Struktol Company of America
201 E. Steels Corners Road • P. O. Box 1649 • Stow, Ohio 44224-0649
www.struktol.com
Producers of Specialty Chemicals

OTR Silica Tread

With

Next Generation

Struktol Process Additives

Struktol Rubber Lab Project 09001

Paul Danilowicz
Benny Bezilla

STP0265

Phone: (330) 928-5188
Fax: (330) 928-8726

Technical Services: 1-800-327-8649
E-mail: customerservice@struktol.com

JV46F

•Blend of fatty acid derivatives
•DP 85C
•Zn ~5%

KK 49

•Blend of fatty acid derivatives
•DP 105C
•Zn 10%

CY 48

•Blend of fatty acid derivatives
•DP 97C
•Zn ~8%

ZB47

•Proprietary zinc compound
•DP 112C
•Zn ~12%
•Designed to modify sulfur network

HPS11

•Blend of fatty acid derivatives
•DP 85C
•Zn 0%

2

Outline

- Formulations
- Mix Spec
- Rheometer Data
- Physical Property Data
- Conclusions

3

Formulations

First Pass	A	B	C	D	E	F	G	H	I	J	K	L
INGREDIENT	**MASS**	**MASS**	**MASS**	**MASS**	**MASS**	**MASS**	**MASS**	**MASS**	**MASS**	**MASS**	**MASS**	**Mass**
SIR 3L - Premass/A96	100.20	100.20	100.20	100.20	100.20	100.20	100.20	100.20	100.20	100.20	100.20	100.20
N220	40	40	40	40	40	40	40	40	40	40	40	40
ZS1165MP	**20**	**0**	**20**	**0**	**20**	**0**	**20**	**0**	**20**	**0**	**20**	**0**
ZS2000MP	**0**	**20**	**0**	**20**	**0**	**20**	**0**	**20**	**0**	**20**	**0**	**20**
ZnO	4	4	4	4	4	4	4	4	4	4	4	4
6PPD	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
TMQ	1	1	1	1	1	1	1	1	1	1	1	1
40MS FL	6	6	6	6	6	6	6	6	6	6	6	6
JV46F	0	0	3	3	0	0	0	0	0	0	0	0
CY 48	0	0	0	0	3	3	0	0	0	0	0	0
KK 49	0	0	0	0	0	0	3	3	0	0	0	0
ZB47	0	0	0	0	0	0	0	0	3	3	0	0
HPS11	0	0	0	0	0	0	0	0	0	0	3	3
Stearic acid	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total	**176.20**	**176.20**	**179.20**	**179.20**	**179.20**	**179.20**	**179.20**	**179.20**	**179.20**	**179.20**	**179.20**	**179.20**

4

Formulations

Final Pass	A	B	C	D	E	F	G	H	I	J	K	L
MB A	176.20											
MB B		176.20										
MB C			179.20									
MB D				179.20								
MB E					179.20							
MB F						179.20						
MB G							179.20					
MB H								179.20				
MB I									179.20			
MB J										179.20		
MB K											179.20	
MB L												179.20
TBBS	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sulfur	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total	179.20	179.20	182.20	182.20	182.20	182.20	182.20	182.20	182.20	182.20	182.20	182.20

5

Mix Spec

FIRST PASS MIX – ROTOR SPEED – 77 – RAM PRESSURE 30 – FILL FACTOR 70

0 SECONDS ADD RUBBER AND PEPTIZER
30 SECONDS ADD BLACK, SILICA, ZINC OXIDE, 6PPD, TMQ AND ADDITIVES
120 SECONDS BRUSH AND SWEEP
180 SECONDS BRUSH AND SWEEP
240 SECONDS DISCHARGE

