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Analysis of the Effect of Sugar Cane Fiber Composition with Polyester Resin Matrix on the Impact Strength of Composite Materials

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Abstract— *This research is a quasi-experimental research which aims to determine the effect of the composition of sugar cane fiber with a polyester resin matrix on the impact strength of composite materials. The specimens were formed according to ASTM A370 standards and then tested for impact using a composite test tool using the Charpy method. This research was conducted at the Physical Metallurgy Laboratory of Mechanical Engineering, Hasanuddin University. There are 4 kinds of fiber to resin percentage ratios, namely 60% fiber and 40% resin, 70% fiber and 30% resin, 80% fiber and 20%, without using fiber, the results of research on the impact strength value of composite materials made from bagasse fiber are 60% with a 40% polyester resin matrix, the average impact strength value was 2278.47 joules/m^2, the impact strength value of 70% fiber with 30% resin obtained an average impact strength value of 2544.26 joules/m^2, while the impact strength value was 80% fiber with 20% resin gets an impact strength value of 2773.96 joules/m^2, and the impact strength value without using fiber gets an average impact strength value of 2052.05 joules/m^2.*

Keywords— *Impact Strength, Composite, Sugarcane Fiber, Polyester Resin.*

I. INTRODUCTION

It is necessary to know the properties of a material because it plays an important role in its use. For example, the properties of the materials that will be used as construction materials greatly influence the strength of the resulting building. Knowledge of the properties of materials is very important because when used, a material experiences many forces. The force of a material is often experienced due to the presence of materials acting on the material. This force can be in the form of tensile, compressive loads and so on. To be able to determine the strength of a material, you can test the material. Knowledge of the expected properties and strengths of materials can be a basis or consideration in selecting materials.

The use of the bagasse produced is still as animal feed, raw material for making fertilizer, pulp, particle board, boiler fuel in sugar factories, and the economic value obtained is also not high, so a technological process is needed to diversify the use of existing agricultural land, one of which is making sugarcane fiber composites (Adyanto Eko Prasetyo, 2006).

According to (Nesimnasi et al., 2015) the mechanical properties of fiber-reinforced composite materials depend on parameters, one of which is the treatment of the fiber, namely alkali treatment (NaOH). NaOH treatment of fiber aims to remove oil, dirt and pollen attached to the fiber surface, so that the fiber and matrix surface can bond better. Not only does natural fiber have many advantages, it also has many disadvantages, including low strength, especially impact load resistance, low reliability, inability to withstand high temperatures, and weather, age, soil conditions and climate. To overcome this deficiency, the fiber is treated with alkali (NaOH).

Research on the impact strength test of bagasse fiber against NaOH solution treatment. The impact strength of sugarcane fiber in a unidirectional fiber arrangement obtained impact strengths of 4247.2 J/m^2, 5468.3 J/m^2, 2821.7 J/m^2, and 2207.6 J/m^2. Meanwhile, for the direction of the random fiber arrangement, the impact strength obtained was 2700.6 J/m^2, 3831 J/m^2, 1891.1 J/m^2, and 1336.9 J/mm^2. Based on tests using alkaline NaOH treatment and fiber direction arrangement, it can increase the tensile strength and impact strength of sugarcane fiber composites (Alfaiz & Hutahaean, 2015).

According to (Budha Maryanti, Sadat & Suwandy 2021). This research was conducted to determine and explain the impact strength results of composites reinforced with bagasse fibers that received alkaline immersion treatment with time variations of 1 hour, 2 hours and 3 hours (65: 35%). In this study, of the three specimens with varying immersion times, namely specimen 1 (1 hour) with an absorbed energy of 26,872 Joules and an impact value of 0.5374 Joules/mm^2, specimen 2 (2 hours) with an absorbed energy of 24,622 Joules and an impact of 0.4924 Joules/mm^2, specimen 3 (3 hours) with absorbed energy of 17.272 Joules and impact value of 0.3454 Joules/mm^2. Meanwhile, for specimens without fiber, the absorbed energy is 11.76 Joules and the impact value is 0.2352 Joules/mm^2. The longer the sugarcane bagasse fibers are soaked in the alkaline solution, the less energy is absorbed. In addition, resin with fiber reinforcement that has gone through alkaline soaking has a higher impact value compared to resin without using fiber reinforcement.

