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Evaluation Of Calcium Carbonate As Filler In The Production Of Middle Polyvinyl Chloride (Pvc) Carpet

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Abstract: The use of filler in polymer products is as old as the polymer industry itself. Fillers such as ground whiting, clay or barytes are added to cheapen the production cost and improve the properties of the final vulcanized products. In this work, the effect of Calcium Carbonate ($CaCO_3$) (filler) in the production of middle layer of PVC carpet was considered and evaluated. The Calcium Carbonate ($CaCO_3$) filler was characterized in terms of moisture content, size (mesh), density and pH value. Eight formulations were prepared: one formulation each for upper layer and back layer, and six formulations for middle layer. The six formulations consist five containing Calcium Carbonate ($CaCO_3$, 700mesh) filler at loading ranging from 20part per hundred (pphr) to 60part per hundred (pphr), while the last formulation for the middle layer contained carbon black at 60pphr as a control. Compounding was carried out using banbury mixer, mixer rollers and calendaring machine. The product was subjected to various tests including resistance to moisture, solvent, lubricating oil and palm oil. The results showed that $CaC0_3$ used was alkaline, with pH value of 9; has density of 0.12g/cm^3 and a moisture content of 0.0%. The results also showed that $CaCO_3$ at 30 - 40pphr, the resistance to solvent was better, but decreases as the loading increased from 50 - 60pphr. When compared to unfilled product, the $CaCO_3$ filler proved to be a good semi reinforcement filler compared with carbon black.

Keywords: *$CaCO_3$ Filler, Middle Layer PVC Carpet, Filler Properties, Compound Formulation, Reinforcement, Resistance to Solvents.*

I. INTRODUCTION

The use of filler in polymer products can be traced back as far as the use of polymer itself. As soon as polymer (rubber or plastic) mixing machinery was developed, fillers such as ground whiting, clay or barites was added to reduce the cost of production and also to improve on the properties of the final products (Blow, C.M. & Hepburn, C., 1978). Zinc Oxide, originally used for whiteness, was the first active filler. This fact was recognized after the work of Ditmas in 1905 and the discovery in 1994, and development of carbon black to become the most important powder used in polymer industries.

Organic fillers have made their appearance at various times in literature and the market without over obtaining a significant place. In most cases, they were incorporated in the latex phase or melt phase rather than in the dry rubber. Reinforcing resins were introduced when Lebvas and Picnic (1951) prepared resorcinol Formaldehyde condensate to the intermediate resole stage and added aqueous solution to rubber latex. Another development in fusion was the particulate filler. These are powder of very fine particles sizes and high surface area. They were incorporated in polymer products by mixing these groups of fillers and were widely used to improve on general properties such as tensile strength, tear strength, abrasion resistance, hardness and modulus of polymer compound (Asore, E.J., 2002 and Blow, C.M. & Hepburn, C., 1978).

There is a limit to the hardness and modulus that can be achieved in polymer vulcanization alone. It is therefore necessary to add materials which will increase the hardness and modulus to the desired level. These materials are generally called fillers. They constitute the second largest materials, in terms of quantity, in polymer products after the base polymer when compounding. Fillers are not only added to improve harness and modulus but also to enhance processability, resistance to abrasion, tensile strength and tear strength. Filler are also incorporated in polymer matrix to reduce cost of production as well as to serve as pigment (Asore, E.J., 2002). The term filler refers to solid additives which are added to the rubber or plastic materials to enhance their properties (Harper, C.A., 1997).

Reinforcement has been defined as the incorporation into rubber of small particles which give to the vulcanization high abrasion resistance, high tear and tensile strength as well as some improvement in stiffness. The concept of reinforcement relate basically to composites built from two or more structural components of different mechanical characteristics in which the strength of these components is imparted to the composites and combined with the set of favourable properties of the other components (Blow, C.M. & Hepburn, C., 1978).

Reinforcing fillers improve the modulus and failure properties of the final products. Carbon black acts as reinforcing agent while other valuable fillers help to adjust the hardness and processing characteristics.

In this work, calcium carbonate was used as a reinforcing filler in the production of middle layer of PVC Carpet at different loadings ranging from 20pphr – 60pphr has been evaluated and compared to the Carbon Black at 60pphr loading in terms of the resistances to solvents such as water, kerosene, palm oil and petrol. The results showed that Calcium Carbonate is a good reinforcing filler that enhances the resistances of the final products to solvents if controlled quantity is used.

II. METHODOLOGY

Materials:

The reagents used in his work are PVC Resins, $CaCO_3$, DOP Liquid, BC 320, Pb St, PM 645, Stearic Acid, TBLS, Carbon Black, All these materials are of industrial grades. Water, Kerosene, Palm Oil and Petrol.

