Effect of Bagasse Mixture On Mechanical Properties and Physical Properties Using Polyester and Vinylester Mixture Matrix

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Abstract.
Thi dy aims to analyze the effect of the variation of bagasse fiber mixture on the mechanical properties and microstructure of composites using a mixture matrix of polyester and vinyl ester. The research method used is an experimental method by making composite specimens through a hand lay-up process. The variation in the fiber content of the bagasse used was 0%, 5%, 10%, 15%, and 25%, while the composition of the polyester and vinyl lester matrix was maintained at a ratio of 70:30. Material characterization was carried out through tensile testing to obtain Tensile Strength (TS), Tensile Strength at Break (TSb), Yield Strength (Sy), Yield Strain (Ey), and modulus of elasticity, as well as fracture morphology observation using Scanning Electron Microscope (SEM). The results showed that the increase in bagasse fiber content led to a decrease in TS, Sy, and EY values, with the highest TS value obtained in PV0 specimens of 32.62 MPa and the lowest in PV25 of 6.47 MPa. The 5% fiber variation provides the best TSb value and modulus of elasticity, of 3.37 MPa and 25.12 MPa, respectively. The results of SEM observations show that the addition of fiber up to 5% still produces a fairly good fiber-matrix bond, while at 25% fiber content there is porosity and uneven distribution of fibers that reduce the mechanical properties of composites.
Keywords: *Bagasse, composite, polyester, vinyl lester, tensile test and SEM.s stu.*

I. INTRODUCTION

The development of material technology in recent decades has led to the development of materials that have high mechanical strength, lightweight, corrosion resistance, economical, and environmentally friendly. Composite materials are one of the solutions that are widely developed because they are able to combine the superior properties of the matrix and reinforcing materials so that they produce better performance than the constituent materials individually [1], [2]. The use of composites has developed widely in the automotive, construction, marine, aerospace, and engineering equipment industries because it has a high strength-to-weight ratio, good corrosion resistance, and ease in the fabrication process [3].

Nevertheless, most commercial composites still use synthetic fibers such as fiberglass or carbon fiber that come from non-renewable resources and are difficult to degrade naturally. This condition causes environmental problems due to the increase in polymer-based composite waste sintetis. Di sisi lain, meningkatnya kesadaran terhadap Sustainable development encourages the use of natural materials as composite reinforcers that are more environmentally friendly [4], [5]. One of the biomass waste that has great potential is bagasse, which is a by-product of the sugar industry with a very abundant amount of production in sugarcane-producing countries, including Indonesia [6].

Bagasse contains about 40–50% cellulose, 25–35% hemicellulose, and 18–24% lignin, so it has the potential as a composite reinforcing material because it is able to increase mechanical strength while reducing material weight [7]. In addition to providing added value to agricultural waste, the use of sugarcane bagasse also supports the concept of circular economy through waste reduction and increasing the efficiency of natural resource use [8]. However, the use of natural fibers still faces several obstacles, including high water absorption, variations in fiber quality, and weak interfacial bonding between fibers and polymer matrices which can reduce the mechanical properties of composites [9].

Previous studies have reported that the mechanical properties of natural fiber-based composites are influenced by the type of matrix, fiber volume fraction, fiber orientation, particle size, as well as the quality of the interface bond between the matrix and the amplifier [2], [10]. Nursyiwana et al. [11] reported that the addition of bagasse fibers by 20% to the polyester composite resulted in the highest crack stress intensity factor value of 1,624 MPa·m^{1/2}. Hesti Istiqlaliyah [12] showed that the combination of bagasse fiber and banana frond fiber was able to increase the tensile strength of composites up to 21 MPa. Meanwhile, Fuazzidin et al. [13] found that an increase in the volume fraction of banana fronds fibers by up to 15% was able to increase the tensile strength, modulus of elasticity, and impact strength of polyester-based composites.

