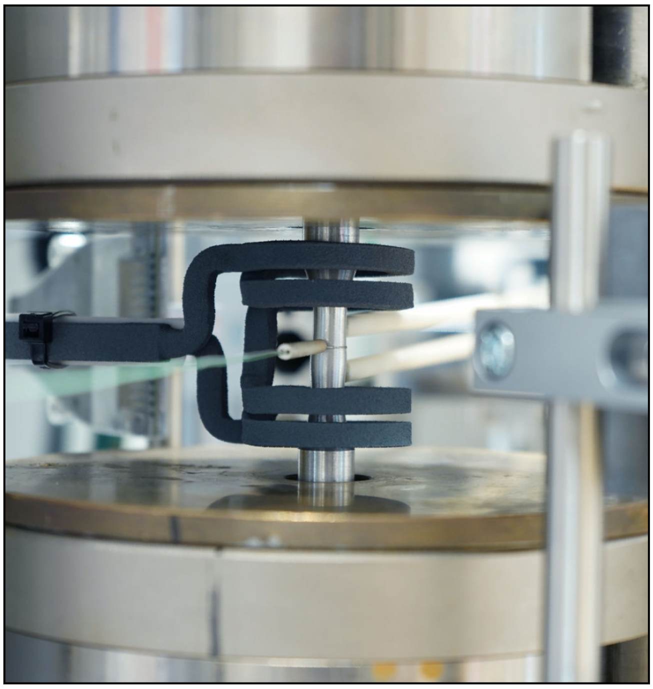
Zwick / Roell

Product Information

Thermomechanical Fatigue Testing System – A Knowledge-Based Expert System for Solving Complex Test Requirements

CTA: 243142 243143

Thermomechanical fatigue testing system



Induction heating system and active cooling

Applications

For the design and construction of thermal and simultaneously mechanical, cyclically loaded components, reliable characteristic values for the prediction of fatigue life and cyclic deformation behavior are required. Since these components are exposed to repeated temperature changes and are limited in their thermal expansion, they are subject to cyclically changing loads. The resulting constraints are caused by adjoining components or in the component itself by inhomogeneous temperature distributions or different expansion coefficients.

For dependable assertions on fatigue life and for optimal and reliable design of these components, precise characteristic values of the deformation behavior of the components used are required.

The testing system for thermomechanical fatigue testing meets all requirements of the European Code of Practice (CoP), and those of ASTM E2368 and ISO 12111.

Knowledge-based expert system – the optimal support for reliable testing

- Tailored TMF control system for real-time acquisition, processing, and evaluation of the measurement data
- Testing system based on the patented, zero-backlash, electromechanical Kappa SS-CF testing machine
- Induction heating system with adjustable heat output for different specimen materials
- Active compressed air cooling for accurate temperature control without overshooting
- Easy to handle and standard-compliant temperature control with ribbon thermocouples
- Development cooperation with KIT, the renowned Karlsruhe Institute of Technology

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Thermomechanical Fatigue Testing System – A Knowledge-Based Expert System for Solving Complex Test Requirements

Easy to handle for repeatable test results

- Workflow oriented operator assistance through automated testing with testXpert
- Easy test configuration
- Flexible and convenient evaluation options
- Stable environmental conditions, operator safety, and unobstructed view of the specimen

Knowledge-based expert system for optimal testing support

Reliably determining material behavior under cyclic thermal and mechanical load is an elaborate test task, which can however be made significantly easier with this knowledge-based expert system.

Depending on the damage mechanisms to be tested, temperature phasing and mechanical strain range are selected accordingly. Depending on the damage mechanisms to be tested different temperature and mechanical strain sequences can be parameterized. Curves are often triangular and hold periods can be added eg. at peak temperature. Furthermore temperature and strain can be applied in-phase or out-of-phase.

