© 2017 IJSRST | Volume 3 | Issue 6 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Studies on The Effect of Partial Replacement of Carbon black with Silica on The Mechanical Properties of EPDM Engine mounts

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ABSTRACT

In this work, EPDM containing carbon black and EPDM hybrid composites containing carbon black and silica were developed by melt-mixing on a two roll mill. These composites were investigated for mechanical properties such as tensile strength, elongation at break, tear strength, hardness and compression set. Results revealed that tensile strength, elongation at break, tensile modulus and tear strength of EPDM composites are improved by 6%, 11% ,23% and 10% as 5 phr CB content is replaced by same content of silica loading. Further the hardness and compression set of EPDM hybrid composites are improved. These hybrid composites can be considered to be good alternatives to the conventional CB filled EPDM in engine mount formulations.

Keywords : EPDM, Carbon Black, Hardness, Tensile Strength, Tear Strength, Compression Set.

I. INTRODUCTION

Ethylene–propylene–diene terpolymer(EPDM) is widely used in automobile sectors due to its good aging properties and high filler-loading capacity[1]. Fillers are mainly added into EPDM rubber matrices with the prime motto of improving the service properties and in many cases to reduce the material cost. The performance of a filler is determined by its characteristics [2–3]. Reinforcement is primarily the enhancement of strength and strength-related properties, abrasion resistance, hardness and modulus [4,5]. In most applications, carbon black (CB) and silica have been used as the main reinforcing fillers that increase the usefulness of rubbers. When CB is compounded with rubbers, tensile strength, tear strength, modulus and abrasion resistance are increased. For this reason, CB has been extensively exploited in numerous rubber engineering products [6]. In general, a CB-reinforced rubber has a higher modulus than a silica-reinforced one. The effects of mixing procedure, different CBs, and sequence of addition of plasticizer on the EPDM vulcanizate properties were studied [7].The hot air ageing properties of EPDM rubber reinforced with various fillers (kaolin, quartz, PVC, talc, graphite, medium thermal CB, semi-reinforcing and high-abrasion CB) were studied[3]. The effect of untreated and nitric acid-treated conductive CB on the mechanical properties of EPDM were investigated [8].

However, silica provides a unique combination of tear vnnjm strength, abrasion resistance, aging resistance and adhesion properties [9]. In tire treads, silica yields a lower rolling resistance at equal wear resistance and wet grip than CB [10]. The effects of coupling agent [(triallyl cyanorate (TAC)] on peroxide vulcanization and mechanical properties of the precipitated silica-filled EPDM were studied[11].

Since CB and silica possess their own advantages, the utilization of hybrid filler or blends of silica and CB in rubber should give the benefits from each filler. It is stated that the addition of precipitated silica in CB-filled rubber components can be applied to tire treads, wire and fabric coating, conveyor belts, hoses, rubbercovered belts,engine mounts, bumper strips, and cable jackets[12]. Although several past studies have been made to elucidate the hybrid filler systems, systematic scientific report on the effect of silica/CB ratio on the properties of EPDM rubber vulcanizates is scarce.

Hence in the present work, 60phr CB filled EPDM based engine mount is taken for study. 5phr of CB in the EPDM engine mount formulation is partially replaced with 5phr of silica. The synergistic effect of CB/silica hybrid filler on the tensile strength, tear strength, hardness and compression set of EPDM composite is investigated.

II. METHODS AND MATERIAL

2.1 Materials

EPDM with Mooney viscosity (ML(1+4) at 100°C) of 60 Mooney unit supplied by SGS rubber industries Pvt. Ltd ,chennai India is used as the matrix. Carbon black, Zinc oxide, Stearic acid, Sulphur, Sunpar 2280, Tetramethylthiuram disulphide and perkadox 14/40 of industrial grade are supplied by Ramcharan chemicals, chennai, India and used as received.

2.2 Preparation of EPDM composites

Table 1. Formulation of EPDM composites.

Ingredients (Phr [a])	CB60	CB55 Si5
EPDM	100	100
CB	60	55
Silica	0	5
Stearic acid	2	2
Zinc oxide	5	5
TEA	0	10
Sunpar 2280	2	2
S-80	0.3	0.3
Perkadox 14/40	9	9

The EPDM compunds were prepared by melt-mixing on a laboratory sized open two roll mill(160 mm X 320 mm) at room temperature and at a speed ratio of 1:1.4 as per ASTM D3182. The compound recipe for EPDM composites is given in Table 1. Processing aids and rubber are first blended. Then CB, Silica and curatives are added orderly. The samples are then cured at 160° C in an electrically heated hydraulic press for their respective cure times (t_{90}) determined from oscillatory disk rheometer measurements.

