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Tailoring the cure characteristics of NBR/LDPE blend at variation composition by employing chlorinated polyethylene

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Abstract

In utilization gradually more spirited soak, the endurance of industries that fabricate modules or parts of polymer is definitely linked to reduce the manufacturing costs. A substitute could be uncompatibilized and chlorinated polyethylene (CPE) compatibilized blends of nitrile rubber (NBR)/Low density polyethylene (LDPE) filled by industrial waste (MW) for the production of thermoplastic elastomers (TPEs) blends. The TPEs were evaluated through the cure, resilience and abrasion loss characteristics of blends, facilitating the performance scrutinizing of the fabrication procedures and applications to design the components. Comparable results are obtained with, and without CPE in the blends. As the ratio of LDPE in blends increased, the scorch time and cure time decreased and at same time, the elasticity of blends drop and torque increased and the resilience, which decreased for the cure systems. Compounds with the higher LDPE and CPE content had greater the both torque values, higher vulcanization rates, and the lower scorch, cure times, resilience and abrasion loss. These observations indicated more viscous along with less elastic replies in these blends. Results of this investigation expose that CPE could be used as a compatibilizer for the NBR/LDPE blend system.

Keywords— chlorinated polyethylene; thermoplastic elastomers; Abrasion.

1. Introduction

Conquering rubber and their blends basically depend on the superiority of the vulcanization process. There should be adequate stoppage of crosslink or three dimension structure development to allocate for an enviable forming. For cost-effective reasons recipes can influence the properties of rubber compounds. Consequently, analysis on the curing characteristics such as scorch time, cure time, minimum and maximum torque and cure rate index are fundamental to anticipate the curing activities of compound in the process.

Curing characteristic is a technique employed to examine the rubber vulcanization reaction rate. It can also be used as a deliberation basis for design of model and even rubber commodities.

Several processes have been exercised to examine the rubber vulcanization reaction rate. For illustration, Jaunich *et al* [1] observed the vulcanization reaction via using online ultrasonic, Bideau *et al*. [2] used a small-wave infrared irradiation, Manchado *et al*. [3], Chough *et al*. [4], and Ding *et al.* [5] used NMR even some used DSC to scrutinize the vulcanization reaction rate. Even though various techniques have been employed to examine the vulcanization reaction rate, though rheometer is used in various rubber industries and research organizations as carried out by Choi [6], Choi *et al.* [7], Mahalling *et al.* [8], Wang *et al*. [9] and *Cotten* [10].

The torque curve against cure time is frequently described rheograph for it can be applied to examine vulcanization reaction rate.

To study the cure characteristic of rubber mixes, various equipments had been designed such as Moving Die Rheometer (MDR). Usually, in this equipment, a certain shear strain is applied and the torque response of the material is measured. The curing characteristics can be depicted by MDR. Curing characteristic can be achieved by assembling the rubber compound and, considering properties can be attained [11]. The invented rubber compound is based on the establishment of curing system and utilize of reinforcing fillers in rubber.

It could also be achieved by varying the order of rubber mixing procedure [12-15]. Although the succession of rubber mixing procedure has been investigated, a process to add industrial waste like marble waste (MW) as filler into uncompatibilized and CPE compatibilized NBR/LDPE blends has yet not been expressly depicted. Fillers an important part of the rubber and their blends can affect the overall properties of rubber compounds and it is essential to find filler effects on the behavior of compound throughout the process.

Therefore, this study seeks to evaluate the effects of NBR/LDPE blend ratio as well as various CPE content and its correlation with curing characteristics, rebound resilience and abrasion lose properties of MW filled uncompatibilized and CPE compatibilized NBR/LDPE blends.

2. Material and methods

2.1. Materials and sample preparation

Acrylonitrile-butadiene rubber (NBR 3310, acrylonitrile, 35 wt %) and Low-density polyethylene [MFR = 4.82 g/10 min (190° C, 2.16 kg), d = 0.923 g/cm^3] used in this study were commercial grade and purchased from the local market. Dicumyl peroxide (DCP, 98%) and triallyl cyanurate (TAC, 50%) were obtained from Akzo Nobel Polymer Chemicals Shanghai, China. Marble waste (MW) was taken from marble cutting industry, dried it at 80 ºC in an oven, ground and passed through the 37 µm sieve.

