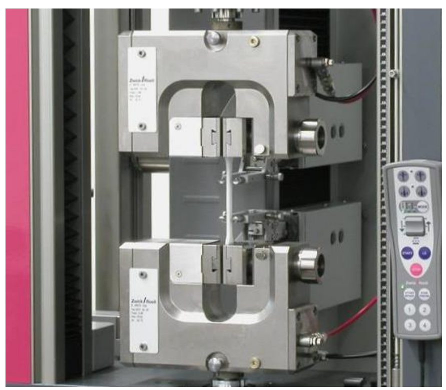
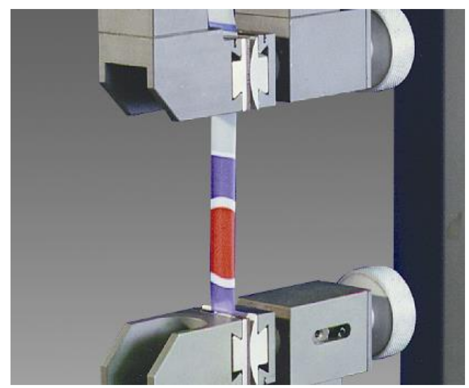
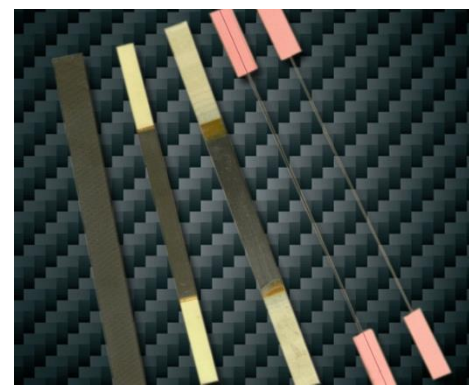
The 2012 version of ISO 527
Plastics: Determination of tensile properties

Helmut Fahrenholz

October 2018







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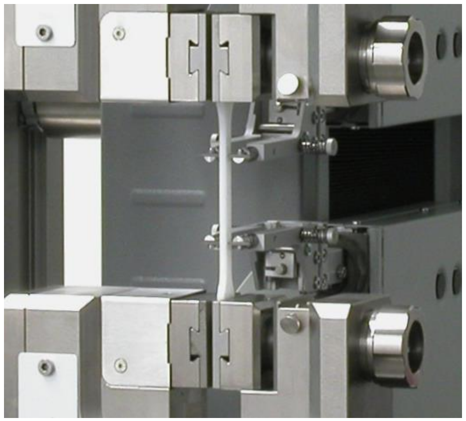
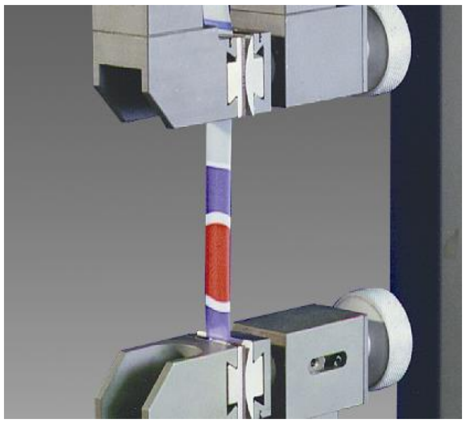
Development of ISO 527-1 and -2

ISO 527 covers plastics as filled and unfilled molding, extrusion and cast materials, plastic film and sheets, as well as long fiber reinforced composites.

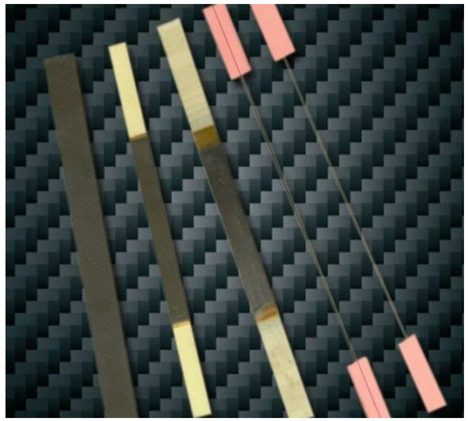
- Part 1: General principles
- Part 2: Test conditions for molding and extrusion plastics
- Part 3: Test conditions for films and sheets
- Part 4: Test conditions for isotropic and orthotropic fiber-reinforced plastic composites
- Part 5: Test conditions for unidirectional fiber-reinforced plastic composites



Part 2



Part 3



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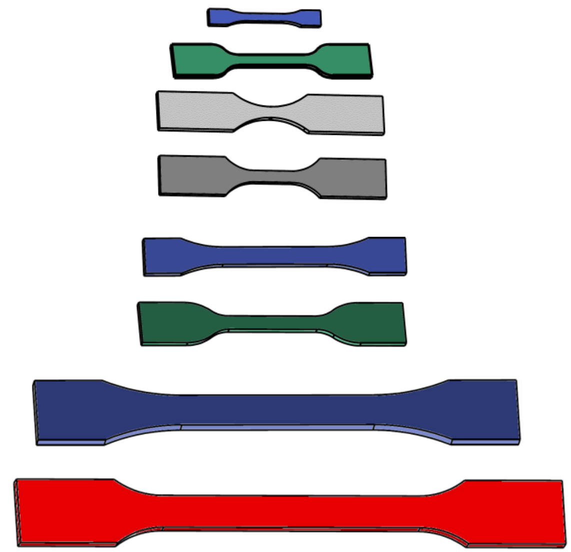
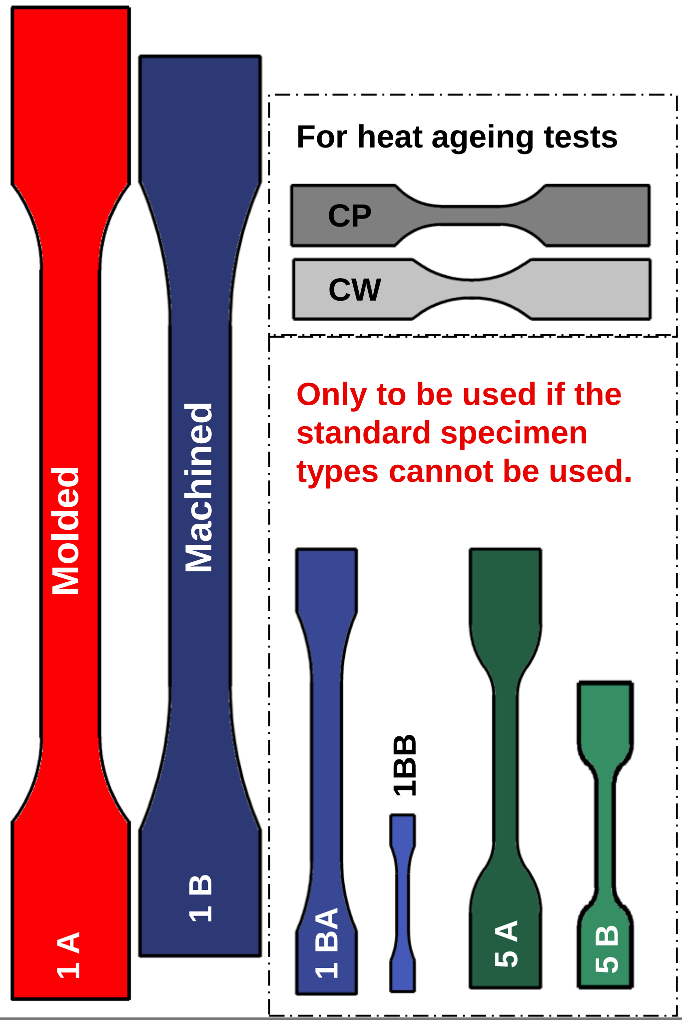


Specimen shapes and dimensions

Type 1A for molded and type 1B for machined specimen are used with ISO 527-2.

