# JORNADAS CAUCHO

BOGOTÁ 2025

**Título de la conferencia**

Nombre del conferenciante

**XVIII** Jornadas Latinoamericanas de Tecnología del Caucho

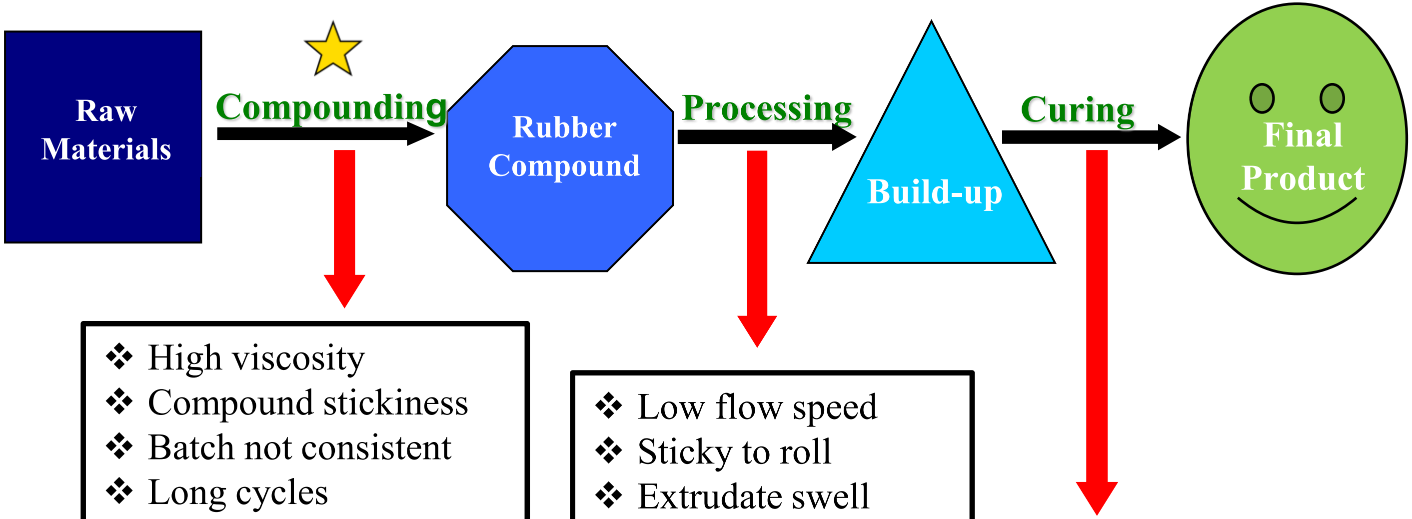
# How Processing Aids Can Improve Mixing Efficiency and Solve Production Difficulties?

Mayu Si
Struktol Company of America

XVIII Latin American Rubber Technology Conference
11/13/2025

JORNADAS CAUCHO
BOGOTÁ 2025

# Production Stages in Rubber Industry




**Compounding**

- High viscosity
- Compound stickiness
- Batch not consistent
- Long cycles
- Poor filler dispersion
- High heat build-up
- Not efficient mixing

***"Do it right the first time"***

**Processing**

- Low flow speed
- Sticky to roll
- Extrudate swell
- Low tack
- Compound scorch
- Low green strength
- Low productivity

**Curing**

- NR Reversion
- Low curing speed
- Mold fouling
- Cured surface defect
- High scrap rate

