

Technical Insight of KURARAY LIQUID RUBBER

Silane modified LBR for SBR / Silica formulation

Elastomer R&D Dept.
Elastomer Division

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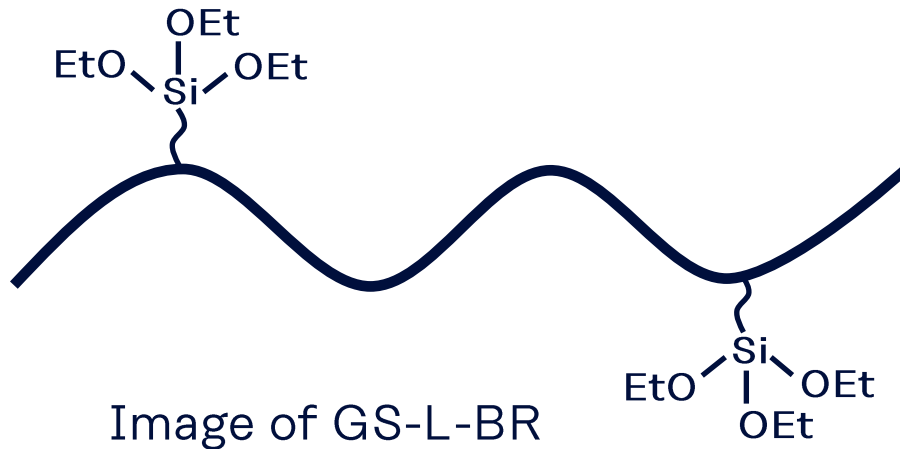
Agenda

Our silane-modified LBR; GS-L-BR is the latest development of KURARAY LIQUID RUBBER grades.

- 1) Silane modified LBR (GS-L-BR)
- 2) Evaluation in SBR / Silica formulation

Silane modified LBR (GS-L-BR)

Grade Name [Development code]	Structure	Functional Group	Mw	Tg (°C)	Number of functional group / chain	Viscosity at 38°C (Pa • s)
GS-L-BR-114 [SB-005]	Polybutadiene /Graft silane	Triethoxysilane	6,000	-50	2	6
GS-L-BR-188 [SB-006]	Polybutadiene /Graft silane	Triethoxysilane	38,000	-88	4	124



- High reactivity with silica
- Improve silica dispersion
- Crosslinkable with base rubber

Agenda

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- 2) Evaluation in SBR / Silica formulation

Formulation & Mixing Conditions

	Control	Formulation	
f-SSBR	80	80	80
BR	20	20	20
Silica	100	100	100
SCA	8	8	8
TDAE	35	23	23
GS-L-BR-114		12	
GS-L-BR-188			12
Chemicals	ZnO 3.0, Stearic acid 2.5, 6PPD 2.5, Wax 2.0		
Sulfur	S 1.5		
Accelerators	DPG 0.5, CBS 0.35, TBTD 1.5		

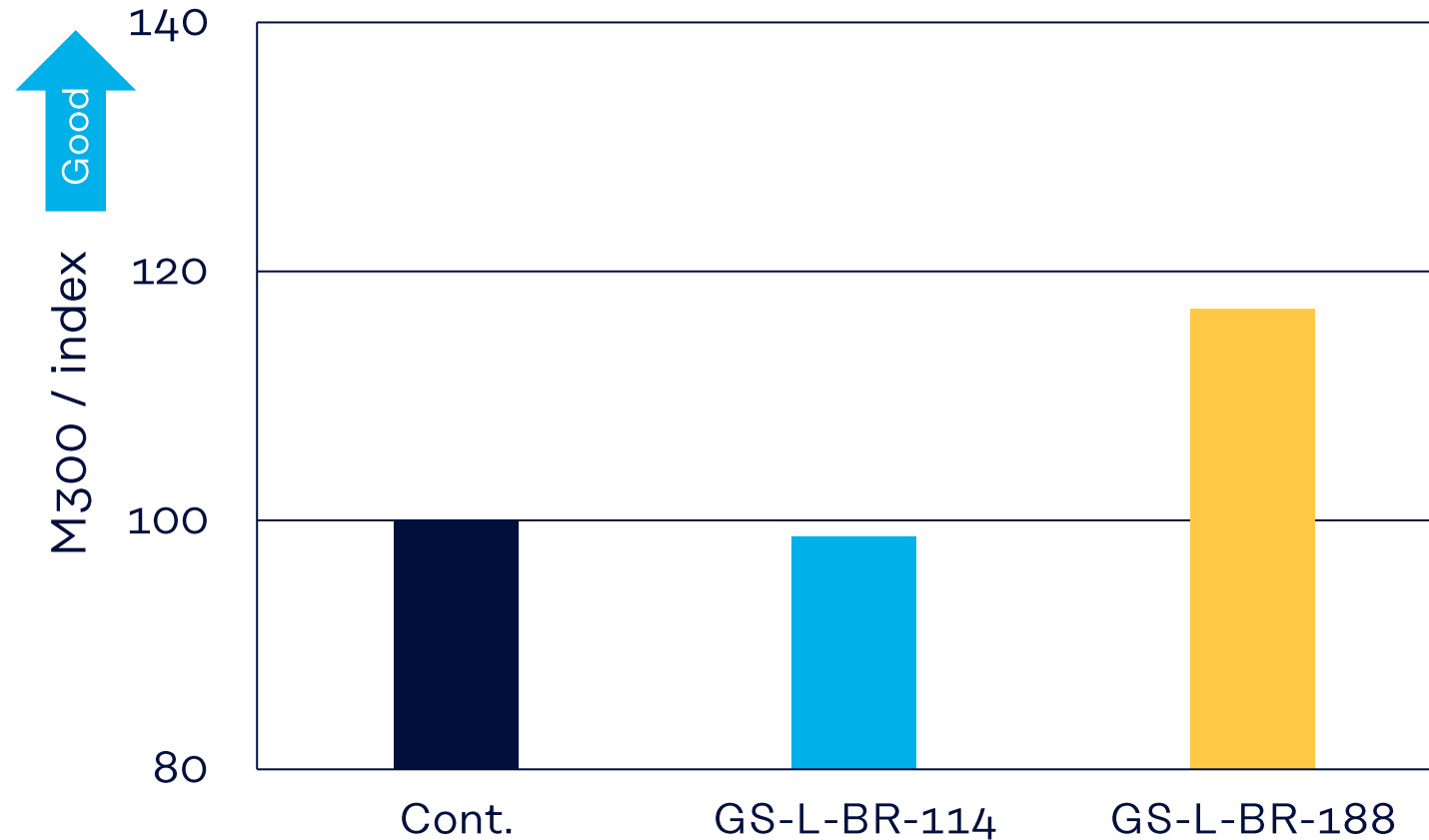
Mixing Conditions		
NP1	sec	Banbury-type mixer*
	0	Solid rubber (60°C)
	20	Silica, SCA, TDAE, LR, Chemicals
	180	Sweep
	360	Dump out (150-160°C)
NP2		Banbury-type mixer*
	0	1 st mixed compound(90°C)
	240	Dump out (150-160°C)
FM		Banbury-type mixer*
	0	Compound, Sulfur, Accelerators (50°C)
	75	Dump out (90-100°C)

*MIXTRON® BB Mixer (by Kobe Steel, Ltd.)

