EFFECT OF PERCENTAGE OF RESIN AND CATALYST OF FIBERGLASS FIBER COMPOSITES, WITH FIBER ORIENTATION DIRECTIONS (0°,45°), (45°,90°) AND (0°,90°) ONTENSILE AND IMPACT STRENGTHS

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Abstract
In the world of aviation industry the use of composite materials began to be widely developed, one of the most frequentlyused composite materials in the industrial world is composite material with fillers in the form of Fiberglass. Currently,fiber-reinforced composite materials are widely used engineering materials because of their specific strength and stiffness which are far above engineering materials in general, so that their properties can be designed close to the needs. The research conducted used WR 200 Fiberglass with fiber direction orientation treatment (0°, 45°), (45°, 90°), (0°, 90°), with 1%, 1.5%, 2% catalyst. The manufacture of composite workpieces/specimens using the hand lay-up methodwith glass molds measuring 22 cm × 17 cm × 0.4 cm and 10 cm × 5 cm × 1 cm. Based on the tensile and impact tests carried out on the WR 200 fiberglass composite, the tensile test obtained the results with the treatment of fiber direction orientation 45 °, 90 ° with 1% catalyst composition getting the highest tensile strength value of 56.87 N / mm2. The treatment of 0°,90° fiber direction orientation with 2% catalyst composition got the lowest tensile strength value of 38.15 N/mm2. In the impact test, the results obtained with the 45°,90° fiber direction orientation treatment with 1% catalyst composition obtained the highest Fracture Stress value of 9.687 Joules and the highest Tenacity Price value of 0.121 Joules/mm2. The 0°,90 fiber direction orientation treatment with 2% catalyst composition got the lowest fracturestress value of 3,935 Joules and the lowest ductility price value of 0.049 Joules/mm2.

Keywords: Composite, Fiberglass, fiber direction, Tensile and Impact Strength

INTRODUCTION

A composite material is a complex material that is composed of two or more materials that are joined together on a macroscopic scale to form a useful product, which is designed to produce the best quality and properties. Composite reinforcing fiber that is commonly circulated and often used is fiberglass, but the price is quite expensive and not environmentally friendly where the glass fiber cannot be degraded naturally and produces CO gas and dust which is harmful to health if recycled.

Composites are materials made of two or more materials that remain separate and distinct at the macroscopic level forming a single component. Composite materials generally use a binder material with plastic (polyester) as the main material. In addition to the binder material (matrix) the composite also uses filler or reinforcing material, the material commonly used is fiber made of strong, stiff and brittle materials.

Some definitions of composite are as follows:

a. Basic level: in single molecules and crystal lattice, when materials composed of two or more atoms are called composites (e.g. compounds, alloys, polymers and ceramics).

b. Microstructure: in crystals, phases and compounds, when materials are composed of two or more phases or compounds called composites (e.g. Fe (iron) and C (carbon) alloys).

c. Macrostructure: materials composed of a mixture of two or more macro constituents that are different in shape or composition and insoluble from one another are called composite materials.

Composites have better mechanical properties than metals, their stiffness and specific strength are higher than metals. Multiple composite laminae can be stacked with different fiber orientation directions, these combined laminae are referred to as laminates.

Fiber-reinforced composites are widely applied to tools that require a combination of two basic properties, namely strength but also lightness. Composite materials have many advantages, including low specific gravity higher strength, corrosion resistance and have a cheaper manufacturing cost. Composite materials consist of matrix and fiber. Fiber plays a role in providing strength and stiffness to the composite. Composites are formed from two different types of materials reinforcement and matrix.

Composites consist of two main materials, namely reinforcement and matrix. Reinforcement has less ductile but more rigid and stronger properties. Reinforcement is a material in the composite that functions as the main support for the strength of the composite or the main load bearer in the composite, while the matrix functions to bind and keep the reinforcement in place (in the structure). The load received by the composite is almost entirely received by this reinforcement, so the high and low strength of the composite is highly dependent on the type of material used as reinforcement. In general, the matrix is a fiber reinforced material, the matrix is liquid with low viscosity, which will harden after the polymerization process. The matrix in the composite material acts as a reinforcing binder, a secondary part that holds the load, so the strength of the composite material is highly dependent on the strength of the forming matrix. Matrices have the following functions:

1) Transfers stress to the fiber evenly.
2) Protects fibers from mechanical friction.
3) Holds and maintains the fiber in position.
4) Protects from adverse environments.
5) Remains stable after the manufacturing process.

