EFFECT OF RESIN PERCENTAGE AND CATALYST ON TENSILE AND IMPACT STRENGTH OF CARBON FIBER COMPOSITES

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ABSTRAK

Persentase resin serta katalis dapat mempengaruhi sifat mekanik terutama kekuatan tarik dan impact pada komposit berpenguat carbon fiber. Kekuatan komposit cenderung berbeda-beda tergantung pada beberapa faktor termasuk persentase resin dan katalis, maka dari itu untuk dapat menciptakan komposit yang berkualitas penghitungan persentase resin dan katalis harus dilakukan. Penelitian ini dilakukan untuk mengetahui lebih rinci mengenai pengaruh persentase resin dan katalis terhadap kekuatan tarik dan impact komposit berpenguat carbon fiber. Metode yang digunakan dalam penelitian ini adalah metode eksperimental dengan cara menguji 6 spesimen 2 dan 3 layer yang memiliki persentase katalis 1%,1,5%, dan 2%. Berdasarkan hasil penelitian dapat diketahui bahwasanya persentase resin dan katalis secara signifikan mempengaruhi kekuatan tarik dan impact, semakin besar persentase katalis maka semakin tinggi kekuatan tarik dan semakin kecil persentase katalis maka semakin besar kekuatan impact komposit. Hasil tersebut menunjukkan bahwa persentase resin dan katalis adalah salah satu hal yang sangat mempengaruhi sifat mekanik pada komposit berpenguat carbon fiber.

Kata kunci: Komposit, carbon fiber, resin, katalis

ABSTRACT

The percentage of resins and catalysts can affect the mechanical properties of the composite, especially tensile and impact strength in carbon fibre-reinforced composites. The strength of composites tends to vary depending on several factors including the percentage of resin and catalyst, therefore to be able to create a quality composite the percentage calculation of resin and catalyst must be done. This study was conducted to find out in more detail the effect of resin and catalyst percentage on the tensile strength and impact of carbon fibre-reinforced composites. The method used in this study is an experimental method by testing 6 specimens of 2 and 3 layers which have catalyst percentages of 1%, 1.5%, and 2%. Based on the results of the study, it can be seen that the percentage of resin and catalyst significantly affects the tensile strength and impact, the greater the percentage of catalyst, the higher the tensile strength and the smaller the percentage of catalyst, the greater the impact strength of the composite. These results show that the percentage of resin and catalyst is one of the things that greatly affect the mechanical properties of carbon fibre-reinforced composites.

Keywords: Composite, carbon fiber, resin, catalyst

1. INTRODUCTION

Composites are a combination of several single materials into a single unit with properties that are superior to the properties of the forming material. Linear with this understanding, Jones (1999) defines composites as a form of product made through the combination of two or more materials with the intention of creating a new material that has qualities superior to the forming material. Composites are widely used in various fields of life, including in the aviation industry. Initially, the use of composites in the aviation industry was an alternative form of replacement for conventional aluminum. Basically, composites have many advantages in terms of quality, for example, composites have light weight, have adaptable strength and stiffness, are corrosion resistant, and are resistant to corrosion. The many advantages that composites have made the aircraft industry widely use composites in its manufacturing. However, the strength of composites tends to vary depending on the constituent material, while the preparation of composites consists of two components, namely the reinforcing phase and the binder. The aviation industry has recently been using carbon fiber reinforced composites in aircraft manufacturing. The use of carbon fiber reinforced composites is considered to be efective and efficient, this is because carbon fiber has many advantages so it is highly recommended for use in aircraft manufacturing. The advantages of using carbon fiber include not being susceptible to moisture, having high tensile and impact strengths, not being vulnerable and having fatigue resistance that tends to be high, having excellent elasticity recovery capabilities, cheaper nurses, and having a lighter density than fiberglass. These advantages are behind the selection of carbon fiber reinforced composites in creating aircraft manufacturing. With regard to carbon fiber, this material cannot be converted into a composite without the help of a binder or matrix. The composite forming phase is divided into two, namely reinforcement and binder, while the ratio between the two is 3:7, in other words, 70% of the composite component is the binder or matrix phase. The main function of the matrix as a composite forming material is to glue between phases in the composite, in simpler terms this matrix functions as a binder for the two phases in the composite so that there is maximum gluing interaction. The matrix must be made with certain criteria, for example: 1) Has a high degree of ductility; 2) Has a smaller elastic modulus than the fiber or reinforcing phase; 3) Able to create a good bond between the two phases. One type of matrix that is commonly used is polyester resin. Polyester resin is a type of polymer that is classified into the thermoset category. In this regard, the polyester resin enhancer is intended to improve the mechanical bonding ability between the preparation fiber and the matrix. Meanwhile, as a material to strengthen mechanical bonding in composite phases, this polyester resin should be added with other chemical compounds in the form of catalysts that function as hardeners in composites. Determining the percentage of resin and catalyst is one of the most important things in making composites. This is because these two materials will influence the level of voids in the composite as well as the resulting mechanical properties. The amount of catalyst mixed into the resin will significantly affect mechanical properties such as tensile and impact strength of the composite. The more the amount of catalyst mixed in the resin, it will increase the speed of the drying process and affect the resulting mechanical strength, and vice versa, there will be a decrease in the level of drying speed and changes in mechanical properties if the amount of catalyst mixed in the resin is less.

