Tensile Properties of Hybridised Fire Retardants in Pineapple Leaf Fibre (PALF) Reinforced Polymer Composites

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Abstract. This paper presents the tensile properties of hybridised fire retardants Pineapple Leaf Fibre (PALF) reinforced polymer composite. The polymer composites were prepared using the hand lay-up method of fabrication, in which two-layer PALF was used, and the epoxy resin with the fire retardants were mixed. The non-hybridised fire retardants are ammonium polyphosphate (APP), magnesium hydroxide (MH) and aluminium hydroxide (ALH), while the hybridised fire retardants are ammonium polyphosphate/magnesium hydroxide (APP/MH), ammonium polyphosphate/aluminium hydroxide (APP/ALH) and magnesium hydroxide/aluminium hydroxide (MH/ALH). The samples were tested using the universal testing machine with load cell 50kN using ASTM D3039 standard. The samples APP/ALH and MH/ALH have better tensile strength, which is 37.10 MPa and 37.05 MPa, respectively. The dispersion of fire-retardants in the reinforced composites seems to affect their mechanical performance. Meanwhile, sample MH/ALH has the highest elastic modulus with 3.65 GPa. Sample MH/ALH likely to be an excellent hybridised fire-retardant filler for the composites.

1. Introduction
Natural fibres as the reinforcement in polymer matrix composite have attracted many researchers in investigating and expanding their use as they are environmentally friendly and low cost [1–5]. On the other hand, pineapple leaf fibre (PALF) has good mechanical properties suitable for reinforcing the polymer matrix composite [6,7]. Nevertheless, natural fibres have high flammability that will reduce the potential of their application to expand [8]. Therefore, adding fire-retardants in the composite observed to reduce the reinforced composite's flammability [9]. Since the composite's fire retardancy properties are essential, the composite's mechanical properties also need to be investigated when adding the fire-retardant filler. Thus, this paper investigates the tensile properties of the hybridised fire retardants in pineapple leaf fibre (PALF) polymer composite.

2. Materials and Method

2.1. Materials Preparation
The pineapple leaf fibre (PALF) plain weave, 1 ply x 1 ply yarn, was supplied by Mecha Solve Engineering, Malaysia. The fire retardants used were ammonium polyphosphate (APP) supplied by Xingxing Flame Retardants Co., Ltd, China while, magnesium hydroxide (MH) and aluminium hydroxide (ALH) were supplied by R&M Chemical, Malaysia. The EpoxAmite™ 100-103 (slow hardener) that supplied by Smooth.ON, United States series resin was mixed in the ratio 100:28.4 by
weight as instructed by the manufacturer and 30% by the mass content of fire retardants were added in the mixture. The fire retardants and the epoxy were mixed using the planetary centrifugal mixer (ARE-310, THINKY Corporation, Japan).

2.2. Alkaline Treatment
The PALF were alkaline treated with a 5% concentration of sodium hydroxide (NaOH) solutions at room temperature for 3 hr. Then, the PALF was washed and rinsed repeatedly using distilled water to remove the excess of NaOH solutions. Next, the PALF was dried under the sun and were oven-dried at 60 ºC for 1 hr. This alkaline treatment is to remove the hemicellulose and other impurities that will affect the composite.

2.3. Composite Fabrication
The PALF reinforced polymer composite was produced in 300 mm x 300 mm x 3 mm and fabricated using the hand lay-up method. The fabrication process started by placing a PALF fabric layer, followed by a coating of the epoxy mixture was applied by rolling the mixture on the fabric fibre. The steps were repeated after two layers of PALF fabric applied. The epoxy mixture was able to penetrate the PALF fabric using this technique. Subsequently, the PALF reinforced polymer composite was left to cure for 24 hours at room temperature.

