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ANALYSIS OF MECHANICAL STRENGTH OF WEIGHT FRACTION VARIATION SUGAR PALM FIBER AS POLYPROPYLENE-ELASTOMER MATRIX REINFORCEMENT OF HYBRID COMPOSITE

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Currently, the availability of polypropylene, elastomer and sugar palm fiber (Arenga pinnata) is very abundant, which has a good impact on the potential for the development of new composite materials that have good properties and characteristics. Composites are generally a new material composed of two or more different materials with the aim of producing a new material that has better properties than the constituent material. In this study, polypropylene (PP) plastic and elastomer were used as a composite matrix reinforced with sugar palm fiber (Arenga pinnata). The purpose of this study was to determine the value of tensile strength, impact strength, and bending strength of composites with a weight fraction of 20 % (80:20), 30 % (70:30), and 40 % (60:40). Based on the results of the research on hybrid composites of polypropylene and fiber-reinforced elastomers, composites with a weight fraction of 20 % (80:20) got the lowest tensile strength value of 1.153 MPa, while composites with a weight fraction of 40 % (60:40) obtained the highest tensile strength value of 2.613 MPa. Composites with a weight fraction of 20 % (80:20) got the lowest tensile strain value of 0.0049 and the highest tensile strain value of 0.0067 was found in composites with a weight fraction of 40 % (60:40). For the impact strength, the 40 % (40:60) weight fraction composite got the lowest value of 45248.234 kJ/mm^2, while the 20 % (80:20) weight fraction composite got the highest impact strength of 17649.97 kJ/mm^2. For bending strength results, the composite with a weight fraction of 20 % (80:20) obtained the lowest bending strength of 1.7778 MPa, while the composite with a weight fraction of 30 % (70:30) obtained the highest bending strength of 4.8867 MPa. The highest bending strain was found in the composite with a weight fraction of 20 % (80:20), which was 0.0207

Keywords: hybrid composite, sugar palm fiber (Arenga pinnata), polypropylene, elastomer, mechanical properties

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1. Introduction

Polypropylene (PP) is a commodity polymer with versatile properties, which can be further modified in various ways. Judging from its versatility, PP production is one of the largest among other commodity polymers. PP has balanced properties, good rigidity, reasonable price, low density, heat distortion temperature, transparency, and fire resistance. PP is widely used in the automotive and construction industries [1]. PP is the second most important and cost-effective thermoplastic polymer after polyethylene on the global market. Polypropylene can be produced by molecular polymerization, which is why many scientists choose PP because of its low production cycle, low cost, and good properties. As a matrix material, PP is very commonly used because it has good properties for composite fabrication [2, 3]. Composites are materials made of two or more constituent materials with different physical and chemical properties, which when combined will produce a material with different characteristics between each component. The latest materials are more in demand than traditional materials because they have advantages such as being stronger, lighter, and cheaper. Composite materials are used in various application fields such as buildings, bridges, ship hull structures, car frames, bathtubs, sinks, marble countertops, and other materials. Composites with good properties and characteristics are the result of the right mixture of fiber and matrix materials. Many of today's composites are made of smart materials such as shape memory polymers (SMP), piezoelectric, magneto-electro-elastic (MEE), electrorheological (ER) [4–6].

Recently, more focus has been given to cellulose-based fibers as reinforcement in polymer composites due to the impact on environmental pollution caused by the use of synthetic fibers such as glass fibers to produce composite materials. Polymer matrix composites are widely used in various fields such as household appliances, vehicle industry, and others. Very different from synthetic fibers, the use of natural fibers in the manufacture of composites has many advantages such as natural fibers having high strength, light weight, being easy to obtain, environmentally friendly, and biodegradable. Various types of natural fibers are being exploited for the purpose of producing biodegradable polymer composites [7, 8]. Natural fiber is a fiber that is produced from animal and vegetable sources. Natural fibers include all natural cellulose fibers (coir, cotton, flax, etc.), as well as protein-based fibers such as silk and wool. Generally, natural fibers are strongly influenced by the nature and environmental conditions of the plant. Good fiber properties are produced due to the high cellulose content and the arrangement of microfibrils in the fiber. Fibers with high cellulose content include flax and kenaf, which also have higher structural advantages [9, 10]. Natural fiber composites are very popular composites in the last few decades. Natural fibers are easily found in the fields such as industry, medical implants, mining, and textiles. In industrial applications, the potential for making natural fiber composites (biocomposites) is closely related to the success of making environmentally friendly materials. Natural fiber composites have good damping properties due to their viscoelastic properties, but also have lower stiffness and strength. Therefore, increasing the strength and stiffness of natural fiber composites is important to produce good natural fiber composites [11–15].

The great advantages of making composites using natural fibers are lower material costs, ease of availability, sustainability, and density. There are various types of natural fibers that are trending such as sugar palm, coconut fiber, hemp, curaua, sisal, and others. Sugar palm, scientifically called (*Arenga pinnata*), is a fast-growing tree. Sugar palm trees are traditionally grown for their sap, which is widely used as granulated sugar and brown sugar [16]. Sugar palm trees grow a lot and can be found in Asian countries, especially Indonesia. Sugar palm fiber has the potential to be used as a reinforcement in the manufacture of composites. Sugar palm fiber has many significant advantages to consider. Sugar palm fiber is known for its low price, biodegradability, very abundant availability. In terms of properties, palm fiber has low density, good mechanical strength, and good thermal properties [17–19].