On the other hand, research on the use of polyester and vinyl lester polymer blends showed promising results. Adnan et al. [14] reported that the composition of a mixture of 60% polyester and 40% vinylester resulted in the highest flexural strength of 126.88 MPa. Hakim [15] also showed that the use of a polyester-vinylester mixture matrix was able to produce better fracture characteristics based on FTIR and SEM observations than the use of a single resin. The findings suggest that mixing the two types of resins has the potential to improve the mechanical properties of composites through improved matrix compatibility and more even stress distribution.

However, based on literature reviews, there is still a fairly clear research gap. Most previous studies have focused on the use of one type of resin as a matrix or examined the effect of fiber volume fractions on one type of mechanical testing, such as tensile, flex, or impact [11]–[15]. Research that combines bagasse waste as a reinforcer with a polyester-vinylester mixture matrix and simultaneously evaluates the mechanical properties and physical properties of composites is still very limited. In addition, there have not been many studies that have analyzed the effect of variations in bagasse content on changes karakteristik komposit menggunakan sistem matriks Polyester-vinyl ester hybrids so that the mechanism of increasing or decreasing material properties is not fully understood.

Based on these conditions, this study aims to analyze the effect of variety of bagasse mixture on the mechanical properties and physical properties of composites using a mixture matrix of polyester and vinyl ester. Testing is carried out to evaluate changes in material characteristics due to variations in fiber content so that a composition that provides optimal performance can be obtained.

The main argument of this study is that the combination of polyester matrix and vinylester is thought to be able to improve the quality of the interface bond with bagasse fibers compared to the use of a single resin. The interaction of the two types of resins is expected to result in better stress distribution, increase tensile strength, as well as improve the physical characteristics of composites. On the other hand, variations in bagasse content will affect fiber distribution, void formation, load transfer ability, and water absorption so that there is an optimal composition that produces a balance between mechanical properties and physical properties of the material.

This research has important value both scientifically and practically. From the scientific aspect, this study expands the study of natural fiber-based composites by utilizing the polyester-vinylester mixture matrix system which is still relatively underreported in the literature. From a practical aspect, the results of the research are expected to be the basis for the development of environmentally friendly composite materials based on agricultural waste that have potential applications in automotive components, light construction, building panels, and other manufacturing products. In addition to increasing the added value of bagasse waste, this research also supports the development of sustainable materials that are in line with circular economy principles and green industrial development.

II. METHODS

The research design method is a stage that systematically explains the process of planning, implementation, and data collection and analysis techniques used in this study. This method is designed to ensure that the research process runs in a structured, measurable, and in accordance with the research objectives, which is to analyze the effect of bagasse fiber mixtures on the mechanical properties and physical properties of composites using a polyester and vinylester mixture matrix.

This study uses an experimental method, where researchers directly make composite specimens with certain compositional variations, then conduct laboratory tests to obtain quantitative data that can be analyzed scientifically.

Determination of Research Variables

The determination of research variables aims to limit the scope of the research as well as ensure that the factors affecting the outcome can be controlled and analyzed systematically. The variables in this study are divided into three types, namely:

a. Variabel Bebas (Independent Variable)

The free variable is a variable that is deliberately changed by the researcher to determine its effect on the characteristics of the composite. The independent variables in this study include:

1. The percentage of bagasse fibers in the composite, which is varied to determine the effect of the amount of fibers on the strength and physical properties of the material.

2. Comparison of polyester and vinyl ester matrices, which are used to evaluate the influence of resin type and composition on composite performance.

b. Dependent Variable

Bound variables are variables that are observed in response to changes in independent variables. In this study, the bound variables analyzed include:

Mechanical properties of composites, which include:

• Tensile Strength

Physical properties of composites, which include:

• Scaning Electron Mycroscopy (SEM)

These values are used as the main indicators in assessing the quality and performance of the composites produced.

Experimental Design and Specimen Planning

The experimental design was arranged to determine the number of variations in composition as well as the number of test specimens in each variation. In this study, each variation in composition was made in several test specimens to improve the accuracy of the data and reduce the potential for measurement errors.

Variations of the designed composition include:

• Percentage of bagasse fiber (0%, 5%, 10%, 15%, and 25%)

• Resin matrix composition (Polyester and Vinylester 70 : 30 %)

This design allows researchers to directly observe the effect of compositional changes on the mechanical and physical characteristics of composites.

