International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I11P210

Volume 69 Issue 11, 83-88, November, 2021

The Effect of a Mixture of Epoxy Resin Matrix Composite Materials and Hardener by Varying the Stirring Speed on The Mechanical Properties

Zainun Achmad[1], Al Emran Ismail [2], Ahmad Hamdan[3]

[1]*Department of Mechanical Engineering, University August 17, 1945, Surabaya, Indonesia.*
[2,3]*Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Batu Pahat 86400 Johor, Malaysia.*

[1] hd190023@siswa.uthm.edu.my,[2] emran@uthm.edu.my; [3]ahmadh@uthm.edu.my

Abstract - *In this research, the process of making epoxy resin composites and hardeners as hardeners has been carried out; epoxy is a thermosetting chemical compound composed of carbon and oxygen atom bonds. This study aims to obtain good mechanical properties from the effect of a mixture of epoxy resin and hardener with varied stirring cycles. The mechanical testing method used in the tensile test is based on the D638 standard, the flexural test is based on the ASTM D790 standard, and the ASTM D256 impact test. The results showed that the sample preparation at a ratio of 10:01 with a stirring rotation of 100 rpm, 150 rpm, and 200 rpm, a ratio of 10:01 with a stirring rotation of 150 rpm for 5 minutes the casting results were still in a liquid state, while in a mixture of 10: While the value of the greatest tensile strength was obtained at 10:03 mixing with 100 rpm stirring speed of 20.27 MPaand the smallest is obtained at a ratio of 10:4 with a stirring rotation of 200 rpm of 15.71 MPa, for the bending stress obtained at a ratio of 10:4 with a stirring rotation of 200 rpm of 78.46 GPa and the smallest is obtained at a ratio of 10:03 with a stirring rotation 100 rpm of 45.20 GPa, while the largest impact strength was obtained at a ratio of 10:03 with a stirring speed of 150 rpm of 199.46 kJ/m^2 and the smallest was obtained at a ratio of 10:03 with a stirring rotation of 200 rpm of 94.73 kJ/m^2.*

Keywords - *epoxy resin, resin hardener, tensile strength, bending strength, impact strength*

I. INTRODUCTION

Composites are becoming more attractive and competitive with traditionally available metal/ceramic materials and parts due to their significant advantages. The use of composites is increasing according to current needs, for example, for automotive components, namely, buckets, oil pans, bumper shafts, vehicle bodies, ship bodies, aircraft bodies, etc. The use of composite materials is not only limited to the application of certain technologies such as spacecraft but continues to develop new material innovations, low prices, and the development of manufacturing processes has increased to raise composite materials in almost every industrial sector. Composites have also been considered as the material of choice for certain industrial sectors. [1] [13][42].

Composite is a mixture of two or more materials, which have different chemical and physical properties and produce a new material with significantly different physical or chemical properties that remain separate and distinct in the final structure. Polymer is defined as large molecules (macromolecules) formed from several molecular units (monomers) repeatedly. The monomer-monomer reaction is called a polymerization reaction, where the chemical bonds of the polymer have a linear, branched, and cross-linked chain structure pattern and network. There are three types of polymers, namely thermoplastic, thermoset, and elastomer [2][5].

Epoxy resin is defined as a molecule with more than one epoxy group that can be hardened into usable plastic. The polymers are usually epoxy, vinyl ester, or polyester thermoset plastics, and phenol-formaldehyde resins are still used. The resin properties depend on several factors such as the pre-polymer structure, the curing agent, the stoichiometry between the resin and the hardener, curing time, and curing temperature. In general, regardless of the type and amount of hardener, curing time, and temperature, epoxy resins exhibit high strength and modulus and have high wear resistance and crack resistance properties. [7][9][44].

Various thermosets can also process the Epoxy resins with little shrinkage and non-volatileduring the curing. In general, epoxy resins have good durability and good dimensional stability.[44]. The epoxy ratio was shown to strongly influence the mechanics by which the epoxy system was formed due to the curing rate and latent presence by difunctional epoxy monomer, diglycidyl ether from the unreacted site, strongly influenced by bisphenol-A (DGEBA) epoxy hardener, and Hexa-functional aliphatic ratio, and for room temperature cured resin [45].

