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Properties of Calcium Carbonate/Mica and Calcium Farbonate/Talc Filled Polypropylene Composites

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Abstract: *Mineral fillers namely talc, calcium carbonate, mica, glass and carbon fibres are common fillers used in plastic industry that can alter thermoplastic properties. With the incorporation of fillers, significant outcome can be observed especially in the mechanical properties of polymer composites produced apart from its rigidity and resistance to temperature. Properties of single and hybrid fillers filled polypropylene (PP) composites were studied in this research work. Mineral fillers such as talc, mica and calcium carbonate ($CaCO_3$) were incorporated into PP composites. Realising the advantage of each mineral filler and the effect of hybrid fillers, $CaCO_3$/Talc (CC/T) and $CaCO_3$/Mica (CC/M) at 40 wt% were investigated. Generally, the results demonstrated that CC/M has higher tensile modulus than CC/T and both hybrids composites did not give significant effect on the tensile strength. Thermogravimetric analysis (TGA) results revealed that CC/M increased thermal stability of PP composites when compared to CC/T. Flammability testing on PP hybrid composites was carried out where lower burning rate indicates better flammability. From the results, it shows that CC/M system have better flammability compared to CC/T system.*

Keywords: Calcium carbonate, polypropylene composites, calcium farbonate, mineral fillers, mica, thermogravimetric analysis

1. INTRODUCTION

Polypropylene (PP) is found to be an interesting matrix for filled materials due to its combined properties such as having good mechanical performance and low in cost.[1] As polymer composite is filled with isotropic filler such as $CaCO_3$ and talc, increase in modulus, and reduction in strength and deformability can be observed.[2] Talc, calcium carbonate and mica are common fillers used in PP. These fillers could provide enhanced properties through their own characteristics and can affect crystallisation behaviour of PP.[3] As mica is filled in PP, this mineral filler can help to improve properties of PP as they are packaged with favourable characteristics such as high strength, and good thermal stability and corrosion resistance.[4]

Many studies have been done on PP filled with a single mineral. On contrary, only a few have been reported on hybrid mineral involving calcium farbonate/talc and calcium carbonate/mica. The main aim of this study is to investigate the tensile properties, thermal degradation temperature and the rate of burning of these hybrid mineral filler filled PPs.

2. EXPERIMENTAL

2.1 Materials

PP (Titanpro 6431) manufactured by Titan Polymer (M) Sdn. Bhd. with melt index of 7 g 10 min^{-1} and density of 0.9 g cm^{-3} was used as the polymer matrix in this study. Mineral fillers used are mica, talc and calcium carbonate that have been processed via jet mill and undergone a fine-grinding process according to our previous work.[5] The properties of the mineral fillers are shown in Table 1. All fillers used are under the average size of ≤ 1 micron.

Table 1: Properties of mica, silica and $CaCO_3$ fillers.

Properties	Mica	Talc	$CaCO_3$
Mean particle size (μm)	1	0.82	0.73
Relative span ratio	3.16	2.95	3.75
Surface area (sq m g^{-1})	2.29	2.90	2.70
Shape	Flake	Flake	Elongated
Density (g cm^{-3})	2.5	2.50	2.70

2.2 Sample Preparation

All mineral fillers were dried in an oven at a temperature of 100°C for 3 h to drive out moisture. This was followed by the mixing process of fillers and PP using Haake internal mixer at a temperature of 180°C for 12 min. PP composites were compounded at the ratio of 10:30, 20:20, 30:10, 40:0 with pure PP as the control sample. In this study, two types of hybrid filled PPs were prepared: mica (M) hybrid with calcium carbonate (CC) and mica (M) with silica (Si). This was followed with compression moulding in an electrically heated hydraulic press at temperature setting of 180°C. The sample is pre-heated for 8 min, hot compressed for 2 min followed by cooling for 4 min.

2.3 Testing Details

Tensile properties were measured by INSTRON 3366 according to ASTM D638. Average of tensile properties using five specimens was reported. The samples were tested at the crosshead speed of 5 mm min^{-1} and gauge length of 100 mm. 1-mm thick dumbbell shapes were prepared from each composition and measured at ambient temperature. The strength and modulus of the specimens were obtained from the recorded data. Perkin Elmer Pyris 6 TGA Analyzer was used in Thermogravimetry Analysis (TGA) in a nitrogen atmosphere that was set at 20 ml min^{-1}. This analysis was employed to measure the changes of samples weight as the function of temperature and time. 10 mg of samples were used and heated from 50°C to 600°C at heating rate of 20°C min^{-1}.

