CHAPTER 1

INTRODUCTION

1.1 Background

A composite material is formed by combination of two or more distinct materials to form a new material with enhanced properties. In automotive industry and aviation, fiber reinforced body are being used due to their extraordinary characteristics, especially in weight reduction, of the most vital design parameters for such application. Due to completely different material specifications between composites, the impact behavior of structures made by these materials also differs. The experiment is based on ASTM D 5628 Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Falling Dart which will investigate how a composite behave subjected to the falling impact. By introducing thermal aging, the effect of temperature parameter can be investigated. The material with best structure behavior will produce a small damage area and vice versa.

1.2 Problem Statement

As the fiber reinforced composite are used as structural materials, they are sometimes used in more complex environments such as in high temperature application. Under thermal loading, large stresses may develop in composite laminates due to the difference in the coefficient of thermal expansion of the fibers and the matrix. These environment is known to cause degradation of composite materials.. In order to be able to use such material in those application, we have to understand how they response when subjected to thermal aging. Impact test is very important to simulate how a structure or body behaves when an impact is applied. In real situation, any foreign object that falls or strike onto the structure will produce damage. Therefore, it is necessary to perform an experiment which will determine how the thermal aging will affect the integrity of that body or structure before the real structure is being produced or manufactured. Previous researchers have done the impact study using drop weight impact test, but they are only focuses on the normal sample without introducing the thermal aging. This study will help us in providing further information on how the composite material behaves when subjected to thermal aging.

1.3 Objectives

This project is mainly about study of impact characteristics of glass fiber reinforced composite by using drop weight impact test. The objectives of the study are:

i. To investigate the effect of thermal aging to the impact properties of glass fiber reinforced epoxy.

ii. To investigate the effect of volume fraction and fiber orientation.

1.4 Scope of work

Scope of work of this research are as below:

i. To fabricate the woven and chopped fiber reinforced composite plates using hand lay up method.

ii. To perform thermal aging to the composite plates.

iii. To investigate the effect of fiber volume fractions and fiber orientations.

iv. To carry out drop weight impact test based on ASTM D 5628.

v. To characterize the damage area by using ultrasonic inspection.

CHAPTER 2

LITERATURE REVIEW

2.1 Review on Previous Researcher's Works

A few studies have focuses on the impact response of fiber reinforced composites. Ross and Sierakowski [1] investigated the effect of impacts exerted by conical head impactors and observed delamination in glass epoxy plates by using a powerful light source. Hosseinzadeh et al. [2] studied the damage behavior of fiber reinforced composite plates subjected to drop weight impacts with the influence of different impact energies and moments. The study concluded that carbon fiber reinforced composite plates shows the best structural behavior under low velocity impacts meanwhile carbon/glass fiber reinforced (hybrid) plates show suitable behavior under high impact energy. Khalid [3] has studied the effect of testing temperature and volume fiber fraction on impact energy of aramid and glass epoxy composite using Charpy impact test. He concluded that impact energy increase with the increase of the test temperature. Hirai et al. [4] also has studied the effect of temperature on the low velocity impact response of vinyl-ester matrix composite reinforced with woven E-glass fabric. The study shows that the extent of damage and the residual properties of the laminates vary with testing temperature. The damage area increases with increasing temperature. Previous researchers have done the impact study using drop weight impact test, but they are only focuses on the normal sample without introducing the thermal aging. This study will help us in providing further information on how the composite material behaves when subjected to thermal aging.

2.2 Background of Composite Materials

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is normally harder and stronger than the continuous phase and is called the reinforcement or reinforcing material. While the continuous phase is called the matrix. [5]

2.2.1 Reinforcement material : Glass Fiber

Glass fiber is the most common of all the reinforcing fibers for polymer matrix composite. The advantage of glass fibers are the low cost and high strength. There are continuous type and discontinuous type of glass fiber. Woven roving is the continuous type and normally called long fiber while chopped-strand or discontinuous fiber is called short fiber (Figure 1). For structural application, two commonly used glass fibers are E-glass and S-glass. Some important properties of glass fiber is shown in Table 1.

Table 1: Properties of E-glass and S-glass fibers [5]

Property, units	**E-Glass**	**S-Glass**
Density, g/cm^3	2.54	2.49
Tensile strength, Mpa	3448	4585
Tensile modulus, Gpa	72.4	85.5

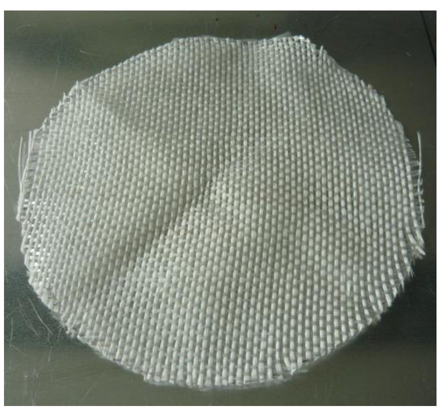

Figure 1 : Woven glass fiber

Figure 2 : Chopped glass fiber

2.2.2 Matrix : Epoxy Resins

The function of matrix is to bind the fibers together, transfer load to the fibers and protect them against environmental attack and damage due to handling. Epoxy resin, which is a thermosetting polymer, can be cured at room temperature. Some important properties of epoxy resins is shown in Table 2.

