Rheometrics Series Rheometers

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TA Instruments, Worldwide

More worldwide customers choose TA Instruments than any competitor as their preferred thermal analysis or rheology supplier. We earn this distinction by best meeting customer needs and expectations for high technology products, quality manufacturing, timely deliveries, excellent training, and superior after-sales support.

Sales and Service

We pride ourselves in the technical competence and professionalism of our sales force, whose only business is rheology and thermal analysis. TA Instruments is recognized worldwide for its prompt, courteous, and knowledgeable service staff. Their specialized knowledge and experience are major reasons why current customers increasingly endorse our company and products to their worldwide colleagues.

Innovative Engineering

TA Instruments is the recognized leader for supplying innovative technology, investing twice the industry average in research and development. The Rheometrics Series Rheometers provide a broad range of instruments, each featuring unique patented capabilities not offered by competitive suppliers. Only TA Instruments can offer the top-of-the-line rheometer with either technology.

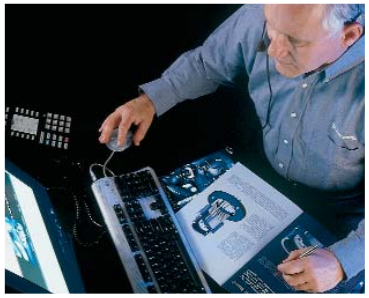
Quality Products

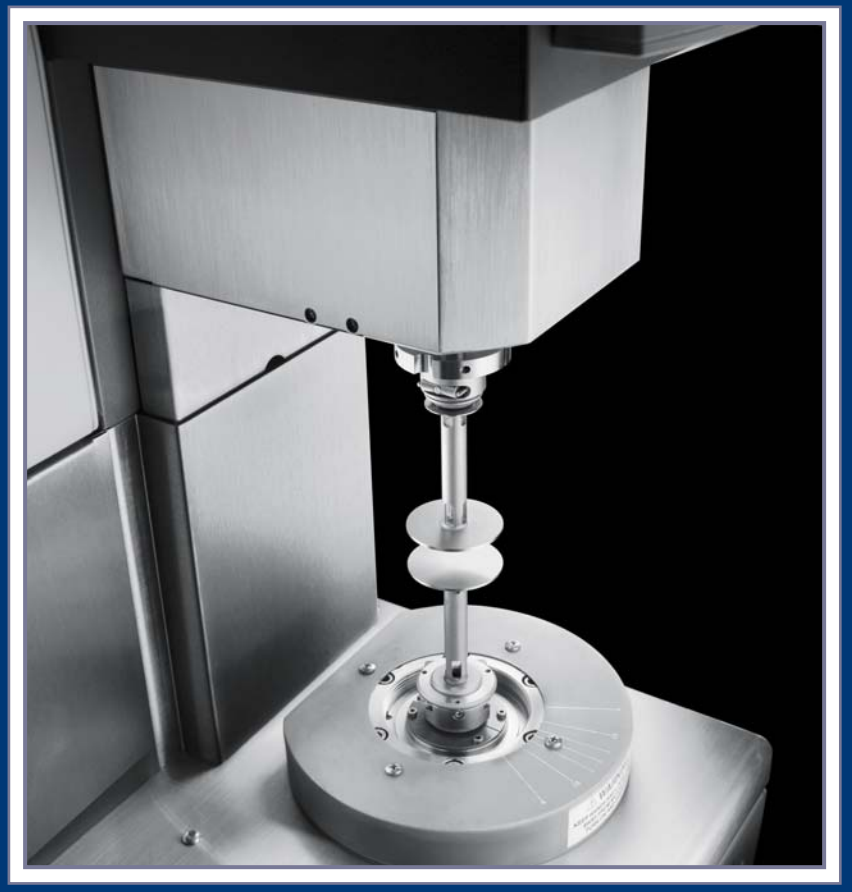
All rheometers and thermal analyzers are manufactured according to ISO 2000 procedures in our New Castle, DE (USA) or our Leatherhead, UK facilities. Innovative flow manufacturing procedures and a motivated, highly skilled work force ensure high quality products with industry leading delivery times.

Technical Support

Customers prefer TA Instruments because of our reputation for after-sales support. Our worldwide technical support staff is the largest and most experienced in the industry. They are accessible daily by telephone, email, or via our website. Multiple training opportunities are available including on-site training, seminars in our application labs around the world, and convenient web-based courses.





Rheometrics Series Rheometers - ARES

TA INSTRUMENTS

The name ARES is synonymous with high performance rheological measurements. The most pure rheological measurements are realized from the ARES unique separate motor and transducer design, available exclusively from TA Instruments. Strain is applied to a material via a high performance direct-drive motor and resultant stress is measured using patented transducer technology. ARES technology represents over 30 years of continued improvements based on input from the world's leading rheologists. Find out why ARES measurements are the standard to which all others are held.

RHEOMETRICS SERIES RHEOMETERS

ARES-LS

The ARES-LS is our most advanced rheometer, featuring our High Performance LS air bearing motor and patented Force Rebalance Transducer™ (FRT). The ARES-LS1 includes the 1KFRTN1 and is the only rheometer in the world capable of providing inertia-free dynamic measurements of low viscosity structured fluids. The ARES-LS2 with the 2KFRTN1 is an outstanding choice for medium to high viscosity materials including polymer melts and solids.

ARES

The ARES is an extremely capable and versatile all-purpose rheometer that incorporates the Standard HR Motor and the 2KFRTN1 Force Rebalance Transducer™. The ARES is appropriate for characterizing a diverse variety of materials including polymer melts, solids and reactive materials, as well as a broad spectrum of medium to high viscosity fluids. Measurements can be made over a wide range of temperatures using any of the available temperature control options.

ARES-RFS

For characterization of both the structure and flow properties of simple and complex fluids, the ARES-RFS is an excellent choice. Configured with the 1KFRTN1 Force Rebalance Transducer™ and the Standard HR motor, the ARES-RFS can solve the most demanding fluid rheology problems including dynamic oscillatory and shear rate controlled measurements on low viscosity structured fluids. The ARES-RFS is normally configured with the Peltier or Recirculating Bath temperature control option.

