Properties of Rubber Compounds Containing Powdered Vulcanized Waste

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ABSTRACT

Powdered vulcanized rubber waste generated in a factory was examined as a compounding additive in natural rubber compounds and in blends of natural rubber and styrene-butadiene rubber. The cure characteristics were evaluated with the Monsanto Oscillating Disc Rheometer while tensile sheets were prepared and stress-strain measurements in simple extension were used to characterize the mechanical properties of the vulcanized elastomers. In all the vulcanizates examined, the incorporation of rubber waste resulted in a slight deterioration of properties. The deterioration of properties is attributed to the poor interfacial bonding between the rubber waste and the virgin matrix elastomer. Also, it was found that at low volume loading, the vulcanized waste has no adverse effect on vulcanizate properties.

Key Words: rubber waste, compounding, natural rubber, styrene-butadiene rubber

INTRODUCTION

Almost all rubber factories produce some amount of rubber waste and rejects. Most of these rubber wastes are produced during finishing operations. Brown and Watson [1] have outlined a process capable of reducing the level of waste. Another method by which these wastes are disposed is by putting them in a landfill [2]. In the case of discarded or rejected tyres, they are reduced to crumbs by a variety of methods such as cryogenic, irradiation, pulverization, chemical and ultrasonic methods [3]. These methods have the objective of reducing the material to crumbs for re-utilization in commercial products. Other disposal methods include pyrolysis to recover raw materials [4] and incineration for energy recovery [5].

Since tyres account for more than half of rubber products, many studies have concentrated on the use or recycling of ground rubber from waste tyres [1–5]. Recently, Kim and Burford [6] also studied the utilization of waste tyres in polar and non-polar rubbers.

The aim of this work is to study the properties of rubber compounds containing factory vulcanized rubber waste as compounding material. The work was carried out to examine the possibility of a rubber

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manufacturer re-using its own production waste.

EXPERIMENTAL

Materials

The natural rubber (NR) used was SMR 20 produced by Malaysian Natural Rubber. The styrene-butadiene rubber (SBR) used was SBR 1502, which was produced by International Synthetic Rubber, U.K. The two types of rubbers were supplied by Piggot Maskew Ltd., Bulawayo. Other compounding ingredients were standard materials used in rubber formulations and were used in compounding as received. Powdered vulcanized waste of unknown composition was obtained from Pigott Maskew Limited, Bulawayo.

Mill Mixing

The mixing of the various rubber batches was on a two-roll mill of 850 mL capacity. The mixing procedures adopted were along the guidelines set in British Standards (BS) 1674; 1976. After the elastomer was first masticated on the mill, activators and other ingredients were added and blended thoroughly.

Cure Characteristics

The cure characteristics of the compound were studied with the aid of a Monsanto Oscillating Disc Rheometer TM 100, using the test procedure specified in BS 1673; Part 10, Method B, 1977.

Moulding

The compression moulding techniques specified in BS 1674; 1976, were used to obtain vulcanized rubber sheets of 2 mm thickness.

Tensile Stress-strain Tests

The tensile stress-strain properties of the resulting vulcanizates were determined according to BS 903; Part A2, 1971, using Type 2, dumb-bell specimens.

Hardness Test

Hardness test was determined according to BS 903; Part A26, 1969.

RESULTS AND DISCUSSION

The data in the various tables show the formulations and the cure characteristics of the mixed compounds.

Table 1. Effects of powdered rubber waste on unfilled natural rubber.

Compounding formulation	1	2	3	4	5	6	7
Natural rubber	100	100	100	100	100	100	100
Stearic acid	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Zinc oxide	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Powdered rubber waste	–	5	10	20	30	40	60
MBTS (Dibenzothiazyldisulphide)	0.75	0.75	0.75	0.75	0.75	0.75	0.75
DPG (Diphenylguanidine)	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Sulphur	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Results							
Scorch time at 180 °C t_2 (s)	91	95	96	76	74	73	66
Cure time at 180 °C t_{90} (s)	146	157	166	145	144	147	139
Hardness, shore A	33	36	37	37	38	40	41
300% modulus (MPa)	0.87	1.21	1.23	1.37	1.73	2.08	2.31
Elongation-at-break (%)	1000	710	663	650	630	590	520
Tensile strength (MPa)	16.9	16.3	13.4	13.2	13.4	10.7	8.7

All measurements are in parts-per-hundred rubber.

