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Effect of Ramie Fibers on Fatique Strength Automotive Product

Effect of Ramie Fibers on Fatique Strength Automotive Product

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Abstract. The automotive industry is already utilizing many composite materials for its products since composite materials are very environmentally friendly, have low economic costs and able to reduce weight. Ramie fiber reinforced by natural composites have a great opportunity to be used as materials for automatic components. The mechanical bonding of the ramie fiber reinforced composite pad can be improved by increasing the compatibility between the matrices and good product handling technique. In addition, the mechanical behavior is also greatly influenced by the orientation of the fibers in different matrices. This paper will discuss the effect of fiber orientation (unidirectional, woven and random) on several resin matrices (epoxy and polypropilene). The purpose of this study is to observe the effect of ramie fiber orientation on fatigue resistance properties in the form of handle components. The observations used SEM (scanning electron microscope) for observing of the failure mechanism. Fatigue test of the specimens using 80s carry-type handles (in situ). Handling fatigue testing equipment is specially designed in accordance with the application of the load. The strength of the fatigue observed in the handle component shows that the optimum value is produced in the handle with the orientation variation of fiber in both the epoxy matrix and the polypropylene matrix, namely 17141 and 8414 cycles. The presence of ramie reinforcement fibers in general can increase the fatigue strength of handle components. Whereas the lowest fatigue strength is owned by fibers which have a random orientation. However, when compared with no fiber, the component handles with randomly oriented fibers still have better fatigue strength.

1. Introduction

The use of natural fiber composites is one solution to support automotive development, as Indonesia is a big producer of fiber. However, the fiber potential has not been utilized optimally for bigger industrial needs. One of the fibrous plants that is currently becoming a trend and is being developed is ramie fiber [1]. This annual plant in the form of clumps is easy to grow and develop in the tropics; the ramie plant known by its Latin name Boehmeria Nivea (L) Goud produces natural vegetable fibers from ribbons on its very hard and shiny wood bark. In certain cases, ramie fiber has advantages over other fibers such as tensile strength, water absorption, and moisture and bacteria resistance.

Some reasons that underlie this research include:

(1) Conserve the environment (government programs, global warming) ultimate disposability a sustainability resources: natural fiber (FRNP)

(2) Natural fibers in Indonesia have very many types and quantities but have not been utilized optimally, especially for technical applications
(3) Effect of natural ramie fiber orientation as reinforcement material on polymer composites can increase the product's life
(4) Natural ramie fiber composites can be used to improve the performance of materials made of plastic materials
(5) Demand for automotive interior products, especially the old type car door panels

Ramie plants that have existed since the Japanese era during World War II are annual plants in the form of clumps that are easily grown and developed in the tropics, which are resistant to diseases and pests, and can support the preservation of nature and the environment. The ramie plant, known by its Latin name Boehmeria nivea (L) Goud, are able to produce natural vegetable fibers from ribbons on its very hard and shiny wooden bark. Ramie fiber has the characteristics of cotton fiber that is both spun and mixed with other fibers to be used as raw material for textiles. In certain cases ramie fiber has advantages over other fibers such as tensile strength, water absorption, moisture and bacterial resistance, heat resistance, ranked number 2 after silk compared to other natural fibers, lighter than sentimental and friendly fibers environment (does not pollute the environment so it is good for health). Ramie fiber can be used as a raw material for textiles, by mixing together cotton or polyester fibers, (as a substitute for cotton / cotton fiber). The development of ramie plants has a very bright prospect, the world's need for ramie fiber is 400,000 tons per year, so far the supply is 270,000 tons per year, with a total supply of 130,000 tons. From the results of the study, the quality of ramie fiber in Indonesia is able to compete with ramie fiber from China, Brazil, the Philippines, Taiwan, Korea, Cambodia, Thailand and Vietnam. Thus the development of this plant has a very bright prospect, because until now Indonesia has great potential to drive the people's economy through the rural economy, farmers' income and non-oil export commodities [2].

Kompas data [3] stated that polypropylene is a safe plastic material in sequence number 5. Safe means that the material can be used as packaging material for both food and drinks. Therefore Polypropylene (PP) is widely used to package soup, tomato sauce and margarine.