Therefore, in this study, natural fibers, namely sugar palm fiber *(Arenga pinnata)*, were used as reinforcement in the manufacture of hybrid composites with a polypropylene-elastomer matrix. This study aims to analyze the mechanical strength of the sugar palm fiber weight fraction as a hybrid polypropylene-elastomer composite matrix reinforcement.

2. Literature review and problem statement

The paper [20] showed the effect of microwaves on the tensile strength of palm fiber mixed with 6 % NaOH-reinforced polyurethane composites. The hot press machine is used to mix palm fiber and polyurethane resin in the manufacture of composites. Temperature variations used are 70, 80, and 90 °C applied in the microwave treatment. Based on the results and discussion, the highest tensile strength was recorded at 18.42 MPa at a microwave temperature of 70 °C and 6 % alkali. The use of palm fiber as a matrix reinforcement in composite materials has various advantages. In addition to having high tensile strength, this composite from natural fibers also has good properties for various applications. Some things that have not been explored in this research are bending testing and impact testing of palm fiber.

The paper [21] presents a study on the tensile strength properties of palm fiber reinforced with high impact polystyrene composite (HIPS). Variations in fiber load used are 10, 20, 30, 40, and 50 % by weight mixed with a polymer to make composites using a hot press. Based on the results of the study, the increase in the load of short fibers on the HIPS matrix can increase the value of the modulus of elasticity and tensile strength. In this study, palm fiber as a composite material has a good modulus of elasticity and tensile strength, so that palm fiber has great potential in making composites. This study has not tested the bending of palm fiber as a composite reinforcement.

The research carried out the manufacture of composites with date fiber reinforcement (DPF) (0 %, 40 %, 50 %, and 60 %) in phenolic composites. Based on the observation, the incorporation of 50 % DPF loading increases the impact strength and modulus, while reducing the tensile strength and flexural strength. 50 % DPF composite has better thermal and mechanical properties with better interfacial bond between fiber and matrix. This material is very well used in building, wall and ceiling applications [22]. Date fiber is a natural fiber easily available as palm fiber. This research has concluded that date fiber has good mechanical and thermal properties, which is feasible as a composite that is applied to buildings.

Oil palm empty fruit bunches (OPEFB) and sugarcane fiber (SCB) attracted the attention of researchers as reinforcing materials in the manufacture of high-potential composites in the building sector. This study showed that the hybridization of OPEFB/SCB fiber composites resulted in better performance and properties than those of pure fiber composites. Based on the results, the highest tensile strength and modulus were found at 5.56 MPa and 661 MPa, where the voids and the pore area were smaller than those of pure composites. This study also discusses agricultural residues, which are alternative green product materials that function as thermal insulation and heat retention on walls [23]. Apart from the use of palm fiber, dates, there is also the use of sugarcane fiber as a reinforcing material in the manufacture of composites, which are very feasible to be applied in the building sector.

Research has been carried out on the manufacture of composites using natural fibers (flax), synthetic fibers (glass) and unsaturated polyester resins. The composite laminates made include hemp/tidy polyester, glass/tidy polyester, and hemp/glass/polyester hybrid. Based on the research results, neat glass/polyester laminates got the best mechanical performance results from other laminates [24]. By producing good mechanical strength, namely neat glass/polyester laminate, this material can be relied upon as a material in the development of composite science.

The paper [25] showed research on making composites using cowhide obtained from the leather industry, which is also polluting the environment. Leather that is not used by the industry is used by adding unsaturated polyester (UPR) as a composite material. Fiber variations are divided into (2, 5, 7, 10, 12, 15, and 20 % by weight). The finished composites were tested for mechanical strength, such as tensile strength, bending strength, and also their elastic modulus. This method is very feasible in overcoming the problem of environmental pollution from leather waste. Where the polluting leather waste is used as a material for the manufacture of composites. The problem that has not been resolved is that the production of a lot of used leather leads to a lot of unsaturated polyester, which causes production costs to also increase.

The tensile strength characteristics of cobalt fillers and fiber-reinforced epoxy composites can be applied to car body parts. The percentage of fiber weight was varied, namely glass fiber (GF) and carbon fiber (CF) filled with epoxy compounds. From the results of the research, the tensile strength of GF is around 96.9 MPa and 120 MPa, while the tensile strength of CF is 194.82 MPa and 393.34 MPa. Using 0.6 % weight cobalt (Co) filler for the combination of GF and CF epoxies can strengthen the results in the strength test [26]. But there were unresolved issues related to the manufacture of composite materials from cobalt fillers and fiber-reinforced epoxy. The reason for this may be that it is very expensive, which makes relevant research impractical. Therefore, research is needed using materials that are easily available and affordable, such as materials derived from natural fibers.

3. The aim and objectives of the study

The aim of this study is to produce a material that has good properties and characteristics in the field of engineering, by making a polypropylene-elastomer hybrid composite material with sugar palm fiber reinforcement.

