An Efficient Mechanical Method for Reclamation of Vulcanized Scrap Rubber

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Abstract

Waste tyre disposal has become a great environmental concern globally. Several waste management techniques are being adopted to tackle the same. Reuse or reclaiming is one of the important ways to overcome this problem. Mechanical breakdown is one of the methods for reclamation of powdered scrap rubber. For the present study tyre crumbs of 30-40 mesh size was used. Reclamation of it was done by mechanical shearing in an open mixing mill at temperatures below 60°C. The regenerated rubber was mixed for additional 2.5 minutes with 10 parts of fresh premasticated rubber. This improved the processability and properties of the regenerated material. The regenerated compound obtained by this method was vulcanized with accelerated sulphur system. Vulcanizates prepared from the material regenerated by the new method showed improved technological propetties compared with that of conventionally reclaimed rubber. Replacement of natural rubber with reclaimed rubber (10 phr) in a retread compound maintained most of its properties. There is an economic advantage for the method reported here.

1. INTRODUCTION

The disposal of waste tyre has become a great environmental concern globally due to the growing stockpiles of used tyres and corresponding increase of disposal charge for discarded tyres. Recycling is the one of the important ways to subdue this propblem. Conventional manufacturing process for reclaim includes digester process, reclamator process, pan process, engeke process etc.

Considerable efforts had been made towards the recycling of scrap rubber. Use of ground flash and scrap rubber in parent compound has been studied (Burgoyne et.al., 1976). Reclamation of vulcanised latex products at higher temperatures using pentachlorothiophenol (Renacit-VII) was tried by Thomas et.al. Okamoto et.al (1979) had studied the mechano-chemical reclamation using vulcanization accelerators.The effect of diphenyl sulphoxide on mechano-chemical reclamation was studied by Onouchi et.al.(1982).The chemical regenaration of old tyre rubber powder at higher temperature using Banbury mixer or Brabender mixer was investigated by Furukawa et. al.in 1981. Continuous ultrasound devulcanization of ground tyre rubber and SBR vulcanisates were studied by Tukachinsky et.al. (1996) and Levin et.al. (1997). The effect of ultrasound devulcanization on SBR vulcanisates and the revulcanization of devulcanized samples were subjected to detailed study by Levin et.al.(1997). The present study aims at developing a suitable method for reclamation of vulcanized scrap rubber. The effect of addition of reclaimed rubber from tyre scrap on the properties of retread compounds was studied in comparison with those containing whole tyre reclaime and untreated tyre crumbs (tyre buffings).

2.EXPERIMENTAL

2.1.Materials

Rubber powder (tyre buffings) used for this study was collected from rubber powdering unit. The composition of the rubber powder is given in Table1. Natural rubber used was ISNR 5 grade block rubber.

Reclamation and compounding were done in a laboratory two-roll mixing mill of 15cm x 30cm size. The processing and cure characteristics of the samples were measured using Mooney viscometer and Monsanto

Rheometer R-100. For the determination of vulcanizate properties the samples were moulded in an electrically heated hydrualic press for their respective cure times at 150 ^{0}C. Testing of the samples for various physical properties was carried out as per the relevant ASTM procedure.

Table.1 Composition of rubber powder

Parameter	Value
Acetone Extract (%)	9.40
Ash Content (%)	4..98
Carbon Black (%)	37.22
Rubber Hydrocarbon (%)	48. 40

2.2. Method of Reclamation and Its Standardisation

The powdered rubber of 30 mesh size was mechanically plasticised by passing through the tight nip of the two roll mixing mill of friction ratio 1:1.25 for 10 minutes at teperatures below 60 ^{0}C. The plasticised material was mixed with different dosages of premasticated natural rubber (Mooney viscosity - 30, ML(1+4),100^{0}C) in different times. The reclaimed rubber obtained by this method was revulcanized with 0.9 parts MBTS, 2.5 parts ZnO and 1.5 parts sulphur per 100 parts of reclaim (Makarov et.al.,1991). The quality of the reclaimed rubber obtained by this method was assessed in terms of Mooney viscosity, tensile strength and elongation at break.