Summary of properties

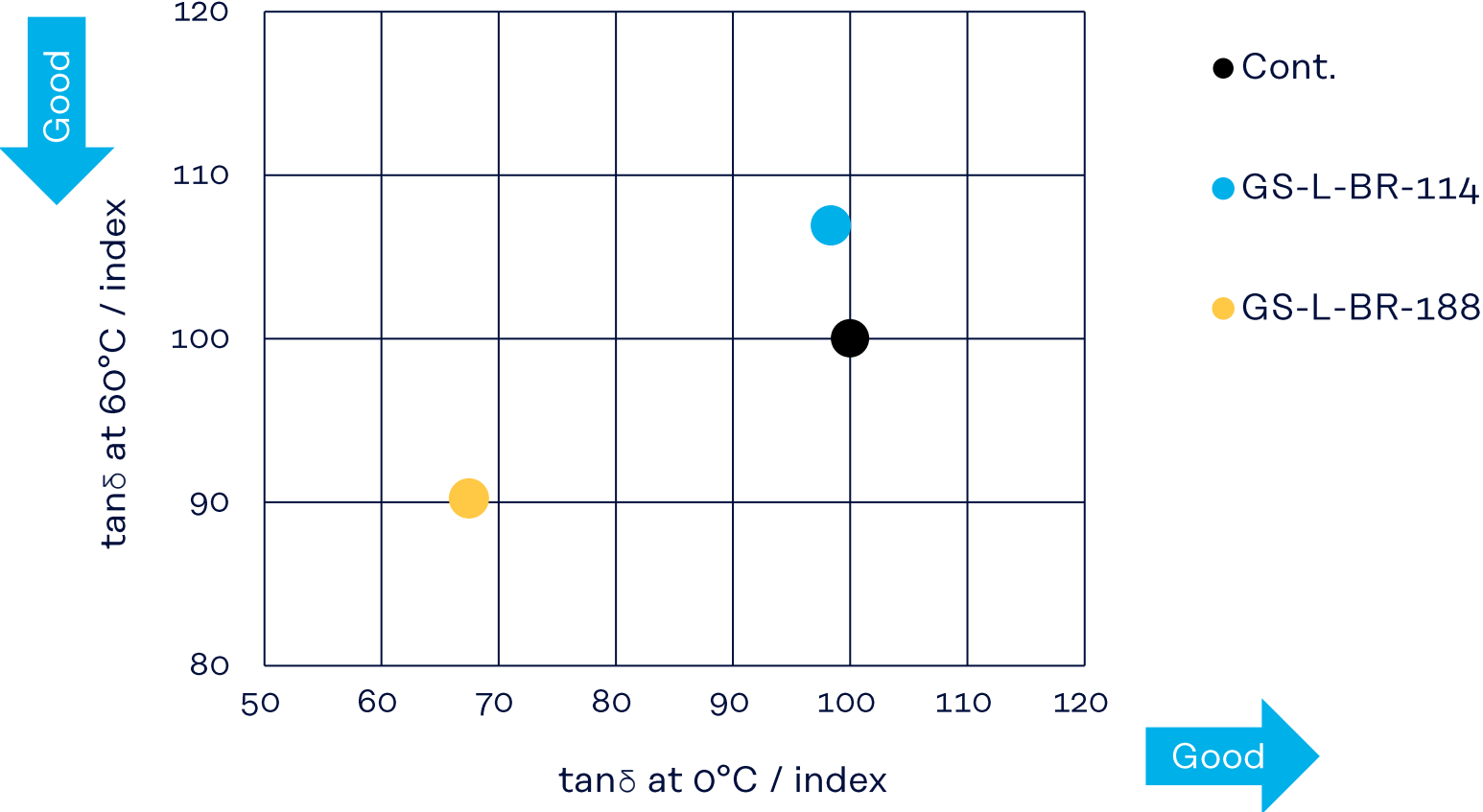
			Control	GS-L-BR-114	GS-L-BR-188
Mooney Viscosity (ML1+4, @130°C)			42.7	42.7	46.8
Mechanical Properties					
Hardness	Type A		63	67	64
EB	(%)		400	445	310
TB	(MPa)		20.9	22.3	17.9
M100	(MPa)		2.45	2.60	3.07
M300	(MPa)		13.9	13.7	16.3
DMA (Dynamic Mechanical Analysis)					
E'	0°C	(MPa)	11.0	15.2	9.31
	25°C	(MPa)	5.74	7.91	6.08
	60°C	(MPa)	4.15	5.51	4.71
tanδ	0°C	(-)	0.650	0.640	0.441
	25°C	(-)	0.291	0.315	0.214
	60°C	(-)	0.151	0.161	0.136
Payne effect (0.5%E'-5.0%E')		index	100	171	73
Friction coefficient on Wet					
20°C		index	100	101	94