Table 2: Properties of epoxy resins (at 23^oC) [5]

Property, units	**Epoxy resin**
Density, g/cm^3	1.2-1.3
Tensile strength, Mpa	55-130
Tensile modulus, Gpa	2.75-4.10

2.3 Rules of mixtures

To fabricate the composite plate, it is compulsory to determine the proportions of matrix and reinforcement fibers to be used. The relative proportions can be referred by weight fractions or the volume fractions. The Rule of Mixtures is used to determine the correct proportion of the fiber and matrix.[5]

$$\mathbf{E_c = E_f V_f + E_m V_m}$$

Where E_c = Lamina modulus in fiber direction

E_f = Fiber modulus in fiber direction

V_f = Fiber volume fraction

V_m = Matrix volume fraction

E_m = Matrix modulus

This relationship is the same for for stresses (σ) and shear modulus (G)

To convert fiber volume fraction (FVF) to fiber weight fraction (FWF) :

$V_c = V_f + V_m$

$W_c = W_f + W_m$

$FVF = 1 \ [\ 1 + \rho_f / \rho_m \ (1/FWF-1)]$ -- (2.1)

To convert fiber weight fraction (FWF) from fiber volume fraction (FVF) :

$FWF = \rho_f \times FVF / [\rho_m + \{(pf- \rho_m) \times FVF\}$ -------------------------------------- (2.2)

Where :

FVF = Fiber volume fraction

FWF = Fiber weight fraction

ρ_m = Density of matrix (g/cm^3)

ρ_f = Density of fiber (g/cm^3)

The other formula to calculate the fiber volume fraction is ;

$V_f = \rho_m W_f / (\rho_f W_m + \rho_m W_f)$ -- (2.3)

Rearranging (3), the weight of the matrix can be calculated ;

$W_m = (\rho_m W_f - V_f \rho_m W_f) / V_f \rho_f$ -- (2.4)

Where :

Note that ;

V_f = volume fraction of fibers

W_f = weight of fibers

W_m = weight of matrix

ρ_f = fiber density

ρ_m = matrix density

2.4 Hand Lay-Up Technique

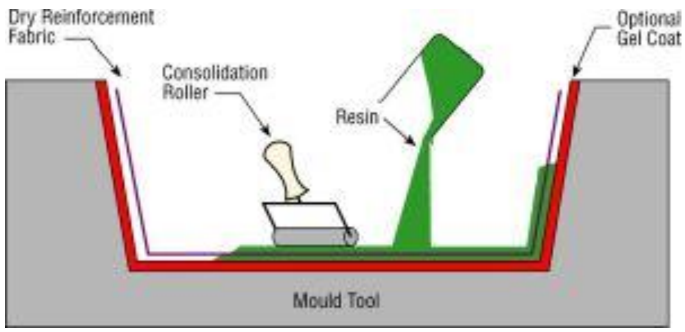

Figure 3 : Hand Lay-up Process [5]

The hand lay-up process may be divided into four basic steps : mold preparation, gel coating, hand lay-up and curing. After the desired mold has been obtained, several coats of wax are applied for the purpose of mold release. The example of release systems are wax, slicones, release papers and films and liquid internal releases. In hand lay up, the fiberglass is applied in the form of chopped strand mat or woven roving. Premeasured resin and catalyst (hardener) are then thoroughly mixed together. To ensure complete air removal, roller is used to compact the material against the mold to remove any entrapped air. After the hand lay up process is completed, the mold is allowed to cure. The time of the curing process is depend on the type of resin system being used.

2.5 Thermal Aging

Thermal aging is performed to simulate the effect of environmental condition such as high temperature to the designed composite material. There will be a degradation of material during that process. A temperature change in a body causes a change in its dimension proportional to the temperature change. In other words, a temperature change produces thermal strains in the body. The laminates are fabricated such that they act as a single-layer material. Thus each lamina influences the expansion or contraction of the other because their coefficients of expansion are different.[5] Differential coefficient of thermal expansion between fiber and matrix resin in a composite may lead to residual thermal stresses at the fiber/matrix interface and is a prime cause of thermal shock. Thermal expansion coefficients in polymers are considerably high. Thus the interfacial de-bonding may occur under extremes of temperature. Thermal shock also produces a large thermal gradient in a composite. The mismatch of the thermal expansion coefficient between fiber and matrix is the most important reason for residual stress in polymer composite. The fiber has a lower coefficient of thermal expansion than the polymer matrix. [6,7]

2.6 Drop Weight Impact Test

The purpose of this test is to study the impact resistance of a polymer or composite material by falling weight. Based on ASTM D 5628 – Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Falling Dart (Tup or Falling Mass) [8], a free falling dart (tup) is allowed to vertically strike a supported specimen directly. The test can vary the mass and of the drop weight according to the requirement of study. There are 5 test geometries can be chosen which can be seen from figure 3. For this project, the geometry C is used.

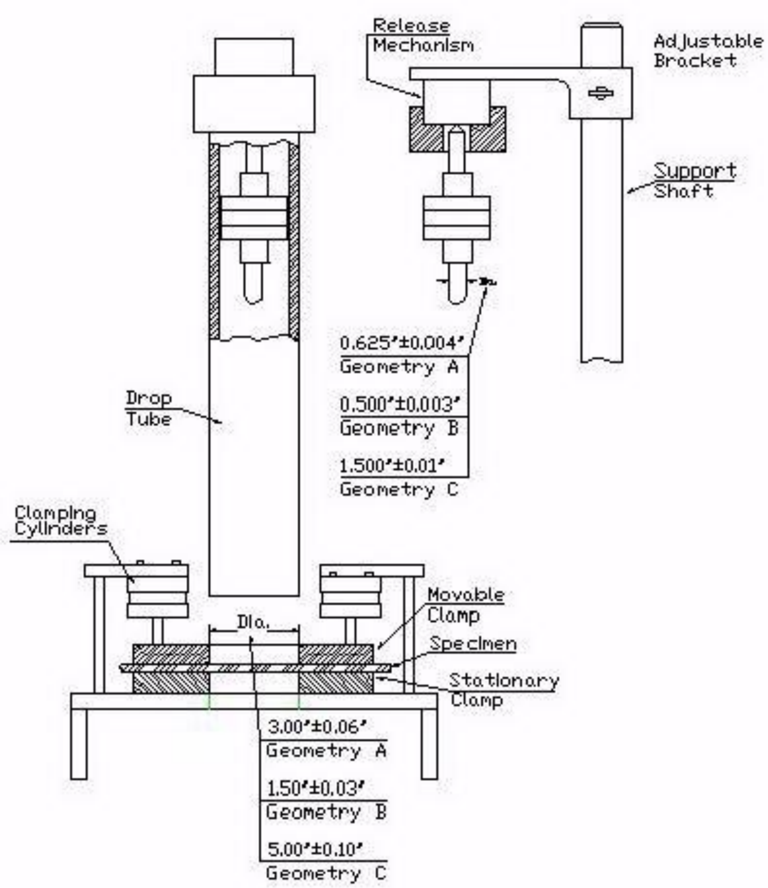

Figure 4 : Types of Falling Mass Impact Tester [8]

Based on ASTM D 5628, a free falling dart (tup) is allowed to vertically strike a supported specimen directly. The test can vary the mass and of the drop weight according to the requirement of study. There are 5 test geometries can be chosen which can be seen from figure 3. For this project, the geometry C is used. This geometry is being used because it can be used to test the proposed sample size. The geometry A, B, C, and D is not suitable because the sample size is smaller. So the geometry C is more suitable.

