Dynamic Rebound Properties of NR Compounds Filled with Fly Ash Particles and Precipitated Silica

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Abstract

In this presentation, the natural rubber compounds filled with silica from fly ash particles (FASi) and commercial precipitated silica (PSi) were investigated through a dynamic rebound test. Effects of silica content and initial drop-height on the height and number of rebounds, dynamic stiffness and the energy loss were of interest. The results suggested that the unfilled NR vulcanizates exhibited greater elastic response than the FASi and PSi-filled vulcanized composites. For given silica contents, the NR compounds with fly ash particles had better elastic response than those with precipitated silica, the elastic response decreasing with increasing silica content.

Keywords: Natural rubber, Hysteresis, Fly ash, Rebounding.

1. Introduction

Natural rubber (NR) has abilities to carry a high load under compression and to deform elastically. Unfilled NR under moderate deformations has relatively low hysteresis loss as compared to filled NR vulcanisates, fillers usually increasing the hysteresis of the NR products. In engineering applications, natural rubber articles with low hysteresis are usually preferred, especially for vibration applications. Many published papers have studied the hysteresis losses in carbon black and silica filled rubber vulcanizates. For examples, Kar *et al* [1] found that the hysteresis loss increased with increasing strain rate, filler loading, strain level and holding time in the NR and SBR vulcanizates filled with carbon black filler. Ismail *et al* [2] found that the poor wetting of the wood flour by the rubber matrix gave rise to poor interfacial adhesion between the filler and rubber matrix as the filler loading increased that exhibited the high hysteresis. Manna *et al* [3] indicated that the hysteresis loss increased with increase in Z-6032 coupling agent loading in the ENR-silica compounds due to a structure breakdown of the silica. This work continues from our previous works recently published by Sombatsompop *et al* [4-5], who found that fly ash particles could be used as new reinforcing filler in natural rubber comparable to commercial precipitated silica that were greatly improved the mechanical properties by a small amount of bis-(3-triethoxysilylpropyl) tetrasulfane (Si69).

In this presentation, the elastic response of the NR composites containing the silica-based fillers was investigated through a dynamic rebound test. This includes effects of silica content and initial drop-height on the height and count of the rebounds, dynamic stiffness, and the energy loss.

2. Experimental

2.1 The rubber compounding and sample preparation

The formulation of the natural rubber (NR) compounds in parts per hundred rubber (phr) was as follows: 100 phr NR Grade STR20, 5.0 phr zinc oxide, 2.0 phr stearic acid, 0.5 phr mercaptobenzthiazole, 0.2 phr diphenylguanidine, and 3.0 phr sulfur. The silica-based materials includes commercial precipitated silica (PSi); Hi-Sil 233-S, and silica in fly ash (FASi) particles from Mae Moh. In this work, the Bis-(3-triethoxysilylpropyl) tetrasulfane (designated as Si69) was used as a chemical coupling agent for surface treatments of the FASi and PSi at 2.0 %wt.

In the mastication step, the NR was masticated on a two-roll mill for 5 min and was then mixed with 30 and 60 phr of silica-based fillers for another 15 min. In the compounding step, the rubber and filler were compounded with prepared vulcanization chemicals on the two-roll mill for another 10 min, and the compounds were then kept at 25°C at 50% humidity before further use. In the moulding step for this work, the rubber test-piece must be specially designed for the dynamic rebound test as shown in Figure 1.

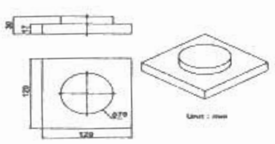

Figure 1. *The dimensions of rubber test-specimen*

Since the rubber test-piece had two different thicknesses, the actual cure time to be used must be calculated based on the fact that the thicker part of the test sample was cured to the required level in a hydraulic press, thus involving a time delay for conducting the heat to the thicker part. The actual cure time (t_{actual}) of the rubber test-piece can be obtained the sum of 90% cure time (t_{c90}) by ODR, and the initial pressing time (t) which is the time required for the heat from surface to reach the central parts of the sample. The cured rubber was cooled in the mould for 10 minutes in order to prevent a blister because of the different temperature in a central plane and on the surface of a specimen.

