The Primary Differences Between:

Moving Die Rheometers and Rubber Process Analyzers

Published By

MonTech®
Rubber Testing Solutions

Is it the Compound or the Process?

RPA VS. MDR

This document analyzes and outlines the specifics that make the MDR and RPA vastly different instruments. Here is what you can expect to learn from this eBook:

- *Dynamic vs. Static Testing*
- *Hardware Similarities and Differences*
- *Instrument Simulations and Correlations*
- *RPA Application Examples*

Why should we compare the two units?

Continuous improvement is driving better processes, products, and compound development. More and more people are making the switch away from the MDRs and Mooney Viscometers. Modern manufacturing processes and increasingly stringent customer requirements need more data than these two units can provide.

Molders, extruders, mixers and any other processors benefit from the dynamic testing of an RPA. It is the most important tool for understanding the quality of base polymers, process analysis, diagnosing process setbacks, cure testing, and advanced dynamic rheology. In many cases, MDRs and Mooney Viscometers cannot satisfy the increasing demands of manufacturing requirements.

Dynamic Testing VS Static Testing

Comparison: Static and Dynamic Testing

The first major concept to understand when comparing MDRs to RPAs is the difference between dynamic testing and static testing. The key parameters of rubber rheometer test configurations are:

Time – Temperature – Oscillation Angle – Oscillation Frequency – Pressure

Static rubber Rheometers set the above parameters at fixed positions at the creation of each test. Therefore, MDR tests do not change these parameters during any test sequence. This makes MDRs perfect for simple tests, such as determining the cure rate of compounds. For some, that may be all that is required their operations. For many others, however, the limitations of static testing can create unnecessary obstacles and costs that could be avoided with the additional insights that can be gained through dynamic testing.

The RPA is a dynamic unit. This means that RPA test sequences can be set up to adjust sequence time, frequency, temperature, strain, and pressure over the course of a test. When one step in a test sequence is complete, the next step begins and the test parameters are changed. In addition to dynamic testing, RPAs can also perform all of the same static tests as MDRs.

For additional information on running dynamic tests: ASTMs are available covering a variety of essential dynamic tests that can be performed with RPAs. We recommend you purchase and review the following ASTMs from the American Chemical Society:

ASTM D6204 – ASTM D5289 - ASTM D6601 – ASTM D6048 – ASTM D7050 – ASTM D7605 – ASTM D8059

What kinds of challenges can Dynamic RPA Testing help to identify?

The list below is only a sample of what RPA data can solve:

Molding:
- Mold flow
- Surface finish
- Cure Shrink Rate
- Green Strength

Extrusion:
- Die swell
- Flow Rate

Calendering:
- Calender Curling
- Surface Finish

Mixing:
- Homogenous Dispersion
- Scorching
- Inconsistent Mixing
- Recipe Differences
- Mixer Differences

Other:
- Improving Processing Times
- Incoming raw material analysis
- R&D Product Development
- Process Simulating
- Laboratory Procedure Simplifications
- Vibration Dampening Characteristics
- Predicting application performance
- Test Cost Reduction
- End-Environment Failures
- Shelf Life

Hardware Similarities and Differences

Hardware Comparison

At first glance, the RPA hardware does not seem much different than the MDR, but there are some distinct differences allow for greater testing capabilities. The list below outlines some key physical differences.

Note: Different RPA manufacturers may have other proprietary components, or features that are unique to their instruments that are not included in this list. The following list is specific to the MonTech D-RPA 3000.

Heavy Load Frame:

The first difference is the load frame construction. One of the keys to accuracy is improving the signal-to-noise ratio. Noise is created when the instrument's sensors pick up electronic or vibrational interference - either from the instrument itself, or from its surrounding environment. This can negatively affect the ability to measure, where there are many of sources of interference – the production floor.

The RPA produces a broader range of strains and frequencies than an MDR, MonTech's reinforced frame guarantees incredible degree of noise reduction resulting in better measurement capability - especially at low torque. Each frame is made of aerospace grade aluminum and stainless steel and includes other proprietary reinforcements. This heavy duty structure gives the RPA's sensors insulation from surrounding interference, for higher accuracy, precision, and repeatability.

Dynamically Controlled Motor:

The second difference is a dynamic motor that provides the ability to produce multiple strains and shear rates coupled with time, temperature, and pressure to simulate real world applications. The MDR motor is limited to static cure testing.

