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AEQ-QEG Technico-Commercial meeting
November 8, 2017

N990 Thermal Black in Natural Rubber isolation bushings for improved dynamic performance

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What is Thermal Carbon Black?

A niche product (specialty chemical)

Produced by thermal decomposition of the natural gas molecule (CH_4)

The largest particle size (100-700nm diameter) carbon black

The lowest structure carbon black

The highest purity carbon black

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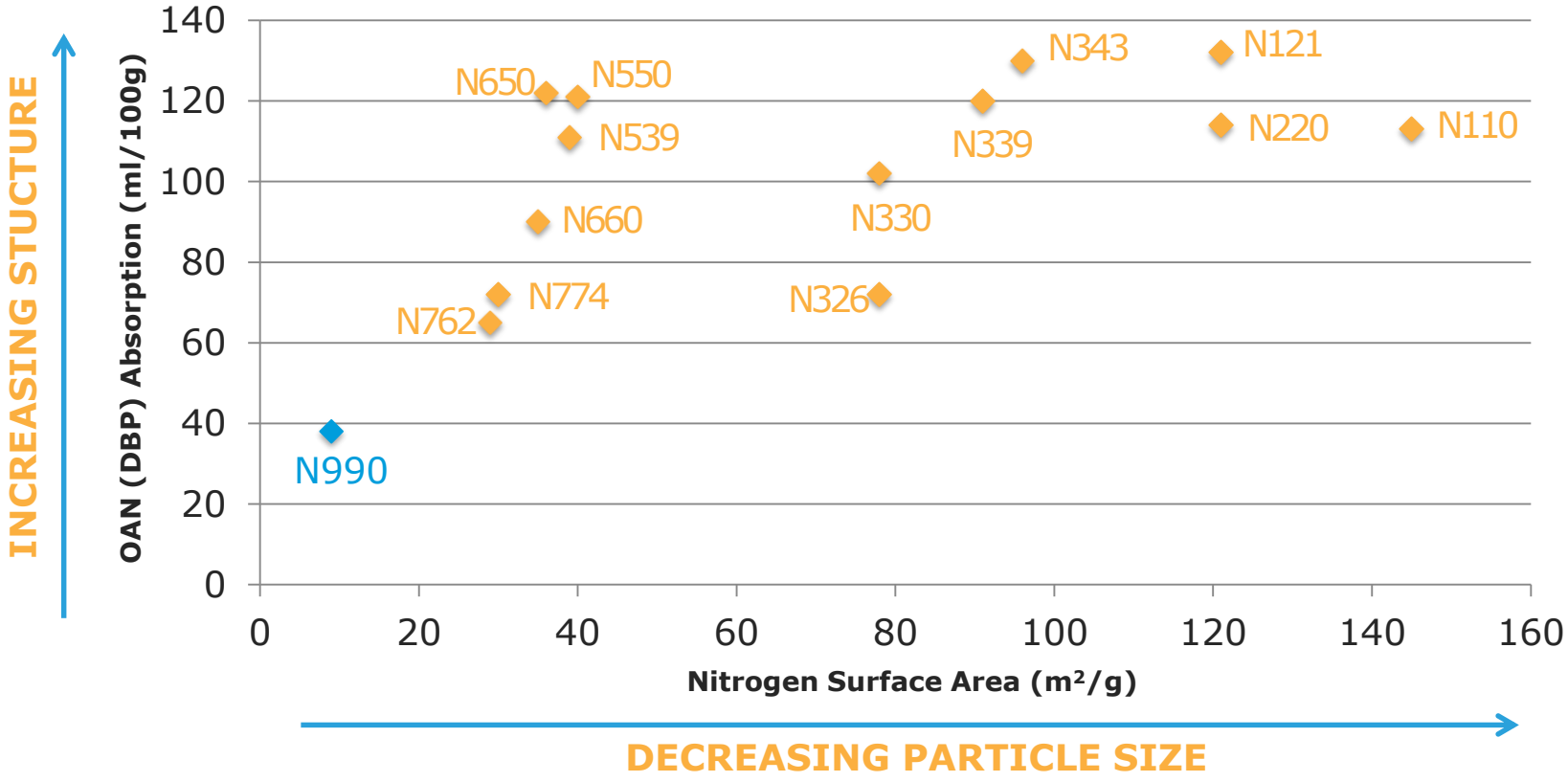
THE CARBON BLACK SPECTRUM



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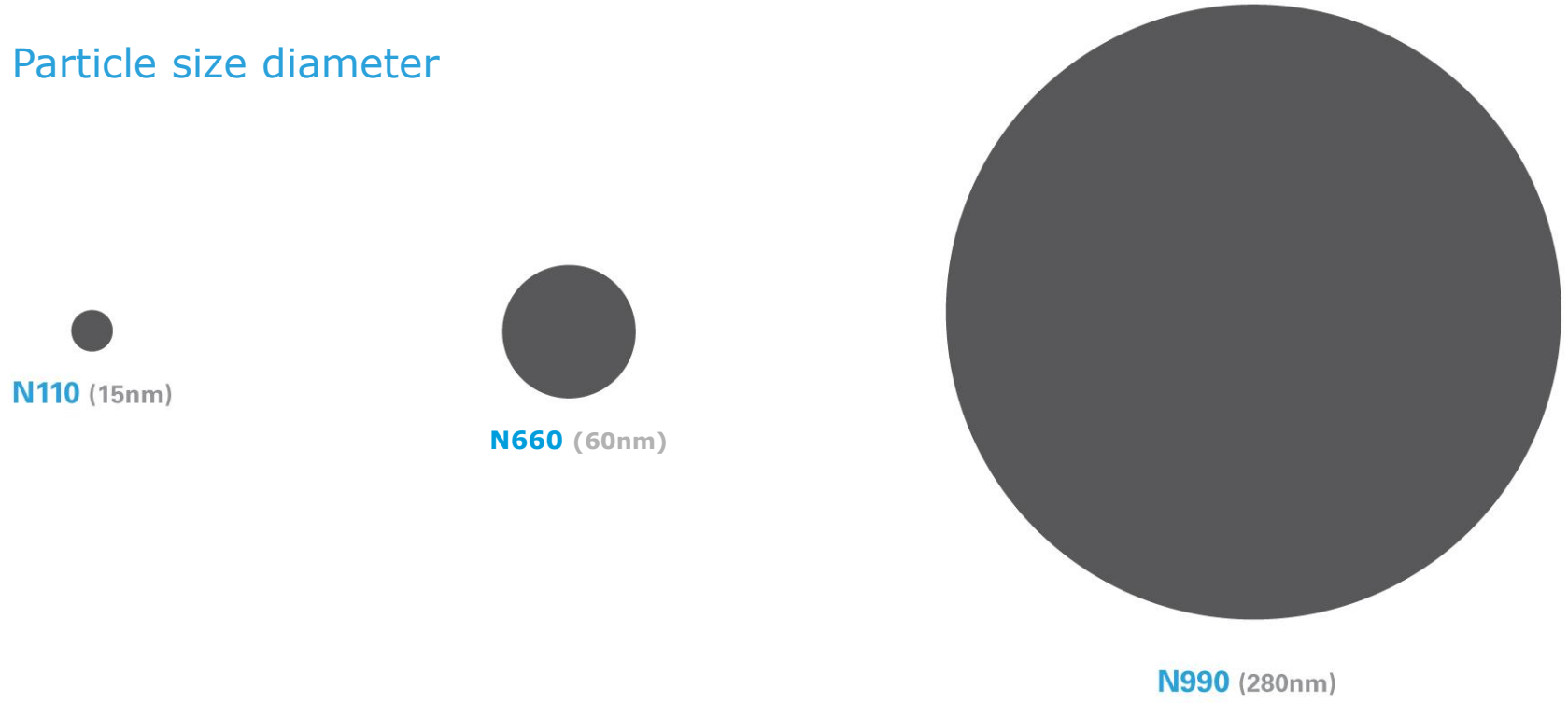
THERMAX® vs FURNACE BLACK GRADES

Particle size diameter



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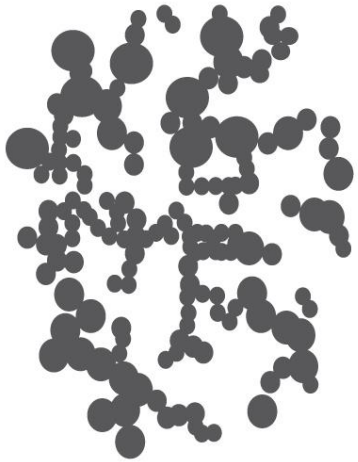
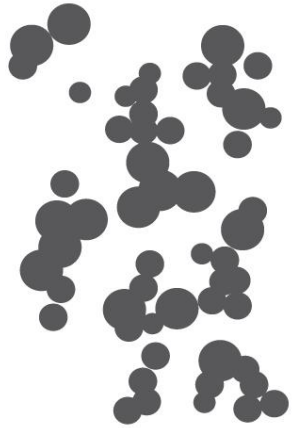
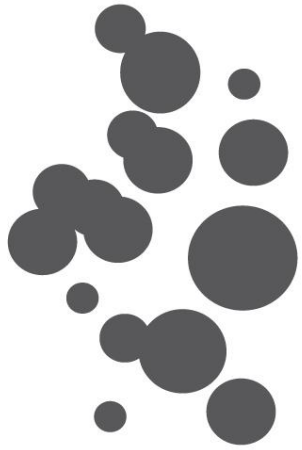
THERMAX® vs FURNACE BLACK GRADES

High Structure	Moderate Structure	Low Structure
		
N550	**N660**	**N990**

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DYNAMIC APPLICATIONS

- Tires
- Motor mounts
- Air springs
- V-belts
- Conveyor belts
- Blow out preventer
- Dynamic seals
- Roll covers
- Shoe soles
- Dynamic mechanical goods
- Bushings
- Shock absorbers
- Hoses
- Bridge bearings

- Foam, sponge compounds
- Innertubes
- Caster wheels
- Sporting goods
- Diaphragms
- Suspension bumpers
- Body mounts
- Vibrations isolators
- Rail pads
- Vacuum tubing
- Wiper blades
- Bladders
- Mats

