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Effect of Volume Fraction Variation of Wool Yarn and Resin Composite on the Strength of Tensile Test and Impact Test

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Abstract:- Technological developments in the use of composites are an important alternative in meeting society's needs, especially in the field of materials that require high quality and superior mechanical properties. Composites consist of fibers and resins, where the fibers serve as reinforcement and the resin acts as a binder. This mixture produces a composite material with superior mechanical properties and characteristics compared to a single material. The main advantages of composites include corrosion resistance, light weight, and high mechanical strength. Fiber, as the main component of composites, can be divided into synthetic fibers and natural fibers. Synthetic fibers are produced through chemical synthesis, while natural fibers are produced from living organisms. Apart from having different characteristics, natural fibers also have environmental advantages with natural degradation capabilities and lower costs compared to synthetic fibers.

Keywords*:- Mechanical properties, characteristics, composites, fibers and resins.*

I. INTRODUCTION

The development of technology using composites is one alternative way to meet the needs of society. Especially in materials, the materials needed are quality materials and have high mechanical properties. Composites are one alternative to produce materials whose mechanical properties are better than other materials.[1]

Composites generally consist of two elements: fiber and resin. The fiber serves as a reinforcing material, and the resin becomes a fiber binder. The mixing will produce a composite material that has different mechanical properties and characteristics from the forming material. Composites also have several advantages such as corrosion resistance, light weight, and strong mechanical properties.

Fiber is the main component of a composite. Fibers are divided into two types: synthetic fibers and natural fibers. Synthetic fibers are fibers made through chemical synthesis, in contrast to natural fibers produced through living organisms. Natural fibers also have other advantages when compared to synthetic fibers, natural fiber composites are more environmentally friendly because they are able to degrade naturally and the price is cheaper than synthetic fibers.[2]

This research aims to obtain scientific data on the effect of volume fraction on changes in mechanical and physical properties of fibers forming composite materials. To obtain optimal data results, the specimen manufacturing process will be carried out using the printing method with hand lay-up technique and testing the specimen according to its specifications. In this study, two types of tests will be carried out, namely, ASTM D3039 tensile test and D6110 impact test.

II. MATERIAL AND METHODS

This research is an experimental study using the process of making wool yarn fibrous composites and resins with variations in volume fractions of 5%, 8%, 10%. This manufacturing process begins with the preparation of materials. The materials and methods used are.

A composite is a structure composed of several single forming materials that are combined into a new structure with better properties than each of the forming materials. Composite materials generally consist of two elements, namely fiber as a filler material and matrix as a fiber binding material. The mixture will produce composite materials that have different mechanical properties and characteristics from the forming material. [3]

Fiber composites are a type of composite that uses fiber as reinforcement or a composite of fiber and matrix as a binder. The fibers used are usually glass fibers (glass), aramid fibers, carbon fibers, and so on. Fiber composites also have strong properties and are lighter than metals. [4]

A. Material :

- *Wool Yarn*

This experiment uses wool yarn because wool yarn has natural fibers and is easy to bind to the matrix to be used. In this research, it is known that the density of wool yarn is 1.307.[5].

Table 1: Degree of Modullation Woll Yarn

Degree of Medullation	Mass (g)	Volume (cm^3)	Density (g/cm^3)
Non-medullated	3.171	2.437	1.307
Low medullation	3.002	2.436	1.235
High medullation	3.193	3.049	1.076
$lsd_{0.05}$	0.238	0.207	0.023

- *Resins*

This study uses Epoxy - Polyester resin for the manufacture of a matrix that serves to bind the material or fiber to be used. It is known that the density of the mixed resin is 1.11.

The advantages of epoxy resin matrices include superior corrosion resistance compared to polyester under wet conditions. In addition, epoxy exhibits good mechanical, electrical, dimensional stability, aroma, and heat resistance properties.[6]

Table 2: Characteristic of Epoxy

1.	Density, ρ	=	1,2 -1,3	g/cm^3
2.	Strength, σ	=	50 – 125	MPa
3.	Modulus, E	=	2,5 – 4	GPa
4.	Poisson Ratio, v	=	0,2 – 0,33	
5.	CTE, α	=	50 – 100	$10^{-6}.K^{-1}$
6.	Cure Shrinkage	=	1 – 5	%
7.	Temperatur	=	150	°C

Polyester resin is the most common type of resin used in various applications using thermoset resins, either as a single material or in the form of a composite material. [7]

