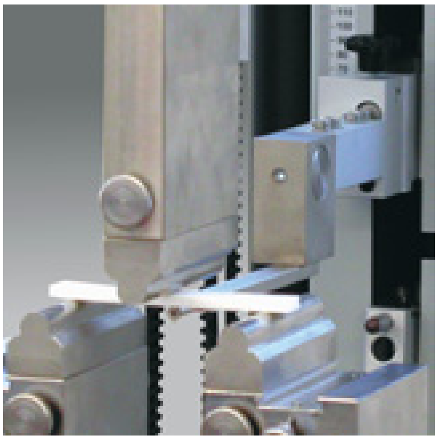
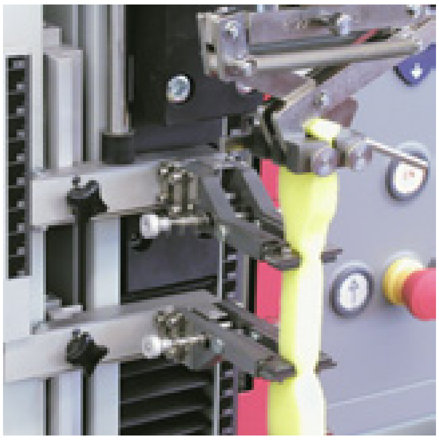
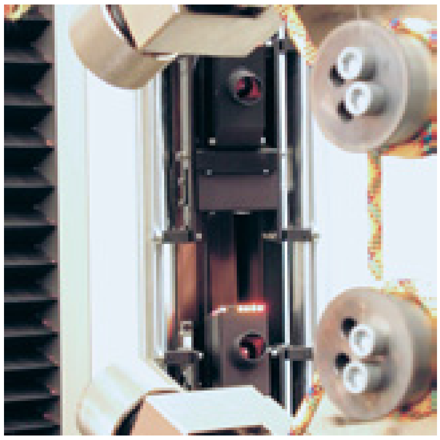
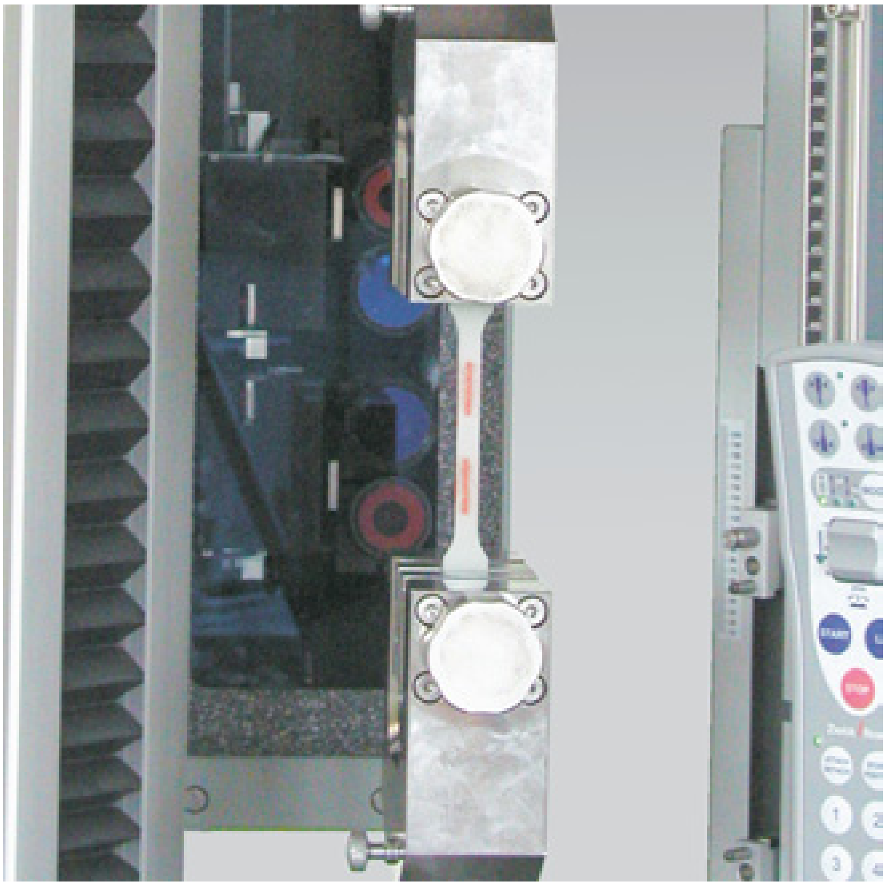
Zwick
Materials Testing

Extensometers for materials testing machines

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Zwick Roell AG - Over a century of experience in materials testing

Mechanical technological testing is the oldest discipline in materials testing. Leonardo da Vinci and Galileo Galilei pondered over flexural loading and the elastic behaviour of materials. Further knowledge has been gained over the years. The first test machines appeared in France in the middle of the 18th century.

The firm Amsler (previously in Schaffhausen, Switzerland) began dealing with materials testing, as did Roell & Korthaus from 1920 onwards. In 1937 Zwick began with the construction of devices, machines and systems for mechanical technological materials testing. Long before this, as far back as 1876, Professor Seger founded a chemical laboratory as a scientific technological advisory company for the earth and stone industry. Today's Toni Technik developed from these beginnings during the 20th century as one of the leading specialists for building material test systems. Excellent performances have been furnished by MFL (Mohr & Federhaff), grounded as early as 1870, by the way, Carl Benz was one of its employees.

These firms constitute the company group Zwick Roell since 1992. Whereby the firms Dartec, Rosand, Kelsey and Indentec in Great Britain joined them in the two years following.

The Zwick Roell company group was reorganized to form Zwick Roell AG, a public limited company (joint-stock company), in July 2001. It encompasses the firms Zwick, Toni Technik, Indentec Ltd. and Zwick Roell Controllers Ltd. These companies supply a comprehensive program for materials, building materials and function tests; from manually operated hardness testers up to complex test systems that can be used for production accompanying applications. Inclusion of the French company Acmel Labo in 2002 supplements the Zwick Roell AG product program with laboratory products for the cement, plaster and lime industry.

Fig. 1: Zwick headquarters

Zwick has many years of experience resulting from the supply of a multitude of equipment. This is complemented by continuous communication with the users of such equipment. The company supplies an extensive program of efficient products based on this solid basis. These products range from economic standard machines to special complex models designed for special test tasks. State of the art mechanics, efficient electronics and the applications oriented software constitute the prerequisites for the versatility and high "intelligence" of these modern test machines and systems.

The Zwick Roell AG, however, offers a lot more than just the supply of products. The company was certified to DIN EN ISO 9001 as far back as 1994 and thus vouches for constant high product and service quality. Accredited DKD[1] or UKAS[2] calibration laboratories authorise the Zwick Roell AG companies to check and calibrate test devices, and to document it with internationally recognised certificates.

[1] DKD: Deutscher Kalibrier-Dienst (German calibration authorities)
[2] UKAS: United Kingdom Accreditation Service

Title pictures:

1	2	3
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5		

1. Macro extensometer with fork sensor arms for 3-point flexure tests
2. Longstroke extensometer for use with the „zwicki“ test machine
3. Optical extensometer
4. Incremental clip-on extensometer
5. Strain gauge extensometer, 6. optiXtens - Non-contact extensometer without measurement marks

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Contents

Why Zwick extensometers?

Extension measurement is one of Zwick's core areas of competency. The result is a comprehensive range of high class equipment. There is an extensometer to meet the needs of a wide range of materials and tests.

The product palette encompasses extensometers of different resolutions, measurement principles and measurement ranges:

- Contact extensometers:
  - Sensor arm extensometers
  - Incremental and analogue clip-on extensometers
  - Extensometers for compression and flexure tests
- Non-contact extensometers with and without measurement marks

The advantages at a glance

- Innovation: Strain measurement is a key technology in the range of test engineering. Zwick is leading in this technology - in the application to extreme damageable materials as well as to tough specimen. The Zwick product program contains extensometers that nobody else can offer.

- Selection: Zwick offers a comprehensive selection of extensometers. You get a suitable system for tests on high-extension specimen like elastomers as well as for tests on brittle materials as ceramics. The choice ranges from analogue clip-on extensometers to fully automated universal extensometers.

- The operator at the forefront: Zwick extensometers are designed with the operator in mind. They should be as simple as possible to clamp on the specimen and to operate. Automated test sequences from clamping sensor arms to unclamping them after specimen break are available to provide high level performance.

- Quality: With the acquisition of an extensometer from Zwick you'll receive the best Zwick quality, this means that the accuracy and high availability of the systems is in the forefront when processing materials of the highest quality.

1. Introduction to extension measurement

Different material characteristic values dictate that not only force but also deformation to the specimen (Extension, strain, compressive deformation, flexure) will be measured when loading a specimen at tensile, compression and flexure tests.

A difference between direct and indirect extension measurement is made in metrology.

Indirect extension measurement

Indirect extension measurement determines the extension of a specimen by measuring the change in distance of the crossheads with respect to one another. In such a case, the deformation of all units within the force chain of the testing machine is included in the extension measurement. This includes deformation to the load frame (Lead screws, columns, crossheads), the load cell, the specimen holders and any yielding of specimen in the specimen holders. The sum of these individual deformations as opposed to the extension to be measured must be negligible for indirect extension measurement. This means that it is less than the permissible measurement error, or that it can be partially eliminated via a so-called correction curve. This correction curve can be determined for a specific machine´s configuration, then it is used for correcting the extension values, but only if the self-deformation is sufficiently reproducible.

The change in the crosshead travel (and thus also the crosshead speed) is recorded by materials testing machines from Zwick via digital crosshead encoders with an extremely high resolution; i.e. better than 0.2 µm for all machine types.