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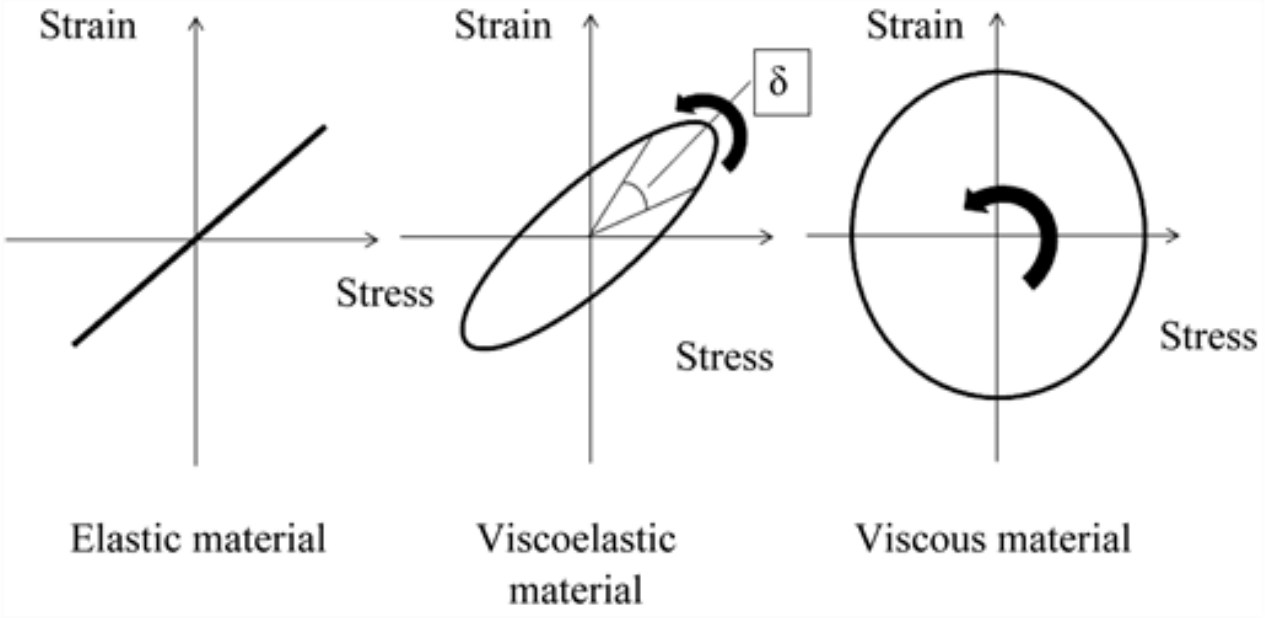
RUBBER VISCOELASTICITY

Rubber exhibits both viscous and elastic properties, allowing for very specialized applications.



"Perfect" spring **Rubber** **Honey**

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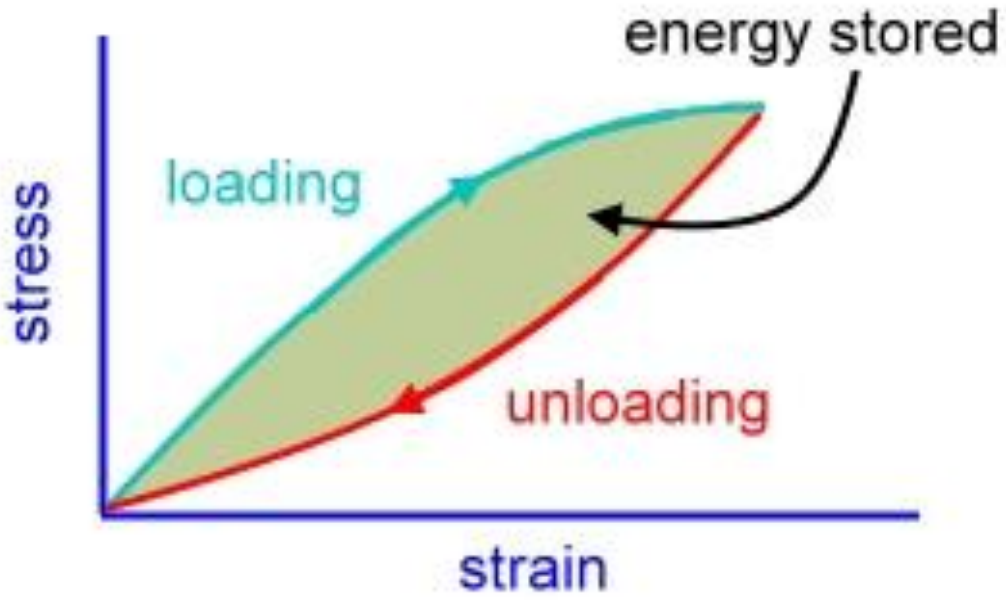
HYSTERESIS

Energy is lost in the viscoelastic material as heat – causes heat buildup and accelerates rubber aging



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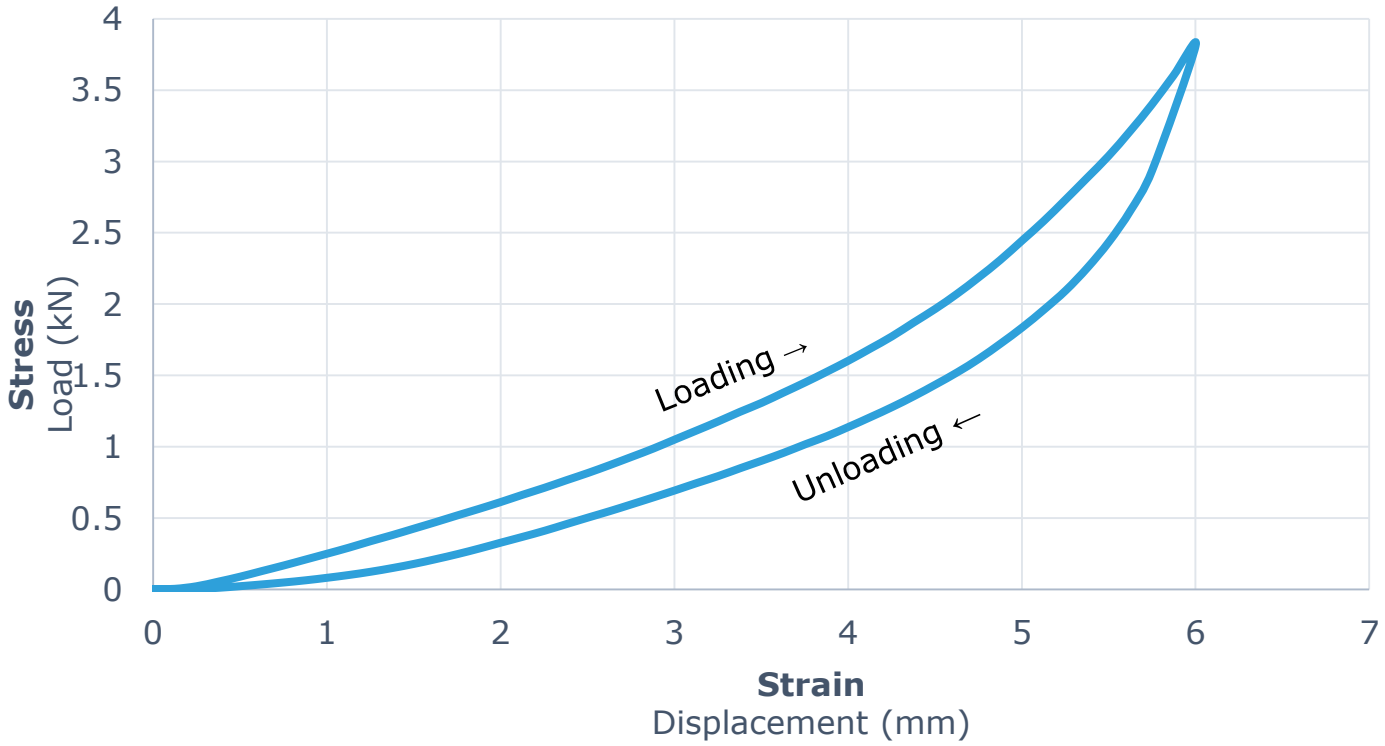

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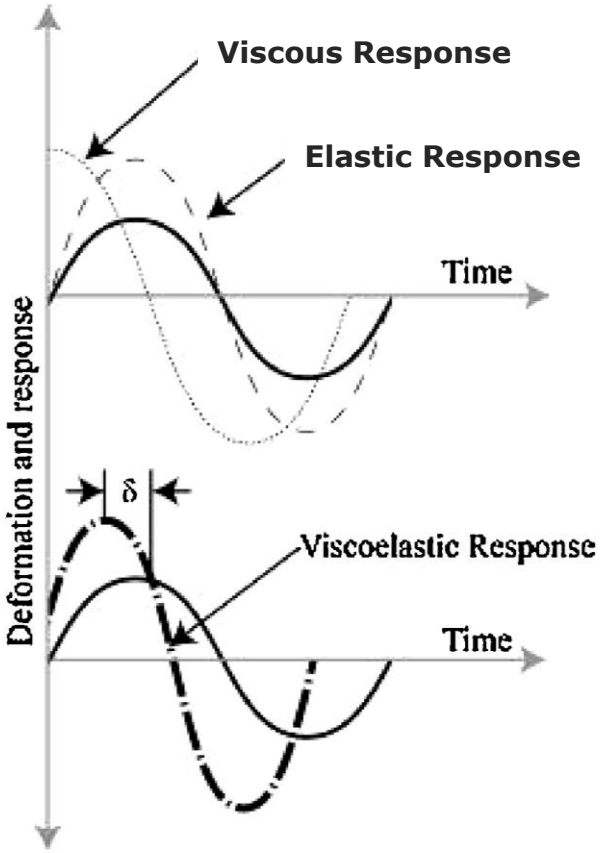
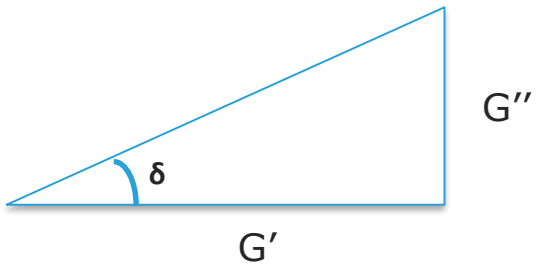
MEASURED DYNAMIC PROPERTIES – WHAT DO THEY MEAN