2ND PASS MIX SPEC – ROTOR SPEED 77 – RAM PRESSURE 30

0 SECONDS LOAD ½ MB, ADD CURES, REST MB
30 SECONDS BRUSH AND SWEEP
120 SECONDS OR 212F DISCHARGE

6

Mixing Observations

Compound	Temp (°C)	Probe Temp(°C)	Energy (WH)	First pass comments	Final pass comments
A (Control)	157	168.0	228	OK	OK
C	151	162.0	195	OK	OK
E	153	163.5	183	OK	OK
G	154	162.2	189	OK	OK
I	158	164.4	196	OK	OK
K	158	166.2	197	OK	OK

Significantly reduced mix energy for all additives
Lower drop temperature for all additives

7

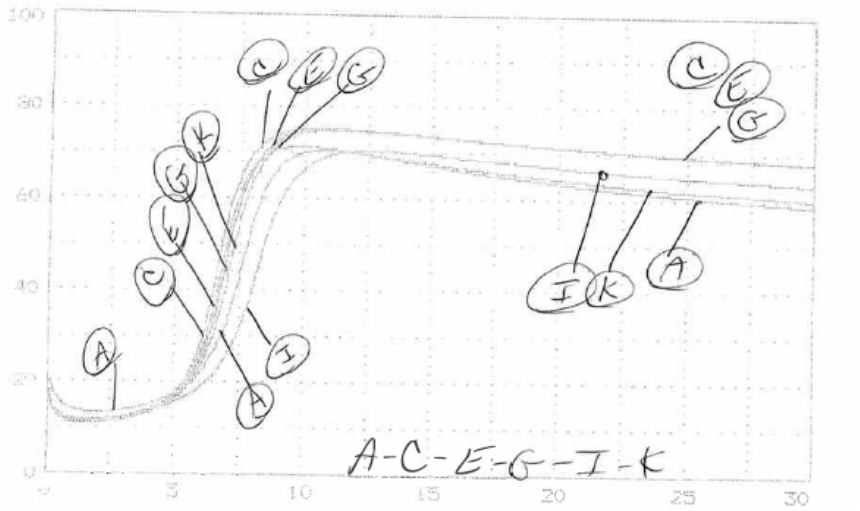
Mixing Observations

Compound	Temp (°C)	Probe Temp(ºC)	Energy (WH)	First pass comments	Final pass comments
B (Control)	171	185.3	243	OK	OK
D	164	172.5	218	OK	OK
F	160	172.8	200	OK	OK
H	163	173.7	206	OK	OK
J	167	180.6	209	OK	OK
L	169	176.4	213	OK	OK

Significantly reduced mix energy for all additives
Lower drop temperature for all additives

