Dynamic Mechanical Analyzer

MCR 702e MultiDrive

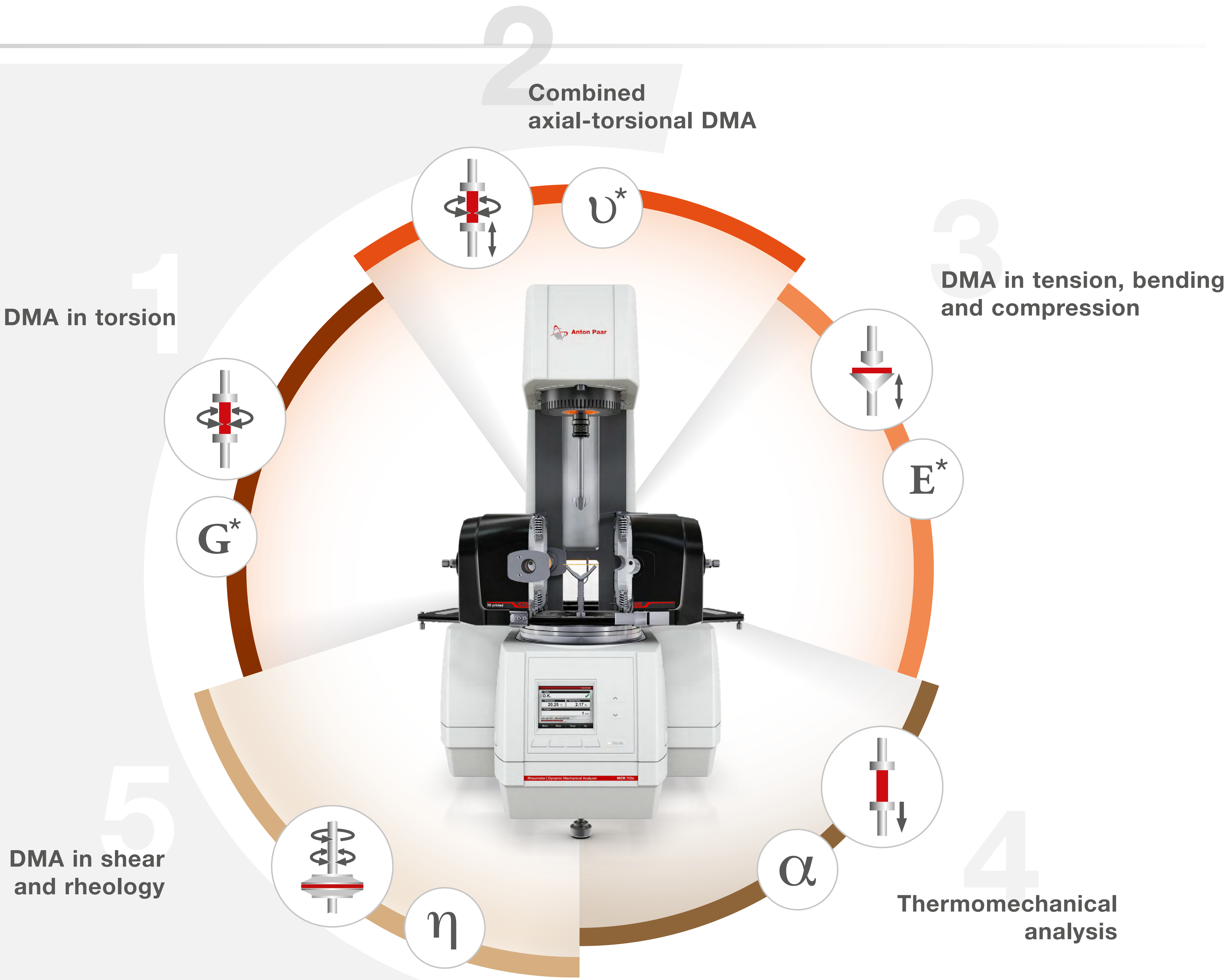
DMA and more

The world's most versatile and powerful platform for dynamic mechanical characterization

MCR 702e MultiDrive combines a state-of the-art linear motor with the renowned EC motor technology from MCR rheometers. This redefines the boundaries of possibilities for the dynamic mechanical analysis (DMA) of liquid, soft, and solid samples. The device enables you to perform DMA in tension, torsion, bending and compression, as well as rheological characterization and thermomechanical analysis (TMA) with one instrument.

Innovation, however, doesn't stop there. MCR 702e MultiDrive enables combined axial-torsional DMA within one test definition. This unique feature facilitates the enhanced characterization of anisotropic materials and the determination of the Poisson's ratio within a single test.

With this groundbreaking 5-in-1 functionality, MCR 702e MultiDrive sets a new standard for dynamic mechanical analyzers and opens up completely new possibilities in dynamic mechanical material characterization.