No	**Bagasse fiber (%)**	***Polyester* : *Vinylester* (70:30 %)**	**Code specific**
1	0	100	PV0
2	5	95	PV5
3	10	90	PV10
4	15	85	PV15
5	25	75	PV25

Prosedur Pembuatan Spesimen Komposit

The manufacture of composite specimens is carried out using the hand lay-up method, because this method is relatively simple, economical, and suitable for small-scale laboratory research.

The stages of specimen making include:

a. Preparation of tools and materials

b. Preparation of Materials as follows:

1. Sugarcane bagasse is obtained from industrial waste/sugarcane milling.
2. Bagasse is washed using clean water to remove dirt and sap residue.
3. Bagasse is dried by drying in the sun until the moisture content is reduced.
4. Dried bagasse is mashed using a blender until a relatively uniform fiber/particle size is obtained.
5. The refined fibers are filtered to obtain a particle size that suits the needs of the research.

c. Preparation of Resin Matrix as follows:

1. Polyester Resin and Vinyl Resin are prepared according to the predetermined mixture ratio in the research variety.
2. Each resin is poured into a measuring cup to ensure the appropriate volume or mass.
3. The resin mixture is gently stirred until homogeneous.

4. A catalyst (MEKP) is added to the resin mixture at a percentage according to the manufacturer's recommendation (±1–2% of the resin volume).
5. The mixture is stirred again evenly and used before the gelation process occurs.

d. Mixing Bagasse with Matrix, as follows:

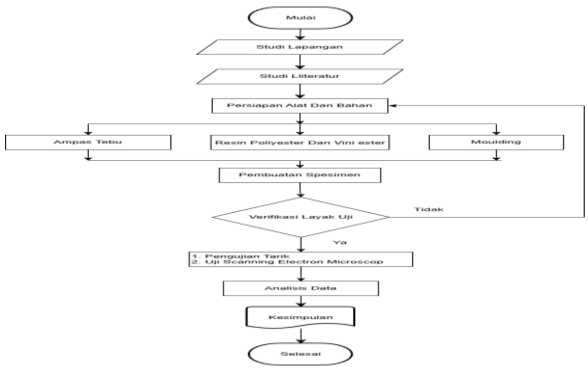
1. The mashed bagasse is weighed according to the variation of the predetermined weight fraction.
2. Bagasse is gradually added to the resin mixture.
3. The mixture is stirred slowly until the fibers are evenly dispersed and no clumping occurs.
4. The stirring process is carried out carefully to minimize the formation of air bubbles.

e. Specimen Printing which is as follows:

1. The mold is cleaned and coated with wax or release agent to facilitate specimen removal.
2. The composite mixture is poured into the mold according to the standard dimensions of the test.
3. The surface is leveled using a spatula to get a uniform thickness.
4. The mold is left at room temperature until the initial curing process takes place.

This process is carefully carried out to ensure that each specimen is of good quality and consistency.

Flowchart



III. RESULT AND DISCUSSION

Tensile testing was carried out to determine the effect of the addition of bagasse on the mechanical properties of composites based on polyester and vinyl resins. The parameters analyzed included Tensile Strength (TS), Tensile Strength at Break (TSb), Yield Strength (Sy), Yield Strain (Ey), and Modulus of Elasticity. The test results are then presented in the form of tables and bar diagrams to facilitate the analysis of changes in mechanical properties due to variations in the composition of bagasse fibers.

Code Spesimen	Ts (Mpa)	Tsb (Mpa)	Sy (Mpa)	Ey (%)	Modulus of Elasticity (MPA)
PV0	32,62	1,17	34,29	1,57	23,81
PV5	21,31	3,37	20,75	0,83	25,12
PV10	11,22	2,60	9,80	0,60	16,44
PV15	9,10	1,97	6,80	0,53	12,16
PV25	6,47	1,3	5,27	0,50	10,07

Based on Figure 1, below can be seen the tensile strength value at the 5% fiber variation against Polyeater and vinyl lester resins with an average tensile strength of 21.31 Mpa, a 10% fiber variation of a maximum tensile strength of 11.22 MPa, a variation of 15% of the maximum tensile strength of 9.10 Mpa, a variation of 25% of the tensile strength of 6.47. The test results showed that the maximum tensile strength value of TS decreased as the percentage of the bagasse mixture increased. PV0 specimens as specimens without the addition of bagasse had the highest TS value of 32.62 MPa. This value indicates that the pure polyester-vinylester matrix has the best ability to accept tensile loads.