The most common types of tests are:
- IP (in phase)
- OP (out of phase)
- CD (clockwise diamond)
- CCD (counterclockwise diamond)

Thermomechanical fatigue tests are mainly strain-controlled, since the load acting on the component is caused by obstruction of the thermal strain. Stress-controlled tests are sometimes associated with non-uniform specimens, e.g. with notches, since here the elongation in the notch base cannot be measured. In both cases, only the total elongation (ε_t) can be measured and controlled. It is composed of thermal elongation (ε^{th}) and mechanical elongation (ε^{me}): Formula $\varepsilon_t = \varepsilon^{th} + \varepsilon^{me}$. In order to load the specimen with the desired mechanical strain in addition to thermal strain, the thermal strain is measured in advance with a time-based, defined temperature sequence and taken into account in the actual test when controlling the total strain.

Tailored TMF control system for real-time acquisition of the measurement data

- Real-time acquisition and processing of temperature, force and strain
- Determination and specification of the mechanical set value sequence for force and strain control
- Determination and specification of the thermal set value sequence for the automatically controlled heating and cooling cycles
- Precise control and synchronization of the mechanical and thermal cycles
- Real-time display of the test sequence for optimal test monitoring
- No separate calculations or external software support required
- testControl II, the proven measurement and control electronics system from ZwickRoell for high data acquisition rates and standard-compliant accuracy

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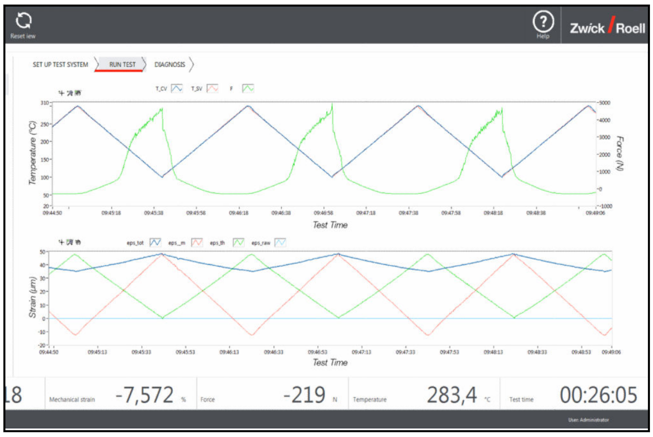

Real-time acquisition and display of measurement data

CTA: 243894

Upper and lower temperature reversal point (red), upper and lower reversal point of the mechanical strain (blue)

All data at ambient temperature.

We reserve the right to make technical changes in the course of ongoing development.

Product Information

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Precise control with patented electromechanical testing machine Kappa SS-CF

For testing with low frequency load cycles, the patented Kappa SS-CF electromechanical testing machine has proven itself time and again. The backlash-free zero crossing during cyclic tensile and compression loading allows for very precise control of the test force and test speed.

The precision planetary gear and servo motor are centrally located in the test axis and move synchronously with the crosshead. With the precise crosshead guidance and adjustable alignment fixture, standard-compliant axial alignment can be ensured in accordance with ISO 23788 and NADCAP.

Excellent control behavior for force, stress and strain are possible with the high-resolution motor encoder, the high-resolution force channel and the corresponding extensometer.

Induction heating system for different specimen materials with adjustable capacity

- Induction heating system (10 kW) with individually adjustable heating capacity for testing materials with varying electrical conductivity
- Specimen-specific inductors for optimal temperature distribution (axial, radial) for different test materials
- Active water cooling of the inductors for optimal heat induction on the specimen
- According to CoP, the temperature deviation from the specified set value in the specimen measuring distance is <10K or < ±2% of the temperature difference
- Max. heating rates 25 K/s

Active compressed air cooling for accurate temperature control without overshooting

- With four symmetrically arranged flat spray nozzles the cooling air is precisely aimed at the specimen surface.
- Proportional pressure control valves provide precise control of the air flow.
- The position of the cooling nozzles is adjustable. The position for future tests is reproducible.
- Depending on the specimen geometry, cooling rates of up to 25 K/s are possible.

