Efficiency increases in tensile testing on metals according to ISO 6892-1 and ASTM E8

testXpo 2023

Zwick Roell

1. **Stress-strain curve and standards**
   Characteristic values from the stress-strain diagram

2. **Test Methods/Test Speeds to DIN EN ISO 6892-1**
   Test speed dependency of materials properties
   Method B: stress-rate control
   Method A: strain-rate control

3. **Summary**
   Typical test results according to DIN EN ISO 6892-1 method A1
   Summary of efficiency increases

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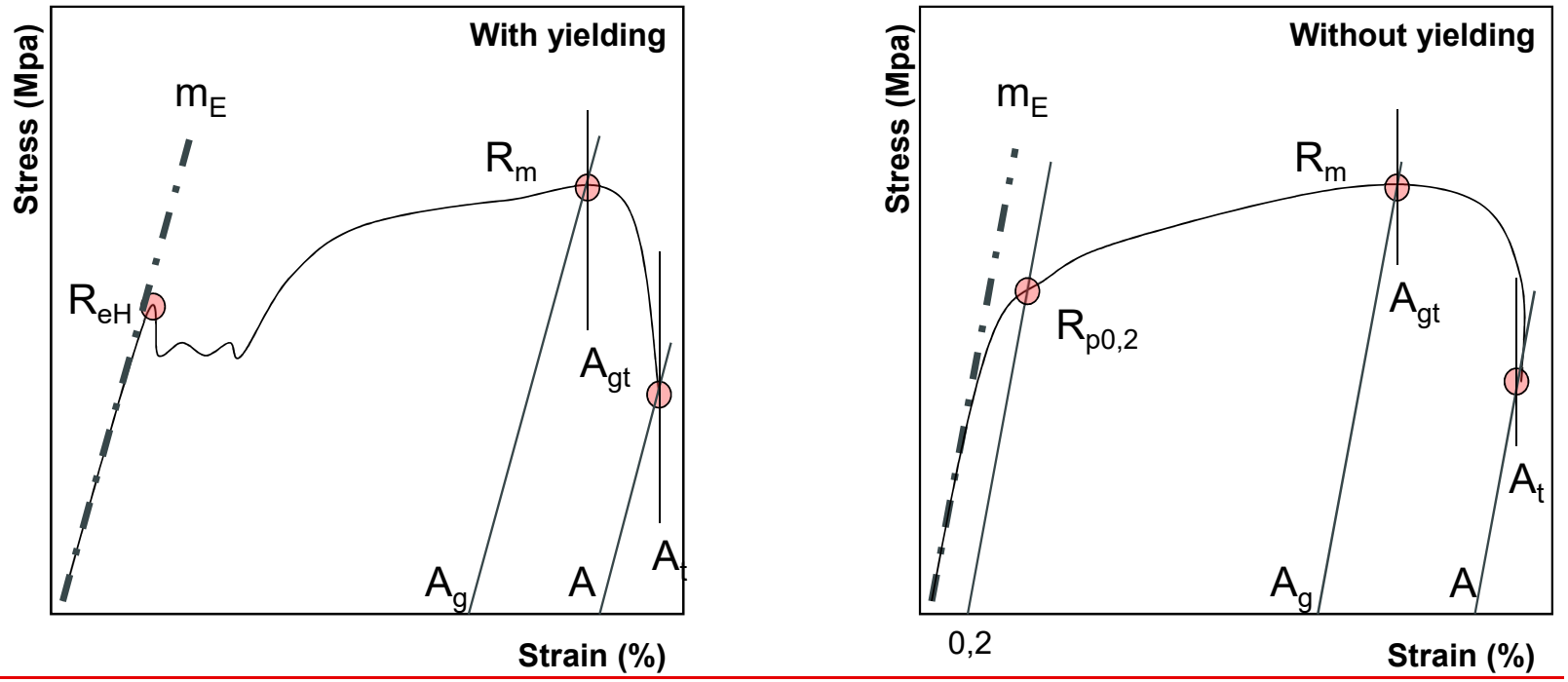
Typical mechanical properties are stress values R_{eH}, $R_{p0.2}$, R_m. Typical strain values are A_g, A and A_{gt} and A_t. An important characteristic is the slope m_E in the beginning.



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testXpert III

Results in testXpert

Active	Abbreviation	Unit	Name
☐	$R_{p0.2}/R_m$	%	Proof stress ratio
☑	R_{eH}	MPa	Upper yield point
☐	R_{eH}/R_m	%	Yield point ratio
☑	R_{eL}	MPa	Lower yield point
☑	A_e	%	Yield point strain
☑	R_m	MPa	Tensile strength
☑	F_m	kN	Maximum tensile force
☐	$A_{gt\ (corr.)}$	%	Total strain at maximum tensile force (corr.)
☐	A{lo gt filtered	%	Total strain (corr.) at maximum tensile force (filtered)
☑	A_g	%	Uniform elongation
☐	$A_{g\ filtered}$	%	Uniform elongation (Filtered)
☐	R_B	MPa	Stress at break
☐	$A_{t\ (corr.)}$	%	Total strain at break (corr.)
☐	$A_{5.65}$	%	Strain at break Ax1
☐	$A_{11.3}$	%	Strain at break Ax2
☑	A_{80mm}	%	Strain at break
☐	L_e	mm	Device gage length
☐	L_0	mm	Initial gage length
☐	L_c	mm	Gage length, crosshead
☑	a_0	mm	Specimen thickness
☑	b_0	mm	Specimen width
☑	$d\sigma/dt_{Set}$	MPa/s	Preset stress increase ...
☑	$d\sigma/dt_{Actual}$	MPa/s	Maximum force increase rate ...
☑	$V_{Actual\ crossh.}$	mm...	Driven crosshead speed ...
☑	$V_{Set\ crossh.}$	mm...	Necessary crosshead speed ...
☑	$k_{Test\ assembly}$	kN/...	Required preset for the stiffness of the test assembly ...
☑	S_0	mm^2	Initial cross-section

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Test Method to DIN EN ISO 6892-1

ISO 6892-1 describes 3 test methods (2 for strain-rate and 1 for stress-rate control). Background is the possible material property's dependency (e.g. $R_{p0.2}$) on test speed.

Test speeds specified in DIN EN ISO 6892-1

Method A Strain-rate control

Method A1 Closed loop | **Method A2** Open loop

Method B Setting a stress speed

Conforms to EN 10002-1 or ISO 6892:1998

NOTE 1 The difference between Method A and Method B is that the necessary testing speed of Method A is defined at the point of interest (e.g. Rp0,2), where the property has to be determined, whereas, in Method B, the necessary testing speed is set in the elastic range before the property (e.g. Rp0,2) has to be determined.

... using Method B (on some steels with a stress rate of ~30 MPa/s in the elastic region, using a system and grips with high stiffnesses and flat specimen with 20 mm width) a strain rate near the range 2 (=0.00025 1/s) of Method A may be observed

Modulus of elasticity of the material E MPa	Stress rate $\dot{R}$ MPa s^{-1}	
	min.	max.
<150 000	2	20
≥150 000	6	60

magnesium, aluminium alloys, brass, titanium

wrought iron, steel, tungsten, nickel-based alloys

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ASTM E8 describes 3 test methods (2 for strain-rate and 1 for stress rate control). Background is the possible material proterty's dependency (e.g. $R_{p0.2}$) on test speed.

Test speeds specified in ASTM E8:2021

Control method B
rate of straining
"closed loop"

e.g. in mm/mm/min

0,015±0.006 mm/mm/min

= 0.00025 1/s ±40%

Control method C
crosshead speed control

e.g. in mm/min

0,015±0.003 mm/mm/min

= 0.00025 1/s ±20%

Control method A
rate of stressing

e.g. in MPa/s

1.5 .. 11.5 MPa/s in elastic region

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The test methods according to ISO and ASTM have different abbreviations (letters) and different meanings (contents).

