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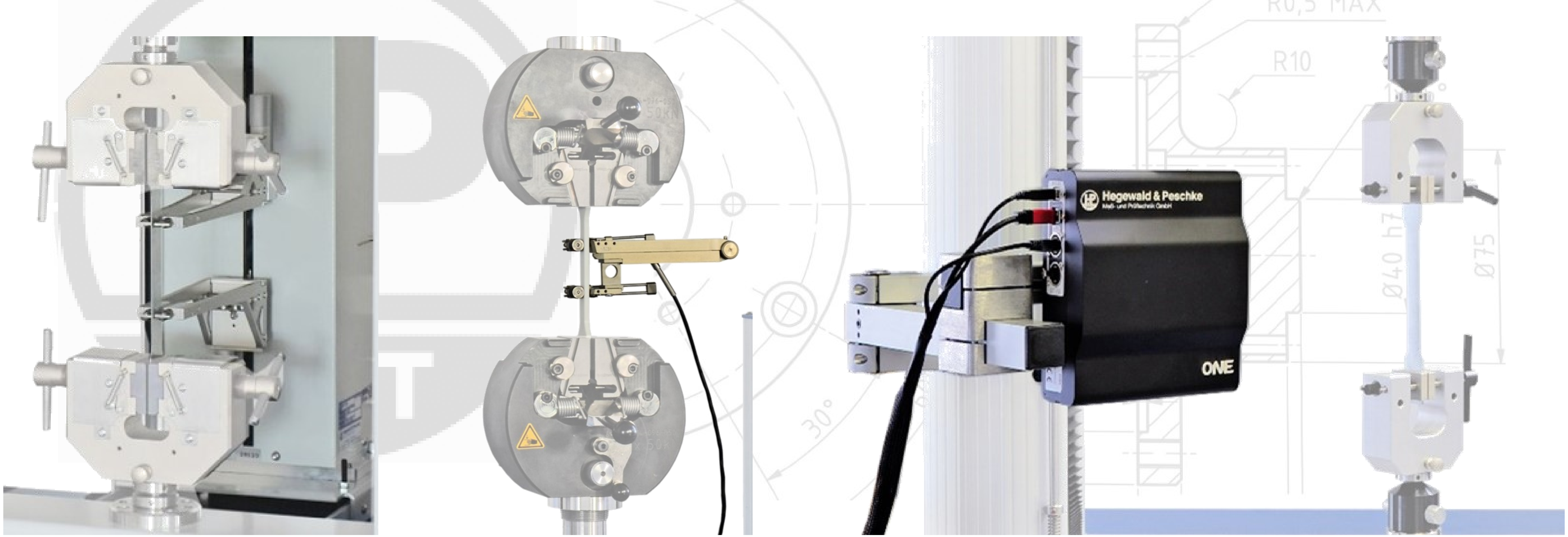
Extensometers – Strain transducer



Content

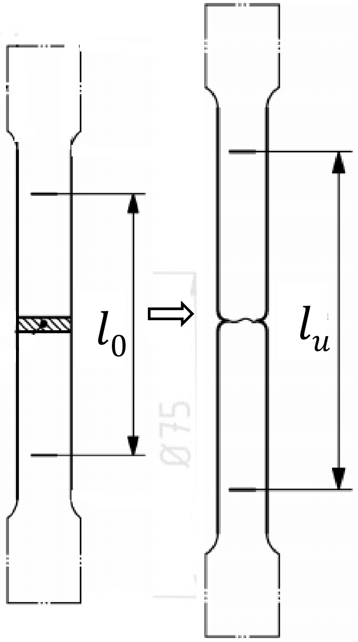
- Definition
- Typical Application
- Criteria for selection
- Overview and Types
- Measurement principles
- Types and their specifications
- Specific application and special solutions
- standards, accuracy and calibration
- sales volumes

Definition

Extensometers, also called strain transducers or strain sensors, are measuring devices used in materials testing to measure the change in length or width directly on the material sample. The strain is determined on the basis of the deformation of the material.

Strain is the measurement channel that describes the change in length (Δl) with respect to the initial length (l_0) of a body under load (shortening or lengthening).

(l_u ... gauge length after fracture).



The test temperature must be taken into account, as temperature changes also result in thermal expansion/shrinkage of the specimen.

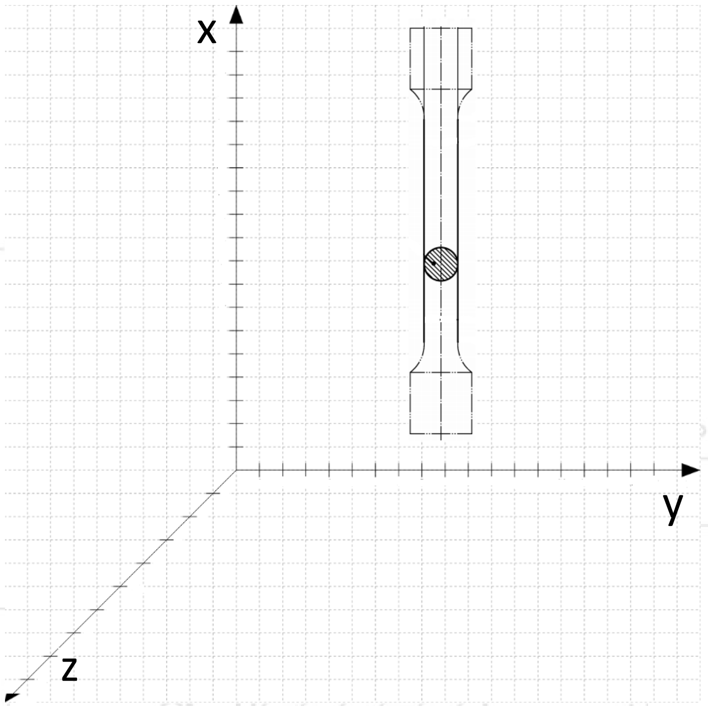
The letter symbol of the longitudinal strain is ε.

If the dimensions of the body increase, as in the tensile test, this is called positive elongation or stretching/extension. In the reverse case, for example in the compression test, it is called negative elongation or compression.

$$\varepsilon = \frac{\Delta l}{l_0}$$

Definition

In order to be able to fully describe the load on a tension rod, the transverse strain must be taken into account in addition to the longitudinal strain. If the tensile axis is designated as the x-axis, transverse strains in the y- and z-directions are at right angles to it. For round specimens, the transverse strain ($\Delta d/d$) can be described as a relative change in diameter. Often the transverse strain is proportional to the longitudinal strain ($\Delta l/l$).



The proportionality factor is called the Poisson's ratio ν and is a dimensionless quantity that is constant in the elastic range and depends on the loaded material.

$$\frac{\Delta d}{d} = \nu \frac{\Delta l}{l}$$

Definition

So far, the change in length in relation to the initial gauge length (l_0) has been discussed. This method is common and particularly simple because the initial length is a constant. It is explicitly referred to as the nominal engineering strain.

