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The utilisation of latex reclaim rubber in natural rubber

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SUMMARY:

Scrap latex products contain rubber hydrocarbon of very high quality, that is only slightly crosslinked. A novel economic technique for converting such latex waste into a processible material is developed. This paper reports the effect of adding this latex reclaim to natural rubber. It is shown that latex reclaim can replace raw natural rubber up to about 50 wt.-% without affecting mechanical properties.

ZUSAMMENFASSUNG:

Latexaltmaterial enthält qualitativ hochwertiges Kohlenwasserstoffelastomeres, das nur geringfügig vernetzt ist. Es wurde eine wirtschaftliche Methode entwickelt, um aus solchen Latexabfällen wieder verarbeitbares Material zu gewinnen. Die Auswirkungen von Zusätzen von Latexaltmaterial zu Naturgummi werden untersucht. Es wird gezeigt, daß dieses wiedergewonnene Latex in der Lage ist, Naturgummi bis zu einem Anteil von 50 Gew.-% zu ersetzen, ohne die mechanischen Eigenschaften zu beeinflussen.

Introduction

The recycling of scrap and used rubber has been practised by the rubber industry for many years by using different methods[1–5]. Despite the obvious incentives to reduce compound cost and to censerve raw materials and energy, the use of reclaim constitutes only a very low percentage of raw rubber consumption. This is mainly due to the deterioration in technical properties[6–10].

In contrast of reclaim rubber, scrap latex products contain rubber hydrocarbon of very high quality which is only slightly crosslinked. Due to the unstable nature of the latex compound and the strict specifications in the quality of latex products such as condoms and examination gloves, the rejections in the latex industry comes to as high as 10 to 15% of the rubber consumed. The Rubber Research Institutes of India[11] and of Malaysia[12,13],

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resp., have developed techniques for reclaiming latex products. Recently we have developed a novel economic procedure for converting latex waste into a processible form (hereafter referred to as latex reclaim). In the present paper, the vulcanization and physical properties of the latex reclaim and its blends with fresh natural rubber (NR) are studied. Fractography was done using a scanning electron microscope (SEM) and the morphology was studied using an optical microscope.

Experimental

Materials

Natural rubber(ISNR-5) was supplied by Rubber Research Institute of India, Kottayam.

Latex reclaim was prepared from waste latex gloves by grinding in presence of chemicals (waste gloves were supplied by AVT Rubber Products Ltd., Kakkanad); volatile matter 0.01%, ash content 2.2%, P_0 40, and Mooney viscosity (100 °C) ML (1 + 4) 54.

Rubber additives zinc oxide, stearic acid, benzothiazyl disulfide (MBTS), tetramethyl thiuram disulfide (TMTD), sulfur, Accinox ZC (N-1,3-dimethyl N′-phenyl, p-phenylene diamine) were all commercial grade.

Toluene (AR grade) was used as solvent.

Natural rubber was masticated on a laboratory mixing mill and the latex reclaim obtained in the form of a sheet was added at different percentages ASTM-D 3182 (1982) and the blends were compounded according to the formulations given in Tab. 1. In the same manner latex reclaim alone was compounded (Tab. 1). The optimum curing time (time to reach 90% of the maximum torque) of the compounds was determined on a Göttfert Elastograph Model 67.85. The compounds were then vulcanized up to their respective optimum cure times in an electrically heated hydraulic press at 150 °C. Dumbbell-shaped test specimens were punched out of these compression-moulded sheets along the mill grain direction. The tensile properties were measured on a Zwick Universal Testing Machine Model 1445 using a crosshead speed of 500 mm/min according to ASTM D 412-80.

Tear resistance of the blends was measured using angular test specimens on the Zwick UTM according to ASTM D 624. Samples for compression set and hardness were moulded and tested as per relevant ASTM standards. The ageing resistance of the vulcanizates was studied after ageing the samples at 100 °C for 24 and 48 h, resp., in a laboratory air oven.

In order to study the change in crosslink density during latex reclaiming, the chemical crosslink density was estimated from equilibrium swelling data[14]. The crosslinking density ($1/2\,M_c$) was determined from the volume fraction of rubber in the swollen gel (Vr) using the Flory-Rehner equation[15,16].

Tab. 1. Blend formulation[a] and vulcanizate properties.