struktol

JORNADAS CAUCHO
BOGOTÁ 2025

# Agenda

- One-stage mixing
- High BR based compound processing

# One-Stage Mixing Study

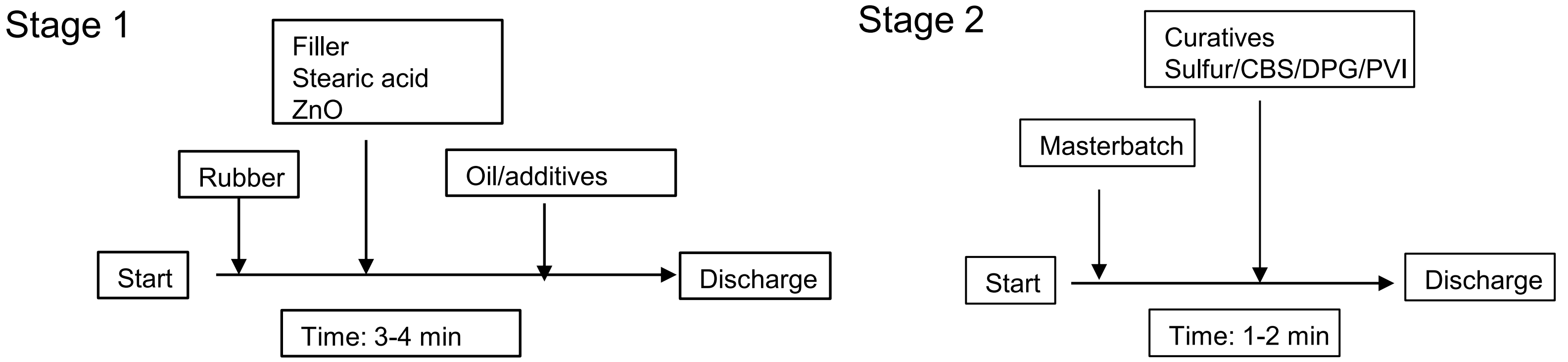
## *With Struktol ZB 47*

struktol

JORNADAS CAUCHO
BOGOTÁ 2025

# Mixing Stage Reduction: A Sustainable Approach

Traditional multi-stage mixing is often necessary for uniform dispersion of ingredients and compound viscosity control, including masterbatch and curative stages.




Mixing stage reduction is the process of consolidating or eliminating mixing steps

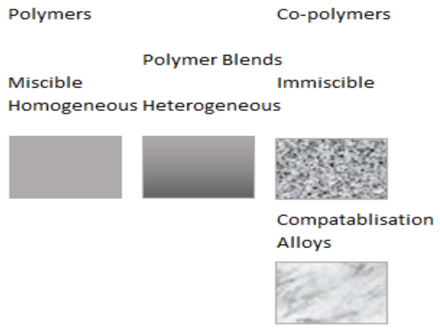
- ❖ Reduced production costs
- ❖ Increased throughput and efficiency
- ❖ Lower logistics costs

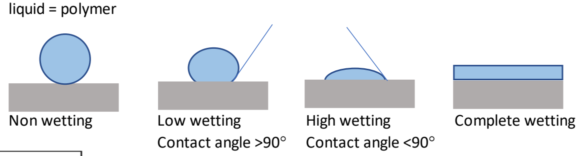
struktol

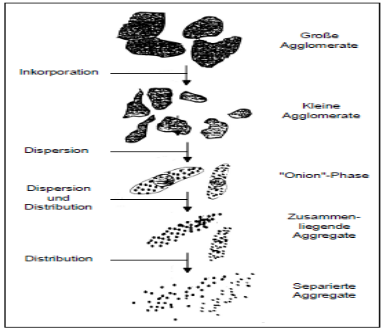
JORNADAS CAUCHO
BOGOTÁ 2025

# Steps inside the Mixing Process

- ❖ Mastication/blending
- ❖ Wetting/incorporation of ingredients
- ❖ Dispersion of ingredients
- ❖ Distribution of ingredients
- ❖ Homogenization
- ❖ Thermo-mechanical reactions; melting, fluxing, bond breaking/forming
- ❖ Evacuation of volatile



