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The Effect of Volume Fraction Variations Epoxy-Rice Straw Composite Fibers with NaOH Treatment on Tensile and Bending Strength

Muhammad Raihan Dwi Wibowo[1], Cok Istri Putri Kusuma Kencanawati[1*], I Putu Lokantara[1]

[1]Department of Mechanical Engineering, Faculty of Engineering, Universitas Udayana, Bali, Indonesia

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***Corresponding author:**
Cok Istri Putri Kusuma Kencanawati

E-mail address:
cok_putrikusuma@unud.ac.id

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A B S T R A C T

Rice straw waste is often a problem for farmers because of the lack of utilization until finally, only burning is done. The use of rice straw for composites aims to increase the economy and maximize the potential of rice straw waste to be more useful in the industry. This research uses epoxy sikadur 52-id mixed hardener in the ratio (2:1) as a matrix, and rice straw fiber as reinforcement, with a fiber length of 3 cm. The composition of fiber and resin uses a volume fraction of 10% fiber: 90% resin, 20% fiber: 80% resin, and 30% fiber: 70% resin. Printing using acrylic prints with a hand lay-up technique. The size of the test specimen refers to ASTM D-3039 for the tensile test and ASTM D790-03 for the bending test. The greatest tensile voltage is found in the volume fraction of 30% fiber of 25,431 MPa. The highest strain occurred in the volume fraction of 30% fiber 1.779. The largest modulus of elasticity comes from the volume fraction of 30% fiber of 1,988 GPa. In the bending test, the largest tensile voltage is found in the volume fraction of 30% fiber, which is 93.260 MPa. The highest strain occurred at a 10% fiber volume fraction of 4.721. The largest modulus of elasticity comes from the volume fraction of 30% fiber which is 3.739 GPa. In both types of testing, it was found that the volume fraction of 30% fiber had the highest tensile and bending strength.

1. Introduction

The development of composite technology has had a major impact on the manufacturing industry. Composites are designed as an alternative material to replace metal, and composites have several advantages over metals, such as the material being lightweight, corrosion-resistant, and inexpensive.[1] In the manufacturing industry, generally, the manufacture of composites uses polymers, namely thermoset resins. One of the most commonly used thermosetting resins is epoxy.[2] Epoxy belongs to a group of polymers commonly used as coatings, adhesives, the matrix on composite materials and has wide application in various fields such as automotive, aerospace, and shipping besides having good properties in terms of chemical reactive adhesives, thermally conductive adhesives, electrically conductive adhesives, and corrosion resistant coatings.[3-6]

Fiber is one of the main components that make up a composite. This fiber will determine the properties of the composite material, such as stiffness, strength, and other physical properties. Natural fiber composites have advantages over synthetic fibers.[7-9] This is due to the nature of synthetic fibers that are difficult to decompose, are not environmentally friendly, and produce toxic gases when burned. Composites with natural fiber reinforcement have advantages such as high specific strength and modulus, low density, low price, abundant in many countries, lower pollution emissions, and can be recycled. Straw is the largest agricultural waste and has not been fully utilized properly due to technical and economic factors. The main components that make up rice straw are cellulose which is a polymer with a polymerization degree of up to 10,000 is strong, crystalline molecules without branching up to (35-50%), hemicellulose (20-35%), and lignin as a component that is detrimental to the surrounding composite material (10-25%). The deficiency of rice straw fiber is usually influenced by the non-uniform fiber size resulting in its tensile strength. Whereas the smaller the diameter of the rice straw fiber, the higher the tensile voltage value. The use of alkaline NaOH solution in natural fiber immersion serves to remove/clean the wax layer (lignin) on the natural fiber surface. The wax layer was removed to improve the fiber bond with the matrix resulting in better composite mechanical properties.[10-13]

This research refers to the manufacture of rice straw fiber-reinforced composites matrix epoxy sikadur *52-en* as a binder, as well as fiber immersion treatment for 2 hours with 5% NaOH alkaline solution. This study aims to obtain scientific data regarding the effect of volume fraction and NaOH immersion on changes in the mechanical properties of the fibers that make up the composite material.

