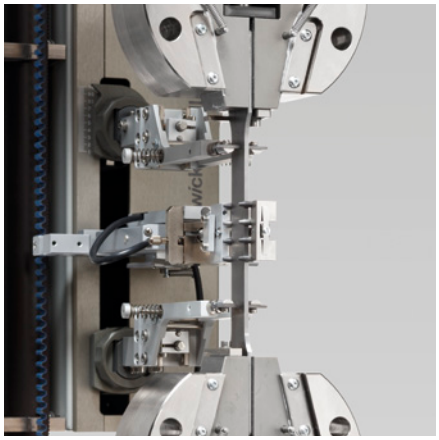
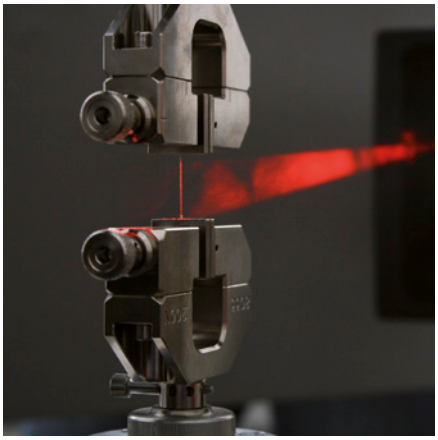
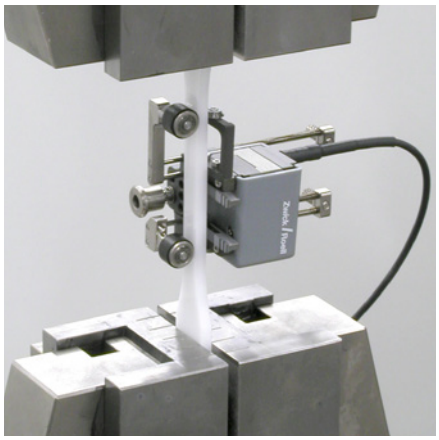
Zwick Roell

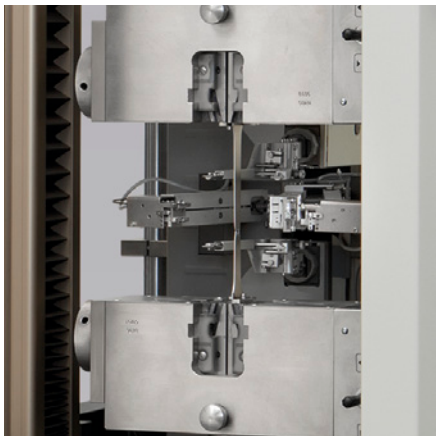
Zwick
Materials Testing

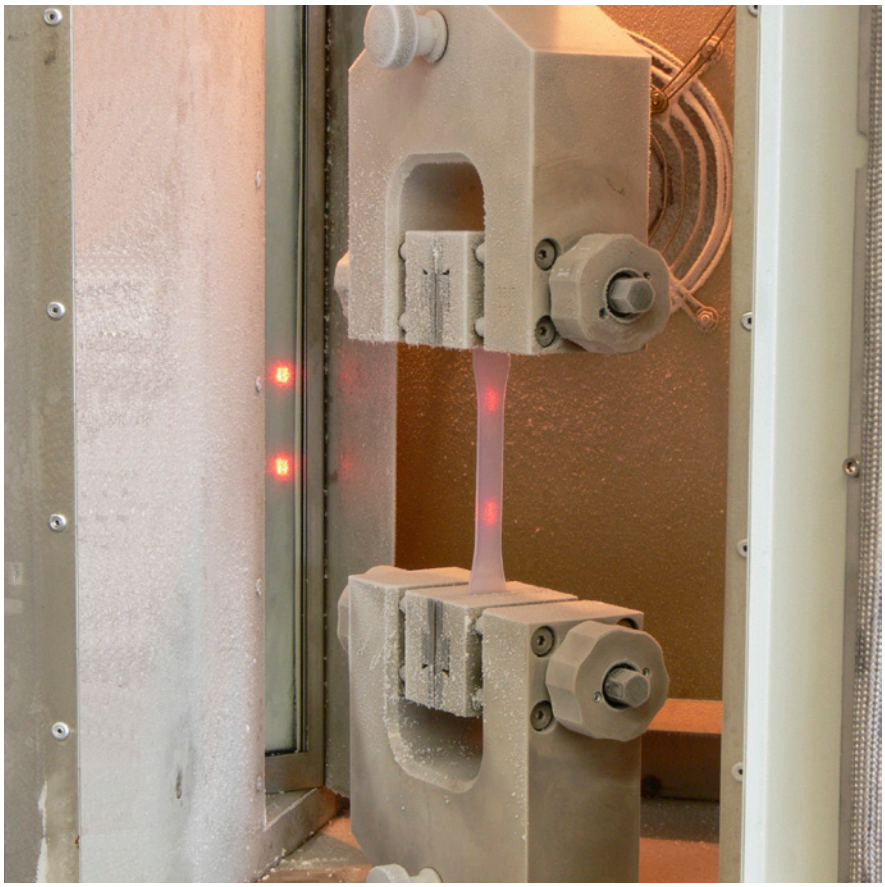
Extensometers for Materials Testing Machines











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Intelligent Testing

Zwick Roell

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1 Extensometers – a Core Area of Zwick Expertise

Extension measurement is one of Zwick's core areas of expertise. Our many years' experience in the in-house development, design and complete manufacture of these instruments, backed by a multitude of commercial installations, are your guarantee of state-of-the-art extensometer technology.

Zwick's extensometer range covers various resolutions, measurement principles and measurement ranges, and there are two basic principles of operation:

- Contact extensometers
  - sensor arm extensometers
  - digital and analog clip-on extensometers
  - extensometers for compression and flexure tests

- Non-contact extensometers
  - with gage marks (specimen preparation mostly required)
  - without gage marks (no specimen preparation required)

Advantages at a glance

- **Innovation:** extension measurement is a key testing machine technology. Zwick is a leading exponent in this field – for highly sensitive materials and tough specimens alike.The product range contains extensometers which are not available from any other manufacturer.
- **Choice:** Zwick has the most comprehensive range of extensometers, from analog clip-on instruments to fully automatic multi-purpose extensometers. We can supply systems for tests on highly elastic specimens such as elastomers or for brittle materials like ceramics. We provide expert advice backed by preliminary tests in our in-house Applications Test Laboratory and will find the best possible system for your requirements.
- **Operator first:** Zwick extensometers are produced with the operator in mind and are designed for maximum ease of attachment and operation. For optimum performance, automated test sequences are available for the whole process from sensor arm application to removal after specimen break.
- **Quality:** as with all our products, Zwick extensometers deliver high quality, with the emphasis on expertly finished high-grade materials, accuracy and high system availability.

2 Choosing the Right Extensometer for Every Materials Testing Application

In materials and component testing the range of applications where extensometers are used is extremely diverse. As a result, the technical requirements for these devices are many and varied, which means that there is no single device which satisfies all needs.

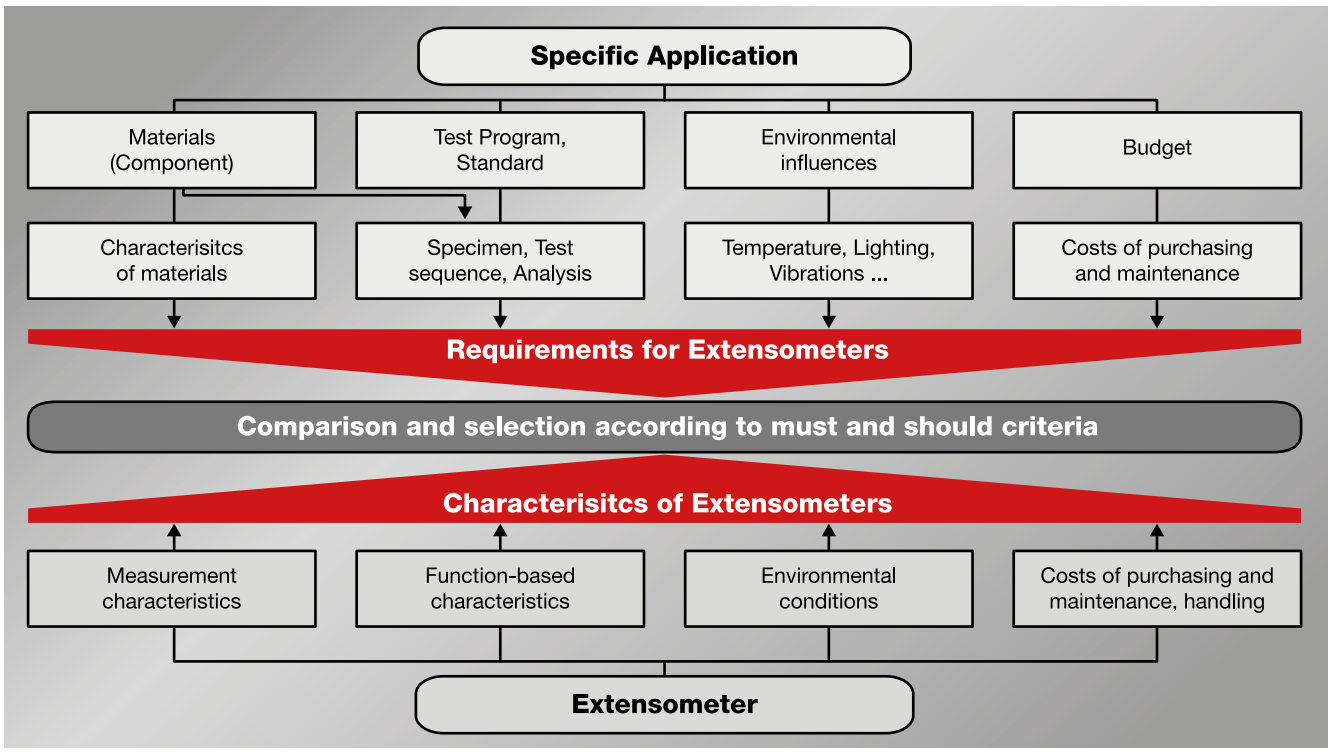
The requirements for an extensometer are determined primarily by the characteristics of the material to be tested. This includes its shape and dimensions, test requirements, and the formal standards which must be met. These define the gage length, accuracy, test sequence, and environmental conditions such as test temperature.