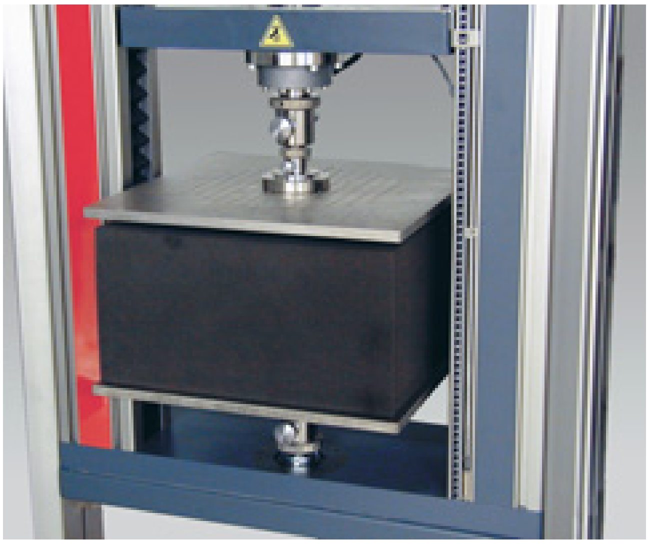

Fig. 2: The extension is measured indirectly at this compression test

Extension measurement over crosshead travel can be suitable for the following cases:

- Compression tests at which correction curves can be recorded
- Compression tests on specimen with high deformation (e.g. higher 30 up to 50 mm)
- Compression tests on specimen with low deformation at compensation of the machine´s self-deformation
- Characteristic values with high strains (Strain at break)
- Strip specimen and parallel clamping specimen grips for which defined grip to grip separations are guaranteed and a marginal yielding behaviour of the specimen
- Solid non-yielding materials

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Direct extension measurement

External influences that could influence test results (Self-deformation of the test machine, strain of the specimen in its non-parallel range and yielding out of the grips) can be avoided by measuring strain directly on the specimen. Special measuring devices are to be used depending upon the set test tasks.

Zwick can make measurement systems available for the following tasks:
- Extension measurement (Strain measurement in tensile direction)

- Change in width measurement (Strain measurement across the tensile direction)

- Deformation measurement for compression and flexure tests

When using direct extension measurement, strain that occurs outside of the gauge length is not included. A suitable extensometer can be selected, with respect to the required resolution, accuracy, gauge length and measurement path as well as the properties of the material, the specimen shape and dimensions, and the environmental conditions.

Direct extension measurement is always necessary if
- it's required by the corresponding test standard.

- the result shouldn't be falsified by the elastic deformation of machine components.

- the specimen behaviour in the clamping area could perhaps falsify the result (This is especially true for soft materials).

- the specimen deformation outside of the gauge length doesn't have to be considered.

- self clamping specimen grips are used, where any movement of the jaw inserts shouldn't be considered.

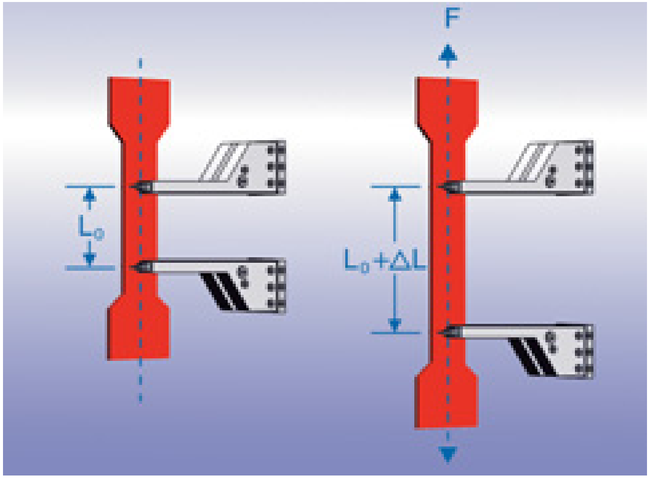

Fig. 3: Direct extension measurement

Zwick offers measurement systems with different measurement principles, gauge lengths, measurement travel and resolutions for direct extension measurement:

- Contact measurement systems for manual clamping to the specimen
  (Clip-on)

- Contact measurement systems for manual or automatic clamping of the sensor arms to the specimen
  (Sensor arm extensometer)

- Non-contact (optical) measurement systems with measurement marks on the specimen
  (Non-contact extensometers)

- Non-contact (optical) measurement system without measurement marks on the specimen
  (optiXtens)

2. Relevant characteristic values

2.1 Extension measurement

The extension measurement during specimen loading up to specimen break can be subdivided into different ranges according to the characteristic values to be determined:

- Fine strain measurement in the elastic range, and at the beginning of the range with permanent deformation
- Determination of proof stress from the beginning of permanent deformation
- Determination of the uniform strain and the strain at break

Fine strain measurement

This serves to determine the elasticity modulus and the technical elasticity limit (0.01% proof stress) for metals, and the elasticity modulus for plastics. The strain range to be recorded here is between 0.05 and 0.25 % (Also up to 1 % for films).

These characteristic values require measurement of extremely low changes in length with a correspondingly high resolution and very tight limits of error. The optiXtens, the clip-on and sensor arm extensometers (multiXtens, Macro extensometer) as well as the video extensometer from Zwick are suitable according to EN ISO 9513 (See diagram 1).

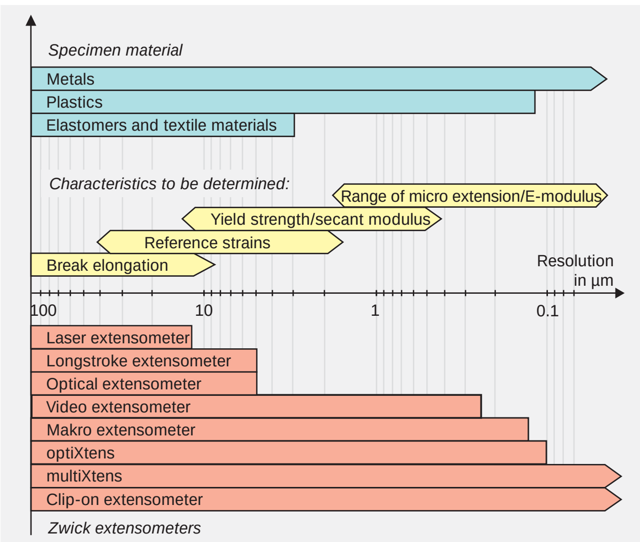

Diagram 1: Range of application of Zwick extensometers dependent upon the test data resolution

Determination of proof stress

Proof stress is determined for characterisation of materials if the transition from the elastic to the plastic range is continuous in the stress - strain diagram when testing metals or plastics.
All analogue and incremental clip-on extensometers, sensor arm extensometers or even non-contact measurement systems such as optical and video extensometers can be used for determination of proof stress (See diagram 1).

Uniform strain and strain at break

Uniform strain is the non-proportional strain under loading at maximum force, and it is determined on metals. Direct extension measurement enables continuous testing from the elastic range through to specimen break.

The strain at break is the remaining extension, related to the initial gauge length, at the specimen after break. An extensometer must be designed for long measurement travel and it must also be capable of dealing with specimen break when testing to determination of strain at break. Sensor arm extensometers with tiltable knife edges, or non-contact measurement systems are suitable for the above purpose. Clip-on extensometers are only conditionally suitable for determination of strain at break.

2.2 Change in width measurement

Poisson's ratio (µ)

Poisson's ratio µ is a dimension for the deformation behaviour in machine and transverse direction in a tensile test. Poisson's ratio is determined preferentially when testing long-fibre reinforced plastics. There must be two strain measurement systems that act simultaneously in both directions for measuring Poisson's ratio.

The solution from Zwick is the analogue and incremental reduction-in-width monitor in conjunction with a sensor arm extensometer (multiXtens, Macro extensometer).

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Vertical anisotropy (r-value)
The vertical anistropy characterises the cold forming capability of fine sheet metal with reference to the deep draw behaviour of the material. The r-value identifies the resistance of sheet metal to reduction in thickness of sheet metal at single-axis tensile loading. The change in width must be measured on a dumbbell specimen for the determination of these values.

An analogue or incremental reduction-in-width monitor in conjunction with the Macro extensometer is suitable for this kind of width measurement. Thus the change in width is measured in 2 or 4 cross-section levels.

The biaxial incremental clip-on extensometer, designed for length and change in width measurement, is foreseen especially for this test.

3. Selection criteria

In principle a decision must be taken as to whether or not direct extension measurement is necessary, or whether indirect extension measurement via the crosshead travel monitor is sufficient (See page 4).

Should the above considerations lead to direct extension measurement being chosen, selection of an extensometer with the appropriate technical properties must be made. Following is a list of criteria, dependent upon the material to be tested and the test results to be determined, to enable the correct extensometer to be selected.

Different **initial gauge lengths L_0** are prescribed by test standards depending upon the shape and dimensions of the specimen to be tested. In most cases L_0 is relatively small for high amounts of strain and relatively large for small strains. The initial gauge length L_0 is directly related to the specimen cross-section for proportional specimen when testing metals.

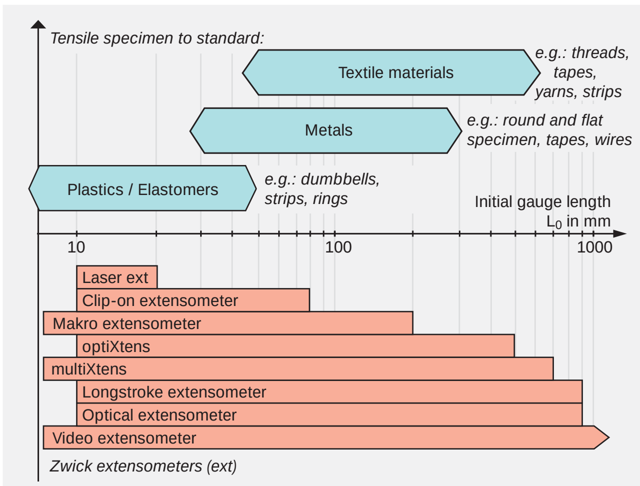

Diagram 2: Application range of Zwick extensometers dependent upon the initial gauge length L_0

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Overview of Zwick extension measurement systems
The selection of suitable extensometers depends upon the test results to be determined, and on the corresponding test standard. The following tables indicate these criteria and their dependencies to one another.

