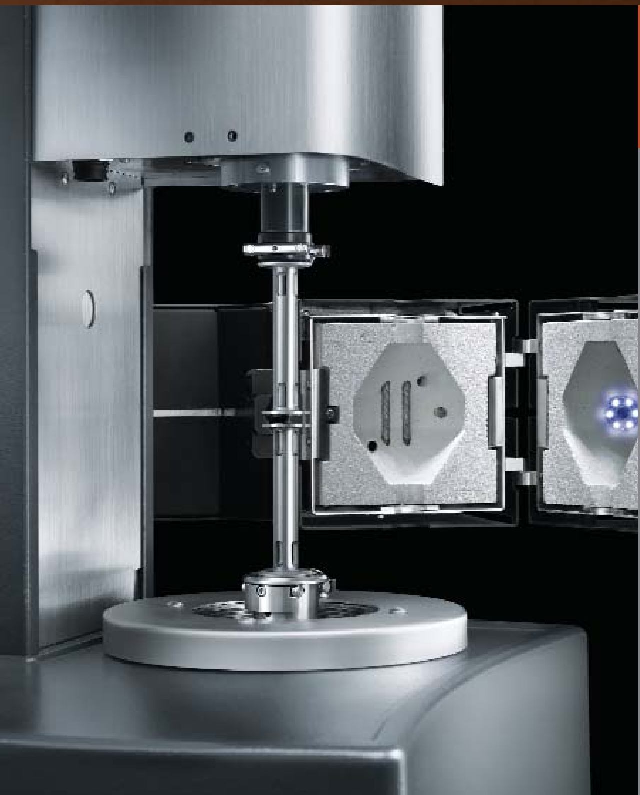
TA Instruments



Rheometers

Local Offices

New Castle, DE USA	+1-302-427-4000
Lindon, UT USA	+1-801-763-1500
Hialeah, FL USA	+1-305-828-4700
Crawley, United Kingdom	+44-1293-658900
Shanghai, China	+86-21-64956999
Taipei, Taiwan	+88-62-25638880
Tokyo, Japan	+81-3-5759-8500
Seoul, Korea	+82-2-3415-1500
Bangalore, India	+91-80-2319-4177-79
Paris, France	+33-1-30-48-94-60
Eschborn, Germany	+49-6196-400-600
Brussels, Belgium	+32-2-706-0080
Etten-Leur, Netherlands	+31-76-508-7270
Sollentuna, Sweden	+46-8-555-11-521
Milano, Italy	+39-02-265-0983
Barcelona, Spain	+34-93-600-93-32
Melbourne, Australia	+61-3-9553-0813
Mexico City, Mexico	+52-55-52-00-18-60

ARES-G2

AR Rheometers

AR

SENSITIVE ‣ VERSATILE ‣ RELIABLE


AR
1500
ex
Flow
Release

AR-G2

TA Instruments is proud to announce another breakthrough in rheometer technology. The new AR-G2 is the first commercial rheometer with patented[1] magnetic thrust bearing technology for ultra-low, nano-torque control. The AR-G2 is packed with new features including new patented[2] advanced drag cup motor technology, Smart Swap™ [3] Geometries, streaming video and image capture software, ETC camera viewer and ethernet communications. With improvements in nearly every rheometer specification, the performance of the AR-G2 stands alone. It is the most advanced controlled stress, direct strain and controlled rate rheometer available.

(1) Patent # 7,017,393 (2) Patent # 6,798,099 (3) Patent # 6,952,950

Technical Specifications

Minimum Torque Oscillation CR	0.003 µN.m
Minimum Torque Oscillation CS	0.003 µN.m
Minimum Torque Steady CR	0.01 µN.m
Minimum Torque Steady CS	0.01 µN.m
Maximum Torque	200 mN.m
Torque Resolution	0.1 nN.m[1]
Motor Inertia	18 µN.m.s
Angular Velocity Range CS	0 to 300 rad/s
Angular Velocity Range CR	$1.4E^{-9}$ to 300 rad/s
Frequency Range	$7.5E^{-7}$ to 628 rad/s
Displacement Resolution	25 nrad
Step Change in Velocity	7 ms
Step Change in Strain	30 ms
Direct Strain Control	Standard[2]
Thrust Bearing	Magnetic
Normal/Axial Force Range	0.005 to 50 N
Smart Swap™	Standard
Smart Swap Geometry	Standard
Peltier Plate	-40 to 200 °C[3]
Environmental Test Chamber (ETC)	-160 to 600 °C
ETC Camera Viewer	Optional
Concentric Cylinder	-20 to 150 °C[3] Peltier Control
Upper Heated Plate	-30 to 150 °C[3]
Electrically Heated Plate (EHP)	-70 to 400 °C
Camera Option with Streaming Video and Image Capture	Optional

CR - Controlled Rate Mode
CS - Controlled Stress Mode
[1] Internal Resolution for D to A converter at torque of 0.1 µN.m
[2] Direct Strain Control provides single cycle oscillation and continuous oscillations during experiments.
[3] Lower temperature limits require use of a suitable fluid in an external circulator.

AR 2000ex

The AR 2000ex brings an all new electronics package to the time-tested hardware of the world's best selling rheometer, further extending the long list of unique features. The AR 2000ex rheometer design includes a unique, ultra-low inertia drag cup motor and porous carbon air bearings for outstanding controlled stress, direct strain and controlled rate performance. The AR 2000ex features the original Smart Swap™ quick interchanging and self-configuring environmental systems. Enhanced features of the AR 2000ex include the new ETC with fast heating rates, ETC and Peltier Camera Viewers (with image capture software), a new Electrically Heated Plate Temperature System, and ethernet communications. The AR 2000ex is extremely versatile and appropriate for a wide variety of applications including fluids of any viscosity, polymer melts, solids and reactive materials.

Technical Specifications

Minimum Torque Oscillation CR	0.03 µN.m
Minimum Torque Oscillation CS	0.1 µN.m
Minimum Torque Steady CR	0.05 µN.m
Minimum Torque Steady CS	0.1 µN.m
Maximum Torque	200 mN.m
Torque Resolution	1 nN.m[1]
Motor Inertia	15 µN.m.s
Angular Velocity Range CS	0 to 300 rad/s
Angular Velocity Range CR	$1E^{-8}$ to 300 rad/s
Frequency Range	$7.5E^{-7}$ to 628 rad/s
Displacement Resolution	40 nrad
Step Change in Velocity	25 ms
Step Change in Strain	60 ms
Direct Strain Control	Standard[2]
Thrust Bearing	Porous Carbon Air
Normal/Axial Force Range	0.005 to 50 N
Smart Swap™	Standard
Peltier Plate	-40 to 200 °C[3]
Environmental Test Chamber (ETC)	-160 to 600 °C
Concentric Cylinder	-20 to 150 °C[3] Peltier Control
Upper Heated Plate	-30 to 150 °C[3]
Electrically Heated Plate (EHP)	-70 to 400 °C

CR - Controlled Rate Mode
CS - Controlled Stress Mode
[1] Internal Resolution for D to A converter at torque of 0.1 µN.m
[2] Direct Strain Control provides single cycle oscillation and continuous oscillations during experiments.
[3] Lower temperature limits require use of a suitable fluid in an external circulator.

