NETZSCH

Proven Excellence.

DMA 523 *Eplexor*® 2000 N and 4000 N
HBU 523 *Gabometer*® 2000 N and 4000 N

Dynamic Mechanical Testing, Fatigue and Heat Build-Up

Analyzing & Testing

Ultra-High Forces

FOR LARGE AND HIGH-MODULUS SPECIMENS

Certain materials and sample geometries require high levels of force for investigating their dynamic-mechanical or static properties, including:

- Very stiff materials such as metals, ceramics and composites
- Specimens of larger dimensions or even components
- Polymers to be measured in the compression or tension mode below their glass transitions

For all such cases, the ultra-high-force DMA 523 *Eplexor*® and the Fatigue and Heat Build-Up tester HBU 523 *Gabometer*® by NETZSCH offer the perfect solution. They combine state-of-the-art technology with more than 40 years of experience in developing and manufacturing premium-quality dynamic testing devices. The DMA 523 *Eplexor*® and the HBU 523 *Gabometer*® cover a static force range up to 6000 N, while the dynamic force range can be ± 2000 N or ± 4000 N.

The ultra-high-dynamic mechanical testing portfolio consists of:

Instrument type	Max. static force	Max. dynamic force
DMA 523 *Eplexor*® 2000 N	6000 N	± 2000 N
DMA 523 *Eplexor*® 4000 N	6000 N	± 4000 N
HBU 523 *Gabometer*® 2000 N	6000 N	± 2000 N
HBU 523 *Gabometer*® 4000 N	6000 N	± 4000 N

Dynamic-Mechanical Analysis

Dynamic-mechanical analysis (DMA) or dynamic-mechanical thermal analysis (DMTA) is the best-suited method for determining a material's mechanical and viscoelastic properties as well as phase transformations such as glass transitions.

During a DMA test, a mostly sinusoidal force (stress, σ) with a certain frequency is applied to a sample (fig. 1). The result is a sinusoidal deformation (strain, ε) as a material response (fig. 2). The delay between the excitation and response is called phase shift (δ). Theoretically, it exhibits a value of 0° for fully elastic samples and a value of 90° for completely viscous substances. In reality, the phase shift of most materials is somewhere between 0° and 90°, depending on the elastic and viscous properties.

By a mathematical processing of the measured data, the complex Modulus E*, the storage modulus E', the loss modulus E'' and the loss factor tan δ are obtained.

The storage modulus E', which is the real part of the complex modulus E*, refers to the elastic part of the response and is a measure for a material's stiffness. The loss modulus E'', the imaginary part, corresponds to the dissipated oscillation energy. The loss factor (tan δ) which is the ratio between E'' and E', describes the mechanical damping or internal friction of a viscoelastic system.

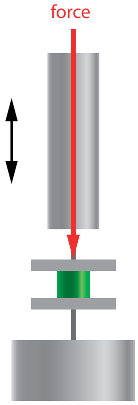


Figure 1: Example of oscillatory stress on a sample in compression mode

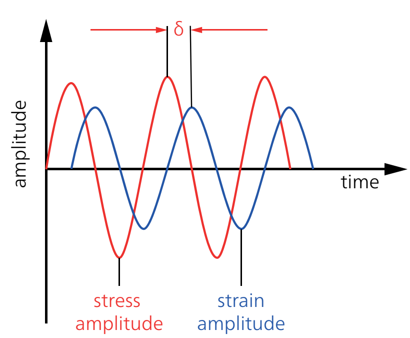


Figure 2: Schematic relationship between the stress and strain for a viscoelastic sample; δ stands for the phase shift between the two curves

Temperature- and frequency-dependent DMA test:

- Glass transition temperatures
- Secondary transitions
- Dynamic modulus (E*,E',E")
- Damping factor (tan δ)
- Master curve generation

Quasi-static universal testing:

- Tensile and compression
- Creep
- Relaxation
- Penetration testing
- And much more…

Additional modes and features:

- Hysteresis analysis
- Heat build-up
- Immersion bath
- Humid atmosphere

Eplexor® Ultra-High-Force

FORWARD-LOOKING SETUP

The *Eplexor*® high-force line is the only DMA series on the market with hardware that can easily be upgraded – also as a retrofit – to meet future needs. A factor such as this is important in maintaining the value of the investment.

Quality and Precision
Made in Germany

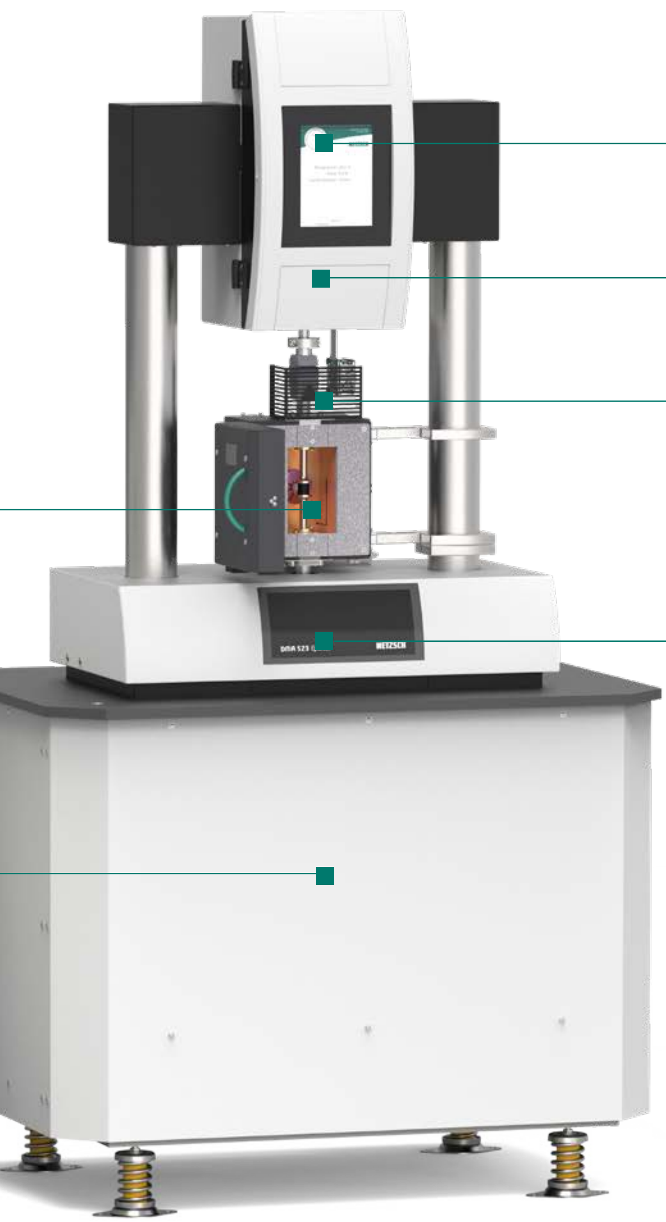
Unrivaled Temperature Range from -160°C to 500°C

The complete temperature range of a DMA is available for dynamic testing

Effective Stroke Protection of the Shaker via the Special Blade Spring System

For maximum safety of the shaker system when using ultra-high static forces and/or for destructive measurements, all *Eplexor*® high-force instruments feature an adjustable blade spring system.

