Water absorption of kenaf/glass/epoxy hybrid composites for insulator core

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Abstract. Kenaf fibres have gained substantial attracted considerable attention due to their economic feasibility and environmental acceptability. Natural fibre (kenaf) has started in mechanical and electrical applications by hybridising synthetic (glass) fibres. In recent years, the hybrid composite has been employed in various functions in industrial engineering. The present study deals with water absorption of glass/kenaf/epoxy hybrid composite materials used in high voltage polymeric insulator rods. Kenaf fibres have substituted two proportions of glass fibres (20 vol% IR20EP and 30 vol% IR30EP) with modified 60% of epoxy resins to fabricate the kenaf/glass/epoxy hybrid composites. The water absorption test was carried out at room temperature, and the water absorption resistance for composites was calculated regarding the rate of water absorption. Remarkable variations in the characteristics of water soaking up of the hybrid composite were obtained demonstrating that the water absorption influence on the insulator rod properties relies on the arrangement profiles and volume fraction of kenaf fibre of composite used. Based on the finding, a minor impact of water absorption on the glass fibre (non-hybrid) composite was noticed. Adding kenaf fibres to the composite fibreglass rod increases the composite’s water absorption. Glass fibres around kenaf fibres have been shown to minimise water absorption. After 330 hours, all the composite specimens attained stability and ceased to soak up water.

1. Introduction

Currently, natural fibre is a compelling new form of reinforcement used in polymer composites [1]. Natural fibres have acquired pervasion over synthetic fibres due to their low cost, light-weight, and vitality as renewables[2]. In various utilizations such as automobile, fabric, texture, air cleaner and dielectric processing, researchers and manufactures have begun to favour natural fibres with good characteristics[3]. Kenaf, as one of these natural fibres, has economic significance and friendliness for the community. Kenaf is capable of consuming carbon dioxide in addition to the short growth period[4]. In high voltage HV-insulator industry, polymer insulation rods are a widespread replacement for porcelain[5]. Polymeric insulators are used in high voltage transmission lines in the range of 69-735 kV. The core of insulator is made using pultrusion machines with fibre-reinforced polymer FRP, and the fibres are axially aligned with the line of manufacturing. Although FRP
provides advantages such as ease of installation, durability, and high mechanical strength, relative to porcelain insulating rods, a fracture during service leads to failing mechanically[6]. The water inside FRP will become nitric acid, which creates fractures. [7]. Fig.1 illustrates the composite insulator, which consists of three parts; the core (FRP), silicon rubber housing, and end-fitting[7]. The FRP insulator rods may be undefended under exceptional circumstances and allow humidity to enter into the composite. It can arise when the insulator's end-fitting is exposed against humidity [8]. Otherwise, the FRP rod is vulnerable from water penetration if the rubber housing coating thickness isn't adequate or is weakened due to corrosion[9]. Nevertheless, only if the acid content inside the FPR rod is high can a crack occur.

On the other hand, water runs around the FRP insulator chain, resulting in electrical breakdowns. The composite insulators' electrical properties have been strongly dependent on water absorption. The quantity of water absorbed must be measured to determine moisture absorption on the composite insulators' electrical properties. The humidity absorption of glass-reinforced-polymer composites used in polymeric insulator FRP rods has been investigated by Kumaso et al. [9]. It was noticed the high reliance on water absorption on the composite design. Akil et al.[10] have investigated the influence of water intake on hybrid jute/glass/polyester hybrid composites' mechanical characteristics. This study found that a cross-sectional configuration of kenaf fibre covered by glass fibre outer layer managed to decrease water absorption to 1000 h. Alaseel et al.[4] investigated the water absorption of glass/unsaturated polyester composites reinforced with kenaf fibre with three different volume fraction and three different fibre profile arrangement. This study discovered that water absorption significantly relies on the kenaf fibres arrangement profiles than its fibre content. Water absorption of pure glass fibres reinforced UPE composite has increased by ten times by hybridisation with kenaf fibres. Numerous laboratory processes can determine the resilience of hybrid composite materials to moisture absorbing [11]. In this study, the water absorption of kenaf/glass/epoxy hybrid composite were investigated for the insulator core application. The existing commercial glass/epoxy composite was used as a control sample for comparison in its properties.