2. Methods

In this study, composite specimens were needed for tensile tests, bending tests, and microstructure tests. This composite specimen is reinforced with rice straw fiber of Variety IR64 obtained in Tengkudak Village, Penebel District, Tabanan Regency, with the matrix used being a 52-id epoxy sikadur. There are three tests carried out. The first test carried out is the Tensile test strength. This test is carried out to determine the properties of a material, namely tensile strength, voltage, and strain. By pulling a material, we will know how the material reacts to the tensile force and know the length of the material if it is given a tensile force. The second test is the bending test. The bending test is one form of testing to determine the properties of the material, namely bending strength, deflection, and strain. By loading at a certain point, we will know how the material will react to the load and know the deflection contained in the material when loading is carried out. The last test is the microstructure test which aims to study the surface morphology of the material specimen and determine the composition of the mixing material.

The composite mold consists of three layers arranged. Composite printers are arranged in order of base, printing sheet, and cover. The base and cover it has dimensions of 40 x 40 x 0.5 cm, and the printer sheet it has an outer dimension of 40 x 40 x 0.3 cm with the printer hole dimensions of 25 x 25 x 0.3 cm. The density of rice straw fiber and resin needs to be known to calculate the volume fraction ratio of fiber and *epoxy*. Composite specimens were made with one type of treatment, namely the treatment of fiber immersion in 5% alkaline NaOH for 2 hours and the volume fraction of rice straw fiber (10%, 20%, 30%). Accuracy is required during the mixing process between resin and hardener and during the printing process using the hand lay-up method. This is done to avoid the formation of voids and to get good printing results in accordance with predetermined standards. In each test volume fraction, it takes 3 tests (3 specimens) in order to obtain valid and accurate data. Thus, for composite specimen manufacture for the tensile test, 9 specimens are needed. This also applies to the bending test. From the two tests, it can be added that for this study, 18 composite specimens were needed.

3. Results and Discussion

Figure 1 shows that the composite with a variation of 30% fiber has an increase in tensile voltage with an average voltage value of 25.431 MPa. For composites with a variation of 20%, fiber has an average value of 19.846 MPa. As for the composite with a variation of 10%, fiber has the lowest voltage with an average value of 16,743 MPa. The average value of 10% fiber variation is also below the voltage value of the pure epoxy resin of 19.818 MPa. This is due to the creation of voids during the process of making specimens, where the variation of 10% fiber is more than the variation of 20% and 30% fiber. The value of tensile strength is influenced by the addition of the number of rice straw fibers in the composite so that the bond between the *epoxy* and the fiber becomes stronger. And the load received by the specimen is not only given to the matrix, but the fiber helps spread it so that the load received can be higher. Figure 1 shows that the composite with a variation of 10% fiber has an average tensile strain value of 1.450. Meanwhile, there was an increase in the average strain value at a variation of 20% fiber which had a value of 1.657. The same thing was also experienced in the 30% variation of fiber which had an average strain value of 1.779. Based on the data taken, the strain between variations in the volume fraction of the composite has an increase that is not too significant according to the percentage of rice straw fibers in the composite. However, the average strain value of each variation of the fiber volume fraction is smaller than the pure resin strain value of 4.686. The decrease in tensile strain is due to the strong bond between the matrix and the fiber, and the matrix without fiber cannot absorb energy at the time of loading due to the absence of reinforcement. The modulus of elasticity increases with each variation of the fiber volume fraction. The highest modulus value at 30% fiber variation has an average modulus value of 1,988 GPa. For the 20% variation, the fiber has an average modulus of 1.778 GPa. In the variation of 10% fiber, the lowest modulus average value is 1.551 GPa. However, the increase that occurs in each variation of the fiber volume fraction is not very significant.[14.15]

Table 1. Tensile test results

Tensile Testing				
Fiber Fraction : Epoxy Resin	Calculation Result Data			
	No.	l (MPa)	l (%)	E(GPa)
	A1	17,130	1,469	1,600
10% Fiber Fraction : 90% Resin	A2	14,970	1,381	1,415
	A3	18,129	1,501	1,637
	Average	16,743	1,450	1,551
	No.	l (MPa)	l (%)	E(GPa)
	B1	20,541	1,580	1,960
20% Fiber Fraction : 80% Resin	B2	20,510	2,042	1,525
	B3	18,487	1,349	1,848
	Average	19,846	1,657	1,778
	No.	l (MPa)	l (%)	E(GPa)
	C1	25,645	1,612	2,391
30% Fiber Fraction : 70% Resin	C2	26,042	1,580	2,426
	C3	24,606	2,146	1,147
	Average	25,431	1,779	1,988