Materials	A	B	C	D	E	F	G	H	I	J	K
NR content (wt.-%)	100	90	80	70	60	50	40	30	20	10	0
Latex reclaim content (wt.-%)	0	10	20	30	40	50	60	70	80	90	100
ZnO	5	5	5	5	5	5	5	5	5	5	5
Stearic acid	2	2	2	2	2	2	2	2	2	2	2
MBTS	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
TMTD	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sulfur	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Accinox ZC	1	1	1	1	1	1	1	1	1	1	1
Curing characteristics											
T^{b}_{10}	2.6	2.5	2.5	2.4	2.4	2.3	2.2	1.8	1.7	1.4	0.9
T^{c}_{90}	4.9	4.8	3.9	3.7	3.6	3.2	2.9	2.7	2.5	2.2	1.8
Maximum torque (Nm)	0.214	0.229	0.246	0.266	0.284	0.303	0.329	0.348	0.366	0.386	0.416
Vulcanizate properties											
Compression set (%)	26.19	25.78	25.26	24.26	24.13	23.92	23.54	22.98	22.02	21.63	19.78
Hardness (Shore A)	40	44	46	48	50	52	54	56	58	60	61

[a] Additive content of all blends: ZnO 5 wt.-%, stearic acid 2 wt.-%, MBTS 0.6 wt.-%, TMTD 0.1 wt.-%, sulfur 2.5 wt.-%, and Accinox ZC 1 wt.-%.

[b] Scorch time.

[c] Optimum curing time.

The morphology of gum natural rubber compound and its blends containing reclaim (60/40 and 20/80) were investigated using an optical microscope (Versamet-2, Union 7596). For optical microscopy, compounds were dissolved in toluene and the solutions were cast to thin films. They were then cut into a convenient size and mounted on a microscope slide. Photographs were taken at a 66-fold magnification.

The scanning electron microscope studies of the tensile fracture surfaces of the gum natural rubber vulcanizate, its reclaim-containing blend (20/80) and the corresponding aged samples were made using an SEM model JEOL JSM 35C. The fracture surfaces of the test specimen were carefully cut from the test pieces and were then sputter-coated with gold within 24 h of testing. The gold-coated surfaces were examined by scanning electron microscopy.

Results and discussion

The curing characteristics of the gum NR compound, its blends with latex reclaim and sole latex reclaim are shown in Tab. 1. There is a gradual reduction in the curing time T_{90} (time for attaining 90% of the maximum torque) and Scorch time T_{10} (time for attaining 10% of the maximum torque). This is possibly due to the presence of crosslinking precursors and/or unreacted curatives in the latex reclaim[2]. The maximum torque is found to increase with increasing latex reclaim content. This may be attributed to the higher crosslinking density in the blends compared to gum natural rubber vulcanizate. The 100% latex reclaim shows the highest value for the maximum torque.

The swelling index is found to decrease with increase in the amount of latex reclaim (data not given). This points towards increased crosslinking density in the blends.

Fig. 1 shows the variation in tensile strength with the addition of latex reclaim. The tensile strength slightly increases and then decreases with further addition of latex reclaim. This shows the good bonding between natural rubber and the latex reclaim. The ageing resistance of the blends is also found to be comparable to that of the gum NR vulcanizate. This again shows that there is good bonding between natural rubber and the latex reclaim.

Fig. 2 shows the variation in tear strength with the amount of latex reclaim. The tear strength slightly increases and then decreases with the addition of latex reclaim. This shows the high quality of hydrocarbon derived from the latex reclaim as well as its good bonding with natural rubber. The ageing resistance of the samples containing latex reclaim is also comparable to that of NR gum vulcanizate.

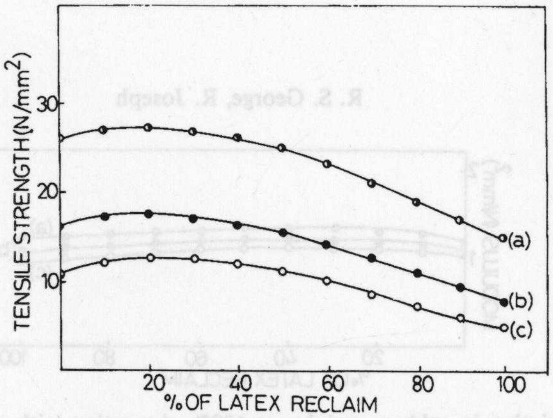

Fig. 1. Variation in tensile strength with percentage of latex reclaim; (◑) original, (●) 24 h at 100 °C, (○) 48 h at 100 °C.