Test results:	Norm	Incremental reduction in width monitor	Analog reduction in width monitor	Analog clip-on extensometer	Incremental clip-on extensometer	Biaxial incremental clip-on extensometer	Macro extensometer	multiXtens	Longstroke extensometer
Plastics and elastomers									
Poisson's ratio	ISO 527	-	•	-	-	-	•	-	-
Tensile modulus	ISO 527	-	-	•	•	-	•	•	-
Compression modulus	ISO 604	-	-	•	•	-	•	•	-
Flexure modulus	ISO 178	-	-	-	-	-	•	•	-
Tensile creep modulus	ISO 899 -1	-	-	•	•	-	•	•	•
Flexure creep modulus	ISO 899 -2	-	-	-	-	-	•	•	-
3.5% Flexural yield strength	ISO 178	-	-	-	-	-	•	•	-
Flexure - Strain at break	ISO 178	-	-	-	-	-	•	•	-
Yield strain	ISO 527	-	-	-	o	-	•	•	•
	ISO 37, DIN 53504	-	-	-	-	-	-	•	•
Stress at X% strain	ISO 527	-	-	o	o	-	•	•	•
Reference values	ISO 37, DIN 53504	-	-	-	-	-	-	•	•
Strain at tensile strength	ISO 527	-	-	o	o	-	o	•	•
	ISO 37, DIN 53504	-	-	-	-	-	-	•	•
Strain at tensile strength Strip specimen	ISO 527 -3	-	-	-	-	-	o	•	•
Strain at break	ISO 527	-	-	-	o	-	o	•	•
	ISO 37, DIN 53504	-	-	-	-	-	-	•	-
Strain at break, strips	ISO 527 -3	-	-	-	-	-	o	•	•
Nominal strain	ISO 604	-	-	-	-	-	-	-	-
	ISO 527	-	-	-	-	-	-	-	-
Metals									
r-values	ISO 10113	•	•	-	•	•	•	•	-
n-value	ISO 10275	-	-	-	•	•	•	•	•
E-Modulus	ISO 6892, EN 10002-1	-	-	•	•	-	((•))	•	-
Compression modulus	ISO 50106	-	-	•	•	-	((•))	•	-
Flexure modulus	ISO 7438, DIN 50,111	-	-	-	-	-	•	•	-
Hysteresis	ISO 6892, EN 10002-1	-	-	-	•	•	•	•	-
Upper yield point	ISO 6892, EN 10002-1	-	-	-	•	•	•	•	-
Lower yield point	ISO 6892, EN 10002-1	-	-	o	•	•	•	•	-
Strain at break	ISO 6892, EN 10002-1	-	-	-	-	•	•	•	-
Yield strain	ISO 6892, EN 10002-1	-	-	o	•	•	•	•	-
Stress at x% strain	ISO 6892, EN 10002-1	-	-	o	•	•	•	•	-
Strain at tensile strength	ISO 783	-	-	o	•	•	•	•	-
Proof stress x	ISO 783	-	-	o	•	•	•	•	-
Proof stress at total strain	ISO 783	-	-	o	•	•	•	•	-
Uniform elongation	ISO 6892, EN 10002-1	-	-	-	•	•	•	•	-

Test results:	Norm	Optical extensometer	Laser extensometer	Video extensometer [1]	optiXtens	Extensometer for 3-Point flexure test	Extensometer for 4-Point flexure test	Digital crosshead travel monitor
Plastics and elastomers								
Poisson's ratio	ISO 527	-	-	-	-	-	-	-
Tensile modulus	ISO 527	-	-	(•)	•	-	-	-
Compression modulus	ISO 604	-	-	-	•	•	-	-
Flexure modulus	ISO 178	-	-	-	-	•	-	x
Tensile creep modulus	ISO 899 -1	-	-	(•)	•	-	-	-
Flexure creep modulus	ISO 899 -2	-	-	-	-	•	•	x
3.5% Flexural yield strength	ISO 178	-	-	-	-	•	•	x
Flexure - Strain at break	ISO 178	-	-	-	-	•	•	x
Yield strain	ISO 527	•	-	•	•	-	-	-
	ISO 37, DIN 53504	•	•	•	•	-	-	-
Stress at X% strain	ISO 527	•	-	•	•	-	-	-
Reference values	ISO 37, DIN 53504	•	•	•	•	-	-	-
Strain at tensile strength	ISO 527	•	-	•	•	-	-	-
	ISO 37, DIN 53504	•	•	•	•	-	-	-
Strain at tensile strength Strip specimen	ISO 527 -3	•	-	•	•	-	-	•
Strain at break	ISO 527	•	-	•	•	-	-	-
	ISO 37, DIN 53504	•	•	•	•	-	-	-
Strain at break, strips	ISO 527 -3	•	-	•	•	-	-	•
Nominal strain	ISO 604	-	-	-	-	-	-	•
	ISO 527	-	-	-	-	-	-	•
Metals								
r-values	ISO 10113	-	-	•	-	-	-	-
n-value	ISO 10275	-	-	•	•	-	-	-
E-Modulus	ISO 6892, EN 10002-1	-	-	-	((•))	-	-	-
Compression modulus	ISO 50106	-	-	-	((•))	-	-	-
Flexure modulus	ISO 7438, DIN 50,111	-	-	-	-	•	•	-
Hysteresis	ISO 6892, EN 10002-1	•	-	(•)	•	-	-	-
Upper yield point	ISO 6892, EN 10002-1	•	•	(•)	•	-	-	-
Lower yield point	ISO 6892, EN 10002-1	•	•	(•)	•	-	-	-
Strain at break	ISO 6892, EN 10002-1	•	•	•	•	-	-	-
Yield strain	ISO 6892, EN 10002-1	-	-	•	•	-	-	-
Stress at x% strain	ISO 6892, EN 10002-1	-	-	•	•	-	-	-
Strain at tensile strength	ISO 783	-	-	•	•	-	-	-
Proof stress x	ISO 783	-	-	•	•	-	-	-
Proof stress at total strain	ISO 783	-	-	•	•	-	-	-
Uniform elongation	ISO 6892, EN 10002-1	-	-	•	•	-	-	-

• = Suitable system
o = Can be used if the specimen strain doesn't exceed the extensometer's measurement range
() = Can be used if the field has been selected small enough
(()) = Can be used if the initial gauge length is big enough
x = Measurements with the crosshead travel monitor supply lower results owing to system deformation and surface pressure effects on the specimen surface
[1] = The video measurement system's objective lens cannot be replaced during the test

The extensometer's **measurement travel** must be sufficient for the specimen to be tested. If the specimen's strain isn't known, it can be estimated for different materials and characteristic values (See diagram 3).

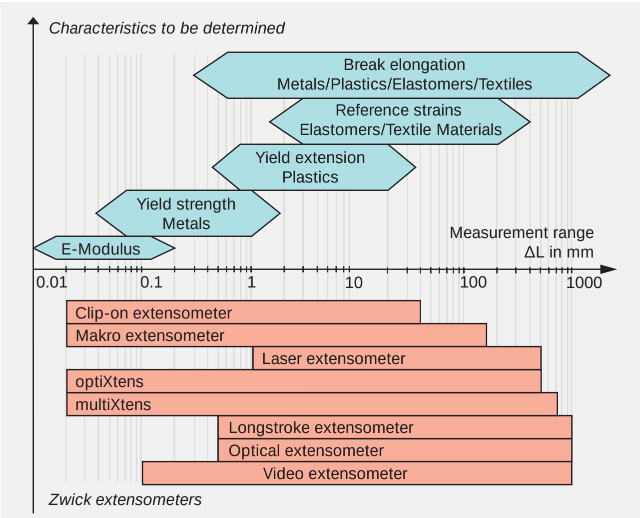


Diagram 3: Range of application of Zwick extensometers dependent upon the measurement travel

The **type of loading** also plays a part for the measurement range. The requirements for compression or alternating load tests are different to those for tensile testing, e.g. the extensometers used for alternating load tests must have zero-play.

Furthermore, the **resolutions and accuracies** indicated in the individual test standards must be considered.

The extensometer must not be damaged by high elastic resilience at **specimen break** and the thus resulting high acceleration forces. Specimen that break with a whiplash effect at break, e.g. elastomers, belts or tapes, or even soft materials with strong yield properties are potentially dangerous. Non-contact measurement systems are suitable for such tests, as are sensor-arm extensometers that enable the slipping of the specimen at break. For this purpose the Zwick sensor-arm extensometers are equipped with tiltable knife edges and sensor arms that are able to side step.

The choice of extensometer also depends upon the specimen material's **notch and flexural sensitivity**. The construction of a clip-on extensometer (Applying a load to a specimen via torque) that is clamped direct on the specimen is influenced by its weight and an eventual weight removal. For example, applying optional counter rollers to specimen of small cross-sections could lead to falsification of the test results.

The **drag forces** must be as low as possible for sensor-arm or clip-on extensometers to make sure that the specimen isn't influenced. Zwick extensometers ensure this.

The material and the specimen shape provide information as to whether or not differing **zone fibre strains**, that must be considered via averaging, could occur. Different zone fibre strains result, for example, from loading of specimen via flexural stresses (For one-sided clip-on extensometers with only one counter roller, or with long levers) or from non-axial clamping of the specimen.

Deformation measurement with sensor-arm extensometers in **temperature chambers** requires the use of extended sensor arms, and special temperature resistant clip-on extensometers are required.

4. Contact measurement systems

4.1 Sensor arm extensometers

Zwick offers a wide range of sensor arm extensometers. This starts with a basic extensometer for use with the „zwicki“ test machines and ends at fully automatic extensometers.

These extensometers are used for direct extension measurement at tensile, compression, flexure or alternating load tests. They all have a large measurement range that can be steplessly adjusted corresponding to the specimen to be tested.

Function description

The Zwick sensor arm extensometers work with incremental measurement systems. Transmission of the extension to the measurement system takes place via play-free, tiltable knife edges on the sensor arms. The sensor arm clamping forces are very small and can be steplessly adjusted so that specimen are not damaged, and so that the knife edges are located perfectly.

Interchangeable sensor arms

The easily replaceable sensor arms (See fig. 4) enable these extensometers to be adapted to the test type, the material to be tested and to the specimen shape. A plug-in connection enables sensor arms for tensile or flexure tests, or fork sensor arms as well as extended sensor arms for use in temperature chambers to be mounted quickly and simply. This system reduces replacement, interchanging and equipping times to a minimum.