The Epoxy resin is a thermoset resin that is hardened with preservatives whose properties are in accordance with the combination of preservatives used. The hardener material is the material that causes the curing process to occur because the hardener has two materials, namely an accelerator and a catalyst, where both of these materials will cause heat, and this heat accelerates the drying process.[8][9][14].

The mechanical properties can be adjusted according to the chemical properties of the epoxy resin according to the required value depending on the specific application, the epoxy resin depends on the amount, and Epoxy resin is a thermoset resin that is hardened with preservatives whose properties are in accordance with the combination of preservatives used. The hardener material is the material that causes the curing process to occur because the hardener has two materials, namely an accelerator and a catalyst, where both of these materials will cause heat, and this heat accelerates the drying process.[37][38].

To determine the effect of the epoxy resin mixture on the mechanical properties of the composite matrix with the compression moulding model for 16 hours, it is known that the highest tensile strength properties are obtained in the ER 60-40 mixture, the flexural strength is obtained in the ER 62-38 mixture, while the greatest impact strength is obtained in the ER 60-40 mixture. mix ER 55-45 [36]

This research was conducted to determine the effect of the ratio of epoxy resin and resin hardener on the mechanical properties. The process of mixing epoxy resin and resin hardener with a ratio of 10:01, 10:02, 10:03, and 10:04, and each variation was stirred at 100 rpm, 150 rpm, and 200 rpm for 5 minutes, then poured into a mould with a given pressure of 40 kg for 48 hours. Furthermore, the results of the mould in the form of slabs are made of mechanical test objects, namely tensile test objects, flexural tests, and impact tests.

II. EXPERIMENTAL PROCEDURE

A. Materials

The material used in this research is Thermosetting Plastic, namely Epoxy Resin with the trademark Bakelite EPR 174 from Korea and Hardener Resin with the brand Versamid 140, marketed in Indonesia by PT. Justus Kimia Raya Surabaya Branch. Mixing Epoxy Resin and Hardener Resin compared 4 variations, namely 10:2, 10:3, 10:4, and 10:5, and each variation of the ratio was mixed and stirred at 100 rpm, 150 rpm, and 200 rpm, respectively. For 5 minutes.

Experiments are carried out by providing certain treatments that can affect the response value. Before experimenting, preparations were made for bio-composite production machines, injection moulding machines, testing machines, and bio-composite materials.

B. Research Equipment

The equipment used in this study were:

a) Mixer Machine
   The stirrer machine is used to stir the epoxy, filler, amplifier, and hardener at a certain speed and time. The mixer machine is equipped with speed regulation because speed and stirring are the process variables under study.
b) Molding
   This mold serves as a mold from a mixture of Epoxy, Hardener, and Fly Ash. The mold is made of steel with a size diameter of 29 cm.
c) Mechanical tests are carried out to determine the mechanical properties, namely tensile strength and Flexural strength.

C. Manufacturing Process

Epoxy resin and hardener resin are mixed in a container in accordance with the ratio, which has been determined, then stirred until evenly distributed at a predetermined speed for 5 minutes. Pour the mixture into a mould with a diameter of 29 mm until evenly distributed, then the curing process is carried out according to room temperature for approximately 2 hours and is still liquid, then the mould is closed with a cover made of steel with a cover weight of 40 kg for 48 hours until the mould dries. After drying, the composite mould can be removed and made into a slab. Then the composite slab is made of four specimens for tensile, bending, and impact tests in accordance with ASTM standards and then cut using a CNC machine and ready for testing.

D. Mechanical Properties Testing

Mechanical testing to determine the mechanical properties, namely tensile strength and flexural strength. Tensile test using the method with the standard ASTM D638. See ASTM D638 for tensile strength testing with the Universal Testing Machine. The number of samples is 4 in each variation. The sample is a slab from a printing machine weighing 40 kg for 48 hours, and then the sample is cut according to the shape of the test object based on ASTM standards.

