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Improved Performance In High Natural Rubber Silica Compounds

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ABSTRACT

Government involvement in legislating reductions in rolling resistance for tires continues throughout the world. In Europe, commercial tires will be included in the labeling program slated to begin in November 2012. The United States Environmental Protection Agency has developed the SmartWay™ Program to recognize low rolling resistance truck tires for steer, drive and trailer positions. California requires SmartWay™ approved tires presently and other states are considering legislation. The development of silica processing additives provides significant reduction in rolling resistance indicators, improved compound processability while enhancing other physical properties in compounds containing natural rubber.

INTRODUCTION

Increasing fuel costs, government regulations requiring better fuel economy and environmental concerns with greenhouse gases are now affecting heavy tire formulations. To meet these new requirements, silica and silane coupling agents are being evaluated in compounds that contain high percentages of natural rubber that are typically found in heavy tires. While these enhanced formulations will provide better physical properties, mixing and downstream processing have become significantly more difficult. Historically processing additives have been used to decrease compound viscosity and aid in processability. This usually resulted in the reduction of many physical properties in the final product. The development of new chemistries have led to new processing additives that enhance the mixing and downstream handling as well as improving physical properties in the compound.

EXPERIMENTAL

All formulations were mixed in a Banbury 1600 internal mixer (Farrel Corp. Ansonia, CT). To evaluate the effect of processing additives on compound properties, a typical all natural rubber tread formulation was used in the lab program. The compounds in Table 1 contain high dispersity silica, ZS 1165 MP produced by Rhodia. The processing additives were introduced in the non-productive pass, which was mixed and dropped at 135C. The productive passes were dropped at 120 seconds or 100 C. The compounds were sheeted on an open two roll mill (Stewart Bolling Co. Cleveland, OH). Rheometer samples were tested on an oscillating disk rheometer, Rheo-Tech (Tech Pro Inc. Cuyahoga Falls, OH). Mooney Viscosity testing was done on a Monsanto Mooney Viscometer 2000 (Tech Pro Inc. Cuyahoga Falls, OH). Tensile and tear testing were performed on an Instron 5500 R Model 4201 (Instron, Canton, MA). RPA data was acquired on the Alpha Technologies RPA2000 (Akron, OH). Heat build up and blow out data were generated on the B. F. Goodrich A 220 Flexometer II by Alpha Technologies (Akron, OH). Samples for abrasion resistance were evaluated on a DIN Abrasion tester from Qualitest (Toronto, Canada). The processing additives evaluated in this study (HT207, HT276, JV46F, and ZB49) are produced by The Struktol Company of America and Schill & Seilacher in Germany.

DISCUSSION

The cure curves and characteristics of each compound were determined with an oscillating disk rheometer and are provided in Figure 1 and Table 2. The rheometer data shows the compounds that contain the processing additives exhibit lower minimum torques and higher delta torques than the control compound and produce an increased cure state. The Mooney Scorch and T90 data shown in Table 3 indicate the processing additives increase the scorch safety of the compounds enhancing processability but have minimal effect on the cure time. HT276 increases T90 slightly. Each of the processing additives also provide a reduction in the Mooney Viscosity as shown in Table 3.

Tables 4 and 5 show physical property data on original and aged compounds. The processing additives provide increased tensile and modulus with little effect on Shore A hardness. Data listed in Table 5 shows the compounds containing the processing additives exhibit very good physical property retention when the samples are aged for 7 days at 70C.

Table 6 lists the Die C tear strength at room temperature. Each of the processing additives produced tear strength that was greater than the control compound.

The Payne Effect plot in Figure 2 shows the effect the processing additives have on the uncured stiffness of the compounds. The reduction in stiffness when compared to the control compound will provide increased downstream processability.

Abrasion resistance was evaluated with a 10 Newton load and the results are provided in Table 7. All of the additives provided better abrasion resistance with HT276 and ZB49 performing slightly better than HT207 and JV46F.

Cured RPA data is shown in Table 8. G’ at 1% strain is reduced in the compounds that contain the processing additives when compared to the control compound. Based on the reduction in the Payne Effect this would be expected. The reduction in G’ at the higher strain level for the additive samples is significantly less. Tangent delta values for HT276, JV46F and ZB49 show a reduction of approximately 20% versus the control compound.

Tables 9 and 10 show the heat build up and blow out data for the HT207, HT276, JV46F and ZB49. Each additive evaluated provided lower heat build up and increased the blow out time.

