EFFECT OF PRESSURE ON COMPOSITE AND ALUMINUM BONDING

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Effect of Pressure on Aluminum and composite bonding” is the result of my own work except as cited in the references

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Materials).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved mother and father

ABSTRACT

Composite and Aluminum bonding type material has been used extensively for years in various manufacturing industry. The stringent demand for this type of material in industry make it necessary to improve their mechanical properties by increasing their strength. Therefore, bonding pressure as a mechanism of bonding have been study in this research. This project starts with fabrication of Cabon Fibre using hand layup method and cutting process. Compression process is a crucial process as it will determine the effect of bonding pressure. The bonding pressure applied from 3 atm, 5 atm,7 atm until 9 atm. The tensile testing used to determine the strength of bonding by evaluation of shear stress value. From the tensile testing result it is found that bonding pressure affect the strength of aluminum composite bonding as the shear stress value obtained differed with different pressure. A bonding pressure under 3 atm pressure level is found has an optimum value of shear stress. However the further investigation and study in mechanism of bonding is suggested for comprehensive study.

ABSTRAK

Bahan Aluminum-komposit telah digunakan secara meluas di dalam industry pembuatan. Permintaan yang tinggi daripada industri menyebabkan pentingnya untuk membaikpulih ciri – ciri mekanikal dengan menambah kekuatan pada bahan tersebut.Maka tekanan ikatan sebagai mekanisme ikatan akan dikaji dalam kes ini . Projek ini bermula dengan proses fabrikasi Karbon fiber Komposit dan proses pemotongan specimen.Proses penekanan adalah kritikal proses kerana melalui proses ini kesan tekanan ke atas ikatan dapat dikenalpasti .Nilai tekanan yang dikenakan adalah pada tahap tekanan 3 atm,5atm,7atm dan 8 atm.Ujian Tensil digunakan untuk menentukan kekuatan ikatan melalui penilaian pada nilai'shear stress'.Keputusan ujian Tensil menunjukkan tekanan ke atas ikatan memberi kesan kepada kekuatan bonding.Tekanan pada tahap 3 atm memberi kekuatan optimum kepada bonding.Walaubagaimanapun kajian yang lebih detail berkenaan mekanisme ikatan disarankan bagi mendapatkan kajian yang lagi menyeluruh.

ACKNOWLEDGEMENT

First of all I want to dedicate my acknowledgements to my supervisor Prof. Madya Ahmad Rivai because of his guidance and encouragements I successfully completing my final year project II for undergraduate program. His contribution in this project made my project smoothly done. Besides that, I also want to give my dedication to Faculty of Mechanical Engineering management especially to technicians because of their guidance during conducting the experiments.

Cooperation, guidance, morale support and encouragements from my supervisor, technician, friends and family are giving me a strength to finish up my final year project and I would like to say many thanks to all of them. Lastly, I hope in the future the results of this project can contributed something to community.

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LIST OF ABBREVATIONS

SLJ	Single Lap Joint
DLJ	Double Lap Joint
ASTM	American Society For Testing and Materials
CSM	Chopped strand mat

CHAPTER 1

INTRODUCTION

1.1 Background

The Aluminum-composite bonding has been used widely in aerospace, automobile area and mineral processing component due to their excellent properties combination which is low density, high thermal conductivity and good strength. Composite advantages such as good strength weight ratio, high specific stiffness, high plastic flow strength, and corrosion resistance are perfect match for Aluminum that has ductile and ligh tweight properties to produce durable with light structural weight material. Significant savings in structural weight can be achieved by using this type of bonding material. It has been shown that Aluminum-composites bonding material are structurally an optimum design solution in cases where minimal weight and high stiffness are required.

Composite is a material made from two or more constituent materials and carbon fiber is one of the type of composite that have been frequently used. Bonding between aluminum and composite in this project are using epoxy adhesive bonding which is the most suitable for bonding of this two substrate, aluminum and reinforced carbon fiber. Two different materials such as composite and aluminum which undergo bonding process will experience one or more issues such as a failure of the bonding between two material. Bonding failure happen when the bonding reaching its maximum point where the bonding unable to stand before fail. Bonding failure test are based on difference pressure where the good bonding can be determined.

Adhesive bonded connections comprise a significant class of joining methodologies, which can be used when attachment of composite to metal structure is required. Often times an adhesive joint is the method of choice when compared to mechanically fastened alternatives. However, careful attention to detail must be paid in use of adhesives for structural connections, especially when dissimilar materials are to be attached. Not only proper adhesive selection is critical but also proper techniques in application of the adhesive must be carried out. There are many issues to consider when selecting an adhesive joint for a structural component

1.2 Problem Statement

Carbon fibre and Aluminum bonding has been used widely in many manufacturing industry included aerocraft, naval, automotive and many other manufacturing. A higher strength of this type bonding with excellent mechanical properties are significance due to current industry requirement. In order to improve the strength of this bonding several factor that will increase the strength of carbon-fibre materials should be identify. In this study, we focused on effect of bonding pressure. The different bonding pressure are applied on the bonding to study the effect of pressure on the strength .The problem is does the compressing bonding pressure applied gives impact on the strength of bonding of Aluminum and Composite ?