Flexural testing using ASTM D790-02 standard using Universal Testing Machine. The dimensions of the test object with a beam length of 100mm, a span length of 50.8mm, a beam thickness of 3.5 mm, and a beamwidth of 12.7mm.

Making impact test specimens according to ASTM D256, with specimen dimensions of 66.5 x 12.7 mm and thickness according to the thickness of the test material. The resulting energy parameters are impact energy and impact strength.

III. RESULTS AND DISCUSSION

The basic ingredients in the initial research were epoxy and hardener mixed with varying ratios of 10:1, 10:2, 10:3, and 10:4. The result of the manufacture is in the form of a slab, and then the specimen is made, as shown in Figure 3.1. While the results of the tensile, flexural, and impact tests can be seen in table 3.1. Making use of matricesEpoxy or polyepoxide is a thermosetting epoxide polymer that improves when mixed with a catalytic agent or hardener. Polyester resin is the most used thermosetting resin in the manufacture of composites.

The catalyst that is often used as a medium to accelerate the hardening of curing resin liquid is methyl ethyl ketone peroxide hardener. The level of use of hardener is that it can be processed at room temperature. Curing is a drying process to change the resin binding material from a liquid state to a solid-state. This curing occurs through a radical copolymerization reaction between vinyl-type molecules that form cross-links through the unsaturated portions of the polyester. Polyester means a polymer composed of monomers containing an ester group.

Fig.3.1 Casting Slabs and Mechanical Test Objects

Fig.3.2 Soft Plate

TABLE 3.1. TENSILE TEST RESULTS OF EPOXY-HARDENER SAMPLES AT 100 RPM FOR 5 MINUTES

Test Object Code	Results	Tensile Strength (MPa)	Flexural Strength (GPa)	Impact Strength (kJ/m²)
A-1	Liquid	-	-	-
A-2	Liquid	-	-	-
A-3	Well	20.27	45,20	110,20
A-4	Well	16.61	74.32	121.03

where A= Stirring speed 100 rpm, 1= Mixed Ratio 10:01, 2= Mixed ratio 10:02, 3= Mixed Ratio 10:03, and 4= Mixed ratio 10:04

TABLE 3.2. TENSILE TEST RESULTS OF EPOXY-HARDENER SAMPLES AT 150 RPM FOR 5 MINUTES

Test Object Code	Results	Tensile Strength (MPa)	Flexural Strength (GPa)	Impact Strength (kJ/m²)
B-1	Liquid	-	-	-
B-2	Mushy	-	-	-
B-3	Well	19.65	53.60	199.46
B-4	Well	15.71	78.45	112.18

where B= Stirring speed 150 rpm, 1= Mixed Ratio 10:01, 2= Mixed ratio 10:02, 3= Mixed Ratio 10:03, and 4= Mixed ratio 10:04

TABLE 3.3. TENSILE TEST RESULTS OF EPOXY-HARDENER SAMPLES AT 200 RPM FOR 5 MINUTES

Test Object Code	Results	Tensile Strength (MPa)	Flexural Strength (GPa)	Impact Strength (kJ/m²)
C-1	Liquid	-	-	-
C-2	Well	20,50	58,78	107.47
C-3	Well	16.58	74.30	94.73
C-4	Well	20.09	63.75	137.70

where C= Stirring speed 100 rpm, 1= Mixed Ratio 10:01, 2= Mixed ratio 10:02, 3= Mixed Ratio 10:03, and 4= Mixed ratio 10:04.

IV. DISCUSSION

In a mixture of Epoxy resin and hardener with a small ratio of 10:1, which is mixed and stirred at 100 rpm, 150 rpm, and 200 rpm for 5 minutes, then poured into the mold, in a few minutes, the mold is closed and pressed with a load of 40 kg for 48 minutes. Hours, then opened the mold still melted, while at a ratio of 10:2 at 100 rpm and 150 rpm, the prints were still liquid and mushy/melted. This is because the epoxy resin is highly dependent on the amount and type of hardener and process parameters. Thus, the amount of hardener, the ratio of Epoxy resin to hardener, and process parameters cause significant changes in most mechanical properties.