To achieve this aim, the following objectives are accomplished:

– to determine the tensile strength of the weight fraction variation sugar palm fiber as polypropylene-elastomer matrix reinforcement of hybrid composite;

– to determine the impact strength of the weight fraction variation sugar palm fiber as polypropylene-elastomer matrix reinforcement of hybrid composite;

– to determine the bending strength of the weight fraction variation sugar palm fiber as polypropylene-elastomer matrix reinforcement of hybrid composite;

– to find out the scanning electron microscopy (SEM) of the weight fraction variation sugar palm fiber as polypropylene-elastomer matrix reinforcement of hybrid composite.

4. Materials and methods of research

4. 1. Materials of research

In this study, natural fiber namely sugar palm fiber (*Arenga pinnata*) is used as a reinforcement in the manufacture of composites, because sugar palm fiber (*Arenga pinnata*) is cheap and easy to obtain in Indonesia, which makes it interesting to analyze as an ingredient in composite manufacture. In addition, as already mentioned, palm fiber has good properties and characteristics as a composite. The matrix used in this research is polypropylene (PP) and elastomer. The reason for using polypropylene in this study is that apart from being relatively cheap and easy to obtain, the use of PP also plays an important role in reducing environmental pollution. The variations in the weight fraction of polypropylene (PP) and elastomer composites with sugar palm fiber reinforcement in this study were 20 % (80:20), 30 % (70:30), 40 % (60:40).

The materials used in this study consisted of sugar palm fiber as reinforcement, polypropylene polymer, and elastomer as a matrix, which can be seen in Fig. 1–3.

Fig. 1. Sugar palm fiber (*Arenga pinnata*)

Fig. 2. Elastomer

Fig. 3. Polypropylene (PP)

The total weight of the composite is 200 grams, divided into 3 variations of weight fraction as follows: 20 % (80:20)=40 grams of fiber, 112 grams of elastomer, 48 grams of PP. 30 % (70:30)=60 grams of fiber, 98 grams of elastomer, 42 grams of PP. 40 % (60:40)=80 grams of fiber, 84 grams of elastomer, 36 grams of PP.

4. 2. Methods of research

The procedure carried out in the following research is to first prepare the tools and materials, followed by the process of cutting the elastomer into small sizes and the process of cutting the fibers and washing the PP. After that, it was continued with the process of soaking the fibers with 5 % NaOH solution for 1 hour. After the immersion was finished, it was followed by a composite molding process with a weight fraction of 20 % (80:20), 30 % (70:30), and 40 % (60:40). The research flowchart can be seen in Fig. 4. The layout of the composite mold is shown in Fig. 5.

Hot Press is used as a method in molding a hybrid composite of polypropylene and sugar palm fiber-reinforced elastomer. The molding procedure begins by preparing a mold that has been cleaned first and then smeared with glycerin to prevent the composite from sticking to the mold. After that, the PP, elastomer matrix, and sugar palm fiber were weighed according to their variations. After the preparation is done, the mold is placed on a hot press machine and is given a pressure of 3,000 psi with a temperature of 160 °C for 2 hours until the composite is formed. The printed composite can be seen in Fig. 6.

