Mileage Evaluation of TBR tyre based on NR and NR/SSBR tread compounds

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Tire & Specialty Rubbers (TSR)
Technical Service & Development

Contributed by: TSR Global TS&D - Dave Hardy, Thomas Gross, Yew Lim Swee, Esther Han, Vivek Bhandari
Agenda

• Arlanxeo – Brief Introduction
• Compounds Formulation and Laboratory testing
• Tire Building and Rolling Resistance & Treadwear Testing
• Summary of Results & Next Steps
More than 100 years of experience in performance elastomers

Selected milestones in our history

- **1909** Bayer Fritz Hofmann invented synthetic rubber
- **1929** Invention of butadiene styrene copolymerization to produce SBR
- **1930** BUNA registered as trademark
- **1936** Start of industrial production of SBR (BUNA)
- **1939** Isobutylene copolymerized with isoprene making Butyl Rubber “cross-linkable”
- **1943** Synthetic rubber production exceeded 120kt p.a.
- **1944** Butyl rubber production in Sarnia (Canada) started
- **1955** Foundation of Marl, largest and most modern synthetic rubber plant in Europe
- **1955** First production of Brominated Butyl Rubber
- **1961** First production of Chlorinated Butyl Rubber
- **1975** Foundation of Marl, largest and most modern synthetic rubber plant in Europe
- **1975** First production of Brominated Butyl Rubber
- **1980** Spin-off of LANXESS from Bayer
- **1983** Acquisition of Polysar
- **1989** First production of Chlorinated Butyl Rubber
- **1990** Acquisition of Petroflex
- **1993** Butyl rubber production in Sarnia (Canada) started
- **1996** EPDM CHN opening
- **1998** Nd-BR SGP opening
- **2004** Spin-off of LANXESS from Bayer
- **2008** Acquisition of Petroflex
- **2010** Groundbreaking for new Singapore site
- **2013** Butyl SGP opening
- **2015** EPDM CHN opening
- **2016** ARLANXEO starts – JV of Saudi Aramco and LANXESS
- **2018** Saudi Aramco agreed to acquire 100% stake in ARLANXEO

ARLANXEO
Tire & Specialty Rubbers (TSR) – world’s leading manufacturer of Performance Rubbers

### Facts
- Part of: ARLANXEO
- Customers: > 250
- Production capacity: > 1,000,000 t/a

### Products & Brands
- **Butyl**
  - Regular
  - Halogenated (Chloro/Bromo)
- **BR**
  - Nd-BR
  - Li-BR
  - Co-BR
- **S-SBR**
  - functionalized and non-fct.
  - High Vinyl and high Styrene
- **E-SBR**
  - Clear and oil extended
  - High SBR latex
- **Buna®**
  - Functionalized and non-fct.
  - High Vinyl and high Styrene

### Applications
- Tire
- Consumer & pharma
- Plastics
- Golf & sport balls
## Compound Formulations

<table>
<thead>
<tr>
<th>Materials</th>
<th>NR / CB24 (Control)</th>
<th>NR / CB24 / SL7518-4</th>
<th>NR / CB24 / SL4525-0</th>
<th>NR / CB24 / SL7518-4 &amp; Si</th>
<th>NR / Nd24 EZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR (Masticated SMR 10)</td>
<td>80.0</td>
<td>50.0</td>
<td>50.0</td>
<td>50.0</td>
<td>80.0</td>
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<tr>
<td>SSBR (Buna SL7518-4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSBR (Buna SL4525-0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NdBR (Buna CB24)</td>
<td>20.0</td>
<td>20.0</td>
<td>20.0</td>
<td>20.0</td>
<td>20.0</td>
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<tr>
<td>NdBR (Buna Nd 24 EZ)</td>
<td></td>
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<tr>
<td>Stearic Acid</td>
<td>1.0</td>
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<tr>
<td>Microcrystalline Wax</td>
<td>1.5</td>
<td>1.5</td>
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<td>TMQ</td>
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<td>6PPD</td>
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<tr>
<td>Zinc Oxide</td>
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<tr>
<td>Naphthenic Oil</td>
<td>4.5</td>
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<tr>
<td>N 234 Carbon Black</td>
<td>50.0</td>
<td>50.0</td>
<td>50.0</td>
<td>40.0</td>
<td>50.0</td>
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<tr>
<td>Silica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15.0</td>
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<tr>
<td>Silane Si69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.3</td>
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<tr>
<td>CBS accelerator</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
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</tr>
<tr>
<td>Sulphur</td>
<td>1.4</td>
<td>1.4</td>
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<tr>
<td>DPG accelerator</td>
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<td></td>
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<td>0.4</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>166.7</strong></td>
<td><strong>166.7</strong></td>
<td><strong>166.7</strong></td>
<td><strong>173.4</strong></td>
<td><strong>166.7</strong></td>
</tr>
</tbody>
</table>
SSBR Properties - 2 Nos. of SSBR are selected for study with similar Tg but different Molecular Weight