In Figure 3.3, the results of the tensile test of the specimen are presented to compare the epoxy resin composition with a hardener of 10:01 at 100 rpm, 150 rpm, and 200 rpm. With a ratio of 10:2 at 100 rpm, the mold is still liquid. In comparison, at a ratio of 10:02 at At 150 rpm, the prints are soft or stretchy; this is due to the inhomogeneity of the mixture and the lack of curing time because this curing occurs through a radical copolymerization reaction between vinyl-type molecules that form cross-links through the unsaturated portion of the polyester. Polyester means a polymer composed of monomers containing an ester group.

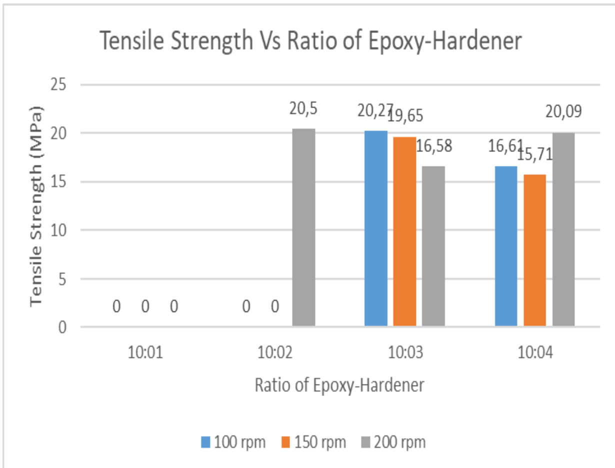

Fig.3.3 Tensile Strength Vs. The ratio of Epoxy and Hardener

If you see the results of the tensile test that the tensile strength has the highest value in this composition, at a ratio of 10:03 with a stirring rotation of 100 rpm of 20.27 MPa, then at a ratio of 10:04 and 10:02 with a stirring rotation of 200 rpm it has a tensile strength value. 20.09 MPa and 20.05 MPa. While the tensile test value at a ratio of 10:03 with 100 rpm, 150 rpm, and 200 rpm, the tensile strength decreased with increasing stirring speed, from 20.27 MPa to 16.58 MPa 18.20%. Then at a ratio of 10:04 at 100 rpm and 200 rpm, it increased from 16.61 MPa to 20.09 MPa or increased by 19.97%, while at 150 rpm, it decreased 6.60%.

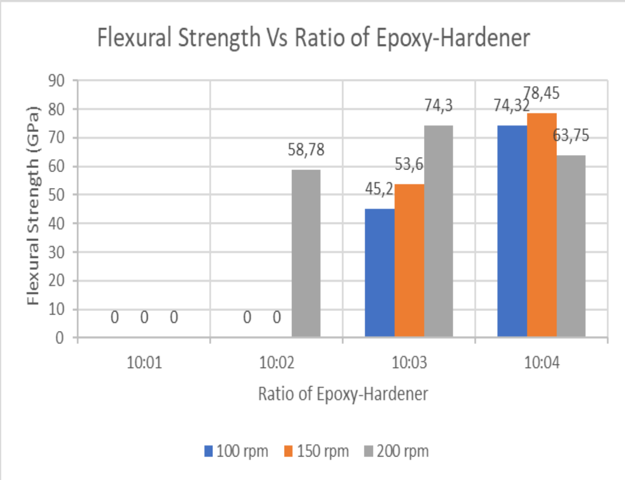

Fig. 3.4 Flexural Strength vs. Ratio of Epoxy and Hardener

The flexural strength graph shown in Figure 3.4 shows that the highest flexural strength is at a ratio of 10:03 epoxy hardener with a stirring speed of 100 rpm of 17.68 GPa. While the 10:4 ratio at the same stirring cycle has a flexural strength value of 6.84 GPa, there is a decrease in flexural strength of 61.31%. At a ratio of 10:03 and 10:04 with a stirring rotation of 150 rpm, the flexural strength value increased by 61.29% from 4.65 GPa, while at a ratio of 10:02 with a rotation of 200 rpm, the flexural strength of 5.39 GPa was not adrift. Large with a ratio of 10:04, which is 5.60%. In Figure 4.3, it can be seen that the ratio of epoxy and hardener is 10:01 at 100, 150, and 200 rpm for 5 minutes, the mixture of epoxy and hardener in a press mold for 48 hours the results of the mold are still in a liquid state. While at a ratio of 10:2 at a stirring rotation of 100 rpm and 150 rpm, the prints are still in a liquid state, and soft Mark