AR 1500ex

The new AR 1500ex is a highly sensitive and rugged general-purpose rheometer for fluids and soft solids. It includes many of the same design features incorporated in our AR-G2 and AR 2000ex, such as high-resolution optical encoder, durable porous carbon bearings with low residual torque, and a low-inertia drag cup motor. The AR 1500ex has broad specification ranges and a wide variety of popular Smart Swap™ temperature systems including Peltier Plates, Peltier Concentric Cylinder, Electrically Heated Plates, and both a Dry Asphalt System and Asphalt Submersion Cell. The AR 1500ex offers unprecedented value in a robust cost-effective package for both research and quality control.

Technical Specifications

Minimum Torque	0.1 μN.m
Maximum Torque	150 mN.m
Torque Resolution	1 nN.m[1]
Motor Inertia	15 μN.m.s
Angular Velocity Range CS	0 to 300 rad/s
Angular Velocity Range CR	1.00E^{-7} to 300 rad/s
Frequency Range	7.50E^{-7} to 628 rad/s
Displacement Resolution	40 nrad
Step Change in Velocity	25ms
Step Change in Strain	60ms
Thrust Air Bearing	Porous Carbon
Smart Swap™	Standard
Peltier Plate	-40 to 200 °C[2]
Peltier Plate Camera	Optional
Peltier Concentric Cylinder	-20 to 150 °C[2]
Upper Heated Plate	-30 to 150 °C[2]
Electrical Heated Plates	-70 to 400 °C

[1] Internal Resolution for D to A converter at torque of 1 μN.m
[2] Lower temperature limits require use of a suitable fluid in an external circulator.

AR Technology

The AR series represents a family of rheometers uniquely designed to deliver optimum system performance.

1 Drag Cup Motor

The motor applies torque, and controls speed and oscillation frequency. Drag cup motors, unlike some motor designs, can apply extremely smooth acceleration and are ideal for creep and recovery measurements. Inertia is kept to an absolute minimum, reducing the influence of the system on test results in oscillation and transient measurements. The result is more accurate measurements of weak material structures and faster response to step changes in torque and strain.

2 Thrust Bearing

Thrust bearings provide stiff, "frictionless" axial support of the drive shaft and measuring geometry. The low-end torque performance of the instrument depends on residual bearing friction, which results in residual torques. The AR-G2 incorporates the new magnetic thrust bearing while the AR 2000ex and AR 1500ex use porous carbon bearings.

3 Radial Bearings

Radial air bearings provide stiffness and support in the radial direction. All AR Rheometers are uniquely designed with two porous carbon radial bearings. The dual radial bearing design is ideal for the testing of high-stiffness samples, such as solids in torsion as well as soft solids and low-viscosity fluids.

4 Optical Encoder

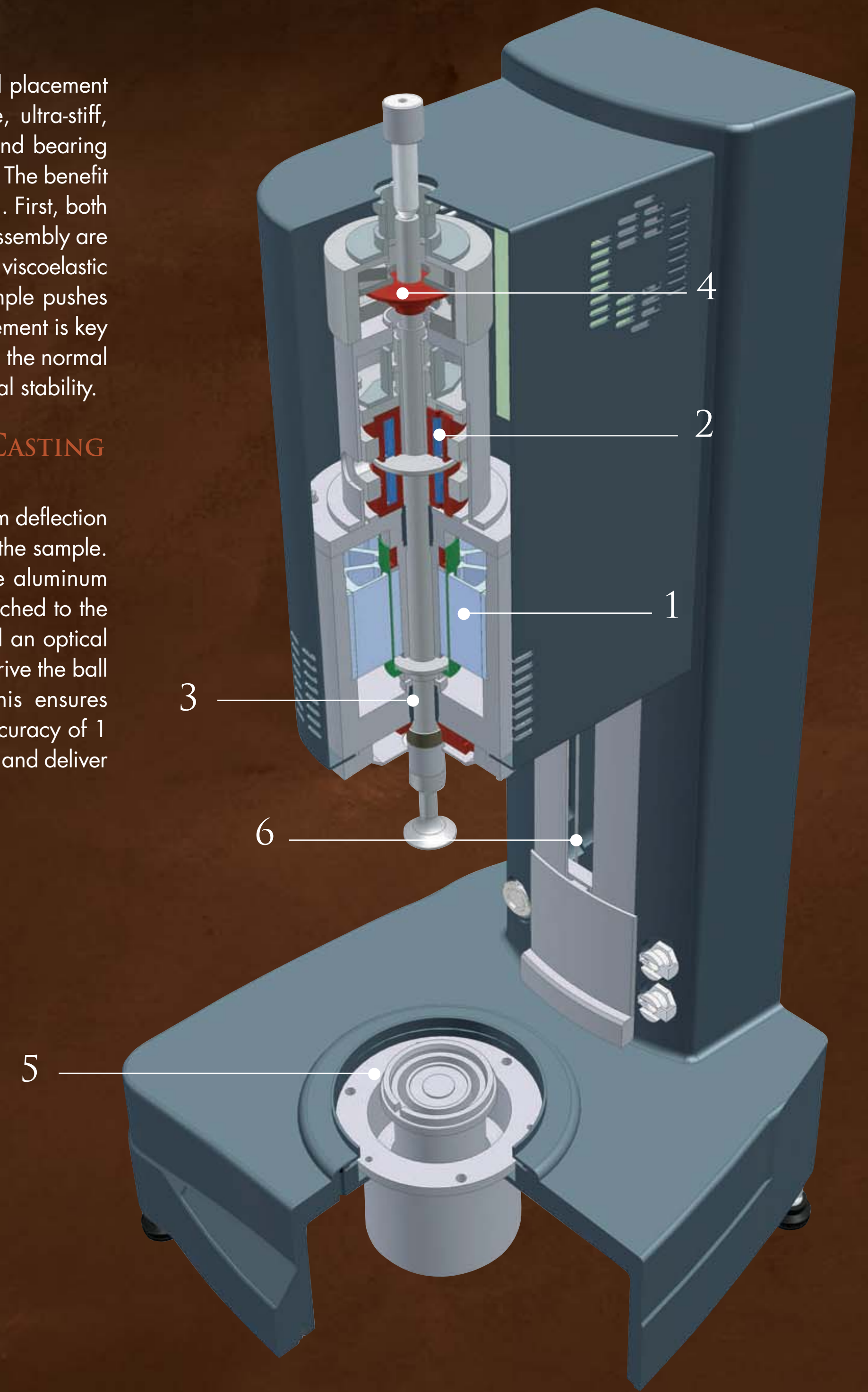
Low-inertia optical encoders are used in all AR rheometers for high-resolution measurement of angular displacement (strain) and speed (shear rate) over wide ranges. The ability to measure very small displacements allows for the characterization of very delicate material structures. The ability to measure and control a wide range of speed adds to the instrument's versatility.