DMA Line – Best in Its Class



DMA 523 *Eplexor*® 4000 N

Integrated Display

Check measurement progress in passing

Static Deformation up to 70 mm

User-Interchangeable Force Sensors

Select a suitable force sensor for your sample – from 12000 N* down to 150 N for highest sensitivity

Dynamic Deformation up to ± 15 mm

*The instrument allows for measurements up to 10000 N.

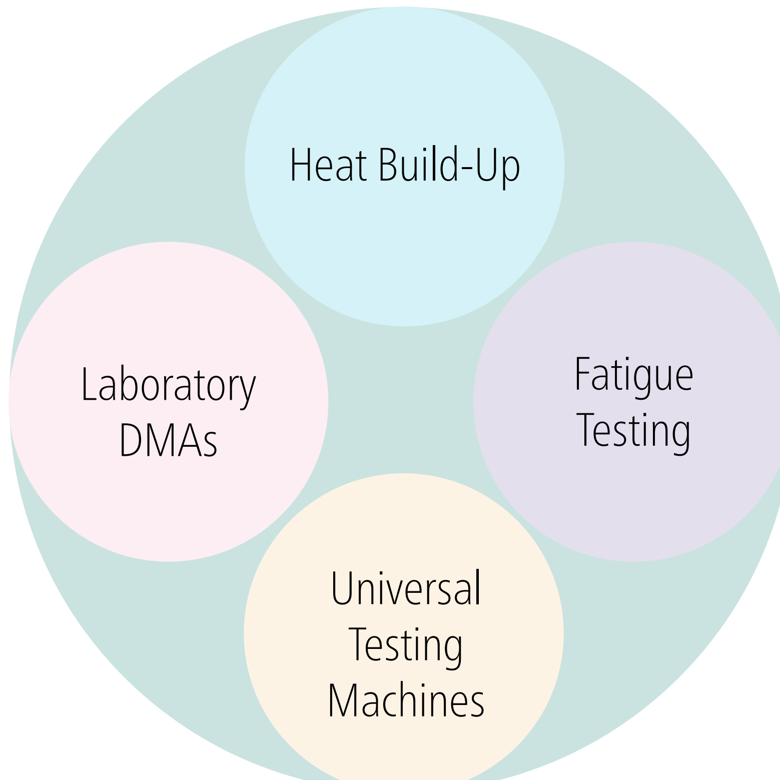
The *Eplexor*® Line – Comprehensive

The Best of Many Worlds in One Instrument Line

The 523 series closes the gap between laboratory DMA instruments with lower total forces up to approx. 50 newtons, the DMA 303 *Eplexor*®, and powerful, large universal testing machines covering force ranges up to several thousand newtons. Ultra-high-force *Eplexor*® DMAs are capable of characterizing both the linear and non-linear viscoelastic behavior of materials.

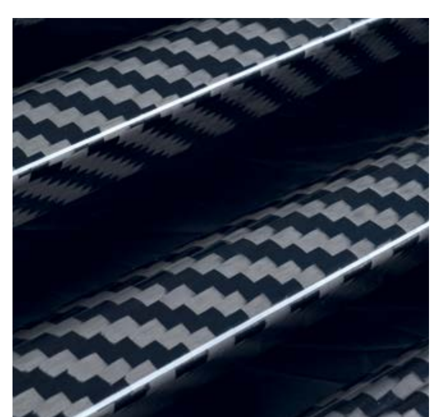
This instrument line can be used for all kinds of mechanical and viscoelastic measurements from determination of dynamic-mechanical standard parameters (tan δ, E′, E′′, etc.) to creep, relaxation, fatigue, heat build-up, tensile or rolling resistance tests and more.

High-Force *Eplexor*®



Designed to Investigate Metals, Ceramics or Composites

Total force levels of up to 10,000 N (static plus dynamic) can be applied to a sample, generating optimal conditions for the study of very stiff materials.