- ISO 20753 defines specimen for testing plastics in a general way
- ISO 527-2 defines specimen to be used for tensile tests
  - Types 1A (A1) and 1B (A2) are standard specimen for comparable data
  - Types 1BA (A22) and 1BB (A25) for reduced-scale specimen (only informative annex)
  - Types 5A and 5B which are proportional to ISO 37, types 2 and 3 (only informative annex)
  - Types CW and CP (identical to types 2 and 4 from ISO 8256) as small tensile specimen for heat ageing tests
  - ISO 293 and 294 define conditions for compression molding and injection molding of specimen.
- Specific conditions and specimen shapes may occur in national or international materials specification standards.

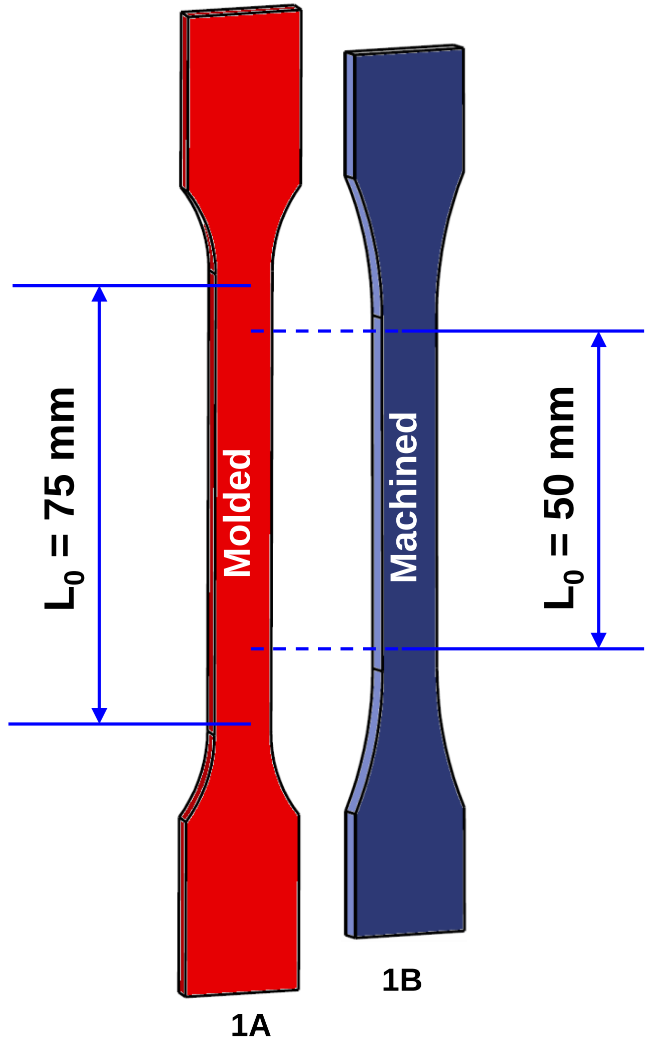


New extensometer gage length

Zwick Roell

The preferred gage length for specimen type 1A is now increased to 75 mm

- Improved accuracy for modulus measurements
- No influence on yield-point determination
- No significant influence on break-point determination
- Better use of the parallel portion of the 1A specimen which is 80 mm long



- But, no change for specimen type 1B !
- Gage length of 50 mm is still allowed, but not preferred for type 1A

Dimension measurement

Zwick Roell

Accurate dimension measurement is needed to obtain accurate results. ISO 16012 applies for plastics, ISO 23529 for rubber.

- Plastic specimen width can be measured either by a caliper, by a micrometer or a cross-section measurement station.
- Plastic specimen thickness can be measured by a micrometer or a cross-section measurement station.
- The contact force is between 5 an 15 N, the measuring face and anvil is circular flat and typically 6.35 mm (6.5 mm) in diameter. But other shapes and dimensions are possible.
- The measurement has to be taken in the middle of the specimen and within the gage length. Injection molded specimen are measured within 5 mm around the center of the gage length.
- An error of 0.1 mm in thickness measurement corresponds to an error of 2.5 % !

Zwick cross-section measurement station (CSM)

Table 1 — Accuracy requirements

Dimensions in millimetres

Range of dimensions	Required accuracy
< 10	± 0,02
⩾ 10	± 0,1

Requirements of ISO 16012

Standard micrometer with ratchet

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- Preparation of the tensile machine
- Alignment
- Pre-stresses, Preload
- Test speeds
- Tensile modulus
- Yield point and break point
- Nominal strain
- Poisson’s ratio

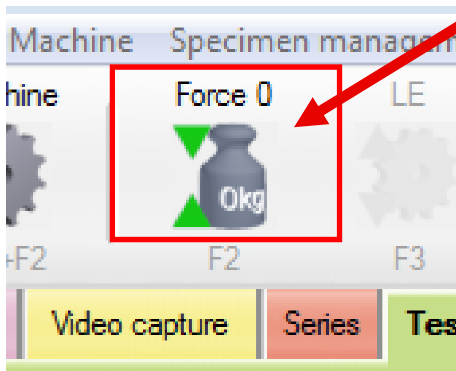
Comparable materials data

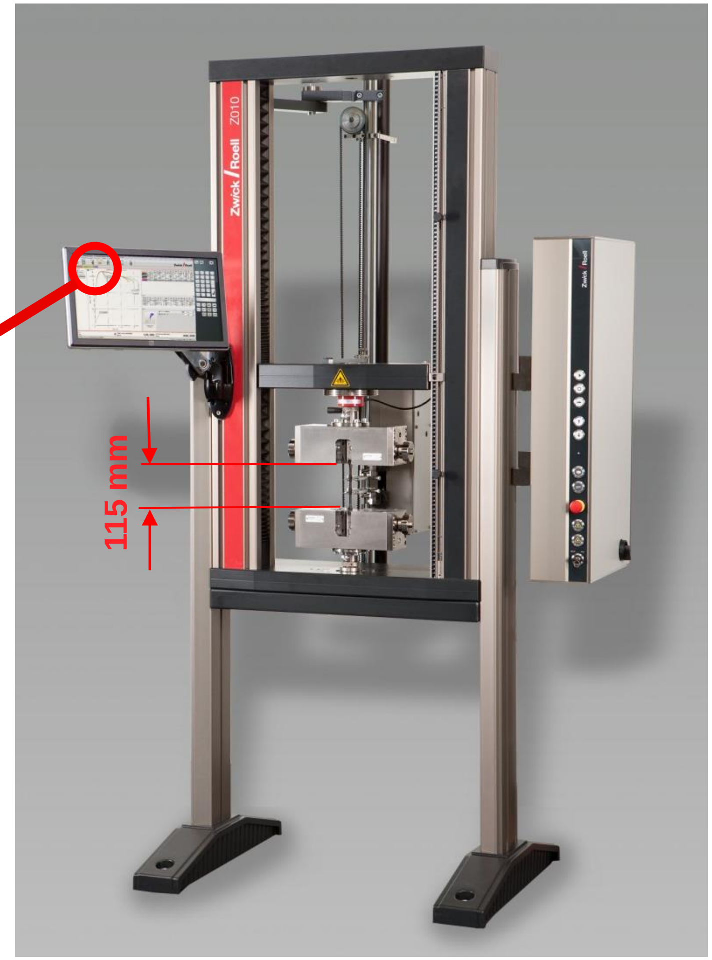
Requirements to the test equipment

Preparation of the tensile machine

Set the machine into a known configuration before starting the test !