2.2 Mechanical properties

2.2.1 Tensile properties

Dumbbell shaped samples are cut from compression moulded sheets according to ASTM D412 for tensile testing. The tests were conducted according to ASTM D-624 on a universal testing machine (Dak system Inc.,7200) at a crosshead speed of 500mm/min. Five samples are taken for each compound and their averages were reported.

2.2.2 Tear strength

Tear tests are conducted using crescent shaped specimens according to ASTM D624. The tests are conducted using a universal testing machine (Dak system Inc.,7200) at a crosshead speed of 500mm/min. Five samples are taken for each compound and their averages were reported.

2.2.3 Hardness

Hardness is determined using Shore A hardness durometer according to ASTM D2240.

2.2.4 Compression set

Compression set are determined in accordance with ASTM D395. Cylindrical button samples of 29mm diameter and 12.5 mm thickness are prepared from the molded slabs. The buttons are placed between the steel plates in a compression device. The plates are tightened using bolts and steel spacers are used. The buttons are then compressed to 25% of its original thickness and held at 100°C for 22hrs. After the test period, the button specimens are removed from the compression device and subjected to a cooling 30-

minute period. The specimens are measured using a dial micrometer and the compression set is calculated as a percentage of the specimen original thickness.

III. RESULTS AND DISCUSSION

3.1 Tensile properties

The tensile properties of EPDM composites are shown in figure 1. Examination of data presented in Figure 1, it is apparent the tensile strength increases by 6 % with the partial replacement of CB with silica. Such an enhancement in tensile strength is attributed to (i) enhanced CB-Silica-EPDM interactions and (ii) improved dispersion of CB and silica in the EPDM rubber. Strong interactions allow more efficient load transfer and hence better tensile strength [13].

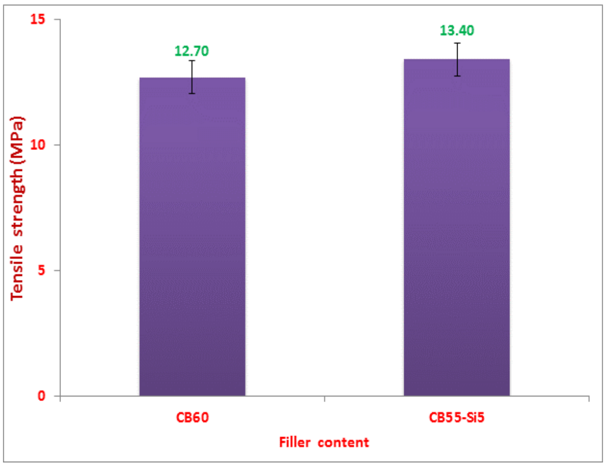

Figure 1. Tensile strength of EPDM composites.

Further it is evident from Figure 2, elongation at break of EPDM composites increases by 11% with the partial replacement of CB with silica. With the incorporation of silica in EPDM matrix, the polymer – filler interactions(EPDM-CB-Silica) are enhanced Because of the aforementioned interactions, the polymer can absorb more energy, which is used to decoil the chains to a greater extent, thus giving higher elongation at break[14].

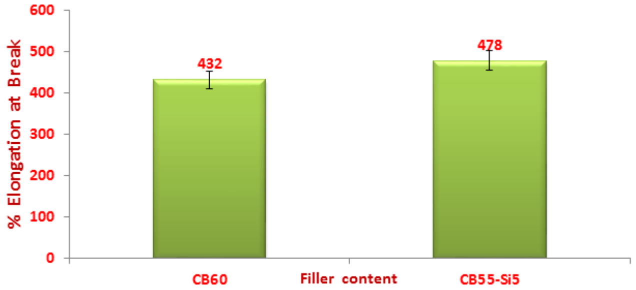

Figure 2. Elongation at break of EPDM composites.

The tensile modulus M_{100} (Sown in Fig, 3) of the EPDM increases by 23% with the incorporation of silica in the EPDM matrix. With the addition of silica, the EPDM matrix becomes stiffer attributed to hydrodynamic effect and is reflected as increase in the 100% modulus value.

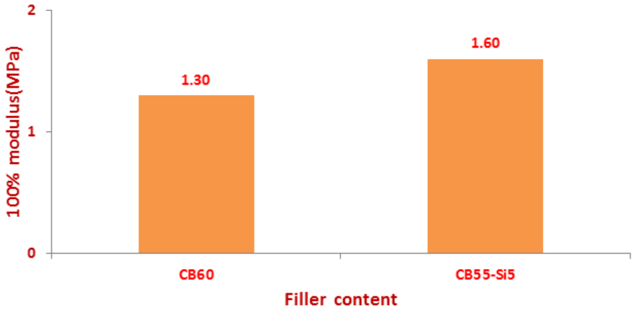

Figure 3. 100% Modulus of EPDM composites.