Dynamic Mechanical Testing

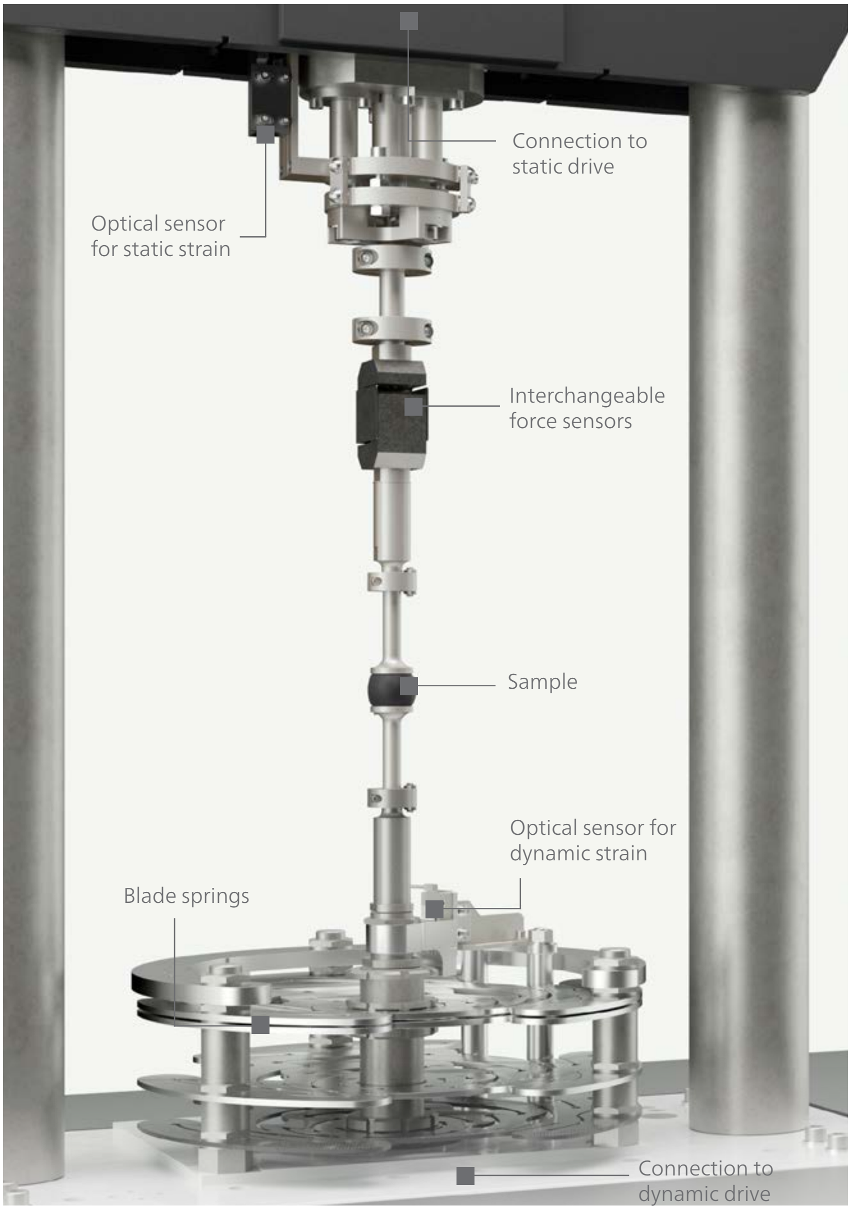


Illustration of the functional principle of the high-force *Eplexor®* line with two independent drives for static and dynamic force

Both a DMA and Universal Testing Machine

Only high-force *Eplexor®* DMA instruments have two independent drives for static and dynamic force.

The static force is generated by a servo motor, the dynamic force by an electrodynamic shaker system. The two drives can be used independently, which allows for *Eplexor®* high-force instruments to be used either as classical DMAs or as universal testing machines.

Maximum Safety During Fatigue and Tensile Tests

Fatigue or tensile tests at the highest force levels are often destructive experiments. In the case of unexpected sample destruction, the unique blade spring assembly absorbs the mechanical oscillation energy and realizes inherent self-protection for the system.

Variety of Dynamic Signal Shapes at One's Option

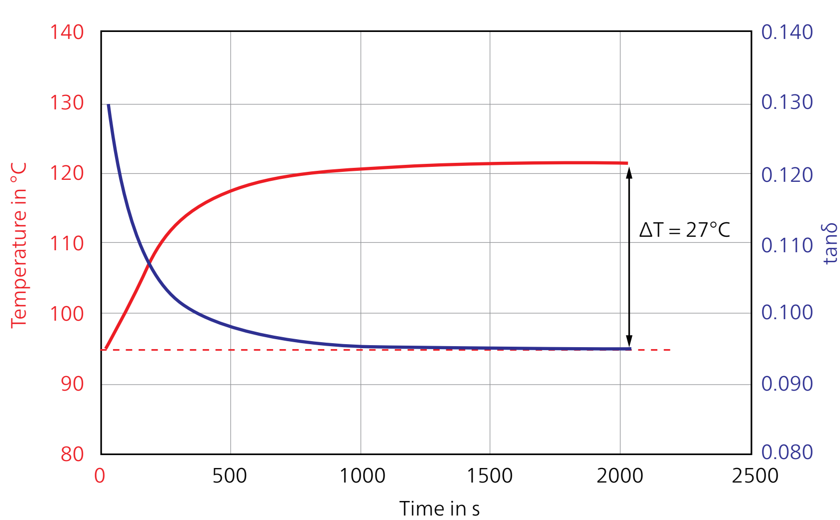
The optional Digital Signal Processor (DSP) offers a great variety of different signal forms for DMA tests such as sine, sine^2, half-sine, double-sine, triangle, saw-tooth, pulse or arbitrary periodic user-defined signals.

HBU 523 *Gabometer®*

Ideal for Heat Build-Up and Blow-Out Tests

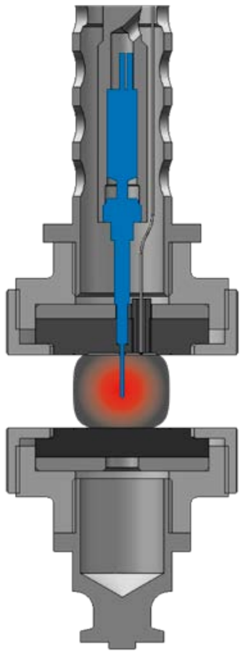
In a conventional Goodrich flexometer, in accordance with ASTM D623, a rubber specimen is exposed to a cyclic load in compression mode at a fixed frequency of 30 Hz and the resulting heat generation is detected at the sample surface. The increase in sample temperature is a consequence of the extremely high internal friction during this treatment while the rubber network decomposes. Furthermore, the sample undergoes deformation (thermal set).

As high deformations are required for these tests, ultra-high-force devices such as the 2000-N and 4000-N testing machines by NETZSCH are needed. They are capable of measuring not only the heat build-up, but also simultaneously measuring the viscoelastic properties of the sample.



Heat build-up measurement on SBR, compression mode, static load: 1 MPa, frequency: 30 Hz, amplitude (peak-to-peak): 4.45 mm

The traditional setup for a heat build-up test consists of a pair of insulated compression sample holders including a contact thermocouple for recording the sample temperature on the surface of the specimen. The result of such a measurement on SBR is depicted on the left. During the heat build-up test, the temperature (red curve) increase on the sample's surface is 27°C. Tan δ (blue curve) is decreasing while the rubber's network decomposes.



Sample arrangement with vertical needle thermocouple (optional)

The HBU 523 *Gabometer*® is Perfectly Suited for Heat Build-Up Tests

Any *Eplexor*® systems of the 523 instrument series can be upgraded to perform heat build-up tests by adding the appropriate flexometer package.

