
Manufacture and Characterization of Bio-Composites Using the Vacuum Assisted Resin Infusion (VARI) Method with Ramie Fiber (Boehmeria Nivea) Reinforcement as Raw Material for Wind Turbines Driving Water Pumps on Saltland

[1]Achmad Kusairi Sam, [2]Ibnu Irawan, [3]Novi DB Tamami, [4]AHM Mahmud

[1]Mechatronics EngineeringStudyProgram, Universitas Trunojoyo Madura, Indonesia

[2]Mechanical Engineering Study Program, Universitas Trunojoyo Madura, Indonesia

[3]Department of Agribusiness, Universitas Trunojoyo Madura, Indonesia

[4]Mechatronics EngineeringStudyProgram, Universitas Trunojoyo Madura, Indonesia

Abstract:-Indonesia with 104,000 km of coastline has great potential for the development of salt production and is expected to be able to meet national salt needs. However, domestic salt production has not been able to meet national salt needs due to low productivity of salt production. The application of technological innovations that are high-efficiency and come from renewable energy sources is needed to be a solution to the problem. One of them is the use of wind turbines as a driver of salt field irrigation pumps. The wind turbine driving the salt land pump currently still uses wood as the main material for its manufacture, the use of wood in addition to having a relatively short lifespan also has the potential to result in massive deforestation. Alternative raw materials for making wind turbines are needed as a substitute for wood, one alternative is to use NATURAL FIBER, namely Ramie Fiber as a raw material in making Wind Turbines. The advantage of making this natural fiber wind turbine is that the costs incurred are relatively cheap and jute fiber is abundantly available. This research is to make and test the characteristics of Bio-Composite materials with ramie fiber reinforcement (Boehmeria Nive) using the VARI (vacuum assisted resin infusion) method for the main raw material for environmentally friendly wind turbines as a driver of water pumps on salt land. The results of this study indicate that all tensile test results of ramie fiber reinforced composites exceed the requirements of the calculated force parameters and CAE simulations for wind turbine blade applications of 9 N/mm^2.

Keywords:*Bio-composite, Ramie Fiber, VARImethod*

1. Introduction

Indonesia's salt demand in 2020 was 4.46 million tons and is estimated to increase to 4.6 million tons in 2021, most of which or around 84% is the need for the manufacturing industry and based on the 2020 salt balance, the volume of salt imports contributed 50.29% of the national salt availability[1], thus making salt a very important strategic commodity both as an industrial raw material and as a food for the Indonesian people. Indonesia with 104,000 km of coastline has the potential to develop large salt production and is expected to be able to meet national salt needs. However, domestic salt production has not been able to meet the national salt demand due to the low productivity of salt production.

The application of high-efficiency technological innovations from renewable energy sources is needed to overcome these problems[2]. One of them is the use of wind turbines as a driver of salt field irrigation pumps. Wind turbines still use wood as the main material for their manufacture. The use of wood has the potential to cause illegal logging.

Therefore, an alternative to the main raw material for making wind turbines is needed as a substitute for wood. One of the alternatives is to use NATURAL fiber, namely Ramie fiber (Boehmeria Nivea) as the main raw material in making wind turbines. The advantages of making this fiber boat are relatively low cost, faster wind turbine manufacturing time, and the model can be easily shaped and easily repaired when damage occurs.

Fibers are classified into two types, namely synthetic fibers and natural fibers. Synthetic fibers are made in industry with specific and homogeneous dimensions, such as glass, graphite/, and kevlar fibers[3]. Synthetic fibers usually have high strength up to 1,800 MPa, but synthetic fibers are less environmentally friendly[4]. As a result, the substitution of the use of natural fibers instead of synthetic fibers began to develop in the industrial world to reduce the amount of synthetic fiber waste. Fiber-producing plants are often known as bast plants, such as kenaf, rosella, flax, ramie, hemp/, and other fiber-producing plants[5]. In addition, natural fibers can also be obtained from fruit fibers, such as kapok, cotton, palm fruit (palm fiber), coconut fruit (coconut fiber or coir), and leaf fibers such as sisal and pineapple[6].

