Properties of Epoxidised Palm Oil (EPO)/Styrene Butadiene Rubber (SBR) Compound

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ABSTRACT

Background: This study deal with the incorporation of EPO into SBR compound. EPO was compounded with SBR using laboratory two roll mill machine. Tensile properties and density test were determine to determine the effect of EPO as a function of softener or plasticizer without the presence of carbon black as filler. Different loading of EPO are used at 25pphr, 30pphr, 35pphr, 40pphr and 45pphr in this research and compared with control compound. The sample was prepared using hot press machine. The sample was cut into dumb-bell shape according to ASTM D412 for tensile test and a square of 20mm×20mm for density test. Scanning electron microscopy (SEM) was used to observe the surface morphology at the rupture part of the tensile samples. Objective: This study is to determine the density and tensile properties of EPO/SBR blend.

Results: By increasing the EPO loading, the elongation at break was extended. The density value however shows an opposite behavior where by increasing the EPO loading it will reduce the density of the compound. The optimum amount of EPO loading was found at 35pphr of EPO loading into SBR as its shows the highest tensile strength. The control compound gives the highest modulus compared to EPO loading. Conclusion: The presence of EPO in SBR compounding really affects the tensile properties and the density value of the compounding when comparing the EPO loading with control compound. The properties gain from the results can suit in any application with high flexibility that does not require high strength to withstand a pulling force without tearing.

INTRODUCTION

Nowadays, the utilization of vegetable oil in the rubber compounding has been reported significantly by researchers due to its outstanding properties and reasonable price besides harmless to human health when compare to aromatic based plasticisers [4,7,9]. Vegetable oils in general have excellent properties such as high viscosity index, high lubricity, high flash point, low evaporative loss, high bio-degradability and low toxicity with regard to their use as base oils for lubricants. On the negative side they are known to possess low thermal, oxidative and hydrolytic stabilities and poor low temperature characteristics. The properties of vegetable oils are determined by their fatty acid composition. A high content of linoleic or linolenic acid decreases thermal oxidative stability. Whereas, a higher proportion of long chain saturated fatty acid leads to inferior cold flow behavior [1]. There are various type of plasticizer such as aromatic, paraffinic, naphthenic and vegetable oils. EPO is derived from palm oil and undergo the process of epoxidation [10].

Recently in the world of rubber compounding, there are few new additives were introduced as the processing aids or extenders. This kind of new additives assuredly to be harmless, non toxic, biodegradable and most important it is obtainable. These are the characteristics of EPO to definitely become replacement to the older additives. In addition to that, research by [4] reported that EPO with rubber compound improved the mechanical and physical properties. SBR was chosen in this research as it is the most widely used synthetic rubber in the world especially in the tyre production [3]. It has outstanding properties such as good processability and thermal stability thus it is easier to mix with other compounding ingredients like zinc oxide, stearic acid, accelerators, sulfur, antioxidants, plasticisers and fillers. In this study, SBR was blend with EPO as a plasticiser without addition of carbon black that act as filler. EPO which act as a plasticiser will soften the...
rubber and thus gives higher value in elongation as the plasticiser makes the rubber becomes flexible. Previous researches that involve EPO loading in their study usually used carbon black or silica as filler in their formulation. Therefore, this study only focuses on effect of EPO loading towards rubber properties without influence of carbon black.

Methodology:
EPO used in this study was obtained from Malaysia Palm Oil Board (MPOB). The compounding was prepared using a two roll mill machine where all the ingredients were added one at a time until all the ingredients becoming homogenized. All the ingredients used as in the Table 1. The temperature of the roller was monitored when the mixing process is in progress. Subsequently after the mixing process, the compounded was left for a day to ensure all the ingredients to be well dispersed. Then the prepared compounds were molded in hot press machine at 150°C for about 10 minutes to 20 minutes in preparation of the tensile and density sample.

The samples for tensile test have a shape of dumb-bell with length of 75mm, width of 4mm, thickness of 2mm and gauge length of 20mm. The sample for density test is a square shape of 20mm×20mm with thickness of 20mm. The tensile test was conducted according to ASTM D412 with the crosshead speed of 500mm/min while density test was carried out as referred to the ASTM D1250 [8]. Density of the samples was determined by weighing the sample using densimeter with water as the medium [6]. All the reported data from both tests are the average of three individual measurements. SEM micrograph as in Figure 5 was observed at the rupture part of the tensile samples.

Table 1: Formulation of EPO/SBR and control compounding.

<table>
<thead>
<tr>
<th>Ingredients/Sample</th>
<th>Amount [pphr]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td>Styrene Butadiene Rubber (SBR)</td>
<td>100</td>
</tr>
<tr>
<td>EPO</td>
<td>0</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>5</td>
</tr>
<tr>
<td>Stearic acid</td>
<td>2</td>
</tr>
<tr>
<td>Antioxidant</td>
<td>3</td>
</tr>
<tr>
<td>Sulphur</td>
<td>1.5</td>
</tr>
<tr>
<td>CBS</td>
<td>1.5</td>
</tr>
</tbody>
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Results:
This section shows the results from both tensile and density test and also the micrograph from scanning electron microscopy (SEM). Tensile test reveal tensile strength, Young’s Modulus and elongation at break. Figure 1 is an illustrate of tensile strength against different EPO loading that produce three trends which is decreasing from control compound to EPO30, increasing from EPO30 to EPO35 and back to decreased at EPO35 towards EPO45. Figure 2 displayed Young’s Modulus against different oil loading which yield a decrement from control compound to the highest EPO loading which is EPO45. Figure 3 shows elongation at break versus different oil loading that produced an increment from control compound towards EPO45. Figure 4 shows density against different oil loading which present a decrement from control compound to EPO45.

