



THE EFFECT OF COCONUT COIR FIBER POWDER CONTENT AND HARDENER WEIGHT FRACTIONS ON MECHANICAL PROPERTIES OF AN EPR-174 EPOXY RESIN COMPOSITE

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Abstract

The development of composite materials is increasingly widespread, which require superior mechanical properties. From many studies, it is found that the mechanical properties of composite materials are influenced by various factors, including the reinforcement content, both in the form of fibers and particle powder. However, those studies have not investigated the effect of the hardener weight fraction on the mechanical properties of resin composite materials. Even though its function as a hardener is likely to affect its mechanical properties, it might obtain the optimum composition of the reinforcing content and hardener fraction to get the specific mechanical properties. This study examines the effect of hardener weight fraction combined with fiber powder content on mechanical properties of EPR-174 epoxy resin matrix composite and determines the optimum of Them. The research was conducted by testing a sample of composite matrix resin material reinforced with coconut fiber powder. The Powder content was made in 3 levels, i.e.: 6%, 8%, and 10%. While the hardener fraction of resin was made in 3 levels, i.e.: 0.4, 0.5, and 0.6. The test results showed that pure resin had the lowest impact strength of 1.37 kJ/m². The specimen with a fiber powder content of 6% has the highest impact strength i.e.: 4.92 kJ/m². The hardener fraction of 0.5 has the highest impact strength i.e.: 4.55 kJ/m². The fiber powder content of 8% produced the highest shear strength i.e.: 1.00 MPa. Meanwhile, the hardener fraction of 0.6 has the highest shear strength i.e.: 2.03 MPa.

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INTRODUCTION

Research related to the mechanical properties of composite materials continues to be carried out, considering the increasing use of composite materials. The use of composite materials includes all equipment, such as electronic devices, sports equipment, public building tools, air, sea, and land transportation equipment, and other engineering tools [1]. Even, human tissue replacement applications and others such as bone implants, etc. [2]. The developing composite materials are metal matrix, cement, and polymer.

However, polymer matrix occupies the top place most researched and developed [3, 4, 5, 6, 7]. Composite materials widely developed today are composite materials with a polymer matrix, such as polyethylene, polypropylene, resin, etc. Along with these developments, research on improving the mechanical properties of composite materials remains a very interesting and seemingly endless research topic by world researchers [3, 4, 8]. Although not all studies are always successful, slowly but surely, there is an increase in the investigation result.

Composite materials have recently been used as a substitute for metal materials. Therefore, an increase in the mechanical properties of composite materials is very much needed, considering that their use extends to structural materials that retain loads. Researchers worldwide have been researched related to the mechanical properties of composite materials [8, 9, 10, 11]. For example, some research on mechanical properties of natural fiber-reinforced composites for engineering applications [10][12], research related to using natural fibers as reinforcement for composite materials, including cement casting [13]. The others researchers also study in terms of Structures and performances of composites [14, 15, 16].

Researchers in the world have investigated many factors that affect the mechanical properties of composite materials. Among them, research on epoxy matrix composite materials reinforced with vetiver fiber. It is known from that study that the fiber volume fraction above 20% will reduce the bending strength and impact strength [17]. Other investigators conducted coco fiber and examined the effect of weight percentage on coconut coir polyester fiber composites [18]. It was found that the percentage of 15% fiber weight has the highest average tensile strength of 24.478 MPa compared to 5% and 10% fiber fractions [18].

The study of the impact strength of composite materials has also been carried out using a polypropylene matrix and palm fiber reinforcement [3]. It was found that the highest impact strength was obtained in specimens with 10% fiber content compared to 5% and 7%. Furthermore, in terms of fiber length, it was found that the highest impact strength was obtained in specimens with a fiber length of 10 mm compared to the fiber length of 5mm and 7mm [3].

The above studies have not examined the effect of hardener fraction on resin composite materials' mechanical and physical properties. While the function of hardener in the manufacture of composite materials is to harden the resin, so there is a possibility that the hardener fraction affects the mechanical properties of the composite material. Therefore, this study examines the effect of fiber content and hardener fraction on the mechanical properties of EPR-174 epoxy resin composites.

The development of the use of composite materials has recently increased rapidly. Especially the polymer matrix is a very dramatic development. This is because the polymer has its advantages, although there are

disadvantages. Today's use of composite materials is for material that does not withstand the load and structural materials that withstand various types of loading on automotive components, ship components, or even aircraft components [1].