ARES-RDA

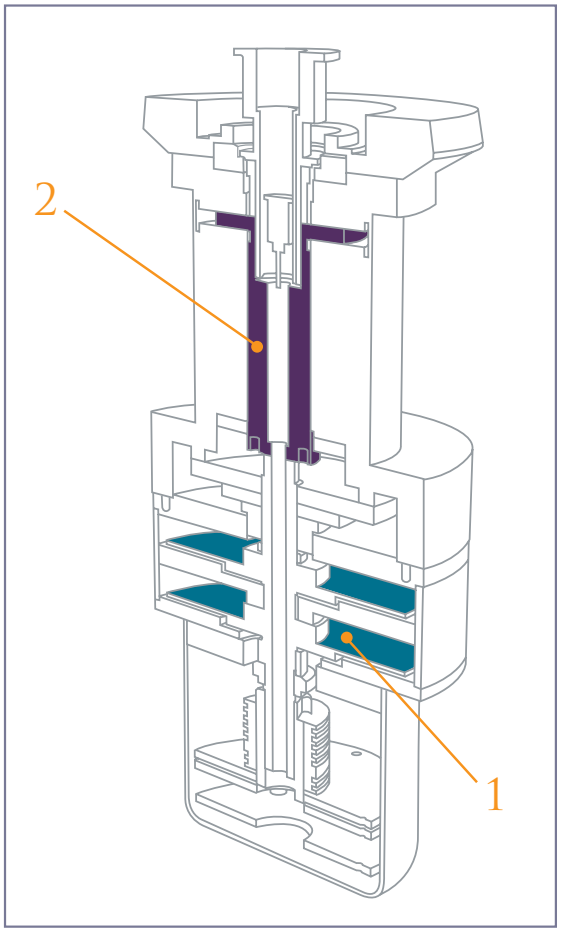
The ARES-RDA is a robust rheometer designed specifically for general rheological characterization of polymers, including thermoplastics, thermosets, and elastomers. The 2KSTD spring transducer is a durable design with excellent sensitivity, linearity, and stiffness over a wide dynamic range. Normally configured with the Forced Convection Oven (FCO), the ARES-RDA is the ideal choice for many analytical and QC labs with polymer characterization needs.

	ARES-LS2	ARES-LS1
Motor	High Performance LS	High Performance LS
Angular Velocity Range	$2x10^{-6}$ - 200 rad/s	$2x10^{-6}$ - 200 rad/s
Strain Amplitude	5 µrad - 500 mrad	5 µrad - 500 mrad
Angular Frequency	10^{-5} - 500 rad/s	10^{-5} - 200 rad/s
Transducer	2KFRTN1	1KFRTN1
Torque Range	2 µN.m - 200 mN.m	0.2 µN.m - 100 mN.m
Normal/Axial Force Range	0.002 - 20 N	0.002 - 20 N
Auto Gap Set	Standard	Standard
Motor Bearings	Jeweled Air	Jeweled Air
Peltier Plate	-30 to 150 °C	-30 to 150 °C
Bath	-10 to 150 °C	-10 to 150 °C
Forced Convection Oven (FCO)	-150 to 600 °C	-150 to 250 °C

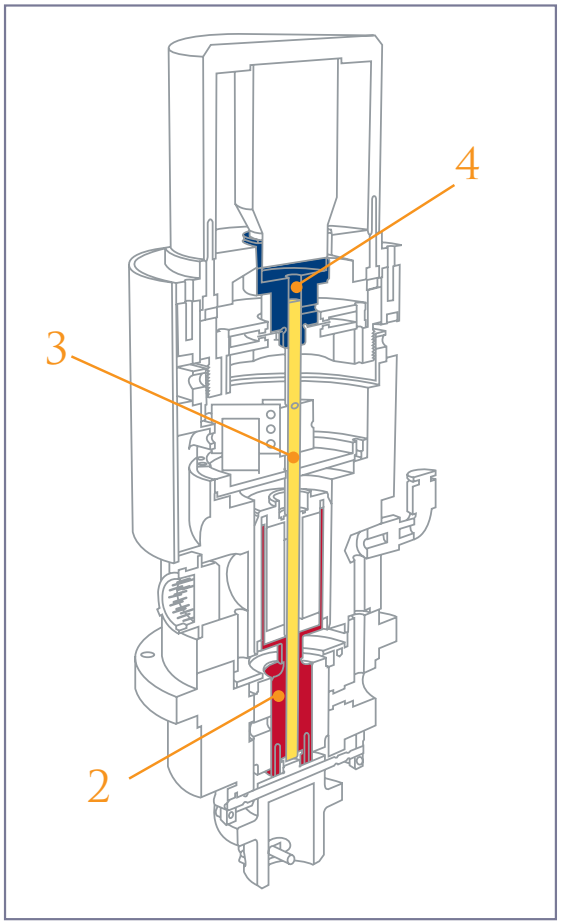
ARES	ARES-RFS	ARES-RDA
Standard HR	Standard HR	Standard HR
10^{-3} - 100 rad/s	10^{-3} - 100 rad/s	10^{-3} - 100 rad/s
5 µrad - 500 mrad	5 µrad - 500 mrad	5 µrad - 500 mrad
10^{-5} - 500 rad/s	10^{-5} - 200 rad/s	10^{-5} - 500 rad/s
2KFRTN1	1KFRTN1	2KSTD Spring
2 µN.m - 200 mN.m	0.2 µN.m - 100 mN.m	20 µN.m - 200 mN.m
0.01 - 20 N	0.01 - 20 N	Qualitative
Standard	Standard	Standard
Mechanical	Mechanical	Mechanical
-30 to 150°C	-30 to 150°C	-30 to 150°C
-10 to 150°C	-10 to 150°C	-10 to 150°C
-150 to 600°C	-150 to 250°C	-150 to 600°C

ARES Technology

Lower Assembly - Motor



Upper Assembly - Transducer



1 Drive Motor

Strain is applied to the sample via the High Performance LS motor in the ARES-LS, or the Standard HR motor in all other ARES rheometers. The motors are direct-drive, DC servo actuators that control strain, strain rate, and frequency. Benefits: Accurate measurements of flow properties and viscoelastic properties are possible, and the fast response ensures exceptional performance during transient tests such as stress relaxation.

2 Air Bearings

The High Performance LS motor incorporates sapphire “jeweled” air bearings that provide a very stiff, yet low friction means of supporting rotational motion. The sapphire inserts are used to ensure precise distribution of air within the bearing. Benefits: Air bearings reduce friction, improve normal force measurements, and ensure precise strain control.

•Frame Assembly & Linear Slide

All the components of the ARES Rheometers are housed in a rigid, cast steel frame with low compliance. The transducer (upper head) is attached to the frame via a linear slide. A motor drives the precision slide via a preloaded spindle to prevent backlash and an optical encoder measures the gap. Benefits: The low compliance, stiff housing and linear slide with optical encoder ensure that all measurements made are accurate and precise.

•Simultaneous Measurements

The ARES is available with several optional simultaneous measuring techniques. These include the Optical Analysis Module (OAM), that provides simultaneous optical and mechanical properties measurements. Optical measurements include birefringence, dichroism, and transmitted light intensity. Options are also available for simultaneous dielectric measurements and electrorheology. Benefits: Simultaneous measurements extend the range of applications.