Table 1. Polypropylene and polypropylene with recycled rice husk fiber, a) melt flow index value, b) mechanical properties [4]

Samples	Tensile Strength (Mpa)	Flexural Strength (Mpa)	Impact Strength (Mpa)
Polypropilene	30.5	52.6	2.76
Polypropilene + Rice husk	21.5	48.7	3.17
Polypropilene + Rice husk (1st Recycled)	20.5	47.0	3.04
Polypropilene + Rice husk (2nd Recycled)	20.5	46.8	2.88
Polypropilene + Rice husk (3rd Recycled)	20.6	45.9	2.82
Polypropilene + Rice husk (4th Recycled)	20.3	43.3	2.61

Thermoplastic resins heated to liquid (plastic) are continuously extruded through the mold hole. The extrusion machine consists of a mold and a pressure unit. The mold provides the shape and pressure unit to push material out of the mold hole, cools and controls the shape and dimensions of the extruded product. This process is widely used to make rods, pipes, thin sheets and so on.

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2. Methodology
The methodology for the research in this paper is shown in Figure 1.

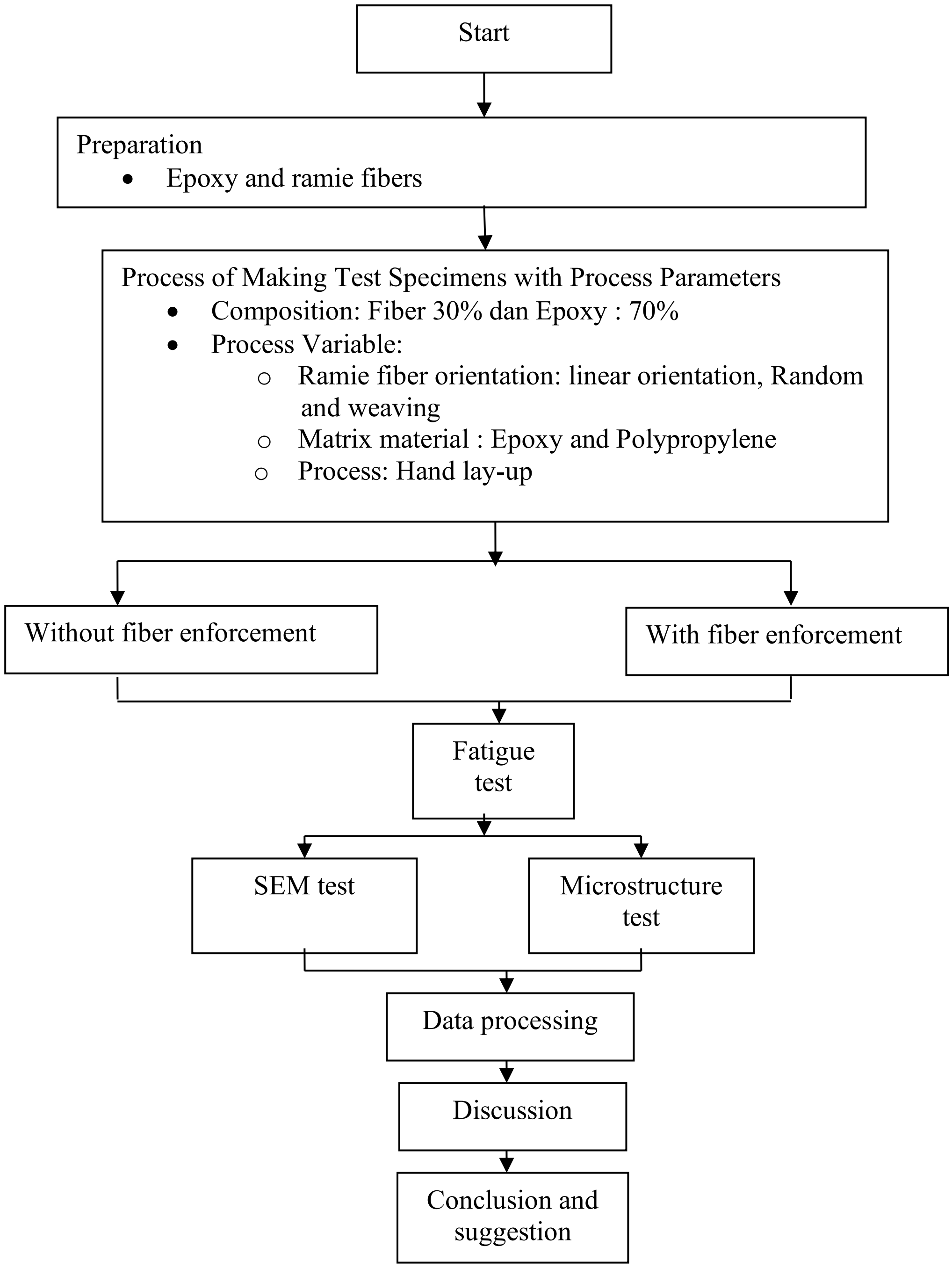

Figure 1. Flowchart of the methodology

3. Result and Discussion

In general, the orientation of the fiber is very influential to the change in fatigue resistance of car door panels. This is indicated by significant data which sequentially the orientation increases the fatigue resistance of the handle product from random orientation with the lowest fatigue strength followed by weaving orientation while the best is at unidirectional orientation. The