Ramie fiber (Boehmeria Nivea) produced by ramie trees (Boehmeria Nivea) grows very well throughout Indonesia, especially at an altitude of 400 to 1000 meters above sea level, however, hemp fiber (Boehmeria Nivea) has not been maximally utilized economically[7].

Composites are a combination of two or more materials, which are formed on a macroscopic scale and physically fused to obtain new properties that are not possessed by the forming material. In the combination of fiber and resin, the fiber will function as a reinforcement filler which usually has high strength and stiffness, while the resin functions as an adhesive or matrix to maintain the position of the fiber, transmit shear forces/, and also functions as a fiber coating[8][5].

The matrix has relatively low strength but is ductile, therefore the fibers will dominantly determine the strength and stiffness of the composite. The smaller the fiber size, the better the adhesion and strength, because the ratio between the surface and volume of the fiber is greater[4]. The mechanical properties of composites are strongly influenced by the orientation of the fibers, composites can be quasi-isotropic when short fibers are used that are oriented randomly, anisotropic when long fibers are used that are oriented in several directions, or orthotropic when long fibers are used that are oriented mainly in mutually perpendicular directions [9]

Composite strength is strongly influenced by several factors such as type, geometry, direction, distribution, and fiber content. Based on the Rule of Mixture (ROM) theory, composite strength increases with the addition of fiber content up to 60-70%.[10]

The matrix serves as an adhesive so that the fibers are well bonded, thus providing stability to the shape of the composite structure, transmitting shear forces between the fibers, and also protecting it from radiation and aggressive media[11]. Both thermoset and thermoplastic polymers are suitable for use as matrix systems to form composite materials. The degree of wettability of the fibers during the production process is an important parameter in obtaining a good bond between the fibers and the matrix[4].

The VARI (vacuum-assisted resin infusion) method is one of the composite manufacturing methods where the composite is made in a mold enclosed by a bag that is sealed tightly and there must be no leaks then the bag is vacuumed by a vacuum motor so that there is a difference in air pressure between the outside and inside of the bag which causes the bag to press the composite product to be made evenly and will also pull out the remnants or excess resin in the manufacture of the composite[12][13][14].

Therefore, the use of resin in making composites with the VARI Method (vacuum-assisted resin infusion) is less than the hand lay-up technique, in resin usage, the VARI Method (vacuum-assisted resin infusion) is more efficient than using the hand lay-up technique [12][15].

FAO on December 20, 2006, declared the "International Year of Natural Fiber (IYNF)" to urge various manufacturing industries to utilize natural fiber materials. The regulation supports the utilization of potential local genius materials in Indonesia, especially "ramie Fiber (Boehmeria Nivea)" as an engineering material for technology products, including natural composite (NACO)[8]. In Indonesia, the development of this material technology is still dominated by artificial materials, especially glass fiber, carbon fiber/, and other synthetic fibers/,and has not been accompanied by the discovery of new materials that have high economic value[16].

This research aims to make Bio-Composite material with reinforcement (filler) ramie Fiber (Boehmeria Nivea) using the VARI (vacuum-assisted resin infusion) method and conduct tests to determine its characteristics and find the Optimum Composition of Bio-Composite material with reinforcement (filler) ramie Fiber (Boehmeria Nivea) which will be used as the main raw material for environmentally friendly wind turbines driving water pumps on salt land.

This research activity is expected to produce new materials that can be an alternative to wood and synthetic fibers, to support the strengthening of the national innovation system. And can provide an alternative to using the main material of wind turbine blades from natural fibers that are environmentally friendly, safe for health/, and cheap to support the efficiency of the National Salt industry that is environmentally friendly and supports the strengthening of the national innovation system.

