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Ubaidillah Sabino
Fitrian Imaduddin
Aditya Rio Prabowo *Editors*

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Comparative Investigation of Matrix and Fiber Orientation Composite Ramie

Komang Astana Widi, Gerald Pohan, Wayan Sujana, Tutut Nani, and Luh Dina Ekasari

Abstract The development on the use of composite materials in the field of engineering is increasing. This is due to its superior properties compared to conventional materials; the ratio between strength and densities is quite high, having high rigidity, the simple manufacturing process, and its resistance to corrosion and fatigue. The purpose of this study was to determine the effect of ramie fibers orientation with Epoxy and polypropylene Resin Matrix on increasing tensile strength, bending strength, impact strength and fatigue strength. However, the utilization of ramie fiber composites is not optimally done because natural fiber composites are very susceptible to failure due to the changes in the orientation of the fiber and the ability of fiber adhesion with a less optimal type of matrix. The object of this research is a composite with ramie fiber using Epoxy Resin and polypropylene as the binding material. The presence of both ramie which is reinforcing fibers with epoxy and polypropylene matrix is greatly influenced by the orientation of the fiber. The tensile strength test results in the epoxy matrix increased up to 140% while the increase in polypropylene matrix could reach 187%. Based on SEM observations, the reduction of composite mechanical properties was due to several factors, namely porosity, adhesiveness between fiber-matrices and between matrices, overlapping fibers and broken fibers.

Keywords Ramie · Fiber orientation · Bending strength · Tensile strength · Impact strength · Fatigue strength

1 Introduction

The price of the component is largely determined by the quality of the material and the manufacturing process. One element of determining quality is based on service life. Composites produced from natural fiber materials offer the potential as

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a reinforcing element to increase the service life of components with a better price (efficiency) by using natural fiber materials of ramie (*Boehmeria nivea*) fiber which is very abundant and widely grown in tropical regions such as Indonesia. Besides, this material is easily available as long as the farmers can continue to produce and will automatically improve the standard of living of Indonesian farmers. In line with these considerations, automotive components have become a major target market for the development of ramie natural fiber materials as a substitute and development of automotive components.

Some of the problems in using ramie fiber as a composite reinforcing material on a product are shows that the results of tensile strength testing in the epoxy matrix were 140% while the PP strength increased by 187%.

2 Literature Review

The development of technical materials especially polymer composites, which include high-tech materials, manufacturing processes and the application of materials this decade has shown an increase [1]. Crawford, 1989 has defined and classified fibers based on the dimensions of length in variations in the diameter. Fiber diameter ranges from 5 to 100 μm. It has a continuous long shape and relatively short fiber pieces. Based on the diameter and length fiber is divided into three phases, namely whiskers, fiber and wires. Crawford also stated that if fiber reinforcement blends well with a matrix or resin which has a very strong adhesive bond, it can produce mechanical properties that meet a technical application. The orientation of the type of reinforcement fiber in the matrix of a composite material is divided into four models including (a) continuous fiber, (b) woven fiber, (c) chopped fiber and (d) hybrid [2].

Polymer material is an arrangement of hydrocarbon atomic bonds which have a repeated chain bond configuration. This material is divided into two groups: (a) thermoplastics and (b) thermosets. Thermoplastics are a group of plastic polymers that are able to be repeatedly heated to become soft and hardened again by a cooling process. Thermoplastic types include polymer styrene, acrylics, cellulostics, polyethylene, vinyls, nylons and flourocarbon types. The thermoset is a group of plastic polymers which will be degraded (unable to return to its original molecular arrangement) due to heating process. This group includes amino (melamine and urea), polyester, alkyds, epoxy and phenolics [3].

According to research by Wargadiputra, 2005, the failure of polyester composites with ramie boosters caused by the variation of load in the form of normal tensile stresses and shear stresses, which is due to the bond between ramie fibers and polyester metrics is not strong enough. Whereas Saidah's research in 2005 which analyzed the predictions of tensile loading on fiber orientation showed that angle orientation of 0°, 0°, 90° had a tensile stress greater than the angle orientation of 0°, 90°, 0°. From those research data, Ansys software will be employed in this study to predict stress based on component design and the effect of fiber orientation.

