Dr. Rikki Lamba
Managing Director, Additives
Polymer Solutions Group, USA

Science of Performance Process Aids for Highly Loaded Silica Compounds

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Agenda

- **Introduction to Polymer Solutions Group**
- **Silica Use in Tire Treads: Then & Now**
- **SureMix® CO^2 Product Design**
- **Product Performance in a Highly Loaded Silica Compound**
- **Conclusion**

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Technology & Services Trusted By The World's Leading Brands

PSG is an innovative manufacturer of proprietary and custom polymer additives, dispersions, and performance chemicals for the rubber, plastic, wood, consumer, construction, and medical industries. PSG's companies include:

- **Flow Polymers** (Cleveland, OH) is a leading manufacturer of proprietary and custom chemical dispersions, process aids, and homogenizing agents.
- **SASCO Chemical** (Albany, GA) global leader in rubber anti-tack market with PolyCoat®, TechKote®, and SureCoat® product lines.
- **Alkon Solutions** (Leeds, UK) proven anti-tack technology and global presence complements SASCO's line of anti-tack products.
- **Peach State Labs** (Rome, GA) is an advanced organic chemistry manufacturer that specializes in surface and stain protection for the carpet, hard surface, and electronics industries.
- **Phoenix Chemical Company** (Calhoun, GA) is a specialty chemical manufacturer and distributor focused on the carpet, textile, water treatment, and household, industrial and institutional chemicals markets.

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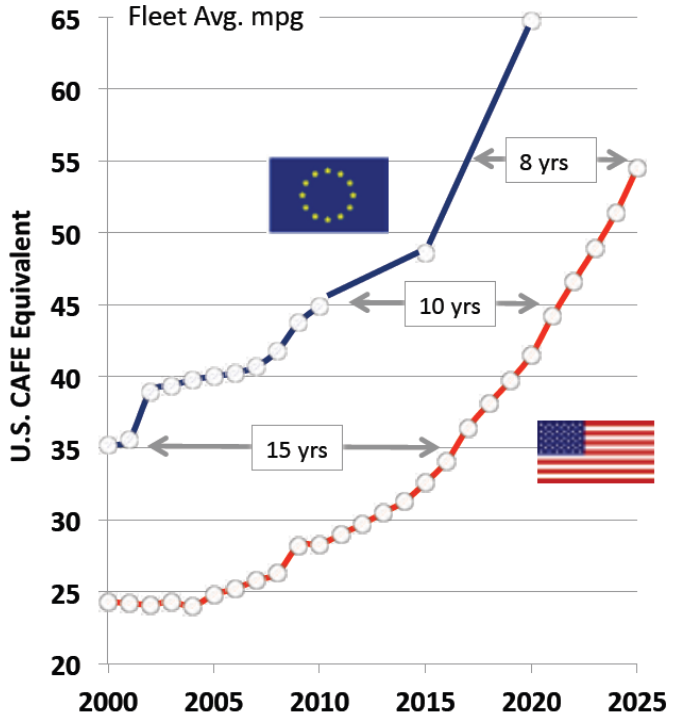
Silica Use in Tire Treads: Then

REGULATORY DRIVER: *FUEL ECONOMY*



AUTO COMPANY SOLUTIONS

- **Propulsion**
  - *Hybrid, Electric & Fuel Cells*
  - *Turbo and Superchargers*
  - *Diesel*
- **Transmissions**
  - *8, 9, 10 speed and CVT's*
- **Aerodynamics**
- **Lighter vehicles**
  - *Advanced design (CAD)*
  - *Aluminum and High Strength Steel*
  - *Composites*
- **Low Rolling Resistance Tires**
  - ***Silica Tread***
  - ***Solution and Functional Polymers***
  - ***Reduced Weight Construction***

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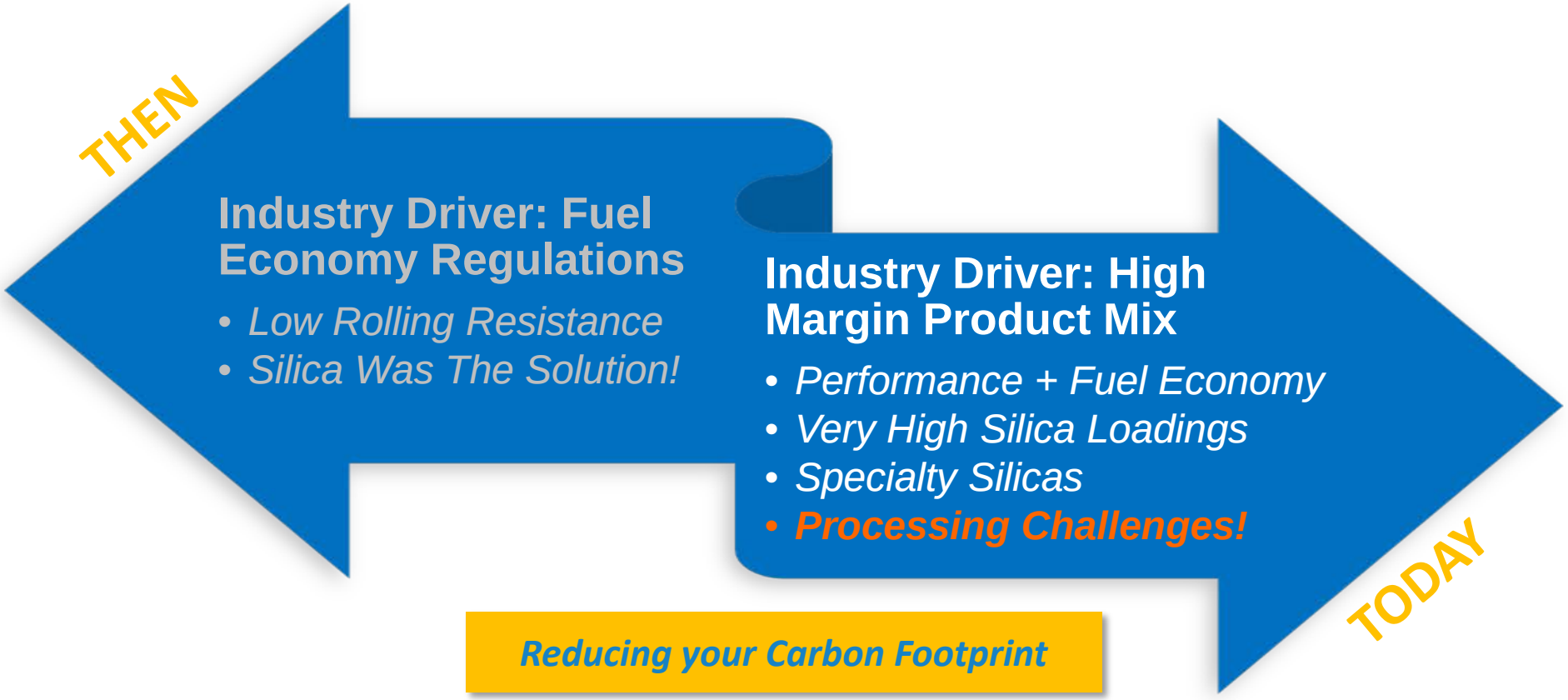
SureMix®: Answering Today's Silica Challenges