2.4. Tensile Testing
The tensile test samples were prepared based on ASTM D3039, where the dimension of the sample is 250 mm x 25 mm x 0.3 mm. The tensile test was carried out toward the PALF reinforced polymer composite with hybridised fire retardants (APP/MH, APP/ALH AND MH/ALH) with a crosshead speed of 2 mm/min using Universal Testing Machine AG-X plus 50kN, SHIMADZU, Japan. Tensile strength and elastic modulus were achieved and recorded from the average of three identical test sample.

3. Results and Discussion
A tensile test was conducted to investigate the influence of the hybridised fire-retardant compounds in the PALF polymer composite. The stress vs strain curve, tensile strength and elastic modulus were recorded from the tensile test.

3.1. Stress vs Strain Curve
Based on stress-strain response shown in Figure 1, the addition of the fire retardants in the PALF polymer composite clearly influences the reinforced composites' mechanical performance. The graph’s curves indicated a transition from the elastic to the plastic regions of the PALF reinforced polymer composites, demonstrating that the steeper the curve’s slope, the less ductile the composites are. The slope of the curve from the PALF polymer composite containing only MH indicates the high ductility of the reinforced composite followed by APP and ALH. Meanwhile, the hybridised fire retardants APP/ALH showed the best ductility than APP/MH and MH/ALH. Therefore, the combination of fire retardants with the best ductility would contribute to the higher tensile strength of the PALF polymer reinforced composites.
3.2. Tensile Strength

From Figure 2, the tensile strength of the reinforced composite seems to decrease as it affiliated with fire retardants. It can be seen that the sample with non-hybridised fire-retardant MH showed the best tensile strength with 41.58 MPa compared to another non-hybridised APP and ALH. The sample with MH fire-retardant appeared slightly decreased of strength which only by 2% compared to the control sample. The samples with APP and ALH were observed to be decreased by 17% and 19%, respectively, compared to the control sample. The results suggest that the decline of the reinforced composite's tensile strength is due to the fire retardants' agglomeration that affects the interfacial bonding between the matrix and the filler. As Bachtiar et al. (2019) and Ramazani et al. (2008) state, the inhomogeneity and adhesiveness between the fibre and the filler could affect the mechanical performance of polymer composite as reported from the previous study [5,7].

Meanwhile, the samples with hybridised fire-retardants APP/MH were sharply decreased by 27% of the tensile strength, while APP/ALH and MH/ALH appeared similar in reducing strength 12% when compared to the control sample. Based on the result, it seems like the combination of APP/ALH and MH/ALH improved their mechanical performance as the strength increased by 6% and 8% compared to non-hybridised APP and ALH, respectively. This means that the combination of fire-retardants APP/ALH and MH/ALH improved the homogeneity and adhesiveness between the fire-retardants and epoxy mixture with the PALF fibre.
3.3. Elastic Modulus

The elastic modulus in the tensile load determined the stiffness of the material tested. From Figure 3, MH had the highest stiffness among non-hybridised samples (APP and ALH) and showed increased stiffness by 19% compared to the control sample. Past studies suggested that MH as fire-retardant fillers increased the tensile properties as it gave good interfacial adhesion between filler and matrix [11]. In the meantime, the highest stiffness of the hybridised fire-retardant in PALF polymer composite is MH/ALH, which increased by 24% from the control sample. Sample MH/ALH observed to have the best stiffness and also better strength among another hybridised sample.

Figure 2. Tensile strength of the reinforced composites

Figure 3. Elastic modulus of the reinforced composites
4. Conclusion
The mechanical performance of the additional fire-retardants in the PALF polymer composite was reduced overall. However, the sample MH showed the lowest reduction, which is only reduced by 2% of tensile strength. Also, the hybridised sample APP/ALH and MH/ALH showed improvement in tensile strength compared to the non-hybridised sample. The hybridised sample MH/ALH contributes to the highest elastic modulus from the elastic modulus result, which means it has the highest stiffness. Therefore, sample hybridised MH/ALH showed a promising combination as the fire-retardants filler in the PALF polymer composite.

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