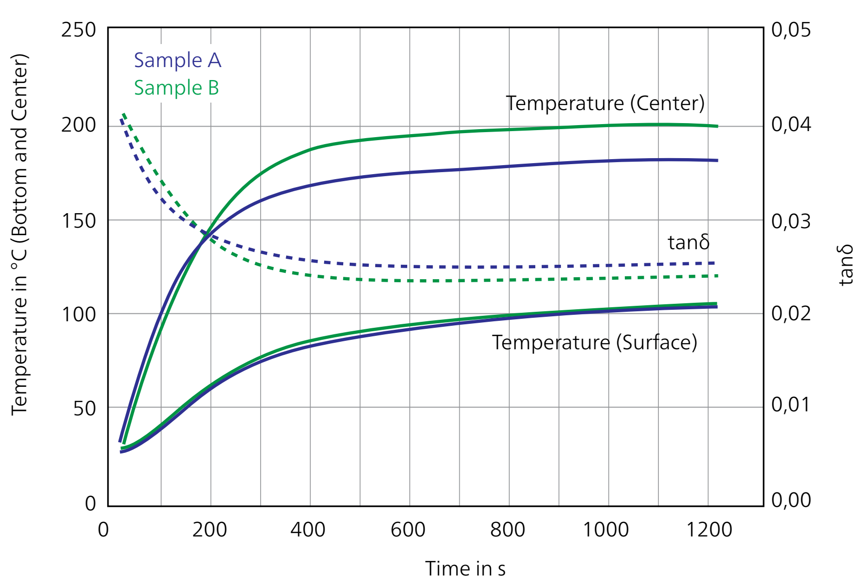
A Needle Thermocouple Measures the Temperature at the Sample's Core

The flexometer sample holder is equipped with an additional thermocouple to detect the surface temperature of the sample during the measurement.

In addition, a needle thermocouple may be used to measure the core temperature after the measurement – either automatically (with a vertical needle) or manually with a horizontal needle.

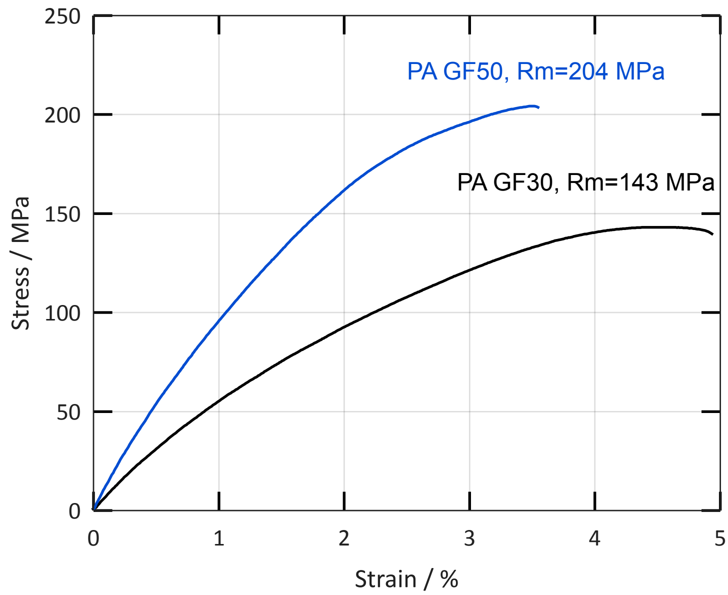
Heat Build-Up Tests of Two Rubber Samples

The graph shows the results for heat build-up tests on two rubber samples (A and B) consisting of the same base compound but filled with different types of carbon black.
There is a significant difference visible between the temperature at each sample's surface and its core, measured with the needle thermocouple mentioned above. In the case of sample B, this difference is approx. 100 K; the temperature jump in sample A is smaller and amounts to approx. 80 K. The reason for the better heat transfer of sample A is the higher thermal conductivity of the material.



Heat build-up tests on cylindrical specimens, height: up to 25 mm, diameter: up to 40 mm, static stress: 1 MPa

APPLICATIONS



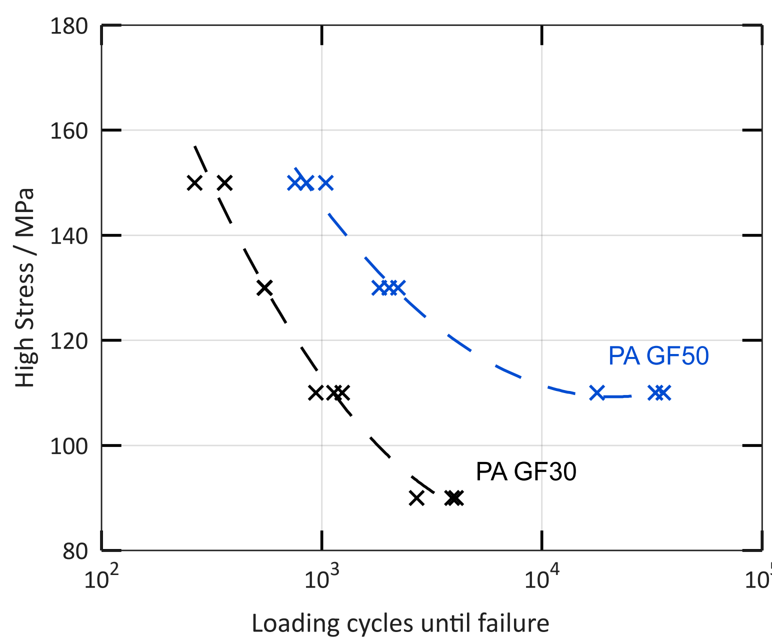
Tensile test on PA6.6 GF30 and PA6.6 GF50 with 1mm/min;
sample dimensions: 5 x 2 mm, L_0 = 20 mm