3 Torque Transducer

ARES torque transducers measure the torque generated by the sample when the motor applies the deformation. The ARES-RDA is configured with a robust bendix spring transducer, while all other ARES rheometers are configured with one of two patented* Force Rebalance Transducers™ (FRT). In an FRT, a capacitive position sensor detects angular movement and a rotary motor measures the reaction torque to drive the geometry back to the original position. Benefits: The ARES-RDA spring transducer is robust and cost-effective, providing outstanding performance for general rheological testing of polymers. The FRT provides a wide torque range (up to 6 decades) with high torque sensitivity and negligible inertia. By decoupling the inertia of the system from the measurement, the FRT permits accurate and precise oscillatory measurements independent of sample viscosity.

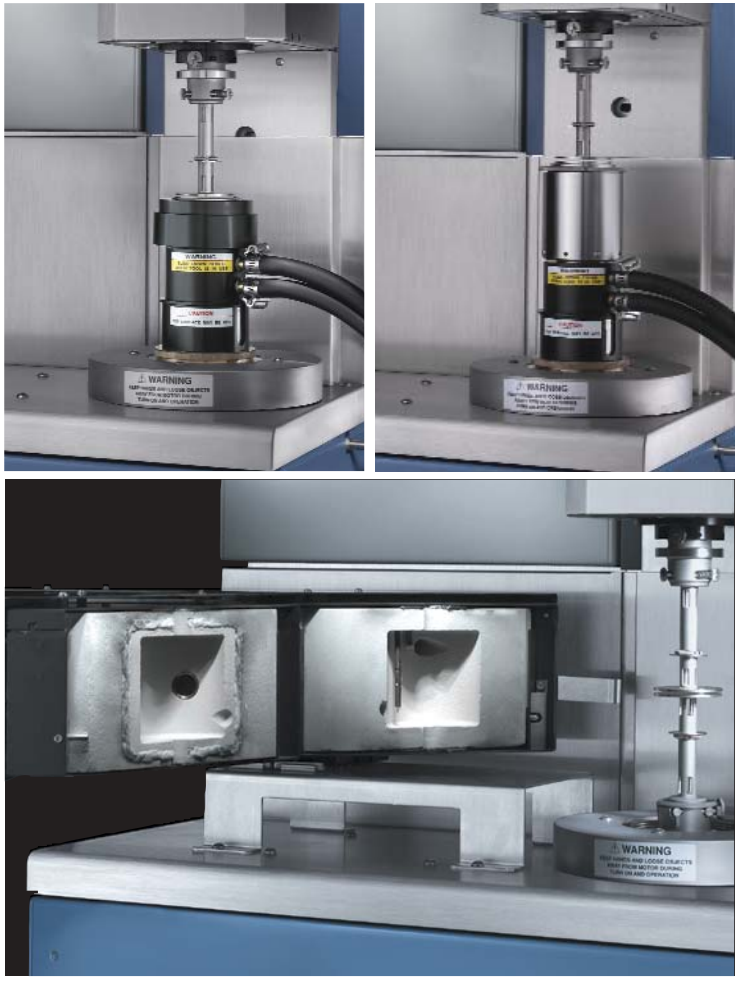
4 Normal Force Transducer

Normal force is measured on the ARES systems that use the FRT transducer. A capacitive position sensor detects a linear motion as a result of normal force being generated, and a linear motor provides a reaction force to drive the geometry to the null position. This reaction force is a quantitative measurement of normal force. Benefits: Quantitative normal force can be measured accurately in a wide range of applications. Where experimentally necessary, normal force can also be precisely controlled.

•Auto Gap Set

The gap can be automatically set using a variety of gap closure methods. Thermal Gap Compensation automatically corrects for any change in sample gap due to thermal expansion. Benefits: Automatic and reproducible setting of the gap ensures data accuracy and precision.

*U.S.Patent No. 4601195



Peltier Plate

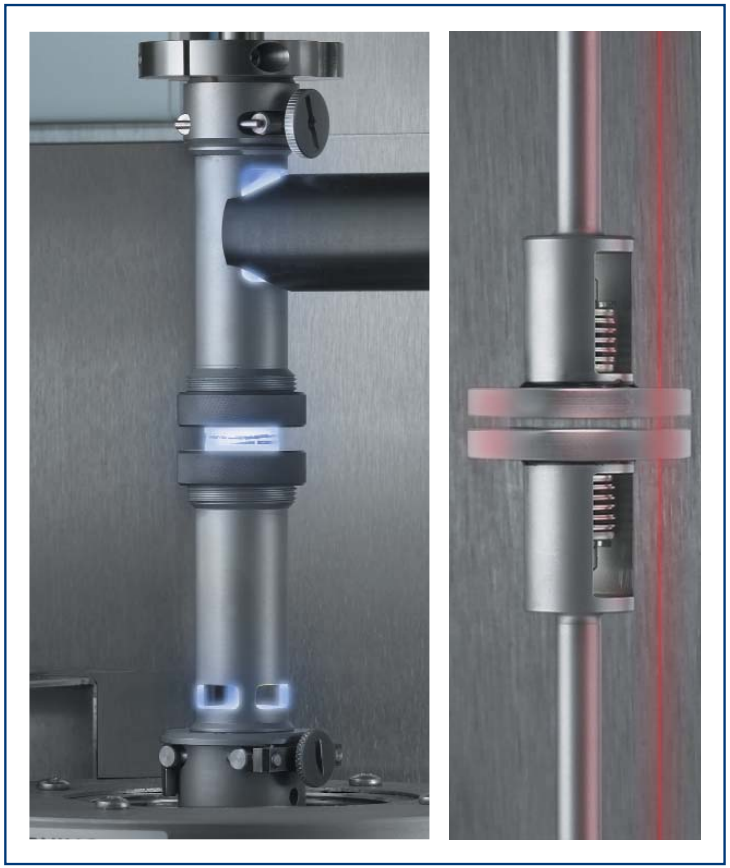
The Peltier Plate temperature control option is available for all models of the ARES Rheometer, and can be used with parallel plate and cone and plate geometries. With a temperature range of -30 to 150 ºC, it is the most common temperature control option for a variety of fluid applications. The open design facilitates easy sample loading and cleaning of geometries. A PRT (platinum resistance temperature) sensor is positioned in the middle of the lower sample plate and ensures accurate measurement and control of sample temperature. Maximum heating rate is 30 ºC/min with a temperature accuracy of +/- 0.1 ºC.

Recirculating Fluid Bath

The Recirculating Fluid Bath option can be used with parallel plate, cone and plate, and concentric cylinder geometries. Concentric cylinders are especially useful for very low viscosity fluids, dispersions of limited stability, and for applications where fluid/solvent evaporation may be a concern. This option is available for all modules of the ARES and can be supplied with a computer-controlled circulator for automated operation. The temperature range is -10 to 150 ºC with the appropriate circulating fluid.