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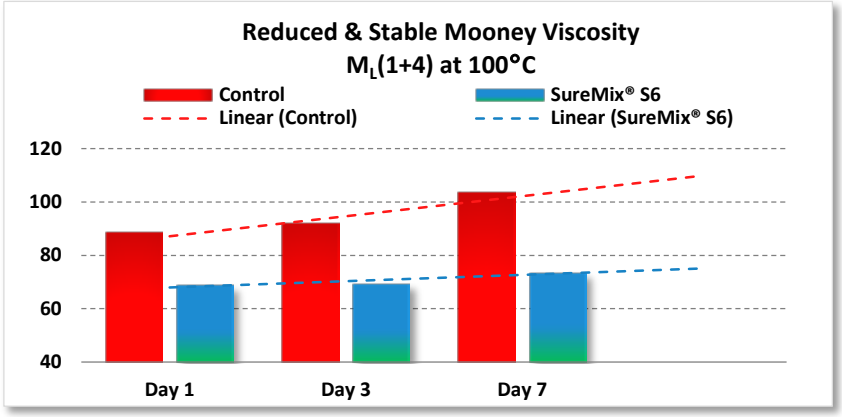
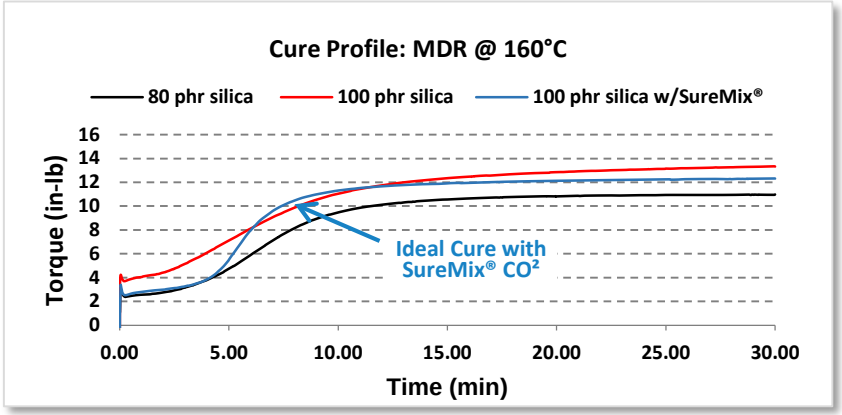
SureMix® CO^2 Product Design

- Viscosity Reduction
  - Reduced Mixing Time / Passes
  - Scrap Reduction
- Improved Green Compound Stability
  - Increased Processing Window
  - Eliminate Rework
- **C**ure **O**ptimization
  - Maintain Scorch Window
  - Accelerates Cure Rates vs. Conventional Products
- **CO**$_2$ Emission Reduction
  - Mixing, Processing, and Scrap
  - Fuel Economy





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Premium Silica Tread Formulation

	80 phr Silica	100 phr Silica
1st Non-Productive Pass – Reactive Mix		
Buna® VSL-4526-2HM	96.25	96.25
Buna® CB 24	30.00	30.00
HD Silica (160 m^2/g)	**70.00**	**70.00**
TESPT Silane	**5.60**	**5.60**
Microcrystalline Wax	3.00	3.00
TDAE Oil	10.00	10.00
2nd Non-Productive Pass – Reactive Mix		
HD Silica (160 m^2/g)	**10.00**	**30.00**
TESPT Silane	**0.80**	**2.40**
TDAE Oil	5.00	5.00
3rd Non-Productive Pass		
N234 Carbon Black	5.00	5.00
Stearic acid	1.00	1.00
6PPD	2.00	2.00
Zinc Oxide	2.50	2.50
Productive Pass		
Sulfur	1.00	1.00
CBS	2.00	2.00
DPG	2.00	2.00

- **High Vinyl SSBR**
- **Nd Polybutadiene**
- **160 m^2/g CTAB Silica**
- **TESPT Silane (8phf)**
- **Silica 80 phr vs. 100 phr**

Higher Silica Loading Is Required for Improved Wet Performance – The Cost Penalty is Higher Viscosity, Mixing Costs, and Increased Carbon Footprint.

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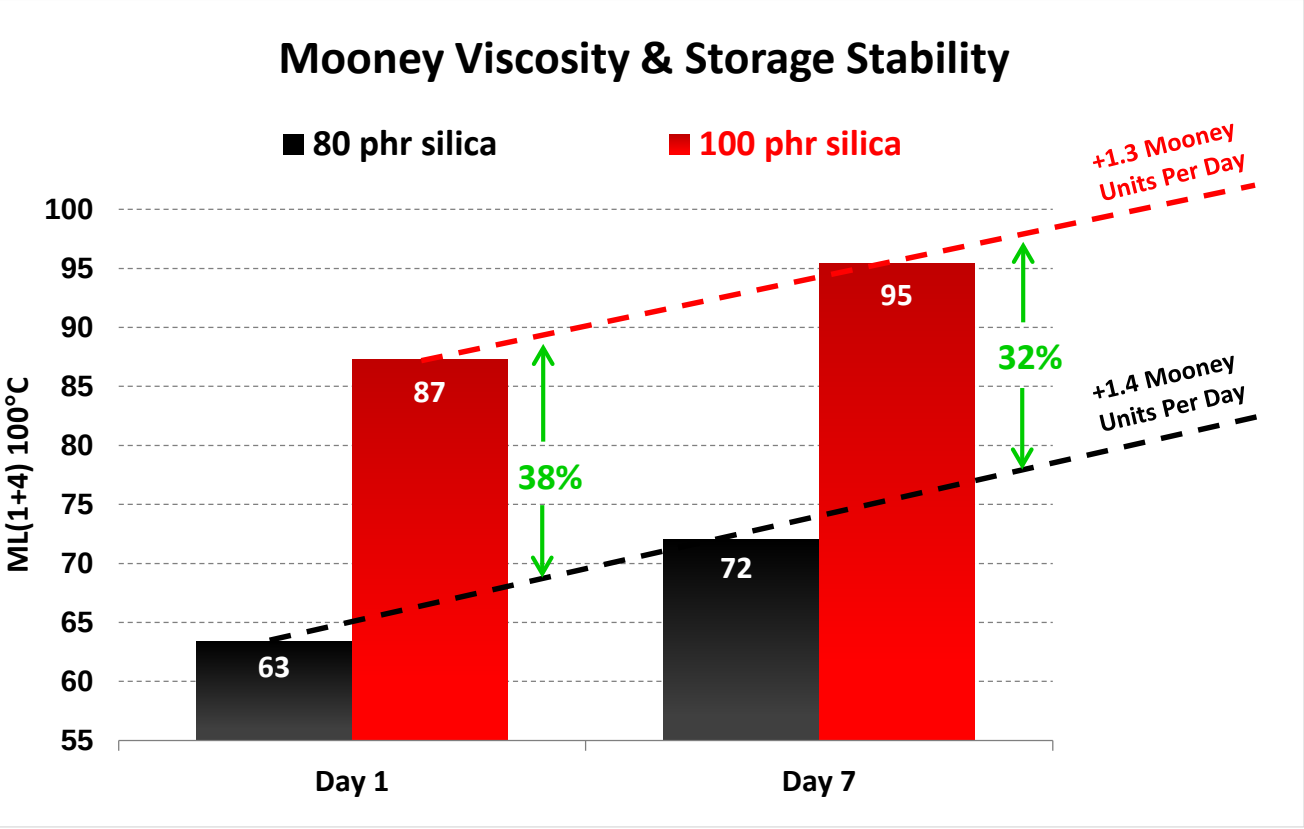
Processability



Higher Silica Loading Reduces Processability:

- Higher Mooney Viscosity (Increased Energy Usage & Slower Extrusion Rates)
- Silica Compound Viscosity Increases During Storage (Instability)