NBR was blended with LDPE and then with DCP and TAC, which was used as the cross-linking agent as well as booster for DCP, by a Brabender mixer at appropriate ratios as shown in Table 1. The blending time was 15 min at 160° C, speed was kept at 60 rpm .

Table 1: Blend formulations of NBR and LDPE at variation of CPE as Compatibilizer

Ingredients	**Blend ratio**			
NBR/LDPE	100/00	75/25	50/50	25/75
DCP	4.0	3.0	2.0	1.0
TAC	2.5	2.0	1.5	1.0
CPE	0, 5, 10, 15			
MW	30			

2.3. Cure Characteristics

The cure characteristics of NBR/LDPE blend was conducted using a Monsanto Moving Die Rheometer (MDR 2000) according to ASTM D 2084. Samples were tested at a cure temperature of 160 °C for 30 min. The torque was noted every 30 second. The cure rate index was also evaluated using the following relation.

$$CRI = \frac{100}{t_{90} - t_{S2}} \qquad (1)$$

2.4. Abrasion Loss

Abrasion testing was conducted using the ASTM D 5963 test method. The abrasion resistance was expressed as relative volume loss in mm^3. The test was conducted on a Gibitre

2.5. Rebound Resilience

Rebound resilience was determined by the vertical rebound method according to ASTM D 2832 (Gibitre Rebound Check from Italy). All performing tests have been conducted at room temperature.

3. Results and Discussion

3.1. Cure Characteristics

The compositions investigated in this attempt are illustrated in table 1. As it can be observed, compositions 100/00 of NBR/LDPE is simple while 75/25, 50/50 and 25/75 are related to blend and exemplify dynamic vulcanized blends. Owing to the great dissimilarity of surface energy between NBR and LDPE, obtaining good properties for their recipes are elaborated. At present universally recognized that a polar group containing polymer can compatibilized the dissimilar polymers.

As a result of DCP vulcanization crosslinking the polymer molecular weight increases and as a result, the viscosity of the compound also increases. When the vulcanization process is studied by a curemeter (commonly called a “rheometer”), the occurrence of crosslinking, increases the viscosity, which reflected by an increase in rheometer torque.

Figure 1 shows the variant minimum torque values with time for dynamically vulcanized MW filled NBR/LDPE blends of various weight ratios.

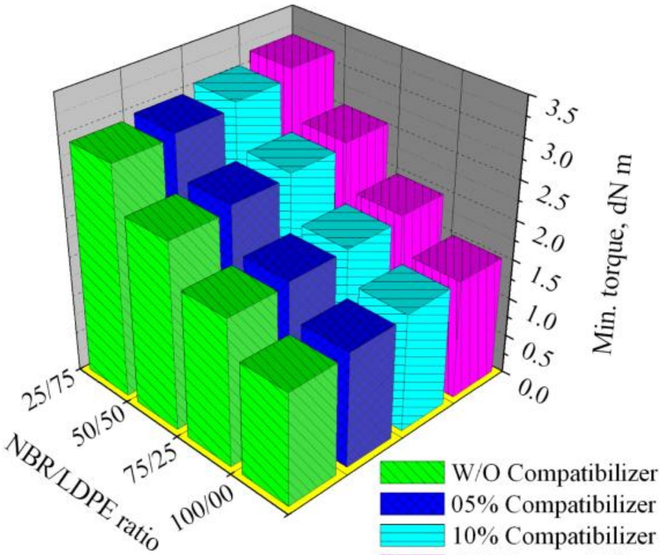

Figure 1. Representation of Minimum torque data.

It could be examined that after incorporation of LDPE in NBR matrix, the addition of the CPE increased the minimum torque value. In all cases the torque values were increased with the increase of LDPE content.

Figure 2 shows the effect of blend ratio and CPE on maximum torque (MT) value of the MW filled NBR/LDPE blends. Hanafi and Hairunezam [16] reported that maximum torque commonly associated with hardness. The enhanced compatibility of particular blends in the presence of CPE as a compatibilizer, where MT value for MW filled NBR/LDPE blends with CPE compatibilizer is higher than the similar blends without CPE compatibilizer. Figure 2 also shows that maximum torque (MT) increases with increase in LDPE content in blend composition. According to Zanzig et al. [17], one approach to improve compatibility of immiscible blends is using block copolymer.