It has also already been mentioned that changes in the cross-section occur during a tensile test. Thus, the specimen begins to constrict after reaching the max. tensile load (Ultimate Tensile Strength R_m). This is why plastic strain at maximum load is also called uniform strain (officially "percentage plastic extension at maximum force")

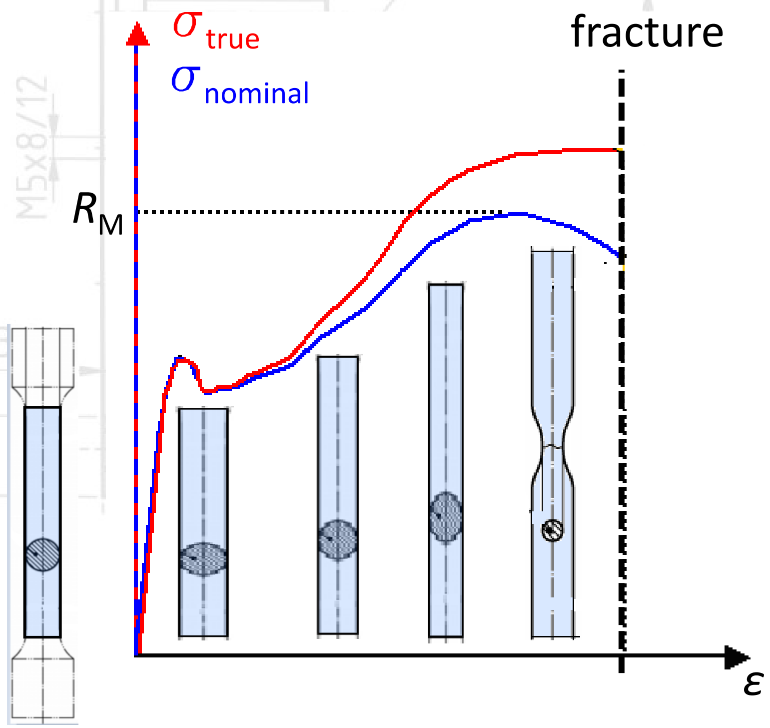
The technical stress-strain curve shows a pronounced maximum, since the nominal stress is related to the constant initial cross-section.

Since the total volume of the sample does not change, the true stress can be calculated from the change in cross-section.

The same applies to the true strain, which is based on the current time-varying initial gauge length instead of the constant initial length ($dl/\ l$).

$$\varepsilon_w \int_{l_0}^{l} d\varepsilon = \int_{l_0}^{l} \frac{dl}{l} = \ln\frac{l}{l_0} = \ln(1+\varepsilon)$$

That is why it is often called logarithmic strain.



Why do I need an extensometer?

Application:

Extensometers are used to determine the deformation directly on the specimen.

The measurement of the deformation is thus significantly more precise than via the crosshead travel.

All influencing factors such as the stiffness of the machine frame, set effects in the test setup like the wedge closing effect in wedge grips do not lead to falsification of the measurement result.

Consequently, many standards, such as ISO 6892-1 for tensile tests on metallic materials or DIN EN ISO527-1 for the determination of tensile properties on plastics, require the use of extensometers to determine parameters such as the modulus of elasticity or the increase in the elastic straight line and the resulting parameters such as the yield strength or the elongation at yield, etc.

Selection criteria

- requested results/characteristic values
- specimen material, shape/geometry and size
- measurement range
- measurement accuracy/resolution
- test mode (tension, compression, bending, …)
- test setup
- ambient test conditions
- required degree of automatization
- Test frequency and user comfort
- price and maintenance costs

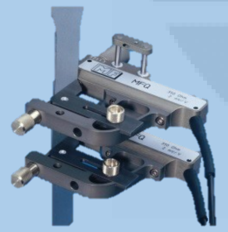
Overview extensometer types

Extensometer

contact systems
tactile / mechanical

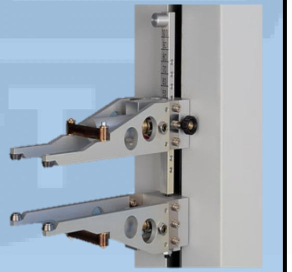
ClipOn extensometer

Transversal

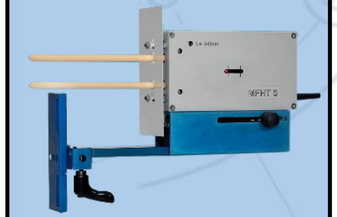


Lateral

Long distance extensometer

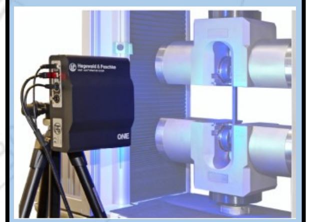


High temperature extensometer



non-contact systems
optical

Video extensometer



Laser Speckle Extensometer

Extensometer for Rebar

Laser extensometer

Overview extensometer types

Extensometer

contact systems
tactile / mechanical

ClipOn extensometer

+ inexpensive solution
+ high measuring accuracy
+ vibration-independent
+ E-modulus determination (double-sided)
+ Strain control possible

- limited measuring range
- only for sufficiently stiff specimens
- manual application/removal
- not suitable for application till fracture

Long distance extensometer

+ easy handling - fully/partially automated
+ high measuring accuracy
+ extended measuring range up to 1100mm
+ determination of characteristic values in the elastic range and up to breakage
+ suitable for strain control
+ various specimen materials (metal & rubber cutting, variable contact pressure)

- not for thinnest and brittle materials
- conversion for different test modules (tension / compression / bending)

non-contact systems
optical

Video / Laser Speckle extensometer

+ no contact with sample necessary (foils possible)
+ high measuring accuracy
+ strain control possible
+ suitable for temperature chamber/oven
+ possible without specimen marking
+ longitudinal & transverse strain possible
+ strain distribution over entire parallel length

- Dependent on optically stable conditions
- Measuring range and resolution are directly dependent

Laser extensometer

+ no contact with sample necessary (foils possible)
+ high measuring accuracy (class 0.2)
+ suitable for strain control
+ suitable for maximum temperature testing
+ suitable for automation

- measurement marking necessary
- set-up effort - recommended as fixed configuration for unchanged testing
- limited field of view (for one system max. 300mm)

quantity in sales

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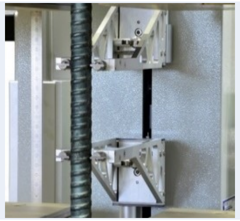
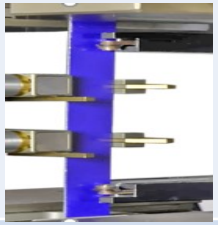
Overview contact extensometer types advantages and disadvantages

Price increases

ClipOn extensometer		Long distance extensometer	
Transversal	Lateral	Lateral	Transversal
			
+ Transversal strain	+ Longitudinal strain	+ Longitudinal strain	+ Transversal strain
+ Class 0.2	+ Class 0.2	+ up to Class 0.5	+ Class 0.5
+ Determination of vertical anisotropy (*r* value) and Poisson's ration *v* + one or two measurement points	+ (**metals**) Determination of elastic modulus *E* (double sided), slope of the elastic straight line m_E, proof stress R_p, yield strength R_e + (**polymers**) Determination of tensile modulus E_t, yield strain ε_y	+ (**metals**) Determination of slope of the elastic straight line m_E, proof stress R_p, yield strength R_e, percentage plastic extension at maximum force A_g, elongation at fracture *A* + (**polymers**) Determination of tensile modulus E_t, yield strain $\varepsilon_{y,}$ strain at strength ε_m, nominal strain at break ε_b	+ Determination of vertical anisotropy (*r* value) and Poisson's ration *v* + one or two measurement points
+ inexpensive + for metals and thermo plastics (flat and round specimens) - limited measurement range - has to be removed during test - not suitable for brittle breaking materials like cast iron exemplary video: https://www.youtube.com/watch?v=W1TTjnzEwtY		+ measurement range from 200mm (e.g. for metals) to 1100mm (rubber) → suitable for metals, thermoplastics and elastomers (use rubber jaws!) + ideal for high test frequency and high test volume (manual, partially and fully automated) + allows determination of elongation at fracture and (depending on accuracy) characteristic values of elasticity exemplary video: https://www.youtube.com/watch?v=VzB87L7JzHs	

