

Reproducing Mooney Viscosity Using the Rubber Process Analyzer

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■ 1) Introduction

Mooney viscosity remains a widely used indicator of elastomer processability for raw polymers and rubber compounds due to its simplicity, long-standing adoption, and strong relationship to molecular weight. However, as a single-point, low-shear measurement, it does not fully represent the nonlinear viscoelastic behavior encountered during modern processing operations such as extrusion, calendering, and injection molding.

The Rubber Process Analyzer (RPA) provides a production-ready alternative by enabling controlled strain, frequency, and temperature testing under processing-relevant conditions. This application note demonstrates how a customized Alpha MV-RPA test on the Premier RPA delivers Mooney-equivalent measurements with excellent correlation to standard Mooney viscosity, while offering deeper insight into material structure and processability.

The Premier RPA bridges traditional Mooney testing with advanced rheological characterization. Unlike the Mooney Viscometer, which operates at a fixed shear rate and deformation mode¹, the RPA applies controlled oscillatory shear over a wide range of strain amplitudes and frequencies which enables evaluation of both viscous flow resistance and elastic network response.²

Rubber Process Analyzer (RPA)			
OSCILLATORY RHEOMETER		DYNAMIC MECHANICAL ANALYZER	
<ul style="list-style-type: none"> Flow Curves: Viscosity/Shear Stress vs. Shear Rate Molecular architecture: MW, PDI (MWD), LCB Stress relaxation Modulus and damping function Stability(Gel formation) 		<ul style="list-style-type: none"> Viscoelastic Properties correlating with Modulus, Hardness, Resilience... Energy Dissipation (Heat Build-up) Damping, Rolling Resistance ... (tanδ) 	
PROCESSABILITY TESTER		ADVANCED CURE METER	
<ul style="list-style-type: none"> Process Viscosity (Pseudoplasticity Index) Die Swell & Mill Shrinkage (tanδ) Filler Structure, Particle Size & Dispersion Mooney Correlation 		<ul style="list-style-type: none"> Isothermal & Non-Isothermal Cure Cure Kinetics & Simulation (Mold Profile) Process Safety (Scorch) 	

Figure 1. Capabilities of the Premier RPA for advanced elastomer characterization, including viscoelastic response, nonlinear deformation, and properties relevant to processing.

Mooney equivalency requires probing the nonlinear deformation regime, where molecular entanglements and transient elastic resistance govern material behavior. The customized Alpha MV-RPA test is designed around this principle, using high strain amplitudes and low oscillatory frequencies to replicate Mooney-like deformation while preserving the repeatability and automation of the RPA.

■ 2) Results

■ a) Raw Elastomers

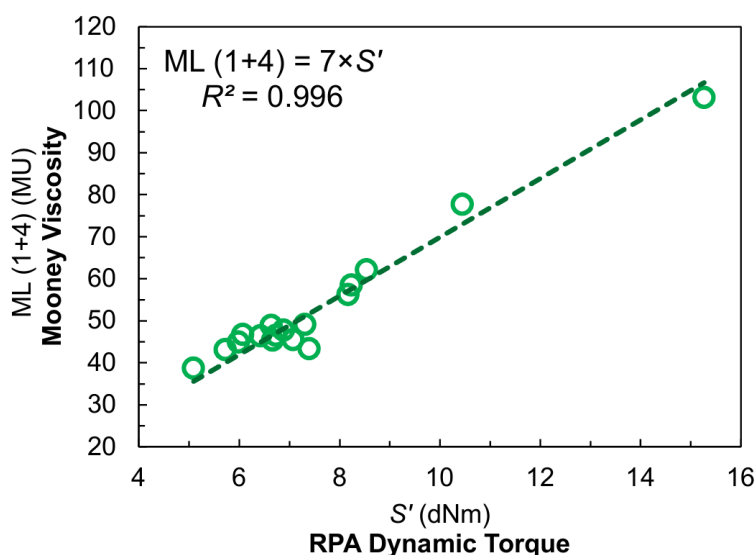


Figure 2. Strong and consistent correlation is observed between Mooney viscosity $ML (1+4)$ and the dynamic elastic torque S' measured by the Premier RPA under high-strain conditions for 17 unfilled elastomers.

Figure 2 demonstrates the relationship between S' measured at 100 °C, low frequency, and high strain amplitude, and Mooney viscosity across a wide range of elastomer types, including EPDM, BR, IIR, NBR, and SBR. Despite significant differences in molecular architecture such as monomer composition, branching, and chain topology, the correlation remains robust.