5 Normal Force Transducer

A unique AR rheometer feature is the design and placement of the normal force sensor. The highly-sensitive, ultra-stiff, normal force sensor is isolated from the motor and bearing assembly, and located below the lower geometry. The benefit of isolating the normal force transducer is twofold. First, both the normal force sensor and the motor/bearing assembly are designed for maximum stiffness. When shearing a viscoelastic material, the normal force generated by the sample pushes against the measuring surfaces. Minimizing movement is key to accurate normal force measurements. Second, the normal force sensor is environmentally isolated for thermal stability.

6 Rigid One-Piece Aluminum Casting & Linear Ball Slide

All TA rheometers are designed to minimize system deflection in order to maximize the deformation applied to the sample. AR rheometers are built on a rigid, single-piece aluminum casting and the rheometer head assembly is attached to the casting via a rigid linear ball slide. A motor and an optical encoder are located in the base of the frame to drive the ball slide vertically and measure its movement. This ensures precision positioning of the geometry with an accuracy of 1 micron. TA Instruments' rheometers are built to last and deliver a lifetime of reliable performance.



AR-G2 Technology

Breakthrough technologies make our new AR-G2 the world's most advanced controlled stress, direct strain and controlled rate rheometer. With a revolutionary, patented, magnetic-levitation thrust bearing and new patented drag cup motor technology, unprecedented nano-torque control is now possible adding a new dimension to rheological characterization. New patented Smart Swap™ Geometries and Real-Time Streaming Video and Image Capture features take ease-of-use to a new level. The AR-G2 represents a whole new approach to rheometer technology.

Magnetic Thrust Bearing

Why a magnetic bearing? Larger gaps in the absence of a continuous flow of pressurized air translates to unprecedented low levels of friction in the bearing. More importantly, the ability to control and measure torques in the nN.m range. No other rheometer can boast such low-end torque sensitivity. The larger gap in the thrust bearing is robust and not susceptible to contamination. The additional benefits of the magnetic bearing over traditional air bearing designs are the following:

- Ultra low torques applied to the sample
- Smaller sample volumes can be used
- Ability to probe delicate material structures
- Study of low viscosity materials over a broad range of conditions

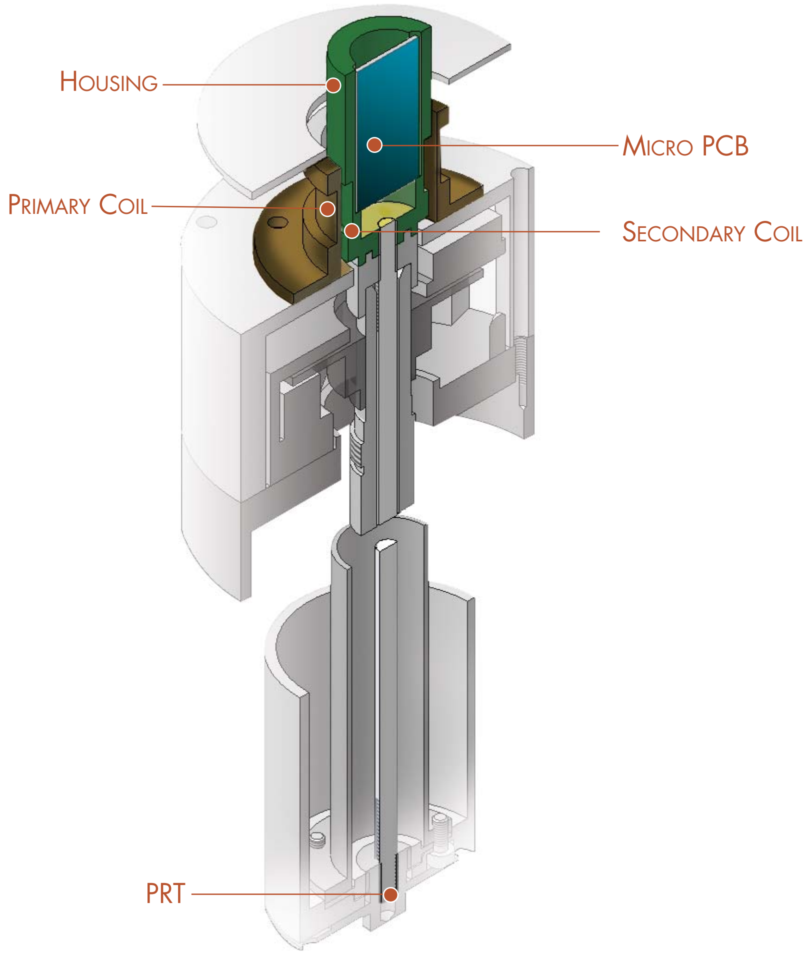
Patented Drag Cup Motor

Our new patented advanced drag cup motor is designed to further reduce system friction by increasing the motor gap by 100%. Dramatic improvements in low end torque performance are realized without compromising high-end performance. The motor delivers enhanced transient response and an extended angular velocity control range. The motor incorporates a patented drag cup temperature sensor. For the first time in any rheometer design, the temperature of the drag cup is measured, ensuring the most accurate torque output.

AR-G2 Technology

Active Temperature Control (ATC)

The AR-G2 Electrically Heated Plate (EHP), Upper Heated Plate (UHP), and Dry Asphalt System all incorporate our new patented(1) non-contact temperature sensor for active measurement and control of the upper plate temperature, using a special draw rod. The draw rod houses a micro PCB and Platinum Resistance Thermometer.