METHODS

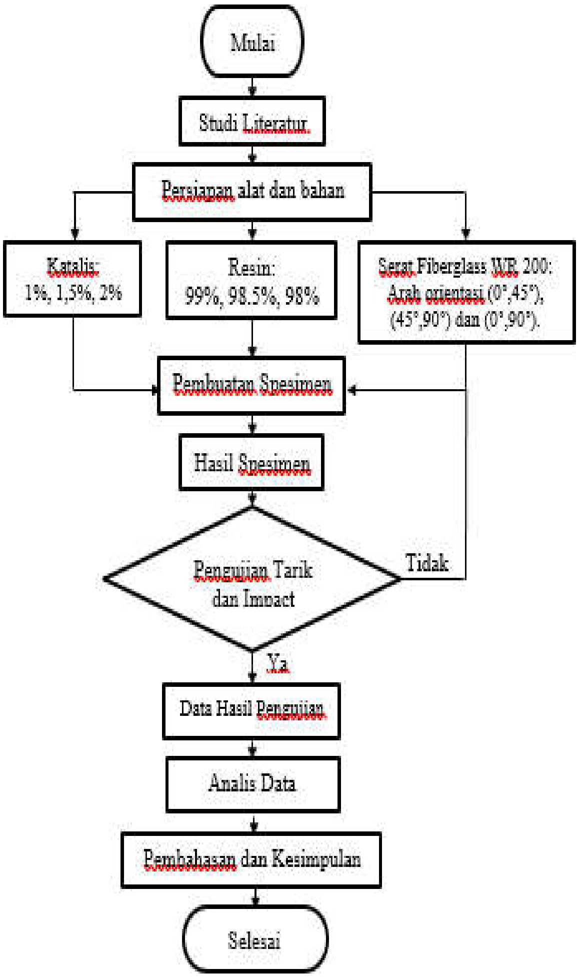

Figure 1. Flowchart of Research

Preparation of Test Samples

Preparations that will be made before testing are materials to make test objects as well as tensile test equipment and impact tests to test these objects. The calculation of the composition carried out must be in accordance with the standards that have been used.

The tools that will be used in this research are:

1) Glass molds 22 x 17 x 0.4 cm and 10 x 6 x 1 cm.
2) Digital scales.
3) Measuring cup.
4) Cutter.
5) Scissors.
6) Ruler.
7) Brush.
8) Sticks.
9) 5 ml injection.
10) Marker pen.
11) Gloves.

Research materials to be used:

1) WR 200 Fiberglass Fiber.
2) Polyester resin.
3) Catalyst (hardener).
4) Mirror Glaze/Wax.

Testing tools that will be carried out:

1) Tensile Test.
2) Impact Test.

The tools used in this research include glass to make molds, digital scales to measure the mass of the mixture of materials, rubber gloves, cutters to tidy up the resin, scissors to cut the fiber, sticks to stir the mixture of resin and catalyst, measuring cups as resin and catalyst containers, brushes to flatten the resin, 5 ml injections to adjust the amount of catalyst, ruler to measure fiber length, saws to cut specimens, wax used to facilitate the release of composites from glass molds, tensile testing machines and impact tests for testing of specimens made. While the materials needed include WR 200 fiberglass fiber, polyester resin and its catalyst.

Data Analysis Technique

Tensile test

Tensile Strength or Tensile stress can be defined as the force per unit area of material that receives the force. To be able to obtain the tensile strength of a material can be calculated using the Equation with the following formula:

$$\sigma = \frac{F}{A_o}$$

Where:

σ : Tensile stress (N/mm2)
F : Applied load (N)
Ao : Initial cross-sectional area (mm)

Tensile strain is a measure of the change inlength of a material after a tensile test, so that the results of tensile testing can be used to find the strainvalue of a material. To find the tensile strain can becalculated using the following formula:

$$\in = \frac{\Delta \boldsymbol{L}}{\boldsymbol{L_o}}$$

Where:

$\in$: Tensile strain
ΔL : Length Increase (mm)
L_0 : Initial length (mm)

The modulus of elasticity (Young Modulus) is the ratio between stress and strain. To find the modulus of elasticity can be calculated using the formula:

$$E = \frac{\sigma}{\in}$$

Where:

E : Modulus of Elasticity (N/mm2)
σ : Stress (N/mm2)
$\in$: Tensile strainStarting from the incoming

Impact test

Impact test data analysis technique After impact testing has been carried out on specimens from each composite, then in the calculation of impact testing to find energy and impact prices using the following formula:

$$E = W \times R\,[\cos(\beta) - \cos(\alpha)]$$

Description:

E = Energy (joules).
W = Weight of hammer.
R = Arm length.
β = Final angle of the pendulum.
a = Starting angle of the pendulum

$$\text{HI} = E \times Ao$$

Description:

HI = Impact price (joules)
E = Energy to break the material
A0 = Smallest cross-sectional area of the notch (cm^2)

RESULTS AND DISCUSSION

In this chapter describes the data of the test results conducted with tensile tests and impact tests. The manufacture of polyester composite materials with WR 200 fiberglass fibers carried out by the hand lay-up method, testing was carried out with the aim of determining the test results with the treatment of differences in fiber direction orientation (0 °, 45 °), (45 °, 90 °), and (0 °, 90 °) with 1%, 1.5%, 2% catalyst composition. The data obtained from tensile testing is the tensile stress data of WR 200 fiberglass fiber material. The data obtained from impact testing is fracture power data and ductility prices. So that it will get which WR 200 fiberglass fiber composite has the best results. The test results are presented in the form of tables and graphs because they are more concise and easy to understand. There are tests in the appendix section to see the complete data.

Tensile Testing Results

Tensile testing was carried out as many as three specimens with different fiber direction orientations and catalyst compositions in each sample. So that the total tensile testing is nine specimens using a tensile testing machine, where the results are different in each specimen. From these results, the value of the tensile stress of each specimen will be taken, then the results are presented in tabular and graphical form.

Tensile Testing Results Orientation (0°,45°) 1%, 1.5%, 2% catalysts

Table 1. Tensile Testing Results Orientation (0°,45°)

No	Sampel	Tebal (mm)	Lebar (mm)	Luas (mm^2)	Beban P (N)	Tegangan tarik (N/mm^2)	L0 (mm)	ΔL (mm)	Regangan (%)	E (N/mm^2)
1.	Katalis 1%	5,53	18,85	82,12	4600	56,01	50	0,29	0,58	108,10
2.	Katalis 1,5%	4,52	17,92	67,43	3500	51,89	50	0,24	0,48	97,73
3.	Katalis 2%	6,05	18,44	93,41	4200	44,96	50	0,23	0,46	96,56

Based on the calculation data in accordance with the calculations in the table above, it can be seen that fiberglass fiber, oriented 0 °, 45˚ fiber direction with 1%, 1.5%, 2% catalyst composition, has the highest stress and strain values and tensile elastic modulus, namely in the use of 1% catalyst with a stress value of 56.01 (N/mm2), a strain value of 0.58% and a tensile elastic modulus value of 108.10 (N/mm2). From the results obtained, fiberglass fiber specimens,oriented 0°, 45˚ with 1%, 1.5%, 2% catalysts get the lowest value, namely with 2% catalyst with a tensile stress value of 44.96 (N/mm2), a strain value of0.46% and an elastic modulus value of 96.56 (N/mm2). The following is a picture of the fiberglassfiber composite, Figure 4.1 specimen before tensile testing and Figure 4.2 specimen after tensile testing.

Figure 2. Composite Specimen (0°,45˚)

Figure 3. Specimen Test Results (0°,45˚)

Tensile Testing Results Orientation (0°,90°) Catalyst 1%,1.5%,2%

Table 2: Tensile Testing Results Orientation (0°, 90°)

Tebal (mm)	Lebar (mm)	Luas (mm^2)	Beban P (N)	Tegangan tarik (N/mm^2)	L0 (mm)	ΔL (mm)	Regangan (%)	E (N/mm^2)
5,77	15,01	86,60	4600	53,11	50	0,29	0,58	91,56
6,79	16,27	110,47	4600	41,63	50	0,24	0,48	86,72
6,43	15,08	96,96	3700	38,15	50	0,23	0,46	82,93