ISO 6892-1	Method description	ASTM E 8	Method description
Method A1	Strain-rate control closed loop	Method B	Rate of straining “closed loop”
Method A2	Strain-rate control open loop	Method C	Crosshead speed control
Method B	Stress-rate control	Method A	Rate of stressing

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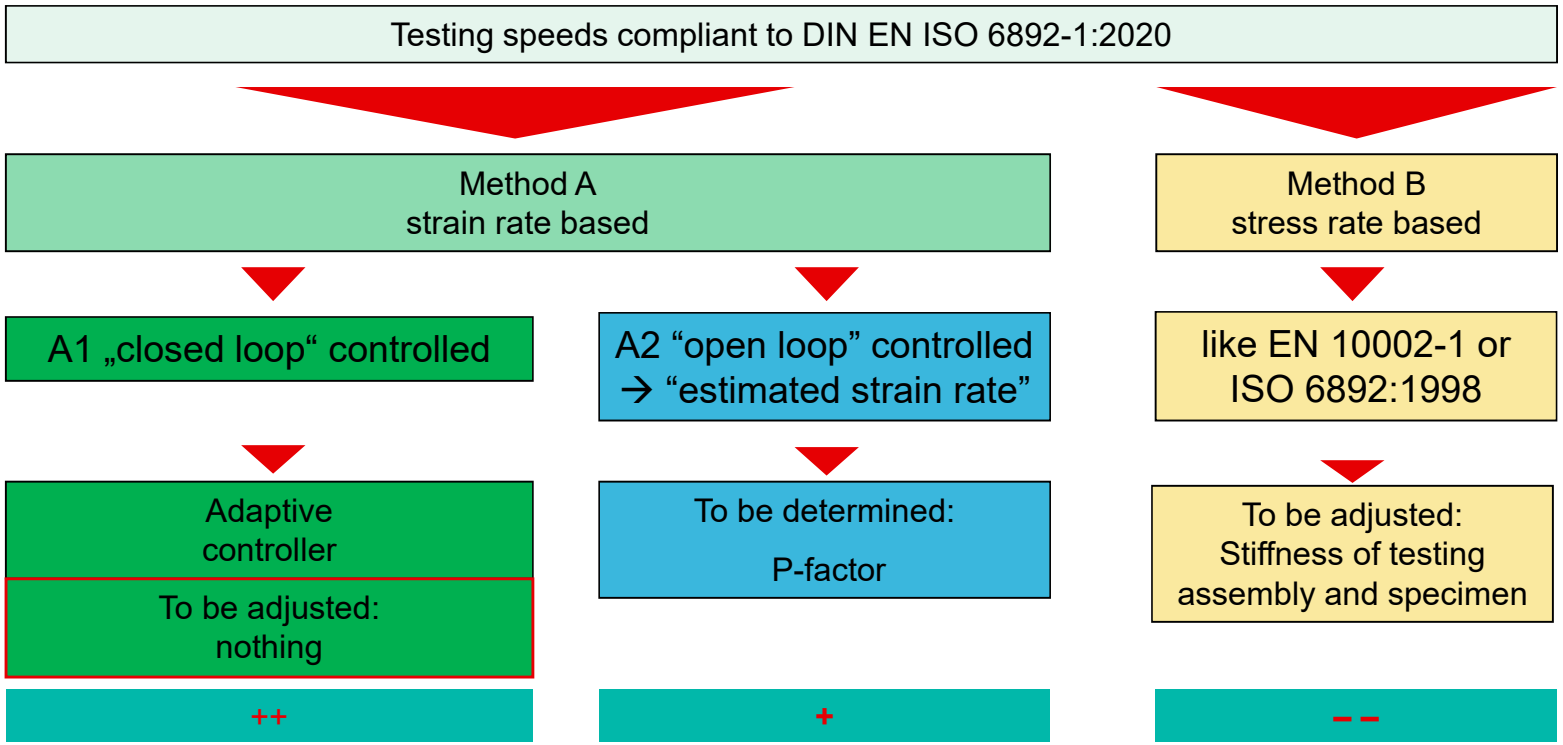
ISO 6892-1:2020 enables three types of controlling testing speeds: the method A, based on feedback of extensometer signal “closed loop”, is recommended.



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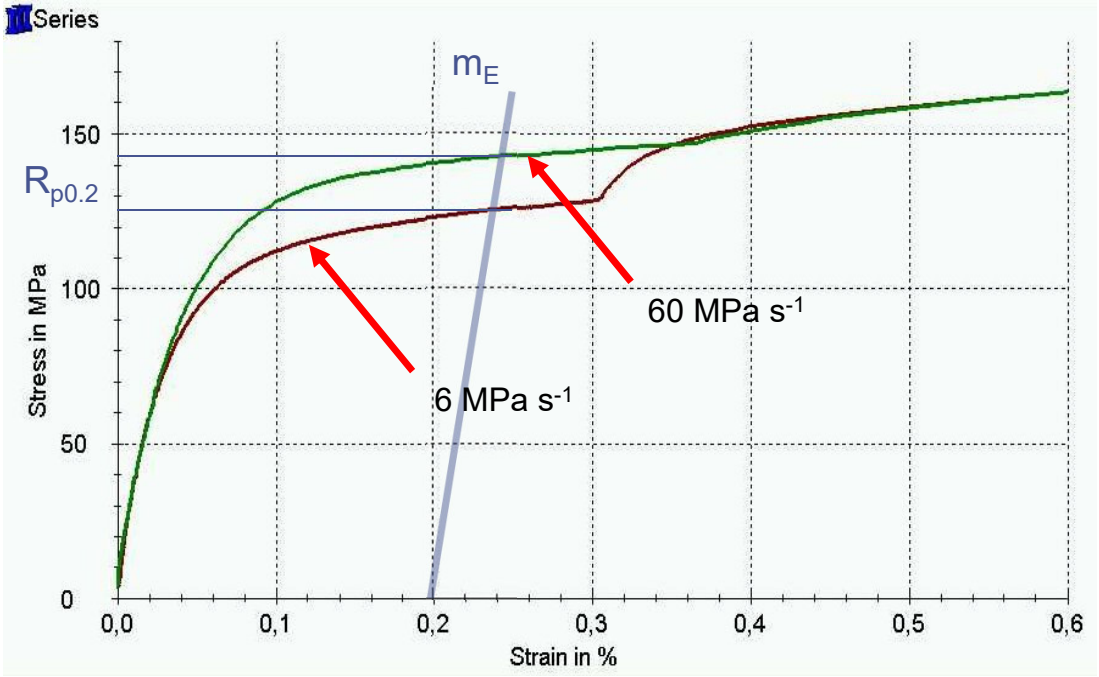
The difference between the methods is in how the set test speed is achieved in the elastic range

➢ The materials properties $R_{p0.2}$ or R_{eH} can be influenced by the test speed

- Method B:
  - Set/calculate a constant crosshead speed to achieve the specified stress speed, e.g. 6/60 or 2/20 MPa/s; achieved significantly before measurement value determination
- Method A2 (open loop):
  - Setting a constant crosshead speed to achieve the specified strain rate, e.g. of 0.00025 1/s, at measurement value determination
  -
- Method A1 (closed loop):
  - Setting of a "controlled" crosshead speed to achieve a constant strain rate in the entire elastic range, e.g. 0.00025 1/s, when determining the measured value

Metal materials show different behavior under different testing speeds. For some metals the Rp0.2 value is depending on the testing speed quite strongly.

Stress-strain diagram at different stress rates



- Reason: Metallic materials behavior is depending on testing rates, i.e. strain rates.