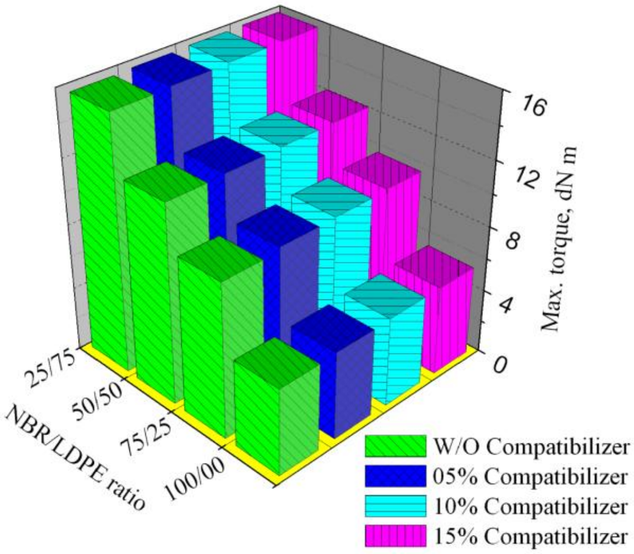

Figure 2. Representation of Maximum torque data.

It is scrutinized that CPE compatibilized blends were effective and maximum torque for dynamic vulcanized blends and higher than the simple blends. It means that maximum torque is more sensitive to the NBR. It may be because that the high LDPE concentration in the composition of particular blend is stiff and it is less sensitive to the applied strain. Thus, the torques rise, as the LDPE concentration increases in the blend. The interaction between filler particles and the polymer chains also prevents the mobility of pendent groups. Filler particles are also hard and have relevant specific surface area, which causes more interactions with rubber chains. Thus, the force extended by the blend during cure process is larger, hence the torques are greater.
Figure 3 shows the effect of blend ratio and CPE as compatibilizer on scorch time, (ts_2) of MW filled NBR/LDPE blends. Obviously, scorch time decreases with increase in LDPE content in the composition of NBR/LDPE blends. The result also illustrates that the ts_2 for MW filled NBR compound is shorter than that of MW filled NBR/LDPE blends. This is due to the crystallinity increased. However, at a similar blend ratio, compatibilized with CPE reveal higher ts_2, than the MW filled NBR/LDPE blends without CPE. This show that the inclusion of CPE as compatibilizer increases the processing safety of the particular blends.

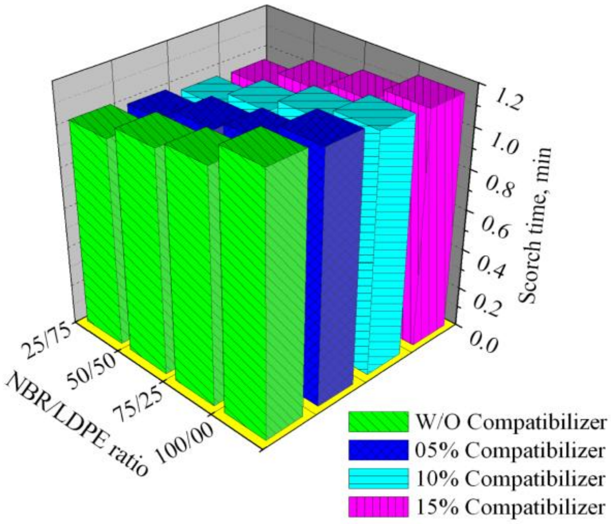

Figure 3. Representation of Scorch time data

Figure 4 shows the effect of blend ratio and compatibilizer on cure time, t_{90} of MW filled NBR/LDPE. Cure time value also revealed a decreasing tendency with increase in LDPE composition in particular blend ratio similar to ts_2. However, at a similar blend ratio, in comparison to the scorch time, the assimilation of CPE as compatibilizer decreased the cure time of the blends. This again designates the valuable effect of CPE as compatibilizer.