This behavior reflects the shared molecular origin of both measurements. Higher Mooney viscosity and higher S' values are both associated with increased molecular entanglement density and longer relaxation times.³ Importantly, the RPA measurement captures this response under deformation levels that are more representative of real processing conditions.

Mooney-Equivalent Result: Raw Elastomers

- $ML (1+4) = 7 \times S'$
- $R^2 = 0.996$
- 17 unfilled elastomers: EPDM, BR, IIR, NBR, and SBR
- 100 °C, low frequency, high strain

■ b) Filled Compounds

In filled rubber compounds, correlation becomes more challenging due to filler-filler networking and strong strain-dependent nonlinearity. The critical strain for network breakdown is often several orders of magnitude lower than that of unfilled elastomers that requires careful selection of test conditions.

Using the Alpha MV-RPA test protocol, excellent agreement between RPA elastic torque S' and Mooney viscosity is also observed for filled compounds when sufficiently high strain amplitudes are applied.

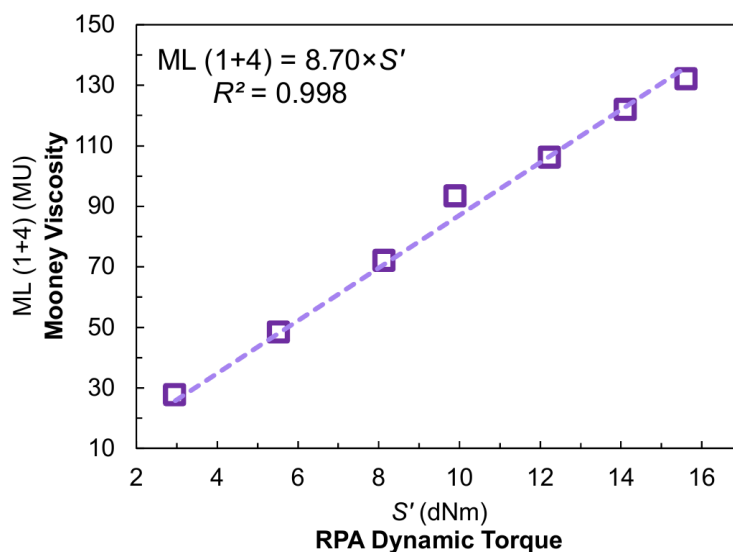


Figure 3. Correlation of the Premier RPA dynamic elastic torque S' with Mooney Viscosity $ML (1+4)$ for 7 rubber compounds at 100 °C, low frequency, and high strain.

As shown in Figure 3, S' measured at high strain amplitude maintains a strong linear correlation with Mooney viscosity for multiple rubber compounds containing reinforcing fillers. This confirms that, when properly configured, the Premier RPA can reproduce Mooney-equivalent rankings even in complex, filler-dominated systems.

Mooney-Equivalent Result: Filled Compounds

- $ML (1+4) = 8.70 \times S'$
- $R^2 = 0.998$
- 7 rubber compounds with reinforcing fillers
- 100 °C, low frequency, high strain

■ 3) Conclusion

Overall, these results demonstrate that Mooney-equivalent metrics derived from the RPA are both statistically robust and physically meaningful when appropriate nonlinear test conditions are applied. The customized Alpha MV-RPA test preserves the practical relevance of Mooney viscosity while extending its value through enhanced sensitivity to material structure and processing behavior.

Beyond correlation strength, the Premier RPA provides several practical advantages over traditional Mooney testing:

- Single-platform testing for raw elastomers and compounds
- Improved sensitivity to molecular architecture and elastic contributions
- Enhanced relevance to processing due to high-strain nonlinear deformation
- Faster data acquisition through automated test execution
- Expanded data output, including elastic and viscous components alongside Mooney-equivalent metrics

■ 4) References

1. Mooney, Melvin. *A Shearing Disk Plastometer for Unvulcanized Rubber*. Rubber Chemistry and Technology 7.3 (1934): 564-75.
2. Pawlowski, H., & Dick, J. (1992). *Viscoelastic characterization of rubber with a new dynamic mechanical tester*. Presented at the Akron Rubber Group Meeting, Akron, OH.
3. Norton, E. (2016). *Processability measurements for improved characterization of synthetic polymers using dynamic oscillatory shear rheometers and rotating shear viscometers*. Presented at the Rubber Division Technical Meeting, ACS.

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