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2. Experimental

2.1. Kenaf Fibre (KF)
Kenaf fibres (KF) possess good potential to be the alternative material in the production of fibre reinforced materials. In recent years, Kenaf fibre has shown promising characteristics for the use in natural fibre based applications as explored by the Malaysian Kenaf and Tobacco Council. Kenaf fibre has particular properties, like hardness, biodegradable, and high impact resistance, making it an attractive material for reinforced polymer composite. Kenaf fibre is made from the Kenaf (Malvaceae family) stem staple that takes less water to cultivate. It usually hits 3-4 metres in four to five months and can mould three times a year. Kenaf is economically inexpensive and readily widely abundant among other natural fibres. The density, specific gravity, diameter, tensile strength, Young's modulus,
and elongation to break of kenaf fibre are (1.19-1.4 g cm\(^{-3}\), 1.04 g cm\(^{-3}\), 17.7-100 µm, 295-930 MPa, 22-53 GPa, and 1.5-6.9 % respectively[12][12].

2.2. Glass Fibre (GF)
Glass fibres (GF) have been manufactured by melting of marbles of glass at approximately 2300 °F (1260 °C), and the blend was drawn with a simple cooling down with a coating device (usually platinum). A further drawing is employed to the fibre dimension. The fibres are then loaded onto a spool into a string. The fundamental forms of glass fibres are "E-glass" and "S-glass." Although E-glass has high resistivity and is known as (electric glass), S-glass has a so-called high tensile strength (structural glass). Glass fibre is typically isotropic. The density of glass fibre is 2.26 g.cm\(^{-3}\), specific gravity is 2.06 g/ cm\(^{3}\), Young's modulus is 72 GPa, tensile strength is 3450 MPa, the diameter is 3-20 µm, and elongation is 4.8%[13].

2.3. Epoxy
Epoxy is the most commonly used as a thermosetting resin in polymers. The epoxy resin is exceptional among all-polymer resins due to its distinct characteristics. Epoxy resin provides excellent thermal and mechanical properties, good electrical insulation properties, high corrosion, and chemical resistance. Epoxy is suitable for matrix materials because of its ability to work under varying conditions. Many researchers have used polymer composites using epoxy resin. Since epoxy is produced from the current insulators, several researchers have used epoxy resin to develop polymer composites. Epoxy (5192-1) is selected as the matrix material for the present study. Local resources supplied the epoxy resin and the hardener HY-5196. Table 1 shows the specification of the epoxy resin.

| Table 1. Mechanical properties of epoxy [14]. |
|---------------------------------------------|
| Density (g/cm\(^3\)) | Tensile strength (MPa) | Viscosity (MPa.s) | Hardness (ShoreD) | Compress strength (MPa) |
| 1.15                      | 85                      | 600-800           | 88                  | 300                    |

2.4. Fabrication of hybrid composite rod
Pultrusion is generally a cost-effective technique to produce a low-cost reinforced fibre composite. It is a constant process for the manufacturing of a cross-sectional composite and offers an attractive performance-to-cost ratio in addition to easy processing. A solid round kenaf/glass/epoxy hybrid rod composites were fabricated at Innovative Pultrusion Sdn. Bhd industry, Seremban, Malaysia. The hybrid fibres soaked in epoxy resin were pulled in a PULTREX Px1000-8T automated pultrusion machine. Kenaf and glass fibres saturated with epoxy were pulled into the mold with 24.7 mm diameter designed to infed area. The materials entered the heated die at temp 110 °C with fixed speed around (1.7 x 10\(^{-2}\) m/s) and pulled out at temperature 160 °C when it was completely dried. Fig.2 shows the two types of hybrid composites, (a) IR20EP vol.20% and (b) IR30EP vol.30% of kenaf fibres hybrid with glass fibres reinforced epoxy resin.
2.5. Water Absorption Test
The water absorption test was carried out according to the procedures described in details in ASTM standard D5229/D5229M-92[15]. To eliminate the machining remains such as soil or grease, the specimens have been washed. The mass of the samples was initially measured then reported and the specimens submerged in water immediately. The weight difference was calculated using a 0.1 mg analytical scale. The specimens were immersed in water until they reached equilibrium state.