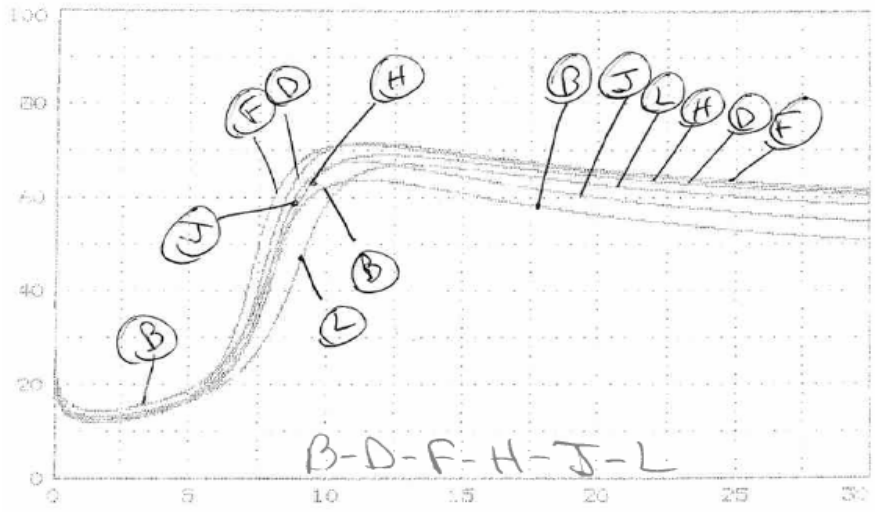
8

Rheometer Curves



9

Rheometer Curves



10

Rheometer Data

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

Compound	Min Torque	Max Torque	Ts_2	T_{50}	T_{90}	T-2 Reversion
A (Control)	13.13	70.48	4.08	7.50	8.79	13.63
C	10.75	75.25	3.79	6.63	7.96	15.50
E	11.10	75.07	3.88	6.92	8.29	15.96
G	10.98	74.84	3.79	7.08	8.50	16.42
I	11.45	70.48	3.96	8.08	9.71	17.04
K	11.33	71.18	3.79	6.75	7.87	13.04

Significantly increased cure state with all additives
Lower minimum torque with all additives
Better reversion resistance with JV46F, CY 48, KK 49 and ZB47 with the ZS1165MP silica
Cure times approximately equal

11

Rheometer Data

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

Compound	Min Torque	Max Torque	Ts_2	T_{50}	T_{90}	T-2 Reversion
B (Control)	14.41	63.74	3.92	7.58	9.17	14.17
D	12.49	71.24	3.96	7.21	8.67	14.50
F	12.03	71.53	3.83	7.63	9.08	14.79
H	11.91	69.09	3.88	7.92	9.50	15.92
J	12.20	67.00	3.83	8.67	10.42	16.79
L	13.07	67.69	4.04	7.79	9.13	13.79

Significantly increased cure state with all additives
Lower minimum torque with all additives
Better reversion resistance with CY 48 and KK 49 with the ZS200MP silica
Cure times approximately equal

12

Mooney Viscosity

ML (1+4) @ 100°C age mooney

Compound	Initial Viscosity	ML (1+4)	Initial Viscosity 1 week	ML (1+4)	Initial Viscosity 2 weeks	ML (1+4)	Initial Viscosity 4 weeks	ML (1+4)
A (Control)	86.1	61.3	112.6	66.0	139.0	66.4	119.5	66.6
C	75.6	51.5	104.7	54.9	100.2	54.9	95.4	55.2
E	77.4	54.1	97.5	58.2	90.2	59.1	98.0	58.7
G	81.5	54.0	96.6	57.2	89.0	57.3	96.1	58.8
I	84.0	56.3	118.0	60.8	107.4	61.3	116.2	62.5
K	80.4	54.8	105.3	59.2	98.9	59.5	102.2	58.7

Decreased viscosity for better processability with all additives
Better viscosity control with time providing more stable stock storage

13

Mooney Viscosity

ML (1+4) @ 100°C age mooney

Compound	Initial Viscosity	ML (1+4)	Initial Viscosity 1 week	ML (1+4)	Initial Viscosity 2 weeks	ML (1+4)	Initial Viscosity 4 weeks	ML (1+4)
B (Control)	98.5	72.6	142.3	81.5	148.3	77.7	189.3	85.3
D	100.0	62.6	139.6	67.1	122.0	67.4	127.4	66.6
F	92.9	62.1	127.0	67.7	116.0	67.5	152.4	68.6
H	93.3	62.3	129.9	68.2	108.9	68.0	151.2	69.2
J	97.7	64.5	141.6	70.2	117.6	70.2	175.3	72.8
L	100.0	66.8	133.7	72.1	118.3	71.1	157.1	70.8

Decreased viscosity for better processability with all additives
Better viscosity control with time providing more stable stock storage

14

Tensile Data

Unaged

Compound	Cure time @ 160°C	Shore A Duro	Tensile (MPa)	Elong (%)	100% Mod. (MPa)	200% Mod. (MPa)	300% Mod. (MPa)
A (Control)	10	65	25.3	555	2.4	6.8	12.5
C	10	71	25.1	546	2.9	7.5	13.0
E	10	69	25.1	530	3.0	7.7	13.4
G	10	71	24.8	520	3.0	8.1	13.9
I	10	67	24.1	522	2.7	7.4	13.2
K	10	69	24.2	524	2.6	7.2	12.9

