MECHANICAL PROPERTIES AND THERMAL PROPERTIES OF PMMA/EVA/KENAF SHORT FIBER COMPOSITES PREPARED BY TWIN SCREW EXTRUDER AND INJECTION MOLDING

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In the name of Allah, the Beneficent, the Merciful

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SIFAT-SIFAT MEKANIKAL DAN TERMA KOMPOSIT PMMA/EVA/GENTIAN KENAF PENDEK YANG DISEDIAKAN DENGAN MENGGUNAKAN PENYEMPRIT SKRU BERKEMBAR DAN PENGACUAN SUNTIKAN

ABSTRAK

Komposit poli (metil metakrilat) (PMMA) dengan perubahan gentian kenaf ringkas (KSF) telah disediakan dengan menggunakan penyemprit skru berkembar dan pengacuan suntikan. Kesan etilena vinil asetat (EVA) keatas keliatan komposit PMMA/KSF telah juga dikaji. Kesan suhu suntikan di zon pemplastikan telah kaji dengan menggunakan sampel PMMA/EVA (70/30) terisi 10% berat KSF. Didapati bahawa sifat tegangan komposit pada 230°C adalah lebih tinggi daripada 220°C seperti kekuatan tegangan, modulus Young, pemanjangan pada takat putus dan keliatan tegangan. Suhu 230°C telah dipilih untuk sampel suntikan kandungan KSF dan kandungan EVA. Kandungan KSF telah diubah dari 0, 5, 10 dan 15% terisi PMMA/EVA (70/30). Keputusan sifat mekanikal menunjukkan bahawa tenaga impak, kekuatan tegangan, pemanjangan pada takat putus dan keliatan tegangan menurun dengan kandungan KSF. Sebaliknya, modulus Young komposit telah meningkat dengan penambahan KSF. Tambahan KSF juga mendorong kenaikan dalam modulus penyimpanan, modulus kehilangan komposit PMMA/EVA/KSF. Untuk kajian nisbah PMMA/EVA (100/0, 80/20 dan 70/30), keliatan komposit PMMA/EVA/KSF diperolehi daripada ujian hentaman menunjukkan bahawa PMMA/EVA nisbah 80/20 lebih baik daripada 70/30 dan100/0. Begitu juga dengan keliatan tegangan. EVA bukan sahaja mempunyai kesan keliatan tetapi memberi kesan pemplastikan yang menyebabkan modulus Young, penyimpanan dan modulus kehilangan PMMA/EVA/KSF komposit lebih rendah daripada komposit PMMA (tanpa EVA). Kehadiran EVA juga merubah puncak δ tan PMMA/EVA/KSF kepada suhu yang lebih tinggi. Kesan punca berasal dari suhu lebur EVA sekitar 120 °C yang diperolehi daripada keputusan DSC. Kehadiran kandungan KSF dan EVA juga meningkatkan kestabilan terma komposit PMMA/EVA/KSF yang diperolehi daripada keputusan TGA.

THE MECHANICAL PROPERTIES AND THERMAL PROPERTIES OF PMMA/EVA/KENAF SHORT FIBER COMPOSITES PREPARED BY TWIN SCREW EXTRUDER AND INJECTION MOLDING

ABSTRACT

Poly (methyl methacrylate) (PMMA) composites with variation of kenaf short fiber (KSF) was prepared by using twin screw extruder and injection molding. The effect of ethylene vinyl acetate (EVA) on the toughness of PMMA/KSF composites was also investigated. The effect of injection temperature at plasticizing zone was investigated using the sample of PMMA/EVA (70/30) filled 10% weight KSF. It was found that tensile properties of composites at 230 °C were higher than those at 220 °C such as tensile strength, Young's modulus, elongation at break and tensile toughness. The temperature of 230 °C was selected for injection sample of KSF content and EVA content. The KSF content was varied from 0, 5, 10 and 15% filled PMMA/EVA (70/30). The mechanical properties results showed that impact energy, tensile strength, elongation at break and tensile toughness decreased with KSF content. In contrast, Young's modulus of composites was increased with KSF loading. The addition of KSF also induces increment in the storage modulus, loss modulus of PMMA/EVA/KSF composites. For investigation of PMMA/EVA ratio (100/0, 80/20 and 70/30), the toughness of PMMA/EVA/KSF composites obtained from impact test showed that PMMA/EVA ratio of 80/20 better than 70/30 and 100/0. This was also in agreement with tensile toughness. EVA exhibited not only toughening effect but also plasticizing effect, which causes Young's modulus, storage and loss modulus of PMMA/EVA/KSF composites lower than those of PMMA composites (without EVA). The presence of EVA also shifted the peak of tan δ of PMMA/EVA/KSF to higher temperature. The root effect originated from melting temperature of EVA around 120 °C which obtained from DSC results. The presence of KSF and EVA content also enhanced thermal stability of PMMA/EVA/KSF composites which obtained from TGA results.