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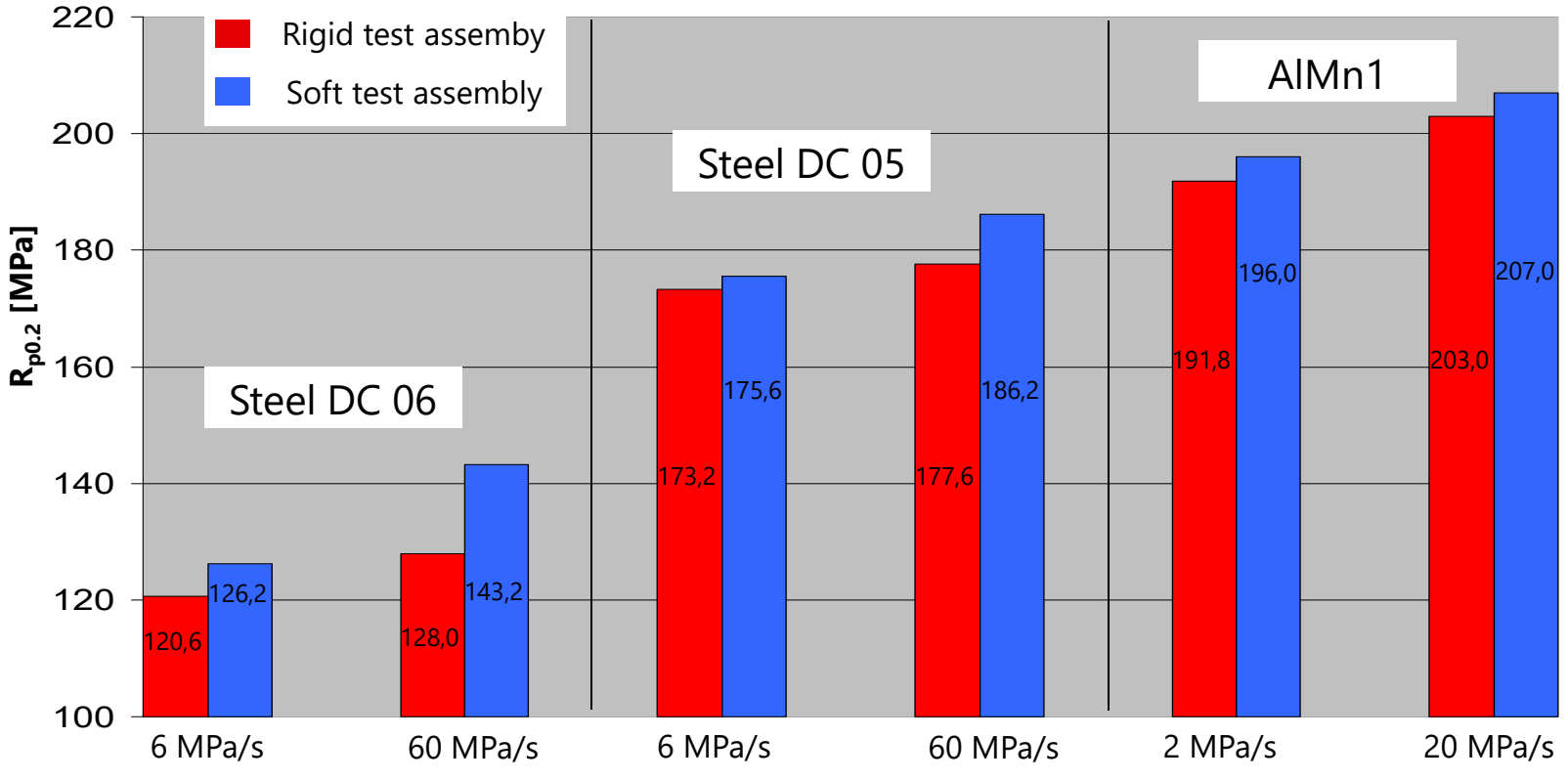
Test speed dependency of materials properties

The proof stress value Rp0.2 can be influenced by the test speed and the rigidity of the test setup/assembly.



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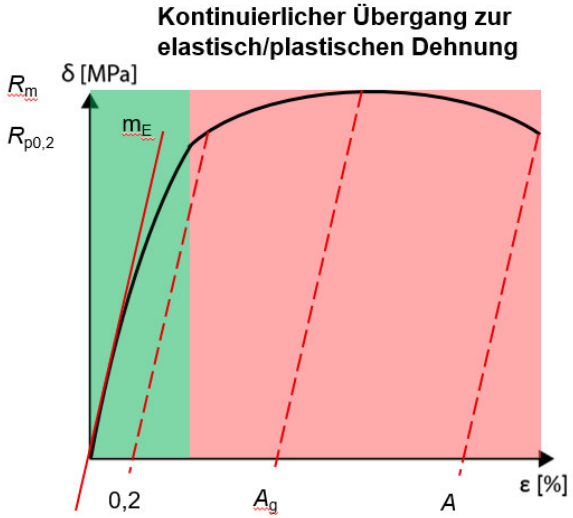
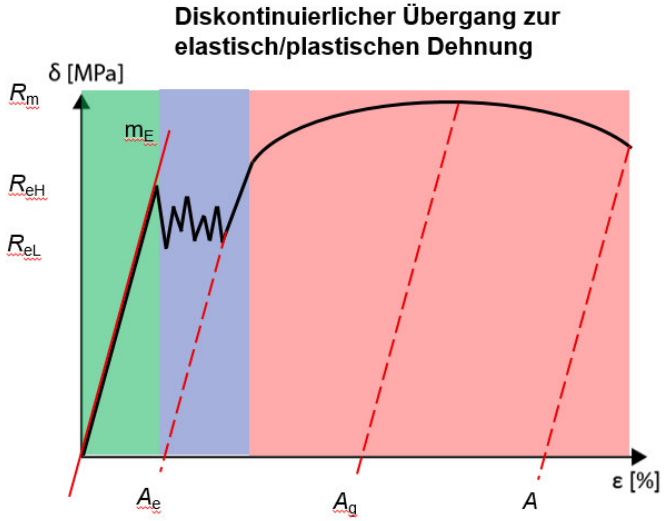
Depending to the existing stress-strain curve, a distinction is made between two or three speed ranges



The test speeds of methods A1, A2 and B only differ in the elastic range (green).



strain-rate control of …

Range 1: 0,000 07 s−1, with a relative tolerance of ±20 %.

Range 2: 0,000 25 s−1, with a relative tolerance of ±20 % (recommended)

Range 3: 0,002 s−1, with a relative tolerance of ±20 % (for R_{eL} and A_e)

Range 4: 0,006 7 s−1, with a relative tolerance of ±20 % (recommended)

