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IMPACT STRENGTH OF PVC-U – EFFECT OF CALCIUM CARBONATE PARTICLES SIZE

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ABSTRACT

Unmodified unplasticised PVC (PVC-U) has the disadvantage of being prone to occasional brittleness and is notch sensitive. To increase the impact resistance, a multi-phase systems consisting of PVC with various additives such as impact modifiers and fillers were developed and are being used in windows frame formulations. There has been considerable effort and interest in the addition of calcium carbonate fillers to the impact-modified PVC-U formulations to modify properties and also to reduce cost. This paper reports the use of Instrumented Falling Weight Impact tester to determine the effect of calcium carbonate fillers on impact strength of impact-modified PVC-U. Scanning Electron Microscopy analysis had also been carried out to correlate the impact strength and the microstructure of the fracture surfaces. The results show that the impact strength of impact–modified PVC-U increases with decreasing calcium carbonate fillers particle size.

Key Words : Fillers; Impact modifier, Poly(vinyl chloride)

1.0 INTRODUCTION

Unplasticised PVC (PVC-U) for high-performance interior and exterior applications is frequently modified with polymeric impact modifier. Although impact modifiers are very effective in improving the impact strength of PVC-U, they are costly. In order to reduce cost, the use of fillers has received increased attention [1].

Calcium carbonate filler is one of the important additives in the PVC-U window frame formulation [2]. Calcium carbonate can also act as impact modifier at certain optimum particle sizes and level of loading. Previous studies have shown that the addition of stearate coated, small-particle-size calcium carbonate fillers improve both notched Izod and drop weight impact strength of PVC profiles [2]. Therefore, a study on the effect of particles size of calcium carbonate on impact strength of PVC-U was conducted using the commercially available natural ground and precipitated. The impact testing were carried out by using Instrumented Falling Weight Impact (IFWI) testing machine. IFWI testing machine is a more versatile and qualitative compared to conventional testing machines as it provides a complete force-deflection curve for the event, allowing the failure process to be monitored and analysed. Scanning Electron Microscopy (SEM) analysis was also carried out to correlate between impact testing results and microstructure.

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2.0 EXPERIMENTAL

The PVC used in this study is a suspension resin with solution viscosity K-value 66 supplied by Industrial Resin Malaysia. The additives used are shown in Table 1. Two types of calcium carbonate fillers are used: precipitated (0.8μm) and natural ground (1, 3, 6 and 10μm).

Table 1 Types and suppliers of additives

Additives	Types	Supplier	Parts per hundred of PVC resin
Impact Modifier	Core/shell Acrylic Modifier	Elf Atochem	As specified
Filler	Precipitated $CaCO^3$	Schaefer Honaik	As specified
Filler	Natural Ground $CaCO^3$	MCC (3, 6 & 10μm) Sun Minerals (1μm)	As specified
Tin Stabilizer	Tin	Elf Atochem	2.0
Internal Lubricant	Calcium Stearate	Sun Ace Kakoh	0.5
External Lubricant	Stearic Acid	-	0.6
Processing Aids	Acrylic Polymer	Kaneka Malaysia	1.5
Pigment	Titanium Dioxide	-	4.0

The dry blending of PVC and additives was done using high-speed mixer for 14 minutes. To produce moulded samples for impact testing, the dry blends of PVC and additives are sheeted on a two-roll mill before compression moulded to form charpy test bars according to BS2782: Part 3: Method 359 (1984).

The impact strength assessment was performed using the Rosand IFWI testing machine and the impactor was dropped from a height of 460 mm to give an impact speed of 3 m/s. Scanning electron microscopy was done to analyse the fracture surfaces of the impact test samples. The fracture surfaces were prepared for SEM examination by sputter coating with gold on biotech machine. Then Philips XL40 was used to examine the coated surface with the working voltage of 10kV.