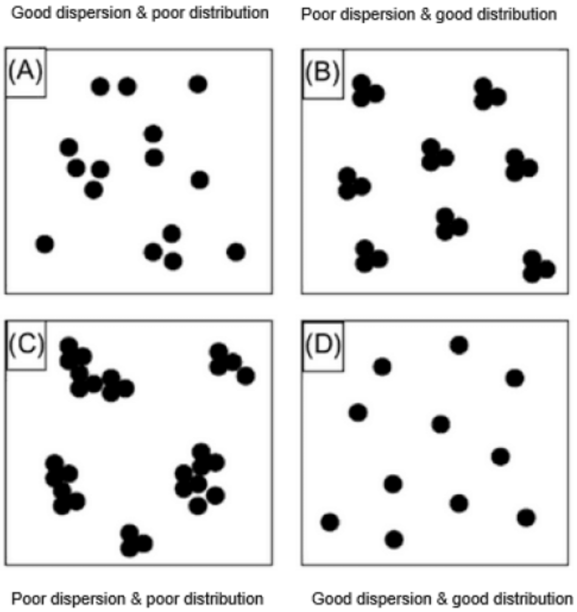



# Mixing Stage Reduction Challenge

A short mixing time due to mixing stage reduction causes:

- ❖ Poor filler dispersion/distribution
- ❖ Potential scorch issue
- ❖ High compound viscosity
- ❖ Compound physical properties deterioration

**Dispersion vs. Distribution**



# Model Premium Compound Initial Trial

| | |
|---|---|
| SBR 1502 | 15.00 |
| Buna CB 24 | 35.00 |
| SIR 20 | 50.00 |
| N220 | 55.00 |
| Sundex 790TN | 7.00 |
| ZnO | 4.00 |
| Stearic acid | 2.00 |
| Akrowax 5084 | 2.00 |
| TMQ | 2.00 |
| 6PPD | 3.00 |
| | |
| PVI | 0.25 |
| Sulfur | 1.25 |
| DPG | 0.32 |
| CBS | 1.00 |

**One-stage mixing spec**

Rotor speed = 80 rpm
0 sec.: add all rubber or 40 MS
30 sec. reduce rotor speed to 60 rpm, add remaining ingredients except curatives
After reaching 95 C, ram up, sweep, add curatives
Discharge at 115 C

Total mixing time is around **130** sec, much shorter than two-stage mixing, $1^{st}$ stage: 220 sec plus $2^{nd}$ stage 70 sec

**Big challenge is temp arise so quickly, not enough time for filler dispersion before possible compound scorch**

struktol

JORNADAS CAUCHO
BOGOTÁ 2025

# One-stage vs. Two-stage

| | Control | 40 MS |
|---|---|---|
| SBR 1502 | 15.00 | 15.00 |
| Buna CB 24 | 35.00 | 35.00 |
| SIR 20 | 50.00 | 50.00 |
| N220 | 55.00 | 55.00 |
| Sundex 790TN | 10.00 | **7.00** |
| ZnO | 4.00 | 4.00 |
| Stearic acid | 2.00 | 2.00 |
| Akrowax 5084 | 2.00 | 2.00 |
| TMQ | 2.00 | 2.00 |
| 6PPD | 3.00 | 3.00 |
| 40 MS | | **5.00** |
| PVI | | 0.25 |
| Sulfur | | 1.25 |
| DPG | | 0.32 |
| CBS | | 1.00 |
| | | |
| PVI | 0.25 | |
| Sulfur | 1.25 | |
| DPG | 0.32 | |
| CBS | 1.00 | |
| | | |
| Total | 180.82 | 182.82 |

| | Control | 40 MS |
|---|---|---|
| **Tensile strength (MPa)** | **24.0** | **21.3** |
| Elongation (%) | 664 | 670 |
| 100% Modulus (MPa) | 1.9 | 1.9 |
| 200% Modulus (MPa) | 4.3 | 3.8 |
| 300% Modulus (MPa) | **7.9** | **6.6** |
| Hardness (Shore A) | 64 | 65 |
| Die C Tear (N/mm) | 117.9 | 97.5 |
| **DIN (mm3)** | **110** | **133** |
| | | |
| ML (1+4) @100 C | **53** | **69** |
| | | |
| Mooney scorch (125 C) | | |
| Minimum torque | 41.8 | 55.2 |
| T5 | **46.47** | **38.12** |
| | | |
| MDR (150 C/30 min) | | |
| ML | 2.59 | 3.02 |
| MH | 16.38 | 17.10 |
| MH-ML | 13.78 | 14.09 |
| Ts1 | **8.67** | **6.84** |
| Ts2 | 9.72 | 7.90 |
| T10 | 9.23 | 7.44 |
| T50 | 11.42 | 9.54 |
| T90 | 16.27 | 13.58 |

struktol

JORNADAS CAUCHO
BOGOTÁ 2025

# Different Approaches

The loss of tensile strength and abrasion resistance could come from poor CB dispersion due to short time mixing

- Introduce Struktol additive, ZB 47, help CB dispersion and improve mixing efficiency
- Increase discharge temp? scorch concern
- Reduce/increase rotor speed?

