

Hydrolytic Studies of Thermoplastic Abs / Epoxy Coated Kenaf Fibres Composites

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Abstract

This research is aimed at determining the degradation extent of Poly (acrylonitrile butadiene styrene) / epoxy coated kenaf fibre composite in certain solvents (water, acid and alkaline) at different exposure conditions. Epoxy coated kenaf fibre was compounded with ABS using a twin screw extruder from which test samples were later moulded. Test samples were later immersed in distilled water at ambient temperature for 24 hrs and 61 days differently, hygrothermal ageing was carried out for 61 days at 70 and 90 °C while resistance to acid and alkaline solutions was investigated for 7 days at room temperature. Results of water absorption followed Frick's law and all composites changed dimensionally, increase in water uptake with increasing number of days at different temperatures during ageing while all composites gained weights and thickness depending on the quantity of percentage fibre loading in their resistance to both acid and alkaline. Impact strength decreases with increase in fibre loading for both acid and alkaline. Hydrolysis of these composites has the indication of performance abilities in their respective medium.

Keywords: ABS, Kenaf fibre, hygrothermal ageing, acid, alkaline

1. Introduction

Lignocellulosic fibres are materials suitable for production of a range of composites used in different applications. The interest in the use of these fibres that are plants origin as reinforcements or fillers for polymers had increased over the years. When these fibres are incorporated into matrix materials such as thermosetting plastics, thermoplastics or even the natural polymers (Kozłowski & Władysław-Przybylak, 2006), they produce better composites (Saliu, et al., 2020). Meanwhile, the polarity and hydrophilic nature of these fibres and non-polarity of some thermoplastics result in compounding problems which in turns lead to irregular dispersion of fibres within the matrix thereby affects the efficiency of the composite. The factors that govern properties of short fibre composites are mostly; fibre dispersion, fibre length distribution, fibre orientation and fibre-matrix adhesion. Clumsiness must be avoided in order to produce efficient composites. However, efficiency of the composite also might be connected with the amount of stress transferred from matrix to fibres. But the coating of kenaf fibres with epoxy in the research of Saliu et al. (2020) in influence of surface modified fibres on properties of engineering thermoplastic ABS/Kenaf fibre composites was able to reduce these problems associated with fibre/plastic composites compounding.

Kenaf is used in place of wood presently in paper industries (Ashori & Raverty, 2007), and fibre reinforced plastics (FRP) is replacing synthetic fibres like glass (Abdullah et al., 2011). Because of the superior toughness of kenaf bast fibre, the potentiality usage as a reinforcing fibre of thermoplastic composites is very high.

Poly (acrylonitrile butadiene styrene) (ABS), terpolymer is an engineering plastic used widely in industries owing to its good mechanical and processing properties (Tang & Liang, 2003). ABS/Kenaf fibre composites were studied by Saliu, et al. (2014 and 2015) in determination of optimum curative concentration of epoxy coated kenaf fibre / ABS thermoplastic composites and the effect of epoxy concentration and fibre loading on the mechanical properties of ABS / epoxy-coated kenaf fibre composites respectively.

The exposure of polymeric composites to a combination of moisture and temperature where degradation of mechanical properties occurred is called hygrothermal ageing. These combinations of physical and chemical changes in the composite materials which affect the physico-mechanical properties of these composites can be reversible or irreversible depending on the exposure time and temperature (Antoon & Koenig, 1980). However, influence of hygrothermal ageing on damage behaviour and mechanical properties of quasi-unidirectional flax-fibre reinforced epoxy (FFRE) composite was studied by Scida and co-researcher (2013), they found out that tensile strength reduced much less for water-saturated composites while Weidi et al. (2016) also found decreasing tensile strength but increasing impact strength in influence of hygrothermal ageing on thermal degradation kinetics and the mechanical properties of long glass fibre reinforced polyamide 6 composites filled with sepiolite. The kinetics of moisture absorption was studied by Moh'd Ishak et al. (2001), the amount of water uptake by the specimens at regular intervals of time in hygrothermal ageing and tensile behaviour of injection-moulded rice husk-filled polypropylene composites. They found that the diffusion coefficients as well as the maximum moisture content of composites are dependent on the immersion temperatures and the filler volume fraction.

In this research, composites of Poly (acrylonitrile butadiene styrene) (ABS)/Epoxy coated Kenaf fibre (EKF) will be exposed to different solvents at different temperatures.

1. Materials and Methodologies

Materials used

Poly acrylonitrile butadiene styrene (The engineering thermoplastic matrix used in this work was Polytac ABS, an extrusion grade resin purchased from Chi Mei Company) pellets, kenaf fibres (KF) cut to 3 mm length from Kenaf Fibre Industries Sdn. Bhd. (KFI) Malaysia, acetic acid, sodium hydroxide (NaOH), epoxy, curing agent (4,4-diaminodiphenyl sulfone, DDS), chloroform and hydrofluoric acid (HF). These materials were supplied by Science and Engineering Research Centre (SERC) of Engineering Campus, Universiti Sains Malaysia, Nibong Tebal, Malaysia.