Specimen-related criteria
Having said this, the right choice of extensometer cannot be limited to the basic material characteristics such as specimen dimensions, stiffness, strength and plasticity alone. It is also necessary to decide whether an extensometer can be connected directly to the specimen without influencing the load measurement or mechanically damaging the specimen itself. Very thin specimens such as foils can be sensitive to clamping forces, whilst very small wire specimens do not provide enough visible area for reliable non-contact measurements.

A high stiffness in the initial extension range, followed by high plasticity traditionally requires more than one extensometer. The first measures small strains (typically up to 5 mm) very accurately in the elastic range, and the second measures very high values (typically 500 mm).

Specimens with very smooth, reflective surfaces, or made of transparent materials are not suitable for non-contact measurement without first fixing measuring marks onto the surface of the specimen.

One very important consideration is the behavior when the specimen fails. Metals and hard plastics will slip through the knife edges of a contact extensometer without damaging them, while swivelling knife edges will further reduce the risk of damage, even if the surface of the specimen is particularly rough.



Extensometer selection chart

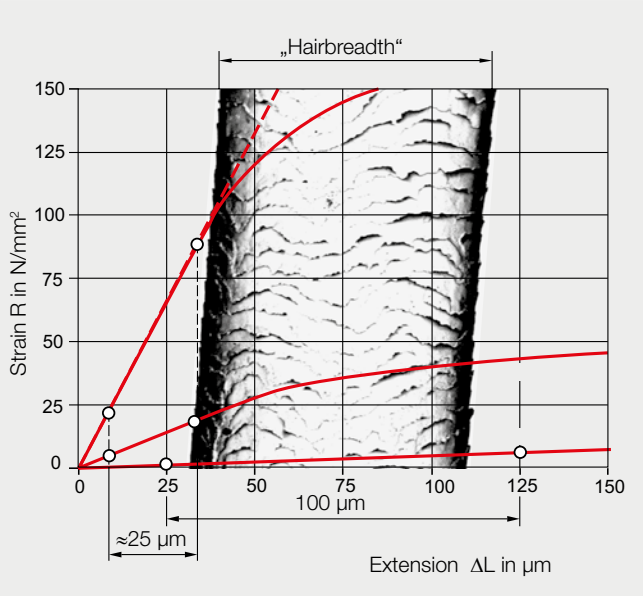
High extension or flexible specimens can damage or destroy the knife edges and even the extensometer itself due to whiplash, splintering, or de-lamination of specimens (for example steel rope). For these applications non-contact measurement is a must.

Criteria for accurate measurements
With contact type measuring extensometers, the measurement travel is normally an engineered and fixed value which is dependent upon the range of the measurement transducer and with fulcrum hinged sensor arms, the leverage ratio. The initial gage length is set manually with fixed steps or automatically over a defined range.

Non-contact extensometers which use a video camera must have the field of view larger than the required range plus the initial gage length. Since the specimen portions which are outside the gage length and the machine components themselves deform in the direction of loading, the position of the measuring marks on the specimen changes during the test. For extension and/or gage lengths which are expected to be outside of the field of view, the objective lens must be changed or the distance between the specimen and the video camera must be increased. All these actions decrease the measuring accuracy, and in addition, every changed measurement configuration must be adjusted and calibrated.

Measurement accuracy
“Accuracy“ is a commonly used, qualitative term. To qualify the integrity of a measured signal, standards use quantitative terms such as “resolution“, “deviation“ or “uncertainty“ and definitive values are given for these. Requirements for the accuracy of extension measurements are normally given in application specific test requirements and international standards. Many test standards, such as those for tensile tests on metals and plastics refer to standards for calibration of extension measurement systems and their required accuracy classes.

Precision measurement for very small strains
The graph shows stress-strain curves with measurement points for evaluation of elasticity or tensile modulus, with a human hair in the background. This illustrates the high accuracy required of an extensometer, for example to determine the tensile modulus of plastics to ISO 527. The strain measurement system used must



Precision measurement on the finest scale

be capable of measuring to an accuracy of 1 µm in the range from 25 µm to 125 µm when using an initial gage length of 50 mm.

Ergonomics
Devices which are easy to set up and sequences which can be automated reduce personnel time and effort and at the same time improve the quality of the test results because subjective influences are minimized. This particularly applies to series testing.

Economics
Higher initial acquisition costs can be quickly amortized, especially when the extensometer can be used for a wide range of applications, making additional purchases unnecessary. Also of relevance are the system operating costs, including maintenance due to wear, time required for configuration of manual systems for testing and time and cost of specimen preparation.

When using a video extensometer the time and costs for marking the specimen must also be considered as well as any potential human error introduced in attaching or aligning the marks.

Contact type measurement extensometers

Clip-on and sensor arm extensometers are in direct mechanical contact with the specimen via knife edges which are perpendicular to the gage length. The extremely small contact force from the knife edges can cause a microscopic indentation into the specimen surface which gives a light form-fit and thereby a precisely positioned contact point. This is an important factor for the large measurement accuracy and small scatter band width of the measured values.

Because of the direct contact with the specimen, sensor arm extensometers can be damaged or even destroyed by whiplash at the failure point of high elasticity / high extension specimens.

Clip-on extensometers

Clip-on extensometers are, as the name implies, usually mounted directly on the specimen. The mechanical parts which transfer extension, via knife edges, from the specimen to the internal transducer are short and stiff. There is practically no relative movement between the specimen and the extensometer and for this reason the measurement accuracy is exceptionally high. The range of a clip-on extensometer is limited to a few millimeters and it applies a load directly to the specimen. Zwick's patented digital extensometers provide a highly compact digital measurement system with a resolution of 0.1 µm and large measurement range (up to 40 mm).

Some extensometers are available with counter-balance weight and double-sided measuring systems are used to compensate for superimposed bending strains. The application and removal is normally manual; however, to minimize setting errors certain products are equipped with motorized application and removal systems.

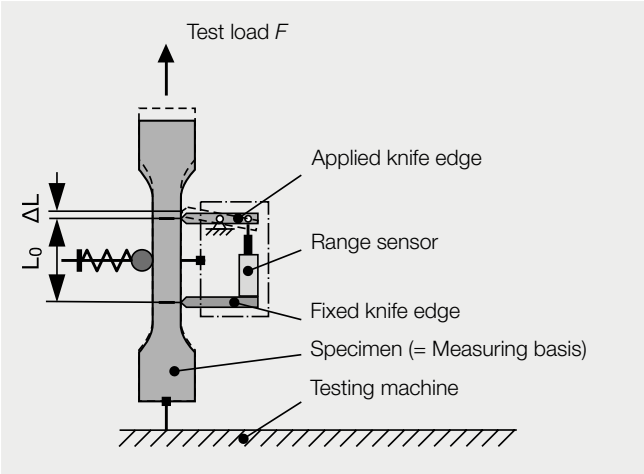


Fig. 1: Measuring with clip-on extensometers

Extensometers with sensor arms

Sensor arm extensometers offer the major advantage of mainly automatic operation and a large measurement range with high measurement accuracy and are suitable for many different applications. Precision designs with a very smooth and balanced mechanical operation apply minimum loading to the specimen (as little as the measurement marks used for non-contact extensometers). Since the sensor arms are in contact with both sides of the specimen, superimposed bending strains are largely compensated.

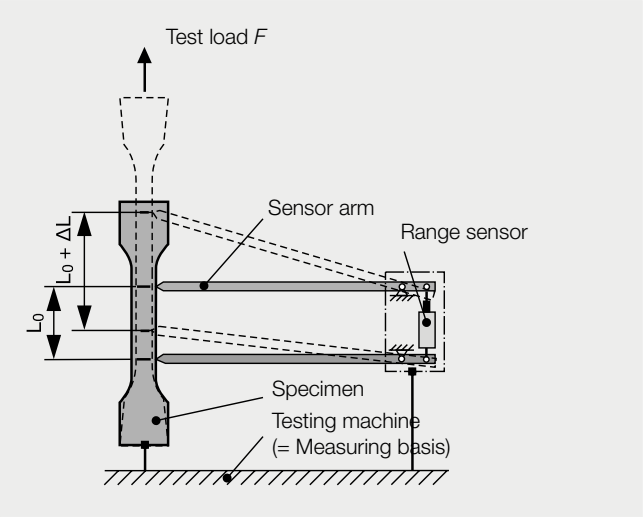


Fig. 2: Measuring with sensor arm extensometers

Non-contact extensometers

The main advantage of non-contact video and laser extensometers is that they can be used up to break without damage even when testing specimens that exhibit whiplash.

videoXtens – measurement with gage marks

The videoXtens require measurement marks to be attached to the specimen which are optically distinct from the surrounding area of the specimen. If no marks are visible on the specimen surface, gage marks are fixed or adhered to the specimen or the specimen is marked directly using paint etc. or a sprayed-on color pattern.

The position of the measurement marks on the specimen is evaluated by software algorithms which determine a certain area around an optical center point. This becomes the gage length and as the specimen is loaded the movement of the marks is converted to extension values. Special lighting for surface or background illumination of the specimen optimizes the contrast to the measurement mark.

During deformation of the specimen, the lighting changes on the measurement marks as well as on the specimen and surrounding influences (reflections etc.) can influence the optical center point. This is often the cause of scatter in the test results.

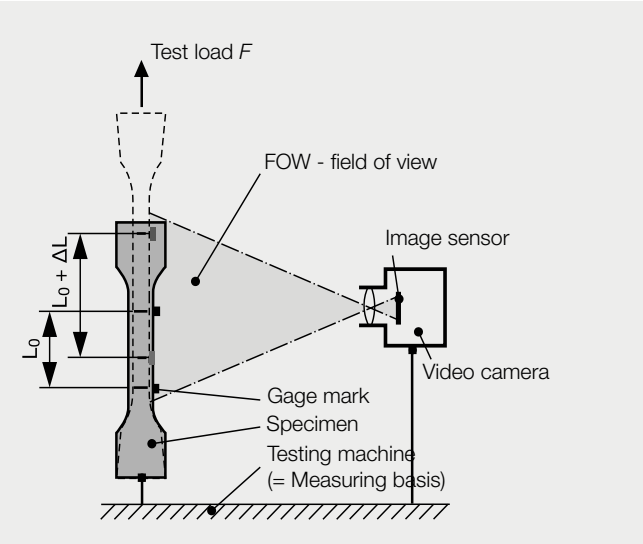


Fig. 1: Measuring with extensometers with video camera

laserXtens – measurement without gage marks
laserXtens, the latest extensometer from Zwick, is a non-contact extensometer which does not require gage marks. It uses the unique structure of a specimen´s surface as a 'fingerprint' to generate a virtual gage mark. Laser light directed on these points is reflected in various directions corresponding to the surface structure and creates a specific pattern of speckles. The selected gage marks are tracked and converted to direct extension values. The change in the surface structure is also continuously evaluated during specimen deformation.

laserXtens combines many advantages in one instrument: it delivers high resolution and accuracy; its non-contact operation does not influence measurement; it is wear-free and it can be used in extended and high temperature ranges.