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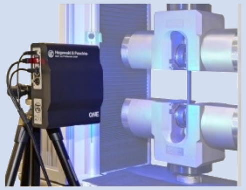
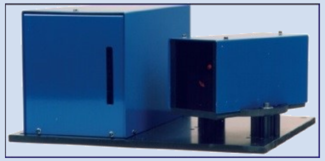
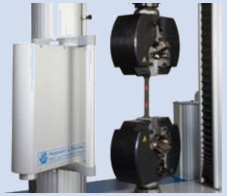
Overview non-contact extensometer types advantages and disadvantages

video extensometer	Laser extensometer	Extensometer for rebar	Laser Speckle extensometer
			
+ contactless measurement procedure			
+ Class 0.5	+ Class 0.2	+ Class 1	+ Class 1
+ Determination of longitudinal and transversal strain		+ determination of strain on rebar and rolled wires/rods	+ Determination of longitudinal and transversal strain
+ suitable for tension, compression and bending tests + determination of slope of the elastic straight line m_E		+ measurement of tensile strain according to DIN 488 + software uses rips as patterns	+ for tensile and compression tests + slope of the elastic straight line m_E
+ works with natural patterns on the specimens → normally no specimen marking necessary	- specimen marking with high contrast necessary	+ high resolution	+ no specimen marking necessary
+ strain control possible (low sampling rate)	+ strain control possible (high sampling rate)	+ extensometer especially for measurement of rebar steel with rips	
+ Suitable for combination with furnaces and temperature/climate chambers			
+ large measurement range and high resolution/accuracy possible with multiple camera systems			- Speckle pattern is applied with Laser (Safety Class); detection takes place via camera system

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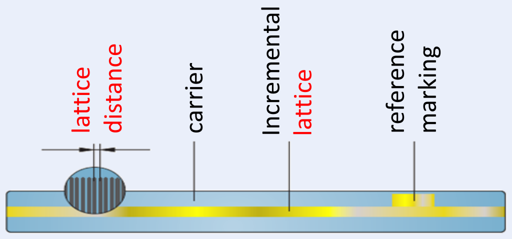
Measurement principles

Incremental

- Fast, reliable and accurate length measurement
- Insensitive to vibrations and shocks
- Defined thermal behaviour
- No influence on accuracy due to changes in air pressure or humidity

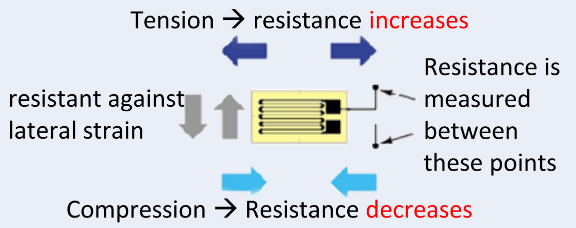
Mostly used in long distance extensometern (also in some measurment probes and electrial drives)



strain gauge

- Strain gauges are supplied with a stabilised DC current
- with additional electronics zero point of strain gauge is set
- any strain leads to change in resistance of strain gauge and brings the Wheatstone bridge out of equilibrium
- Output 2 or 4 mV/V
- temperature and mechanically sensitive
- only very small strokes (several %)

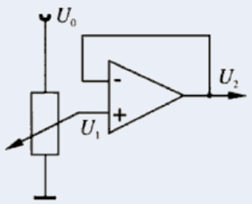
- Used in ClipOn extensometers



Potentiometric

- The input signal (kinematic measurement and = angle or position) is converted into a resistance change
- temp. / mechanically sensitive
- Supply voltage contributes to the measurement

- For measurement probes and as short distance measurement system in long distance extensometers

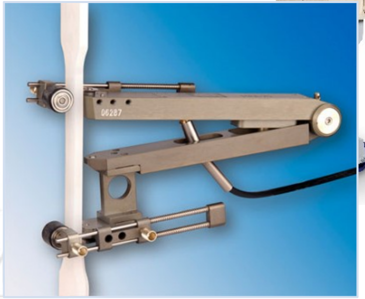


Optical

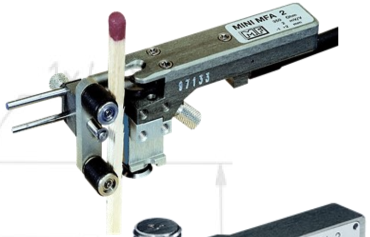
Measuring basis is an optical measuring system:
- Accuracy dependent on wavelength
- temporal comparison of image recordings or reflection information with downstream mathematical algorithms to determine the strain.

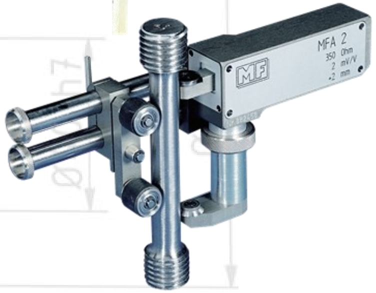
Used in:
- Video
- Laser
- Laser Speckle

ClipOn extensometer



ClipOn extensometers are clamped to the tensile specimen prior to the test start. Usually, this type of extensometer is used to determine the yield strengths R_{eH} / R_{eL} / $R_{p0,2}$ / $R_{p1,0}$ / $R_{t0,5}$ and the slope of the elastic straight line. Furthermore, it can be used to determine the modulus of elasticity (double-sided). Due to the limited measurement range (e.g. < 2 mm / < 25mm), the devices are removed after determining these characteristic values during the test. Therefore, the term extensometer is more precise than strain gauge.
In addition to MFA systems for axial strain, there are also clip-on extensometers (MFQ) for transverse strain determination with one or two measuring points.





+ inexpensive devices with high resolution/accuracy (Class 0.2 according ISO 9513 possible)
+ device is mounted directly on the specimen. Thus, no negative vibrations can be introduced into the extensometer
+ suitable for both: strain measurement AND strain control
+ suitable for utilization in temperature chambers
+ double sided version available for determination of elastic modulus
+ biaxial strain measurement (longitudinal and transversal) possible through combination of two ClipOn extensometers

- Removal of extensometer prior to specimen fracture is recommended (Mechanical stops protect against unintentional overloading, even in the event of premature breakage of the specimen with the extensometer attached)
- not suitable for brittle breaking specimens (safety concerns) or very thin (and thus flexible) specimens due to influence by weight/cutting edge
- not suitable for determination of elongation at fracture
- fixed initial gauge length, not suitable for variable L_0 (ISO 6892-1, $A_{5.65}$ or $A_{11.3}$)

Measurement principle … … strain gauge Wheatstone bridge

different versions in regards of extensometer weight, edges (round/square, metal/rubber), measurement range
initial gauge length L_0 between 10 mm and 300 mm with spacers

+ suited especially for stiff specimens (metals, plastics, composites)

contact measurement II

Long distance extensometer
These transducers are in direct mechanical contact with the sample and can be used for extension measurement up to breakage. Depending on the type, the devices have a high measuring resolution of up to 0.01 µm. They are applied manually or automatically before the start of the test and are used to determine elastic parameters, yield strengths, proof stresses and the uniform strain up to the elongation at break.
+ direct extension measurement + variable initial gauge length from 10mm (up to full measurement range) + excellent for tensile tests with strain control + large maximum measuring travel for determination of properties up to specimen break, even with soft plastics/elastomers; also suitable for determination of elastic characteristics such as yield and equivalent yield strengths + Automatic attachment and removal of the measuring arms possible + use in temperature chamber possible (special measuring arms and slotted temperature chamber needed) + Different cutting systems possible (round/square; carbide/blunt/rubberised) - Tactile measuring system - critical for brittle sensitive samples (foils, fibres)
maximum measurement range up to 1100 mm (minus L_0)
+ Depending on the test quantity, partially or fully automated systems should be used, which offer clear handling advantages. Thus, long distance extensometers are recommended for tests on metals and plastics where, on the one hand, the determination of elastic characteristic values is required and, on the other hand, the strain to break is to be determined. In addition, automated extensometers facilitate the testing process and are particularly recommended for higher test volumes.