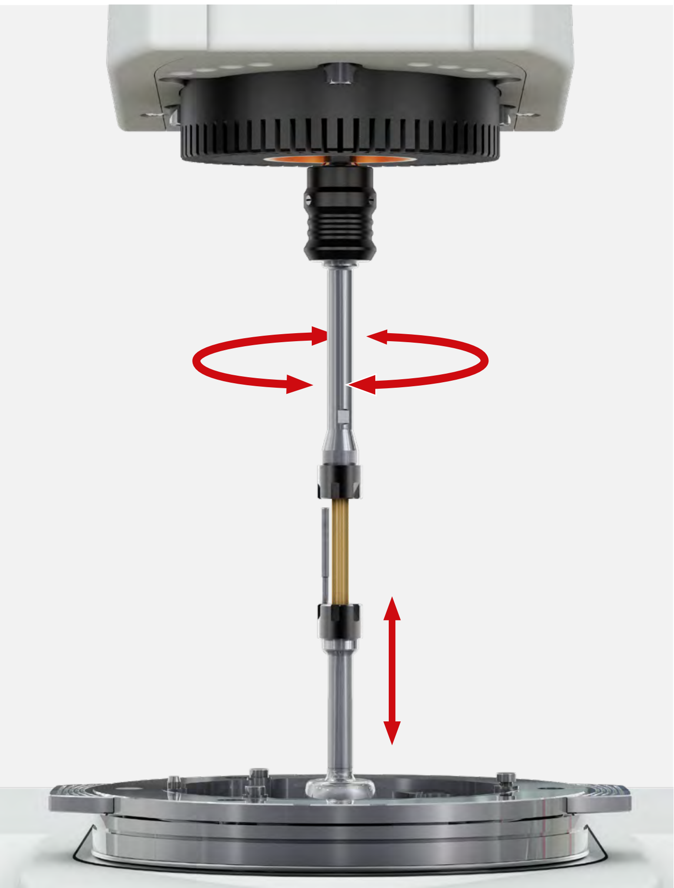


The modes that make it possible

Due to the combination of an upper EC motor with a lower moving-magnet linear drive, MCR 702e MultiDrive is the first device worldwide that's suitable for dynamic mechanical measurements in torsional and linear direction, as well as combined axial-torsional mode, thermomechanical analysis, and the broad range of different rheological measurements known from air-bearing-based rheometers. Thus, Anton Paar offers full flexibility applicable for both industry and research. With MCR 702e MultiDrive you can characterize the greatest variety of materials – from the solid to the liquid state – with your method of choice in order to get the most reliable and comprehensive results out of your characterization.

LINEAR DRIVE | **ROTATIONAL DRIVE**

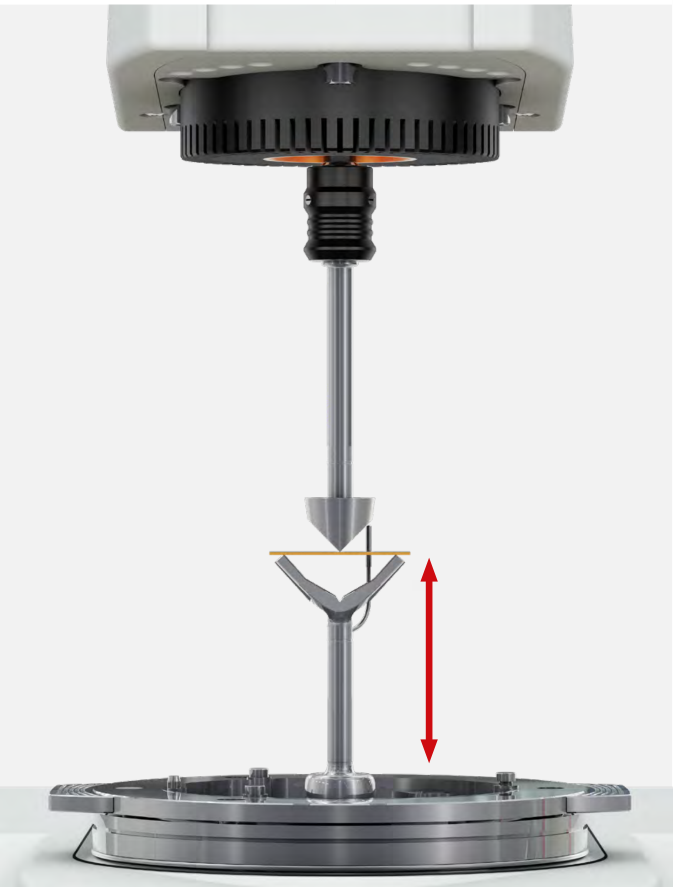
LINEAR & ROTATIONAL DRIVE IN ACTION



Combined measurements with the linear drive and the rotational drive using solid circular and rectangular fixtures (SCF, SRF) enable the determination of the complex Young's (E*) and the complex shear (G*) modulus as a function of temperature, frequency, time or humidity within a single experiment. In this way the Poisson's ratio of isotropic materials can be, for the first time, determined accurately and quickly using a single sample. In addition, when investigating anisotropic materials such as composites, a fast direction-dependent and a more comprehensive analysis of the sample properties is possible.

LINEAR DRIVE | **ROTATIONAL DRIVE**

LINEAR DRIVE IN ACTION



In this mode the rotational drive is brought into a fixed position, while the linear drive is used to control either the force or the displacement. In combination with measuring systems such as three-point bending, single cantilever, dual cantilever, fixtures for DMA in tension, or fixtures for DMA in compression, this mode is suitable for performing 'classic' dynamic mechanical analysis as precisely as possible. Furthermore, the mode enables you to perform creep and recovery tests, constant stress or strain measurements, and thermomechanical analysis.