2.2 Dynamic rebound apparatus

Figure 2 shows our arrangement for the dynamic rebound apparatus. The guide post was made of stainless steel and the fixture was used to hold a rubber specimen in a firm place during testing. The hammer was hemi-sphere in shape was attached to the shaft that simultaneously moved vertically on a groove during rebound. The moving hammer of 4.8kg was freely released onto the vulcanized rubber specimen at various drop heights ranging from 500, 750 or 1000 mm from the specimen surface. The data acquisition system and the PC connected to the hammer were used for recording a deceleration value as a function of time during the drop-tests. All the data were then calculated and plotted to obtain stress-strain curves which were used to analyze the hysteresis behavior of the rubber sample. A video camera was used to capture the rebound counts and heights of the moving hammer during the drop-tests, with a recording speed of 25 frames per second.

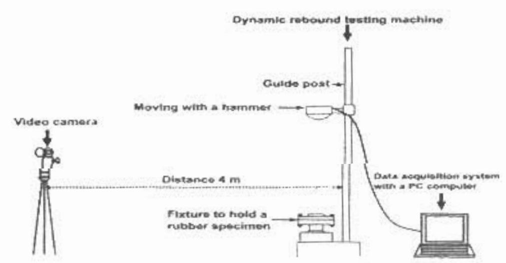

Figure 2. *Arrangement of dynamic rebound apparatus*

3. Results and discussion

The unfilled NR compound gave the highest rebound height as compared with the NR compounds filled with 30 and 60phr of silica-based fillers as shown in Figure 3. In addition, the number of rebound cycles for the neat NR was greater. It was found that the NR with fly ash particles tended to have better elastic response than those with precipitated silica for any given filler contents.

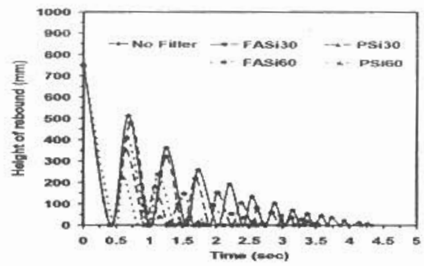

Figure 3. *Plots of height of rebound as a function of time for NR and silica-filled NR composites*

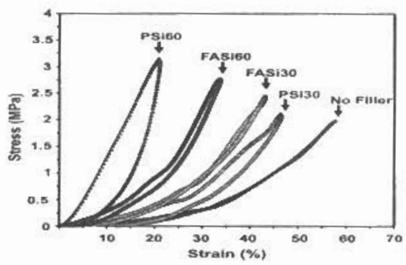

Figure 4. *Stress-strain curves for NR and silica-filled NR composites*

The hysteresis loss (area in the stress-strain loop) increased in the order of unfilled NR < FASiNR < PSiNR as illustrated Figure 4. This result confirms that the elastic response for the NR compounds decreased with addition of silica fillers, and the FASi-NR composites had greater elastic responses than the PSi-NR composites. Another parameter to consider is dynamic stiffness as shown in Table 1 which shows the greater stiffness of silica-filled NR composites than unfilled compounds and the greater the silica content the higher the composite stiffness.

From Figure 5, it can be seen that the increasing drop height had no effect on the energy loss of the unfilled NR composites, and caused an increase in the energy losses of the filled NR composites. The PSi-NR composites exhibited greater energy losses than the FASi-NR composites, this behavior being more pronounced at higher initial drop-heights.

Table 1. *Dynamic stiffness of neat NR and silica-filled NR composites*

Materials	Dynamic Stiffness (x10^5, N/m)
Neat NR	4.40
NR + PSi30	5.82
NR + FASi30	7.32
NR + PSi60	18.70
NR + FASi60	10.50

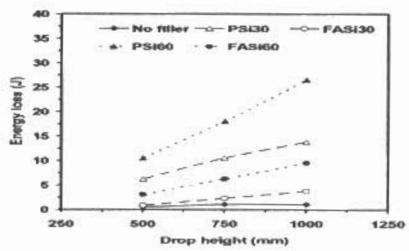

Figure 5. *Energy loss of NR and silica-filled NR composites at different drop heights*

4. Conclusion

The results indicated that the unfilled NR compound gave the highest rebound height as compared with the filled NR compounds. The rubber compounds with fly ash particles had better elastic response than those with precipitated silica for given filler contents. The greater the silica content the lower the elastic response and the higher the dynamic stiffness.

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