Development of Natural Rubber (NR) and Ethylene-Propylene-Diene-Monomer (EPDM) Rubber Blend for Tie Down Strap Compound

A.K.S. Karunarathna, N.S. Withanage
Uva Wellassa University, Badulla, Sri Lanka

and

A.J.M. Withanachchi
Samson Compounds (Pvt) Ltd, Galle, Sri Lanka

Introduction

Tarpaulins or tarps are basically heavy duty waterproof covers that are used to secure loads in pickup trucks, tractors, dump trucks, etc. preventing from any untoward incidences happening during transportation. The tarps for trucks come with hooks or tie down straps to attach them securely to the vehicle body. These tie down straps are mainly used to hold tarps securely in place by providing high tensile strength and constant tension. Tie down strap is made out of natural rubber (NR), ethylene propylene diene monomer rubber (EPDM) or a combination of the both NR & EPDM by using cross-blending of two master batches method. Both NR and EPDM rubber have unique properties inherent to each material. Strap material selection is based on the climate they are used in. Natural rubber is ideal for cooler climates, as it will not crack and split in colder conditions. EPDM rubber was designed for warmer climates as it stands up better to extended sun exposure and hot UV rays (Anonymous, 2013).When concern the properties, NR will stretch further than EPDM rubber and will return to its normal non-stretched state quicker than EPDM rubber. To obtain the desired properties of both NR and EPDM, blends of the NR & EPDM are being used. The development of blends of NR and EPDM will deliver superior physical properties with the combination of excellent resistance to weathering of EPDM, in particular to attack by ozone (Rattanasupa, 2007). The addition of compatibilizer improves the compatibility of the NR/EPDM blends. It has been reported that graft copolymers widely used as compatibilizing agents, usually to enhance interfacial interaction in polymer blends, thus improving their mechanical properties (Arayapranee and Rempel, 2007). Based on above literature, a study was conducted to identify the most promising NR/EPDM blend ratio depend on cure characteristics and physical properties and to identify the effect of Methyl-methacrylate-butadiene-styrene (MBS) as a compatibilizer on NR/EPDM blend for tie down strap compound.

Methodology

The research study was carried out in a laboratory of Samson Compounds (Pvt) Ltd, Bataduwa, Galle. Complete randomized design (CRD) was used as the experiment design and the experiment was divided into two sub experiments as experiment 01 and experiment 02 aligning with the objectives. Total mixing time and the ingredients were different for each experiment but the blending procedure for both experiments was remained same.

In experiment 01, the different blend ratios of NR/EPDM (N90, N80, N70, N60, N50, N40, N30, N20, N10) were prepared by mechanical blending and blend ratios were tested for cure characteristics, physical properties and thermal aging characteristics aged at 70°C for 22 h in respect of product specifications (Samson rubber products, 2012) of tie down strap. Replicates of hardness and tearing were three and replicates of tensile strength, elongation at break and tension set were arranged as four.

Table 1. Treatment combination of experiment 01

Compound Notation	N90	N80	N70	N60	N50	N40	N30	N20	N10
NR:EPDM Blend Ratio (phr*)	90:10	80:20	70:30	60:40	50:50	40:60	30:70	20:80	10:90

phr*- Parts per hundred rubber

As the experiment 02, same series of blend (M90, M80, M70, M60, M50, M40, M30, M20, M10) were prepared after adding 10 phr of compatibilizer (Methyl-methacrylate-butadiene-styrene /MBS) and then those were evaluated for similar properties. All the data were analyzed with one-way ANOVA and two sample t-test using MINITAB 16 statistical package. Dunnett test was used to compare the test results with specification at 5% significance level.

Results and Discussion

The product specifications (Table 2) of tie down strap were used as control values for experiment 01 and the obtained results from different blends were compared with those specifications.

Table 2. Product specifications for tie down strap

Required Property	Unit	Test Method	Specification
Hardness	IRHD	ISO 48-2010	58±5
Tensile Strength	MPa	ISO 37-2005	>14
Elongation at Break	%	ISO 37-2005	>450
Tear Strength	kNm^{-1}	ISO 34-1:2007	>45
Tension Set	%	ISO 2285:2007	<30
Rheometer Data (FF/MONSANTO 160/180 ^0C)			
Scorch Time (ts_2)	Min	ISO 34171977E	0.70-1.30
Curing Time (tc_{90})	Min	ISO 34171977E	1.60-2.40

Source: Samson rubber products (2012)

According to the table 3, all blends except N70 have achieved acceptable scorch time which gives better processing safety during the processing. Optimum cure time is the time at 90% of cure has taken place. When concern the optimum cure time, N90, N50, N30 and N10 blends have achieved the given test specifications whereas other blends have violated the specification. Therefore, only N90, N50, N30 and N10 blends have achieved both acceptable scorch time and optimum cure time.