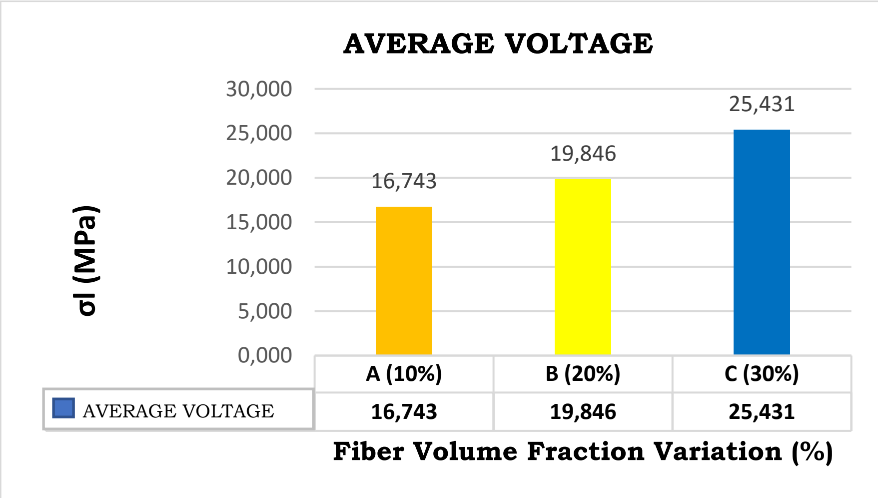
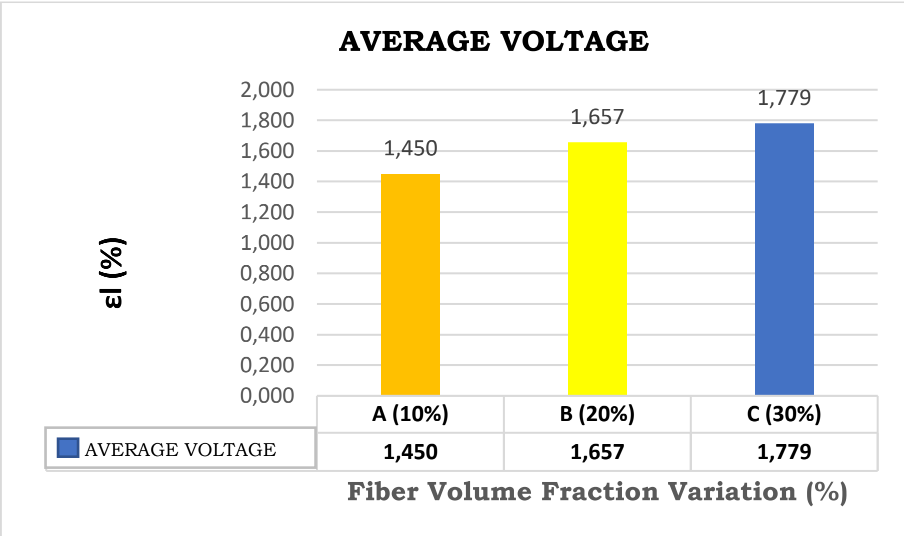


Figure 1. Average tensile voltage.



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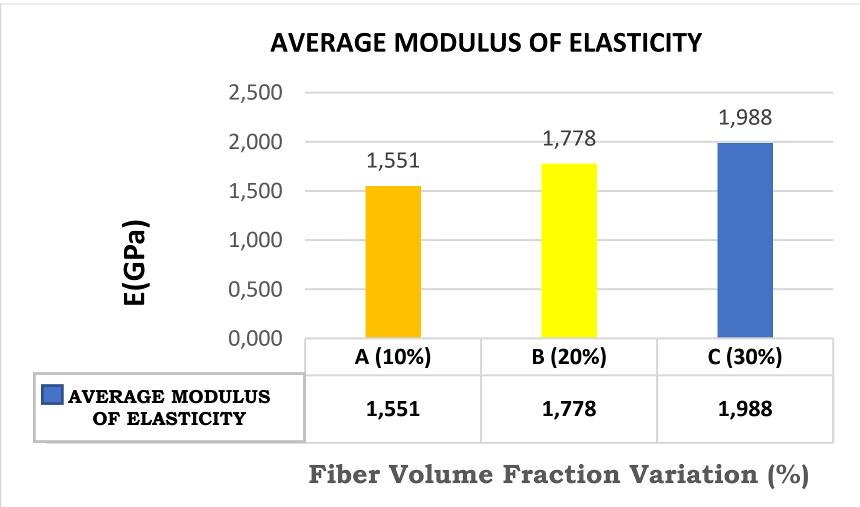

Figure 3. Average of tensile elasticity modulus.

