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Microcellular Rubber: A Study on Reclaimed Natural Rubber (NR) Latex Gloves/Standard Malaysian Rubber (SMR) 20 Blends

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ABSTRACT

Reclaimed rubber from rejected natural rubber (NR) latex gloves (r-NRG) was evaluated as partial replacement for Standard Malaysian Rubber (SMR) 20 in producing microcellular rubber. In the study, the amount of reclaimed rubber varied from 20 pphr to 95 pphr for the purpose of cost reduction, environmental interest and as processing aids in reducing internal porosity, swells and to minimize shrinkage and air-trapped problems in producing microcellular rubber. A typical formulation in making microcellular rubber slab was developed and two-roll mill was used for compounding. The cure characteristics and mechanical properties, such as density, hardness, tensile strength, and elongation at break, were evaluated. Scorch time and cure rate index performed marginal decreased with increasing of r-NRG content. 95 pphr r-NRG blends showed a consequential drop in hardness. Both tensile properties and elongation at break decreased as the r-NRG content was increased.

Keywords: Cure characteristic, mechanical properties, microcellular rubber, reclaimed natural rubber latex gloves, standard Malaysian rubber (SMR) 20

INTRODUCTION

Malaysia is currently the world's largest rubber glove producer and exporter (Tan, 2009; Xin Hwa News Agency, 2009). The export earnings for Malaysian rubber gloves were RM7.03 billion, and this was equivalent to nearly 49 billion pairs of gloves (Xin Hwa News Agency, 2009). The Malaysia latex industry has expanded over the years to meet the world demands and to comply with a more stringent defect standard of the US Food and Drug Administration (FDA) (Yew, 2009). Rajan *et al.* (2006) reported that about 15% of the final latex products were rejected due to the strict specifications and the unstable nature of latex. These rejects create a major disposal problem for the rubber industry. In order to alleviate this environmental issue, reclaiming is an important method rather than landfill or incineration. Since latex product waste represents a source of high quality rubber hydrocarbon and it is widely used to reduce compounding cost as additive in various rubber article formulations because it is easier to be broken down and hence reduced the mixing time. Besides, reclaimed rubber is used as a processing aid to give a better dimensional stability to the compounds and products, as well as to reduce internal porosity in the manufacturing of rubber goods. It is not a necessity to attain the physical properties of the final compound, with or without the addition of crude rubber or synthetic rubber (Dhingra). These non-black reclaimed rubbers have extra advantages in the manufacture of coloured rubber products. Thus, latex gloves from the local gloves manufacturers, which had undergone the reclamation process, were utilized in this study to produce microcellular rubber.

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Microcellular rubber is like any solid rubber, with an exception that the chemical blowing agent (CBA) is added into compounding. CBA is a combination of inorganic and organic compounds that are stable at room temperature, but decompose and liberate gas at suitable higher temperature. The cells structure of microcellular is normally closed with gas trapped within the cells and gives the material a porous or cellular structure, as well as a low specific gravity (lightweight). Microcellular polymers have been commercially accepted in a wide range of applications since 1940s because of the advantages of light weight, buoyancy, cushioning performance, thermal and acoustic insulation, impact damping, and cost reduction. Although microcellular rubber is widely manufactured, the available articles concerning their electrical and mechanical properties are still limited in number. The correlation between the experimental data in microcellular rubber is attractive from the experimental and theoretical point of view (Lee *et al.*, 2007). Therefore, an evaluation on the partial replacement of reclaimed rubber from rejected natural rubber latex gloves (r-NRG) was carried out. The amount of reclaimed rubber varied from 20 pphr to 95 pphr in a typical formulation in making microcellular rubber slab.

MATERIALS AND METHODS

Sample Preparation

Natural rubber (SMR 20) and natural rubber latex gloves reclaimed rubber (r-NRG) were purchased from KL Kepong Berhad and HSB Reclaimed Rubber Sdn. Bhd., respectively. The r-NRG was analyzed and natural rubber (74.6%), calcium carbonate (14.3%), ash (4%), total sulphur (0.85%) and others ingredients (6.25%) were found in the content. All the mixing ingredients used are shown in Table 1. Meanwhile, the compound formulation is given in Table 1. In this study, microcellular with 100/0, 80/20, 60/40, 40/20, 20/80, 5/95 pphr ratio of SMR20/r-NRG were prepared. All the blends possess the same chemical composition. The mixing was carried out in Carter 9" x 18" two-roll mill. The preparation process was started with the mastication of polymers to viscosity at about 25±5 in Mooney unit, followed by the addition of activators, fillers, chemical blowing agent, and curing agents. Then, the finished compounds were cured to t_{90} obtained from Monsanto Moving Die Rheometer MRD 2000P at 160°C using an electrical heated hydraulic press after conditioning for 24 hours.