2. Literature Review

Ramie began to be planted in Indonesia in 1937, which includes planting areas in West Java, Central Java, East Java, North Sumatra, and Sulawesi (Anonymous, 1986). The jute plant was first discovered by a botanical researcher from the Netherlands named George E. Rumphius in 1660 in East India and named RamiumMajus. Then in 1737, the plant was described in Hortus Cliffortianus by Carl Yon Linne (Linnaeus) as Boehmeria nivea. The ramie plant was first introduced to the Netherlands in 1733, the Ramie -plant has been known to humans since approximately 2000 years BC. Ramie is thought to have originated in central and western China and until now, Ramie has developed very well[15].

Ramie (Boehmeria nivea) is an annual plant that is easy to grow and develops well in the tropics. Ramie is a versatile plant. The leaves are compost and high-fiber animal feed, the tree is good for fuel, but the most economically valuable is the fiber from the bark. Ramie fiber is classified as a long, strong fiber and is used for textile raw materials because it has a structure similar to cotton fiber[7].

The results of previous studies show that the addition of ramie fiber volume of 36% to 42% can significantly improve the strength and stiffness of polyester matrix composites. The heat absorption and heat transfer rate increase with the increase of fiber volume. The epoxy resin composite with jute fiber can optimally resist X-ray radiation at a resin composition of 300 g epoxy resin and 12 g ramie at a voltage of 20-35 kV[9]. The resin material and jute fiber have the potential to be developed as X-ray radiation shielding[9]. The tensile strength of ramie epoxy composites has increased due to the effect of immersion in Potassium Hydroxide (KOH) solution with the results of tensile tests on specimens with fiber without immersion having the highest tensile strength of 14.12 Mpa, at 5% concentration having the highest tensile strength of 36.83 Mpa[17][3]. The tensile strength of ramie epoxy composites has increased due to differences in fiber length. The increase due to differences in fiber length in tensile test specimens with 5mm fiber length has a strength of 36.83 and 14.12 Mpa, at 10mm has a strength of 24.22 Mpa and 10.96 Mpa, while 15 mm has a strength of 20.37 Mpa and 9.49 Mpa[12].

3. Specimen Mix Methods

Design

This research was conducted at the Automation Laboratory of Universitas Trunojoyo Madura, at the Materials Testing Laboratory of the Department of Mechanical Engineering, State Polytechnic of Malang and Haka Engineering Pamekasan with the main ingredient of ramie fiber (Boehmeria nivea) for the manufacture and characterization of fiber-reinforced biocomposites as an alternative raw material for wind turbines using the VARI (Vacuum Assisted Resin Infusion) method.

Ramie Fiber (Boehmeria Nivea) from Jogjakarta Area, Alkalinization Pre-treatment with 5% and 10% NaOH solution on Rami Fiber (Boehmeria Nivea) for 2 hours[18][19][20], Making test specimens with VARI composite manufacturing technique (vacuum assisted resin infusion), Sample testing conducted in this study include: Tensile Test, Impact Test and Macro Structure Observation.

Specimens were made based on mixed design to obtain the most optimum characterization and composition formulation, manufacture, and characterization of composites with ramie fiber (Boehmeria nivea) as reinforcement (filler) as an alternative raw material for wind turbine blades. The steps taken in this mix design include the proportion of each mixture with the composition of Resin: Ramie Fiber (Boehmeria nivea) with the composition of the mixture as shown in Table 1:

CompositionCodes	Numberoflayers	VacuumPressure (Psi)	PercentageofNaOH (%)	Description
B11	5	2	5	1) Fiber to resin ratioof 1:1 2) Hardener 1% of Resin proportion 3) EachComposition Code made 24 testspecimens
B12	5	6	5	
B13	5	10	5	
B14	5	14	5	
B21	5	2	10	
B22	5	6	10	
B23	5	10	10	
B24	5	14	10	

Table 1. Specimen Mix Design

Composites in this study use the VARI (vacuum-assisted resin infusion) method, which is one method of making composites made in a mold that is closed with a tightly closed bag and there must be no leaks then the bag is vacuumed with a vacuum motor so that there is a difference in air pressure between the outside and the inside of the bag which causes the bag to press the composite product to be made evenly and will also remove the remnants or excess resin in making the composite.