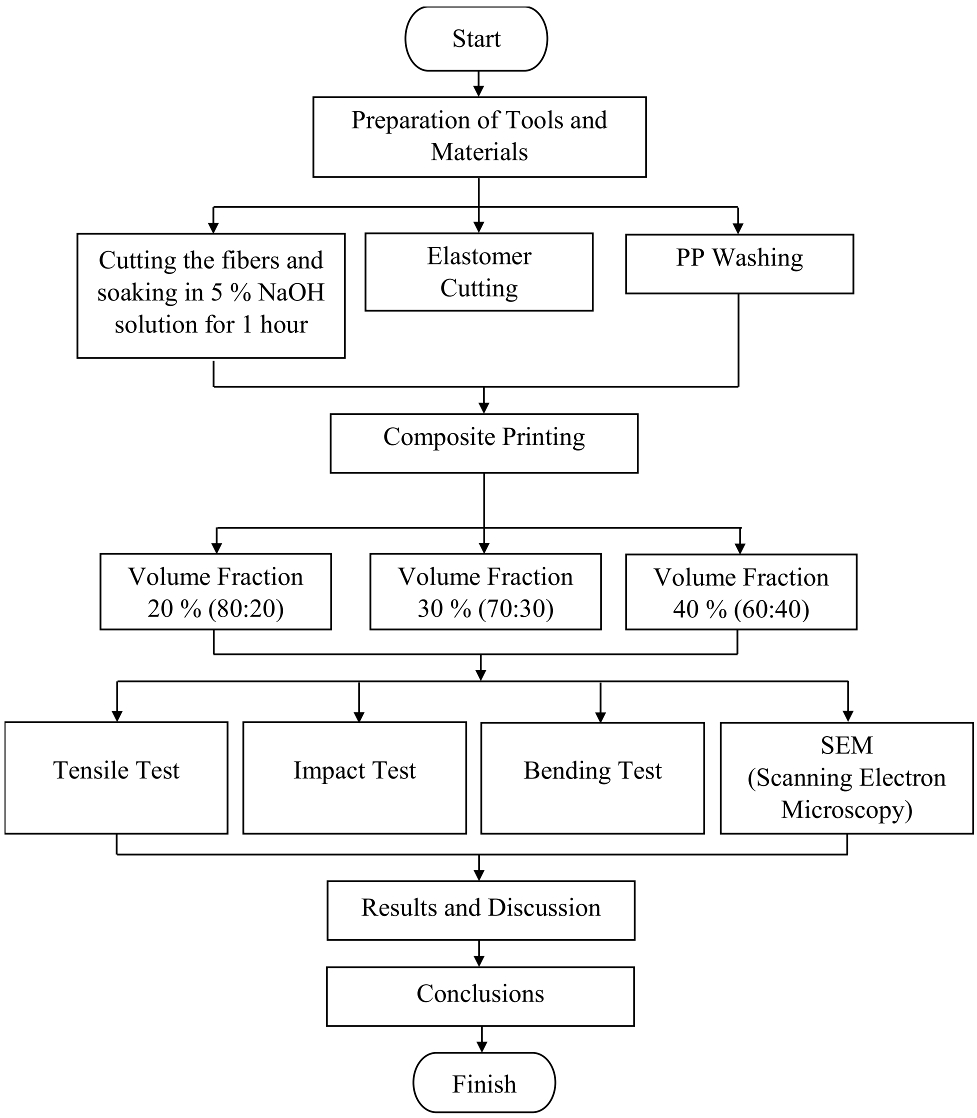


Fig. 4. Research flowchart

Fig. 6 is a hybrid polypropylene-elastomer composite mold with fiber reinforcement, which is finished and ready for various mechanical tests such as tensile tests, impact tests, bending tests, and SEM photos. This composite mold is molded through a hot press machine with high pressure and temperature in order to produce a good composite mold that is ready to be tested. At the testing stage, this mold will be divided by cut to facilitate the testing process.

5. Results of research on the analysis of mechanical strength of weight fraction variation sugar palm fiber as polypropylene-elastomer matrix reinforcement of hybrid composite

5. 1. Tensile strength

The tensile strength of each composite weight fraction (20 %, 30 %, 40 %) can be described in Table 1.

Fig. 7 is a graph of the tensile strength of the composite weight fraction (20 %, 30 %, 40 %).

The tensile strain of each composite weight fraction (20 %, 30 %, 40 %) can be described in Table 2.

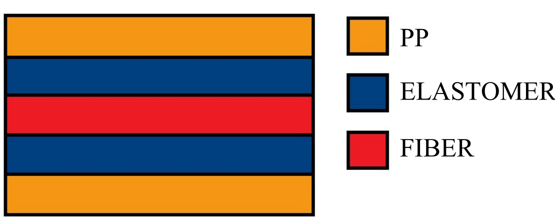


Fig. 5. Composite layout of sugar palm fiber-reinforced polypropylene-elastomer

Fig. 6. Composite molding of sugar palm fiber-reinforced polypropylene-elastomer

Table 1

Tensile Stress

Weight Fraction	Stress (MPa)	Average (MPa)
60–40	3.089	2.613
	2.34	
	2.411	
70–30	2.691	2.46
	2.55	
	2.14	
80–20	1.203	1.153
	1.246	
	1.01	

Fig. 8 is a graph of the tensile strain results of each composite weight fraction (20 %, 30 %, 40 %).

The tensile elastic modulus of each composite weight fraction (20 %, 30 %, 40 %) can be described in Table 3.

Fig. 9 is a graph of the tensile elasticity modulus of each composite weight fraction (20 %, 30 %, 40 %).

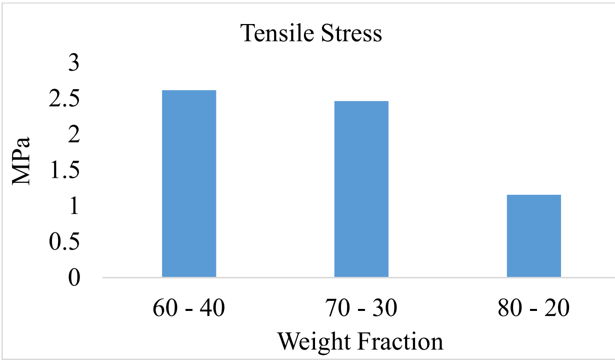


Fig. 7. Tensile Stress

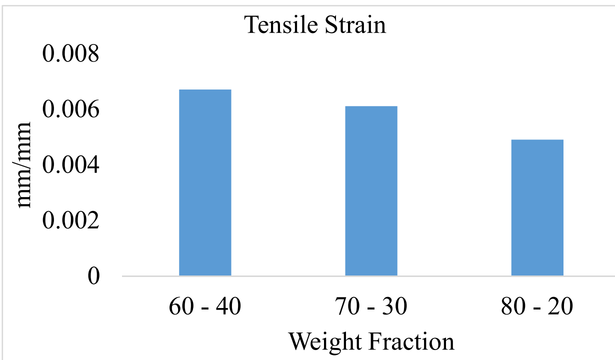


Fig. 8. Tensile strain

Table 2

Tensile Strain

Weight Fraction	Strain	Average
60–40	0.0066	0.0067
	0.0065	
	0.0071	
70–30	0.0056	0.0061
	0.0057	
	0.007	
80–20	0.0043	0.0049
	0.0063	
	0.0042	