Analysis of 300% modulus [M300] for Silica-polymer interaction



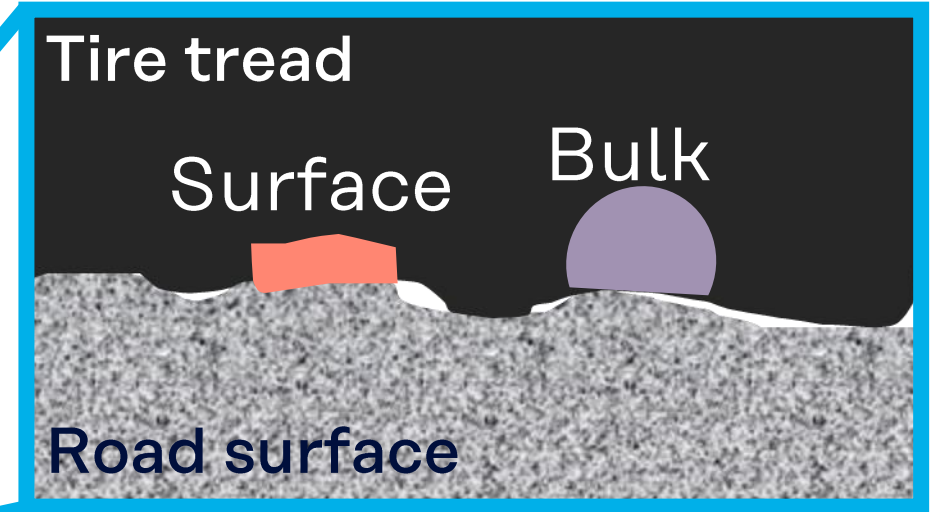
- GS-L-BR-188 enhances silica-polymer interaction from the result of higher M300

DMA (Dynamic Mechanical Analysis)



- GS-L-BR-188 shows better rolling resistance
tan δ at 0 °C: Wet grip
tan δ at 60 °C: Rolling Resistance

Background



$$\text{Grip} = \text{Adhesion} + \text{Hysteresis}$$

In general, $\tan\delta$ at 0°C is used as wet grip index.
However actual wet grip is improved by multiple factors.
Effect of Liquid Rubbers to Adhesion factor was evaluated.

Measurement of Friction Performance



RTM friction tester



Size:
Diameter 80mm
Width 16mm



Road surface :
Ice, Safety walk, Asphalt

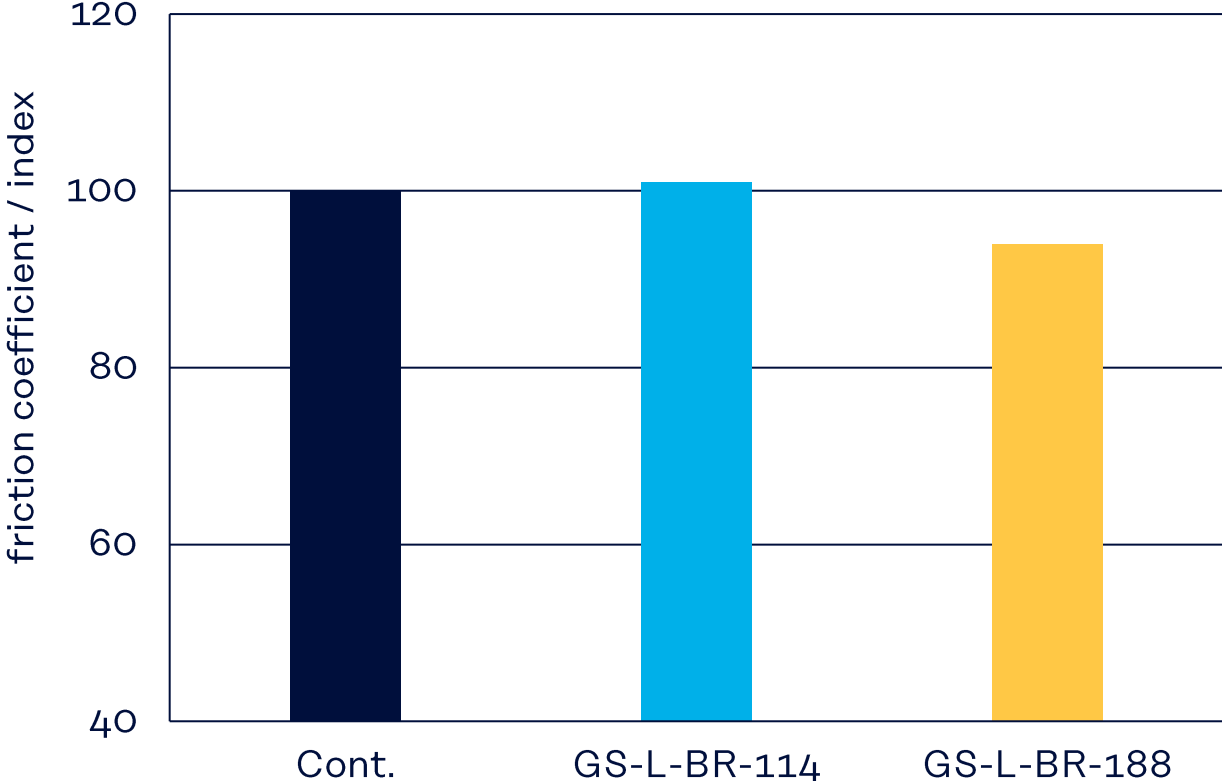
Mode :
Ice, Wet, Dry grip, RR

- RTM measures grip performance comprised of Adhesion & Hysteresis.