analysis shows that fatigue strength is greatly influenced by the stress distribution contained in the component due to changes in the position of the fiber (fiber orientation). This stress distribution is also influenced by the design of the handle components [5].

Table 2. Data on Testing Results of epoxy matrix products with Ramie Fiber Orientation and Without Ramie Fiber

No	Fiber Type	Speed (rpm)	Cycle to Broken Specimens (N)				
			1	2	3	4	Average (∑)
1	Without fiber	800	6896	5287	6495	7479	6540
2	Random	800	9495	8479	10676	8297	9236
3	Weaving	800	13622	14246	11275	11387	12632
4	Linear	800	19721	17174	16557	15113	17141

Table 3. Data on Testing Results of polypropilene matrix products with Ramie Fiber Orientation and Without Ramie Fiber

No	Fiber Type	Speed (rpm)	Cycle to Broken Specimens (N)				
			1	2	3	4	Average (∑)
1	Without fiber	800	8522	7089	7255	6692	7389
2	Random	800	5485	7634	3795	4314	5307
3	Weaving	800	7233	8101	5244	3805	6095
4	Linear	800	9324	10112	6787	7436	8414

Table 4. Data on Test Results of fatigue matrix products and polypropylene matrices with Ramie Fiber Orientation and Without Ramie Fiber

No	Fiber Type	Cycle to Broken Specimens (N)	
		Epoxy Matrix	Polypropylene Matrix
1	Without fiber	6540	7389
2	Random	9236	5307
3	Weaving	12632	6095
4	Linear	17141	8414

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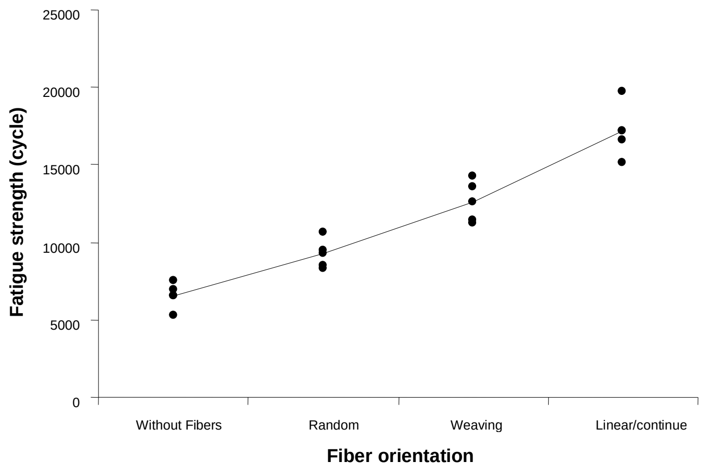


Figure 2. Test results of Epoxy matrics product fatigue with Ramie Fiber Orientation and Without Ramie Fiber Orientation

