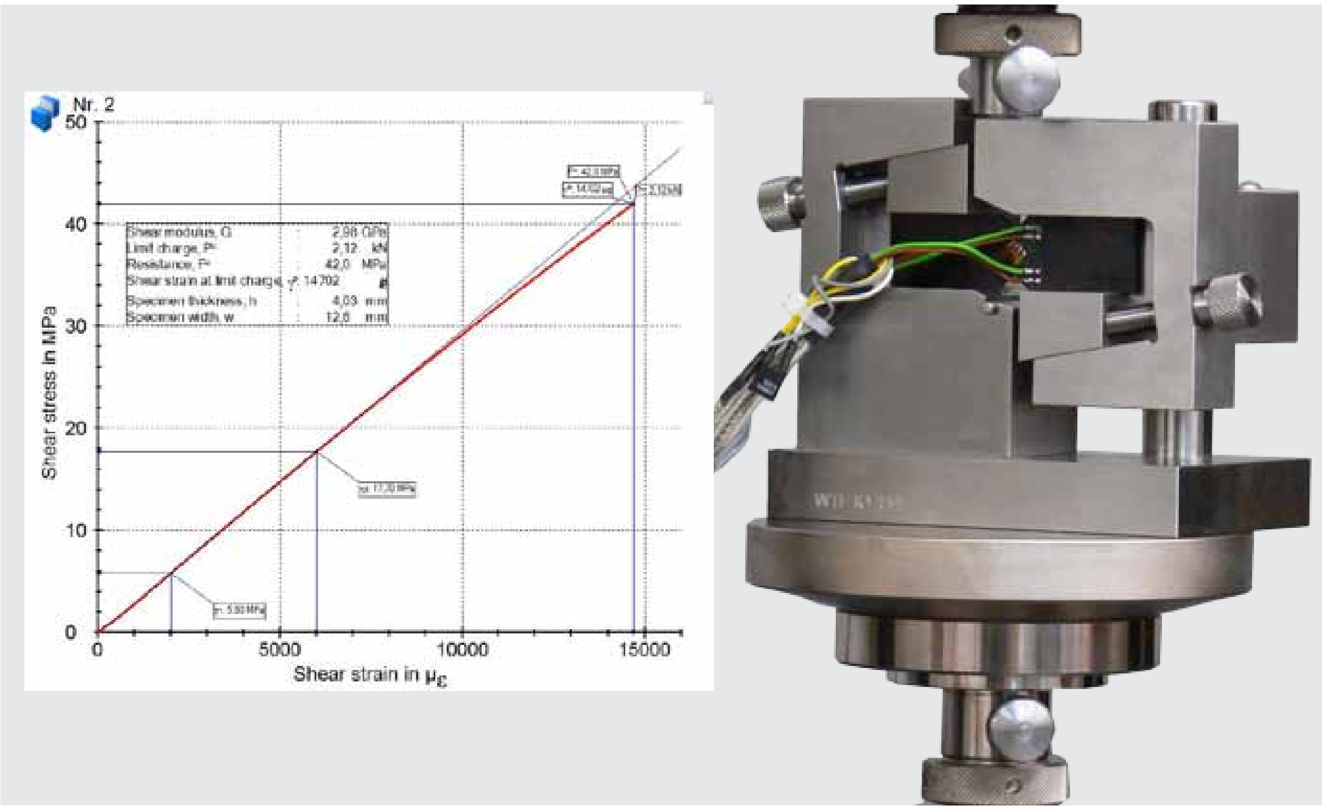

Fig. 1: Iosipescu method for the v-notch shear test. *testXpert*® II provides accurate determination of shear stresses and shear strains and of individual characteristic values.

Interlaminar shear strength (ILSS) using the short-beam shear method (SBS)

In this test the ratio of support span length to specimen thickness is low. As a result the specimen is subjected to a shear load and breaks.

The ILSS test fixture is designed for use over a wide range of temperatures.

Support and loading nose can be aligned exactly. A laterally positioned guide arm ensures exact centering; lateral movement for the first 0.5 mm deflection is only around 1 micron.

Reference surfaces located on the inner sides of the supports allow accurate monitoring of support span.

Various setting gages and lead-screw adjustment options are available to enable testing of different specimen thicknesses.

Standard	Loading nose, R	Support radius, r	Support distance, L	Centering accuracy
ISO 14130	5 mm	2 mm	5 h ± 0.3 mm	-
ASTM D 2344	3 mm	1.5 mm	4 h ± 0.3 mm	± 0.3 mm
EN 2377	3 ... 5 mm	2 ... 3 mm	5 h ± 0.1 mm	-
EN 2563	3 mm	3 mm	5 h ± 0.1 mm	± 0.02 mm
CRAG method 100	3 mm	3 mm	4 h ± 0.5 mm 5 h ± 0.5 mm	-

h = specimen thickness

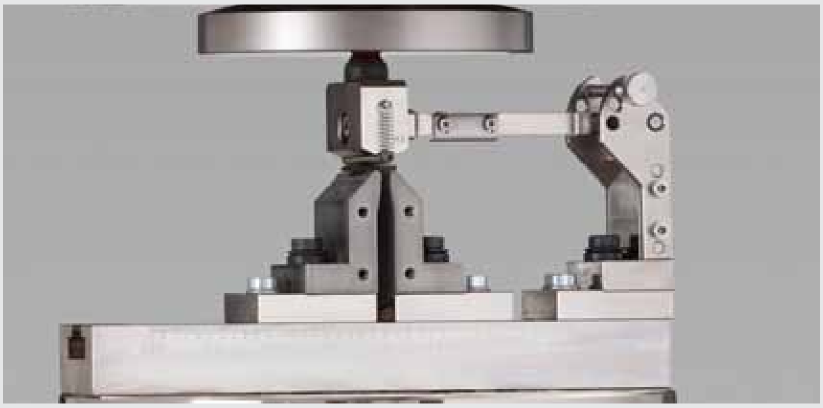

Fig. 2: ILSS fixture. The side-mounted upper-anvil guide-arm ensures exact central force application

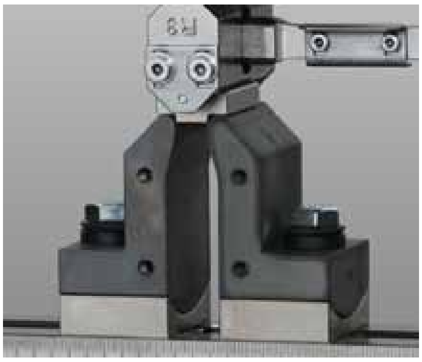

Fig. 1: Standard 10 mm setting gage for exact alignment

Fig. 3: Setting gage with variable support span

Fig. 4: Mounting a temperature sensor close to the specimen

Flexure test

3-point and 4-point flexure tests are performed with support spans of from 16 to 40 times the specimen thickness to ensure that shear stresses remain negligible.