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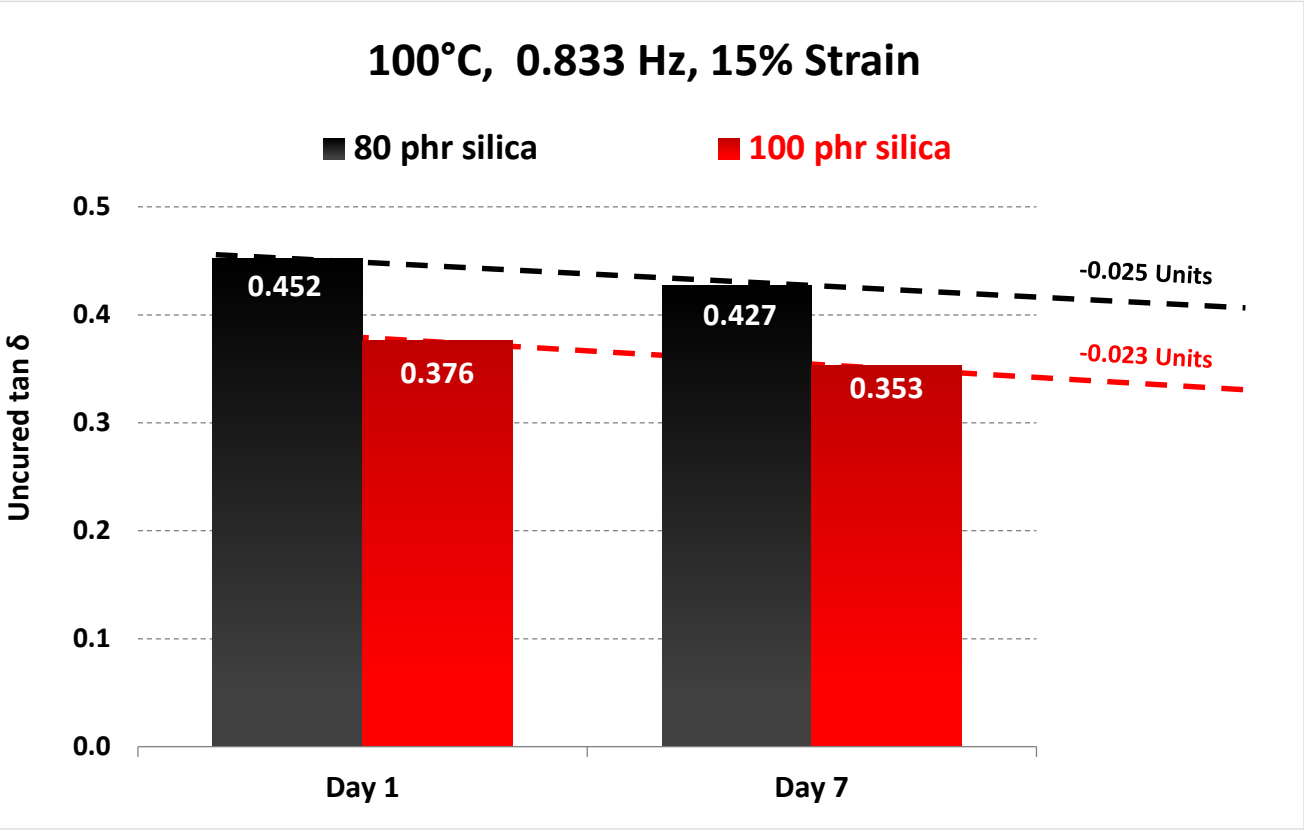
RPA Processability Predictor: Uncured Tan δ



Higher Silica Loading Reduces Processability:

- Lower Uncured Tan δ (Reduced Extrusion Quality, More Nerve)

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Increasing Silica Impact Extruded Quality

100°C, 20 rpm — Garvey Extrusion After 7 Days

80 phr Silica	72 Mooney
100 phr Silica	95 Mooney

Higher Silica Loading Reduces Processability:

- Poor Extrusion Performance Due to Higher Viscosity and Reduced Storage Stability

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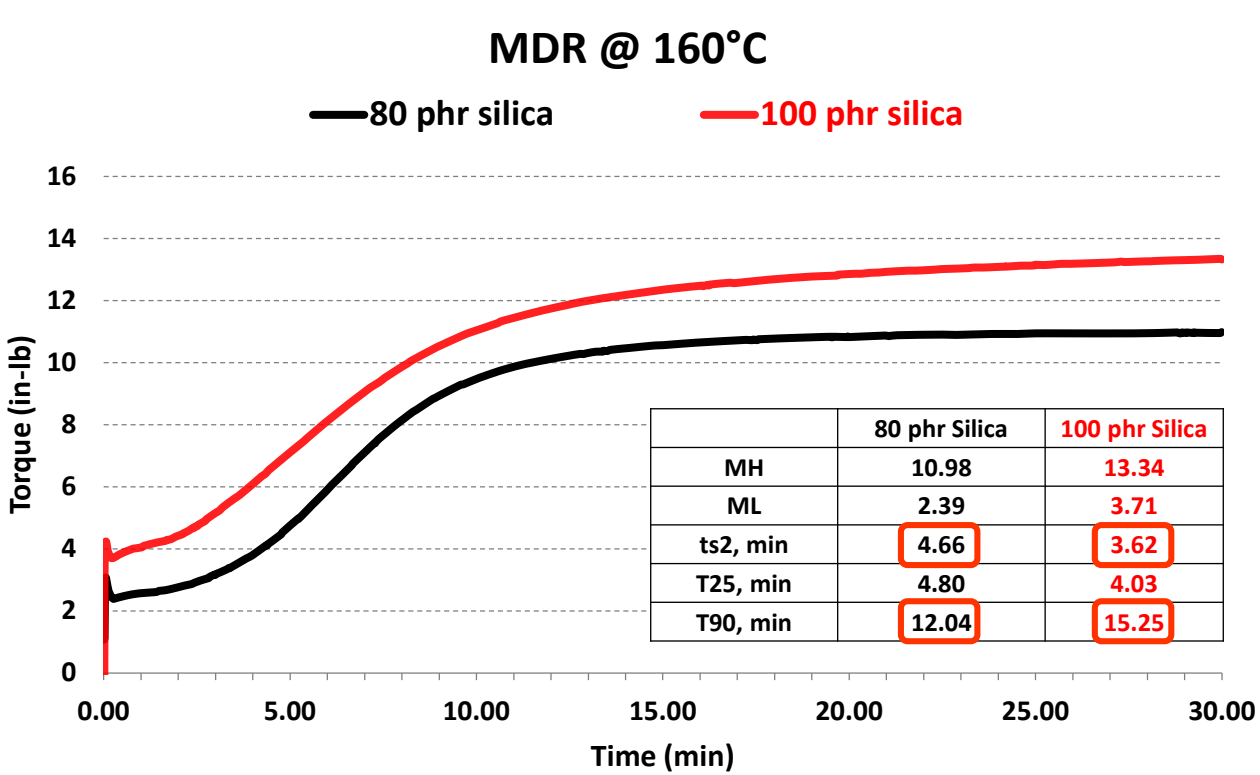
Cure Profile



	80 phr Silica	100 phr Silica
MH	10.98	13.34
ML	2.39	3.71
ts2, min	4.66	3.62
T25, min	4.80	4.03
T90, min	12.04	15.25

Higher Silica Loading Affects Cure Profile:

- Early Viscosity Build From Silica-Silica Interaction
- Marching Modulus

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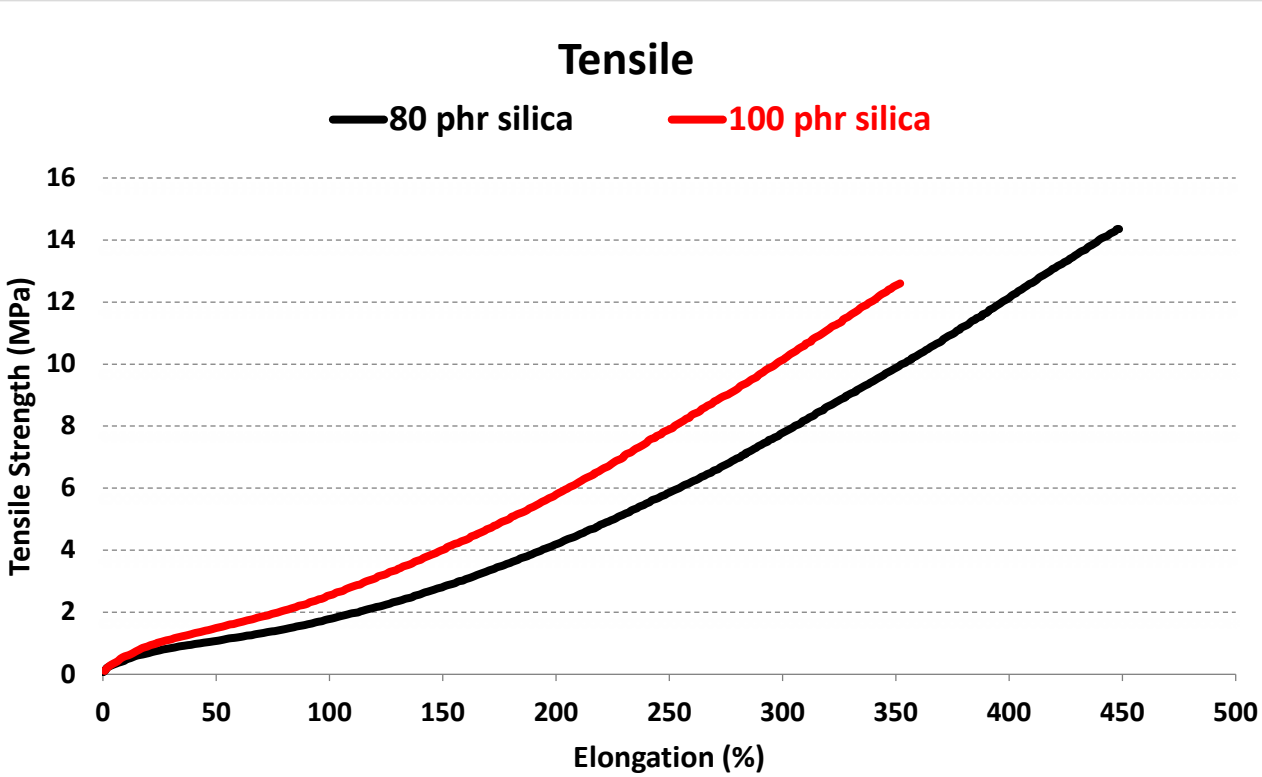
Increase in Stiffness with Silica



Higher Silica Loading Reduces Tensile Properties:

- Lower Tensile Strength & Elongation (Reduced Toughness)

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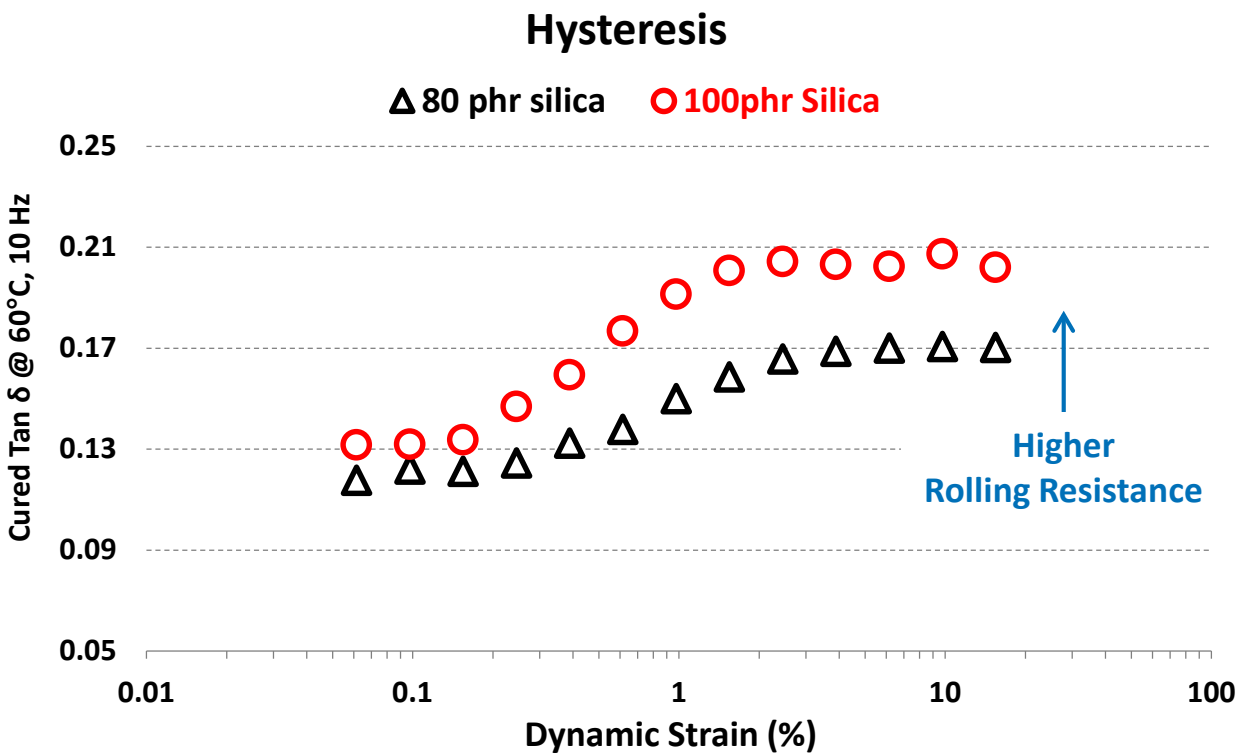
Higher Loading Increases Energy Losses



Increased Hysteresis From Higher Silica Loading:

- Increased Tan δ (Higher Rolling Resistance - Reduces Fuel Economy)