Friction Coefficient on Wet Surface

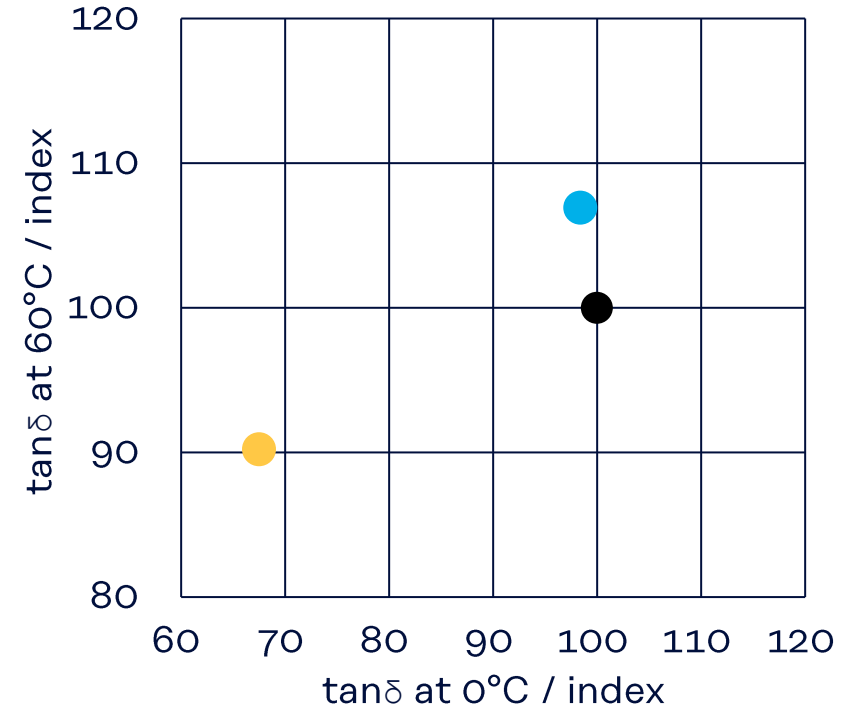
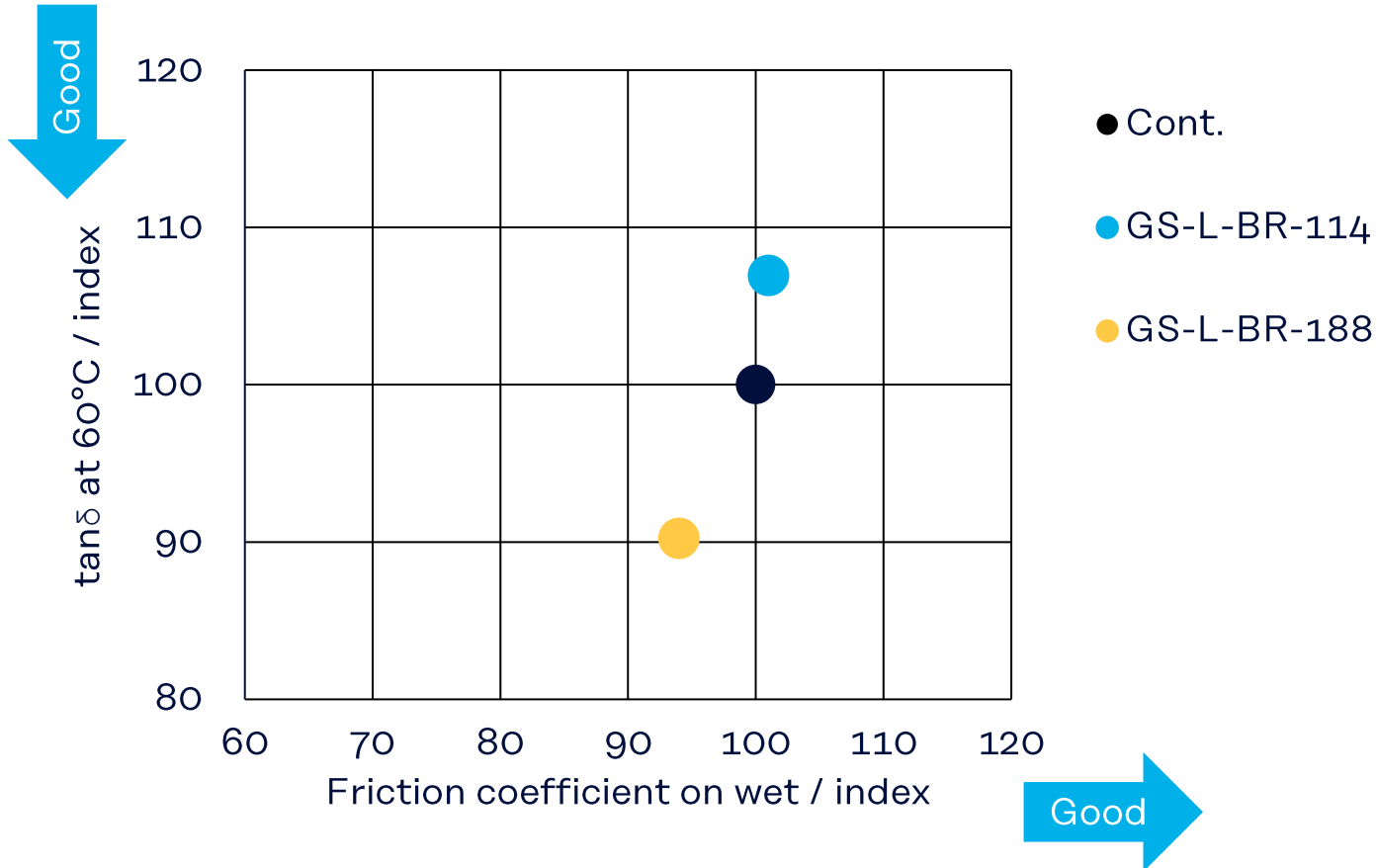
Measured friction performance by RTM friction tester

Temp 20°C
Water temp 20°C
Initial circumferential speed 30km/h
Load 50N
Slip rate 0 to 40%
Friction coefficient: Peak top value was read



- GS-L-BR-188 shows good wet grip despite its low $\tan\delta$.