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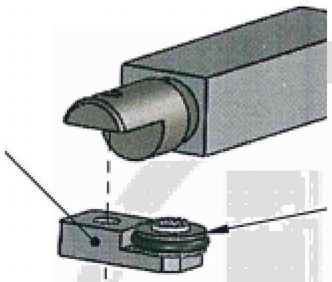
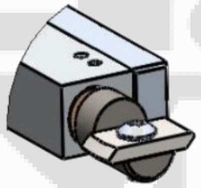
contact measurement III

Features of long distance extensometers for tensile tests

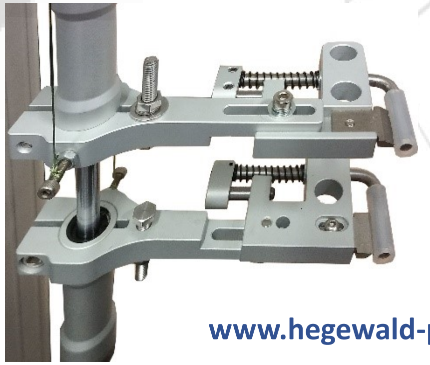


Rubber knifes/edges for plastic specimen



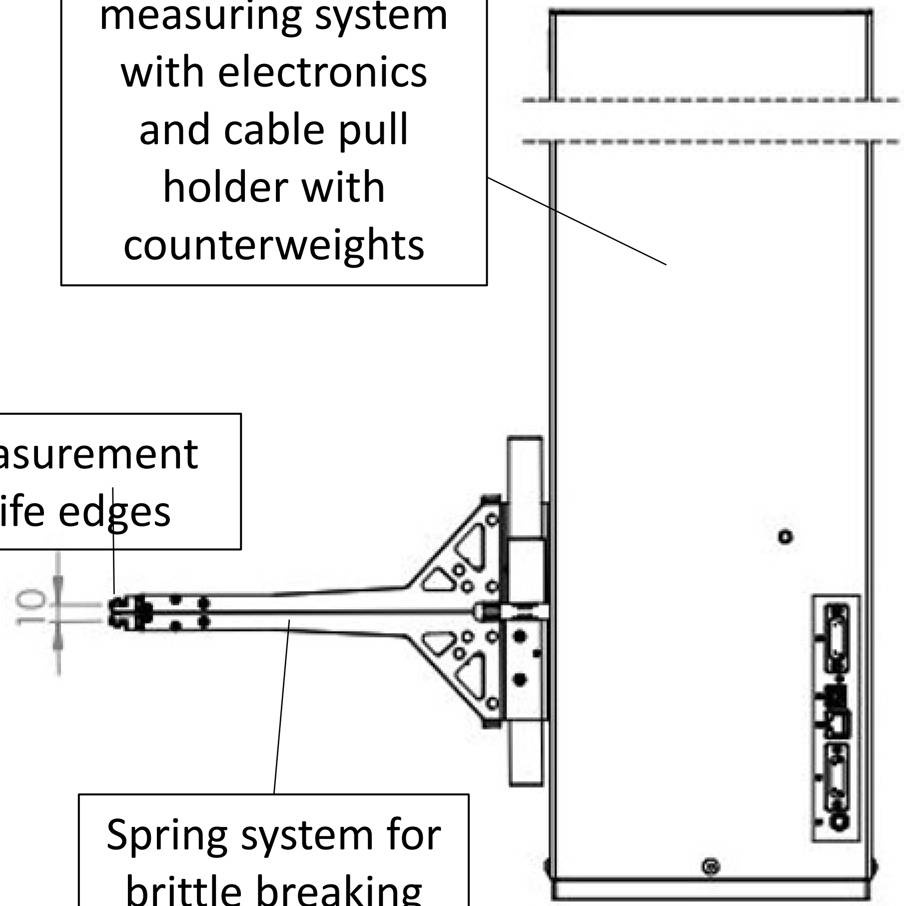
High strength steel double knife edges:
one side for round specimen
one side for flat specimen

Various forms of measuring arms and measuring edges



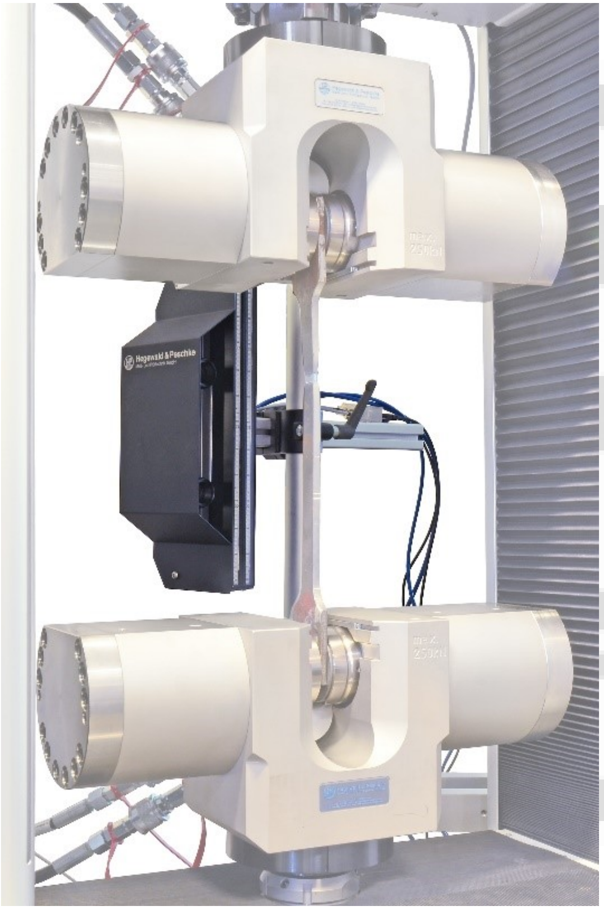
Protected measuring system with electronics and cable pull holder with counterweights

Measurement knife edges



Spring system for brittle breaking specimens

optical strain measurement I



+ contact less
+ no mechanical influence of extensometer on specimen behaviour
+ Suitable for broad range of materials (metals, foils, ropes, textiles, …)
+ suitable for RT and high temperature application
+ Evaluation of complete specimen length possible (incl. working with several gauge lengths, maximum strain recognition and strain mapping)

- Dependency on optical conditions (sun light, lightning, shadowing)
- reduced sampling rates (depending on technology)
- Limitations in the suitability for strain-controlled tests

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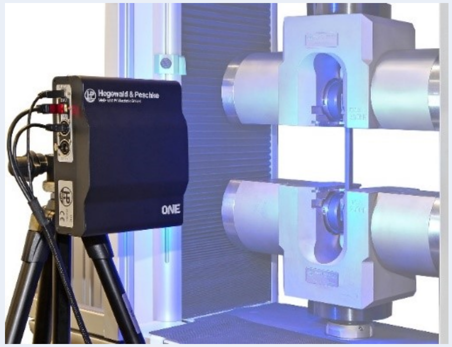
optical strain measurement I – video extensometer

video extensometer

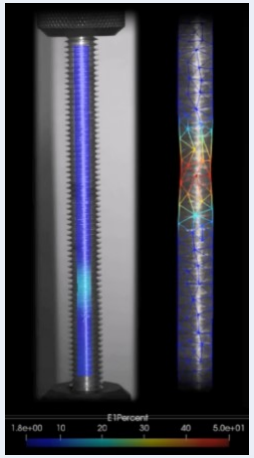
The video extensometer is a non-contact deformation measuring device for material testing, based on high-resolution camera technology using the surface structure or, if required, additionally applied markings.