In PV5 specimens, the TSb value decreased to 21.31 MPa, or a decrease of about 34.7% compared to PV0. This decrease indicates that the addition of bagasse by 5% begins to affect the continuity of the matrix so that the material's ability to withstand tensile loads is reduced. The decrease was further seen in PV10, PV15, and PV25 specimens with values of 11.22 MPa, 9.10 MPa, and 6.47 MPa, respectively. Compared to

PV0, the decrease in tensile strength reached about 65.6%, 72.1%, and 80.2%. These results show that the higher the bagasse content, the lower the tensile strength of the composite.

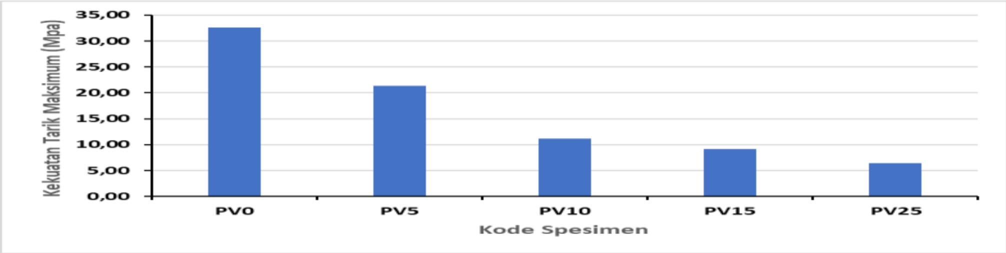


Fig. 1. Maximum Tensile Strength (Ts)

The TSb test results are shown in Figure 2, showing different patterns compared to the maximum tensile strength. The PV0 specimen had a TSb value of 1.17 MPa, then increased to 3.37 MPa in PV5. After that, the TSb value decreased again to 2.60 MPa in PV10, 1.97 MPa in PV15, and 1.30 MPa in PV25.

The increase in TSb value in PV5 specimens shows that the addition of bagasse by 5% is still able to increase the material's ability to maintain the load until it is close to the breaking point.

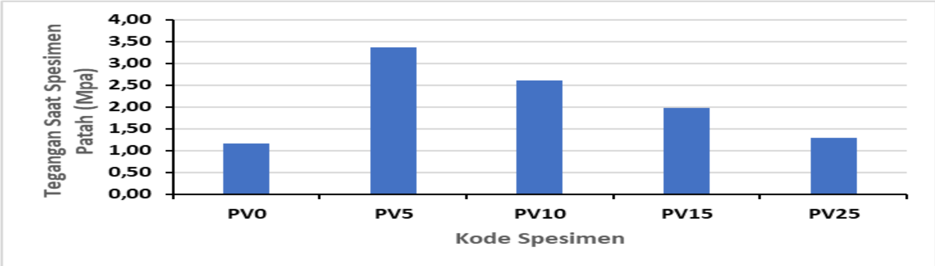


Fig. 2. Voltage When Specimen Breaks (TSb)

Based on the test results in Figure 3, the value of the Sy melt stress also decreases as the bagasse content increases. PV0 specimens had the highest Sy value of 34.29 MPa, then decreased to 20.75 MPa in PV5. Furthermore, the value continued to decrease to 9.80 MPa in PV10, 6.80 MPa in PV15, and 5.27 MPa in PV25.

When compared to PV0, the decrease in Sy value reached around 39.49% in PV5, 71.42% in PV10, 80.17% in PV15, and 84.63% in PV25. The decrease indicates that the material's ability to maintain elastic deformation before entering the plastic area is getting lower.