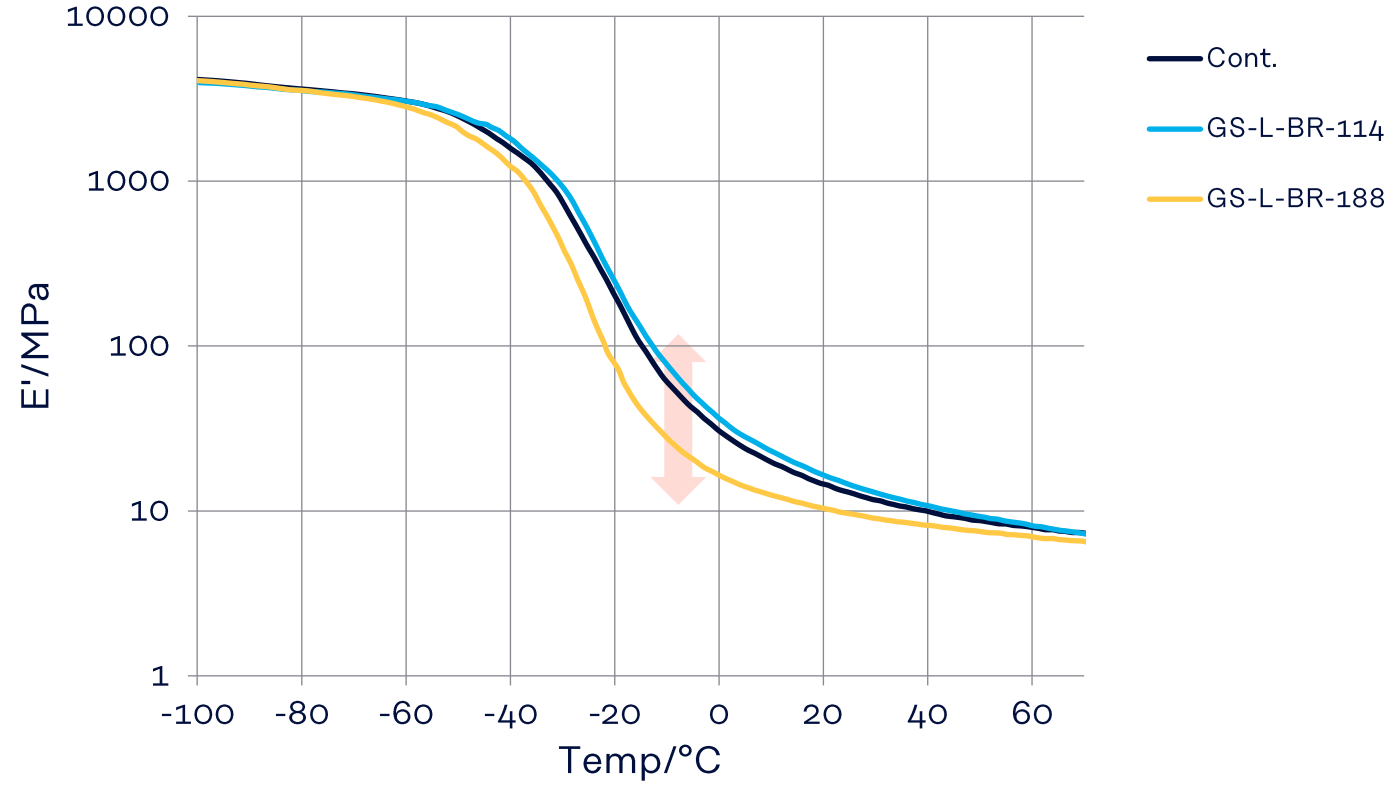
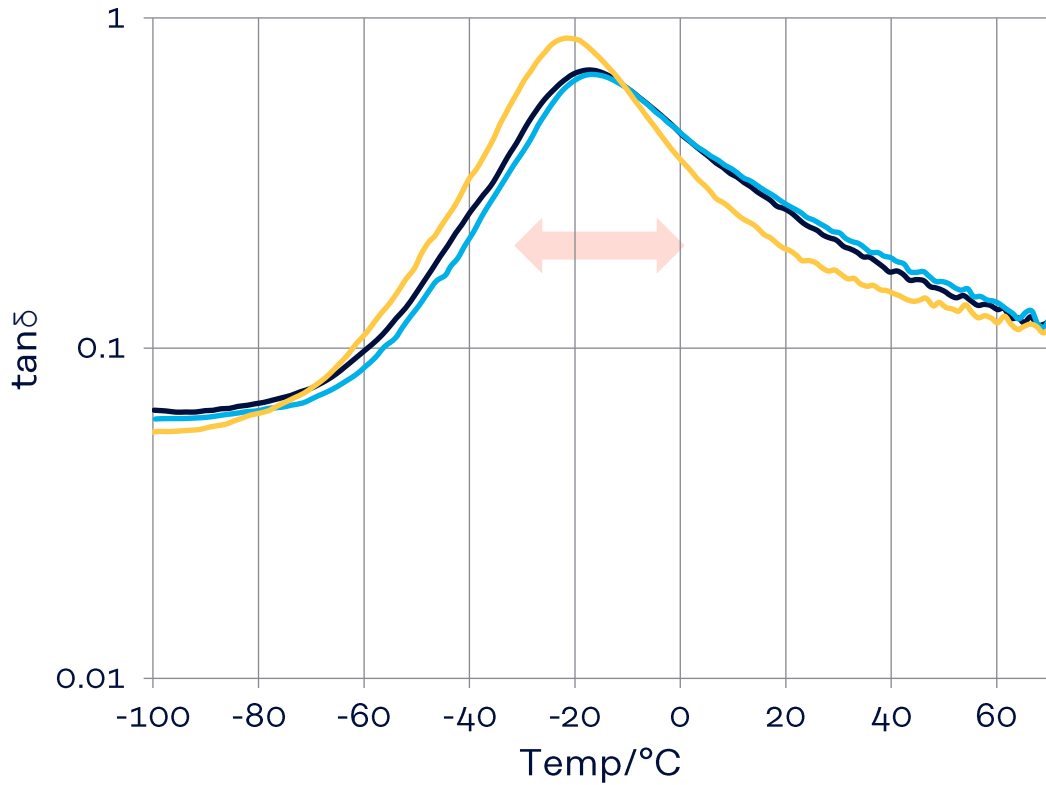
Wet Grip vs Rolling Resistance (RR)



- GS-L-BR-188 shows good RR/Wet balance.

DMA (Dynamic Mechanical Analysis)