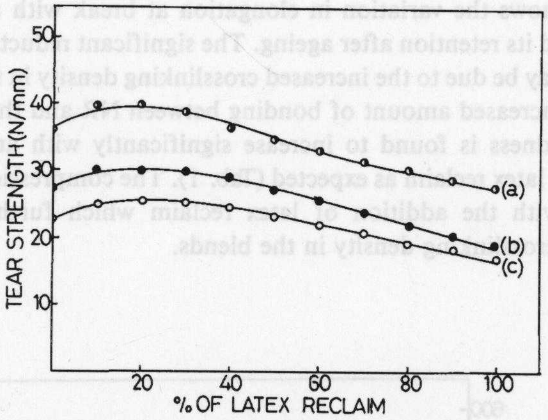

Fig. 2. Variation in tear strength with percentage of latex reclaim; same symbols as in Fig. 1.

Fig. 3 shows the variation in rubber modulus with the amount of latex reclaim and the retention in modulus with ageing. There is a slight increase in modulus with addition of latex reclaim. This may be attributed to the increased amount of crosslinking density in the blends.

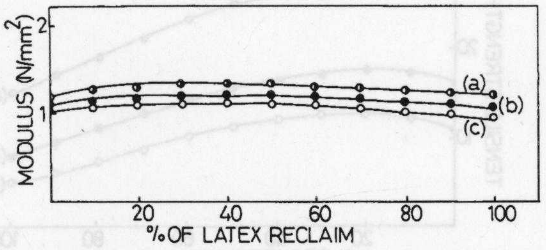

Fig. 3. Variation in rubber modulus at 100% elongation with percentage of latex reclaim; same symbols as in Fig. 1.

Fig. 4 shows the variation in elongation at break with addition of latex reclaim and its retention after ageing. The significant reduction in elongation at break may be due to the increased crosslinking density in the blends as well as to the increased amount of bonding between NR and the latex reclaim.

The hardness is found to increase significantly with an increase in the amount of latex reclaim as expected (Tab. 1). The compression set is found to decrease with the addition of latex reclaim which further confirms the increased crosslinking density in the blends.

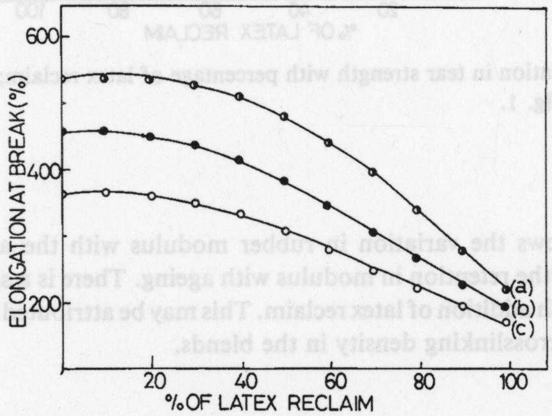

Fig. 4. Variation in elongation at break with percentage of latex reclaim; same symbols as in Fig. 1.

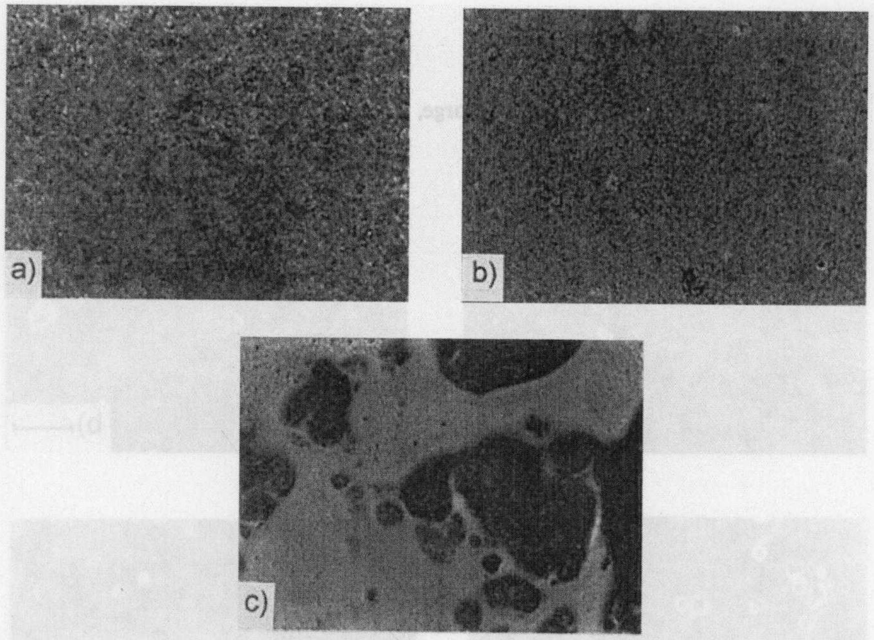

Fig. 5. Optical microscope photograph of a) the natural rubber gum compound, b) the 60/40 natural rubber/latex reclaim blend, and c) the 20/80 natural rubber/latex reclaim blends. The width of the photopraphs corresponds to 400 µm.