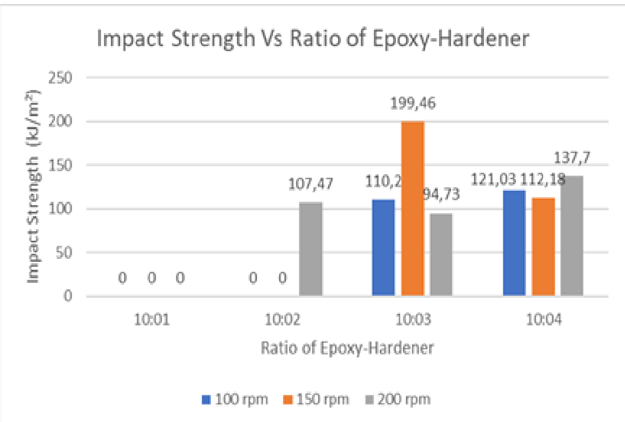

Fig. 3.5 Impact Strength Vs. The ratio of Epoxy and Hardener

In Figure 3.4, the impact strength of the epoxy resin above, it can be seen that the sample ratio of epoxy hardener 10:3 with a stirring rotation of 150 rpm gives an impact strength value of 199.46 kJ/m², where the value of this impact strength is the highest or largest impact strength value among the ratios. epoxy hardener on top. Furthermore, a ratio of 10:4 with a rotation of 200 rpm gives an impact strength value of 137.70 kJ/m². At a ratio of 10:3 and a ratio of 10:4 with a stirring rotation of 100 rpm, the impact strength increased from 110.2 kJ/m² to 121.03 kJ/m² or 9.82 %. In Figure 4.3, it can be seen that the ratio of epoxy and hardener is 10:1 at agitation cycles of 100, 150, and 200 rpm for 5 minutes, the mixture of epoxy and hardener in a press mold for 48 hours the results of the mold are still in a liquid state. While at a ratio of 10:2 at a stirring rotation of 100 rpm.

The tensile strength resulting from the tensile test in each mixing and stirring process at each ratio did not experience a significant change; namely, the lowest was 15.71 MPa at a ratio of 10:04 with a stirring rotation of 150 rpm, and the highest was 20.27 MPa at a ratio of 10: 03 with a stirring speed of 200 rpm, as shown in Figure 3.5 and Figure 3.6. Likewise, the flexural strength resulting from the 10:04 ratio of epoxy and hardener mixed and stirred at 100 rpm, 150 rpm, and 200 rpm, respectively, did not experience significant changes, namely 6.84 GPa, 7.5 GPa, and the lowest 4.5 GPa. Likewise, the 10:03 ratio with 100 rpm has a higher flexural strength of 17.68 GPa or 61.31% greater than the flexural strength at a 10:04 ratio at the same rotation.

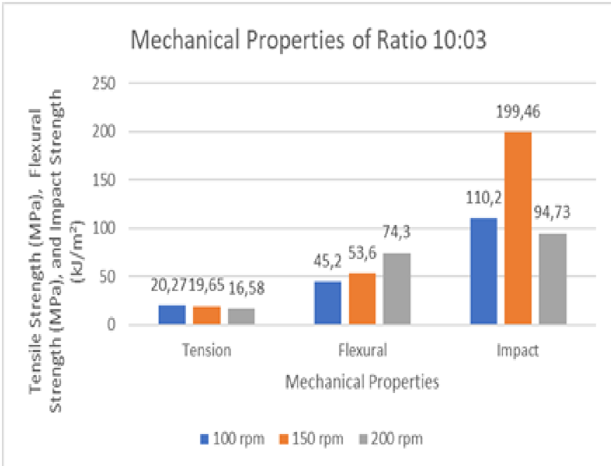

Fig.3.6 Mechanical properties at a ratio of 10:03 (Epoxy-Hardener) with variations in stirring rotation

