


STUDY OF THERMO-MECHANICAL PROPERTIES OF SUGAR PALM FIBRE REINFORCED THERMOPLASTIC POLYURETHANE COMPOSITES FOR USE AS EXTERIOR MATERIAL IN AUTOMOTIVE INDUSTRY

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ABSTRACT

The present work aimed to develop of sugar palm fibre (SPF) to reinforce thermoplastic polyurethane (TPU) composites. The extruder and the compression molding machine were used to fabricate this composite. Fibre surface treatment then conducted to enhance the properties of sugar palm fibre composites. Different factors are studied the optimization of processing, fibre size, and mixing ratio of SPF-TPU. Alkali, permanganate, and the microwave methods were used to enhance the surface properties to make it to have more adhesion between the fibre and polymer. Tensile, flexural, impact, properties and scanning electron microscope (SEM), thermogravimetric (TG), Fourier transform infrared (FTIR), and the energy dispersive X-ray (EDX) for SPF/TPU was tested. Composites of 10, 20, and 30% fibre loadings were fabricated and tested. Degradation behavior of the composites also be conducted by using accelerated weathering chamber follow the ASTM standard. This composite system could apply in automobile industry as reinforced plastic parts in different types of vehicles also produce friendly environment materials.

1. INTRODUCTION

Nowadays, polymer composite materials mostly employed well-established fibres such as glass, carbon and aramid as the reinforcement. Fibre reinforced composites industries essentially began in 1940 with the introduction of glass fibres as reinforcement [1]. In the last half century, the technology has enabled us to put fibres into almost all structural plastics. These composites have high mechanical and physical properties [2]. These composite performance characters such as strength–weight ratios and modulus–weight ratios are markedly superior to those of metallic materials, and natural fibre reinforced composite. For these reasons, synthetic fibre reinforced polymers have emerged as a major class of structural materials and are widely used as substitution for metals in many weights critical components in aircraft, aerospace, automotive, marine, construction industries and other industries [3]. However, most of the traditional reinforcing fibres such as glass, aramid, and carbon fibres are non-recyclable and non-degradable. Composite materials that enter the synthetic fibre in its composition be expensive, while composite materials made from natural fibre are exactly the opposite [4, 5].

The increasing demand for greener and biodegradable materials leading to the satisfaction of society requires a compelling towards the advancement of green-materials science. The biodegradability of the natural fibre is considered as the most important and interesting aspects of their utilization in polymeric materials. Green-materials show considerable applications in different fields, such as aerospace, automotive, electronics, and biotechnology industries. Light weight composite material, also commonly referred to as fibre-reinforced thermoplastic (FRTP), provide opportunities for reducing vehicle weight by increasing fuel efficiency and reducing an emission of harmful pollutants [6-8].

Design car engines depend on the basis weight of the vehicle, the great vehicle increased weight that needs to use a high-capacity engine to be of acceptable performance and homogeneous cars. Accordingly, the increase in the vehicle weights increases prices and costs of manufacturing reduce exponentially in cars this side of the markets. The other side of large engines poses carbon monoxide CO gas is greater than that posed by small engine into the atmosphere of increasing the proportion of pollution quantities in the environment [9]. The use of natural composites in the vehicle replacement of some parts of the vehicle provides an opportunity for additional to get less weight in addition to its ability to decomposition, which cannot be observed in fibreglass or carbonate and others [9-11]. This push for the use of natural composite materials as a substitute for other materials such as synthetic fibre and metals because of a unique property such as lightweight, low- cost and easy for manufacturing and recycling. Composite materials are two types, the biodegradable, a composite reinforced by natural fibre such as Kenaf, Sugar Palm, sisal, jute, and others in the composition, and the second is the composites, which enters into the composition of synthetic fibre such as glass fibre, carbon fibre or others [12].

The research on natural fibre composites is gaining increased recently due to the advantages of the natural fibre. The advantages include the fibre which is very less harmful to human health and environment, low density as well as their low cost since they are available in abundance; and have high specific properties compared to synthetic fibre composites [13-16]. Natural fibres such as jute, kenaf, hemp, sisal, coir, sugar palm fibre, etc. are abundantly available in countries such as India, Sri Lanka, Indonesia, Philippines, Brazil and South African countries. Tropical countries like Malaysia and Indonesia are homes to many types of natural fibres. One of them is sugar palm (Arenga pinnata) fibre. Sugar palm fibres are known for their high durability and their resistance to sea water. These two characteristics are the main advantages of sugar palm fibre. Traditionally, sugar palm fibres were used to make ropes broom, paintbrush, filter, doormat, chair/sofa cushion and for roof because of its strength and durability [17]. Moreover, it comes from the family Arecaceae which has a high economic value and a good prospect to be developed [18]. All parts of the plant can be utilized and converted into a variety of products such as sugar sap, starch, kolang-kaling (endosperm), or fibre [19, 20].