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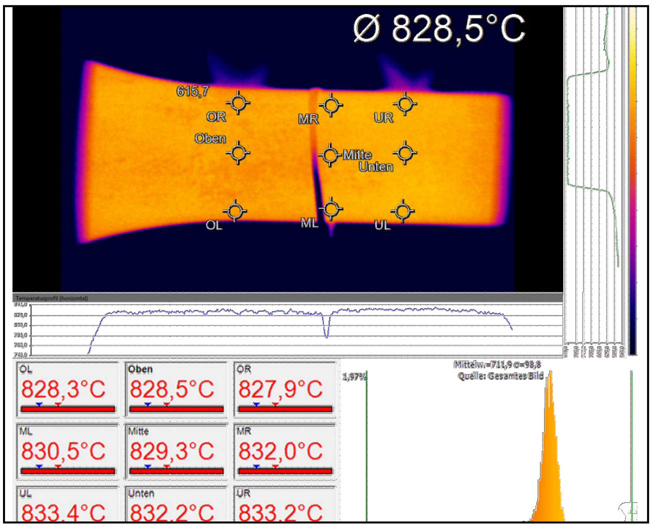
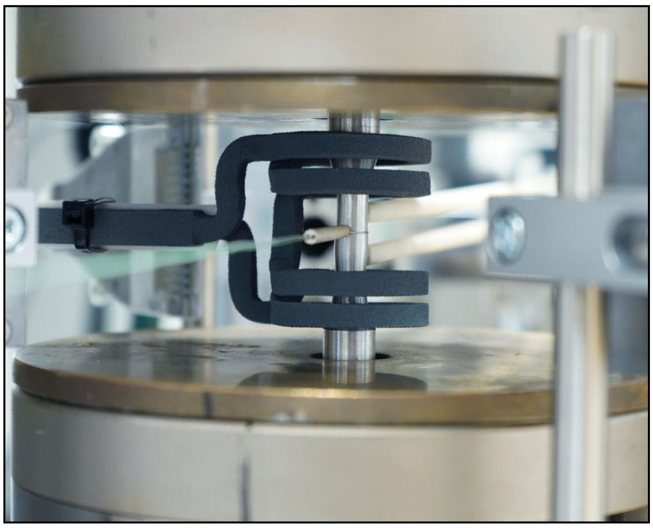


Δ < ±3.5°C according to CoP Δ_{max} = 10 K



Induction heating system and active cooling

All data at ambient temperature.

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Thermomechanical Fatigue Testing System – A Knowledge-Based Expert System for Solving Complex Test Requirements

Easy to handle and standard-compliant temperature control with ribbon thermocouples

- Temperature measurement is carried out with standard-compliant ribbon thermocouples in the center of the measured specimen section:
  ≤ 850°C: Type K
  > 850°C: Type S
- Easy to handle – especially when compared with welded thermocouples
- Easy and reliable attachment with adjustable spring pre-tensioning for dependable contact pressure
- Attached to 180° of the specimen circumference
- Up to three specimen thermocouples can be used

Secure hold with the appropriate specimen grips

- Hydraulic grips for common cylindrical specimens with 6 mm specimen diameter and 15 mm shoulder end diameter
- Version for tensile/compression alternating load and backlash-free during force-zero pass-through
- Water cooling for fast temperature stabilization along the specimen and for direct heat outflow from the specimen end

Reliable strain measurement with contact extensometer

- Specially designed and developed for use in high temperatures to meet the strict requirements for strain-controlled tests to ISO 6892
- Automatic adjustment of the gauge length between individual tests
- Controllable contact force for repeatable positioning with the same force on subsequent specimens
- Meets the accuracy requirements of ASTM E83 class B2 and ISO 9513 in accuracy class 0.5
- With water cooling and class A silicon carbide ceramic sensors for use in up to 1,600°C
- Quick connections for water cooling lines

