

MCR 702e  
MultiDrive



Dynamic mechanical analyzer



# DMA and more

## The world's most versatile platform for dynamic mechanical characterization

MCR 702e MultiDrive is the most versatile and powerful platform on the market for the dynamic mechanical analysis (DMA) of liquid, soft, and solid samples. The device combines a completely new linear motor with the renowned EC motor technology from MCR rheometers. This state-of-the-art linear motor enables you to perform DMA in tension, bending, and compression as well as thermomechanical analysis (TMA) with one instrument.

Moreover, the EC motor enables you to perform measurements in torsional direction, well-known from the established MCR rheometer series by Anton Paar. In this way DMA in torsion as well as all rheological measurements are possible at the highest level of precision.

This unrivalled 4-in-1 functionality together with the multifunctional software RheoCompass™ open up completely new possibilities in dynamic mechanical material characterization.



# The modes that make it possible

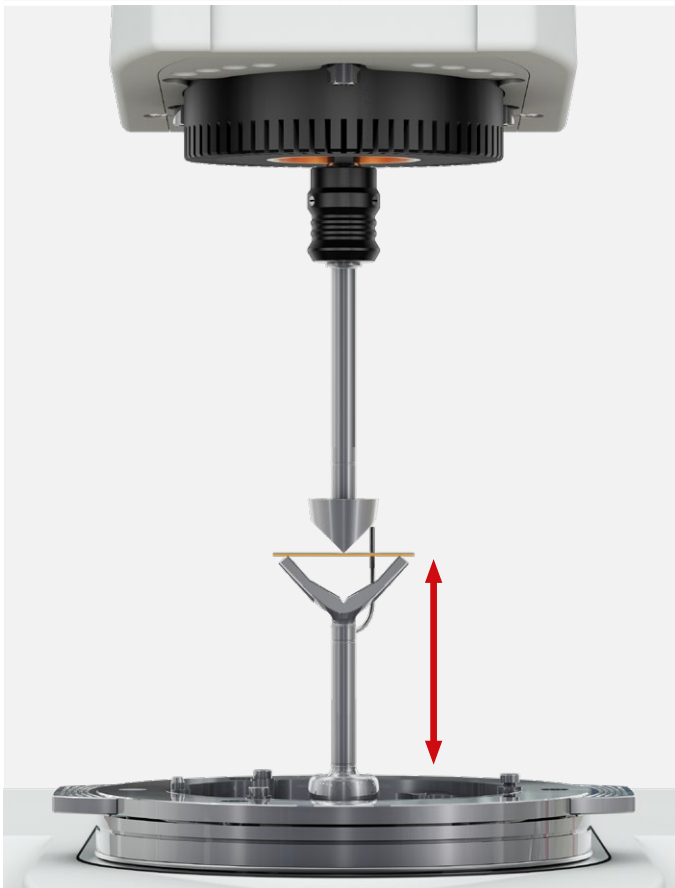
Due to the combination of an upper EC motor with a lower moving-magnet linear drive, MCR 702e MultiDrive is the first device worldwide suitable for dynamic mechanical measurements in torsional and linear direction, thermomechanical analysis, and the broad range of different rheological measurements known 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 results out of your characterization.

Choose the test mode which fits best to your requirements

LINEAR DRIVE

ROTATIONAL DRIVE

LINEAR DRIVE IN ACTION


A 3D cutaway diagram of the MCR 702e MultiDrive showing the linear drive mechanism. A central vertical shaft is connected to a motor at the top. A red double-headed arrow indicates the vertical movement of the shaft. The shaft is positioned above a sample stage.