Sugar cane is a plant used as raw material for sugar. This plant is often found in tropical climates. So in this research, discarded sugar cane plants were used to carry out the ASTM D3379 Impact test and ASTM 638 Tensile test to see how strong the sugar cane plants can be used. The variations in the different ingredients and mixtures of BQTN 157 resin with sugar cane fiber are 70 : 30%, 80 : 20%, 90 : 10%. The test results show that sugarcane fiber in the best impact test is at a composition of 80%: 20% with the highest value of 0.1179

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j/mm^2 and in the Tensile test the composition at the highest stress is 80%: 20% with a stress value of 6.70996 N/mm^2 (Dicky Hidayatullah & Yovila Mahjoedin, 2022)

Therefore, in this research, impact testing will be carried out on two types of sugarcane fiber and polyester resin compositions, namely; to determine the effect of differences in impact strength using fiber on the composition of composite materials without using fiber; to determine the effect of the composition of 60% sugarcane fiber composite material with 40% polyester resin matrix on impact strength; to determine the effect of the composition of 70% sugarcane fiber composite material with 30% polyester resin matrix on impact strength; to determine the effect of the composition of 80% sugar cane fiber composite material with 20% polyester resin matrix on impact strength.

II. Literature Review

1. Composite

Composites are new materials formed from a combination of two or more raw materials with the aim of obtaining better mechanical properties. Some of the advantages that composites have when compared to metal materials include their lower density when compared to metal materials which easily expand when given a certain temperature. Metal materials are also very susceptible to corrosion, while composites are corrosion resistant (Nayiroh, 2013).

The emergence of composites as a separate material classification began in the mid-20th century with the creation of intentionally designed and manufactured multiphase composites, such as glass fiber reinforced polymers (Callister Jr. & Rethwisch, 2009).

Composite materials are materials formed from a combination of two or more constituent materials, through inhomogeneous mixing, where the mechanical properties of each constituent material are different. Composite materials have better mechanical properties than metals, good fatigue strength, higher specific strength (strength/weight) and specific stiffness (Young's modulus/density) than metals, are corrosion resistant, have heat and sound insulating properties.

2. Preparation of composites

Composite preparation consists of at least two different materials, which are then put together to get better mechanical properties from the material. The following are composite constituents:

a. Reinforcement (strengthener)

Reinforcement (strengthening) is the main component that functions as a foundation in determining whether the strength of the composite is large or small (Khotimah, 2018).

b. Matrix (constructor)

The constituent matrix is the main component that functions as a fiber binder to coat the fibers to avoid various kinds of damage (Khotimah, 2018)

3. Charpy impact test

Impact testing using the Charpy impact method is one of the hardness testing methods used in this research to determine the ductility of the material.

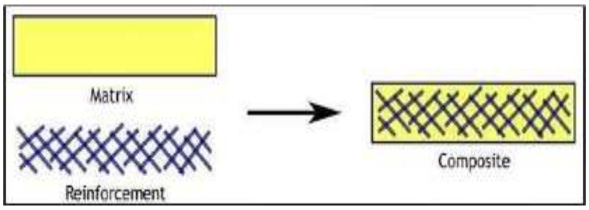

Figure 1. Reinforcement and Matrix (Pujiati, 2017)

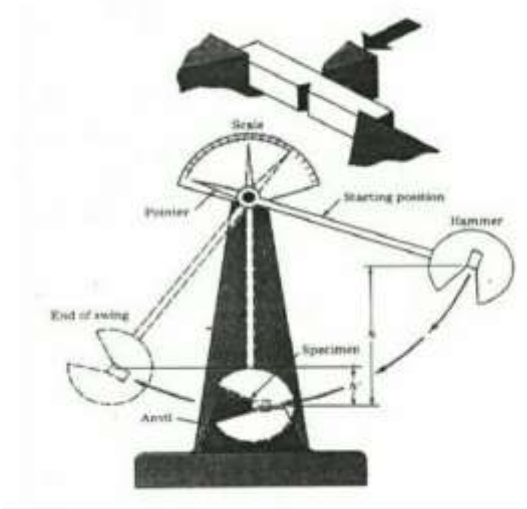

Figure 2. Charpy Impact Test Equipment

Impact toughness is the resistance of a material to shock loads, this is what differentiates impact testing from tensile testing, hardness where the loading is carried out slowly (Fhandymas, 2021).