The drop tube will be 5 inch in diameter to ensure the weight (impactor) can fit into the drop tube.

Table 3 : Various Test Geometries in ASTM D 5628 [8]

Geometry	Dimension (in)	
	Tup Diameter	Inside Diameter Support Ring
A	0.625±0.004	3.00±0.12
B	0.500±0.003	1.50±0.03
C	1.500±0.010	5.00±0.10
D	0.500±0.010	3.00±0.12
E	0.787±0.008	1.57±0.08

2.7 Non Destructive Testing – Ultrasonic Inspection

Ultrasonic inspection is the most used nondestructive technique to detect the presence of manufacturing defects in composite parts. In order to evaluate the damage zone, two inspection methods are chosen which are visual inspection and ultrasonic inspection. Ultrasonic inspection will be used to inspect the sub surface damage . Any defect or damage such as delamination, resin crack and fiber crack can be detected by this method. For the damage at the surface of the plates, the damage zone will be observed through visual inspection. Ultrasonic measurements are used to detect internal damage in the composite structures. A piezoelectric transducer is placed on one surface of the specimen to introduce sound waves in the ultrasonic frequency range. Ultrasonic waves are reflected from the back surface of specimen as echoes. As the sound waves propagates through the material, some of them are interrupted by the presence of defects or materials discontinuities. Any echo reflected from discontinuities within the specimen will be received before the back surface echo.[5]

CHAPTER 3

METHODOLOGY/ PROJECT WORK

3.1 Project Methodology

The whole project is completed in two semesters. For the first semester, the major milestone is to modify the jig and complete the fiber configuration. The jig is basically already completed by another student. This project is continuation of his research. The modification being done to the jig is changing the drop tube height according to the proposed impact energy needed to be applied. For the second semester, the project proceed with the fabrication of the composite plates, performing thermal aging and conducting the impact test and finally analyzing the results. The project work flow for this project is shown in the flow chart in Figure 5.

3.2 Project Work Flow

The project is completed based on the project work flow which is shown in Figure 4. The project work flow is important to ensure the project work is done in sequence and systematic.

After the initial research work such as literature review is completed, the next step is to modify the test jig according to the standard ASTM D 5628 . Once the materials to fabricate composite plates are ready, the fabrication process takes place. After that, the thermal aging process being performed to the plates and finally the impact test being conducted and the results will be analyzed.

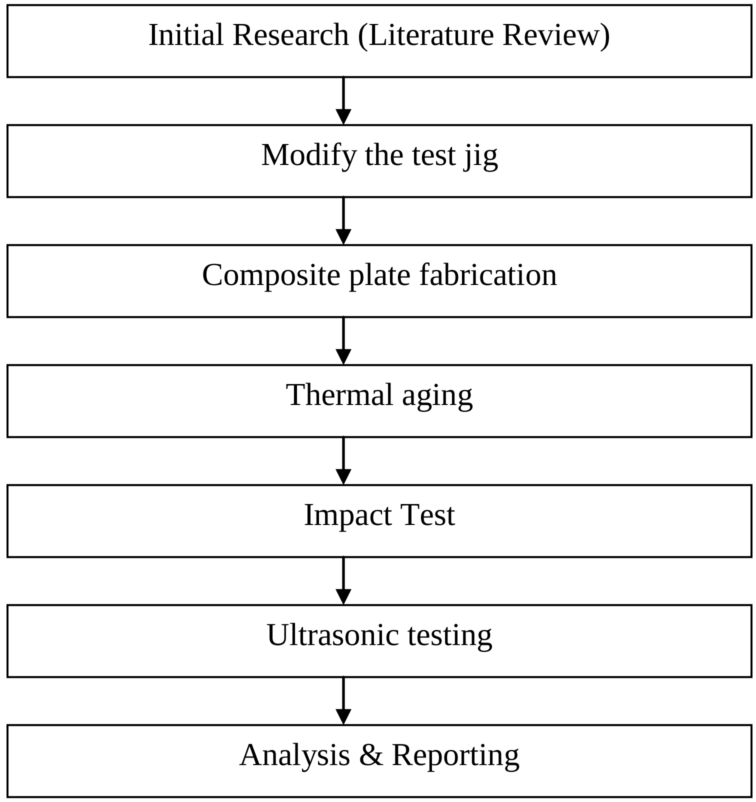

Figure 5 : Project Work Flow Diagram

3.3 Tools (Equipment, software, hardware)

The list of software needed for this project are shown in the Table 4 below.

Table 4 : List of software

Software	Function/use
Microsoft Excel	Composition calculation
Microsoft Office	Report writing

For the fabrication of the composite plates, the hardware required are shown in table 5 below.

Table 5 : List of hardware for fabrication

Hardware	**Function/use**
Roller	To remove excess air
Mold	To allow the fibers and matrix cure
Wax	As the release agent
Weight measurer	To measure the mixture
Fibers and matrix	Composite plates materials

For the impact test, the hardware required are shown in table 6 below.

Table 6 : List of hardware for testing

Hardware	**Function/use**
Oven	To perform thermal aging
Ultrasonic testing device	Failure inspection

3.4 Drop weight impact test jig

This jig was designed by the previous semester student. The modification has been done was adjusting the length of the drop tube (blue color) which will determine how much impact energy will be impacted to the composite plates.