Hardware Similarities and Differences

Encoder:

MDR Die position is controlled by a mechanical drive train eccentric fixing the angle of oscillation. RPA die position is controlled by a computer and measured by a high precision encoder. Mounting the encoder inline with motor and lower die reduces the uncertainty of angular measurement. High resolution encoders are critical for accurately measuring and applying the broad range strain needed for advanced rheology.

Correlations and Simulations:

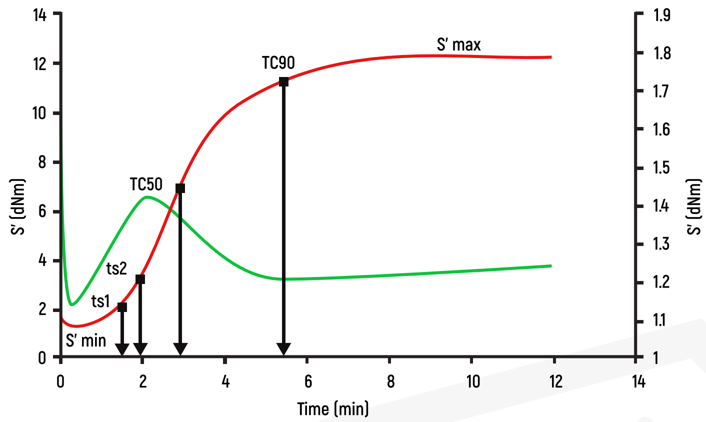
By manipulating time, temperature, pressure, strain, and frequency, the RPA simulates, or correlates with the following:

- *Moving Die Rheometers*
- *Mooney Viscometers*
- *Other Viscometers*
- *Hardness Testing*
- *Heat Buildup*
- *Permanent Set*
- *Rebound Resilience*
- *Solution Viscosity*
- *Lab Extrusion Tests*
- *Process Equipment*
- *Dynamic Mechanical Analyzer*
- *Dynamic Shear Rheometer*
- *Plastimeters*
- *Capillary Rheometer*
- *Flex Fatigue*
- *Tensile Modulus*
- *Shear Modulus*
- *Compression Modulus*
- *Glass Transition*
- *And more...*

Isothermal Cure:

The isothermal cure experiment determines the cure rate of rubber. This test as the most common quality control test in rubber and elastomer processing. With over 3500 data points available on MonControl, all characteristics including minimum / maximum elastic torque, scorch times, cure times and reaction rates are precisely calculated.

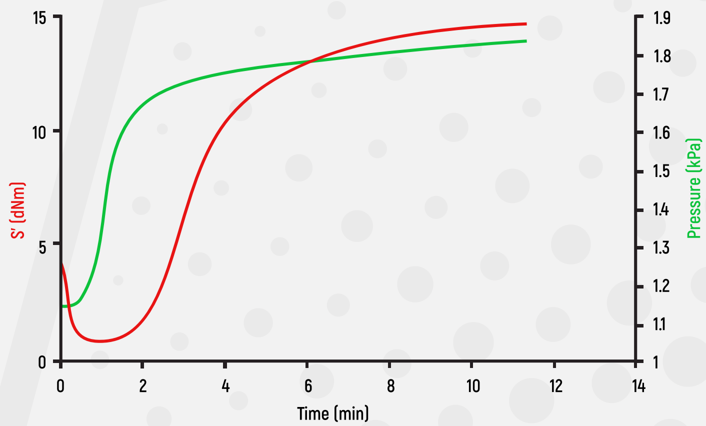
Pass / fail statuses and tolerance gates can be easily set and evaluated with each test.



Foaming / Sponging / Blowing Reactions:

Taking place during the curing process, foaming reactions produce cellular membrane-like structures within mixes and are vital part of compound development. The cellular matrix created during the foaming reaction reduces the material's density, increases properties of thermal and acoustic insulation, and affects the stiffness of the material.