Flexural moduli and strengths are strongly influenced by the laminate ply-stacking and therefore do not correlate with the tensile properties obtained.

Standard	Method	Thickness, h	Loading nose, R	Support radius, r
ISO 14125	3-Point	≤ 3 mm	5 mm	2 mm
		> 3mm	5 mm	5 mm
	4-Point	≤ 3 mm	2 mm	2 mm
		> 3mm	5 mm	5 mm
ASTM D 7264	3-Point, 4-Point	-	3 mm / 0.125 in	3 mm / 0.125 in
ASTM D 790	3-Point	-	5 mm	5 mm
EN 2562	3-Point	-	12,5 mm	5 mm
EN 2746	3-Point	-	5 mm	2 mm

Deflections are generally determined using a clip-on extensometer. However, Zwick testing machines are equipped with a highly accurate deformation compensation system, which in many cases allows sufficiently accurate deflection measurement via the integral crosshead travel encoder.

The flexure test kits can be used over a wide temperature range (between -80°C and +250°C).

Fig. 1: Exact positioning of specimen via end-stops

Fig. 3: Loading nose and supports are aligned under load

Fig. 5: A special jig is used in the four-point flexure arrangement

Fig. 2: Three-point flexure test with indirect deflection measurement via crosshead travel

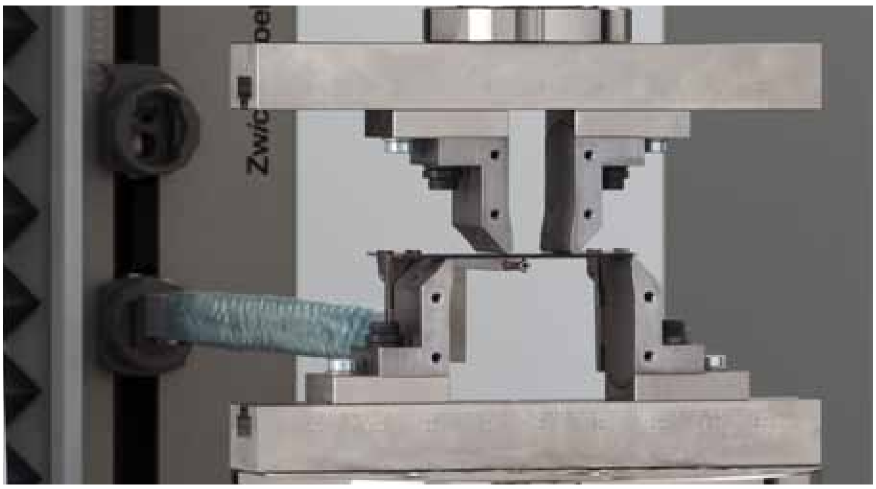

Fig. 4: F-point flexure test with direct travel measurement

Energy release rate (G) and fracture toughness (K)

The critical energy release rate (G_c) is defined as the energy per unit of surface needed to propagate a crack over a known distance.

Mode I – crack opening – is usually measured with a DCB (Double Cantilever Beam) arrangement and is described in many standards.

Mode II – in-plane shear – is frequently measured by the ENF (End Notch Flexure) method, using a 3-point or, less commonly, 4-point flexure setup. The ISO standard is based on the C-ELS (Calibrated End Loaded Split) method. Less common is the TCT (Transverse Crack Tension) method.

The Mixed Mode I/II Bending (MMB) method allows the setting of defined mode proportions and simulates the superimposed loads which occur frequently in practice.

In the case of matrix materials, Mode I stress intensity factor K_{IC} is usually determined.