2. METHODS

2.1 Research Design

This research was designed using an experimental research method by making carbon fiber reinforced composites. Experiments in this study were conducted with the aim of creating carbon fiber reinforced composites and finding out the effect of the percentage of resin and the amount of catalyst or matrix used on the tensile and impact strength of the composite. This research was conducted by comparing the percentage of catalyst using the hand lay up process.

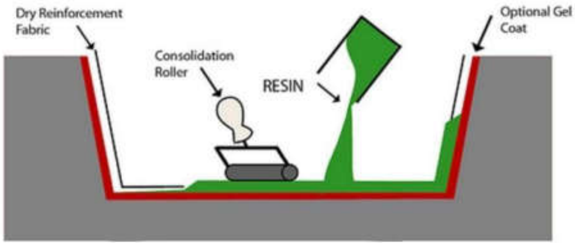

Figure 01. Schematic of hand lay up (Gibson, 1994)

The hand lay up process is a method used to make composites, Alamsyah (2020) in research states that this hand lay up process utilizes layers in manufacturing in order to get a predetermined thickness.

Many factors can affect the results of this research so that more additional sources of regression are needed to complement and assist the course of research. Linear to this, apart from relying on experimental results, this study also conducted a document study by using many sources of written documents such as books, journals, and other sources that can be accounted for and are related to the research conducted (Sugiyono, 2013). Meanwhile, the utilization of written documents is carried out with the aim of helping to complete the research as an additional source of information.

2.2 Place and Time of Research

This research was conducted from September 2022 to April 2023 at the Aviation Polytechnic campus in Surabaya. More specifically, the preparation of scientific papers began in December 2022.

2.3 Composition Calculation Process

In order to support the smoothness and courage of the research and experiments carried out, various preparations must be made in many aspects, including in calculating the composition of the composite manufacturing materials to be used. Calculation of the composition in this study can be done by calculating the total volume of the mold used by the ratio between the volume of fiber (reinforcing phase) and the resin used. With regard to this, the researcher used two molds with different sizes. The first mold has a size of 220 mm × 170 mm × 4 mm, while the second mold has a size of 10 cm × 5 cm × 1 cm.