2.3. Characterisation of Reclaimed Rubber

2.3.1. Comparison with a virgin compound

A retread compound was prepared in a laboratory two-roll mixing mill as per the formulation given in Table 2. The compound was vulcanized at 150 ^{0}C. The vulcanized material was powdered and sieved through standard sieve of 30 mesh size. This powder was then reclaimed by mechanical reclamation in a two-roll mixing mill. After reclamation it was revulcanized with same dosage of curing system (DCBS and sulphur with respect to rubber hydrocarbon) used for the retread compound. The processing and cure characteristics of the virgin and reclaimed compounds and their vulcanizate properties were evaluated as per the ASTM test methods.

Table 2 Formulation of mixes

Ingrediens	Quantity (phr)
Natural rubber	65
Cis 1,4- Polybutadiene rubber (Cisamer 1220)	35
Zinc oxide	4
Stearic acid	2
2,2,4- trimethyl 1,2 dihydroquinoline	1
N-isopropyl N'-phenyl p- phenylene diamene	0.5
ISAF black (N-220)	55
Naphthenic oil	10
Dicyclohexyl benzthiazyl sulphenamide	0.9
Insoluble sulphur	2.75

2.3.2. Effect of reclaimed rubber on retread compound.

Compared the properties of retread compounds containing equivalent loadings of reclaimed rubber prepared from 30 mesh size rubber powder by mechanical reclamation, 30 mesh untreated rubber powder and those containing whole tyre reclaim (WTR). Table3 shows the formulations of the compounds

Table 3. Formulation of mixes

Ingredients	Quantity (phr)			
	A	B	C	D
Natural rubber	65	55	55	55
Cis 1,4- Polybutadiene rubber (Cisamer 1220)	35	35	35	35
Reclaimed rubber	–	10*	–	–
Whole tyre reclaim	–	–	10*	–
Untreated rubber powder	–	–	–	10*
Zinc oxide	4	4	4	4
Stearic acid	2	2	2	2
2,2,4- trimethyl 1,2 dihydroquinoline	1	1	1	1
N-isopropyl N'-phenyl p- phenylene diamene	0.5	0.5	0.5	0.5
ISAF black (N-220)	55	55	55	55
Naphthenic oil	10	10	10	10
Dicyclohexyl benzthiazyl sulphenamide	0.9	0.9	0.9	0.9
Insoluble sulphur	2.75	2.75	2.75	2.75

* Rubber hydrocarbon content

prepared. The processing and technological properties of these compounds were evaluated.

3. RESULTS AND DISCUSSIONS

3.1. Standardisation of reclamation.

Table 4 shows the effect of time on mechanical reclamation of powdered tyre crumb. In all cases the Mooney viscosity was above 100. Vulcanisate prepared from reclaim showed maximum tensile strength and elongation at break for the samples plasticised for 20 minutes. After reaching maximum these properties dropped as a result of excessive degradation. From the above observation the maximum time for mechanical reclamation was fixed as 20 minutes and added premasticated rubber (PMR) in different times during the course of plasticisation. The properties of reclaimed rubber obtained are given Table 5. The addition of PMR after 10 minutes of plasticisation showed low Mooney values and higher tensile strength and elongation at break.

Table4. Effect of time on mechanical plasticisation

Time of plasticisation (Min)	Tensile strength (MPa)	Elongation at break (%)	Mooney viscosity, ML(1+4),100 °C
10	9.46	215	> 100
15	10.37	226	> 100
20	11.45	242	> 100
25	10.66	193	> 100
30	10.08	191	> 100

Table5. Effect of time and addition of PMR

Time of addition of PMR (Min)	Tensile strength (Mpa)	Elonga-tion at break (%)	Mooney viscosity, (ML(1+4),100 °C
0	13.6	232	>100
5	13.7	251	>100
10	16.4	304	96
15	16.4	302	95
20	16.3	303	97

Table 6 shows the effect of time on mechanical plasticisation after the addition of premasticated rubber. It is observed that there is no significant difference between the Mooney viscosity of the reclaimed rubber samples prepared under different conditions. Maximum tensile strength and elongation at break were observed after 2.5 minutes of plasticisation with premasticated rubber (in addition to 10minutes of mechanical plasticisation without PMR). Next we evaluated the quantity of premasticated rubber. The properties given in Table 7 show that the reclaim containing 10 parts of PMR per 100 parts of rubber powder gives the best result.