Also shown in the tables are the physical properties of the cured vulcanizates.

Effect of Rubber Waste on Natural Rubber

In Table 1, an unfilled natural rubber compound served as a control while similar compounds containing different levels of powdered rubber waste were also studied to enable a comparison to be made. The results show a tendency towards scorchiness at higher loading of powdered rubber waste. An increase in the loading of rubber waste led to a slight increase in the hardness and 300 % modulus values. However, the tensile strength and the elongation-at-break values decreased with an increase in the loading of rubber waste. Burgoyne, Leaker and Krekic [7] have reported a 15 % reduction in tensile strength for a compound containing 10 % of 425–600 μ ground vulcanizate.

Effect of Rubber Waste on NR/SBR Blend

In Table 2, the possibility of substituting carbon black with powdered rubber waste in NR/SBR blend was investigated. The hardness and tensile properties of the carbon black-filled compound are superior to those incorporated with powdered ruboer waste. However, the results of compounds 9–13 where carbon black has been excluded, show that there is a slight improvement in hardness and modulus values when powdered rubber waste was introduced; this may be due to increase in cross-link density arising from the increase in loading of rubber waste. There is no particular trend in elongation-at-break and tensile strength values.

Effect of Rubber Waste on Carbon Black-filled NR/SBR Blends

In another study, we sought to find out the effect of increasing the loading of powdered rubber waste on the properties of a black-filled NR/SBR blend. The results in Table 3 show a slight increase in hardness and modulus values with increase in volume loading

Table 2. Effects of powdered rubber waste on unfilled NR/SBR blends.

Compounding formulation	8	9	10	11	12	13
Natural rubber	60	60	60	60	60	60
SBR 1500	40	40	40	40	40	40
Reclaim rubber	20	20	20	20	20	20
Stearic acid	1.5	1.5	1.5	1.5	1.5	1.5
Zinc oxide	5.0	5.0	5.0	5.0	5.0	5.0
Carbon black N550	40	–	–	–	–	–
Powdered rubber waste	–	–	5	30	45	60
Kaolin	30	30	30	30	30	30
Flectol H flakes	2.0	2.0	2.0	2.0	2.0	2.0
Orflex PP	1.0	1.0	1.0	1.0	1.0	1.0
Dutrex RT	5.0	5.0	5.0	5.0	5.0	5.0
Coumarone resin	3.5	3.5	3.5	3.5	3.5	3.5
MBTS	0.75	0.75	0.75	0.75	0.75	0.75
DPG	0.25	0.25	0.25	0.25	0.25	0.25
Sulphur	2.0	2.0	2.0	2.0	2.0	2.0
Results						
Scorch time at 180 °C t_2 (s)	180	180	156	144	144	144
Cure time at 180 °C t_{90} (s)	321	324	312	291	285	264
Hardness, shore A	49	33	35	40	41	41
300% Modulus (MPa)	5.4	1.7	2.3	2.6	2.7	2.8
Elongation-at-break (%)	530	670	695	585	530	525
Tensile strength (MPa)	10.6	7.9	8.0	7.5	5.9	5.8

Table 3. Effect of powdered rubber waste on carbon black-filled NR/SBR blends.

Compounding formulation	14	15	16	17	18
Natural rubber	60	60	60	60	60
SBR 1500	40	40	40	40	40
Reclaim rubber	20	20	20	20	20
Stearic acid	1.5	1.5	1.5	1.5	1.5
Zinc oxide	5.0	5.0	5.0	5.0	5.0
N550 Carbon black	40	40	40	40	40
Powdered rubber waste	–	5	10	40	60
Kaolin	30	30	30	30	30
Dutrex RT	5.0	5.0	5.0	5.0	5.0
Flectol H flakes	2.0	2.0	2.0	2.0	2.0
Orflex PP	1.0	1.0	1.0	1.0	1.0
Coumarone resin	3.5	3.5	3.5	3.5	3.5
MBTS	0.75	0.75	0.75	0.75	0.75
DPG	0.25	0.25	0.25	0.25	0.25
Sulphur	2.0	2.0	2.0	2.0	2.0
Results					
Scorch time at 180 °C t_2 (s)	180	153	153	159	153
Cure time at 180 °C t_{90} (s)	321	294	309	339	312
Hardness, shore A	49	51	55	56	57
300% Modulus (MPa)	5.4	5.6	5.5	5.9	6.0
Elongation-at-break (%)	530	520	480	430	395
Tensile strength (MPa)	10.6	10.6	11.5	9.2	8.4