The PRT senses temperature at the upper cone or plate geometry, and the signal is transmitted from a secondary coil on the draw rod to a primary coil in the head assembly. Together with a PRT in the lower plate, real-time control of both plates is possible. The AR-G2 is the first rheometer to actively measure and control the upper plate temperature. (1) Patent # 6,931,915

Smart Swap™ Geometries

The AR-G2 features our new patented Smart Swap Geometries with automatic detection. Smart Swap geometries include an integrated magnetic cylinder that stores unique geometry information. When attached, the information is automatically read and the software is configured with appropriate parameters (type, dimension, material). The Smart Swap option brings the AR-G2 one step closer to being a truly “intelligent” rheometer system.

Smart Swap™ Accessories

Smart Swap™ Temperature Systems

Only TA Instruments offers the convenience and versatility of Smart Swap temperature control options. Smart Swap temperature control options are attached to the instrument on its unique magnetic base. Intelligent Smart Swap options can be interchanged in as fast as 10 seconds. Once attached, the instrument automatically detects and configures the system.

Peltier Plate

The most common temperature control option for the AR rheometers is the Peltier Plate. AR Series Peltier Plates have a temperature range of -40 to 200 °C with a typical heating rate of up to 20 °C /min and a temperature accuracy of +/- 0.1 °C. A PRT (platinum resistance thermometer) sensor positioned at the center of the plate ensures accurate temperature measurement and control. The Peltier Plate is also available in a "stepped" model that uses removable lower plates. This unique design allows the Peltier Plate to easily be configured with custom lower plates and cups. Other Peltier accessories include: Peltier immersion cover, solvent trap, purge cover, and camera viewer.

Concentric Cylinder

Concentric Cylinders are commonly used for very low viscosity fluids, dispersions of limited stability, and applications where fluid/solvent evaporation may be a problem. The Smart Swap Concentric Cylinder system features Peltier temperature control and provides a temperature range of -20 to 150 °C with heating rates up to 15 °C/min.

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 less than +/- 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 AR-G2 UHP features our new patented Active Temperature Control, ATC. The ATC makes the AR-G2 UHP the only Peltier/upper heated plate system combination available that incorporates direct temperature control of both the upper and lower plates. Flexible cooling options include an external circulator or innovative vortex cooling.

SMART SWAP™ ACCESSORIES

ENVIRONMENTAL TEST CHAMBER (ETC)

The ETC uses a controlled convection/radiant-heating concept and is available for AR-G2 and AR 2000ex Rheometers. It is typically used for polymer applications and can be used with parallel plate, cone and plate, disposable plate, and rectangular torsion clamps for solids. The ETC has a temperature range of –160 to 600 °C with heating rates up to 60 °C/min. It can be connected directly to a bulk liquid nitrogen source for subambient temperature control. The ETC features our new camera viewer with remote illumination and focusing. Used in conjunction with the new streaming video and image capture software, real-time images can be displayed in the software and an image is stored with each data point for subsequent viewing. The ETC camera viewer is an ideal tool for data validation.

Electrically Heated Plates (EHP)

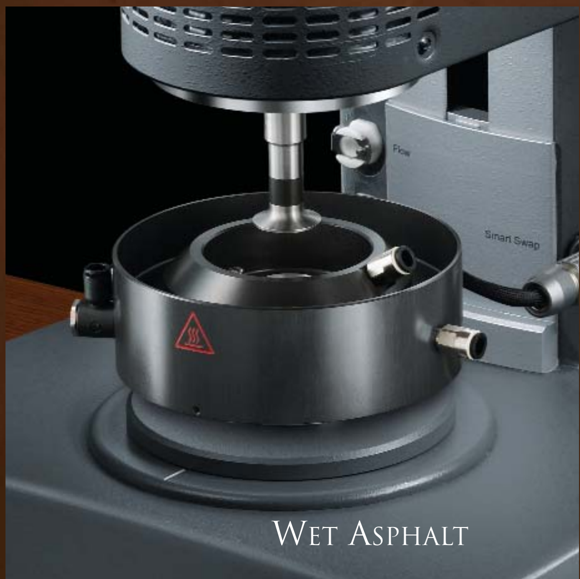
The EHP is a Smart Swap™ temperature option that provides active heating and cooling of parallel plate and cone and plate geometries. The EHP is perfect for rheological characterization of polymer melts up to a maximum temperature of 400 °C. Other features include an environmental cover and heated purge gas and an optional Gas Cooling Accessory for temperature control to -70˚C. An optional clear purge cover is available for sample viewing and integration with camera viewer. Additionally, for the AR-G2, the EHP offers patented Smart Swap Geometries and newly patented Active Temperature Control, ATC. ATC makes the AR-G2 EHP the only electrically heated plate system capable of direct temperature control of both the upper and lower plates.

Smart Swap™ Accessories

Dry Asphalt & Asphalt Submersion Temperature Systems

The AR Series offers a traditional Asphalt Submersion Cell and new Dry Asphalt temperature control accessories. Both temperature systems meet SHRP, ASTM, and AASHTO requirements, and include 8 mm and 25 mm parallel plates and sample molds. The Dry Asphalt System combines our superior Upper Heated Plate with a unique lower stepped Peltier Plate. Automated zero heat flow calibration yields temperature gradients of less that +/- 0.1°C. The AR-G2 Dry Asphalt System features our newly-patented Active Temperature Control, ATC. The ATC makes the AR-G2 Dry Asphalt system the only stepped Peltier/upper heated plate system combination available that incorporates direct temperature control of both the upper and lower plates. Flexible cooling options includes an external circulator or innovative vortex cooling. The Asphalt Submersion Cell is a direct port of temperature control technology used on our popular CSA series of rheometers. Temperature control of an asphalt sample is by fluid submersion.