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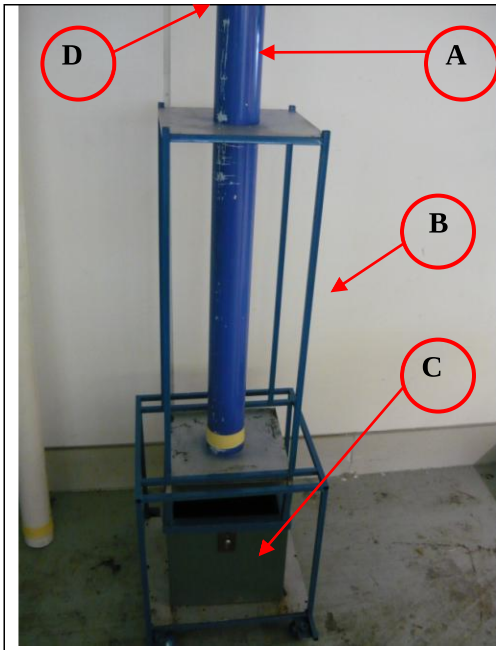
<tr>
<td>
</td>
<td>A – Drop tube
Purpose : As the guiding tube to allow the mass impactor to fall in vertical direction

B – Tube support
Purpose : To support the drop tube while the mass impactor is released.

C – Base
Purpose : To support the overall structure

D – Impactor holder
Purpose : As a release mechanism</td>
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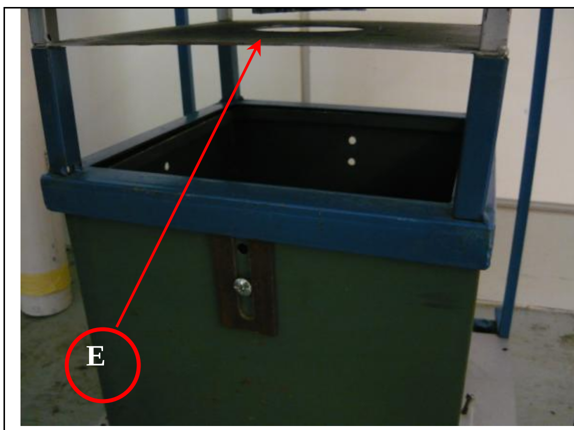
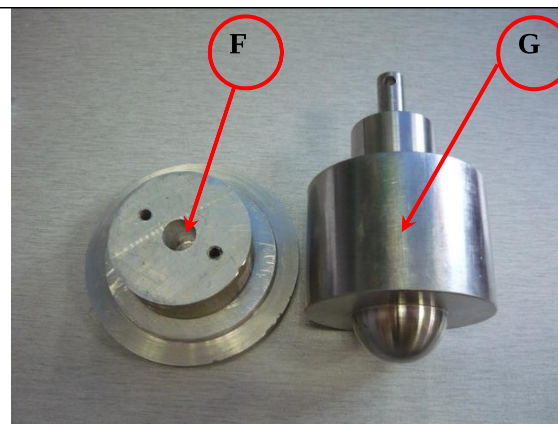
<td>

E- Plate support
Function : To hold the composite plate while the mass is impacted</td>
<td>

F – Impactor holder
G – Impactor
Function : As the mass release mechanism</td>
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</table>

Figure 6 : Impact test jig

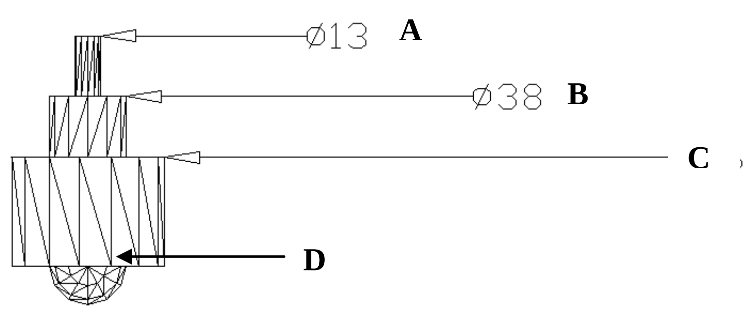
When conducting the test, the mass is hanged to the holder by a pin through the hole. Both impactor and mass support have holes to fit the pin. To release the mass impactor, the pin is pulled so that the impactor is falling and striking directly vertical on the composite plate.

3.4.1 Impactor

The impact energies applied to the composite plates is exerted by the impactor. The impactor has round nose with the specification described below. The round shape of the head makes the load distribution is more uniform. Below are the specifications of the impactor.

Table 7 : Specification of the Impactor

Parameter	Specification
Weight	2.5 kg
Dimension A	Diameter : 13 mm
	Height : 30 mm
Dimension B	Diameter : 38 mm
	Height : 30 mm
Dimension C	Diameter : 76 mm
	Height : 53 mm
Dimension D	Diameter : 38 mm



Dimension of the impactor

The mass impactor

Figure 7 : The impactor

Different impact energies can be applied to the composite plate by simply varying the height of the released impactor.

The theory of Potential Energy is :

$$Ug = -(-mg)h = mgh$$

The theory of kinetic energy is :

$$E_k = -(-mg)h = mgh$$

The total energy is the summation of potential energy and kinetic energy. For this test, the weight is drop down perpendicular to the ground. Hence, the kinetic energy can be ignored.

$$Ug = -(-mg)h = mgh$$

Therefore, we can get various impact energies by changing the height of the impactor before it is released.

For instance, for energy 10 J :

$U = mgh$

10 J = (2.5 kg)(9.81 m/s^2)(h)

h = 0.4078 m

Thus, the impactor must be positioned 0.4078 m from the composite plate.

3.5 Fabrication of composite plates

The procedures of fabricating the composite plates are shown below.

i. A release agent (wax) is applied to the mold to remove any contaminants and to make the removal of the sample easier.
ii. Epoxy is weighted according to the desired weight and was homogenized with hardener in the ratio 10:6.
iii. Then the desired size of reinforcing fiber layer is placed on the mold and then it is impregnated with epoxy resin.
iv. By using a roller, the epoxy resin is distributed uniformly around the surface for good fiber impregnation to remove the excess air or bubble.
v. Apply another layer and pour another epoxy resin mixture until all the 4 layers of glass fibers are achieved.
vi. All the weighted epoxy that has been prepared early is placed into the reinforcing fiber layers.
vii. The epoxy is uniformly distributed around the surface.
viii. Cure the mold at room temperature for overnight.
ix. Remove part from mold.