The test methods are fully included in testXpert,

e.g. test speeds and test parameters respectively

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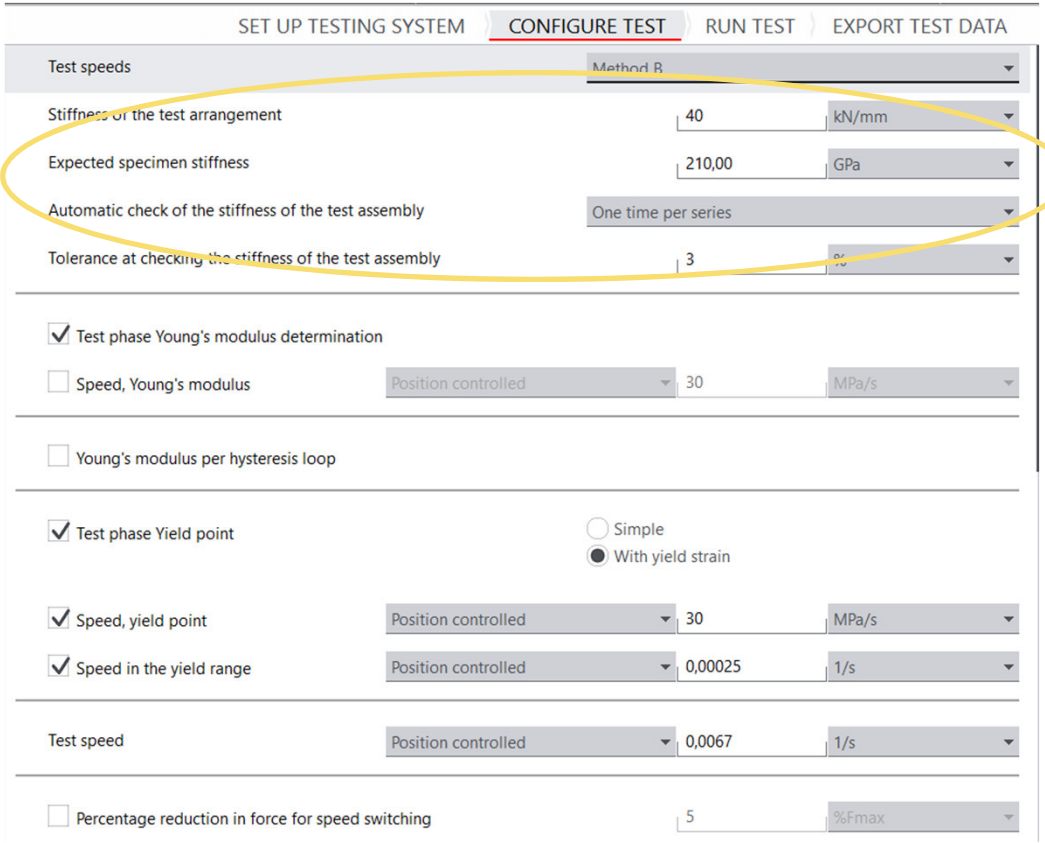
Method B of ISO 6892-1 incl. test speed and all test parameters are fully configured in the testXpert software.



- A pre-test is required to check the stiffness of the test assemby
- Then stiffness of test arragmenet and specimen stiffness are re-calculated

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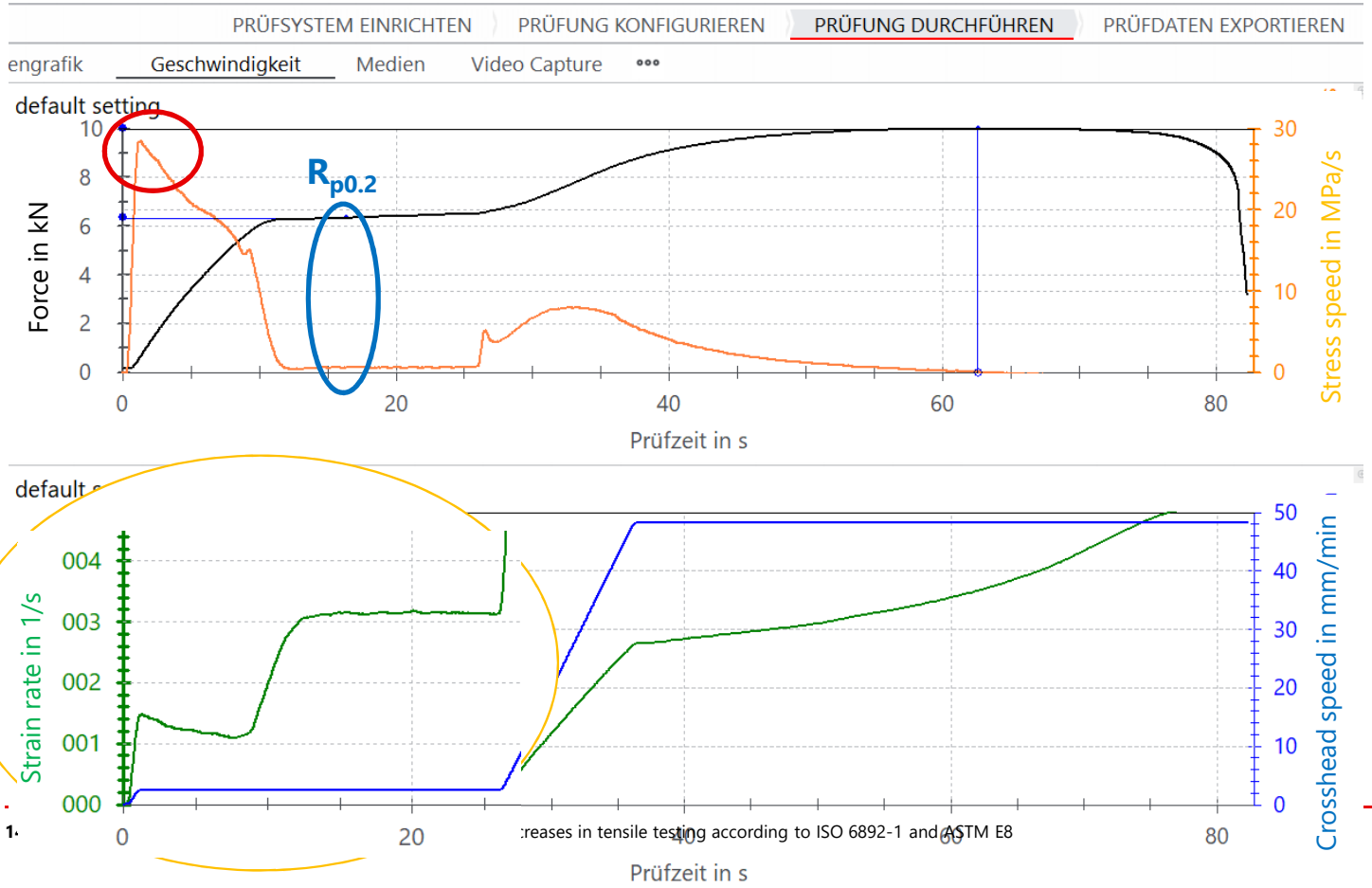
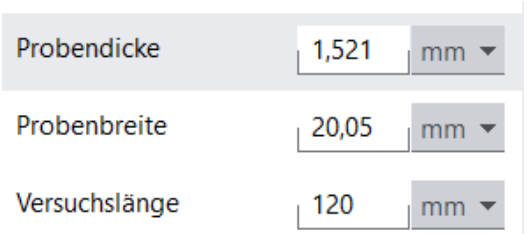
Test Method to DIN EN ISO 6892-1 Method B (Pre-test!)

Method B - Set/calculate a constant crosshead speed to obtain a specified stress speed in the elastic range



Pre-test:

- Preset of the stress speed: 30 MPa/s
- Preset of the testing machine stiffness: default: 40 kN/mm
- Material: steel 210 GPa
- Cross section b_0 x a_0: 20 mm x 1.5 mm