In this test we will analyze the impact price of composite materials made from bagasse fiber mixed with polyester resin. By calculating the required impact price using the formula used:

a) Height of load before release (H_1)

$H_1 = R + R\sin(\alpha - 90)$(m)

Where :

R = Pendulum radius (m)

α = Deviation of the pendulum before it is released (°)

Solution:

$H_1 = R + R\sin(\alpha - 90)$(m)

$H_1 = 49 + 49\sin(160 - 90)$m

$H_1 = 49 + 0{,}46$ m

$H_1 = 0{,}95$ m

b) Load in units = m

$U = m.g.H_1$(joules)

$m = \frac{U}{g.H_1}$(kg)

Where :

m = Mass of the pendulum (kg)

g = Gravitasi Bumi (m/s^2)

H_1 = Height of load before release (m)

Is known :

m = 160 Grams = 0.16 kg

g = 9.81 m/s^2

H_1 = 0.95 m

Solution:

$U = m.g.H_1$(joules)

$U = 0{,}16 \text{ kg} \times 9{,}81 \text{ m/s}^2 \times 0{,}95 \text{ m}$
$U = 1{,}49$ joules
$m = \frac{U}{g.H_1}$(kg)
$m = \frac{1{,}49}{0{,}16 \times 9{,}81}$ kg
$m = \frac{1{,}49}{1{,}57}$ kg
$m = 0{,}95$kg

3) Height of load after release (H_2)
$H_2 = R + R\sin(\beta - 90)$(m)
Where :
R = Pendulum radius (m)
β = Angle of deviation of the pendulum after release (°)
Is known ;
R = 49 cm = 0.49 m
β = 133°
Solution:
$H_2 = R + R\sin(\beta - 90)$m
$H_2 = 0{,}49 + 0{,}49\sin(133 - 90)$m
$H_2 = 0.49 + 0{,}49 \sin(43)$ m
$H_2 = 0.49 + 0{,}49\ (0{,}73)$ m
$H_2 = 0{,}82$ m

4) Calculation load height (Hs)
$H_s = H_1 - H_2$ (m)
Where :
H_1 =Height of load before release (m)
H_2 =Height of load after release (m)
Is known :
$H_1 = 0{,}95$ m
$H_2 = 0{,}82$ m
Solution:
$H_s = H_1 - H_2$ (m)
HS =$0{,}95 \text{ m} - 0{,}82 \text{ m}$
H_S = $0{,}13$ m

5) The effort made to break the specimen (Us)
$U_s = (m.g.H_s)$(Joules)
Where :
m = Mass of the pendulum (kg)
g = Earth's gravity (m/s^2)
Is known :
m = 160 gram ⟶ 0,16 kg
g = $9{,}81 \text{ m/s}^2$
H_s = 0,13 joule
Solution:
$U_s = (m.g.H_s)$(Joules)
$U_s = (0{,}16 \times 9{,}81 \times 0{,}13)$Joule
$U_s = 0{,}21$ Joule

c) Impact strength (U_1)
$U_1 = \frac{U_s}{A}$(Joules)
Where :
A = Cross-sectional area (mm^2)
U_S = Work done to break the specimen (joules)
Is known :
$U_s = 0{,}20$ Joule
Solution:
$A = W \times T \text{ mm}^2$
$A = 10 \times 8{,}8 \text{ mm}^2$
$A = 88 \text{ mm}^2$
$U_1 = \frac{U_s}{A}$(Joules)
$U_1 = \frac{0{,}20 \text{ joule}}{88 \text{ mm}^2} = 2252{,}20 \text{ Joule/m}^2$

From the above calculations, it is obtained that the work done to break the specimen (Us) is 0.208 joules and the impact strength value (U_1) is 2.854 joules/m^2.

III. Method

1. Type of research

This type of research is research using experimental methods, which is a way to find the impact strength of materials made from sugar cane fiber. where the data that will be taken is primary data. What is meant by primary data is data resulting from measurements in Impact testing with composite samples that have been made. This research data was obtained by measuring composite samples with testing equipment.