Meanwhile, in this composite measurement, researchers use several linear formulas, including:

1. Determining the V of the mold

   V (mold) = p × l × t

2. Determining the volume of resin

   V (resin) = 99% × V mold

   V (resin) = 98.5% × V of the mold

   V (resin) = 98% × V mold

3. Determining catalyst volume

   V (catalyst) = 1% × V of resin

   V (catalyst) = 1.5% × V resin

   V (catalyst) = 2% × V resin

Through calculating the composition through the formula, the results are obtained:

No. Sampel	Metode Uji	Persentase Katalis (%)	Vresin (ml)	Vkatalis (ml)
1.	Tarik	1	148,1	1,49
2.	Tarik	1,5	147,3	2,24
3.	Tarik	2	146,6	2,99
4.	Impak	1	49,5	0.5
5.	Impak	1,5	49,25	0,75
6.	Impak	2	49	1

Figure 02. Fiber volume fraction

2.4 Material Manufacturing

After the composition of each material is known, the next thing to do is to make the test material. Broadly speaking, there are six main steps in making test materials starting from measuring the composition to the end, namely:

1. In the first step, take measurements with the aim of determining the volume of resin and catalyst used using two different molds including 220 mm × 170 mm × 4 mm and 10 cm × 5 cm × 1 cm.
2. In the second step, pour the resin and catalyst according to the measurement ratio into a measuring cup and mix them thoroughly.
3. In the third step, mix the previously made resin composition and catalyst into the mold evenly, then place the diber and leave it to cover the resin, then smooth it using a brush. Do it repeatedly until 2 and 3 layers are created.
4. The fourth step is to cover the mold in order to hold the laminate at the pre-set thickness. The mold cover should be made of glass and pre-weighed as required.
5. Step fifth, dry the laminate, once dry then disassemble the laminate.
6. Step sixth, the material is ready to be tested using the standard ASTM D638 tensile test and ASTM A370 impact test.

2.5 Material Testing Plan

No.	Sampel	Katalis	Resin	Uji
1.	2 layer	1%	148,1 ml & 49,5 ml	Tarik & *Impact*
2.	2 layer	1,5%	147,3 ml & 49,25 ml	Tarik & *Impact*
3.	2 layer	2%	146,6 ml & 49 ml	Tarik & *Impact*
4.	3 layer	1%	148,1 ml & 49,5 ml	Tarik & *Impact*
5.	3 layer	1,5%	147,3 ml & 49,25 ml	Tarik & *Impact*
6.	3 layer	2%	146,6 ml & 49,5 ml	Tarik & *Impact*

Figure 03. Sample test plan table

Based on the table above, it can be seen that the tests in this study will be carried out on six different samples for each test both tensile and impact tests. The samples consist of two and three layers with each predetermined resin volume and catalyst percentage.

2.6 Data Testing Techniques

Data testing techniques in this study were carried out using tensile and impact tests on research samples. There are several steps that must be taken in the tensile test of the sample, namely:

1) Prepare the materials to be tested.
2) Place the millimeter block paper on the printer and turn on the printer.
3) Start the testing machine and position the test piece on the grip.
4) Tighten the grips but be sure to pay attention to the tightness of the grips so as not to damage the surface of the test piece.
5) Attach the extensometer and ensure that the elongation value lies at zero.
6) Change it after the load and make sure it is exactly at zero.
7) Set the test rate accordingly and press the start and down buttons. Keep repeating these steps until the last sample.

Similar to the tensile test, the impact test also has certain steps that must be taken to support success, namely:

1) Prepare test samples in accordance with the provisions of ASTM A370.

2) Make notches (nicks) with a size of 0.25 to 0.005 mm.
3) Check the condition of the test material.
4) Measure and record the length and width of each sample after piercing.
5) Measure and record the remaining material below the notch on each test material.
6) Place the test material in a horizontal position on the support so that the surface of the test material is impacted.
7) Lift and support the pendulum in the release mechanism and change the indication of absorbed energy to zero.
8) Release the pendulum and position the pendulum test so that it can hit the test object and then record the breaking energy that occurs.
9) Discard test materials that do not break or do not break completely.
10) Calculate the impact resistance value of each test material (J/m).
11) Calculate the average impact resistance value.
12) Calculate the standard deviation of the test material group (specimen).