Methodologies

Surface treatment with alkali and thermosetting resin

Kenaf fibres were oven dried in the lab for 2 days at 37 °C before immersing for 3 hrs in 6 % NaOH, washed and neutralized by using 100 % acetic acid and finally washed thoroughly with distilled water. The treated fibres were oven dried at 80 °C for 16 hrs, and then coated with 30 % low viscosity epoxy resin that had been diluted with chloroform. Thereafter, the epoxy coated fibres were first oven dried in a range of 30 – 40 °C for 16 hrs and then at 80 °C for more 8 hrs to dry finally.

Compounding and Moulding of Composites

The mixing of epoxy coated kenaf fibres (EKF) with curative (DDS) was done prior the mixing of fibres with engineering thermoplastic, ABS in a bowl container before pouring into the hopper feeder of the twin screw extruder for compounding. The mixed materials were extruded in a twin screw extruder, (PSM 30, SINO-ALLOY Machinery Inc., HIS-ChiH, TAIPEI HSIEN, Taiwan) with temperatures profile of 175 – 230 °C at 70 rpm, extrudate



was immediately quenched in water (20 °C) and pelletized. Moulding was then carried at 210 °C temperature using 65 kg/cm² pressure after pellets has been dried for 3 hrs at 60 °C.

Hydrolytic Studies

Three different types of hydrolytic studies (water absorption, hygrothermal ageing and acid/alkaline resistance) were carried out in this research:

Water Absorption

Tensile samples of composites were submersed in distilled water at room temperature. Weight gains determinations were done periodically removing the samples from water, wiped, cloth dried and weighed using an electronic balance. The absorption test was carried out for 61days. The percentage of weight gained, %W, from water absorption was then determined using equation 1:

$$\%W = \frac{W_f - W_i}{W_i} \times 100 \quad 1$$

Where W_i is the initial weight of composite, W_f is the final weight of composite.

Also, the amount of water absorbed by the composites and their associated dimensional changes were determined by immersing the composite specimens in water at room temperature for 24 hrs. An ASTM D570 method was followed (the impact test specimens of 63.8 mm length, 12.7 mm width and 2.8 mm thickness). At the end of the experiments, test specimens were then removed, cloth-dried and weighed. Also, changes in the dimension in the thickness direction were recorded and changes in weight were calculated using the Equation 1.

Hygrothermal Ageing

This test was done by immersing the tensile test samples in distilled water inside beakers and placing them in water bath (Memmert made in Germany) at different temperatures (70 and 90 °C). Hygrothermal ageing was performed for 61days for both temperatures. The changes in weight of the samples were determined by the procedures similar to that used in the water absorption test. The physical changes were also noted.

Resistance to Acid and Alkaline Solutions

The dimensional changes of the test specimens of composites caused by the exposure to acidic and alkaline environments were determined following the ASTM D543 method. Composite materials of 63.8 mm length, 12.7 mm width and 2.8 mm thickness (Impact strength test samples) were immersed for 7 days at room temperature in aqueous solutions of hydrofluoric acid (50 % by weight) and sodium hydroxide (66 % by weight) in sealed containers. Cloth-dried weight, changes in dimensions, as well as the external appearances were noted. Thereafter, changes in weight were calculated by using the Equation 1.

The sorption of water by non-polar polymers especially those that contained fillers are believed mainly to have depended on the nature of the fibres. In case of cellulosic fibres like kenaf that is hydrophilic in nature, uptake of water is always expected to increase. Therefore, it was observed that all the sample composites absorbed moisture with an increasing numbers of days, from 0 to 61 days because they all contained kenaf fibres. That is to say, they all followed the Fick's law. This corresponded to Scida, et al. (2013), Wang, et al. (2016) and Salem, et al. (2020) findings but in contracts with that of Toubal, et al. (2016).