2. Research Design

This research design uses the ASTM (American Society Testing and Materials) A370 impact test specimen standard, the following is the Impact Test specimen design:

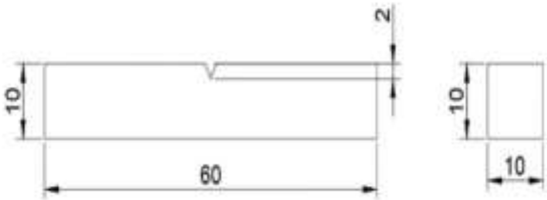

Figure 3. Impact Test Specimen

3. Research Object.

The research object was carried out on 12 composite material samples from bagasse and Polyester Resin that had been made (60: 40%, 70: 30% and 80: 20%) with varying sizes (thickness 10 mm), which had been soaked for a period of time (1 hours) in soaking using 5% NaOH + Aquadesh, this soaking aims to clean dirt on the sugar cane fiber which will be used as a specimen.

4. Research Procedures

The procedures in this research can be explained as follows:

a) Fiber treatment

Sugarcane bagasse waste is collected and dried in the sun. After the drying process, the fiber is soaked in 5% NaOH solution with Aquades for 1 hour. Fiber surface treatment is carried out by conventional methods in the ratio of solution to fiber. After the soaking process, the fiber is washed with clean water until it is free from alkali (NaOH) and dried in the sun to dry. To ensure that the water content is removed, the bagasse will be dried in the sun for 8 hours. The bagasse will be stored in an airtight plastic bag until it is time to use.

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b) Composite Manufacturing

Method Sample fabrication uses the hand-lay up method. The resin and catalyst are mixed then homogenized with bagasse fiber and the mixture is cast into an open mold measuring 120 mm x 120 mm x 50 mm made of glass or steel. The samples were conditioned at room temperature for a week and shaped using a grinder or hand saw to each predetermined size.

c) Impact testing

*Impact*is one of the methods used, the hardness and ductility of the material. Impact toughness is the resistance of a material to shock loads. This is what differentiates impact testing from tensile and hardness testing where loading is carried out slowly.

5. Data Collection Methods

The data analysis technique used to analyze the data in this research is quantitative descriptive. This data analysis technique is carried out by analyzing the data obtained by experiments, where the results are in quantitative form which will be made in tabular form and displayed in graphical form.

The next step is to describe or describe the data as it is in the form of sentences that are easy to read, understand and present so that in essence it is an effort to provide answers or problems being researched.

Research Flow Chart

Figure 4. Research diagram

IV. RESULTS AND DISCUSSION

From the results of the tests carried out, the following data table was obtained:

TABLE 1. Measurement results of 2024 source specimens

Fiber (%)	No	T(mm)	W(mm)	A (mm^2)	R (m)	H_1 (m)	m (kg)	G (m/s^2)
0%	1	8.7	10.1	87.9	0.49	0.95	0.16	9.81
	2	8.6	10.0	86.0	0.49	0.95	0.16	9.81
	3	8.8	10.0	88.0	0.49	0.95	0.16	9.81
60%	1	8.8	10.0	88.0	0.49	0.95	0.16	9.81
	2	8.6	10.0	86.0	0.49	0.95	0.16	9.81
	3	8.7	10.0	87.0	0.49	0.95	0.16	9.81
70%	1	8.4	10.2	86.1	0.49	0.95	0.16	9.81
	2	8.7	10.0	87.4	0.49	0.95	0.16	9.81
	3	8.7	10.0	87.7	0.49	0.95	0.16	9.81
80%	1	8.7	10.0	87.0	0.49	0.95	0.16	9.81
	2	8.6	10.0	87.1	0.49	0.95	0.16	9.81
	3	8.8	10.0	88.0	0.49	0.95	0.16	9.81

Source: Research Results, 2024

Based on the table of results from specimen measurements above, it shows the results of measurements of specimen samples which show differences in size in the height, width of the notch W (mm), height of the notch T (mm), and area of the notch A (mm2), this is not intentional. This can be a differentiator during impact testing later. Apart from size, there are also similarities in the data analysis, namely the height of the load before it is released H_1 (m) is 0.95 m long, the radius of the pendulum R (m) is 0.49 m long, the weight of the pendulum m (kg) is 0.16 kg, and where gravity (m/s^2) is 9.81 m/s^2.