Based on the calculation data in accordance with the calculation formula in the table above, it can be concluded that fiberglass fiber orientation of 0 °, 90˚ fiber direction with 1%, 1.5%, 2% catalyst composition, has the highest value of stress and strain and tensile elastic modulus value, namely in the use of 1% catalyst with a value of 53.11 (N/mm2) stress, 0.58% strain, and 91.56 (N/mm2) elastic modulus. After that the results obtained from fiberglass fiber specimens, oriented 0 °, 90 ° with 1%, 1.5%, 2% catalysts get the lowest value, namely at 2% catalyst with a value of 38.15 (N/mm2) Stress, 0.46% Strain, and 82.93 (N/mm2) Modulus of elasticity. The following is a picture of the fiberglass fiber composite, Figure 4.1 specimen before tensile testing and Figure 4.2 specimen after tensile testing..

Figure 4. Composite Specimen (0°,90˚)

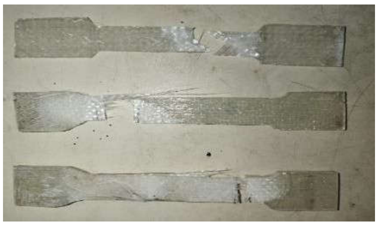

Figure 5. Specimen Test Results (0°,90˚)

Tensile Testing Results Orientation (45°,90°) Catalyst 1%,1.5%,2%

Table 3. Tensile Testing Results Orientation (45°, 90°)

Tebal (mm)	Lebar (mm)	Luas (mm²)	Beban P (N)	Tegangan tarik (N/mm²)	L0 (mm)	ΔL (mm)	Regangan (%)	E (N/mm²
4,78	15,45	73,85	4200	56,87	50	0,29	0,58	98,05
4,43	15,15	67,11	3300	49,16	50	0,28	0,56	87,78
6,49	15,19	98,58	4400	44,63	50	0,31	0,62	70,84

From the calculation results in accordance with the calculation formula in the table above, it can be concluded that fiberglass fiber, oriented 45 °, 90˚ fiber direction with 1%, 1.5%, 2% catalyst composition, has the highest tensile stress, strain and elastic modulus values, namely in the use of 1% catalyst with a tensile stress value of 56, 87 (N/mm2), Strain 0.58% and Modulus of elasticity 98.05 (N/mm2), after that the results obtained from fiberglass fiber specimens, oriented 0 °, 45˚ with 1%, 1.5%, 2% catalysts get the lowest value, namely in 2% catalysts with a Tensile Stress value of 49.16 (N/mm2), Strain 0.62% and Modulus of elasticity 70.84 (N/mm2). Based on the tests that have been carried out, it can be concluded that fiberglass fiber treatment, oriented 45 °, 90 ° with 1%, 1.5%, 2% catalyst in the specimen. The following are images of fiberglass fiber composites, Figure 4.3 specimens before tensile testing and Figure 4.4 specimens after tensile testing.

Figure 6. Composite Specimen (45°,90˚)

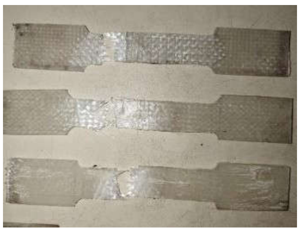

Figure 7. Specimen Test Results (45°,90˚)