- Set the grip-to-grip separation to 115 mm
- Set the force measurement system to zero <u>before</u> the specimen is gripped at both ends !



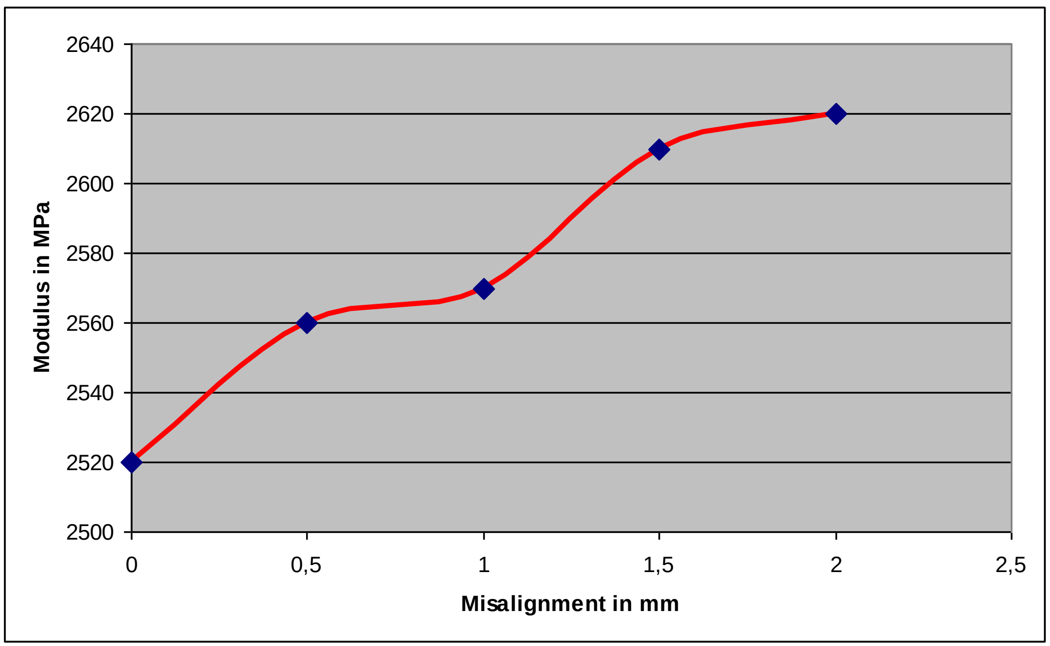


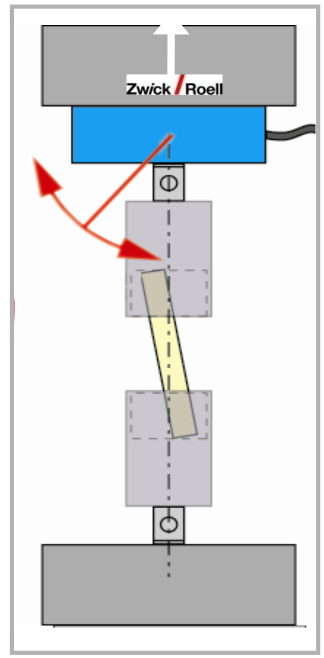
Zwick testing machine

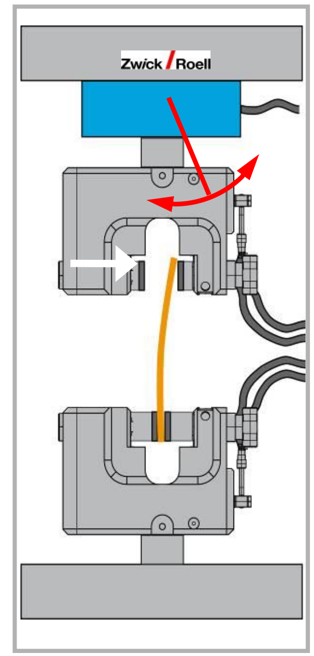
Forces occurring during the clamping process in fact are really present on the specimen !

Specimen alignment errors cause problems for the measurement of tensile modulus

- Misalignment creates bending within the specimen
- For a PBT sample, the modulus changed about 4% for only 2 mm axial misalignment.





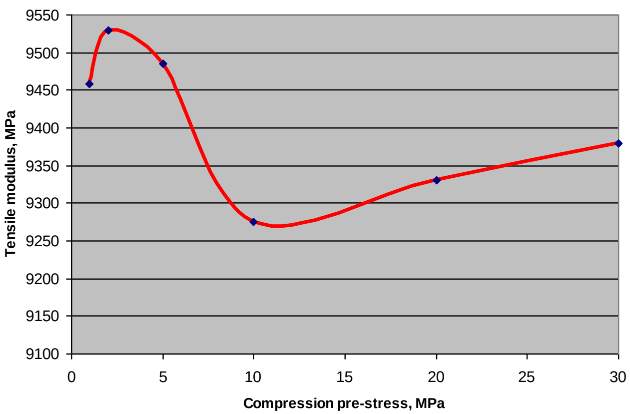


Pre-stresses

Zwick Roell

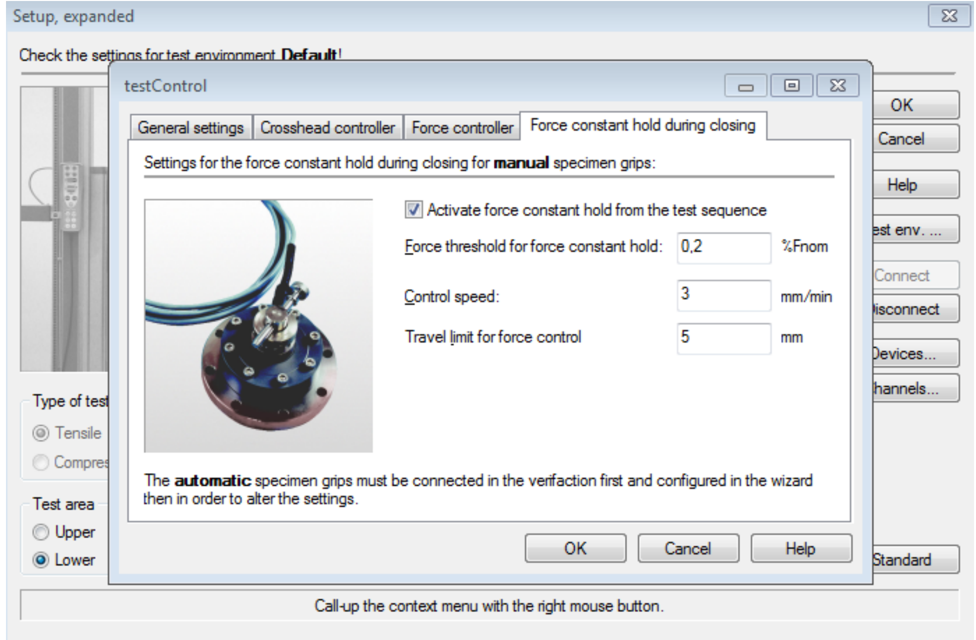
Pre-stresses that may for example occur during the clamping process shall be avoided, i.e. by using the force constant hold function of testXpert II.

- Compression stresses during clamping may change the tensile modulus by more than 3 %
- testXpert II offers a “force – zero” control of the testing machine during clamping that can avoid this problem.



Example of variation of tensile modulus, E_t , at different compression pre-stress levels.