Previous research has been conducted using the hand lay-up method. The disadvantage of this method is the need for the manufacturer skills so that the resulting composite specimens have minimum void levels. Research conducted by Thomson, 1995 found that void were the main factors affecting the quality of glass/polyester fiber composite materials. The use of a suitable rolling tool can determine the quality of the composite panel made. This can be seen on the surface of a composite specimen whether it is distributed evenly or not.

Fillers are materials that are added to the matrix to reduce the amount of matrix volume in a composite material. The cheap price of filler materials will cause the price of the final product to be lower. Materials commonly used as fillers are between 10 nm to macroscopic size [4].

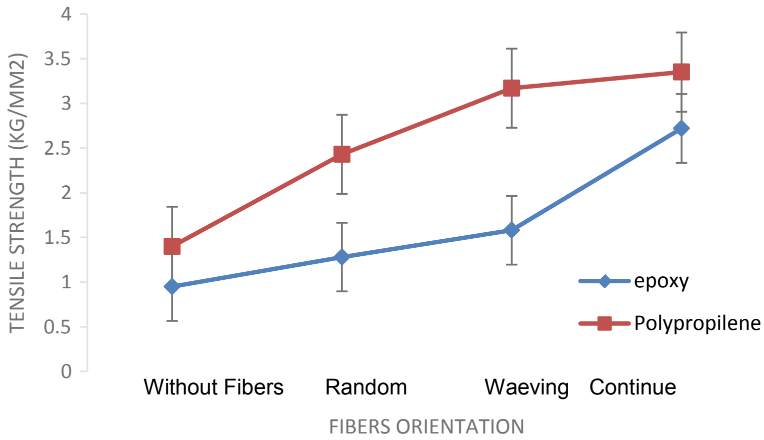
3 Research Method

Ramie fiber originates from Malang, East Java. The epoxy matrix will be made as a constituent material using the hand lay up manufacturing process. While polypropylene as a specimen will be made by injection molding manufacturing process. The processing of these components will use molds specifically designed for composite materials therefore it is necessary to add design tools to install the position of the fibers. Preparation matrices Epoxy and polypropilene. Reinforcement with ramie fibers orientation (random, woven and continues). Process of Making Test Specimens with Process Parameters with composition: Fiber 30% and Epoxy: 70%. Process Variable used in these research are ramie fiber orientation: linear orientation, Random and weaving, matrix material: Epoxy and Polypropylene, process: Hand lay-up. Mechanical universal testing machine used to knew their strength and elongation. Microscope and SEM (Scanning electron microscope) applied for the analysis.

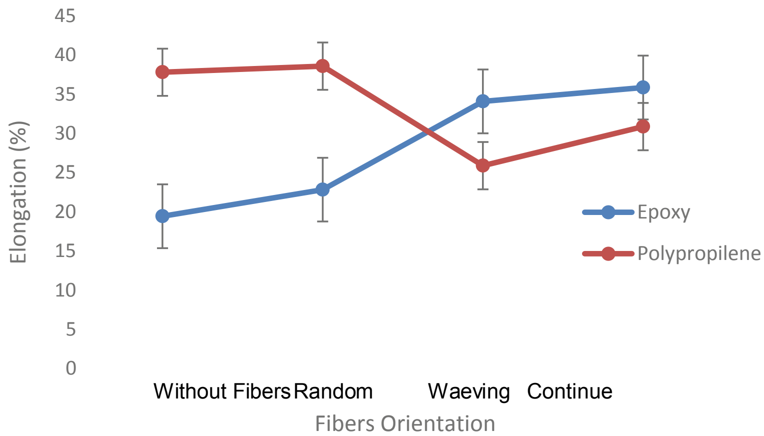
4 Result and Discussion

A tensile test is carried out to determine the tensile strength and elongation of the tested specimens. Tensile test data are presented in Graphs 1, 2.

Test results from the tensile strength and elongation on epoxy and polypropilene electric specimens showed different phenomena where the elongation values in epoxy electric specimens showed a very high value compared to the elongation formed in the polypropylene matrix as shown in Fig. 1, in which the elongation value was highly influenced by the type of matrix. Meanwhile the tensile strength will be more determined by the reinforcing fibers. It is proved by the value of the tensile strength of epoxy and polypropylene electrified specimens having a difference that is not too high when compared to the elongation values of the two matrices. This phenomenon is easier to find in bending testing as the graph model is generally formed on test specimens which is given loading in a perpendicular direction such as bending testing.



