Mechanical Properties of Talc and Calcium Carbonate Filled PVC

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Abstract

The main aim of this work was to compare the mechanical properties of calcium carbonate ($CaCO_3$) and talc filled PVC. Talc and $CaCO_3$ are common fillers in plastics such as PVC to reduce cost and modify mechanical properties. The PVC resin and additives were blended by using high speed laboratory mixer to produce a homogenized PVC formulation. Then, the dry blended samples were melted and sheeted on the two roll mill machine. The sheeted PVC compounds were compression moulded into impact and flexural test specimens. Flexural and impact tests were then performed to determine and compare the mechanical properties of both PVC composites. Talc filled PVC composite gave the highest flexural modulus but the lowest impact strength compared to all grades of $CaCO_3$ filled PVC composites. The SM90 $CaCO_3$ gave the most optimum properties in trems of impact strength and flexural modulus compared to all grades of $CaCO_3$.

Introduction

Polyvinyl chloride, (PVC) is one of the largest volume commodity plastics produced in the world and is expected to continue with a good high growth rate. Due to its poor thermal stability making processing difficult, it was not commercially importance until about 1930. It started to gain commercial importance when the problems caused by poor thermal stability were overcome by development of additives. Polyvinyl chloride is used in a wide range of applications because of its combined properties of high modulus, ease of fabrication, low flammability and low cost. The main objective of this study is to compare the mechanical properties of the talc and different types and size of $CaCO_3$. The influence of the filler is not only dependent on the degree of filling but the fineness of grind and the chemical nature of the talc grades concerned. The finer particles size of calcium carbonate is more effective in impact strength.

Xie, *et al.* (2004) indicated that $CaCO_3$ nano-particles stiffen and toughen the PVC. They also found that $CaCO_3$ nano-particles acted as stress concentrators leading to interface debonding or voiding and matrix deformation. These mechanisms lead to the toughening of nano-composites. According to Wiebking (2006), the addition of talc can significantly increase the flexural modulus of a rigid PVC formulation, but it can lower the impact strength. Previous studies have shown that the addition of calcium carbonate and talc improved the stiffness of PVC. Talc increases the flexural modulus or stiffness of a rigid PVC formulation, but this increase in stiffness is usually accompanied by a severe decrease in impact strength. $CaCO_3$ is effective in improving impact strength of PVC without lowers the flexural modulus of PVC. According to Sun, *et al. (2005),* the tensile and impact strength of $CaCO_3$/PVC greatly increased with the decreasing of $CaCO_3$ particles size. The decreasing of $CaCO_3$ particles size attributed to increase the interfacial contact area and enhance interfacial adhesion between $CaCO_3$ particles and PVC matrix.

Methodology

PVC Blend Formulation

The PVC blend formulations use in this research are based on the commercial PVC window frames formulations with some modifications. The PVC blend formulation used in this research was showed in Table 3.1 and Table 3.2. The contents of the fillers are varied according to the commercial loading level. Table 3.1 was used to find out the type of $CaCO_3$ with the highest impact strength and considerable flexural modulus. Table 3.2 was used to find out the content of NPCC filled PVC composite gives the optimal impact strength.

Table 3.1: PVC Blend Formulation 1.

Ingredients	**Compound Formulations, parts**					
Types of fillers	**SP-FG** 30	**SP-FG-C** 30	**SM90** 30	**PC100** 30	**PC100** 30	**Talc** 30
Polyvinyl chloride, PVC (Resin)	100	100	100	100	100	100
Tin Stabilizer (Stabilizer)	2	2	2	2	2	2
Calcium Stearate (Internal Lubricant)	0.5	0.5	0.5	0.5	0.5	0.5
Stearic Acid (External Lubricant)	0.6	0.6	0.6	0.6	0.6	0.6
Titanium Dioxide, TiO_2 (Pigment)	4	4	4	4	4	4
Acrylic Polymer (Processing Aids)	1.5	1.5	1.5	1.5	1.5	1.5

Sample Preparation of Talc filled PVC and $CaCO_3$ filled PVC Composite

The PVC resin and additives were blended by using a high speed laboratory mixer to homogenize the formulation. The mixing time of the dry blending process was 5 minutes with the rotor speed of mixing is 50rpm. After dry blending of the PVC compound formulations, the dry blends of the PVC powder and additives were melted and sheeted on a two roll mill machine with the front roll and back roll temperature of $180\pm5^{0}C$. The sheeted PVC compounds were cut and compression moulded into the impact and flexural test specimen.