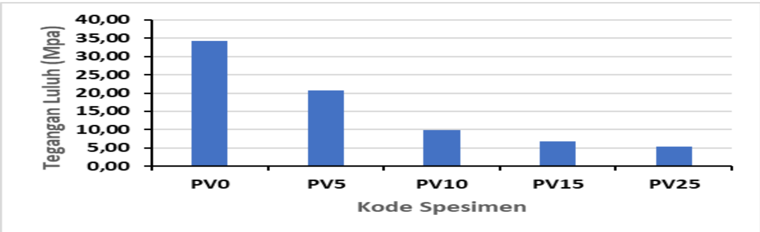


Fig. 3. Melt Voltage (Sy)

In Figure 4, the Ey yield strain shows a decreasing tendency as the percentage of the bagasse mixture increases. PV0 specimens had the highest strain value of 1.57%, then decreased to 0.83% in PV5, 0.60% in PV10, 0.53% in PV15, and 0.50% in PV25.

The decrease in strain value indicates that the material's ability to undergo elastic deformation before it fades becomes smaller. This shows that composites become stiffer and tend to be brittle with the increase in bagasse content.

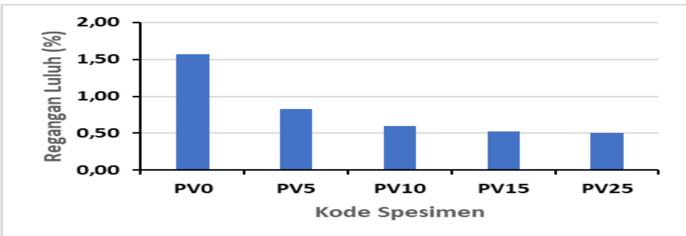


Fig. 4. Regangan Luluh (Ey)

The modulus of elasticity is a parameter that describes the degree of rigidity of a material to elastic deformation. Based on the test results, the modulus value of elasticity at PV0 was 23.81 MPa, then increased to 25.12 MPa at PV5. The increase of about 5.50% shows that the addition of bagasse by 5% is able to increase the rigidity of the composite.

However, when the bagasse content is increased to 10%, 15%, and 25%, the modulus values of elasticity decrease to 16.44 MPa, 12.16 MPa, and 10.07 MPa. The decrease shows that the addition of a larger amount of fiber actually decreases the material's ability to maintain elastic deformation.

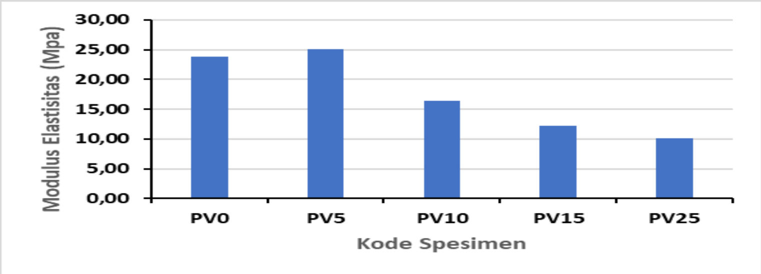


Fig. 5. Modulus of Elasticity

SEM Test Results

Photo SEM was conducted to determine the bond structure between fibers as a reinforcer with a mixture of Polyester resin and Vinylester as a binder. In figure 6 shows the results of the SEM test with a mixture of 70:30 Polyester Resin and Vinyl Resin after the tensile test was carried out, it can be seen that the fracture surface results carried out were clearly irregular bond waves, this is because the polyester and vinyl lester bonds are perfectly bonded forming a plastic deformation that makes cracks spread.