Tensile Test

The composite tensile test conducted in this study used the ASTM D638 -03 standard. This method is done because the process is easy. The process is to install the specimen in the tensile test chamber and then run the tensile tester so that over time the specimen will break according to the addition of the tensile load.

Impact Test

The composite impact test process uses the ASTM D 5942-96 standard. The MRT Stars calibration steps are then the Puji specimen is placed on the impact test equipment, then the pendulum is moved to release the lever of the impact test equipment. then the specimen test results can be seen in the figure below. The impact strength is calculated based on the impact energy per expansion of the specimen area.

4. Results and Discussion

a. Results

Tensile strength Results

Tensile test results on ramie fiber reinforced biocomposites with 5% NaOH alkali treatment and Vacuum pressure of 2 Psi, 6 Psi, 10 Psi, and 14 Psi obtained results as shown in Figure 1.

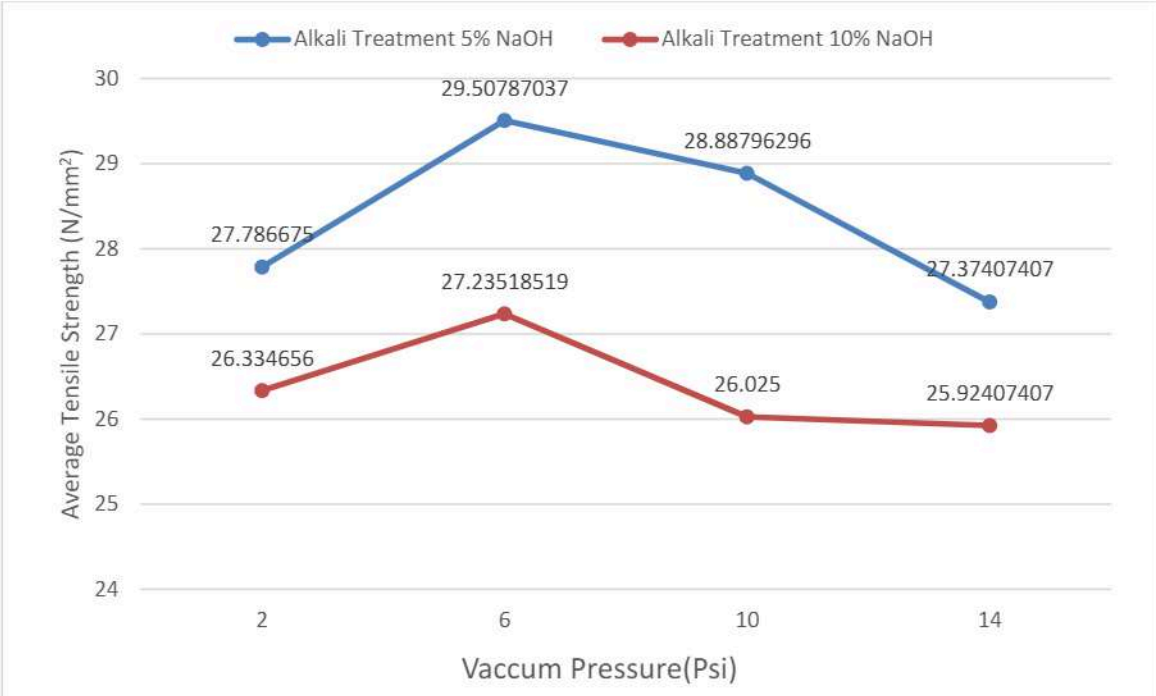

Figure1.Comparison Chart of Tensile Test Data of Composites with Alkali Treatment of 5% NaOH and 10% NaOH

Impact Strength

The results of the Impact Test on jute fiber-reinforced biocomposites treated with 5% NaOH alkali and Vacuum pressure of 2 Psi, 6 Psi, 10 Psi ,and 14 Psi obtained results as shown in Figure 2.