# Curative Addition Sequence?

- Later addition: believe to be safe to control scorch, but leave a short time for curatives to be mixed well

- Early addition: worry about compound scorch, but better for curatives dispersion, more homogenous

If the compound is scorch safe, early addition should be a better way to go, easy to run in production

# Introduce Struktol ZB 47

| | Control (two-stage) | One-stage | ZB 47 |
|---|---|---|---|
| SBR 1502 | 15.00 | 15.00 | 15.00 |
| Buna CB 24 | 35.00 | 35.00 | 35.00 |
| SIR 20 | 50.00 | 50.00 | 50.00 |
| N220 | 55.00 | 55.00 | 55.00 |
| Sundex 790TN | 10.00 | 10.00 | 10.00 |
| ZnO | 4.00 | 4.00 | 4.00 |
| Stearic acid | 2.00 | 2.00 | 2.00 |
| Akrowax 5084 | 2.00 | 2.00 | 2.00 |
| TMQ | 2.00 | 2.00 | 2.00 |
| 6PPD | 3.00 | 3.00 | 3.00 |
| ZB 47 | | | **2.00** |
| PVI | | 0.25 | 0.25 |
| Sulfur | | 1.25 | 1.25 |
| DPG | | 0.32 | 0.32 |
| CBS | | 1.00 | 1.00 |
| | | | |
| PVI | 0.25 | | |
| Sulfur | 1.25 | | |
| DPG | 0.32 | | |
| CBS | 1.00 | | |
| Total | 180.82 | 180.82 | 182.82 |

## One-stage mixing spec

Rotor speed = 80 rpm
0 sec.: add all rubber
30 sec. reduce rotor speed to 60 rpm
add remaining ingredients
75 sec, ram up, sweep
105 sec, ram up, sweep
Discharge at 115 C

| | One-stage | ZB 47 |
|---|---|---|
| Mixing time (sec) | 145 | 158 |
| Batch temp (C) | 134 | 134 |

struktol®

JORNADAS CAUCHO
BOGOTÁ 2025

# Compound Data/ZB 47 Benefit

| | Control (two-stage) | One-stage | ZB 47 |
|---|---|---|---|
| **Tensile strength (MPa)** | **22.9** | **22.5** | **22.8** |
| Elongation (%) | 711 | 646 | 641 |
| 100% Modulus (MPa) | 1.8 | 2.0 | 2.1 |
| 200% Modulus (MPa) | 3.7 | 4.5 | 4.5 |
| 300% Modulus (MPa) | 6.8 | 7.8 | 7.8 |
| Hardness (Shore A) | 55 | 62 | 56 |
| Die C Tear (N/mm) | 112.5 | 82.2 | 79.9 |
| Rubber window Tear (N/mm) | 252.0 | 242.6 | 228.8 |
| **DIN (mm3)** | **117** | **125** | **117** |
| | | | |
| ML (1+4) @100 C | **53** | **82** | **78** |
| | | | |
| Mooney scorch (125 C) | | | |
| Minimum torque | 38.6 | 61.3 | 58.8 |
| T5 | **40.87** | **31.08** | **34.11** |
| | | | |
| MDR (150 C/30 min) | | | |
| ML | 2.51 | 3.59 | 3.85 |
| MH | 15.98 | 17.00 | 16.49 |
| MH-ML | 13.47 | 13.41 | 12.64 |
| Ts1 | **8.18** | **6.07** | **7.41** |
| Ts2 | 9.07 | 7.08 | 8.26 |
| T10 | 8.62 | 6.55 | 7.71 |
| T50 | 10.65 | 8.66 | 9.95 |
| T90 | 14.8 | 12.61 | 14.19 |