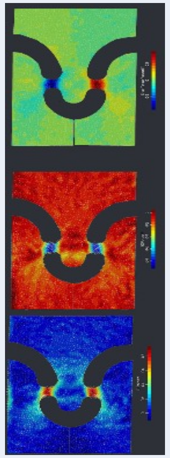
+ suitable for tensile, compression, bending, shear and torsion tests on all materials
+ for most materials/specimens no additional specimen marking is required
+ Combined determination of longitudinal and transverse strain possible
+ Expandable to multi-camera systems for larger measuring ranges
+ Stable and precise: Class 1 (optional class 0.5) in accordance with ISO 9513 in the defined field of view (higher accuracy reduces field of view)
+ Can be used for strain measurement and control
+ Can be used in conjunction with temperature and climate chambers and ovens



→ **Optional:** Digital Image Correlation (DIC) with Post-Processing

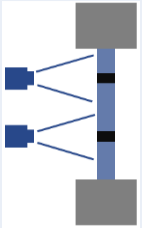
- Determination and 2D visualisation of local strain distribution (spatially and directionally resolved).
- Creation of colour-coded area maps for visualisation of strain distribution
- Visualisation and evaluation of complex changes in component tests
- Amount of real-time information significantly increased



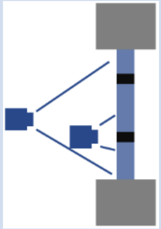


→ **Optional:** Multi-Camera-Systems

"Multi Camera - Splitted mode
Evaluation of very large samples via two cameras (one camera per measuring mark)



"Multi Camera - Area near and far":
a high-resolution measuring area for the evaluation of elastic deformation + a large field of view for the evaluation of elongation at break

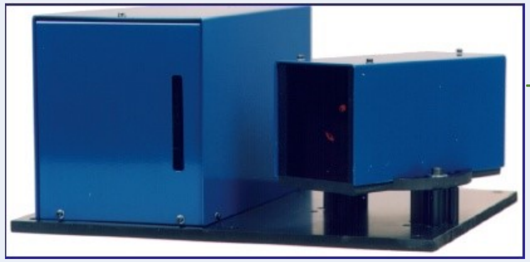


+ for a broad range of materials such as metal, plastics, elastomers, composites but also thin sensitive foils
+ can also be used for the smallest strains on very small specimens (like additive form-fitting specimens) → (tele)centric lens systems

berührungslose Prüfverfahren III – Laser extensometer

Laser extensometer

The laser extensometer is a non-contact deformation measuring device which detects the change in length with high resolution by means of the diffuse reflection of laser beams on sample markings to be applied in advance.



+ High resistance against interference from external influences (e.g. ambient light conditions)
+ Very high precision over full measurement range
+ no additional lightning necessary
+ Measurement of specimen movements towards/away from the measuring device possible
+ different modes possible: tension, compression, bending
+ stable strain control possible
+ spatial strain measurement possible (for inhomogeneous materials)
+ utilization in RT and high temperature application possible
- specimen preparation with high accuracy and quality necessary

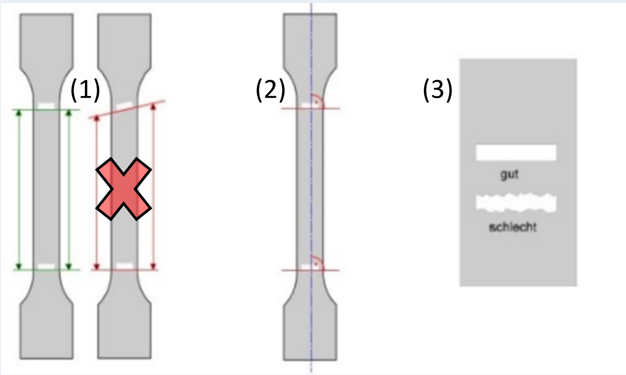
Measurement range up to 300 mm (higher on request)	**Accuracy class** 0,2 accroding ISO 9513	**Initial gauge length** L_0 from 2 mm

Influence of the quality of the marking

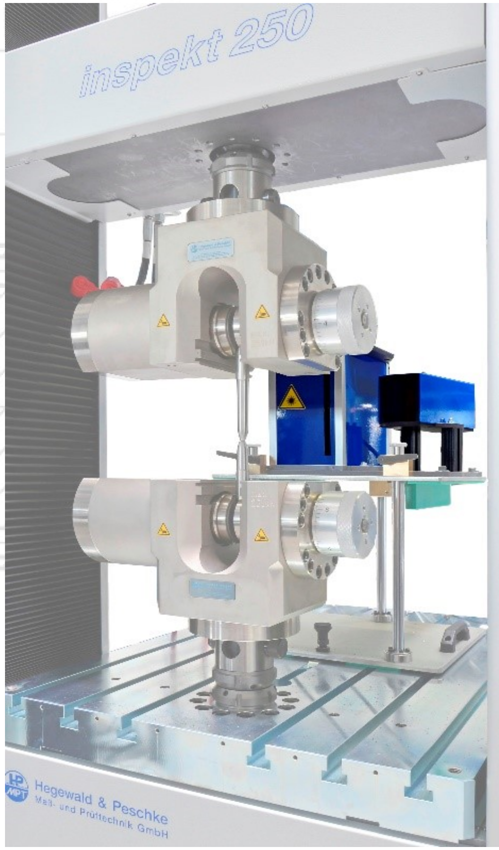
High accuracy requires high quality of specimen marking

- parallel alignment of markings (1)
- perpendicular alignment to the measuring axis (2)
- sharp and straight edges of markings (3)

→ High-contrast marking is done using adhesive tape, permanent marker, Inkjet printing (follows the sample deformation well) or airbrush



+ Particularly suitable for long-term measurements with high resolution (drift-free system)



Non-contact test methods IV – Laser Speckle Extensometer

Laser Speckle Extensometer

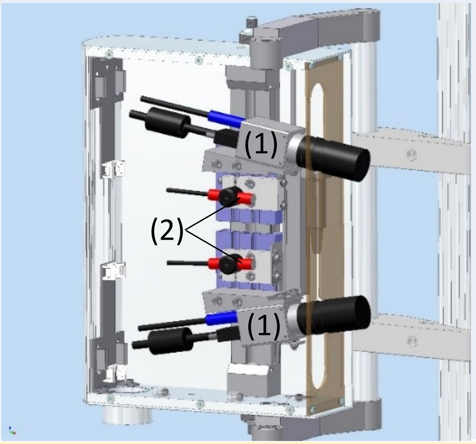
The Laser Speckle method is a non-contact deformation measuring device for material testing, based on laser speckle evaluation.