Several studies have shown that sugar palm fibres have great potential to be used in many composite applications, just like other natural fibres such as kenaf, jute, oil palm, sugarcane bagasse, pineapple leaf and banana pseudo stem fibres [21-24]. However, the characterization of the role of sugar palm fibres in the reinforcing of thermoplastic composites has been still limiting studied.

2. RESEARCH METHODOLOGY

The following Figure 1 showed the flow chart for research methodology procedure.

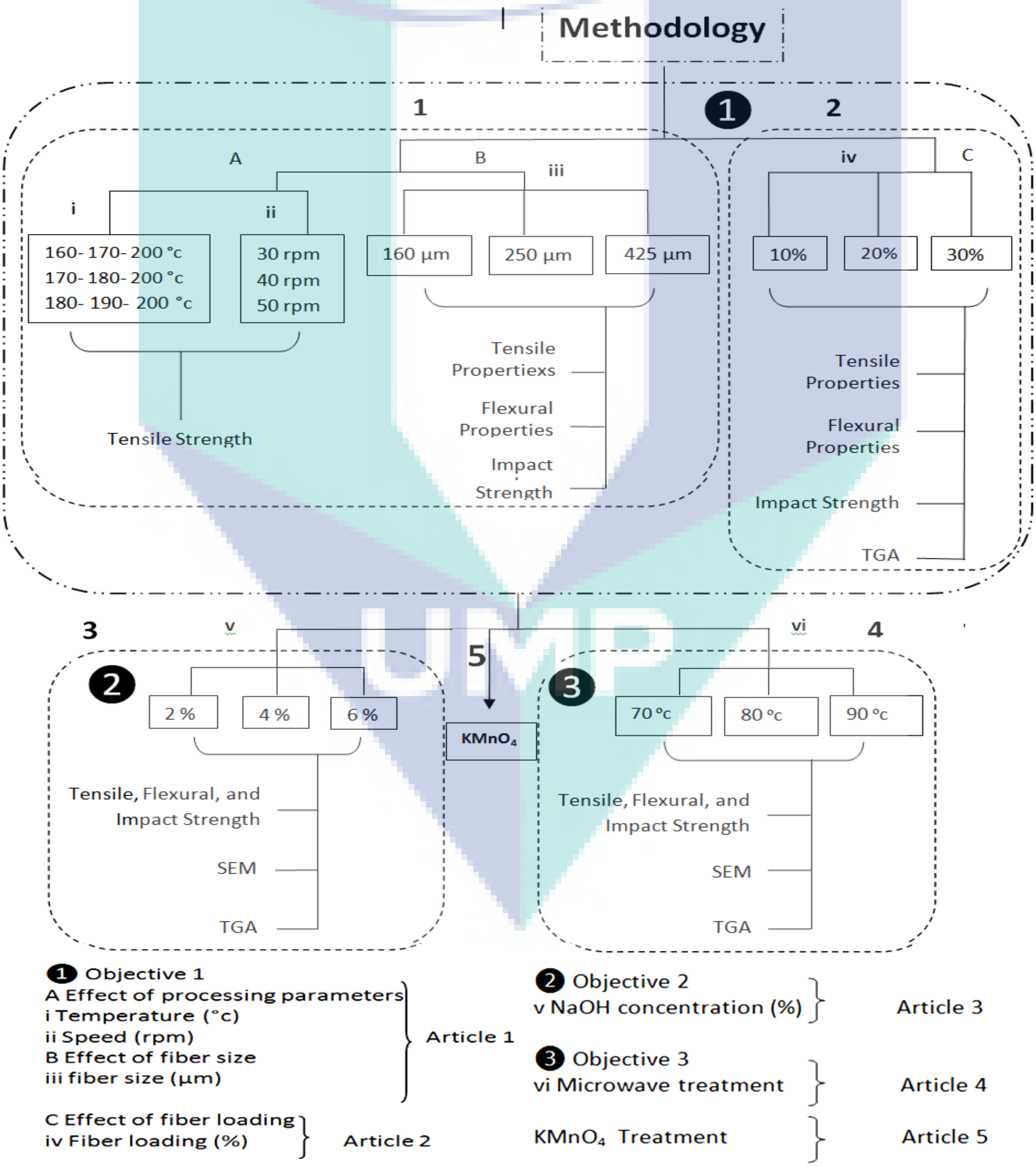

Figure 1 Flow chart of research methodology

3. LITERATURE REVIEW

In recent years, issues of climate changes, global warming, deforestation, non-degradable waste materials, water and air pollutions have become major concerns to the entire mankind. These concerns have forced scientists and engineers to search for solutions that would ensure the preservation of sustainable forests and green environment.

Tropical countries like Malaysia and Indonesia are homes to many types of natural fibres. One of them is sugar palm (Arenga pinnata) fibre. However, little research has been done to date on the significance of sugar palm fibre and its composites. Leman et al. (2005) studied the effect of fibre orientations (long and short fibres) on the impact strength of sugar palm fibre used to reinforce epoxy composites [25]. The result showed that the impact strength of long fibre composites was higher compared to the impact strength of short fibre composite. The study also found that both long and short fibre composites have higher impact strength than pure epoxy matrix. This indicates that fibre absorbs energy and reduces crack propagation in brittle epoxy matrix. Leman (2009) carried out a series of mechanical tests namely tensile, flexural and impact tests on the composites with 10%, 15%, 20% and 30% (by volume) of randomly short chopped sugar palm fibres [25]. The results showed that the strengths increased with the increase of fibre loadings of up to 20%, but the composite with 30% fibre content showed conflicting behaviour.