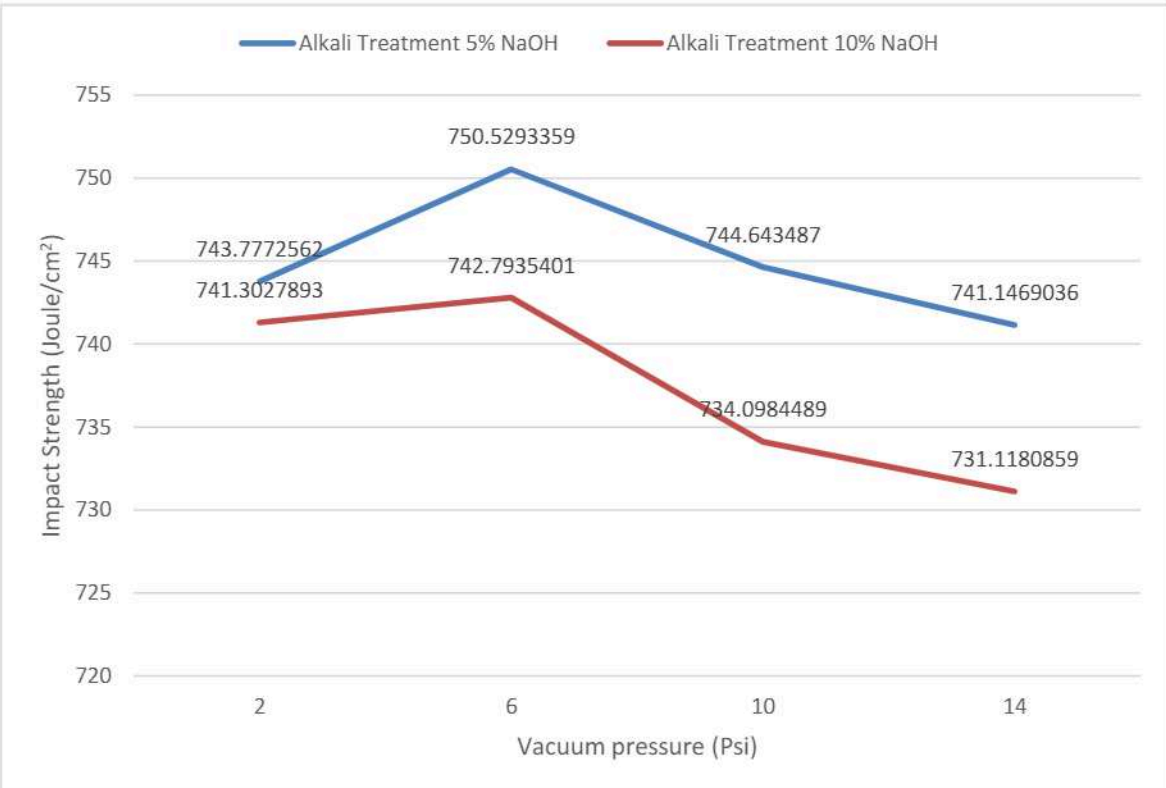

Figure2. Comparison Chart of Impact Test Data of Composites with Alkali Treatment of 5% NaOH and 10% NaOH.

Macro Photos of Tensile Test Results of Ramie Fiber Reinforced Composites

Figure 3 to Figure 6 are the results of macro photographs of tensile test fractures of ramie fiber-reinforced composites treated with 5% NaOH and 10% NaOH.

Figure 3. Macro Photograph of Ramie Fiber Reinforced Composite with Alkali Treatment of NaOH 5% and Vacuum Pressure 6 N/mm^2

Figure 4. Macro Photograph of Ramie Fiber Reinforced Composite with Alkali Treatment of NaOH 5% Vacuum Pressure 14 N/mm^2

Figure 5. Macro Photograph of Ramie Fiber Reinforced Composite with Alkali Treatment of NaOH 10% and Vacuum Pressure 6 N/mm^2