Table 3

Modulus of elasticity

Weight Fraction	Modulus of Elasticity (MPa)	Average
60–40	465.71	387.6833333
	359.01	
	338.33	
70–30	474.49	398.7266667
	440.36	
	281.33	
80–20	276.85	236.9266667
	194.9	
	239.03	

Fig. 7 shows that the tensile strength of the composite with a weight fraction of 20 % (80:20) is the lowest point with a value of 1.153 MPa, then followed by a 30 % weight fraction (70:30) of 2.46 MPa, and the highest tensile strength value is found in the composite with a fraction of 40 % (60:40) with a value of 2.613 MPa. The addition of the fiber weight fraction in the composite material can increase the tensile strength value. This is because the fiber is the main load reinforcement or support for a composite material so that the greater the fiber weight fraction, the greater the tensile strength that the composite can withstand. Fig. 8 shows the tensile strain value for each composite, which is similar to the tensile strength, namely the greater the percentage of fiber weight fraction, the higher the strain value. Composites with a weight fraction of 20 % (80:20) got the lowest strain value of 0.0049, while composites with a weight fraction of 30 % (70:30) got a value of 0.0061, and the highest strain value of 0.0067 was found in composites with a weight fraction of 40 % (60:40). Fig. 9 shows the results of the modulus of elasticity for each composite. Composites with a weight fraction of 20 % (80:20) got the lowest modulus value of 236.926 MPa, then a composite with a weight fraction of 30 % (70:30) got a value of 398.726 MPa, and the highest value of modulus of elasticity of 387.683 MPa was found in composites with a weight fraction of 40 % (60:40).

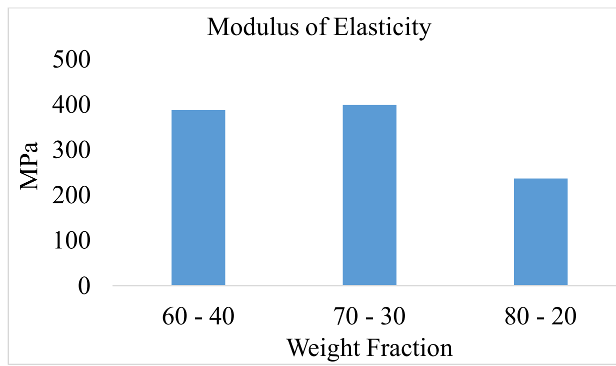


Fig. 9. Modulus of elasticity

5. 2. Impact strength

The impact strength of each composite weight fraction (20 %, 30 %, 40 %) can be described in Table 4.

Table 4

Impact strength

Weight Fraction	Energy Pendulum (kg)	Sleeve Length (mm)	Area (mm^2)	Impact Strength (kJ/mm^2)	Average (kJ/mm^2)
60–40	12	230	94.5	64113.778	45248.234
	12	230	97.02	34290.909	
	12	230	97.79	37340.014	
70–30	12	230	98.56	176185.23	168600.96
	12	230	94.72	168764.44	
	12	230	96.52	160853.21	
80–20	12	230	90.88	91370.335	176495.97
	12	230	82.55	215925.28	
	12	230	86.43	222192.29	

Fig. 10 is a graph of the impact strength of each composite weight fraction (20 %, 30 %, 40 %).

Fig. 10 shows the impact strength results for each composite weight fraction. Composites with a weight fraction of 20 % (80:20) have the highest impact strength value of 176495.97 kJ/mm^2, while composites with a weight fraction of 30 % (70:30) have a value of 168600.96 kJ/mm^2, and the lowest impact strength value is found in composites with a weight fraction of 40 % (60:40), which is 45248.234 kJ/mm^2. The large number of fiber weight fractions in the composite material can reduce the impact strength value.

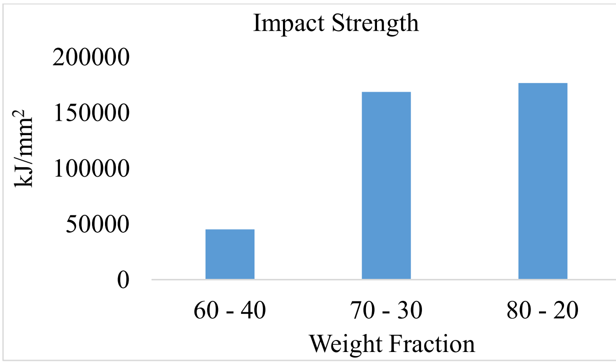


Fig. 10. Impact strength

5. 3. Bending strength

The bending strength of each composite weight fraction (20 %, 30 %, 40 %) can be described in Table 5.

Table 5

Bending stress

Weight Fraction	Stress (N/mm^2)	Average (N/mm^2)
60–40	3.496414881	3.358956025
	3.042755599	
	3.537697594	
70–30	7.971980728	4.886720804
	3.531695469	
	3.156486215	
80–20	2.571218674	1.777857348
	1.345606451	
	1.41674692	

Fig. 11 is a graph of the bending strength of each composite weight fraction (20 %, 30 %, 40 %).