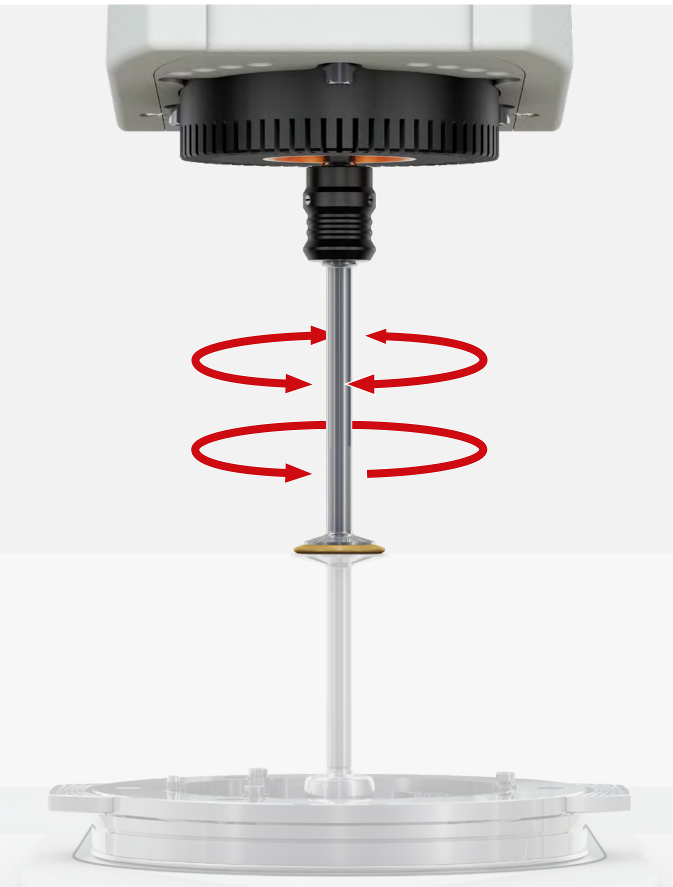
LINEAR DRIVE | **ROTATIONAL DRIVE**

ROTATIONAL DRIVE IN ACTION

In this mode the linear drive is brought into a fixed position, while the rotational drive is used to control shear strain or shear stress. In combination with available fixtures such as solid circular and rectangular fixtures (SCF, SRF) and plate-plate or cone-plate geometries, this option opens up the possibility to perform dynamic mechanical analysis in torsion and also rheological measurements.

ROTATIONAL DRIVE

THE SINGLE-DRIVE TEST MODE



In this mode the linear drive is removed and the measuring device is operated as a conventional rotational rheometer. With the linear motor unit removed, the device is ready to be equipped with any measuring system, temperature device, and/or application-specific accessory known from the Anton Paar MCR series in order to carry out standard and sophisticated rheological analysis of your sample. Instead of the linear drive, a second rotational drive can be mounted below to perform advanced rheological measurements with all testing modes available for rheometers.

Key features

Advanced concept for the highest flexibility in DMA and rheometry

The unique combination of linear drive and rotational drive within one measuring device enables true dynamic mechanical analysis in both linear and torsional direction, as well as combined axial-torsional measurements, and even rheological measurements to obtain the particular type of characterization which fits the application of your material best.

Unique motor design – the air bearing technology

Due to its design, the air bearings of both the linear and rotational drive offer extraordinary sensitivity for dynamic mechanical analysis and all kinds of rheological measurements from the high quality MCR rheometer series.

Precise force measurements and a large displacement range

Due to the optimized design and the advanced material selection of the moving-magnet motor, the linear drive shows the lowest magnetic hysteresis. This enables highly precise measurements over a broad force range up to 40 N to characterize soft and stiff materials with the highest precision and over a displacement range of 9.4 mm which is of advantage e.g. for tensile tests.

Displacement determination with the highest resolution

A linear optical encoder is used in the measuring device to determine the displacement. This optical technology allows stable strain measurements with resolutions in the subnanometer range.

Optimized measuring systems for highly reproducible results

The innovative design of the measuring systems – optimized by using computational fluid dynamics (CFD) – guarantees negligible temperature gradients inside the sample for highly accurate and reliable results. Each measuring system includes an integrated temperature sensor close to the clamped sample to measure the actual sample temperature with the highest reproducibility over the complete temperature range.

Easy-fitting and automatic configuration of all accessories

When changing between measuring systems, the proven QuickConnect coupling provides great ease of use as there is no screwing mechanism nor any need for additional alignment procedures. Toolmaster™ is a completely contact-free, automatic tool and configuration system for recognizing all measuring systems available. This enables time-saving and error-proof change of measuring systems and accessories without needing to enter the currently used configuration or complex geometry data manually in the software.

MCR 702e Space MultiDrive

The perfect choice when maximum working space is required

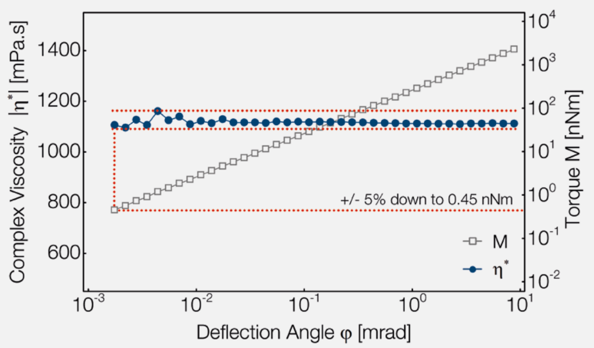
Its exposed support plate gives you maximum working space for easy combination with all MCR accessories, especially for the broad variety of rheological applications and with additional external setups, e.g. confocal microscopy. As this instrument has an external electronics box, it provides maximum flexibility with regard to installation conditions, e.g. for setup in a glove box.

