PRE PREPARATION OF KENAF/CARBON PPL COMPOSITE TO BE EMPLOYED IN SELECTIVE LASER SINTERING MACHINE

Golnar Kiani[1], Rahinah Ibrahim[1], Kalinah Abdan[2]

[1]Faculty of Design and Architecture, Universiti Putra Malaysia.
[2]Faculty of Engineering, Universiti Putra Malaysia.

*Correspondance author:
golnar_k@upm.edu.my

ABSTRACT

Abstract. Although many researchers have developed natural fibres as reinforcements for industrial composite materials, the available information regarding these natural fibres to be applicable in the Rapid Manufacturing (RM) system is insufficient. For RM systems and products, the main materials used are thermoplastic materials, epoxy resin, acrylonitrile butadiene styrene plastic and polyester materials. Natural and biodegradable composites provide important environmental advantages to the automotive industry, and sustainability, eco-friendliness. Hence obtaining green chemistry materials for RM system are the main objectives of this study for the development of bio-based industrial materials. To obtain stronger products, hybridisation of these so-called natural fibres with other fibres is necessary. Bio-composites employ polymers as matrices, resulting in lighter, stronger, and more cost-effective products that in some cases they can be melted, sintered, or solidified, similar to RM systems' environment. The combination of Kenafbast fibres, a type of natural fibre, with polymer matrices results in satisfactory performance that can compete with synthetic fibre composites. Prior to test the designed material in the aimed RM system; which in this research is Selective Laser Sintering (SLS), tailoring and predicting its performance is necessary to avoid any high cost breakdown of RM machine due to usage of inappropriate consumables. Hence the present study aimed to evaluate the effect of special features of RM on Kenaf/carbon hybrid composites by performing the compression moulding of it insimilar temperature and sequence of Rapid Manufacturing of this designed material.Assessing the resulted properties, by means of tensile and shear strengths of the end products were of reasonable values compared with carbon or Kenaf/polymer matrices. Further study to process the same material in actual Selective Laser Sintering machine is suggested to obtain more accurate result.

Keywords: *Sustainable bio-composites; hybrid composite polymer matrix kenafbast carbon/kenaf fibre reinforcement*

1. INTRODUCTION

Various types of materials are used in the house construction industry depending on the process to be used, the specifications of instruments, or the design employed.Akovalı(2005) stated that currently, the materials used in rapid manufacturing (RM) are neither biodegradable nor eco-friendly. Although the main materials in use for rapid prototyping system include thermoplastic materials, epoxy resin, acrylonitrile butadiene styrene plastic and polyester materials, making efforts to develop bio-fibres as fillers and composite reinforcements to be applicable in end product-building systems seems interesting to many researchers. Alter (2008) explained that materials currently in use in RM are limited to those that can be sintered or meltedand solidified quickly. The problem with using polymeric materials lies mainly in their price and non-eco-friendliness, both of which make the system inappropriate for adoption in the construction field. Providing an eco-friendly material with cost-effective components can allow the use of such systems within the construction industry.

Ashori (2008) demonstrated that Kenaf fibres can be used in large quantities as excellent reinforcing fillers in plastics and in thermoplastics, such as polypropylene (PP), for their many unique properties and lower cost. Moreover, Kenaf, as a natural fibre composite, has been shown to perform better in some mechanical activities, such as flexural testing, compared with a number of other natural fibres as Nishinoa (2003) mentioned. A new generation of materials, such as fibre-reinforced plastics and composites, is believed to exhibit many advantages over conventional sources of steel, polymer-based materials, and, to some extent, concrete.

The present study focuses on Kenaf-based composites and tries to verify if this composite can show acceptable strength and performances to be used for actual building and construction components. The processing of designed

composite should comply with internal condition of Selective laser Sintering (SLS) system. To achieve this compliance, the main objective is to achieve layer by layer object production and also keep the processing in the same temperature as that of SLS chamber.

1.1 Compression Moulding Employment Vs SLS Processing

The SLS of materials involves producing parts layer by layer, generating whole components, and providing heat (by laser beam) to melt the matrix to fuse particles together (Salmoriaa, 2008).These special characteristics affect the porosity and strength of the end products which mainly focuses on the placement of powdered materials layer by layer, and the effects of the process on the mechanical properties of the resulting product.

In compression moulding the process employs method of moulding in which apreheated polymer is placed into an open, heated mould cavity. The mouldis closed with a top plug and pressure is applied to force the material tocontact all areas of the mould. Heat and pressure are maintained throughoutthe process until the polymer has cured.