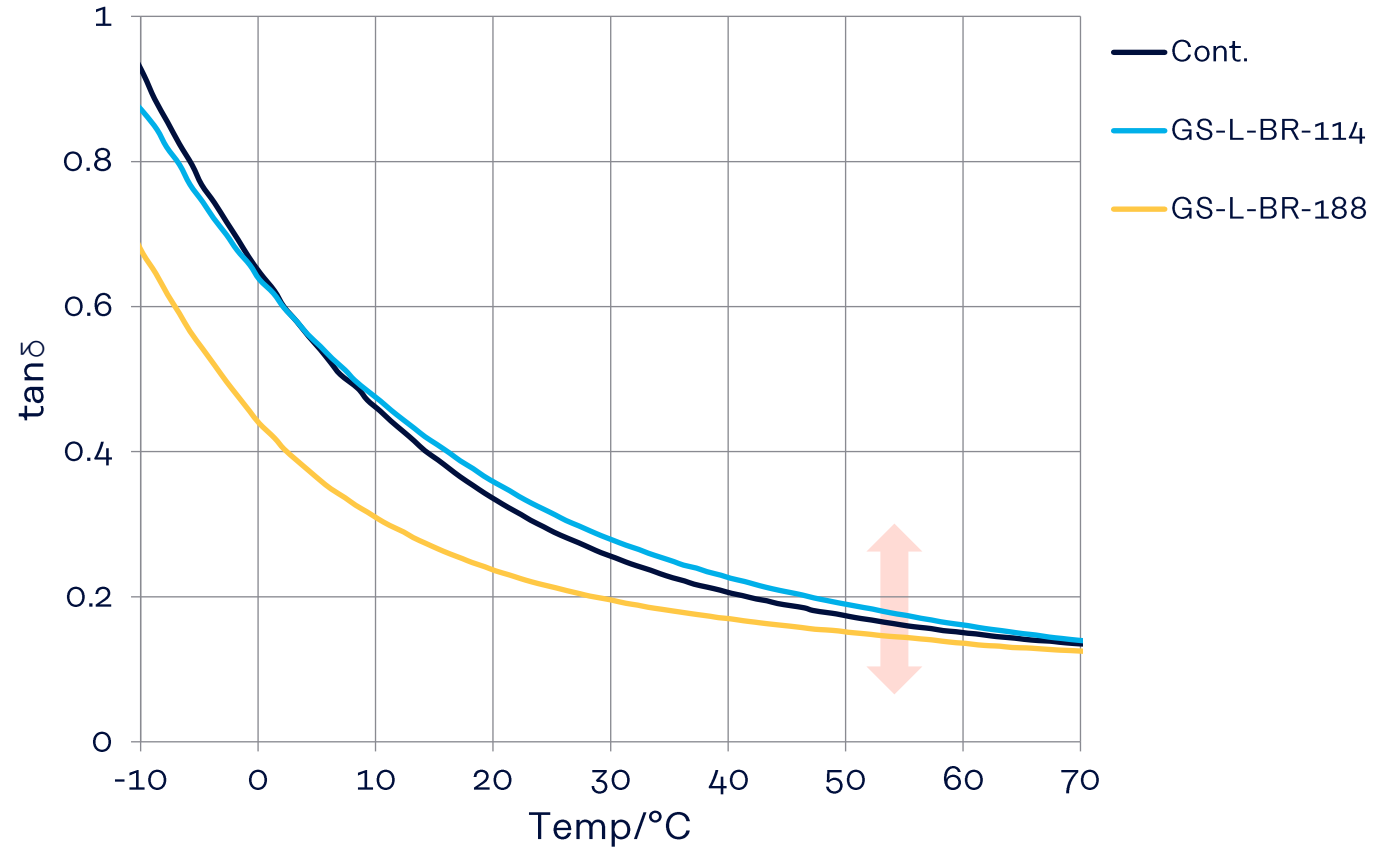
Static strain 0.5%
Dynamic strain 0.1%
Frequency 10Hz



- GS-L-BR-188 improves silica dispersion from the result of sharp $\tan \delta$.
- GS-L-BR-188 improves ice grip from the result of low E' at -20°C .

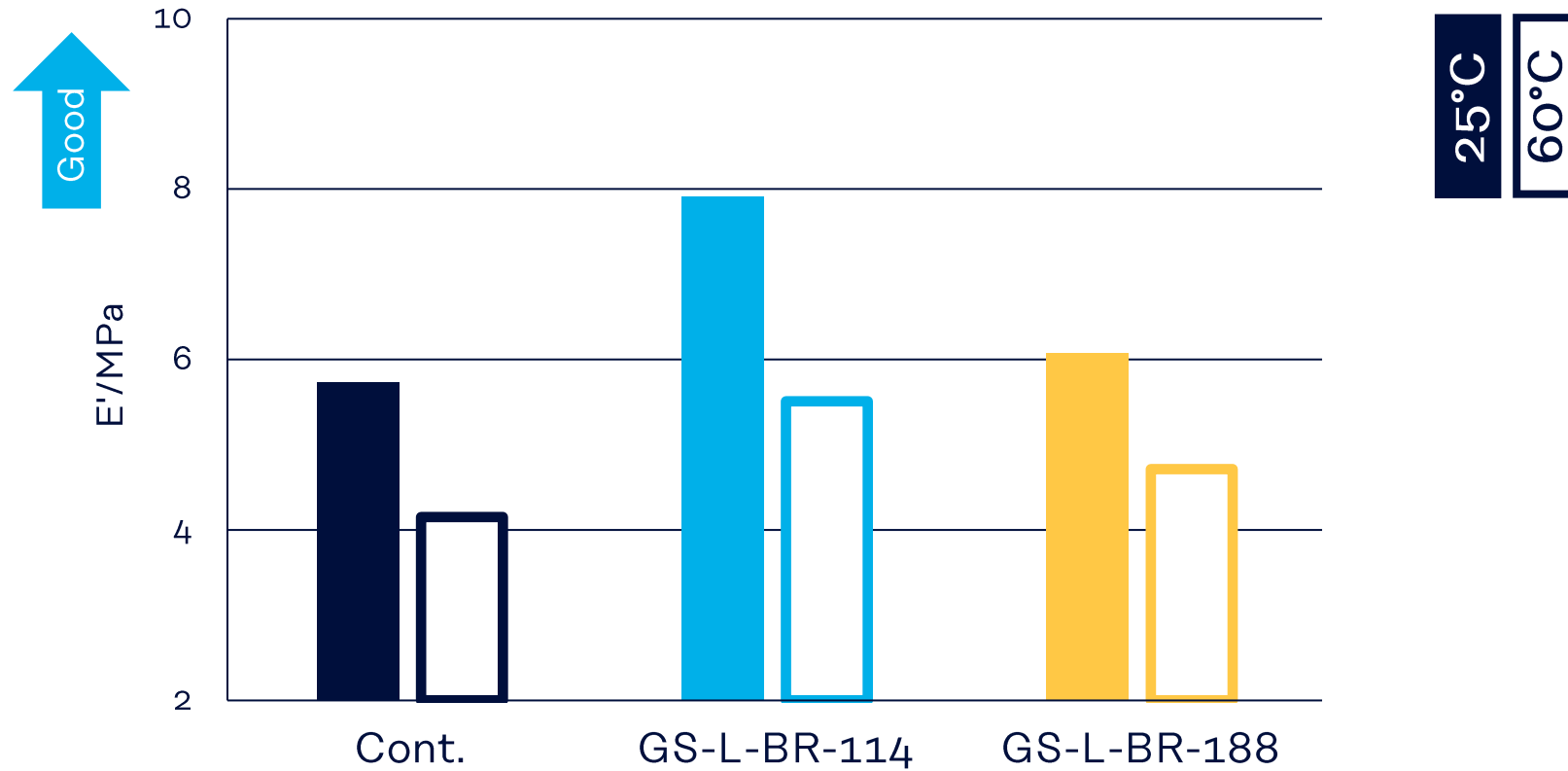
DMA (Dynamic Mechanical Analysis)

Static strain 10%
Dynamic strain 2%
Frequency 10Hz



- GS-L-BR-188 improves rolling resistance by lower $\tan \delta$.

E' (Steering stability)



- GS-L-BR-114 improves steering stability even at high temperature by higher E'.