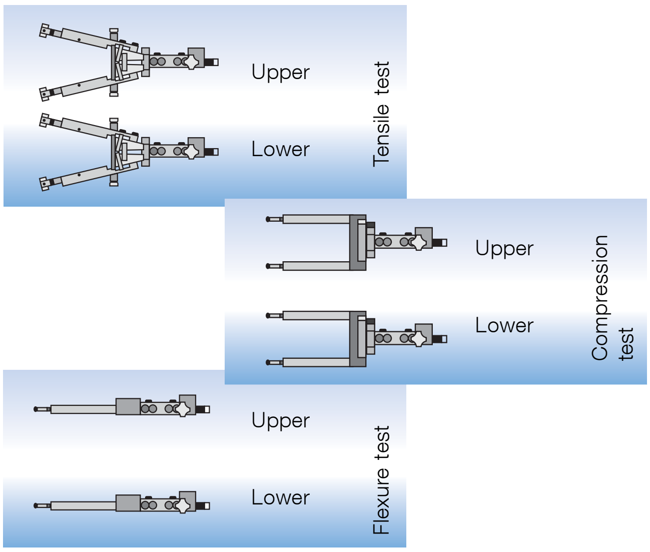


Fig. 4: Different types of sensor arm increase the range of application

Interchangeable knife edges

The knife edges are also easily replaceable. They consist of straight and convex sides. They can be simply rotated so that the knife edges will always be in single-point contact to the specimen (Flat or round specimen, see fig. 5), thus ensuring extremely precise measurements.

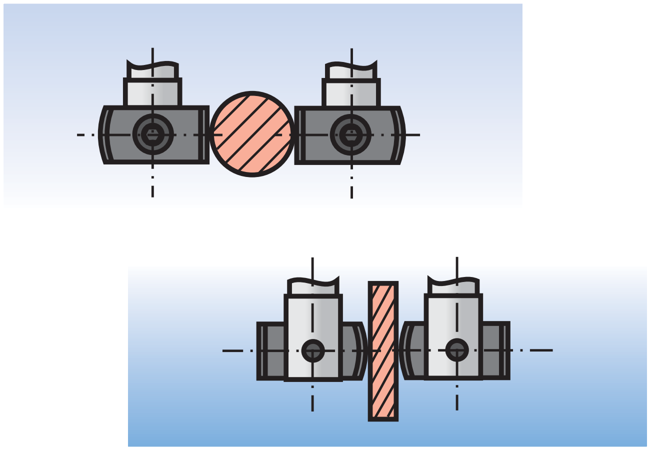


Fig. 5: Round specimen with straight knife edges, and flat specimen with convex ones

Knife edges with vulkollan surfaces for notch sensitive specimen and knife edges with corundum surfaces for extremely smooth specimen are available thus enabling the optimum knife edge to be used for all materials.

Measurements can be run through to specimen break without any risk of damaging the sensor arms: The knife edges (They can be tilted by 180°) only transmit extremely low forces to the sensor arms at specimen break, whereby damage to the sensor arms and the extensometer at specimen break is reliably prevented (See fig. 6).

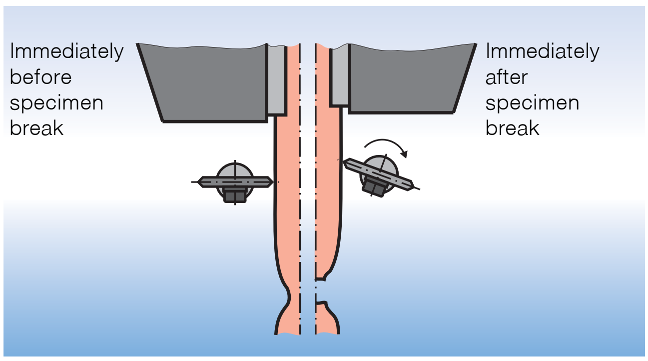


Fig. 6: Principle function of the tiltable knife edges

Use in temperature chambers

Extended length sensor arms enable extensometers to be used for extension measurement in temperature chambers. These arms access the temperature chamber through lateral apertures in the chamber wall. Thereby the full functionality and simple operation of the extensometers is upheld.

General advantages of the sensor arm extensometers

- The gauge length can be steplessly adjusted corresponding to the specimen to be tested.
- Extended length sensor arms enable extensometers to be used for extension measurement in temperature chambers.
- Sensor arm control can take place via the test software *testXpert*® as well as via a remote control unit.
- The geometrical shape of the knife edges enables their use with both round and flat specimen (See fig. 5).
- Tiltable knife edges prevent damage to the extensometer systems at specimen break.
- The extensometer used determines the degree of automation of the extension measurement. Thus enabling a high degree of accuracy and reproducibility, and shorter test durations to be achieved.

4.1.1 multiXtens

Range of application

multiXtens is a high resolution extensometer that can be put to universal use. The use of special sensor arms enables this extensometer to be used for tensile, compression, flexure and cyclic tests. It is used for tests on plastics, elastomers and hard foam materials, as well as for tests on metals and composites.

The extremely high measurement accuracy combined with the extremely large measurement range makes multiXtens the ideal tool for changing applications that make different demands on the extension measurement system (Tests on plastics and metals).

System description

This universal extension measurement system can be used for the most varied testing tasks because of its consequential modular construction.

The most important components:

- Guidance system with integrated but traveling independent of one another measuring carriages
- Measuring heads and sensor arms, both easy to change
- Central measurement and control system

Fig. 7: The measurement heads were mounted on the measurement carriages. The easy to change sensor arms get fixed on the measurement heads.

Fig. 8: The universal extensometer multiXtens

Scope of functions

multiXtens' large scope of function is a prerequisite for exact and reproducible test data and guarantees simple and safe handling.

The most important functions are:

- Self identification of the components
- Automatic test area measurement
- Automatic centring with respect to the middle
- Automatic setting of the initial gauge length
- Monitoring all safety distances
- Securing against erroneous operation
- Optional connection of reduction-in-width monitor and/ or fine strain extensometer

Advantages of the multiXtens

- Highest precision, even for long measurement paths (Up to 700 mm) and in temperature chambers.
- Specimen deformation is recorded in the elastic and plastic deformation ranges during the entire test.
- The multiXtens drag forces are extremely low.
- multiXtens is also suitable for alternating load tests.
- Compression and flexure tests can be run by simply exchanging the sensor arms.
- A third measurement carriage enables reduction-in-width monitors and fine strain extensometers to be automatically adapted to multiXtens. This is an important function not only for exact E-Modulus determination but also for determination of r&n values and Poisson's ratio.
- The sensor arms can be exchanged without the need for any tools and are automatically detected by multiXtens.
- The extensometer is automatically controlled via the test program. The sensor arms are automatically clamped/unclamped and the initial gauge length is automatically set at the beginning/end of test.
- multiXtens can be mounted on the testing machine via a high precision swivel device. Thus tests can be run quickly and flexibly with or without using an extensometer.
- It fulfills accuracy grade 0.5 to EN ISO 9513.

4.1.2 Universal extensometer „Macro“

Range of application
The Macro extensometer is a universal, high resolution extensometer for tensile, compression, flexure and cyclic tests on plastics, hard foam materials and metals that have low to average amounts of specimen strain. Sensor arms suitable for tests in temperature chambers are available from the Zwick range for use with this extensometer.

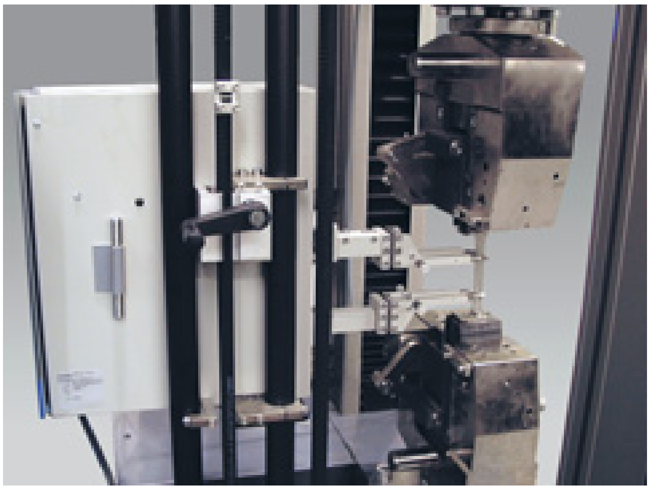


Fig. 9: Universal extensometer „Macro“

System description
This multi-purpose extensometer is also characterised by its modular construction. Thus, for example, the manual operation extensometer can be converted to an automatic clamping extensometer.

Furthermore, a range of optional units for expanding the functionality of the Macro extensometer is available:

- Different basic models with resolutions up to 0.12 µm
- Automatic L_0-setting
- Interface for the sensor arms
- Different sensor arms for tensile, compression and flexure tests as well as for tests in temperature chambers
- Different reduction-in-width monitors as well as a drive unit for them

Optional reduction-in-width monitors
The optional reduction in width monitors are designed for tensile tests on metals. They are mounted on the Macro extensometer and can be operated, selectively, manually or automatically via the test software *testXpert*®. The change in width can be measured in 1, 2 or 4 cross-section levels.

Advantages of the Macro extensometer

- Specimen deformation is recorded in the elastic and plastic deformation ranges during the entire tensile test up to specimen break.
- The drag forces are extremely low.
- The resolution and measurement accuracy is extremely high over the entire measurement range.
- It’s also suitable for alternating load tests.
- The extensometer can be combined with all analogue or incremental clip-on extensometers, as well as reduction-in-width monitors (Especially important for r-value determination of metals).
- Can easily be integrated in systems for fully automatic tests.
- It fulfills accuracy grade 1 to EN ISO 9513.