Higher hardness and modulus for all additives
Tensile and elongation approximately equal for all additives

15

Tensile Data

Unaged

Compound	Cure time @ 160°C	Shore A Duro	Tensile (MPa)	Elong (%)	100% Mod. (MPa)	200% Mod. (MPa)	300% Mod. (MPa)
B (Control)	10.5	65	23.7	544	2.3	6.5	12.0
D	10.5	69	25.3	546	2.7	7.3	13.0
F	10.5	67	25.0	528	2.7	7.3	13.2
H	10.5	67	24.2	537	2.6	7.1	12.6
J	10.5	67	24.8	545	2.6	7.1	12.8
L	10.5	67	24.1	537	2.5	6.9	12.5

Higher hardness and modulus for all additives
Tensile and elongation approximately equal for all additives

16

Oven Aged

70 Hrs @ 100ºC

Sample	Shore A	Points Chg	Tensile (Mpa)	Pct. Chg	Elong %	Pct. Chg	100% Mod. (Mpa)	Pct. Chg	200% Mod. (Mpa)	Pct Chg	300% Mod (Mpa)	Pct Chg
A	74	9	22.4	-11.5	444	-20.0	4.8	100	11.4	67.6	17.0	36.0
C	77	6	21.2	-15.5	412	-24.5	5.0	72.4	11.3	50.7	16.7	28.5
E	76	7	20.3	-19.1	414	-21.9	4.7	56.7	10.7	39.0	16.1	20.1
G	77	6	20.8	-16.1	386	-25.8	5.4	80.0	12.3	51.9	17.8	28.1
I	77	10	20.2	-16.2	389	-25.5	5.1	88.9	11.9	60.8	17.4	31.8
K	74	5	20.7	-14.5	425	-18.9	4.3	65.4	10.5	45.8	15.9	23.3

Rate of change after oven aging for hardness, modulus and elongation approximately equal to control

17

Oven Aged

70 Hrs @ 100ºC

Sample	Shore A	Points Chg	Tensile (Mpa)	Pct. Chg	Elong %	Pct. Chg	100% Mod. (Mpa)	Pct. Chg	200% Mod. (Mpa)	Pct. Chg	300% Mod (Mpa)	Pct. Chg
B	74	9	21.5	-9.3	444	-18.4	4.4	91.3	10.7	64.6	16.1	34.2
D	75	6	21.0	-17.0	398	-27.1	4.7	74.1	11.0	50.7	16.6	27.7
F	75	8	21.6	-13.6	418	-20.8	4.8	77.8	11.3	54.8	16.9	28.0
H	74	7	21.7	-10.3	418	-22.2	4.9	88.5	11.6	63.4	17.1	35.7
J	74	7	22.1	-10.9	419	-23.1	5.0	92.3	11.7	64.8	17.5	36.7
L	74	7	20.9	-13.3	429	-20.1	4.2	68.0	10.4	50.7	16.0	28.0

Rate of change after oven aging for hardness, modulus and elongation approximately equal to control

18

Tear Strength ASTM D – 624 Die C N/MM

Compound	Die C 23ºC	Die C 100ºC	Trouser Tear 23ºC	Trouser Tear 100ºC	Die B 23ºC	Die B 100ºC
A (Control)	124.6	107.7	58.0	36.6	127.1	114.1
C	91.8	100.6	58.2	42.6	130.9	110.6
E*	130.1	99.9	71.9	43.3	123.8	110.0
G*	139.8	95.3	65.8	38.3	134.0	128.2
I	104.5	97.8	60.9	44.6	118.6	104.9
K	100.3	104.2	57.3	50.8	114.6	119.1