SUMMARY and CONCLUSIONS

The use of processing additives in compounds containing high dispersity silica/silane coupler and high levels of natural rubber can provide a variety of processing and physical property benefits.

☐ Reduced Viscosity for Improved Processing
☐ Increased Cure State
☐ Improved Scorch Safety
☐ Better Modulus and Tensile
☐ Significant Decrease in Payne Effect
☐ Abrasion Loss is Reduced
☐ Lower Tan D (Better Fuel Economy)
☐ Lower Heat Build Up (Better Durability)
☐ Longer Blow Out Times (Better Durability)

The selection of a processing additive for a particular application can be accomplished by evaluating the physical property and processability benefits.

Formulations

SIR 20	**100**	**100**	**100**	**100**	**100**
Zeosil 1165 MP	**50**	**50**	**50**	**50**	**50**
Struktol 40 MS Flakes	**4**	**4**	**4**	**4**	**4**
Struktol SCA 98 (TESPT)	**4**	**4**	**4**	**4**	**4**
N-330	**5**	**5**	**5**	**5**	**5**
6PPD	**2**	**2**	**2**	**2**	**2**
Struktol HT 207		**3**			
Struktol HT 276			**3**		
Struktol JV 46F				**3**	
Struktol ZB 49					**3**
ZnO	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**
Stearic Acid	**1**	**1**	**1**	**1**	**1**
CBS	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
DPG	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Sulfur	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**
Sum	**172.1**	**175.1**	**175.1**	**175.1**	**175.1**

Table 1

Rheometer Curves

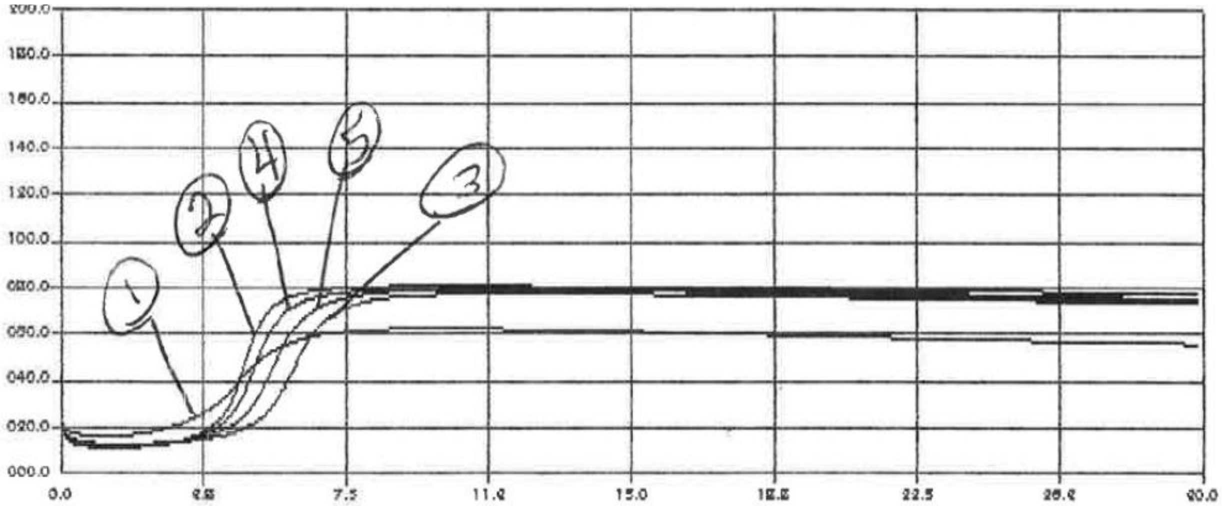

Figure 1

Rheometer Data

160°C; 3° arc; 100 range; 30 minutes – Tech Pro

Compound	Min Torque	Delta Torque
1 (Control)	18.64	52.12
2 (HT207 3 phr)	13.30	78.00
3 (HT276 3 phr)	14.78	72.70
4 (JV46F 3 phr)	13.82	76.00
5 (ZB49 3 phr)	14.15	76.60

Table 2

Rheometer/Mooney Data

Compound	Mooney Scorch	T90	Mooney Viscosity
1 (Control)	18.13	6.29	63
2 (HT207 3 phr)	21.58	5.73	53
3 (HT276 3 phr)	24.03	7.43	53
4 (JV46F 3 phr)	23.58	6.19	53
5 (ZB49 3 phr)	21.33	7.05	51