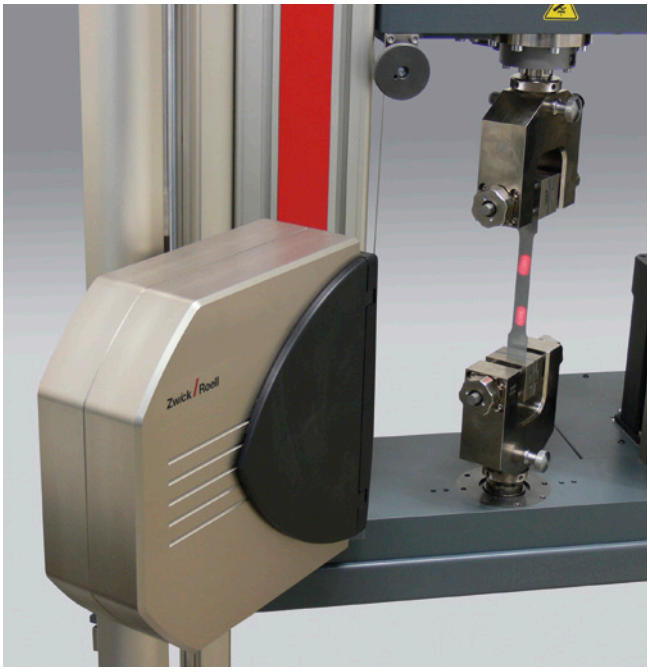


Fig. 2: LaserXtens with typical speckle pattern

Zwick is offering a wide range of extensometers
Contact type extensometers measure extension extremely accurately and are very cost effective. However, clip-on extensometers require much more manual intervention and without care can introduce scatter in the test results. Sensor arms extensometers offer extremely high accuracy, excellent repeatability, and ease of use due to fully automatic operation which includes the setting of variable gage lengths. Non-contact extensometers are required whenever the specimen reacts critically to knife-edges or would damage contact extensometers at failure.

In short, there is no such device as a universal extensometer which meets every customer's specific needs regarding measurement technology, day-to-day operation and with a price that matches all budgets. The large range of applications demands various devices with different functions and characteristics, and the extensometer must be selected for each application.

Users of Zwick testing equipment benefit from the wide range of extensometers available, as well as expert advice and consultation together with the opportunity to carry out pre-testing in the Applications Test Laboratory before purchase to make sure that the optimum device is chosen for each testing application.

3 Direct and Indirect Extension Measurement

Differing material properties require that both force and deformation (extension, strain, compressive deformation, deflection) for a specimen under load are measured during tensile, compression and flexure tests.

A distinction is made between direct and indirect extension measurement.

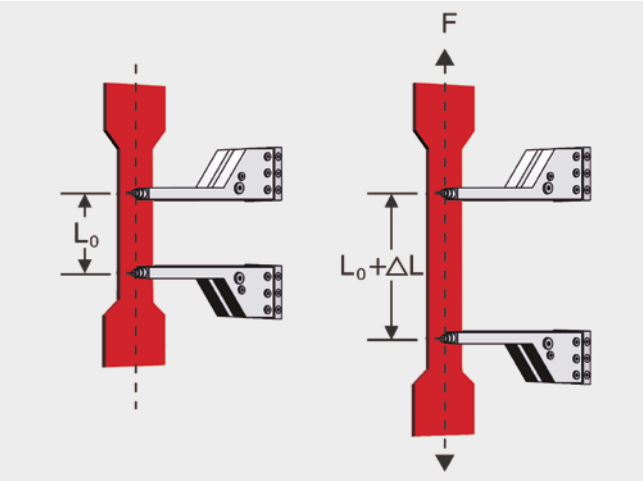
Indirect extension measurement
Indirect extension measurement determines specimen extension by measuring the change in the distance between the testing machine crossheads. The deformations of all units within the testing machine load frame are therefore included. The sum of these individual deformations must be negligible compared to the extension to be measured, which means either that it must be less than the permissible measurement error, or it can be partially eliminated via a computed correction curve. This correction curve can be determined for a specific machine configuration and used to correct the measured extension values, provided the deformation of the test arrangement is sufficiently reproducible.

The change in crosshead travel (and therefore in crosshead speed) is recorded by Zwick materials testing machines via digital crosshead encoders with extremely high resolution (better than 0.2 µm for all machine types).

Extension measurement via crosshead travel may be suitable for the following cases:
- Compression tests where influences from the test arrangement can be compensated for via a correction curve,
- Compression tests on specimens with high deformation (e.g. > 30 to 50 mm),
- Characteristic values with high strains (strain at break),
- Strip specimens and parallel clamped specimen grips for which defined grip-to-grip separations are guaranteed and the specimen has stable, non-flowing characteristics,
- Stable, non-flowing materials.

Direct extension measurement
Measuring extension directly on the specimen eliminates all unwanted side-effects, including load-frame deformation (lead-screws, columns, crossheads), load-cell deformation, deformation of the specimen grips and any specimen slippage.

Zwick supplies measurement systems for the following:
- Axial strain measurement (measurement in tensile direction),
- Transverse strain measurement (measurement perpendicular to the tensile direction),
- Deformation measurement for compression and flexure tests.



Direct extension measurement

Direct extension measurement is always necessary if:
- Required by the relevant test standard,
- The result is not to be distorted by elastic deformation of machine components,
- Specimen behavior in the clamping area could distort the result, particularly with soft materials,
- Specimen deformation outside the gage length is not to be included,
- Self-clamping specimen grips are used and movement of the jaw inserts is not to be included.

4 Relevant Material Properties

4.1 Extension measurement

Extension measurement during loading up to specimen break can be divided into different ranges according to the material properties to be determined:

- Fine strain measurements in the elastic range and at the beginning of the permanent deformation range,
- Determination of offset yield from the start of permanent deformation,
- Determination of uniform strain and strain at break.

Fine strain measurement
This is primarily used to determine Young's modulus and the technical elastic limit (0.01 % proof strength) for metals and Young's modulus for plastics. The strain range to be recorded here is typically between 0.05 and 0.25 % (also up to 1 % for foils / films).

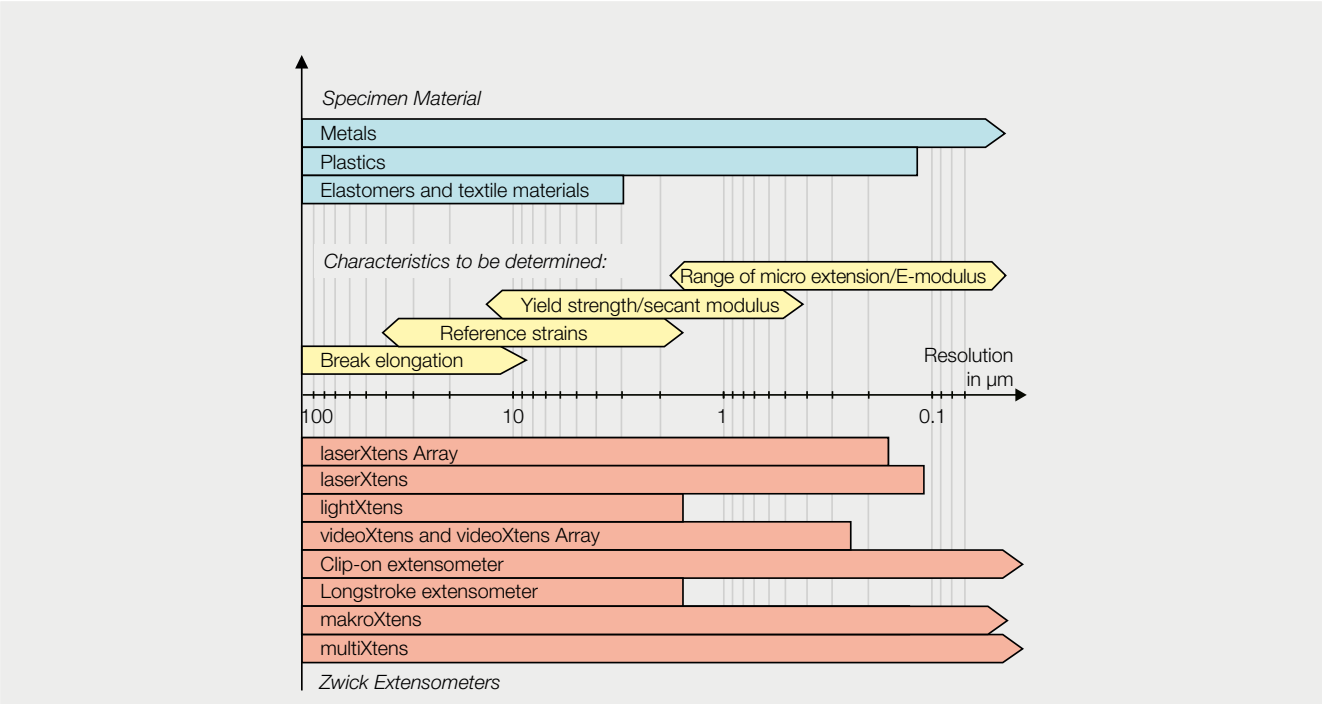
These material properties require measurement of extremely small extensions at correspondingly high resolution and very small errors. Clip-on and sensor-arm extensometers (multiXtens, makroXtens) plus laserXtens and videoXtens are suitable, according to ISO 9513 (see graphic).

Determination of offset yield (proof strength)
Offset yields are determined for characterization 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 analog and digital clip-on extensometers, sensor-arm extensometers and non-contact measurement systems such as lightXtens, videoXtens and laserXtens can be used for determination of offset yield (see graphic below).

