Degradation of vulcanized natural rubber using soybean and sesame oils

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Introduction

Vulcanized rubber products used in various applications cause serious environmental issues due to their very slow degradation (Treloar, 2005, Blackley, 1997). The present research focuses on enhancing degradation of vulcanized rubber products which are discarded after their usage. Due to the unsaturated nature, rubber molecules are susceptible to degradation in the presence of peroxide radicals (Adhikari, *et al* 2000). Therefore, it is expected that the peroxide radicals produced in the oxidation of natural oils can enhance degradation. The oxidation of a natural oil increases with it's degree of unsaturation which increases the rate of degradation. Therefore, highly unsaturated locally available soybean and sesame oil were used in the study.

Materials and Methods

Vulcanized rubber samples were prepared according to the tire tread formulation. Technically specified rubber (TSR) (100.00 g) was added into the internal mixer and allowed to crush well. Then stearic acid (2.00 g) and zinc oxide (5.00 g) were added and mixed well. After about 3 minutes carbon black (N 375 black) (73.00 g) and process oil (naphthenic oil) (5.00 g) were collected into the internal mixer. Finally, antidegradent N- isopropyl- N- phenyl-p- phenylenediamine (IPPD) (2.70 g) and wax (1.00g) were added and allowed to mix well. The prepared mixture was taken out from the internal mixer and set aside to cool. After cooling, the mixture was processed in the two roll mill for about 7-8 minutes at the same time adding the accelerator N- tert- butyl- 2- benzothiazolesulferamide (TBBS) (1.00 g) and sulphur (2.50 g). Finally a thick rubber sheet was obtained. Then the sample was cooled for 16 h and vulcanization of the samples was carried out in the hydraulic hot press at 150 ºC for 28 minutes to produce sheets of thickness approximately 3 mm (White, 1995). The resulting rubber sheets were cut into square pieces (7.5 × 11.0 cm^2) and immersed in soybean and sesame oil for different period of times at room temperature. In addition, the effect of these oils on degradation in the presence of sun light and copper catalyst, only for 5-week time period was also studied. At the end of the each time period, samples were taken out from the oil and wiped well before testing and characterization. Tensile properties (ISO 37-1977) and tear strength (ISO 34-1979) were determined with reference to the vulcanized rubber sample which was not immersed in oil (blank). The thermal properties were obtained by exposing the samples to a temperature range of (23-500) ºC at an increasing rate of 5 ºC min^{-1} using the Thermogravimetric analyzer (TGA).

Results and Discussion

Stress- Strain curves for natural rubber samples immersed in soybean oil and in sesame oil are given in Figures 1 and 2, respectively. According to the results all the samples immersed in sesame oil and

soybean oil, have reduced their tensile strengths compared to the blank. The tensile strength values of the samples immersed in soybean oil for equal time period are lower than those immersed in sesame oil. According to the results, when the exposure time is increased the tensile strength values in both type of oils have decreased significantly. The greater losses of tensile strengths were shown by the samples in the presence of sun light and copper catalyst. Similar pattern of results were obtained for tear strength (Figure 3). TGA results show that the degradation temperatures of all the samples immersed in sesame oil and soybean oil have been reduced compared to the blank sample. The degradation temperatures of the samples, immersed in soybean oil are lower than those immersed in sesame oil for the same time period.

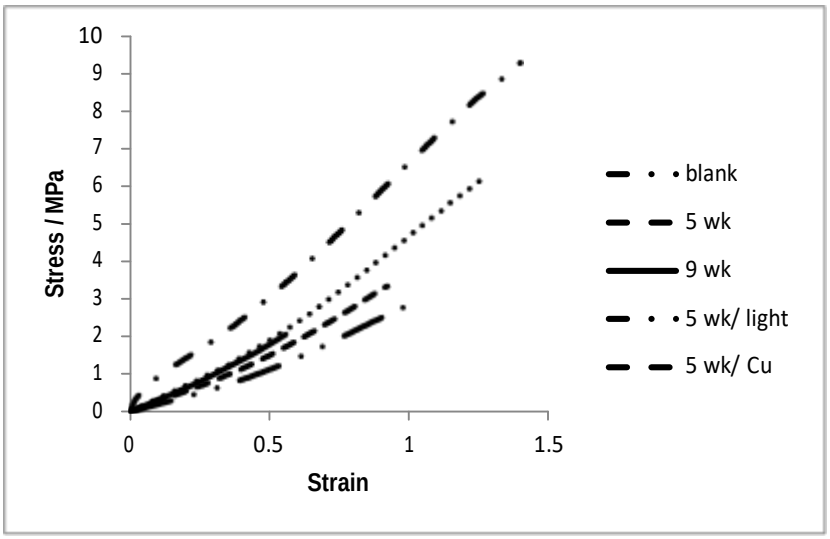

Figure 01. Stress- Strain curves of natural rubber samples immersed in soybean oil