2. Results and Discussion

Water Absorption

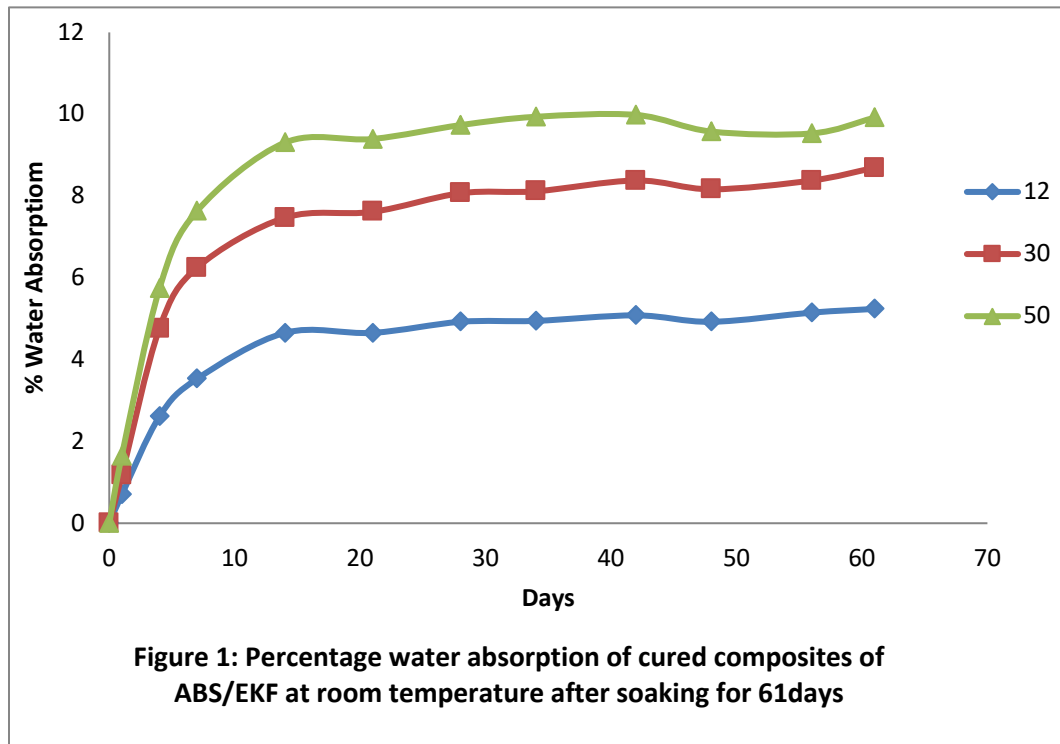


Figure 1 indicates the percentage water absorption of the composites from 0 day to day 61 at room temperature. It can be seen that uptake of water increased with increasing fibres content as depicted in the Figure. This is due to the cellulosic fibres love for water like Kenaf. The plot is in a progressive manner providing a wide margin between 12 and 30 % but a minor gap between 30 and 50 %. This observation is similar to that of Supri & Ismail (2011) and Rashid et al. (2010) but in contrasts with that of Ramaraj (2006). Good wetting of fibres by the matrix as well as adequate fibre-matrix bonding can cause a reduction in the rate and that of amount of water imbibed in the interphasial region of composites. For this reason, 50 % that has good wetting of fibres by the matrix as is expected to have less uptake of water, but due to the quantities of fibres in the composites, it's able to absorb more. The 12 % has the least water uptake due to having the least fibre contents.

Moisture/water absorption can result in the swelling of the fibres, causing dimensional stability problems in some of the lignocellulosic fibre composites. But this can be minimised in composites where the polymer has a good fibre-matrix bonding. Besides, water absorption can result to a decrease in some properties especially the lignocellulosic-based composites due to a accumulation of moisture in the fibre cell wall and inside the interphase region of fibre-matrix.

Figure 2 shows the percentage change in water absorption of composites after soaking for 24 hrs. It was clearly observed that all composites increased in weight after 24 hrs of soaking due to the cellulose content involved. Consequently, changes in dimensional values were observed too. However, the changes in weight were positives as all composites absorbed water, but that of the dimension could either be increased or shrinkage as the case of negative values. Increase in water uptake follows an increase in fibre content loading as 12, 30 and 50 wt. % fibre

loading increased from 0.46, 0.96 to 1.35 % weight, respectively (Figure 2). In general, all composites increased length-wise width and thickness except for 12 % which shrunk in width and thickness. They all increased dimensionally with an increasing fibre loading. This is attributed to an increase in the hydrophilicity of the fibres.