3.5.1 Composite plate configuration

Two groups of composite configurations will be tested. They are reference group (without thermal aging) and also another group with thermal aging. There are few configurations of the composite plates. Below table is the detail specification of the glass-epoxy composites (woven and chopped). A non-woven fiber is called chopped fiber. For a woven glass fiber reinforced plate, 4 layers of fibers is configured due to symmetry of $[0/90_2/0]$ direction. While, non-woven fibers do not have fixed direction and it is randomly oriented. The epoxy-hardener mixture ratio are base on 10:6 which is provided by the vendor.

Based on basic fibers calculation by using the rules of mixtures, the thick plate is determined by its volume fraction which is 20% fiber and 80% of epoxy resin. The thin plate is 30% of fiber volume and 70% of epoxy resin volume. They are all have 4 layers each.

For a thin glass fiber reinforced plate (woven);

Area for 1 layer : 153.96 cm^2

Fiber density : 2.50 g/cm^3

Weight for 1 layer : 5.51 g

Weight for 4 layers : 22.02 g

Fiber volume, v_f

$v_f = m_f / \rho_f$

$v_f = 22.02\ g/2.5\ g/cm^3 = 8.808\ cm^3$

If 0.2FVF = 8.808 cm^3

Assume 1.00FVF = Total volume fraction for 1 composite plate

FVFc = 1.00/0.2 X 8.808 cm^3

= 44.05 cm^3

Matrix volume, v_m

$v_m = v_c - v_f$

$= 44.05\ cm^3 - 8.808\ cm^3$

$= 35.242\ cm^3$

Matrix weight, w_m

$w_m = \rho_m v_m$

$w_m = 1.3\ g/cm^3 \times 35.242\ cm^3$

$w_m = 45.81\ g$

Matrix calculation ;

Weight : 45.81 g

Weight ratio : Epoxy :Hardener = 10:6

W_{epoxy} =(45.81)(0.625) = 28.63 g

$W_{hardener}$ =(45.81)(0.375)=17.18g

Table 8 : Configuration for composite plates

Parameter	Woven Glass Fiber		Chopped Glass Fiber	
Volume Fraction Fiber – Matrix	20 – 80	30 – 70	20 – 80	30 – 70
Fiber Density (g/cm^3)	2.50	2.50	2.50	2.50
Area (1layer) cm^2	153.96	153.96	153.96	153.96
Weight (1layer)	5.51	5.51	6.20	6.20
Weight (4layers)	22.02	22.02	24.78	24.78
Fiber Volume (cm^3)	8.81	8.81	9.91	9.91
Matrix Volume (cm^3)	35.24	20.56	39.65	23.13
Epoxy Density (g/cm^3)	1.3	1.3	1.3	1.3
Matrix Weight (g)	45.81	26.72	51.55	30.07
Epoxy Weight (g)	28.63	16.70	32.22	18.79
Hardener Weight (g)	17.18	10.02	19.33	11.28

From the calculation, the weight is determined for each composite plate. The matrix part is the combination of epoxy and hardener. The weight ratio for the epoxy and the hardener is 5:3 respectively. The samples are fabricated according to the proposed configuration using hand lay up technique. The calculation for all configurations are shown in the Appendix 3.

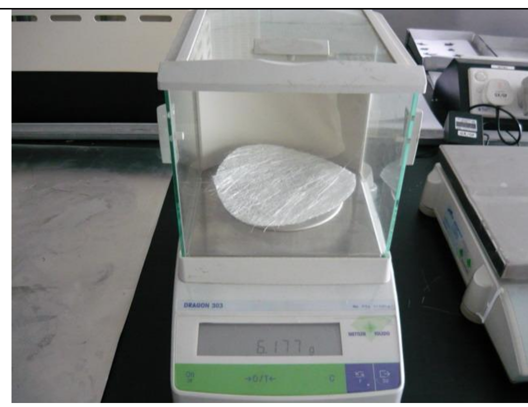
Table 9 : Set of samples

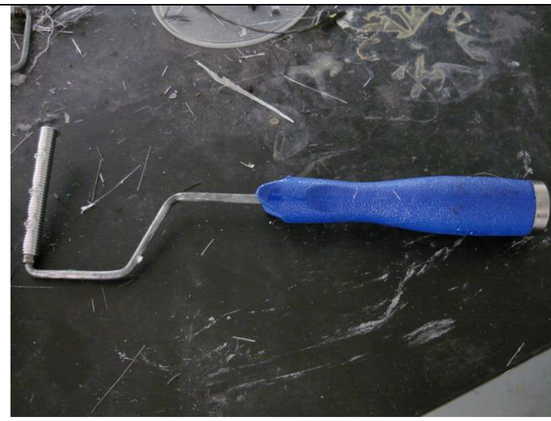
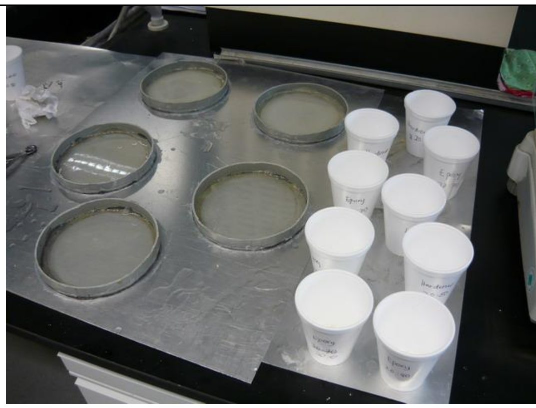
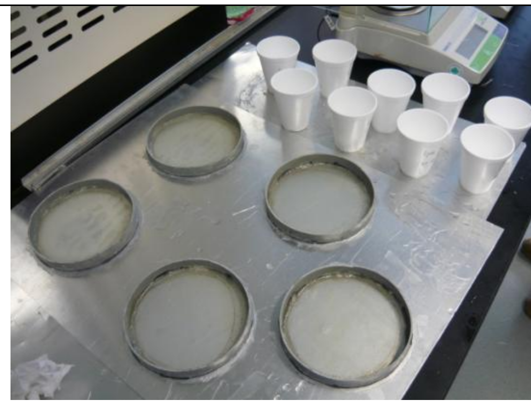
Parameter	Woven Glass Fiber		Chopped Glass Fiber	
Volume Fraction	20 – 80	30 – 70	20 – 80	30 – 70
Standard	3	3	3	3
Thermal Aging	3	-	3	-

There are eighteen composite plates are fabricated with different volume fraction and fiber type. There are 12 samples as the reference group, which is not being exposed by thermal aging. While the other gruup of 6 samples used to study the effect of thermal aging by keeping the volume fraction constant. Every test will have 3 samples to eliminate errors and to have better accuracy.

