

## **STUDIES ON THE CELL STRUCTURE AND MECHANICAL PROPERTIES OF NR/LATEX RECLAIM/HSR BASED MICROCELLULAR SHEETS**

REENA SUSAN GEORGE and RANI JOSEPH

*Department of Polymer Science  
and Rubber Technology  
Cochin University of Science and Technology  
Cochin—682022, India*

### **Abstract**

In natural rubber/high styrene resin microcellular sheets, part of natural rubber was replaced by latex reclaim prepared from waste latex products. The mechanical properties and cell structure of the products were evaluated. It was found that latex reclaim can replace about 30% of natural rubber without affecting the technical properties of the microcellular sheets.

### **INTRODUCTION**

Cellular rubber products are probably more varied than any other rubber products. Apart from the technical property variation between compound formulations, the degree of expansion causes significant changes in the properties and these are further varied by the cellular structure, which may be open or closed. Microcellular rubber soles are used in footwear applications due to their high strength-to-weight ratio, wearing comfort, and flexural strength. Natural rubber/high styrene resin (NR/HSR) blends are used in the manufacture of microcellular products

due to their high abrasion resistance, fairly constant Mooney viscosity and cure characteristics, high crack initiation and crack growth resistance, etc.

For reducing the compound cost and environmental pollution and to conserve raw materials and energy, use of reclaim rubber has been practiced widely in the rubber industry for making useful rubber products [1-3]. For example, the footwear industry uses microcellular crumb. In the present work, we have studied the effect of replacing part of the NR by the latex reclaim (LR). The latex reclaim was produced in our laboratory by a novel economical process from waste latex products. The technical properties of microcellular sheets produced from ternary blends of NR/LR/HSR were evaluated and compared with those prepared from natural rubber/high styrene resin. The cell structure of these microcellular sheets was studied using a Nikkon trinocular research microscope model Alphaphot-2.

### EXPERIMENTAL

Materials used were:

1. Natural rubber: ISNR-5 (supplied by Rubber Research Institute of India, Kottayam).
2. SBR-1958: high styrene resin (supplied by Synthetics and Chemicals Ltd., Bareilly); bound styrene content: 49%.
3. Latex reclaim: prepared from waste latex gloves (waste gloves were supplied by AVT Rubber Products Ltd., CEPZ, Kakknad)
  - Volatile matter: 0.01%
  - Ash content: 2.2%
  - Acetone extract: 14.27%
  - Rubber hydrocarbon content: 83.52%
  - $P_0$ : 40
  - Mooney viscosity ML (1 + 4) 100°C: 54.
4. Additives: Zinc oxide, stearic acid, vulcafor F, precipitated silica, china clay, naphthenic oil, styrenated phenol, titanium dioxide, diethylene glycol, wood rosin, wax, sulfur, and dinitroso pentamethylene tetramine used were all commercial grade.

Natural rubber was masticated on a laboratory mixing mill and latex reclaim was added at different percentages. SBR-1958 in the form of a

sheet was then added and the blends were compounded according to the formulations given in Table 1.

The optimum cure time (time to reach 90% of the maximum torque) and the scorch time (time to reach 10% of the maximum torque) of the compounds were determined using a Goettfert Elastograph, model 67.85.

Microcellular sheets were molded in an electrically heated hydraulic press at 150°C. The mold was loaded with 3% excess of the compound on a volume basis. The compounds were precured in the mold to 80% of their respective optimum cure times. The expanded precured sheets were then postcured in an oven for 5 h at 80°C.

The mechanical properties such as relative density, hardness, change in hardness after aging, compression set, split tear strength, heat shrinkage, and water absorption were evaluated according to relevant Indian standards. The flexing resistance, in number of cycles (initial crack development) and cut growth at the end of 1,00,000 cycles was tested

TABLE 1  
Formulations

| Materials           | A   | B   | C   | D   |
|---------------------|-----|-----|-----|-----|
| NR                  | 70  | 60  | 50  | 40  |
| LR                  | 0   | 10  | 20  | 30  |
| HSR                 | 30  | 30  | 30  | 30  |
| Clay                | 50  | 50  | 50  | 50  |
| Precipitated silica | 40  | 40  | 40  | 40  |
| Naphthenic oil      | 5   | 5   | 5   | 5   |
| Diethylene glycol   | 1   | 1   | 1   | 1   |
| ZnO                 | 5   | 5   | 5   | 5   |
| Stearic acid        | 6   | 6   | 6   | 6   |
| DNPT                | 6   | 6   | 6   | 6   |
| Vulcafor F          | 1.2 | 1.2 | 1.2 | 1.2 |
| Sulfur              | 2.5 | 2.5 | 2.5 | 2.5 |
| Wax                 | 1.0 | 1.0 | 1.0 | 1.0 |
| Antioxidant SP      | 1.0 | 1.0 | 1.0 | 1.0 |
| Titanium dioxide    | 2.0 | 2.0 | 2.0 | 2.0 |
| Wood rosin          | 1.5 | 1.5 | 1.5 | 1.5 |

using a Ross flexing machine as per IS: 3400 (Part 16)—1974. Abrasion resistance was tested using a DIN abrader as per DIN 53516 standards with a load of 5 N.