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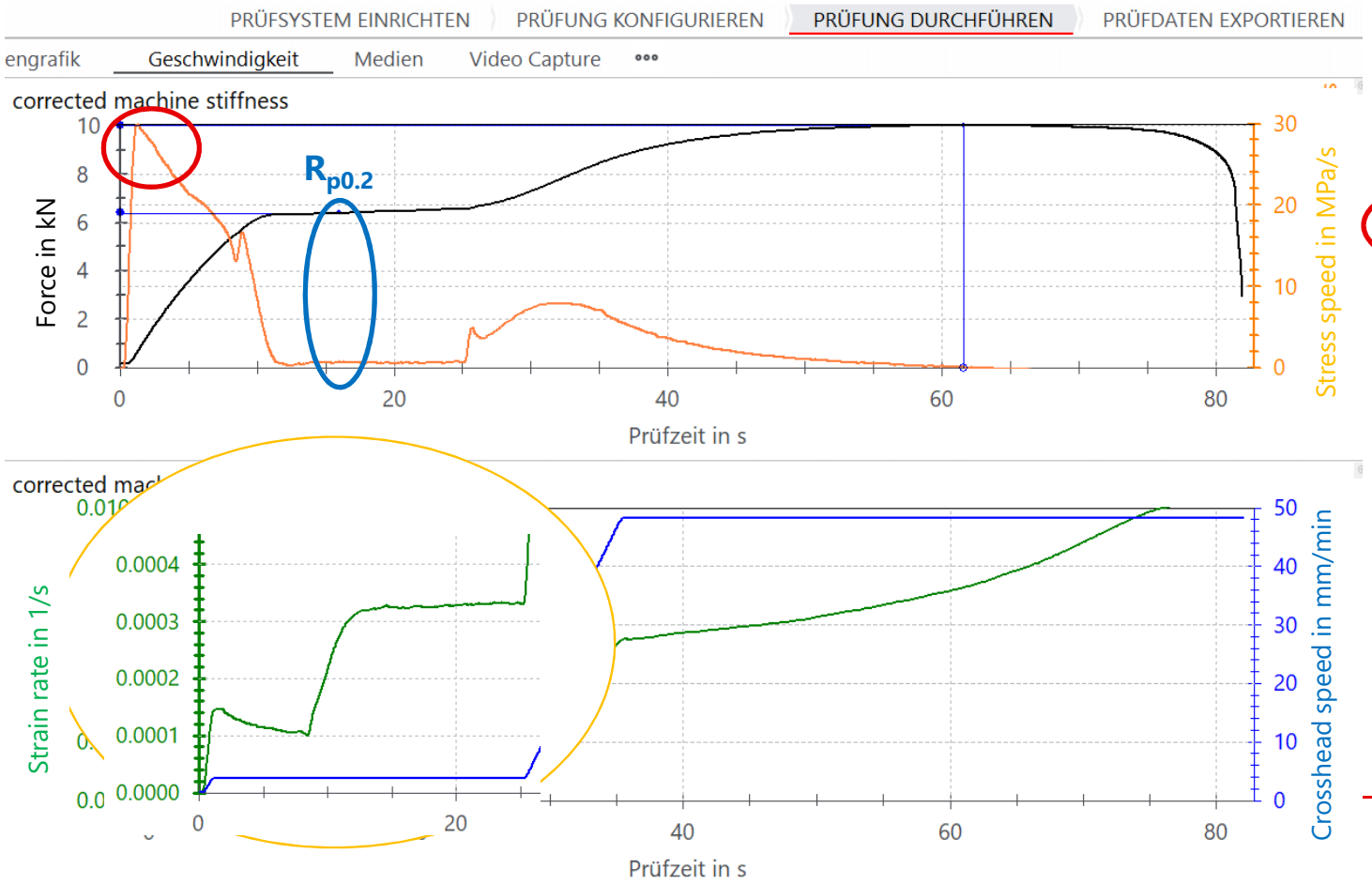
Test Method to DIN EN ISO 6892-1 Method B (valid test)

Method B - Set/calculate a constant crosshead speed to obtain a specified stress speed in the elastic range



Valid Test:

- Set of the stress speed: 30 MPa/s
- Corrected machine stiffness: 36,7 kN/mm
- Material: steel 210 GPa
- Cross section b_0 x a_0: 20 mm x 1.5 mm

Probendicke	1,516	mm
Probenbreite	20,03	mm
Versuchslänge	120	mm

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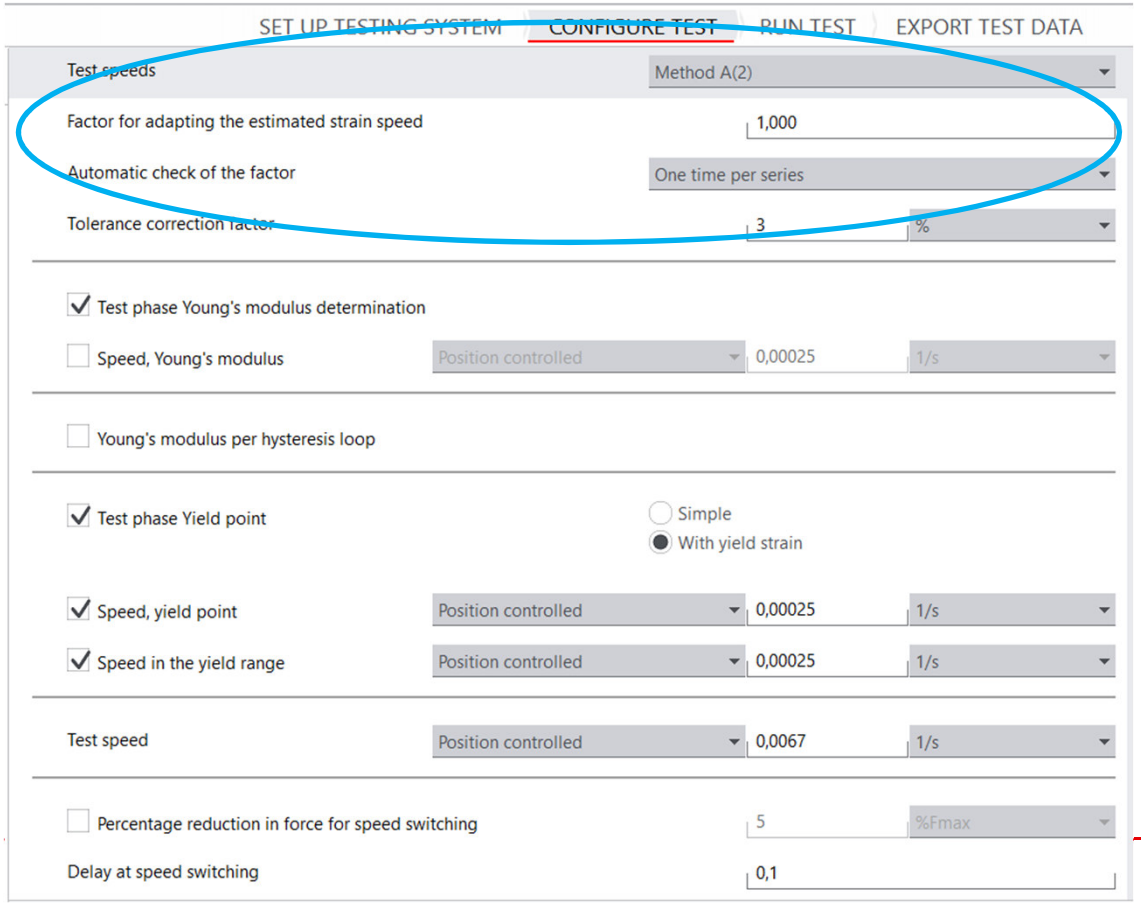
testXpert test program to ISO 6892-1: Method A2 (with yield strain)

Method A2 of ISO 6892-1 incl. test speed and all test parameters are fully configured in the testXpert software.