Table 3: Characteristic of Polyester

Item	Units	Tipical Score	Note
The specific gravity of need to resort to violence	gr/cm3	1.4	25^{0}C
The temperature of distortion heat	°C	70	
The uptake of water (room temperature)	%	0.188	24 hours
	%	0.446	7 day
Power fleksural	Kg/mm2	9.4	
Modulo fleksural	Kg/mm2	300	
tensile strength	Kg/mm2	5.8	
modulus of elasticity	Kg/mm2	300	
Elongation	%	2.4	

B. Methods:

The method process is uses hand lay up the preparation of a mold for the fiber and resin mixing process with a molding tool made of acrylic material because acrylic material does not make epoxy resin stick, the surface is flat, and transparent. The composite mold consists of three components. The composite mold is arranged in the order that the first is the base, the molding sheet, and the lid. The printer sheet has an outer dimension of 35 x 25 x 0.3 cm with a printer hole dimension of 25 x 2.5 x 0.3 cm.

- *Hand Layup*

Hand lay-up is the simplest technique in composite fabrication and is an open method. In this process, liquid resin is manually poured onto fibers that are arranged in a woven manner. After that, pressure is applied and the surface is leveled using rollers or brushes. This step is repeated several times until the desired thickness is achieved. In this method, the resin is in direct contact with air, and generally the molding process is carried out at room temperature.[8]

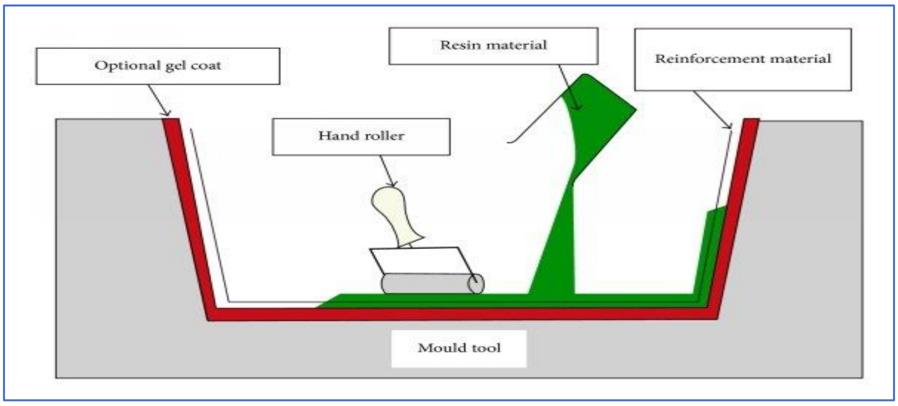

Fig. 1: Hand Layup Process

➢ *Volume Fraction*

The ratio between fiber and matrix is a crucial factor. Usually, this ratio is expressed in terms of fiber volume fraction or fiber weight fraction. However, fiber volume fraction is more commonly used due to its higher accuracy and ease of determining the value of the ratio between fiber and matrix.

- Mold Volume
  $Vc = pxlxt$
  p = length (cm)
  l = width (cm)
  t = height (cm)

- Fiber Volume
  $Vf = FraksiVolumeSerat$ (%) xVC

- Fiber Weight
  $Bf = Vfx\rho f$

- Matrix Volume
  $Vmatrix = Vc - Vf$

- Matrix Weight
  $Bm = Vmatrixx\rho matrix$

  Description :
  ρf = Fiber Density (*gr/cm3)*
  ρm = Resin Density (*gr/cm3)*
  Vc = Mold Volume (*cm3)*
  Vf = Fiber Volume (*cm3)*
  Vm= Resin Volume (*cm3)*
  Bf = Fiber Weight (*gr)*
  Bm= Resin Weight (*gr)*

➢ *Tensile Test*

Tensile strength testing involves applying an opposing force to a material in a direction away from its center point. The purpose of tensile testing is to reveal the mechanical properties of a material.[9] The guidance provided by ASTM D3039 covers aspects of sample preparation, test conditions, as well as the measurement of various relevant mechanical properties, including tensile strength, tensile modulus of elasticity, and elongation at break of the fiber composite material.