Equipment:

The apparatus employed are Banbury Mixer, Mixing Roller, Inverted L Calendar Configuration, Laminating Machine, Petri-dish, Weighing Balance, Oven, Volumetric Cylinder, Relative Density Bottle.

Experimental Procedures:

Determination of Moisture Content:

The weight of the empty dish, W, was determined. 10g of the fresh filler ($CaCO_3$) was placed in the Petri-dish, weighed and recorded as W_3. This was then placed in an oven at temperature $65^oC \pm 5^oC$ for 1hour 30minutes. The sample was removed from the oven and allowed to cool to room temperature. The new weight was measured and recorded as W_2. Thus, the moisture content was evaluated as given below:

$$\% \text{ Moisture Content} = \frac{W3 - W2}{W3 - W} \times 100$$

This value is an indication of the accurate weight of the filler and also reduces defects such as voids, bubbles.

Determination of Filler Density:

The density of the filler was determined using immersion method. A volumetric cylinder was half filled with water and its volume recorded as V_1. An empty density bottle with cap was weighed and weight recoded as $W_1$and then immersed in the volumetric cylinder. The volume of distilled displaced was recorded as V_2. The density bottle was then filled with the filler ($CaCO_3$) and closed tightly with the cap and immersed in the cylinder. Its weight and volume of water displaced was measures and recorded as W_2 and V_3 respectively. Thus, the relative density of the filler is evaluated as given below:

$$\text{Relative Density} = \frac{W2 - W1}{V3 - V1}$$

Compounding and Calendering:

The PVC, filler and other reagents were measured in the right proportion and fed into Banbury mixer. A batch factor of four was used. After few minutes, the mixture was passed to the mixing roller through the conveyor belt where effective mixing was obtained. The final thickness of the sheet was obtained in the calendering section. The calendering nip was set to accurate thickness of the layer about 0.04mm thickness was used for upper layer, 0.08mm thickness for middle layer and 0.24mm for the back layer. The total thickness of the PVC carpet from these three layers composite was 1.04mm. This was achieved by laminating the layers together.

Resistance to Solvent Test

A small quantity of the test piece was cut and weighed, W_1. It was allowed to remain in water (solvent) for 24hours after which it was removed, cleaned and re-weighed W_2. Thus, the resistance to moisture is evaluated as given below:

$$\% \text{ Absorbed Moisture} = \frac{W2 - W1}{W1} \times 100$$

The higher the moisture absorbed, the lower the resistance to moisture. This procedure was repeated using Kerosene, Palm Oil and Petrol as solvent and the resistances were determined accordingly.

III. RESULTS AND DISCUSSIONS

3.1 Results:

The results of the evaluation of calcium carbonate Filler in the Production of Middle Layer PVC Carpet are presented as follow:

Table 3.1 Properties of Calcium Carbonate ($CaCO_3$) used in this work

S/N	PARAMETERS	VALUE
1	Moisture Content (%)	0.00
2	Particle Size (mesh)	700.00
3	Density (g/cm^3)	0.12
4	pH Value	9.00

In Table 3.1 above, the moisture content of the filler is often used to predict the degree of defect arising from shrinkage during processing of products at elevated temperature. Thus, if the moisture content of the filler is known, such effects could be reduced or eliminated by pre-heating the filler. This problem is associated with $CaCO_3$ due to its powdery nature. The particles size of the filler helps to improve the reinforcing properties of the filler. The smaller the particle size, the more the filler can be easily dispersed. The density of the filler determines the bulkiness of the product. If the density is too low, a higher volume of the filler will be required and this will lead to an increase in the bulkiness of the products.