of powdered rubber waste; the tensile strength and elongation-at-break values decreased with increase in powder loading. It is interesting to note from Tables 2 and 3 that the addition of rubber waste to unfilled and carbon black-filled NR/SBR produced similar effects, i.e. a slight increase in modulus and hardness values with increase in rubber waste loading and an overall decrease of tensile strength and elongation-at-break. The carbon black-filled compounds generally possess higher mechanical properties than the unfilled compounds; this is attributed to the reinforcing effect of carbon black.

General Discussion

Generally, the effects of powdered rubber waste on compounding are not universal and they must be studied for each compound. Indeed, further studies will be necessary to optimize vulcanizate/compound properties. The tendency towards scorchiness in compounds containing powdered rubber waste may be due to additional effect of unreacted curatives in powdered rubber. For example, Gibala and Hamed [8] have shown that accelerator fragments migrate from vulcanized rubber waste to the rubber matrix, causing decreased scorch time. Also, the source of the waste will affect final compound and vulcanizate properties.

It has been suggested that the little interfacial bonding between the powdered rubber waste and the virgin matrix elastomer may be responsible for the reduction of properties when rubber waste was incorporated [9]. Efforts directed at modifying the surface of rubber waste particles in order to promote its rebonding and incorporation into elastomer compounds may result in improved properties [4].

Even though the physical properties obtained for vulcanizates containing powdered rubber are reduced, such vulcanizates may be suitable for static applications that do not require high strength (e.g., foot mats, road markers, pads, etc). Thus rubber waste can be used to cheapen the compound in the manner of a diluent filler.

CONCLUSION

The effect of using powdered rubber waste as a compounding material in NR and NR/SBR blends tend to lead to a reduction of the tensile strength and elongation-at-break values of the resulting vulcanizates, and a slight increase in the modulus and hardness values. In most of the compounds, the incorporation of powdered rubber waste as a compounding additive lead to a reduction of processing safety. Further compounding studies will have to be undertaken before generalizations can be made. This work shows that rubber waste could be used as a compounding additive in non-critical application areas where it serves in a manner similar to diluent fillers.

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REFERENCES

1. Brown C.J. and Watson W.F., "Recycling of vulcanized factory waste", *Rubber World*, **218**, 2, 34, 1998
2. Duarte J.M., Paper 97, presented at the 152nd Meeting of the Rubber Division, ACS. Cleveland. Oct., 21–24, 1997.
3. Kelly K.F., Nikoleskii V.G., V.N. Balyberdine, N. Benham I. Morris and B.M. Kelly, Paper 98, ibid.
4. Dierkes W., Paper 6, presented at the 148th Meeting of the Rubber Division, ACS, Cleveland. Oct., 17–20, 1995.
5. McDonel E.T. and Hoover J., Paper 22C, presented at the International Tire Exhibition and Conference, Akron. September 15–17, 1998.
6. Kim J.K. and Burford R.B., "Study on powder utilization of waste tires as a filler in rubber compounding", *Rubber Chem. Tech.*, **71**, 5, 1028, 1998.
7. Burgoyne M., Leaker G. and Krekic Z., "The effect of reusing ground flash and scrap rubber in parent compound", *Rubber Chem. Tech.*, **49**, 375, 1976.
8. Gibala D. and Hamed G.R., "Cure and mechanical behaviour of rubber compounds containing ground vulcanizates. Part I-Cure behaviour", *Rubber Chem. Tech.*, **67**, 4 636, 1994.
9. Myhre M.J. and MacKillop D.A., Paper 21, presented at the 148th Meeting of the Rubber Division, ACS. Cleveland. Oct. 17–20, 1995.