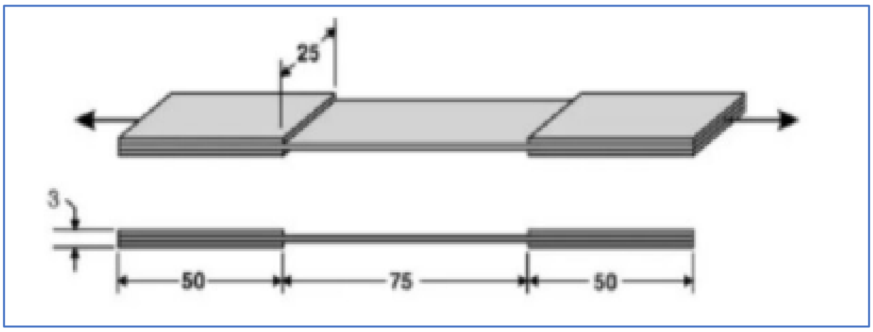

Fig. 2: Tensile Test

- Stress
  $\sigma = \frac{P}{A}$

- Strain
  $\varepsilon = \frac{\Delta L}{L0} \times 100$

- Modulus of elasticity
  E = σ/ε

- Description :
  σ = Stress(Mpa)
  ε = Strain (%)
  P = Force (N)
  A = Specimen Cross-Sectional Area(mm2)
  L0 = Specimen Length Before Testing (mm)
  ΔL = Specimen Length After Testing (mm)
  E = Modulus of elasticity(GPa)

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➢ *Impact Test*

Impact testing is done to measure the mechanical strength of a material in manufacturing against shock loads where in impact testing the loading is carried out suddenly. The basic principle of the impact test is to absorb the potential energy of a pendulum load that oscillates from a certain height and acts on the test load so that the test load is deformed as much as possible to cause damage. In this study using ASTM D6110 with Charpy method.[10]

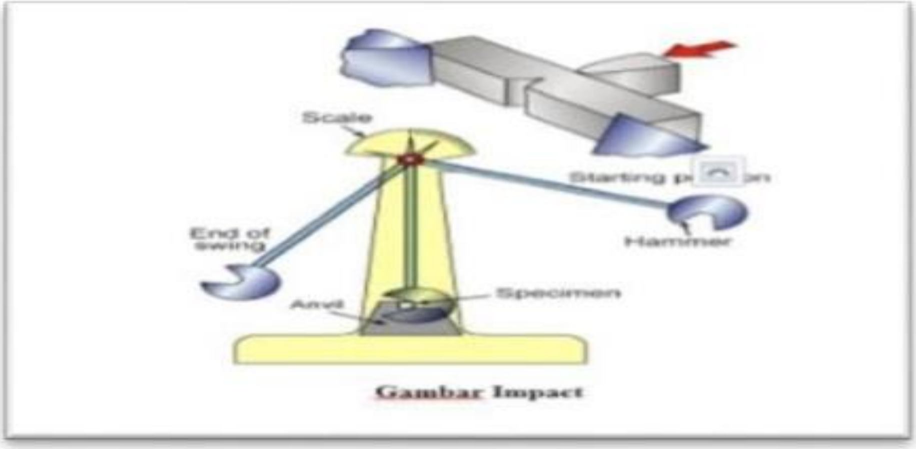

Fig. 3: Impact Charpy Test

$$HI = \frac{GxD(\cos\beta - \cos\alpha).L}{A} \quad (\text{joule/mm}^2)$$

Description :

D = 0.6345 m

G = 26.12 kg

L = 0.75m

cos λ = initial position angle of the pendulum

III. RESULTS AND DISCUSSION

Tensile testing of wool yarn composites with epoxy-polyester resin was carried out at the Tarumanagara University Machine Laboratory. This test uses ASTM D3039. This test uses 3 (three) specimens for each variation of fiber volume fraction with a total of 9 test specimens.

Table 4: Tensile Testing

Tensile Testing			
Fiber Fraction 5% (A)			
Specimen	**Voltage(MPa)**	**Strain(%)**	**Modulus of Elasticity(GPa)**
A1	22.2284	2.72	8.1722
A2	20.9208	2.61	8.0156
A3	23.536	2.83	8.3166
Average	22.228	2.720	8.1681
Fiber Fraction 8% (B)			
Specimen	**Voltage(MPa)**	**Strain(%)**	**Modulus of Elasticity(GPa)**
B1	26.151	3.26	8.0217
B2	24.8434	3.07	8.0923
B3	27.4586	3.48	7.8904
Average	26.1510	3.2700	8.0015
Fiber Fraction 10% (C)			
Specimen	**Voltage(MPa)**	**Strain(%)**	**Modulus of Elasticity(GPa)**
C1	31.3813	4.15	7.5617
C2	32.6888	4.31	7.5844
C3	33.9964	4.43	7.6741
Average	32.6888	4.2967	7.6067

From the tensile test results data in table 4, the data is then plotted in the form of a bar diagram to illustrate the average values of stress, strain and modulus of elasticity.