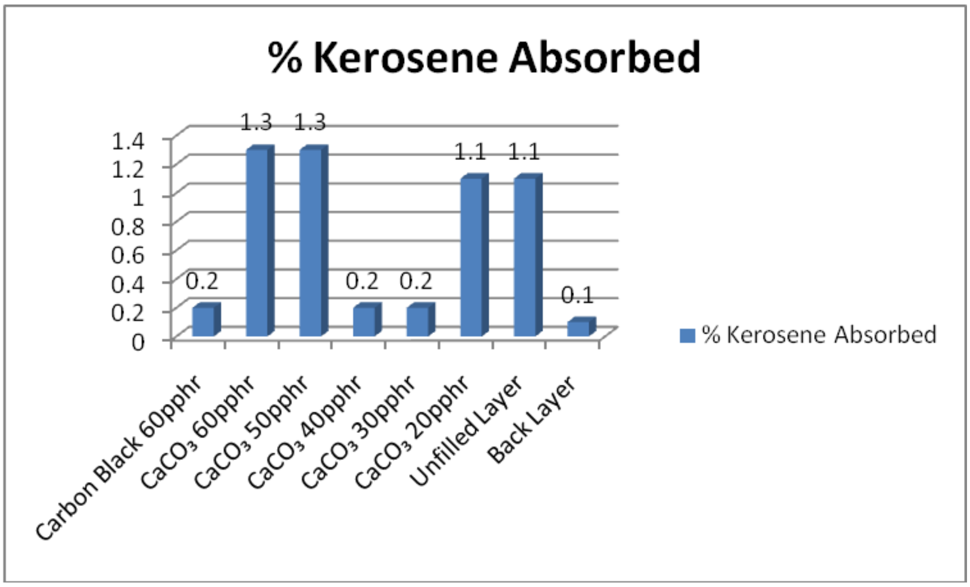

Fig. 3.1: % Kerosene Absorbed against Filler Loading in the three PVC Layers

Fig. 3.1 shows that the resistance to kerosene absorption is improved by increasing the $CaCO_3$ filer loading from 30pphr to 40pphr while there was considerable decrease in this resistance to kerosene absorption from 50pphr to 60pphr.

In Fig. 3.1 above, it is evident that the resistance to kerosene absorption is improved by increasing the filler loading from 30pphr to 40pphr and considerably decreased from 50pphr to 60pphr for the $CaCO_3$ filler. The carbon black filler loading at 60pphr has resistance of 0.2% compared to 60pphr loading of $CaCO_3$. The back layer has a better absorption due to its composite nature. Fig. 3.1 also revealed that the resistance of the layers to kerosene is good. As such, they can be used in such areas of application with better modification to give excellent services.

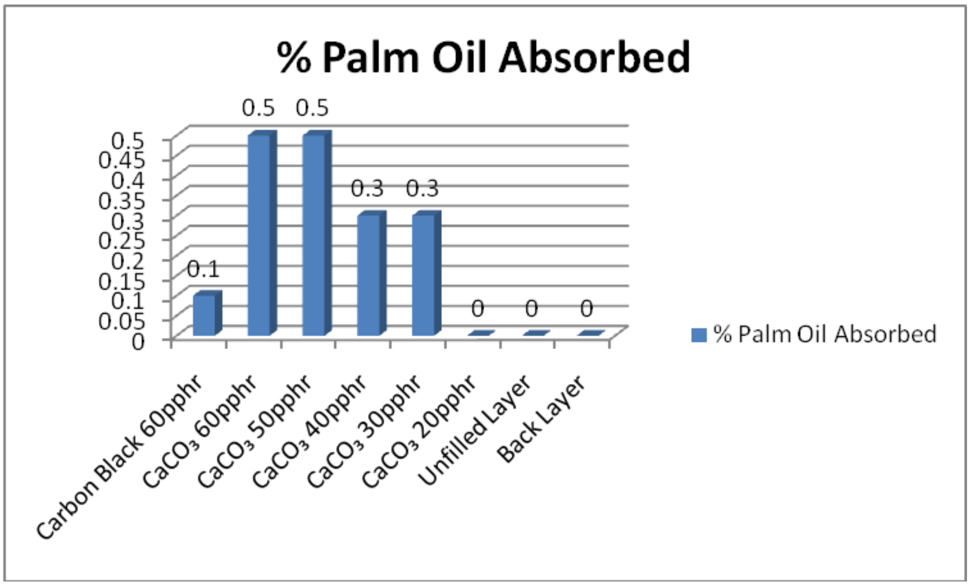

Fig. 3.2: % Palm Oil Absorbed against Filler Loading in the three PVC Layers

Fig. 3.2 above shows that the resistance to palm oil absorption is good. An increase in filler loading to some extent, gave good resistance to palm oil and the rate decreases from 50pphr. This implies that the $CaCO_3$ filler will give poor resistance to palm oil if the quantity used is not controlled. Meanwhile, carbon black was found to be more resistant to palm oil absorption than $CaCO_3$ at filler loading of 60pphr, indicating that carbon black is more reinforcing than $CaCO_3$.