Summary

- GS-L-BR
 - improve dispersibility of silica
 - crosslinkable with base rubber
 - improve silica-polymer interaction
- GS-L-BR-114
 - good for steering stability due to its high modulus
- GS-L-BR-188
 - enhanced interaction between silica-polymer
 - for better abrasion resistance
 - for better rolling resistance
 - good Wet/RR balance

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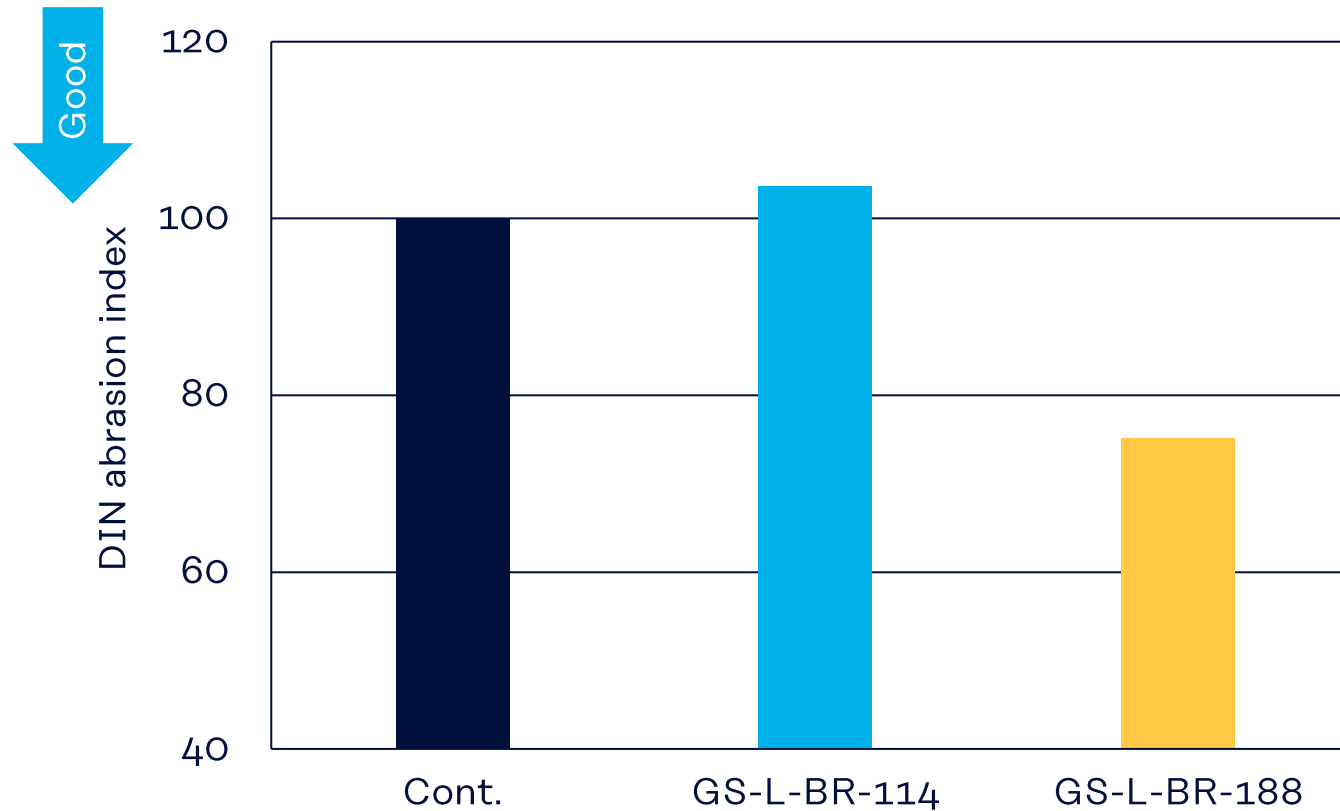
Precautions should be taken in handling and storage. Please refer to the appropriate Safety Data Sheet for further safety information. In using KURARAY LIQUID RUBBER, please confirm related laws and regulations, and examine its safety and suitability for the application.

For medical, health care and food contact applications, please contact your Kuraray representative for specific recommendations. Even so, users must conduct their own assessment, revisions, registrations as well rely in their own technical and legal judgment to establish the safety and efficacy of their compound and/or end product with KURARAY LIQUID RUBBER for any application. KURARAY LIQUID RUBBER should not be used in any devices or materials intended for implantation in the human body. Nothing contained herein constitutes a license to practice under any patent and it should not be construed as an inducement to infringe any patent and the user is advised to take appropriate steps to be sure that any proposed use of the product will not result in patent infringement.