Figure 4 explains that the higher the fiber volume fraction, the higher the voltage. This is shown in the 10% fiber volume fraction. The average bending voltage is 39.509 MPa, smaller than the 20% fiber volume fraction, which is 58,488 MPa. Meanwhile, the 30% volume fraction has an average voltage value of 93,260 MPa, which is higher than the 10% volume fraction and 20% fiber volume fraction. This is influenced by the addition of the number of fibers in the composite so that the loading that occurs is not only given to the matrix but also given to the fiber properly. The more fibers, the higher the bending voltage. Figure 5 shows that the composite with 10% fiber fraction variation has the highest bending strain value with an average strain value of 4.721. The variation of the 30% fraction has the lowest strain with an average value of 2.811. For the variation of the 20% fiber fraction, the average value is 3,616. Based on the data taken, the strain value between volume fractions decreased as the percentage of fiber volume fraction in the composite increased. The increasing number of fiber volumes and stiff fiber conditions due to alkali treatment make when the test object is given a load, the matrix is better at spreading the load so that it causes flexibility. This can be proven by the number of fibers the strain value decreases. The more the number of fibers, the bending strain gets weaker because the composite only rests on the fiber. Figure 6 shows the modulus of elasticity of the composite of rice straw fiber and *epoxy* with variations in volume fraction of 10%, volume fraction of 20%, and volume fraction of 30%. From the graph of the relationship between the modulus of elasticity, it is known that the 10% fiber volume fraction variation composite has an average elastic modulus value of 0.959 GPa. While the volume fraction variation of 20% fiber has an average modulus of elasticity of 2,000 GPa, and the volume fraction of 30% fiber has an average modulus of elasticity of 3.739 GPa. In general, from the graphs and descriptions above, it can be seen that the value of the modulus of elasticity in the composite of rice straw fiber and *epoxy* with volume fraction variations of 10%, 20%, and 30% increased with increasing volume fraction. This is due to an increase in the ratio of bending voltage to bending strain. It also relates to the voltage and strain values obtained for each volume fraction where the greater the value of the modulus of elasticity of the material strength will be greater, where the stretching ability will decrease. So that the greater the value of the modulus of elasticity, the less deformation or decreasing the value of the strain.[16.17]

Table 2. Bending test results

Bending Test				
Fiber Fraction : Epoxy Resin	Calculation Result Data			
10% Fiber Fraction: 90% Resin	No.	1 (MPa)	1 (%)	E(GPa)
	A1	34,630	3,787	0.869
	A2	41,981	5,219	1,077
	A3	41,914	5,157	0.932
	Average	39,509	4,721	0.959
20% Fiber Fraction : 80% Resin	No.	1 (MPa)	1 (%)	E(GPa)
	B1	58,217	3,460	2,111
	B2	58,409	3,382	1,980
	B3	58,838	4,005	1,910
	Average	58,488	3,616	2,000
30% Fiber Fraction : 70% Resin	No.	1 (MPa)	1 (%)	E(GPa)
	C1	87,589	2,744	3,478
	C2	94.186	2,416	4.267
	C3	98.005	3,273	3,472
	Average	93,260	2,811	3,739