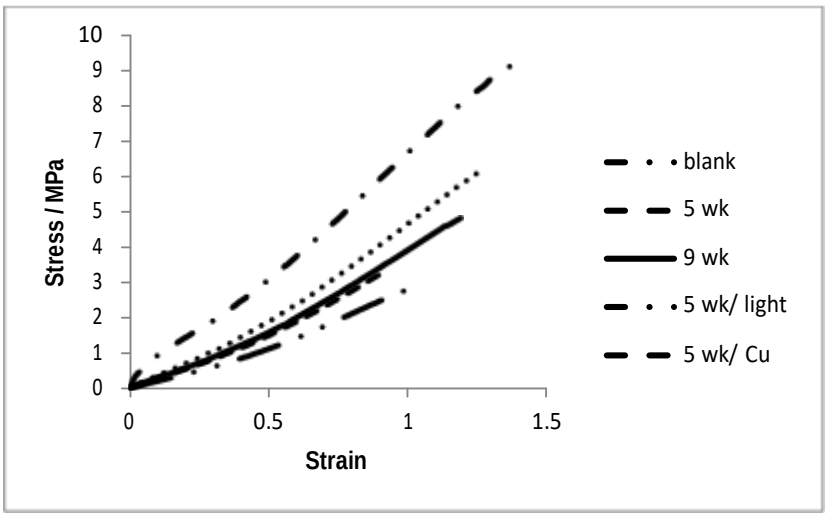

Figure 02. Stress- Strain curves of natural rubber samples immersed in sesame oil

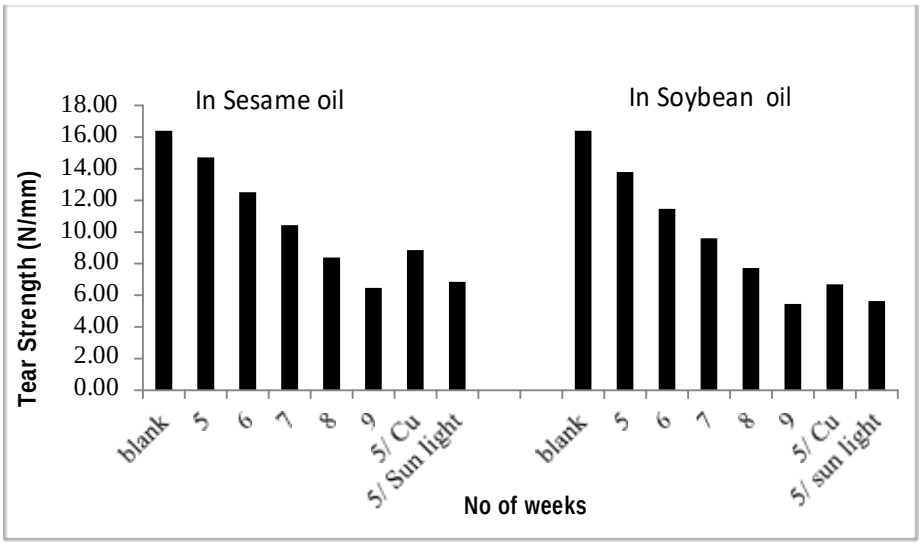

Figure 03: Tear strength of natural rubber samples immersed in sesame oil and soybean oil

Degradation can occur by breaking the existing cross links in the vulcanized rubber or by promoting scission of the main chain of the polymer or by both processes and resulting in hardening, softening, tackiness, random or orientated cracking, loss of tensile and tear strength, loss of elasticity, etc. (Rajan, *et al*, 2006) Loss of tensile strength and tear strength in the present research show evidence of enhanced degradation. In addition, the reduction in degradation temperatures also provides more evidence. In the presence of sun light and copper catalyst loss of these parameters is higher than sample immersed in room temperature for the same time period. Usually oxidation of edible oils is influenced by sun light, metals (iron, copper), etc and it can produce more peroxide radicals which may account for the enhanced degradation of rubber molecules. Loss of the tensile and tear strengths is considerably higher in soybean oil than in sesame oil due to high amount of polyunsaturated fatty acids in soybean oil compared to sesame oil. The polyunsaturated fatty acid amounts in soybean oil and sesame oil used in this research are 61% and 47%, respectively.

Conclusions

The degradation of vulcanized rubber can be enhanced using soybean and sesame oil. Longer the time immersed in oils, lower the tensile strength, tear strength and the degradation temperature of vulcanized rubber samples indicating enhanced degradation. In addition, the presence of sun light and copper catalyst also has enhanced degradation. From the two types of oils used, soybean oil shows better enhanced properties. The enhanced degradation which could possibly be achieved by simply immersing the vulcanized rubber products in highly unsaturated oils before they are discarded will provide a solution for environmental problems caused due to non-degradable rubber waste.

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