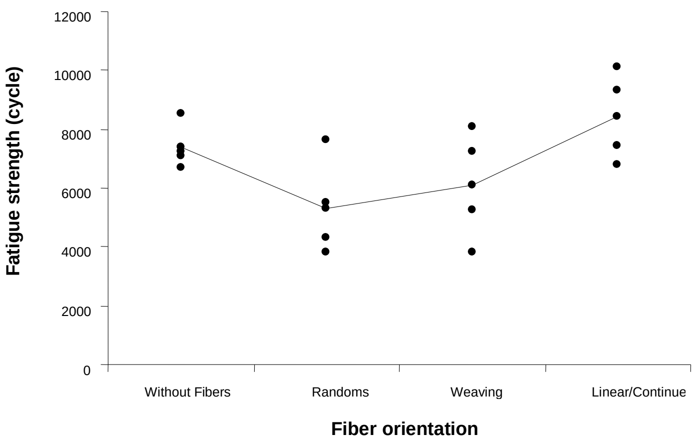


Figure 3. Test results of polypropilene matrics product fatigue with Ramie Fiber Orientation and Without Ramie Fiber

The initial fatigue resistance before the use of ramie fiber as a reinforcing element in both matrices, shows the fatigue resistance of the polypropilene matrix is better than the epoxy matrix. Meanwhile, if viewed from the results of fatigue strength testing by using fiber as a reinforcement shows that compared to polypropylene composites, epoxy matrix that is not too strong in this composite has two important roles, namely as a medium for transferring loads to the fiber, and the fiber-matrix interface deflects and stops small cracks, so that the composite can withstand cracks better than the single component/material forming. This is what causes the composite with the ramie-epoxy combination to be more effective than the ramie-polypropilene combination. Therefore, it can be concluded that the effectiveness of the epoxy matrix is better than polypropilene.

The fatigue test data shows that the presence of fiber as a reinforcement in the car door panel components can increase the service life of the car door panel components. However, fiber orientation can also affect the decreasing fatigue life of the component, ie from PP matrix without fiber with a fatique value of 7389 with the use of fiber in the direction of random orientation showing a decrease in the value of the average cycle endurance to 5307 cycles (N) and this fatigue strength will increase in the orientation of woven and unidirectional fibers. The influence of orientation of the fiber with random directions can increase the concentration of stress on the component, as evidenced by the number of initial cracks which are more numerous than other orientations. In addition, other factors that can increase concentration are increased formation of porosity due to uneven bonding between the fiber and the matrix, which with random orientation or irregularity, so that more air is trapped because the matrix or epoxy resin cannot unite the overlapping fibers. Then the bond between the fiber and the matrix cannot be so fused. The surface area of the trapped air (porosity) in the area of the fiber that is not or is less integrated is the beginning of the crack (Figure 4).

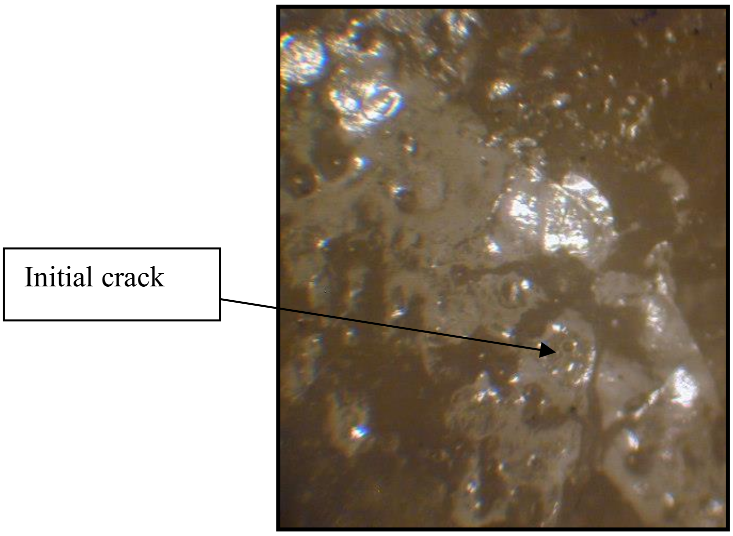


Figure 4. Random orientation microstructure shows a number of initial cracks.