Graph 1 Tensile strength of epoxy and polypropilene matrix products test results with and without ramie fiber



Graph 2 Strain of epoxy and polypropylene matrix product tensile results with and without ramie fiber

As for in tensile testing, this is formed because the tensile test on the test specimen gets the initial loading in perpendicular direction to the specimen but right after that it will experience pulling loading at a parallel direction to the fiber.

The results of the analysis of observations of composite ramie yield results with reinforced epoxy and PP showed different actual strength differences with the results of the analysis predicted by using Ansys software on the specimen tensile test. Experimental results and analysis have differences in fiber distribution; theoretically the mechanics of fiber layers contained in resin can be predicted by equations based on fiber distribution, including square and hexagonal distributions. However, the actual

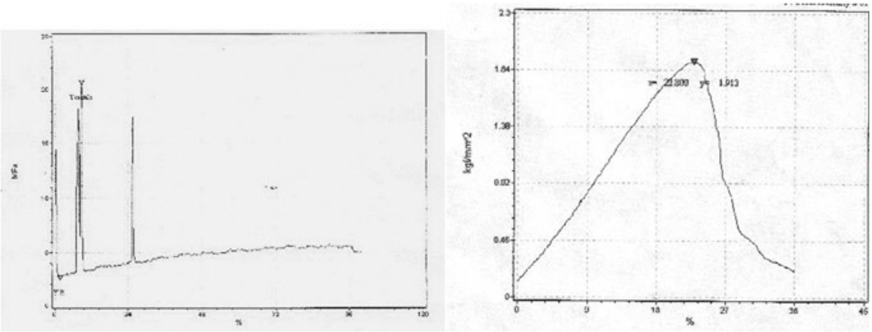
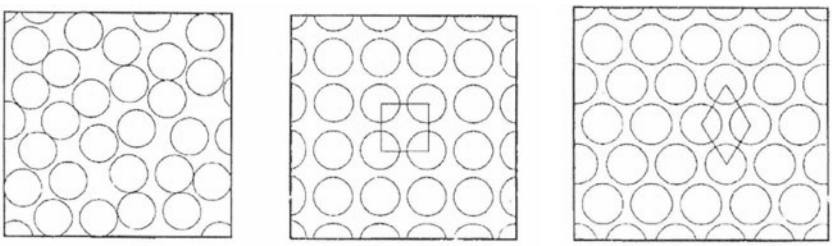


Fig. 1 Graph model of tensile strength towards elongation in epoxy and PP matrix specimens [5]

distribution is very difficult to predict therefore it results in significant deviations. The layered fiber distribution model inside the matrix showed in Fig. 2.

According to the fracture position, the specimens carried out by tensile testing are generally broken in areas that have the smallest volume of component size. By reducing the volume of components, the amount of fiber volume fraction will be greater than other regions and thus the fiber density will be greater so that the strength will be low.

In general the highest strength occurs in the direction of the direct fiber and the lowest strength in the weaving orientation. This can be observed based on the analysis of fiber distribution in the matrix where the phenomenon of failure will be easier to occur in fibers which have a shorter arrangement of spacing between fibers, namely the order of random, woven and then directional orientation. With a shorter distance between fibers, fiber density will increase and the strength will decrease due to decreased fiber strength. Besides, it will result in uneven strength as there are parts of fiber that have shorter spacing between fibers so that the difference in strength increases. It shows an increasing stress concentration. This phenomenon will be easier to occur in random fiber orientation. Whereas for the woven fiber, this phenomenon can also occur because by using two fiber orientations namely the x



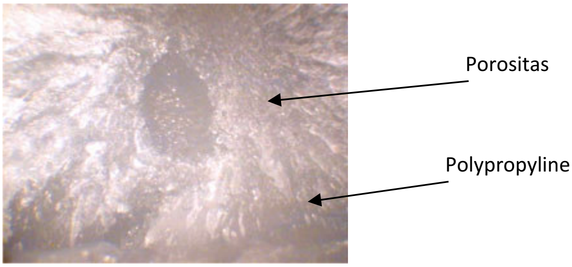
a. b. c.