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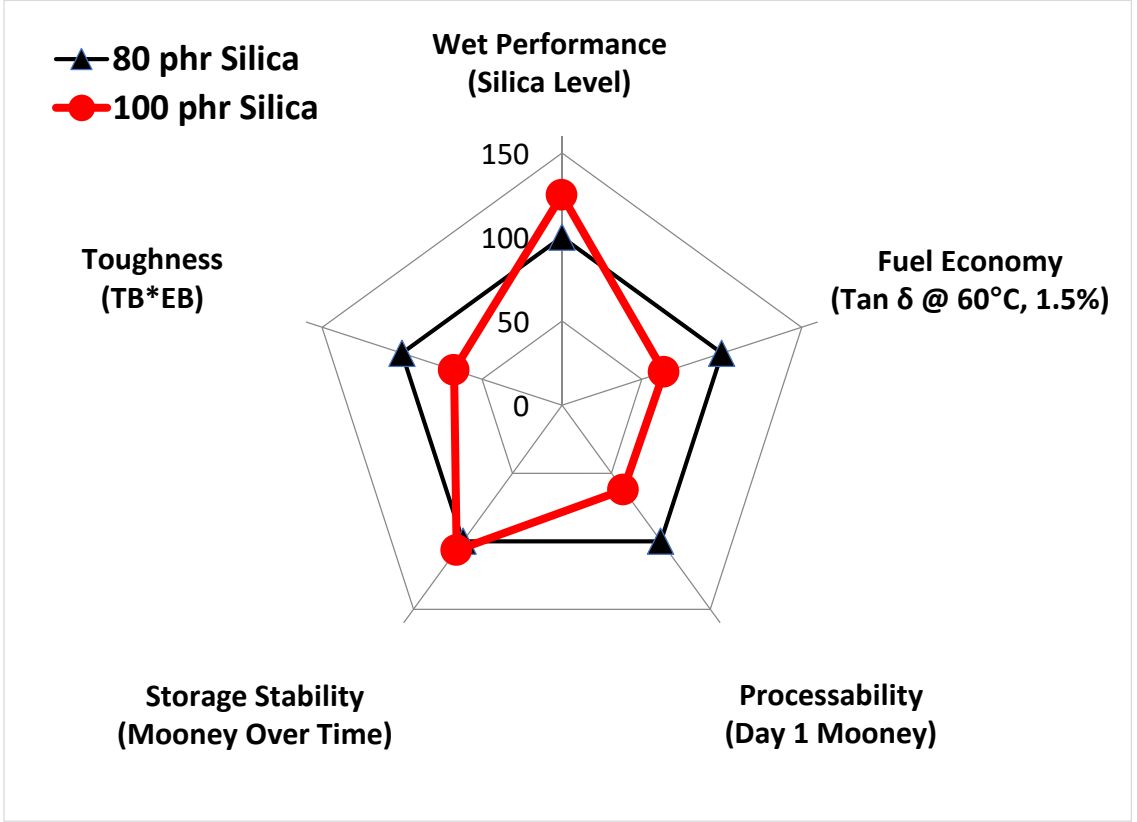
Premium Silica Tread: 80phr vs. 100phr

The Cost of Improved Wet Performance:

- Dramatically Reduced Processability (Mooney/Extrusion)
- Reduced Fuel Economy (Higher Tan δ)
- Reduced Toughness (TB*EB)
- Poor Storage Stability (Flocculation)

SureMix® CO^2 Was Designed to Alleviate Performance Disadvantages



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Premium Silica Tread Formulation

	80 phr Silica	100 phr Silica Control	100 phr Silica SureMix® CO^2
1st Non-Productive Pass – Reactive Mix			
Buna® VSL-4526-2HM	96.25	96.25	96.25
Buna® CB 24	30.00	30.00	30.00
HD Silica (160 m^2/g)	**70.00**	**70.00**	**70.00**
TESPT Silane	**5.60**	**5.60**	**5.60**
SureMix® CO^2	**-**	**-**	**5.00**
Microcrystalline Wax	3.00	3.00	3.00
TDAE Oil	10.00	10.00	10.00
2nd Non-Productive Pass – Reactive Mix			
HD Silica (160 m^2/g)	**10.00**	**30.00**	**30.00**
TESPT Silane	**0.80**	**2.40**	**2.40**
TDAE Oil	5.00	5.00	5.00
3rd Non-Productive Pass			
N234 Carbon Black	5.00	5.00	5.00
Stearic acid	1.00	1.00	1.00
6PPD	2.00	2.00	2.00
Zinc Oxide	2.50	2.50	2.50
Productive Pass			
Sulfur	1.00	1.00	1.00
CBS	2.00	2.00	2.00
DPG	2.00	2.00	2.00

- High Vinyl SSBR
- Nd Polybutadiene
- 160 m^2/g CTAB Silica
- TESPT Silane (8 phf)

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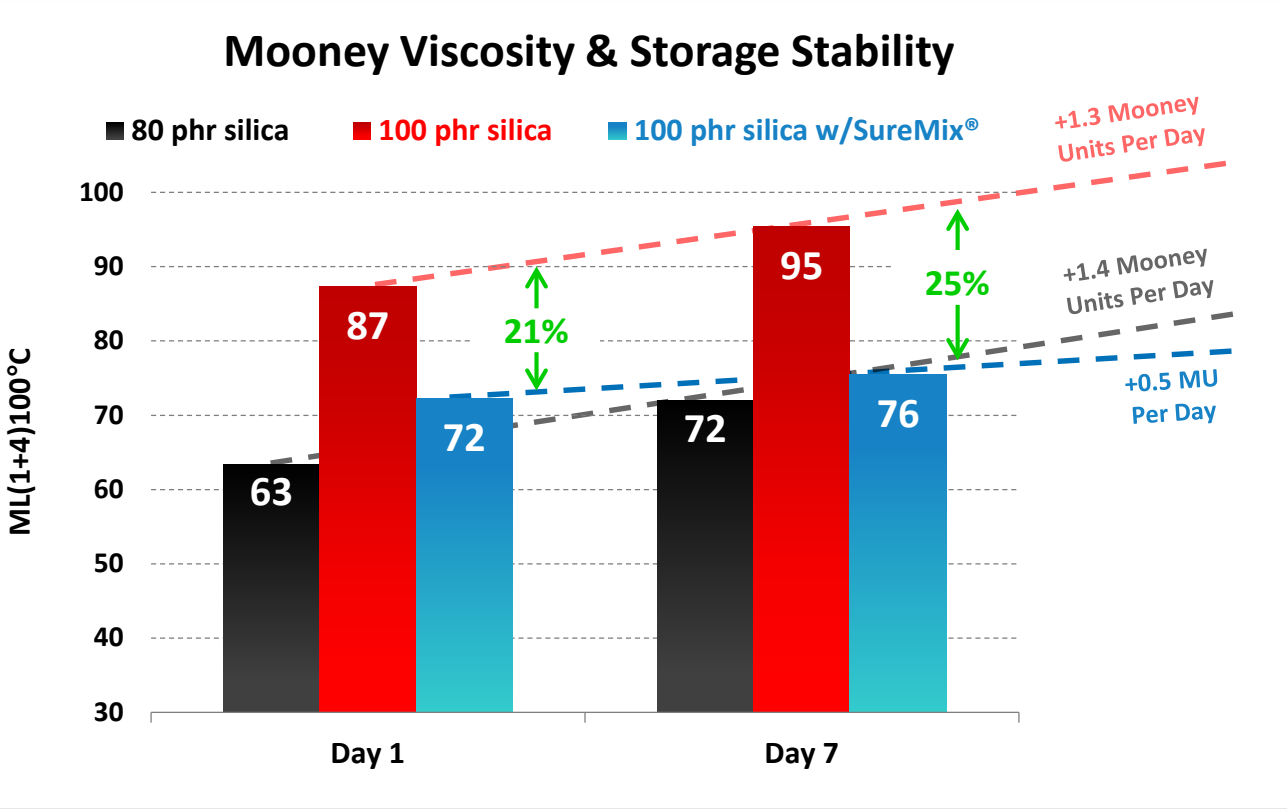
Processability



SureMix® CO^2 Improves Processing and Storage Stability:

- Lower Mooney Viscosity (Reduced Energy Usage & Faster Extrusion Rates)
- Maintains Low Viscosity During Storage (Stability & Uniformity)