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

Strain at break is the permanent extension, with reference to the initial gage length on the specimen after break. To determine strain at break, an extensometer must be designed to have a long measurement travel and for testing up to specimen break. Sensor-arm extensometers with swiveling knifeedges and non-contact measurement systems are the most suitable types for this. Clip-on extensometers have only limited suitability for determination of strain at break.



Range of application of Zwick extensometers based on resolution

4.2 Transverse Strain Measurement

Poisson's ratio (μ)
Poisson's ratio μ is a measure of the deformation ratio between axial and transverse strain in a tensile test. A preferred use of Poisson's ratio is when testing long-fiber reinforced plastics. Measuring Poisson's ratio requires two strain measurement systems operating simultaneously in both axes.

Zwick's solutions include analog and digital transverse strain extensometers, or a video-based non-contact transverse strain measurement system (videoXtens transverse strain extensometer). The transverse strain extensometers are used in conjunction with a sensor arm extensometer (multiXtens, makroXtens).

Vertical anisotropy (r-value)
Vertical anisotropy characterizes the cold workability of thin sheet metal with regard to the behavior of the material during deep drawing. The r-value denotes the resistance of sheet metal to a reduction in thickness under single-axis tensile loading. To determine these values, transverse strain must be measured on a dumbbell specimen.

An analog or digital transverse strain extensometer used in conjunction with the makroXtens is suitable for this.

An alternative is the videoXtens transverse strain extensometer, our video-based non-contact transverse strain measurement system.

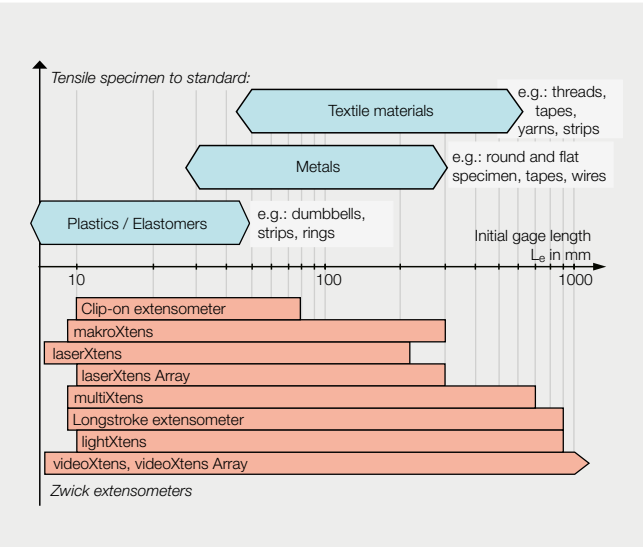
The biaxial digital clip-on extensometer is specifically intended for this test and is designed for axial and transverse strain measurement.

5 Selection Criteria

A basic decision which has to be made is whether direct extension measurement is necessary, or if indirect extension measurement via crosshead travel is sufficient.

If direct measurement is to be used, an extensometer with the appropriate characteristics must be selected. Listed below are some of the criteria governing this choice, depending on the material to be tested and the results to be determined.

Initial gage length (L_e)
Various initial gage lengths are prescribed by test standards, according to the shape and dimensions of the specimen to be tested. In most cases the gage length is relatively small for high levels of strain and relatively large for lower strain levels. In metals testing, the initial gage length is directly related to the specimen cross-section (for proportional specimens).



Range of application of Zwick extensometers based on initial gage length

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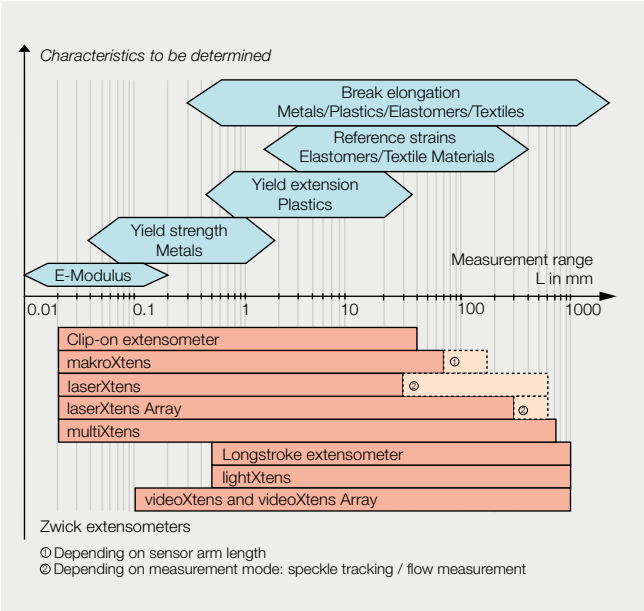
Measurement travel

The extensometer measurement travel must be sufficient for the specimen to be tested. If the specimen strain is unknown, it can be estimated for various materials and characteristic values (see graphic below).



Range of application of Zwick extensometers based on measurement travel

Type of loading

The type of loading also has a bearing on the measurement range. The requirements for compression or cyclic tests are different from those for tensile testing, for example, extensometers used for cyclic tests must have zero mechanical hysteresis.

Resolution and accuracy

The resolutions and accuracy levels specified in the individual test standards must be observed.

Specimen break

The extensometer must not be damaged by high specimen resilience at break and the resulting high acceleration forces.

This risk is present with specimens liable to a whiplash effect at break, including elastomers, ropes and straps. Non-contact measurement systems are suitable for such tests.

At Zwick sensor arm extensometers are equipped with swiveling knife edges and sensor arms. At the break of the specimen they move aside and out of the way to avoid the damage of the extensometer.

Notch and flexure sensitivity

The choice of extensometer also depends upon the notch and flexural sensitivity of the specimen material. The design of a clip-on extensometer (specimen loading via torque), which is attached directly to the specimen, is influenced by weight or possible weight compensation, while the way it is attached influences the test. For example, applying optional counter-rollers to specimens with thin cross-sections could lead to distortion of the test results.

Drag forces

Drag forces of sensor-arm and clip-on extensometers must be as low as possible to avoid any influence on the specimen – guaranteed with Zwick extensometers.

Edge-fiber strain

The material and the specimen shape provide indications of the possible occurrence of differing edge fiber strain, which must be allowed for during strain measurement by averaging. For example, differing edge fiber strains result from loading specimens with flexural stresses (with single-sided clip-on extensometers with only one counter-roller or with long levers) or from imprecise axial clamping of the specimen.

Testing in temperature chambers

Deformation measurement in temperature chambers requires the use of extensometers with extended sensor arms or non-contact extensometers.

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6 Overview of Zwick Extension Measurement Systems

The selection of a suitable extensometer depends upon the material to be tested, the results to be determined and the relevant test standard. These criteria and their interdependency are shown in the following tables.

		Contact measuring systems							Non-contact measuring systems			
Test results	**Standards**	multiXtens	makroXtens	Longstroke extensometer	Incremental clip-on extensometer	Biaxial incr. clip-on ext. (length & width)	Analog clip-on extensometer	Transducer for 3-point flexure testing	videoXtens[1], videoXtens Array[1]	laserXtens / HP laserXtens Compact / HP	laserXtens Array	lightXtens
Plastics and Elastomers												
Poisson´s ratio	ISO 527	•[2]	•[2]	-	-	-	-	-	•	-	-	-
Tensile modulus	ISO 527	•	•	-	•	-	•	-	•	-	-	-
Compression modulus	ISO 604	•	•	-	•	-	•	•	•	-	-	-
Flexure modulus	ISO 178	•	•	-	-	-	-	•	-	-	-	-
Tensile-creep modulus	ISO 899-1	•	•	•	•	-	•	-	•	•	•	-
Fluxure-creep modulus	ISO 899-2	•	•	-	-	-	-	•	-	-	-	-
3.5 % Flexure strength	ISO 178	•	•	-	-	-	-	•	-	-	-	-
Flex. deform. at break	ISO 178	•	•	-	-	-	-	•	-	-	-	-
Yield extension	ISO 527	•	•	•	o	-	-	-	•	•	•	•
Strain at x % elongation	ISO 527	•	•	•	o	-	o	-	•	o	•	•
Modulus values	ISO 37, DIN 53504	•	-	•	-	-	-	-	•	o	•	•
Elong. at tensile strength	ISO 527	•	o	•	o	-	o	-	o	o	o	•
	ISO 37, DIN 53504	•	-	•	-	-	-	-	o	o	o	•
Elongation at tens. str., strips	ISO 527-3	•	o	•	-	-	-	-	o	o	o	•
Elongation at tear	ISO 527	•	o	•	o	-	-	-	o	o	o	•
	ISO 37, DIN 53504	•	-	-	-	-	-	-	o	o	o	•
Elongation at tear, strips	ISO 527-3	•	o	•	-	-	-	-	o	o	o	•
Metals												
r-value	ISO 10113, ASTM E 517	•[2]	•[2]	-	-	•	-	-	•	•[2]	•[2]	-
n-value	ISO 10275, ASTM E 646	•	•	•	•	•	-	-	•	•	•	-
E-modulus/hook´s gradient	ISO 6892-1, ASTM E8	•	•	-	•	•	•	-	•	•	•	(•)
Compression modulus	DIN 50106	(•)	(•)	-	•	-	•	-	•	-	•	-
Flexure modulus	ISO 7438	•	•	-	-	-	-	•	-	-	-	-
Hysteresis (E-modulus)	ISO 6892-1	•	•	-	•	•	-	-	•	-	•	•
Elongation at break	ISO 6892-1, ASTM E8	•	•	-	-	•	-	-	•	o	•	•
Yield point elongation Ae	ISO 6892-1, ASTM E8	•	•	-	•	•	o	-	•	•	•	(•)
Strain at x % elongation	ISO 6892-1	•	•	-	•	•	o	-	•	o	•	(•)
Elongation at tensile strength	ISO 6892-1, ASTM E8	•	•	-	•	•	o	-	•	•	•	(•)
Yield strength x	ISO 6892-1, ASTM E8	•	•	-	•	•	o	-	•	•	•	(•)
Yield str. at total elongation	ISO 6892-1, ASTM E8	•	•	-	•	•	o	-	•	o	•	(•)
Proportional elongationg	ISO 6892-1, ASTM E8	•	•	-	•	•	-	-	•	•	•	(•)
Strain control	ISO 6892-1, ASTM E8	•	•	-	•	-	•	-	-	•	-	-

• = Suitable system
(•) = If the initial gauge length L_e is sufficient
o = Can be used if the specimen´s extension does not exceed the extensometers measurement range

[1] = The appropriate field of view is selected by using different lenses
[2] = In conjunction with a suitable transverse strain extensometer

Table showing solutions available from Zwick for obtraining test results as per standards

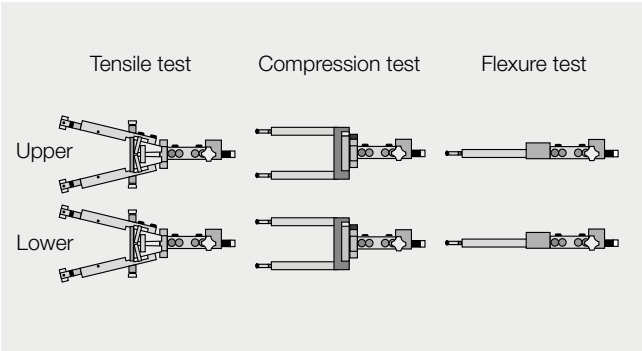
7 Contact Measuring Systems

7.1 Sensor Arm Extensometers

These extensometers are used for tensile, compression, flexure and cyclic tests. The gage length is infinitely adjustable to suit the specimen to be tested.

