Studies on Retread Compounds Containing Reclaim Rubber

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INTRODUCTION

Reclaim rubber finds application in many fields of the rubber industry. It is used in products such as cycle tyres and tubes, camel back (retread compound), belts and hoses, cables and wires and battery boxes. It is stated that ten percent of the total reclaim produced in the country is consumed by the retread compound manufacturing industry.[1]

The introduction of synthetic yarn for the construction of automobile tyres has increased the life of carcass considerably. So it has become possible to retread a tyre five or six times. This in turn has helped in a spectacular growth in the tyre retreading industry. The performance requirements of the retread compounds have already been described in detail[2]. The retread compound should have high abrasion resistance, good tear resistance, crack growth resistance, low heat build up, high flex fatigue resistance, wet skid resistance and better ageing properties.

With an objective to reduce the cost of production, it is a usual practice in the retreading industry to extend the polymer content of the camel back compound by reclaim and other ingredients. But it is known that the incorporation of reclaim results in deterioration of physical properties of the vulcanizates[3].

The object of the present study is to assess the variation in physical properties of retread compounds containing varying proportions of reclaim rubber in order to select a suitable formulation for light commercial vehicle (Jeep) tyre tread compounds which can accommodate maximum reclaim rubber without sacrificing physical properties, and to evaluate the service performance of the tread prepared using the selected formulation.

EXPERIMENTAL

Whole tyre reclaim used in the study was received from M/s. Super Rubber Works, Coimbatore and the percentage composition of constituents of the same are given in Table 1. Natural Rubber (ISNR-5) was obtained from the Pilot Crumb Rubber Factory of the Rubber

TABLE 1. Composition of Reclaim

Acetone extract, %	12.972
Total ash, %	7.92
Volatile matter, %	0.6095
Carbon black, %	30.49
Rubber hydrocarbon, %	48.01
Relative density	1.147
Mooney viscosity ML (1 + 4) @ 100°C	32

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Board, and the limits for the specification parameters for the same are given in Table 2. Polybutadiene was procured from Indian Petrochemicals Ltd., Vadodara and its specifications are given in Table 3.

TABLE 2. Specifications for ISNR 5

Dirt, % max	0.05
Ash, % max	0.6
Volatile matter, % max	1.0
Nitrogen, % max	0.7
Wallace Plasticity Po min	30
Plasticity Retention Index (PRI) min	60

TABLE 3. Typical Properties of Polybutadiene

Microstructure	96% *cis*
Mooney viscosity (ML 1 + 4 @ 100°C)	42
Volatile matter, %	0.5
Ash, %	0.2
Specific gravity	0.92

Blends of Natural Rubber and Reclaim. Five compounds were prepared on a two roll mixing mill of size 6″ × 12″ with varying amounts of NR and reclaim and a control sample having no reclaim. The formulations of the above compounds are given in Table 4. The processing characteristics of the compounds and physical properties of their vulcanizates are listed in Tables 7 and 10 respectively.

Blends of Natural Rubber, Polybutadiene and Reclaim. As the abrasion resistance of samples having higher proportion of reclaim was found to decrease considerably, a part of natural rubber was substituted by 10 parts of polybutadiene. Six compounds were prepared as per the formulations given in Table 5. Another set of six compounds was also prepared with a part of NR substituted by 20 parts of polybutadine.

Preparation of Retread Compounds. Two retread formulations were selected on the basis of the laboratory evaluation of the compounds for assessing the actual service performance. The formulations of these compounds are given in Table 6.

The compounds were prepared on a two roll mill of size 12″ × 30″ and extruded through an extruder having screw of 4½″ diameter. The extruded compounds were retreaded on jeep tyres. The tyres were cured for 85 min and were fitted on the rear wheels of the jeeps. On the same jeep experimental and control tyres were fitted on opposite sides. The results of the service performance of the tyres are given in Table 13.

Testing. Cure characteristics of the compounds were evaluated using Monsanto Rheome-

TABLE 4. Formulation of Compounds with NR and Reclaim

Ingredients	Compound No.					
	1	2	3	4	5	6
ISNR 5	100	90	80	70	60	50
Reclaim WTR	—	20.8	41.6	62.4	83.2	104
Zinc oxide	5	5	5	5	5	5
Stearic acid	2	2	2	2	2	2
Phenyl-β naphthyl amine	1	1	1	1	1	1
N (1, 3-dimethyl butyl)-N′-phenyl-p-phenylene diamine	1	1	1	1	1	1
HAF Black	50	50	50	50	50	50
Aromatic oil	5	5	5	5	5	5
N-Cyclohexyl-2-benzo-thiazyl sulfenamide	0.6	0.6	0.6	0.6	0.6	0.6
Sulfur	2.5	2.5	2.5	2.5	2.5	2.5