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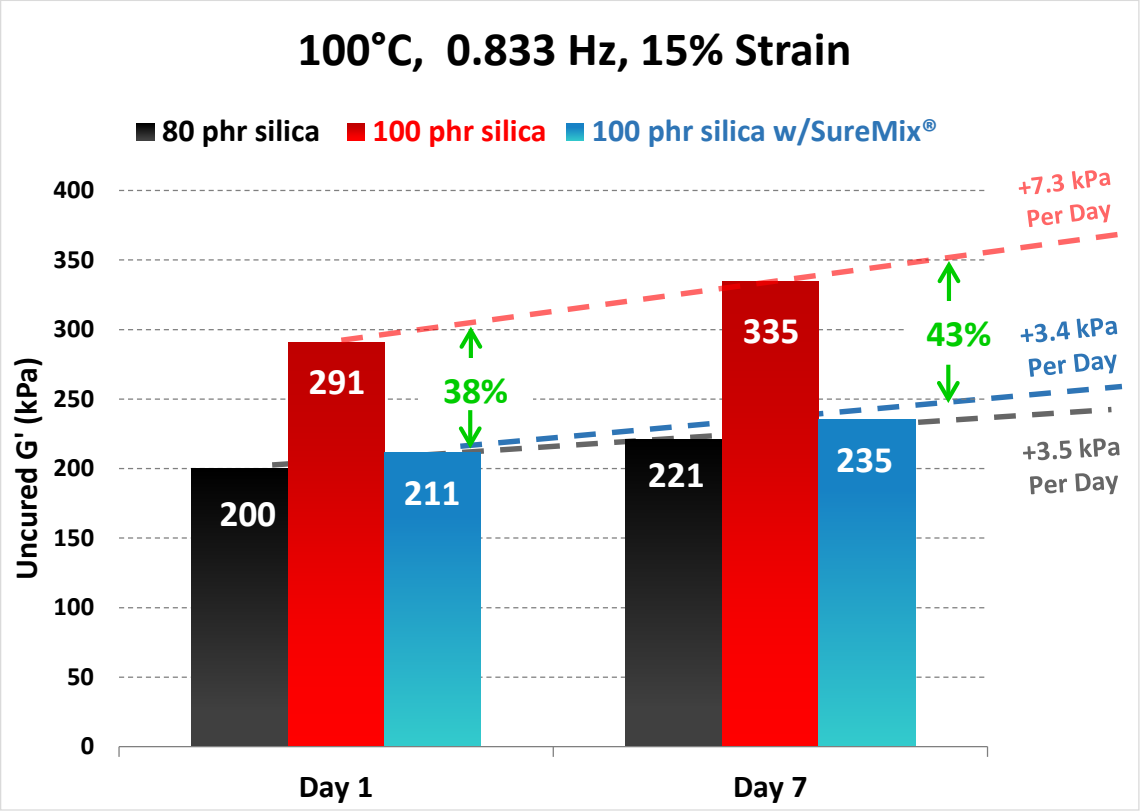
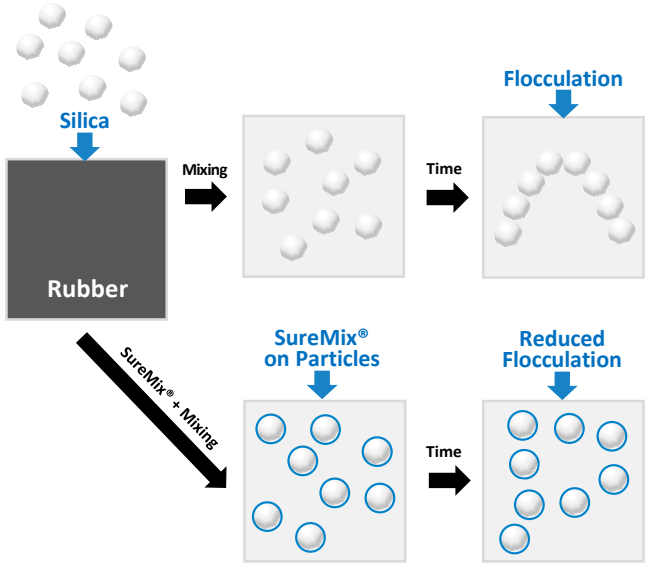
RPA Processability Predictor: Uncured G'



SureMix® CO^2 Improves Processing & Storage Stability:

- Lower Uncured G' (Reduced Energy Usage & Faster Extrusion Rates)



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Benefits of Reduced Viscosity & Flocculation

100°C, 20 rpm – Garvey Extrusion After 7 Days

80 phr Silica	72 Mooney
100 phr Silica	95 Mooney
100 phr Silica 5 phr SureMix® CO^2	76 Mooney

SureMix® CO^2 Improves Processing & Storage Stability:

- Lower Viscosity & Higher Uncured Tan δ (Improved Extrudate Quality)
- Maintains Low Viscosity During Storage (Stability & Uniformity)

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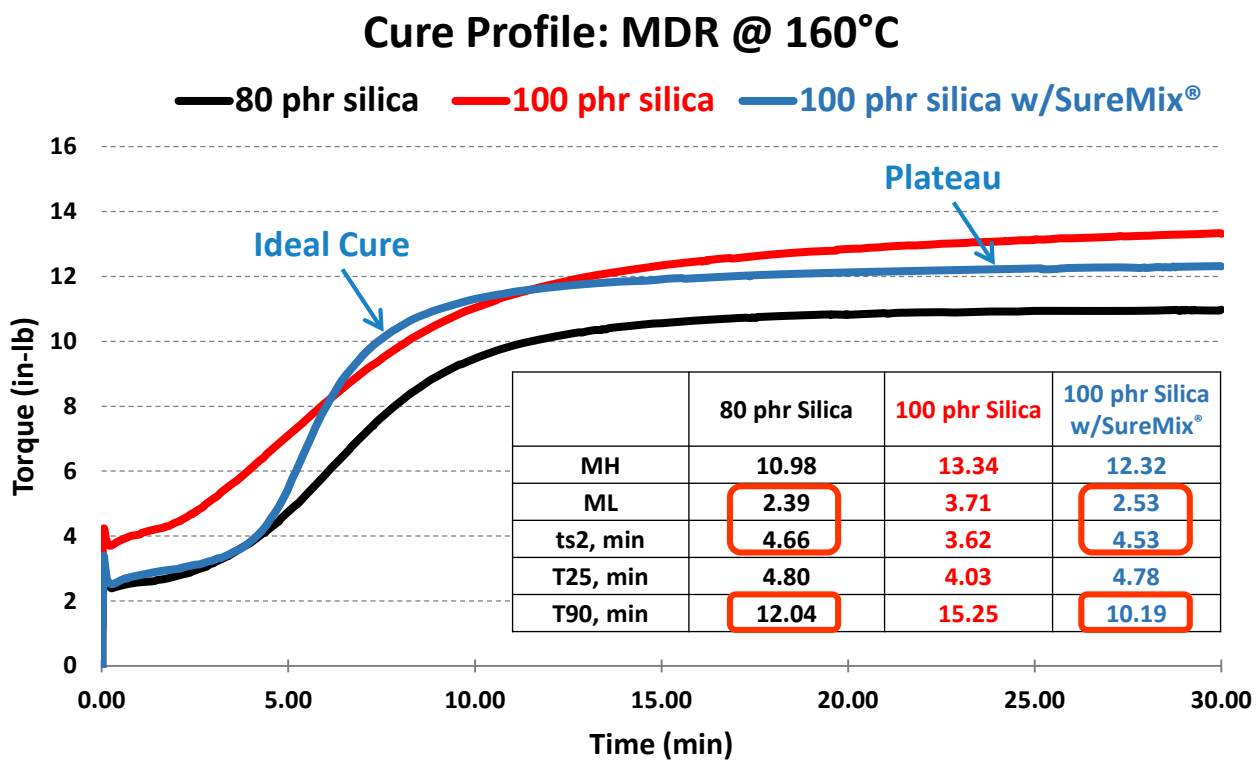
Cure Cycle Optimization



	80 phr Silica	100 phr Silica	100 phr Silica w/SureMix®
MH	10.98	13.34	12.32
ML	2.39	3.71	2.53
ts2, min	4.66	3.62	4.53
T25, min	4.80	4.03	4.78
T90, min	12.04	15.25	10.19

SureMix® CO^2 Provides Optimal Cure:

- Eliminates Early Viscosity Build Seen with Higher Silica Loading
- Eliminates Marching Modulus, Optimizes Cure Profile

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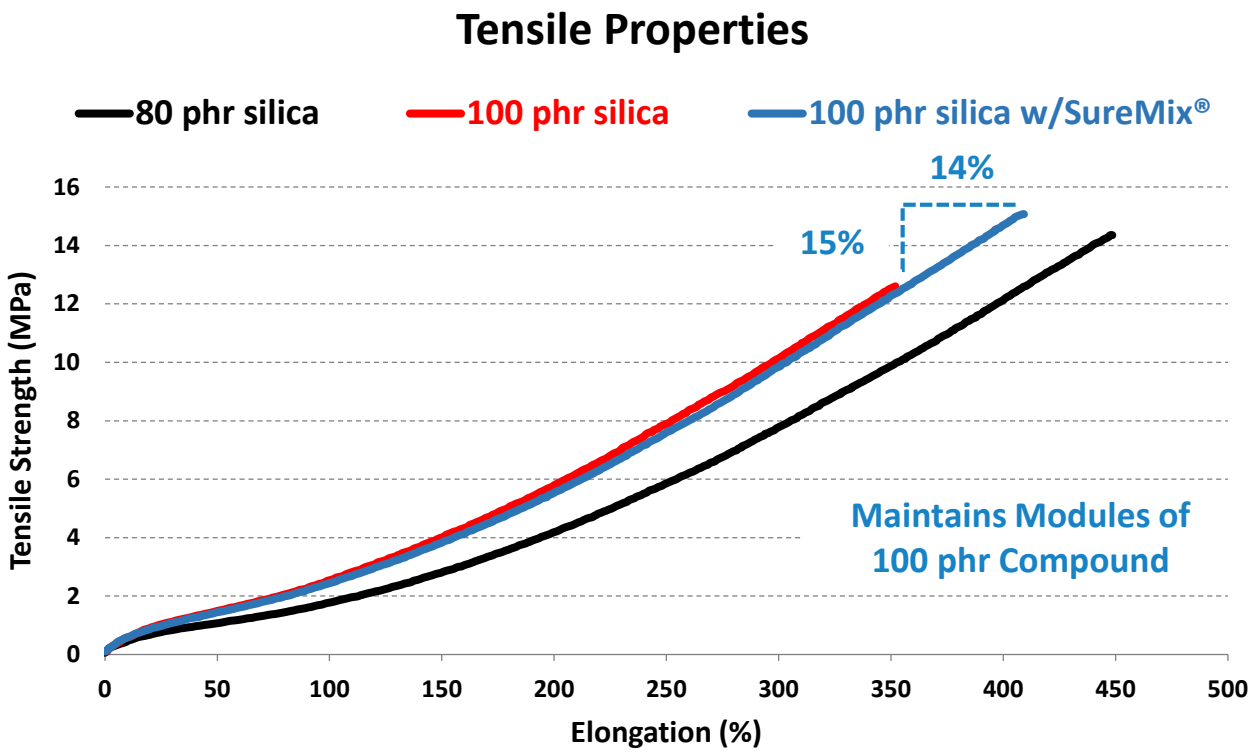
Improved Microdispersion



SureMix® CO^2 Improves Physical Properties:

- Higher Tensile Strength & Elongation (Increased Toughness)

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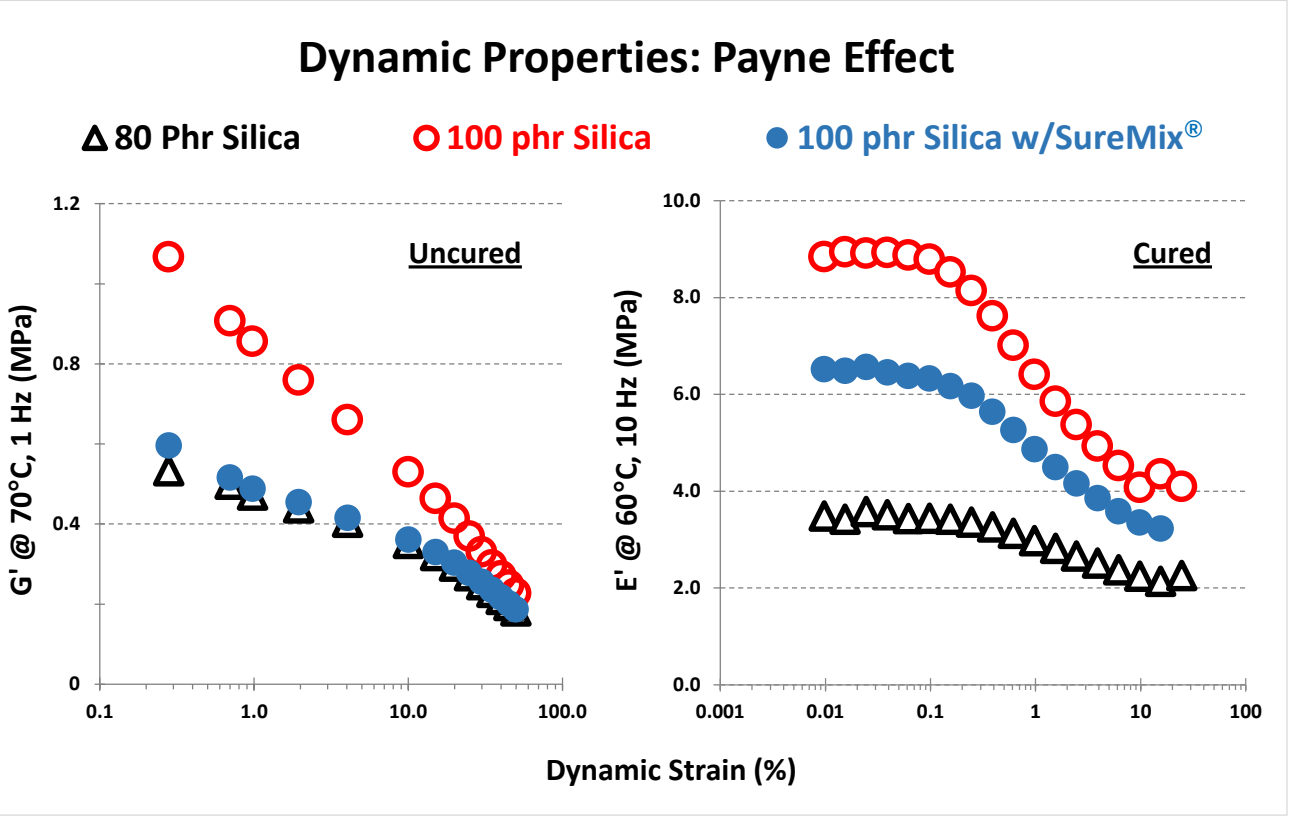
Improved Dispersion



SureMix® CO^2 Improves Filler Dispersion:

- Reduces Payne Effect (Improved Filler Dispersion) — Both Cured & Uncured

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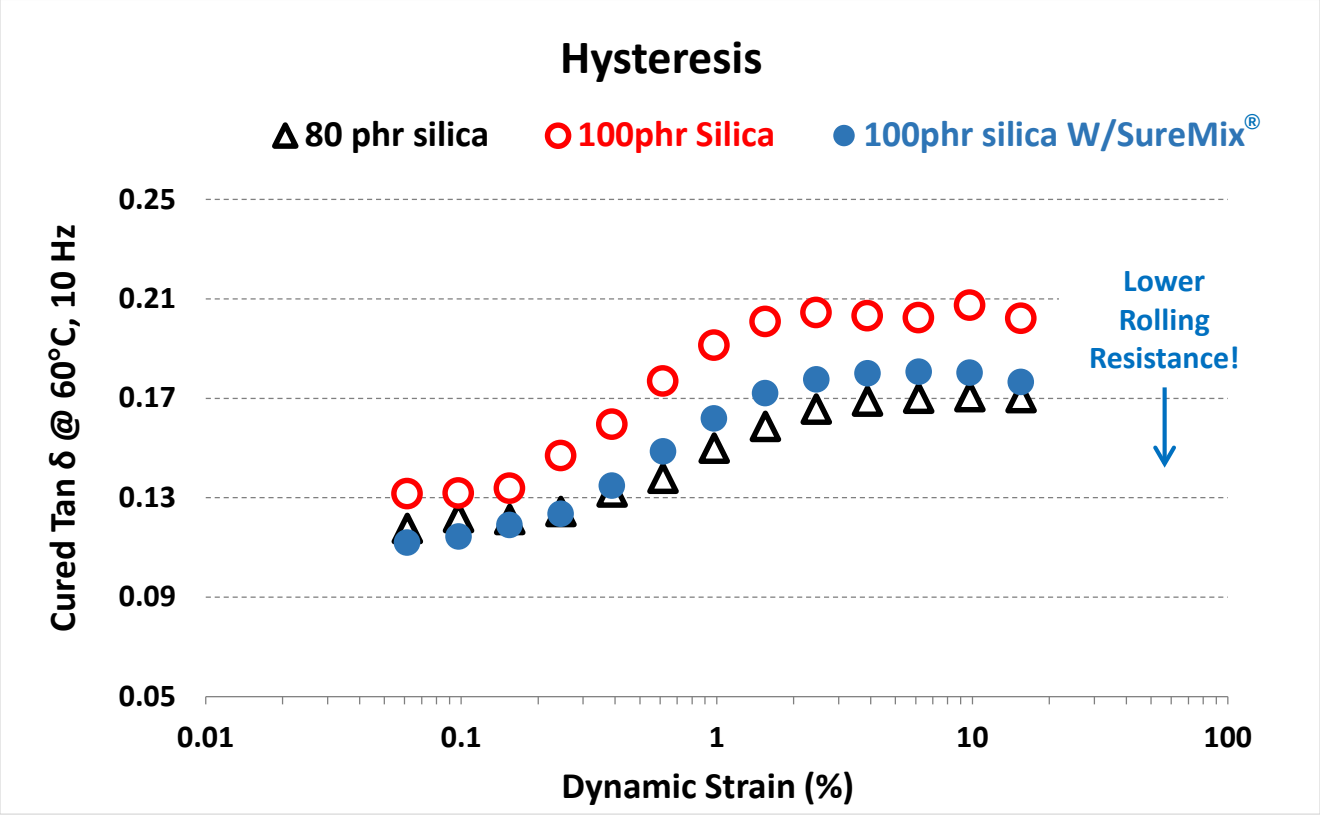
Fuel Economy: Reduced CO_2 Emissions



SureMix® CO^2 Improves Dynamic Properties:

- Reduced Tan δ (Lower Rolling Resistance — Better Fuel Economy)

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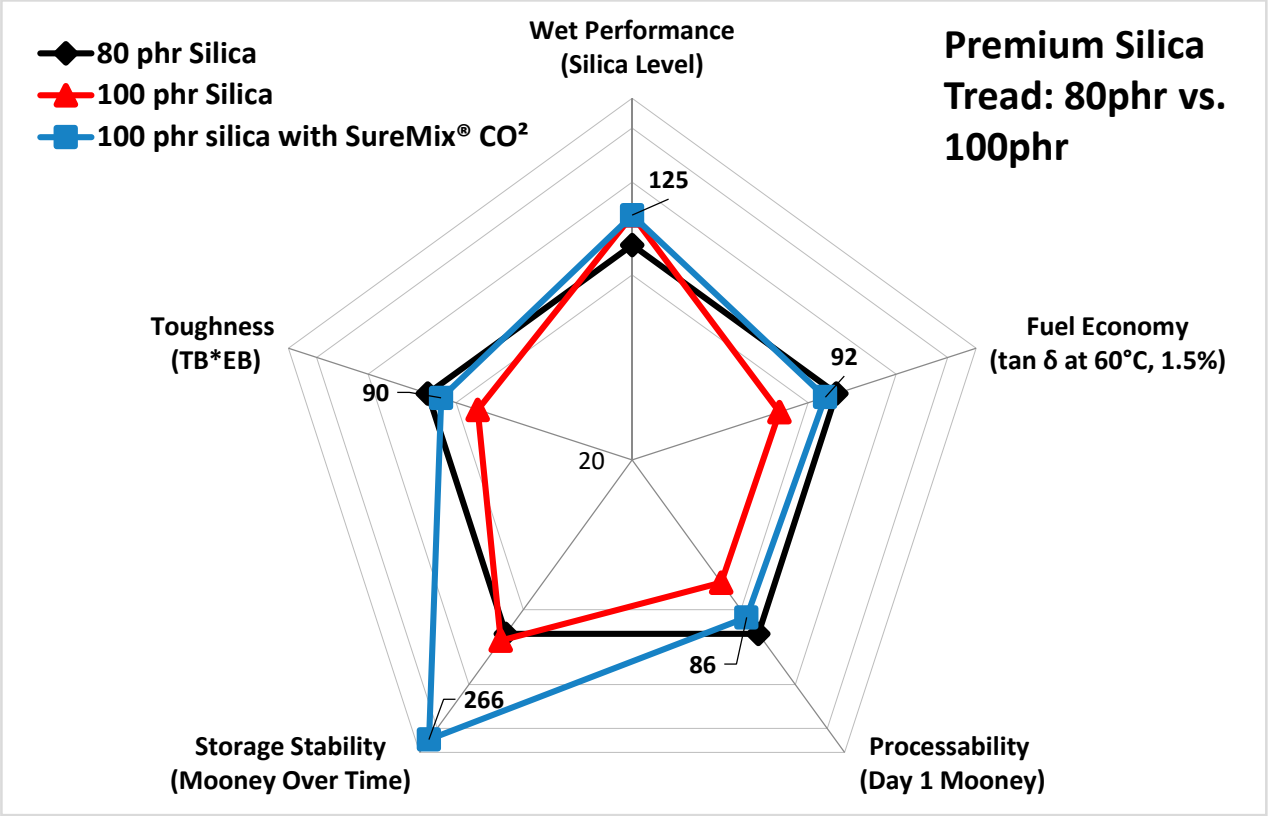
Wet Traction Without Compromise

SureMix® CO²

Maximize Wet Traction Tires Without Compromise!



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SureMix®: Three Products with Distinct Benefits

SureMix® S6

BEST-IN-CLASS
Processing & Storage Stability

- ✓ Reduce the Number of Mix Passes
- ✓ Maximize Extrusion Rate and Quality
- ✓ Optimize Processing While Maintaining Performance

SureMix® S8

BEST-IN-CLASS
High Dynamic Stiffness

- ✓ Improve Handling of Low Silica Ultra Low RR Tires
- ✓ Maximize Fuel Economy Benefit From Pre-Treated Silicas
- ✓ Improve BOTH Handling and Fuel Economy

SureMix® CO^2

BEST-IN-CLASS
High Silica Loadings

- ✓ Maximum Wet Traction with the Highest Silica Loadings
- ✓ Wet Traction with Low Rolling Resistance
- ✓ Achieve Fast Cure Rates at High Silica Loadings

SureMix® Performance Process Aids Addressing the Needs of Silica Tire Manufacturers!

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For More Information, Samples, or Pricing, Contact:

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