+ No specimen marking necessary, but generation of the speckle pattern by the lasers
+ Use in temperature chamber possible
+ Tests on a wide variety of materials possible
- Protection class for laser
- Evaluation of the speckle pattern is done by video cameras
- Carrying of the measuring system for the determination of the technical elongation (depth of field critical)

Measuring length L_0: 0 up to 250 mm
Accuracy class 0.5 according to DIN EN ISO 9513

Measuring principle laser speckle pattern

- 2 laser diodes - 2 speckle patterns - 2 detector cameras
- Scattering of laser light on natural specimen surface creates specimen-specific pattern ("fingerprint")
- Generated patterns serve as imaginary measurement marks
- Detection takes place via the high-resolution CCD cameras
- At the beginning of the measurement, the first speckle pattern is recorded and stored as a reference.
- With each further recording, reference patterns are searched for in the image and offset or displacement to the live recording is calculated



(1) High-resolution CCD cameras for detection

(2) Laser diodes for the generation of speckle patterns

+ Especially suitable for long-term measurements, as high accuracy is maintained over a long period (drift-free system)

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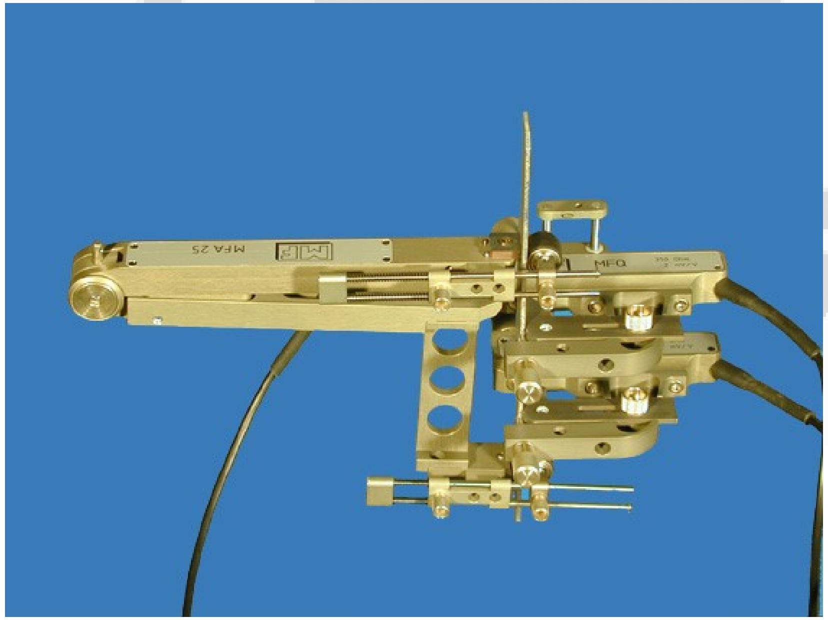
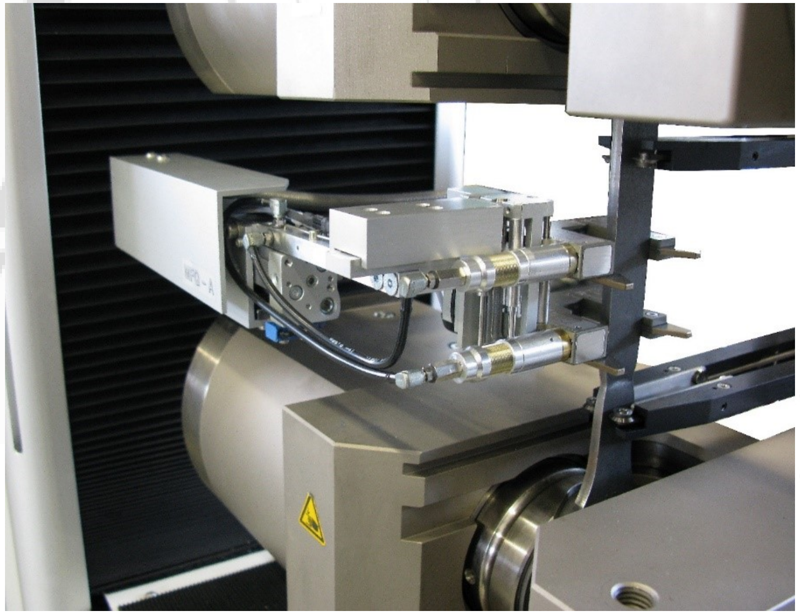
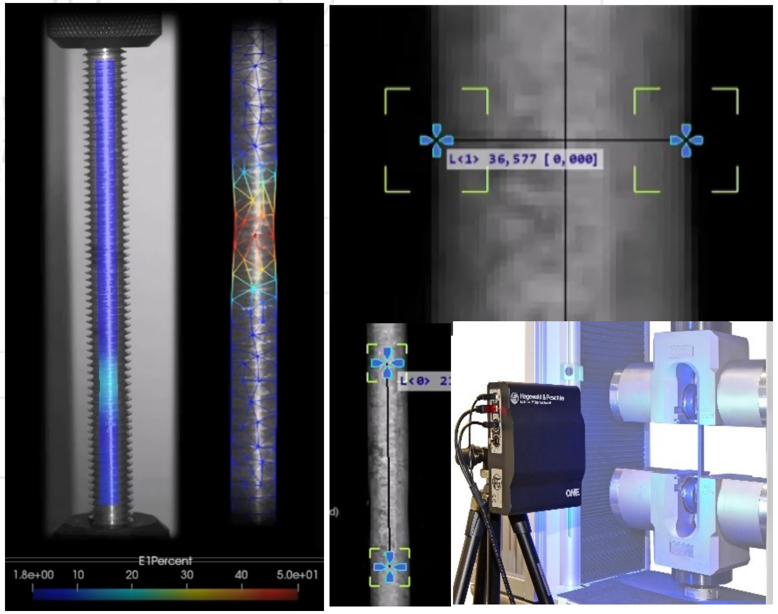
Combined measurement of longitudinal and transverse strain

Tactile via clip-on extensometer	Tactile via long distance extensometer	Optical via video extensometer
• L_0 >50mm necessary • Complicated handling	• L_0 >50mm necessary • Automatic guidance of the width transducer • Automatic width detection	• No restriction for L_0 • Measuring range instead of measuring points • Automatic detection of the largest narrowing