Unique motor technology – the key to the highest precision

ROTATIONAL DRIVE

Based on an EC motor (permanent magnet synchronous motor)

- The rotor is equipped with permanent magnets 1
- Coils produce magnetic poles in the stator
- The rotating flux of input current in the coils produces frictionless synchronous movement of the rotor
- Supported by axial 2 and radial 3 air bearings that enable both the characterization of very stiff samples in DMA mode and also low-torque rheological measurements



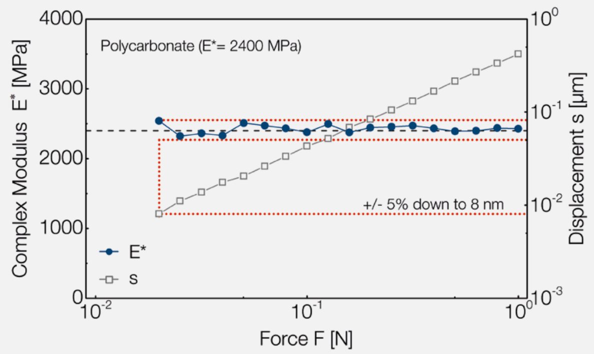
Benefits for the measurement

- Linear relationship between stator current and torque for precise torque measurements down to 0.5 nNm (see figure above)
- High thermal stability without heat production and temperature-induced signal drifts in the motor for permanent torques up to 230 mNm
- Instantaneous build-up of magnetic field for rapid torque control

LINEAR DRIVE

Based on a moving-magnet motor

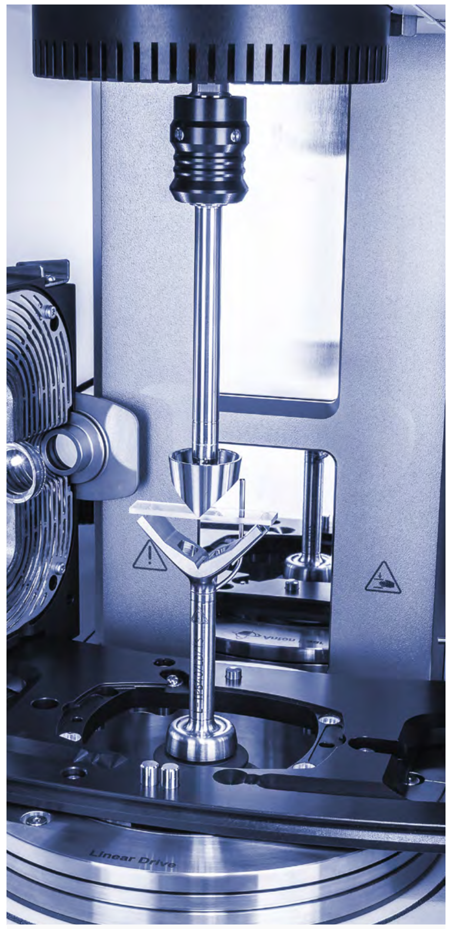
- Lightweight drive shaft equipped with a permanent magnet 4
- Stator coils 5 induce a magnetic field and affect axial movement of the drive shaft
- Due to the unique magnetic field technology, displacements can be realized with the lowest currents and measured using an optical encoder
- Supported by radial 6 and torsional 7 air bearings that enable low-force measurements in DMA in tension, bending, and compression as well as DMA in torsion with highly stiff materials



Benefits for the measurement

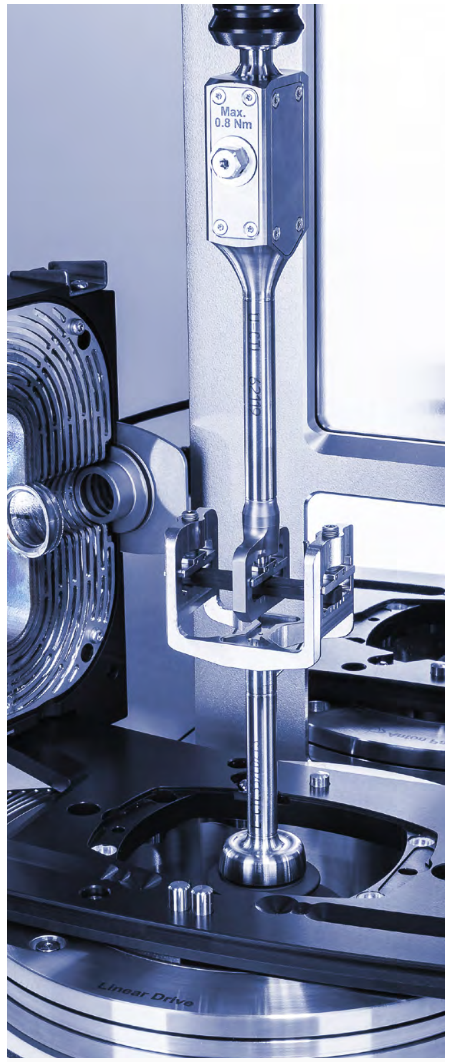
- Magnetic field technology guarantees force measurements with excellent signal-to-noise ratio down to 0.5 mN
- Motor concept provides perfect thermal management and eliminates temperature-induced signal drifts even with high loads up to 40 N and long measuring times
- Combination of optical encoder and the most precise linear drive results in an outstanding displacement range from 9.4 mm down to 10 nm (see figure above)