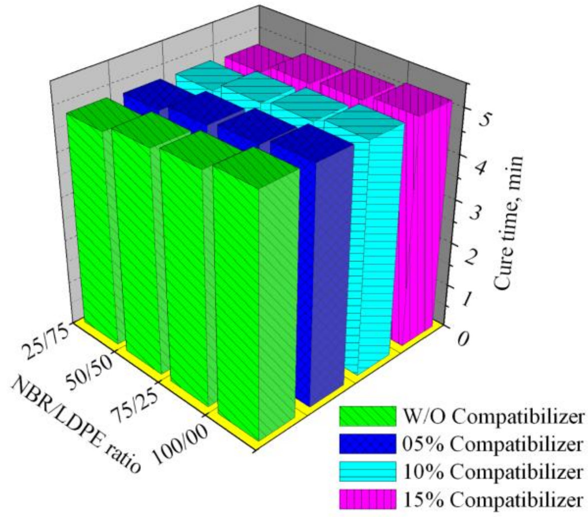

Figure 4. Representation of Cure time data.

Figure 5 presents the curing rate index (CRI) of without and with CPE as compatibilizer MW filled NBR/LDPE blends versus LDPE content. It seems as the LDPE content increases in NBR/LDPE blend ratio, the CRI increases. It can be explained by the fact that the active groups on the NBR are effective in the curing reaction and speed up the vulcanization process. Therefore, with incorporation of more LDPE content in the NBR/LDPE blends the cure process take place in less time and result in higher CRI, while scorch time decreases and cure rate increases. The addition of CPE in the blend affects the cure characteristics of NBR/LDPE blends.

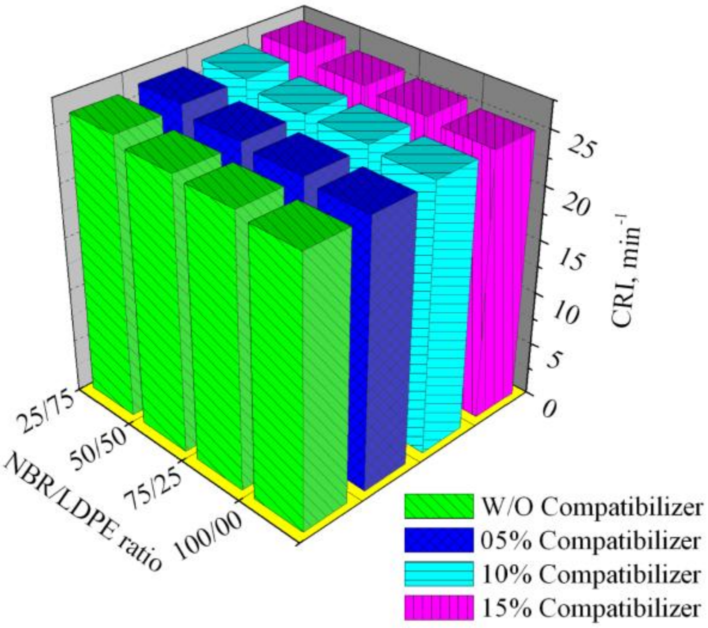

Figure 5. Representation of Cure rate index data.

3.2. Abrasion Loss

The value of abrasion loss, has decreased for all blends with LDPE content up to 75 %. The abrasion lose values for the blends content with three different weight ratio of LDPE, are higher than the MW filled NBR over the whole 75/25, 50/50 and 25/75 blend ratio (Figure 6).

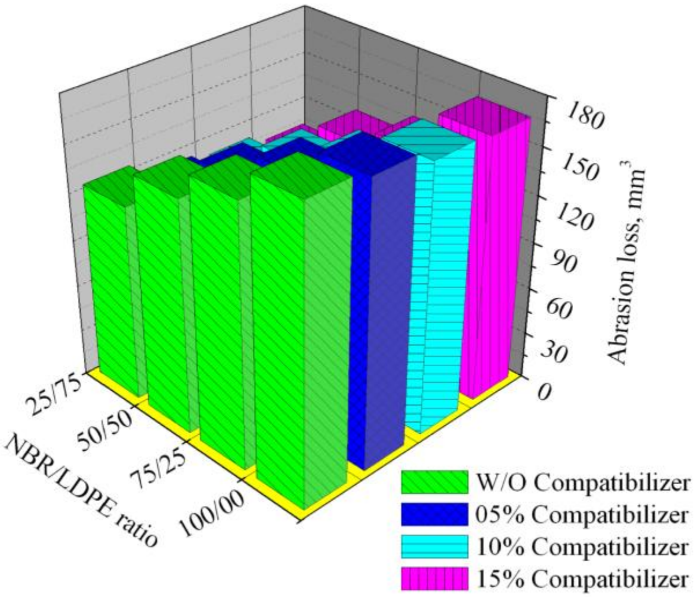

Figure 6. Representation of Abrasion lose data.