From the results of impact testing data calculations, the following data results table is obtained:

TABLE 2. 2024 source impact test results

Fiber (%)	No	U (Joules)	β°	H_2 (M)	H_S (M)	U_S (Joules)	U_1 (J/m2)	Average U_1 (J/m^2)
0%	1	1.49	135	0.84	0.11	0.18	2033.75	2052.05
	2	1.49	138	0.85	0.10	0.15	1757.74	
	3	1.49	132	0.82	0.13	0.21	2364.66	
60%	1	1.49	133	0.82	0.13	0.20	2252.20	2278.47
	2	1.49	134	0.83	0.12	0.19	2191.36	
	3	1.49	132	0.82	0.13	0.21	2391.84	
70%	1	1.49	131	0.81	0.14	0.22	2533.61	2544.26
	2	1.49	130	0.80	0.15	0.23	2611.66	
	3	1.49	131	0.81	0.14	0.22	2487.50	
80%	1	1.49	127	0.78	0.17	0.26	2986.93	2773.96
	2	1.49	129	0.80	0.15	0.24	2740.06	
	3	1.49	130	0.80	0.15	0.23	2594.90	

Source: Research Results, 2024

Based on the table of calculation results with impact strength values above, it shows the results of calculating impact strength values, namely the energy absorbed divided by the cross-sectional area of the specimen below the notch. From 12 specimens with a dissolution time of 1 hour with a sure percentage ratio of fiber and resin of 60%:40%, 70%:30%, 80%:20% and without using fiber. So the effort to break the specimen for a ratio of 60% fiber to 40% resin with specimen 01 has an effort to break the specimen of 0.20 joules, for specimen 02 it has an effort to break the specimen of 0.19 joules, and for specimen 03 it has an effort to break the specimen of 0.21 joules.

Without using a specimen, the value of the effort to break the specimen without using fiber is 0.18 joules for specimen

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01, for specimen 02 the value of the effort to break the specimen is 0.15 joules, in specimen 02 this is the lowest value among the other specimens. And for specimen 03, the effort value for breaking the specimen was 0.21 joules.

At a ratio of 70% fiber to 30% resin, the effort to break the specimen with specimen 01 is 0.22 joules, for specimen 02 the effort to break the specimen is 0.23 joules, and for specimen 03 the effort to break the specimen is 0.22 joules, and at a ratio of 80% fiber to 20% resin, the value of the effort to break the specimen is obtained with specimen 01 having an effort to break the specimen of 0.26 joules, specimen 02 having an effort to break the specimen of 0.24 joules and specimen 03 having an effort to break the specimen of 0.23 joules, at a percentage ratio of 80% fiber to 20% resin, has the highest breaking effort value for the specimen compared to other percentage ratios.

Meanwhile, without using fiber, the value of effort to break the specimen without using fiber is 0.18 joules for specimen 01, for specimen 02, the value of effort to break the specimen is 0.15 joules, in specimen 02 this is the lowest value among the other specimens. And for specimen 03, the effort value for breaking the specimen was 0.21 joules. Based on the impact strength values in table 2, a comparison graph can be made as follows:

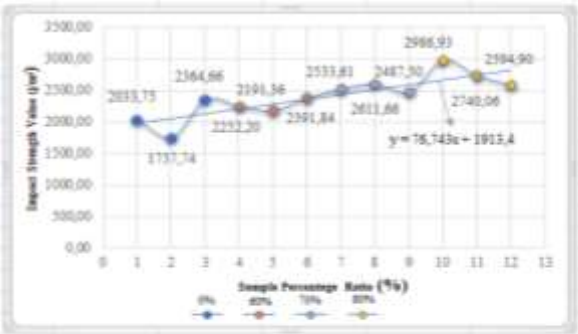

Figure 5. Diagram of a comparison of impact values from the calculation results
primary data source 2024