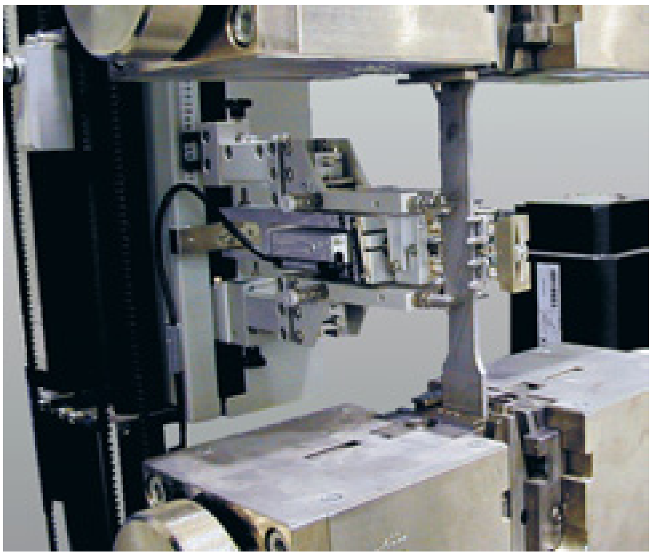


Fig. 10: Macro extensometer in combination with a reduction in width monitor (With 4 measurement lines)

4.1.3 Longstroke extensometer

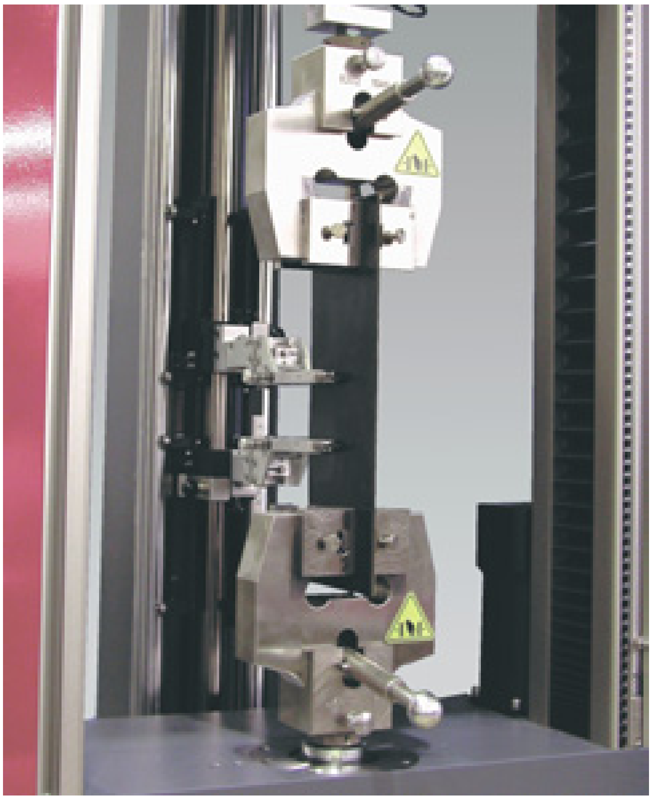


Fig. 11: Longstroke extensometer

Range of application

The longstroke extensometer is designed for tests on stretchable materials such as elastomers, flexible plastics, foils, textiles and leather. Even with specimen that show a whiplash effect at break, the solid mechanical design of the guide elements ensures reliable functionality.

The extensometer is used for direct extension measurement for specimen with average and high strains during tensile and cyclic tests. Extended length sensor arms enable tests to be carried out in temperature chambers.

System description

The bearings for the measurement carriages and the tiltable knife edges make the system insensitive to impact loading such as may happen when some elastomeric specimen break. The measurement carriage guide on two precision guide columns ensures, with the help of low-friction guide elements, a low force transmission of the extension whereby transmission errors are minimised. The mass of the carriage is counter balanced by counter weights.

Test sequence

The gauge length is set by means of a scaling. After starting the test the sensor arms are clamped automatically, once the test is ended they are automatically unclamped (Manual for extensometers for the „zwicki“ testing machines). The initial gauge length is reset via the crosshead movement of the materials testing machine, and the extensometer is ready for the next test.

Optional reduction in width monitor

The optional, manual reduction-in-width monitors are designed for tensile tests on metals. The change in width can be measured in 1, 2 or 4 cross-section levels.

Advantages of the longstroke extensometer

- The resolution is high over the entire measurement range.
- It has an extremely long measurement travel.
- The drag forces are extremely low.
- It is robustly built and has a measurement system that is insensitive to impact loading.
- The measurement carriage's low friction bearing minimises transmission errors.
- The extensometer can be combined with all analogue or incremental clip-on extensometers, as well as with a manual reduction-in-width monitor.
- It complies to accuracy grade 2 to EN ISO 9513, at 1 mm and higher to accuracy grade 1.

4.2. Clip-on extensometers
4.2.1 Incremental clip-on extensometers

General
Incremental measurement systems have, until now, only been used for sensor arm extensometers. The size of the incremental scale and the optical read-head made it impossible to use and manufacture such systems in „miniature". This is however the prerequisite for realising an incremental clip-on extensometer.

The Zwick incremental clip-on extensometers are unique in their functionality and construction, and cover a wide applicational range not only as single devices but also in their scope of variants.

Range of application
The Zwick clip-on extensometers are designed for tests on plastics and metals. They fulfill all requirements for extension and change in width measurements especially for metals testing.

System description
The incremental system's accuracy is uniform over the entire gauge length. The clip-on extensometer's compact construction is enabled by minimising the size of the incremental scale. In addition the extremely lightweight measurement system is seated very close to the specimen. Thereby the loading of the specimen is minimised.

The range of application of the incremental clip-on extensometer is expanded by the number of different initial gauge lengths and through the flexible measurement path alteration that can be altered from „Tensile only" to „Tensile and compression" at change in length.

Equipment
Zwick offers four different variants of the incremental clip-on extensometer for extension and/or change in width measurement.

These clip-on extensometers are powerful and great value for the money. They have considerable advantages to the DMS systems usually used with reference to the measurement range, accuracy and signal processing.

The incremental measurement system makes these clip-on extensometers a world-wide innovation, for which Zwick Roell has a patent.

Handling
The incremental clip-on extensometers can be clamped single-handedly on the specimen quickly and safely. Whereby the initial gauge length is automatically locked at clamping and is then released when letting go of it. You neither need to operate any levers nor any screws. Thus one step is saved and the influence on L_0 is avoided and with it potential mistakes.

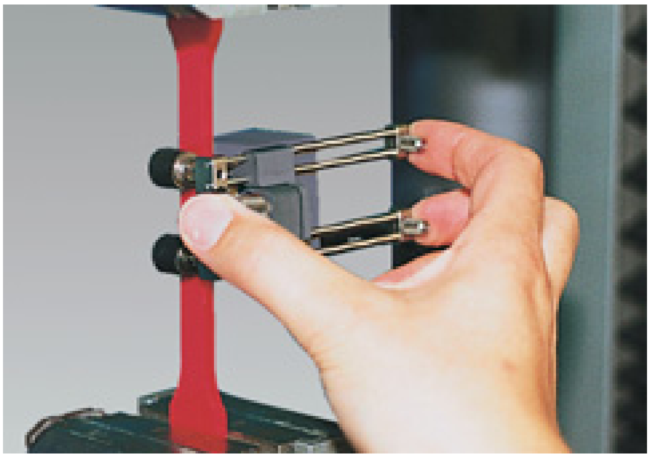


Fig. 12: The incremental clip-on extensometer guarantees simple and rapid handling.

Advantages of the incremental clip-on extensometer

- The resolution and accuracy are extremely high over the entire measurement range.
- The measurement range at extension measurement can be switched from „Tensile only" to „Tensile and compression".
- Its low height enables it to be used for short grip to grip separation. The low weight and compact construction minimises loading of the specimen.
- An adjustable depth stop with scales for usual specimen widths assists in always clamping the clip-on extensometer at the middle of the specimen.
- Measurement up to specimen break is always possible without unclamping the extensometer (Fmax 50 kN).
- The resolution is 0.1 µm for all variants.
- The accuracy grade 0.5 to EN ISO 9513 is reached.

Zwick / Roell

Incremental clip-on extensometer for extension measurement

Zwick offers two versions within the incremental clip-on extensometers for extension measurement. They differ in the measurement path length.

They are suitable for precise modulus and yield point determination to ISO 527-1 on stiff and slightly flexible plastics as well as for determination of strain at maximum stress, and for strain at break on stiff plastics. Apart from this, they are also suitable for determination of the compressive strength of plastics or for determination of the compressive E-Modulus for metals.

The second version is especially suitable for tests up to break on metals owing to its long measurement paths, they cover up to 50 % strain.

The initial gauge lengths for both systems are adjustable.

Incremental reduction in width monitor

The incremental reduction in width monitor is designed for r-value determination on metals to ASTM E 517 and ISO 10 113.

The clip-on extensometer measures the change in width on metallic specimen via a measurement line. It can be used either alone or in combination with the Macro, Multisens or Longstroke extensometer.

Its low height enables it to be easily clamped on the specimen between the sensor arm pairs, thus enabling extension and change in width to be recorded in one gauge length.

Biaxial incremental clip-on extensometer

The Zwick biaxial clip-on extensometer for determination of the extension and change in width is unrivalled owing to its compact construction and its long measurement paths.

It is especially used for determination of extension as well as for r&n value determination on metals to ISO 10113 and ISO 10275. Its measurement path is very long both for extension and change in width measurement.

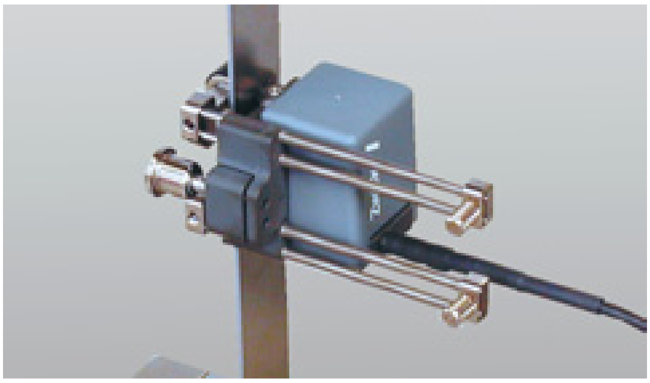


Fig. 13: Incremental clip-on extensometer (TC-EXICLEL.001)

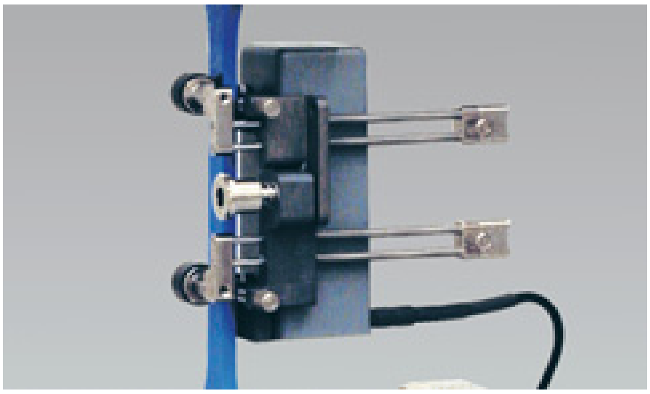


Fig. 14: Incremental clip-on extensometer (TC-EXICLEL.002)

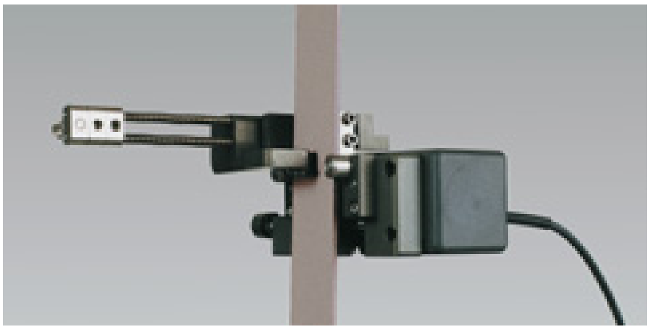


Fig. 15: Incremental reduction-in-width monitor

Fig. 16: Biaxial incremental clip-on extensometer

4.2.2 Analogue clip-on extensometers

Range of application
These extensometers are clamped directly on the specimen and are designed for length measurement on metals and plastics. There ranges of application encompass the entire fine strain and proof stress measurement, as well as E-Modulus determination.