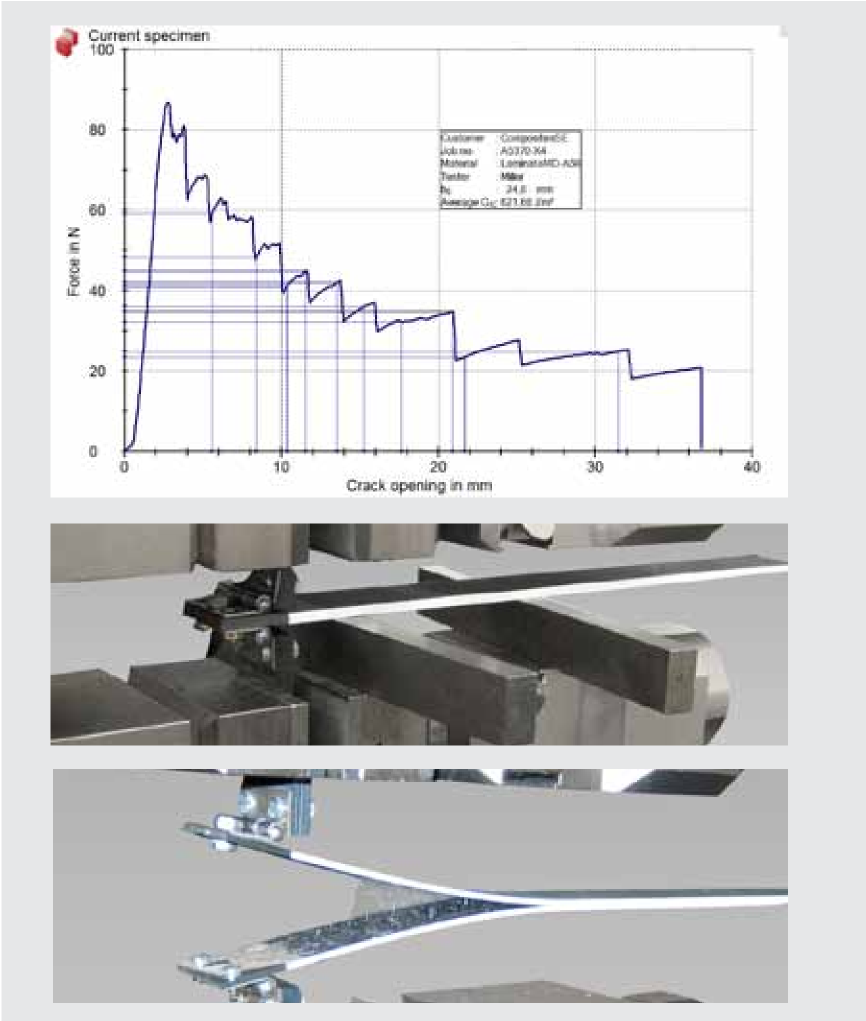

Fig. 2: Mode I energy release rate G_{IC}) in double cantilever beam (DCB) arrangement. Top: specimen alignment; bottom: bridging during the test

Fig. 1: Mode II energy release rate G_{IIC}, end notch flexure (ENF) method

Fig. 3: Adjustable Mode I / Mode II proportions in mixed mode bending (MMB) method

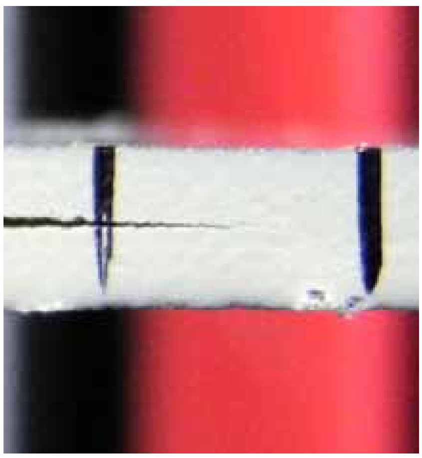

Fig. 4: The crack-propagation has to be closely followed.

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Pin-bearing strength and hole deformation

Evaluation of the load-bearing capacity of pin or bolted joints forms part of many standards and quality assurance instructions.

The choice of test arrangement is governed by the anticipated in-service loadings. Both single lap and double lap shear configurations are employed with a single or two-pin joint. The two-pin joint is used to determine bypass strength.

Methods also differ with regard to the type of joint, which may be a pin joint with a known clearance between specimen and retaining plate or a bolted joint with a known tightening torque.

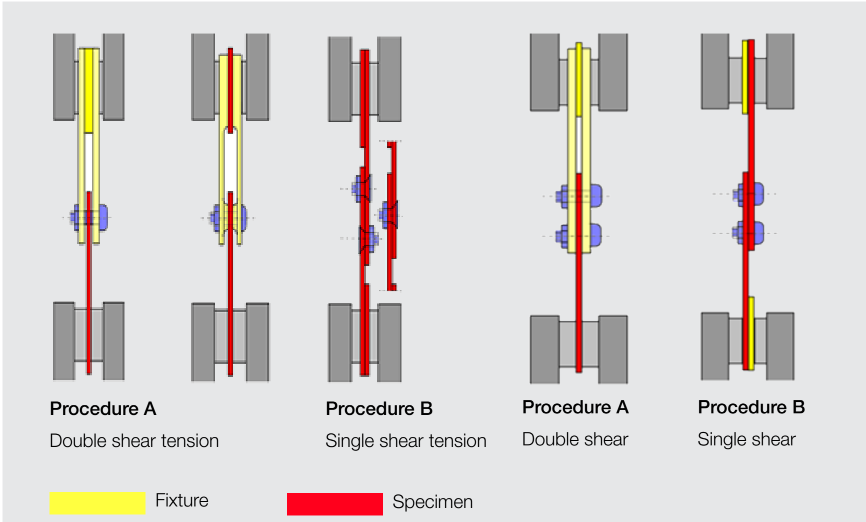

Fig. 2: Methods for measuring pin-bearing strength and hole deformation with direct and bypass loading

Hole deformation is measured using an extensometer attached between the retaining plate and the specimen.

Tests are usually performed in the tensile direction; compression tests are less common.

Ready-to-use testXpert II Standard Test Programs ensure exact compliance with the standard.

Fig. 1: Pin-bearing strength, single-shear, in compression test, Method B to ASTM D 5961

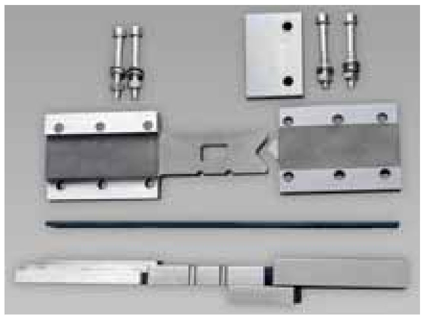

Fig. 3: Anti-buckling guide OHC-FHC according to ASTM

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Electro-mechanical testing machines

zwicki-Line
These high-quality, easy-to-operate single-column load frames were specially designed for mechanical tests involving test loads up to 5 kN.

In composites testing laboratories they are frequently used as an auxiliary machine to larger load frames to avoid the need to reconfigure the latter for various flexure, shear and adhesion tests.

ProLine range for simple testing situations
Many standard types of test involving shear or peel load do not require a high level of sensor equipment. In such cases a ProLine testing machine may represent the best option.

Table-top models - Allround-Line
Several different table-top machines are available for standard tests in a load range up to 150kN. They possess two columns constructed of patented aluminium hollow profiles. These are light, extremely rigid and act both as lead-screw guides and protection.

The Allround-Line table-top models can be provided with a free-standing support frame, enabling the test area to be positioned at the optimum height for the operator or the application. This allows the machine to be operated conveniently from a sitting position with completely free leg-space, making the system well-suited to operation by wheelchair-users.

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Floor-standing models - Allround Line
Floor-standing models with electromechanical drives are available in a load range from 100kN to 1200kN and are often used for tensile and compression tests on materials specimens or structural components.

The extremely stiff load frame design featuring two or four guide-columns ensures optimum conditions for exact alignment of test axes.