Fig. 2 Fiber distribution in the matrix **a** actual distribution, **b** square distribution, **c** hexagonal distribution [2] and y directions, the layer arrangement also tends to be more uneven compared to the orientation of the fiber. From the results of observations of the orientation of the resulting strength values, it can be concluded that the installation of fibers greatly affects the strength in the composite and with the increasing direction of orientation of fiber installation arrangements, a more complex composite manufacturing method is needed to produce a good distribution arrangement. The tendency is if the direction of fiber orientation is less, the strength will be better as the arrangement of fiber installation will be easier with a smaller distribution error rate (Figs. 3, 4, 5, 6, 7 and 8).

Composite testing does not necessarily bring good results but it has to consider the cause of the decrease in strength. The decrease in tensile strength is caused by several factors, namely (Figs. 9, 10, 11 and 12).

- In composite strength measurement tests caused by the lack of uniform fiber conditions and uneven mixture of epoxy resin and ramie fiber in the mold.
- Decrease in composite strength is also due to the presence of voids in the composite that cause damage before testing occurs.
- In addition, it is also due to the influence of the position of non-interconnected fibers which makes it easy to crack the composite in the matrix. In the theory of fiber length also affects its strength, short fiber strength is smaller than long fibers.

Fig. 3 Macro porosity in the PP matrix is the concentration or initial crack



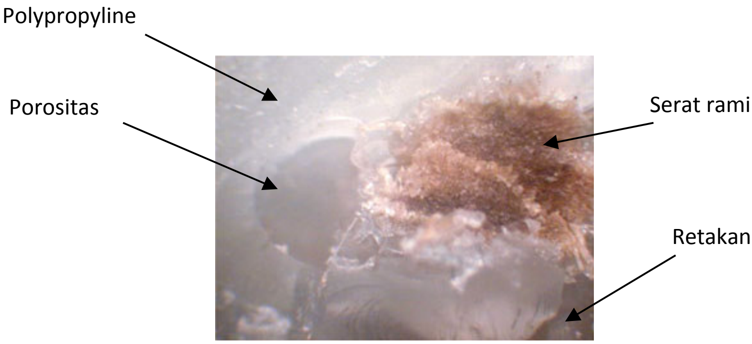


Fig. 4 Macro photo of the crack in PP matrix begins with the fiber-matrix interface

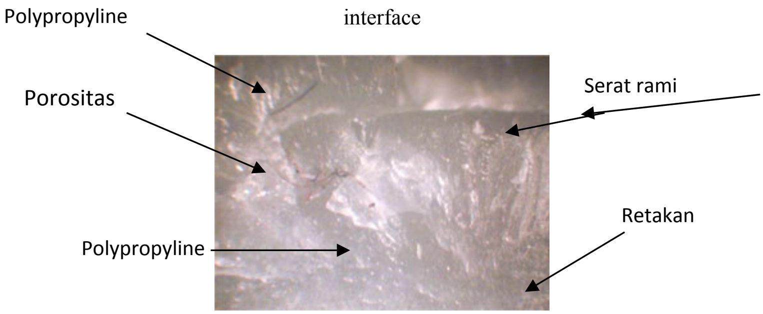


Fig. 5 The presence of crack propagation in the PP matrix

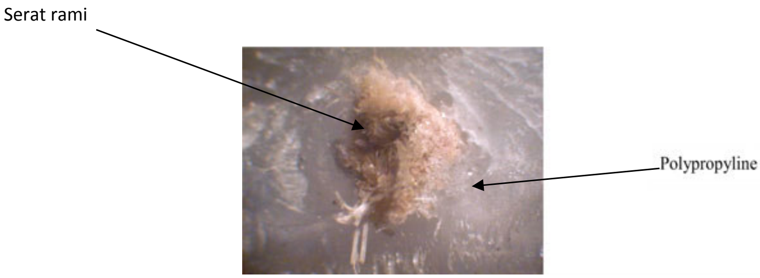
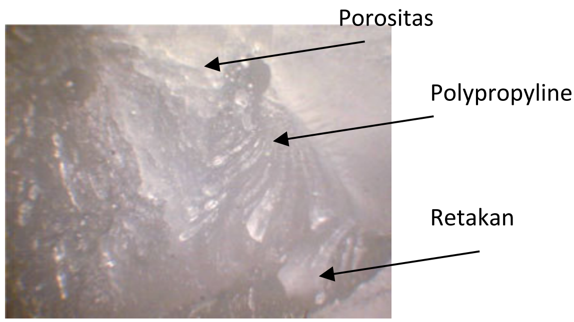