- A pre-test is required to check the factor for adopting of the estimated strain speed
- Then factor for adopting of the estimated strain speed re-calculated

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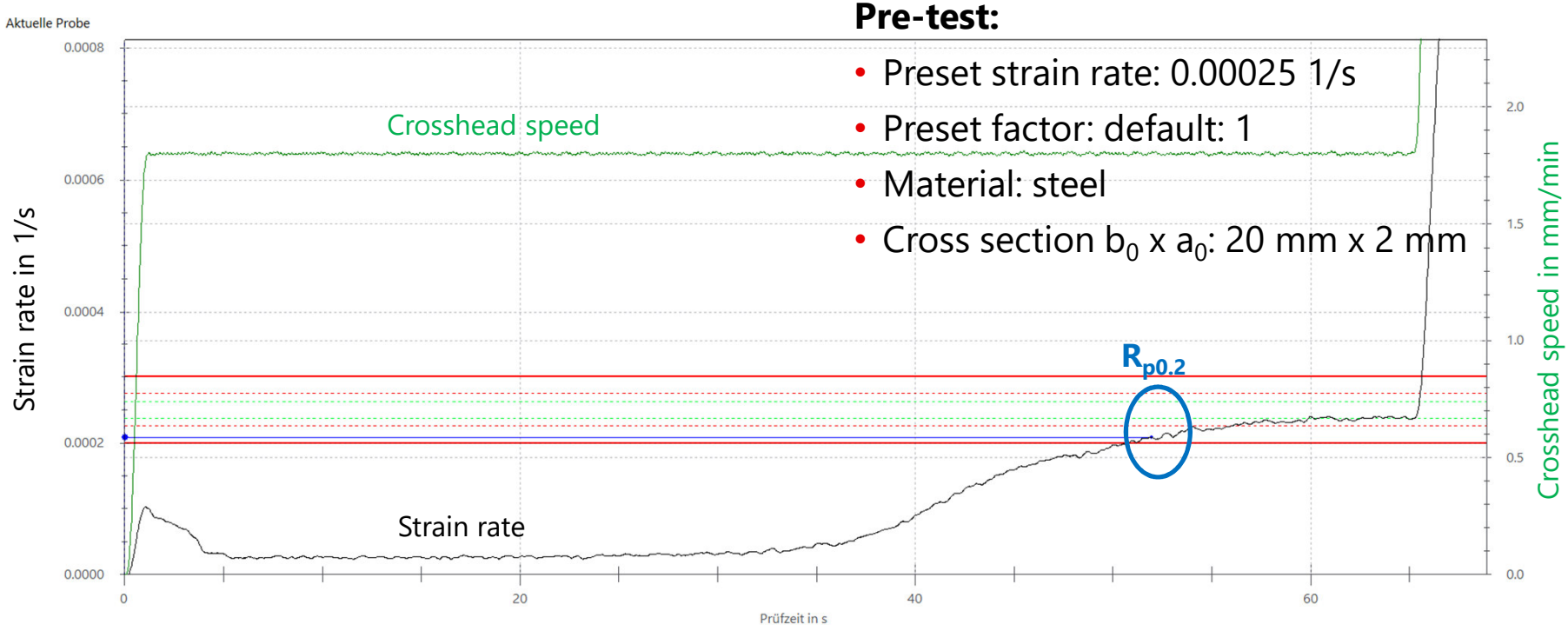
Method A2 - Set a constant crosshead speed to achieve specified strain rate (when taking measurements)



Pre-test:

- Preset strain rate: 0.00025 1/s
- Preset factor: default: 1
- Material: steel
- Cross section b_0 x a_0: 20 mm x 2 mm

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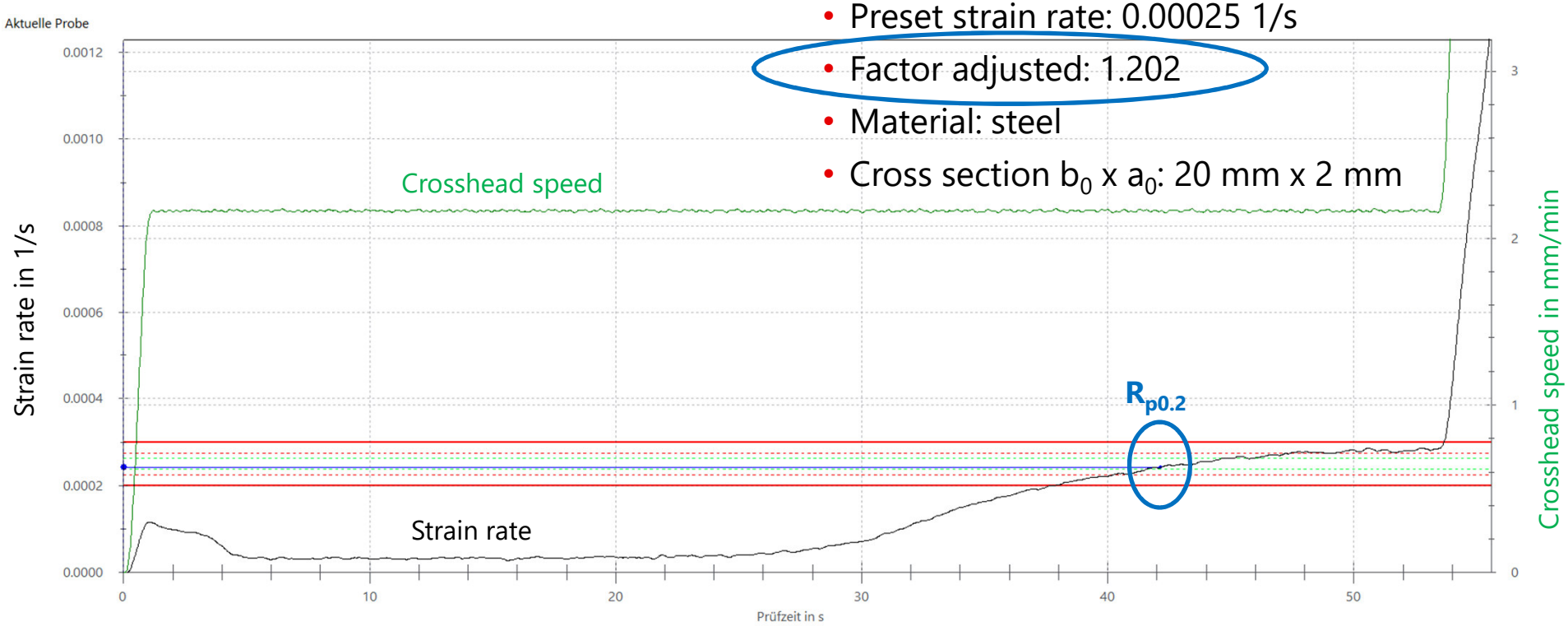
Method A2 - Set a constant crosshead speed to achieve specified strain rate (when taking measurements)

Valid Test:

- Preset strain rate: 0.00025 1/s
- Factor adjusted: 1.202
- Material: steel
- Cross section b_0 x a_0: 20 mm x 2 mm