Zwick sensor-arm extensometers use digital measuring systems. Transmission of the extension to the measurement system is via play-free, swiveling knife edges on the sensor arms. The sensor-arm clamping forces are very small and can be steplessly adjusted to avoid specimen damage and ensure correct location of the knife-edges.

Interchangeable sensor arms
Easily changed sensor arms allow different types of test, material and specimen shape to be accommodated. A plug-in connection enables sensor arms for tensile, compression or flexure tests, or for use in temperature chambers, to be mounted quickly and easily, minimizing changeover and set-up times.



Fi. 1: The various types of sensor arms cover a wide range of applications

Interchangeable knife edges
The knife-edges are also easy to change and comprise one flat and one convex side. They can be simply rotated so that they are always in single-point contact with the specimen (flat or round specimen), ensuring extremely accurate measurements.

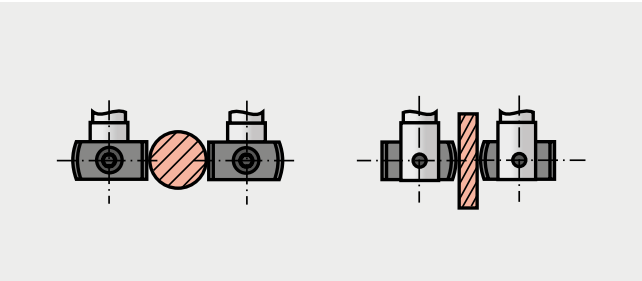


Fig. 2: Round and flat specimens with straight and convex knife-edges respectively

Knife-edges are available with Vulkollan coating for notch-sensitive specimens and with aluminium oxide coating for extremely smooth specimens.

Tests up to specimen break
The knife-edges which can swivel through 180° only transmit extremely low forces to the sensor arms at specimen break, reliably avoiding damage to the sensor arms and the extensometer at specimen break.

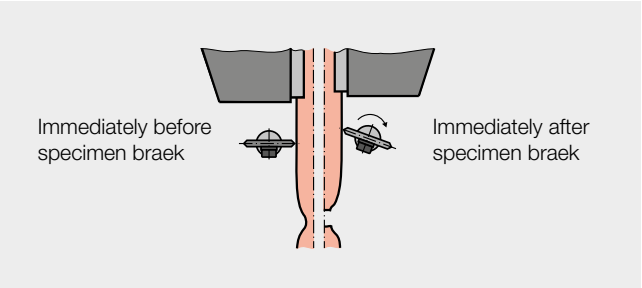


Fig. 3: Operating principle of swivelling knife-edges

Use in temperature chambers
Extended sensor arms enable extensometers to be used for extension measurement in temperature chambers. These arms enter the temperature chamber through lateral apertures in the chamber wall, maintaining full functional capability and ease of operation.

High level of automation
Depending on the extensometer used, extension measurement can be automated to a high degree. This includes both automatic adjustment of the initial gage length, including cross-section-related gage length and application and removal of the sensor arms, providing a greater degree of accuracy and reproducibility and shortening test times.

Zwick / Roell

multiXtens®

Range of application

multiXtens is a versatile high-accuracy extensometer, ideally suited to tensile, compression, flexure and cyclic tests on plastics, elastomers, metals, composites, rigid foams and many other materials.

The extremely high measurement accuracy combined with the extremely large measurement range makes multiXtens the ideal tool for varying requirements (e.g. testing plastics and elastomers or plastics and metals).

Description of system

The truly modular design of this multi-purpose extensometer allows it to be used in a wide range of testing situations. It consists of a guide system with integrated measuring carriages which can be moved independently of each other, attached to which are easily exchanged measuring heads and sensor arms. All components are automatically identified.

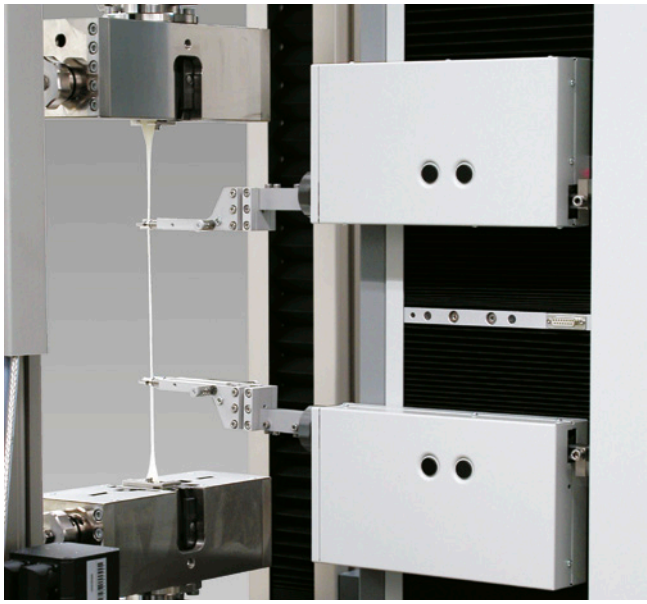


Fig. 2: The easy-change sensor arms are attached to the carriage-mounted measuring heads

Fig. 1: multiXtens universal extensometer

Advantages / Features

- Can be used up to specimen break, even with high forces and brittle specimen material
- Highest precision, even for long measurement paths (up to 700 mm)
- Accuracy class 0.5 according to ISO 9513
- Maximum error ± 1 µm in differential movement measurement between two measuring points in a range from 20 µm to 200 µm, completely satisfying the additional requirement to ISO 527-1 (2011)
- multiXtens is calibrated from 20 µm measurement travel in Class 0.5
- Very low drag-force and freely adjustable sensorarm contact-pressure enable safe, reliable, traceable testing of sensitive specimens
- Compression and flexure tests can be performed simply by changing the sensor arms
- Fully automatic system:
  - measurement of clearance between specimen grips
  - measuring-slide centering
  - automatic application and withdrawal of sensor arms
  - automatic gage length setting

Options

- Mechanical and video transverse strain extensometers (e.g. for determining r-value or Poisson's ratio)
- Fine-strain extensometer
- Precision swivel unit

Zwick / Roell

makroXtens®

Range of application
The makroXtens is a versatile high-accuracy extensometer operating on the contact principle. Ideal for tensile, compression, flexure and cyclic tests on metals, plastics, composites and many other materials.

Description of system
This multi-purpose extensometer also features modular design, allowing for example the manually operated version to be upgraded to automatic attachment and removal.

Types
The makroXtens is available as a P variant and a HP variant, each with three different gage length ranges. The HP variant is distinguished by higher resolutions, the intelligent tracking unit and the release for „closed loop“ strain control according to ISO 6892-1 method A(1) plus ASTM E 8-09 method B.

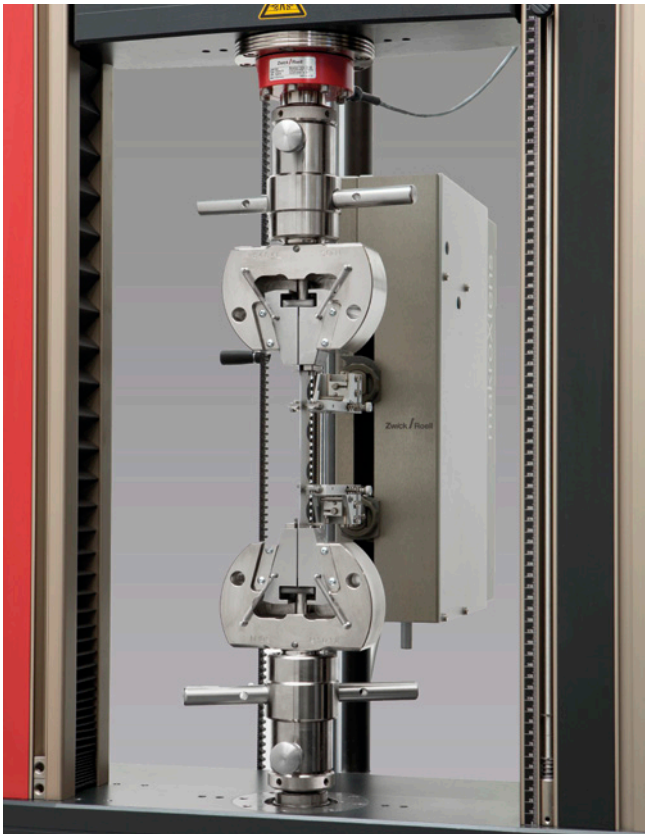


Fig. 1: makroXtens

Optional transverse strain extensometers
The optional transverse strain extensometers are designed for tensile tests on metals. They are mounted on the makroXtens and can be operated manually or automatically as required via *testXpert*® II testing software. Transverse strain can be measured in one, two or four cross-sectional planes.

A product unique to Zwick is the videoXtens transverse strain extensometer for non-contact, high-resolution transverse strain measurement – the result is an ideal system combining tactile and optical strain measurement.