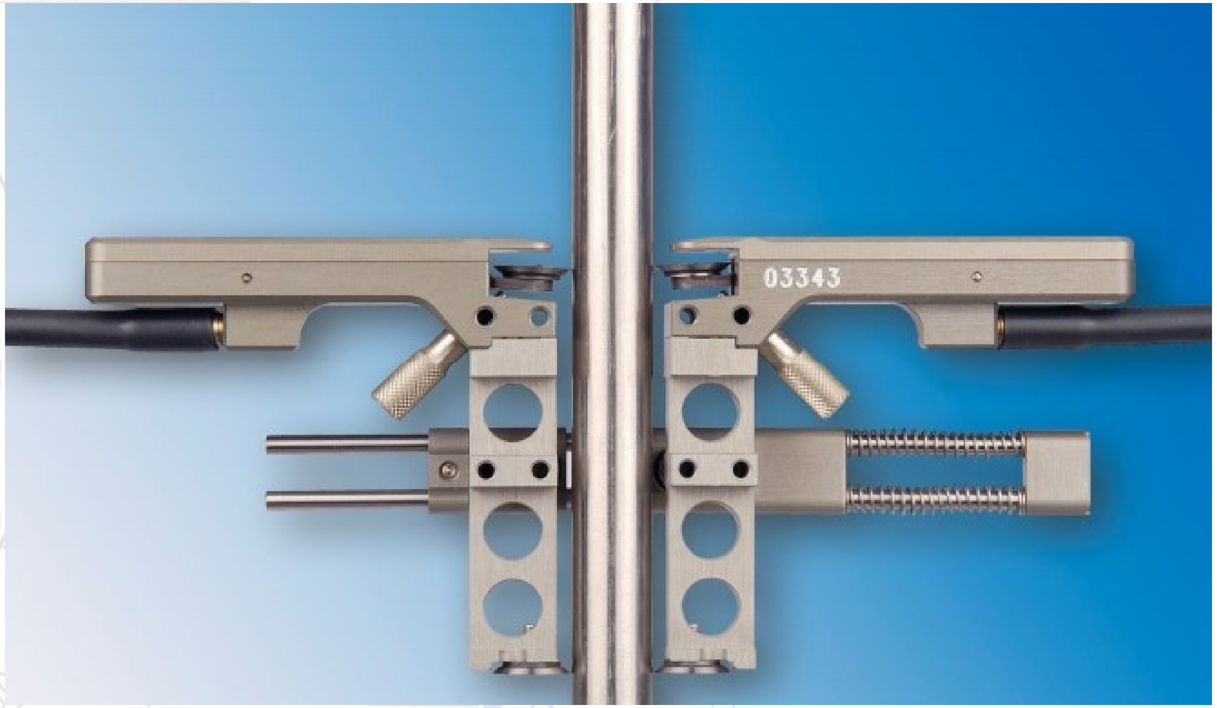




Metal tensile test according to ISO 6892-1 Appendix G: Determination of the modulus of elasticity E

In order to determine modulus of elasticity values in uniaxial tensile tests with an acceptable level of uncertainty, the standardization requires:

- A strain gauge system better than class 0.5, ISO9513.
- A long measuring length (≥ 50mm).
- That the strain is measured on opposite sides of the specimen.
- Evaluation of each side (at least two strain channels).
- Optimum test conditions (vibration-free, high axiality).



⇨CONCLUSION: To ensure these conditions, a **double-sided clip-on extensometer** MUST be used in which the strain is determined separately on both sides of the specimen and which, unlike long-distance extensometers, does not transmit vibrations from the machine to the specimen.

Extensometer for construction steel

Optical extensometer for construction steel and wire rod

Field of application:

Optical non-contact strain measurement for tensile testing in accordance with DIN 488 on reinforcing steel and wire rod.

Measuring principle / Suitability:

- Non-contact system based on video-optics for measuring the actual tensile strain during the tensile test and for determining uniform strain Agt, elongation at break A10, A5 and A11.2

+ Optional determination of the rib geometry

Clip-on extensometer for construction steel and wire rod

Field of application:

Tactile extensometer from class 0.5 according to ISO 9513 for tensile tests on construction steel

Measuring principle / Suitability:

- Suitable for many specimens from Ø 4mm and 15 mm width to determine yield strength and uniform elongation.
- Initial device measuring length 50 to 200 mm

+ due to robust design especially suitable for construction steel and coarse specimens with tinder

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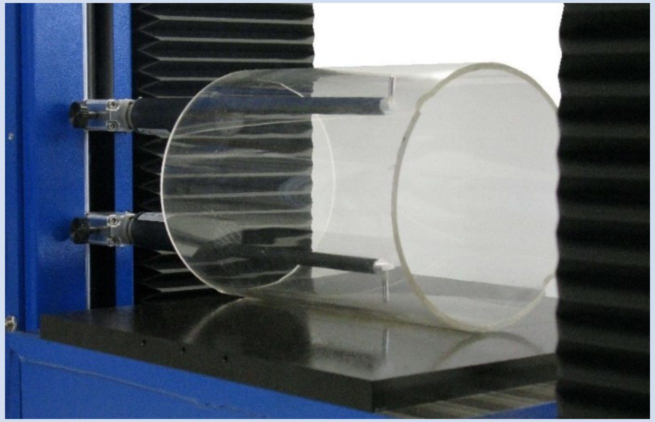
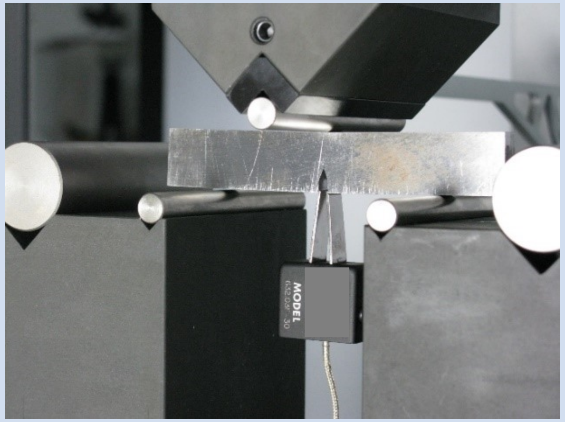
Special extensometers I

Special extensometer for inner diameter testing	Clip-on deformation measuring device for crack and fracture toughness determination
	
• Long distance extensometer for deformation measurement inside the tube • Inner diameter from 100 mm to 1500 mm (optionally extendable) • Maximum tube length of 450mm • Accuracy class from Cl. 0,5 according to DIN EN ISO 9513	• Clip-on deformation measuring device for the determination of the crack or fracture toughness in notch geometries • Can be used in static and dynamic tests • Accuracy class 1 according to DIN EN ISO 9513 (optionally class 0.5) • Measuring principle wheatstone brigde • Standard temperature range -100 °C to +150 °C
Particularly suitable for deformation measurement during peak pressure tests on synthetic and lightweight materials as well as for ring stiffness tests according to ISO 9969, DIN 5086 and DIN 50086-2-4	Ideally suited for determining K_{IC} and J_{IC}as well as for recording crack resistance curves (R-curves)

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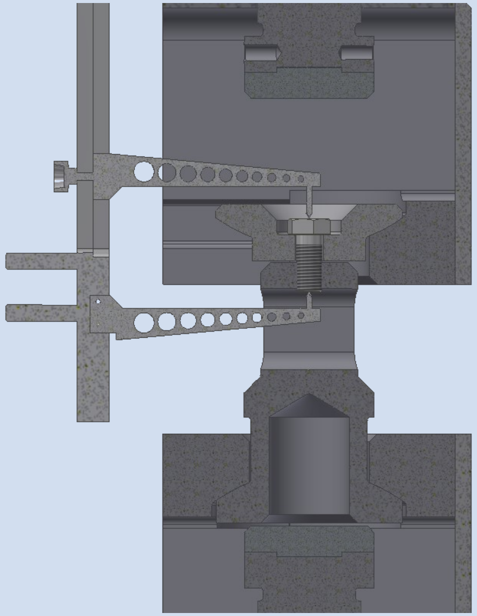
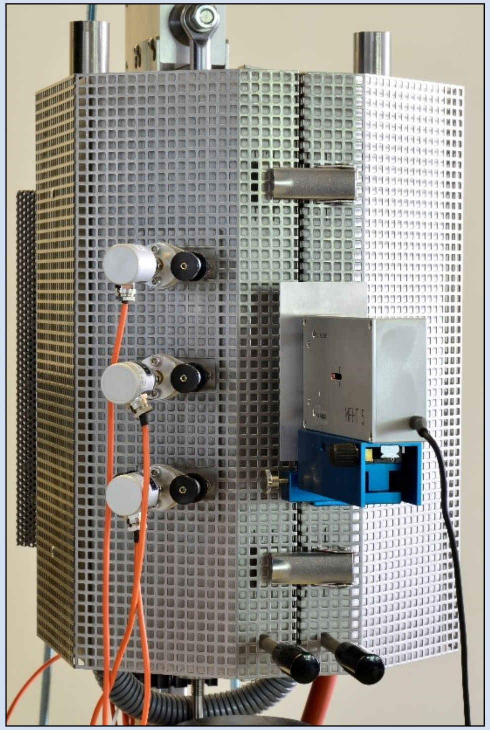
Special extensometers II