Izod Impact Test

The notch Izod impact strength was measured under the ASTM D256-93 standard test method. The Izod tests will be carried out at room temperature. The purpose of this testing was to determine the pendulum impact resistance of notched specimen of plastic. The thickness of each sample was determined.

Flexural Test

The flexural test was conducted according to the ASTM D790-86 standard test method by using the Instron machine model 5567. The samples were tested at crosshead speed of 3mm/min and the support span for the flexural testing was 50mm. The result values of flexural strength and flexural modulus were collected and analyzed.

Result and Discussion

Flexural Strength

Table 3.1: The impact strength, flexural modulus and flexural strength of PVC composites filled with different types of fillers.

Types of Fillers	Impact Strength, KJ/m^2	Flexural Modulus, MPa	Flexural Strength, MPa
30phr SP-FG	7.29±0.748	4178.5±381.11	78.85±3.456
30phr SP-FG-C	7.65±1.588	4145.3±1289.01	80.83±5.793
30phr SM90	15.05±6.030	4453.0±357.58	80.35±3.199
30phr PC100	10.15±3.348	4299.5±349.59	82.31±1.209
30phr NPCC	6.35±0.549	3694.1±256.41	81.89±1.841
30phr Talc	5.70±0.434	5575.4±299.10	92.88±2.591
Without filler	6.47±1.103	3690.7±197.758	96.42±1.525

Table 3.1 showed the flexural strength, flexural modulus and impact strength of the unfilled PVC composites and PVC composites filled with different types of fillers. From Figure 3.1, the unfilled PVC composite (without filler) gave higher flexural strength compared to all filled PVC composites with the flexural strength of 96.42MPa. Among all filled PVC composites, the 30phr talc filled PVC composite gave the highest flexural strength with the value of 92.88MPa. The decrease in flexural strength of 30phr talc filled PVC composite was very little when compared with all grades of $CaCO_3$ filled PVC composites. 30phr talc filled PVC composite which had the highest flexural strength further confirms that talc has better reinforcement than all types of $CaCO_3$. The aspect ratio and particles orientation of talc particles in PVC composite contributed to the high flexural strength of 30phr talc filled PVC composite. The increment in flexural strength of talc filled PVC was also minimal. This could be attributed to the skin formed during the molding of specimen, which was more sensitive to flexural stress. Talc tends to orient with the plane surface parallel to the melt flow direction during processing at the sample skin, this causes slippage of the filler against the matrix, thus reducing the reinforcing effect of the filler. The 30phr PC100 filled PVC composite gave the second highest flexural strength with the value of 82.31MPa and was followed by 30phr NPCC filled PVC composite with the value of 81.89MPa. The 30phr SP-FG-C filled PVC composite had the fourth highest flexural strength with a value of 80.83MPa and closely followed up by the 30phr SM90 filled PVC composite as the fifth highest flexural strength with a value of 80.35MPa. The 30phr SP-FG posed the poorest flexural strength with a value of 78.85MPa. According to Leong, *et al.* (2003), the flexural strength of all filled composites was lower than the unfilled Polypropylene. The flexural strength from the result of $CaCO_3$ and talc fillers filled PVC in this research was found similar to the $CaCO_3$ or talc fillers filled Polypropylene composites in the study carried out by Leong, *et al.* (2006). According to Leong, *et al.* (2006) this could be due to the effect of cavities formed after the corporation of $CaCO_3$ into the composites.