A composite material that world researchers are heavily investigating is a natural fiber composite material. The second phase of this composite material that functions as a reinforcement is derived from natural materials usually not utilized or underused or even rubbish. Among them are palm fiber, coconut fiber, water hyacinth fiber, oil palm fiber, etc. Utilizing these natural fibers as reinforcement in composite materials increases community income and reduces organic waste to cleaner the environment.

Coconut coir is one type of natural fiber that is underutilized, so it tends to become trash. In contrast, abundant availability due to coconuts for various community needs every day and continuously, especially for cooking needs. In rural areas, coconut coir waste may not be a problem because some rural communities use it for various purposes such as making brooms, cooking instead of firewood, etc. But in urban communities, coconut fiber is almost useless, so coconut fiber is one of the sources of waste problems in big cities. Because of this, efforts to expand the use of coconut fiber as reinforcement on composite materials are very urgent to be developed to assist the government in reducing the volume of waste, especially in urban areas.

Impact testing, as well as fatigue testing, is included in the classification of dynamic load testing. Many studies have been carried out on composite materials related to the impact strength of the material. One of them is the research on the impact strength of polypropylene composite materials reinforced with oil palm fiber [3].

Other researchers investigate the Influence of fiber content on Kenaf fiber kenaf fiber's mechanical and thermal properties [19] and natural synthetic fiber [20]. Those researchers found that the mechanical properties of composite materials were affected by the fiber content. If the fiber content is too low, the composite material will not improve the material's mechanical properties. The fiber length in the composite material also affects the mechanical properties of the resulting composite material. If the fiber length is too short, the fiber does not function as reinforcement but only as a filler [21].

There were some researches regarding coconut fiber composite [22]. Processing of coir fibers and application in hybrid-fiber composites have been investigated [23]. It Was obtained from the research that Mix P05 (5% cement replaced by coir pit ash) showed better strength than Mix CM (ordinary mix without cement replacement), at all curing periods The compressive strength of CM and P05 at 90 days was 34.31 MPa and 36.95 MPa respectively. The split tensile strength of CM and P05 at 90 days was 2.74 MPa and 2.97 MPa respectively, and flexural strength of CM and P05 at 28 days was 7.47 MPa and 7.6 MPa respectively [23].

The research regarding the influence of coconut coir fiber length and content on the impact strength of resin matrix composite has been investigated [24], The research obtained that the highest impact strength 2.78kJ/m² of

composite specimens from 1.8% fiber content with 8mm fiber length, whereas the lowest impact strength of 0.75kJ/m² resulted from 1.8% fiber content with 10mm fiber length.

In addition, research has also been carried out regarding properties of tensile strength and flexural strength of coconut fiber reinforced PVC matrix composite [25][26] and Coir Pith Ash as Supplementary Cementitious Material in Concrete has been investigated [22]. However, those studies have not generated a regression model of the composite material's mechanical properties, which can be used to predict the mechanical properties of coconut coir fiber-reinforced composite base on some factors. The summary of Previous research and knowledge gap regarding coconut fiber composite is shown in Table 1.

Table 1. Previous research and knowledge gap regarding coconut fiber composite

No.	Reff	RM		Treatment		Factor			Matrix		Process		Testing					Result			
		Fiber	Fiber Powder	Un- treated	Alkali	Vol %	Wgt. %	B. Time	E- poxy	PVAc	PLA	Manual	Inject.	1	2	3	4	5	6	7	
1	[22]	o		o		o					o	o	o						o		
2	[23]			o				o											o		
3	[24]	o		o			o				o		o			o			o		
4	[25]	o		o		o				o				o	o						
This research		o		o	o	o		o		o		o		o	o				o	o	o

Remarks:

- 1. Charpy Impact
- 2. tensile / Compressive
- 3. Flexural test
- 4. SEM / OM
- 5. Twisting/Shear
- 6. Conclusion only (without any model)
- 7. Regression Model of shear strength

It is known from Table 1 that the factors of previous research have not to include % weight of fiber. Whereas % weight is the easiest and the most accurate factor to be measured. In addition, previous research has not tested the shear strength through torsional testing, and the test results have not been expressed in the form of a regression model. This is the gap in research related to coconut fiber-reinforced composites. Therefore, this gap was the focus of this research.

