Effect of Storage Conditions on Viscoelastic Properties of Crepe Rubber

A.C.C. Jayasinghe, R.M.S.D. Rathnayaka
Uva Wellassa University, Badulla, Sri Lanka

and

U. N. Ratnayake
Rubber Research Institute, Telewala Road, Ratmalana, Sri Lanka

Introduction

Latex crepe rubber is one of main raw natural rubber types produced in Sri Lanka. Rubber is a viscoelastic material, which consists of both viscous and elastic properties. Viscoelastic properties of raw rubber influence the processability of a rubber compound. Even though Sri Lanka is the leading manufacturer of latex crepe rubber, converting crepe rubber into products is carried out in other countries and as a result, manufactured crepe rubber should be kept under storage conditions prior to processing. The objectives of this study were to study the effect of storage conditions on the viscoelastic properties of raw crepe rubber, viscoelastic properties of compounded crepe rubber and the effect of the non-rubber content on viscoeastic properties of crepe rubber.

Methodology

Two factor factorial design was employed as the statistical design of the study. Three different grades of crepe rubber such as Fractionated Bleached (FB), Un-Fractionated Un-Bleached (UFUB), Yellow Fraction (YF) crepe rubber samples were obtained, same batch from crepe rubber factory at Dartonfield, Agalawatta. These crepe rubber were stored at different temperatures such as 2 ^{0}C, 22 ^{0}C, 30 ^{0}C and 40 ^{0}C. Samples were drawn in every two weeks interval up to six weeks. Crepe rubber samples were analyzed for viscoelastic behaviour by analyzing Mooney viscosity and stress relaxation. Plasticity Retention Index (PRI) and un-aged plasticity (P_0) of crepe rubber were also measured to study the thermo-oxidative respect to different storage temperature and time. Three different grades of crepe rubbers were compounded by adding Calcium Carbonate as the filler and Mooney viscosity and stress relaxation were measured at the initial stage and at the end of the sixth week, under different storage temperatures. SAS statistical software was used for the analysis of the data and Duncan's Multiple Range Test was used for mean comparison.

Results and Discussion

Mooney Viscosity is a measurement of flow behavior of raw rubber. Higher Mooney viscosity implies a higher resistance to flow and also provides indirect measurement of molecular weight of raw rubber as un-aged plasticity. By considering the three grades of crepe rubber, an increment of Mooney viscosity and un- aged plasticity was observed with the increase of the storage temperature and storage time (Figure 1 and 2). This phenomenon is named as the storage hardening. The phenomenon of storage hardening in solid natural rubber (NR) is presumed to occur by means of reactions between some non-rubber components and abnormal groups in rubber molecule. The main non-rubber constituents in natural rubber composed of proteins and lipids (Yunyongwattanakorn et al., 2003). Carbonyl groups present in the rubber molecule are responsible for cross linking on storage of dry rubber. The highest increase of the Mooney viscosity was exhibited by Yellow Fraction crepe rubber. That might be the highest non- rubber content in that crepe. High amount of non-rubbers cause to create large number of cross links during storage. Highest Mooney viscosity values were depicted at 40 ^{0}C storage temperature in each storage time. This could be due to low humidity storage condition in the oven of which crepe rubber samples were stored. Significant increase can be seen in the storage hardening during the storage under low humidity conditions, because proteins and phospholipids at the chain-ends of rubber molecules may interact with water under ambient condition, thus the water may disturb the formation of branching points by hydrogen bonding (Jitladda et al.,2012).

