Manufacture of polymeric foam and polyurethane composites with fiberglass boosters

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Abstract. The purpose of this research is to know the mechanical characteristics of polymeric foam and polyurethane with fiberglass reinforcement. The focus of the observations on the average maximum compressive force, mean maximum stress and elastic modulus where the observed characteristics are obtained from static press test. Furthermore, tensile testing is performed to observe the mechanical characteristic of mean maximum force, mean maximum stress and elastic modulus. The polymer as a matrix is use 157 BQTN-EX with thermoset resin with fiberglass reinforcement. Tensile test specimens were made according to ASTM D638 standard and ASTM 1621-00 standard for static press test. Three variation of composition is A, B and C where fiberglass used 10%, catalyst 5%, resin 55% and polyurethane 30%. The test result showed that the test specimen on composition C value of characteristic compressive force average 22.838 kN, the mean maximum compressive stress average 19.128 MPa and average modulus of elasticity is 161.447 MPa. While on tensile test the variation of material composition with the same fiber was obtained on compositional test specimen C value of the mean gravity characteristics of the average maximum of 1.214 kN, the mean maximum tensile stress is 20.243 MPa and average modulus of elasticity is 803.634 MPa.

1. Introduction
The development of science and sustainable technology, especially in the manufacturing industry is a very good prospect [1]. Polymeric foam composites are an alternative material that can compete with conventional materials. The excellent physical and mechanical properties of this composite material are the driving factors of increasing market demand. Variations of materials are used to produce good mechanical characteristics [2]. Composites with synthetic fibers are continuously conducted research to obtain alternative materials metal substitute that has strong properties, tough and light [3]. The composite is a combination of two or more materials formed in which the mechanical properties of the constituent material differ, in which one material as the filler phase (matrix) and the other as the reinforcing phase [4]. The natural fibers reacted with the 157 BQTN-EX polyester resin can enhance dimensional stability and stiffness. Focuses the research on fabrication and analysis of material strength to obtain the right polymeric foam composition with fiberglass content. The purpose of this study was to generate mechanical characteristics due to static and tensile presses. Where
Characteristics to be generated are compressive forces, compressive stresses and modulus of elasticity [5]. Composite materials are materials made of two or more constituents with different physical (chemical) properties, when combined will produce materials with different characteristics and structures [6]. Fiber-reinforced composites are widely applied to tools that require materials that have two basic properties, namely strong and lightweight [7]. Fiberglass used as reinforcement, corrosion resistant and chemically resistant [8]. Catalyst administration aims to accelerate the polymerization reaction of the composite structure at room temperature and atmospheric pressure. The catalyst is used from Methyl Ethyl Ketone Peroxide (MEKPO) type. The matrix used is the unsaturated thermoset resin 157 BQTN-Ex [9]. Typical mass, tensile strength, and resistivity modulus of 157 BQTN-Ex are 1215 kg / m3, 55MPa, and 3000 MPa. Blowing agents are materials used to produce hollow structures on composites that are formed. Type of Blowing Agent used in this research is Polyurethane the forms is Polyol and isocyanate [10].

There are several methods of making composite materials such as: direct casting method, compression or pressure method and pressure and heat methods. This research making compression or pressure methods.

2. The relationship of stress and strain.
Tensile strength is measured by pulling composite test specimen with uniform dimension. The tensile stress \( \sigma \), is a delicate force \( F \), divided by the cross-sectional area \( A \), the equation is:

\[
\sigma = \frac{F}{A}
\]  

(1)

\( \sigma \) = Tensile stress (N)

\( F \) = Working force (N)

\( A \) = Area of cross section (mm)

The test result of a tensile extension, \( \varepsilon \), is the change in the length of the sample, \( \Delta l \), divided by the initial length, \( l \), the equation is:

\[
\varepsilon = \frac{\Delta l}{l}
\]  

(2)

The ratio between stress and strain in the elastic boundary is called the constant of proportionality \( E \). Another name of this constant is called young’s modulus or the modulud of elasticity. \( E \) is a measure of the stiffness of a materials since strain is dimensionless, the unit of \( E \) are the same as stress. The equation is shown in:

\[
E = \frac{\sigma}{\varepsilon}
\]  

(3)

Which:

\( E \) = Modulus of Elatisitas (MPa)

\( \sigma \) = Tensile Stress (N)

\( \varepsilon \) = Strain
3. Materials and Methods

This research was conducted at the Laboratory of Impact and Fracture Research Central (IFRC) Department of Mechanical Engineering Universitas Sumatera Utara.

3.1 Tools

Some of the auxiliary equipments used in this study include stirring bowls, stirrer bars, fiber-cutting shears, gloves, masks, digital scales and specimen prints. The mixing aids serve as a mixing medium for some composite materials.

3.2 Measuring tool

Digital scales for measuring the mass and volume of matrices, fiberglass and catalysts with units of ml. Measuring cup to measure the volume of the 150 ml capacity matrix.