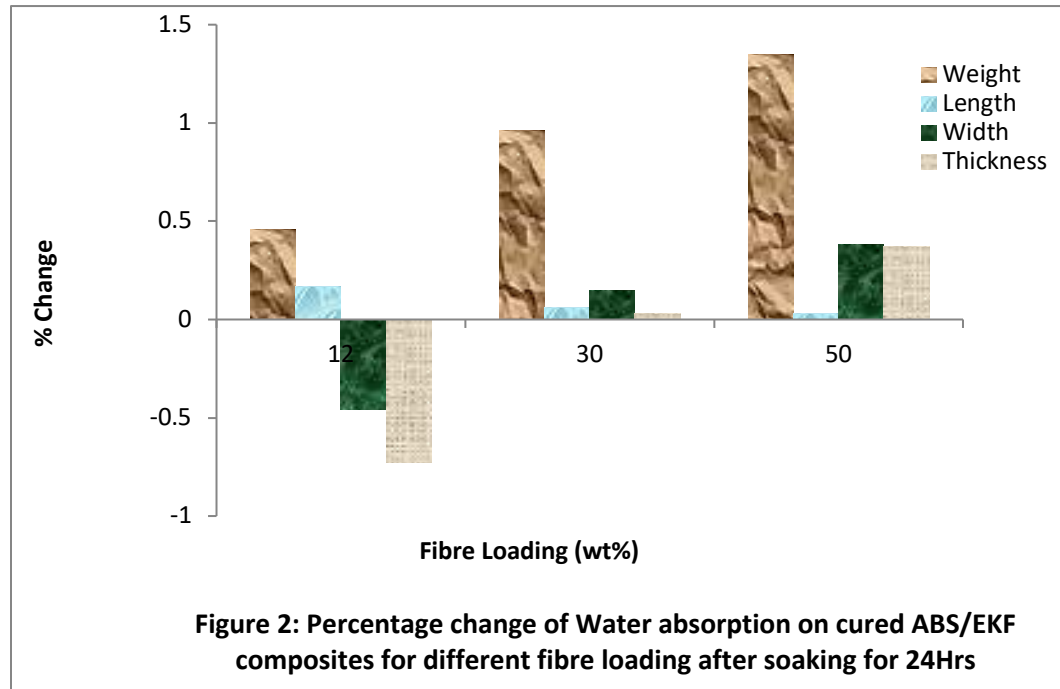


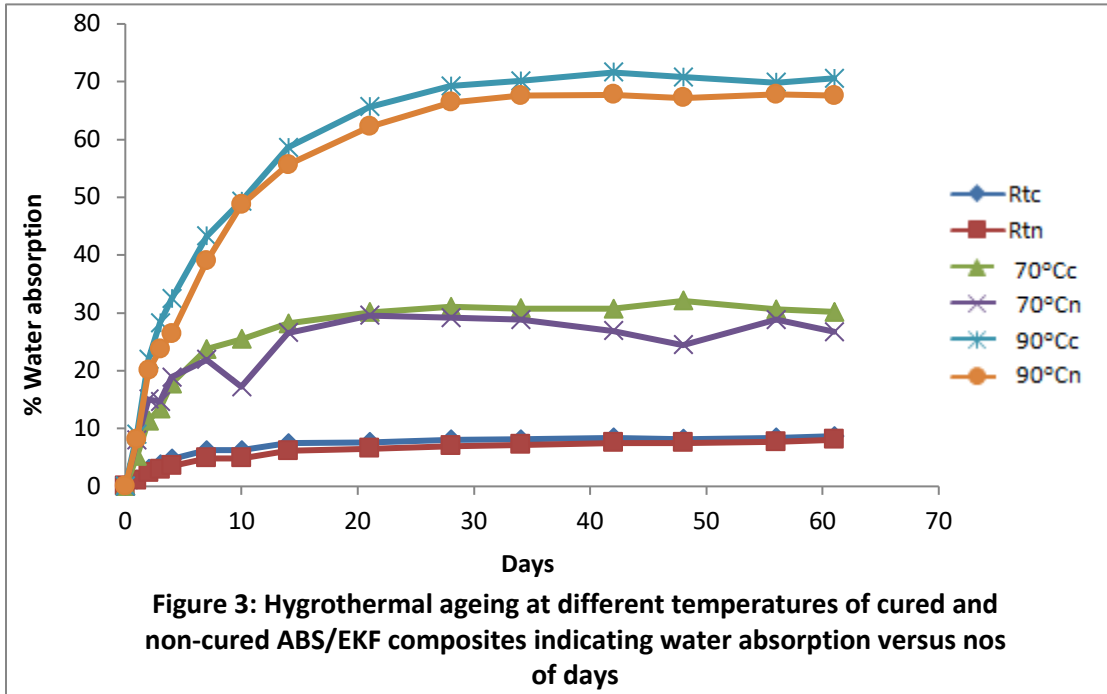
Figure 2: Percentage change of Water absorption on cured ABS/EKF composites for different fibre loading after soaking for 24Hrs