Initial degradation temperature, thermal stability and amount of filler content were obtained from this analysis. Three samples were used to study the flammability characteristics of the composites specimens. This flammability characteristic referred to relative linear rate of burning that was measured according to ASTM D635. Composite samples were mounted horizontally in flammability chamber with the flame applied at 45° to the samples. The extent time of burning per constant length of 100 mm is measured using Equation 1 after the flame reach 100 mm mark.

$$V = 60L/t \tag{1}$$

where L = original length of sample (mm) and t = time takes for the sample to burn until 100 mm mark(s).

3. RESULTS AND DISCUSSION

3.1 Tensile Properties

Young's modulus and strength of pure PP and hybrid mineral filler filled PP are presented in Figure 1. From the bar graphs, it can be observed that as 40 wt% of $CaCO_3$ is included in PP, the value of Young's modulus is increased. The increasing trend continues at 30/10, 20/20 and 10/30 wt% for both CC/T and CC/M hybrid components. The increase in modulus can be explained by the filler presence in PP that limits mobility and deformability of the matrix through the introduction of mechanical restraint in the composites system.[3]

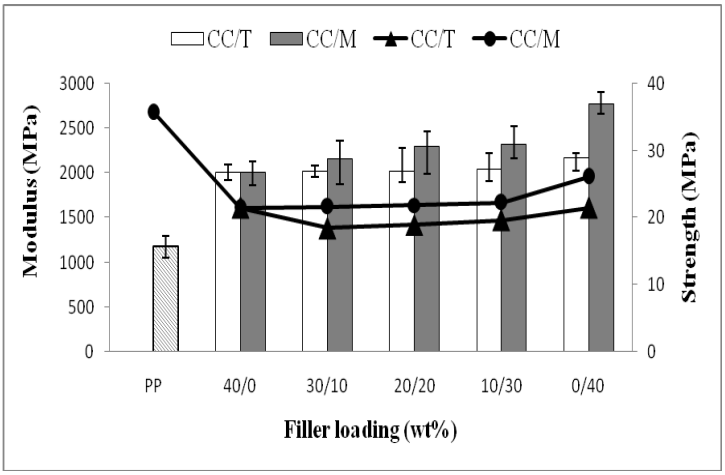

Figure 1: Bar chart and graph line indicates Young's modulus and strength, respectively for CC/T and CC/M. Filler loading is fixed at 40 wt%.

Moreover, the results showed that Young's modulus increase with the increase of talc and mica filler. This indicates that rigid particles such as talc and mica could increase Young's modulus of PP. On the other side, tensile strength of PP composites is not significantly improved with the existence of fillers. This might be due to the fact that flaky talc and mica can form cracks in polymer matrix easily as there is no adhesion between these particles with PP matrix as has been reported in a previous work.[6] As the comparison between CC/M and CC/T is made, CC/M hybrid system showed better tensile strength. This indicates that more stress is transferred from PP matrix to CC/M compare to CC/T system.[7]

3.2 Thermal Stability

The degradation temperature at T_5% and T_{50}% of pure PP and hybrid mineral filler filled in PP is presented in Table 1. From the data, it can be observed that the incorporation of filler into PP improved thermal stability of PP composites component as the degradation temperature at T_5% and T_{50}% are both increased compared to the pure PP. As the comparison between hybrid component of CC/T and CC/M, it can be observed that at T_5% weight loss, CC/M demonstrated higher thermal stability than CC/T.

In a previous study,[8] particulate mica was incorporated into polymer composites in an attempt to improve heat stability of the thermoplastic. Mica, which has low specific heat in room temperature can lower the degradation temperature and have the shielding effect that can raise the stability of PP composites. Thus, hybrid systems with mica showed higher thermal stability compare to those of CC/T system.

Table 1: Degradation temperatures for unfilled PP and hybrid mineral fillers PP composites at 40 wt% of filler.

Sample	Initial degradation temperature at 5% (T_5%) weight loss (°C)	Initial degradation temperature at 50% (T_{50}%) weight loss (°C)	Weight residue (wt%)
PP	432.24	477.66	0
10CC30T	442.20	492.84	40.85
20CC20T	434.35	480.20	38.90
30CC10T	437.80	486.47	39.53
10CC30M	459.62	489.17	38.59
20CC20M	462.88	489.76	39.29
30CC10M	445.13	486.14	38.98

3.3 Flammability

Variations of burning rate of pure PP and hybrid mineral fillers filled PP can be observed in Figure 2. When fillers are added into PP, the burning rate of PP composites is decreased. Lower burning rate indicate better flammability of the system,[9] thus it could be said that filler improved the flammability of PP as can be seen in the bar chart. When comparison between CC/T and CC/M is made, it is concluded that CC/M has better flammability as it shows lower burning rate. Better flammability of CC/M hybrid system is contributed by mica filler. Referring to the previous research done,[10] mica is known to delay the time taken for polymer to ignite and improved thermal stability of polymer composites. In addition, higher thermal stability of CC/M components compared to CC/T as indicates by the initial degradation temperature at 5% in TGA also play an important role. With higher thermal stability, the time taken for the sample to burn until the end is slower and thus results in lower burning rate.