In this research we employ compression moulding instead of SLS processing of material in the way that we tries to apply the material fibres and pallets in the mould in a layer by layer manner and then proceed to the heating and compressing stages. The source of heat in compression moulding is different from SLS but the amount of that was kept equal.

2. AIM AND OBJECTIVE

In previous researches carbon and nylon was successfully compounded by Athreya(2010) to form a new material to be used in Selective laser Sintering machine. Also in 2006 University of Loughborough embarked on producing a bio based material for SLS system using Hydroxyapatite reinforced polyethylene.

In this section the material ingredients are going to be processed to a specimen using compression moulding technique. The material arrangement and sequence of manually placing them inside the mould is similar to what is happening in SLS machine but digitally. The temperature inside the Compression moulding machine is also keep between 160-180c which is similar to SLS machine chamber temperature.

2.1 Material Preparation

Kenafbasts and carbon fibres were ground separately into short fibres using a Pulverisette from Universiti Putra Malaysia INTROP 3 (0.5 mm) and sifted through a 0.3 mm sieve. Kenaf fibres were then immersed in water and dried for 48 hrs at room temperature. The dried fibres were heated in an oven for 1 hrs at 120ºC as suggested by previous scholars such as Nishinoa (2003). Polyester powder was grounded to 0.5 mm and sifted through a 0.3 mm sieve. The sieved polymer was dried in the oven at 120 ºC for 4 h and set aside. The prepared fibres and matrices were blended in the proportions of 45% Kenaf, 5% carbon, 3% polyester, 45% PP, and 2% maleic anhyride additive. The materials were blended using a Brabender blending machine run for 10 min at 170 ºC and 50 rpm. Afterwards, the compounds were powdered into 0.05 mm particles by cryogenic grinding. Several batches of the prepared powder mixture were set aside to produce 15 samples (15 cm x 15 cm) illustrated in figure 1.

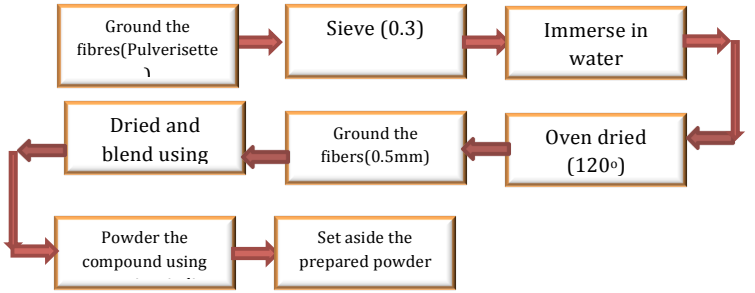

Figure 1: Material preparation

2.2 Composite Compression Moulding Sample Preparation

A mould was pre-coated with a non-stick mould release agent, and the machine was preheated to 160ºC (Dickenson, 2003). During the processing the temperature still rises to 180ºC which is equal to SLS chamber temperature during production of parts.

The powdered compound was then spread manually in layered by layered manner (as that of taking place in SLS processing) and then moulded carefully into the compartment, preheated for 7 min, pressurised under 50 MPa for 10 min, cooled for 3 min, and then finally removed from the machine to allow cooling at room temperature for 24 hours (Hao, 2006), figure 2.

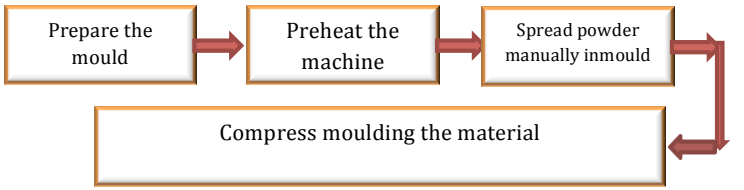

Figure 2: Compression moulding of Material

2.3 Property Measurements for Compressed Moulded Composites

Adherence to specific standards and associated parameters was required during the testing proper. American Society for Testing and Materials (ASTM) standards were followed in the current study. The prepared composites were removed from the mould and cut according to ASTM D638 for tensile strength testing and ASTM D3846 for shear strength testing (figure 3). In total, three to four specimens were cut from three composite plates for various mechanical tests and measurements. For each test, 10 samples were provided and measured. The measurements were conducted in two directions of longitudinal (0º) and transverse (90º) orientation. The Archimedes method, in which deionised water is used as the immersion and infiltration liquid, was applied to measure the bulk density of each test specimen.