Measuring systems



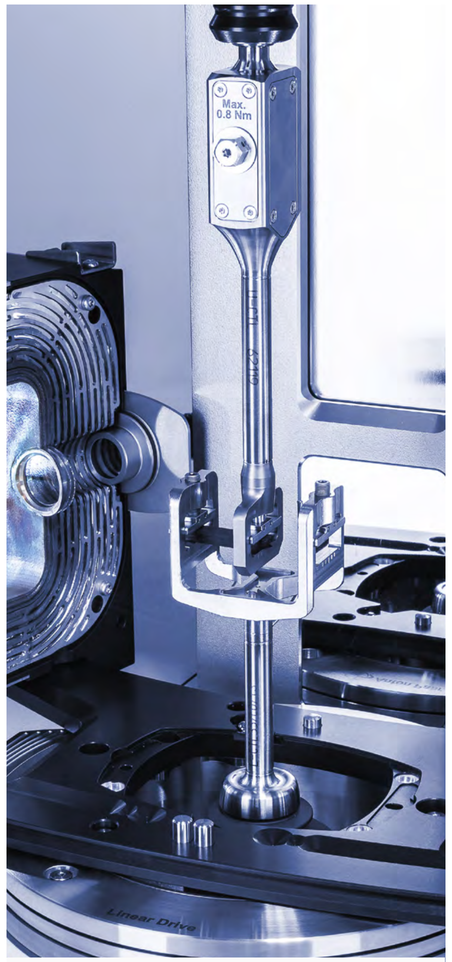
THREE-POINT-BENDING SYSTEM

The sample is positioned on two movable supports on both ends while a static shaft is placed at the midpoint of the sample. Because no additional clamping of the sample is necessary, measuring errors due to restraints are minimized. The measuring system is suitable for characterizing stiff materials such as composites and thermoplastics below their T_g, thermosets, but also metals and ceramics.



DUAL CANTILEVER

In this measuring system the sample is fixed between two clamps on both ends with a central clamp at the midpoint of the sample. Due to the clamping the measuring system is suitable also for materials with low stiffness which could otherwise exhibit sagging.

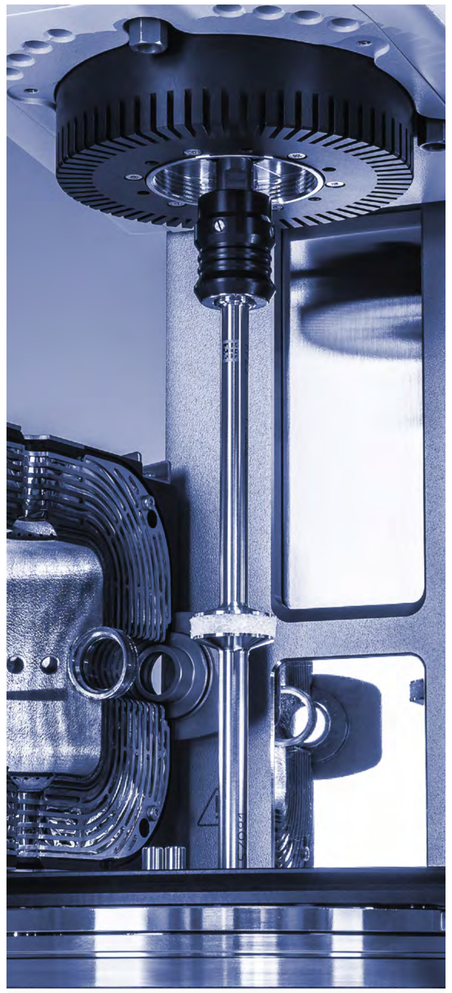


SINGLE CANTILEVER

The sample is fixed in this measuring system between the central clamp and only one clamp at the end. This system can be used for samples with a shorter length. In a similar way to the dual cantilever, this measuring system enables you to characterize materials which could show sagging. Examples include thermoplastics and elastomers.

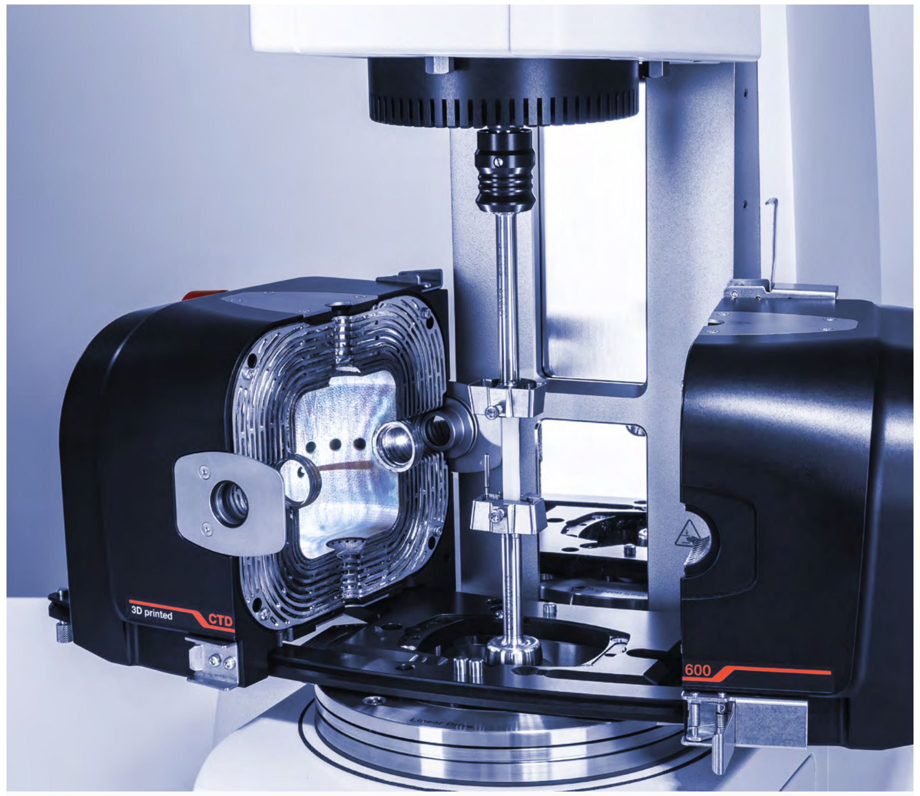
YOUR BENEFITS

- The integrated temperature sensor detects sample temperature with the highest reproducibility
- The CFD-optimized design guarantees lowest possible temperature gradients within the sample
- The robust geometry ensures characterization of stiff samples without compliance issues



COMPRESSION SYSTEM

For DMA in compression, conventional plate-plate measuring systems are available. The sample is placed between the upper and lower measuring system and is subjected to an uniaxial load. This deformation mode is particularly useful for the characterization of foams, elastomers, and other soft solids like food systems and gels.