$$\tan\delta = \frac{G''}{G'} = \frac{viscous\ modulus}{elastic\ modulus}$$



Tan delta is indicative of heat buildup, noise transmission, rolling resistance

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MEASURED DYNAMIC PROPERTIES – WHAT DO THEY MEAN

Dynamic stiffness and static stiffness

$$spring\ ratio = \frac{K_d}{K_s}$$

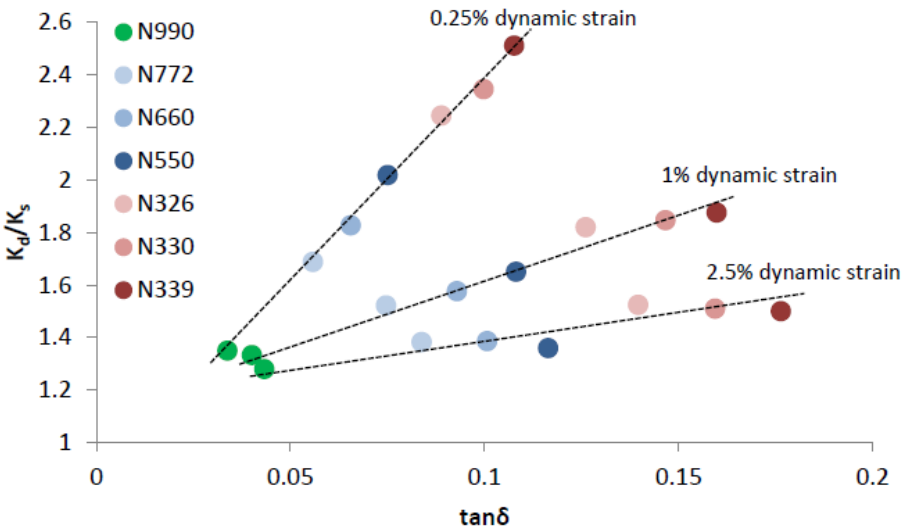
Surface area

Structure

Want a low spring ratio

–low K_d and high K_s

Low dynamic stiffness (K_d) is a predictor of vibration isolation performance. Sufficient static stiffness (K_s) is required to support a load



Sunnicliffe, L. (2017). Carbon black reinforcement of rubber for vibration isolation applications. Presented at: *Technical Meeting of Rubber Division, ACS*.

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OBJECTIVES FOR AN IDEAL RUBBER BUSHING

1. Reduce tan delta
(heat buildup, noise transmission)
2. Increase static stiffness
(mechanical integrity)
3. Increase processability and cost effectiveness

The compound must balance the requirements for static stiffness with minimized dynamic stiffness and hysteresis in order to suppress the frequency of resonance

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TESTING MATERIAL AND FORMULATIONS

Objective:
Evaluate the replacement of N660 with N990 in natural rubber isolation bushings for use in automobiles

Anticipated results:
- Increased N990 loading to obtain same hardness
- Decreased tensile strength
- Increased adhesion between rubber and steel with N990 addition

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LABORATORY TESTING

Dynamic and static testing – Tokai Chita Lab

- Tensile strength
- Resilience
- Rheometry
- Dynamic and Static moduli

Dynamic testing - ESI Lab

- Dynamic and Static Moduli
- Heat buildup upon compression cycles
- Rubber hysteresis

Adhesion testing - RDAbbott

- Rubber Pull Test (ASTM D429 Method B)

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FORMULATIONS

Compound #	1	2	3	4	5	6	7	8	9
	A-0	B-9.65	C-19.3	D-28.95	E-38.5	F-48.25	G-57.9	H-67.55	I-77.2
Carbon black loading in phr									
N660	40	35	30	25	20	15	10	5	0
N990	**0**	**9.65**	**19.3**	**28.95**	**38.6**	**48.25**	**57.9**	**67.55**	**77.2**
Total carbon black loading	40	44.65	49.3	53.95	58.6	63.25	67.9	72.55	77.2

Additional Materials: Natural rubber (100phr), Aromatic process oil (5phr)
Antioxidant (1phr), Zinc oxide (5phr)
Stearic acid (3phr), Accelerator (0.75phr)
Sulfur (2.25phr)

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HARDNESS – MAINTAINED WITH ADDED N990 LOADING

Compound #	1	2	3	4	5	6	7	8	9
	A-0	B-9.65	C-19.3	D-28.95	E-38.5	F-48.25	G-57.9	H-67.55	I-77.2
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Total carbon black loading	40	44.65	49.3	53.95	58.6	63.25	67.9	72.55	77.2
Hardness	57	57	57	58	57	58	59	58	58
Hardness after aging	62	62	62	62	63	63	64	63	63

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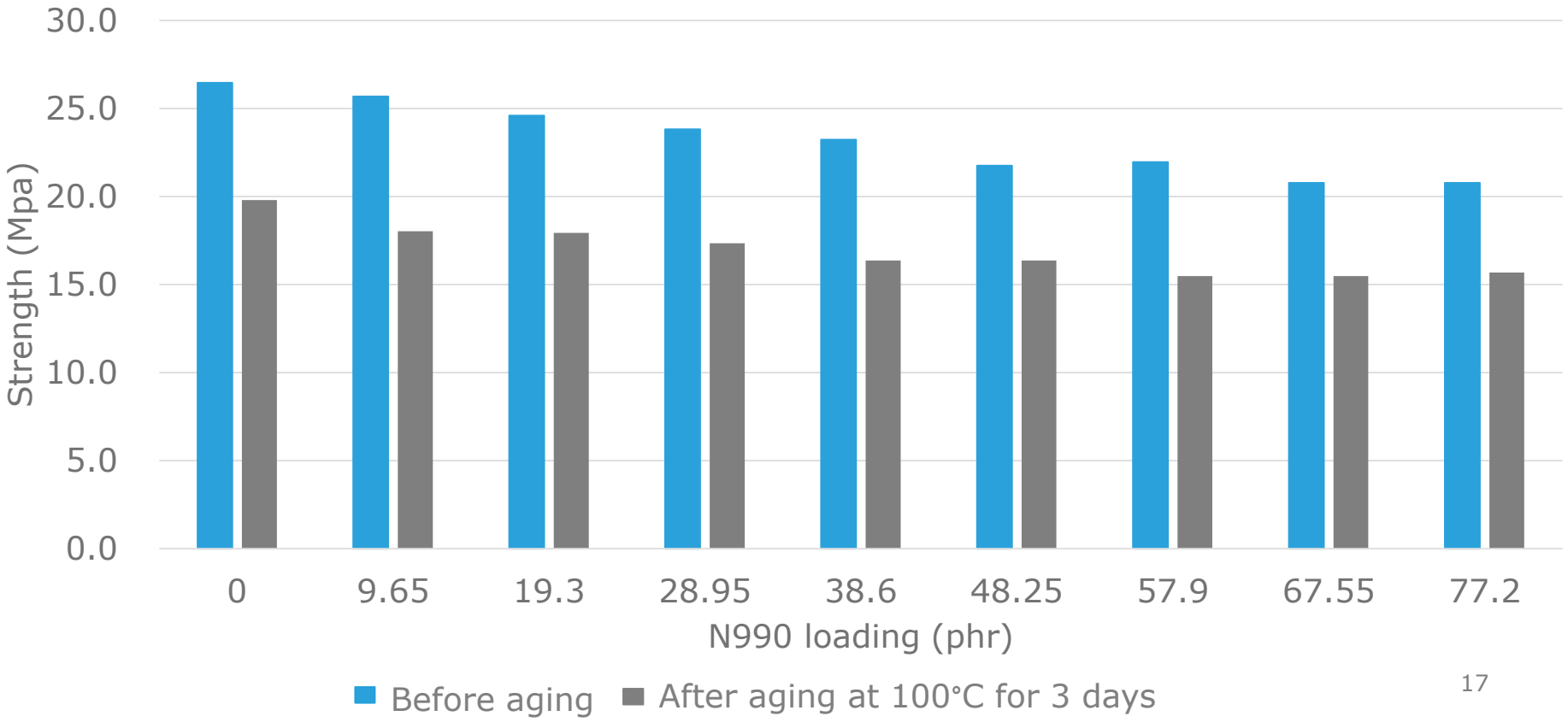
TENSILE STRENGTH BEFORE AND AFTER AGING

Tensile strength decreases with increasing N990 loading. Effects are less pronounced after aging. This is to be expected when replacing a furnace black with thermal black.



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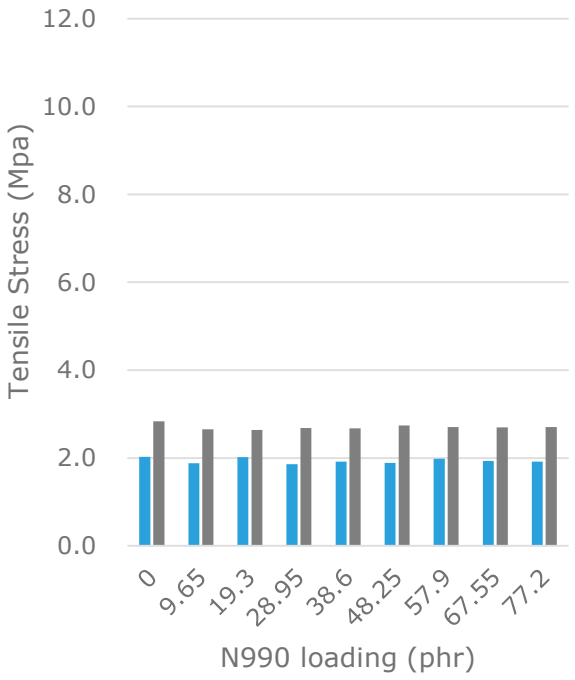
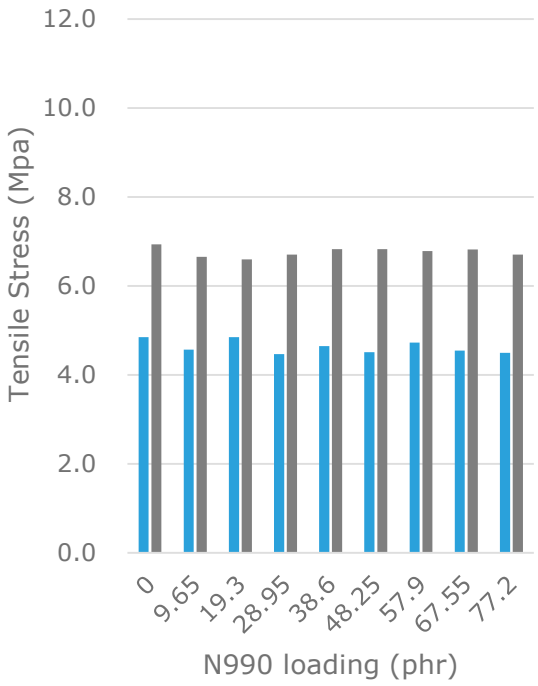
TENSILE STRESS BEFORE AND AFTER AGING

Tensile stress is relatively unaffected by N990 loading.