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LIST OF SYMBOLS AND ABBREVIATION

PMMA	Poly (methyl methacrylate)
EVA	Ethylene Vinyl Acetate
K	Kenaf short fiber
H_2O	Water
CO_2	Carbon dioxide
OH	Hydroxyl group
VA	Vinyl acetate group
mm	Millimeter
cm	Centimeter
m^2	Square meter
cm^3	Cubic centimeter
kg	Kilogram
g	Gram
°C	Degree Celsius
%	Percentage
%wt	Weight percentage
min	minute

s	Second
rpm	Rotation per minute
T	Temperature
T_m	Melting temperature
T_g	Glass transition temperature
ASTM	American society for testing and materials
UTM	Universal testing machine
H_z	Hertz
MPa	Megapascal
GPa	Gigapascal
J	Joule
kJ	Kilojoule
E'	Storage modulus
E''	Loss modulus
ΔH	Heat of melting temperature
DMA	Dynamic mechanical analysis
DSC	Differential scanning calorimeter
TGA	Thermogravimetric analysis
SEM	Scanning electron microscope

ME0K	PMMA/EVA (100/0) with 10% kenaf short fiber composites
ME20K	PMMA/EVA (80/20) with 10% kenaf short fiber composites
ME30K	PMMA/EVA (70/30) with 10% kenaf short fiber composites
ME30K0	PMMA/EVA (70/30) with 0% kenaf short fiber composites
ME30K5	PMMA/EVA (70/30) with 5% kenaf short fiber composites
ME30K10	PMMA/EVA (70/30) with 10% kenaf short fiber composites
ME30K15	PMMA/EVA (70/30) with 10% kenaf short fiber composites

CHAPTER 1

INTRODUCTION

1.1 Research Background

The products are an increasing need to investigate more environmentally friendly, sustainable materials to replace the existing glass fibre and carbon fibre reinforced materials. Therefore, attention has recently shifted to the fabrication and properties of natural fibre reinforced materials (Anuar, et al., 2011).

Natural fibers that have been evaluated as replacements for glass and other non-recyclable fibers include flax, hemp, kenaf and sisal. These fibers are abundant, cheap, renewable, and easily recycled. Other advantages include low density, high toughness, comparable specific strength properties, reduction in tool wear, ease of separation, decreased energy of fabrication, and CO_2 neutrality (Mohanty, et al., 2000).

The automotive and aerospace industries have both demonstrated an interest in using more natural fibre reinforced composites. This has led to predictions that in the near future plastics and polymer composites will comprise approximately 15% of total automobile weight (Mohanty, et al., 2002). The plastics and polymers which use in composites are many types of them such as PMMA and EVA.

Kenaf is one of the natural (plant) fibers used as reinforcement in Polymer Matrix Composites (PMCs). Kenaf (Hibiscus cannabinus, L. family Malvacea) has been found to be an important source of fibre for composites, and other industrial applications (Karnani, et al., 1997). Kenaf is well known as a cellulosic source with both economic and ecological advantages; in 3 month (after sowing the seeds), it is able to grow under a wide range of weather conditions, to a height of more than 3 m and a base diameter of 3–5 cm (Aziz, et al., 2005). This statement is supported by previous studies, which mentions that growing speed may reach 10 cm/day under optimum ambient conditions (Nishino, et al., 2004). From the viewpoint of energy consumption, it takes 15 MJ of energy to produce 1 kg of kenaf; whereas it takes 54 MJ to produce 1 kg of glass fibre (Nishino, et al., 2004).

Kenaf exhibits low density, non-abrasiveness during processing, high specific mechanical properties and biodegradability. It can be used as a domestic supply of cordage fibre in manufacture of rope, twine carpet backing and burlap. In automotive industry works as a substitute for fiber glass or other synthetic fibers, and can be found in automobile dashboards, carpet padding and corrugated medium. The main processes by which the fibre and matrix can turn into final product are injection molding and extrusion (Mohanty, et al., 2002).

Poly (methyl methacrylate) (PMMA) is one of the well know brittle materials. The common method for promoting the toughness of PMMA is blending with the rubber modifier. Ethylene-vinyl-acetate (EVA) elastomer is a suitable material to improve the toughness of PMMA compare to other materials. That is due to PMMA and EVA can be mixable based on chemical structure. Also, the refractive index of EVA is very close to those of the PMMA.