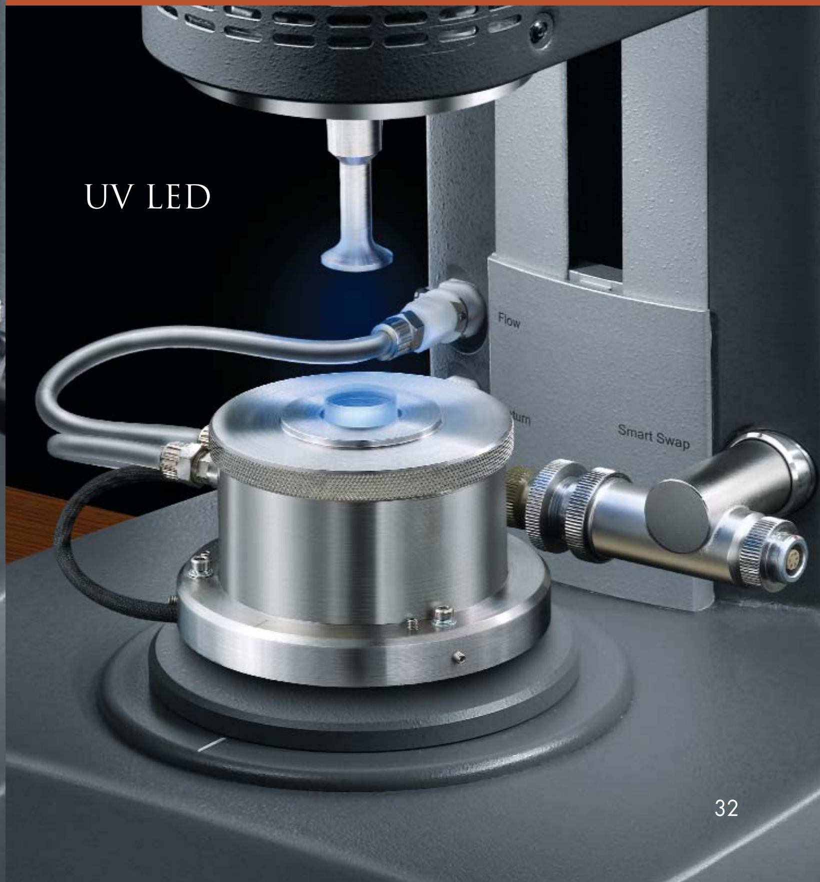
Dry Asphalt



Wet Asphalt

UV Curing

Two Smart Swap accessories for rheological characterization of UV curable materials are available for the AR-G2 and AR2000ex rheometers. One accessory uses a light guide and reflecting mirror assembly to transfer UV radiation from a high-pressure mercury light source. The UV Light Guide accessory is configured using a lower Smart Swap assembly with light source mount, collimator, and 5 mm light guide. A UV light source (Exfo Omnicure S2000), with wavelengths in the range of 320 to 500 nm, and triggering cable are optional. A second accessory uses self-contained LED's to deliver UV light with a very narrow band around a peak of 365 nm. Both the LED and Light Guide Accessories include removable 20 mm quartz plate, remote radiometer/dosimeter, UV light shield, and nitrogen purge cover for working under ambient conditions. Optional temperature control to a maximum of 150 °C is available using AR Series Electrically Heated Plates (EHP) option. Disposable plates are available for hard UV coatings that cannot be removed from the plates once cured.



Smart Swap™ Accessories

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.

Starch Pasting Cell (SPC)

The SPC is a powerful and accurate tool for rheological characterization of the gelatinization process and final properties of starch products. It 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 up to 30 °C/min, controls and measures actual sample temperature and is designed to minimize water loss during the cooking cycle.

Interfacial Accessory

Traditionally, rheometers have been used to characterize the bulk properties of materials. In many materials, such as pharmaceuticals, foods, personal care products and coatings, there is a two-dimensional liquid/liquid or gas/liquid phase with distinct rheological properties. In the past, massive biconical geometries have been used to make limited interfacial measurements in steady shear mode. The ultra-low friction nano-torque sensitivity of the AR-G2 has now been combined with a Pt/Ir Du Noüy Ring system, enabling viscoelastic characterization of interfaces in oscillation and transient modes. This makes the AR-G2 the only rheometer in the world capable of measuring bulk rheology, as well as both steady shear and dynamic interfacial properties of materials.

FIGURE 1

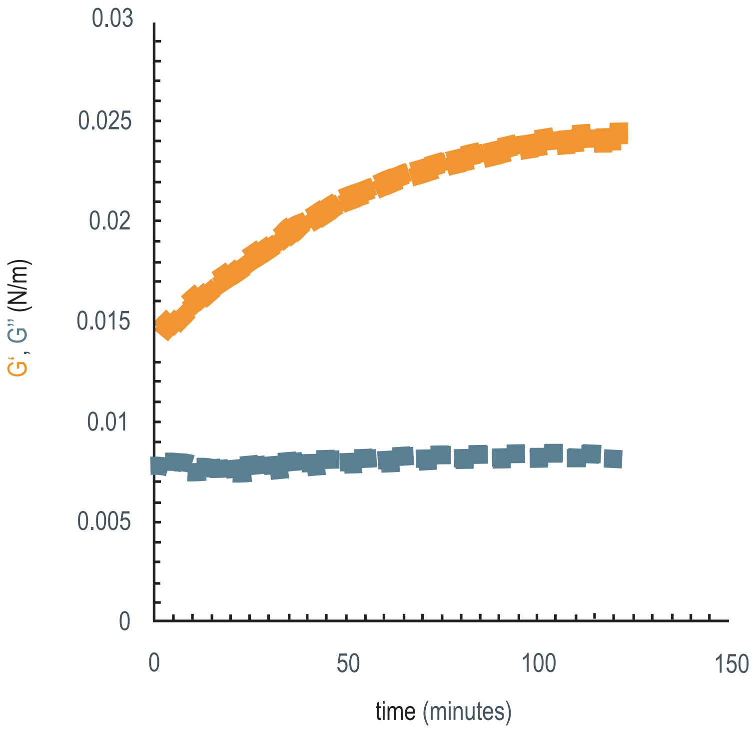


Figure 1: Absorption of a 0.05% whey protein solution in distilled water.

Dynamic Interfacial Shear Rheology Using the AR-G2

The dynamic interfacial shear moduli G′ and G″ are used to monitor the network structure build-up, resulting from the adsorption of proteins at the interface. Proteins unfold at the interface and, therefore, are crucial to the stability of emulsions and foams. The measurement is done with a Du Noüy Ring, positioned at the interface of two liquids, or a liquid and air in a circular glass dish. The ultra-sensitive, nano-torque range of the AR-G2 rheometer is required to make these measurements. Figure 1 shows the dynamic storage modulus of this material continuously increases as the protein migrates to the surface and forms a network structure.