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

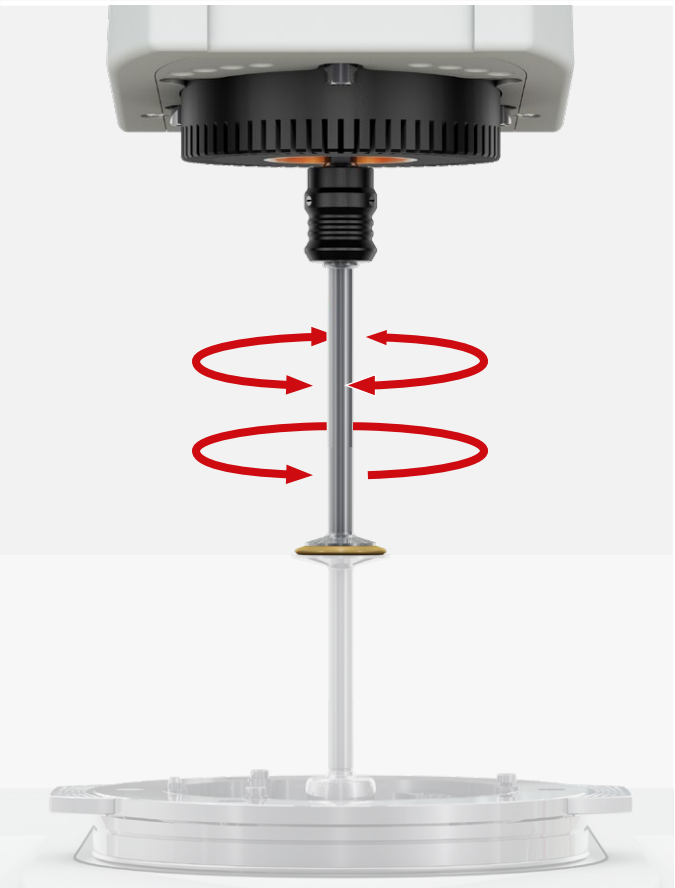
ROTATIONAL DRIVE IN ACTION

A 3D cutaway diagram of the MCR 702e MultiDrive showing the rotational drive mechanism. A central vertical shaft is connected to a motor at the top. Red curved arrows indicate the rotation of the shaft. The shaft is positioned above a sample stage.

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

A 3D cutaway diagram of the MCR 702e MultiDrive showing the single-drive test mode. The linear drive is removed, and the rotational drive is used to control shear strain or shear stress. Red curved arrows indicate the rotation of the shaft. The shaft is positioned above a sample stage.

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, but also 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 provide an extraordinary sensitivity for dynamic mechanical analysis and all kinds of rheological measurements as known from the high quality of the 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 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 or any need of additional alignment procedures. Toolmaster™ is a completely contact-free automatic tool recognition and configuration system to recognize 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 the maximum flexibility with regard to installation conditions, e.g. for setup in a glove box.



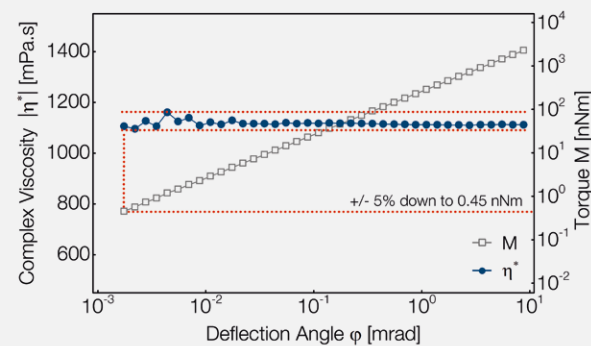


# Unique motor technology – the key to the highest precision

## 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 highly stiff samples in DMA mode and also low-torque rheological measurements