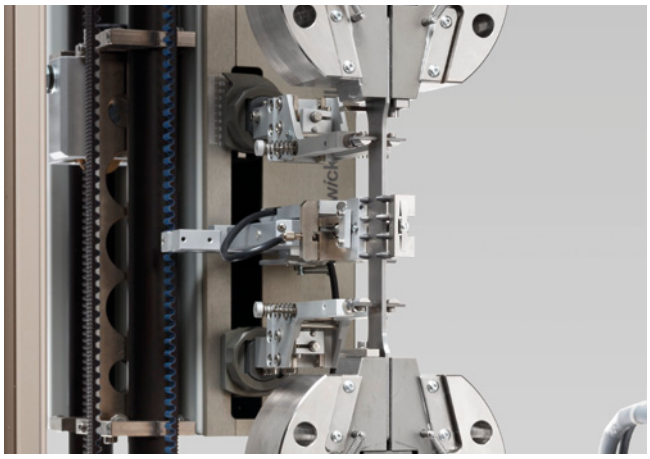


Fig. 2: makroXtens in combination with transverse strain extensometer, (4 measurement lines)

Advantages / Features
- Standard extensometer in the metals, plastics and automotive industries, with an installed base of over 2.500 systems
- Robust measuring system, also suitable for use in automated testing systems
- Can be used up to specimen break, even with high forces and brittle specimen material
- Accuracy class 0.5 according to ISO 9513
- Maximum error ± 1 µm in differential movement measurement between two measuring points in a range from 20 µm to 200 µm, completely satisfying the additional requirement to ISO 527-1 (2011)
- makroXtens is calibrated from 20 µm measurement travel in Class 0.5
- Compression and flexure tests can be performed simply by changing the sensor arms
- The measuring system is automatically guided into the optimum position between the specimen grips. Maximum measurement travel is always available

Zwick / Roell

Long stroke extensometer

Range of application

The long stroke extensometer has been designed for testing highly-elastic plastics, elastomers, foils, textiles, leather and similar elastic materials. It is primarily used for direct extension measurement on specimens with medium and large strain levels in tensile or hysteresis tests, as well as in temperature chambers (by means of extended sensor arms).

Description of system

Widely spaced measurement-carriage mountings plus swivelling knife-edges make the system resistant to impact loading, as occurs with some elastomers at specimen break. The provision of two precision guide-columns for the measurement carriages plus especially low-friction guide elements ensure low-force transmission of the extension, minimizing errors. The mass of the measurement carriage is balanced via counter-weights.

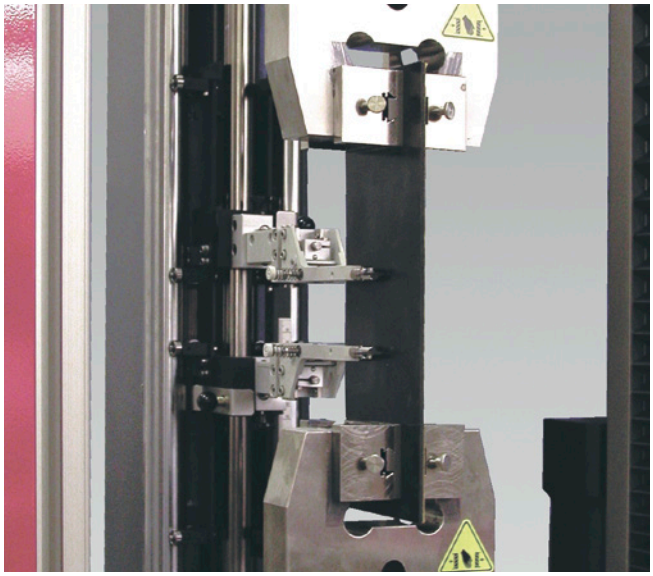


Fig. 2: Swivelling knife-edges prevent damage at specimen break

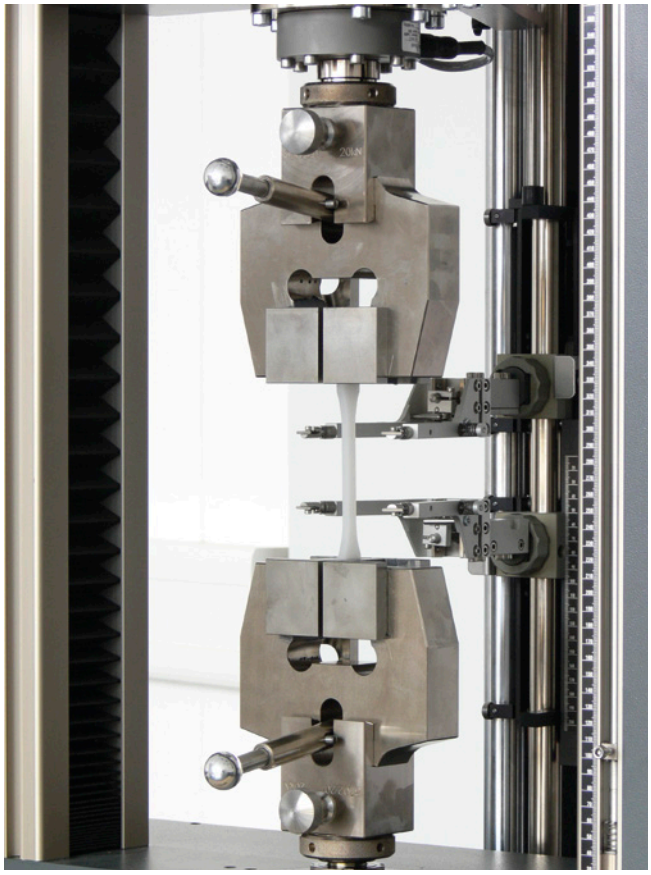


Fig. 1: Long stroke extensometer

Advantages / Features

- Can be used up to specimen break, even with high forces and brittle specimen material
- Resolution is high over the entire measurement range
- Availability of a very large measurement path
- Synchronous force-travel recording
- The drag forces are very small
- The long travel extensometer can be combined with all analog and incremental clip-on extensometers
- Control of the extensometer is via the testing program. The sensor arms are electromechanically clamped at the beginning of test, unclamped at the end of test and the initial gage length is set again

7.2 Clip-on extensometer

Incremental clip-on extensometer

Range of application
Zwick clip-on extensometers are designed for testing plastics and metals:
- Determination of Young's modulus and strain measurement to ISO 527-1 on plastics,
- Strain measurement on metals, composites and many other materials,
- Determination of the compressive strength of plastics and the compression E-Modulus of metals.

Description of system
The core of the system is a miniaturized digital measuring unit, which delivers uniformly high accuracy over the entire gage length. The lightweight measuring system is located very close to the specimen, minimizing specimen loading.

Advantages / Features
Zwick's digital clip-on extensometers are unique in both design and operation. The Zwick patented design offers the following advantages:
- Highly robust extensometer – can remain attached to plastic and composite specimens up to break. With metals this depends on the energy released at specimen break
- Accuracy Class 0.5 to EN ISO 9513
- Maximum error ± 1 µm in differential displacement measurement between two measuring points in the range from 20 µm to 200 µm, completely satisfying the additional requirement to ISO 527-1 (2011)
- Calibrated from 20 µm measurement travel in Class 0.5
- The short leverage minimises mechanical transmission errors, and increases the reproducibility
- Low weight and compact design for minimal influence on the specimen
- The initial gage length is automatically arrested when attaching the extensometer and released when it's let go of

Versions / models
Three different versions are available.
- Extension measurement: two versions with different measurement-travel ranges are available; in both cases initial gage lengths are adjustable and extension pieces for greater gage lengths are available

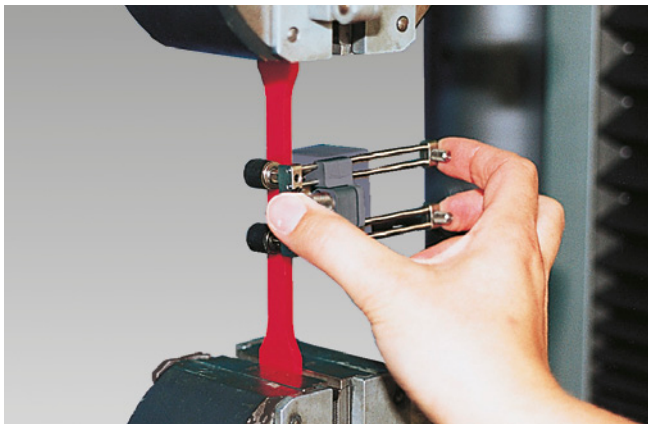


Fig. 1: Quick, easy, reliable handling

- Transverse strain extensometer: the digital clip-on extensometer measures the transverse strain with one measurement line
- Biaxial measurement: Zwick biaxial clip-on extensometer for determining extension and change in width

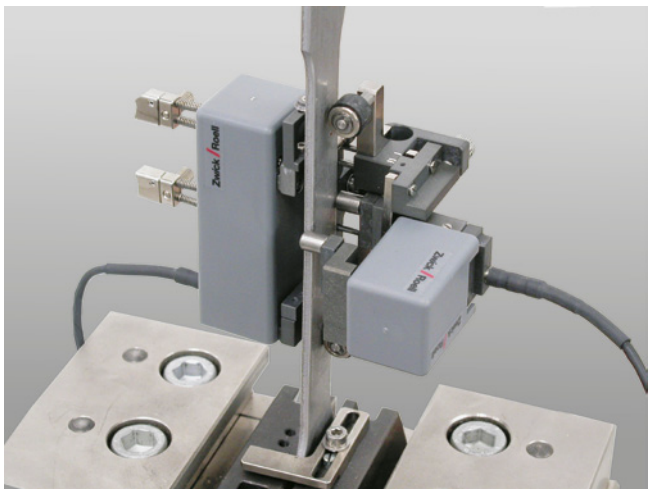


Fig. 2: Biaxial digital extensometer

Zwick / Roell

Analog clip-on extensometers

Range of application

These extensometers are clipped directly to the specimen and are designed for strain measurement on metals and plastics. Their range of application covers fine strain and yield point (proof strength) measurement, as well as E-Modulus determination.

These clip-on extensometers are available in manual or automatic clip-on versions and can be supplied with inductive or strain gage measuring systems.

Inductive (analog) clip-on extensometer

Inductive travel measurement involves moving a core and a coil of defined cross-section relative to each other, causing a change in inductance, which is proportional to the specimen extension.

Specimen extension is transmitted via pairs of knife-edges attached to two sides of the specimen, each pair transmitting to the inductive measurement system in the extensometer.