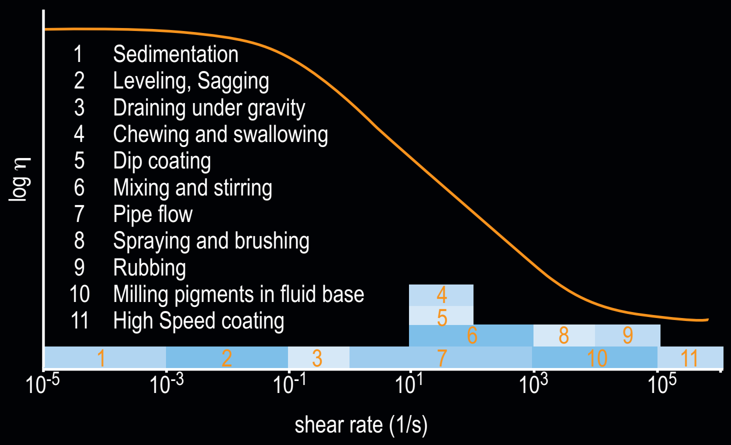
Applications

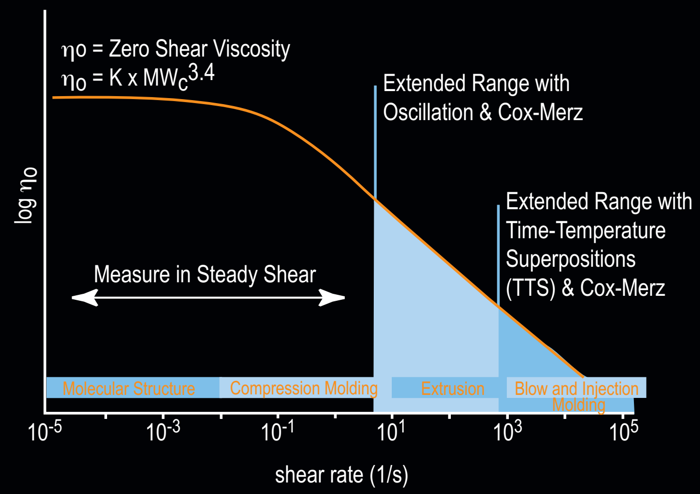
Flow Curve for Dispersions

A generalized flow curve for dispersions is illustrated below. 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, shear thickening, thixotropy, and correlates to processing and product performance. Simple techniques like spindle viscometers can only measure a point or a small part of the total flow curve.

Flow Curve for Polymers

The figure below shows a generalized flow curve for polymers and corresponding process shear rate ranges. A polymer's molecular weight greatly influences its zero shear 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.



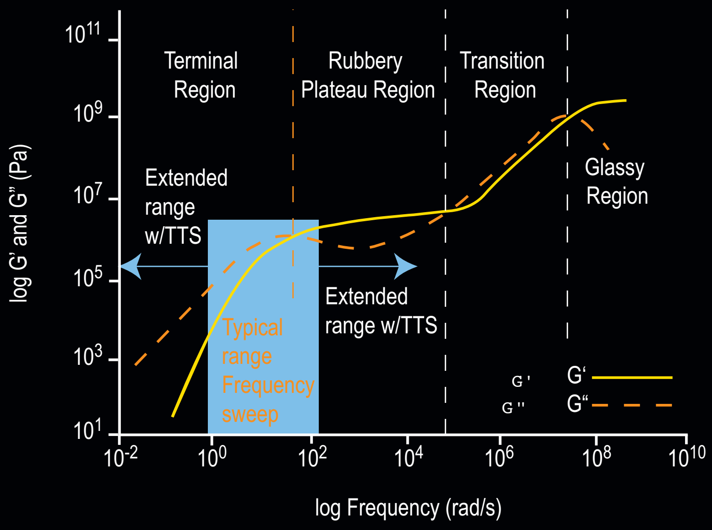


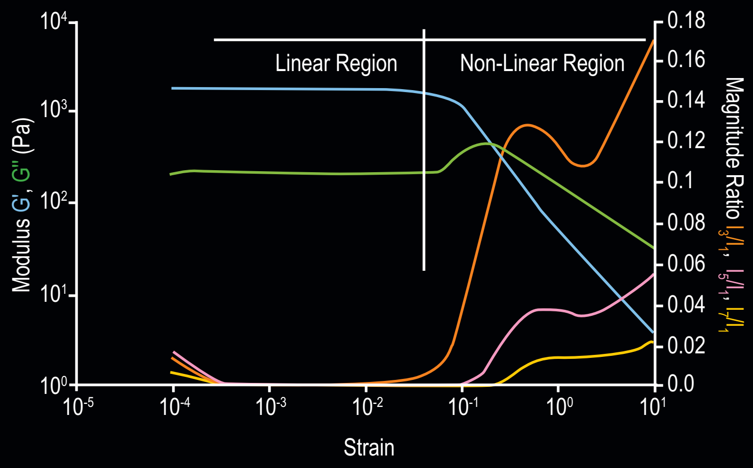
Viscoelastic Properties

The viscoelastic properties of polymer melts are commonly studied in the dynamic oscillation mode. The figure below illustrates a viscoelastic fingerprint for a linear homopolymer and shows the variation of the storage modulus (G') and loss modulus (G'') with frequency. Since 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 and to build a master curve at a reference temperature. The magnitude and shape of the G' and G'' curves depend on the molecular structure of the polymer.

Strain Sweep

Key viscoelastic parameters **(G′, G″, η*, tanδ, etc.)** can be measured in oscillation as a function of stress, strain, frequency, temperature and time. The figure below illustrates an oscillation strain sweep used to determine the onset of non-linear viscoelastic behavior. In the linear viscoelastic region (LVR), the material responds linearly to a stress or strain input and the moduli G′ and G″ are independent of strain. The internal structure of the material remains intact under linear testing conditions. Beyond the limit of the LVR the material's response is highly non-linear. The dynamic moduli G′ and G″ drop rapidly with increasing strain and higher harmonic stress contributions appear. Under these high-strain test conditions the material experiences a catastrophic breakdown of the internal structure. Rheological analysis using higher harmonics in the non-linear oscillation regime is referred to as "Fourier Rheology."