Figure 6. Macro Photograph of Ramie Fiber Reinforced Composite with Alkali Treatment of NaOH 10% Vacuum Pressure 14 N/mm^2

b. Discussion

Alkali treatment of the fiber causes the fiber surface to become rough, making it easier for the fiber to be wetted by the resin so that the bond between the fiber and the matrix becomes stronger[18]. Alkali treatment of fibers can reduce weak layers such as wax, fat/, and other impurities on the fiber surface that can hinder the bond between fiber and matrix[21][22]. Ramie fiber composites with alkali treatment have maximum tensile strength and impact strength at 5% NaOH alkali treatment with values of 29.50787 N/mm^2 and 750.5 Joule/cm^2, respectively, then tensile strength and impact strength at each Vacuum pressure condition decreased as the concentration of alkali solution increased. This is because alkali treatment with higher solution concentrations can damage the cellulose element in the fiber, where cellulose is the main supporting element of fiber strength. so that jute fibers treated with alkali at certain concentrations experience a significant decrease in strength. Fibers that have decreased in strength make the strength of the composite also go down.

Tensile Test on ramie fiber reinforced composite with 5% NaOH alkali treatment produces maximum tensile strength at 6 Psi vacuum pressure which is 29.5 N/mm^2, and the tensile strength value decreases with increasing vacuum pressure, and the lowest tensile strength occurs at 14 Psi vacuum pressure which is 27.37 N/mm^2.

Likewise, ramie fiber-reinforced composites with 10% NaOH alkali treatment have the same tensile strength pattern, namely composites with 10% NaOH alkali treatment have a maximum tensile strength at 6 Psi vacuum pressure of 28.873 N/mm2, and the tensile strength value also decreases with increasing vacuum pressure and the lowest tensile strength occurs at 14 Psi vacuum pressure of 25.924 N/mm^2.

The average value of the tensile test of jute fiber-reinforced composites is shown in Figure 3. shows that the ramie fiber-reinforced composite with 5% NaOH treatment at each vacuum pressure has a higher tensile strength than the ramie fiber-reinforced composite with 10% NaOH alkali treatment.

Figure 3 illustrates that the tensile strength of the composite increased at 6 Psi vacuum pressure but decreased again at the next pressure. The highest composite tensile strength occurred at a pressure of 6 Psi of 29.5 N/mm^2 for composites with 5% NaOH alkali treatment and a tensile strength of 28.873 N/mm^2 for composites with 10% NaOH alkali treatment. This is due to the tensile strength of the fiber combined with the strength of the resin which is evenly distributed to all parts of the fiber and creates a perfect bond and no voids are found trapped in the composite.

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The lowest composite tensile strength occurred at a pressure of 14 Psi of 27.37 N/mm^2 and 25.924 N/mm^2 respectively for composites with alkali treatment of 5% NaOH and 10% NaOH. At pressures of 10 Psi and 14 Psi, the tensile strength decreases because the higher pressure causes the matrix to dry quickly and the resin has not evenly entered the fiber pore cavity, resulting in several voids in the specimen as shown in Figure 4. and Figure 6.

Impact Test Ramie fiber-reinforced composites with 5% NaOH alkali treatment produced maximum impact strength at 6 Psi vacuum pressure of 750.5 Joule/cm^2, and the impact strength value decreased with increasing vacuum pressure and the lowest impact strength occurred at 14 Psi vacuum pressure of 741.2 Joule/cm^2.

Likewise,Ramie fiber-reinforced composites with 10% NaOH alkali treatment have the same pattern of impact strength as composites with 5% NaOH alkali treatment, the impact strength increases and is maximum at 6 Psi vacuum pressure which is 741.3 Joule/cm^2, and the impact strength value decreases with increasing vacuum pressure and the lowest tensile strength occurs at 14 Psi vacuum pressure which is 731.5 Joule/cm^2.

Figure 2. shows that the average value of the compressive test of jute fiber reinforced composite with 5% NaOH treatment in each Vacuum pressure treatment is higher than that of ramie fiber reinforced composite with 10% NaOH alkali treatment.