Advantages / Features

- Very high measurement accuracy
- The measurement leverage involved is very small as the measurement system is arranged very close to the specimen, giving enhanced measurement accuracy and reproducibility
- Two measurement systems for averaging different edge-fiber extensions
- The two measuring systems can optionally be evaluated separately via an additional sensor plug

Strain-gage extensometers

A strain gage is an electrical resistor attached to an insulating foil in a zigzag pattern perpedicular to the strain measurement direction. If the strain gage is stretched in the measurement direction, its electrical resistance increases. The specimen extension is transmitted via the sensor arms to mechanical elements equipped with strain gages, producing a defined deformation.

Strain-gage clip-on extensometers are available for axial and transverse strain measurement in single or doublesided versions. Strain gages are also available in temperature-resistant versions for use in temperature chambers.

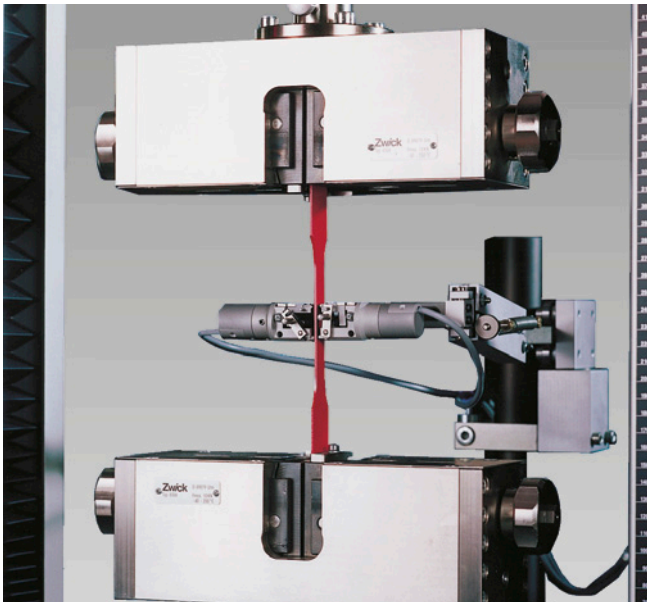


Fig. 1: Clip-on extensometer with optional counter-weight

Advantages / Features

- Excellent linearity, ensuring reliable test results
- Gage lengths are adjustable from 10 to 100 mm, enabling use for specimens of different sizes
- Miniaturized, lightweight construction also makes them suitable for use with short specimens
- The transverse strain extensometers are designed for use in conjunction with sensor-arm extensometers, or without an extensometer. They are specially designed for tests on metals, but can also be used to determine Poisson's ratio on fiber-reinforced laminates to ISO 527-1

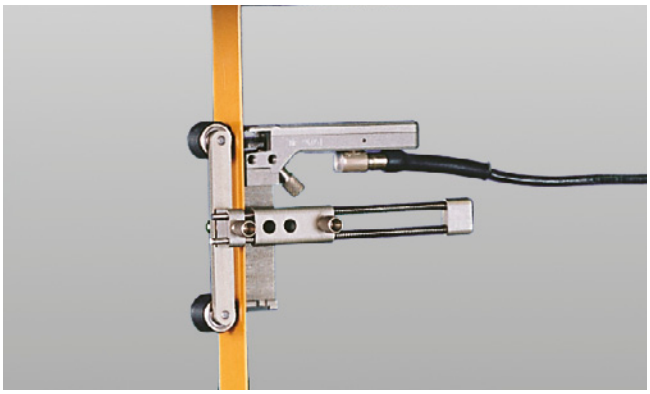


Fig. 2: Strain-gage extensometer

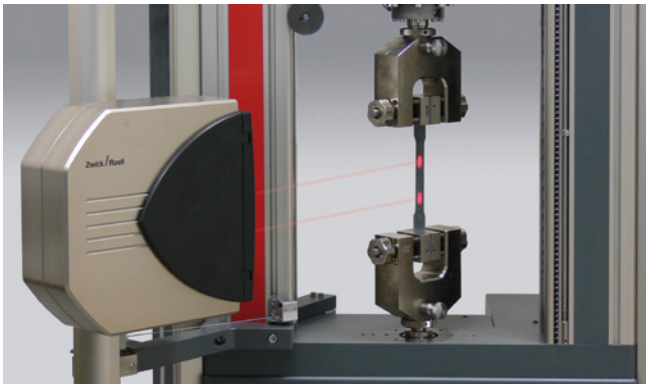
8 Non-contact measurement system

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.

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.

The laserXtens is sticking out of the series of contact-free extensometers as it is a special development. It is working without measurement marks, so it has absolutely no influence on the specimen.



A technology only offered by Zwick: Non-contact extensometers according to the laser speckle principle

Advantages of the non-contact measurement systems

- The behaviour of the specimen is not 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 0.5 and 1 are available
- Any required gage length obtainable by application of gage marks at appropriate intervals; alternatively can be set as required using an inherent (e.g. rebar ribs) or generated pattern (sprayed pattern, laser speckle pattern)
- No thermal bridges when using temperature chambers as measurement takes place via a heatable window
- Biaxial optical measurement is possible

Additional information through non-contact measuring systems

Strain distribution

The option strain distribution is used to determine localized strains which are then available as channels in *testXpert*®. The automatic recognition and evaluation of up to 16 measurement marks is possible. In addition, a balancing of the beginning gage length can be performed in order to follow the necking-in automatically in real time (according to ISO 6892-1, annex H).

Test Re-Run

The optional Test Re-Run module allows an image series recorded during a test to be used for subsequent recalculation of the strain with a different initial gage length (if several markings are present). This can be especially advantageous if local strains must be evaluated at different locations in component testing or if the necking of the specimen in a standard tensile test occurred outside the original initial gage length. If the test was recorded with *testXpert*® II, the recalculated strain can naturally be synchronized afterward with the other measured values. This option is available from *testXpert*® II version 3.4.

8.1 videoXtens®

Range of application
videoXtens provides contact-free, high-resolution measurement of extension, both in the tensile and compression direction, on all types of plastic, metal, rubber, composites, and foils. It is also suitable for determining transverse strain, r-values to ISO 10113 and ISO 10275 and proof strength (offset yield) in tensile tests to ISO 6892-1.

Operating principle
A full-view camera generates the digitized image of the specimen, which is processed in real time. The gage marks are automatically identified and the displacement of the marks from frame to frame is converted to an extension value and transmitted to the measurement and control electronics.

Advantages / Features
- The flexible illumination system (Frontlight / Backlight) can be adapted individually for each test task
- Extensions as well as optional transverse strain are possible at the same time. No separate marking is required for measuring the transverse strain. The transverse strain can be determined at one or more locations. This permits the offset yields to be measured in a tensile test according to ISO 6892-1, as well as the r-values according to ISO 10113 and ISO 10275
- In addition the videoXtens can be used for compression and flexure tests.
- Measurement range is variable and very large, according to the selection of the picture size or objective
- Automatic test mark recognition and acquisition of the initial gage length L_e
- Preparation-free testing of specimens with a textured surface by pattern tracking. Alternative preparation of specimens with a homogenous, non-textured surface using pattern spray
- When connected to *testXpert*® II, the Video Capturing Plus functionality of the videoXtens can be used without additional hardware. This requires the integration of the image sequence in *testXpert*® II and synchronization with the measurement data

videoXtens - Non-contact measurement in a temperature-controlled fluid bath

Multi-camera measuring systems videoXtens Array
The resolution of the videoXtens depends on the camera's field of view. The smaller the image, the better the resolution but the smaller the measuring range. If an application requires a large measurement displacement combined with very high resolution, the Array variant of the videoXtens offers a flexible solution. Here, the overlapping fields of view from two or more cameras are combined to form one large field of view. Markings leaving the one camera's field of view are automatically forwarded to the next camera's field of view, etc.

Different combinations are thereby possible, for example, two cameras in one videoXtens standard housing, with a total field of view ideal for most metal tensile tests with an initial gage length of up to 100 mm. A measuring head consisting of three cameras is offered in an enlarged videoXtens housing. It is particularly suitable for testing heavy plates, structural steel, wires and many plastics. It is also possible to combine cameras, each in a standard videoXtens housing, to form an array with a very large total field of view.

8.2 laserXtens® Systeme

Applicational range

Extensometers from the laserXtens system family can be used to measure strain or deformation on a wide range of materials. Using the latest laser speckle technology means that there is no contact with the specimen during the test and no need to attach marks. This enables the laserXtens systems to work in a wide range of applications:

- Tensile and compression tests on metals and plastics
- Tests on components
- Tests on specimens where contact is undesirable or not possible due to specimen condition or properties
- Deformation measurement on specimens prone to whipping on break which could result in damage to a contact-based measuring system
- Tests in temperature chambers
- Applications where non contact biaxial strain measurement is necessary

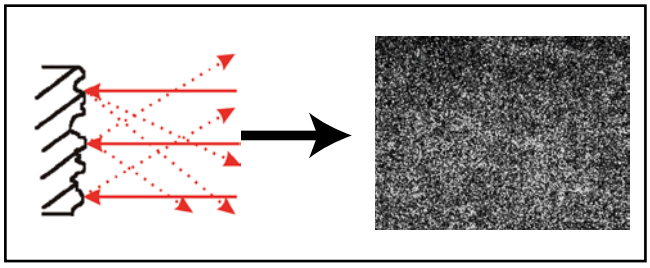
Flexible – yet easy to operate, the laserXtens systems are perfectly suited for quality control applications and yet offer major technological benefits to organizations engaged in research and development.

Function description

The laserXtens systems consists of measuring heads containing digital cameras and laser light source. The specimen is illuminated with the laser light and this generates a speckle pattern on the surface of the test specimen.

The speckle pattern can be thought of as a ‘virtual measuring mark’ or ‘digital fingerprint’ on the surface of the specimen and is monitored with the two full frame digital cameras. The laserXtens software tracks this virtual measuring mark in consecutive images taken during the test and this procedure is called speckle tracking.

As load is applied to the specimen by the testing machine the speckle pattern moves and the laserXtens software tracks the speckle pattern iteratively from image to image in real-time and determines the strain in the specimen.



A speckle pattern is generated on the surface of the specimen with the laser light

Each camera image is displayed in an analysis window on the PC and the gage length is defined by yellow crosshair lines. For the optional measurement of transverse strain crosshairs are available to set up the transverse measurement systems.