Tensile Test on Reinforced PA 6.6

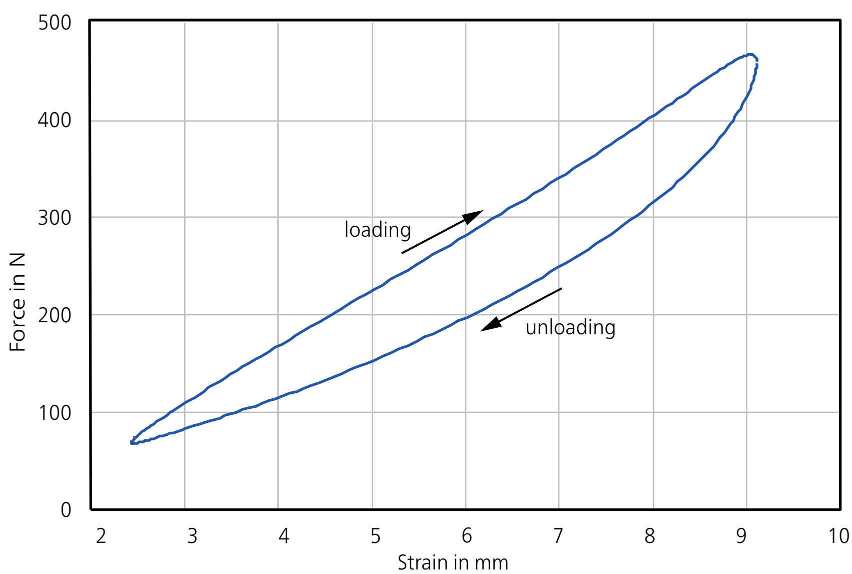
Short fiber-reinforced PA 6.6 is widely used in engineering applications due to its excellent mechanical properties.
A tensile test was performed on one sample with 30% (black curve) and one sample with 50% (blue curve) glass fiber content. With increasing filler content, the material becomes stiffer and exhibits enhanced strength. The ultimate tensile strength (Rm) rises from 143 MPa to 204 MPa.
However, the higher filler content also leads to failure at lower strains. The strain at break (ε_b) is approximately 3.5% for PA GF50 and around 5% for PA GF30.

Fatigue Test on Reinforced PA 6.6

Fatigue testing assesses the failure behavior of a material or component by subjecting it to repeated cyclic loading. The Wöhler curve, also known as the S-N curve (ISO 1099), graphically depicts the relationship between the cyclically applied stress (S) and the number of loading cycles (N) until the material fails.
In this particular example, PA6.6 with 30-% and 50-% glass fiber content was subjected to uniaxial tensile loading at high stresses as depicted and a low stress of 0 MPa (ratio R=0).
The higher filler content notably increases the number of applicable cycles. At a high stress of 110 MPa, for instance, PA GF30 (black curve) fails after around 10^3 cycles. PA GF50 (blue curve), however, breaks only after 10^4 cycles.



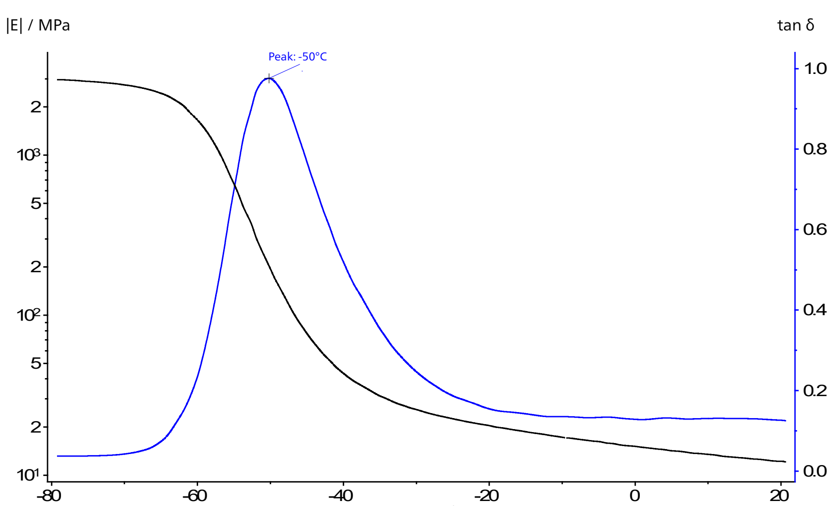
SN curves of PA6.6 GF30 and PA6.6 GF50;
sample dimensions 5 x 2 mm, L_0 = 20 mm, frequency 10 Hz, R=0



Dynamic stress-strain diagram (total force levels between 50 N and 450 N; resulting strains between 2.5 mm and approx. 9 mm); cylindrical specimen of 30-mm diameter and 30-mm height; compression test at RT

Hysteresis on Micro-Cellular Polyurethane

DMA instruments are capable of performing loading/unloading cycles on large polymer specimens. Displayed here is a measurement on PUR conducted using a static preload of 250 N, a superimposed dynamic force of ± 200 N and a frequency of 5 Hz.
The area spanned by the resulting hysteresis loop correlates to the amount of energy lost as heat during loading/unloading and is caused by the viscoelastic behavior of the sample material. The larger the area, the greater the amount of energy dissipated. For linear viscoelastic behavior, this curve is an ellipse; the present curve, however, indicates that the material already exhibits non-linear mechanical behavior.



Temperature sweep of an EPDM sample 30 x 7 x 2 mm
Dynamic 0.1% strain at 10 Hz, static 1% strain, -80°C to 20°C at 2 K/min

Low-Force Temperature Sweep Test on EPDM

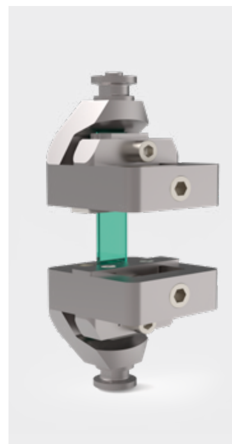
When equipped with a sensitive force sensor, it is also possible to perform applications that are suitable for low-force laboratory DMAs (e.g., NETZSCH DMA 303 *Eplexor*®). Here, a small EPDM rubber sample was measured in tensile mode. After the glass transition (peak tan δ at -50°C), stable signals can be achieved down to 0.1 N. The 150 N-force sensor provides reliable signals even when measuring forces in the lower range.

Sample Holders

THE RIGHT DESIGN FOR ANY SCOPE OF WORK

Tension up to 700 N

Tension up to 2000 N



Tension up to 6000 N

In order to achieve reliable measurement results, appropriate sample holders for the various sample geometries are needed.

In addition, special sample holders are available for:

- Single/dual cantilever
- Heat build-up tests (see page 12)
- Symmetrical 4-point bending
- Asymmetrical 3-point bending
- Measurement of cords (T and H tests)
- Gabo tackiness measurements

Compression for large samples

Double shear

3 – Point bending with immersion bath

Immersion Tests for Studying Materials in Liquid Media

Sample holders for tension, bending and compression can be inserted into a container filled with such substances as water or oil to investigate the material's aging or the plasticizer effect of the liquid.