The clip-on extensometers are obtainable in manual or automatic clip-on variants.

Inductive (Analogue) clip-on extensometer

General
This sensor's clip-on extensometer essentially consists of a coil of defined cross-section as well as a movable armature. The core and armature are moved relatively towards one another in the inductive travel measurement principle. Thus a change to the inductivity results. Also the change in inductivity is a dimension for the extension at the specimen.

One or two sensors are integrated in a mechanical arrangement that transmits the extension of the specimen via knife edges to the measurement system(s).

System description
The specimen's extension is transmitted via knife edge pairs, that are clamped on two sides of the specimen, each to one inductive measurement system in the extensometer. The average value of the measurement voltage formed in these two measurement systems is fed to the carrier frequency amplifier.

Advantages of the inductive clip-on extensometers

- The measurement lever is very small as the measurement system is arranged very close to the specimen. Thus increasing the measurement accuracy and reproducibility.
- The resolution is extremely high over the entire measurement range.
- They have two measurement systems for averaging different zone fibre strains.
- They are suitable for tensile, compression and alternating load tests.

Inductive clip-on extensometer for fine strain measurement (Fine strain extensometer)
The fine strain extensometer with a measurement range of 2 mm is put to use in conjunction with the multiXtens. It is automatically driven at half of the test speed. The materials testing machine switches to the digital extensometer before specimen break and the fine strain extensometer is unclamped from the specimen.

The fine strain extensometer is suitable for r&n value determination in combination with the multiXtens and a certain reduction-in-width monitor.

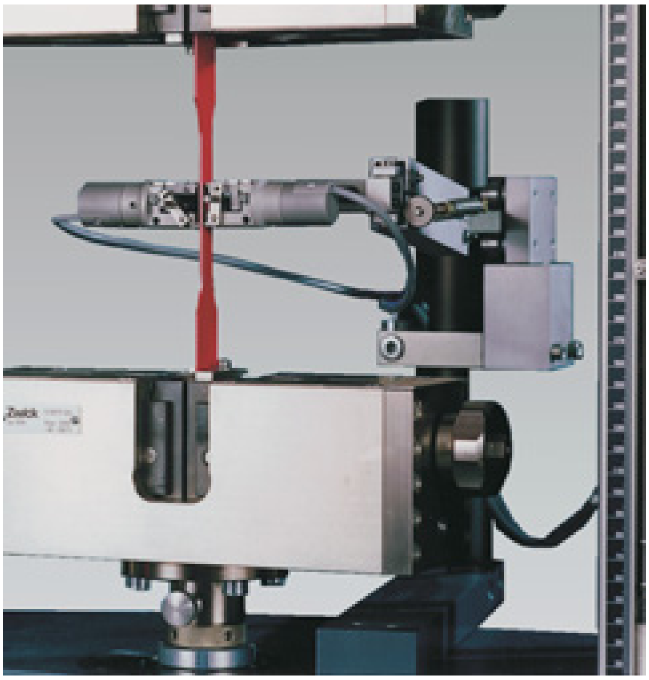


Fig. 17: Analogue clip-on extensometer 066251 with optional counter weight system

Inductive clip-on extensometer
This extensometer is foreseen for fixed gauge lengths L_0 = 10 mm and 20 mm (Optional up to 100 mm) at a measurement range of 2mm in tensile and compression directions.

The inductive extensometer can be additionally equipped with a counter weight unit for testing thin and sensitive specimen. Whereby a stabilising arm, which enables the clip-on extensometer to be clamped on the specimen easier and reproducibly, is used.

Strain gauge extensometers

General

A strain gauge is an electrical resistance that is attached to an insulating foil crosswise to the strain measurement direction. If the strain gauge is stretched in the direction of measurement its electrical resistance increases. One or more sensors are applied to a mechanical arrangement. The specimen extension is transmitted to the mechanical part(s) that are equipped with strain gauges via the sensor arms. Thus the parts equipped with strain gauges are deformed.

System description

The measurement spring is contained in a high strength aluminium housing. It is applied with a temperature compensated strain gauge full-bridge. The extensometer clamped to the specimen is protected by stops against overshooting the measurement path or at specimen break.

Strain gauges are also available in temperature resistant variants for use in temperature changes.

Advantages of the strain gauge clip-on extensometer

- The measurement systems show a very good linearity and thus supply reliable test results.
- The gauge lengths are adjustable from 10 to 100 mm and can thus be used for different sized specimen.
- Owing to their miniaturised, light construction they are also suitable for use with short specimen.

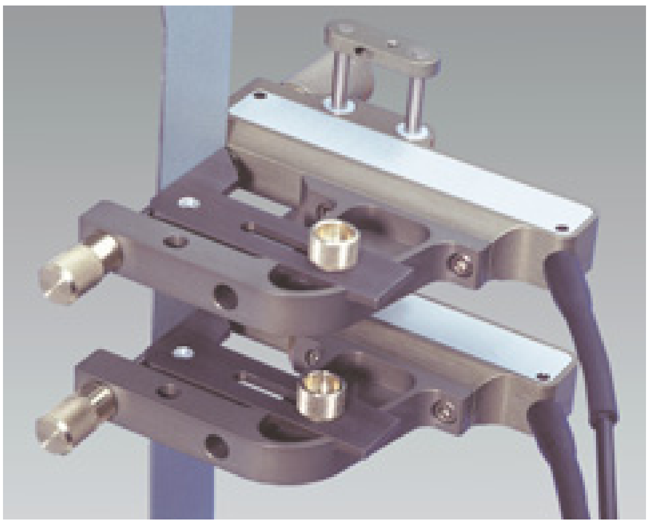


Fig. 18: Strain gauge clip-on extensometer for width measurement

Fig. 19: Strain gauge clip-on extensometers

Strain gauge clip-on extensometers for extension measurement

The clip-on extensometers are foreseen for fixed gauge lengths, e.g. for the

L_0 of 10 or 20 mm at a measurement path of 2 mm in the tensile direction, and 1 mm in the compression direction

L_0 of 25 or 50 mm at a measurement rage of 25 mm.

There are one or two-sided versions of the systems. A clip-on extensometer especially designed for use in temperature chambers is also available from Zwick.

Strain gauge clip-on extensometers for width measurement

The reduction-in-width monitors are designed for use in conjunction with the sensor arm extensometers, or for use without an extensometer.

They are especially designed for tests on metals, but also the determination of Poisson’s ratio on fibre reinforce laminates to ISO 527-1 is possible.

The reduction in-width-monitors are foreseen for fixed specimen widths (B_0 from 20.5 mm to 16.5 mm) at a measurement path of 4 mm.

Zwick Roell

4.3 Extensometers for compression and flexure tests

Zwick also offers extensometers for measurement of deflection at 3 or 4-point flexure tests, as well as the deformation path at compression tests.

These extensometers are incremental travel measurement systems that are clamped direct on specimen.

Range of application

The extensometers for 3-point flexure tests are designed for flexure tests on stiff and slightly flexible plastics to ISO 178, the 4-point flexure test extensometers for tests to DIN 53457.

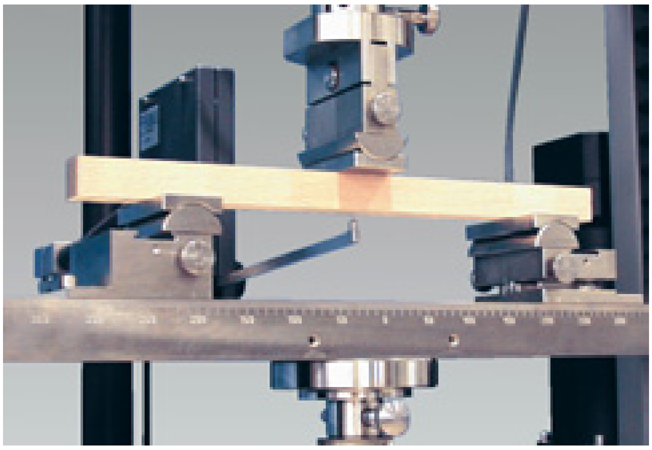


Fig. 20: Extensometer for 3-point flexure test

Advantages

- Easy to operate
- Direct measurement on the specimen
- Extremely precise E-Modulus determination
- Optional with motorised clamping device
- Optionally available with increased resolution

5. Non-contact measurement systems

The dimensional stability of solid bodies differs depending upon the material and environmental conditions. Strains at break must be recorded exactly from a low percentage for metals up to some 100 percent for plastics and elastomers.