The fatigue strength of the same direction orientation is the highest compared to other orientations namely, an average of 9124 cycles (N), this is due to the arrangement of the position or placement of fibers that are evenly distributed (unidirectional), in every part of the component and gives an influence on dynamic loads. Where the stress concentration of the components can be reduced, it can be made more evenly as indicated by the broken position of the car door panel, the same as the initial design simulation (Ansys).

Figure 5. There is an unequal stress concentration due to the influence of the handle design

The lower resistance of ramie-polypropilene fatigue is also caused by the fabrication factor of making composites where the fabrication process that utilizes the injection process with a process temperature of around 120 0C will cause some ramie fibers to burn so that it will cause combustion gases trapped inside the fibers to form porosity. This is due to the topography of the ramie fiber surface which has a variety of surface textures and ramie fiber has pores ranging from 20 - 500 Angstroms (mesoporous type). With the size of these pores, the temperature of oxygenation and oxygen trapped inside the fiber pore can cause fiber burning and an increase in the size of porosity in the composite (Figure 6).

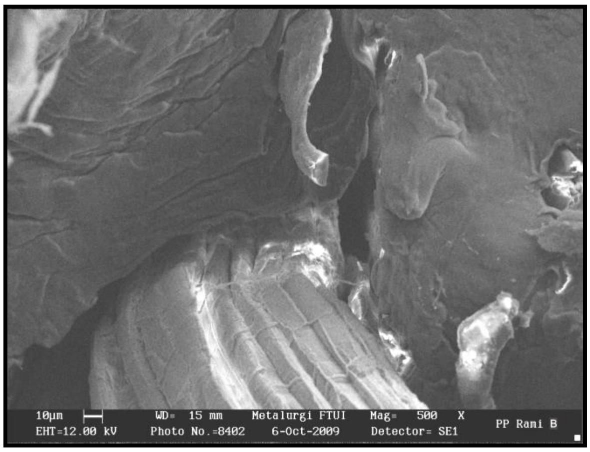


Figure 6. SEM analysis photo forming porosity around the burning fiber.

In addition, the injection of this matrix will also change the composition of the ramie reinforcement fibers inside the matrix so that the resulting stress becomes uneven in each handle component, thus resulting in lower fatigue resistance as shown in the ideal geometry model of fiber-packing by Gibson (Figure 7) following the equation below:

Volume of fiber fraction in the square model: $V_f = \pi/4 \, . \, (d/s)^2$ (1)
The maximum fiber fraction volume if s = d: $v_{fmak} = v_{fmak} = \pi/4 = 0.785$ (2)
Volume of fiber fraction in the triangle model: $V_f = \pi/2\sqrt{3} \, . \, (d/s)^2$ (3)
The maximum fiber fraction volume if s = d: $V_f = \pi/2\sqrt{3} = 0.907$ (4)

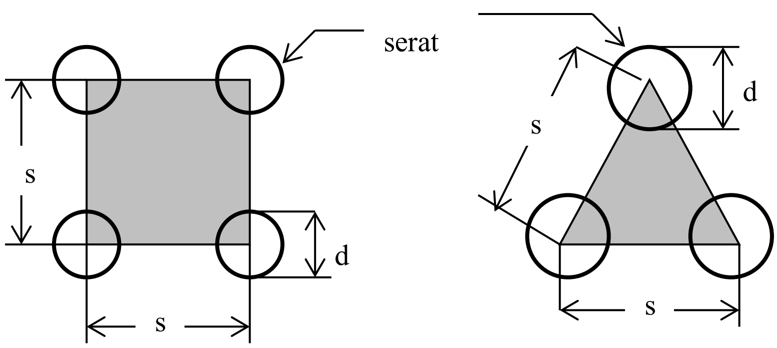
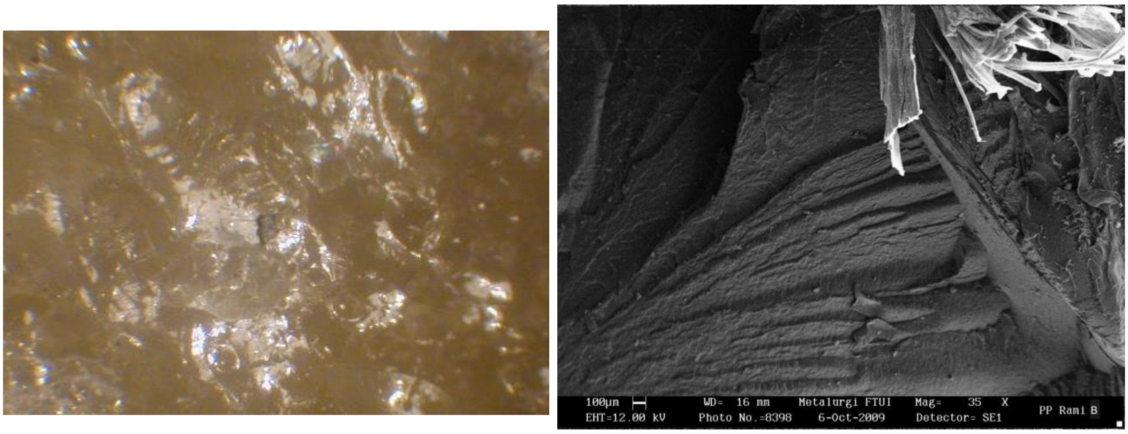