2.7 Data Analysis Technique

The data analysis technique in this study was carried out by performing numerical calculations using certain formulas, namely:

1) To determine the tensile strength

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

2) Determine the strain result of the tensile test

$$\varepsilon = \frac{\Delta L}{Lo} \text{ x } 100\%$$

3) Calculating the energy in the impact test

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

4) Determining the impact value

$$HI = E \times Ao$$

3. RESULTS

3.1 Tensile Test Results and Discussion

The tensile test in this study was conducted on 6 different specimens both in the number of layers (2 and 3) and the percentage of catalyst (1%, 1.5%, 2%). The following are the results of the tensile test on the specimen with layer 2:

Spesimen	Lebar (mm)	Tebal (mm)	Luas (mm²)	Beban Normal (N)	Tegangan Tarik (N/mm²)	L0 (mm)	ΔL (mm)	Regangan (%)	E (N/mm²)
1%	16,85	3,57	60,15	2500	41,56	50	0,23	0,46	90,34
1,5%	16,81	3,53	59,33	2600	43,82	50	0,24	0,48	91,29
2%	17,50	3,26	57,05	3000	52,58	50	0,29	0,58	90,65

Figure 04. Table of tensile test results of 2 layer specimens

Through this table, it can be seen that the largest tensile stress value is owned by specimen 3, which is a 2 layer specimen with a percentage of 1% catalyst which reaches 52.58 (N/mm^2). The second position in the tensile test results on the specimen is owned by the 2nd specimen, which is 2 layers with a percentage of 1.5% catalyst with a value that reaches 43.82 (N/mm^2). While the lowest value is owned by specimen 1, which is a specimen with 2 layers and 1% catalyst, while the total value reached 41.56 (N/mm^2). The three test specimens show different results, thus indicating that there are many factors that can affect the tensile strength of the catalyst, including the volume of resin and the percentage of catalyst mixed.

Figure 05. Tensile test of 2 layer (1%) specimen

Similar to the results of the tensile testing of the 2-layer specimens, the 3-layer specimens were also screened for three different specimens with a catalyst percentage of 1%, 1.5%, and 2%, respectively. Referring to the results of the tests carried out, the tensile tests on the three specimens produced numbers:

Spesimen	Lebar (mm)	Tebal (mm)	Luas (mm²)	Beban Normal (N)	Tegangan Tarik (N/mm²)	L0 (mm)	ΔL (mm)	Regangan (%)	E (N/mm²)
1%	16,58	4,38	72,62	3900	53,70	50	0,31	0,62	86,61
1,5%	16,76	4,34	73,83	4200	63,65	50	0,33	0,66	86,18
2%	16,95	4,37	74,07	4700	70,98	50	0,36	0,72	88,13

Figure 06. Table of tensile test results for 3 layer specimens

Based on the attached data, it can be seen that the tensile test value on specimens with 3 layers is owned by specimen 3 with a value reaching 70.98 (N/mm^2). This value is higher when compared to other specimens, namely the 2 layer 1% specimen with a value that only reaches 53.70 and the 2 layer 1.5% specimen with a value of 63.65 (N/mm^2). Based on the test data that has been attached, it can be concluded that the percentage of catalyst and resin can affect many things in the composite, including the tensile strength of the composite.

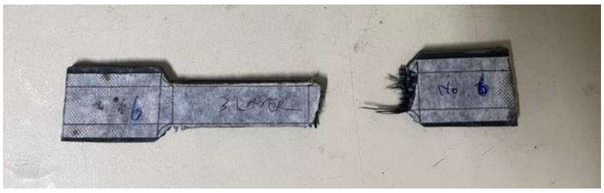

Figure 07. Tensile test of 3-layer specimen (2%)

Figure 08. Tensile test result chart

Based on the data generated through testing, different values were obtained from each specimen both 2 and 3 layers with 1%, 1.5%, and 2% catalysts. The highest value in the test is found in specimen 2 (2%) and specimen 3 layer (2%), this shows that the difference in the percentage of catalyst and resin mixed to make composites can change the mechanical properties of composites, including tensile strength, the higher the percentage of catalyst, the greater the tensile strength of the composite.

3.2 Impact Test Results and Discussion

As with the tensile test, the impact test in this study was also carried out on six different specimens coated with 2 layers with 1%, 1.5%, and 2% catalyst and 3 layer specimens with 1%, 1.5%, and 2% catalyst percentage.