Figure 1: Tensile strength of control compound and different oil loading.
Fig. 2: Young’s Modulus of control compound and different oil loading.

Fig. 3: Elongation at break of control compound and different oil loading.

Fig. 4: Density of control compound and different oil loading.
Discussion:

Referring to Figure 1, the first trend that can be seen is decreasing from control compound towards EPO30. The second trend is increasing from EPO30 to EPO35. The last and third trend is decreasing from EPO35 to EPO45. These decrement from control compound towards EPO30 and from EPO35 to EPO45 is acceptable probably due to increase in EPO loading in the compound will makes the sample more flexible and less strength in withstand the load. Thus, the entire sample that contains EPO loading were not included any filler to reinforced the sample and increase the strength. Without the presence of fillers such as carbon black or silica, the rubber compounding cannot achieve excellent strength due to no bonding between rubber and filler. There are also some rules that must be follow if there is any filler involves which is structure of filler and surface chemistry. These characterize are important to achieved excellent properties of rubber compound. In addition to that, in order to create significant reinforcement, the filler must have high specific surface area and small particle size. The relation between surface area and particle size is when small particle size of filler involves, it will have large surface area to work together with the rubber thus make the particle-particle spacing in the compound closer. The increasing trend from EPO30 to EPO35 due to the function of EPO as a plasticiser in the compound that enhance the interaction at the phase boundaries thus improves the flexibility and mechanical strength of the compound [6].

According to Figure 2, the trend is decreasing from control compound towards the highest loading of EPO which is EPO45. As the EPO loading is increase, the bonding between oil and rubber phase becomes closely packed together as shows in Figure 5 of SEM observations. This explains the effect of EPO on Young’s Modulus properties when looking at the large difference between control sample and EPO loading. Young’s Modulus or also known as elasticity is describe as deformation which takes place when a force which is parallel to the axis of the object is applied to one face while the opposite face is held fixed by another equal force. Young’s Modulus also can be defined as the ratio of the stress to the strain. In addition to that, when the Young’s modulus is high, the material will be stiffer since for the same fractional change in length or strain, the bigger force or stress is needed. Different plasticiser produced different plasticization effect due to the differences in the strength of plasticiser rubber and plasticiser-plasticiser interactions. Besides that, different loading of plasticiser also yield different plasticization effect. At low loading of EPO, the plasticiser-rubber interactions are the dominant interactions while at high loading of EPO, the plasticiser-plasticiser interactions become more significant. The term of anti-plasticization can be observed when low EPO loading incorporated. Thus, makes the rubber properties increase in stiffening as measured in tensile strength, Young’s Modulus and elongation at break [2].

Rubber molecules normally packed closely but it is not perfectly packed. Thus, the internal space available within the rubber or also known as free volume is low and the molecules cannot move past each other very easily; makes the rubber not flexible and high elongate. As rubber is heated to above $T_g$, the thermal energy and molecular vibrations generate additional free volume that allows the rubber molecules moving past each other quickly. The effect from heating the rubber is flexible and chewy. The free volume can be increased by adding
more side chains or end groups. Addition of EPO into rubber molecules will lower the Tg by separating the rubber molecules adding the free volume and making the rubber flexible and high elongate [2].

As referred to Figure 3, the increasing trend is expected from sample without EPO loading to the highest loading of EPO. Elongation at break or strain at break can be defined as the tensile strain build up in the sample at maximum tensile strength before rupture under prescribed conditions where strain is the ratio of change in dimension to the original dimension, [2] reported that when the structure of EPO and rubber is heated, the EPO molecules distributed or spread into the rubber and weaken the interaction between rubber or van der waals’ forces. At this point, the EPO molecules act as a guard to reduce the interaction between rubber forces and avoid the formation of a rigid network. Thus, this will lower the rubber glass transition temperature, Tg and allows the rubber chain to move rapidly causing in flexibility, softness and elongation. The intermediate state of EPO/SBR is hold together by a three-dimensional network of weak secondary bonding forces. These forces that exist between EPO and rubber are easily overcome by putting external stresses that allowing the sample to elongate and become flexible.

Figure 4 shows a single trend which is decreasing of density value from control sample to EPO45. Increases in EPO loading yields decreases in density value. This is probably due to the porous surface as shown in Figure 5. Density of water is equal to 1g/cm$^3$ while density of oil is less than 1g/cm$^3$. Therefore, samples that contain EPO loading having less density value than the control sample.

**Conclusion:**

It can be conclude that the tensile properties and density of EPO/SBR blend have been determined based on the results and discussions above. The properties gain from the data collected is the proof to previous study that claims unfilled rubber cannot improved the mechanical and physical properties of rubber. The effect of EPO gives to rubber properties probably can be used in certain applications that require high flexibility with low strength resistance. This study also can be used as a guideline for future research related to EPO/SBR blending.

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