Accessories

UNSURPASSED VERSATILITY

Humidity Generator (HYGROMATOR®) for Measurements under Controlled Humid Atmospheres

To simulate various climates or to study the influence of moisture on samples, the HYGROMATOR® can be attached to any *Eplexor®* DMA. This humidity generator operates between 20°C and 95°C and provides relative humidity levels from 5% to 95%. It can be used together with a modified standard furnace (see on the right).

Humidity generator connected to the standard furnace

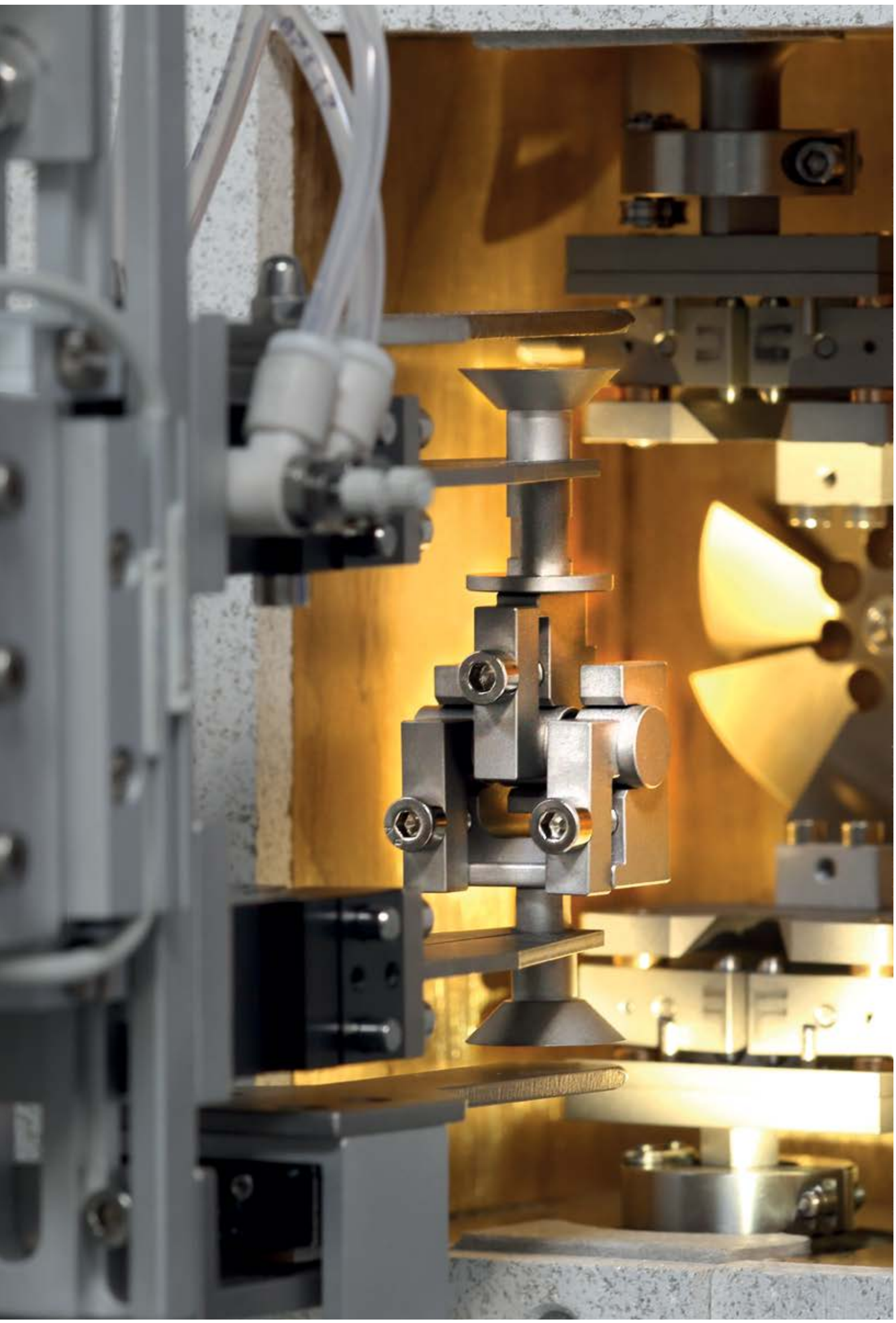
Cooling Options for Measuring Subambient

The devices can be equipped with several cooling options, depending on your needs:

- An air intracooler that operates without liquid nitrogen achieves temperatures as low as -60°C.
- To achieve temperatures as low as -160°C, a liquid nitrogen cooling system is available as a reliable and cost-effective solution.

Cooling Options	
LN_2	DMA -160°C ... 500°C HBU -160°C ... 300°C
Air Cooler	DMA -60°C ... 500°C HBU -60°C ... 300°C