METHOD

The flow chart shows the flow of the research in Figure 1. The study begins with the tools and material preparation for manufacturing the specimen samples. Then proceed with impact testing, twist testing. The impact test results are used to calculate the impact strength of the specimens for the analysis. Next, twisted testing to obtain shear stress the specimen. Then the regression model is then made of impact strength and shear stress based on fiber powder content and hardener fraction.

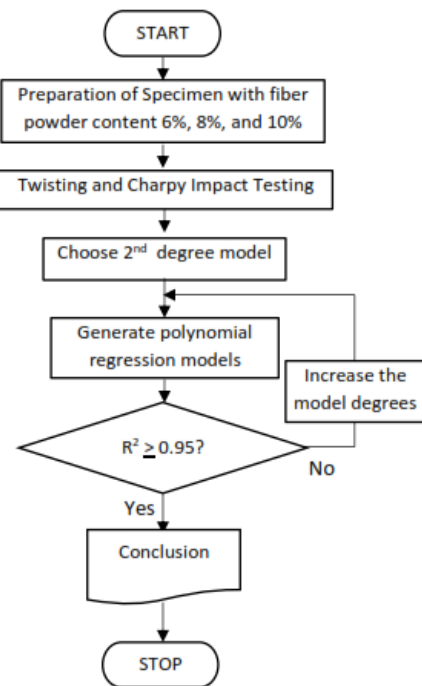


Figure 1. Research Flowchart

The regression equation's validation processes were checked by the value of determination coefficient (R^2), which in ordinary the range between 0 and 1. The determination coefficient (R^2) of the regression model should be higher than 0.95. The best validity should have $R^2 = 1$.

Specimens Preparation

The Coconut coir was washed clean with water, then dried until completely dry. Then the clean coconut husk is cut into short fiber and is blended to become powder. Figure 2 shows the process of making coconut coir powder. Starting from the cutting process, the blending, and the sieving process until it becomes a fine powder.

The coir fiber was cut short around 10 mm until 15 mm to make the blending process easier, put in a blender machine, and processed until the fibers turned into powder. After that, the coconut coir powder was filtered using a 0.5mm sieve. The filtered powder was then weighed to prepare specimens according to the predetermined content, i.e., 6%, 8%, and 10%.

The specimen was prepared to follow the specimen size according to ISO 179-1: 2000 standard Type 1 number 1, notch (notch) B [27] as shown in Figure 3.

There are two factors studied, i.e., the content of Fiber powder and the hardener fraction, which consists of 3 levels as follows:

1. Fiber powder content, i.e.: 6%, 8% and 10%.
2. The hardener fraction, i.e.: 0.4, 0.5, and 0.6.

The results of specimen manufacturing are shown in Figure 4.

Figure 4 shows the Charpy impact test specimen (a) and twisting test specimen (b). The study was designed based on complete factorial design (Full factorial design), so the number of combinations of sample types must be prepared: $3 \times 3 = 9$ type combinations. Each type is made of 5 samples so that the total number of samples was 45 samples.

Mechanical Properties Testing

In mechanical testing properties, the type of load on a structural material can be static, dynamic (fluctuating), or shock loads. The results of these tests are to ensure the ability of the material to withstand these loads. The material's ability to static load is usually done by testing the tensile strength of the material. The tensile test results in the tensile strength of the specimen. But many composite materials retain the shear load.