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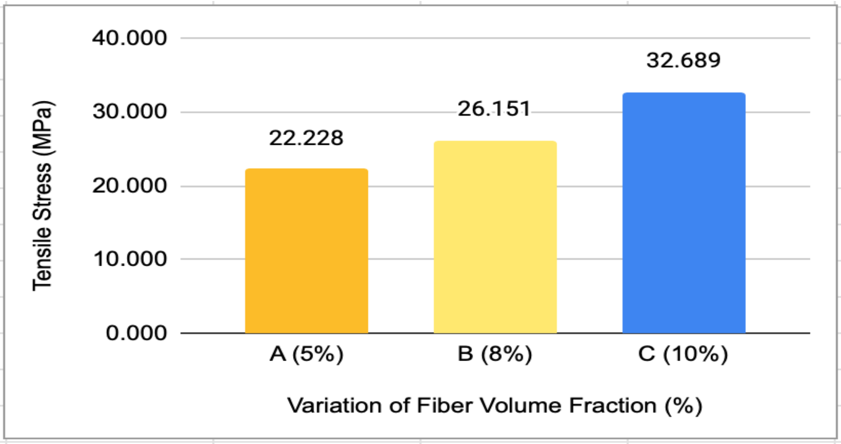

Fig. 4: Tensile Stress Graph

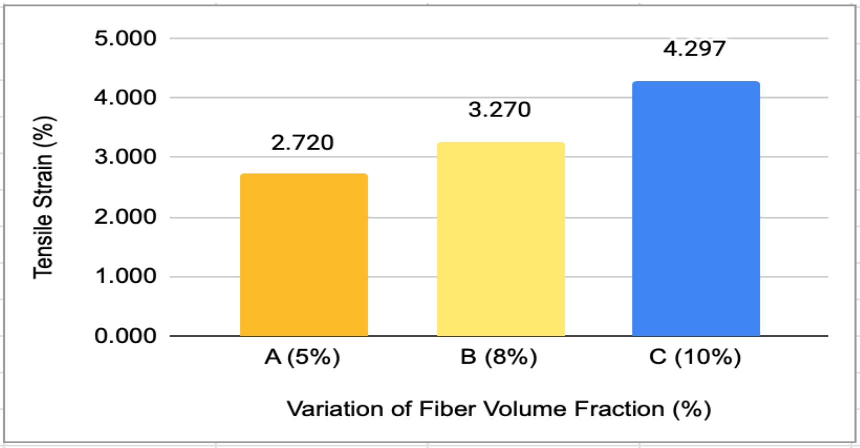

Fig. 5: Tensile Strain Graph

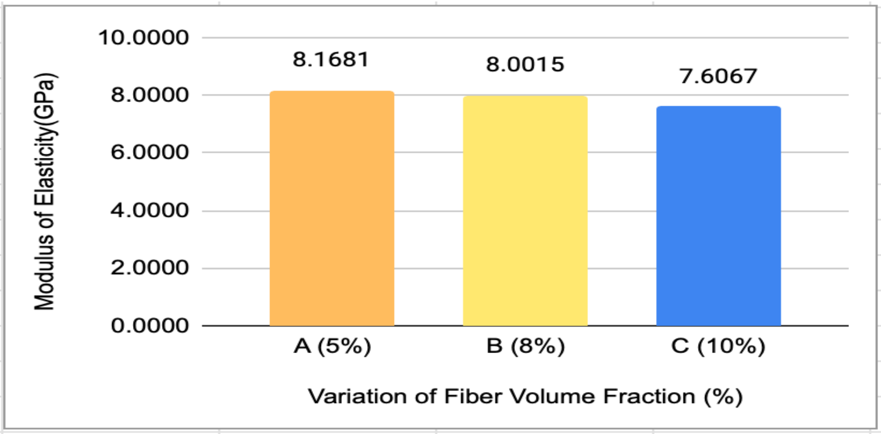

Fig. 6: Modulus of Elasticity Graph

Based on the data obtained in Figures 4, 5, and 6, it shows that the largest tensile stress value was obtained for a 10% variation in wool yarn of 32.689 MPa, the smallest value was obtained for a 5% variation of wool yarn of 22.228 MPa. In terms of tensile strain, the largest value when adding rice stalks occurred in the 10% wool yarn variation of 4.297%, the smallest value was obtained in the 5% wool yarn variation of 2.720%. In the elastic modulus, the largest value was obtained in the 5% wool yarn variation of 8.168 GPa and the smallest value was obtained in the 10% wool yarn variation of 7.606 GPa.