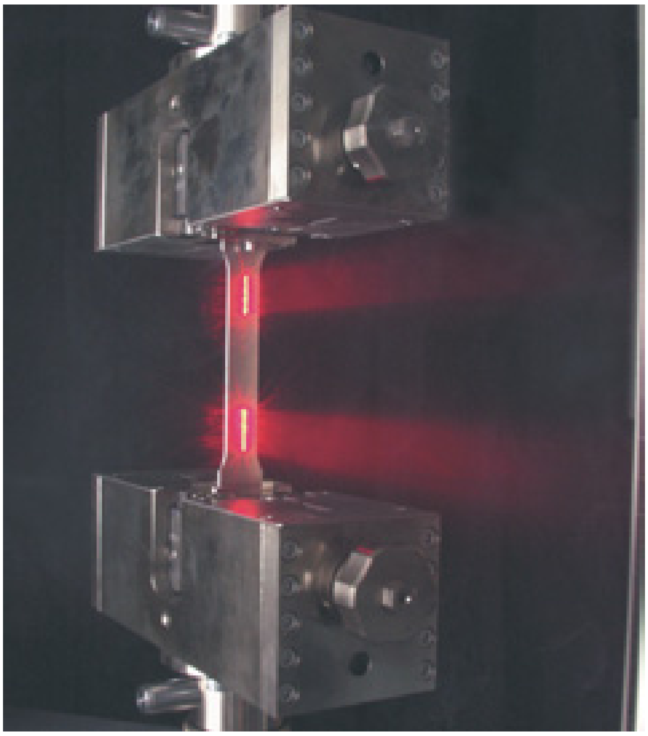


Fig. 21: A technology only offered by Zwick: Testing with optiXtens

Contact extension measurement up to break on high-elastic, flexible specimen such as wire or synthetic ropes is problematic. At specimen break the broken ends of the specimen whiplash and usually hit those parts of the specimen that are still in the grips. This effect is caused by elastic resilience. The specimen ends could then wrap around the sensor arms and damage them. For safe and exact measurements when testing high extension, high elastic and contact sensitive materials, we recommend the use of non-contact measurement systems.

These systems measure changes in length exactly and without being in contact with the specimen at normal temperatures as well as at varying temperatures for tests in temperature chambers. Non-contact measurement systems offer a high degree of operational safety for specimen that whiplash at break, thus releasing high mechanical energy, or which unravel at break, for example wire ropes and hemp, fibre reinforced plastics and elastomers.

Advantages of the non-contact measurement systems

- The behaviour of the specimen isn't subjected to any influences caused by knife edges and any drag force. As the specimen won't be subjected to any force infuences, it won't be damaged and falsification of test results is ruled out.
- The systems have an extremely long life-span.
- Non-contact extensometers are suitable for specimen that tend to „whiplash" at specimen break (Elastomers, wires, ropes) as well as for notch and break sensitive specimen.
- Necessary accuracy grades are maintained.
- A free selection of the gauge length by attaching measurement marks at an appropriate separation, or by omitting the measurement marks (optiXtens).
- No thermal bridges when using temperature chambers as measurement takes place via a heatable window.

Zwick / Roell

5.1 Optical extensometers

Range of application

Optical extensometers are especially suitable for safe and exact measurements during tensile and hysteresis tests on high extension, high elastic and contact sensitive materials such as elastomers. It measures the deformation exactly and without touching the specimen, even when testing in temperature chambers.

Test sequence

Once the test machine has applied the pre-load, the extensometer measures, if required, the actual gauge length. The first scan head approaches both of the marks on the specimen and determines the initial gauge length L_0. The second scan head positions itself at the other „free" mark. The test then starts automatically.

The two optical scan heads follow the marks during the test via servo drive systems. The travel difference of both optical scan heads corresponds to the change to the device gauge length and is recorded incrementally via an impulse generator with mechanical differential.

The test program *testXpert®* automatically runs the control of the optical extensometer from the clamp procedure to resetting the scan heads to their initial positions.

Specimen marking

Self-adhesive, specially coated reflective spots serve as the optical markings for the initial gauge length. Strong illumination is advantageous as the optical detection of a mark basically relies upon the contrast between the mark and the specimen surface. The optical scans work with visible, continuous illumination, a light spot indicates the targeted mark. The scan heads still find the marks even if they are slightly off-centre as the scan grab range diameter has a diameter of 6 mm.

Fig. 22: Marked specimen for optical measurement

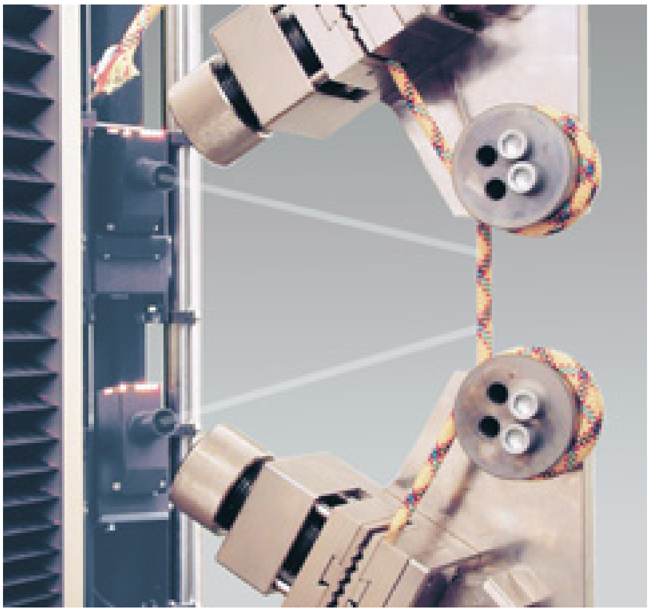


Fig. 23: The optical extensometer for non-contact measurement

The necessary specimen marking are also included in the assortment. Regardless of whether the decision is to use a simple hand-held device or an automated device, all specimen marking devices ensure simple and functionally safe application of specimen marks with defined gauge lengths.

Advantages of the optical extensometer

- The optical extensometer has a high resolution and measurement accuracy.

- Interferences from light sources and from reflecting surfaces and edges are suppressed via a signal pattern detection. Thus making safe operation possible with continuous light that plays a role in a further increase to the sensitivity.

- The integrated microprocessor control simplifies operation of the extensometer whether it works in manual tensile tests or is integrated in an automatic process. The test always runs without time consuming positioning work and can be reduced to a few operating steps.

- Its measurements fulfill accuracy grade 1 to EN ISO 9513 from 3 mm on.

5.2 Laser extensometer

Range of application

The laser extensometer serves to carry out non-contact measurements of tensile or compressive deformations on differing materials, especially on rubber and elastomers. It can be used not only at normal temperatures but also under expanded temperature conditions in temperature chambers.

System description

A laser beam is deflected by a rotating, multi-faced mirror so that it continuously scans the specimen lengthwise. A cylindrical lens between the mirror and specimen ensures a parallel beam over the entire measurement path (See picture).

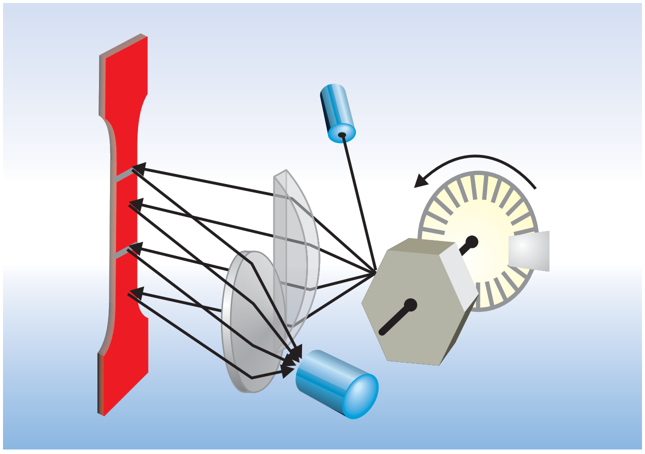


Fig. 24: The principle of the laser extensometers

The light reflected from the specimen surface is guided via a lens system to a photodiode that generates an analog measurement system that is dependent upon the brightness. The measurement marks are detected by their difference in brightness to that of the specimen.

Test sequence

Two marks that indicate the initial gauge length L_0 are applied to the specimen before the beginning of the test. The extensometer grasps the markings on the specimen at the start of test. The test program *testXpert®* starts the test as soon as the marks are detected.

Different specimen markings are available for use with this extensometer.

Fig. 25: The laser extensometer, here separated from a test system

Advantages of the laser extensometer

- This offers a high operating safety especially for specimen that show a whiplash like resilience at break.
- A non-contact and exact measurement not only at ambient temperature but also under other temperature conditions is ensured.
- It fulfills accuracy grade 1 to EN ISO 9513 from 5 mm on.

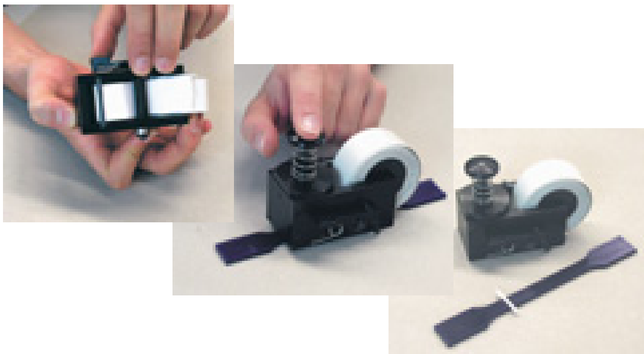


Fig. 26: The specimen marking devices are simple to operate and are functionally safe (Here a simple manual device)

5.3 Video extensometer

Range of application

The video extensometer makes non-contact and high resolution tensile and compressive deformation measurements on all types of plastics, metals, rubber, laminates, wafers and foils. It is also suitable for determining the change in width, the r & n values to ISO 10113 and ISO 10275, as well as the proof stress in tensile tests to EN 10002-1.

System description

The measurement system consists of a digital video camera with a picture editing system. The resolution and measurement range can be adjusted to the materials properties to be tested by interchangeable and adjustable objective lenses.

The specimen must have test marks which have a brightness which is clearly different from the surrounding area. The extensions to be measured are determined by these differences in brightness and the associated picture elements: The specimen's surface is digitalised by the video camera by splitting it into discrete picture elements. Each pattern element is, in principle, a photo element that generates an analogue measurement signal, that is converted to a digital signal by the measurement electronics, corresponding to the brightness of the recorded surface area. These patterns are processed by a PC supported video processor in real time and thus determines the extension. Immediate display of strain is guaranteed as not only the initial gauge length but also the change in length is measured with the same measurement system.

Marking of the specimen takes place for materials with smooth and monochrome surfaces with a colour marker, otherwise via self-adhesive measurement marks. Scanning the contour is usually sufficient for optional measurement of the transverse contraction in most cases.