(PBT GF 10%)

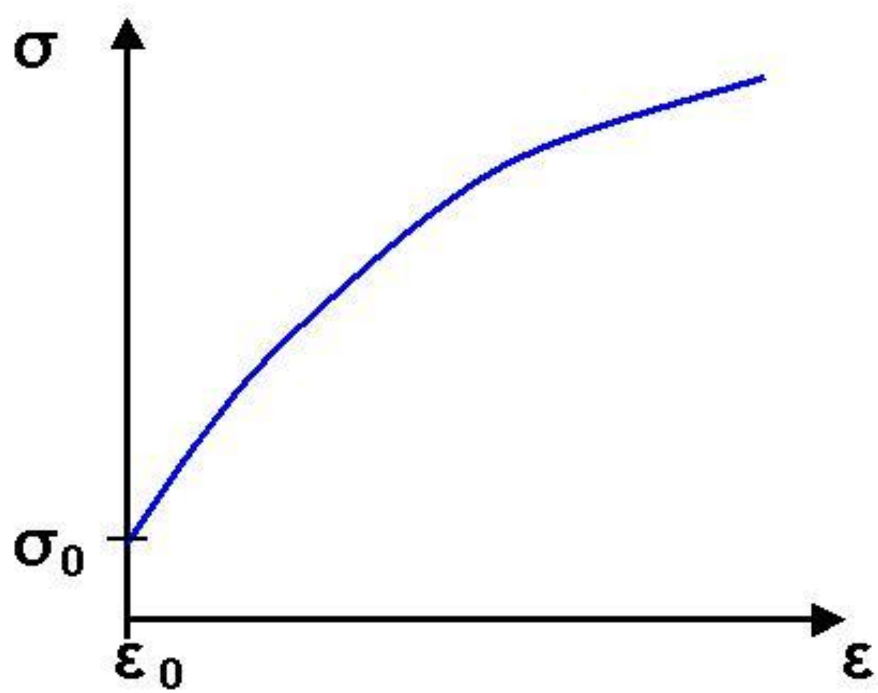


testXpert II settings to activate the function “Force constant hold during clamping”

Pre-stress, pre-load

Small positive pre-stresses (σ_0) are necessary to avoid a toe region at the start of the stress/strain diagram.

- The point of pre-stress σ_0 is the zero-point of extension
- This definition ensures a repeatable starting point of the test which is quite independent from operator or equipment influences.



For modulus measurement:

$\sigma_0 \leq E_t / 2000$

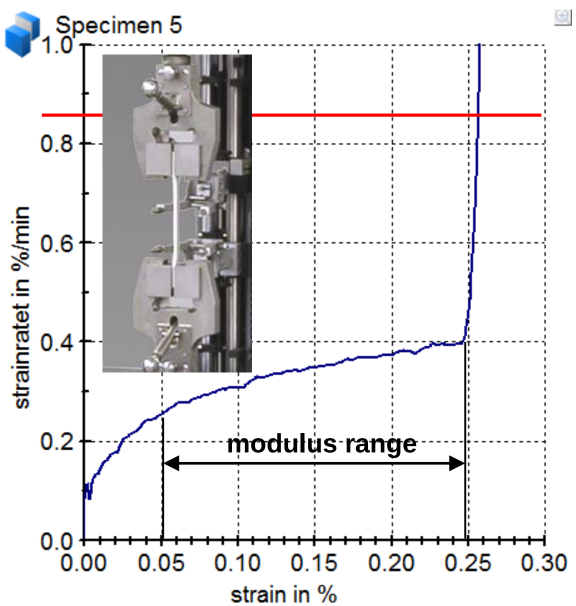
Means that the extension that is cut-off from the diagram is smaller than 0,05 %.

For measurement of relevant stresses:

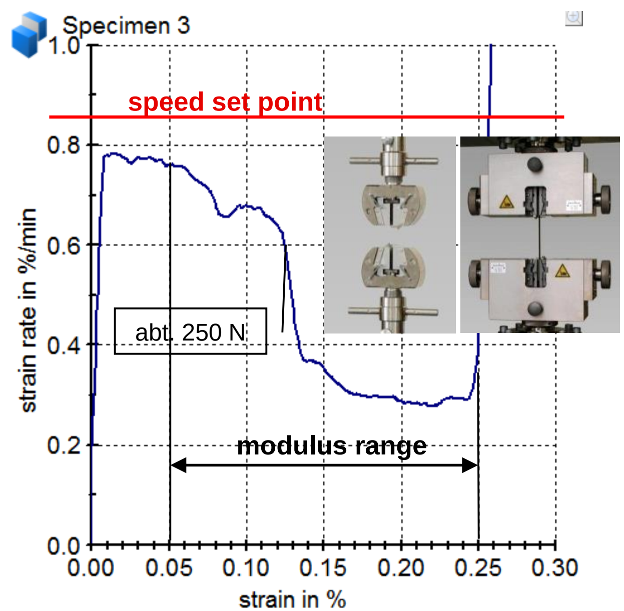
$\sigma_0 \leq \sigma / 100$

Parallel clamping ensures the correct deformation speed being respected.

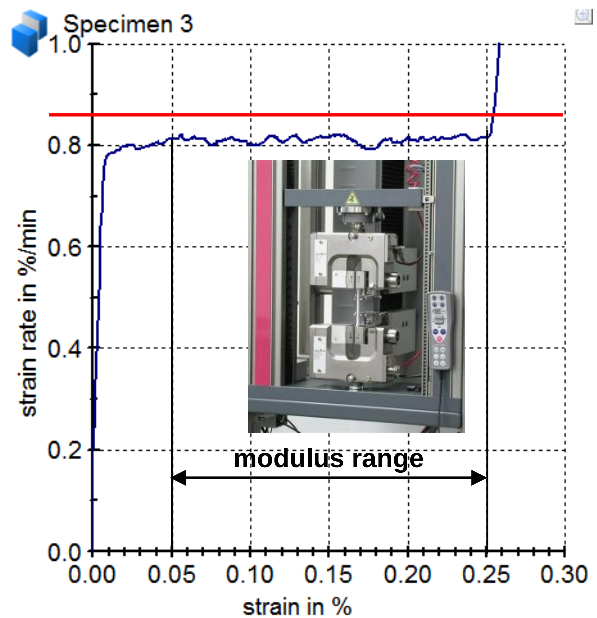
- The speed for modulus determination shall be set in a way to achieve a strain rate of 1 %/min by using one of the speeds from table 1 in ISO 527 part 1.
- A crosshead speed of 1 mm/min calculates to a deformation speed of 0.87 %/min. (Std. specimen)
- Self tightening grips lead to low deformation speeds, pre-stressed grips lead to speed variations