Cell structure studies were done on a cut portion of the microcellular sheets using a Nikon trinocular research microscope model Alphaphot-2. Photographs were taken at a magnification of 50.

### RESULTS AND DISCUSSION

Table 2 shows the cure characteristics of the compounds. The optimum cure time and the scorch time were found to decrease with the addition of latex reclaim. This is possibly due to the presence of crosslink precursors and/or unreacted curatives in latex reclaim [4]. In latex product

TABLE 2  
Cure Characteristics and Technical Properties of the Microcellular Sheets

|   | A       | B       | C       | D       |
|---|---------|---------|---------|---------|
| Scorch time ( $T_{10}$ in minutes)              | 2.9     | 2.4     | 2.2     | 2.0     |
| Optimum cure time ( $T_{90}$ in minutes)        | 10.6    | 9.4     | 8.2     | 7.8     |
| Maximum torque (Nm)                             | 0.27539 | 0.33545 | 0.36719 | 0.38525 |
| Relative density                                | 0.382   | 0.403   | 0.416   | 0.423   |
| Hardness (Shore A)                              | 38      | 40      | 42      | 44      |
| Change in hardness (after aging at 100°C, 24 h) | +3      | +2      | +3      | +2      |
| Compression set (%)                             | 15.63   | 14.48   | 14.34   | 14.19   |
| Split tear strength (kg)                        | 7.2     | 7.56    | 8.21    | 8.67    |
| Expansion ratio <sup>a</sup> (%)                | 138     | 137.5   | 136.9   | 136     |
| Abrasion loss (cc/h)                            | 4.58    | 4.47    | 4.39    | 4.30    |
| Water absorption (%)                            | 1.06    | 1.065   | 1.08    | 1.09    |
| Heat shrinkage (%) (at 100°C, 1 h)              | 2.06    | 2.08    | 2.1     | 2.14    |
| Flex resistance (number of cycles)              |         |         |         |         |
| a. Initial crack                                | >60000  | >60000  | >60000  | >60000  |
| b. Cut growth at the end of 1,00,000 cycles (%) | <600    | <600    | <600    | <600    |

$$^a \text{Expansion ratio} = \frac{\text{area of the microcellular sheet}}{\text{area of the mold}} \times 100.$$

manufacture, usually ultra-accelerators such as ZDC, ZMBT, TMTD, etc., are used and these accelerators even at very low dosages can accelerate the curing reaction at 150°C. It was also noticed that the maximum torque was found to be increasing with the addition of latex reclaim as observed in natural rubber/latex reclaim compounds [5].

Relative density increased slightly with the addition of latex reclaim in microcellular sheets, as shown in Table 2. The expansion ratio of the microcellular sheets was found to decrease marginally with the addition of latex reclaim since the modulus of the blends increased with the addition of latex reclaim in natural rubber compounds [5]; the addition of latex reclaim slightly restricts the expansion of the matrix when compared with those of NR/HSR based microcellular sheets.

Table 2 shows the variation in compression set with the addition of latex reclaim. Compression set decreases with increasing latex reclaim content. This is again due to the increased crosslinking of the microcellular sheets prepared from the latex reclaim blends.

Heat shrinkage was found to be almost constant irrespective of the polymer variation, and the water absorption marginally increased with the addition of latex reclaim as shown in Table 2.

Abrasion loss of the microcellular sheets decreased with the amount of latex reclaim as shown in Table 2. This may be attributed to the higher modulus of the latex reclaim containing blends.



FIG. 1. Photograph of NR/HSR (70/30) microcellular sheet.

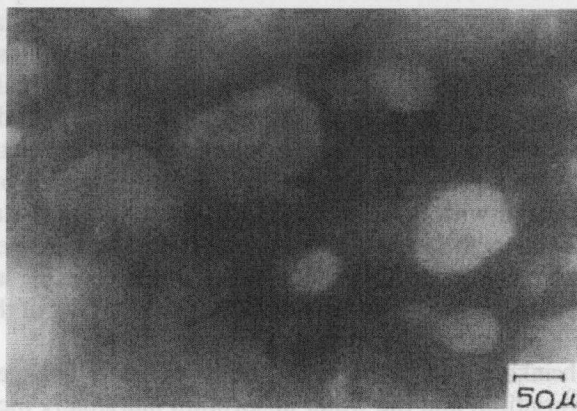


FIG. 2. Photograph of NR/LR/HSR (60/10/30) microcellular sheet.