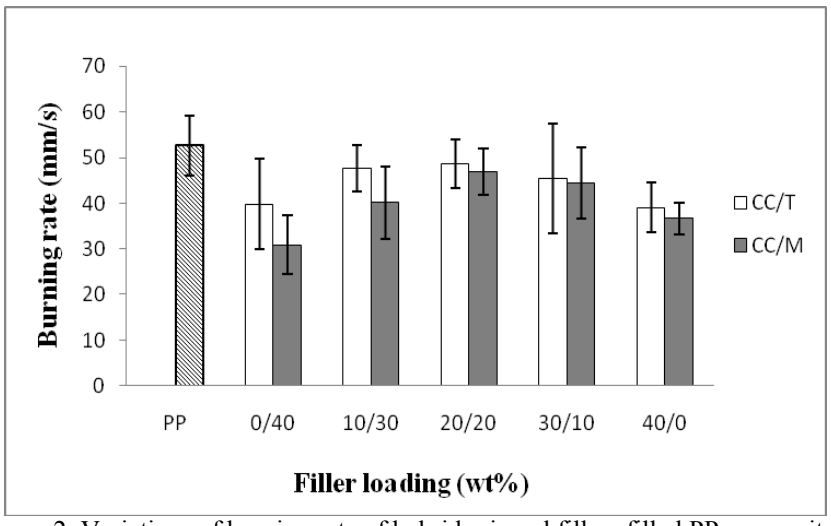

Figure 2: Variations of burning rate of hybrid mineral fillers filled PP composites.

4. CONCLUSION

In this present study, comparison between CC/T and CC/M hybrid PP composite system is made based on tensile properties, degradation temperature and burning rate. Addition of fillers into PP improved tensile modulus in which CC/M demonstrated higher tensile modulus compare to CC/T. Both hybrid composites did not give significant effect on tensile strength. In thermal stability, CC/M component have higher thermal stability and better flammability compared to CC/T.

5. ACKNOWLEDGEMENT

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6. REFERENCES

1. Morelli, C. L., Pouzada, A. N. S. & Sousa, J. A. (2009). Influence of hybridization of glass fiber and talc on the mechanical performance of polypropylene composites. *J. Appl. Polym. Sci.*, 114, 3592–3601.
2. Pukanszky, B. et al. (1994). Effect of nucleation, filler anisotropy and orientation on the properties of PP composites. *Compos.*, 25, 205–214.

3. Guerrica-Echevarriâa, G., Bal, J. I. E. & Bal, J. N. (1998). Influence of molding conditions and talc content on the properties of polypropylene composites. *Eur. Polym. J.*, 34, 1213–1219.
4. Yazdani, H., Morshedian, J. & Khonakdar, H. A. (2006). Effect of maleated polypropylene and impact modifiers on the morphology and mechanical properties of PP/mica composites. *Polym. Compos.*, 27, 614–620.
5. Palaniandy, S., Kadir, N. A. & Jaafar, M. (2009). Value adding limestone to filler grade through an ultra-fine grinding process in jet mill for use in plastic industries. *Min. Eng.*, 22, 695–703.
6. Liu, Z. et al. (2011). Effect of inorganic fillers on morphology and mechanical properties of PA66/POE-g-MAH/Filler composites. *J. Macromol. Sci. B*, 50, 484–492.
7. Leong, Y. W., Ishak, Z. A. M. & Ariffin, A. (2004). Mechanical and thermal properties of talc and calcium carbonate filled polypropylene hybrid composites. *J. Appl. Polym. Sci.*, 91, 3327–3336.
8. Baral, D., De, P. P. & Nando, G. B. (1999). Thermal characterization of mica-filled thermoplastic polyurethane composites. *Polym. Degrad. Stabil.*, 65, 47–51.
9. Razak, J. A., Akil, H. M. & Ong. H. (2007). Effect of inorganic fillers on the flammability behavior of polypropylene composites. *J. Thermoplas. Compos. Mater.*, 20,195–205.
10. Hanu, L. G., Simon, G. P. & Cheng, Y.-B. (2006). Thermal stability and flammability of silicone polymer composites. *Polym. Degrad. Stabil.*, 91, 1373–1379.