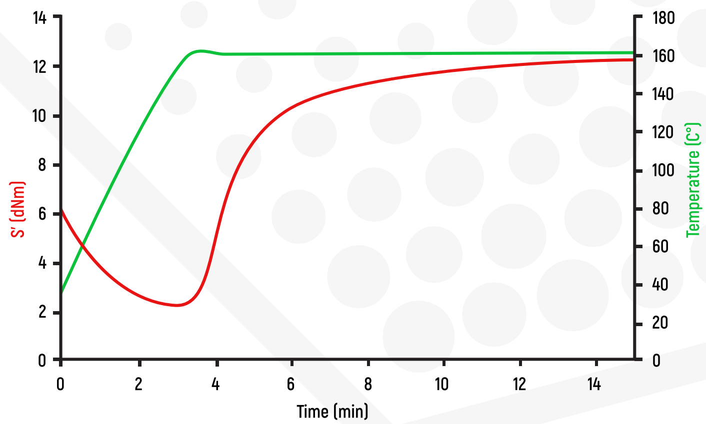
MonTech Rheometers are optionally equipped with a precision normal force transducer in the die cavity. This advanced transducer reveals interrelations between the simultaneous cure and expansion of the foaming reaction.

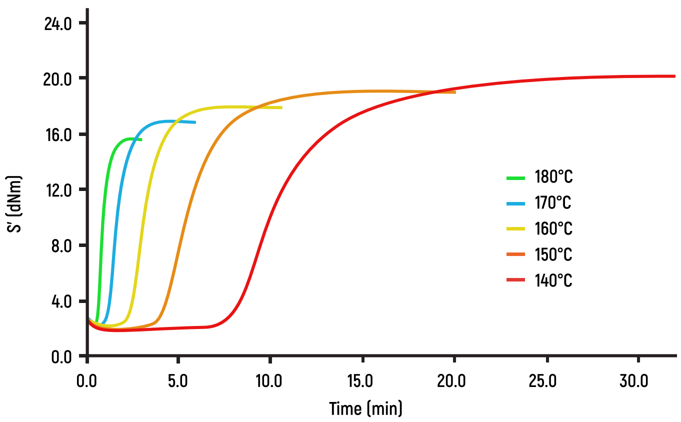


Non-Isothermal Cure:

MonTech MDRs and RPAs can be programmed to follow any non-isothermal temperature profile to simulate mixing, milling, extrusion, compression molding, injection molding and storage conditions.

Non-isothermal test sequences are executed in a single test and can be included with other dynamic tests for an even deeper analysis of a material's behavior.



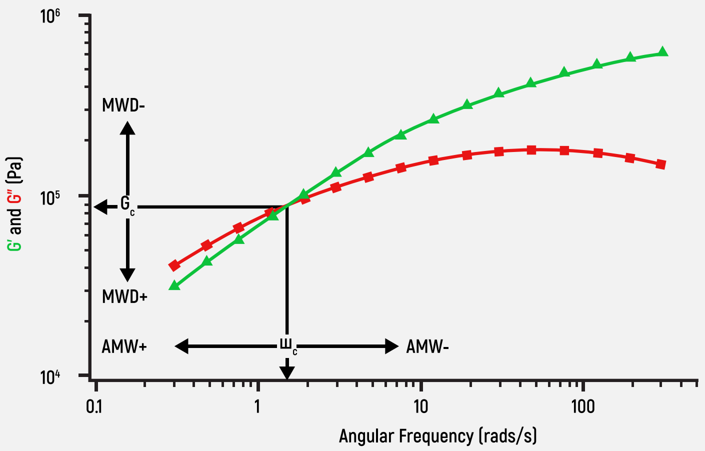


Advanced Cure Kinetics Modeling:

Test data from similar static or dynamic test sequences executed at different temperatures are evaluated and modeled for an advanced cure kinetics analysis.

Information acquired includes:

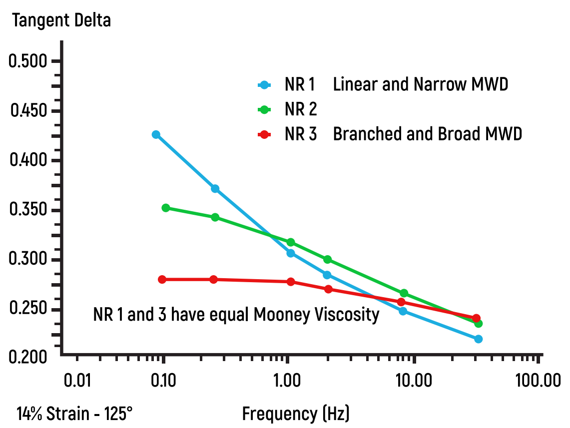
- *Reaction Rate*
- *Order of Reaction (n)*
- *Rate Constant (k)*
- *Activation Energy (E)*
- *Incubation Time (ti)*



Frequency Sweep Material Analysis:

Isothermal frequency sweeps provide detailed analysis on the molecular weight distribution MWD (*crossover modulus*) and the average molecular weight AWM (*crossover frequency*) for any elastomeric compound. Based on the frequency and given temperature during a test, mechanical properties can be easily predicted.