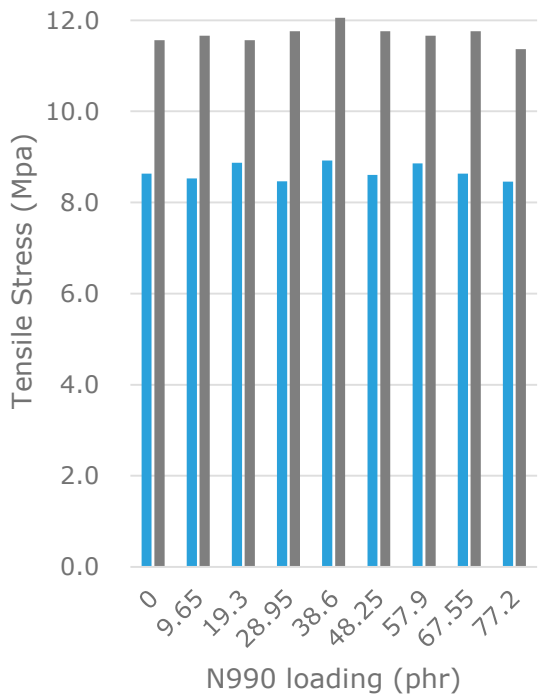
100% Elongation



200% Elongation



300% Elongation



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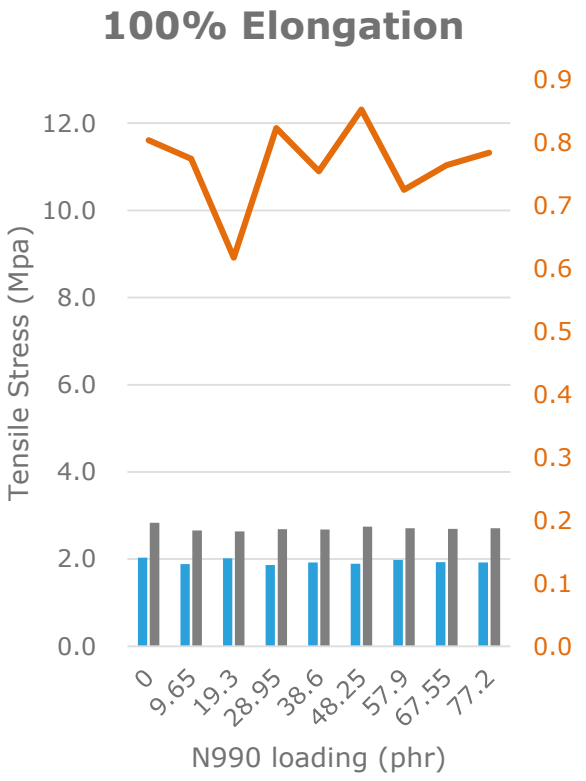

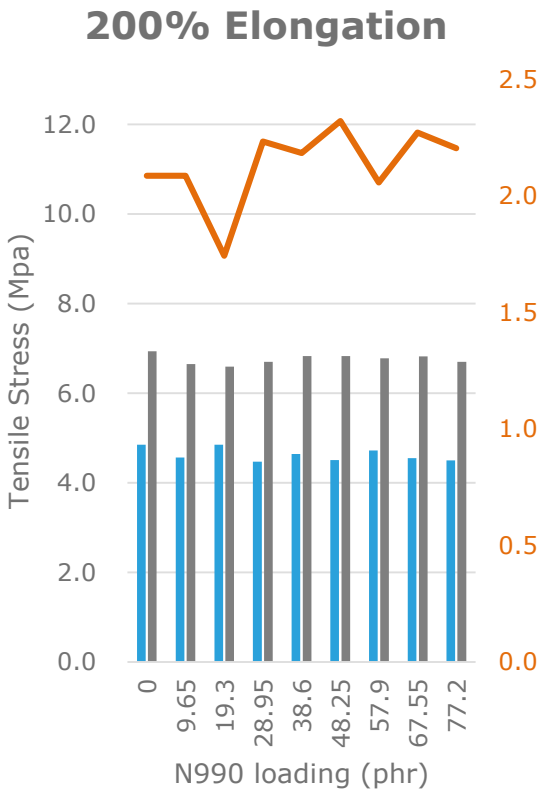

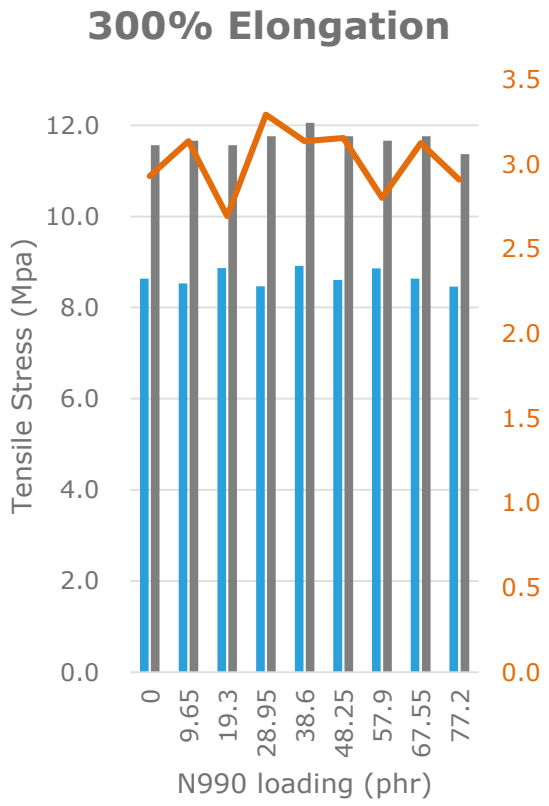

Before Aging After Aging Change

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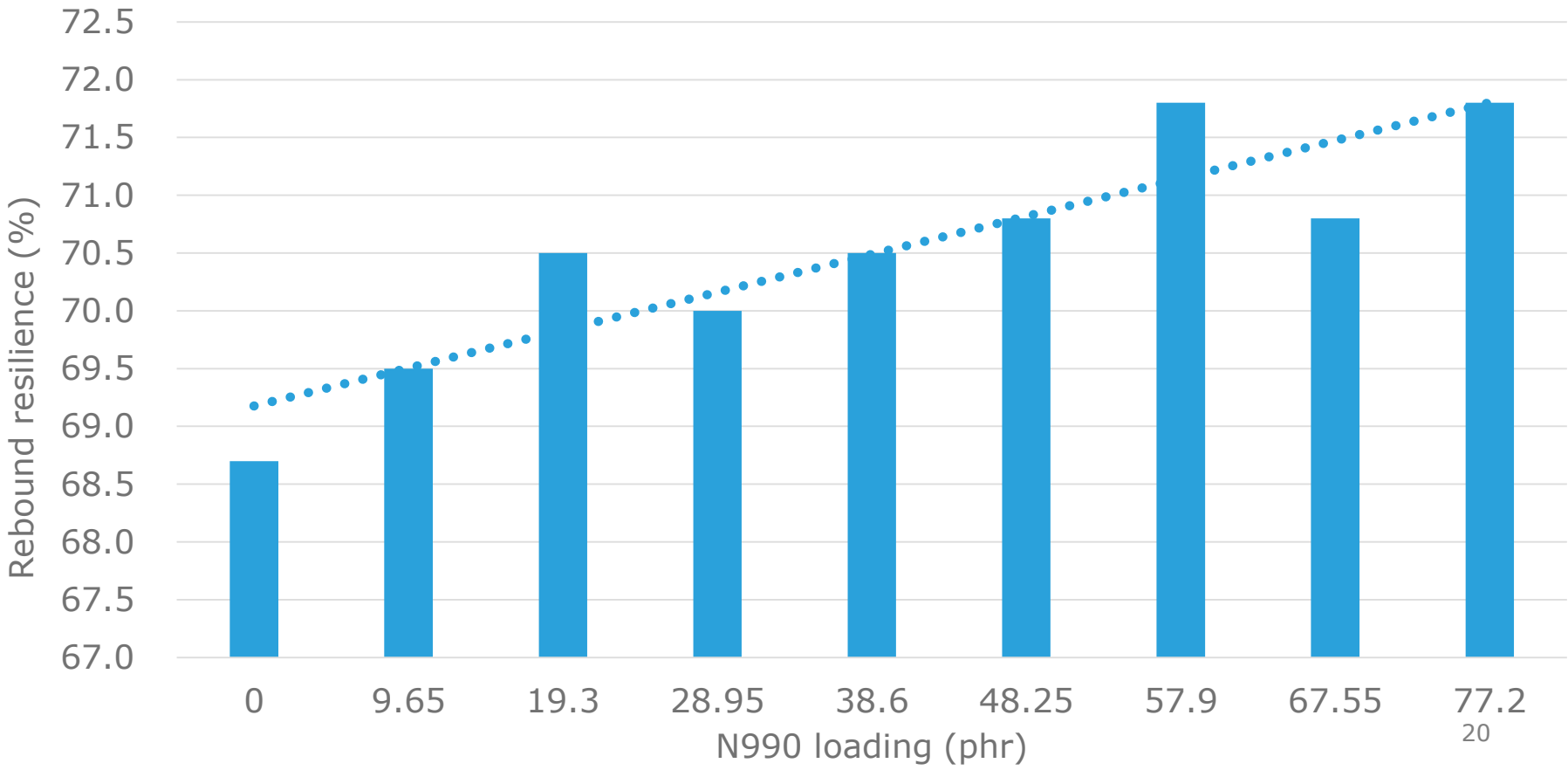
REBOUND RESILIENCE

Rebound resilience increases with N990 loading.