## ZB 47 Contributes

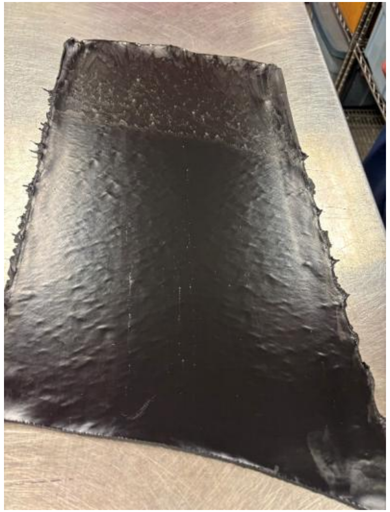
- Improve CB dispersion, achieve better compound abrasion resistance.
- Reduce compound Mooney viscosity, help production processing
- Improve compound scorch, boost production safety

struktol

JORNADAS CAUCHO
BOGOTÁ 2025

# Compound Slab Picture

Two-stage Control



One-stage w/ZB 47

struktol®

JORNADAS CAUCHO
BOGOTÁ 2025

# Further Study with Rotor Speed/Discharge Temperature

| | ZB 47 |
|---|---|
| SBR 1502 | 15.00 |
| Buna CB 24 | 35.00 |
| SIR 20 | 50.00 |
| N220 | 55.00 |
| Sundex 790TN | **8.00** |
| ZnO | 4.00 |
| Stearic acid | 2.00 |
| Akrowax 5084 | 2.00 |
| TMQ | 2.00 |
| 6PPD | 3.00 |
| ZB 47 | **2.00** |
| PVI | 0.25 |
| Sulfur | 1.25 |
| DPG | 0.32 |
| CBS | 1.00 |
| | |
| Total | 180.82 |

## One-stage mixing spec

Rotor speed = 80 rpm
0 sec.: add all rubber
30 sec. reduce rotor speed to **variable** rpm
add remaining ingredients
75 sec, ram up, sweep
105 sec, ram up, sweep
Discharge at **variable** temperature

# Rotor Speed Effect

| Rotor Speed (rpm) | 50 | 60 | 70 |
|---|---|---|---|
| Tensile strength (MPa) | **22.6** | **22.9** | **21.3** |
| Elongation (%) | 706 | 682 | 633 |
| 100% Modulus (MPa) | 2 | 1.9 | 2.1 |
| 200% Modulus (MPa) | 4 | 4 | 4.3 |
| 300% Modulus (MPa) | 6.9 | 7.1 | 7.5 |
| Hardness (Shore A) | 57 | 58 | 58 |
| Die C Tear (N/mm) | 85.8 | 79.4 | 81.3 |
| DIN (mm3) | **113** | **113** | **111** |
| | | | |
| ML (1+4) @100 C | 72 | 75 | 76 |
| | | | |
| Mooney scorch (125 C) | | | |
| Minimum torque | 56.2 | 58.3 | 57 |
| T5 | 34.63 | 34.4 | 32.63 |
| | | | |
| MDR (150 C/30 min) | | | |
| ML | 3.51 | 3.76 | 3.69 |
| MH | 16.78 | 16.64 | 17.14 |
| MH-ML | 13.28 | 12.88 | 13.45 |
| Ts1 | **7.67** | **7.38** | **7.08** |
| Ts2 | 8.0 | 8.25 | 8.02 |
| T10 | 8.07 | 7.71 | 7.48 |
| T50 | 10.42 | 9.97 | 9.69 |
| T90 | 15.18 | 14.52 | 14.87 |

The same discharge temp: 125 C

| Rotor speed (rpm) | 50 | 60 | 70 |
|---|---|---|---|
| Mixing time (sec) | 241 | 175 | 138 |
| Batch temp (C) | 134 | 142 | 143 |