3.0 RESULTS AND DISCUSSION

The effect of calcium carbonate particles size on the impact properties of impact-modified PVC-U is shown in Figure 1. The content of filler and impact modifier were fixed at 20phr and 6phr respectively. The results clearly show that impact strength decreases with increasing particles size. The precipitated calcium carbonate (0.8μm) is the most effective filler in enhancing the impact strength. This is followed by samples filled with 1μm natural ground calcium carbonate particles. Interestingly, a sharp decrease is observed as particles size increases from 0.8μm to 1μm. A more gradual decrease is seen with a further increase of fillers particles size from 1 to 10μm. The ten-fold increase in filler particle size (from 1 to 10μm) results in a 50% decrease of impact strength (from 15.05 to 7.65 kJ/m^2)

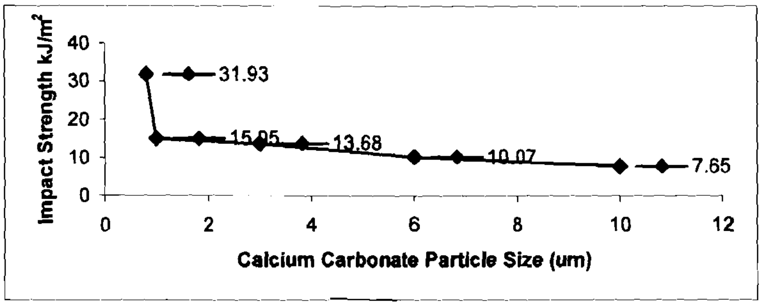

Figure 1 Effect of Particles Size on Impact Strength

One of the major functions of core/shell impact modifiers in improving the impact resistance of a plastic is to act as stress concentrators located through the polymer matrix [3]. The stress concentrations are produced at the equator by the large difference that exists between the modulus of the rubber impact modifier particles and the polymer matrix. These localized concentrations stress when dispersed throughout the polymer matrix provide multiple sites at which shear yielding of the polymer can be initiated simultaneously upon impact.

Providing stress concentrations in a PVC-U is not a function unique to impact modifiers, however. Calcium carbonate can also serve this function and consequently increase the impact resistance, although not necessarily as effectively as impact modifiers. In this case, a tensile stress is amplified at the poles rather than at the equator of the particle and a much reduce stress is found at the equator. Even though the stress distribution produced by the calcium carbonate is different from the ones produced by the impact modifiers, the stress concentrations are still able to induce shear yielding resulting in an increase in the impact resistance of the PVC-U. The effectiveness of the smaller particles can be explained in the increase in the numbers of stress concentration sites with decreasing particles size.

Another investigation that was done is the effect of calcium carbonate content on impact strength for samples without impact modifier. The filler used in this study is precipitated calcium carbonate (0.8μm) and natural ground (1μm). The results show that the samples with 0.8μm average particle size are more effective than 1 μm in enhancing the impact strength of PVC-U samples at all filler content level. Refer to Figure 2. For the samples containing 0.8μm particles size, the impact strength increases with increasing filler content level. However for the samples containing 1μm, a slight gradual decrease in impact strength is observed as the filler content level increases from 5 to 20phr

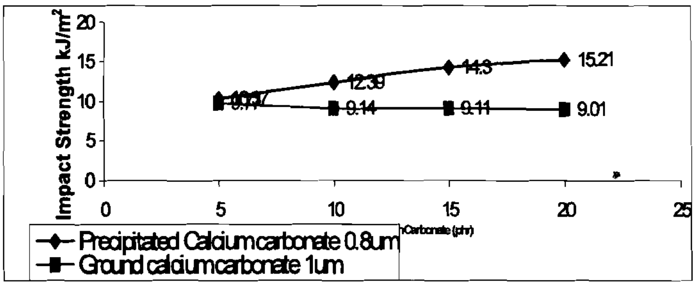

Figure 2 Effect of Fillers Content Level on Impact Strength on Unmodified PVC-U

Figure 3 shows the SEM micrographs taken from the impact-modified PVC-U samples containing 8μm calcium carbonate with impact strength of 31.93 kJ/m^2. The micrograph shows evidence of yielding and fibrillation suggesting high impact energy has been absorbed. The SEM micrograph in Figure 4 is from the sample containing 10μm calcium carbonate with impact strength of 7.65kJ/m^2. The micrographs shows jagged and cratered appearance with no evidence of yielding seen at the fracture surface. It's correlates with the low impact strength of the sample.