Figure 7. Fiber geometry bound by a matrix

The equation is in accordance with the simulation model ansys which shows the maximum voltage tendency with the variation of fiber orientation will form a packing system in which the ramie-polypropilene changes in the volume fraction from a square model to a triangle model which means the distance d/s will increase due to injection pressure so that the strength packing will be lower which means the strength of fatigue will also be reduced. this points to an increase in the maximum stress value in the simulation results for the composite ramie-polypropilene (Table 4).



(a) **(b)**

Figure 8. Photograph of (a) macro structure and (b) SEM Analysis of grooved fractures on the surface of the handle components

Based on the analysis of failure due to fatigue on the handle products on natural fiber fiber composite materials can be correlated with the theory of failure due to fluctuating loads, generally there are two possible mechanisms, namely due to fiber breaking (matrix breaking) and matrix cracking.

The mechanism of failure of broken fibers generally occurs in epoxy matrix composites. Because this epoxy matrix has quite resilient properties which is shown by the strain value which is quite high when compared with the polypropylene matrix. What is analyzed is based on the modulus of elasticity which shows the stress value formed on the epoxy matrix is lower than the polypropylene matrix (as Ansys analysis shows). So that the fibers at the crack ends will be broken and the cracks on the matrix will propagate. If the cracks that occur are long enough, the shear stress that occurs will be able to damage the bond between the fiber and the matrix so as to allow parallel cracks with the fiber. This mechanism occurs due to the high loading level so that it exceeds the weakest fiber strength of the composite and will cause a shear stress which is concentrated at the fiber end. This shear stress will cause the fiber to be separated from the matrix and the length of the area released from the matrix depends on the magnitude of the shear stress that occurs. In the area of fiber that is separated from the matrix (debanded area) stress concentrations will occur and eventually cause failure in the composite material. This mechanism can be shown from the results of photo analysis on the following epoxy matrix composites.