The increase in abrasion lose for MW filled NBR/LDPE blends was as follows: 100/00, 25/25> 50/50 > 25/75 blends. This array is also correlated with the addition of CPE in the blend. The increase in CPE is assigned to decrease the magnitude of abrasion lose. For all CPE compatibilized blends it is influential to believe that the reasonable improvement in the abrasion loses may be due to the compatibilization effect of CPE besides the increased induced toughing by LDPE. The compatibilizing effect of the CPE mainly depends on its polarity and amount. Also, CPE exhibits chlorine in their structure which induces the fine dispersion in the blends, which may be attributed to bonding between MW particles and blend constituents.

3.3. Rebound Resilience

The influence of blend ratio and CPE content on the rebound resilience of MW filled NBR/LDPE blends is shown in Figure 7. It can be seen that the reliance of % rebound resilience of the blend is also equal trend to that of abrasion loss, as reported earlier. Both abrasion loss and rebound resilience frequently specify the resistance of the blend to abrasion as well as elastic recovery in presence of LDPE in blends.

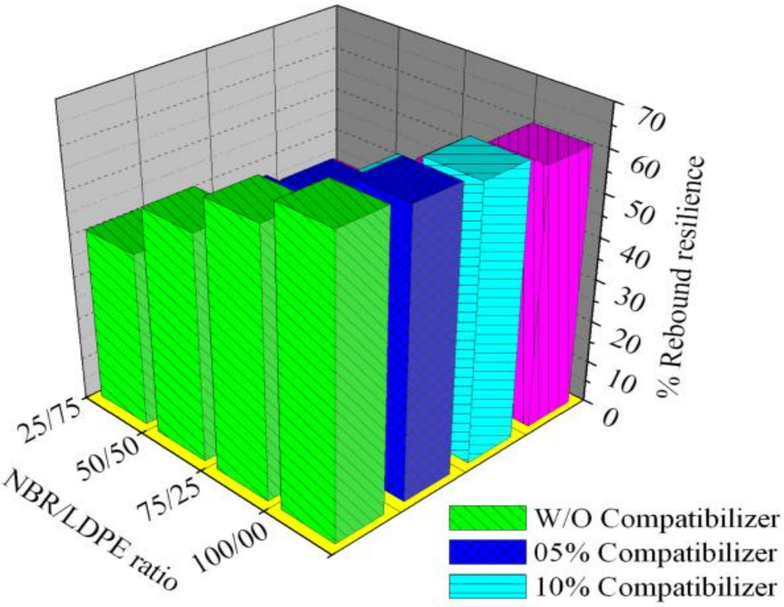

Figure 7. Representation of % Rebound resilience data.

These findings agree with those obtained by several researchers on various unreinforced thermoplastic polymers using a rubber wheel abrasion test; the properties can depend on the composition of the plastic material involved along with the various parameters associated with it [18-20].

Conclusion

The curing behavior of DCP induced cross linked MW filled NBR/LDPE blends was investigated by applying MDR technique, which is appropriate for actual-time isothermal curing study. In this work, the effects of blend ratio and CPE content on the cure characteristics, rebound resilience and abrasion lose of blends were studied and following conclusions were achieved:

1. As the LDPE ratio increased in NBR/LDPE blend the scorch and cure time decreased, and the cure rate increased.
2. Blends containing the CPE showed the shorter scorch and cure time and the slightly increased CRI.
3. As the LDPE amount increased in the particular blends, elasticity decreased as blends showed high minimum and maximum torque values. However CPE compatibilized blend exhibit greater cure torque as compare to prior.
4. With increased LDPE amount, more drops in rebound resilience and abrasion lose were observed, and CPE incorporated blends also showed notable reduction in both properties.

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