3. Results and Discussion
In general, the absorption of water in a hybrid composite depends on the form of fibre, the surface of the exposed and covered fibre, the matrix's density, temperature and volume fraction. The behaviour of water absorption considered as it rises over time until reaching the saturation level. The water absorption tests of control (epoxy), IR20EP, and IR30EP specimens are conducted under the same water absorption test conditions of kenaf/glass/Epoxy hybrid composites. The average reading of three specimens of each hybrid composite profile was recorded and compared with the control (epoxy) composite results. Fig.3 illustrated the water absorption behaviour in composite samples. The percentage of water gain and time are presented in the x-axis and y-axis respectively. The water absorption of hybrid composites needed more than 350 hours to reach saturation level. For the IR20EP composite, the percentage of water absorption raised steadily from zero to a saturated level at 0.84%. Simultaneously, the water absorption in the IR30EP composite elevated from zero to 0.25% on the first day, then decreased to 0.22% on the next day. Then it substantially rised up to 0.42% in the next three days. In the days (6, 7, 8, and 9), the water absorption percentage slightly increased. It increased significantly in day 10 (0.42% - 0.55%), then it stayed with small constant increased until the saturated level at 0.6% after 17 days. Based on this finding, it can be inferred that the control sample consists of glass/epoxy had the lowest water absorption which was 0.1 %. However, addition of 20 and 30 vol. % of kenaf fibre in the composites resulted in increment of water absorption to 0.84 and 0.6 % respectively. This was attributed to the cellulose structure of kenaf fibre which contains -OH groups that could form hydrogen bonding with water molecules thus increased the water absorption until it reached fibre saturation point.
Figure 3. Water absorption of the hybrid and non-hybrid composites.

It was also observed that the specimen with 20 vol. % of kenaf fibre had higher water absorption compared to specimens with 30 vol. % of kenaf fibre. This is explained by the arrangements of fibre in the pultruded samples. Since the fibres were arranged loosely in the IR20EP composite, it had greater surface area with free -OH groups that could react with water molecules and finally absorbed more water. On the other hand, the fibres in specimen IR30EP were arranged tightly in the centre of the rod and had lesser exposed -OH groups thus resulted in lower water absorption. Therefore, it can be concluded that arrangement of fibres plays a very important role in determining its water absorption capacity.

4. Conclusions
Apart from the concern towards environmentally friendly material, the hybridization of natural fibres and synthetic fibres has subsequently reduced the manufacturing cost and its weight. However, the water absorption of the hybrid composites needs to be taken into consideration because it would affect the durability of the composites during its service as insulator core. The research emphasises on the effects of adding kenaf fibres in the water absorption of kenaf/glass/epoxy hybrid composite. The effect of kenaf fibre percentages (20 vol.% and 30 vol.%) and its fibre arrangement were studied. The following findings are drawn from this study:

- The control specimen (pure glass fibres reinforced epoxy) had a very minimal water absorption which was less than 0.11%.
- The incorporateion of kenaf fibres affects the composite's water absorption. Water absorption of kenaf/glass/epoxy hybrid composite had increased seven times more than pure glass/epoxy (non-hybrid) composite.
- The influence of the arrangement profile of kenaf fibre was more significant than its percentage. IR30EP hybrid composite had lesser water absorption due to its glass-material surroundings with kenaf fibre. Maximum absorption of water was achieved in IR20EP because the fibres were not completely enclosed with glass fibres and had more free hydroxyl groups.
• Overall, the percentage of water absorption of the epoxy hybrid composites was low and below 1% of the composite weight. Therefore, the kenaf fibres have an excellent possibility for hybridisation with glass fibres and binded with epoxy matrix.

Author’s contribution
M.N.M.Ansari1,* - Idea & concept generation, suggestion and advice on the water absorption studies, suggestion on the interpretation of the data, supervision of the project and manuscript editing. Alaseel Bassam2 – the first draft of the manuscript, analyses and interpretation of the data, A.R.M.Nazim3 – analyses and interprets the results, manuscript editing, Noor Afeefah Nordin1 - project management and co-supervision, suggestion and advice on the analyses, manuscript editing and revision. Zainudin Yahya2 – co-supervision of the project.

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