Self tightening wedge grips



Pre-stressed self tightening wedge-screw grips

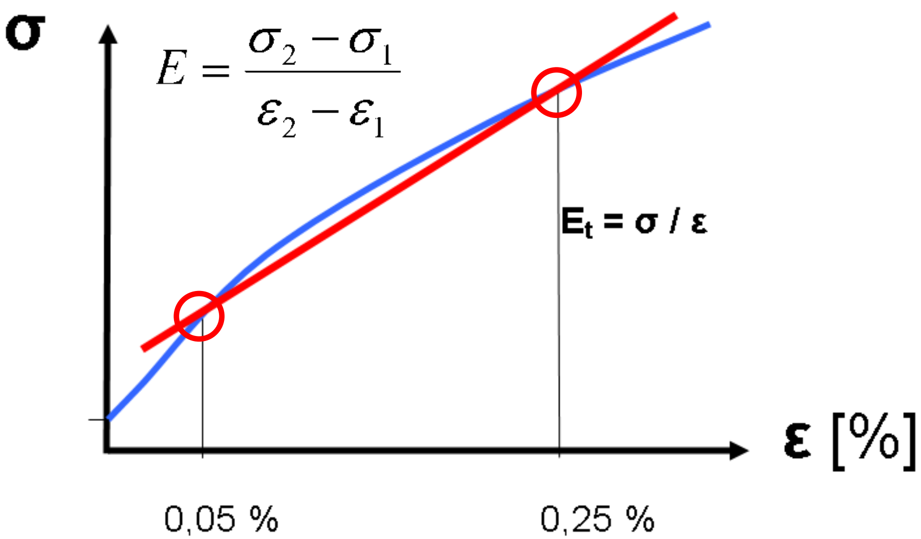


Parallel clamping pneumatic grips

Tensile - modulus

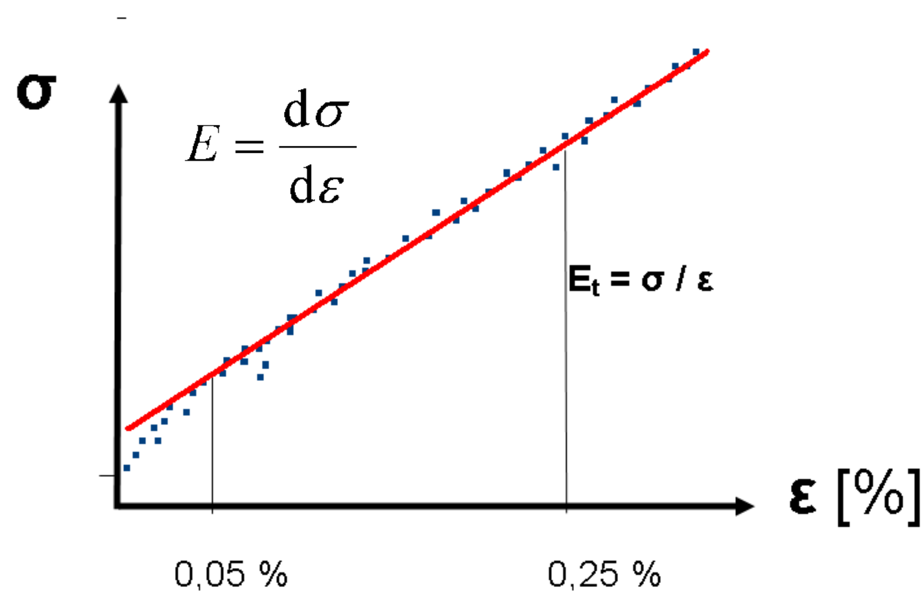
The tensile modulus has to be calculated between two strains.

- It is the slope in the stress-strain diagram between 0.05% and 0.25% strain
- It can be calculated as a secant between 2 points or by a linear regression calculation.



Secant slope

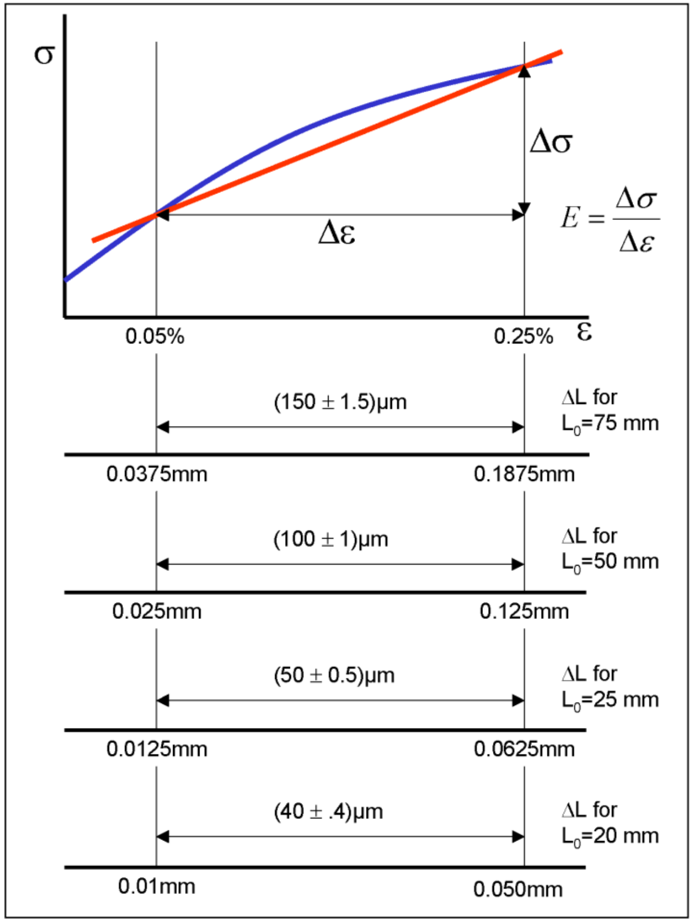
Easy to use for manual determination, statistically sensitive to noisy signals.



Regression slope

Takes into account all measured points and leads to statistically more safe results.

Modulus measurement requires for a highly accurate extensometer



Extension measurement for modulus determinations

Requirements to ISO 527-1, §5.1.5.1 :
Since the modulus of elasticity is normally taken on the larger specimen types 1A or 1B, the accuracy requirement for the extensometer is ± 1,5 µm for type 1A and ± 1,0 µm for type 1B.

The minimum requirement in terms of resolution, referencing to ISO 9513, lies therefore at 0.5 microns.

For smaller specimens with smaller gage lengths the requirements become higher.

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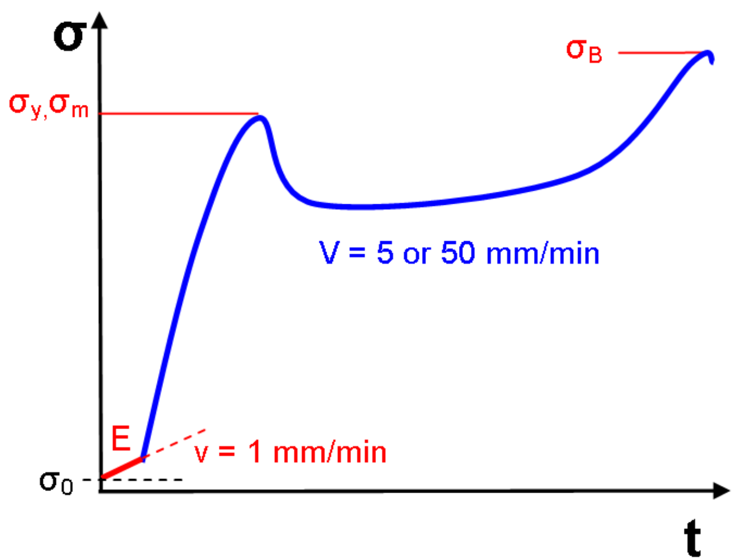
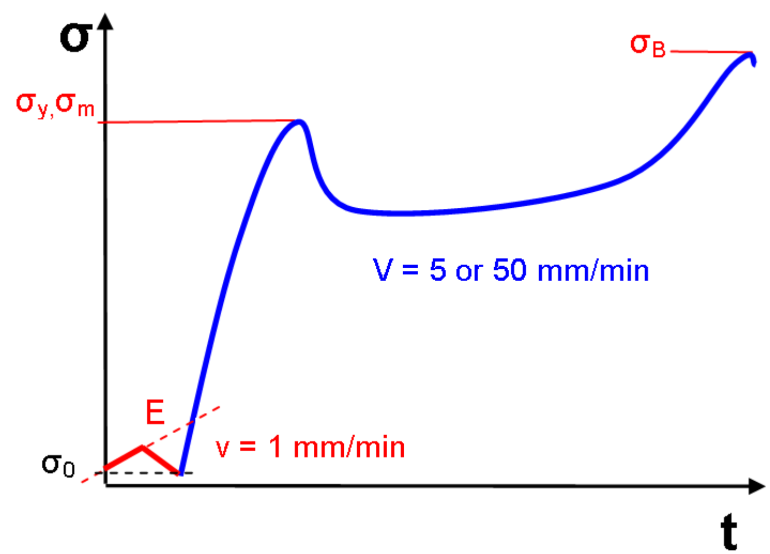
Once the modulus determination is completed, the speed has to be changed. Typical speeds are 5 mm/min or 50 mm/min.