In general, there is an increase in the composite value with each additional variation of wool yarn. The decrease is due to the bonds formed with each additional variation of wool yarn not being optimal. This is caused by natural fibers containing wax and silica which can prevent the formation of bonds between the fiber and the matrix.

Judging from the elastic modulus graph, the highest figure occurs with a 5% variation with 8.168 GPa, while the lowest figure with a 10% variation is 7.606 GPa. It can be concluded that the higher the variation, the stiffer the material and conversely, the lower the variation, the more flexible or difficult it is to deform.

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Table 4: Impact Testing

Impact test results with 5% wool fiber										
Specimen	Length (mm)	Width (mm)	Thickness (mm)	Cross-sectional area	Angle α (°)	Angle β (°)	Distance from Pendulum Axis to Center of Weight (m)	Tool Length (m)	Pelundum Weight (kg)	Impact Energy (Joules/mm²)
A1	65	15	3	45	120	93	0.6345	0.75	26.12	0.137212415
A2	65	15	3	45	120	90	0.6345	0.75	26.12	0.348658700
A3	65	15	3	45	120	95	0.6345	0.75	26.12	0.023204443
Average										0.169691853
Impact test results with 8% wool fiber										
Specimen	Length (mm)	Width (mm)	Thickness (mm)	Cross-sectional area	Angle α (°)	Angle β (°)	Distance from Pendulum Axis to Center of Weight (m)	Tool Length (m)	Pelundum Weight (kg)	Impact Energy (Joules/mm²)
B1	65	15	3	45	120	85	0.6345	0.75	26.12	0.496795786
B2	65	15	3	45	120	89	0.6345	0.75	26.12	0.083971660
B3	65	15	3	45	120	95	0.6345	0.75	26.12	0.023204443
Average										0.201323963
Impact test results with 10% wool fiber										
Specimen	Length (mm)	Width (mm)	Thickness (mm)	Cross-sectional area	Angle α (°)	Angle β (°)	Distance from Pendulum Axis to Center of Weight (m)	Tool Length (m)	Pelundum Weight (kg)	Impact Energy (Joules/mm²)
C1	65	15	3	45	120	86	0.6345	0.75	26.12	0.330877054
C2	65	15	3	45	120	84	0.6345	0.75	26.12	0.412727663
C3	65	15	3	45	120	80	0.6345	0.75	26.12	0.255383308
Average										0.332996008

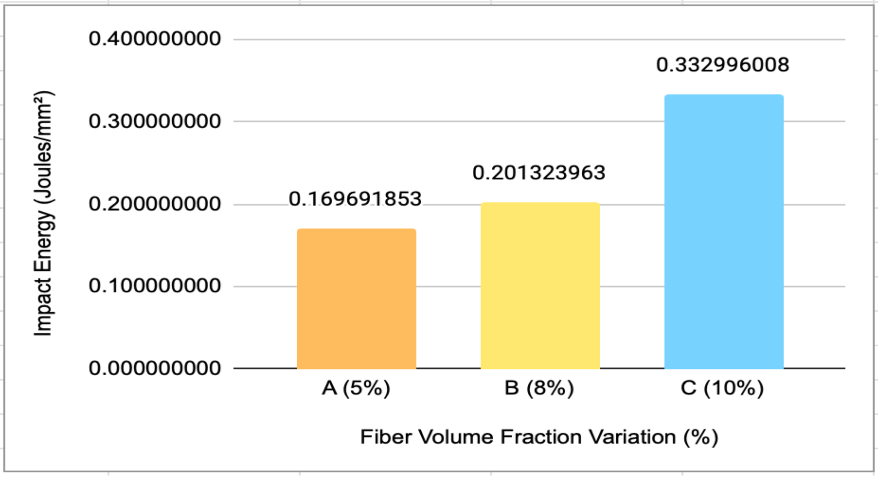

Fig 6: Impact Testing Chart

Based on the results of the tests that have been carried out, data is obtained that shows the high impact energy value due to the large number of fibers used. The diagram in Figure 4.5 explains that the more fibers used, the strength increases. In the 5% fiber volume fraction, the average strength is 0.169 joules/mm2, which is smaller than the 8% and 10% fractions, which have values of 0.201 joules/mm2 and 0.332 joules/mm2.