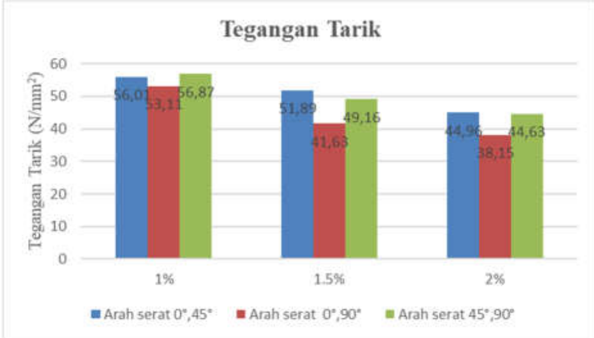

Figure 7. Tensile Stress Value Chart

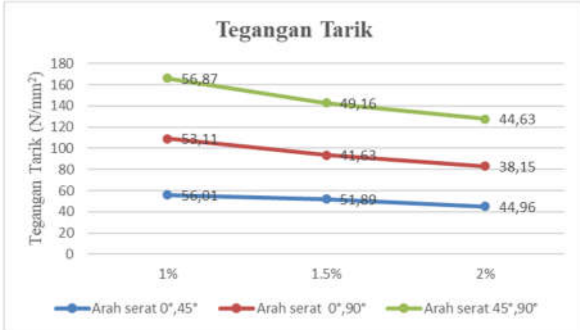

Figure 8. Tensile Stress Value Chart

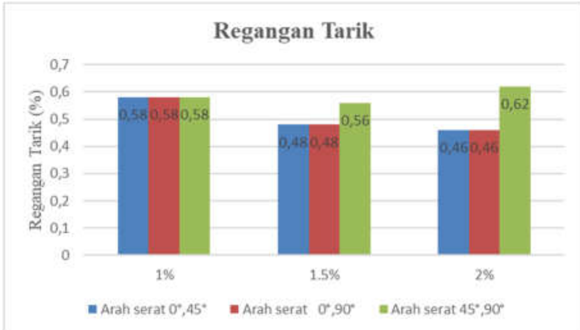

Figure 9. Graph of Tensile Strain Values

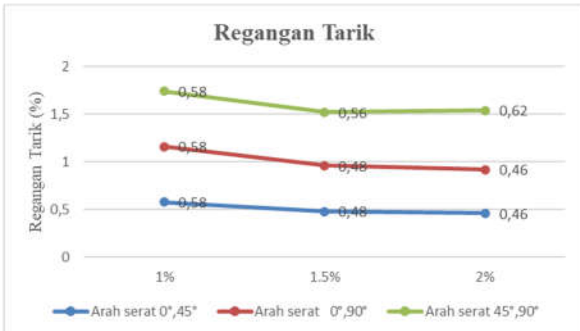

Figure 10. Graph of Tensile Strain Values

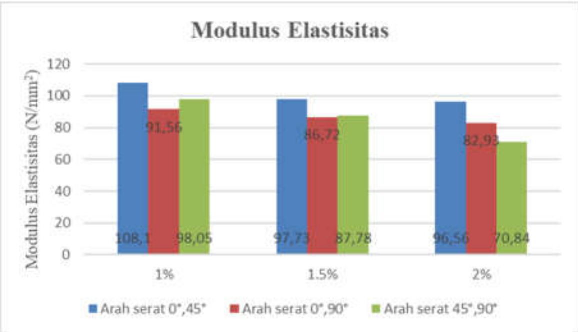

Figure 11. Modulus of Elasticity Value Chart

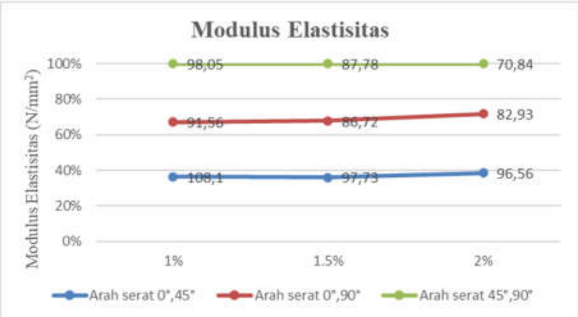

Figure 12. Modulus of Elasticity Value Chart

Impact test results

Impact testing was carried out as many as six specimens, each angle / direction of orientation, namely (0 °, 45 °), (45 °, 90 °), (0 °, 90 °) with 1%, 1.5%, 2% catalyst. So that the total impact test is six specimens using an impact testing machine where the results are different in each treatment variation. From these results will be taken the average value of energy and impact price, then the results are presented in the form of tables and graphs.

Impact Testing Results With Fiber Direction Orientation 0˚,45˚

Table 4. Impact Test Results 0˚,45˚

No.	Komposisi katalis (%)	W (kg)	α	β	Tegangan Patah (*Joule*)	Harga Keuletan (*Joule*/mm²)
1.	1%	13,17	140	124	9,687	0,112
2.	1,5%	13,17	140	125	9,016	0,064
3.	2%	13,17	140	132	4,535	0,056

Based on the results of calculations in accordance with the formula, in the table above it can be seen that fiberglass fibers oriented in the direction of 0 °, 45˚ fibers with 1%, 1.5%, 2% catalysts, have the highest value of fracture stress and ductility prices, namely in the composition of 1% catalyst with a fracture stress of 9.687 Joules and a ductility price of 0.121 Joules / mm2. From the results obtained, fiber specimens fiberglass, oriented 0 °, 45˚ with 1%, 1.5%, 2% catalysts get the lowest value at 2% catalyst composition with a fracture stress of 4.535 joules and a ductility price of 0.056 Joules / mm2. Based on the tests that have been carried out, it can be concluded that the treatment of fiberglass fibers oriented 0 °, 45˚ with 1%, 1.5%, 2% catalysts in the specimen has the highest and lowest fracture stress and ductility test results where in the tensile stress test and the highest ductility in the 1% catalyst composition. For the lowest tensile stress and ductility test results at 2% catalyst composition.