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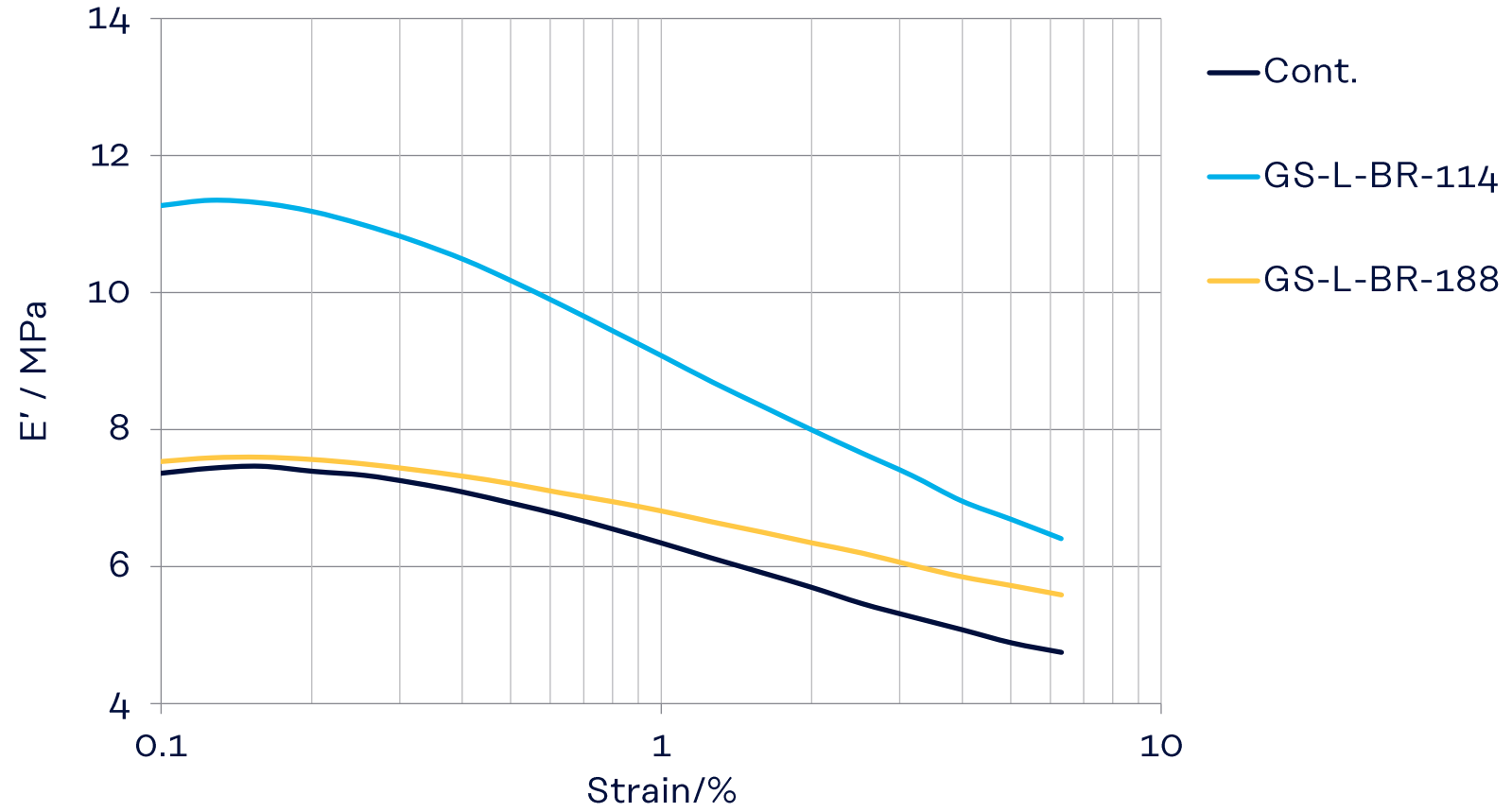
APPENDIX

DIN abrasion resistance

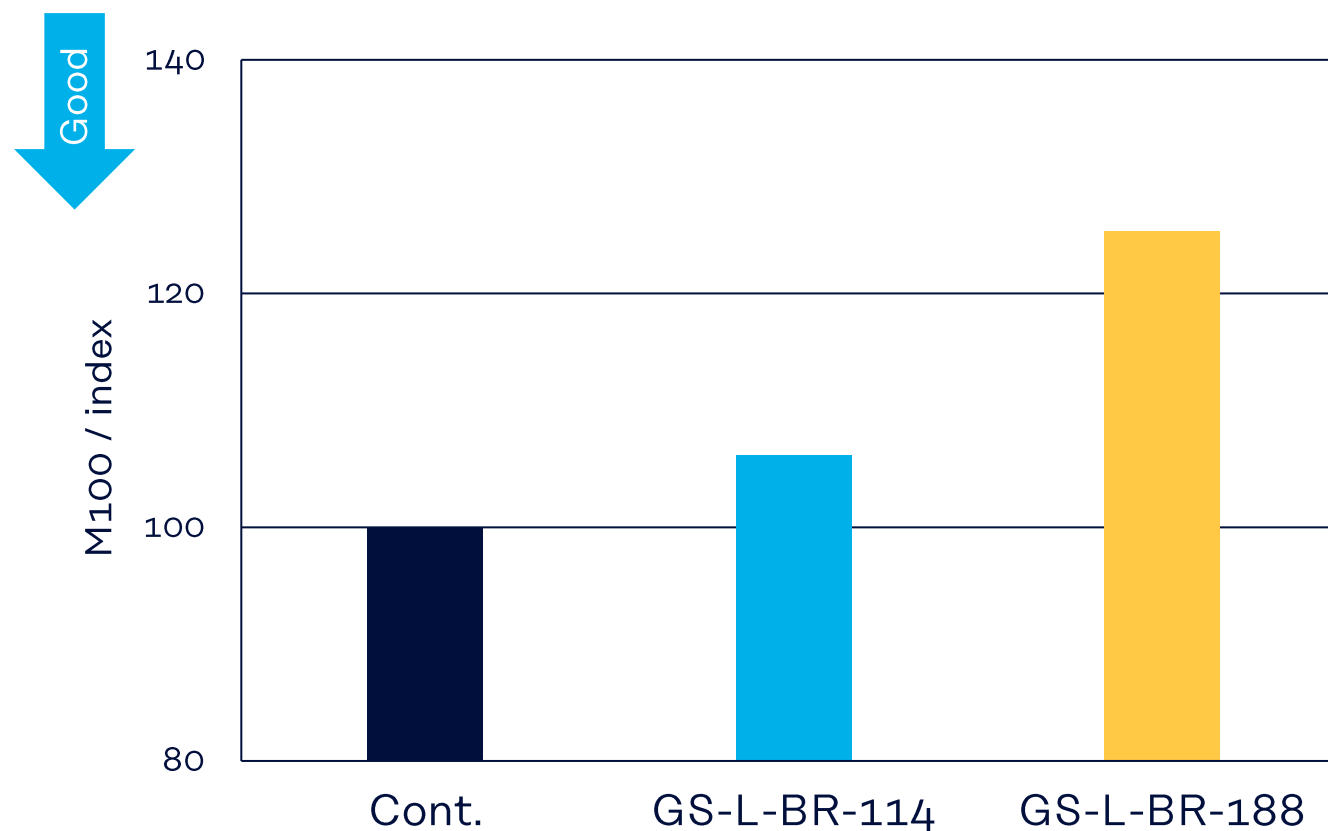


- GS-L-BR-188 is able to improve abrasion resistance significantly.

Payne effect



Analysis of 100% modulus [M100] for silica-silica interaction



Raw material

Material	Product Name	Manufacturer	Note
Styrene-butadiene rubber	JSR HPR355	JSR Corporation	Styrene content: 27% Mooney Vis. @100°C: 44 Tg: -24°C
Butadiene Rubber	JSR BR01	JSR Corporation	Cis content: 95% Mooney Vis. @100°C: 45
Silica	ULTRASIL® 7000GR	Evonik Industries AG	Specific surface area (N2) 175 m ² /g
Silane Coupling Agent	Si 75®	Evonik Industries AG	
TDAE	VIVATEC 500	H&R GmbH Co. KGaA	