Hygrothermal Ageing

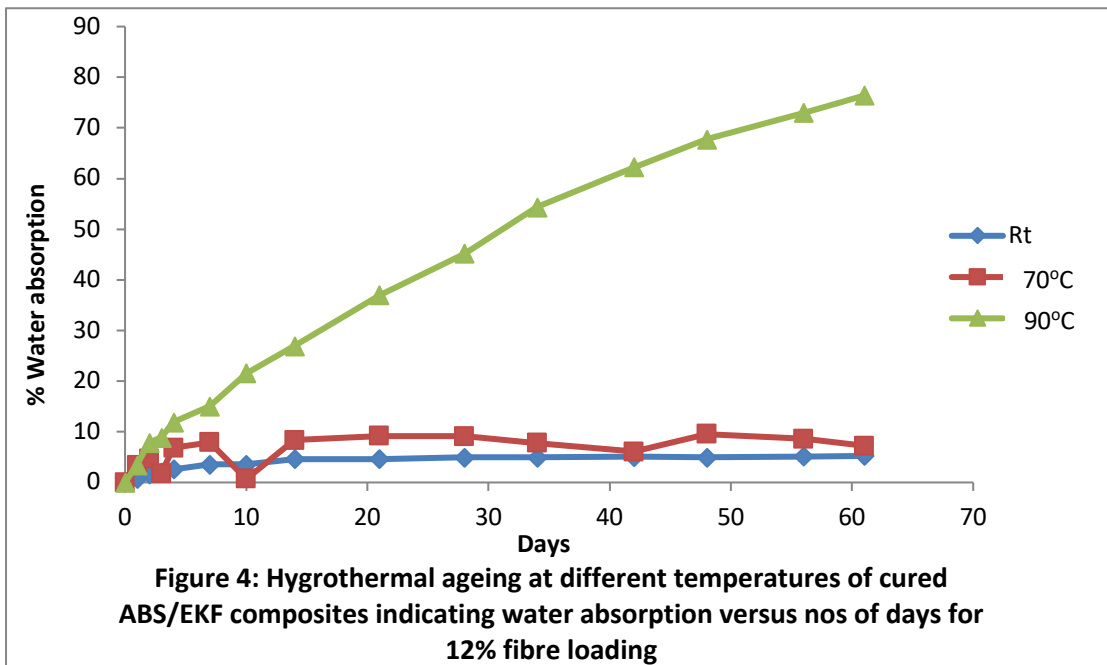
This test involved the use of test samples soaked in distilled water in the beakers embedded in hygrothermal ageing water bath at the stipulated temperatures for 61 days. Topping up of both distilled water in which the samples were soaked as well as the water in the bath took place regularly to prevent the drying of the samples and machines damage as well.