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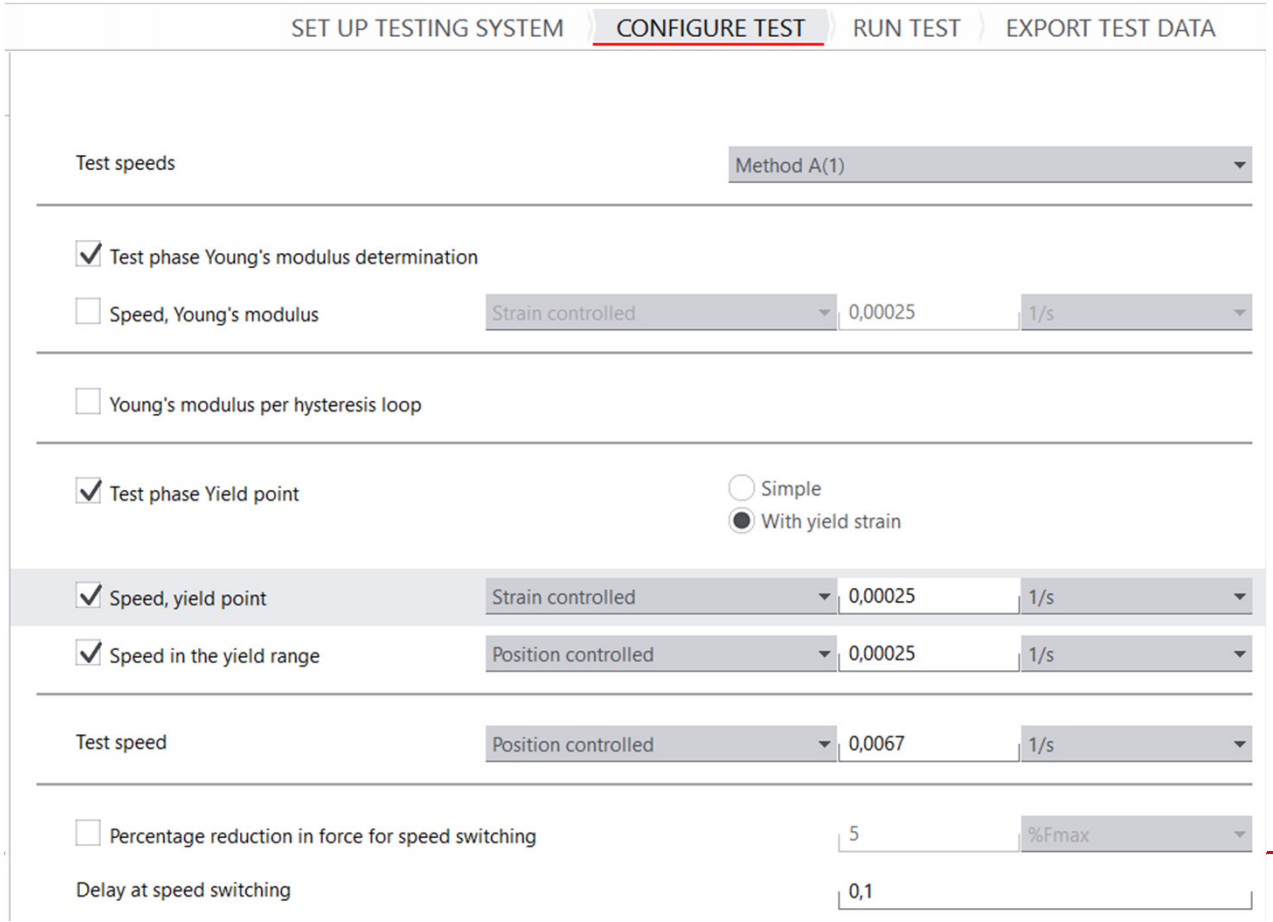
testXpert test program to ISO 6892-1: Method A1 (with yield strain)

Method A1 to ISO 6892-1 incl. test speed and all test parameters are fully configured in the testXpert software.



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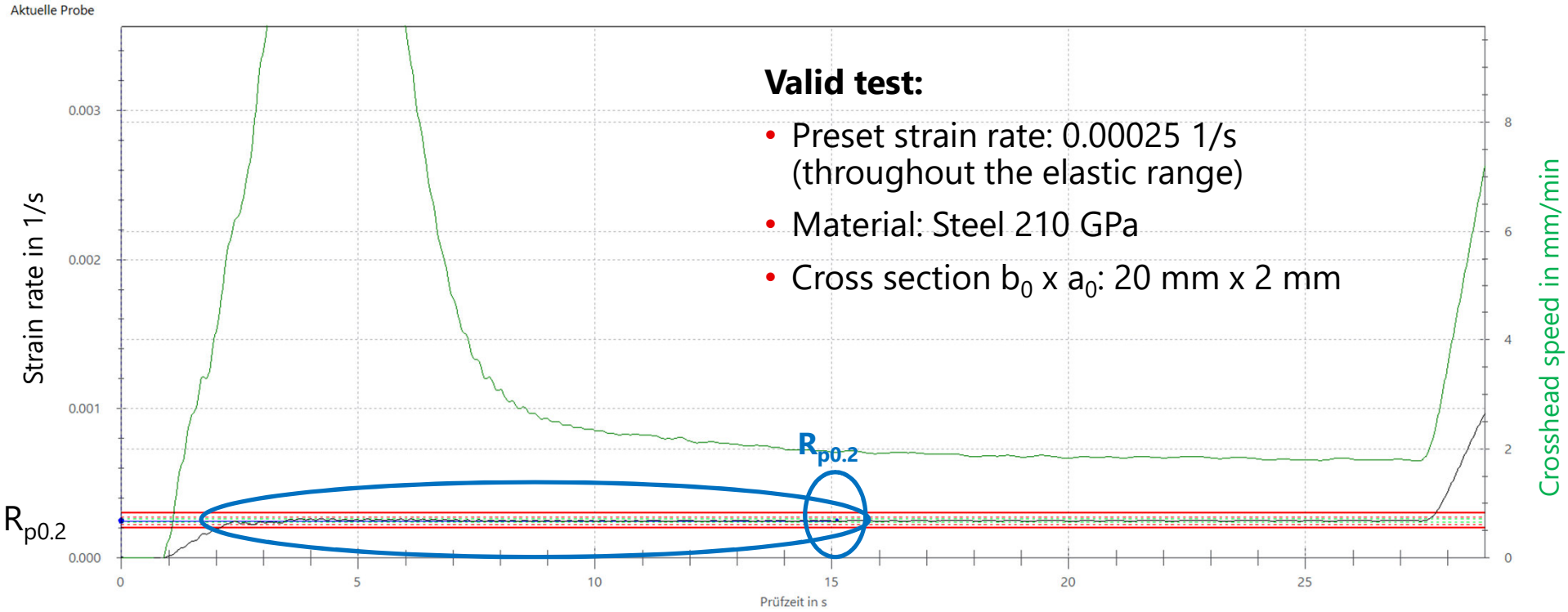
Method A1 - Setting of a "controlled" crosshead speed to achieve a constant strain rate throughout the elastic range



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1. **Stress-strain curve and standards**
   Characteristic values from the stress-strain diagram

2. **Test Methods/Test Speeds to DIN EN ISO 6892-1**
   Test speed dependency of materials properties
   Method B: stress-rate control
   Method A: strain-rate control

3. **Summary**
   Typical test results according to DIN EN ISO 6892-1 method A1
   Summary of efficiency increases

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Typical test results to DIN EN ISO 6892-1 Method A1

Example of test results on sheet metals - Method A1

SET UP TESTING SYSTEM | CONFIGURE TEST | RUN TEST | EXPORT TEST DATA

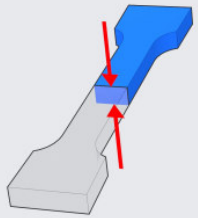
Series layout | Specimen graph | Speed | Media