The load frames can be equipped with one or two test areas, while the lower crosshead can be supplied as a mounting platform for component testing. For torsion tests the load frame is equipped with torsiondrive plus testControl II and appropriate sensors.

***testControl* II – the measurement and control electronics for Allround-Line**

testControl II is 'Made by Zwick' and is therfore ideally equipped to cope with the demands of composite materials testing. The measured values from the sensors are scanned at a rate of 400kHz, then processed at 2000Hz. Combined with 24-bit signal resolution, this achieves optimum signal quality over the entire speed range.

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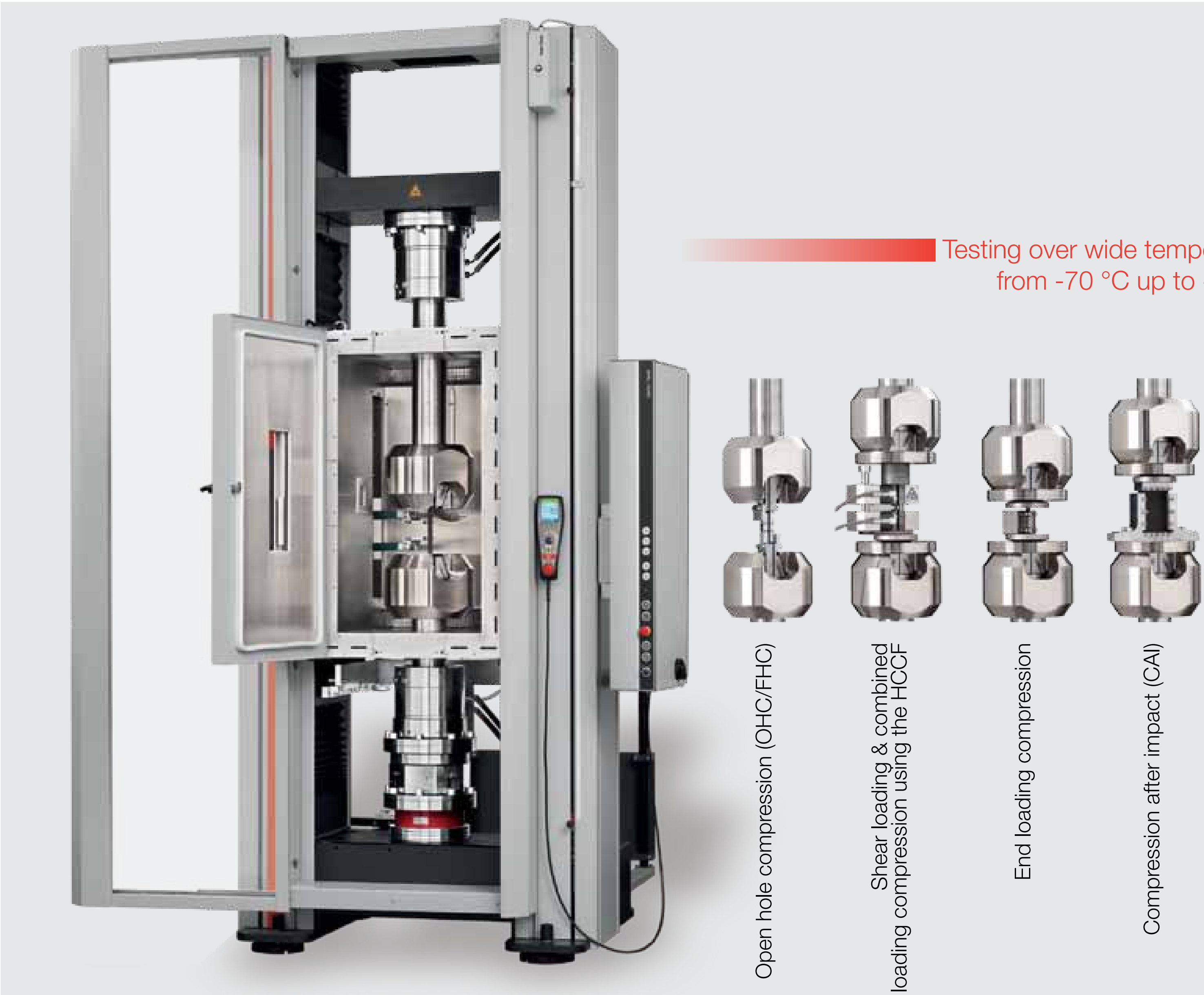
A modular concept for tests in temperature chambers

Composites used in aircraft are routinely subjected to temperatures of -55°C on the outer skin and over +200 °C in the vicinity of the exhaust plume. To reproduce this in tests, temperature chambers are available which can be moved on guide-rails into the test area of the Allround-Line load frame model if required.

Fixtures for the various tests can be connected to the hydraulic grips in use via mechanical adapters.

Variable load-frame
With the lowest possible load-frame height, the available installation space is optimized. Rigid flange connections to the specimen grips ensure good lateral stability, enabling compression tests involving higher loads. Provision is made for optional installation of an alignment fixture to ensure exact straightness of the test axis for alignment-sensitive tests.



Tensile, OHT, FHT, load bearing, lap shear, in-plane shear (IPS)

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21 types of test, 115 standards
The modular testing system covers all the principal standard tests on fiber-reinforced composites:
- plain tensile tests
- open-hole tensile (OHT) and filled-hole tensile (FHT)
- in-plane shear tests (IPS)
- interlaminar shear tests (ILS)
- compression tests
- open-hole (OHC) and filled-hole (FHC) compression tests
- v-notch shear tests
- load bearing tests
- CAI compression tests

320 °C temperature range
Grips, fixtures and temperature chamber are standardized designed for a temperature range from -70 °C up to +250 °C.

Further tests at ambient temperature
Withdrawing the temperature chamber allows additional tests requiring a smaller load cell:
- three-point and four-point flexure tests
- measurement of energy release rates G_{IC} and G_{IIC}
- lap shear and in-plane shear tests at low forces.

erature range
+250 °C

Testing under ambient temperature

Interlaminar shear (ILSS)

Iosipescu V-Notch shear

V-notch rail shear

G_{IIC} Energy release rate

Flexural test (3-Point, 4-Point)

Mixed mode bending

G_{IC} Energy release rate

Iosipescu V-notch shear with extra load cell

Lap shear, 90° tensile, in-plane shear (IPS)

testXpert® II – intelligent and reliable - the new generation of materials testing software

In *testXpert®* Zwick has created a uniform operating concept for all applications - no matter whether quasi-static or dynamic tests are involved.