TABLE 5. Formulation of Compounds with NR, Reclaim and Polybutadiene

Ingredients	Compound No.					
	1	2	3	4	5	6
ISNR 5	90	80	70	60	50	40
Reclaim WTR	—	20.8	41.6	62.4	83.2	104
Polybutadiene	10	10	10	10	10	10
Stearic acid	2	2	2	2	2	2
Zinc oxide	5	5	5	5	5	5
Phenyl-β-naphthyl amine	1	1	1	1	1	1
N (1. 3-dimethyl butyl)-N′-phenyl-p-phenylene diamine	1	1	1	1	1	1
HAF Black	50	50	50	50	50	50
Aromatic oil	5	5	5	5	5	5
N-Cyclohexyl-2-benzo-thiazyl sulfenamide	0.8	0.8	0.8	0.8	0.8	0.8
Sulfur	2.0	2.0	2.0	2.0	2.0	2.0

TABLE 6. Formulation of Compounds Selected for Preparing Retreads

Ingredients	Compound No.		
	A	B	C
ISNR 5	90	70	80
Polybutadiene	10	10	10
Reclaim WTR	—	40	20
Stearic acid	2	2	2
Phenyl-β-naphthylamine	1	1	1
N (1, 3-dimethyl butyl)-N′-phenyl-p-phenylene diamine	1	1	1
HAF Black	50	50	50
Aromatic oil	5	5	5
N-Cyclohexyl-2-benzo thiazyl-sulfenamide	0.6	0.6	0.6
Sulfur	2.5	2.5	2.5

TABLE 7. Proeessing Properties of Blends with Natural Ruber and Reclaim

Property tested	Compound No.					
	1	2	3	4	5	6
1. Optimum cure time at 150°C (min)	11.5	11	11.5	11.5	11.5	11
2. Cure rate index	12.2	12.5	12.5	11.4	12.2	12.1
3. Money scorch time at 120°C (min)	21	21	19	17	17	17
4. Minimum compound viscosity	48	35	37	35	42	41
5. Die swell (%)	119.3	113.7	113.7	115.6	115.6	117.4

ter R-100, and Mooney Viscometer. Die Swell was measured on stereobinocular microscope with micrometer attachment. Physical properties such as tensile strength, elongation at break, modulus (300%), hardness, rebound resilience (Dunlop Tripsometer), compression set, abrasion resistance (DuPont abrader) and flex resistance (DeMattia Flexing Machine) were evaluated as per IS test methods for vulcanised rubber[4]. Heat build up of these samples was evaluated in Goodrich Flexometer as per ASTM[5].

The service performance of retreaded tyres was assessed by measuring the projected mileage of the same. This is calculated by measuring the original non-skid depth of the tyres (using a micrometer which reads 1/32") and the final non-skid depth after covering approximately 9000 KM. The projected mileage was calculated as:

$$\text{Projected mileage} = \frac{\text{kilometers covered} \times \text{initial non skid depth}}{\text{Worn out skid depth}}$$

RESULTS AND DISCUSSION

Blends of NR and Reclaim. There was no change in the cure characteristics of the above compounds as shown in Table 7. Mooney scorch time was reduced as the percentage of reclaim increased. Die Swell (%) decreased with increasing proportion of reclaim.

Physical properties especially tensile properties were affected with the incorporation of reclaim. It has already been established that the inferior tensile properties of reclaim were due to its molecular disintegration, consequent on extensive chain scission during the thermal treatment in the manufacturing process[6]. The deterioration in physical properties was predominant as the reclaim percentage was increased above 30%. Abrasion resistance, an important property as far as tread compound is concerned, also decreased with increase in the content of reclaim.

Most significant change was observed in the heat build up values of the above vulcanizates. As the proportion of the reclaim increased upto 30%, the increase in heat build up values was more pronounced and the effect became less with further increase in the amount of reclaim. The rebound resilience also decreased correspondingly as the reclaim level was increased. Other properties like flex resistance, compression set etc. also showed the same pattern of deterioration. Hardness increased as expected by the addition of reclaim as the reclaim already contained a proportion of carbon black. So NR-reclaim binary blend was found unsuitable for designing good quality retread compounds.

Blends of NR, Polybutadiene and Reclaim. Processing properties of the ternary blends are given in Table 8. Though the optimum cure time of the above compounds did not change, there was appreciable change in the cure rate index. Mooney scorch time also decreased with increasing proportion of reclaim.

Among the physical properties, abrasion resistance of these six compounds improved when compared to that of the NR/reclaim blends. But there was no improvement in the heat build up values even after substituting a part of NR with 20 parts of polybutadiene. So it was decided to select three formulations for designing retread compounds containing reclaim rubber. The formulations of the selected compounds are given in Table 6.

Performance of Retreads. The most important requirement of camel back compounds is the abrasion resistance, as the service life of the retread will depend upon this property. Though the laboratory evaluation indicated that abrasion resistance decreased with increase in the proportion of reclaim in the tread compound, actual service trials of the retreaded tyres showed that the performance of the tyres retreaded with control compounds and those with the selected formulation in Table 6 were almost comparable. The tread formulation containing less percentage of reclaim showed better service properties as expected (Table 13).