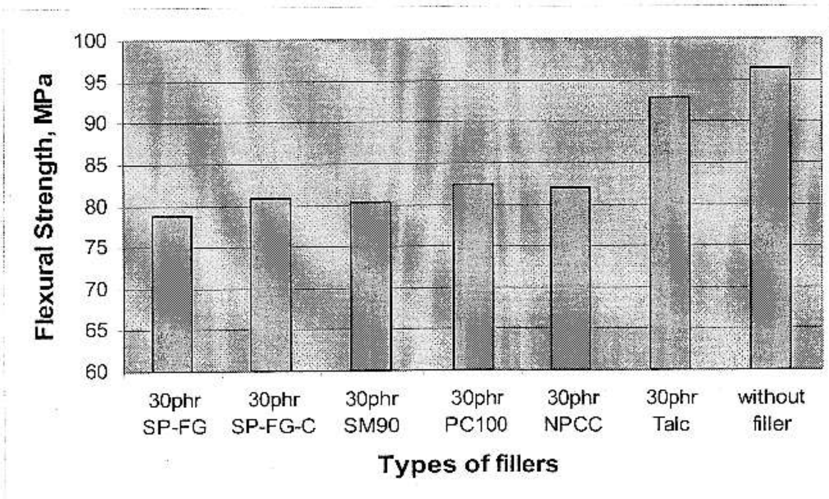

Figure 3.1: The flexural strength in MPa of PVC composites filled with different types of fillers.

Flexural Modulus

From Figure 3.2, the 30phr talc filled PVC composite gave the highest flexural modulus compared to all types of $CaCO_3$ filled PVC composites. The talc filler improved the flexural modulus of the PVC composite from 3690MPa to 5575.4MPa. Wiebking (2006) quoted that talc can stiffen and strengthen a rigid PVC formulation and the flexural modulus increases as the loading level of talc filled to PVC composite increases. The 30phr SM90 filled PVC composite gave the highest flexural modulus among all types of $CaCO_3$, but its flexural modulus was much lower than the flexural strength of 30phr talc filled PVC composite. According to Wiebking (2006), $CaCO_3$ can improve little in stiffness or increases the flexural modulus of PVC composite, but not as effective as talc does. This could be caused by the low aspect ratio of $CaCO_3$ particles and high aspect ratio of talc particles. Weibking (1996), also quoted that stiffness is a function of shape or aspect ratio of filler. The 30phr PC100 filled PVC composite was the second highest flexural modulus in all types of $CaCO_3$ and as the third highest flexural modulus in all types of fillers with the value of 4299.5MPa. The 30phr SP-FG filled PVC composite has the fourth highest flexural modulus in all types of fillers with a value of 4178.5MPA, and followed by the 30phr SP-FG-C filled PVC composite which gave the fifth highest flexural modulus with the value of 4145.3MPa. The flexural modulus of 30phr SP-FG and SP-FG-C had shown that the surface coated, SP-FG-C had no significant effect on flexural modulus. The 30phr NPCC posed the poorest flexural modulus compared with all types of fillers with the value of 3694.1MPa. This could be attributed by the agglomeration of nano-particles $CaCO_3$.

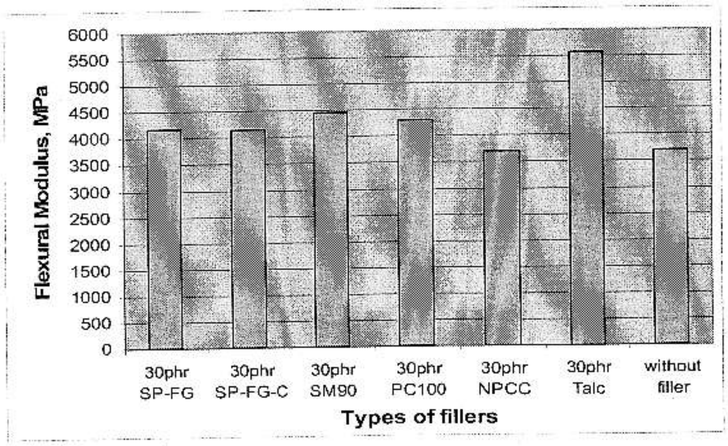

Figure 3.2: The flexural modulus in MPa of PVC composites filled with different types of fillers.