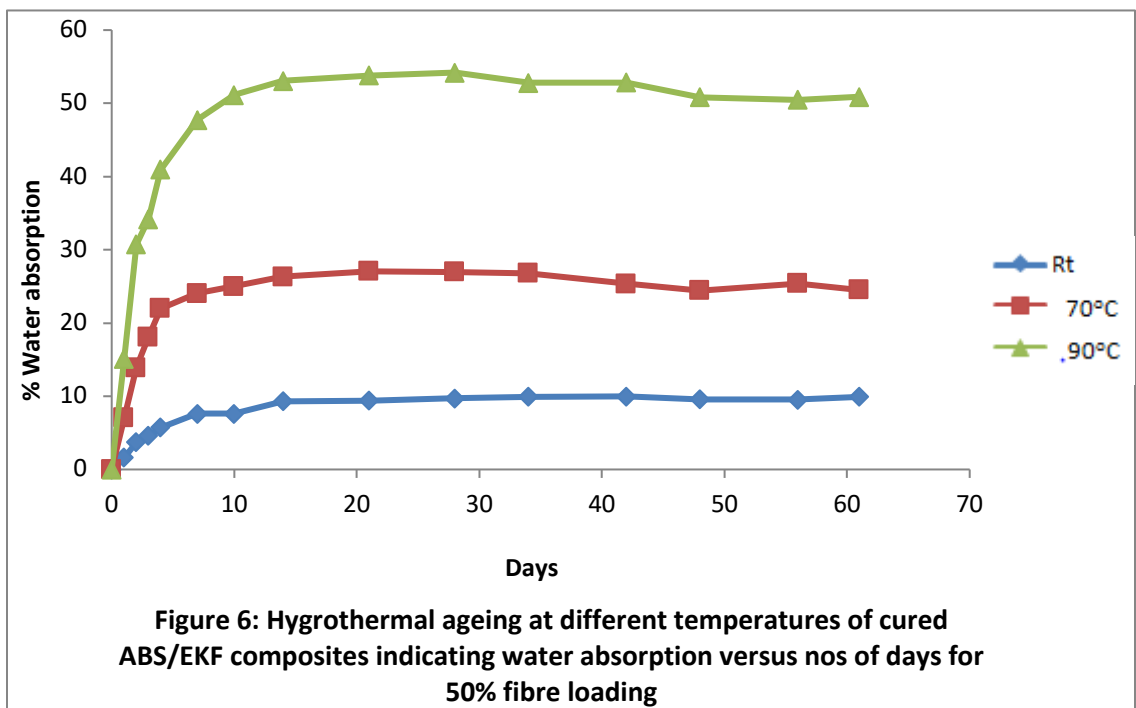
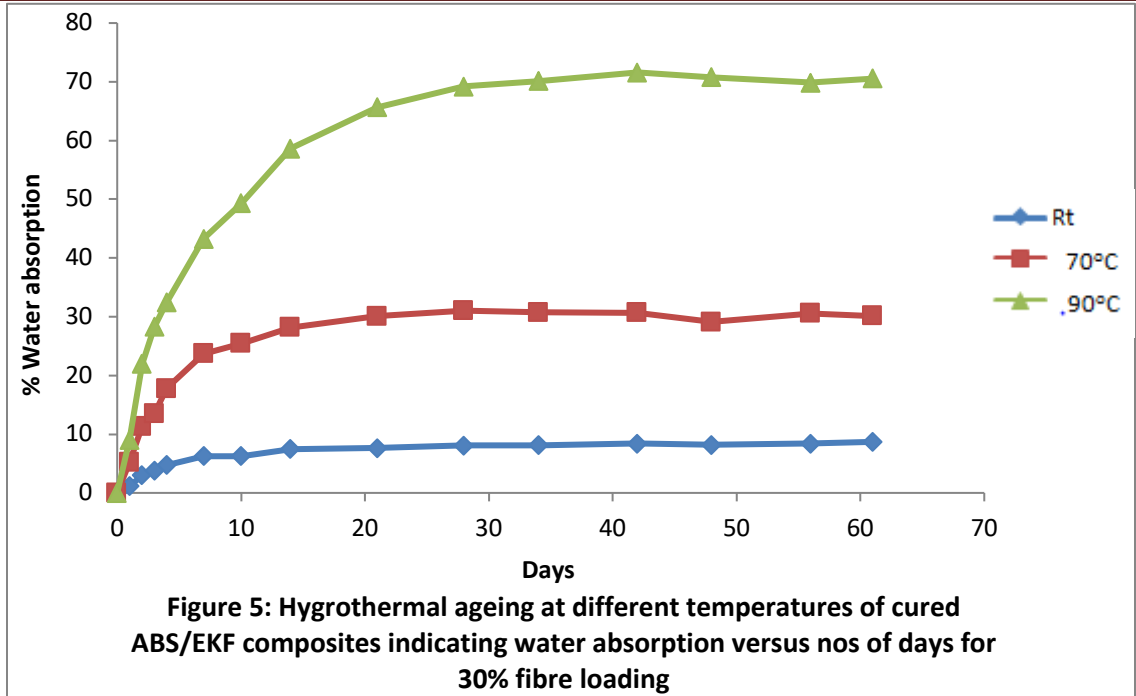
The natural water uptake ability of the composites could make it easy to reduce the physical bonding of the matrices. Therefore, it was assumed as reported by Bergeret et al. (2001) that water enters into the amorphous region of polymer at a phase where hydrolysis takes place at a rate depending on the crystallinity and content of the initial products. Figure 3 represents the hygrothermal ageing at different temperatures of 30% weight fibre cured and non-cured of ABS/EKF composites, and it is clearly observed that the percentage water uptake increased with an increasing number of days at different temperatures as observed by Bastioli et al. (1990) and Bergeret et al. (2001), due to the constant content of cellulose (30 %wt. of fibre) in the matrices. It is noteworthy that moisture sorbed do affect composites physically as the matrix is been plasticized and this further lowers its glass transition temperature. Although, these changes that occurred as a result of plasticization and swelling can be reversed by drying off the moisture from the composite. From this Figure 3, it can be seen that the hygrothermal ageing results of both the cured and non-cured composites behaved alike (i.e. the plots are very close to each other) water uptake of the cured composites have a better absorption rate with a clear margin between each temperature. At low temperatures especially at room temperature, polymers would be in a glassy state. Therefore, moisture sorption by the polymer matrix lowers its T_g , thereby making the polymer to soften at lower temperature. This happened in case of thermoplastic composite, especially for the room temperature absorption of moisture. On the other hand, at

increased temperature, there is an increase in thermal energy that causes rotation and translation (Surathi & Karbhari, 2006).



Rtc = Room temperature of cured composite; Rtn = Room temperature of non-cured composite