In the comparison value diagram for impact strength values above, there are differences in the price values for each fiber percentage ratio, while the impact strength value at a fiber ratio of 60% to 40% resin in specimen 01 has an impact strength value of2252.20 j/m^2, for specimen 02 which has the lowest impact strength value of 2191.36 j/m^2, and for specimen 03 it has a high impact strength value at a fiber percentage ratio of 60% fiber with 40% resin 2391.84 h/m^2,

At a ratio of 70% fiber to 30% resin in specimen 01 with an impact strength value of2533.61 j/m^2, and for specimen 02 which has the highest impact strength value for 70% fiber with 30% resin of 2611.66 j/m^2, and specimen 03 has an impact strength value of 2487.50 j/m^2

At a ratio of 80% fiber to 20% resin, specimen 01 has the highest impact strength value of2986.93 j/m^2, for specimen 02 it has an impact strength value of 2740.06 j/m^2, and for specimen 03 it has the lowest impact strength value compared to the other specimens at a ratio of 80% fiber to 20% resin with a value of 2594 .90 j/m^2.

The impact strength value without using fiber in specimen 01 is 2986.93 j/m^2, in specimen 02 the value is2740.06 j/m^2, and specimen 03 got a value of 2594.90 j/m^2

The factor that causes uneven differences in impact strength values in each impact test is that there are differences in the size of the notch area in making the specimen.

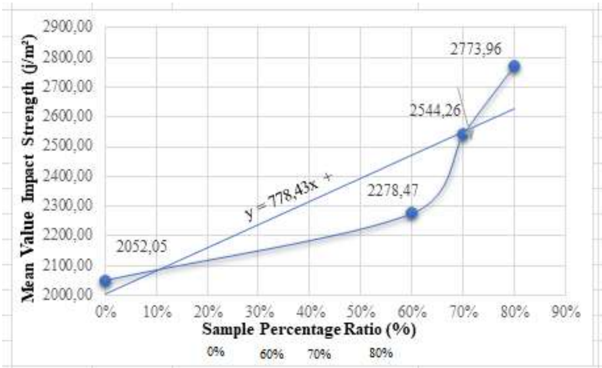

Figure 6. Comparison diagram of impact strength values from calculation results
primary data source 2024

The diagram above can show the average results for each fiber percentage ratio, for a fiber ratio of 60% to 40% resin it has an impact strength value of 2278.47 j/m^2, this impact strength value has the lowest value with the percentage ratio value being others without using fiber with an impact strength value of 2052.05 j/m^2. For the ratio of 70% fiber to 30% resin the value is 2544.26 j/m^2, and for the ratio of 80% fiber to 20% resin the value is 2775.96 j/m^2, this value is the highest value of the other percentage ratios.

V. CONCLUSION

Based on the research results, data analysis and discussion, it is concluded that:

1. Tests show that the impact strength of composites using fiber and without using fiber with varying volume fractions, produces different impact strength values. It can be seen from the test results that composites using fiber are stronger than those without fiber, this happens because the fiber functions as a composite cross section.
2. There is an influence of the composition of the composite material on the impact strength. Where the composite is reinforced with natural sugarcane bagasse fiber and a polyester resin matrix, with a percentage ratio of 60% fiber and 40% polyester resin. The fibers with their respective reinforcements have impact strength values of 2252.20 joules/m^2, 2191.36 joules/m^2, 2391.84 joules/m^2 resulting in an average impact strength value of 2278.47 joules/m^2.
3. There is an influence of the composition of the composite material on the impact strength. Where the composite is reinforced with natural fiber bagasse with a polyester resin matrix, with a percentage ratio of 70% fiber and 30% polyester resin. The fibers with their respective reinforcements have impact strength values of 2533.61

joules/m^2, 2611.66 joules/m^2, 2487.50 joules/m^2 resulting in an average impact strength value of 2544.26 joules/m^2.

4. There is an influence of the composition of the composite material on the impact strength. Where the composite is reinforced with natural fiber bagasse with a polyester resin matrix, with a percentage ratio of 80% fiber and 20% polyester resin. The fibers with their respective reinforcements have impact strength values of 2986.93 joules/m^2, 2740.06 joules/m^2, 2594.90 joules/m^2 resulting in an average impact strength value of 2773.96 joules/m^2.

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