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Article

Optimization of Bending Strength in Hybrid Polyester-Wood Powder (*Eusideroxylon zwageri*) Composite with Variations in Volume Fraction and Fiber Orientation of Wire Mesh

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Abstract: A composite is a material formed from the combination of two or more constituent materials through a non-homogeneous mixture. This research aims to determine the effect of volume fraction and fiber orientation angle of the hybrid polyester-ulin wood powder (*Eusideroxylon zwageri*)-wire mesh composite on bending strength. The bending test was conducted using ASTM D-790 standard with a three-point bending test method. The composite was made using the hand lay-up method with various compositions of particles and polyester. The results showed that the composition with less ulin wood powder and finer mesh size with a 45° wire mesh angle orientation had the highest bending strength and high deformation capability. The addition of wire mesh did not significantly increase the bending strength but could reduce the effect of decreased deformation capability.

Keywords: hybrid composite; polyester resin; ulin wood dust; wire mesh reinforcement; bending strength; volume fraction

Introduction

In an effort to create materials with superior mechanical properties and high economic value, research on composites has rapidly developed. A composite is a material formed from the combination of two or more non-homogeneous materials aiming to obtain new properties not possessed by the constituent materials separately. Composites can be found in various applications ranging from the automotive and aviation industries to construction (Gibson 2016). One composite that is interesting to study is the combination of polyester with ulin wood powder and wire mesh.

Ulin wood (*Eusideroxylon zwageri*) is a type of hardwood known for its durability and strength. However, the waste of ulin wood produced by the wood processing industry is often not utilized optimally and only becomes waste (Nuryawan et al. 2018). Therefore, this research attempts to utilize ulin wood powder waste as a filler in polyester composites. Additionally, the addition of wire mesh as a reinforcement is expected to improve the mechanical strength of the resulting composite.

Polyester matrix composites have several advantages including resistance to corrosion and chemicals and relatively low production costs (Strong 2008). The addition of fillers such as ulin wood powder can improve the mechanical and thermal properties of the composite while the addition of reinforcing fibers such as wire mesh can provide additional strength and increase resistance to deformation (Mallick 2007).

The composite manufacturing method used in this research is the hand lay-up method, which is a simple and economical method for making composites. This method involves mixing resin with filler followed by the addition of reinforcement before being molded and allowed to harden (Callister & Rethwisch 2018). The main variables studied in this research are the volume fraction of ulin wood powder and the fiber orientation angle of the wire mesh.

This research aims to evaluate the effect of variations in the volume fraction of ulin wood powder and the fiber orientation angle of the wire mesh on the bending strength of the resulting composite. The bending test was conducted using the ASTM D-790 standard with a three-point bending test

method (ASTM International 2010). The results of the research are expected to provide useful information for the development of stronger and more economical composite materials.

Composites have become the material of choice in various industries due to their ability to combine the superior properties of their constituent materials. The use of wood powder in composites is not a new concept; previous research has shown that wood powder can improve the mechanical and thermal properties of polymer composites (Rowell et al. 1997). In this context, ulin wood has great potential due to its superior mechanical properties compared to other types of wood (Burmana et al. 2020).

Research on wood powder-based composites has shown that particle size and distribution can affect the mechanical properties of the resulting composite. For instance, research by Joseph et al. (2003) found that finer particles tend to produce composites with better mechanical properties due to more even load distribution in the polymer matrix.

Moreover, the orientation of reinforcing fibers in composites also plays an important role in determining the mechanical properties of the resulting material. Fibers oriented at certain angles can improve bending strength and resistance to deformation (Hull & Clyne 1996). Therefore, in this research, variations in the fiber orientation angle of the wire mesh are used to evaluate their effect on the bending strength of the composite.

The hand lay-up method used in this research is one of the most commonly used methods in composite manufacturing due to its simplicity and ability to produce composites with good quality (Chawla 2012). However, this method also has some limitations including dependence on the skill of the operator and difficulty in controlling uniform thickness and resin distribution (Babu et al. 2013).

The use of wire mesh as reinforcement in composites has also been previously studied. For instance, research by Ramesh et al. (2014) showed that the addition of wire mesh can improve the tensile and bending strength of polymer composites. However, this research focuses on evaluating the effect of variations in the volume fraction of ulin wood powder and the fiber orientation angle of the wire mesh on the bending strength of hybrid polyester-ulín wood powder composites.

Thus, this research is expected to make a significant contribution to the development of stronger and more economical composite materials. Furthermore, the use of ulín wood powder waste as a filler in composites also has the potential to reduce industrial waste and add value to the resulting material (Pickering et al. 2016).

Overall, this research aims to evaluate the effect of the volume fraction of ulín wood powder and the fiber orientation angle of the wire mesh on the bending strength of hybrid polyester-ulín wood powder composites. The use of the hand lay-up method is expected to provide useful information for the development of stronger and more economical composite materials.

Methods

This research was conducted using main materials in the form of ulín wood powder, wire mesh, polyester resin, mepox catalyst, and car wax/kit. The ulín wood powder was obtained from ulín wood processing waste, which was then sieved to obtain the desired particle size, namely 80 mesh and 100 mesh. Polyester resin was used as the composite matrix with the addition of mepox catalyst to accelerate the hardening process. Car wax/kit was used as a lubricant to facilitate the release of the composite from the mold.