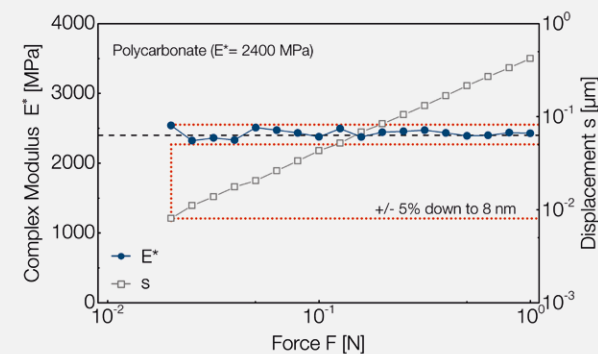
### Benefits for the measurement

- 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

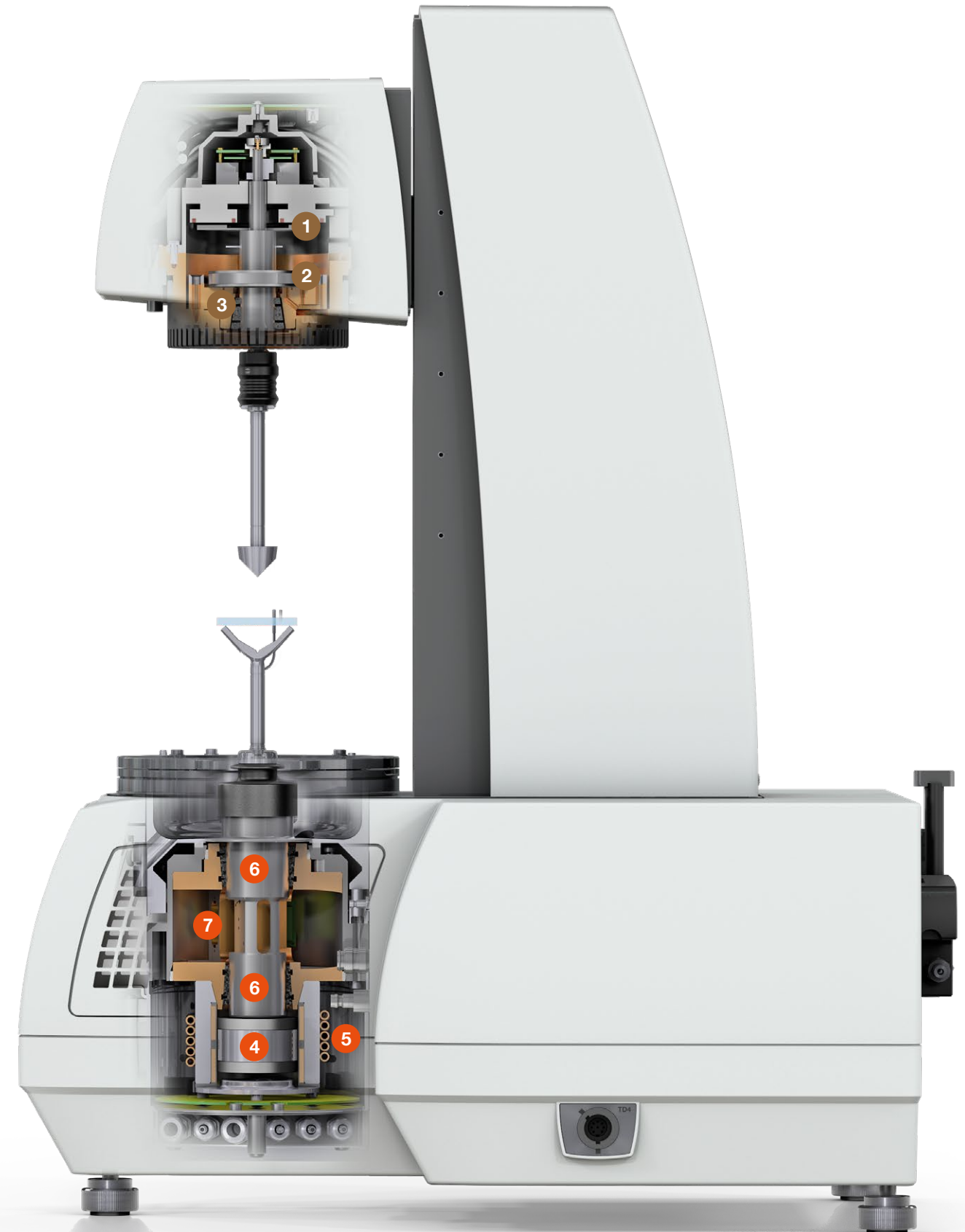
### Based on a moving-magnet motor

- 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



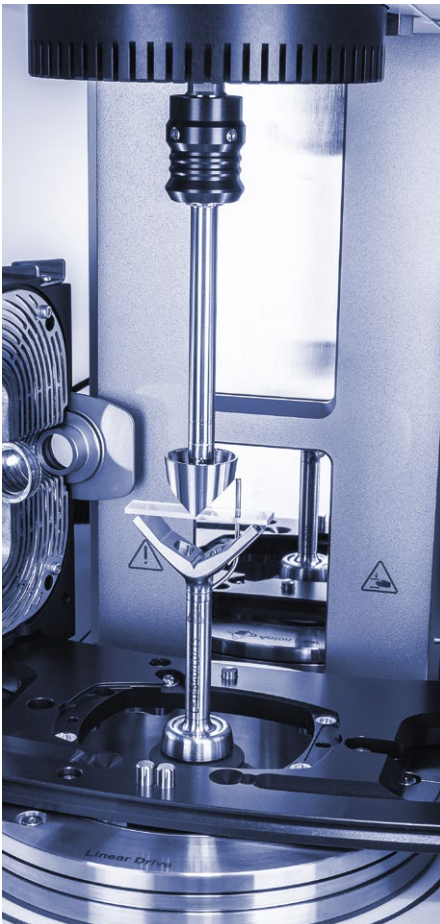
### Benefits for the measurement

- 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)