*** Equal to better tear for additives CY 48 and KK 49**

19

Tear Strength ASTM D – 624 Die C N/MM

Compound	Die C 23ºC	Die C 100ºC	Trouser Tear 23ºC	Trouser Tear 100ºC	Die B 23ºC	Die B 100ºC
B (Control)	133.2	91.9	64.7	54.8	110.5	118.0
D	102.6	104.5	74.0	40.1	120.9	110.1
F*	130.7	103.8	79.9	50.9	137.0	134.4
H*	115.2	103.6	66.6	62.6	154.3	120.3
J	110.0	107.5	73.6	48.3	134.6	131.4
L	93.7	81.3	61.6	57.3	118.0	109.7

*** Equal to better tear for additives CY 48 and KK 49**

20

Heat Build Up

250 lb. Weight; 0.325” Throw; 45 minute test

Compound	Cure time 160C	Duro	Temp
A (Control)	40	58	156.8
C	40	66	142.4
E	40	67	146.8
G	40	67	140.2
I	40	64	147.0
K	40	64	147.7

Lower heat build-up for all additives

21

Heat Build Up

250 lb. Weight; 0.325” Throw; 45 minute test

Compound	Cure time 160C	Duro	Temp
B (Control)	42	62	206.2
D	42	64	155.3
F	42	64	155.1
H	42	62	150.2
J	42	62	163.3
L	42	59	166.2

Significantly lower heat build-up for all additives

22

Capillary Rheometer Data

100 C, 180 sec preheat

Die L/D ratio: 15:1: 90 entrance angle: 1.5 mm orifice

	Apparent Stress (Pa)	Apparent Viscosity (Pa-s)	Apparent Stress (Pa)	Apparent Viscosity (Pa-s)
Shear	**500/s**	**500/s**	**1000/s**	**1000/s**
A (Control)	214,340	428.70	219,220	438.48
C	177,700	355.42	200,900	200.89
E	183,190	366.41	208,840	208.83
G	183,810	367.63	211,280	211.27
I	188,690	377.41	219,830	219.82
K	179,530	359.09	205,180	205.17

Significantly reduced apparent viscosity with all additives
Better Extrudability
Less scrap/workaway

23

Capillary Rheometer Data

100 C, 180 sec preheat
Die L/D ratio: 15:1: 90 entrance angle: 1.5 mm orifice

	Apparent Stress (Pa)	Apparent Viscosity (Pa-s)	Apparent Stress (Pa)	Apparent Viscosity (Pa-s)
Shear	**500/s**	**500/s**	**1000/s**	**1000/s**
B (Control)	263,190	526.41	307,160	307.14
D	208,840	417.71	244,870	244.86
F	208,840	417.71	241,210	241.19
H	211,280	422.60	244,870	244.86
J	213,120	426.26	249,790	249.74
L	222,890	445.80	260,140	260.12

Significantly reduced apparent viscosity with all additives
Better extrudability
Less scrap/workaway

24

MER

Tension/Compression/Cylindrical / 1 HZ

COMPOUND	Tan delta/ average of 3 / 23c	Tan delta/ average of 3 / 100c
A (Control)	.153	.110
C	.131	.100
E	.129	.100
G	.131	.091
I	.139	.088
K	.138	.094

Reduction of Tan Delta with all additives provides lower tire operating temperatures

25

MER

Tension/Compression/Cylindrical / 1 HZ

COMPOUND	Tan delta/ average of 3 / 23c	Tan delta/ average of 3 / 100c
B (Control)	.178	.148
D	.150	.106
F	.135	.103
H	.143	.105
J	.156	.109
L	.162	.108

Significant reduction of Tan Delta with all additives provides lower tire operating temperatures

26

Conclusions

Struktol Additives Provide

- **Reduced mix energy.**
- **Increased cure state.**
- **Better reversion resistance.**
- **Reduced viscosity for better processability/ extrudability (less scrap/workaway).**
- **Higher hardness and modulus.**
- **Equal to better tear.**
- **Lower heat build-up.**
- **Lower tan delta providing cooler running temperatures.**

27