Fig. 27: The specimen surface is digitalised by a full-frame camera

Advantages of the video extensometer

- It's the ideal measurement system for strain measurement on whiplashing materials (Safety belts, steel rope, rubber rope, thin wires, etc.).
- The resolution and measurement accuracy is extremely high over the entire picture size.
- Length and width measurement is possible simultaneously.
- The measurement paths are variable and very big depending upon the selected picture size or objective lens.
- Automatic measurement detection and recording of the initial gauge length L_0.
- The entire test sequence can be followed on screen. Certain illustrations, e.g. the time of specimen failure, can be recorded and printed.
- The extensometer measures at accuracy grade 1 (At field of view ≤ 200mm) to EN ISO 9513.

5.4 optiXtens - Non-contact extensometer without measurement marks

Range of application
The optiXtens is used to run deformation tests on a range of materials. Measurements on metals, plastics and composites are carried out optically without mechanical contacting and without application of measurement marks.

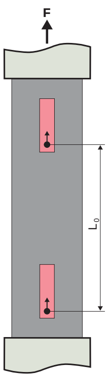
Especially suitable is the optiXtens for measurements on notch sensitive specimen as well as specimen with low test loads. Its high accuracy and its constant high resolution enable measurements on deformations in the range below the elasticity limit up to strain at break.

Function description
optiXtens consists of two optical measurement heads with evaluation units and a linear carriage system. Each measurement head illuminates the specimen surface via a lens system in lines with coherent laser light.

The reflected light generates a characteristic interference pattern the speckle pattern that is characteristic of the specimen surface.

This speckle pattern with typical bright and dark speckles is reproduced by a sensor via the optics.

Reference speckles are selected from this pattern with distance as the initial gauge length $L_{0.}$ These speckles are followed during specimen deformation in real time. The extension between both measurement points is determined in this manner.



The measurement heads track the reference speckles when they move towards the end of the optic´s field of view. Hereby the speckles always get reproduced in the sensor at the same place. The movement travel in the macro measurement range is identical to the extension of the specimen.

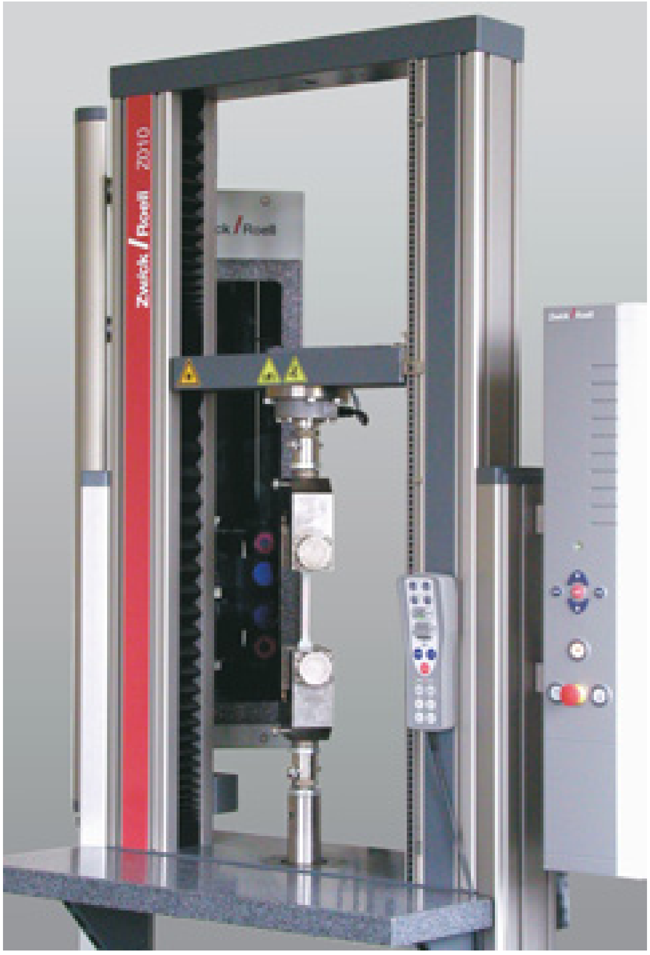


Fig. 28: optiXtens - The new direction in extension measurement

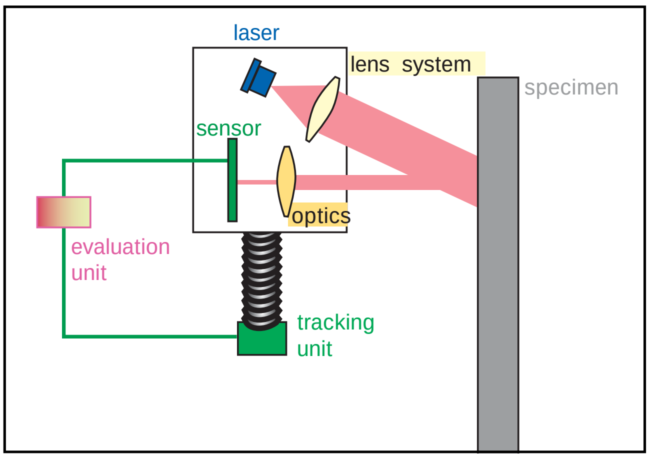


Fig. 29: optiXtens (Upper measurement head) setup and principle of tracking the reference speckle

The Zwick Roell patent

Previously known extension methods via speckle interferometry use the desired non-contact method, but they have the disadvantage that the temporal resolution is low via the comprehensive evaluation and the necessary computing time or that the measurement range is insufficient.

The Zwick Roell patent does away with these disadvantages: The Zwick Roell principle concentrates on the essential data in that it reduces the originally two-dimensional speckle pattern in a one-dimensional pattern. In spite of the data reduction this pattern includes all informations of the extension. Thus enabling exact measurement to standards via continuous tracing of two points.

Fig. 30: optiXtens in conjunction with a temperature chamber

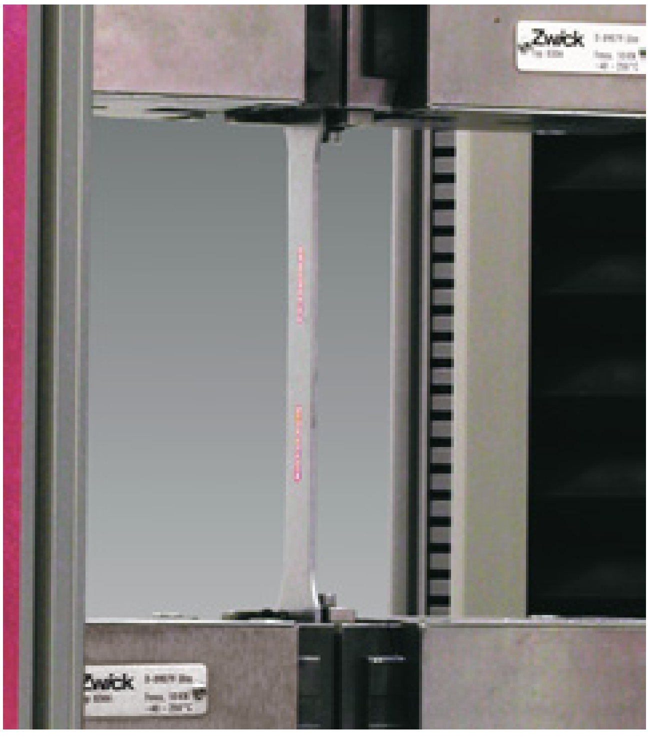


Fig. 31: The line lighting of the specimen surface with coherent laser light.

Advantages of the optiXtens

- The extensometer works with highest precision in the micro and macro measurement range up to measurement paths of 500 mm.

- Non-contact measurements to standards are run without measurement marks.

- The extensometer bears absolutely no influence on the specimen and measurement: There is no contact to the specimen. Surface optimizers produce relief if specimen absorb or reflex the laser light.

- It offers highest operation and operational safety.

- Measurements of higher strains and E-Modulus determination can be realized without an additional extensometer or retrofit time. Pretests secure this performance also when used in conjunction with temperature chambers.

- Furthermore it is especially suited for notch and break sensitive specimen.

- High user friendliness achieved by:
  - Automatic centring up to the middle of the specimen
  - Automatic setting of the initial gauge length L_0
  - Automatic setting of the virtual measurement marks
  - Automatic setting of the required laser energy
  - Securing against incorrect operation

- High system availability as the optiXtens is best protected against soiling, wear, de-adjustment and irreparable damage.

- optiXtens can be used manifold: It operates independent of the available illumination, can be used for a large range of materials, and has a very high degree of automation.

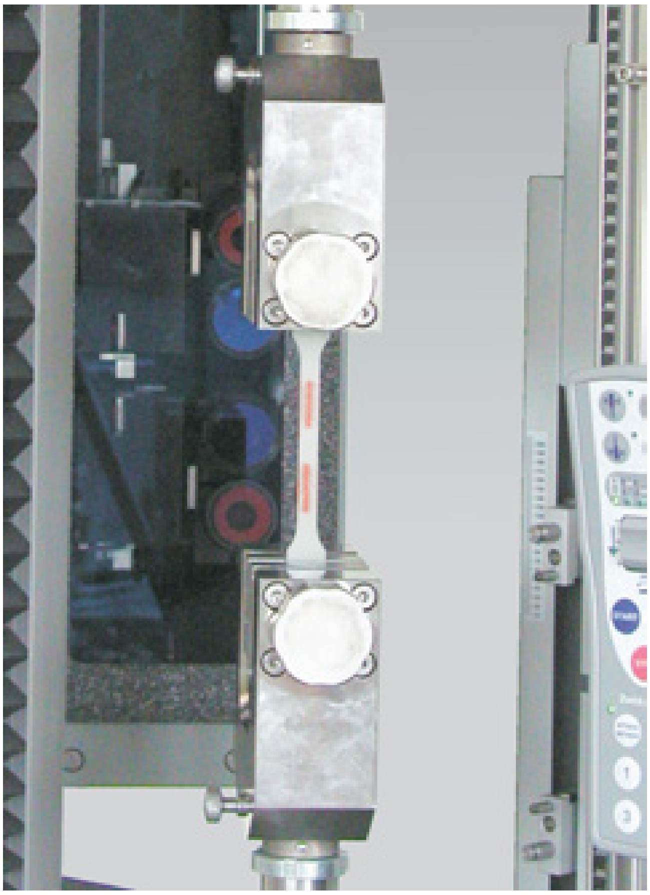


Fig. 32: A glance behind the pane of glass: Objective lens and tracking unit