The advantage? Less time is needed to learn to use the software. *testXpert®* II users benefit from over 80 years' materials testing experience, with over 20,000 successful installations around the world.

Fig. 2: Over 20,000 successful installations worldwide - No. 1 materials testing software *testXpert®*

Simply ingenious
testXpert® II stands out for one thing in particular – its incredibly simple and intuitive operation. Expressive icons and a clear menu structure allow rapid orientation, with a significantly reduced familiarization phase.

Ready-to-use Standard Test Programs
Pre-programmed, ready-to use standard test programs are available for all established standards, simplifying getting started and ensuring that test sequence and result evaluation are in compliance with the standard.

Flexible Master Test Programs
Master test programs provide greater flexibility in generating test sequences and operating sequences, calculating results and creating reports. Each parameter can be set individually.

Testing
The individual data are shown on the screen - online with the test sequence. The test can be followed live. In addition, an exactly synchronized video recording can be integrated if required.

The results are actually calculated during the test, enabling the test sequence to be result-controlled, for example via a change in speed following determination of the tensile or compression modulus.

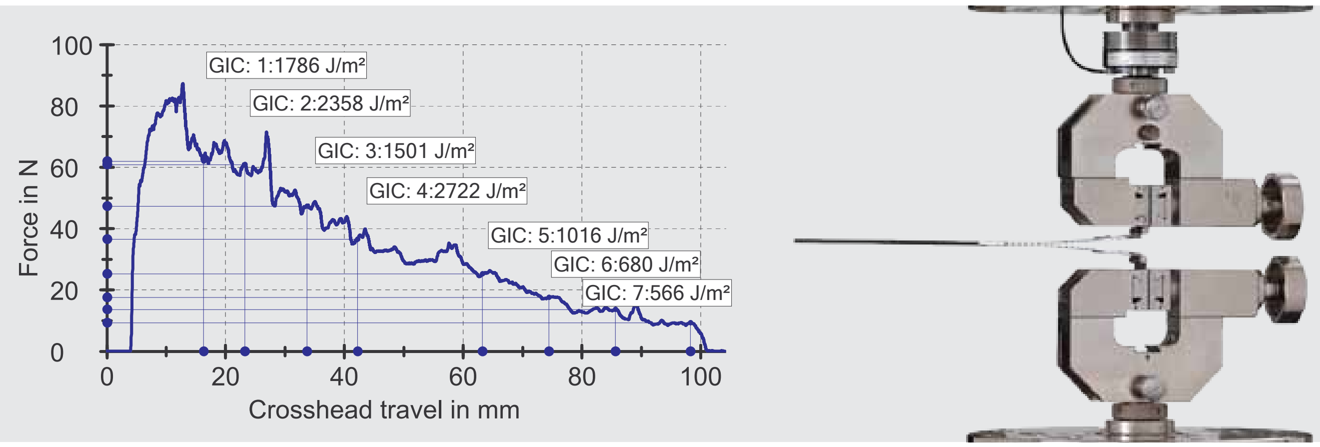

Fig. 1: The oprator is well guided through all test sequences by *testXpert®* II which also provides comprehensive protocolling functions.

Zwick / Roell

Automation

Qualification of new composite systems requires a comprehensive testing campaign.

Zwick is the automation specialist in testing technology and supplies proven systems with exceptional features.

'roboTest L' robotic testing system
This automated system operates with pneumatic vacuum grippers or claw grips. Up to 450 specimens are placed in magazines in stacks or compartments on a table. The specimen cross-section can be measured during the automatic sequence, while an integrated barcode-reader system is available for specimen identification.

'roboTest R' robotic testing system
This automated system is useful if several testing machines are integrated into a system, for applications in a temperature-conditioning unit and for tests requiring special specimen handling.

Advantages
- objectivity assured by operator-independent test results
- improved reproducibility
- expanded capacity via unmanned testing at night or at the weekend
- sorting of specimen remains
- documentation of failure types

Fig. 2: Robotic testing system `roboTest L`

Fig. 3: Robotic testing system `roboTest R`

Fig. 1: Fully automatic testing system with two load frames for tensile, OHT, FHT, IPS, lap-shear tests, ILSS, load bearing and flexure tests over a wide temperature range

HIT 230F drop-weight testers

The main area of application for this drop-weight tester is pre-damaging test panels of fiber-reinforced composites for the Compression After Impact (CAI) test, for example to ISO 18352, Airbus AITM 1.0010, Boeing BSS 7260, ASTM D 7136, EN 6038 or DIN 65561. Variants of the HIT 230 F are used for instrumented puncture tests.

Advantages
- simple, safe and reliable operation
- good accessibility
- variable damage energy setting
- integrated instrumentation provides accurate measurement of damage progression
- reliable prevention of multiple impacts
- actual impact speed monitored

Pendulum impact testers

Conventional and instrumented Izod and Charpy tests to ISO and ASTM standards in the impact energy range up to 50 joules.

Zwick supplies manual and automated testing solutions for a wide temperature range with operator-friendly *testXpert*® II software.

Fig. 1: The instrumented HIT 230F drop-weight tester is used for pre-damaging test panels for the CAI test. The force-travel diagram shows the damage progression.

Fig. 2. Pendulum impact tester HIT 5.5P

Hardness testing

Zwick has the right instrument for almost any hardness testing method.

Fig. 3. Barcol hardness tester

Load cells

Load cells must satisfy the most exacting quality requirements.

The basis for this is calibration to ISO 7500-1 or ASTM E4 performed in-house at Zwick. DKD, COFRAC or NAMAS re-calibration can be performed by our field-service engineers, ensuring that you can always rely on your testing machine.

But Zwick load cells can do much more than this.

Automatic identification combined with integrated zero-point and sensitivity adjustment ensure that any load cell can be used with any testing machine without repeated re-calibration.