**Increase rotor speed**

- No big effect on physical properties
- Compound scorcher

# Discharge Temperature Effect

| Discharge temp | 115 C | 125 C |
|---|---|---|
| Tensile strength (MPa) | 21.0 | 22.9 |
| Elongation (%) | 648 | 682 |
| 100% Modulus (MPa) | 2 | 1.9 |
| 200% Modulus (MPa) | 4.1 | 4 |
| 300% Modulus (MPa) | 6.9 | 7.1 |
| Hardness (Shore A) | 58 | 58 |
| Die C Tear (N/mm) | 76.14 | 76.9 |
| DIN (mm3) | **122** | **113** |
| | | |
| ML (1+4) @100 C | 79 | 75 |
| | | |
| Mooney scorch (125 C) | | |
| Minimum torque | 57.3 | 56.3 |
| T5 | 35.77 | 34.4 |
| | | |
| MDR (150 C/30 min) | | |
| ML | 3.96 | 3.76 |
| MH | 17.03 | 16.64 |
| MH-ML | 13.07 | 12.88 |
| Ts1 | **7.7** | **7.38** |
| Ts2 | 8.53 | 8.25 |
| T10 | 8.03 | 7.71 |
| T50 | 10.29 | 9.97 |
| T90 | 14.89 | 14.52 |

The same rotor speed: 60 rpm

| Discharge Temp (C) | 115 | 125 |
|---|---|---|
| Mixing time (sec) | 147 | 175 |
| Batch temp (C) | 133 | 142 |

## Increase Discharge Temperature

- Better physical properties
- Lower viscosity
- Compound scorcher

# One–stage Mixing Factory Trial

# Summary

- Struktol ZB 47: great benefit to one-stage mixing, make it possible to run in production

- Recommend early addition of curatives, dependent on curing system

- Higher discharge temp contributes better compound physical properties

# High BR Based Compound Processing

## *With Koresin*

# Abrasion Resistance Compound Needed

Conveyor Belt

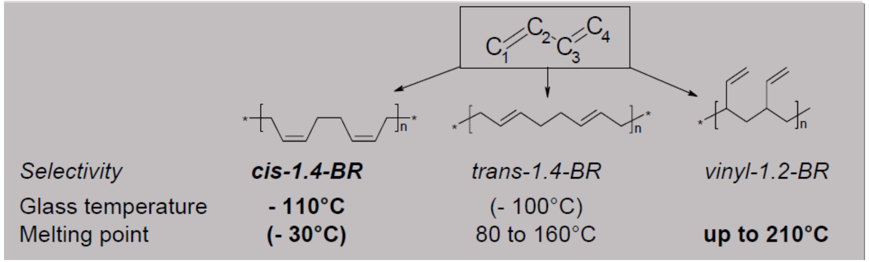
Mill liner

## Key Factors: rubber and filler

- NR: high tensile and tear strength, low heat buildup
- **BR: excellent abrasion resistance, too high-level causing bagging issue**
- SBR: better crack initiation and good processing

# BR Structure Effect on Abrasion Resistance

**BR Structure**




- With very low Tg (-106 ºC), good chain flexibility, high resilience and less heat buildup under dynamic deformation, BR provides excellent abrasion resistance. Need to increase BR to certain high level without sacrificing processing

- Neodymium catalyzed BR have the highest cis-1,4 content, >97%, and even lower Tg (-109 ºC), providing better abrasion resistance: such as Buna CB24

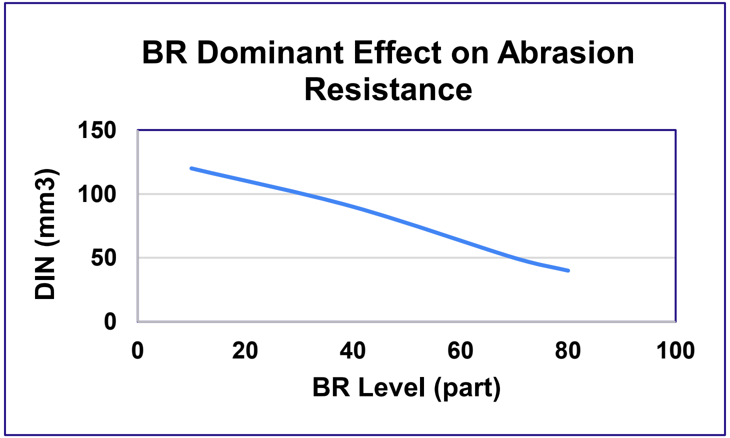
| Catalyst | Cis 1.4 (%) | Trans 1,4 (%) | Vinyl 1,2 (%) | Tg (ºC) |
|---|---|---|---|---|
| Nd | >97 | 2 | <1 | -109 |
| Co | 96 | 2 | 2 | -107 |
| Ti | 92 | 4 | 4 | -105 |
| Li | 38 | 52 | 10 | -93 |