Technicians can incorporate additional advanced testing capabilities such as the Time-Temperature Superposition principle (*TTS*). MonTech Rheometers can be used for WLF master-curve modeling, to predict material performance at temperatures and frequencies outside the normal range.



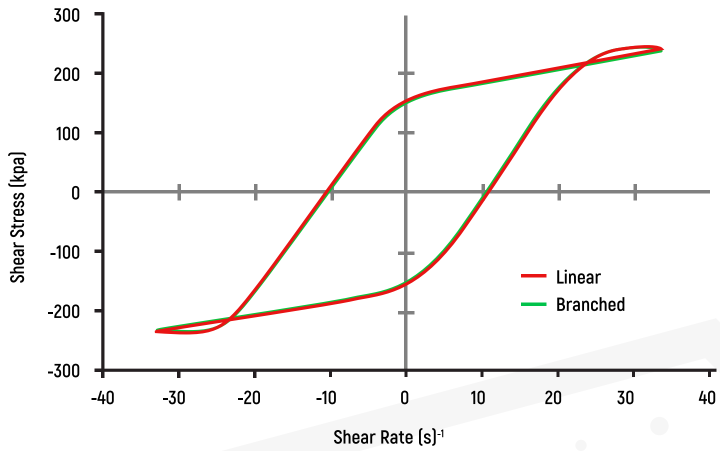
Structural Characteristics and Processability:

Structural characteristics of elastomeric compounds influence material behavior during processing and final product performance. In order to simulate various processing methods or evaluate material states, tests are performed in the linear or non-linear viscoelastic range. MonTech Dynamic Rheometers conduct frequency sweeps over a large shear range to reveal substantial material characteristics pertaining directly to processability.

LAOS and SAOS testing:

Dynamic oscillatory shear tests, commonly known as small-amplitude (SAOS) and large-amplitude (LAOS) oscillatory shear tests, are an effective method for measuring viscoelastic properties of rubber compounds or polymers – an integral part of discerning material response in processing operations.

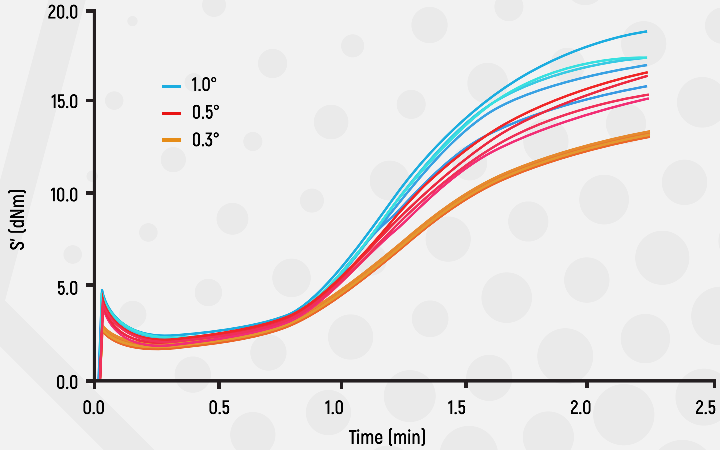
MonTech Rheometers can be equipped with a High-Speed Data Acquisition System. This enables Fourier transformation analysis of the periodic data, including full raw data access, for research into viscoelastic behavior. By using LAOS testing, the material stress response is easily quantified enabling a fuller understanding of filler content, structure, and polymer architecture.