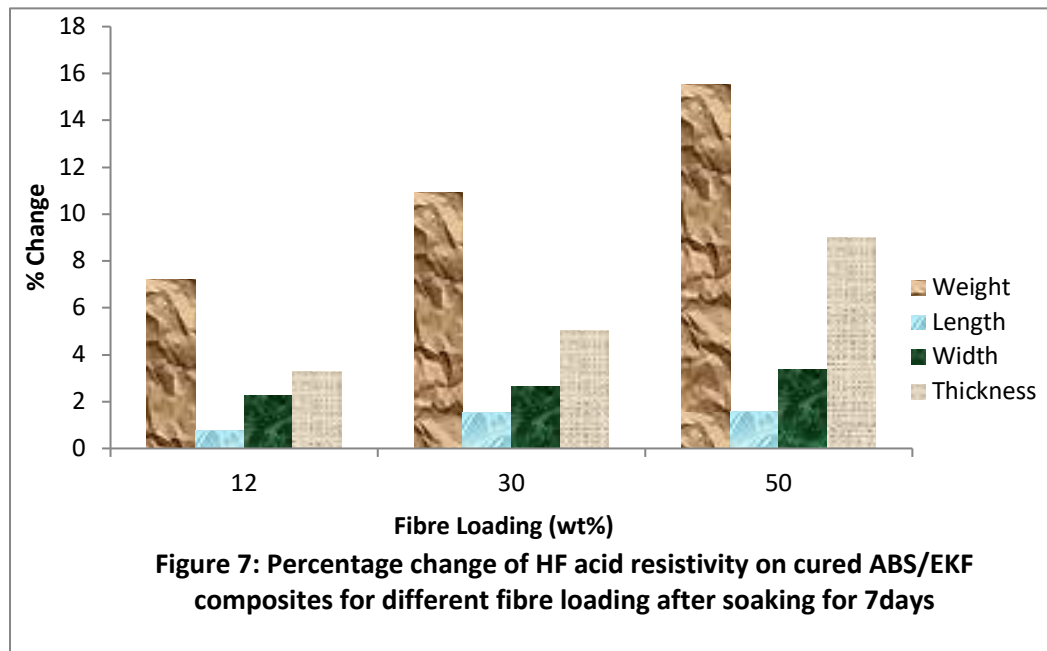


Figures 4 – 6 indicate the hygrothermal ageing of cured ABS/EKF at different temperature for 12, 30 and 50 % fibre loading respectively. Increase in water uptake was observed with an increasing temperature for the entire fibre loading. Comparing samples of 70 °C and that of 90 °C in Figure 4, it was observed that 12 % composite is the first sample to reach saturation level at room temperature and at 70 °C, an unidentified pattern was produced for this 12% fibre loading. (It can be said that ageing took place almost at the same period with little disparities), but it was still very active in absorbing more water at 90 °C. This can be due to small content of fibres in composite. A well defined Fickian pattern was observed for room temperature, 70 °C and that at 90 °C for 30 and 50 % fibre loading

(Figures 5 & 6). It is also noteworthy a decrease in water uptake with increasing fibres content. However, there was plastic deformation of samples in 90 °C especially connected with the ABS and deformation increase with fibre loading, this corresponds with the findings of Birnin-Yauri, et al. (2020). It is important to mention that deformation of all samples was observed as from day 21 but that of 12 % was observed to be less affected among others. This might not be unconnected with the quantity of ABS present in it formulation.

Resistance to Acid and Alkaline Solutions

The ability of composites to withstand HF acid and NaOH alkali solutions as composites soaked for 7 days in air tight containers (Plastics).