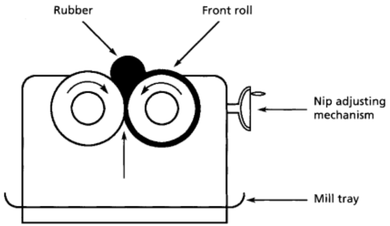
struktol®

JORNADAS CAUCHO
BOGOTÁ 2025

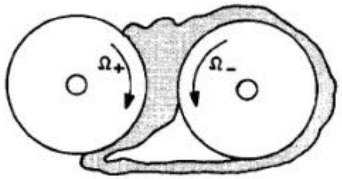
# High BR: Performance Up/Processing Down

High BR contributes significant abrasion resistance improvement, but creates bagging issue during milling and calendering




Normal Operation



Mill Bagging

# Mill Bagging: Further Discussion

**Rubber type related:** internal tack of the rubber is critical, BR, NBR and EPDM

**Rubber structure impact:** high molecular weight and narrow molecular weight distribution

Improvement in

| Processing | | *Dynamic Compound Properties* |
|---|---|---|
| high | **branching degree** | *low* |
| broad | **molecular weight distribution** | *narrow* |
| | **microstructure**<br>(stress crystallization) | *high cis*<br>*low vinyl* |

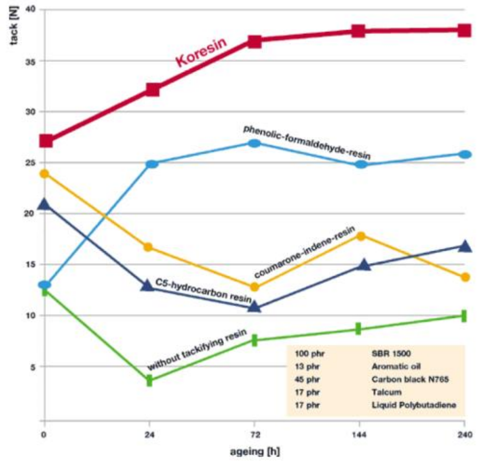
**Approach:**

- ❖ Powdered milk to help create a temporary sticky surface
- ❖ Mixing time and temperature
- ❖ Mill nip distance and surface temperature, roll friction ratio
- ❖ **Tackifier resin**