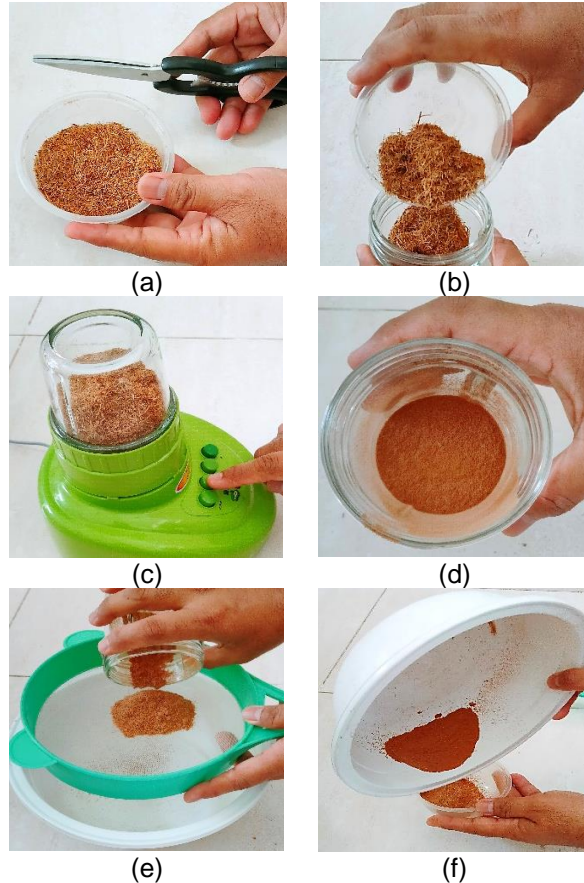


Figure 2. a) The coir fibers that have been cut (b) The coir fibers are then put into the blender machine, (c) the fibers in the blender, (d) the fibers turn into powder, (e). The coconut husk powder was filtered using a 0.5mm sieve, (f) The filtered powder is ready to be used.

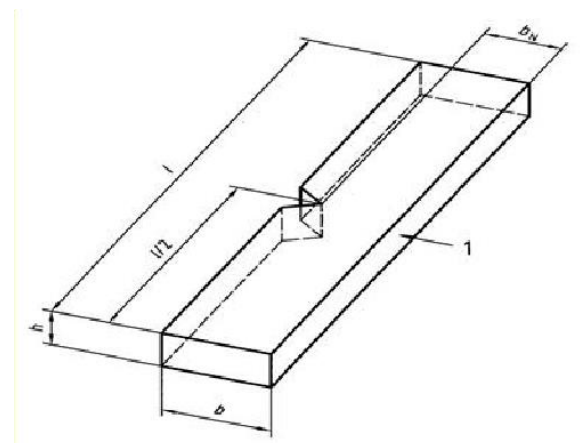


Figure 3. Charpy impact specimen dimensions based on ISO 179 standard, type no.1 type notch B [27]



Figure 4. (a) Impact test specimens, (b) Twisting test specimens

Usually, the shear strength of specimens is lower than their tensile strength. This research will focus on shear stress and impact properties of the specimens by conducting. Twisting test and Charpy impact test in the Mechanical Engineering Laboratory of Mercu Buana University.

Analyze Test Results

The impact test results are in the form of impact energy from each specimen. This data is then used to calculate the impact strength of each specimen and the average impact strength for each condition. Then the test results were displayed in graphical form and then analyzed to obtain the regression model for the relationship between the content (% weight) of Fiber powder and the hardener fraction to the impact strength of the specimen. At the same time, the twisting test results are displayed in graphical form and then analyzed to obtain the regression model for the relationship between the content (% weight) of fiber powder and a fraction of hardener to the shear stress of the specimens.

Regression Model

The regression model is a model in mathematical equations obtained from the processing of research data. This model consists of independent variables and dependent variables. This model can be simulated then how many values of the independent variables are to get the value of certain dependent variables. For example, if the independent

variable is the hardener weight fraction and the fiber powder content. Then, using a regression model can simulate how much fiber powder content and fiber hardener weight fraction must be made to obtain certain mechanical properties of the composite material.

RESULT AND DISCUSSION

Impact Testing and Twist Testing

The impact test specimens will use the impact test equipment of plastic material in the Mechanical Engineering Laboratory of Mercu Buana University. Likewise, the Twist testing was carried out using the Torsional testing machine in the Mechanical Engineering Laboratory of Mercu Buana University.

The impact test results and the calculated impact strength are shown in Table 2. From the testing result on Table 2 can be made resume as shown in Table 4 and Table 5. The pure resin has the lowest impact strength of 1.37 kJ/m². The content of coir powder which produced the highest impact strength was 6%, which was 4.92 kJ/m².

Meanwhile, the hardener fraction with the highest impact strength is 0.5 (50% resin and 50% hardener), which was 4.55 kJ/m². From these data, it can be concluded that the presence of coconut coir fiber in the EPR-174 epoxy resin composite material increases its impact strength.

However, the optimum content also has a limit of 6%. Meanwhile, from this study, it is also proven that the Hardener fraction also affects the impact strength. The best hardener fraction is 0.5, which is 50% hardener and 50% resin. Furthermore, the test results are displayed in graphical form and then analyzed using Microsoft Excel to obtain a regression equation for the relationship between hardener fraction and the content of the fiber powder to the impact strength of the specimen.