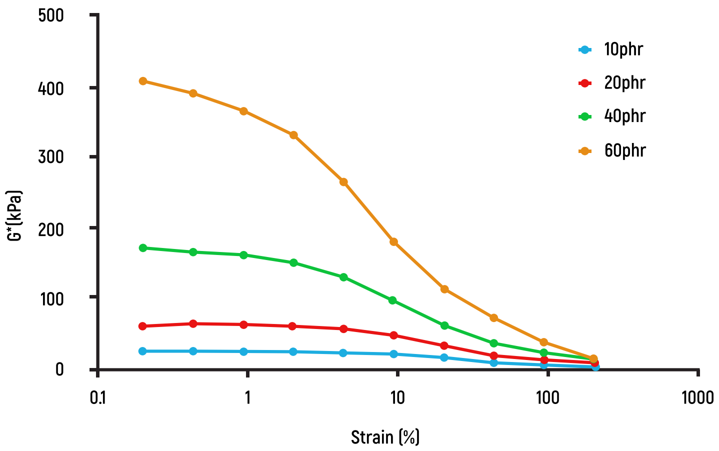


Isothermal Cure at Variable Strain:

MonTech Rheometers provide precise test results at variable oscillation angles for ideal strain amplitude, optimal signal-to-noise ratio, while avoiding any structural breakdown or slippage of the sample in the die cavity.

The variable oscillation angle can be set according to the needs of the compound. For example, a higher oscillation angle may better distinguish differences between batches of soft materials, such as silicones or epoxy resins, while a lower oscillation angle used with stiff materials may improve variability by minimizing strain induced damage beyond the linear viscoelastic range.

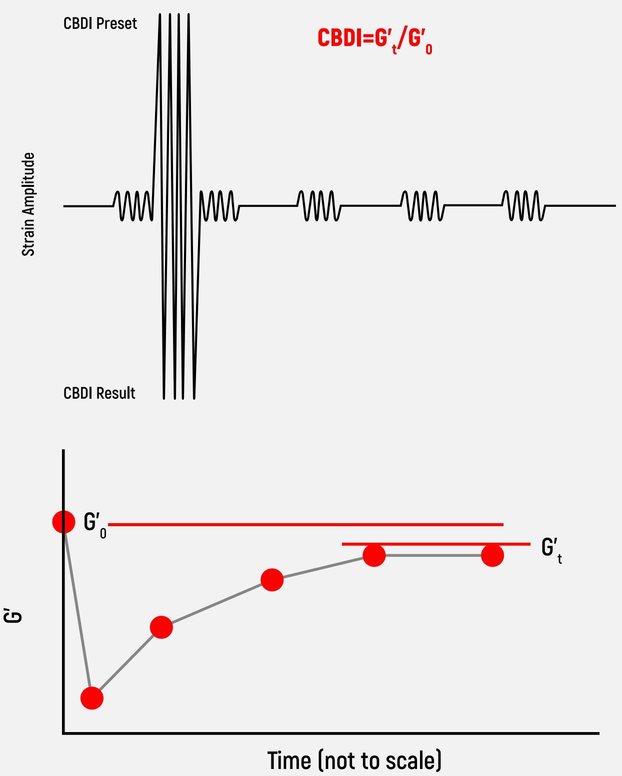




Payne Effect Testing:

The Payne Effect testing measures the stress-strain behavior of tested materials. Physically, the Payne effect can be attributed to deformation-induced changes in a material's microstructure, i.e. the breakage and recovery of weak physical bonds linking adjacent filler clusters.

By discerning the relationship between modulus and strain in the low strain/high strain areas, users can quantify filler loading, dispersion, and filler-filler interactions. The resulting material characterizations directly impact dynamic stiffness, damping behavior, and final product performance.



Carbon Black Dispersion:

In filled rubber compounds, carbon-black particles form a network of mutually interactive agglomerates that can be measured and quantified using a simple D-RPA 3000 Matrix test.