3.5.2 Composite plate fabrication process

The fabrication process of the composite plate can be shown in the figure below ;

	
Circular mold	Chopped glass fiber
	
Woven glass fiber	The fiber layer being measured

	
The premeasured epoxy and hardener	Roller used for compaction
	
Lay up process completed	Curing process

The completed sample

Figure 8 : Sample preparation process

3.6 Thermal aging

Thermal aging is performed to six (6) samples which consists of :

Table 10 : Thermal aging samples

Parameter	Woven Glass Fiber		Chopped Glass Fiber	
Volume Fraction Fiber : Matrix	20 : 80	30 : 70	20 : 80	30 : 70
No of samples	3	-	3	-

The samples are exposed in the oven at a temperature of 100 ^{o}C for about 50 hours. This duration is chosen based on the previous research that study the thermal aging.

3.7 Impact Testing

The impact test used in this project is based on ASTM D 5628, which is Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Falling Dart (Tup or Falling Mass). This test is used to test the impact resistance of a polymer or composite subjected to falling weight.

3.7.1 Impact testing procedures

The procedures for the impact testing are :

i. Determine the number of specimens to be tested.

ii. Mark the specimens and the conditions.

iii. Prepare the test apparatus for the geometry selected.

iv. Measure and record thickness of each specimen in the area of impact.

v. Position the specimen. Clamping is required to keep the specimen on position. Make sure the specimen is flat against the specimen support plate before the striker foot is brought in contact with the top surface of the specimen.

vi. Raise the weight in the tube to the desired impact value, and release it so that the weight drops on the specimen.

vii. Remove the specimen and examine it to determine whether it has failed or not.

viii. Use one symbol, such as X, to indicate a failure, and a different symbol, such as O, to indicate a non-failure at height level.

3.8 Failure Inspection

According to ASTM D 5628, the failure (of test specimen) is the presence of any crack or split created by the impact of the falling weight that can be seen by the naked eye under normal laboratory condition. Failure shall include the following:

Complete shattering of the plate ;

i. Any crack radiating out toward the edges of the plate on either surface of the plate

a. Any radial crack within or just outside the impact area of the striker ;

b. Any hole in the plate, whether due to brittle or ductile puncture, where unobstructed light or water could pass through ;

ii. Any brittle splitting of the bottom surface of the plate ;

iii. Any glassy-type chip dislodged from or loosened from the plate.

But for this project, the aim is to inspect the internal damage of the composite plates which cannot be observed visually. There will be potential delamination, fiber cracks and etc. This is done by using ultrasonic inspection.

While performing ultrasonic inspection, the method of balancing the peaks can determine the size of the damage area. The point that the peaks are balance shows that the boundary of the damage area.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Result

The samples are impacted by a single mass 2.5kg impactor with 10J impact energy. The damage area of the samples after the tests were examined using ultrasonic inspection. The damage area were measured and from both front and back faces of the samples. After several tests, here are the results which shows the damage area for different testing parameters. The figure of the sample surface after the impact is shown in the Appendix.

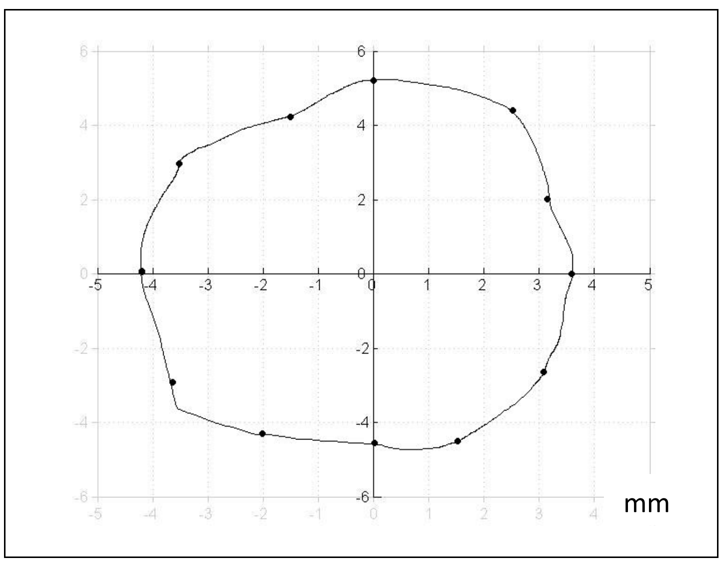


Figure 9: Thin Woven Glass Fiber Damage Diameter (9mm)

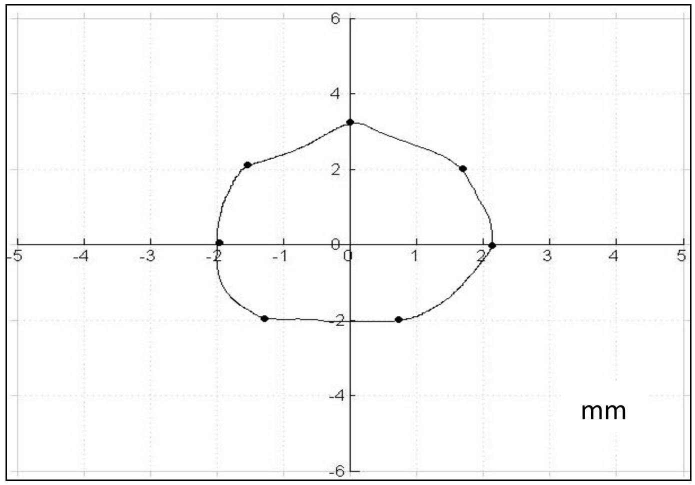


Figure 10 : Thick Woven Glass Fiber Damage Diameter (4.5mm)