Fully Automatic Testing System

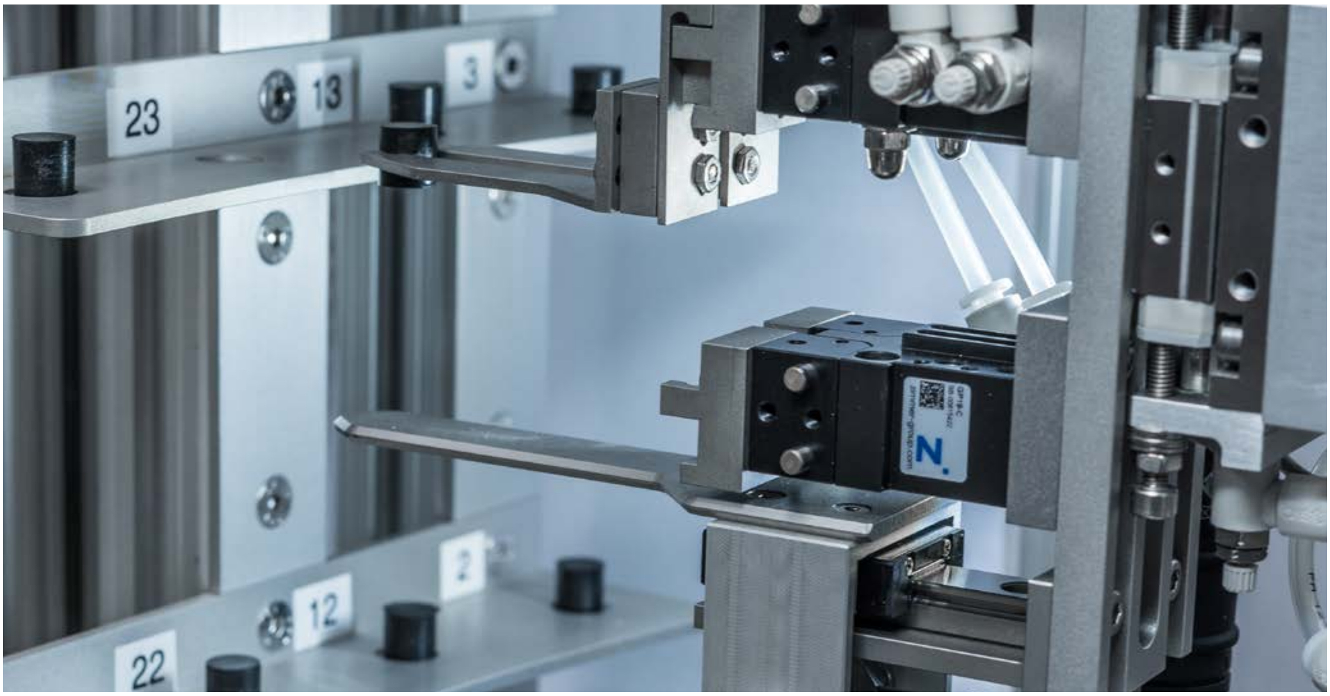


Non-Stop Operation with the Unmatched Autosamplers

Two automatic sample changers (ASC or MPAS – MPAS stands for multi-purpose automatic sample supply system) are available to convert any *Eplexor®* high-force DMA into a true hands-off system. While the ASC supports bending, tension and compression modes, MPAS is additionally capable of supporting the shear mode. MPAS allows free combination of different modes (tension, bending or shear) in arbitrary order.

Multi-purpose automatic sample changer (MPAS) with sample gripper in removal process, holding a double shear sample holder. The complete sample holder is transferred along with the specimen.

for up to 150 Samples



Autosampler (ASC) for compression mode; only the specimen is changed out

Exchanging the Entire Sample Holder or Just the Sample

Specimens which are not fixated inside a sample holder, such as samples for compression or bending modes, can be handled by the ASC individually (see above). For specimens which are fixated to a holder, however, the complete sample holder with implemented sample is changed out. An example showing the tension sample holder can be seen in the picture on the left.

A robot arm with two grips takes hold of the sample holder at both its lower and upper ends, removes it from the magazine (see previous page) and places it into position for measurement inside the furnace.

A complete autosampling system consists of:

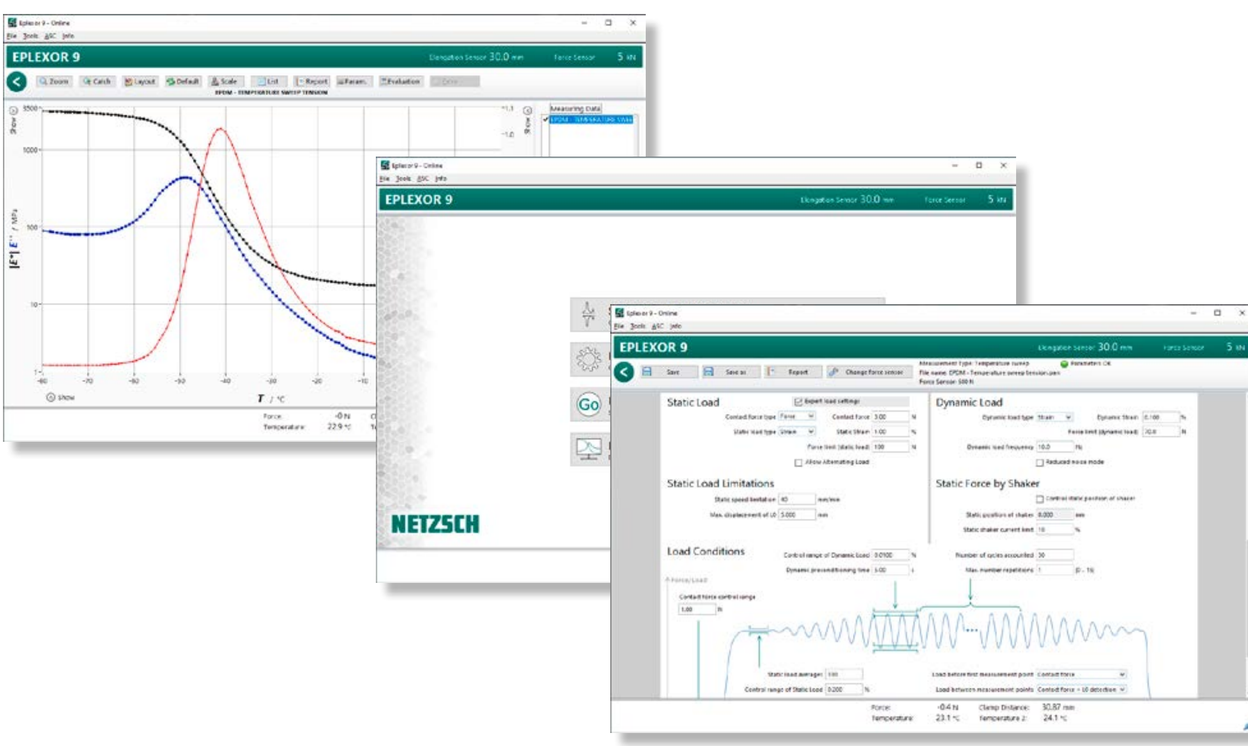
- A storage magazine with vertical pneumatic lift
- A pneumatic gripping arm with gripper(s)
- An automatic mechanism for opening and closing the furnace door