Stable environmental conditions and unobstructed view of the specimen

- The safety enclosure ensures optimal operator protection as well as stable environmental conditions, especially for sensitive strain measurements
- The clear safety glass and open design of the cooling system provide an unobstructed view of the specimen

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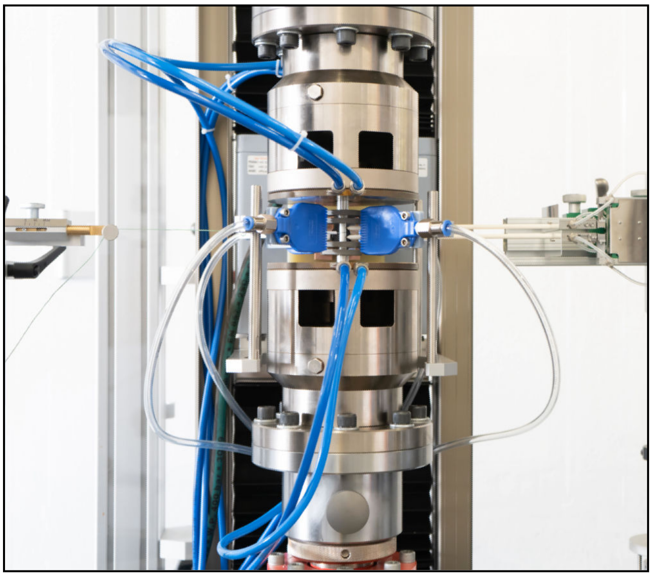
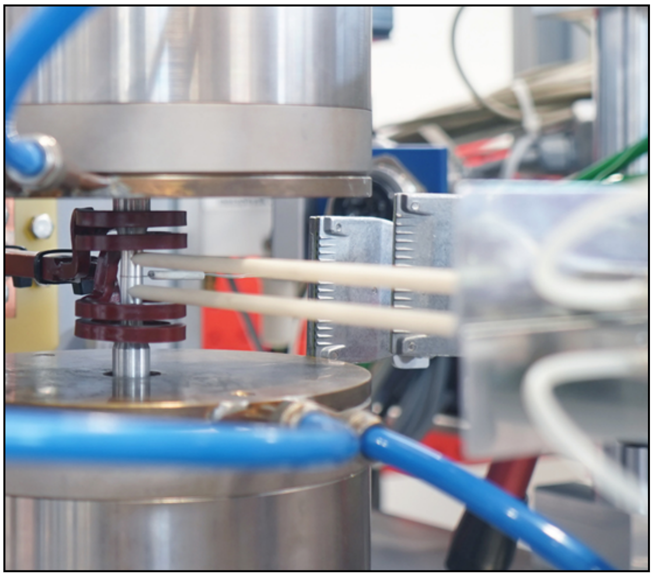


Water-cooled hydraulic grips for secure holding



Reliable strain measurement with contact extensometer

All data at ambient temperature.

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Thermomechanical Fatigue Testing System – A Knowledge-Based Expert System for Solving Complex Test Requirements

Workflow oriented operator assistance through automated testing with testXpert

Testing system operation is designed to be purely intuitive. The operator is guided through the various steps of a test, from preparing and running the test to analyzing the results. According to CoP, the actual thermomechanical fatigue test is preceded by the determination of the Young's modulus and pre-cycles for control optimization. The system users are supported by special test programs, making separate calculations or external software a thing of the past. The temperature control deviation is determined by the difference between the temperature commands and the measured temperature (tolerance according to CoP is ±5°C or ±1% of the temperature difference).