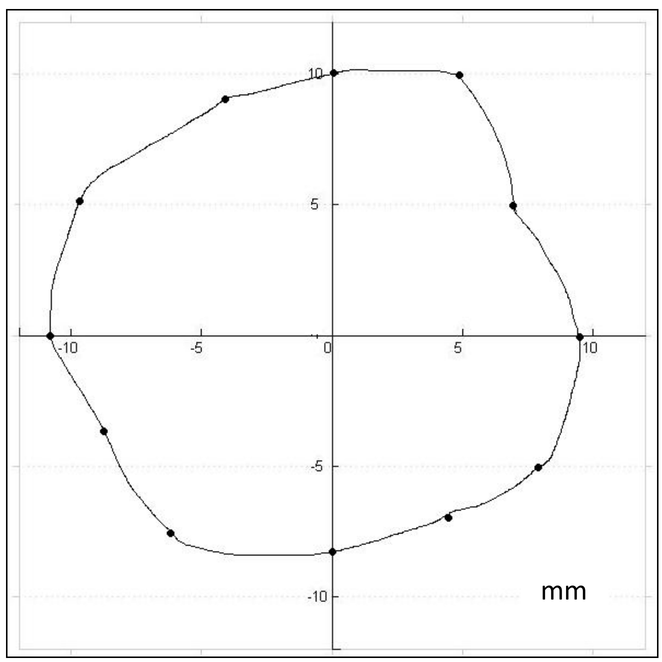


Figure 11 : Thin Chopped Glass Fiber Damage Diameter (19mm)

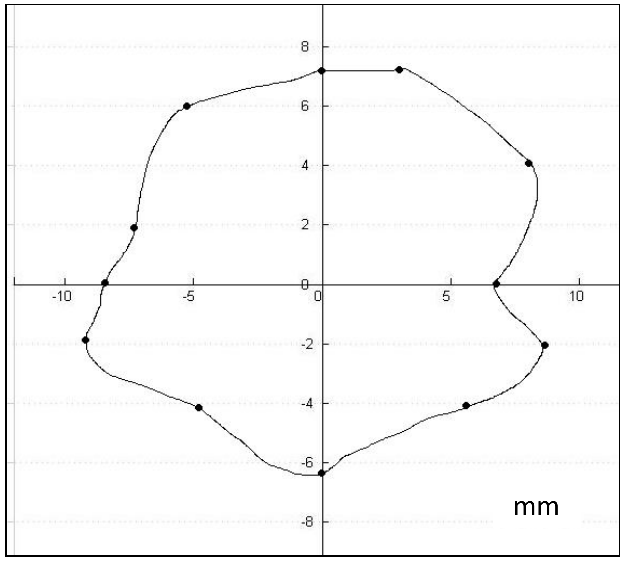


Figure 12 : Thick Chopped Glass Damage Diameter (13mm)

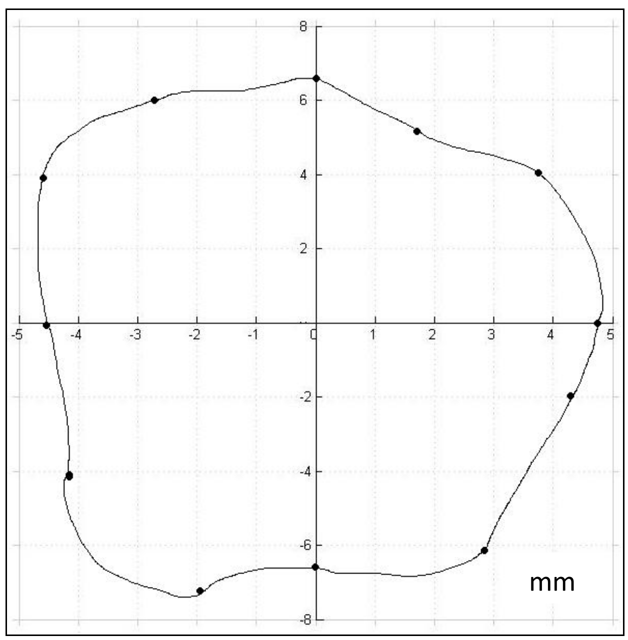


Figure 13 : Thick Woven Glass Fiber With Thermal Aging Damage Diameter (13mm)

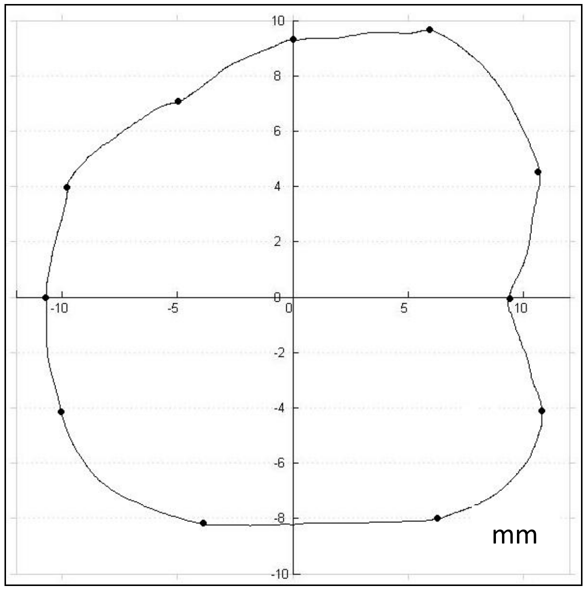


Figure 14 : Thick Chopped Glass Fiber With Thermal Aging Damage Diameter (20mm)

4.2 Discussion

The impact characteristics of various samples are characterized by comparing the damage area after the impact using ultrasonic inspection. This kind of technique is useful to detect any crack and delamination in the internal structure of the composite material. Basically, the samples were inspected and the crack is detected by the UT probe and results in a kind of unstable peak. The points crack was marked and direct measurements were calculated and presented in the graph showed before. The diameter of the damage area is calculated based on the longest points.

Combining the test results, Figure 15 summarizes comparisons of different materials and their advantages and disadvantages. The result shows that the thick woven glass fiber shows the best impact behavior by having only small damage area. This shows how thick woven glass fiber has a determining effect on strengthening the whole structure.