Table 2. Impact test data sample

No.	Sample code	Fiber powder (%)	Fraction of hardener resin	Impact Energy (J)	Impact Strength (kJ/m ²)
1	0604		4 : 6	0.126	3.20
2	0605	6	5 : 5	0.266	6.67
3	0606		6 : 4	0.192	4.88
4	0804		4 : 6	0.122	3.00
5	0805	8	5 : 5	0.166	4.06
6	0806		6 : 4	0.146	3.42
7	1004		4 : 6	0.116	2.94
8	1005	10	5 : 5	0.120	2.93
9	1006		6 : 4	0.150	3.70
10	Pure resin	-		0.064	1.37

Table 3. Recapitulation of Twisting test result

No.	Code	Fiber Powder (%)	Fraction of hardener resin	Shear Strength
1	0604		4 : 6	0.27
2	0605	6	5 : 5	0.45
3	0606		6 : 4	1.87
4	0804		4 : 6	0.16
5	0805	8	5 : 5	0.20
6	0806		6 : 4	2.65
7	1004		4 : 6	0.29
8	1005	10	5 : 5	0.29
9	1006		6 : 4	1.57

Table 4. Impact test resume base on fiber Table powder content

Fiber powder content (%)	Impact Strength (kJ/m ²)
0	1.37
6	4.92
8	3.49
10	3.19

Table 5. Impact test resume base on a fraction of hardener

Fraction of hardener	Impact Strength (kJ/m ²)
0.4	3.05
0.5	4.55
0.6	4.00

Table 4 and Table 5 are used to generate the regression models of impact strength and Shear strength of composite coconut coir powder reinforced composite. The result is shown in Figure 5 and Figure 6.

The regression model of the impact strength of coconut fiber-reinforced composites based on the fiber powder content is shown in Figure 5 as follows:

$$Y_1 = 0.0303x^3 - 0.5876x^2 + 3.0244x + 1.37 \quad (1)$$

where Y₁ is Impact strength (kJ/m²) and x is Fiber powder content (%)

The coefficient of determination (R²) of the regression equation is 1. It indicates that the percentage of powder content 100% affects the impact strength of the composite material. Or in other words, the variation in the percentage of powder content in the composite material in this research is 100% able to explain variations in impact strength. The Highest impact strength 4.92 kJ/m², is obtained by the samples with 6% fiber powder content.

It is known from the curve of Figure 5 that the presence of fiber increased the impact strength of the specimen. The content of coconut coir powder that gives the optimum impact strength was around 4%. Proven on the curve for the fiber content below or more than 4%, the decrease of impact strength occurred.

The regression model of the impact strength of coconut fiber-reinforced composites based on Fraction of hardener is shown in Figure 6 as follows:

$$Y_1 = -103.12x^2 + 107.89x - 23.611 \quad (2)$$

where Y₁ is Impact strength (kJ/m²) and x is the fraction of hardener

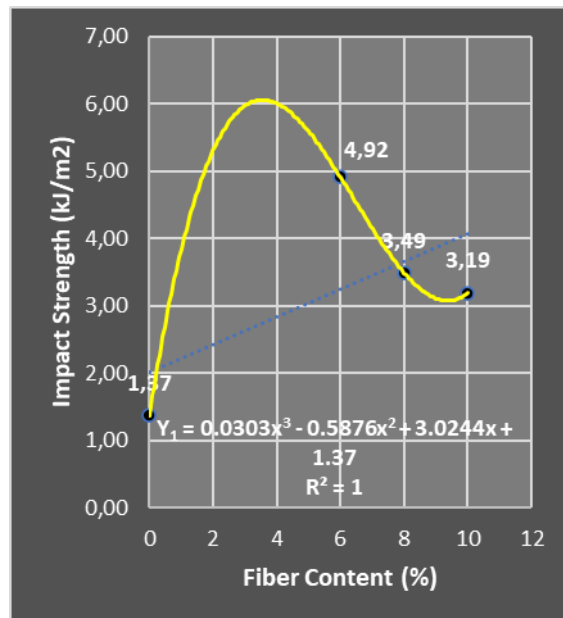


Figure 5. The regression model of the impact strength of coconut fiber reinforcing composites based on the fiber powder content