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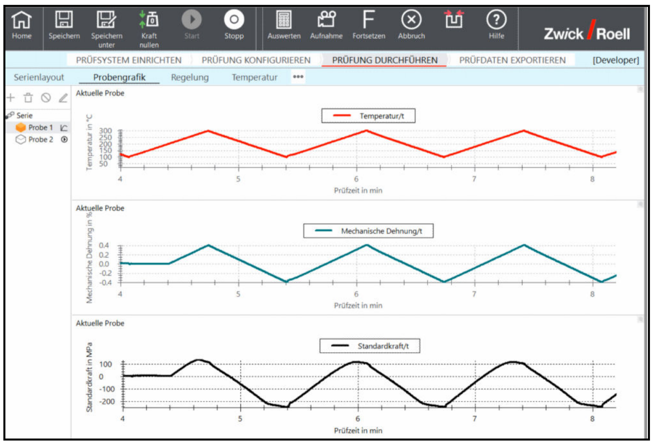
Step 1: Temperature control, stabilization
Step 2: Determination of thermal strain

CTA: 244017

Step 3: Zero-stress test verification

CTA: 244018



Step 4: Testing (in phase)

Step 1: Temperature control, stabilization

Repeatable temperature cycles are essential for accurate mechanical strain control. In order to produce the required thermal equilibrium, force-free pre-cycles are therefore carried out in the first step with force control.

Step 2: Determination of the thermal strain

In the next step, the thermal strain is determined dependent on the temperature. The force is regulated to zero and the thermal strain is measured.

Step 3: Zero-stress test verification

In this step, the accuracy of the thermal strain compensation is verified. Therefore, in this cycle the mechanical strain is held at zero ($\varepsilon^{me}=0$), which results in the correspondence of the total strain with the thermal strain ($\varepsilon_t = \varepsilon^{th}$). According to CoP, the resulting stresses must not exceed the following tolerances:

- Max. values: < 5% of the stress difference of the TMF test
- Mean value: < 2% of the stress difference of the TMF test

Step 4: Performing the test

The software performs the current tests according to the selected test parameters.

Test data
Material: Aluminum specimen
Specimen shape: cylindrical
L_0: 10 mm
Test type: in phase

All data at ambient temperature.

We reserve the right to make technical changes in the course of ongoing development.

Product Information

Thermomechanical Fatigue Testing System – A Knowledge-Based Expert System for Solving Complex Test Requirements

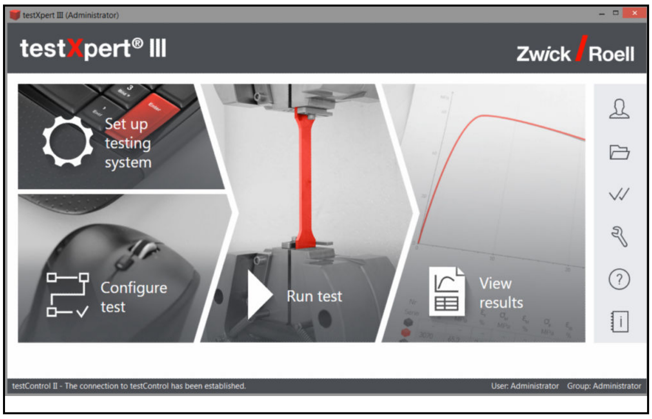
Easy test configuration and traceable test results

- The intelligent wizard shows the user which test parameters must be configured and automatically checks all entries for plausibility.
- Freely selectable heating ramps, maximum and minimum temperatures, hold times, etc.
- Separate parameters for heating and cooling
- Various phase shifts
- Freely selectable number of pre-cycles
- Storage of test parameters for future tests
- Logging of the testing system and system settings. This always provides you with the answer to the question: "When does who do what, why and who is responsible?"