SOLID RECTANGULAR FIXTURE AND SOLID CIRCULAR FIXTURE

In this measuring system the sample is positioned vertically, fixed at the upper and lower fixture, and deformed uniaxially. The special design of these measuring systems ensures that samples of different thicknesses and diameters can be measured exactly aligned with the axis of the measuring system. In this way reproducible results can be obtained for films, fibers, and also bars.

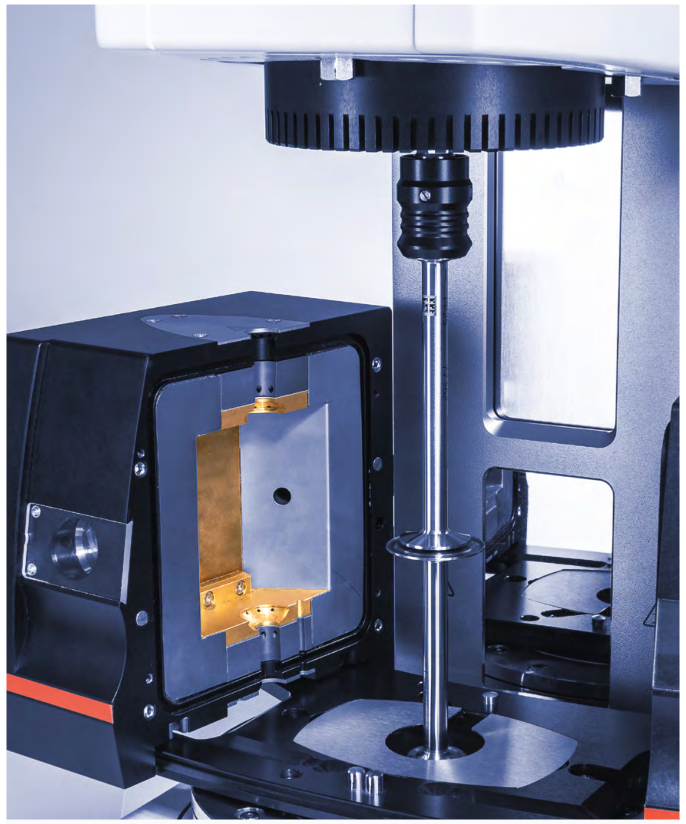
The same measuring systems can be used in combination with the rotational motor to enable dynamic mechanical analysis in torsion complementary to DMA in tension with the linear drive. As a result, for the first time, Young's modulus and the shear modulus of the same specimen can be measured within a single test definition without changing the sample, measuring systems, or any other accessory. This enables the simple determination of material properties previously not determinable with a DMA, such as Poisson's ratio, the direction-dependent characterization of anisotropic materials or simply the determination of the complete material behavior without the need for converting data from DMA in tension into DMA in torsion and vice versa.

YOUR BENEFITS

- QuickConnect functionality offers screwless and fast changes of the measuring system within seconds
- Toolmaster™ functionality enables automatic tool recognition and configuration without any manual settings in the software
- Automatic ZeroGap/ZeroAngle guarantee reproducible positioning of the measuring system without complex alignment procedures

Accessories to apply temperature and humidity

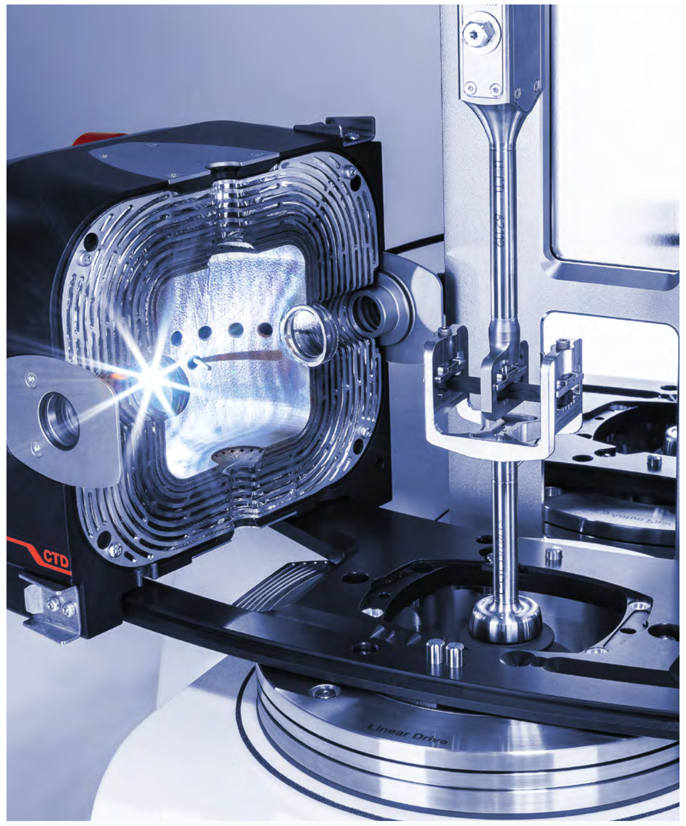
Anton Paar offers a wide range of convection temperature devices (CTDs) tailored to the specific demands of DMA and rheology. The temperature devices cover a temperature range from -160 °C to +1,000 °C and can be used with air or inert gas. All systems are easily exchangeable and ensure accurate temperature control over the whole temperature range.