The high value of impact strength in Specimen C with 10% wool fiber content is due to the presence of bonds between cellulose molecules which are able to transmit the load evenly when receiving shock loads. Apart from that, it is also due to the presence of a small amount of empty space in the material making it an energy storage place, where This energy is absorbed in the bioplastic structure. So it can be concluded that the less empty space in the material provides more space for energy absorption, this can increase the impact strength.

IV. CONCLUSION

Based on the research that the author has conducted, the effect of variations in the volume fraction of epoxy - polyester biocomposites on tensile strength and impact strength can be concluded as follows.

In the tensile test, the stress, strain and modulus of elasticity values were obtained. The average value of tensile stress increased with each additional variation in volume fraction, the largest value was found in the 10% volume fraction variation in wool yarn of 32.689 MPa and the lowest value was obtained in the 5% volume fraction variation of 22.228 MPa. The largest average value of tensile strain was obtained at a 10% volume fraction variation of 4.297% and the lowest value was found at a 5% volume fraction variation of 2.720%. This is different from the elastic modulus value, but it decreases with increasing variations in volume fraction, the largest value is obtained at a 5% variation of 8.168 GPa and the smallest value is obtained at a 10% variation of 7.760 GPa. Thus the maximum value is obtained when varying the volume fraction of 10% wool yarn.

Impact testing shows that the effect of 10% wool yarn fibers on specimens with 90% resin content reaches the best value, namely 0.3322 Joule/$mm2$, which is the highest value compared to the other two variations of 8% and 5%, namely 0.2013 Joule/ mm and 0.1696 Joule/mm.

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REFERENCES

[1]. CHALLABI, A. J. H. (2019). PREPARATION AND CHARACTERIZATION OF PINEAPPLE LEAF FIBER/POLY LACTIC ACID-BASED BIOCOMPOSITE.
[2]. Al-Oqla, F. M., & Sapuan, S. M. (2017). Materials selection for natural fiber composites. Woodhead Publishing.
[3]. Stokke, D. D., Wu, Q., & Han, G. (2013). Introduction to wood and natural fiber composites. John Wiley & Sons.
[4]. Fuqua, M. A., Huo, S., & Ulven, C. A. (2012). Natural fiber reinforced composites. Polymer reviews, 52(3), 259-320.
[5]. Merrick, N. C., Scobie, D. R., & Baird, D. B. (1998). A rapid method for the measurement of wool volume and density. Journal of the Textile Institute, 89(3), 449-456.
[6]. Langer, E., Waśkiewicz, S., Kuczyńska, H., & Kamińska-Bach, G. (2014). Self-stratifying coatings based on Schiff base epoxy resins. Journal of Coatings Technology and Research, 11, 865-872.
[7]. Ojahan, R. T., Ansyori, A., & Alimuddin, Z. (2020, March). The Ratio Resin Polyester Composite Basal The To Testing Pull. In IOP Conference Series: Materials Science and Engineering(Vol. 807, No. 1, p. 012028). IOP Publishing.
[8]. Elkington, M., Bloom, D., Ward, C., Chatzimichali, A., & Potter, K. (2015). Hand layup: understanding the manual process. Advanced manufacturing: polymer & composites science, 1(3), 138-151.
[9]. Diniardi, E., Nelfiyanti, N., Mahmud, K. H., Basri, H., & Ramadhan, A. I. (2019). Analysis of the tensile strength of composite material from fiber bags. Journal of Applied Sciences and Advanced Technology, 2(2), 39-48.
[10]. Vijaya Ramnath, B., Rajesh, S., Elanchezhian, C., Santosh Shankar, A., Pithchai Pandian, S., Vickneshwaran, S., & Sundar Rajan, R. (2016). Investigation on mechanical behaviour of twisted natural fiber hybrid composite fabricated by vacuum assisted compression molding technique. Fibers and polymers, 17, 80-87.