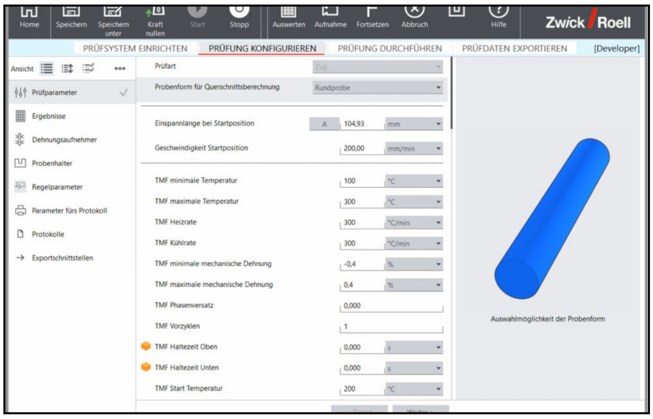
Determination of the Young's modulus for verification of the correct test operation

According to the European Code of Practice, determination of the Young's modulus at room temperature, minimum temperature, maximum temperature, and at least one additional average temperature value, is recommended before every test.

A subsequent comparison of the measured Young's modulus value with data from a reference database serves as verification of the correct control and measurement values of force, strain and temperature. If the measured values lie within the tolerance limit of max. 5%, the correct test operation is ensured.



Intelligent wizard



Easy test configuration

All data at ambient temperature.

We reserve the right to make technical changes in the course of ongoing development.

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Thermomechanical Fatigue Testing System – A Knowledge-Based Expert System for Solving Complex Test Requirements

Flexible and convenient evaluation options

- Storage of all test cycles, with clear evaluation options and flexible export interface in NI TDMS file format for easy further use, e.g. in Excel
- Complete recording of up to 500 cycles with the software, individual or group presentation of the cycles.
- Additional verification of all test data of the test performed in protected mode
- Easy export of data to all common evaluation/analysis platforms
- Comparison of individual test type cyclic stress-strain curves
- For the cycles recorded, the following results are available: Fmin, Fmax, Dmin and Dmax

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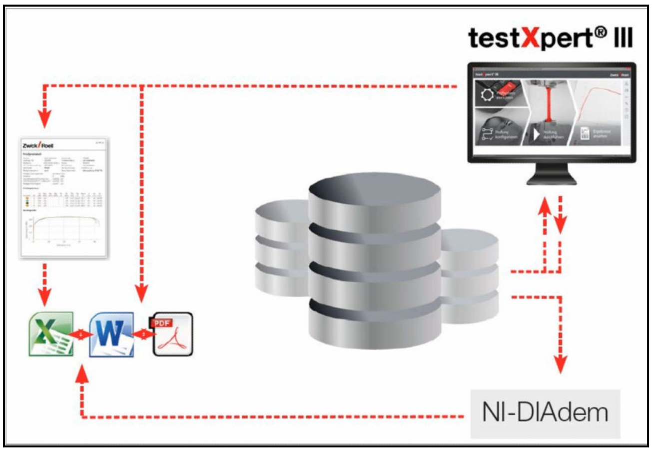
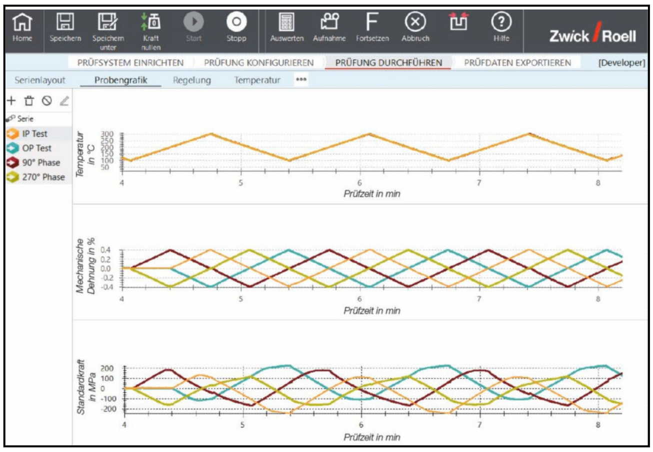


Flexible export interface



Chronological sequences of temperature, mechanical strain and standard force (IP, OP, CD, CCD)