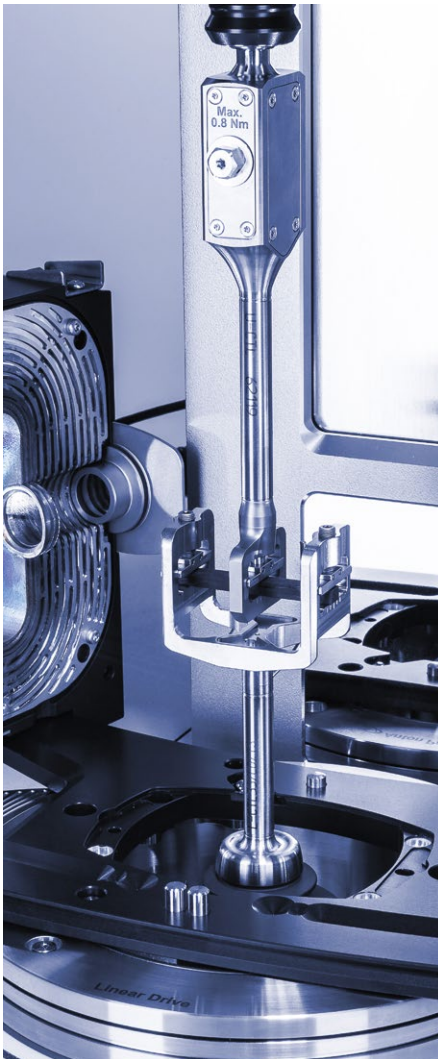


# Measuring systems



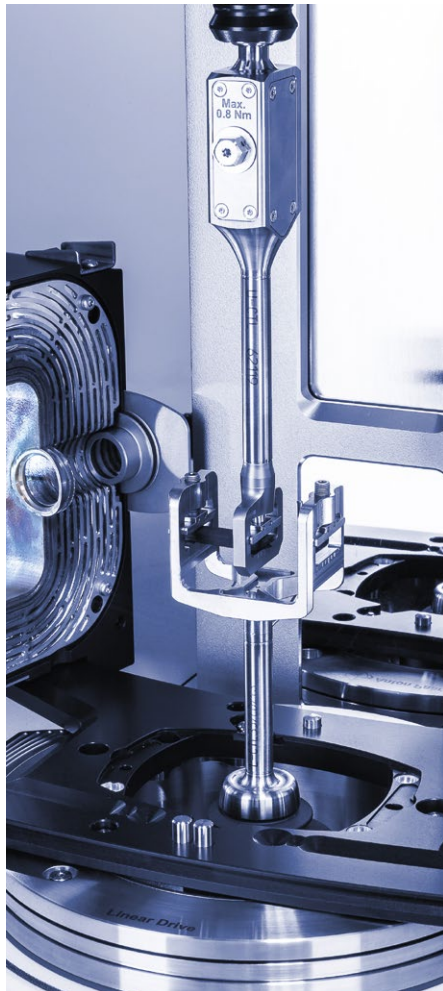
### THREE-POINT-BENDING SYSTEM

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.