Forced Convection Oven

The Forced Convection Oven (FCO) is an air convection oven with dual-element heaters and counter-rotating airflow for optimum temperature stability, and is used primarily for polymer melts and solids. The temperature range is -150 to 600 ºC with heating rates up to 60 ºC/min. Optional cooling devices include a liquid nitrogen cooling device for subambient operation to -150 ºC or a mechanical chiller for operation to -60 ºC. The FCO can be used with parallel plate, cone and plate, or torsional clamps for solids. Disposable plates are available for thermoset cures. The FCO includes a sight glass so that the sample can be viewed during the experiment.



Optical Analysis Module OAM II

The OAM II offers both parallel plates and concentric cylinder flow cells for fluids and melts. An optical train directs light through the flow cell at normal incidence. Transmitted light is received directly by a detector for dichroism measurements, or after passing through a circular polarizer for birefringence measurements. Applications include determination of the stress optical coefficient, separating the component dynamics in compatible polymer blends, analysis of polydomain structure in liquid crystals, and reorientation of internal structure under flow in dispersions (emulsions, suspensions).

UV-Curing and Photocuring Accessory

The UV-Curing Accessory includes tools with a reflecting mirror, removable quartz plates, and a light source interface. The Photocuring Accessory includes a high-pressure mercury lamp UV light source. The light source includes a broadband filter for transmitting 320-500 nm light at a maximum intensity of >12,000 mw/cm^2. When used with the new fast data sampling option, it is now possible to capture previously unobtainable data during fast curing reactions.

Electro-Rheological (ER) Analysis Option

The ER option allows study of rheological properties of materials under the influence of AC/DC voltages. The ER option is designed for use under ambient conditions or with the Peltier Environmental Control System, and is now available for use with both 1KFRT and 2KFRT transducers. The Option includes upper tool insulator assembly, oscilloscope, safety panels, interlocks, a high Voltage/ Current Amplifier with ability to apply up to 4000 Volt potential, up to 15 mA current (both AC & DC) and slew rate of 100 V/microseconds, and gain bandwith of 35 MHz.

Dielectric Analysis Option, DETA

The DETA provides simultaneous dielectric (permittivity, loss factor, tan delta) and rheological data (G', G", tan delta) during time and temperature testing. This option includes the Agilent 4284A LCR bridge, with frequency range of 20 Hz to 1 MHz and voltage range of 0.01 to 10 volts. Up to 10 frequencies can be entered for a test. Electrodes are 25 or 40 mm diameter stainless steel plates. The DETA option will work with the FCO up to temperatures of 350 °C.

Rheometrics Series Rheometers - AR

TA INSTRUMENTS

This is the world's best selling line of rheometers. The overwhelming acceptance of AR technology is due to the superior performance of TA's unique combined motor and transducer technology. AR rheometers use advanced non-contact induction motors to control stress and measure strain with a highly sensitive optical encoder. AR rheometers offer unparalleled controlled stress measurements and direct strain control. They are versatile by design and appropriate for a wide range of applications.

RHEOMETRICS SERIES RHEOMETERS

AR 2000

The AR 2000 is based on breakthrough motor and transducer technology and is the world's most popular rheometer. Its innovative Mobius Drive™ with porous carbon air bearings offers unprecedented controlled stress and direct strain performance. Smart Swap™ allows quick interchange of temperature control options. The AR 2000 is extremely versatile and appropriate for a wide variety of applications including fluids of any viscosity, polymer melts, solids, and reactive materials.

AR 1000

Designed as a research-grade rheometer, the AR 1000 incorporates a unique motor design with an advanced air bearing that provides excellent torque performance and low inertia. As with all AR Rheometers, it is designed for a broad range of applications, but is particularly well suited for fluids of any viscosity, soft solids, gels, and dispersions. Options include a normal/axial force sensor and multiple temperature control options.

AR 550

The AR 550 is a general purpose rheometer with many features of our research grade instruments including a durable air bearing, unique motor design, and optical encoder. The AR 550 is upgradeable and can grow as your applications expand, and can be equipped with a variety of temperature control options. It is ideal for users interested in a robust, cost-effective system with outstanding basic performance.

QCR

Are you ready to transfer rheological tests from the research lab to manufacturing facilities, or quality control labs? Based on the robust AR 550 and configured with Navigator software that provides automated operation, the QCR II automates the analysis of a broad range of samples. A key advantage of the system is that technicians can easily perform complicated rheological tests.

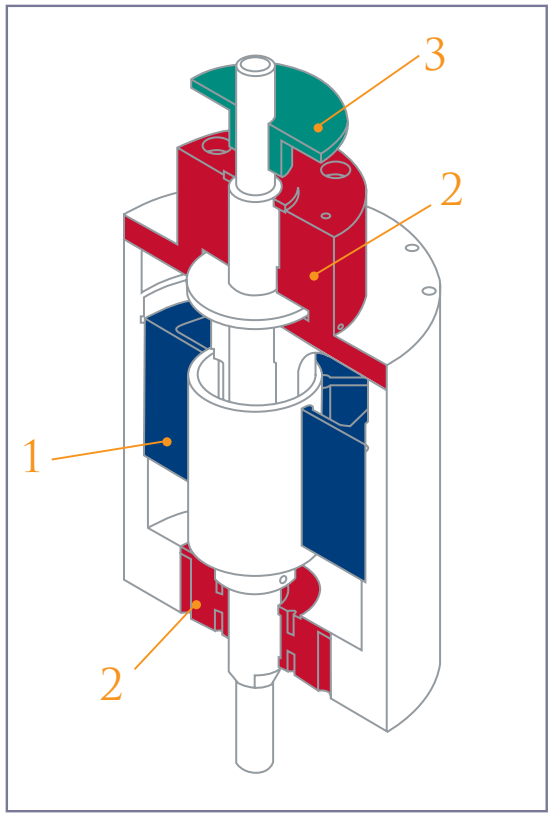
	AR 2000
Torque range CS	0.1 µN.m - 200 mN.m
Torque range CR	0.03 µN.m - 200 mN.m
Motor Inertia	15 µN.m.s^2
Angular Velocity Range CS	10^{-8} - 300 rad/s
Angular Velocity Range CR	10^{-4} - 300 rad/s
Mobius Drive™	Standard
Frequency Range	$7.5x10^{-7}$ - 628 rad/s
Displacement Resolution	0.04 µrad
Step change in velocity	30 ms
Step change in strain	60 ms
Step change in stress	<1 ms
Air Bearing	Porous Carbon
Auto Gap Set	Standard
Normal/Axial Force Range	0.005 - 50 N
Smart Swap™	Standard
Peltier Plate	-20 to 200 °C [2]
Environmental Test Chamber	-150 to 600 °C
Concentric Cylinder - Peltier Control	-10 to 150 °C[3]
Concentric Cylinder - Circulator	Not Available