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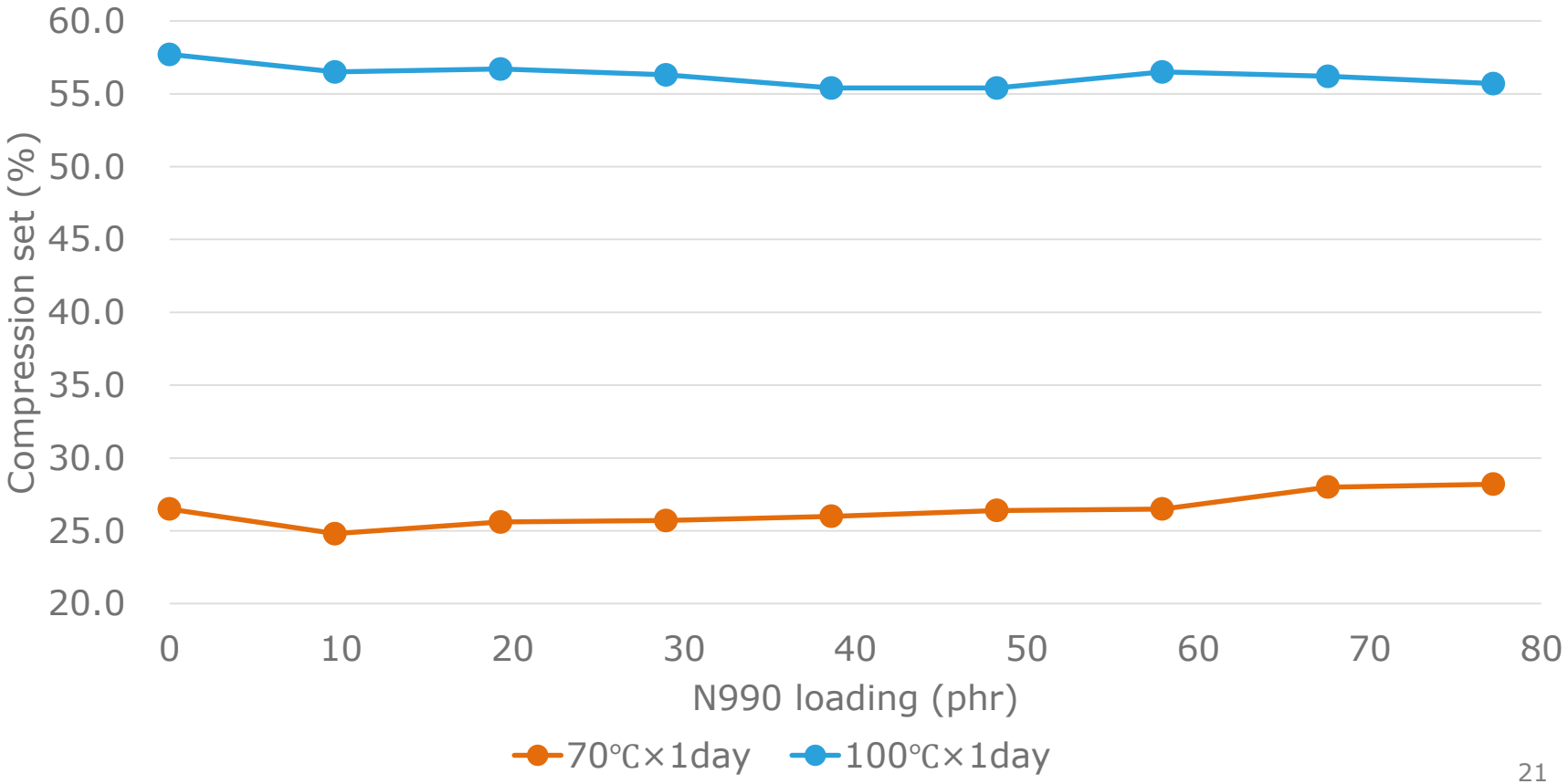
COMPRESSION SET

Slight decrease in compression set at elevated temperatures. Compression set does not increase with additional filler loading.



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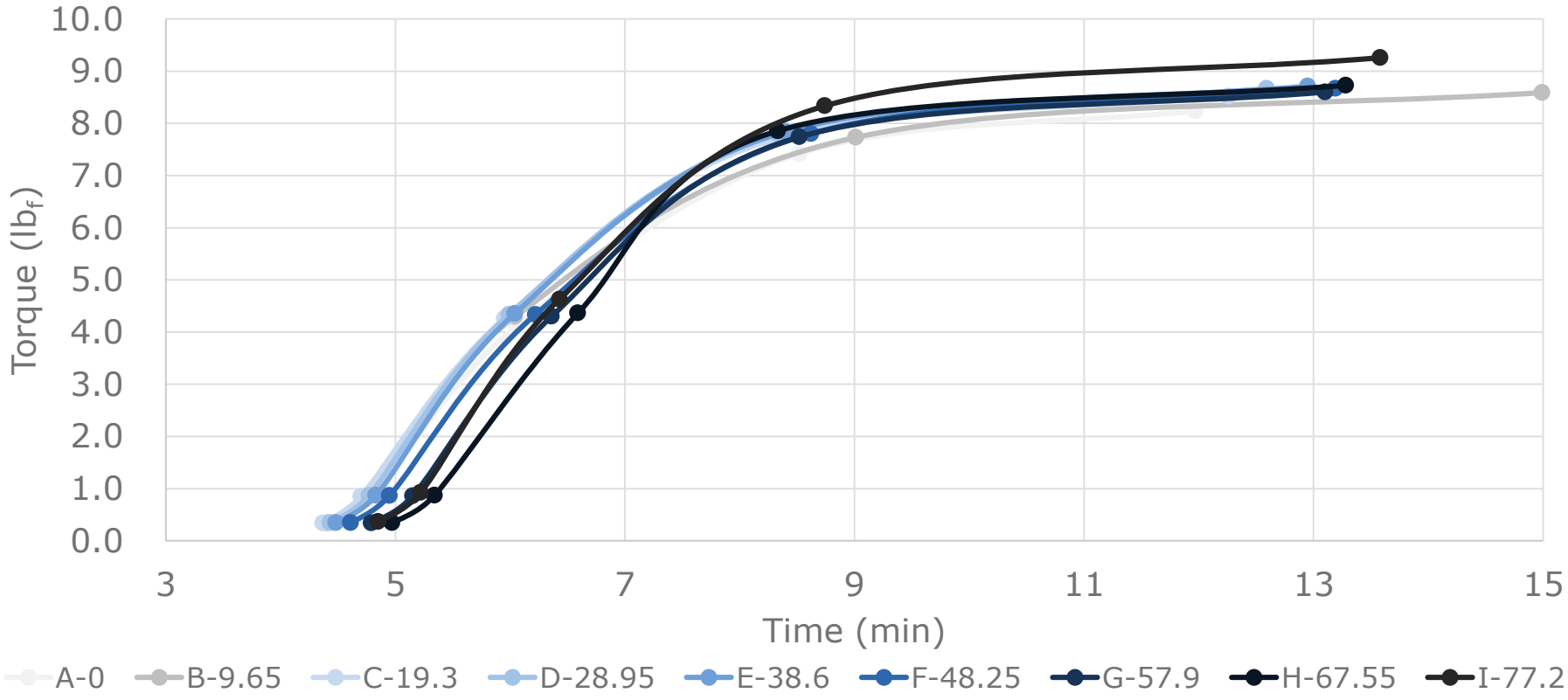
RHEOMETRY – VULCANIZATION PROPERTIES

Slight change in rubber vulcanization characteristics, increased Mooney scorch with increasing N990



N990 loading **0 phr** → **77 phr**

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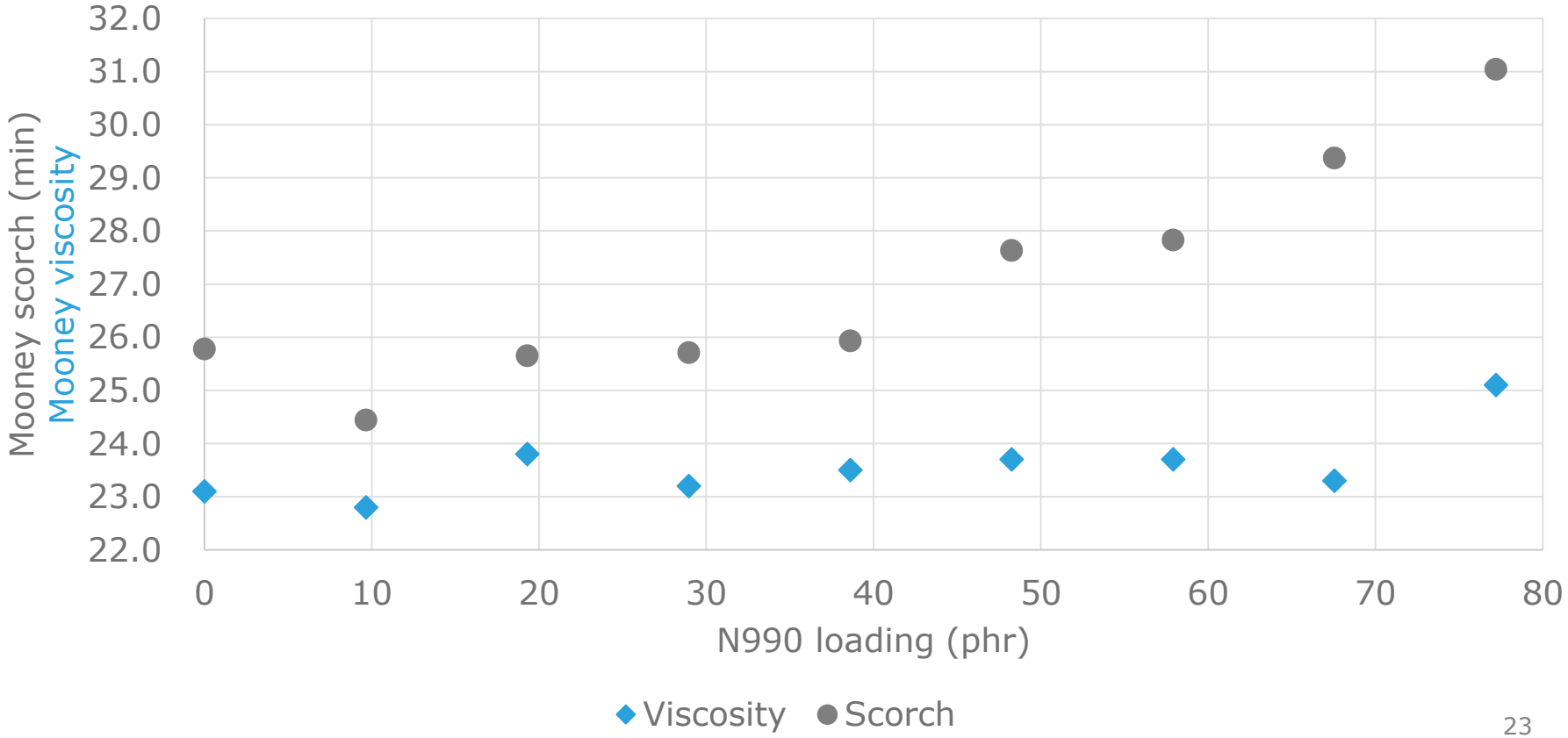
MOONEY VISCOSITY AND MOONEY SCORCH

Mooney scorch increases with N990, Mooney viscosity unaffected up to 70phr N990 loading. This allows for high filler loading without a decrease in processing abilities.