Table 6. Effect of plasticisation after the addition of PMR

Additional time (min)	Tensile strength (MPa)	Elongation at break (%)	Mooney viscosity, ML(1+4) 100 °C
0	15.2	262	96
2.5	16.4	312	96
5	16.4	305	97
7.5	16.3	302	98
10	16.3	293	98

Table7. Quantity of premasticated rubber (PMR)

Quantity of PMR	Tensile strength (MPa)	Elongation at break (%)	Mooney viscosity, ML(1+4),100°C
5	15.2	230	>100
7.5	15.4	249	>100
10	16.6	308	96
12.5	16.4	309	96
15	16.5	313	92

From the above results the optimum conditions for getting reclaimed rubber with minimum Mooney viscosity and maximum tensile strength and elongation at break were arrived at.

These conditions are

(a) Pass rubber powder through the tight nip of a two-roll mixing mill of friction ratio 1:1.25 for about 10 minutes below 60°C.
(b) Mix with 10 parts of PMR per 100 parts of rubber powder for an additional 2.5 minutes.

3.2. Comparison with a virgin compound

Figure1 shows the cure curves for virigin and reclaimed rubber prepared by mechanical reclamation. It is noticed that the cure behaviour of virgin and reclaimed rubber is significantly different. Reclaimed rubber shows much shorter induction period compared to that of virgin compound under the same experimental conditions. A drastic decrease in cure time and scorch time (ts_2 at 150 ^{0} C) was also observed for reclaimed rubber. The above observations is in line with the earlier reports that the interaction between rubber molecules chemically modified in the course of reclamation and unmodified rubber molecules results in crosslinking (Levin et.al.,1997).

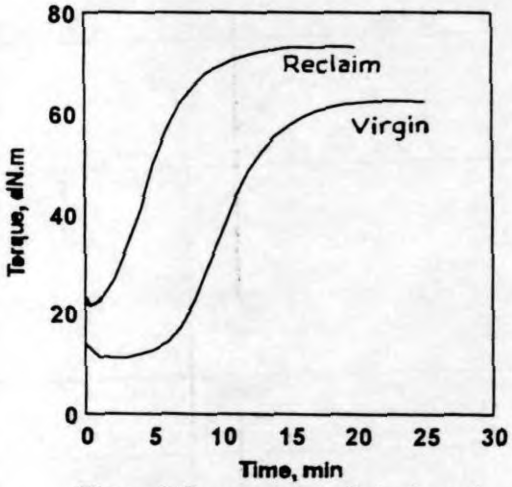

Figure1 Cure graphs of virgin and reclaimed rubber

The processing and technological properties of the virgin retread compound and reclaimed compounds are given in Table 8. The reclaim rubber possess higher Mooney value compared to that of virgin compound. The technological properties such as hardness, modulus, resilience and compression set values were higher for reclaimed rubber. Reclaim vulcanizate also showed lower tensile strength, elongation at break , tear strength and heat build up values.

Table 8. Processing and technological properties of Virgin and Reclaim

Properties	Virgin	Reclaim
Mooney viscosity (ML(1 +4),100^{0}C)	51.4	87.3
Cure time ,150 ^{0}C (min)	14.4	8.5
Scorch time t_2 ,150 ^{0}C $_{(min)}$	5.5	1.5
Hardness (Shore A)	60.0	65.0
Modulus 300% (MPa)	7.9	12.3
Tensile strength (MPa)	23.8	16.5
Elongation at break (%)	630.0	355.0
Tear strength (kNm)	103.6	35.5
Rebound resilience (%)	46.6	60.4
Compression set (%)	39.9	48.6
Heat build up (Δ T^{0}C)	41.0	21.0