AR 1000	AR 550 / QCR
0.1 µN.m - 100 mN.m	1 µN.m - 50 mN.m
0.1 µN.m - 100 mN.m	1 µN.m - 50 mN.m
14 µN.m.s^{2}	26 µN.m.s^{2}
10^{-8} - 100 rad/s	10^{-8} - 100 rad/s
10^{-3} - 100 rad/s	10^{-3} - 100 rad/s
Not Available	Not Available
6.3x10^{-4} - 628 rad/s	6.3x10^{-4} - 250 rad/s
0.62 µrad	0.62 µrad
1 s	1 s
Not Available	Not Available
<1 ms	<5 ms
Porous Carbon	Jet
Standard	Standard
0.01 - 50 N	0.01 - 50 N
Not Available	Not Available
-10 to 100 °C (1,2)	-10 to 150 °C(2)
-150 to 400 °C	-150 to 400 °C
Not Available	Not Available
-20 - 150 °C	-20 - 150 °C

[1]Extended Peltier available with temperature range -20 to 180 °C.
[2]Lower temperature can be reduced to -40 °C by use of a suitable fluid in the external circulator.
[3]Lower temperature can be reduced to -20 °C by use of a suitable fluid in the external circulator.

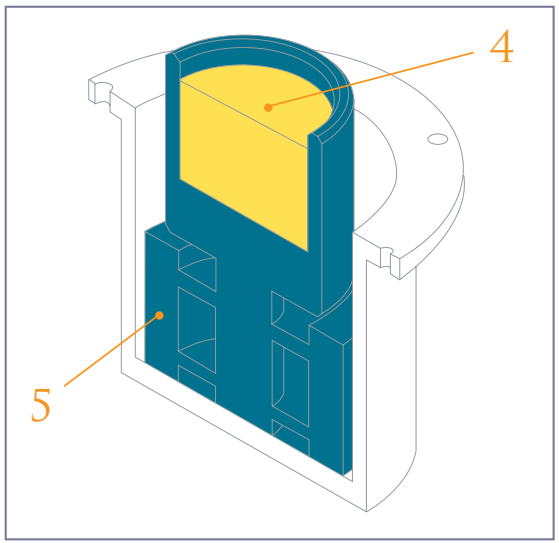
CS - controlled stress mode
CR - controlled rate mode

AR Technology



1 Drive Motor

The drive motors used on all AR rheometers are non-contact, induction designs that provide a broad torque range (6 decades) and excellent torque to inertia ratios. Competitive instruments attempt to obtain similar performance using synchronous motors with permanent magnets, which degrades the torque to inertia ratio and complicates recovery measurements. The Mobius Drive™ on the AR 2000 is specifically designed to provide superior controlled stress and strain performance. “Continuous Oscillation” is used for fast and accurate data collection in controlled strain oscillation. Benefit: A broad spectrum of materials can be studied from very low viscosity materials to polymer melts and solids using either controlled stress or strain. The absence of permanent magnets eliminates residual torque errors.



•Rigid One-Piece Aluminum Casting

The key components of the rheometer are mounted in this stiff, high mass casting. Benefit: Low system compliance with high mechanical integrity.

2 Air Bearings

Unique air bearings provide stiff, frictionless support of the drive shaft. Long life jet air bearings are used for the AR 550 and porous carbon bearings used on the AR 2000/1000 provide low levels of residual torque. Rotational Mapping automatically corrects for residual torque in the system. Benefits: The bearings provide excellent torque resolution and allow the application of a wide range of torque (stress). The porous carbon air bearings on the AR 2000/1000 extend the low torque performance.

3 Optical Encoder

The optical encoder measures angular deflection with high resolution. Benefit: Sample measurements can be conducted at low shear rates, small displacements (strain), and high velocities.

4 Smart Swap™

All temperature control options on the AR 2000 are attached to the instrument on this unique, magnetic base. The instrument automatically senses which device is connected and sets the instrument parameters accordingly. Benefit: The Smart Swap base allows rapid exchange of temperature control options while maintaining precise location.

5 Normal Force Transducer

This highly sensitive, ultra-stiff transducer is located below the Smart Swap base. Eight environmentally isolated strain gauges provide a direct measure of normal force. Benefits: Quantitative normal forces exhibited by materials with different viscoelastic properties are measured. Normal forces generated during sample loading can be controlled and monitored.

•Linear Ball Slide

The motor, air bearing, and optical encoder head assembly are all attached to the base casting via a linear ball slide. A motor in the base drives the high precision slide vertically. An optical encoder is located in the base to measure movement of the slide. Benefits: Precise geometry location relative to the sample is assured. The long travel permitted by the ball slide allows for a large working space to simplify sample loading and cleaning.

•Auto Gap Set

The gap can be automatically set using a variety of gap closure methods including linear, exponential, and by normal force. Thermal Gap Compensation automatically corrects for any change in sample gap due to thermal expansion. Benefits: Automatic and reproducible setting of the gap ensures data accuracy and precision. Monitoring normal force during gap closure ensures that delicate structures are not damaged.

Peltier Plate

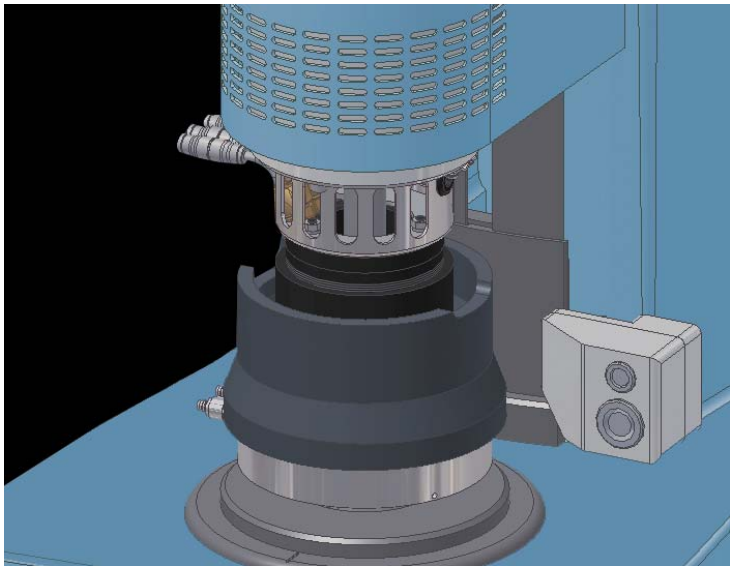
The most common temperature control option for the AR rheometers is the Peltier Plate. For the AR 2000, the Peltier Plate is based on the Smart Swap™ technology, and has a temperature range of -20 to 200 ºC with a typical heating rate of up to 20 ºC /min. and a temperature accuracy of +/- 0.1 ºC. A PRT (platinum resistance temperature) sensor positioned at the center of the plate ensures accurate temperature measurement and control. Smart Swap allows temperature control options to be changed quickly, and the intelligent firmware automatically senses the type of device present, configures the software accordingly, and loads all relevant calibration data.