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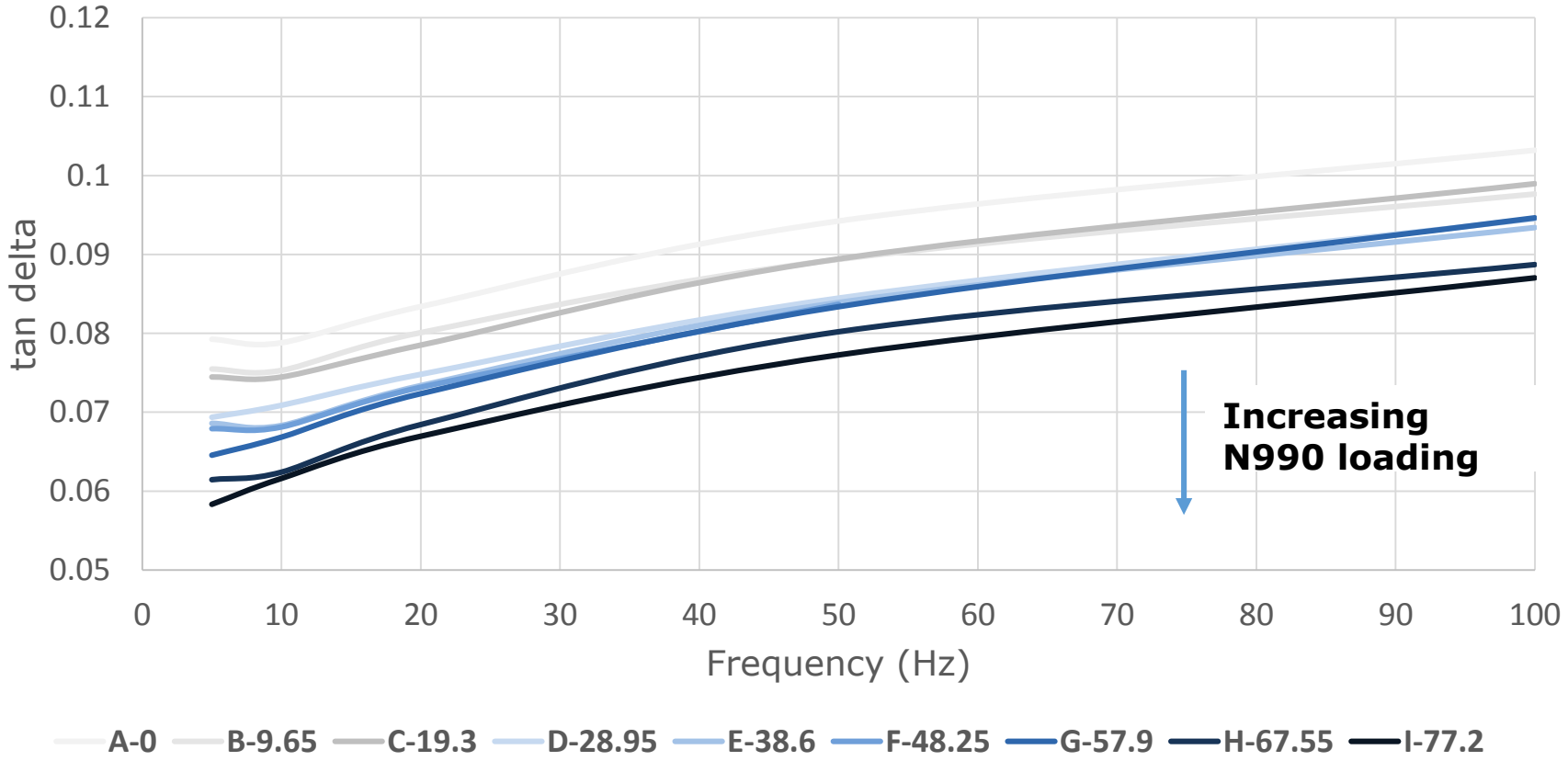
1% DYNAMIC STRAIN

Tan delta decreases with increasing N990



N990 loading **0 phr** → **77 phr**

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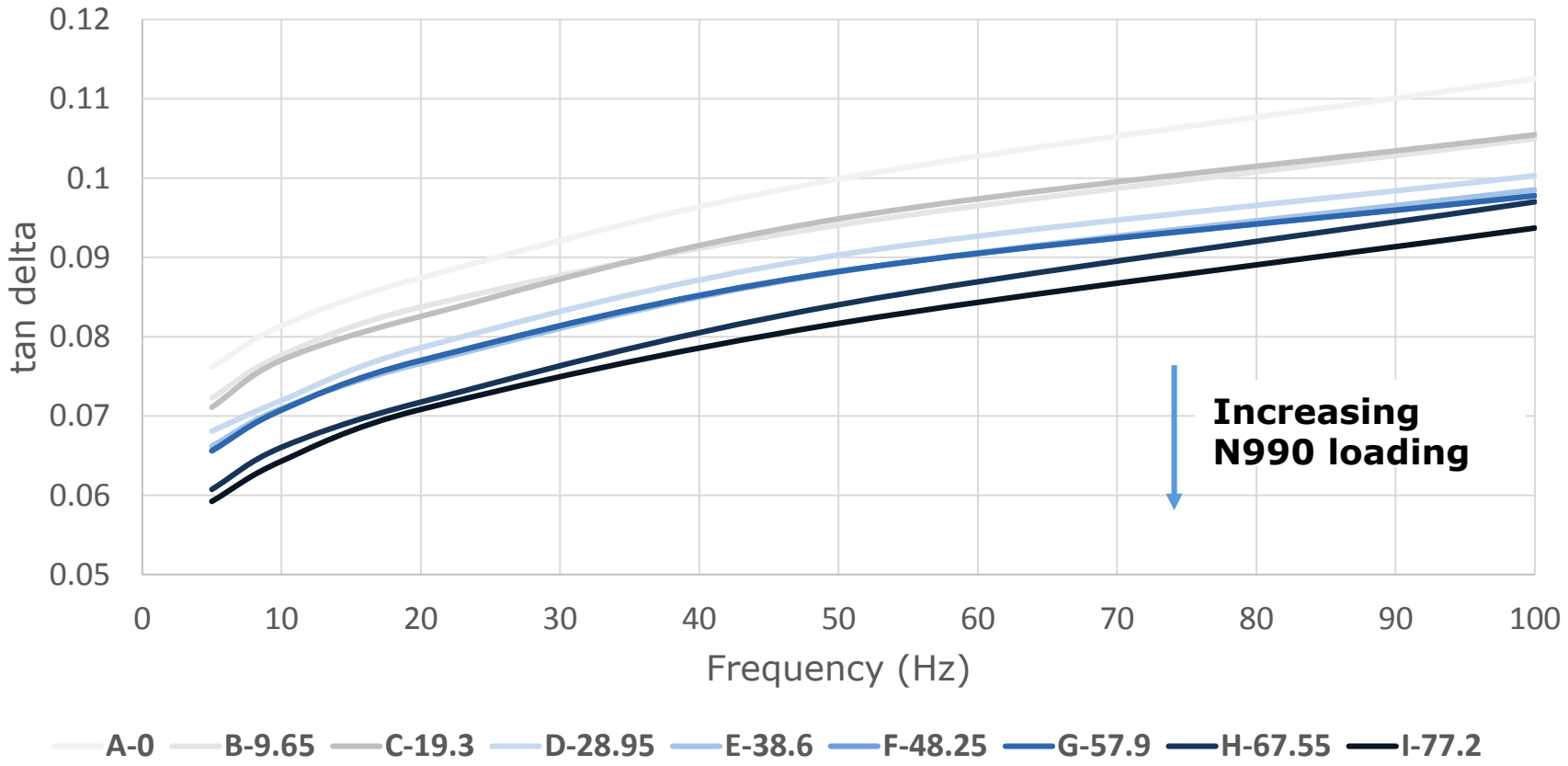
2% DYNAMIC STRAIN

Tan delta decreases with increasing N990



N990 loading **0 phr** → **77 phr**

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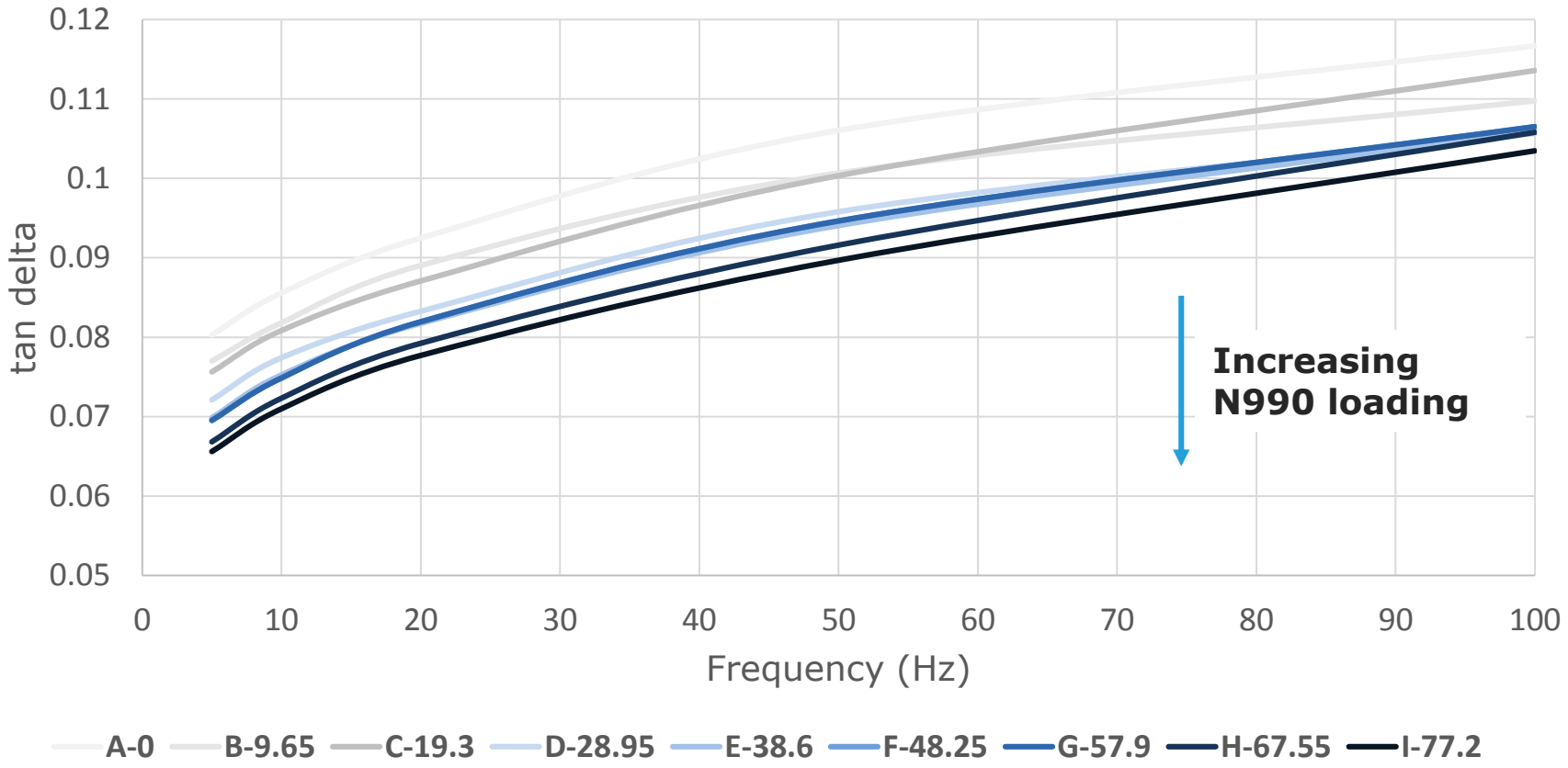
5% DYNAMIC STRAIN