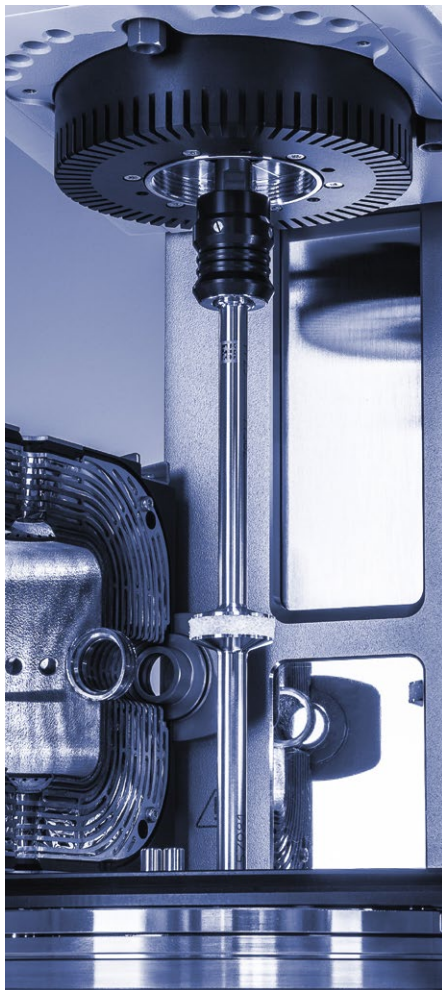
### DUAL CANTILEVER

In this measuring system the sample is fixed between two clamps on both ends and 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.



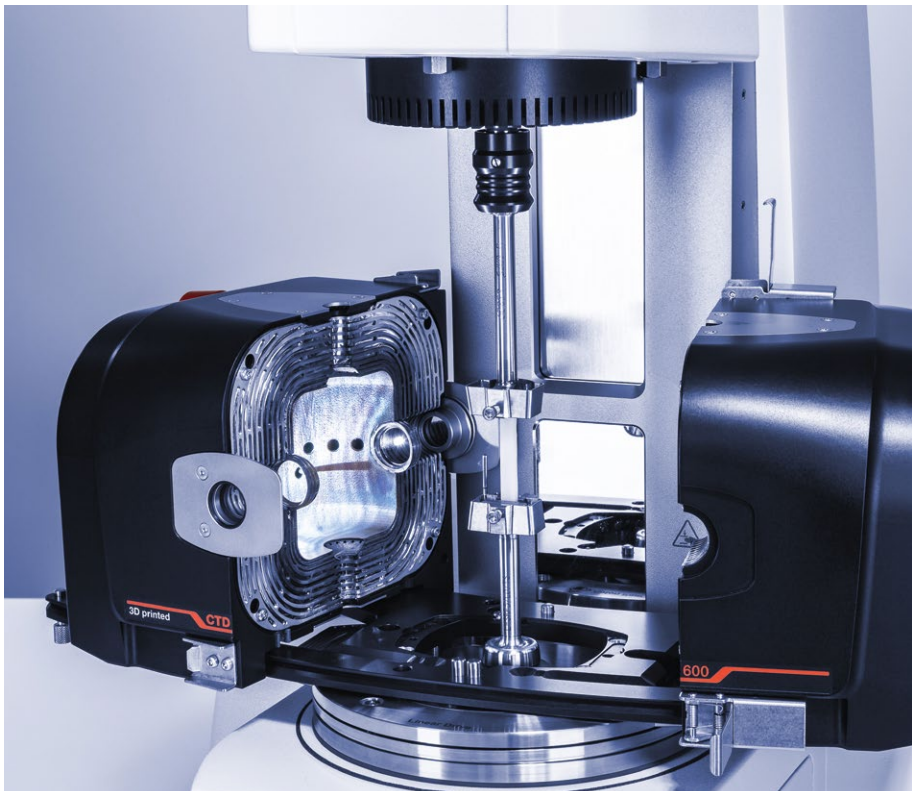
### SINGLE CANTILEVER

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. Similar to the dual cantilever this measuring system enables you to characterize materials which could show sagging. Examples are thermoplastics and elastomers.



### 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 a 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 IN TENSION AND TORSION

In this measuring system the sample is positioned vertically, fixed at the upper and lower fixture, and deformed uniaxially. The special design of this measuring system ensures that samples of different thicknesses 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 thin solid bars. Next to dynamic mechanical analysis the measuring system is also suitable for measuring the thermal expansion of solid bars.

The same measuring system 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. In this way it is possible to determine the complete material behavior without the need for converting data from DMA in tension into DMA in torsion and vice versa.