Temperature compensation means that measuring is largely independent of the current ambient temperature.

Fig. 2. Every load cell is calibrated by Zwick as soon as it is put into service on a testing machine

This all takes place over an extremely wide measuring range, within Accuracy Class 0.5 or 1.

Xforce HP and P load cells offer a linearity better ± 1% already from 0.1 % of their full scale force.

Fig. 1: Load cells for the most exacting quality requirements at Zwick: left, a load cell from the Xforce range employing multiple beams; centre, Xforce HP model using the ring-torsion measurement principle

Zwick Roell Group
Fiber-reinforced composites
Products / Services
Standards

Precise strain and extension measurement

Strain gages are still widely used in the composites field. They can be attached directly to the specimen or act as the measuring element in a clip-on extensometer.

The measurement signals are acquired precisely, directly and synchronously by Zwick's testControl II measurement electronics.

Alternatively there are measurement amplifiers by HBM, e.g. the MGCplus, which are fully integrated into *testXpert*® II.

Fig. 2: Strain gages applied directly to the specimen

Fig. 5: Clip-on axial extensometer

Fig. 3: HBM measurement amplifiers are supported by *testXpert*® II

Fig. 6: Clip-on transverse strain extensometer

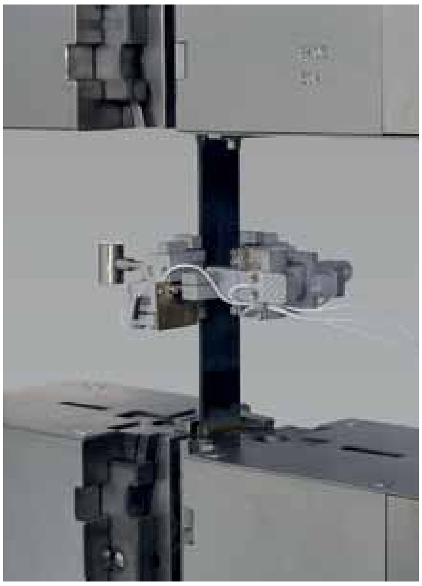

Fig. 1: The biaxial clip-on extensometer can be used at both high and low temperatures

Fig. 4: Direct connection of strain gages to testControl II via a ready-configured control box

Zwick / Roell

Fig. 1: Mechanical measurement, automatic attachment: makroXtens

Fig. 2: Tensile tests in temperature chamber, makroXtens with long feeler arms

Fig. 5: In-plane shear (IPS) at ambient: makroXtens with reduction-in-width monitor

Automatic extension measurement

Automatic extensometers using a mechanical or optical measuring principle simplify test preparation and performance.

makroXtens employs mechanical measurement and is used for many types of test. With a high resolution (up to 0.03 µm), it satisfies the enhanced additional requirements for modulus measurement in tensile tests to ISO 527-1. Its swiveling knife-edges provide reliable protection up to specimen break.

Zwick is the leading provider of non-contact extensometers. videoXtens tracks the displacement of multiple gage-marks via image analysis, while laserXtens generates a speckle pattern which acts as specimen markings.

Fig. 3: Three- and four-point flexure tests: makroXtens with feeler flexural

Fig. 6: Modulus determination, compression test

Fig. 4: Optical measurement with videoXtens

Fig. 7: Optical measurement with no markings: laserXtens

Zwick Roell

Exact alignment of testing machine and loading members

Testing machine alignment errors result in the introduction of non-axial specimen deformations. Especially with unidirectional (0°) reinforced composites this can have a significant influence on test results.

Zwick testing machines are precision manufactured, with guide components which satisfy the most exacting quality requirements.

Exact axial alignment of specimen grips and elimination of angular errors is achieved by accurate adjustment, performed by means of an alignment fixture.

The result of these adjustments is checked with a precision alignment gage which satisfies the requirements of ASTM E 1012, ISO/DIS 23788 and, for the aviation industry, Nadcap Audit Criteria AC7122.

Zwick supplies the necessary alignment fixtures and measuring equipment, together with alignment checks by trained, competent service technicians.

Misalignments generate peak-strains and lead to apparently lower resistance.

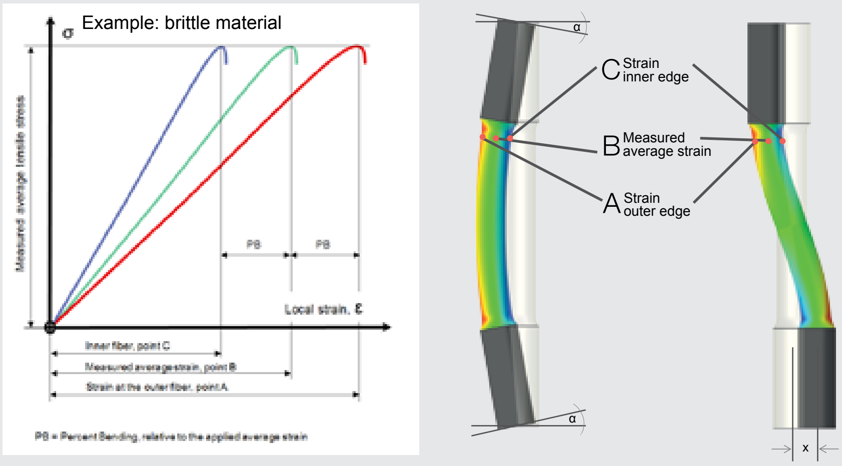

Fig. 2: Typical alignment errors, left: angular, right: concentric

Fig. 1: Testing machine alignment and verification by a Zwick technician using an alignment equipment in accordance with ASTM E 1012.

Services from start to finish. Zwick Service – support you can rely on!

Your testing system is in good hands with Zwick. In addition to our technical advisors, experienced applications technicians are there to provide expert advice, while our applications laboratories are comprehensively equipped with static and dynamic materials testing systems.

Zwick's service technicians guarantee successful, trouble-free commissioning – from preliminary acceptance and installation, through initial calibration, to instruction on hardware and software, including full safety briefing. Our service technicians also carry out the required annual inspection and calibration.

Our Hotline staff provide support on questions regarding both hardware and software malfunctions, while the Support Desk guarantees individual advice or rapid support via remote access.