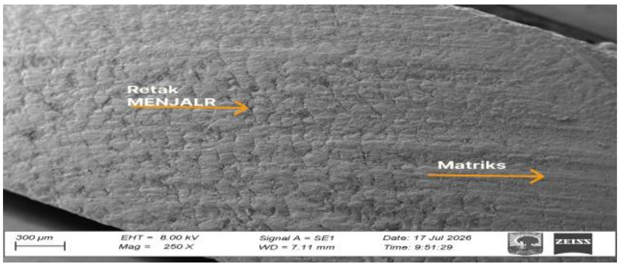


Fig. 6. Magnification 250x Polyester resin and Lintless Vinylester

The results of the 5% bagasse fiber composite sem test after a dance test with a mixture of Polyyester and Vinylester resin binders can be seen in Figure 7 From the results showing the fracture surface of the 5% fiber addition mixture sample, the surface shows a wavy and separate fracture between the metric shape and the renpos between the binder and the reinforcing seen in the 250x magnification test of Figure 7. Where fiber-shaped fibers have little resistance that results in creeping cracks in the fibers, while the fracture surface on the creeping crack metric does not have an obstacle

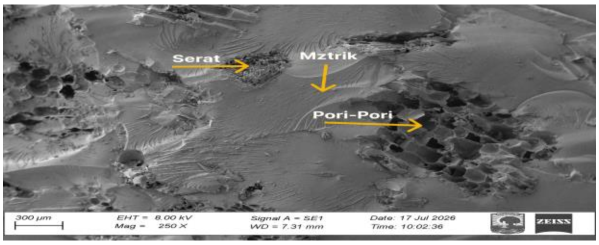


Fig. 7. 250x Magnification Polyester and Vinyl Resin Blend and 5% Fiber

The results of the 25% bagasse fiber composite sem test after a dance test with a mixture of Polyyester Resin and Vinylester can be seen in Figure 8. From the results of the SEM test, it can be seen that voids such as porosity in a matrial are because the mixed fibers are not evenly dispersed so that the mixture between the binder and the reinforcing is not homogeneous, and causes the matrial to become brittle.

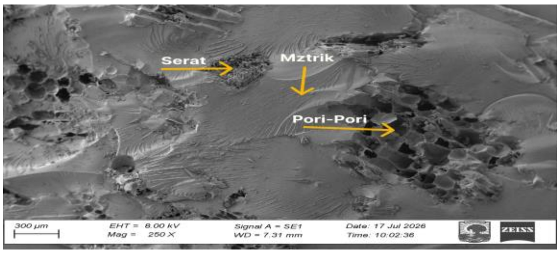


Fig. 8. 250x Magnification Polyester and Vinyl Resin Blend and 25% Fiber

IV. CONCLUSION

Based on the results of the study, it can be concluded that the addition of bagasse fibers affects the mechanical properties of composites with a mixed matrix of polyester resin and vinylester. The values of Tensile Strength (TS), Yield Strength (Sy), and Yield Strain (Ey) tend to decrease as the percentage of bagasse fiber increases. Specimens without fibers (PV0) had the highest TS values of 32.62 MPa, Sy of 34.29 MPa, and Ey of 1.57%, while the lowest values were obtained in PV25 specimens with TS of 6.47 MPa, Sy of 5.27 MPa, and Ey of 0.50%. The decrease shows that the addition of larger amounts of fiber causes the composite's ability to withstand tensile loads and elastic deformation to be lower. Meanwhile, the Tensile Strength at Break (TSb) value and modulus of elasticity showed optimal results at the 5% fiber variation (PV5), of 3.37 MPa and 25.12 MPa, respectively, indicating that the addition of small amounts of fiber is still able to increase the rigidity of the material and the ability to withstand load until close to the breaking point.

The results of observations using Scanning Electron Microscope (SEM) show that the microstructure of composites is greatly influenced by the fiber content of bagasse. The PV0 specimen showed a relatively homogeneous polyester-vinyl-lester matrix bond, while in PV5 there was a fiber pull-out but the bond between the fiber and the matrix was still quite good. In the PV25 specimen, porosity (void) and uneven fiber distribution were found so that the bond between the amplifier and the matrix became weak. These conditions cause cracks to propagate more easily and materials become more brittle, which is in line with the degradation of properties mekanik hasil pengujian tarik. Dengan demikian, dapat disimpulkan bahwa penambahan serat ampas Sugarcane of 5% is the composition that provides the best mechanical performance compared to other fiber variations in this study.

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