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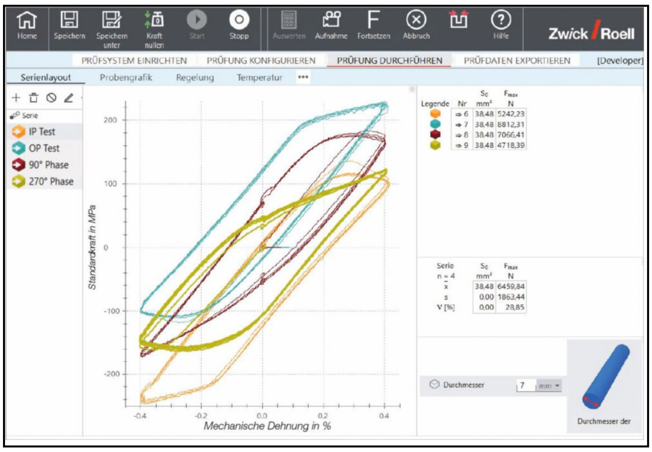
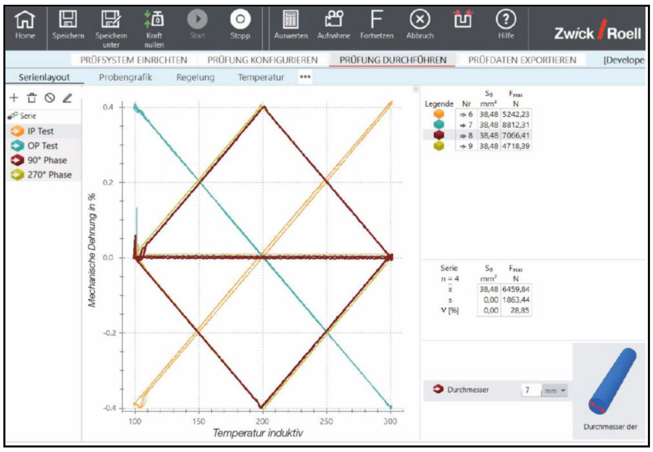


Stress strain curve (IP, OP, CD, CCD)



Strain temperature curve (IP, OP, CD, CCD)

All data at ambient temperature.

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Technical data

Thermo-mechanical fatigue testing system	
TMF control system	
Data acquisition rates	50 kHz
Control frequency	1 kHz
Requirements	To European Code of Practice, ASTM E2368 and ISO 12111
Testing machine	
Test load capacity	100 kN (tensile/compression)
Crosshead travel	200 mm
Test speed range	0.001 mm/h to 250 mm/min
Position transducer travel resolution	0.14 nm
Temperature control unit	
Test temperatures	From RT to 1,600 °C dependent on the specimen material (pre-tests required)
Heating rate	Up to 25 K/s
Cooling rate	Up to 25 K/s
Power rating of the induction heating system	10 kW
Thermocouples	Up to 3 specimen thermocouples
≤ 850°C:	Type K
> 850°C:	Type S
Specimen grips	Hydraulic, water cooled, clamping insert Ø 15 mm
Extensometer	
Initial gauge length	10 mm
Measurement range	+20 % / -10 %
Requirements for strain control	To ISO 6892
Accuracy	To ASTM E83 class B2 and to ISO 9513 class 0.5
Max. operating temperature	1,200°C without water cooling | 1,600°C with water cooling
Safety enclosure	Operator guard
	Thermal stability
	Safety interlocking
Software	Test program for determination of the Young's modulus
	Test program for the thermomechanical fatigue test

Option: Retrofitting to test frames from other manufacturers

We are certain that the Kappa SS-CF electromechanical testing machine provides the optimal foundation for precise control of the test force and test speed in thermomechanical fatigue testing. Nevertheless, we gladly accept the challenge to transform existing test frames with other manufacturer's electronics and analog inputs and outputs into an almost equally reliable thermomechanical fatigue testing system.