Hasil Pengujian Impact dengan orientasi arah serat 0°,90°

Table 5. Impact Test Results 0°, 90°

No.	Komposisi katalis (%)	W (kg)	α	β	Tegangan Patah (*Joule*)	Harga Keuletan (*Joule*/mm²)
1.	1%	13,17	140	127	7,404	0,092
2.	1,5%	13,17	140	131	5,152	0,064
3.	2%	13,17	140	133	3,935	0,049

The results of the calculation in accordance with the formula, in the table above, it can be seen that fiberglass fiber oriented in the direction of 0 °, 90˚ with 1%, 1.5%, 2% catalyst, has the highest value of fracture stress and ductility price, namely in the composition of 1% catalyst with a fracture stress of 7.404 Joules and a ductility price of 0.092 Joules / mm2. From the results obtained, fiberglass fiber specimens, oriented 0 °, 90 ° with 1%, 1.5%, 2% catalysts get the lowest value in the composition of 2% catalyst with a fracture stress of 3.935 Joules and a ductility price of 0.049 Joules/mm2.

Based on the tests that have been carried out, it can be concluded that the treatment of fiberglass fibers oriented 0 °, 90 ° with 1%, 1.5%, 2% catalysts in the specimen has the highest and lowest yields of fracture stress and ductility testing where the highest tensile stress and ductility testing is at 1% catalyst composition. For the lowest tensile stress and ductility test results found in 2% catalyst composition.

Impact Testing Results With 45°, 90° Fiber Direction Orientation

Table 5. Impact Test Results 45°, 90°

No.	Komposisi katalis (%)	W (kg)	α	β	Tegangan Patah (*Joule*)	Harga Keuletan (*Joule*/mm^2)
1.	1%	13,17	140	125	9,016	0,112
2.	1,5%	13,17	140	126	8,344	0,104
3.	2%	13,17	140	132	4,535	0,056

Based on the results of calculations in accordance with the formula, in the table above it can be seen that fiberglass fiber oriented in the direction of 45 °, 90 ° with 1%, 1.5%, 2% catalyst, has the highest value of fracture stress and ductility price, namely in the composition of 1% catalyst with a fracture stress of 9.016 Joules and ductility price of 0.112 Joules / mm2. From the results obtained, fiberglass fiber specimens, oriented 45 °, 90 ° with 1%, 1.5%, 2% catalysts get the lowest value in the composition of 2% catalysts with a fracture stress of 4.535 Joules and a ductility price of 0.056 Joules / mm2.

Based on the tests that have been carried out, it can be concluded that the treatment of fiberglass fibers oriented 45 °, 90 ° with 1%, 1.5%, 2% catalysts in the specimen has the highest and lowest fracture stress and ductility test results where in the tensile stress test and the highest ductility in the 1% catalyst composition. For the lowest tensile stress and ductility test results at 2% catalyst composition.