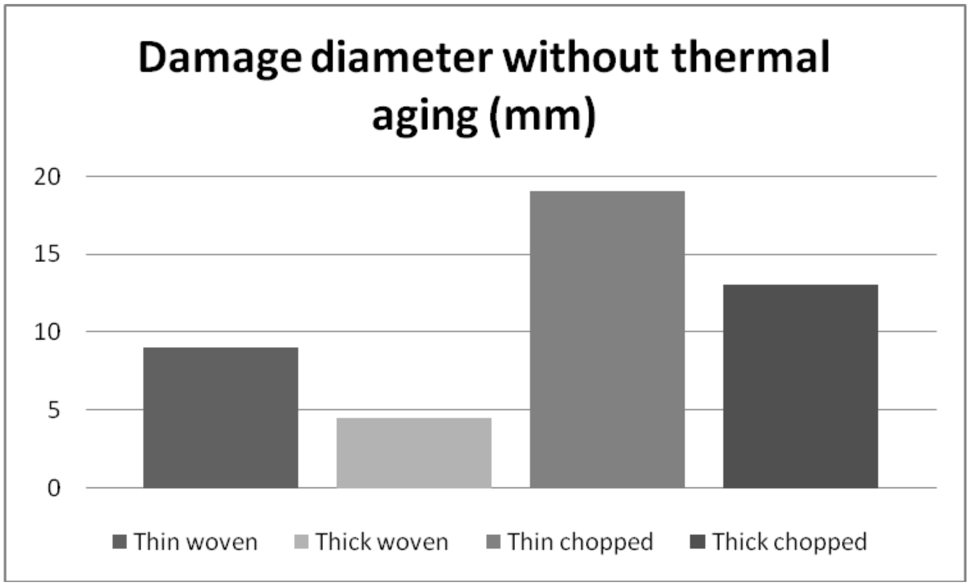


Figure 15 : Damage diameter without thermal aging

Between thick and thin woven glass fiber sample, the damage area for thin woven fiber is larger compared to thick glass fiber. Meanwhile, the damage for woven fibers are much lesser compared to chopped glass fibers. This is because the woven glass fiber is strong, ductile and more stabilized while chopped glass fiber is harder but more brittle. In general, in comparison between woven and chopped glass fiber, obviously woven glass fiber is stronger, more ductile and can sustain high impact energy before being seriously collapsed.

Thermal aging has a great influence on the impact characteristics of the both woven and chopped glass fiber. Figure 16 revealed that the damage area produced on the samples are increased on both type of fibers.

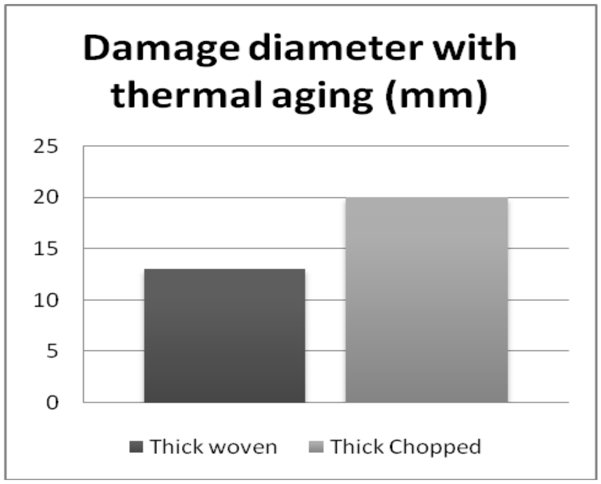


Figure 16 : Damage diameter of sample with the influence of thermal aging

CHAPTER 5

CONCLUSION

5.1 Conclusion

Drop weight impact test by using 2.5kg, 19 mm diameter stainless steel impactor was conducted on two type of glass fiber forms, which are woven and chopped glass fibers. The samples were clamped on a support and the impactor with 10-J impact energy strikes onto the center of the plates. Before the test, a number of samples are also thermally conditioned by exposing them in temperature of 100^0C for 50 hours. The damage area was reported by non-destructible inspection and charted by visual inspection. The test results in various damage areas. The test revealed that the woven glass fiber are more ductile than the chopped glass fiber. The impact resistance of both form of fibers are declined when subjected to thermal aging. The damage area produced is larger and it shows that extreme temperature greatly affect the structural intergrity of the structures. The crucial point of this research is that woven glass fiber can be useful solution to many applications by taking advantage of its good properties. In designing infrastructural systems with glass fiber composite, it is extremely important to provide the information on how the materials behaves when thermally aged so that catastrophic failure can be avoided.

5.2 Recommendation

This research would be better if further detail study including ;

i. Testing newly discovered material which has potential to be the replacing material such as natural sources like wood, plant and agricultural waste.

ii. Introducing thermal cyclic which include extreme temperatures.

iii. Using hybrid composites.

REFERENCES

[1] Ross CA, Sierakowski RL. *Studies on the impact resistance of composite plates. Composite* 1973 ;4 ;157-61.

[2] Ramin Hosseinzadeh, Mahmood Mehrdad Shokrieh, Larry Lessard. *Damage behavior of fiber reinforced composite plates subjected to drop weight impacts*. Sharif University of Technology, Tehran, Iran, 2005

[3] Asad A. Khalid. *The effect of testing temperature and volume fraction on impact energy of composites*. International University Malaysia (IIUM), Gombak, Malaysia, 2004.

[4] Yasnobu Hirai, Hiroyuki Hamada, Jang-Kyo Kim. *Impact response of woven glass-fabric composites – Effect of temperature*. Kyoto Institute of Technology, Kyoto Japan, 1996.

[5] Bhagwan D. Agarwal, Lawrence J. Broutman, K.Chandrashekhara. *Analysis and Performance of Fiber Composites*, John Wiley & Sons, Inc, New Jersey (2006)

[6] Arridge, R. G. C., in *Handbook of composite reinforcements*, Stuart M. Lee, Ed., VCH New York, 1993, Chap. 37.

[7] Jang, B. Z., *Advanced Polymer Composites: Principles and Applications*, ASM International, Materials Park, OH, 1994.

[8] ASTM D 5628 *Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Falling Dart*. ASTM INTERNATIONAL (2007)