Fig. 6 Ramie fiber shows a burning condition

Fig. 7 PP matrix fracture model in the presence of porosity



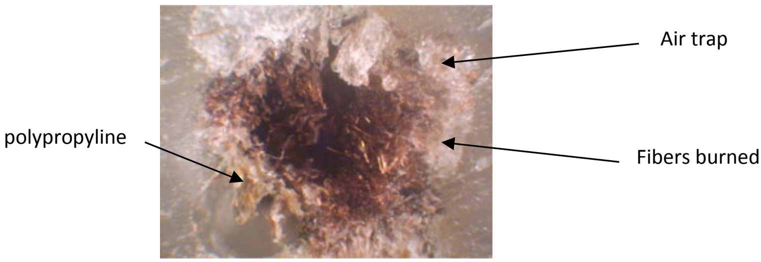


Fig. 8 Ramie fiber that burns tends to be followed by the presence of air trapped inside

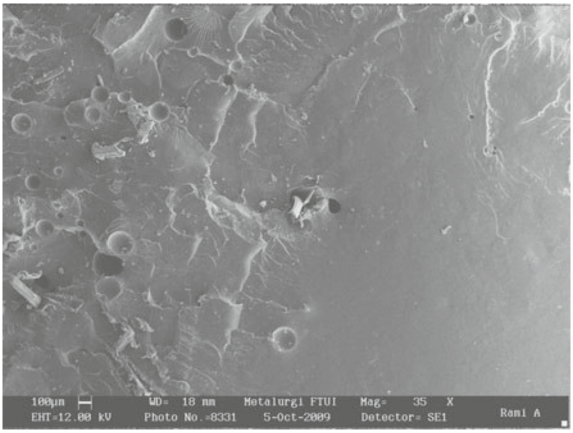


Fig. 9 The SEM examination of epoxy matrix composite

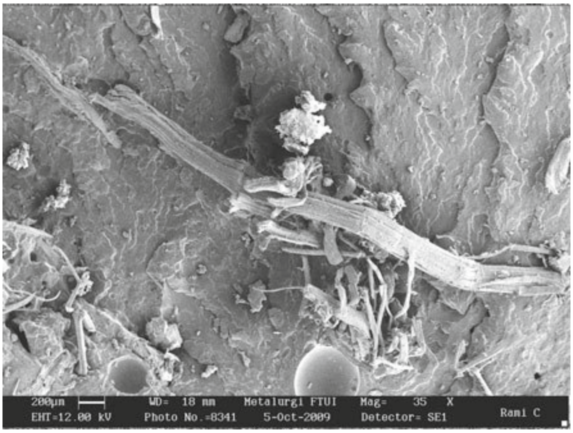


Fig. 10 Results of SEM testing of 35× enlargement in composite specimens with a woven orientation epoxy matrix

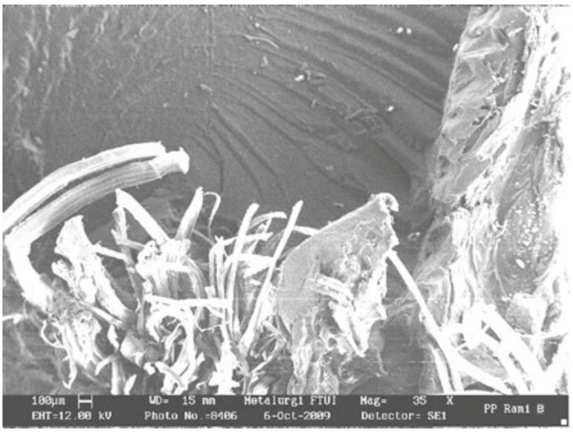


Fig. 11 Results of SEM testing of 35× magnification in composite specimens with a polypropylene matrix