Software

SPEEDING UP WORKFLOWS

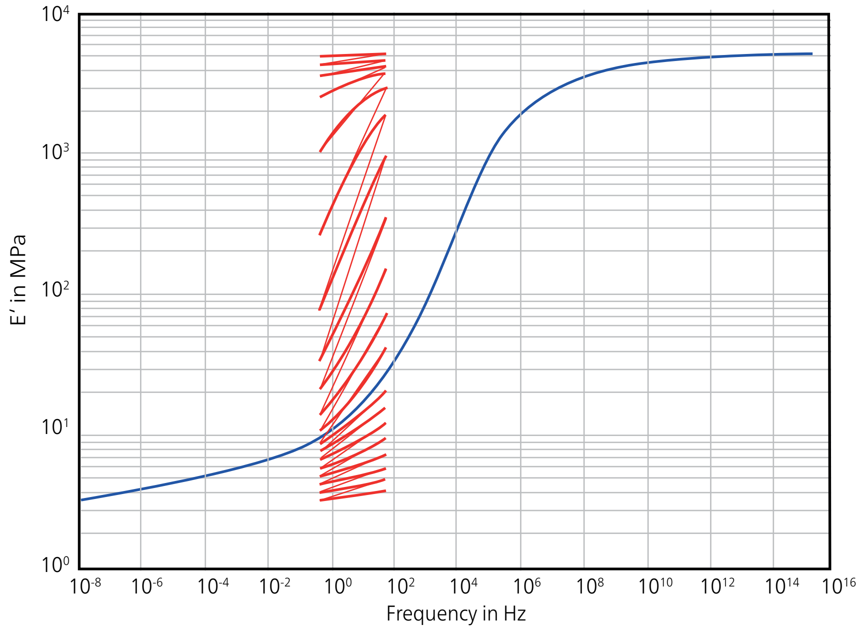
Any sophisticated measuring system comes with well-engineered software. The *Eplexor*® software runs under the Microsoft® Windows® operating system and offers comprehensive possibilities for defining measuring programs and analyzing data and curves.

- Manual control of temperatures and static loads
- Simple editing of measurement parameters based on a wide range of templates
- Multiple programmable sweeps may be combined in a segment program
- Online control of running measurements with freely configurable graphic or additional list of signals
- Powerful evaluation function within *Proteus*® analysis across different instruments



Key Software Features

- Frequency sweep from 0.0001 up to 100 Hz
- Time sweep
- Temperature sweep
- Static and dynamic stress or strain sweep
- Temperature and frequency sweep
- Constant stress amplitude mode per ASTM D623 (heat build-up test – optional)
- Universal test, either driven by the servo motor (Mini Tester, optional) or by shaker
- Time-temperature superposition – TTS (WLF, numeric)
- Evaluation of complex modulus (E*, G*), storage modulus (E', G'), loss modulus (E'', G''), damping factor (tan δ) and glass transition temperature
- Testing of creep, relaxation and retardation, fatigue and energy loss
- Payne/Mullins effect analysis
- Hysteresis presentation of results (optional)



Calculation of a master curve (according to the William-Landels-Ferry, or WLF, equation) based on a multi-frequency measurement on a rubber sample (stepwise isothermal temperature profile, frequency scan between 0.5 Hz and 50 Hz, tension mode)

Technical Specifications

HBU 523 *Gabometer*® Series up to ± 4000 N	
Temperature range	RT to 300°C -160°C to 300°C with LN_2
Drives	Two, independent of each other: ▪ Servo motor for static force ▪ Electrodynamic shaker for dynamic force
Static force	Up to ± 6000 N
Dynamic force	HBU 523 *Gabometer*® 2000 up to ± 2000 N HBU 523 *Gabometer*® 4000 up to ± 4000 N
Force measurement	User-exchangeable force sensors (various load ranges up to ± 12000* N)
Static deformation	Up to 70 mm
Dynamic deformation (amplitude)	Up to ± 15 mm
Frequency range	▪ 30 Hz ▪ 0.0001 Hz to 100 Hz (optional)
Measurement types	Flexometer test Blowout test
Temperature measurement	▪ PT100 inside furnace ▪ Type K at sample surface ▪ Automatic vertical needle thermocouple for core temperature (option) ▪ Manual horizontal needle thermocouple for core temperature (option)
Automatic sample length determination	Yes
Options	▪ Automatic sample changer: type ASC or MPAS ▪ Measurement of Young's modulus

* The instrument allows for measurements up to 10000 N.

DMA 523 *Eplexor®* Series up to ± 4000 N	
Temperature range	-160°C to 500°C with LN_2 -60°C to 500°C with Air Cooler
Drives	Two, independent of each other: ▪ Servo motor for static force ▪ Electrodynamic shaker for dynamic force
Static force	Up to ± 6000 N
Dynamic force	DMA 523 *Eplexor®* 2000 up to ± 2000 N DMA 523 *Eplexor®* 4000 up to ± 4000 N
Force measurement	User-exchangeable force sensors (various load ranges up to ± 12000* N)
Static deformation	Up to 70 mm
Dynamic deformation (amplitude)	Up to ± 15 mm
Frequency range	0.0001 Hz to 100 Hz
Wave forms	Sine (standard); triangle, sin^2, half-sine, double-sine, saw-tooth, user-defined wave forms, pulses (optional)
Main measurement types	▪ Time sweep ▪ Temperature sweep ▪ Frequency sweep ▪ Temperature/frequency sweep ▪ Static-dynamic sweep ▪ Creep, relaxation/retardation ▪ Fatigue tests ▪ Humidity sweep (optional) ▪ Flexometer test (optional) ▪ Heat build-up/blow-out tests (optional) ▪ Universal testing (optional)
Automatic sample length determination	Yes
Options	▪ Humidity generator (HYGROMATOR®) ▪ Immersion bath ▪ Automatic sample changer: type ASC or MPAS

The 523 *Eplexor®* High-Force series is in line with the following standards:

DIN 53513, ISO 6721-1, ISO 6721-4, ISO 6721-5, ISO 6721-6, ISO 4664,
ISO 4666-3, ISO 4666-4, ASTM D4065, ASTM D4473, ASTM D623

The NETZSCH Group is an owner-managed, international technology company with headquarters in Germany. The Business Units Analyzing & Testing, Grinding & Dispersing and Pumps & Systems represent customized solutions at the highest level. More than 4,000 employees in 36 countries and a worldwide sales and service network ensure customer proximity and competent service.

Our performance standards are high. We promise our customers Proven Excellence – exceptional performance in everything we do, proven time and again since 1873.

When it comes to Thermal Analysis, Calorimetry (adiabatic & reaction), the determination of Thermophysical Properties, Rheology and Fire Testing, NETZSCH has it covered. Our 60 years of applications experience, broad state-of-the-art product line and comprehensive service offerings ensure that our solutions will not only meet your every requirement but also exceed your every expectation.

Proven Excellence.

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