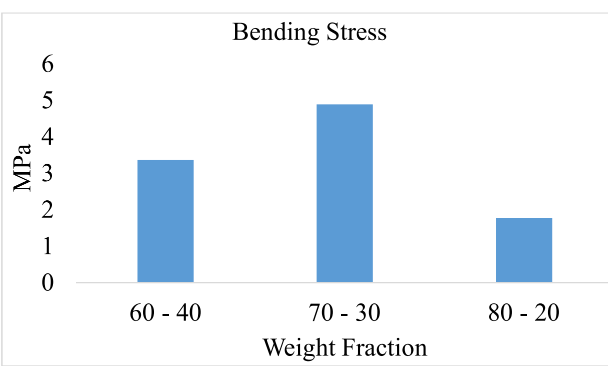


Fig. 11. Bending stress

The bending strain results of each composite weight fraction (20 %, 30 %, 40 %) can be described in Table 6.

Fig. 12 is a graph of the bending strain of each composite weight fraction (20 %, 30 %, 40 %).

The bending elastic modulus of each composite weight fraction (20 %, 30 %, 40 %) can be described in Table 7.

Fig. 13 is a graph of the bending modulus of elasticity of each composite weight fraction (20 %, 30 %, 40 %).

Table 6

Bending strain

Weight Fraction	Strain	Average
60–40	0.003950415	0.005714445
	0.008869994	
	0.004322927	
70–30	0.026523597	0.013243149
	0.001588072	
	0.011617777	
80–20	0.018741869	0.020735332
	0.022146429	
	0.021317698	

Table 7

Modulus of elasticity

Weight Fraction	Modulus of Elasticity (MPa)	Average
60–40	429.4268976	379.5691338
	218.1926299	
	491.087874	
70–30	120.4530394	105.6547612
	56.88440945	
	139.6268346	
80–20	78.18683465	48.08768504
	19.31086614	
	46.76535433	

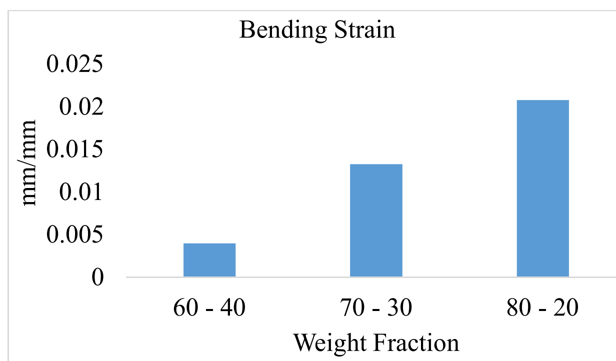


Fig. 12. Bending strain

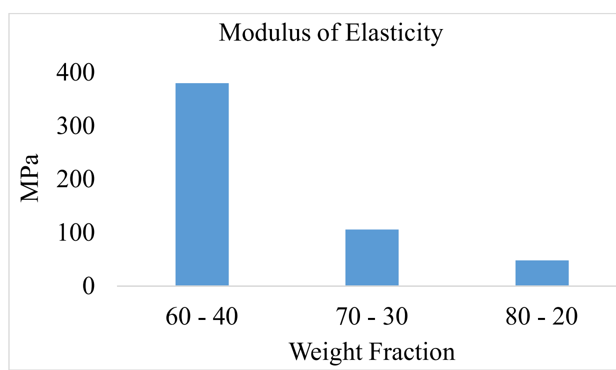
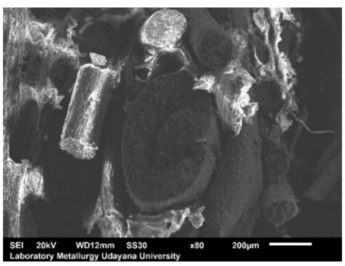


Fig. 13. Modulus of elasticity

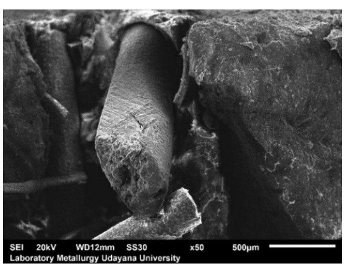
Fig. 11 is the result of the average bending stress calculation for each composite weight fraction. Where the composite with a weight fraction of 40 % (60:40) obtained an average of 3.3589 MPa, while the composite with a weight fraction of 30 % (70:30) obtained the highest bending stress value of 4.8867 MPa, and composites with a weight fraction of 20 % (80:20) obtained the lowest bending stress of 1.7778 MPa. Fig. 12 is the average bending strain calculation result for each composite weight fraction. Where the composite with a weight fraction of 40 % (60:40) obtained the lowest bending strain value of 0.0057, while the composite with a weight fraction of 30 % (70:30) gets a value of 0.0132, and composites with a weight fraction of 20 % (80:20) obtained the highest bending strain value that is equal to 0.0207. Fig. 13 shows the results of the calculation of the bending elasticity modulus for each composite weight fraction. Where the composite with a weight fraction of 40 % (60:40) got the highest modulus value of 379.569 MPa, while the composite with a weight fraction of 30 % (70:30) obtained 105.547 MPa, and composites with a weight fraction of 20 % (80:20) obtained the lowest elastic modulus of 48.087 MPa.

