A357

Rheometer

Rheometer, Anton Paar, MCR 502

Document Type	Article
Document Identifier	357
Themes	• Materials deposition and consolidation management • Thermal management
Relevant Class	Equipment
Tags	• Material characterization • Test lab • Process modelling
Factory Cells	• Test lab

Introduction[edit | edit source]

A rheometer is an instrument used to study material flow and deformation under external loads. Rheology, the 'study of flow behaviour' is not only about studying the flow behavior of liquids but also about deformation and rate of deformation of solids. All types of shear response stands somewhere between flow of an ideal viscous liquid and deformation of an elastic solid. Therefore, the material's response is a blend of both a viscous and elastic response, and is referred to as viscoelastic. Viscosity and elasticity are essential characteristics of material behavior, which can be quantified by applying a rotational and oscillatory load on a sample of the material.

Rheometry is the technology for measuring rheological properties of materials. To evaluate viscous behaviour, rotational tests are performed. For characterizing viscoelastic behaviour, creep, relaxation and oscillatory tests are performed.

Features[edit | edit source]

Rheometers can control the applied stress or strain and measure the resulting strain or stress, respectively. In a parallel plate configuration, the rheometer comprises two parallel plates with the sample positioned between them. The upper plate rotates while the lower plate remains stationary. The temperature of the plates can be controlled to maintain a constant temperature or gradually increased to reach a specific point.

A wide range of measuring geometries are available, depending on the characteristics of material being tested and information required. For instance, disc spindles prove effective in assessing the viscosity of a diverse range of liquids. On the other hand, cylindrical spindles are well-suited for examining the shear stress, shear rate, and viscosity of non-Newtonian fluids, while vane spindles are adept at measuring the viscosity of gels. Additionally, Couette cells show excellent sensitivity when dealing with low-viscosity fluids and fluid suspensions. In contrast, parallel plate, cone, and plate geometries are common for analyzing polymeric materials.

Uses and Test Types[edit | edit source]

Simple instruments, used to measure the viscosity values of a sample via speed-controlled rotational tests used to be called rotational viscometers. Instruments are termed as rotational rheometers when further rheological tests are possible such as torque- or shear stress-controlled rotational tests. With most rheometers, also the viscoelastic behavior of samples can be characterized by performing creep tests, relaxation tests, and oscillatory test. The rheometer can be used to model the behavior of a wide variety of liquids over time and at different temperatures. Rotational tests conducted with a rheometer can operate in one of two modes. In the first mode, velocity is applied through either rotational speed or shear rate, known as controlled shear rate (CSR or CR). This mode effectively replicates processes dependent on flow velocity or volume flow rate, such as coating with a brush or spraying. In contrast, the second mode involves applying force through torque or shear stress, referred to as controlled shear stress (CSS or CS). Tests conducted in this mode simulates force-dependent applications, such as the force required to pump liquid, to extrude sealing materials from a cartridge, or to dispense paste from a tube. In oscillatory tests, the frequency of oscillation and strain can also be varied.

Analysis of Results[edit | edit source]

For rotational tests, shear stress vs shear rate or viscosity vs shear rate is usually plotted. In the latter case, the log of both variables is usually plotted to better visualize the relative changes in viscosity response. In oscillation tests, shear lag and shear strain are plotted to determine the phase shift, or how much one variable lags behind the other. From that, we can then determine the storage and loss moduli vs frequency or strain, which describes the viscoelastic behavior of the sample.

Frequency sweeps generally serve the purpose of describing the time-dependent behavior of a sample in the non-destructive deformation range. High frequencies are used to simulate fast motion on short timescales, whereas low frequencies simulate slow motion on long timescales or at rest.

Equipment Demonstration[edit | edit source]

The video below provides an introduction to the Rheometer. It outlines it's uses, parts of the instrument, different geometries, and tests that can be conducted with a Rheometer. In the second half of the video, tests are performed on two different resin systems and results are analyzed and discussed.

Related pages

Page type	Links
Introduction to Composites Articles	
Foundational Knowledge Articles	• Conduction - A118 • Convection - A106 • Cure of thermosetting polymers - A162 • Degree of cure - A104 • Glass transition temperature (Tg) - A210 • Heat of reaction - A114 • Specific heat capacity - A117 • Thermal conductivity - A116 • Thermal diffusivity - A143 • Thermoplastic polymers - A161 • Thermoset polymers - A105 • Viscosity (resin) - A203
Foundational Knowledge Method Documents	• How to measure gel time - M101 • How to measure reinforcement content (and corresponding matrix content) - M109
Foundational Knowledge Worked Examples	
Systems Knowledge Articles	
Systems Knowledge Method Documents	
Systems Knowledge Worked Examples	
Systems Catalogue Articles	
Systems Catalogue Objects – Material	
Systems Catalogue Objects – Shape	
Systems Catalogue Objects – Tooling and consumables	
Systems Catalogue Objects – Equipment	• Dynamic Mechanical Analyzer (DMA) - A344 • Rheometer - A357 • Thermogravimetric Analyzer (TGA) - A329 • Thermomechanical Analyzer (TMA) - A353
Practice Documents	• Practice for developing a thermal transformation process step - P105
Case Studies	• Troubleshooting of room temperature processes for large recreational and industrial parts - C100

Perspectives Articles

- Case Study: Optimizing a Press Moulding Process - A324
- Composite materials engineering webinar session 1 - Introduction - A120
- Composite materials engineering webinar session 12 - Testing - A131
- Composite materials engineering webinar session 3 - Constituent materials - Resin - A122
- Composite materials engineering webinar session 4 - Thermal management and resin cure - A123
- Composites Process Simulation: A Review of the State of the Art for Product Development - A283
- Dr. Anoush Poursartip's cdmHUB global composites expert webinar - A136
- Fabric Forming: how it affects design and processing, and how simulation can address this - A310
- Interview with Prof. Kevin Potter - A134
- Simulation models for rapid liquid composite molding - A333.0
- Understanding Polyester Resin Processing: The Effect of Ambient Temperature on the Final Part - A286

About **Help**

In composites processing, viscosity is an indicator of how easily the resin matrix will mix with the reinforcement and how well it will stay in place during processing. The lower the viscosity, the more easily resin flows. Resin viscosity ranges considerably across chemistries and formulations.

By scientific definition, viscosity is a measure of a material’s resistance to deformation. For liquids, it is in response to imposed shear stresses.

For polymer matrix composites (PMCs), resin refers to the matrix; the continuous material phase that binds the reinforcement together, maintains shape, and transfers load. Resins are divided into two main groups: thermosets and thermoplastics.