Vacuum pressure in the alkali treatment of 5% NaOH or 10% NaOH provides an optimum contribution to the increase in impact strength. The lowest impact strength occurs at a pressure of 14 Psi and gets a price of 741.1 Joule / cm^2 and 731.1 Joaule / cm^2, respectively/ because the higher pressure causes the matrix to dry quickly and the unevenness of the resin into the fiber pores to produce voids in the specimen so that the bond between the matrix and the fiber is not good.

Vacuum pressure of 6 Psi produces the best strength respectively producing an impact strength of 750.5 Joule/cm2 for 5% NaOH alkali treatment and 741, 3 for 10% NaOH Alkali treatment, the flow of resin at a vacuum pressure of 6 Psi produces a composite where the resin with the matrix is well bonded. this is shown in Figures 3 and Figure 5 which show that no voids occur in the composite.

From the results of tensile testing of jute fiber-reinforced composites with 5% NaoH and 10% NaoH alkali treatment at each vacuum strength, it can be seen that there are various forms of specimen fractures. This condition is certainly influenced by the perfection of the bond between the fiber and the matrix. The existence of a strong bond between the fiber and the matrix will make the specimen's fracture shape neater and the fracture surface tends to be flat. To observe the shape of the fracture in each specimen due to tensile testing, visual observations (macro photos) were made on each specimen's fracture surface.

The purpose of macro photos is to determine the failures that occur in the composite[4]. In addition, macro photos are also taken to see the characteristics of the fractures resulting from tensile testing on the composite. In the cross-section of the fracture of the jute fiber composite with 10% NaOH alkali treatment at 14 Psi Vacuum conditions, there are typical fracture characteristics, namely there are fiber fibers that are pulled out (Fiber Pull Out). This is due to the release of fibers from the matrix before the composite is broken during tensile testing. In areas that have the weakest adhesion bond between the fiber and the matrix, the composite causes the fiber to detach from the matrix resulting in pull-out (Figure 5 and Figure 6). The 10% NaOH-treated jute fiber reinforced composite has a longer fiber pull-out and looks irregular compared to the 5% NaOH alkali-treated jute fiber reinforcedcomposite (Figure 3 and Figure 4).

Simulation of wind turbine blade design Type NACA 4412 (National Advisory Committee for Aeronautics) conducted by Sriyono[23] using Pro Engineer and CAE software obtained the maximum von Mises stress that occurs in the turbine blade is 9 N/mm^2 and the minimum von Mises stress is 1. 52 x10-3 N/mm^2 The displacement that occurs in the turbine blade construction is 1.247 x 10-1 mm and the min displacement is 0 mm, thus all the tensile test results of flax fiber reinforced composites with 5% NaOH and 10% NaOH alkali treatment for compressive strength of 2Psi, 6 Psi, 10 Psi ,and 14 Psi meet the requirements of the calculated force parameters and CAE simulations for wind turbine blade applications.

5. Conclusion

Basedontheresearchresults,itcanbeconcludedthat :

1. The maximum tensile strength of the composite with 5% NaOH alkali treatment occurs at a 6 Psi vacuum strength of 29.5 N/mm2 and the lowest occurs at a 14 Psi vacuum pressure of 27.374 N/mm2.
2. The maximum tensile strength of composites with 10% NaOH alkali treatment occurred at a 6 Psi

vacuum strength of 26.33 N/mm2 and the lowest occurred at a 14 Psi vacuum pressure of 25.9 N/mm2.

3. Ramie fiber-reinforced composites with 5% NaOH treatment at each vacuum pressure have higher tensile strength than ramie fiber-reinforced composites with 10% NaOH alkali treatment.

4. The maximum impact strength of the composite with 5% NaOH alkali treatment occurs at a vacuum strength of 6 Psi which is 750.5 Joule/cm2 and the lowest occurs at a vacuum pressure of 14 Psi which is 27.374 N/mm2.

5. The maximum impact strength of composites with 10% NaOH alkali treatment occurred at a 6 Psi vacuum strength of 741.3 Joule/cm2 and the lowest occurred at a 14 Psi vacuum pressure of 27.374 N/mm2 5.

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