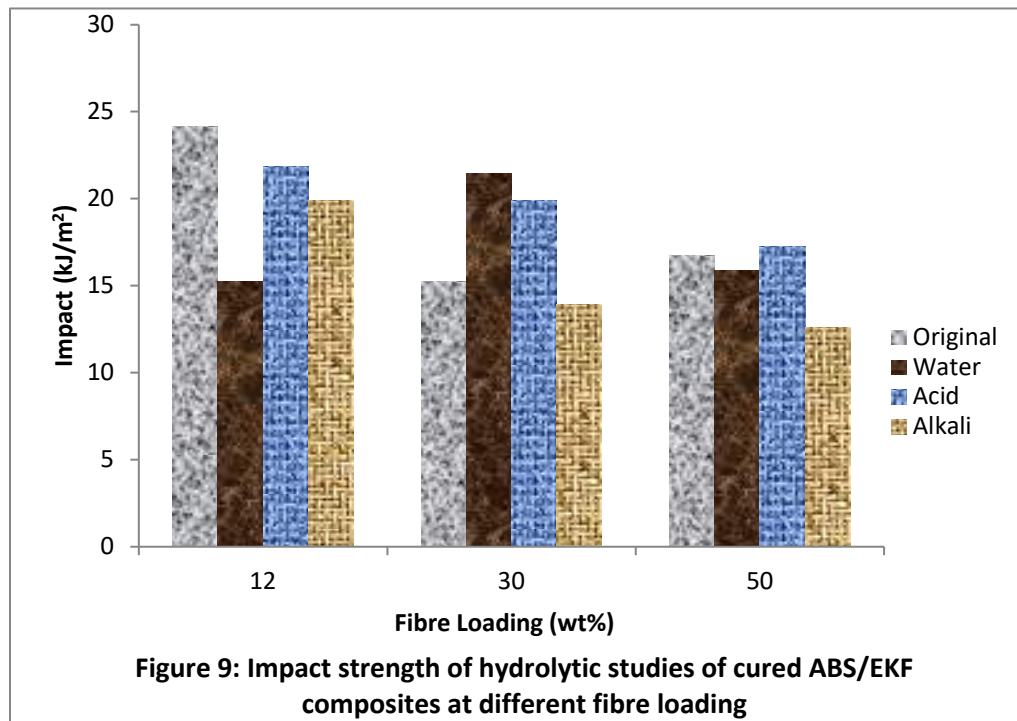
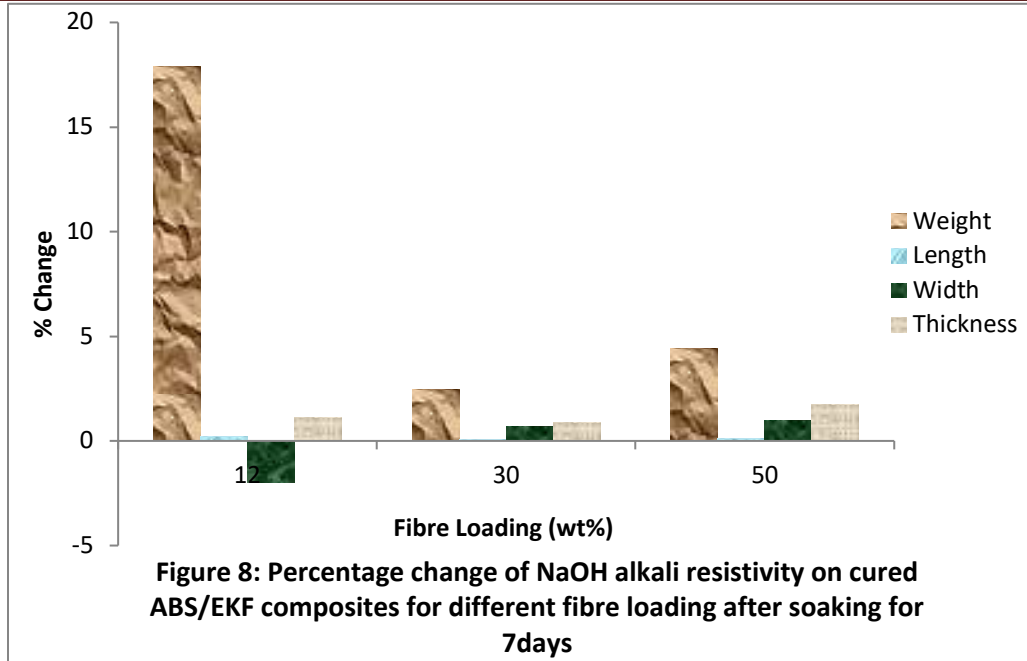


All composites performed well in acid (HF solution) medium as they all gain weight and increase in percentage change in all dimensions as the results depicted in Figure 7. The 50 % has the highest value change while 12 % is the least as shown in Figure. This might be attributed to their corresponding fibre contents in the matrix. It was also observed that there are increases in weight with increasing fibre content. This is due to the hydrophilic nature of the fibre which increases with an increasing fibre content. This confirms the finding of Jana & Prieto (2002). This test is able to demonstrate that all composites tested can perform creditably well in an acid medium.

There are weight gains by all composites in the alkali (NaOH solution) medium results as presented in Figure 8. It was observed from this Figure, that apart from 12 % which has the highest gain in weight and shrinkage in width, all samples increased in weight and all dimensions. The swift increase in the weight of 12 % composite might be due to the ability of thermoplastic ABS to absorb NaOH solution which has the highest percentage of ABS. This gained in weight is in agreement with the Jana & Prieto (2002) results.

Effect of Hydrolytic Studies on Impact Strength of Composites

Impact strength was carried out on the hydrolysed samples from water absorption, acid and alkaline tests to determine changes in impact strength as compared to the original ones carried out on those not hydrolysed and the results presented Figure 9;



From Figure 9, it can be observed that impact strength of all composites is affected either as percentage change (increase in weight) or percentage degradation (reduction in weight) depending on whether there was an increase or decrease in strength, respectively, when compared with the original values. Considering each sample from Figure 9, degradation occurred in all medium with 12 % composite having the least impact value in acid and highest degradation when soaked in distilled water for 24 hrs. 30 % fibre loading performed well in the entire medium as there was an increase in strength with the exception of composites in alkaline that loss in strength occurred with minimal margin. The 50 % is stronger in acid as it gained 3.17 % impact strength (Weidi et al., 2016), less degraded



in water than when in alkaline. Summarily, there was decrease in the impact values of hydrolysis with acid and alkaline as fibre content increases. This might be due to fibres hydrolysis by these reagents.

3. Conclusions

The ability of composites to perform in certain media at different conditions was carried out in this research and found that the extents of degradations are dependent on the fibre loading and temperatures at which hydrolysis takes place. It can be deduced that 12% fibre loading is better not hydrolysed at all to improve its strength while distilled water and acid are better used to impact tangible and quality strength into the 30 and 50% fibre loading respectively. Generally, acid hydrolysis produced better strength than that of the alkaline for all composites.

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