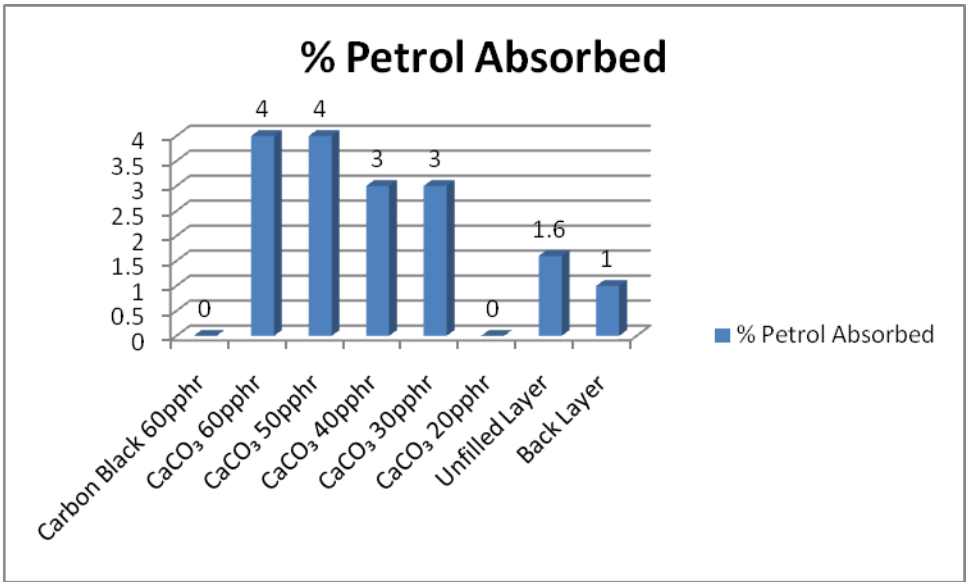

Fig. 3.3: % Petrol Absorbed against Filler Loading in the three PVC Layers

Fig. 3.3 shows that the resistance to petrol absorption is good to some extent by increasing the $CaCO_3$ filler loading from 20pphr to 40pphr while the resistance to petrol absorption was quite poor from 50pphr to 60pphr.

Similarly, it is obvious as shown in Fig. 3.3 that the resistance to petrol absorption is good, though at 30pphr to 60pphr of $CaCO_3$ filler loading, the resistance tends to decrease. At 20pphr $CaCO_3$ filler, the value of resistance to petrol absorption is the same as that of the 60pphr carbon black. This means that the $sCaCO_3$ filler could be an excellent reinforcing agent if the quantity used is well-controlled. The figure also revealed that the resistances of the filled and unfilled layers are good.

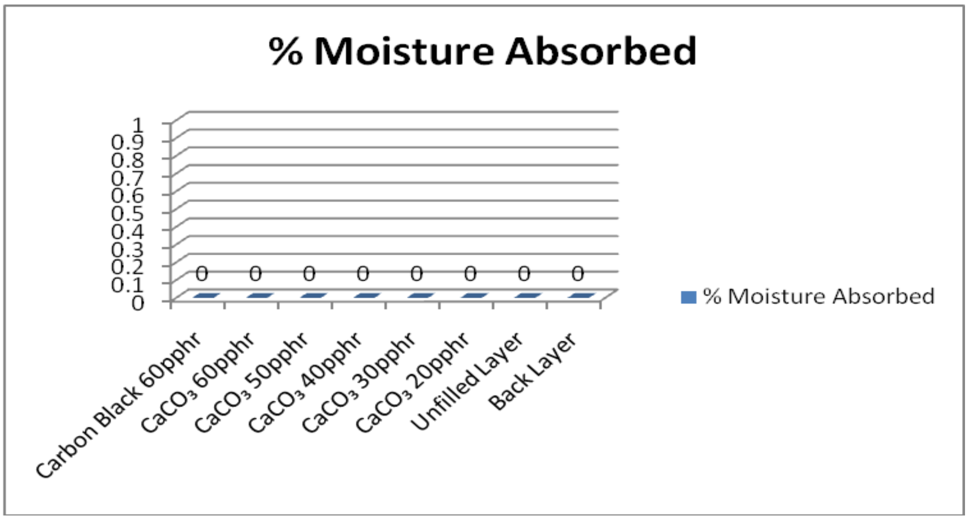

Fig. 3.4: % Moisture (Water) Absorbed against Filler Loading in the three PVC Layers
Fig. 3.4 shows that the resistance to water absorption is excellent for all the $CaCO_3$ filler loading

In Fig. 3.4 above, it is obvious that the PVC layers do not absorb water. As a result, the resistances of the fillers at all loading are excellent. This will increase their applications in areas where they can easily come in contact with water. There was no swelling after being soaked in water for 24 hours. The high resistance to water absorption can increase the applications of the layers in marine applications.

IV. CONCLUSION

The filler particle size should be very small to allow enough surface area exposure which will apparently improve the mechanical properties. The particle size may vary from 200 mesh and 700 mesh. Comparing the variations between the reinforcing properties of the filled and unfilled layers, the mechanical properties of the unfilled layer is lower than that of the filled layers. This indicates the reinforcement of $CaCO_3$ filler, though the properties tend to decrease from 50pphr and 60pphr. The layer containing carbon black at 60pphr has higher physico-mechanical properties. This means that Calcium Carbonate ($CaCO_3$) filler at 30pphr and 40pphr are most preferable to other Calcium Carbonate ($CaCO_3$) filled layers for applications which easily come in contact with solvents. The back layer had better resistance to solvents when compared to the upper and middle layers due to its composite nature.

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