5. 4. Scanning Electron Microscopy (SEM) photos

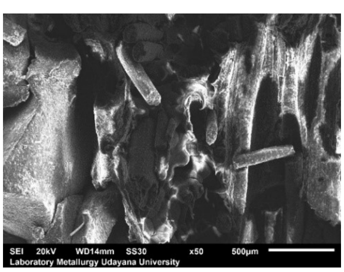
SEM photos after the tensile test on the composites of each weight fraction (20 %, 30 %, 40 %) can be seen in Fig. 14.



a



b

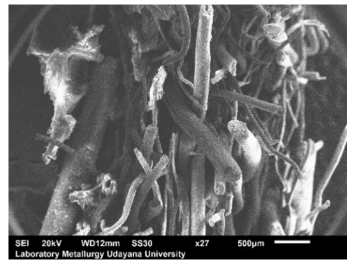


c

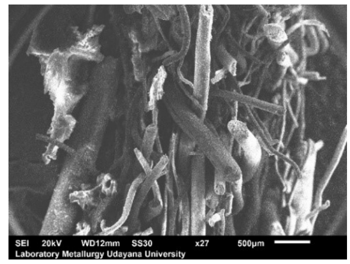
Fig. 14. SEM photos of composites with weight fraction after the tensile test: *a* – 40 % (60:40); *b* – 30 % (70:30); *c* – 20 % (80:20)

SEM photos after the impact test on the composites of each weight fraction (20 %, 30 %, 40 %) can be seen in Fig. 15.

SEM photos after the bending test on the composites of each weight fraction (20 %, 30 %, 40 %) can be seen in Fig. 16.



a



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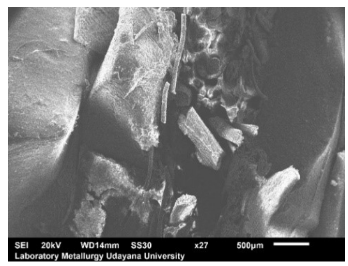
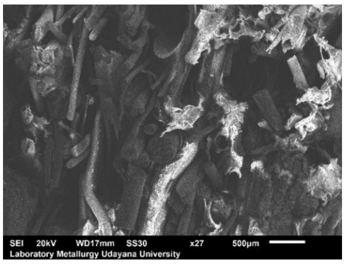


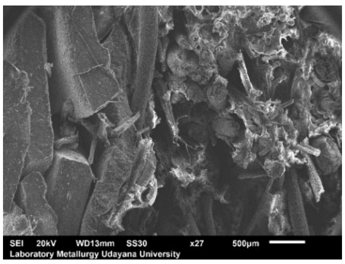
c

Fig. 15. SEM photos of composites with weight fraction after the impact test: *a* – 40 % (60:40); *b* – 30 % (70:30); *c* – 20 % (80:20)

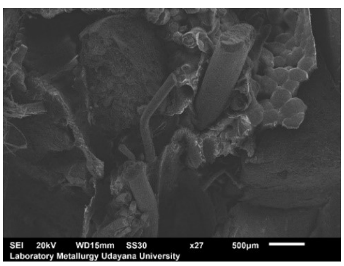
Fig. 14 shows the SEM observation test on composites with a weight fraction of 40 % (60:20) and 20 % (80:20). It can be seen that there is an average fracture between the fiber and the matrix and there is no pull out. This is because the fiber and the matrix have a good interfacial bond, so that when a tensile load is applied, the fiber and the matrix break at the same time [27]. While in composites with a weight fraction of 30 % (70:30) in SEM photo observations, it is clearly seen that pull outs occur. This is due to imperfect compatibility between the fiber and the matrix, so that when receiving a tensile load, the fiber and the matrix are separated from their bonds [28]. Fig. 15 shows the results of SEM composite observations with a weight fraction of 40 % (40:60) at 27 times magnification. It can be seen clearly that there is a pull out. This is due to imperfect compatibility between the fiber and the matrix. While the results of SEM observations on composites with a weight fraction of 30 % (70:30), and 20 % (80:20) with 27 times magnification show that there is an average fracture between the fiber and the matrix and no pull out occurs. This is because the fiber and the matrix have a good interfacial bond, so that when subjected to an impact load, the fiber and the matrix break at the same time. Fig. 16 shows the results of the composite SEM observation test with a weight fraction of 40 % (60:40) and 30 % (70:30) at 27 times magnification. The bond between the fiber and the matrix occurs well, so that when subjected to bending loads, the fiber and the matrix fracture at the same time as indicated by a clean fracture on the SEM photo. The composite with a weight fraction of 20 % (80:20) explains that pull out occurs in the interfacial bond between the fiber and the matrix is not perfect, so that when exposed to bending loads, the fiber and the matrix are separated from the bond.



a



b



c

Fig. 16. SEM photos of composites with weight fraction after the bending test: *a* – 40 % (60:40); *b* – 30 % (70:30); *c* – 20 % (80:20)