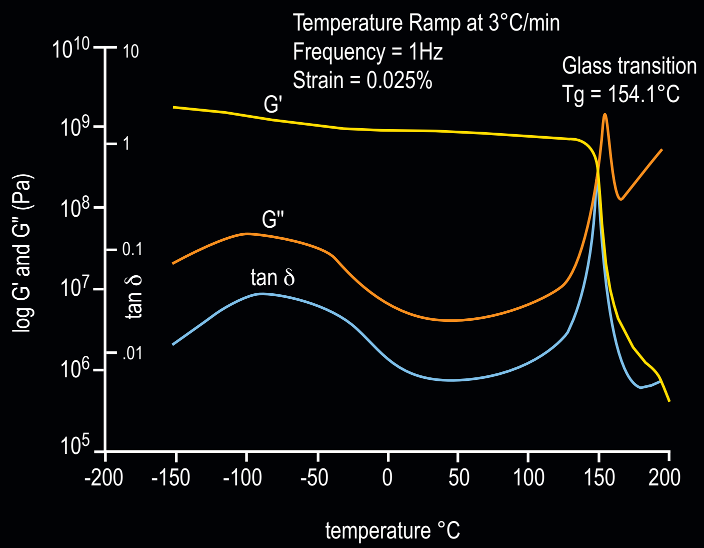
Applications

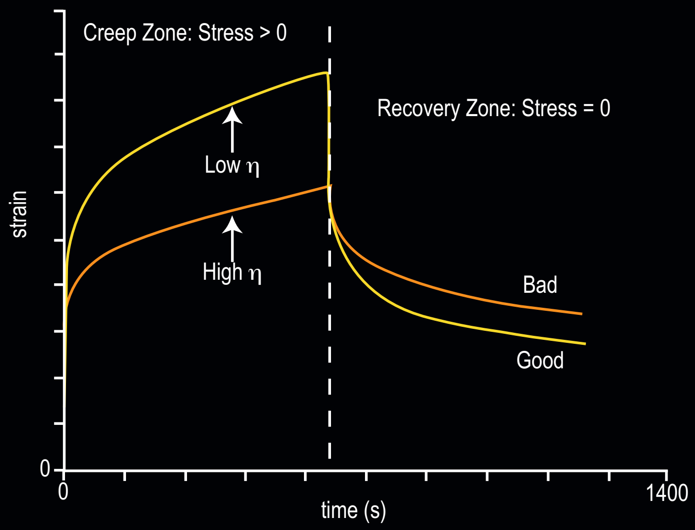
Dynamic Mechanical Properties of Solids in Torsion

The ability to characterize the viscoelastic properties of solids in torsion is a feature of TA Instruments' rheometers, as illustrated below 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'), loss modulus (G'') and damping (tan delta) will depend on chemical composition, crystallinity, molecular structure, degree of cross-linking, and the type and amount of fillers.

Transient Tests (Creep and Stress Relaxation)

In a creep recovery test, illustrated below, a constant stress is applied to the sample and the resulting strain is measured over time. The stress is then removed and the recovery (recoil) strain is measured. For polymer melts, the zero shear viscosity (η_o) and equilibrium recoverable compliance (J_{eo}) 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-G2 and AR 2000ex with direct strain control.



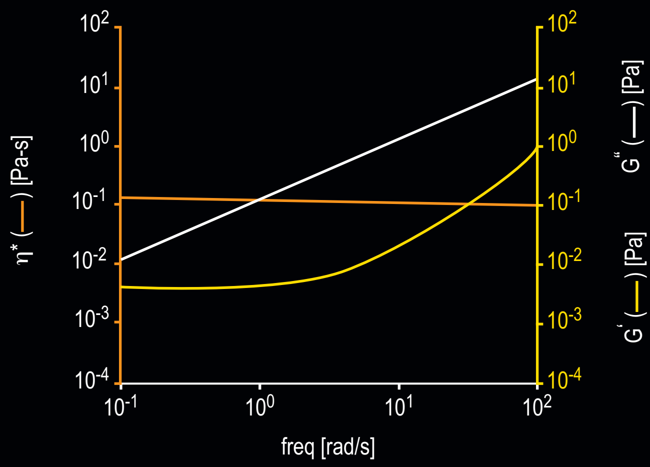


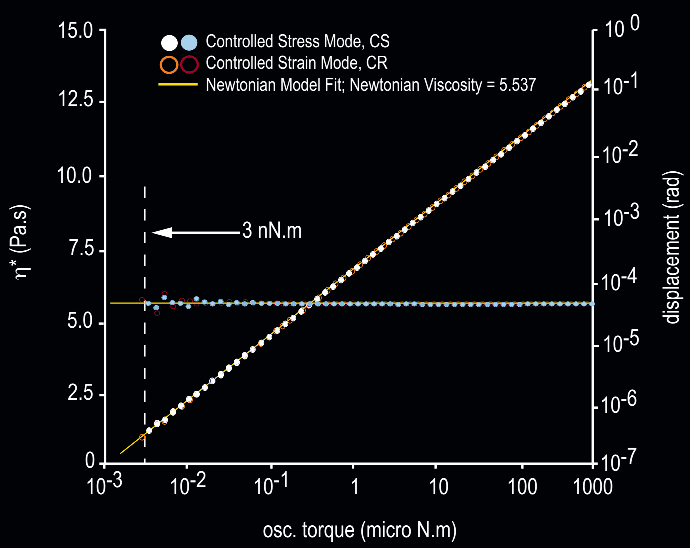
Dynamic Oscillation on Low Viscosity Fluids Using ARES

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. Below 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.

AR-G2 Nano-Torque Measurements in Stress & Strain Control Oscillation

The minimum torque on rheometer designs which use only air bearings is specified at a higher value for controlled stress (CS), as compared to controlled rate or strain (CR). The new magnetic thrust bearing and advanced drag cup technologies incorporated on the new AR-G2 allow for ultra-low, nano-torque control in both controlled stress and controlled strain modes. This unprecedented torque performance is shown below. Note, viscosity and displacement values at instrument torque levels of 3 nN.m.