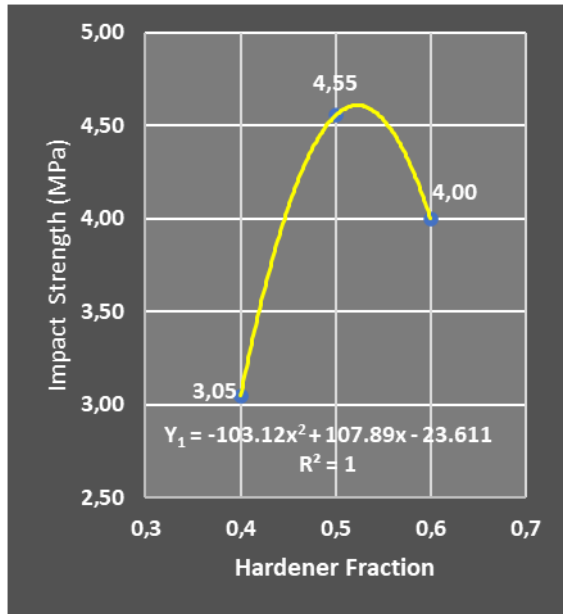


Figure 6. The regression model of the impact strength of coconut fiber reinforcing composites based on Fraction of hardener

The coefficient of determination (R^2) of the regression equation is 1. It indicates that the fraction of hardener 100% affects the impact strength of the composite material. Or in other words, the variation in the fraction of hardener in the composite material in this research is 100% able to explain variations in impact strength. The Highest impact strength 4.55 kJ/m², is obtained by the samples with 0.

Figure 6 shows that the fraction of Hardener 0.5 obtained the best impact strength of the specimen. Proven on the curve for the fiber fraction below or more than 8%, the decrease of impact strength occurred.

From the testing result in Table 3 can be made resume as shown in Table 6 and Table 7.

Table 6. Torsional test resume base on fiber powder content

Fiber powder content (%)	Shear Strength (MPa)
0	0.02
6	0.86
8	1.00
10	0.72

Table 7. Torsional test resume base on the fraction of hardener

Fraction of hardener	Shear Strength (MPa)
0.4	0.24
0.5	0.31
0.6	2.03

The pure resin has the lowest impact strength of 1.37 kJ/m². The content of coir powder which produced the highest Shear strength was 8%, which was 1.00 MPa. Meanwhile, the hardener fraction with the highest Shear strength is 0.6, which means 40% resin and 60% hardener. From this, it can be concluded that the presence of coconut coir powder in the EPR-174 epoxy resin composite material increases its Shear strength. However, the optimum content also has a limit of 8%. Meanwhile, from this study, it is also proven that the Hardener fraction also affects the impact strength. The best hardener fraction is 0.6, which is 60% hardener and 40% resin, i.e., 2.03 MPa.

Furthermore, the test results are displayed in graphical form and then analyzed using Microsoft Excel to obtain a regression equation for the relationship between hardener fraction and the percentage content of the second phase to the Shear strength of the specimen.

The data from Table 6 and Table 7 are used to generate the regression models of Shear strength of coconut coir powder reinforced composite. The result is shown in Figure 7 and Figure 8.

The regression model of the shear strength of coconut fiber-reinforced composites based on fiber powder content is shown in Figure 7, as follows:

$$Y_2 = -0.0044x^3 + 0.0534x^2 - 0.0198x + 0.02 \quad (3)$$

where Y_2 is Shear strength (MPa) and x is powder content (%).

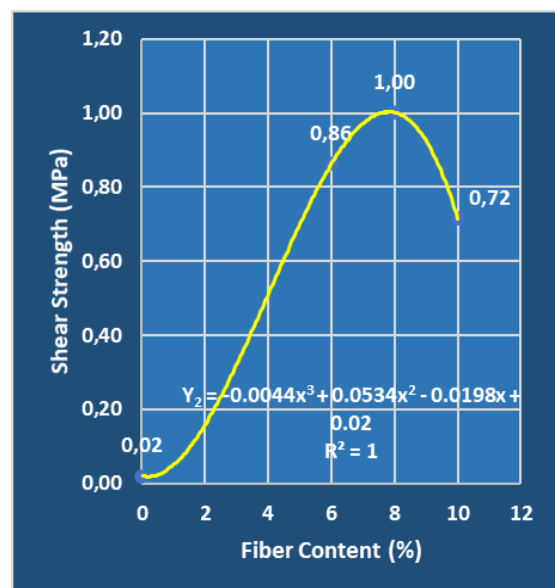


Figure 7. The regression model of the shear strength of coconut fiber reinforcing composites based on Fiber powder content