- ISO 527-1 now clearly allows a speed change after modulus determination (§ 9.6)
- Tensile modulus and further tests results can be determined from one single specimen
- The speed change shall occur at strains below or equal 0,3%
- It is preferable to unload the specimen before testing at a different speed, but it is also acceptable to change the speed without unloading.



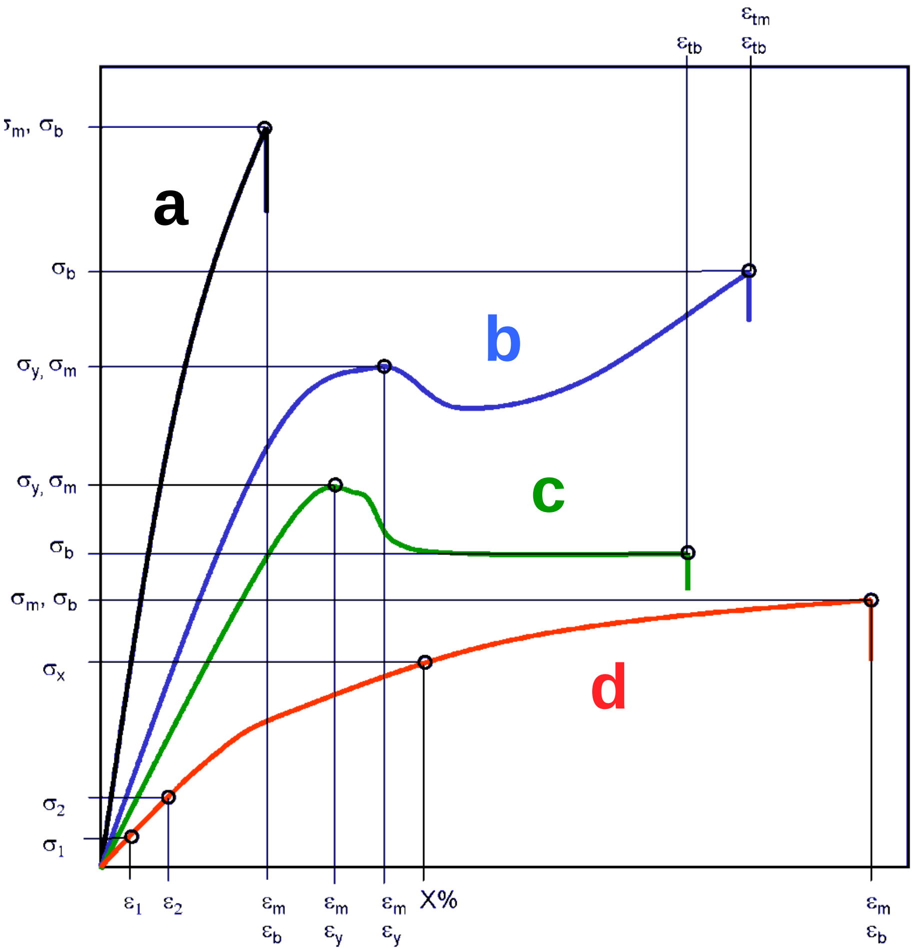
Direct speed change



Speed change with unloading

Tensile - yield and break point

ISO and ASTM distinguish between different result determinations according to the type of stress-strain curve obtained.

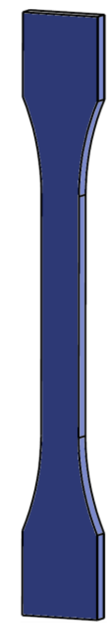


Stress-strain curve types:

Curve a:	Brittle materials
Curve b and c:	Tough materials with yield point
Curve d:	Tough materials without yield point

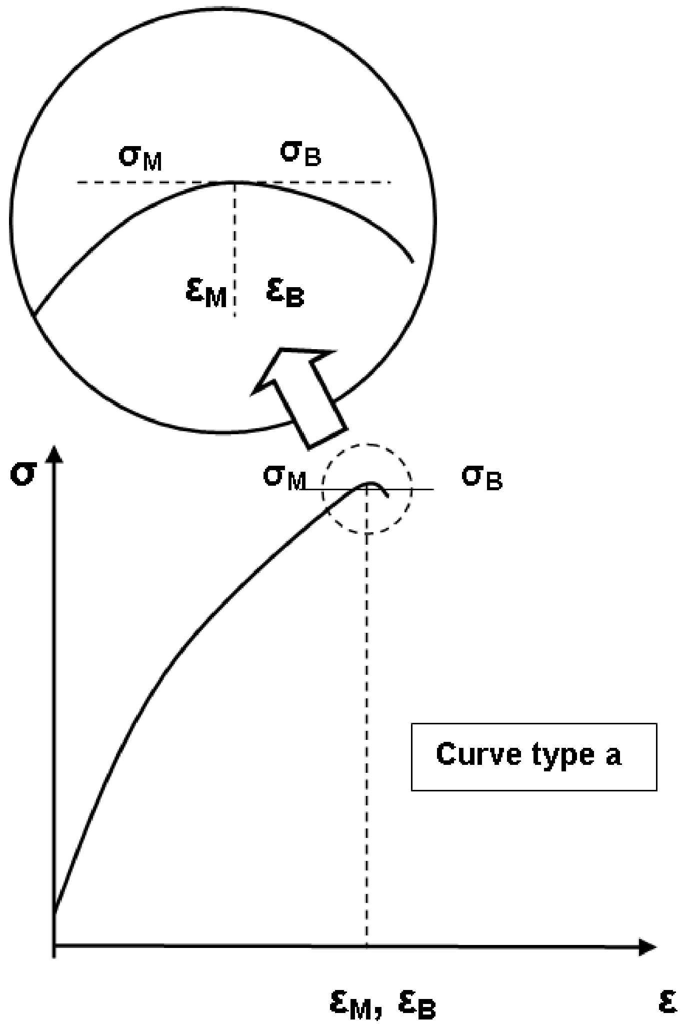
Results:

- Tensile-Modulus, E_t
- Yield (ε_y, σ_y)
- maximum force , σ_M, ε_M,
- Break point, σ_B, ε_B, ε_{tB}
- Strain results determined beyond a yield point are measured as "Nominal Strain"



Tensile - curve type a

For curve type “a” all results are determined in one single point.