Figure 13. Impact Specimen 1%, 1.5%, 2% Catalyst

Figure 14. Impact Test Results of 1%, 1.5%, 2% Catalysts

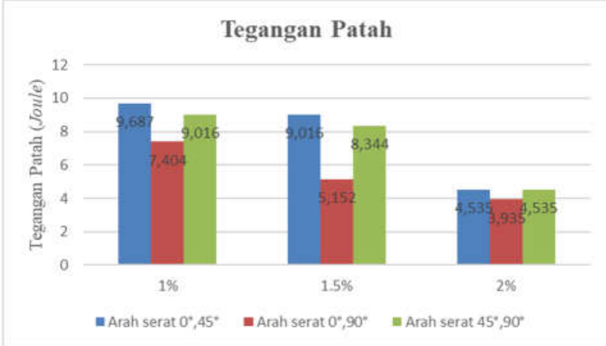

Figure 15. Graph of Fracture Stress Value

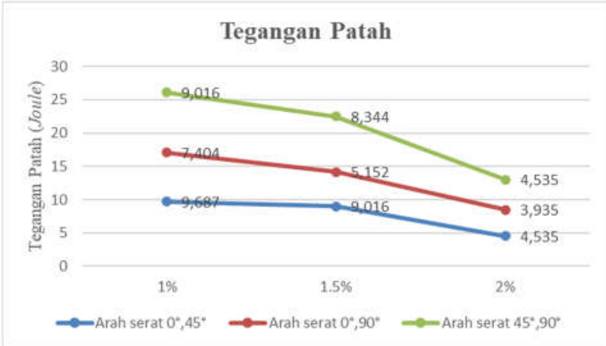

Figure 16. Graph of Fracture Stress Value

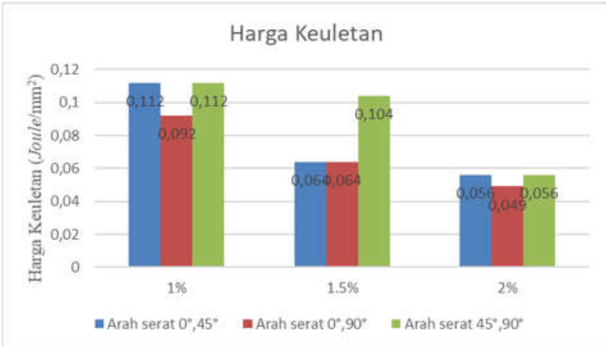

Figure 17. Tenacity Price Value Chart

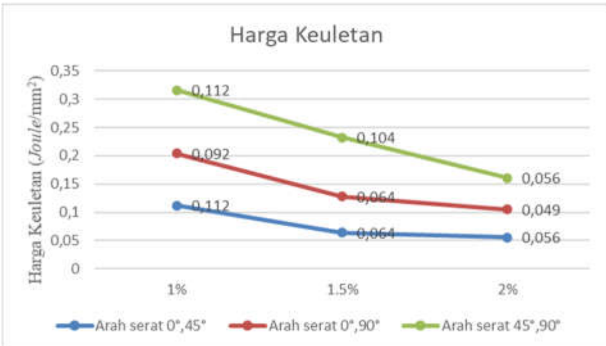

Figure 18. Tenacity Price Value Chart

CONCLUSION

Based on the results of research and discussion about the comparison of tensile tests and impact tests, it can be concluded as follows:

1. Making workpieces by pouring resin by hand lay-up method into a mold to adjust the resin content into fiberglass fibers that form a 2-layer fiber direction with orientation angles, namely (0 °, 45 °), (45 °, 90 °), (0 °, 90 °), with 1%, 1.5%, 2% catalyst.In testing the air *pressure* sensor, using testing media, namely air generated by a *heat gun* and an airtight testing ground. Some of these testing media have a level of sensitivity that can affect the air pressure value displayed on the monitor screen.
2. Composites made with fiber direction orientation treatment (0°,45°), (45°,90°), and (0°,90°) with 1%, 1.5%, 2% catalyst composition get the highest tensile strength value at 45°,90° fiber direction orientation of 56.87 (N/mm2) with 1% catalyst composition, then specimens with the lowest tensile strength value at 0°,90° fiber direction orientation of 38.15 (N/mm2) with 2% catalyst composition. From the test results, it can be concluded that theprocess of fiber direction treatment and catalystsmay not necessarily improve the mechanical properties of fiberglass fibers.
3. Composites made with the treatment of fiber direction orientation (0°,45°), (45°,90°), and (0°,90°) at 1% 1.5%, 2% catalyst composition get the highest value of Fracture Strength and Tenacity Price at 45°,90° fiber direction orientation of 9.687 Joules for the value of Fracture Stress and 0.121 Joules/mm2 for the value of Tenacity Price with 1% catalyst composition. Then the specimen that got the lowest Fracture Power and Tenacity Price at 0°,90 ° fiber direction orientation of 3,935 Joules for the Fracture Stress value and 0,049 Joules/mm2 for the Tenacity Price value with 2% catalyst composition. From the test results, it can be concluded that using too high a catalyst will reduce the mechanical properties of fiberglass fibers.

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