3.3 Test equipment.

In the static press test and specimen tensile test carried out using a special test machine that is Servo Pulser Shimadzu. The test machine is capable of measuring the maximum compressive load up to 2000 Kgf with adjustable press speed as desired.

3.4 Materials Used

The production process of specimen is based on the printed volume of each test. The large correlation of volume between matrix, fiber and composite can be seen in the following equation:

\[ V_C = V_S + V_M \]  \hspace{1cm} (4)

Where:
- \( V_C \) = Composite volume (ml)
- \( V_S \) = Volume of fiber (ml)
- \( V_M \) = Volume matrix (ml)

For static press test the composition is A, B and C. Specifically for composition A the volume value of the resin is 65\% of the total composite volume, if the total volume of 83 ml tensile test specimen, the required resin volume is 65\% x 83 ml = 53.95 ml or if it is rounded to 54 ml. Each material material can be seen in Table 1:

| Constructing Materials | Composition A | Composition B | Composition C |
|------------------------|---------------|---------------|---------------|
|                        | % (ml)        | % (ml)        | % (ml)        |
| Resin                  | 65 (53.95)    | 60 (49.8)     | 55 (45.65)    |
| Blowing Agent          | 20 (16.6)     | 25 (20.75)    | 30 (24.9)     |
| Katalis                | 5 (4.15)      | 5 (4.15)      | 5 (4.15)      |
| Fiberglass             | 10 (8.3)      | 10 (8.3)      | 10 (8.3)      |

For tensile compression test the A, B and C compositions are the same as the compressive test, but different only at the total composition of volume.

3.5 Stage of fiber processing.

Fiberglass cut short using scissors along the 2-3 mm. Both the compositions A, B, and C in the static and blistering test of each fiber volume of 10\%. For static press test measure 10\% fiberglass volume of total polymer composite volume of 10\% x 83 ml = 8.3 ml. While for tensile fiberglass volume test 10\% x 8.8 ml = 0.88 ml.
3.6 **Stage of blowing agent forming.**
This material is used to produce a hollow structure in the composite forming process. Blowing agent is made of polyurethane which consists of two materials, polyol and isocyanate. The volume varies where each composition is different in value. If on static compressive test of composition A, 20% blowing agent volume, then its total volume is 20% x 83 ml = 17 ml. While on the composition test A blowing agent 20% x 8.8 ml = 1.76 ml.

3.7 **Stage printing of test specimens**
Rub the inner surface of the mold with wax. Insert fiberglass into a saucer containing a flat stirring resin. Enter the catalyst solution and mix well. Polyol and isocyanate solutions are slowly introduced into the resin, fiber and MEKPO solution. Insert the solution into the mold by gently pressing. At least 72 hours the mixture will dry out, after drying out from the mold. Static compression test specimen and tensile test specimen has been formed according to ASTM D1621-00 standard as shown Figure 1 and 2.

![Figure 1 Specimen Static press test specimen A, B and C](image1)

![Figure 2 Compression tensile test specimens A, B and C](image2)

3.8 **Phase testing of specimens.**
The static press test and tensile testing were performed to obtain the mechanical characteristics of the material carried out in the laboratory of Impact and Fracture Research Center (IFRC) Master of Mechanical Engineering Faculty of Engineering, Universitas Sumatera Utara.

4. **Results And Discussion**
This study focuses on the fabrication and analysis of material strength to obtain the correct polymeric foam composition with fiberglass content and mechanical characteristics obtained from static press testing and tensile testing. Testing static press done using Servo Pulser Shimadzu engine. The main focus of this test is to find out the average maximum compressive force, average stress and elastic modulus. The tensile test is carried out using the Shimadzu Servo Pulser engine also with the main focus of the test to find out the maximum tensile force, maximum tensile stress and elastic modulus.

4.1 **The process of making polymeric foams**
Fiberglass fiber that has been cut short measure according to composition needs, then mix with resin according to the composition and mix well. To speed up the polymerization, insert the catalyst according to the composition and mix well. within 5 minutes this process will be completed. Combine polyol and isocyanate and stir for 0.5 minutes aja. Then mix the fiber solution with this polyurethane solution. If it is finished directly insert into the mold that has been smeared wax. Within 3x24 hours the test specimen has been completed.

4.2 **Mechanical characteristics of polymeric foam**
Mechanical characteristics were obtained by several tests, including: Static press test, the static press test is carried out by using the static test machine Servo Pulser Shimadzu until the load reaches 2000
kgf, test specimen based on ASTM D1621-00 standard. Static press tests are carried out in several compositions in which each composition is performed at least three times the test. The test results of each specimen shows the value of each other so that this value is considered true. The focus of tensile stress tests on the maximum stress and strain and the modulus of elasticity. The static test specimen is shown in Figure 3.