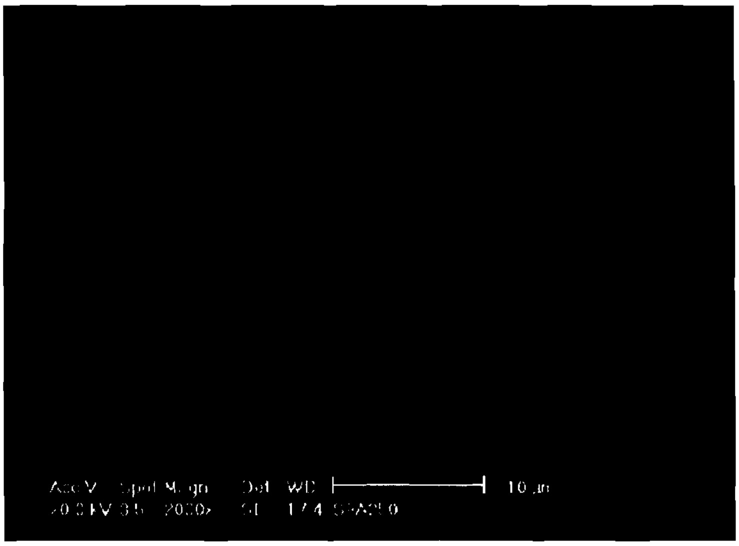

Figure 3 SEM Micrograph of Impact-modified PVC-U Sample Filled 0.8μm Precipitated Calcium Carbonate (Magnification X 2000)

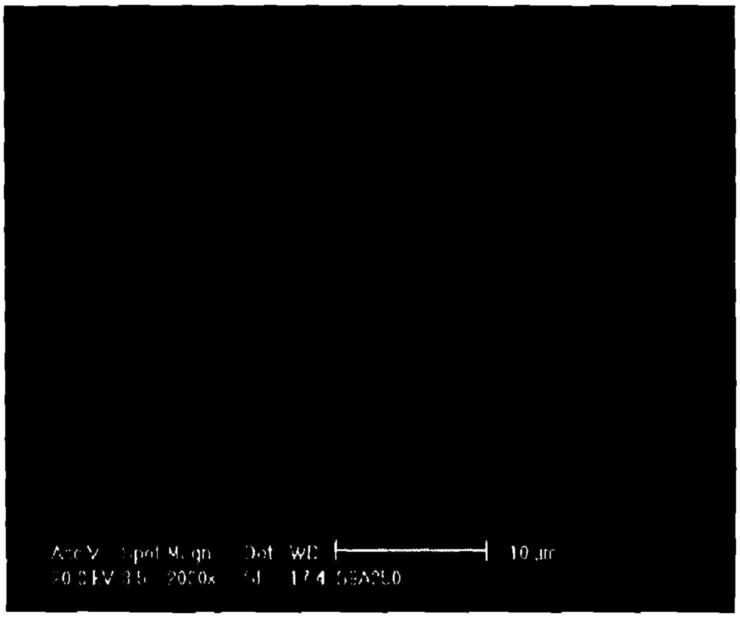

Figure 4 SEM Micrograph of Impact-modified PVC-U Sample Filled 10μm Precipitated Calcium Carbonate (Magnification X 2000)

4.0 CONCLUSIONS

The main conclusions that can be derived from the study are as follows:

(1) The impact strength of impact-modified PVC decreases with increasing particles size for samples containing 20phr filler content level. The precipitated calcium carbonate (0.8μm) is the most effective filler in enhancing the impact strength.

(2) The impact strength increases with increasing filler content level from 5 to 20phr for the unmodified PVC-U samples containing 0.8μm precipitated calcium carbonate. However, for similar increase of filler content level, impact strength of samples containing 1μm calcium carbonate decreases.

(3) Evidence from the SEM micrographs taken from fractured samples correlates with the impact strength values obtained from IFWI test of 31.93 kJ/m^2. The micrograph which shows yielding and fibrillation has high impact strength values compared to the micrographs which shows jagged and cratered appearance.

(4) The study demonstrated the possibility of lowering the impact modifiers content from the formulation containing precipitated calcium carbonate product.

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