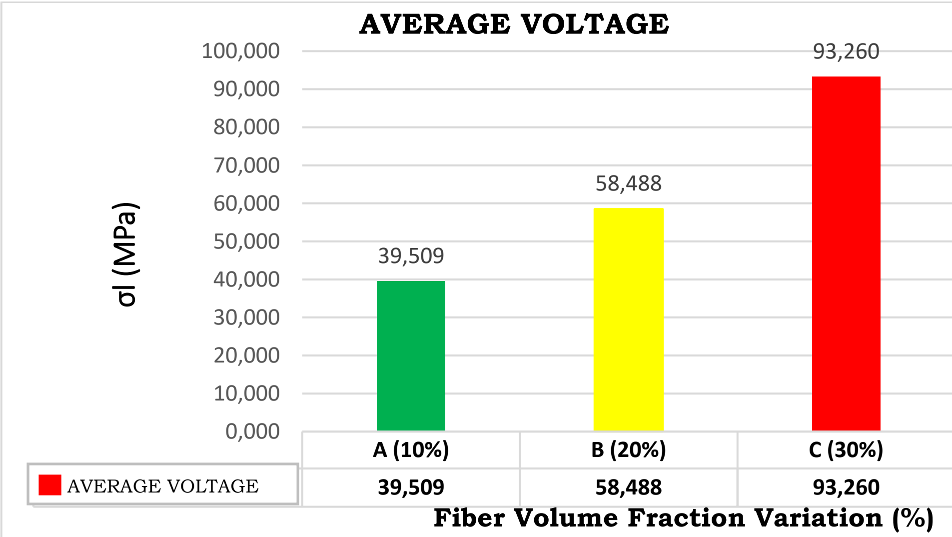

Figure 4. Average bending voltage.

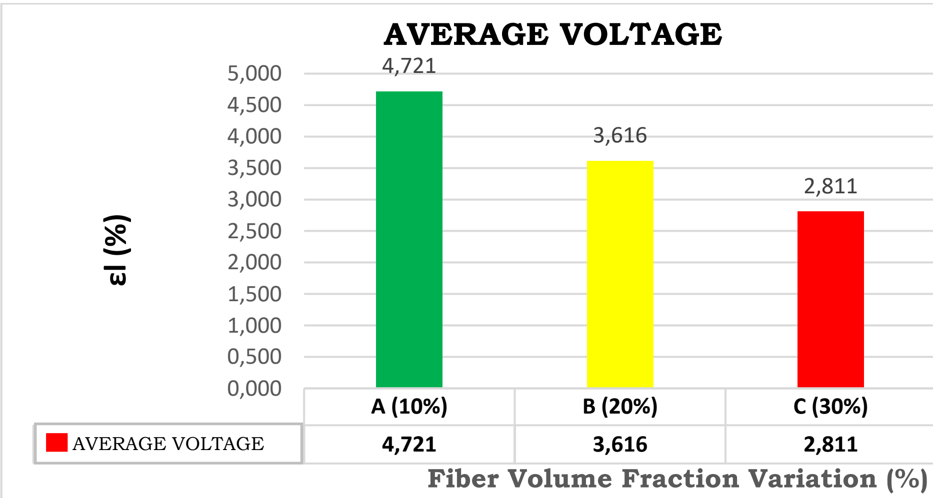

Figure 5. Average bending voltage.

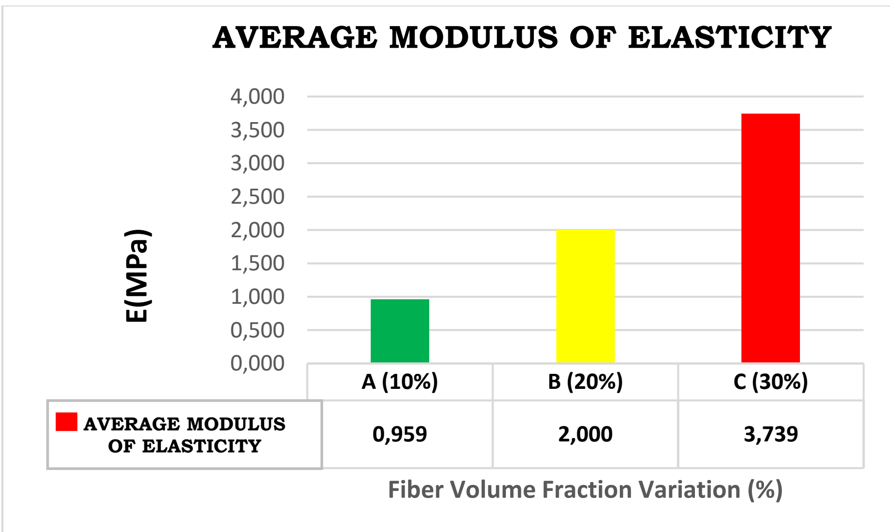

Figure 6. Average modulus of bending elasticity.