Fig. 2: Zwick is active in over 56 countries worldwide with one aim – to provide first-class service

Repairs are carried out directly on-the-spot or at Zwick's premises, including 24-hour emergency spare part dispatch and individually tailored spare parts packages.

Training courses at the ZwickAcademy cover all aspects of materials testing, either in Ulm or at a location near to our customers.

Does the testing machine no longer meet the latest requirements? Zwick will be happy to modernize the testing system, leaving you with a machine once more conforming to state of the art in all respects.

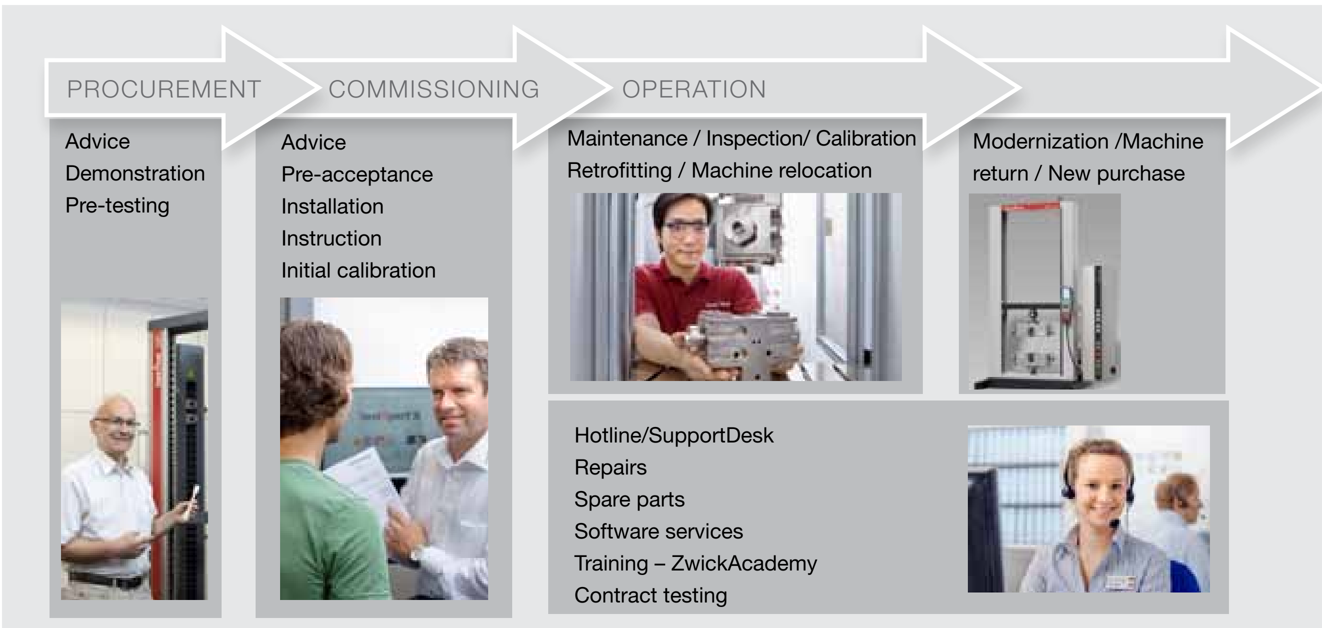

Fig. 1: Zwick provides continuous support throughout the entire life-cycle of materials testing systems

Subject	Standard	Test Equipment
Testing Equipment: Design, Verification, Accuracy, Alignment		
Tensile, compression and bending machines	DIN 51220, Airbus QVA-Z11-01-00, Airbus QVA-Z11-01-03	
Impact testing machines	ISO 13802, EN 10045-2, DIN 51230	
Verification of force-measuring systems	ISO 7500-1, -2, ASTM E 4	
Verification of extensometers	ISO 9513, ISO 5893, ASTM E 83	
Alignment of testing machines	ASTM E 1012, ISO/DIS 23788, Nadcap AC 7122/Annex A	
Environmental Conditions		
Humidity, moisture absorption	ASTM D 5229, EN 2489, EN 2823	
Influence of test fluids	EN 2489	
Preferred test temperatures	EN 2744	
Conditioning	EN 2743, SACMA SRM 11	
Sample Preparation		
Production of test plates	ISO 1268, ISO 9353, EN 2374, EN 2565	
Machining	ISO 2818	
Installation of bonded strain gages	ASTM E 1237	
Long-Fiber Reinforced Composites		
Guide for Testing Composite Materials	ASTM D 4762	
Tensile properties of single filaments	ISO 11566	Materials Testing Machine
Tensile properties of filament tows	ASTM D 4018	Materials Testing Machine
Tensile properties of pultruded rods	ASTM D 3916	Materials Testing Machine
Tensile properties of hoop wound cylinders	ASTM D 5450	Materials Testing Machine
Tensile properties of prepregs	DIN 65469, DIN 29971	Materials Testing Machine
Tensile properties of laminates	ISO 527-1, -4, -5, ASTM D 3039, EN 2561, EN 2597, DIN 65378, AITM 1.0007, Airbus QVA-Z10-46-34, Airbus QVA-Z10-46-36, Boeing BSS 7320, SACMA SRM 4R-94, SACMA SRM 9-94, TR 88012 CRAG Methods 300-303	Materials Testing Machine
Open- and filled hole tensile tests, OHT, FHT	ASTM D 5766, ASTM D 6742, AITM 1.0007, prEN 6035, SACMA SRM 5-94, NASA RP 1092 ST-3	Materials Testing Machine
Poissons ratio	ASTM E 132, ISO 527-4, -5	Materials Testing Machine
Compression properties of rods	ISO 3597-3	Materials Testing Machine
Compression properties of hoop wound cylinders	ASTM D 5449	Materials Testing Machine
Compression properties, End loading	ISO 14126 method 2, ASTM D 695, prEN 2850 B, DIN 65375, JIS K 7076, Boeing BSS 7260 - type III and IV, SACMA SRM 1R-94, SACMA SRM 6-94, RAE-TR 88012 CRAG Methods 400 and 401	Materials Testing Machine
Compression properties, Shear loading	ISO 14126 method 1, ASTM D 3410, prEN 2850 A, JIS K 7076, AITM 1-0008, Airbus QVA-Z10-46-38, RAE-TR 88012 CRAG Methods 400 and 401	Materials Testing Machine
Compression properties, Combined loading	ISO 14126 method 2, ASTM D 6641, ASTM C 1358, AITM 1-0008	Materials Testing Machine
Open- and filled hole compression tests, OHC, FHC	ISO 12817, ASTM D 6484, ASTM D 6742, prEN 6036, AITM 1-0008, Boeing BSS 7260 - Type 1, SACMA SRM 3R-94, NASA RP 1092 ST-4, RAE-TR 88012 CRAG Method 402, Northrop NAI-1504C	Materials Testing Machine
Compression after indentation	ASTM D 6264	Materials Testing Machine
Damage tolerance by compression after impact, CAI	ISO 18352, ASTM D 7137, prEN 6038, AITM 1.0010, Boeing BSS 7260 - type II, CRAG method 403, SACMA SRM 2R-94, DIN 65561, NASA RP 1092 ST-1	Falling Weight Impact Tester & Material Testing Machine
Puncture impact	ASTM D 7136	Falling Weight Impact Tester
Flexural properties of laminates	ISO 14125, ASTM D 790, ASTM D 7264, EN 2562, EN 2746, TR 88012 CRAG Method 200, HSR/EPM-D-003-93	Materials Testing Machine
Flexural properties of pultruded profiles and rods	ISO 3597-2, ASTM D 4476, EN 13706-2	Materials Testing Machine