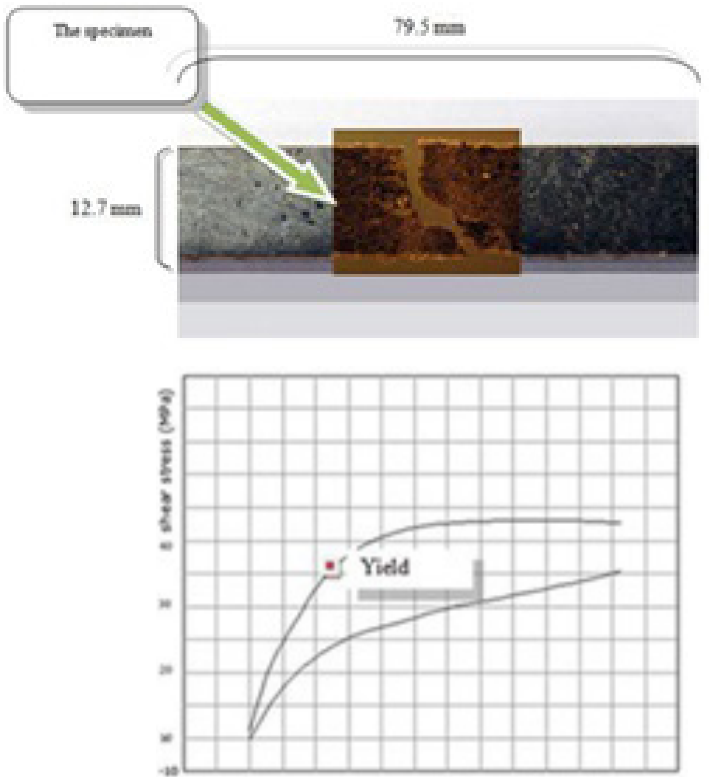

Figure 3: In plane-shear property failure and shear stress-strain behaviour (up to 5% strain)

Foe tensile testing primarily, the specimen was positioned in the grips which were tightened. Todetermine the transverse direction properties, a specimen was cut from thesame composite plate but in 90o orientation which is shown in figure 4.

The applied tensile load was at a stable rate of displacement equal to 5mm/min. Testing was ceased after failure (tensile rupture) of the specimen.

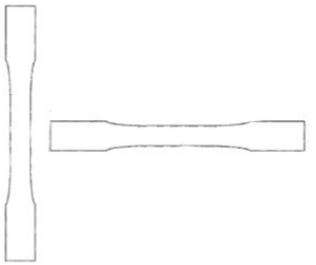

Figure 4: Cutting specimen in different orientation

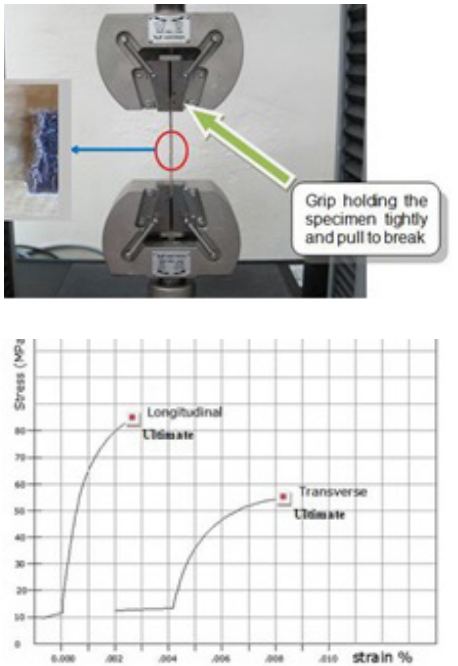

Figure 5: Failure mode of tensile strength test and ultimate tensile strength

The strain-stress result of each specimen was plotted (figure 5) and considered as thebase for calculation of the other related properties of composite. The ultimatestress was divided by the cross sectional area of the specimen to producethe tensile strength, while the modulus of elasticity was taken from slope ofstress-strain diagram. The area between zero to 0.001 mm/mm strain wasconsidered accordingly. The reason is that all the materials perform linear-behaviour in this range.The Poisson's ratio was also determined from this test in the way that thestrain behaviour in transverse and longitudinal direction was plotted andtaken to calculation,figure 6.

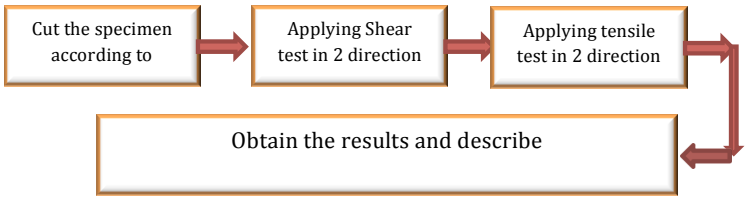

Figure 6: Testing the material properties and obtain the results

3. Results and Discussion

The failure mode in the tensile tests occurred through fibre and matrix breakage. Fibre pull-out was also observed in the present study. When failure of the specimen occurred, the test was stopped and the related data were obtained.