TABLE 1
Compound formulation

Ingredients	p.p.h.r.
Natural rubber (SMR 20)	variable
Latex gloves reclaimed rubber (r-NRG)	variable
Zinc oxide (ZnO)	5.0
Stearic acid	2.0
Kaolin clay/Refined clay	50
Polymerized 2,2,4- Trimethyl-1, 2– dihydroquinoline (TMQ)	1.0
N-(1,3-Dimethylbutyl)-N´-phenyl-p-phenylenediamine (6PPD)	1.5
Sulphur	2.0
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	0.6
Azodicarbonamide (ADC)	4.0

Testing

Cure characteristic of vulcanizates were tested with Monsanto Moving Die Rheometer MDR 2000P (Alpha Technologies) under ISO 6502. Both the density and hardness (Shore Instrument & Mfg. Co. Jamaica, New York 23352-00) of the vulcanizates were determined in accordance with ISO 1855 and ISO 48, respectively. In addition, the tensile properties of the specimens were measured according to ISO 1798, Type 1A. The crosshead rate for the tensile testing was 500mm/min, with an initial gauge length of 40mm, using Instron 5500R Series IX Automated Material Tester.

RESULTS AND DISCUSSION

The cure characteristics of microcellular rubber, with different natural rubber latex gloves reclaimed (r-NRG) contents, are presented in Table 2. Scorch time, t_{s2}, is the time taken for the minimum torque value to increase by two units. It is defined as time to incipient cure (measure of time) when the premature vulcanization occurs. The cure rate index is calculated as hundred divided by the difference between cure time, t_{90} and incipient scorch time, t_{s2} (Lee *et al.*, 2007). It can be seen that the scorch time and cure rate index performed marginal decreased with the increase of the r-NRG content. This observation might be attributed to the filler and sulphur content left in the reclaimed rubber (Farahani *et al.*, 2006). An increasing trend of the cure time, t_{90}, was also observed upon the increasing reclaimed rubber content.

TABLE 2
Rheometric characteristic of the SMR20/r-NRG microcellular rubber

r-NRG content, pphr	Minimum torque, ML (dNm)	Maximum torque, MH (dNm)	Scorch time, T_{S2} (minutes)	Cure time, T_{90} (minutes)	Cure rate index
0	0.27	9.77	2.72	6.54	26.18
20	0.18	7.46	2.14	5.57	29.15
40	0.30	8.46	2.18	5.85	27.25
60	0.34	8.89	2.25	6.06	26.25
80	0.33	9.18	2.40	5.94	28.25
95	0.14	7.61	2.15	5.75	27.78

TABLE 3
Variation of the tensile properties and hardness of the microcellular foam

SMR/r-NRG	Density, g/cm^3 ISO 1855	Hardness, IRHD (N) ISO 48	Tensile strength, MPa ISO 1798	Elongation at break, % ISO 1798
100/0	0.625	67.4	3.12	391.00
80/20	0.519	34.9	2.85	371.45
60/40	0.593	44.4	2.59	351.90
40/60	0.624	48.8	2.40	312.80
20/80	0.649	54.6	1.82	205.75
5/95	0.524	32.8	0.57	117.30

Table 3 shows the variation of the tensile properties and hardness of the microcellular foam. Both the density and hardness of vulcanizates are shown in *Figs. 1* and *2*, respectively. The r-NRG has less crosslink density as compared to virgin rubber due to the fact that chain scission has lowered the molecular weight of reclaimed rubber during the reclaiming process (Gonzalez *et al.*, 1996). Therefore, more cells could easily be formed with gas entrapped in between the matrix, with 20 pphr of r-NRG added and hence, the vulcanizate density was reduced and it also became softer. In contrast, 95 pphr r-NRG blends showed a consequential drop in hardness. It can be explained that the hemispherical indenter of Durometer penetrated and slightly broke the vulcanizates because the microcellular network was very dense and brittle (Srilathakutty *et al.*, 1999).