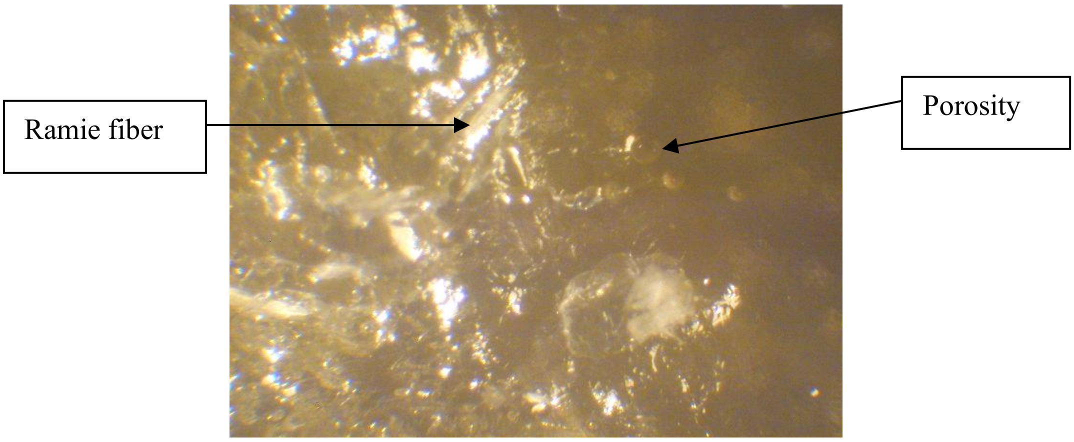


Figure 9. Random fiber fatigue test result

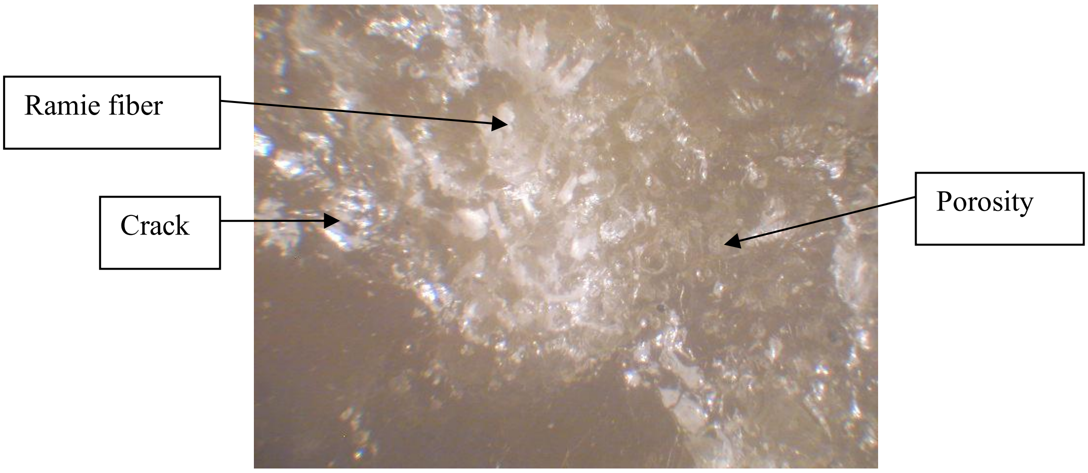


Figure 10. Linear fiber fatigue test result

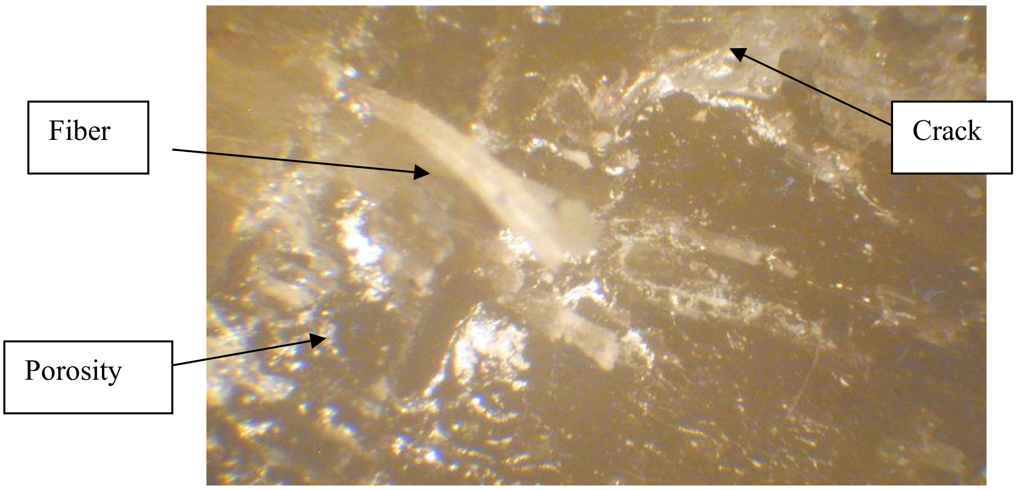


Figure 11. Testing results for woven fiber fatigue

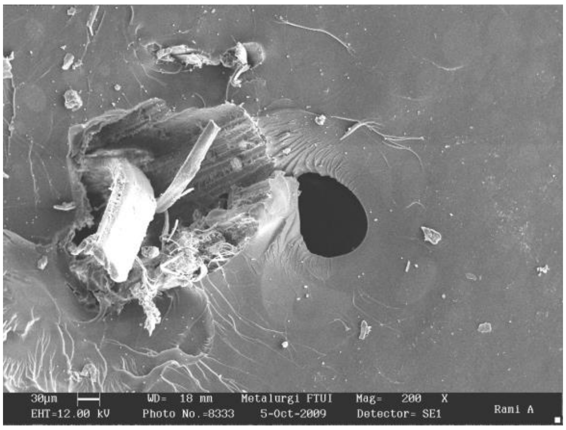


Figure 12. SEM image showing fracture analysis begins with cracked ramie fibers (fibers released from the matrix) on the surface of the epoxy composite matrix

Mechanism of damage due to fatigue in the matrix (matrix damage) generally occurs in polypropilene bermatrik composite where the results of the analysis of the following photo shows it begins with a crack initiation which is then followed by crack propagation. As explained earlier that the initial cracking in the matrix is generally caused by the porosity formed in the PP matrix due to the gas resulting from the burning of trapped fibers. The formation of cracks in this matrix will propagate to areas that have the highest stress and in general at the interface area of the fiber matrix and these cracks will stop propagating if the stress at the crack end is unable to break the fiber. This generally occurs in matrices that have a fairly low strain so that cracking only occurs in matrices with a sufficient number of cracks.

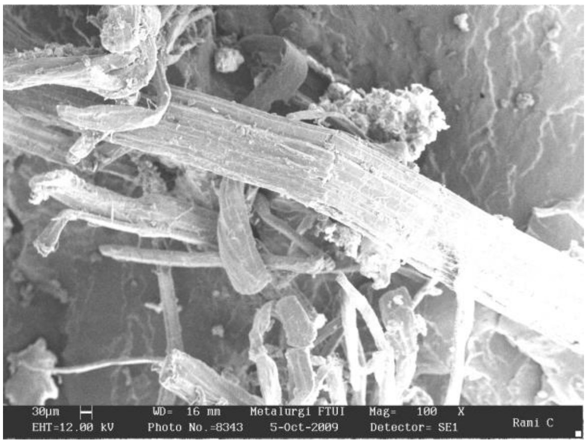


Figure 13. SEM Photo Fracture analysis begins with a matrix crack on the surface of the Polypropilene matrix composite

From the results of the fatigue test analysis, it can be concluded that some conditions can reduce the failure rate due to fluctuating loads on these handle products, including:

1) The function of the fiber, which is the reinforcing element, determines the mechanical properties of the composite because it continues the load distributed by the matrix. Orientation, size and shape and fiber matrial are factors that influence stress concentration.