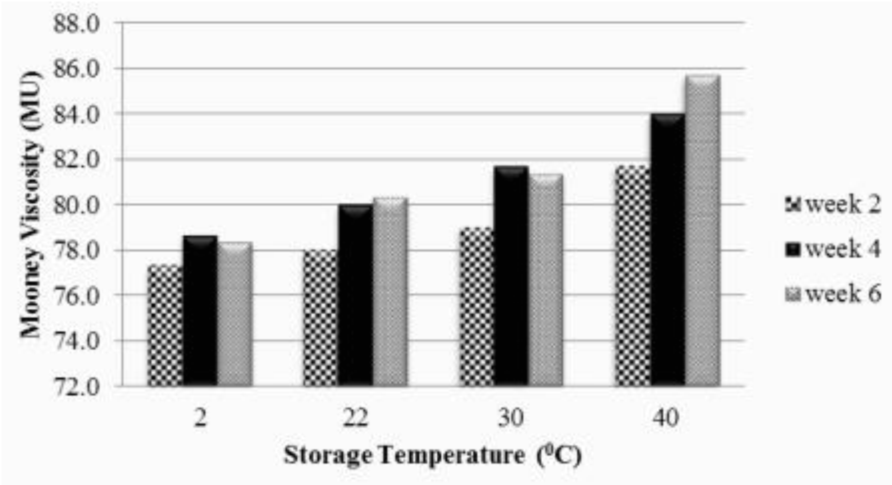

Figure 1. Storage temperature vs mooney viscosity of fractionated bleached crepe.

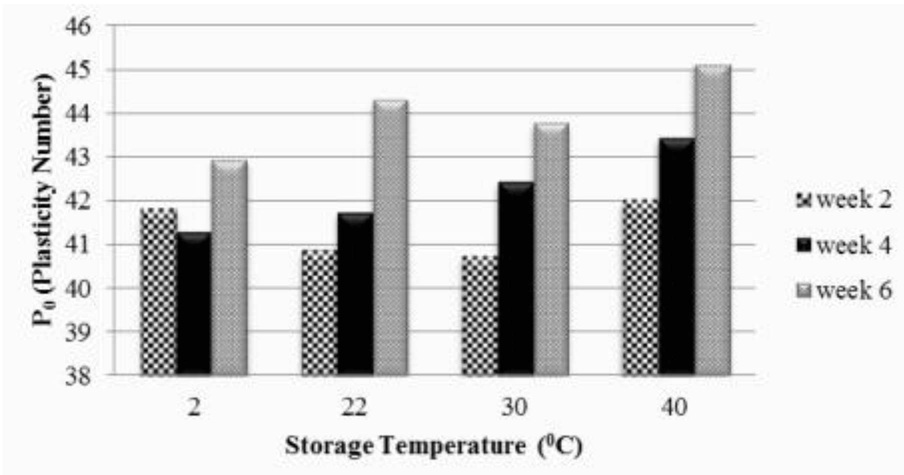

Figure 2. Storage temperature vs. un-aged plasticity of fractionated bleached crepe.

Plasticity Retention Index is a measurement which reflects the resistance to thermal oxidation of natural rubber. By considering the three grades of crepe rubber, there was a gradual decline of PRI with the increase of the storage temperature and storage time. Significant decline was exhibited in both UFUB and YF crepes (Figure 3). At low temperature storage conditions that were exhibited slow rate of PRI decline by comparing with the high temperature storage conditions. Significantly high PRI value was exhibited by UFUB crepe, because it contains high amount of natural anti-oxidants as non- rubber substances. Unsaturation in the rubber chains makes the materials more susceptible to heat because the energy required breaking π -bonds in the C=C linkages to form active radicals are relatively low. Oxidation process causes the main degradation phenomenon of the natural rubber molecules. It generally occurs quite slowly at low temperatures, but in greater consequence with increasing temperatures.

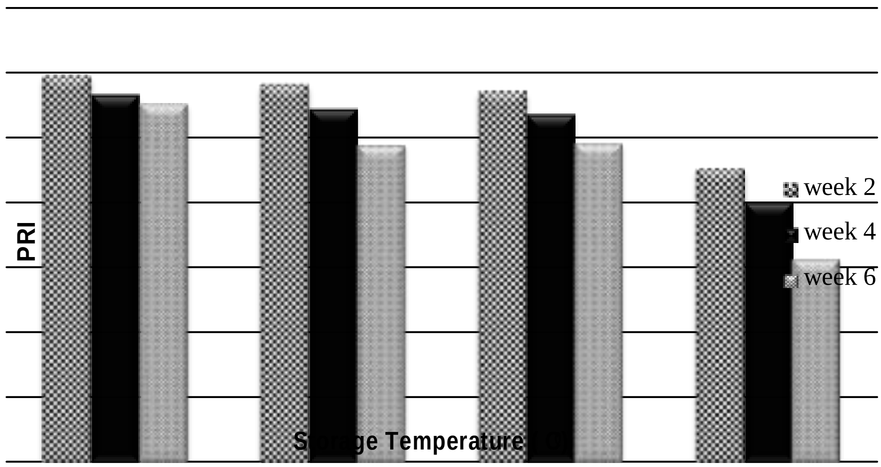

Figure 3. Storage Temperature vs. Plasticity Retention Index of Un-Fractionated Un-Bleached Crepe.