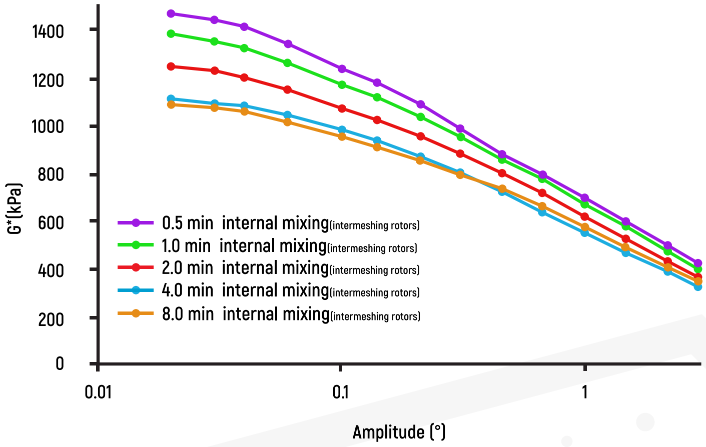
Storage shear modulus (G') results at low strains (e.g. +/- 1%) are typically high and get reduced after a larger strain amplitude (e.g. +/-50%) is applied for a short period of time. With lower strain amplitudes applied over time, the reduced Storage shear modulus (G') will partially recover. This effect relates to a breakage of the Van der Waals forces linking the agglomerates and their partial recovery over time.

The extent of recovery of the Storage shear modulus (G') directly relates to the Dispersion Rating (DR) of the rubber compound. If the carbon black is poorly dispersed, the recovery of the Storage shear modulus (G') will be much lower, indicating a weaker filler structure and reduced mechanical performance properties.

Process Simulations:

MonTech RPAs can simulate almost any production process to provide invaluable data for rubber compound development. Process simulation is a powerful tool for shortening R&D time and improving quality control for:

- Mixing
- Molding
- Extruding
- Calendering



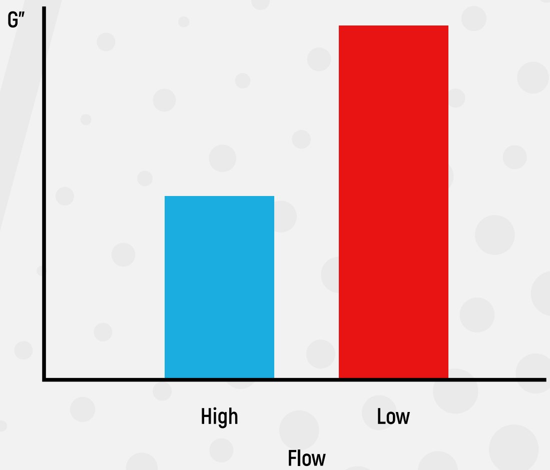
Extrusion Prediction:

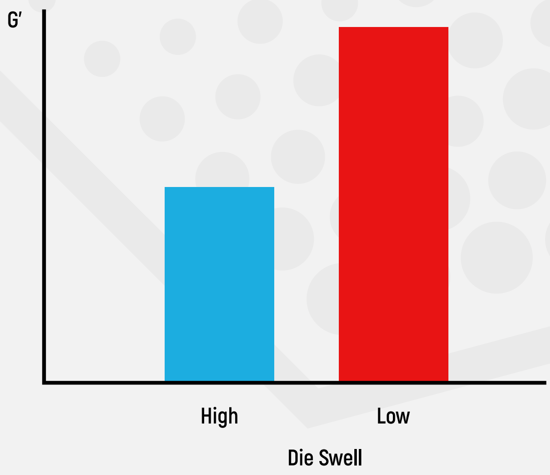
Good processing performance is influenced by three main criteria: throughput flow, die swell and surface finish.

The flow will be controlled by the viscosity of the rubber. The shear rate from an extruder and extrusion die can easily be calculated and used as the specific test parameters in a Rubber Process Analyzer test setup. A low viscosity will mean that rubber will easily flow through the extruder with low die pressure.

Once the rubber is extruded it is required to be in the correct size. When leaving the die, the elastic nature of the compound will cause the rubber to expand, resulting in die swell. MonTech Rubber Process Analyzers can obtain the storage shear modulus G' at high strains (typically 100%) allowing an excellent prediction of die swell.

The surface finish of the extrudate is required to be smooth, and not rough. Roughness tends to occur when a stick-slip resonance occurs between the speed of the extruder and the elastic response of the compound. Testing at variable shear rates using a frequency sweep allows the comparison of compounds that extrude with smooth and rough finishes, revealing processing differences.





Testing Comparison

MDR		RPA
■	Cure	■
□	Processability	■
□	Base Polymer	■
□	Mix Quality	■
□	Process Simulations	■
□	Instrument Simulations	■
□	Cured Performance Simulations	■

To learn more about how Dynamic RPA Testing could benefit your company – Contact us for a demonstration!

Contact Us to Schedule a Demonstration!