3.3. Effect of reclaimed rubber on a retread compound.

Table.9 shows the processing and cure characteristics and vulcanisate properties of retread compounds containing reclaimed rubber, whole tyre reclaim and untreated rubber powder. The results indicate that addition of these materials has only marginal effect on processing and cure charecteristics of the retread compound. The vulcanisate containing reclaimed rubber, whole tyre reclaim and untreated rubber powder showed higher hardness and modulus compared with the control sample(A). The vulcanisate containing reclaimed rubber has higher tensile strength,elongation at break, tear strength and rebound resilience compared with those containing whole tyre reclaime and the untreated crumbs. However, it has lower physical properties compared with the control sample.

Table 9. Processing and technological properties of retread compounds

Properties	Compounds			
	A	B	C	D
Scorch time, t_2,150 ^{0}C (min)	5.5	4.5	4.0	5
Cure time,150 ^{0}C (min)	14.5	13.5	13.5	13.5.
Rheometric torque, (Max. torque - Min.torque)	51.5	55	54.5	54.5
Hardness (Shore A)	60	64	63	64
Modulus 300% (Mpa)	7.9	9.9	8.2	10.6
Tensile strength (MPa)	23.8	21.8	16.8	18.5
Elongation at break (%)	630	563	538	513
Tear strength (kN/m)	103	75.8	66	66.2
Rebound resilience (%)	46.6	47.6	44.6	46.9
Compression set (%)	39.9	40.1	44.1	42.3

Two very important requirements of retread compounds are lower abrasion loss and heat buildup. Fig. 2 shows the abrasion loss of vulcanizates. It can be observed that the abrasion loss of vulcanisate containing reclaimed rubber was only marginally higher than that of the control sample. The effect is prominent in the case of compound containing untreated rubber powder. Fig.3 shows the heat build up of the vulcanizates containing these materials. The addition of reclaimed rubber did not affect the heat buildup of the vulcanizate.

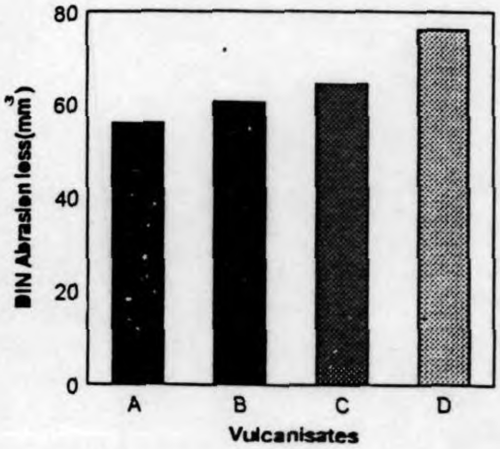

Fig.2 DIN Abrasion loss

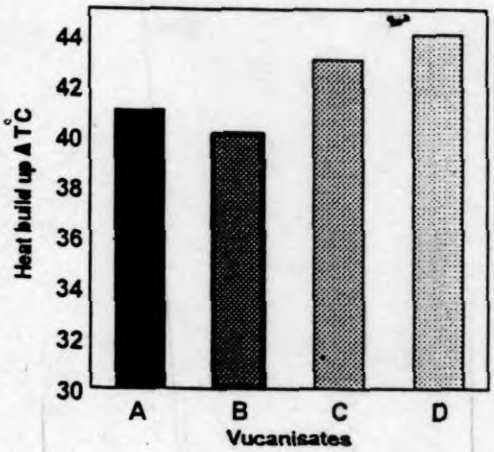

Fig.3 Heat buildup

4. CONCLUSIONS

Vulcanized rubber can be reclaimed by mechanical plasticisation in two-roll mixing mill at temperature below 60^0 C. The addition 10 parts of freshly prepared premasticated rubber per 100 parts of the regenerated material improves its processing and technological properties.

The reclaimed rubber prepared by mechanical process retained 70% of its original tensile strength and also possess higher resilience and lower heat build up than virgin compound.

Use of mechanically prepared reclaimed rubber in retread compounds maintains most of its properties, and thus significantly improving the cost effectiveness.

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