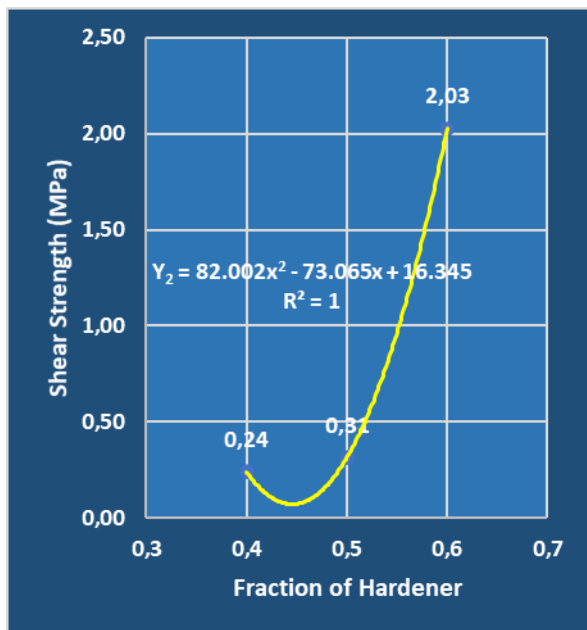


Figure 8. The regression model of the shear strength of coconut fiber reinforcing composites based on the fraction of hardener

The regression model of the shear strength of coconut fiber-reinforced composites based on fiber powder content is shown in Figure 7, as follows:

$$Y_2 = -0.0044x^3 + 0.0534x^2 - 0.0198x + 0.02 \quad (4)$$

where Y₂ is Shear strength (MPa) and x is powder content (%).

The coefficient of determination (R²) of the regression equation is 1. It indicates that the percentage of powder content, 100%, affects the composite material's shear strength. Or in other words, the variation in the percentage of powder content in the composite material in this research is 100% able to explain variations in Shear strength. The high shear strength of 1,00 MPa, is obtained from the samples with 8% powder content.

Figure 7 shows that the presence of fiber increases the shear strength of the specimen, but there is a limit to it. The content of coconut husk powder that gives the optimum shear strength was around 8%. Proven on the curve for the fiber content below or more than 8%, the decrease of shear strength occurred.

The regression model of the shear strength of coconut fiber-reinforced composites based on the fraction of hardener is shown in Figure 8 as follows:

$$Y_2 = 82.002x^2 - 73.065x + 16.345 \quad (5)$$

where Y₂ is Shear strength (kJ/m²) and x is the fraction of hardener.

The coefficient of determination (R²) of the regression equation is 1. It indicates that the fraction of hardener, 100% affects the shear strength of the composite material. Or in other words, the variation of the fraction of hardener in the composite material in this research is 100% able to explain variations in shear strength. For example, the highest shear strength of 2.03 MPa, was obtained by the samples with 0.6 Fraction of the hardener. Figure 8 shows that the fraction of hardener around 0.45 obtained the best of shear strength of the specimen. Proven on the curve for the hardener fraction below or more than 0.45, the decrease of shear strength occurred.

CONCLUSION

The conclusions from the results of this study are as follows. The mechanical properties of different materials of the hardener fraction and the fiber powder content produced different impact and shear strengths. It appears that pure resin has the lowest impact strength of 1.37 kJ/m². The fiber powder content that produces the highest impact strength is 6%, which is 4.92 kJ/m². In comparison, the hardener fraction with the highest impact strength is 0.5, meaning 50% resin and 50% hardener, which is 4.55 kJ/m². The fiber powder content that produces the highest Shear strength is 8%, which is 1.00 MPa. At the same time, the hardener fraction, which has the highest shear strength is 0.5, meaning 50% resin, and 50% hardener, which is 2.03 MPa. Thus, fiber powder content and hardener fraction greatly affect the physical and mechanical properties of composite materials. However, certain limitations of the fiber powder content and the hardener fraction obtain optimum mechanical properties.

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