The injection molding is one of the most attractive polymer processes in industry. It is especially used to produce a wide variety of complex geometry articles (e.g. precision gear wheel, hampers, etc.) in a single operation and low wear of the processing equipment. High production rate, short cycle times and low percentage of scrap are also accounting the advantages that make. This process is very attractive from engineering and economical point of view. However, molding complicated parts, multi-gated mold cavities and cavities containing inserts may generate serious difficulties in terms of mold filling and final production especially.

1.2 Problems statements

Natural fibre composites normally can be thermal degraded during processing by using injection temperature. Injection temperature in the injection moulding can lead to thermal damage to the natural fibre composites. To overcome the thermal degradation problem, so injection temperature during injection molding process was investigated.

Poly (methyl methacrylate) (PMMA) is one of the well know brittle materials. In order to enhanced the physical and mechanical properties of PMMA. The most common method for improving the toughness of PMMA is blending with the rubber modifier. Moreover, the most common compounding method is melt mixing by internal mixer. So, less of study is using extruder and injection molding. Therefore, the effect of EVA content on the toughness of PMMA by using extruder and injection molding was studied.

Natural short fiber using extruder and injection molding, it was difficult to process. Therefore, the effect of kenaf short fibre on the mechanical properties of PMMA/EVA/kenaf short fibre composites by using twin screw extruder and injection molding process was studied.

1.3 Research Objectives

These objectives were carried out in this study as below:

- To study effect injection temperature on tensile properties of PMMA/EVA/kenaf short fibre composite (PMMA/EVA ratio: 70/30 and 10% of kenaf short fibre).
- To study the effect of EVA content on the mechanical, toughness, thermal properties and dynamic mechanical analysis of PMMA/EVA/kenaf short fibre composites (PMMA/EVA ratio: 100/0, 80/20, 70/30 and 10% of kenaf short fiber).
- To study the effect of kenaf short fibre content on the mechanical, toughness, thermal properties and dynamic mechanical analysis of PMMA/EVA/kenaf short fibre composites (0, 5, 10 and 15% of kenaf short fibre and PMMA/EVA ratio: 70/30).

1.4 Scope of study

The influence of injection temperature on mechanical properties (tensile test) of PMMA/EVA/kenaf short fibre composites by using injection molding was investigated. Besides that, the effect of EVA on mechanical properties (tensile test, impact test and fracture observation), thermal properties (DSC test, TGA test) and dynamic mechanical analysis of PMMA also important to carried out at different ratio of PMMA/EVA. At last, the effect of kenaf short fibre on the mechanical properties (tensile test, impact test and fracture observation), thermal properties (TGA test) and dynamic mechanical analysis of PMMA/EVA/kenaf short fibre composites was studied.

CHAPTER 2

LITEARATURE REVIEW

2.1 Thermoplastics Matrix Composites

Composites are considered as a standard option for structural applications when high performances are necessary, and among the large variety of composites certainly polymeric matrix composites are the most used, in particular thermosetting matrix composites. Their use, initially in aeronautics applications, is now covering all types of engineering sectors, showing a great choice of possibilities for peculiar fabrication technologies, as well as for mechanical, thermal, chemical properties (Abdulla, 2011).

After the fast developments of new types of fibres with extremely high properties that took place in the last decades of the last century, the commercial availability of thermoplastic matrix composites (TPMC) represents an important recent innovation in the field of composites. The success of such a type of composites is due to different reasons, interesting from the side of fabrication technologies, from the point of view of eco-sustainability of the entire process, and from the side of final performances (Abdulla, 2011).

In particular, the use of thermoplastic matrices avoids the presence of dangerous vapours in the working shops as in the case of thermosetting matrices and this represents at the same time a strong environmental improvement and an economical challenge for the fabrication, the latter being further strongly improved if one considers the necessity of expensive hardware and procedures needed in the use of pre-preg thermosetting composites.

TPMC are based on the use of thermoplastic polymer as matrix of the composites and this implies the reversibility of thermal actions on the material during fabrication of the final element. In other words it is possible to pre-fabricate semi-finished items and later take them to final shape and dimensions with no time limit for that (Abdulla, 2011).

The main technological advantages of thermoplastic composites are:

- Low production cycle time
- High toughness and impact resistance
- Reforming possibility
- High reparability
- Joining and assembly by local fusion bonding
- Uncontrolled shelf life
- Recyclability and environmental protection
- Good chemical resistance