Spesimen	Lebar (mm)	Tebal (mm)	α	β	Tenaga Patah (Joule)	Harga Keuletan (Joule/mm^2)
1%	13,17	0,6	140	125	9,016	0,112
1,5%	13,17	0,6	140	131	5,152	0,064
2%	13,17	0,6	140	134	3,342	0,041

Figure 09. 2 layer impact test results

Based on the data generated from the specimen testing, it can be seen that the highest fracture power value is owned by the 2 layer (1%) specimen with a fracture power value of 9.016 Joules, this value is much higher when compared to other specimens, namely the 2 layer (1.5%) specimen with a value of 5.152 Joules and the 2 layer (2%) specimen which only reaches 3.42 Joules.

Figure 10. Impact test of 2 layer specimen (1%)

Impact test on 3 layer specimens with 1%, 1.5%, and 2% catalyst. This test was conducted to determine the fracture strength of each specimen.

Spesimen	Lebar (mm)	Tebal (mm)	α	β	Tenaga Patah (Joule)	Harga Keuletan (Joule/mm^2)
1%	13,17	0,6	140	131	5,152	0,064
1,5%	13,17	0,6	140	133	3,935	0,049
2%	13,17	0,6	140	132	4,535	0,056

Figure 11. 3-layer impact test results table

Referring to the table attached above, it can be seen that the highest impact value in the 3-layer specimen is found in the 3-layer specimen (2%) with a value that reaches 5.152 Joules. This value is higher when compared to the value of other specimens, namely specimens with 1.5% and 2% catalyst.

Gambar 12. Uji impact spesimen 3 layer (1%).

The test results on 2 and 3 layer specimens show relatively similar results where the highest value is owned by specimens with a percentage of 1% catalyst. However, this study does not fully guarantee that the smaller the percentage of catalyst in the composite, the greater the impact strength of the composite, this is because the 3 layer specimen (1.5%) has a smaller fracture strength value than the 3 layer specimen (2%). The results shown in the layer 3 specimen are inversely proportional to the layer 2 specimen which shows a higher value at a small percentage of catalyst.

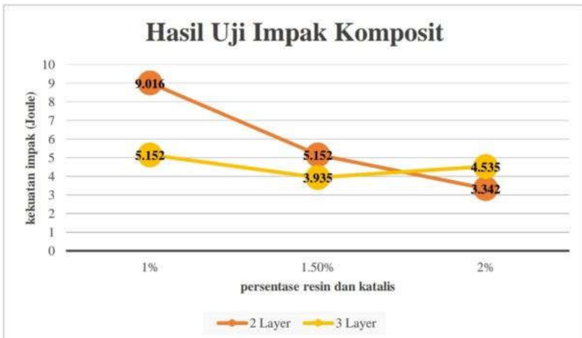

Figure 13. Impact test results chart

4. DISCUSSION

The percentage of catalyst and resin in making composites is one of the things that must be considered, so because the percentage of these two materials will affect the mechanical properties of composites including tensile and impact strength. Based on the research that has been done, the highest tensile value is obtained from the test results of specimens 2 and 3 layers (2%) with values of 52.48 and 70.98 (N/mm^2) so it can be concluded that the greater the percentage of catalyst and resin, the greater the tensile strength of the composite. In contrast to the tensile test results, the impact test obtained the highest results in specimens 2 and 3 layers (1%) with a value of 9.016 and 5.152 Joules, it can be concluded that the smaller the percentage of catalyst, the greater the impact strength possessed by *carbon fiber* reinforced composites. Based on this research, it can be concluded that the percentage of resin and catalyst can affect the tensile and impact strength of the composite, however, this value cannot be fully trusted considering that this research was carried out manually using the hand lay up method so that many factors affect the test material, for example air trapped in the composite is uneven and so on which causes unevenness in the test material. Therefore, future research is expected to use more competent testing equipment in order to produce satisfactory results.

AUTHORS' CONTRIBUTIONS

F. N. A. S contributed to all research processes, starting from submitting the title, planning, making test materials, testing specimens, analyzing data, and writing scientific papers.

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