![Graph stress vs strain grade test specimens A](image)

**Figure 3** Graph stress vs strain grade test specimens A

The highest stress value of the compressive test is on specimen A1 with a value of maximum pressure 17.248 MPa. Specimen A2 with a value of stress 15.042 MPa and specimen A3 with a value of stress 11.627 MPa, so an average maximum stress value is 14.639 MPa.

![Graph stress vs strain test specimen B](image)

**Figure 4** Graph stress vs strain test specimen B

The highest stress value of the compressive test is found on specimen B1 with a value of a maximum pressure of 18.038 MPa, specimen with a value B2 15.171 MPa and specimen B3 with a value is 14.102 MPa, so an average maximum stress value is 15.770 MPa.
Test specimen C2 value Maximum tension 21.717 MPa with an average maximum stress value 19.128 MPa. Thus, the test results for specimens A, B and C on static press testing of the highest test value are on test specimen C (C2) with a value of compressive stress of 21.717 MPa. While the value of the maximum stress of 19.128 MPa average. The value is summarized as we see in the following table:

| Specimen | Force (kN) | Strain (mm) | Stress (MPa) | Modulus Young (MPa) | Average Force (kN) | Average Stress (MPa) |
|----------|------------|-------------|--------------|---------------------|--------------------|---------------------|
| A1       | 20.594     | 0.3105      | 17.248       | 55.55               | 17.478             | 14.639              |
| A2       | 17.96      | 0.2302      | 15.042       | 65.344              |                    |                     |
| A3       | 13.882     | 0.2629      | 11.627       | 44.226              |                    |                     |
| B1       | 21.537     | 0.082       | 18.038       | 219.984             | 18.831             | 15.770              |
| B2       | 18.114     | 0.0606      | 15.171       | 250.357             |                    |                     |
| B3       | 16.838     | 0.0724      | 14.102       | 194.79              |                    |                     |
| C1       | 21.888     | 0.1072      | 18.332       | 171.012             | 22.838             | 19.128              |
| C2       | 25.929     | 0.0979      | 21.717       | 221.83              |                    |                     |
| C3       | 20.699     | 0.0754      | 17.336       | 229.931             |                    |                     |

Tensile press testing, the static press test is carried out by using the static test machine Servo Pulser Shimadzu up to load of 2000 kgf, test specimen based on ASTM D1621-00 standard. Static press tests are carried out in several compositions in which each composition is performed at least three times the test. The test results of each specimen shows the value of each other so that this value is considered true. The focus of tensile stress tests on the maximum stress and strain and the modulus of elasticity. The static test specimen is shown in the following Figure 6.
A test specimen obtained by the maximum tensile stress value on A3 specimen is 23.244 MPa with an average maximum stress value of 18.011 MPa.

In specimen B, the maximum stress value obtained on the B3 specimen is 27.154 MPa with an average rated average value of 18.011 MPa.
The maximum press stress of compressive testing is found on specimen C3 with 26,092 MPa with an average maximum stress value of 20,123 MPa.

Thus the test results for specimens A, B and C at the highest test of tensile test value are on test specimens C (C1) with a maximum tensile value of 27.154 MPa. While the value of tensile stress Maximum average 20.243 MPa. The value is summarized as we see in the following table:

| Specimen | Force (kN) | Strain (mm) | Stress (MPa) | Modulus Young (Mpa) | Average Force (kN) | Average Stress (MPa) |
|----------|------------|-------------|--------------|--------------------|-------------------|---------------------|
| A1       | 0.641      | 1.09        | 10.697       | 354.09             | 1.08              | 18.004              |
| A2       | 1.205      | 2.048       | 20.092       | 730.636            |                   |                     |
| A3       | 1.394      | 2.369       | 23.224       | 1037.714           |                   |                     |
| B1       | 1.04       | 1.767       | 17.334       | 1025.696           | 0.920             | 15.344              |
| B2       | 0.092      | 0.157       | 1.545        | 117.944            |                   |                     |
| B3       | 1.629      | 2.768       | 27.154       | 1534.128           |                   |                     |
| C1       | 1.11       | 0.02        | 18.516       | 907.665            | 1.214             | 20.243              |
| C2       | 0.967      | 0.017       | 16.122       | 910.888            |                   |                     |
| C3       | 1.565      | 0.042       | 26.092       | 613.952            |                   |                     |

Through tensile testing found on specimen A3 with a value of maximum tension 23.244 MPa with an average maximum stress value of 18.011 MPa. The highest stress value of the compressive test is in the specimen B3 with a maximum pressure value of 27.154 MPa with an average maximum stress value of 18.011 MPa. The highest stress value of the compressive test is present in specimen C3 with a maximum value of 26.092 MPa with an average maximum stress value of 20.123 MPa.
The achievement of the maximum tensile stress is obtained on test specimen C with an average maximum stress of 20.123 MPa. The C test specimen with 55% resin composition, 35% polyurethane, 5% catalyst and 10% fiberglass can be used as guidance for the application of the manufacture of alternative material.

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