Concentric Cylinder

Concentric Cylinders are commonly used for very low viscosity fluids, dispersions of limited stability, and for applications where fluid/solvent evaporation may be a problem. For the AR 1000/550, the Concentric Cylinder System uses an external fluid circulator to precisely control temperature. The AR 2000 Smart Swap Concentric Cylinder System features Peltier temperature control and provides a temperature range of -10 to 150 ºC with heating rates of up to 15 ºC/min.

Environmental Test Chamber

The ETC is typically utilized for polymer applications and can be used with parallel plate, cone and plate, disposable plates, and torsion clamps. The design is based on a controlled convection/radiant-heating concept. The ETC for the AR1000/550 has a temperature range of -150 to 400 ºC with heating rates up to 15 ºC/min. The Smart Swap ETC for the AR 2000 has a temperature range of -150 to 600 ºC with heating rates up to 20ºC/min. For subambient operation, the ETC can be connected to a bulk liquid nitrogen source.



Starch Pasting Cell (SPC)

The SPC is a new Smart Swap™ cell designed with leading scientists at one of the world's largest starch producers. It is the most powerful and accurate tool for enhanced rheological characterization of the gelatinization process and final properties of starch products. The SPC uses TA's innovative new impeller design for superior mixing and control of sedimentation during testing. A precision temperature controlled chamber, with heating/cooling rates of up to 30 °C per minute, controls and measures actual sample temperature and is designed to minimize water loss during the cooking cycle.

Pressure Cell

The Pressure Cell is an optional accessory for use with the Peltier controlled Smart Swap Concentric Cylinder System. The Pressure Cell is a sealed vessel that can be pressurized to 140 bar (2000 PSI), over a temperature range of -10 °C to 150 °C. The Cylinder in the vessel is driven using an innovative high-powered magnetic coupling and low-friction bearing design. The cell is ideal for characterizing materials that volatilize under atmospheric pressure.

Peltier Upper Heated Plate (UHP)

The UHP is designed for use with the Smart Swap Peltier Plate and provides both upper plate temperature control and an enclosed purge gas environment. Designed for optimum heat transfer and minimum thermal equilibration time, the UHP sets a new standard in non-contact heating. Automated zero heat flow calibration yields temperature gradients of +/- 0.1 °C. The UHP is modeled to provide matched upper and lower plate temperature during heating ramps of up to 15 °C/min to a maximum temperature of 150 °C. The UHP features cone and plate sizes up to 50 mm in diameter and can be used with special 25 mm and 8mm plates for asphalt testing. Flexible cooling options include an external circulator, or innovative new vortex cooling.

The ARES and AR Rheometers with powerful and user-friendly software, combined with the appropriate accessories and geometries, provide rapid characterization (with complete mathematical data modeling) of a broad range of materials from water to asphalt (~12 decades in viscosity). Commonly analyzed groups of materials include oils, gels, dispersions, pastes, slurries and polymers (melts and solids). Rheology is used in new product research, prediction of end-use properties, competitive comparisons, selection of processing conditions, and quality control.

Materials	Process/Product Concerns	Related & Measurable Rheological Properties
Polymers - Thermoplastics	Processability and Product Performance	Viscosity, Shear Thinning, Elasticity, Compliance
	Die Swell	Normal Force
	Structure (MW, MWD)	Elasticity, Viscosity Profile, Zero Shear Viscosity (η_0)
	Effects of Branching, Fillers, Melt Flow	Changes in η_0, Elasticity, Compliance
	Regrind Materials - Detection & Use	Comparison of Viscoelastic Properties (η_0, G^I, G^{II}, tan d, compliance) with virgin material
Polymers - Thermosets	Minimum Viscosity	Minimum in Viscosity Profile
	Gel Point (Time / Temperature)	Intersection of Storage (G^I) & Loss (G^{II}) Moduli
	Cure Profile / Cure Kinetics	Examine Modulus Profile with Temperature or Time (G^I, G^{II} vs T or t)
	Cross-link Density	Examine Plateau Modulus (G^I) - is G^I in acceptable range?
Polymers - Elastomers	Cross-link Density	Examine Plateau Modulus (G^I) or Complex Viscosity (η^*) Profiles
	Effect of Fillers	Comparison of Viscoelastic Properties (G^I, G^{II}, η^*)
	Effect of Compounding	Strain Dependence of the Material (Length of Linear Viscoelastic Region)
	Tire Traction / Tire Wear	Examine G^I, G^{II}, tan d
Adhesives	Tack and Peel Characteristics	Frequency / Time Dependence of G^I, G^{II}
	Dalquist Criterion (pressure sensitive)	Examine Plateau Modulus - is G^I in acceptable range?
Coatings - Paints	Ease of Application	Viscosity, Shear Thinning, Yield Stress
	Sagging - Brush, Spray Applications	Elasticity, Structure Recovery
	Leveling - Brush Applications	Elasticity, Structure Recovery
	Ribbing - Roller Applications	Viscoelastic Profile, Elasticity, Structure Recovery
	Spatter	Normal Force, Elasticity

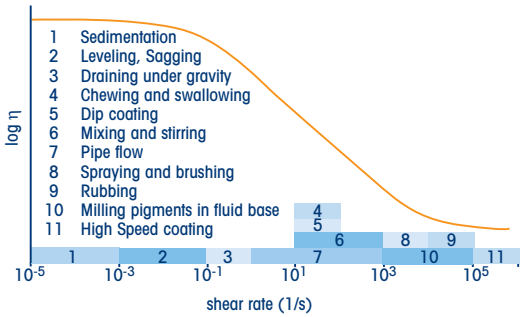
The chart below relates the major material classifications and process/product concerns, with the rheological properties that can be measured using TA Instruments rheometers. The specific TA Instruments rheometer required will depend on the particular type of test and the nature of the material, along with the rheometer performance required. Contact your local TA Instruments representative for advice on the optimum configuration for your application.