Table 3

Original Physical Property Data

Compound	Shore A Duro	Tensile (MPa)	100% Mod. (MPa)	300% Mod. (MPa)
1 (Control)	65	28.6	2.3	11.0
2 (HT207 3 phr)	65	31.3	3.1	14.2
3 (HT276 3 phr)	64	31.2	2.9	13.3
4 (JV46F 3 phr)	65	29.4	2.9	13.4
5 (ZB49 3 phr)	66	30.2	3.1	14.3

Table 4

Aged Physical Property Data
7 Days 70C

Compound	Shore A Duro	Tensile (MPa)	100% Mod. (MPa)	300% Mod. (MPa)
1 (Control)	67	32.8	2.9	13.4
2 (HT207 3 phr)	67	32.5	3.4	15.4
3 (HT276 3 phr)	67	31.5	3.3	15.0
4 (JV46F 3 phr)	65	30.5	3.2	15.5
5 (ZB49 3 phr)	68	31.8	3.3	15.4

Table 5

Tear Strength N/mm
Die C

Compound	Tear Strength 23ºC
1 (Control)	109
2 (HT207 3 phr)	130
3 (HT276 3 phr)	120
4 (JV46F 3 phr)	135
5 (ZB49 3 phr)	124

Table 6

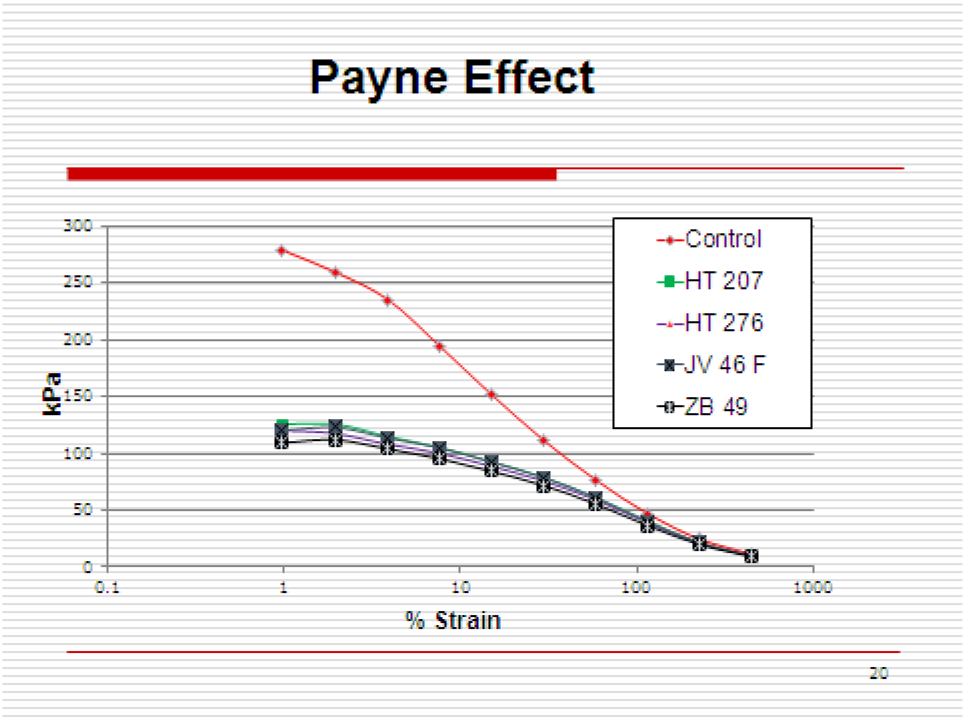

Figure 2

DIN Abrasion (10N)

	Control	HT 207	HT 276	JV46 F	ZB49
DIN	126	106	100	107	101

Table 7

Cured RPA Data 50C 10 Hz

Compound	G’ 1% kPa	G’ 10% kPa	Peak TD
1 (Control)	5301	2170	0.182
2 (HT207 3 phr)	3749	1938	0.151
3 (HT276 3 phr)	2960	1614	0.138
4 (JV46F 3 phr)	3318	1844	0.137
5 (ZB49 3 phr)	3436	1880	0.140

Table 8

Heat Build Up

Compound	Shore A	Temp C
1 (Control)	65	110
2 (HT207 3 phr)	65	76
3 (HT276 3 phr)	64	86
4 (JV46F 3 phr)	65	84
5 (ZB49 3 phr)	66	82

Table 9

Blow Out

Compound	Shore A	Time min
1 (Control)	65	7
2 (HT207 3 phr)	65	14
3 (HT276 3 phr)	64	12
4 (JV46F 3 phr)	65	12
5 (ZB49 3 phr)	66	12

Table 10