CTD 180 HR

Peltier-based convection temperature control

- Temperature range: from -20 °C to +180 °C
- Suitable for cooling without any additional cooling option like a gas chiller or liquid nitrogen
- Perfect choice for the characterization of the impact of relative humidity on polymers, food and pharmaceuticals



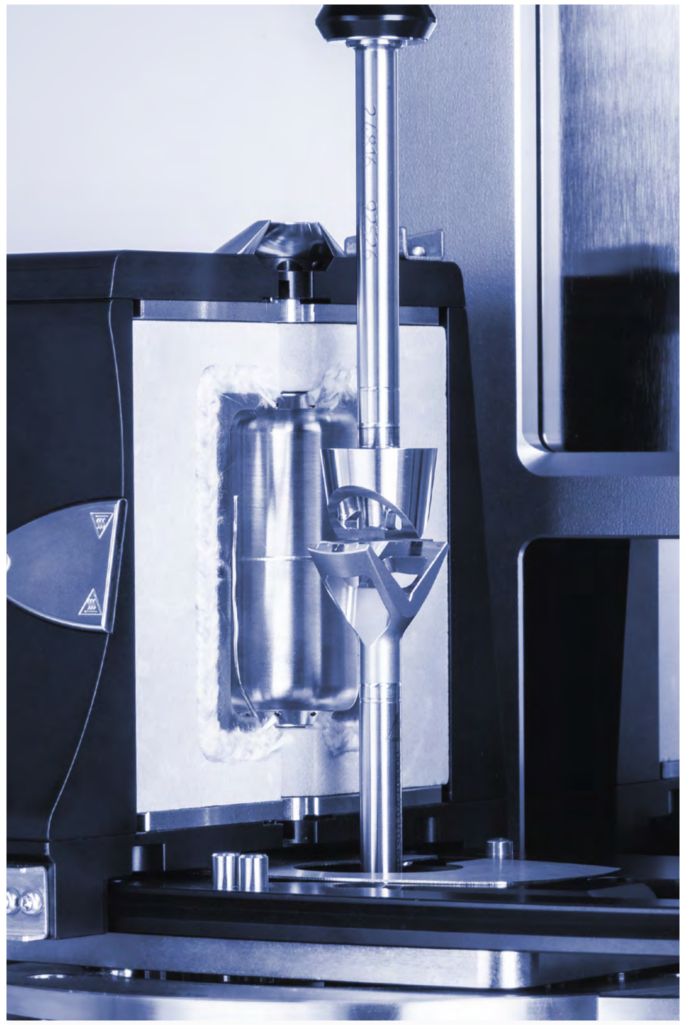
CTD 600 MDR

Most precise, state-of-the-art temperature control based on combined convection and radiation

- Temperature range: from -160 °C to +600 °C
- Innovative 3D metal printing production technology for precise and stable temperature control even at minimum and maximum temperatures
- Digital eye camera option available to identify measurement effects such as sagging, slip, break, or optically visible phase transitions

YOUR BENEFITS

- ✔ Temperature control with homogeneous gas flow within the system and thus high accuracy
- ✔ Long-term measurements even at maximum temperatures
- ✔ Low (inert) gas consumption for reduced operating costs and precise measurements even at low torques and forces



CTD 1000 MDR

Powerful convection temperature control for widest temperature range

- Temperature range: from -150 °C to +1,000 °C
- Suitable for the characterzation of metals and alloys, glass and ceramics

LOW TEMPERATURE OPTIONS

Option 1: EVU 20 for temperatures down to -160 °C
- Controls the evaporation of liquid nitrogen and the continuous flow of nitrogen into the CTD 600 MDR or the CTD 1000 MDR
- Gas supply switches automatically to air or inert gas to cover the full temperature range of the CTD 600 MDR

Option 2: Gas chiller unit for CTD 600 MDR and temperatures down to -90 °C
- Uses compressed gas (air or inert gas)
- Perfect choice if the use of liquid nitrogen is prohibited by internal safety regulations.

HUMIDITY OPTION FOR CTD 180 HR

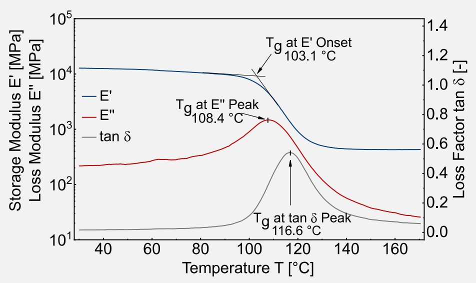
- External humidity generator controls the relative humidity from 5 % to 95 % depending on the actual temperature
- Used to study the impact on drying, softening, but also curing of materials

READY FOR ALL MCR ACCESSORIES

By removing the linear drive MCR 702e MultiDrive can be used as a CMT (combined motor transducer) rheometer. The configuration is ready for any temperature device and application-specific accessory you may require – and there are countless options to choose from. Additionally, Anton Paar supplies customized products for specific applications such as systems for DMA on solids immersed in liquid, shafts combinable with any disposable or customized geometry, and even material pockets for testing powdery samples with typical DMA measuring systems in bending mode or a shear sandwich to characterize viscoelastic materials with DMA in axial shear direction. For a full overview, have a look at the Anton Paar website.