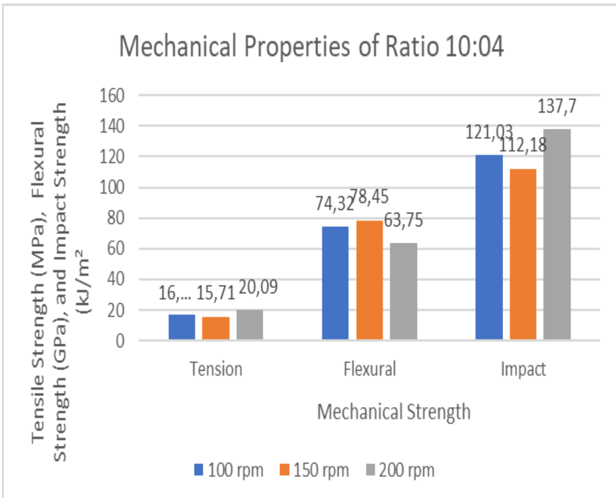

Fig.3.7 Mechanical properties at a ratio of 10:04 (Epoxy-Hardener) with variations in stirring rotation

The highest impact strength resulted from the impact test for a 10:04 ratio at 200 rpm, which was 137.70 kJ/m², and at 100 rpm, it had an impact strength of 121.03 kJ/m², and at 150 rpm, it decreased by 7.31%. While at a ratio of 10:3 with a rotation of 100 rpm, the impact strength value is lower than the ratio of 10:04 at the same rotation, which is 8.95%, and at a rotation of 150 rpm, it has a higher impact strength of 43.76%, while at a rotation of 200 rpm lower 45.36%. From Figures 3.6 and 3.7it, the value of the ratio is 10:03 at 100 rpm, 150 rpm. And 200 rpm has a value of tensile strength, flexural strength, and impact strength on average higher than the 10:04 ratio.

Thus, from the description above, it can be stated that the value of tensile strength and impact has increased, followed by a decrease in the value of flexural strength or vice versa, and this occurs in each rotation of the epoxy and hardener stirring.

From the above description, the low tensile strength capacity can be attributed to the relative excess of resin monomers. There will not be enough hardener to form cross-links as soft spots such as voids in the polymer structure can lead to crack initiation (42). This happens because of the inhomogeneity of the mixture so that the formation of voids in the sample is predicted. The volume fraction of the hardener increases in the composition of the epoxy resin, the harder the hardness increases (37).

V. CONCLUSION

Based on the above discussion, it can be concluded that in sample preparation at a ratio of 10:01 with a stirring rotation of 100 rpm, 150 rpm, and 200 rpm, a ratio of 10:01 with a stirring rotation of 150 rpm for 5 minutes the casting results were still in a liquid state, while at a mixture of 10:2 at a stirring rotation of 150 rpm the resulting mould is a soft slab. While the value of the greatest tensile strength was obtained at 10:03 mixing with 100 rpm stirring speed of 20.27 MPa.and the smallest is obtained at a ratio of 10:4 with a stirring rotation of 200 rpm of 15.71 MPa, for the bending stress obtained at a ratio of 10:4 with a stirring rotation of 200 rpm of 78.46 GPa, and the smallest is obtained at a ratio of 10:03 with a rotation of stirring at 100 rpm was 45.20 GPa, while the largest impact strength was obtained at a ratio of 10:03 with a stirring rotation of 150 rpm of 199.46 kJ/m², and the smallest was obtained at a ratio of 10:03 with a stirring rotation of 200 rpm of 94, 73 kJ/m².

ACKNOWLEDGMENT

This research is communicated through monetary assistance by Universiti Tun Hussein Onn Malaysia and the UTHM Publisher's Office via Publication Fund E15216.

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