6. Discussion of the results of analysis of mechanical strength of weight fraction variation sugar palm fiber as polypropylene-elastomer matrix reinforcement of hybrid composite

This study describes the test results obtained from each research objective. The highest results of the tensile strength test were obtained for the composite with a weight fraction of 40 % (60:40), which was 2.613 MPa, while the lowest tensile strength was obtained for the composite with a weight fraction of 20 % (80:20), which was 2.46 MPa as seen in Fig. 7. The addition of the fiber weight fraction in the composite can increase the tensile strength. This is because the fiber is the main load reinforcement or support for the composite material. Therefore, the higher the fiber weight fraction, the higher the tensile strength. The highest impact test results of 176495.97 kJ/mm^2 were obtained in the composite with a weight fraction of 20 % (80:20), while the composite with a weight fraction of 40 % (60:40) had the lowest impact strength of 45248.234 kJ/mm^2 as can be seen in Fig. 10. The higher the fiber weight fraction, the lower the impact strength. So the addition of the weight fraction is very important, as it causes lower impact strength in the manufacture of composite materials. For bending testing, the composite with a weight fraction of 30 % (70:30) obtained the highest bending strength of 4.8867 MPa, while the lowest bending strength was obtained in the composite with a weight fraction of 20 % (80:20), which was 1.7778 MPa as seen in Fig. 11. For SEM photo observations of the composite weight fraction of 40 % (60:20) and 20 % (80:20), it can be seen that there is an average fracture between the fiber and the matrix and there is no pull out. This is because the fiber and the matrix have a good interfacial bond, so that when a tensile load is applied, the fiber and the matrix break at the same time as seen in Fig. 14. As for the 30 % weight fraction composite (70:30) in SEM photo observations, it is clearly seen that pull outs occur. This is due to imperfect compatibility between the fiber and the matrix so that when receiving a tensile load, the fiber and the matrix are separated from their bonds as can be seen in Fig. 14. In Fig. 15, the results of SEM photo observations for composites with a weight fraction of 40 % (60:40) clearly show that there is a pull out. This is due to imperfect compatibility between the fiber and the matrix, and the results of SEM observations for composites with a weight fraction of 30 % (70:30), and 20 % (80:20) show that there is an average fracture between the fiber and the matrix and no pull out occurs. This is because the fiber and the matrix have a good interfacial bond, so that when subjected to an impact load, the fiber and the matrix break at the same time. Fig. 16 shows the results of the composite SEM observation test with a weight fraction of 40 % (60:40) and 30 % (70:30). The bond between the fiber and the matrix occurs well, so that when subjected to bending loads, the fiber and the matrix fracture at the same time as indicated by a clean fracture on the SEM photo.

The solution that can be proposed in the research for the future is to increase the use of natural fibers as reinforcement in the manufacture of composites. Besides natural fiber, there is no need to worry about availability issues. One of the natural fibers offered is palm fiber. Sugar palm fiber is a natural fiber that is very suitable to be used as a reinforcement in the manufacture of composites because it has good properties in mechanical tests such as tensile tests, bending tests, and impact tests. Sugar palm fiber as a reinforcement in the manufacture of composite materials has many advantages. In terms of material availability, sugar palm fiber is very abundant, especially in Indonesia, which causes sugar palm fiber to become a cheap and easy to obtain raw material. The recommended matrix is polypropylene (PP) plastic because besides being able to be used as a matrix in the manufacture of composites, the use of PP also helps reduce the problem of plastic wastes that can pollute the environment.

The advantages obtained in this study are the use of natural fibers, especially palm fiber compared to the use of other materials because the fibers have good tensile and bending strength as a composite material. The availability of raw materials, namely palm fiber, is very abundant, especially in Indonesia, so there is no need to worry about production problems.

The limitation of this study is the temperature on the hot press machine to print composite materials that must reach 200 °C. If the temperature is below 200 °C, the PP matrix will not be able to blend well with other matrices.

The disadvantages in this study are found in the use of elastomeric materials as a matrix, where elastomeric materials have relatively expensive prices, so the research costs required are also high. So, in the manufacture of composite materials, it is advisable to use other materials that are easily available and inexpensive as a matrix so that this can save costs in the research process.

7. Conclusions

1. The highest tensile strength was obtained for the composite with a weight fraction of 40 % (60:40), while the composite with a weight fraction of 20 % (80:20) had the lowest tensile strength.

2. The highest impact strength was found in composites with a weight fraction of 20 % (80:20), and the lowest impact strength was found in composites with a weight fraction of 40 % (40:60).

3. The highest bending strength was found in the composite with a weight fraction of 30 % (70:30), while the composite with a weight fraction of 20 % (80:20) obtained the lowest bending strength.

4. SEM photos after the tensile test of the composite with a weight fraction of 40 % (60:40) resulted in a photo that did not occur in the fiber and matrix pull out. While the SEM after the impact test of the composite with a weight fraction of 30 % (70:30) resulted in a photo that did not occur in the fiber pull out. For the SEM photo, the bending test of the composite with a weight fraction of 40 % (40:60) got a photo of the average fracture between the fiber and the matrix without any pull outs.

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