Impact Strength

Figure 4.3 revealed that the impact strength of the unfilled PVC composite was 6.47KJ/m^2 and all types of $CaCO_3$ had improved the impact strength of PVC. However, the 30phr talc filled PVC composite had lowered the impact strength of PVC composite. The addition of talc filler reduced the impact strength of PVC composite from 6.47KJ/m^2 to 5.70KJ/m^2. Wiebking (2006) quoted in his study that talc can produce poor impact performance to a rigid PVC formulation. From Figure 3.3, the 30phr SM90 filled PVC composite gave the highest impact strength compared with all types of fillers filled PVC composites. The 30phr PC100 filled PVC composite gave the second highest value in impact strength, and followed up by the 30phr SP-FG-C filled PVC composite as the third highest impact strength. The 30phr SP-FG filled PVC composite has the fourth highest impact strength. The 30phr NPCC filled PVC composite gave the lowest impact strength among all grades of $CaCO_3$. The addition of NPCC had slightly reduced the impact strength of PVC composite. According to Sun, *et al.* (2005), the addition of nano-$CaCO_3$ in PVC composite is supposedly imparted better impact strength result compared with the micron-particles $CaCO_3$. However, the 30phr NPCC filled PVC composite gave the poorest impact strength compared with all grades of micron-particles $CaCO_3$ and it had even lowered the impact strength of PVC composite. According to Sun, *et* al. (2005), this might be caused by the uneven dispersion of nano-$CaCO_3$ in PVC matrix and severe aggregates occur in the PVC matrix. The agglomeration reduced the effective number of nano-particles, which would absorb the impact energy. The 30phr talc filled PVC composite not only gave the lowest impact strength compared with all $CaCO_3$ filled PVC composites, but it also highly decreased the impact strength of PVC composites. The 30phr SM90 filled PVC composite had imparted the highest impact strength due to its finer particles size compared to all grades of $CaCO_3$ except NPCC.

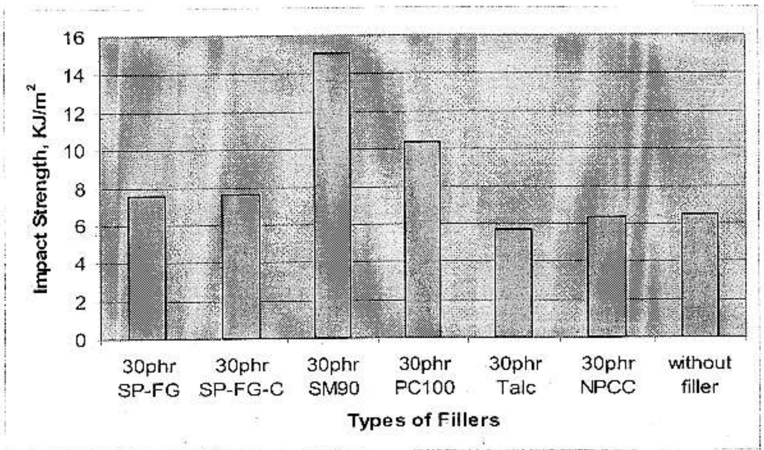

Figure 3: The impact strength in KJ/m^2 of PVC composites filled with different types of fillers.

Conclusion

The 30phr talc filled PVC composite gave the highest flexural properties (flexural strength and modulus), but the lowest in impact strength. The high values in flexural properties were contributed by the high aspect ratio of talc filler. The SM90 filled PVC composites gave the highest flexural modulus among the $CaCO_3$, filled PVC composites but still much lower than the talc filled PVC composite. This was caused by the low aspect ratio of SM90 particles which was spherical in shape. The talc fillers reduced the impact strength of PVC composites significantly. The 30phr SM90 filled PVC composite gave the highest impact strength compared to all grades of $CacO_3$. NPCC filled PVC composite was found to decrease the impact strength of PVC composite. This might be caused by the uneven dispersion of nano-$CaCO_3$ in PVC matrix and severe agglomeration in the PVC matrix.

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