The equipment used in this research includes composite molds, plastic cups, digital scales, calipers, scissors, knives, sandpaper, gloves, syringes, markers, and brushes. The composite molds were made of materials resistant to heat and pressure to ensure the shape and size of the resulting composite were as desired.

The research variables were divided into three types, namely independent variables, dependent variables, and controlled variables. The independent variables in this research were the ratio of polyester to particles (5%:95%, 10%:90%, 15%:85%, 20%:80%, and 25%:75%), particle size (80 mesh and 100 mesh), and wire mesh angle orientation (0° and 45°). The dependent variable was the bending strength test results, while the controlled variables were the catalyst mixture (1% of the total volume of polyester resin) and the open mold with the pouring process (hand lay-up).

The composite manufacturing process began with mixing ulín wood powder with polyester resin and catalyst. This mixture was then poured into the mold and added with wire mesh at the desired angle orientation. After that, the mold was closed and allowed to harden for some time until

the composite was ready for testing. The bending strength test was conducted using a universal testing machine according to ASTM D-790 standards.

Result

The bending strength test results showed that the composition with 5% ulin wood dust and 95% polyester at a 45° wire mesh angle orientation had the highest bending strength, namely 6102 MPa for 80 mesh and 7845 MPa for 100 mesh. Conversely, the composition with 25% ulin wood dust and 75% polyester at a 0° wire mesh angle orientation showed the lowest bending strength, namely 3487 MPa for 80 mesh and 2615 MPa for 100 mesh.

The finer mesh size, namely 100 mesh, generally produced higher bending strength compared to the coarser mesh size, namely 80 mesh. This indicates that finer ulin wood dust particles can spread more evenly in the polyester matrix and provide more effective reinforcement.

The addition of wire mesh as reinforcement did not significantly increase the bending strength of the composite. However, wire mesh could reduce the effect of decreased deformation capability, so the resulting composite had better overall mechanical properties. Macro photo results showed fiber pull-out fracture types on specimens with the highest bending strength and single fracture on specimens with the lowest bending strength.

Overall, this research showed that the volume fraction of ulin wood dust and the angle orientation of wire mesh fibers significantly affect the bending strength of hybrid polyester-ulín wood dust composites. The composition with a lower volume fraction of ulin wood dust and a 45° wire mesh fiber angle orientation produced composites with higher bending strength. Additionally, finer ulin wood dust particle size also contributed to the increased bending strength of the composite.

Discussion

The results of this research provide valuable insights into the development of hybrid composite materials that utilize ulin wood dust waste and wire mesh. The use of ulin wood dust waste as filler in composites not only helps reduce waste but also adds value to the resulting material. Additionally, the addition of wire mesh as reinforcement provides additional strengthening that can improve the mechanical properties of the composite, although it does not significantly increase bending strength.

The angle orientation of wire mesh fibers also proved to have a significant effect on the bending strength of the composite. The 45° angle orientation produced higher bending strength compared to the 0° angle orientation. This may be due to more even load distribution on the wire mesh fibers oriented at a 45° angle, thus providing more effective reinforcement.

The particle size of ulin wood dust also plays an important role in determining the bending strength of the composite. The finer particle size, namely 100 mesh, produced higher bending strength compared to the coarser particle size, namely 80 mesh. This indicates that finer particles can spread more evenly in the polyester matrix and provide more effective reinforcement.

The hand lay-up method used in this research is a simple and economical method for making composites. However, this method also has some limitations, including dependence on operator skill and difficulty in controlling uniform thickness and resin distribution. Therefore, further research is needed to develop more effective and efficient methods for making hybrid composites with ulin wood dust and wire mesh.

In conclusion, this research showed that the volume fraction of ulin wood dust and the angle orientation of wire mesh fibers significantly affect the bending strength of hybrid polyester-ulín wood dust composites. The composition with a lower volume fraction of ulin wood dust and a 45° wire mesh fiber angle orientation produced composites with higher bending strength. Additionally, finer ulin wood dust particle size also contributed to the increased bending strength of the composite. The results of this research provide valuable insights into the development of stronger and more economical composite materials.

Conclusions

This study successfully demonstrated that the volume fraction of ulin wood dust and the orientation angle of wire mesh fibers significantly affect the bending strength of hybrid polyester-ulín wood dust composites. The composition with a lower volume fraction of ulin wood dust and a 45° orientation angle of the wire mesh fibers resulted in composites with higher bending strength.

Additionally, finer particle size of ulin wood dust also contributed to the increase in bending strength of the composite.

The addition of wire mesh as reinforcement provided additional strength, enhancing the mechanical properties of the composite, although it did not significantly increase the bending strength. The hand lay-up method proved effective in producing hybrid composites with good mechanical properties.

The results of this research provide valuable insights for the development of stronger and more economical composite materials, while also contributing positively to the management of ulin wood waste and environmental sustainability. Further research on other variables and more advanced composite manufacturing methods is expected to yield better and deeper results.

Therefore, this study opens opportunities for the development of new composite materials that are stronger, economical, and environmentally friendly. The use of ulin wood waste as a filler in composites not only helps reduce waste but also adds value to the resulting material. Proper orientation of the wire mesh fibers and fine particle size of ulin wood dust can improve the bending strength of the composite, thus providing wider application potential in various industries.

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