The specific Young's modulus and specific strength of the composites constituted the comparison criteria, while the critical factor for the composites was the tensile property (table 1). As shown in table 2, the specific strength of the bio-composite is greater than the reported strength of Kenaf/PP fibrecomposites obtained by previous researchers. Such an improvement is attributed to the incorporation of carbon fibres into the composite.

The figures illustrate that the composite exhibited properties in good agreement with common structural materials, such as carbon fibre-reinforced plastic, and even better than those of Kenaf/PP composites (figures 7).

The results also show satisfactory properties compared with concrete as a general structural material. The composite can produce curvalinear forms without imposing extremely high costs. Hence, it can be claimed that the composite can be used for a wide range of structural purposes provided that the total distributed stress and strain loads do not exceed its design allowances.

Table 1: Calculated mechanical properties derived from tensile,

Property	Description	Value Gr/cm^3	Standard deviation	Coefficient of variation	Design allowable
ρ	Density	1.14	----		----
E_{11}	Longitudinal Young's modulus (GPa)	30.2	8.28	0.27	10.7
E_{22}	Transverse Young's mModulus (GPa)	6.9	0.45	0.065	5.84
X_t	Longitudinal tensile strength (MPa)	72.58	16.22	0.22	34.38
Y_t	Transverse tensile strength (MPa)	40.1	11.34	0.28	13.39
G12	Longitudinal in-plane shear modulus (GPa)	9.92	1.19	0.12	7.11
G23	Transverse in-plane shear modulus (GPa)	8.46	6.8	0.807	0.69
Sc	Shear strength (Mpa)	40	4.1	0.1025	30.34

Table 2: Comparison of the properties of Kenaf/PP and carbon/PP composites

	Kenaf/PP 50/50	Carbon/PP 50/50	K/C/PP 50/50
Tensile strength (MPa)	62	2495	72.58
Tensile modulus (GPa)	7.7	125-150	30.2
Flexural modulus (MPa)	3.6	37.92	19.88
Shear strength (MPa)	6.36	310	40
Density (Kg/m3)	1400–1500	1070	1140
Cost $/kg	6	7.5	6.2

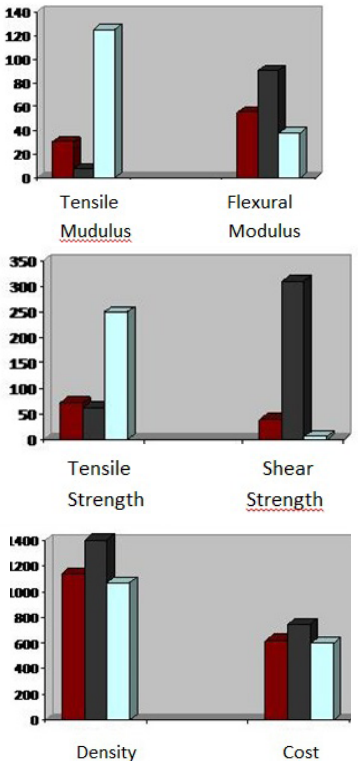

Figure 7: Comparisons of tensile and flexural moduli, tensile and shear strength, and density and cost

4. CONCLUSION

In the current study, we aimed to evaluate the mechanical properties of Kenaf/carbon/PP fibre composites fabricated from randomly scattered fibres. First, the process (heating and compressing) was performed well below 180 ºC to avoid fibre degradation. Control of the moulding process (time, temperature, and press) was crucial to reduce fibre damage. During determination of the processing parameters that needed to be adjusted to each thermoplastic polymer, the rheological and thermal properties of neat polymers must be considered. The second part of the study focused on the mechanical behaviour of the polymeric matrix composites reinforced by the hybrid fibres. With volume fractions of 45% Kenaf and 5% carbon fibres, satisfactory performance levels were obtained for the Kenaf/carbon/PP fibre bio-composites.

The substitution of PP by Kenaf/carbon/PP fibre bio-composites for RM may yield a stronger product. The results are very encouraging for the development of bio-composites for structural applications. Complementary studies, such as the application of the material under Selective Laser Sinteringmachine and adoption of different fibre designs and matrices, will be conducted in the future. The standard deviation and allowable stress design were calculated for further design considerations and comparison between expected loads, thus allowing calculation of the design allowance.

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