Tan delta decreases with increasing N990



N990 loading **0 phr** → **77 phr**

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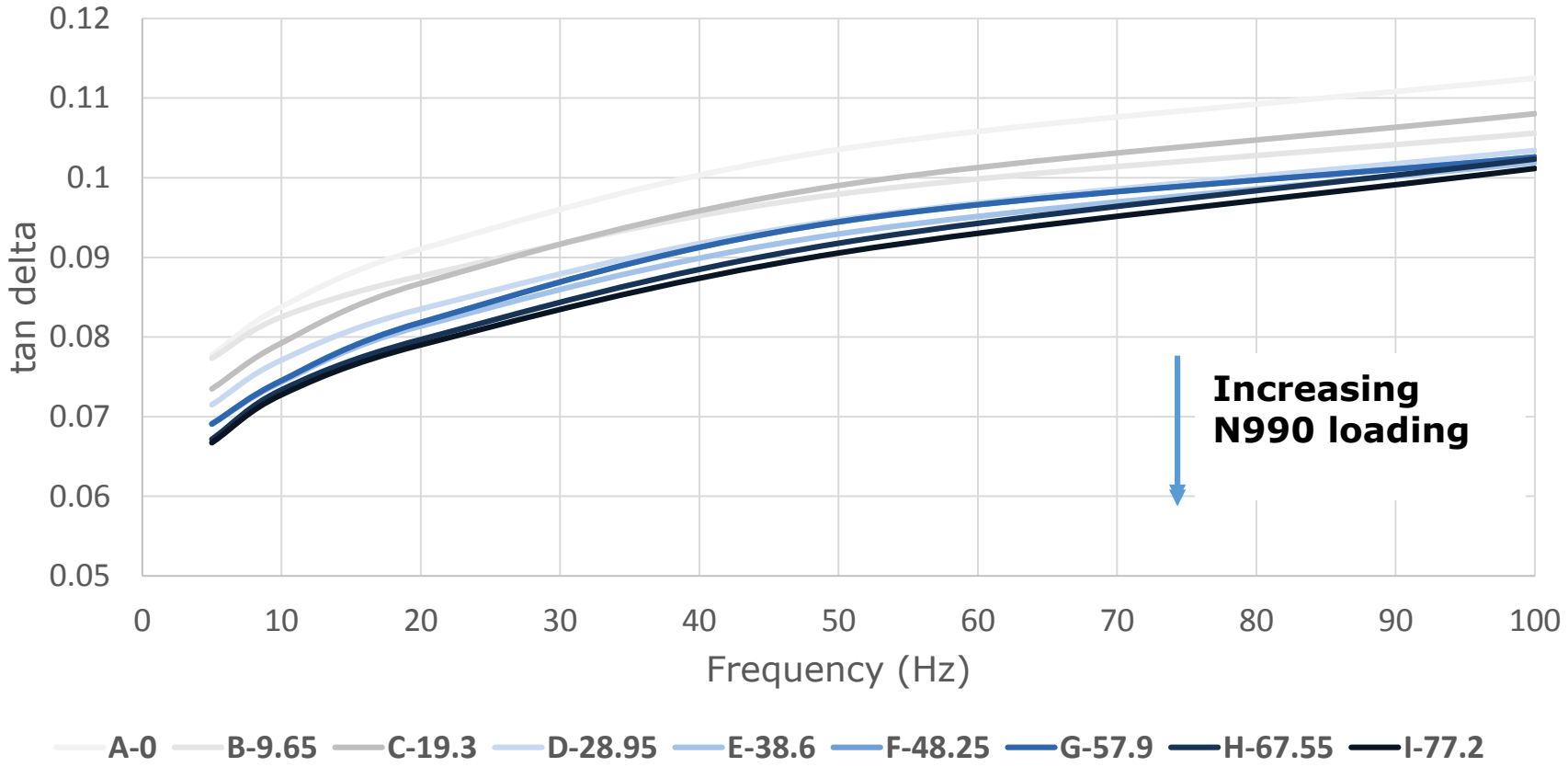
10% DYNAMIC STRAIN

Tan delta decreases with increasing N990



N990 loading **0 phr** → **77 phr**

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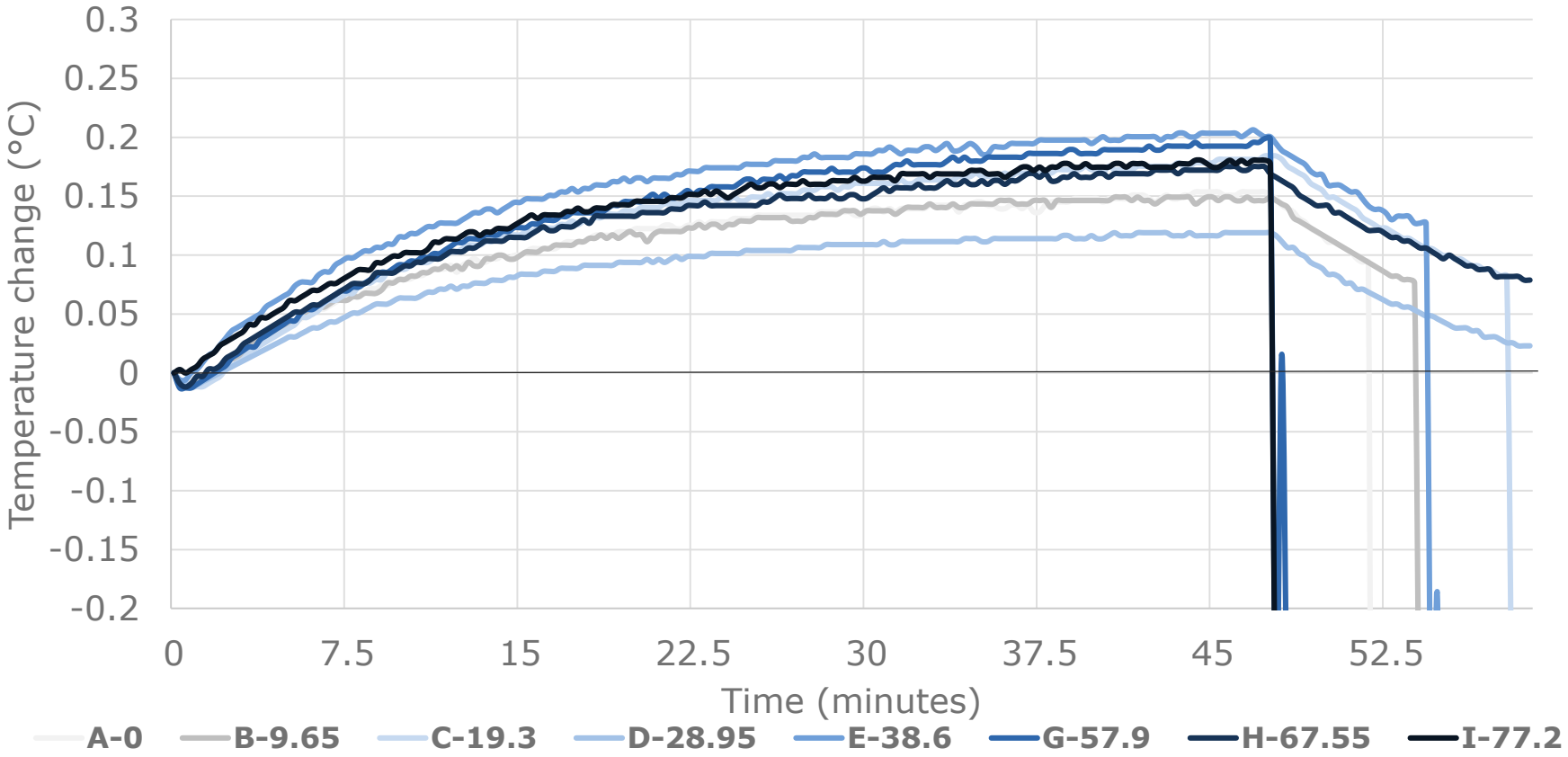
NORMALIZED HEAT BUILD-UP

