Evaluation of Suitability of Disulfide based Natural Product as a Reclaiming Agent for Ground Rubber Tyre

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Introduction

Reclaimed ground rubber tyre is a solution for the shortage of raw rubber and the rise in the cost of virgin rubbers. Also, it reduces the rubber waste and hence the pollution caused by that waste. Therefore, there is a continual development of reclaiming technologies over the last few years. Ground rubber tyre (GRT) is already a vulcanized material. In the vulcanization process of rubber compounds crosslinks occur between polymer chains. Many researchers have shown that bonds between GRT and the rubber matrix are very weak because of the crosslink structure of GRT and lack of reactive sites on the GRT surface, resulting in a decrease of the mechanical properties of GRT and virgin rubber blend vulcanizates. A possible way to overcome this problem is to break the sulfur crosslinks in GRT before blending with other polymers. Therefore, work has been carried out in the past to modify GRT to enhance interfacial adhesion between the two phases. This process is called reclaiming or devulcanization. Zhang, et al., (2009) compared rubber blends containing raw GRT and rubber blends containing devulcanized GRT and have concluded that the rubber blends containing devulcanized GRT were easier to mix and exhibited much better mechanical properties than natural rubber/GRT vulcanizates. There are several physical and chemical devulcanization techniques. Physical and chemical processes normally are energy demanding or require hazardous chemicals. Tetramethylthiuram disulfide (TMTD) has been used as one of the disulphide reclaiming agents for GRT. TMTD is a synthetic and hazardous chemical. Therefore finding a natural reclaiming agent is a potentially attractive recycling and utilizing way of GRT. In this study disulfide based natural product (NP) was used as the reclaiming agent for ground rubber tyre (GRT) with the aim of replacing the hazardous reclaiming agent TMTD to formulate the tyre tread compounds.

Methodology

The current study was carried out at the Rubber Research Institute of Sri Lanka (RRISL), Ratmalana. Laboratory analysis was done at RRISL. In this study as step one, a series of samples of reclaimed GRT was produced by adding different amounts of the selected natural product and one sample was produced by adding TMTD. In the second step, rubber compounds were produced by blending the reclaimed rubber prepared using different amounts of NP and TMTD with virgin natural rubber (NR).In the third step, rubber vulcanizates were produced using the compounds prepared in step 2. Cure characteristics, physico-mechanical properties and anti-oxidant property of both rubber compounds and vulcanizates were evaluated and compared with those of the control; blend compound containing virgin NR and reclaimed rubber prepared with TMTD. Treatments adopted were 5phr (parts per hundred parts rubber) of TMTD [Control (1)], 1 phr of NP(2),3 phr of NP(3),5 phr of NP(4),7 phr of NP(5),9 phr of NP(6). The data were analyzed adopting the analysis of variance (ANOVA) using Minitab 16 software programme. Significant means of treatments were separated using the Least Significant Difference $p<0.05$.

Results and Discussion

According to ANOVA, P=0.0001.Therefore, there is a significant difference in at least one treatment. Means that do not share a same letter are significantly different (Table 1).The hardness of the five treatments is significantly different from that of the Control and at a lower level, but at the required level of tyre treads(55-65 IRHD).

Table 1. Hardness of vulcanizates

Vulcanizate	Mean hardness (IRHD)	Standard deviation
1	72.9^{A}	±0.265
2	63.8^{B}	±0.458
3	61.733^{C}	±0.115
4	62.3^{C}	±0.300
5	62.867^{BC}	±0.513
6	62.333^{C}	±0.862

At least one vulcanizate is different from the others as the P value is less than 0.05. Table 2 shows the mean values of tear strength. The mean that shares the same letter are not significantly different from each other. Therefore, the other five vulcanizates are not significantly different and the Control vulcanizate is different from other five vulcanizates. Higher tear strength of vulcanizates 2,3,4,5 and 6 may be due to less heterogeneity of phases in the revulcanized rubber produced with the reclaimed rubber prepared with the natural product compared to that of the revulcanizate produced with the reclaimed rubber prepared with TMTD.

Table 2. Tear and Tensile strength of vulcanizates.

Vulcanizate	Mean tear strength (Nmm)[1]	Mean Tensile strength(Nmm)[2]
1	31.939^{A}	13.868^{A}
2	67.96^{B}	15.458^{A}
3	62.309^{B}	14.759^{A}
4	64.079^{B}	15.481^{A}
5	67.946^{B}	14.303^{A}
6	66.93^{B}	14.714^{A}

And also table 2 shows the mean values of tensile strength, there is no significant difference between the Control sample and the other five samples as the P value (0.134) is not less than 0.05.But considering valuethe control sample shows the lowest tensile strength.

Figure 1 shows that at least one vulcanizate is significantly different from the other vulcanizate ($p<0.05$). Control is significantly different from the other five vulcanizates and it indicates the least value for elongation at break. TMTD as the reclaiming agent shows a lower value for elongation at break of the vulcanizate in comparison with the others. The elongation at break of the revulcanized samples prepared with the natural product is higher than 400% and hence it is in accordance with the requirement for tyre treads.

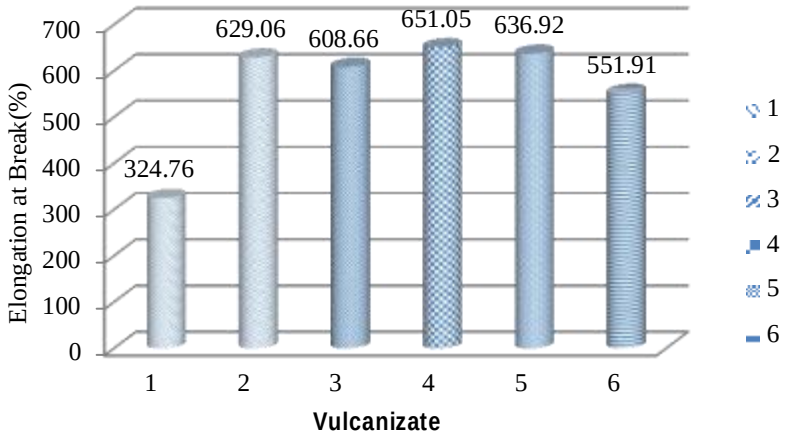

Figure 1. Elongation at break of vulcanizates.

According to ageing properties of the six vulcanizates, the control vulcanizate shows greater decrease of tear and tensile strengths, while the other five vulcanizatesshow resistance to ageing (Table 3). This is probably due to the antioxidant effect of the natural product incorporated as the reclaiming agent.

Table 3. Ageing properties of vulcanizates.

Vulcanizate	Aged tensile strength (Nmm^{-2})	Aged tear strength(Nmm^{-1})
1	3.576^{A}	8.43^{A}
2	12.099^{B}	43.227^{B}
3	12.772^{B}	45.653^{B}
4	12.665^{B}	48.766^{B}
5	12.399^{B}	49.693^{B}
6	12.075^{B}	41.338^{B}

Conclusion

Readily available environmental friendly disulfide based natural product selected for this study could be an alternative to hazardous TMTD in reclaiming of ground rubber tyre as it possesses improved tear strength, elongation at break and the ageing properties compared to those of the control.

References

Zhang, X., Lu, C., Liang, M., 2009. Properties of natural rubber vulcanizates containing mechanochemically devulcanized ground tire rubber. Journal of Polymer Research, 16(4), 411-419.