3.2 Tear strength

Tear strength of EPDM composites are presented in Figure 4 It is worth noting that the tear strength of EPDM content increases from 24.3 KN/m to 26.7 KN/m or by 10% when the content of CB is partially replaced by silica content. The tearing of rubbers has two different stages: the deformation of the crack tip followed by the growth of the cut. Stress dissipation at the tip of a growing crack through a viscoelastic process results in high strength of the rubber composite. When suffering from load, the interaction between CB and the EPDM rubber matrix can easily allow for the orientation of the CB particles . The oriented CB particles can act as bridging elements that have strong resistance to crack initiation and propagation and thus prevent failure at low stresses. Additionally, these CB particles bridge silica to form a local filler network, which ensures an effective load transfer from the matrix to the fillers. All these factors may lead to an increase in the energy dissipation and crack resistance of rubber nano composites during deformation.

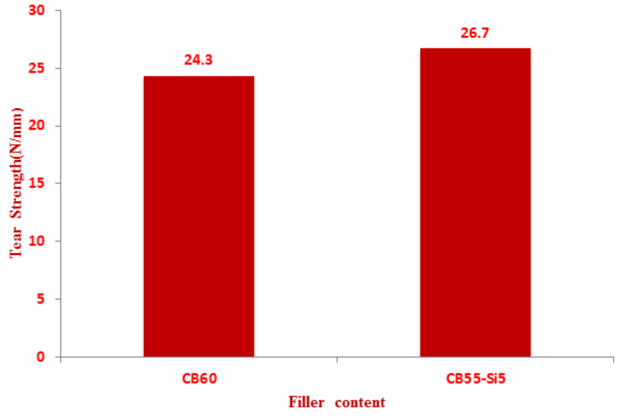

Figure 4. Tear strength of EPDM composites.

3.3 Hardness

Hardness is primarily influenced by the distribution of rigid particles in the rubber matrix. It can be inferred from Fig. 5. that Hardness of EPDM composites increases from 49 to 53 shore A as the CB content ispartially replaced increased by silica. The better performance of EPDM composites containing hybrid fillers in terms of hardness can be attributed to increase in crosslink density of the composites[15].

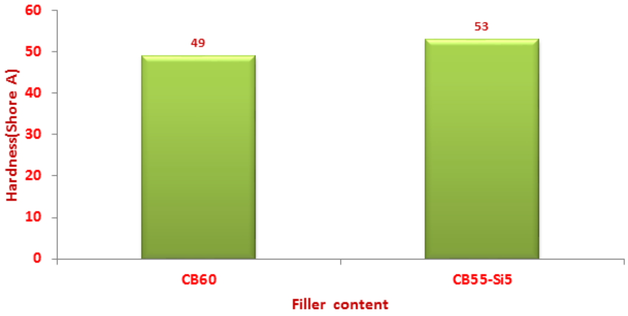

Figure 5. Hardness of EPDM composites.

3.4 Compression set

Compression set of the EPDM composites are shown in Fig. 6. It can be observed that compression set of EPDM composite decreases with the partial replacement of carbon black with silica. The better performance of EPDM composites reinforced with both CB and silica in terms of compression set can be attributed to enhanced EPDM-CB-silica interactions and formation of permanent cross-linked chains networks. These networks which are unable to relax during compression state cause elastic recovery during recovery stage and thereby leading to lower compression set values[16].

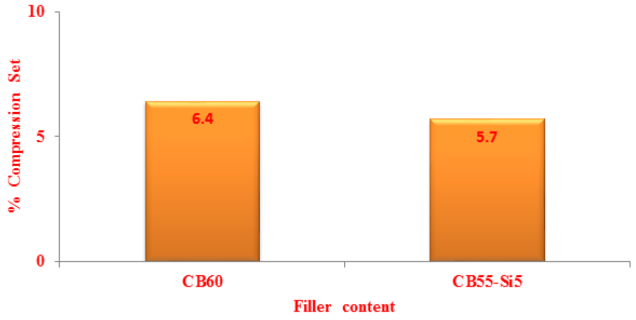

Figure 6. Compression set of EPDM composites.

IV. CONCLUSION

The following conclusions are derived based on the experimental works carried on EPDM-CB composites.

1. Good dispersion of CB and silica filler in EPDM matrix and enhanced EPDM-CB-silica interfacial interactions improved the mechanical properties of the EPDM composites.
2. Tensile strength of EPDM composites increases by 6% as the CB content is partially replaced by silica.
3. The elongation at break of EPDM composites increases by 11% as the CB content is partially replaced by silica.
4. The 100% modulus of EPDM composites increases by 23% as the CB content is partially replaced by silica.
5. The tear strength of EPDM composites increases by 10% as the CB content is partially replaced by silica..
6. The hardness of EPDM composites increases from 49 to 53 shore A as the CB content is partially replaced by silica.
7. The Compression set of EPDM composites increases from 6.4 to 5.7 A as the CB content is partially replaced by silica.

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