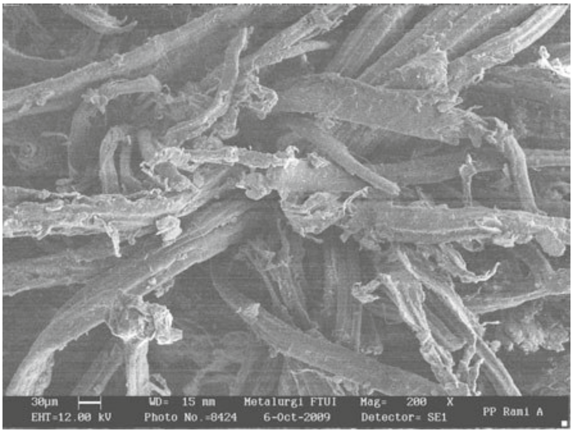


Fig. 12 Results of testing of 200× magnification SEM on composite specimens with the polypropylene matrix

Overall, the specimens with the epoxy matrix in continuous orientation show that the fault characteristics are caused by several factors, including (Fig. 9) in the form of formed porosity which tends to form like a bubble (trapped gas/air) which is cause by poor processing fabrication of specimens. In addition, the presence of this porosity, especially those that form around the fiber, will cause the fault model to become filamentous. The presence of withdrawn fiber is indicated by voids and fibers that are separated from the matrix. This fiber separation is due to the rupture of the fiber.

In the orientation of the woven fiber, Fig. 10 generally illustrated the presence of fibers that are transverse and/or overlapping with perpendicular fibers will produce fiber-matrix bond strength as indicated by the matrix fault groove along the transverse fiber which begins at the position of the overlapping fiber. The overlapping and subsequent crack propagation will be easier to occur along the transverse fiber. It will cause the strength of the woven position composites to have a lower strength than composites with continuous fiber orientation. The more overlapping fibers will cause the composite strength to be lower.

Fibers tend to accumulate because in the injection process the orientation of the fibers is arranged in ramie. The pressure on the manufacturing process of the specimens causes fibers to often gather on the opposite side of the injection hole. This causes the fiber-matrix interface to be very low. It is shown on the surface of the fault that most fibers (collected) will be separated from the matrix. The low bond is indicated by the presence of a gap formed in the fiber-matrix interface area and on the fiber surface there is no matrix attached to the fiber. Meanwhile, fibers which are generally found in the matrix as well as in the epoxy matrix, are not shown in SEM observations with polypropylene. This is due to the position of the collected fiber has the weakest bond therefore it acts as the beginning of the crack and then the crack propagation occurs in the matrix.

The results of tensile testing on composite specimens (fiber reinforced) showed good performance in epoxy and polypropylene matrices in which specimens given ramie reinforcement fibers had better properties (especially in direct orientation) than test specimens without ramie reinforcement fibers. Natural composites with a PP matrix that are given an injection process tend to produce poorer fiber orientation because the pressure will cause the fibers to collect in the area formed which results in the spread of uneven fibers so that the concentration formed will initiate cracks in the specimen. On the other hand, the injection process by utilizing the temperature will also cause the fiber to burn especially if the fibers are spreading.

5 Conclusion and Recommendation

5.1 Conclusion

From the results of all the mechanical tests, it can be concluded that the presence of ramie reinforcing fibers in both specimens with epoxy and polypropylene electricity is strongly influenced by the orientation of the fibers. The results of tensile strength testing in the epoxy matrix were 140% while the PP strength increased by 187%. Based on observations of microstructure and SEM for all tests in general showed a reduction in the properties of composite tensile strength due to several things including porosity, adhesion between fibers-matrix and between matrices, the presence of overlapping fibers and broken fibers.

5.2 Recommendation

For further research, it is expected to focus more on the manufacturing process of a product as the results of observations which is shows that strength can be optimized by reducing defects formed during the fabrication. The main obstacle in processing components by utilizing materials from natural fiber composites is that the result of these products (quality and quantity) are very varied.

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