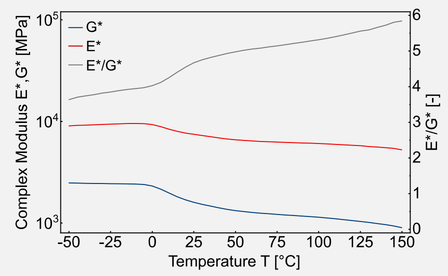
MCR 702e MultiDrive – The world's most versatile platform for dynamic mechanical characterization

Due to its 5-in-1 functionality, MCR 702e MultiDrive offers the most comprehensive range of testing modes available for dynamic mechanical characterization. The following four measurements describe crucial applications in the polymer industry in order to characterize and optimize typical composites. Using MCR 702e MultiDrive, all these measurement tasks can be performed with a single device in outstanding quality.



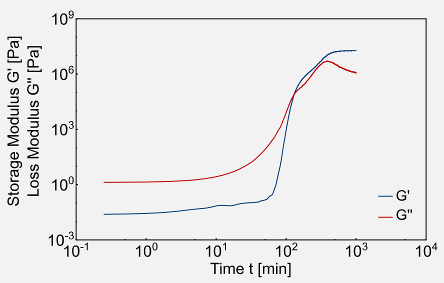
1. DMA in bending

To determine the viscoelastic properties of carbon-fiber-reinforced polymers (CFRP), often DMA in bending mode is performed. The figure depicts three commonly used methods to measure the Tg (Onset G', Peak of G", and Peak of tan δ). This can be used to determine the suitable service temperature and the actual mechanical properties of the material during its use.



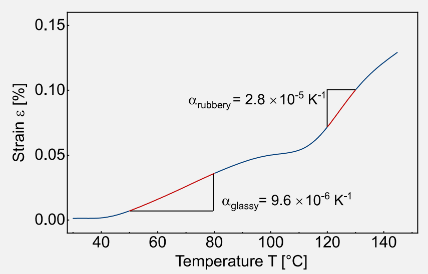
2. DMA in combined axial-torsional mode

Due to their anisotropy polymeric composites can show viscoelastic properties which are strongly dependent on the deformation mode. The example shows temperature-dependent results for DMA in torsion and DMA in tension of a CFRP. A changing ratio between E* and G* indicates that the mechanical properties of the CFRP are influenced to varying degrees by the temperature, depending on the direction of loading.



3. Rheology

Epoxy resins are often used as the polymeric matrix of CFRP. Its mechanical properties change during the cross-linking reaction. By performing an isothermal oscillatory time-sweep the onset and rate of the cross-linking, the cross-over point of G' and G", and the final mechanical properties can be measured easily. Thus, the behavior of resin systems can be controlled and improved to guarantee superior component quality.



4. Thermomechanical analysis

Knowledge of thermal expansion behavior is important for component design and simulation. A discontinuity of the dimensional change can be seen starting at about 100 °C, which correlates well with the glass transition temperature determined by the DMA tests. The results show that the coefficient of thermal expansion (CTE) exhibits different values in the rubber elastic state compared to the glassy state.

Specifications

	Unit	Specifications
Linear drive for DMA in tension, bending, and compression		
Maximum force	N	40
Minimum force	N	0.0005
Maximum displacement	µm	9,400 [1]
Minimum displacement	µm	0.01
Maximum frequency	Hz	100
Minimum frequency	Hz	0.001
Rotational drive for DMA in torsion and rheology		
Maximum torque	mNm	230
Minimum torque, rotation	nNm	1
Minimum torque, oscillation	nNm	0.5
Maximum angular deflection (set value)	µrad	∞
Minimum angular deflection (set value)	µrad	0.05
Maximum angular velocity	rad/s	314
Minimum angular velocity	rad/s	0 [2]
Maximum angular frequency	rad/s	628 [3]
Minimum angular frequency [4]	rad/s	10^{-7} [5]
Normal force range	N	-50 to +50
Temperature control		
Maximum temperature range	°C	-160 to +1,000 [6]
Maximum heating rate	K/min	60 [6]
Maximum cooling rate	K/min	30 [6]

Further information regarding general features, measuring systems, accessories, and specifications when using only rotational drives can be found in the MCR Evolution brochure.

Features	
DMA in tension, bending and compression	✓
DMA in torsion	✓
DMA in combined axial-torsional mode	✓
Thermomechanical analysis	✓
Toolmaster™, measuring system	✓
Toolmaster™, measuring cell	✓
QuickConnect for measuring systems, screwless	✓
T-Ready™	✓
Low-temperature option, nitrogen evaporation unit	○
Low-temperature option, gas chiller	○
Humidity option	○

✓ included | ○ optional

1) In oscillation a maximum displacement of ±4500 µm.
2) In controlled shear stress (CSS) mode. In controlled shear rate (CSR) mode depending on measuring point duration and sampling rate.
3) Higher frequencies are possible using multi-wave functionality (942 rad/s (150 Hz) or even higher, depending on measuring system and sample).
4) Set frequencies below 10^{-4} rad/s are of no practical relevance due to the measuring point duration >1 day.
5) Theoretical value (duration per cycle ≈ 2 years).
6) Limits depend on convection temperature device used and measuring systems. Customized low-temperature option for temperatures down to -170 °C available upon request.

www.anton-paar.com