Materials	Process/Product Concerns	Related & Measurable Rheological Properties
Coatings - Inks	Stability / Shelf Life Flowability	Examine Linear Viscoelastic Region (G^{l} versus Time), Resistance to Creep Viscosity at a Given Temperature
Coatings - Powders	Flowability	Viscosity at a Given Temperature
Foods - Pastes, Gels, Dispersions (Suspensions, Emulsion)	Stability / Shelf Life Phase Separation Gelation Product Consistency / Texture Pourability & Dispensing under Pressure	Examine Linear Viscoelastic Region (G^{l} vs Time), Resistance to Creep Change of Structure with Time Gain of Structure, Elasticity Viscosity and Viscoelastic Behavior Viscosity, Shear Thinning
Pharmaceuticals & Personal Care products - Pastes, Gel Dispersions (Suspensions, Emulsions)	Stability / Shelf life Phase Separations Application to Skin / Skin Feel Gelation Pourability, Pumping (in Plant)	Examine Linear Viscoelastic Region (G^{l} vs Time), Resistance to Creep Change of Structure with Time Viscosity, Shear Thinning, Structure Breakdown / Recovery Gain of Structure, Elasticity Viscosity, Shear Thinning
Ceramics - Slurries	Stability / Shelf life Pouring, Pumping Slip Casting, Casting Performance	Examine Linear Viscoelastic Region (G^{l} versus Time), Resistance to Creep Viscosity at a Given Temperature Viscosity, Yield Stress, Structure Changes
Oils, Greases, Lubricants	Oils - Pouring, Pumping Effects of Modifiers Outwaxing of Crude Oils Greases / Lubes - Composition, Structure Mixing & Lubrication	Viscosity at a Given Temperature, Compliance Viscosity, Shear Thinning, Structure Changes Viscosity at a Given Temperature Structure and Viscosity Changes Viscosity Profile, Yield Stress, Compliance, Structure Changes

Flow Curve for Dispersions

A generalized flow curve for dispersions is illustrated in Figure 1. TA rheometers generate flow curves by applying a stress ramp (or shear rate) and measuring the shear rate (or stress). Flow curves can also be produced using "steady state" flow where each viscosity data point is generated at a constant stress after equilibration. The data generated provides information on yield stress, viscosity, shear thinning and thixotropy, and correlates to real world processes. Simple techniques like spindle viscometers can only measure a point or a small part of the total curve.

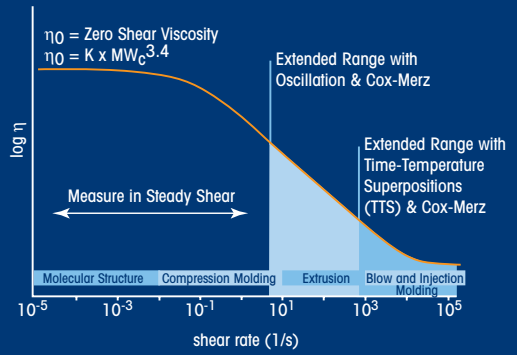
FIGURE 1
Flow Curve For Dispersions



Flow Curve for Polymers

Figure 2 shows a generalized flow curve for polymers and corresponding process shear rate ranges. A polymer's molecular weight greatly influences its viscosity, while its molecular weight distribution and degree of branching affect its shear rate dependence. These differences are most apparent at low shear rates not possible with melt flow index or capillary devices. TA rheometers can determine molecular weight based on the measured zero shear viscosity. Cox-Merz and TTS can be used to extend the data to higher shear rates.

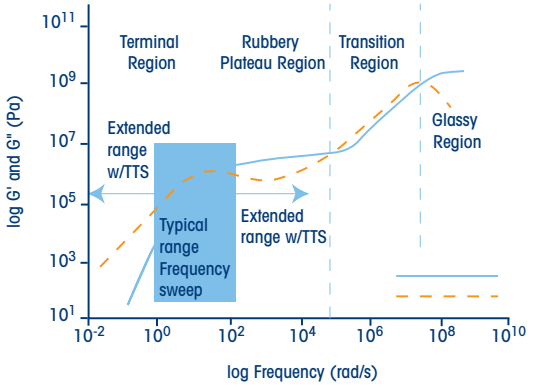
FIGURE 2
Flow Curve For Polymers



Viscoelastic Properties

The viscoelastic properties of polymer melts are commonly studied in the dynamic oscillation mode. Figure 3 illustrates a viscoelastic fingerprint, or master curve, for a linear homopolymer and shows the variation of the storage modulus (G') and loss modulus (G'') with frequency. As polymer melts are viscoelastic, the mechanical response will be time dependent, so low frequencies correspond to long times. TTS is used to extend the range of data to higher and lower frequencies. The magnitude and shape of the G' and G'' curves depends on the molecular structure of the polymer.

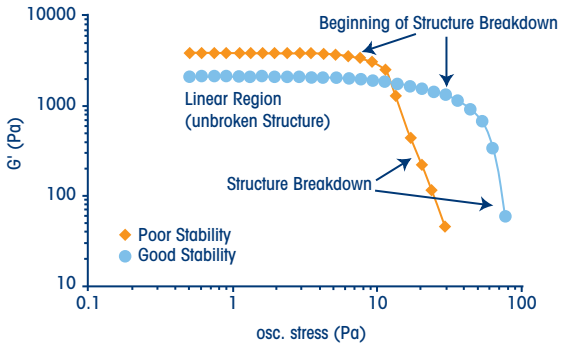
FIGURE 3
Frequency Sweep: Material Response



Oscillation Stress or Strain Sweeps

Key viscoelastic parameters (G^{I}, G^{II}, η^*, tan delta, etc.) can be measured in oscillation as a function of stress, strain, frequency, temperature or time. Figure 4 illustrates a common oscillation stress sweep used to determine the linear viscoelastic region (LVR) and to investigate dispersion stability. In the LVR, the material responds linearly to the stress or strain (elastic) and the structure remains unbroken. Once the structure has been broken, G^{I} becomes dependent on the stress. Similar studies can be conducted as a function of strain.

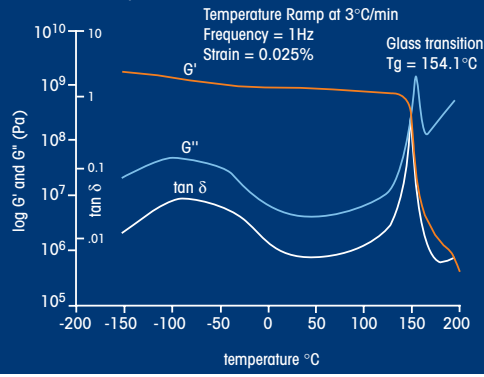
FIGURE 4
Oscillation Stress Sweeps on Ink Dispersions



Dynamic Mechanical Properties of Solids in Torsion

The ability to characterize the viscoelastic properties of solids in torsion is a feature of TA Instrument's rheometers as illustrated in Figure 5 for polycarbonate (PC). Transitions or relaxations of molecular segments are observed as step changes in the storage modulus, and as peaks in the loss modulus and damping. The magnitude and shape of the storage modulus (G^{I}), loss modulus (G^{II}) and damping (tan delta) will depend on chemical composition, crystallinity, molecular structure, degree of cross-linking, and the type and amount of fillers.