Table 3. Cure characteristics of normal blends in experiment 01

	Blend Ratio								
Cure Characteristic	N90	N80	N70	N60	N50	N40	N30	N20	N10
Scorch time, ts_2 (min)	0.9	0.75	0.68	0.75	0.88	0.73	0.77	0.7	0.92
Optimum cure time, tc_{90} (min)	1.71	1.35	1.3	1.37	1.6	1.45	1.67	1.57	1.9
Curing status	PASS	FAIL	FAIL	FAIL	PASS	FAIL	PASS	FAIL	PASS

NR/EPDM blend ratio versus all tested properties including heat aged properties, p value 0.000 < 0.05 (α), therefore blend ratio has significantly affected for the physical properties. According to the table 4, N90 blend has achieved all the required physical properties except tension set. Regardless of their composition, all of the blends showed negative change in tensile strength and elongation at break indicating deterioration of these properties with thermal aging. But NR rich blends were more affected by heat than the EPDM rich blends. These results have agreed

with the findings of Hofmann (1989) and Arayapranee and Rempel (2007). Compared to mean values of the physical properties and cure characteristics, N90 NR/EPDM blend has significantly complied with most of the product specifications of tie down strap whereas other blends have violated the properties.

Table 4. Mean value of physical properties of the normal blends in experiment 01

Physical Property	Specs*	Blend Ratio N90	N80	N70	N60	N50	N40	N30	N20	N10
Hardness (IRHD)	58±5	60.33	61.00	61.00	63.33	64.33	65.66	67.33	67.33	64.33
Tensile strength (MPa)	>14	15.86	12.83	10.50	9.63	7.14	6.58	7.52	9.70	10.59
Elongation at break (%)	>450	587.7	525.4	396.8	302.0	237.8	228.0	286.9	321.0	361.4
Tear strength (kNm^{-1})	>45	59.38	49.15	43.73	42.89	40.42	34.03	40.77	41.96	42.16
Tension set (%)	<30	41.71	39.97	37.05	37.00	36.01	34.32	33.68	31.80	29.35
After thermal aging										
Tensile strength (MPa)		5.13	5.90	6.44	6.62	7.13	6.54	6.94	9.53	10.03
Elongation at break (%)		122.3	125.6	107.9	120.6	200.8	200.5	281.9	320.9	350.4

*Specifications

Cure characteristics of compatibilized blends were measured. According to table 5, all the blends except M70 and M80 have achieved acceptable scorch time which gives better processing safety. M90, M50, M30 and M10 blends have achieved the given test specifications of optimum cure time. P value of cure characteristics > 0.05 (α), when comparing normal NR/EPDM blends with compatibilized NR/EPDM blends by using two sample t-test. Therefore compatibilzed blends were not significantly different for cure characteristics in respect to normal blends.

Table 5. Cure characteristics of NR/EPDM blends with compatibilizer in experiment 02

Cure Characteristic	Blend Ratio M90	M80	M70	M60	M50	M40	M30	M20	M10
Scorch time,ts_2 (min)	0.81	0.67	0.65	0.70	0.73	0.73	0.80	0.7	0.82
Optimum cure time, tc_{90} (min)	1.7	1.38	1.23	1.43	1.5	1.32	1.82	1.49	1.55
Curing status	PASS	FAIL	FAIL	FAIL	PASS	FAIL	PASS	FAIL	PASS

Table 6 represents the mean values of the physical properties of NR/EPDM blend with compatibilizer. Physical properties of compatibilized blends were compared with the normal NR/EPDM blends. There were no significant difference between the physical properties of normal blends and compatibilized blends (p value > 0.05). This may be due to poor interaction of NR and EPDM with the presence of filler though MBS was added. Arayapranee and Rempel (2007) have find tensile strength and elongation at break show improvement by the addition of MBS in gum NR/EPDM blend. Mean value of heat aged properties were decreased with increasing proportion of the NR which shows similar behavior as in experiment 01. Therefore physical properties and cure characteristics of the NR/EPDM blends were not significantly affected by the incorporation of MBS compatibilizer.

Table 6. Mean values of physical properties of compatibilized NR/EPDM blends in experiment 02

	Blend Ratio								
Physical Property	M90	M80	M70	M60	M50	M40	M30	M20	M10
Hardness (IRHD)	61.00	60.66	61.00	63.00	64.66	65.66	67.00	67.33	64.33
Tensile strength (MPa)	11.95	8.44	7.78	6.68	4.48	7.26	8.39	6.14	7.99
Elongation at break (%)	340.3	321.5	167.0	188.7	170.7	220.6	280.3	227.5	261.5
Tear strength (kNm^{-1})	50.59	35.91	35.74	35.15	29.42	33.47	38.34	36.81	31.03
Tension set (%)	40.45	39.5	39.17	37.52	35.5	35.55	35.6	34.22	33.85
After thermal aging Tensile strength (MPa)	4.94	5.90	5.92	5.3	4.44	6.2	9.16	8.37	9.21
Elongation at break (%)	120.5	120.2	110.6	110.6	130.2	170.6	252.9	382.6	410.2

Conclusions

Only NR: EPDM blend ratios of 90:10 has significantly different from other blends while achieving given test specifications of tie down strap. Therefore NR/EPDM blend ratio of 90:10 is more suitable for tie down strap compounding. Addition of 10phr of compatibilizer (MBS) has not significantly affected on cure characteristics and physical property improvement of NR/EPDM blend.

References

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