Stress Relaxation Rate is a measurement of the elasticity of raw rubber. By considering the three grades of crepe rubber, higher stress relaxation rates were exhibited in both FB and UFUB crepes in all storage temperature levels and storage time levels (Figure 4), because of the availability of high rubber content. YF crepe was exhibited comparatively low stress relaxation rates in all storage temperature levels and storage time levels. That because YF crape contains low amount of rubber content. The relaxation rate decreases as the amount of natural rubber decreases and the overall relaxation process depends more upon the rubber content (Asaletha, 2010).Three grades of crepe rubber exhibited that the high stress relaxation rates at low temperatures and low stress relaxation rates at high temperatures. That expresses low elasticity at low temperatures and high elasticity at high temperatures.

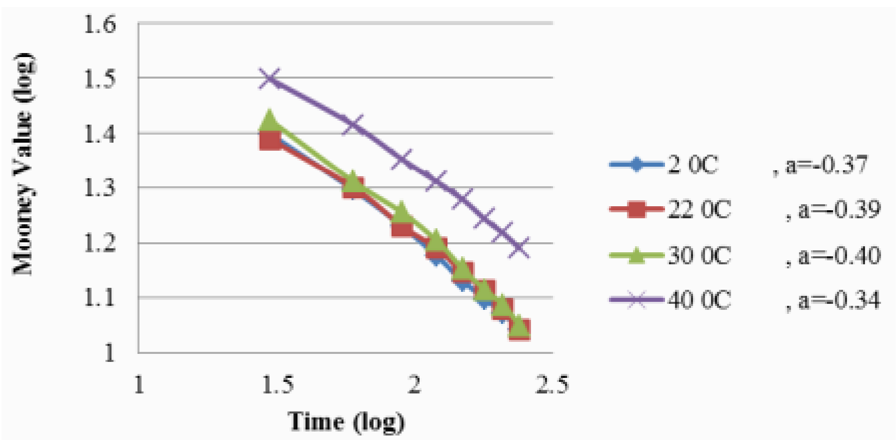

Figure 4. Mooney value (log) vs. Time (log) of un-fractionated un-beached crepe after six weeks storage time.

By considering the three grades of compounded crepe rubber, at the initial stage higher moony viscosity values were expressed in UFUB and YF crepes (Table 1). This might be the effect of higher non- rubber content. FB crepe was expressed comparatively lowest moony viscosity value. This might be the effect of low non- rubber content. By comparing with the three grades of uncompounded crepe rubber, compounded crepe rubbers exhibited low moony viscosity, because of the molecular breakdown of crepe rubber during the mastication process. By considering the stress relaxation of three grades of compounded crepe rubbers at initial stage and at sixth week storage time under different storage temperature levels were exhibited rapid relaxation after stopping the motor of the Mooney viscometer. The effect of adding fillers to a raw rubber, caused to increase the rate of stress relaxation (Frankley *et al*., 1978). Calcium carbonate was added as the filler for these compounds and calcium carbonate might be interacted with masticated rubber molecules and that might be affected to higher stress relaxation rate.

Table 1. Mooney viscosity of compounded crepe rubbers.

Type of crepe	Initial mooney value	Sixth week storage time Mooney value		
		2 ^{0}C	30 ^{0}C	40 ^{0}C
FB	46	48	59	34
UFUB	53	51	52	51
YF	50	45	49	47

Conclusion

Low Temperature storage conditions are most preferable to maintain satisfactory viscoelasticity and resistance to oxidation of crepe rubber which could finally affect to the better processabiity of rubber compound.

References

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