<table>
<thead>
<tr>
<th>Sample</th>
<th>Buna SL 7518-4 (Previously PBR 4089)</th>
<th>Buna SL 4525-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML-1+4 (MU)</td>
<td>72</td>
<td>44,5</td>
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<tr>
<td>Oil Type</td>
<td>Lubnor NH 140</td>
<td></td>
</tr>
<tr>
<td>Oil Content (%)</td>
<td>13,0</td>
<td></td>
</tr>
<tr>
<td>Styrene (%)</td>
<td>18,7</td>
<td>25,6</td>
</tr>
<tr>
<td>Typical Vinyl (%)</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Typical Tg (°C)</td>
<td>-73</td>
<td>-69</td>
</tr>
<tr>
<td>Mn (kg/mol)</td>
<td>267</td>
<td>170</td>
</tr>
<tr>
<td>Mp (kg/mol)</td>
<td>446</td>
<td>253</td>
</tr>
<tr>
<td>PDI</td>
<td>2,4</td>
<td>2,3</td>
</tr>
</tbody>
</table>
Vulcanization Behavior (MDR, 160°C):

- Partial replacement of NR by SSBR leads to improvement in scorch safety with increase in Tc90 values.
Compound with Low molecular weight SSBR (NR / SL4525-0) exhibits lower modulus
Temperature Sweep Results (10 Hz, 1K/min)

- Replacing NR with higher mol. wgt. SL 7518-4 maintains RR
- Replacing NR with lower mol. wgt. SL 4525-0 results in worse tanδ at 60°C
Strain Sweep Results (60°C, 1 Hz)

- Replacing NR with SL 7518-4: improved Payne effect (better polymer-filler), improved max tanδ
- Adding silica further improves Payne effect (polymer-filler) and lower max Tan δ → improved RR
SSBRs improve abrasion loss
Higher mol wtg (SL 7518-4) have better R@ 60°C (RR)
Adding silica/silane further improves R@ 60°C

Replacing NR with SSBR (SL 7518-4) maintains HBU
Nd 24 EZ shows improved HBU
HBU not changed with silica/silane
Tire Building

<table>
<thead>
<tr>
<th>Retreading Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Worked with TARRC Rubber Consultants in UK.</td>
</tr>
<tr>
<td>▪ Retreaded Truck Tires (295/80 R 22.5) using Orbitread, first grade end of 1st life.</td>
</tr>
<tr>
<td>▪ Buffed casings inspected and repaired if necessary.</td>
</tr>
<tr>
<td>▪ Drive pattern from top 5 tire maker was used. The compounds were applied to the casings with a typical extrusion temperature of 90 to 100°C.</td>
</tr>
<tr>
<td>▪ Tires were cured in a steam heated press with the heat being applied from the outside only for 85 minutes at 150°C.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orbitread Strip winding</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Photo used with permission by TARRC Rubber Consultants</td>
</tr>
</tbody>
</table>

RRc Test Details

- Two uni-sectional tires were built for each compound, for the testing of the rolling resistance.

- Drum speed 60 km/h with a load of 3017 Kg. Tire is run for 90 minutes to reach equilibrium running conditions.

- 4 runs are then made at 30 minute intervals taking the average of 15 measurements of the on-load and skim-load. Data is collected every 15 seconds during each run as well as the room temperature.

- The RRc is calculated by averaging those calculated for the last three runs.

Drum Rig Test

- Photo used with permission by TARRC Rubber Consultants
Treadwear Testing

- 9 Bi-sectional tires were used to test the different compounds, each tire had 4 circumferential grooves.
- One section on each tire was always a control compound.
- Measurements were taken at the center of each tread segment and 60° either side. The average of 12 readings are taken for tread depth. All compounds were run on both the off side and near side of the axles (see diagram).
- All wear measurements were done in reference to the control used on each tire – with an original tread depth of 21mm becoming 2 mm at the conclusion of the test.
- 3rd axle: Medium severity
- 4th axle: Highest severity

Photo used with permission by TARRC Rubber Consultants
Summary of Truck Tire Test Results

**RRc & Treadwear: 50,000 km to 100,000 km**

- **Replacing 30 phr of NR with Buna SL 7518-4:**
  - improved medium and high severity treadwear
  - similar values for RRc

- **Buna SL 7518-4 vs Buna SL 4525-0:**
  - Improved treadwear and improved RRc due to the increased molecular weight

- **Replacing 10 phr of carbon black with 15 phr of silica:**
  - improved high severity treadwear but not significant change in RRc

- **Buna Nd 24 EZ vs Buna CB 24:**
  - slight drop in the RRc (not predicted by lab tests)
  - medium severity treadwear similar
  - improved high severity treadwear

**Index – Higher is better**
Benefit of SR (SSBR & NdBR) in Truck Tread & Next Steps

- Partially replacing NR in truck tread with low Tg SSBR (Buna SL 7518-4) helps improve wear without sacrificing RR and HBU.
- Higher molecular weight (oil extended) low Tg SSBR offers better high severity wear and RRc vs clear SL grade.
- Nd “EZ” technology showed some improvement vs standard NdBR (HBU, high severity wear) but not seen in RRc.
- Next: Develop functionalized low Tg SSBR microstructures. (both silica and carbon black)
Acknowledgement

Many thanks go to all colleagues and friends of Arlanxeo TSR, whose various studies and presentations are used here.