No correlation



N990 loading **0 phr** → **77 phr**

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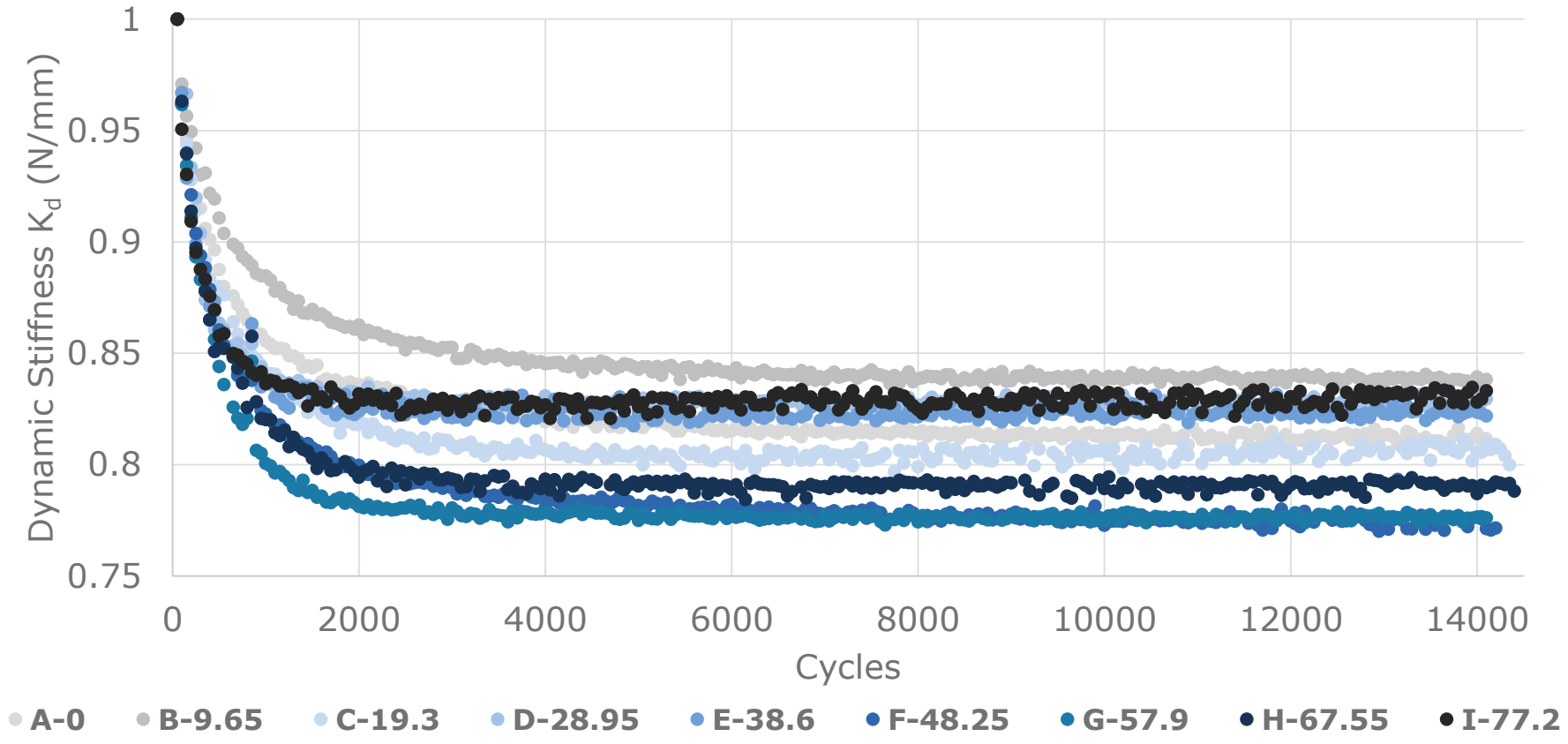
NORMALIZED DYNAMIC RATE FALLOFF DURING HEAT BUILD-UP

Dynamic stiffness (K_d) decreases with N990 loading



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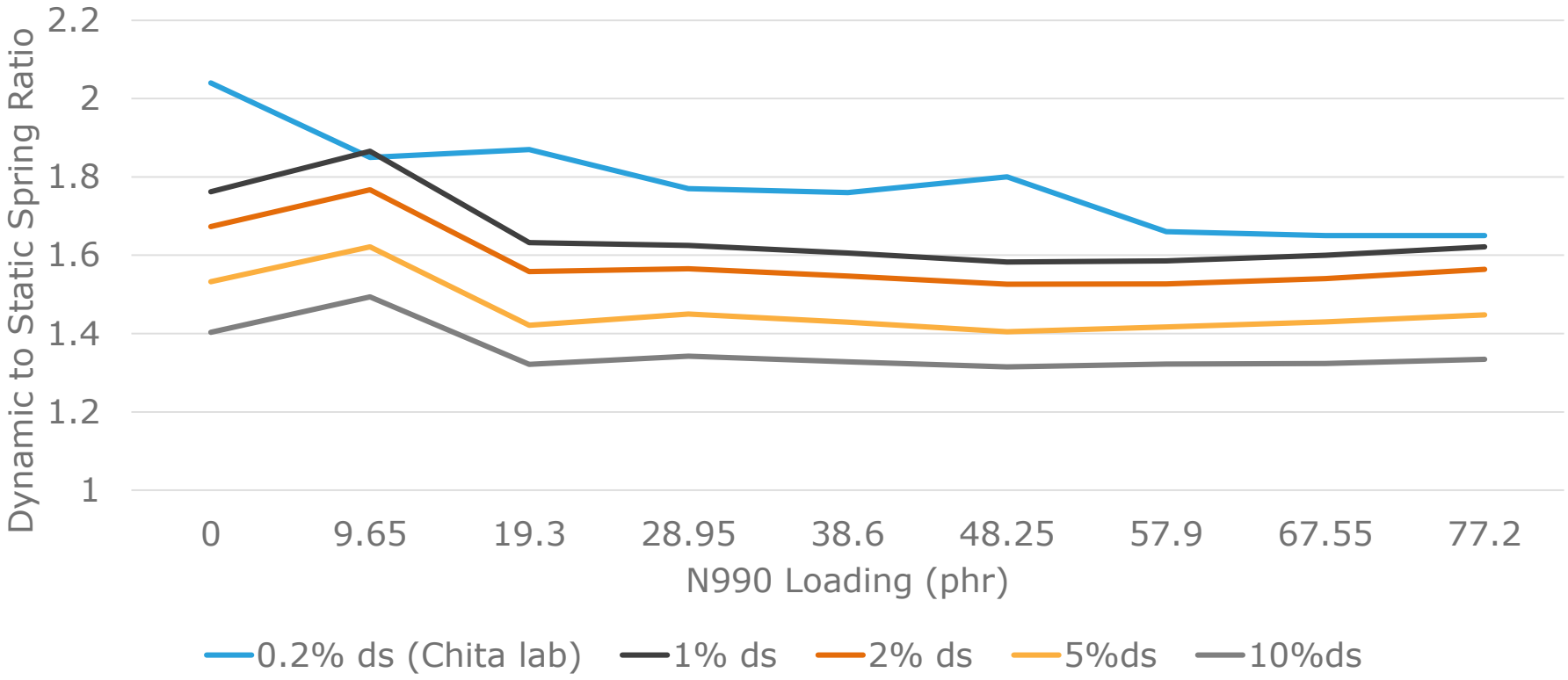
SPRING RATIO $\frac{K_d}{K_s}$

Decrease spring ratio with increased N990 loading. A lower spring ratio indicates improved dynamic properties



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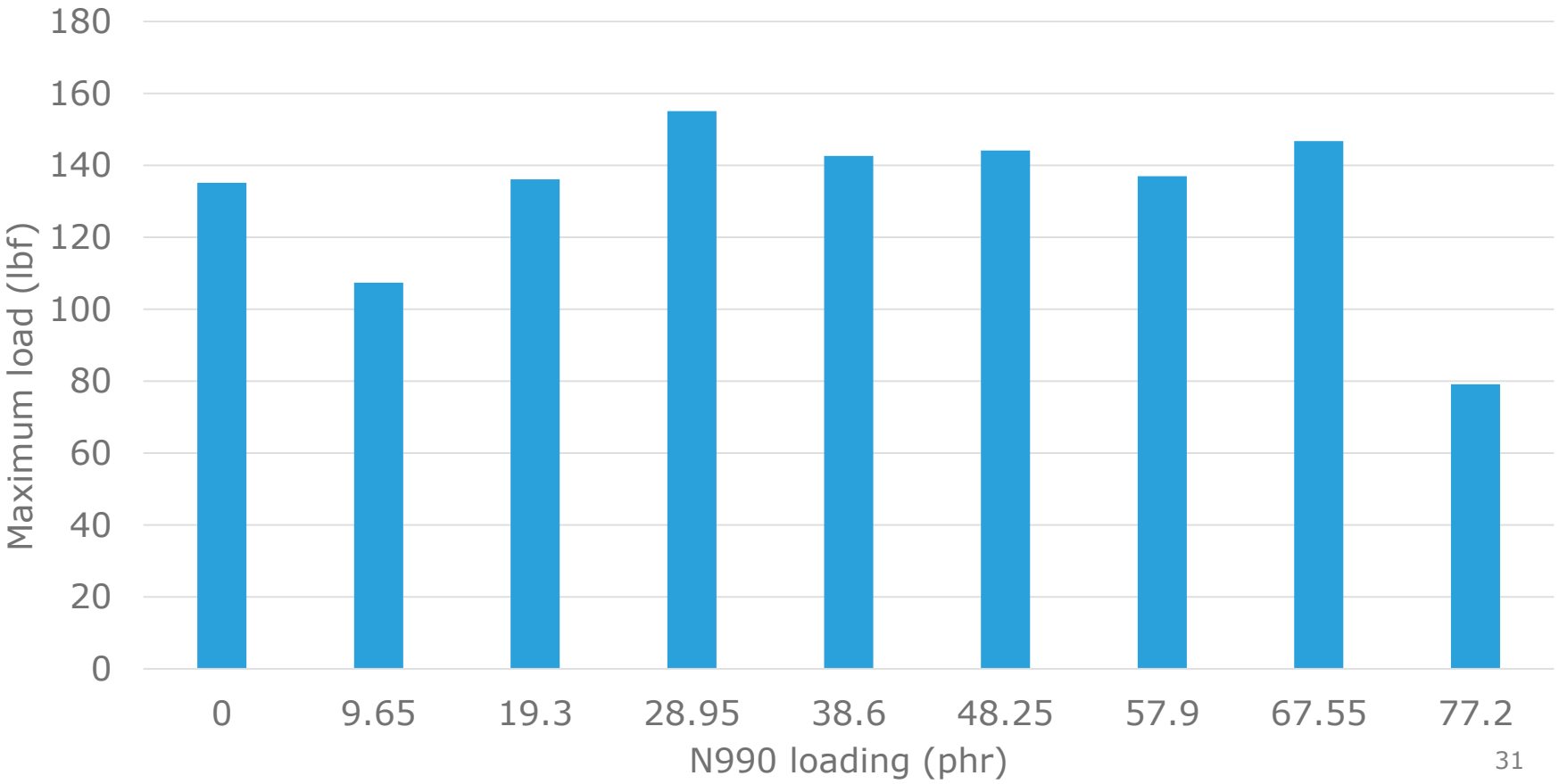
PEEL ADHESION

All samples failed in the rubber substrate, not by the adhesion of rubber to metal.



OVERALL BENEFITS OF USING N990

Good static properties

- Higher rebound resilience

Better dynamic properties

- Lower tan delta
- Lower dynamic to static spring ratio
- Lower dynamic stiffness

Better adhesion

Potential Cost savings

- Higher filler loading of N990 at same hardness value vs smaller particle size carbon blacks

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GLOBAL ADVANTAGE