The variation of split tear strength with the addition of latex reclaim is shown in Table 2. Latex reclaim based microcellular sheets showed higher split tear strength compared to NR/HSR based microcellular sheets. The tear strengths of natural rubber/latex reclaim blends were found to increase with the addition of about 50% of latex reclaim [5].

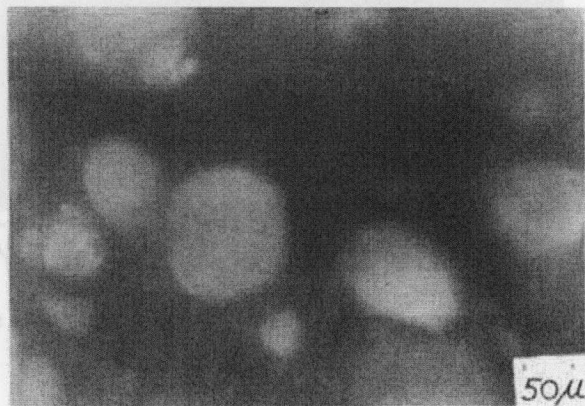


FIG. 3. Photograph of NR/LR/HSR (50/20/30) microcellular sheet.

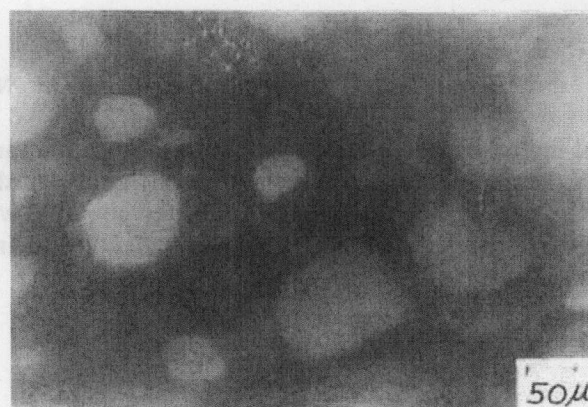


FIG. 4. Photograph of NR/LR/HSR (40/30/30) microcellular sheet.

This may be due to the faster cure rate and higher degree of crosslinking of latex reclaim containing blends.

Table 2 shows the variation of the flex resistance with the amount of latex reclaim. The flex resistances of all the samples were found to be in the specification limit given in Indian Standard [IS: 3400 (part 16)—1974].

Figures 1–4 are optical photographs of NR/HSR (70/30), NR/LR/HSR (60/10/30), NR/LR/HSR (50/20/30), and NR/LR/HSR (40/30/30) microcellular sheets. Compared to the cell structure of NR/HSR microcellular sheets, the average sizes of cells were smaller and the cell numbers were larger in the NR/LR/HSR based microcellular sheets. This may be attributed to the uniform distribution of latex reclaim in the compounds and the higher viscosity of the compound containing latex reclaim [6].

### CONCLUSION

The curing of the latex reclaim based blends was faster compared to NR/HSR blends. The technical properties such as hardness, compression set, split tear strength, and abrasion resistance were found to be superior in the latex reclaim based microcellular sheets. There was only

a marginal increase in heat shrinkage, water absorption, and relative density on the addition of latex reclaim in microcellular sheets. The latex reclaim can replace raw natural rubber to about 30 wt% in NR/HSR based microcellular products without affecting their technical properties.

#### ACKNOWLEDGMENT

Reena Susan George wishes to thank the Council of Scientific and Industrial Research for financial support.

#### REFERENCES

1. A. Acetta and J. M. Vergnaud, *Rubber Chem. Technol.*, **54**, 302 (1981).
2. A. A. Phadke, S. K. Chakraborty, and S. K. De, *Rubber Chem. Technol.*, **57**, 19 (1984).
3. V. N. Kalinichenko, G. A. Blokh, A. Ya. Vasker, and N. P. Sulyaeva, *Int. Polym. Sci. Technol.*, **11**, 12 (1983).
4. A. A. Phadke, A. K. Bhattacharya, S. K. Chakraborty, and S. K. De, *Rubber Chem. Technol.*, **56**, 726 (1983).
5. R. S. George and R. Joseph, *Angew. Makromol. Chem.* (in press).
6. J. G. Webster and R. R. Heathfield, in *Rubber Technology and Manufacture* (C. M. Blow and C. Hepburn, eds.), 2nd ed., Butterworths, 1982, p. 474.

#### CONCLUSION

The curing of the latex reclaim based blends was faster compared to NR/HSR blends. The technical properties such as hardness, compression set, split tear strength, and abrasion resistance were found to be superior in the latex reclaim based microcellular sheets. There was only