A study by Siregar (2005) also looked at the effects of fibre orientations but with a slight difference in focus from that of Leman's et al. (2005) [25, 26]. They studied the fibre orientation of woven, long and short random fibres and tested for tensile and flexural properties of sugar palm fibre used to reinforce epoxy composites. The results indicated that with the same fibre loading (10 wt%), the composite with orientation of woven fibre gave higher tensile and flexural properties than long fibre, while short random fibre composite had the lowest properties [26]. This study was continued by Suriani et al. (2006) who investigated the correlation between the interfacial bonding with their fibre orientations (woven, long and short random fibres) at various fibre weight fractions (10, 15 and 20%) [27]. Fractured surface of the composites were analysed and evaluated in details using scanning electron microscope (SEM). It was observed that composites with orientation of long and short random fibre composites showed clear evidence of having poor interfacial bonding where more fibre pulled out especially for short random fibre composites, at all fibre weight fractions.

Based on good mechanical performance of woven sugar palm fibre composites obtained by previous research (Siregar, 2005), Ishak (2009) carried out a study on the effect of fibre content (wt%) on mechanical properties of woven sugar palm fibre composites at fibre weight fractions of 13% (1 layer), 18% (2 layers), 22% (3 layers) and 29% (4 layers) with the matrix being unsaturated polyester [28]. In general, the results showed that tensile strength, tensile modulus, elongation at break, flexural strength and impact strength of the composites significantly increased (at $p \leq 0.05$) as the fibre content increased, while no significant increase was seen in flexural modulus. In general, it can be said that composites with higher fibre contents require higher force to break them after tensile and flexural tests. It was also observed that the addition of high amount of reinforcement fibres (29% (4 layers)) act to reduce the crack propagation in composite as well as increase the ability of the composite to resist fracture energy after impact test.

4. FINDINGS

Figure 2 that give high strength values for microwave method than untreated and chemical treatment one according to the same reason above [29]. The same results get for comparative studies between untreated, and treated samples by two methods (physical & chemical) with high values for chemical treatment by 6% NaOH reached 100kJ/m^2 than other physical and untreated one of 70 and 40 kJ/m^2 respectively see figure 19. According to the reducing the free hydroxyl group that give high interfacial forces with molecules of matrix at high temperatures.