The average crosslink density of the latex gloves ($4.42 \cdot 10^{-5}$ g · mol/cm^3) was found to decrease during the reclaiming process. The average crosslinking density of the latex reclaim was found to be $2.35 \cdot 10^{-5}$ g · mol/cm^3.

Fig. 5a–c show the optical photographs of NR gum compound, 60/40 (NR/LR) blends and 20/80 (NR/LR) blend. This shows that when the content of latex reclaim in the blend is below 60 wt.-%, the particles are uniformly distributed in the compound and form a part of the NR phase. When the content of latex reclaim in the blend is above 70 wt.-%, the particles of the reclaim are found to be more visible. This may be due to the higher amount of interparticle bonding when the amount of NR in the blend is higher than 30%.

Fig. 6a–d show SEM photographs of the tensile fracture surface of NR gum vulcanizate and its blend with latex reclaim, respectively. SEM studies show that the blends undergo fracture by a similar mechanism as that of gum

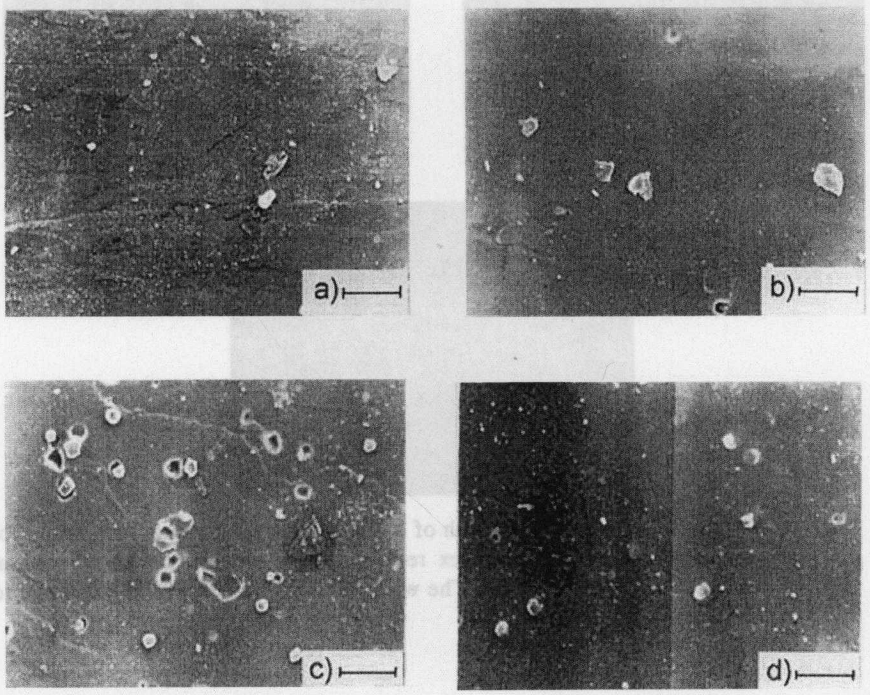

Fig. 6. SEM photographs of a) the original tensile fracture of natural rubber gum vulcanizate, b) the aged tensile fracture (24 h, 100 °C) of natural rubber gum vulcanizate, c) the original tensile fracture of 20/80 natural rubber/latex reclaim vulcanizate, and d) the aged tensile fracture (24 h, 100 °C) of 20/80 natural rubber/latex reclaim vulanizate. The length of the bars corresponds to 40 µm.

NR vulcanizate. The aged samples also follow a similar pattern. The original as well as the aged blend sample do not show any signs of cracks or chunking out of the particles. This again shows that there is good interparticle bonding between NR and the latex reclaim.

Conclusion

The study shows that latex reclaim obtained from waste latex gloves will make high quality hydrocarbon which can replace raw natural rubber up to about 50 wt.-% without any deterioration in mechanical properties. The morphology sudies show that there is uniform distribution of the latex reclaim in the blends with NR and good bonding. The SEM studies show that there is good interparticle bonding between NR and the latex reclaim.

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