#### YOUR BENEFITS

- ✓ The integrated temperature sensor enables detection of 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

#### YOUR BENEFITS

- ✓ QuickConnect functionality offers screwless and fast changes of the measuring system
- ✓ 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



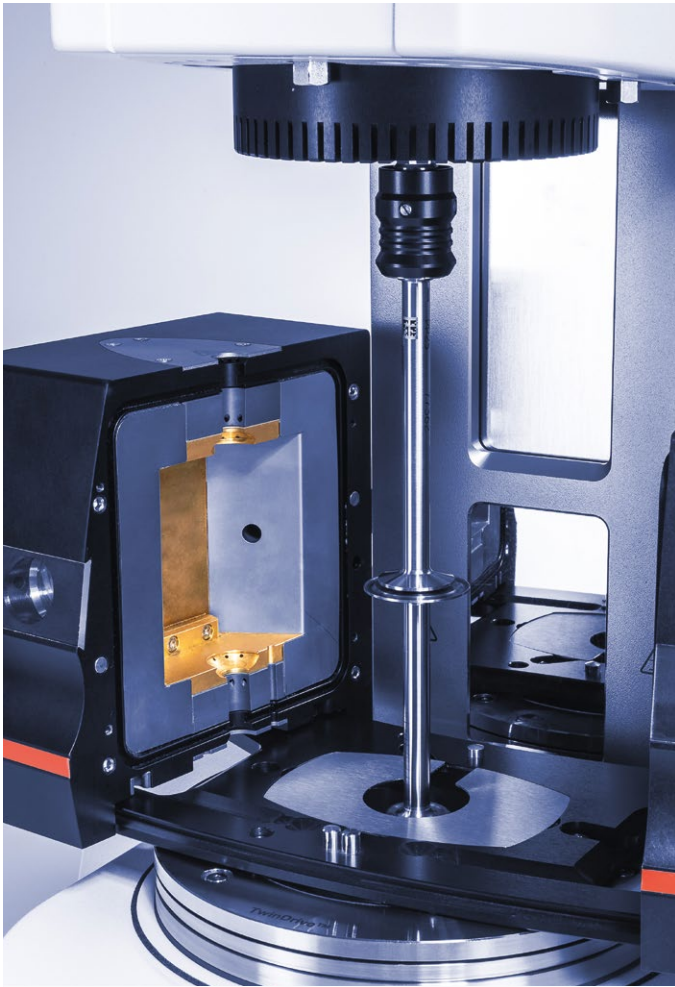
# Accessories to apply temperature and humidity

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 600 °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.



### HUMIDITY OPTION FOR CTD 180 HR

- Is optionally connected to CTD 180 HR enabling tests with measuring systems for DMA and rheology
- 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



### 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



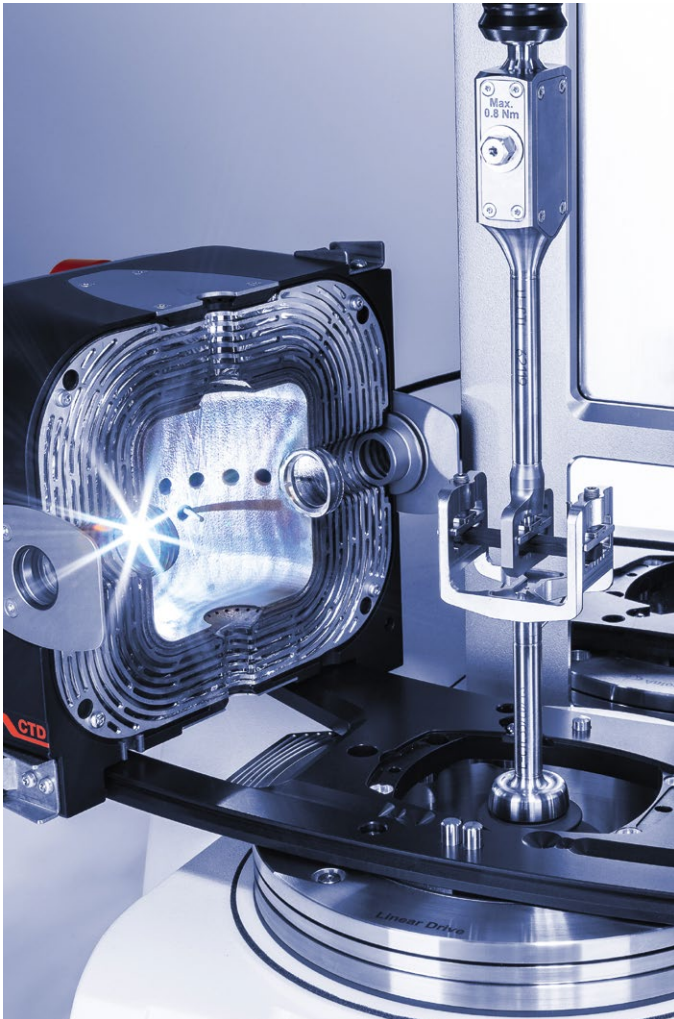
### LOW-TEMPERATURE OPTIONS FOR CTD 600 MDR