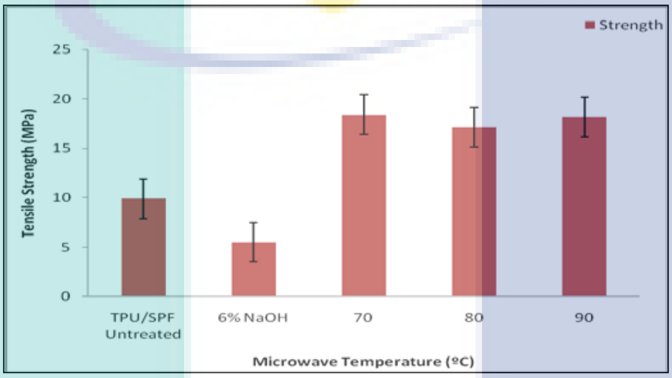

Figure 2 Comparative strength property between untreated,treated samples with NaOH 6%, treated fibre with physical plasma microwave method at different temperature

Fig. 3 shows the tensile strength of the fibre treated with different treatment methods for untreated sample serving as control. It was evidenced from the plots that permanganate solution had highest effect on the tensile strength of the fibre. All the chemical treated fibres had improved tensile strength compared to the untreated fibre. The chemical treatment used resulted in the removal of certain portions of hemicelluloses, lignin and other extractives covering materials. As a result, fibre surface became cleaner as evidenced in the SEM analysis. In other words, finer surfaces become more uniform due to the elimination of micro voids and thus stress transfer capacity between the ultimate cells improved. This resulted to higher tensile strength when compared with the untreated fibres. The effect of treatment method on the tensile strength of SPF fibre is shown in figure 13 from the graph, it can be seen that $KMnO_4$ had highest effect on the tensile strength of the fibre. The effects were ascertained at time of from 15-51 hours' time of drying and (0.033-0.125) wt. % from $KMnO_4$ respectively.

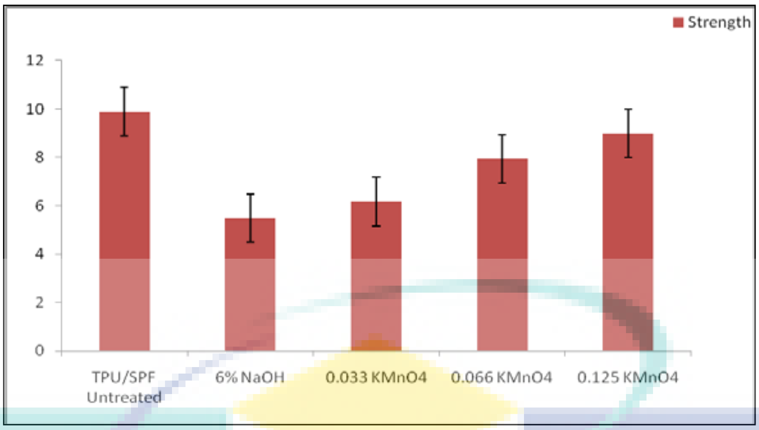

Figure 3 Comparative strength property between untreated and treated samples with both chemical materials (NaOH, KMnO4)

5. CONCLUSIONS

From the above study it could concluded that:

1. The design and development of a new TPU/ SPF composite system was successful for utilization of many applications.

2. Different operating conditions for manufacturing process of TPU/ SPF composite showed significant effect on tensile strength property as (temperature extrusion, and rotor speed).

3. Optimum study for manufacturing process get optimum values of operating conditions as 190 °C of temperature, and 40 rpm for rotor speed respectively, that chosen based on the best tensile strength of 14.01 MPa.

4. Different fibre size showed significant influence on the tensile, flexural and impact strength properties.

5. The 250 µm Fibre sizes exhibited the best tensile, flexural strength and modulus. Therefore, a fibre size 250 µm was considered to be the optimum size amongst the three size ranges examined.

6. The chemical treatment by sodium hydroxide solutions was eco- friendly method because it was cheap, less harmless and more safety, to improving the mechanical properties of final composite systems.

7. The optimum concentration of chemical solutions (NaOH) was 6% by weight that gain best mechanical tensile properties.

8. Alkali treatment, for sugar palm fibres are improved the structure of prepared composite material by removes waxy materials, and impurities. This action often leads to improvement of the interfacial bonding and improves the computability reaction between natural sugar palm fibre and thermoplastic polyurethane, then improves their surface and final mechanical properties.

ACHIEVEMENTS

Publications

1. Mohammed, A.A., Bachtiar, D., Siregar, J.P. and Rejab, M.R.M., Effect of sodium hydroxide on the tensile properties of sugar palm fibre reinforced thermoplastic polyurethane composites, 2016, *Journal of Mechanical Engineering and Science (JMES)*, 10(1), 1765-1777 [Scopus indexed]

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