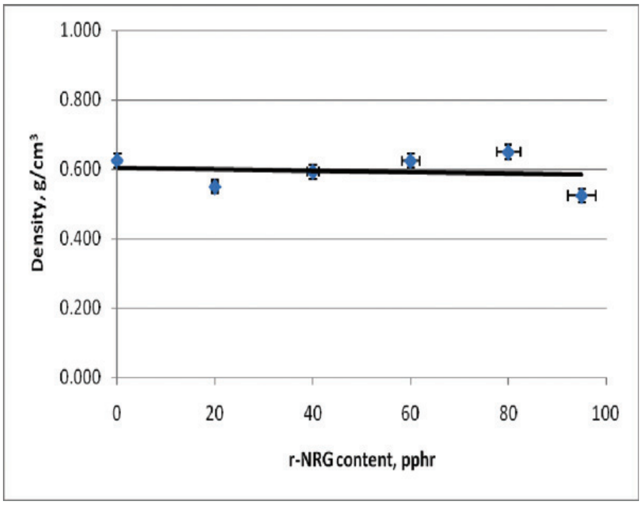

Fig. 1: The density of vulcanizates as a function of r-NRG blend ratio

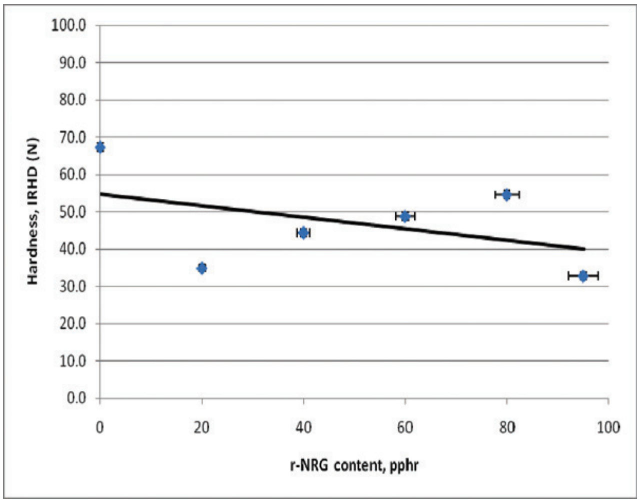

Fig. 2: Hardness of vulcanizates as a function of r-NRG blend ratio

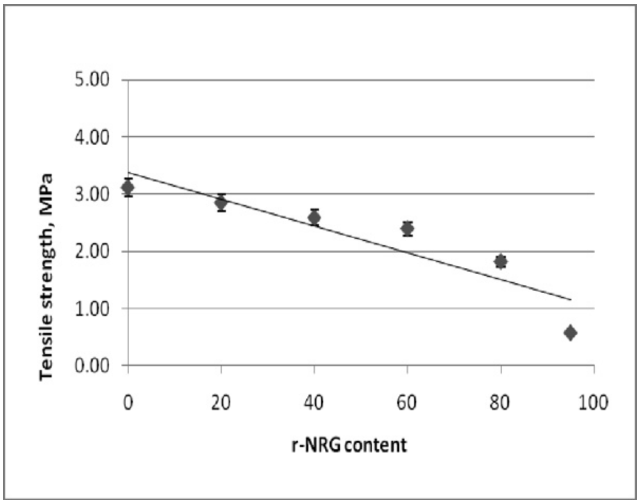

Fig. 3: Tensile strength of vulcanizates as a function of r-NRG blend ratio

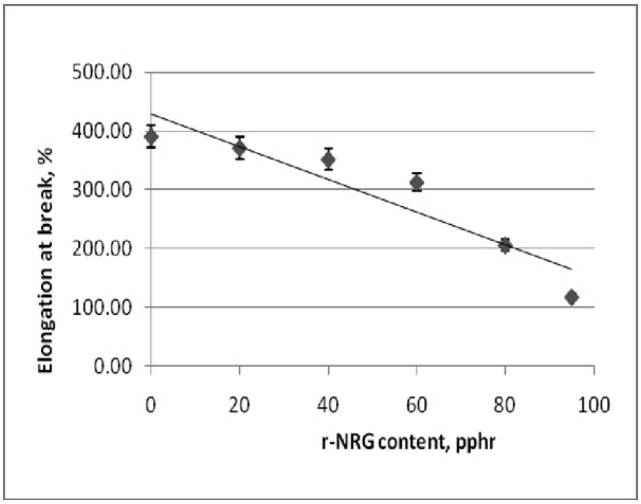

Fig. 4: Elongation at break of vulcanizates as a function of r-NRG blend ratio

Plots of tensile strength and elongation at break, as a function of r-NRG content of vulcanizates, are shown in *Figs. 3* and *4*, respectively. It is evident that both the properties decreased as the r-NRG content was increased. This might be attributed to the presence of the crosslinked gel in the matrix which originated from the reclaimed rubber gel that is difficult to disperse in the fresh rubber matrix. Such gels remained as weak sites for stress concentration; as a result, the tensile strength of reclaimed rubber is inferior to the virgin natural rubber (Adhikari *et al.*, 2000).

CONCLUSIONS

From the results of the study, it can be deduced that reclaimed natural rubber latex gloves (r-NRG) affect the curing characteristics due to the residual sulphurs and fillers in them. Moreover, the presence of the crosslinked gel from the reclaimed rubber remained as a weak site for stress concentration; its lower molecular weight (as a result of chain scission during reclaiming process) could cause reduction in density, hardness, tensile and elongation of Standard Malaysian Rubber (SMR) 20 with addition of r-NRG.

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