Results of curve type a:

- tensile modulus
- max stress
- max strain

Accuracy requirements for the Extensometers for further results

ISO 527-1, §5.1.5.1:

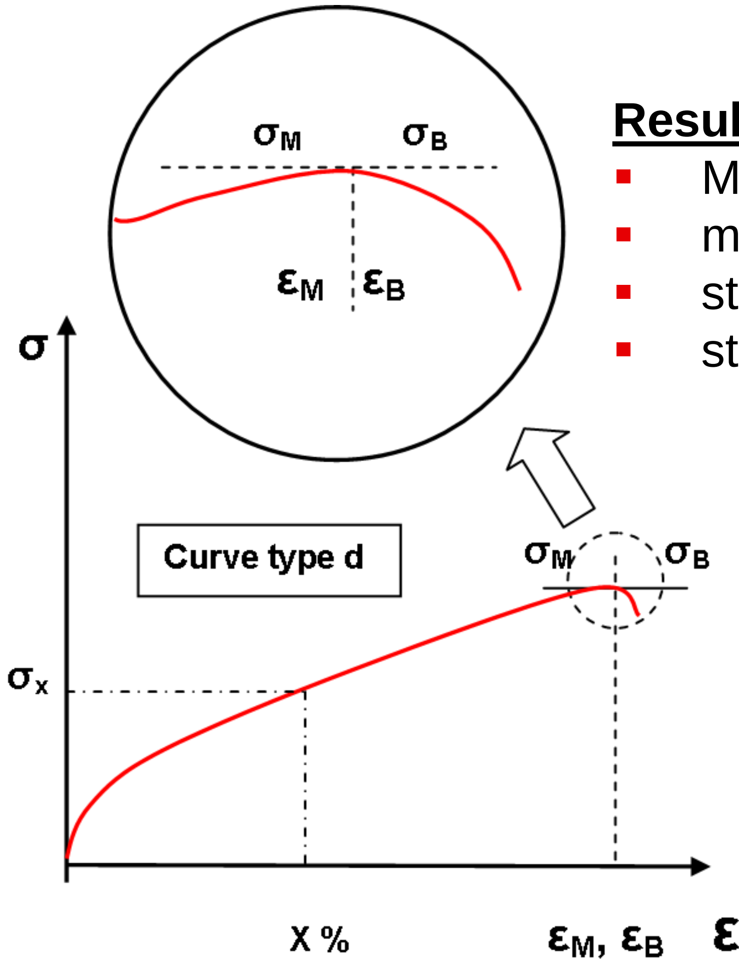
“Extensometers shall comply with ISO 9513, class 1, except for modulus determinations …”

This means that the extensometer shall basically be capable of measuring the change of gage length with an accuracy of ± 1% of the reading or ± 3µm, whichever is greater.

Example:
The extension at break for a specimen type 1A is measured at 4%. This corresponds to a change of gage length of 3 mm. The accuracy requirement at this point is ± 0.030 mm or better.

Tensile - curve type d

If higher elongations occur, it may be helpful to use a conventional strain point.

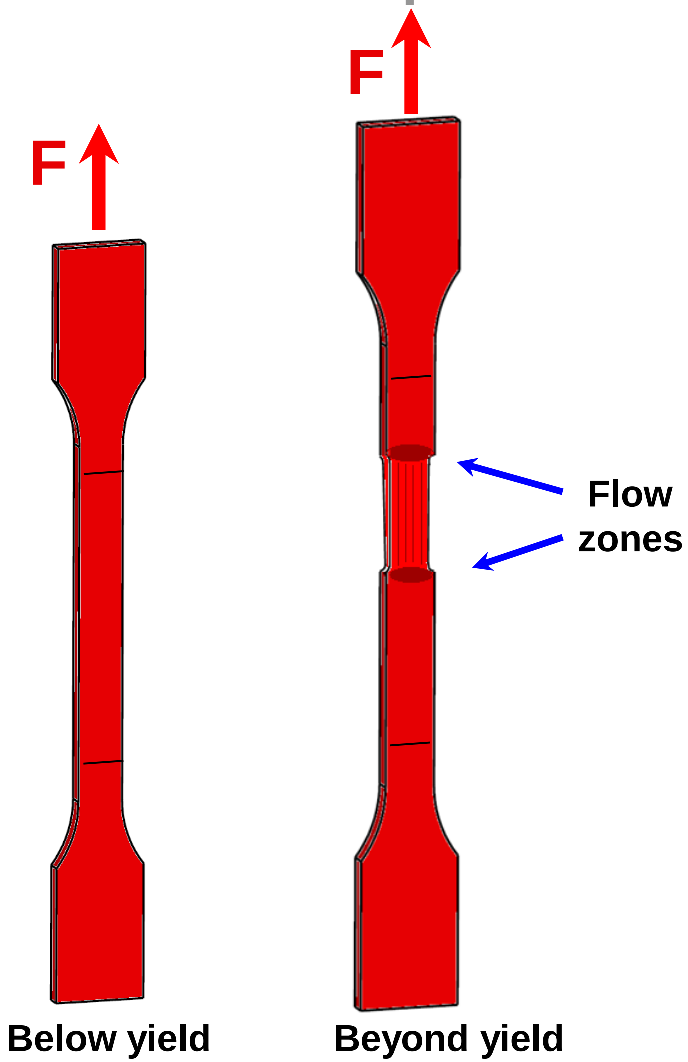


<u>Results of curve type d:</u>

- Modulus
- max stress and strain
- stress and strain at break
- stress at X% strain

Tensile - curve types b and c

Unfilled thermoplastic materials typically show a yield point



<u>Inhomogeneous strain distribution beyond yield</u>

- <u>Below yield</u>, the strain is quite homogenously distributed within the parallel portion of the specimen.
- <u>When approaching the yield point</u>, the strain rate increases within a limited area while it decreases in other areas.
- <u>Beyond yield</u> very high strain rates can be observed within the flow zones. These local strain rates can be more than 10 times higher than the average strain rate.

Direct strain measurement beyond yield leads to statistically unsafe results

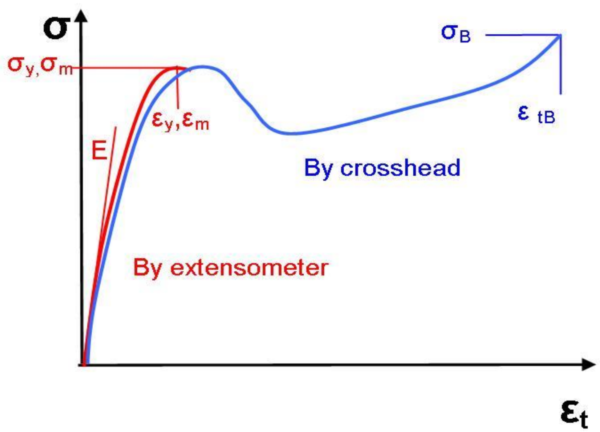
Film

Nominal strain

The solution is the use of nominal strain. ISO 527-1 defines two ways of measuring nominal strain.

Method A

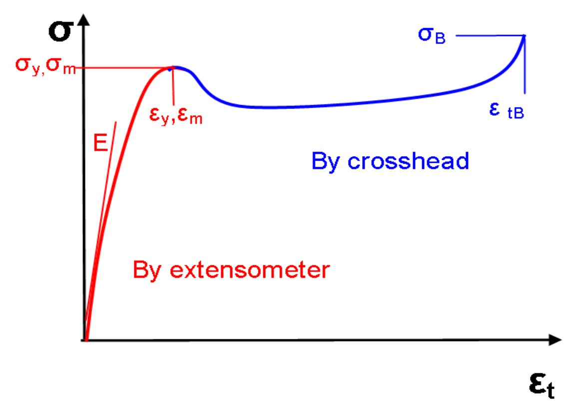
- Used in ISO 527 since 1993
- Needs two graphics to show all results correctly in stress-strain diagrams



Strain:	$\varepsilon = \Delta L_0 / L_0$
Nominal Strain:	$\varepsilon_t = \Delta L_T / L$