Types

- laserXtens and laserXtens HP: The measuring head consists of two cameras mounted on motorized slides. This makes it possible to vary the spacing between the cameras and thereby set different initial gage lengths
- laserXtens Compact and laserXtens Compact HP: Singlecamera systems for small to micro specimens
- laserXtens Array: One measuring head equipped with four fixed cameras. The fields of view from these cameras are combined to form one large image

Advantages / Features of the laserXtens systems

- The laserXtens systems combines high precision for large, normal, and micro specimens
- The laserXtens systems makes no contact with the specimen and there is no influence on the test caused by the laser light
- Specimen markings are not necessary. This results in several advantages:
  - Saving of time – especially for high specimen throughput
  - Use in temperature chambers and high temperature furnace
  - Simple use in automated systems, as no manual specimen preparation is needed
- Unlike traditional contacting extensometry the laserXtens can measure strain with high accuracy on short specimens with gage lengths down to 1.5 mm
- The laserXtens systems are totally integrated into the *testXpert*® II application software. A second monitor is recommended for parallel view of *testXpert*® and laserXtens live picture

laserXtens®

Types
The laserXtens can be mounted at different distances to the specimen and it is therefore suitable for use with temperature chambers, for example. The laserXtens HP is mounted close to the specimen and is then suitable for strain controlled tests according to ISO 6892-1 method A1closed loop.

Function description
The software algorithm has two modes of operation. As the virtual marks move within the field of view of the camera the software automatically moves the analysis window. An elongation of typically 40 mm can be measured in this mode. When the analysis window reaches the edge of the field of view, there is an automatic switch to the second measuring mode. Now the flow of material within the analysis windows is measured and the calculation of the strain value calculated accordingly. Depending on material and behaviour of specimen this mode leads to high accurate measurements (class 1), even being not according to the standard.

The extensometer is mechanically and securely connected to the testing machine and follows the crosshead at half the test speed. This ensures that the laserXtens is always in the middle of the test area and as a result the effective measuring range for speckle tracking is increased.

Advantages / Features
- The laserXtens HP can be used for strain controlled tests to ISO 6892-1 method A1closed loop. Suitable for gage lengths of ≥ 50 mm
- The laserXtens meets or exceeds class 1 (0.5 for laserXtens HP) of ISO 9513 (class B2 of ASTM E83)
- The resolution is 0.15 µm (0.11 µm for laserXtens HP)
- The laserXtens can also be used for a simultaneous measurement of axial strain and torsion.

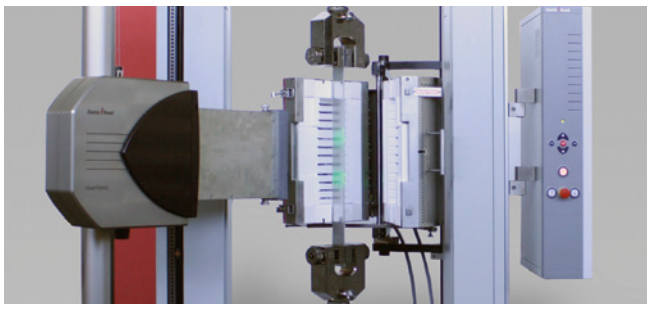


Fig. 2: Equipped with green laser light and high temperature tunnels the laserXtens can also be used for high temperature testing up to 1000 °C

laserXtens Compact

Range of application
These single-camera measuring systems are particularly suited for testing small to micro specimens.

As an option, the laserXtens can work with just one camera head. In this configuration, both analysis windows are set within the single camera image and the gage length is represented by the distance between the analysis windows. The gage length is therefore limited to the size of the field of view of the camera.

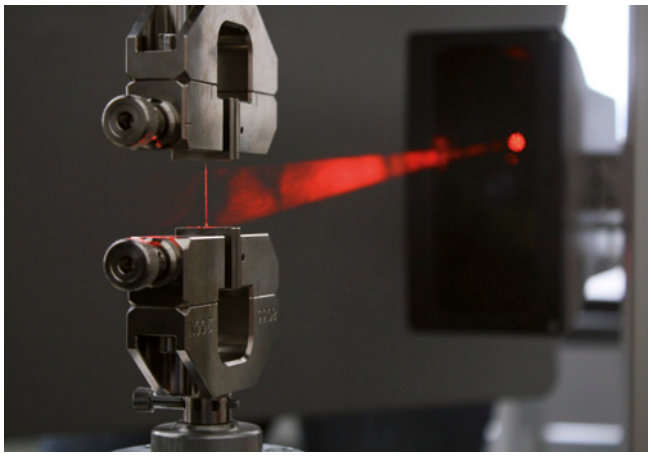


Fig. 1: laserXtens Compact

Types
The laserXtens Compact can be used with all Allround-Line table-top and floor testing machines. The laserXtens Compact HP is designed for mounting on the PrecisionLine Vario.

Advantages / Features
- The laserXtens Compact meets or exceeds class 0.5 of ISO 9513 (class B2 of ASTM E83)
- The resolution is 0.15 µm (0.04 µm for laserXtens Compact HP on PrecisionLine Vario)
- The laserXtens Compact can be used for biaxial testing. It measures transverse strain without the need to attach additional specimen marks on specimen

laserXtens Array

Range of application

Unlike the standard laserXtens, on which two digital cameras mounted on motorized slides can be used to set different initial gage lengths, the laserXtens Array measuring head consists of four fixed high-resolution cameras.

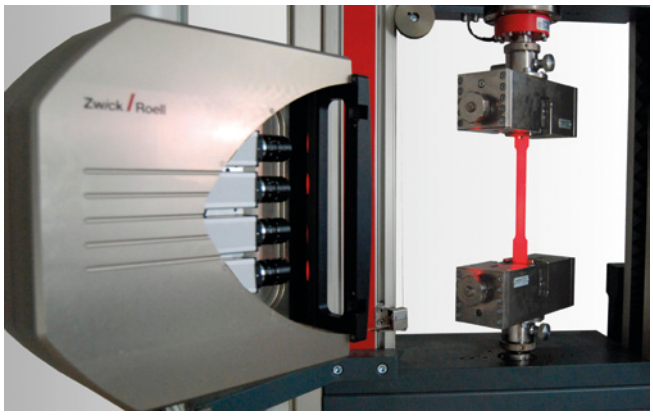


Fig. 1: laserXtens Array with four cameras

Function description

The overlapping fields of view of the four cameras are combined to form a single, large image. Here too, the two virtual gage marks are followed during the loading process (speckle tracking). When a gage mark meets the edge of one camera's field of view, it is forwarded to the adjacent camera's field of view. This method significantly expands the measuring range.

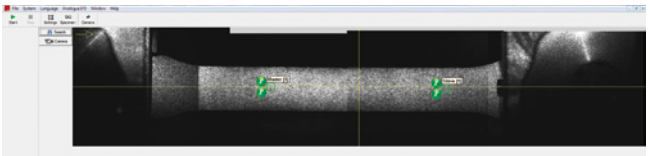


Fig. 2: Complete specimen image assembled from four images

Only when one of the gage marks reaches the edge of the total field of view does the system switch to flow mode, in which the flow of the material below the evaluation window is measured to determine the measured value. Depending on the material and/or the deformation of the specimen, good results (i.e. accuracy grade 1) are also obtained with this non-standard method.

Advantages / Features

- The laserXtens Array features a very large measuring range
- The laserXtens Array has no moving parts and is completely maintenance free
- The laserXtens Array complies with class 1 of ISO 9513 (class B2 of ASTM E83)
- The resolution is 0.15 µm
- Different gage lengths are set in fractions of a second
- The laserXtens Array can also acquire transverse strain without additional markings; biaxial measuring is possible
- Optionally, the extensometer can be expanded into a laserXtens Array/videoXtens hybrid system. With a further camera for transverse strain measurement, it is then possible to determine the r-values according to ISO 10113 and ISO 10275, for example

8.3 lightXtens®

Range of aplication
This optical extensometer is ideal for providing reliable, accurate measurements in tensile tests on highly ductile, highly elastic and touch-sensitive materials such as elastomers and latex plus all types of foil.

It is suitable for all specimens that exhibit high energy or whiplash at break and are therefore liable to damage mechanical, contact-measuring systems. This is often the case with belts, ropes and steel litz wire, for example.

It provides accurate, non-contact strain measurement, even over extended temperature ranges in temperature chambers.

lightXtens' robustness in test conditions and ease of operation make it an attractive alternative to video or laser-based extensometers.

Fig. 1: lightXtens

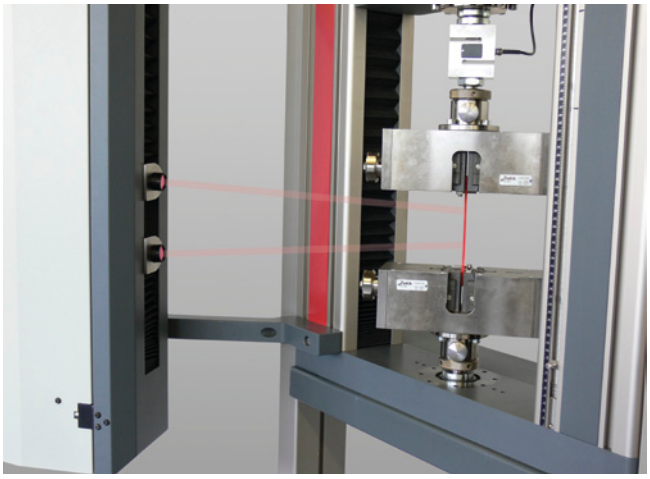


Fig. 2: lightXtens identifies gage marks automatically

Advantages / Features
- Non-contact operation - suitable for tensile and compression tests
- Suitable for use over an extended temperature range when employed in conjunction with temperature chambers, as changing between ambient and raised temperature requires no special set-up operations
- Fulfils Accuracy Class 1 to ISO 9513 from 3 mm
- Connection to *testControl* electronics via a digital bus system, with synchronized force-travel measurement
- Automatic gage mark recognition
- Initial gage length is measured automatically during the test and transmitted to *testXpert*® II
- Wear-free, low-maintenance operation
- lightXtens is very easy to operate:
  - Straightforward specimen preparation using manual or automatic marking devices
  - No need to adjust or configure optics
  - Fully automatic test sequence (including attachment, automatic determination of initial gage length and automatic positioning of extensometer at start location)
  - Insensitive to varying environmental conditions such as extraneous light

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