TABLE 8. Processing Properties of Blends with NR, Reclaim and Polybutadiene (10 parts)

Property tested	Compound No.					
	1	2	3	4	5	6
1. Optimum cure time at 150°C, min	9	8	8	8	8	8
2. Scorch time at 120°C, min	27	22.5	21	20.5	19	19
3. Cure rate index	25	22	20	20	20	18

TABLE 9. Processing Properties of NR, Reclaim and Polybutadiene (20 Parts)

Property tested	Compound No.					
	1	2	3	4	5	6
1. Optimum cure time at 150°C, min	8.5	8.5	8.5	8.5	8	8
2. Scorch time at 120°C, min	25	22	22	20	19	18
3. Minimum compound viscosity	43	43	48	45	49	50

TABLE 10. Physical Properties of Compounds of NR and Reclaim

Property tested	Compound No.											
	1		2		3		4		5		6	
	b.a.*	r.a.a. (%)	b.a.	r.a.a. (%)	b.a.	r.a.a. (%)	b.a.	r.a.a. (%)	b.a.	r.a.a. (%)	b.a.	r.a.a. (%)
Modulus 300%, kg/cm²	100	120	95	121	95	121	98	120	85	135	103	110
Elongation at break, %	610	92	555	88	510	88	450	89	420	83	363	83
Tensile strength, kg/cm²	258	99	212	93	175	98	152	97	130	99	123	90
Abrasion resistance, cm³/h	0.6140		0.7563		0.8472		0.9156		0.9827		1.1352	
Heat build-up at 122°F, ΔT°C	35		46		62		62		66		66	
Rebound resilience, %	55		50		47		44		41		39	
Tear strength, kg/cm	146		131		104		80		67		65	
Compression set, %	31.5		39.5		42.9		42.9		35		35	
Flex resistance, kilocycles												
Crack initiation	26.3		23.1		21.9		17.6		15.5		15	
Crack failure	194.2		156.8		134.8		98.2		96.3		95	

*b.a. = before ageing.
r.a.a = retention after ageing at 70°C for 96 h.

TABLE 11. Physical Properties of NR, Polybutadiene (10 Parts) and Reclaim Blend

Properties tested	Compound No.											
	1		2		3		4		5		6	
	[a]b.a.	r.a.a. (%)	b.a.	r.a.a. (%)	b.a.	r.a.a. (%)	b.a.	r.a.a. (%)	b.a.	r.a.a. (%)	b.a.	r.a.a. (%)
Madulus, 300%, kg/cm²	75	166	100	125	100	120	105	124	90	136	85	147
Tensile strength, kg/cm²	245	99	210	95	160	95	160	94	130	99	115	103
Elongation at break, %	667	83	550	89	480	80	450	78	422	82	400	75
Abrasion resistance, cm³/h	0.5296		0.6834		0.6506		0.7150		0.7416		0.7946	
Heat build up at 122°F, ΔT°F	35		45		61		62		65		70	
Rebound resilience, %	53		46		63		42		36		34	
Hardness, Shore A	63		66		67		68		68		70	
Tear strength, kg/cm	147		120		81		84		72		73	
Compression set, %	32.1		34		32.8		39.4		34.6		37.7	
Flex resistance, kilocycles												
Crack initiation	29.2		25.6		25.6		19.5		16		15	
Crack failure	186.3		153.6		122.3		104.7		104.7		101	

[a] b.a. = before ageing.
r.a.a. = retention after ageing at 70°C for 96 h.

TABLE 12. Essential Physical Properties of NR, Reclaim, and Polybutadiene (20 Parts) Blend

Property tested	Compound No.					
	1	2	3	4	5	6
Heat build up at 120°F, ΔT°C	33	45	51	64	68	72
Abrasion Resistance, cm³/h	0.4634	0.5038	0.6316	0.6018	0.5818	0.6343
Compression set, %	28	31	36	34	40.5	41

TABLE 13. Service Performance of Retreads A, B and C

Vehicle No.	Compound No.	Moulding time, (min)	Original non skid depth (1/32")	Distance covered, (km)	Present non skid depth (1/32")	Projected mileage
1	A	85	14.5	8880	5.5	14306
	C	85	14.5	8880	5	13553
2	A	85	14	9509	6	16640
	B	85	14	9509	5	14791

CONCLUSION

Physical properties of vulcanizates decreased with increase in concentration of reclaim in tyre retread compounds. Road wearing properties of light commercial vehicle tyres retreaded with selected compounds (as in Table 6) were found to give performance comparable to that of control compounds. Hence the formulation (B) suggested in Table 6 can be selected for preparing cost saving retread compounds, without sacrificing performance properties.

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