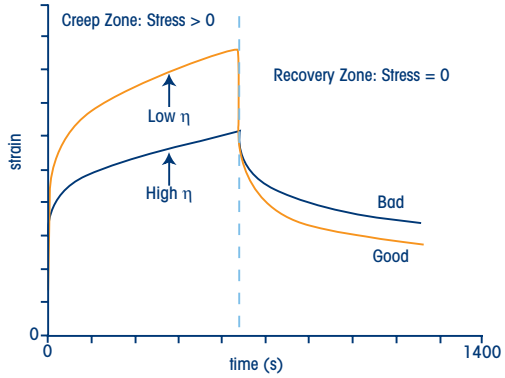
FIGURE 5
PC - Polycarbonate



Transient Tests (Creep and Stress Relaxation)

In a creep recovery test, illustrated in Figure 6, a constant stress is applied to the sample and the resulting strain is measured with time. The stress is then removed and the recovery (recoil) strain is measured. For polymer melts, the zero shear viscosity (η_0) and equilibrium recoverable compliance ($J^{o}e$) can be determined. Creep is a sensitive technique and best suited for the unmatched stress control performance of the AR. In a stress relaxation test a strain is applied and stress is measured as a function of time yielding stress relaxation modulus G(t). Stress relaxation can be performed on all ARES and on the AR 2000 with direct strain control.

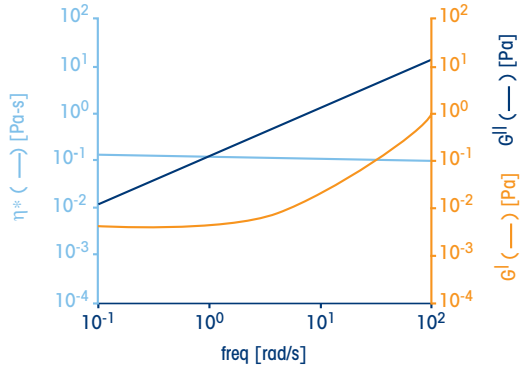
FIGURE 6
Creep Curves of Paint Samples



Dynamic Oscillation on Low Viscosity Fluids Using ARES

An advantage of the ARES design is that the motor generates the torque to overcome the viscosity of the material as well as the inertia of the sample holder. As a result, the ARES can be used to conduct inertia free measurements on the viscoelastic properties of very low viscosity fluids. Figure 7 shows an example of this for a polymer solution, where the viscoelastic parameters are determined using a frequency sweep up to 100 rad/s with no inertial effects.

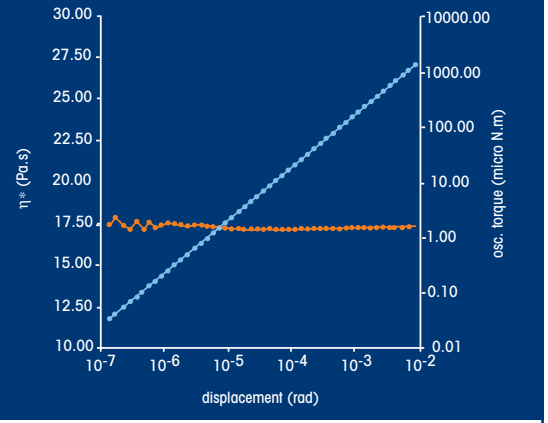
FIGURE 7
Dynamic Oscillation on Low Viscosity Fluids Using ARES



AR 2000 Direct Strain Control with Enhanced Data Accuracy

The enhanced Mobius™ Drive of the AR 2000 speeds data collection through the ability to directly control strain in a single oscillation cycle. This advanced feature of Mobius Drive called Continuous Oscillation, not only speeds data acquisition but also improves data accuracy. Figure 8 shows an example of an oscillatory strain sweep on standard oil using these advanced features. Accurate viscosity can be obtained at amplitudes as low as $9x10^{-7}$ rad and oscillatory torques of 0.03 µN.m.

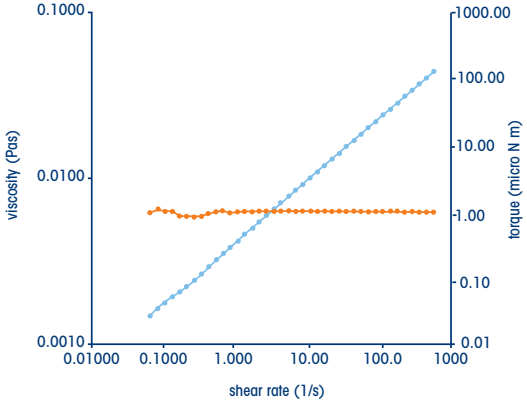
FIGURE 8
Controlled Strain in Oscillation on AR2000 with Mobius Drive™



Controlled Shear Rate with Extended Low Torque Performance

Another benefit of the Enhanced Mobius Drive of the AR 2000 is the ability to extend the low torque performance for controlled rate, steady shear flow tests. This is made possible through the "advanced mapping" routines of the Mobius Drive technology. Figure 9 provides an illustration of the result on a standard oil. Accurate viscosity data can be obtained at torques as low as 0.05 µN.m. The benefit of this capability is that the AR 2000 can accurately measure flow properties of very low viscosity materials.

FIGURE 9
Controlled Strain in Flow on AR2000 with Mobius Drive™



Rheometrics Series Geometries

TA Instruments offers a wide range of measurement geometries including parallel plate, cone and plate, concentric cylinder, disposable, and torsion solid clamps.

Parallel plate and cone and plate geometries are available for both the ARES and AR Rheometers in an extensive variety of diameters and cone angles. Materials of construction include stainless steel, aluminum, plastic (Acrylic/PPS), or titanium. Disposable plates and cones are also available for applications such as thermoset curing.

A wide selection of concentric cylinder geometries is available for both the ARES and AR Rheometers. Options include conical DIN, recessed, vaned, and double wall. For the ARES rheometers, the geometries are constructed of stainless steel and titanium. For the AR rheometers, stainless steel and anodized aluminum are used.

A variety of other geometries are available for both the ARES and AR Rheometers, including clamps to measure solids in torsion using the high temperature ovens and immersion clamps. The ARES is available with many specialty fixtures including linear tack-testing fixtures, glass plates for optical measurements, and film/fiber fixtures.