Series
- Specimen 1
- Specimen 2
- Specimen 3
- Specimen 4
- Specimen 5

Specimen thickness 0,9 mm

Specimen width 20 mm

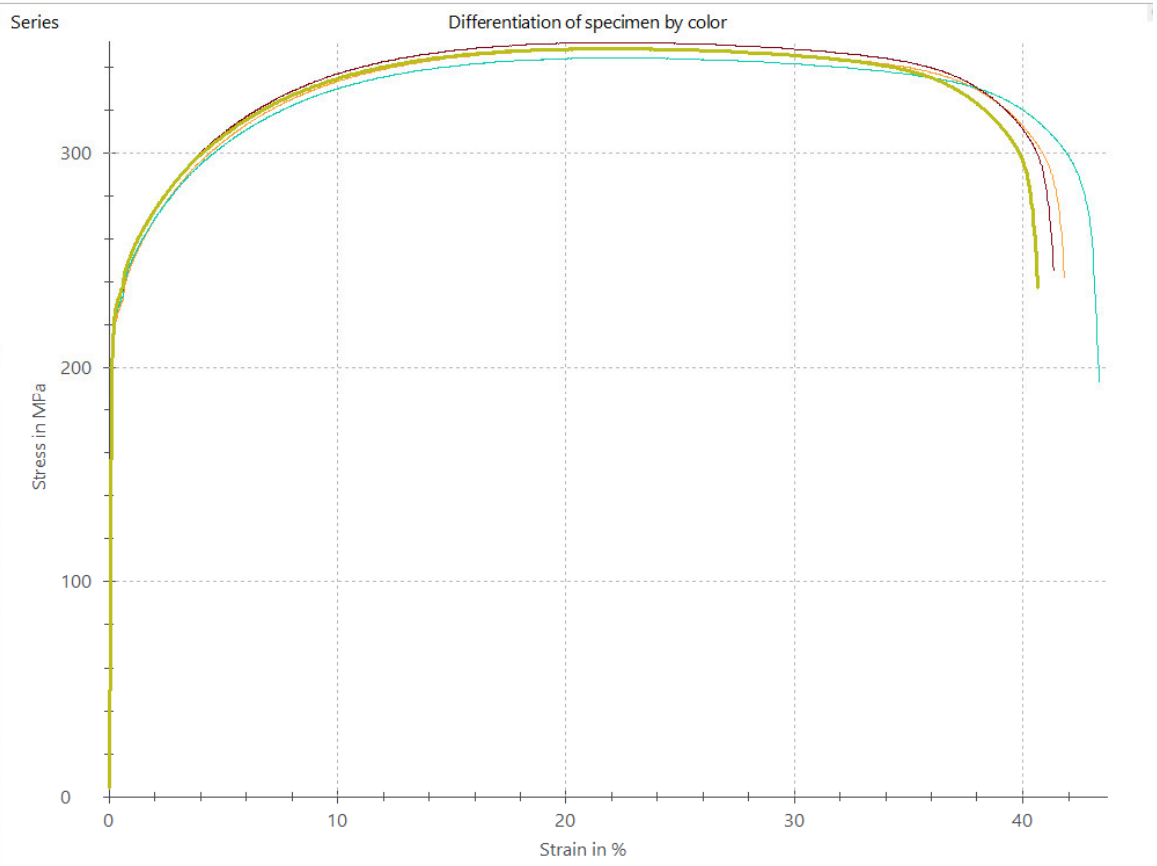
Test length 120 mm



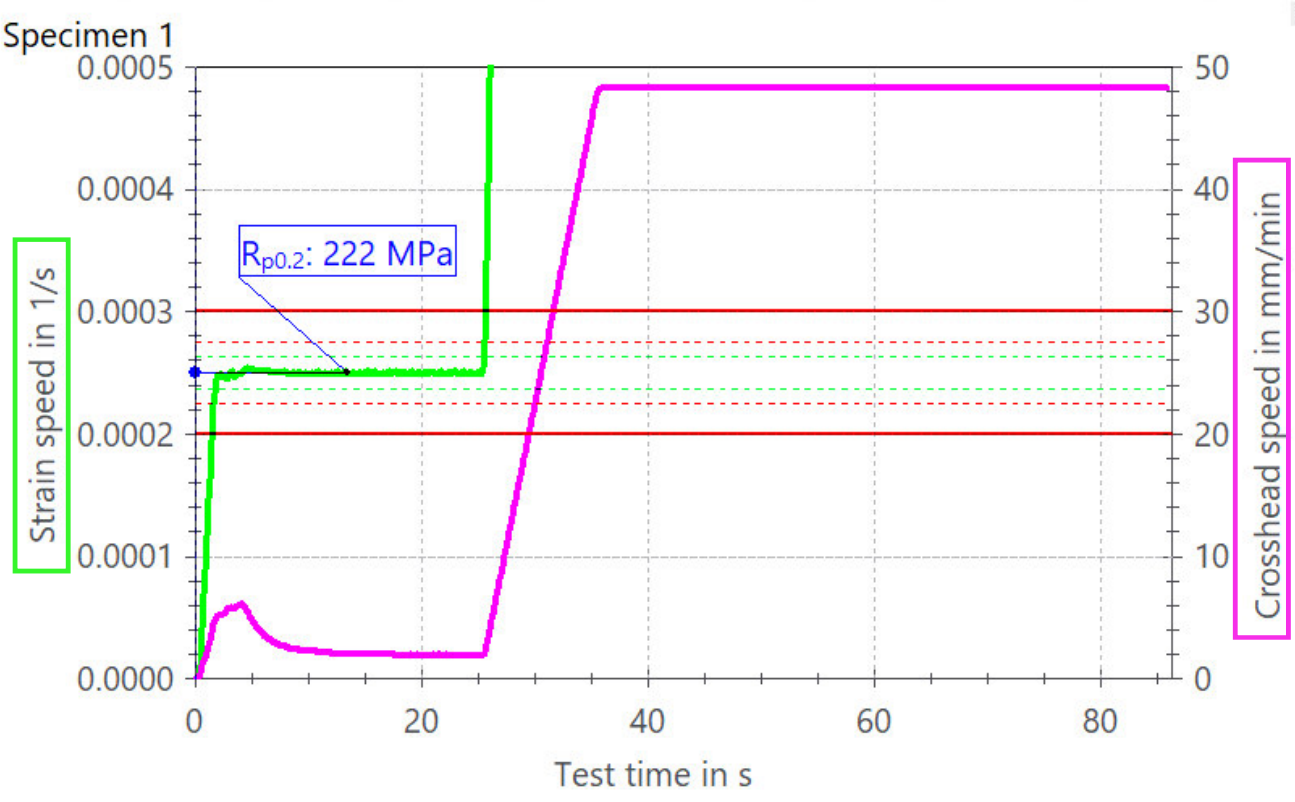
Thickness of the specimen

Legend	No.	m_E GPa	$R_{p0.2}$ MPa	R_m MPa	F_m kN	A_g %	A_{80mm} %	a_0 mm	b_0 mm	S_0 mm²
	1	198	222	348	6,27	22,23	41,7	0,9	20	18,00
	2	199	225	344	6,19	21,91	43,3	0,9	20	18,00
	3	201	228	351	6,33	21,88	41,2	0,9	20	18,00
	4	223	229	349	6,27	21,85	40,6	0,9	20	18,00

Series n = 4	m_E GPa	$R_{p0.2}$ MPa	R_m MPa	F_m kN	A_g %	A_{80mm} %	a_0 mm	b_0 mm	S_0 mm²
$\bar{x}$	205	226	348	6,27	21,96	41,7	0,9	20	18,00
s	12	3	3	0,05	0,18	1,1	0,000	0,000	0,00
ν [%]	5,77	1,21	0,86	0,86	0,81	2,74	0,00	0,00	0,00



TestXpert automatically proves the correct strain rate control according the standard's requirement.



Legend	No.	$(de/dt)_{Le}(R_{p0.2})$ 1/s	$\overline{(de/dt)_{Le}}$ 1/s
	1	0,000250	0,000250
	2	0,000250	0,000250
	3	0,000250	0,000250
	4	0,000249	0,000249

- Set and achieved strain rate is shown in a graph and as a result

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Summary: Efficiency increases

The efficiency gains are largely due to testXpert's assistance and choice of testing procedure.

- When changing the specimen, preliminary tests are necessary for test methods B and A2.
- For method B, information on the stiffnesses of the test setup and of the specimen are necessary.
- For method A2, the P-factor must be specified to ensure the exact test speed in the interested points.
- For procedure A1, no preliminary tests or complex test parameterisation are necessary if the test system is already equipped with adaptive control.
- The assistance of testXpert supports in the appropriate parameterization of the test. This also reduces potential input errors by the operator. The test results are automatically prepared and can be easily transferred, processed and exported by activating them.
- The test speeds according to standard specifications are directly available in testXpert as a diagram or as a result, which in addition to qualification also makes auditing of the test system easy. This also applies analogously to the crosshead speed.
- Specimen gauges are integrated in testXpert, saving you time and reducing input errors.
- Automatic import of specimen and organisation data from your ERP or host system.
- Automatic export of results and data to your ERP system via standardised ODBC interface or Excel.

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