#### Option 1: EVU 20 for temperatures down to -160 °C

- Controls the evaporation of liquid **nitrogen** and a continuous flow of nitrogen into the CTD 600 MDR
- The nitrogen consumption is optimized depending on the required temperature to reduce operation costs
- Gas supply switches automatically to air or inert gas (e.g. nitrogen) above ambient temperature to cover the full temperature range of the CTD 600 MDR

#### Option 2: Customized gas chiller unit for temperatures down to -90 °C

- Uses **compressed gas (air or inert gas)**
- Minimized energy consumption, noise, and heat emission by automatically and continuously switching from the cooled gas to warm gas, depending on the temperature
- Perfect choice if the use of liquid nitrogen is prohibited by internal safety regulations.



### CTD 600 MDR

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

### READY FOR ALL MCR ACCESSORIES

By removing the linear drive the 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 solutions for characterizing materials at temperatures up to 1000 °C. 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

Specifications

Due to its 4-in-1 functionality MCR 702e MultiDrive offers the most comprehensive range of testing modes available for dynamic mechanical characterization. Given as examples 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. Dynamic mechanical analysis in torsion

To determine the viscoelastic properties and maximum service temperature of carbon-fiber-reinforced polymers (CFRP), usually absolute moduli values are of interest. This example shows the results of DMA in torsion performed with the rotational drive of the measuring device. The figure depicts three commonly used methods to measure the Tg (Onset of G', Peak of G'', and Peak of tan δ).

### 2. Dynamic mechanical analysis in bending

This example shows the results of DMA in bending of CFRP. Comparing the results of DMA in torsion and DMA in bending reveals that the viscoelastic properties of polymeric composites strongly depend on the deformation mode. Based on the anisotropic material behavior, the glass transition temperatures show different values in DMA in bending and in DMA in torsion.

### 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.

	Unit	Specifications
Linear drive for DMA in tension, bending, and compression		
Maximum force	N	40
Minimum force	N	0.0005
Maximum displacement	µm	9400 <sup>(1)</sup>
Minimum displacement	µm	0.01
Maximum frequency	Hz	100
Minimum frequency	Hz	0.001
Maximum temperature	°C	600 (950) <sup>(2)</sup>
Minimum temperature	°C	-160 <sup>(3)</sup>
Maximum heating rate	K/min	35 <sup>(2)</sup>
Maximum cooling rate	K/min	30 <sup>(3)</sup>

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 <sup>(4)</sup>
Maximum angular frequency	rad/s	628 <sup>(5)</sup>
Minimum angular frequency <sup>(6)</sup>	rad/s	10 <sup>-7</sup> <sup>(7)</sup>
Normal force range	N	-50 to + 50
Maximum temperature range	°C	-160 to +1000

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		✓
Rheology		✓
Thermomechanical analysis		✓
Toolmaster™, measuring system		✓
Toolmaster™, measuring cell		✓
QuickConnect for measuring systems, screwless		✓
T-Ready™		✓
Low temperature option, nitrogen evaporation unit		○
Low temperature option, customized gas chiller		○
Humidity option		○

✓ included | ○ optional

<sup>1)</sup> In oscillation a maximum displacement of ±4500 µm.  
<sup>2)</sup> In combination with CTD 600 MDR. Standard measuring systems are for use up to 350 °C. Measuring systems for testing up to 600 °C are available upon request.  
In combination with CTD 1000 customized solutions up to 950 °C are available upon request.  
<sup>3)</sup> In combination with CTD 600 MDR and low temperature option.  
<sup>4)</sup> In controlled shear stress (CSS) mode. In controlled shear rate (CSR) mode depending on measuring point duration and sampling rate.  
<sup>5)</sup> Higher frequencies are possible using multi-wave functionality (942 rad/s (150 Hz) or even higher, depending on measuring system and sample).  
<sup>6)</sup> Set frequencies below 10<sup>-4</sup> rad/s are of no practical relevance due to the measuring point duration >1 day.  
<sup>7)</sup> Theoretical value (duration per cycle = 2 years).