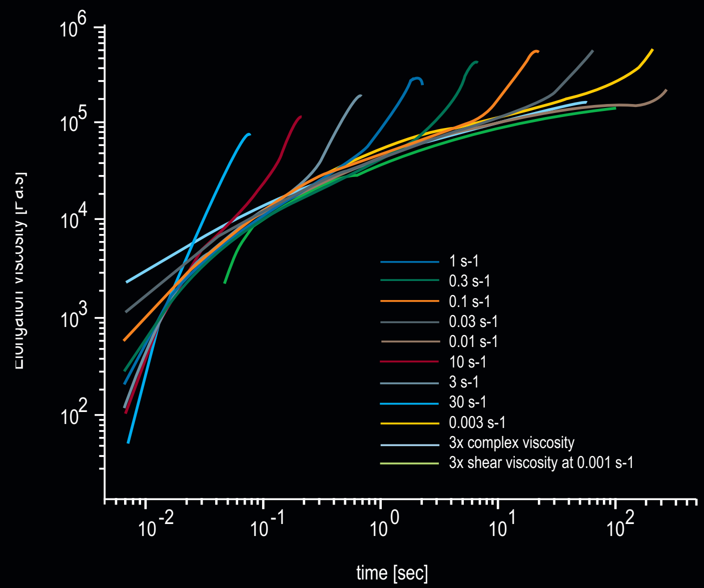
Applications

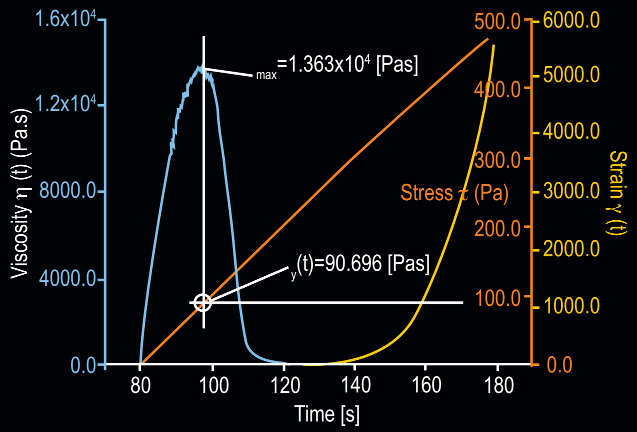
Extensional Viscosity Measurements on ARES

Extensional viscosity is fundamentally important in many polymer-processing techniques such as blow-molding, fiber spinning, and injection molding. The EVF is a polymer melt elongation fixture that transforms an ARES oven system into a shear and extensional rheometer. The EVF uses a unique patented dual cylinder, or drum, wind-up technique. The figure below shows the data on a LDPE sample, superposed with three times the shear and complex viscosity measured at a rate of 0.01 1/s and frequency w = 1/t. The EVF clearly shows excellent data over a wide range of rates.

Stress and Shear Rate Ramps

Stress and shear rate ramps are common transient experiments that provide fast and easy ways of characterizing yield stress and thixotropic behavior in materials. Both of these phenomena are typical time dependent behaviors of structured fluids that are important for understanding how a material will perform in an application. The stress ramp is a standard way of measuring yield stress of a structured fluid. While ramping the stress linearly with time, the strain and instantaneous viscosity are recorded. It can be seen below that the viscosity increases initially and goes through a maximum. The stress value at the characteristic maximum in viscosity is a measure of the yield stress. Beyond this maximum, the material's structure breaks and the instantaneous viscosity decreases, or shear thins, with increasing stress. Rate ramps are more commonly used to observe thixotropic behavior. A test procedure involving a shear rate ramp from zero to a final rate and back to zero at constant ramping rate is referred to as thixotropic loop. The magnitude of the stress profile will be higher in the up-ramp then in the down ramp. The area between the up and down stress curves as a function of rate is called the thixotropic index.



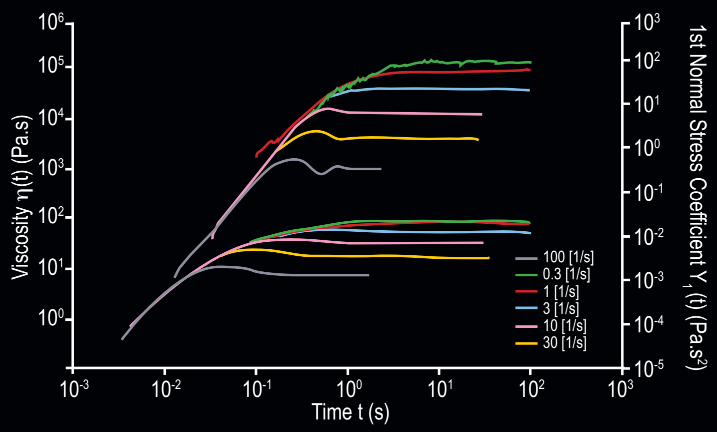


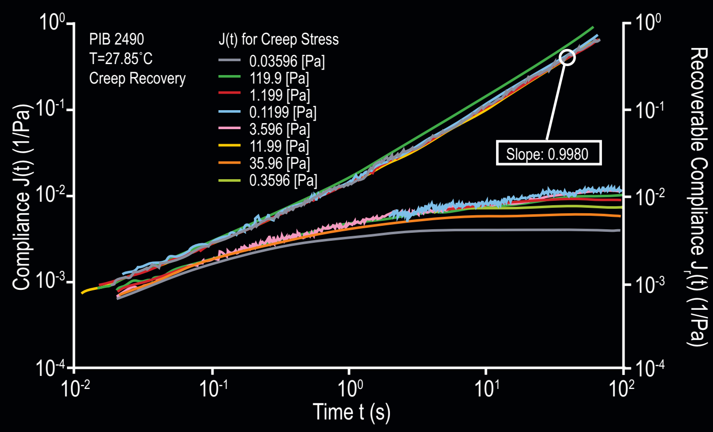
Stress Growth in a Transient Step Rate Experiment

Transient viscosity and first normal stress coefficient measurements on a viscoelastic material in cone plate configuration are challenging rheological measurements. The instrument must have extremely low axial compliance in order to minimize inward flows, which subsequently affect the normal force. The ARES G2 uses a motor air bearing with high axial stiffness and a non-compliant force rebalance transducer to reduce axial movement to less than 0.1μm/N. The figure below shows results of a series of step rate experiments performed over a shear rate range from 0.1 to 100 1/s. The ARES-G2 can easily make these challenging measurements. Both transient viscosity and 1st normal stress coefficient superpose well at short times at all shear rates. At longer times, the viscosity and normal stress coefficient traces diverge due to the non-linear material response at higher shear rates. The characteristic overshoot in both the viscosity and the 1st normal stress coefficient is due to changes of the material's structure under strong shear fields.

Creep and Recovery of a Viscoelastic Fluid

Creep and recovery testing is well suited for measuring the effect of long relaxation times (200 sec). The strain recovery is a very sensitive measurement of elasticity. In creep a constant stress is applied and the resulting strain is monitored. Upon steady state, the stress is reduced to zero and the elastic recoil, or recovery, of the sample is measured. The elastic component of the recoil is characterized by the equilibrium compliance J_e. Both the AR-G2 and ARES-G2 provide the most accurate J_e data by overcoming inertial effects at the critical transition between the creep and recovery zones. The AR-G2 offers extremely low residual torques and a creep-braking routine, while the ARES-G2 offers excellent torque sensor resolution and employees a novel control algorithm. The figure below shows the creep and recoverable compliance for the NIST PIB 2490 standard reference material as measured on the ARES-G2. Stresses used range from 100 Pa down to 0.03 Pa. The superposition of the creep as well as the recoverable compliance proves that conditions of linearity have been fulfilled at low stress. The data shown here are unprecedented on a separate motor and transducer instrument.





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 are 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.

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