2) There is a good placement and position of the fiber so that the bond between the fiber and the matrix is very good. In unidirectional fibers have a good level of direction arrangement of fiber and the surface area can bind entirely between the fiber and the matrix.

3) Reduced porosity, since porosity is the initial occurrence of cracks or cracks where the shape and size greatly affect the amount of stress concentration. In the same direction the porosity of the fiber is very little compared to the others.

4. Conclusion

From the results of all the mechanical tests, it can be concluded that the presence of ramie reinforcing fibers in both the epoxy and polypropylene-patterned handle products is strongly influenced by the orientation of the fiber. Some randomly oriented specimens even exhibit lower mechanical properties compared to handle specimens without reinforcing fibers. On the results of fatigue testing, for epoxy matrix has a significant increase of 162% while the PP matrix only has a low fatigue strength value of only 13%

Based on observations of microstructure and SEM for all tests in general, it shows that the mechanical properties of the composite are reduced due to several things, including porosity, adhesion between fiber-matrices and between matrices, overlapping fibers and broken fibers. Natural composites with PP matrix given an injection process tend to produce poor fiber orientation because the pressure will cause the fibers to accumulate in a given area which results in uneven distribution of fibers so that the concentration formed is the beginning of cracking in the handle product.

The utilization of technology will greatly assist in producing more optimal mechanical properties both in terms of quantity of processing and product quality. With a consistent result it is hoped that later it can be easily applied en masse both for SMEs and industries who want to develop the use of these composite materials as their products.

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