Figure 7 shows a micro photo of the volume fraction of 10% of the fiber type failure that occurs is dominated by fiber pull out (fiber separated from the matrix bond). In addition, there are also a large number of flow matrices as well as delamination and voids in the fault area, where some of these factors are indicators that can reduce the effectiveness of the composite in transmitting the load because the load given only relies on the matrix due to the lack of fiber, The number of voids contained in the composite is quite large compared to other variations, where the number of voids that arise causes a decrease in the effectiveness of a composite in transmitting voltage and makes the strength of a composite less than optimal. So that it can cause less than the maximum tensile and bending strength of the composite. Figure 8 shows that the fracture surface is dominated by overload (fiber breaking due to the limit of fiber strength and a strong bond between the reinforcement and binder) compared to fiber pullout, which has more fiber pullout in the previous volume fraction. However, there are still some voids and delamination which are less than the previous volume fraction. The greater number of overloads in the fracture area indicates that the cross-linking bond created between the fiber and the matrix is quite good. So the value of tensile and bending strength in this volume fraction is better than before. Figure 9 is dominated by overload than fiber pullout. Where is the overload which appears in this fraction is more than the total volume fraction of 10% and 20%. This indicates that the cross-linking bond created between the fiber and the matrix is better than the previous two fractions. Where it affects the effectiveness of the composite in transmitting the voltage so that it can produce optimal bending strength and is better than the composites of 10% and 20% fractions. Besides that, there are a few voids. In this variation, where there are fewer voids in the composite, it can maximize the strength of the composite.[18-20]

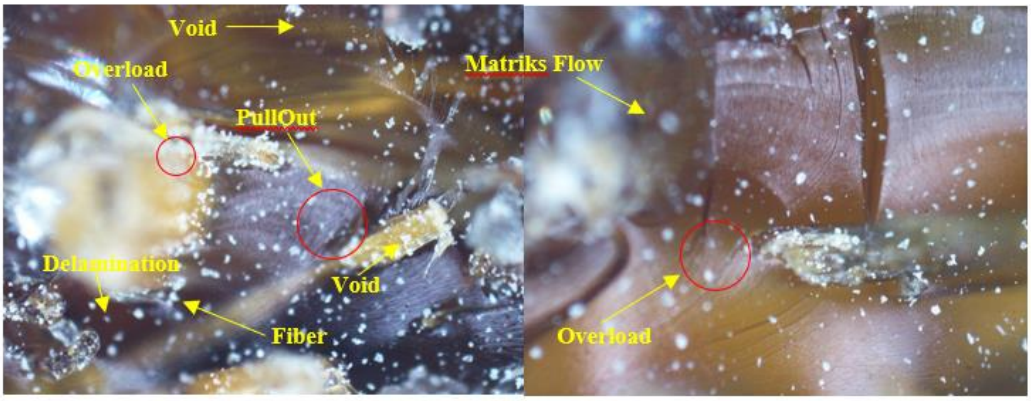

Figure 7. Micro photo of bending & tensile fractures volume fraction variation of 20% Fiber 5x magnification.

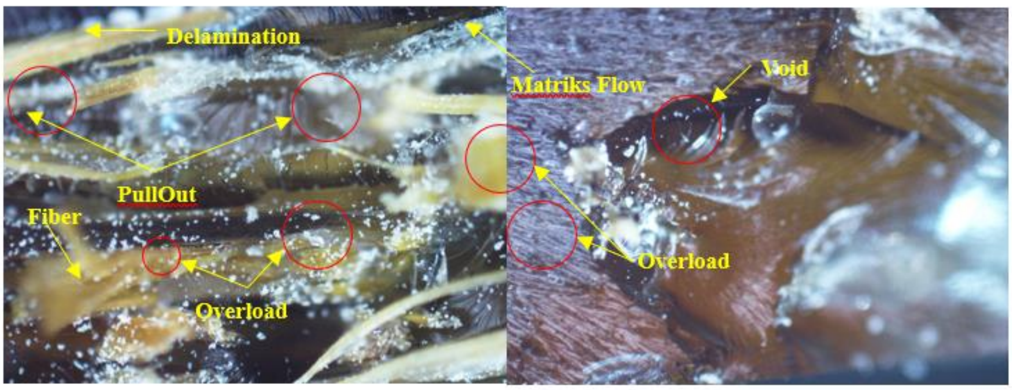

Figure 8. Micro photo of bending & tensile fractures volume fraction variation of 10% Fiber 5x magnification.

Figure 9. Micro photo of bending & tensile fractures volume fraction variation 30 % Fiber 5x magnification.

4. Conclusion

Volume fraction 30% fiber : 70% resin has the highest tensile and bending strength compared to volume fractions of 10% and 20% fiber.

5. References

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