struktol®

JORNADAS CAUCHO
BOGOTÁ 2025

# Koresin: A Super Tackifier




**A "Super Tackifier"**

- Increased initial tack
- Extended long-term tack

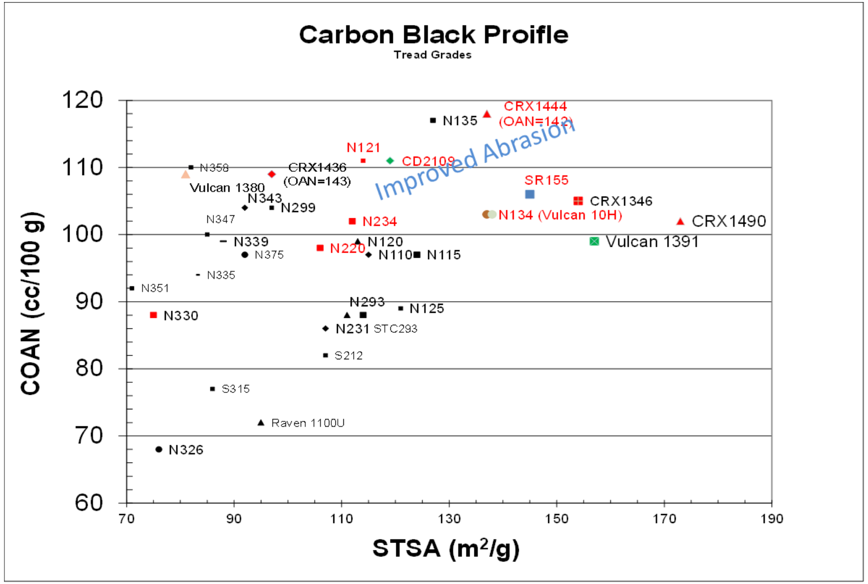
- **High tack**
- **Long-term tackiness ⇨ prefabrication, stocking time**
- Low heat build up ⇨ tire dynamics
- Unmeasurable effect on vulcanization and on scorch time ⇨ processing reliability
- Good extrudability, smooth surface
- **Excellent dispersion of carbon black**
- Physical characteristics of the vulcanized rubber remain nearly unchanged

struktol®

JORNADAS CAUCHO
BOGOTÁ 2025

# Filler: Carbon Black Dominate

## Carbon black parameters for highly abrasion resistant compound




- **Small particle size/high specific surface area**

- **High structure**

  Narrow particle/aggregate size distribution

  Strong polymer-filler interaction

  Good carbon black dispersion

- **Optimal carbon black loading**

  Polymer system dependent

  Filler distribution, oil loading, crosslinking

# Further High BR Level?

| | |
|---|---|
| SIR 20 | 30/20 |
| Buna CB 24 | 70/80 |
| N234 | 45.00 |
| Aromatic oil | 3.00 |
| ZnO | 3.00 |
| Stearic acid | 2.00 |
| 6PPD | 3.00 |
| TMQ | 2.00 |
| Wax | 1.00 |
| | |
| Sulfur | 1.25 |
| CBS | 1.25 |
| PVI | 0.20 |
| | |
| Total | 161.70 |

| BR level | 70 BR | 80 BR |
|---|---|---|
| **Physical properties** | | |
| Tensile strength (MPa) | 23.4 | 21.1 |
| Elongation (%) | 605 | 607 |
| 100% Modulus (MPa) | 2 | 1.8 |
| 200% Modulus (MPa) | 4.3 | 3.5 |
| 300% Modulus (MPa) | 8.2 | 6.7 |
| Hardness (shore A) | 58 | 62 |
| DIN abrasion ($mm^3$) | **42** | **40** |
| | | |
| **ML (1+4)** | 74 | 76 |

**BR >70 parts, compound tends to be baggy**

struktol

JORNADAS CAUCHO BOGOTÁ 2025

# Bagging Issue Resolved: Koresin

| **NR/BR (20/80)** | **Control** | **w/ 5 parts Koresin** |
|---|---|---|
| **Physical properties** | | |
| Tensile strength (MPa) | 21.3 | 20.6 |
| Elongation (%) | 614 | 654 |
| 100% Modulus (MPa) | 1.7 | 1.6 |
| 200% Modulus (MPa) | 3.4 | 3.1 |
| 300% Modulus (MPa) | 6.8 | 6.1 |
| Hardness (shore A) | 59 | 57 |
| DIN abrasion ($mm^3$) | **40** | **38** |
| | | |
| **ML (1+4)** | 75 | 73 |
| **Milling** | Baggy | Good |

# Mill Bagging Improvement

BR/NR: 80/20 Control

BR/NR: 80/20 with 5 parts Koresin

| Tested @10N/10Sec | Control | 5 parts Koresin |
|---|---|---|
| Tack (N) | 2.73 | 10.93 |

struktol®

JORNADAS CAUCHO
BOGOTÁ 2025

# Koresin: Optimize Processing and Performance

- ❖ Koresin, as a super tackifier, solves high BR caused bagging issue to enable high BR approach, not sacrificing abrasion resistance
- ❖ Koresin can ensure high abrasion compound practically run in production

JORNADAS CAUCHO

BOGOTÁ 2025

**Gracias** / Thank you