Special extensometer for screw testing according to DIN EN ISO 898-2



- Determination of the change in length of screws by means of measuring tips over **total length**
- Accuracy class 0.5 according to DIN EN ISO 9513

Special extensometer for use with furnaces



- Determination of elongation in furnaces up to max. 1700°C
- Measuring principle wheatstone bridge, with ceramic measuring tips
- Determination of the increase of the elastic straight line, yield strength - not recommended up to fracture
- Accuracy class 0.5 according to DIN EN ISO 9513

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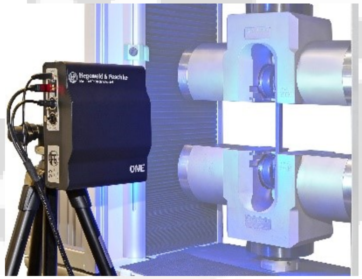
Holders for extensometers

… detached from testing machine

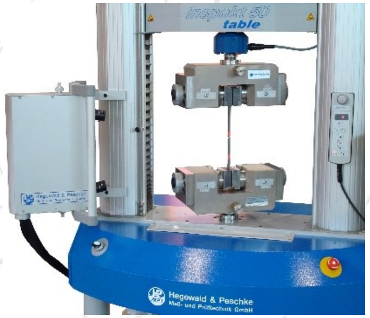


- Camera tripod
- Standalone device
- Clip-on systems

… attached to testing machine

Mounting on:

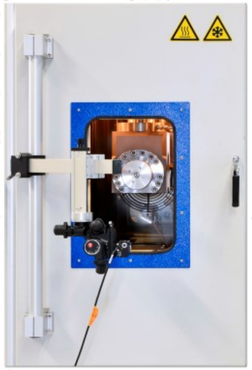
- Fixed crosshead
- Moving crosshead
- Upper traverse
- Frame



… for temperature chambers or furnaces

Mounting on:

- On machine frame
- On tempering device



A fixed location and stable low-vibration fixation are important for reproducible tests and for minimizing or even avoiding setup effort in daily test applications!

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Calibration according to DIN EN ISO 9513:2013-05

DIN EN ISO 9513 --> Subdivision of the extensometers into four accuracy classes

Class 0.2 Class 0.5 Class 1 Class2

Standard requirements

→ The accuracy class required for the tests is specified by the respective application standard (e.g. metallic tensile test - DIN EN ISO 6892, ...).
→ The extensometer used must be suitable for the application
→ Standard calibration is class 1, as this is sufficient for most tests, occasionally class 0.5 is also required.

Criteria for classifying according to table 2 from DIN EN ISO 9513:2013

Class of extensometer system	Relative error of the gauge length q_{Le}	Resolution *		Bias error *	
		Percentage of reading r_{rel}	Absolute value r	Relative value q_{rb}	Absolute value q_b
0.2	± 0.2 %	0.10 %	0.2 µm	± 0.2 %	± 0.6 µm
0.5	± 0.5 %	0.25 %	0.5 µm	± 0.5 %	± 1.5 µm
1	± 1.0 %	0.50 %	1.0 µm	± 1.0 %	± 3.0 µm
2	± 2.0 %	1.00 %	2.0 µm	± 2.0 %	± 6.0 µm

* The larger value is admissible
l_i: Display at the respective measuring point extensometer
L_e: Initial gauge length (L_0) Setpoint
r: Resolution at the respective measuring point
l_t: Display at the respective measuring point calibration device
L'_e: Initial gauge length (L_0) Actual value

The extensometer is classified by including and excluding the measurement uncertainty calculated during calibration. It is possible that the instrument fulfills the respective class without measurement uncertainty, but not with measurement uncertainty. This depends on the calculated value of the measurement uncertainty.

Exemplary calculation for calibration according to class 1:

Initial gauge length L_e= 50.0 mm L'_e= 50.2 mm

Resolution *r= 1 µm (at the measuring point 0.1 mm)*
Deviation l_i= 0.500 mm l_t= 0.504 mm

$$q_{le} = \frac{(50.2\ mm\ - 50.0\ mm)}{50.0\ mm} \cdot 100 = 0.4\ \%$$

→ **0.4% is less than ±1.0%, thus fulfilled**

$$r_{rel} = \frac{1\ \mu m}{100\ \mu m} \cdot 100 = 1.0\ \%$$

→ **1.0 % is outside the standard specifications, but 1 µm is admissible (absolute value larger value), thus fulfilled**

$$q_{rb} = \frac{(0.500\ mm\ - 0.504\ mm)}{0.504\ mm} \cdot 100 = -0.8\ \%$$

→ **Absolute deviation of 4 µm is larger than the required 3 µm, but -0.8 % corresponds to the standard specification, thus fulfilled**

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Calibration according to DIN EN ISO 9513

- Before calibration, the length measuring device must be stored for a sufficiently long period of time in the vicinity of the calibration device or attached to it (same calibration temperature)
- Temperature must be recorded during the entire calibration - nominal range from 18 °C to 28 °C, temperature constancy of ± 2 °C must be ensured
- Selected calibration steps are approached one after the other via the extension display of the testing machine and the values from the display of the calibration device are transferred to the protocol

<u>Sequences of a typical calibration procedure:</u>

1. Visual inspection of the extensometer and preparation of the examination protocol
2. Determination of the measuring ranges and the resulting calibration steps
3. Determination of resolution r and the relative deviation of the initial instrument measuring length → Entry of all relevant parameters in calibration software
4. Before calibration, move through the relevant range twice with the calibration device attached
5. Record measurement series 1 and 2 → Calibration program then determines results and generates calibration certificate
6. Make remaining order-related entries

<u>Extract from exemplary calibration protocol:</u>

mea-sure-ment	resolution in µm	relative resolution	real elongation for check-up	real elongation on calibration device in mm		absolute display deviation in µm		relative display deviation		expanded measure-ment uncertain- ty k=2	expanded measure-ment uncertainty + deviation series 1	expanded measure-ment uncertainty + deviation series 2
				series 1	series 2	series 1	series 2	series 1	series 2			
1	1,00	0,33%	**0,300 00**	0,299 77	0,299 61	0,23	0,39	0,08	0,13	0,80	1,03 µm	1,19 µm
2	1,00	0,17%	**0,600 00**	0,598 95	0,598 07	1,05	1,93	0,18	0,32	1,43	0,41 %	0,56 %
3	1,00	0,11%	**0,900 00**	0,898 80	0,898 28	1,20	1,72	0,13	0,19	1,64	0,32 %	0,37 %
4	1,00	0,08%	**1,200 00**	1,198 80	1,196 64	1,20	3,36	0,10	0,28	2,96	0,35 %	0,53 %
5	1,00	0,07%	**1,500 00**	1,498 53	1,497 81	1,47	2,19	0,10	0,15	2,58	0,27 %	0,32 %
6	1,00	0,06%	**1,800 00**	1,799 35	1,796 98	0,65	3,02	0,04	0,17	3,79	0,25 %	0,38 %
7	1,00	0,05%	**2,100 00**	2,098 96	2,096 33	1,04	3,67	0,05	0,18	4,32	0,26 %	0,38 %
8	1,00	0,04%	**2,400 00**	2,397 53	2,396 14	2,47	3,86	0,10	0,16	4,14	0,28 %	0,33 %
9	1,00	0,04%	**2,700 00**	2,698 41	2,696 46	1,59	3,54	0,06	0,13	4,79	0,24 %	0,31 %
10	1,00	0,03%	**3,000 00**	2,998 44	2,996 39	1,56	3,61	0,05	0,12	5,27	0,23 %	0,30 %

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