Zwick / Roell

Subject	Standard	Test Equipment
Flexural properties of curved beams	ASTM D 6415, AITM 1.0069	
Interlaminar shear stress (ILSS),short beam shear (SBS) method	ISO 14130, ASTM D 2344, EN 2377, EN 2563, JIS K 7078, Airbus QVA-Z10-46-10, SACMA SRM 8-88, CRAG method 100	Materials Testing Machine
Short beam shear of pultruded rods	ISO 3597-4, ASTM D 4475,	Materials Testing Machine
In-plane shear properties, IPS, ± 45° laminates	ISO 14129, ASTM D 3518, prEN 6031, DIN 65466, JIS K 7079, AITM 1-0002, Airbus QVA-Z10-46-22, SACMA SRM 7-94, RAE TR 88012 CRAG Method 101,	Materials Testing Machine
In-plane shear properties , plate-twist method	ISO/CD 15310	Materials Testing Machine
In-plane shear properties, hoop wound cylinders	ASTM D 5448	Materials Testing Machine
Lap-shear properties	ASTM D 3846, ASTM D 3914, EN 2243-1, EN 2243-6, prEN 6060, DIN 65148, AITM 1.0019, Airbus QVA-Z10-46-09, Airbus QVA-Z10-46-01, CRAG method 102	Materials Testing Machine
Rail sheat properties	ASTM D 4255,	Materials Testing Machine
V-notch shear properties	ASTM D 5379, ASTM D 7078,	Materials Testing Machine
Load bearing response, Fastener testing	ISO/FDIS 12815, ASTM D 5961, ASTM D 7248, prEN 6037, DIN 65562, AITM 1-0009, AITM 1-0065, TR 88012 CRAG Method 700, SACMA SRM 9-89	Materials Testing Machine
Fastener pull-through resistance	ASTM D 7332	Materials Testing Machine
Load bearing response of pultruded profiles	EN 13706-2	Materials Testing Machine
Energy release rate G_{IC} DCB	ISO 15024, ASTM D 5528, prEN 6033, AITM 1.0005, AITM 1.0053, Boeing BSS 7273, Boeing BMS 8-276, ESIS TC 4, NASA method RP 1092 ST-5	Materials Testing Machine
Energy release rate G_{IIC} ENF	ASTM WK22949, prEN 6034, AITM 1.0006,	Materials Testing Machine
Energy release rate G_{IIC} C-ELS	ISO/DIS 15114,	Materials Testing Machine
Energy release rate, Mixed Mode G_I/G_{II}	ASTM D 6671	Materials Testing Machine
Fatigue properties of laminates	ISO 13003, ASTM D 3479, HSR/EPM-D-002-93	Servo-hydraulic Testing Machine
Bearing fatigue response of laminates	ASTM D 6873	Servo-hydraulic Testing Machine
Mode I fatigue delamination growth onset	ASTM D 6115	Servo-hydraulic Testing Machine
Hardness	ASTM D 2583, EN 59	Barcol Hardness Tester
Heat deflection temperature, HDT	ISO 75-1, -3, ASTM D 648	HDT Instrument
Creep properties	ASTM D 7737	Creep Instrument
Pendulum impact strength, Izod	ASTM D 256, ISO 180	Pendulum Impact Tester
Pendulum impact strength, Charpy	ISO 179-1, -2	Pendulum Impact Tester
Sandwich-, Core and Honeycomb-Type Composites		
Flatwise tensile strength	ASTM C 297, EN 2243-4, prEN 6062, DIN 53292, AITM 1-0025, Airbus QVA-Z10-46-04	Materials Testing Machine
Node tensile strength of honeycombs	ASTM C 363	Materials Testing Machine
Poissions ratio of honeycombs	ASTM D 6790	Materials Testing Machine
Flatwise compressive properties	ASTM C 365, ASTM D 5467, DIN 53291	Materials Testing Machine
Edgewise compressive properties	ASTM C 364	Materials Testing Machine
Shear properties	ASTM D 273, DIN 53294, Airbus QVA-Z10-46-06	Materials Testing Machine
Flexural properties	ASTM C 393, ASTM D 6416, DIN 53293, AITM 1.0018; Airbus QVA-Z10-46-31	Materials Testing Machine
Climbing drum peel test	ASTM D 1781, DIN 53295, Airbus QVA-Z10-46-05	Materials Testing Machine
90° peel test (T-Peel)	ASTM D 1876	Materials Testing Machine
Floating Roller Peel (Bell)	ASTM D 3167, ISO 4578, Airbus QVA-Z10-46-03	Materials Testing Machine
Flexure creep	ASTM D 480	Creep Instrument
Shear Fatigue	ASTM C 394	Servo-hydraulic Testing Machine