Soybean Oil-Based Additives for Low-Friction Rubber Compounds

Dean Webster, PI

Olena Shafranska, coPI

Department of Coatings and Polymeric Materials, North Dakota State University

<u>Objectives of the research</u>

In this project, we are developing a new soybean oil-based additive for low-friction rubber. We are exploring soybean oil-based additives for compatibility with poly(styrene-butadiene) (SBR) rubber and reducing the surface friction of SBR. The low-friction SBR rubber formulated with the soy-based additive will be used for the manufacturing of conveyor belts and rubber belts for harvesting equipment with improved properties such as reduced friction and friction heat.

<u>Completed work</u>

- Initial screening of soy-based additives (SBA)
- The additive which provides lowest surface friction identified
- Compounding of SBR rubbers with different content of SBA
- Testing of the coefficient of friction at time intervals of 2 weeks (this step will continue till the end of project)
- Initial testing of mechanical properties

<u>Preliminary results</u>

The work on this project was started with screening the different modified soybean oils (SBO) as additives for SBR rubber formulations and testing of static coefficient of friction (COF). The list of soy-based SBAs used for initial screening includes different polystyrene-modified SBOs, hydrogenated SBOs with different hydrogenation levels, SBO modified with the copolymer of styrene and acrylic acid, soy octaester of sucrose (sucrose soyate), soy lecithin, acryl-aminoethyl soyate (AAS) and AAS hydrogenated AAS (HAAS). A set of rubbers with Composition 1 presented in Table 1 was prepared and vulcanized. The lowest COF was observed for the compound containing HAAS and the second low value for COF was found for partially hydrogenated SBO (PHSBO) having an iodine value of 50. Other SBAs showed only a little reduction of surface friction and were rejected after initial screening. PHSBO was selected for more detailed study as it is the commercially available product with a low price.

Next, a set of rubbers with compositions similar to the compositions of SBR rubber used for conveyor belts was prepared with different amounts of PHSBO. The Compositions 2 was agreed with engineers from WCCO Belting Inc. while Composition 3 was found in the literature (Table 1).

Table 1. Compositions of SBR compound for surface friction testing. Each compound contained 5phr of ZnO, 1 phr of stearic acid, 1.5 phr od sulfur and 1.5 phr of activator TBBS

Compound	Composition 1	Composition 2				Composition 3		
		AO50	AO40S10	AO25S25	S50	AO12	S12	AO12S5
SBR	100	100	100	100	**100**	100	100	100
Carbon black	100	75	75	75	75	70	70	70
Aromatic oil	30	50	40	25	0	12	0	12
Soy-based additive (SBA)	7.5							
PHSBO		0	10	25	50	0	12	5

The rubbers were vulcanized and tested for surface friction at 2 and 14 days after vulcanization. The corresponding COF_2 and COF_{14} are given in Table 2. The reduction of COF was calculated as the decrease in % of COF_{14} for the PHSBO-containing rubbers compared to the reference rubber with the same amount of petroleum-based process oil. The rubbers AO40S10, AO25S25 and S50 were compared to the reference rubber AO50 and the rubbers S12 and AO12S5 were compared to the reference rubber AO12. It can be seen from Table 3 that the increase of PHSBO content results in lowering of COF. The reference rubber AO50 with Composition 2 has very high COF and shows the highest adhesion to metal. The replacement by only 10 parts of aromatic oil with PHSBO reduces the COF by 66%. The rubbers formulated with complete replacement of process oil with PHSBO show the lowest COF in each group. The better results show the rubbers with the Composition 3 since the reference rubber AO12 was less sticky to metal and the rubber S12 compounded with PHSBO shows the lowest COF. COF for PHSBO-containing rubbers decreases over time as PHSBO migrates to the surface providing a slip layer. It is expected that rubber can lose the slip layer as it will be worn during the use, however, during "out-of-season" storage of equipment the slip layer will be rebuilt.

Table 2. COF for different rubbers with Compositions 2 and 3.

Compound	**Composition 2**				**Composition 3**		
	AO50	**AO40S10**	**AO25S25**	**S50**	**AO12**	**S12**	**AO12S5**
PHSBO content	0	10	25	50	0	12	5
COF_2	2.42	1.13	0.97	0.70	2.04	1.13	1.50
COF_{14}	2.20	0.75	0.64	0.59	1.56	0.48	1.02
COF_{14} reduction	00%	66%	71%	73%	0%	69%	35%

The PHSBO-containing rubbers were tested for durometer hardness and in a tensile test in order to evaluate the impact of PHSBO on the mechanical properties of rubber. The results presented in Table 4 demonstrate some improvement in tensile moduli and the increase of hardness when petroleum-based aromatic oil was partially or completely replaced with soy-based PHSBO. At the complete replacement of aromatic oil, tensile strength was even higher for S50 rubber, comparing to AO50. The same tendency was observed for the rubbers with low oil content. When aromatic oil was replaced with PHSO, tensile strength, moduli and hardness increase while elongation is maintained.

Table 3. Physical properties of different rubbers with the composition as given in Table 1.

Compound	**Tensile strength, MPa**	**Elongation at break, %**	**Modulus at 100% Elongation**	**Modulus at 300% Elongation**	**Hardness**
AO50	13.7 ± 0.9	705 ± 56	1.96 ± 0.04	5.91 ± 0.07	50
AO25S25	13.7 ± 0.5	652± 26	2.20 ± 0.04	6.49 ± 0.08	58
S50	14.2 ± 0.3	546 ± 17	3.02 ± 0.06	8.06 ± 0.19	61
AO12	21.0 ± 1.0	465 ± 12	4.12 ± 0.12	14.62 ± 0.36	70
S12	22.0 ± 0.6	453 ± 12	4.26 ± 0.09	15.24 ± 0.14	71
Target properties*	>13.8	>400			

*Target properties found in literature

Conclusion

Partially hydrogenated soybean oil shows promising results in reducing surface friction of SBR rubber used in conveyor belt applications. For the rubbers formulated with PHSBO in place of petroleum-based aromatic oil, COF was reduced up to 73% while tensile properties and hardness were improved.

Work to be completed

We plan to continue testing of COF over time and optimize the composition of SBR compounds to achieve the lowest COF. Additionally, we plan to test the rubbers with lowest COF in an abrasion resistance test.