Method B

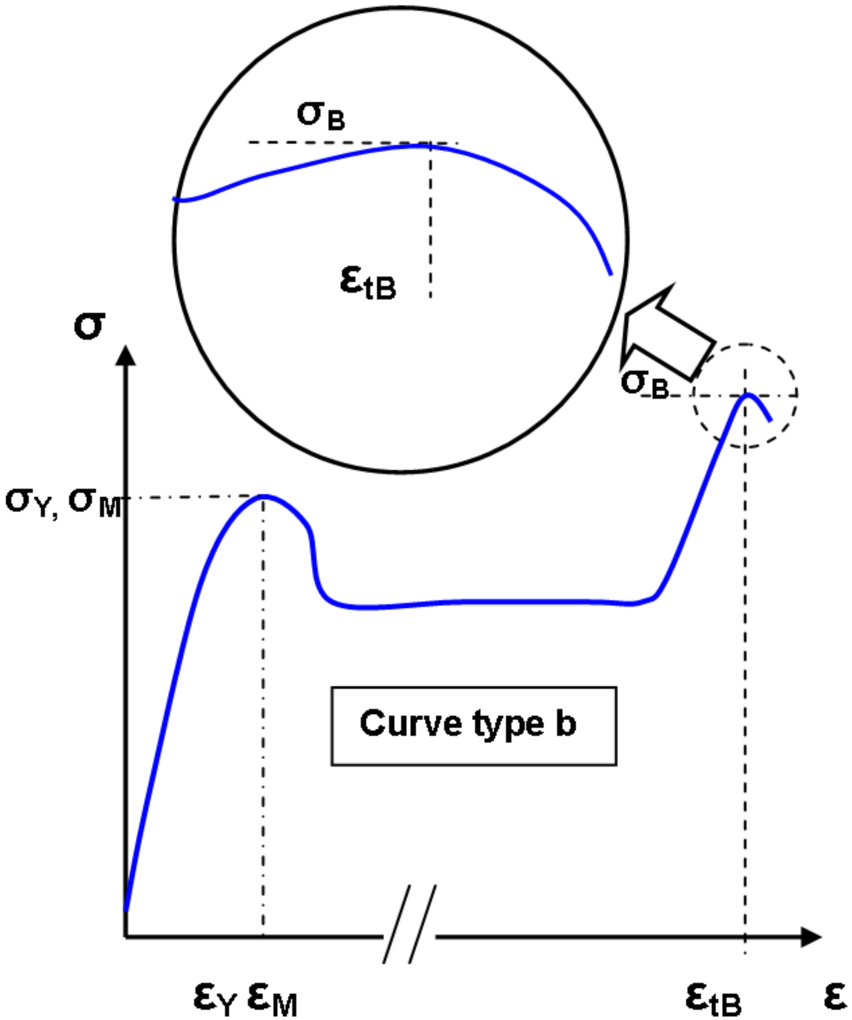
- New method in ISO 527
- Preferred for use with multipurpose specimens (types 1A and 1B)
- All results are shown in one diagram
- There is only one definition for strain.



Strain at yield:	$\varepsilon_y = \Delta L_y / L_0$
Strain:	$\varepsilon_t = \varepsilon_y + \Delta L_T / L$

Tensile - curve type b

The point of max. stress is now defined as the first maximum.



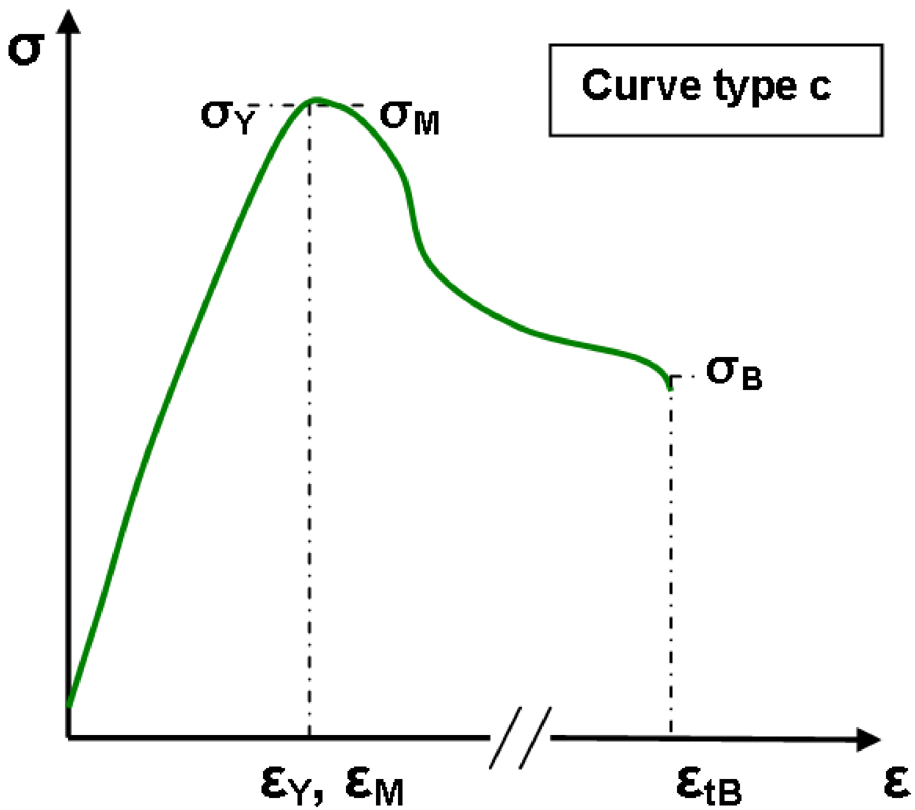
The definition of the first maximum avoids, that the result σ_M "flickers" between the yield point and the break point, depending upon the shape of the curve, as it did in former versions.

Results of curve type b:

- Modulus, E_t
- Yield stress, σ_y
- Yield strain, ε_y
- Max stress, σ_M
- Strain at max. stress, ε_M
- Stress at break, σ_B
- Nominal strain at break, ε_{tB}

Tensile - curve type c

All strains beyond yield are presented as nominal strains.



Results of curve type c:

- Modulus, E_t
- Yield stress, σ_y
- Yield strain, ε_y
- Max stress, σ_M
- Strain at max. stress, ε_M
- Stress at break, σ_B
- Nominal strain at break, ε_{tB}

Requirements for the extension measurement system for specimen 1A, 1B (ISO) and Type I (ASTM):

ε_Y	extension to be measured	allowable measurement uncertainty to ISO	allowable measurement uncertainty to ASTM
5%	2.50 mm	± 0.025 mm	± 0.050 mm
10%	5.00 mm	± 0.050 mm	± 0.050 mm
15%	7.50 mm	± 0.075 mm	± 0.075 mm
20 %	10.0 mm	± 0.100 mm	± 0.100 mm
25%	12.5 mm	± 0.125 mm	± 1.25 mm

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Comparable materials data

The CAMPUS working group defined rules for performing more comparable tests, that have strongly influenced the ISO standards.

Comparable Single Point Data (ISO 10350-1)

- **Rheological characteristics** (MVR, MFR, shrinkage)
- **Mechanical characteristics** (tensile, flexural, creep, impact)
- **Thermal characteristics** (transition temperature, deflection temp.)
- **Electrical characteristics** (permittivity, dielectric loss factor, ..)
- **Other characteristics** (water absorption, density, ...)

Comparable Multipoint Data (ISO 11403)

Comparable Design Data (ISO 17282)

See also www.campusplastics.com

Campus members

Zwick Roell

CAMPUS members (as per June 2018):

Participants
Visit the individual websites of the CAMPUS members:

- A. Schulman
- ARKEMA
- Celanese – The chemistry inside innovation
- DSM
- EMS – EMS-GRIVORY
- HEXION
- kuraray
- Mitsubishi Engineering-Plastics Corporation
- SOLVAY
- ALBIS
- BASF – We create chemistry – BASF SE and BASF Polyurethanes
- covestro
- DUPONT – The miracles of science
- EVONIK – POWER TO CREATE
- INEOS STYROLUTION
- LANXESS
- RADICI GROUP PERFORMANCE PLASTICS
- eni versalis

Thank you for your attention