1.3 Objective

The objectives of this project are as follows:

1. To study the effect of the pressure applied on the composite-Aluminum bonding
2. To determine the optimum pressure for composite-Aluminum bonding

1.4 Scope of Project

The scopes of this project are:

1. Literature review on the bonding between carbon fiber (composite) and Aluminum
2. To apply pressure by compressing the specimen after substrates attachment process by using epoxy adhesive
3. To conduct static shear tensile test on the specimen

CHAPTER 2

LITERATURE REVIEW

2.1 Composite and Aluminum Bonding

Structural composites proposes various advantages such as light in weight, resistance to corrosion, and versatility of design. Composites provide directed, purposeful stress management using strategic placement of reinforcing fibers, often combined with core materials to provide stiffness. Over years, Fiberglass reinforced composites have been extensively used in marine and other extreme environment industry. Carbon fiber reinforced composites propose the ultimate in strength-to-weight ratio and are now universal in aerospace and marine applications. Carbon fiber is considered one of the most applicable composite in industries due to high strength to weight ratio, good tensile strength but brittle and low coefficient of thermal expansion.

Aluminum is a one best known metal that is usually chosen in numerous manufacturing processes due to imperative physical properties including; light weight, corrosion resistance, excellent conductivity, and high strength, along with low cost. The ability for joining it properly using an epoxy adhesive is important in the manufacturing process since aluminum is such a common metal in manufacturing industries. Aluminium exist in several forms such as ironadized Aluminium but commonly alloyed with copper, magnesium, manganese, silicon, and zinc. With proper handling and preparation Epoxy can bond well to almost all types of aluminum and aluminum alloys .

Recently, Aluminum is the second most used metal in the world industry after iron. The properties of aluminum which are low in density, high strength, superior malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity are among aluminum's excellent properties. Aluminum alloys commonly have tensile strengths of between 70 and 700 MPa. Aluminum does not become brittle at low temperatures unlike most steel grades instead, its strength increases. At high temperatures, aluminum's strength decreases. At temperatures continuously above 100°C, strength is affected to the extent that the weakening must be taken into account. One of the well-known properties of aluminum is that it is light and their features facilitating easy jointing are often included into profile design.

Fiber reinforced composites and metals are both widely used as structural materials. These two materials are often used together and become an excellent bond mate within a single load carrying structure. Joining methods between composites and metals almost particularly depend on the joining techniques of adhesive bonding, the use of mechanical fasteners, or a combination of the two. Due to the differences between the two materials both adhesive bonding and mechanical fastening result in significant penalties in terms of structural efficiency (Joesbury,2015).

2.2 Adhesive Bonding

An adhesive may be defined as a material which when applied to surfaces of materials can join them together and resist separation. Adhesive is a non-metallic substance with capability of joining materials and resist separation. The term adhesion is used when referring to the attraction between the substances, while the materials being joined are commonly referred to as substrate or adherends (Diharjo K et al,2013)

Adhesive bonding is a joining process of materials in which an adhesive, placed between the adherends surfaces, solidifies to produce an adhesive bond. Adhesive bonded joints are increasing alternatives to mechanical joints in engineering applications that provide many advantages over conventional mechanical fasteners. (Diharjo K et al,2013). Bonding is the best method compare to joining due to relatively low stress concentration of material, weight saving, and cost saving and improve damage tolerance. The application of these joints in structural components made of fiber-reinforced composites has increased significantly in recent years (Diharjo K et al ,2013). The advantages of traditional fasteners is commonly result in the cutting of fibers, and hence introduce stress concentrations, both of which minimize structural integrity.

Adhesive bonding minimizes weight and complexity in the fabrication of many structural components, most noticeable in the automotive industry. For example, chasis are made from metal whether steel or aluminum alloy by adhesive bonding composite panels to a low density with exceptional specific stiffness (Diharjo K et al, 2013). Adhesive bonding become as primary method to repair structural composites for scarf and doubler repairs. In recent times, composite doubler repairs have also been extended to Aluminum and composite components where a bisphenolic-fiberglass composite patch is applied to the metal surface using an epoxy adhesive film. (Diharjo K et al, 2013). The composite doubler and the adhesive film are co-cured for creating a composite patch spanning the substrate crack. These patches extend the lifetime of the parent structure and thus reduce the cost for expensive repair.

2.3 Epoxy as Adhesive

Epoxy adhesives is universally used in manufacturing industry and is also one of the most various adhesive available. In the unhardened state, the chemical structure is characterised by the ring-like shape of the epoxide group, explained how epoxy adhesive gets its name. All epoxy adhesives contain two or more of these groups per molecule of adhesive. Although they are all similar in this respect, the form in which they are available diverse in term of variant, from low-viscosity liquids to solid pastes or films. The diversity of basic epoxy resins, in consolidation with over 70 different curing agents - ranging from simple amines to complex anhydrides - give the group its diversity.

The mechanism of curing is always the same through out all the variations. The ring structure is broken by an active molecule - typically an amine - and the two monomers link. A polymeric network is formed thus harden the adhesive in result from constant repetition of this process. The accurate quantities of resin and hardener necessary for this mechanism, hence the need for precise mix-ratios and the thorough mixing of resin and hardener in two-part systems. Without these, the polymer will not form correctly and often inferior properties will result typically lower strength and reduced environmental resistance.

Single-part epoxy adhesives are available, in liquid, paste or film form. The resin and catalytic hardener are pre-mixed but polymerisation cannot occur as the catalyst is in an inactive form at room temperature. It only becomes reactive towards the epoxide group as the room temperature is raised in excess of 100 C. Curing process of the two-part adhesives can be accelerated by heat.The higher the temperature, the faster the reaction becomes thus obtain shorter curing times.These materials have good mechanical strength and chemical resistance, do not volatilize during curing, and have low shrinkage. Therefore they form extremely strong with most materials in well designed joints. The development of toughened formulations has increased the demanding uses of these type adhesives in various industries today. The Figure 2.1 shows the example of Epoxy type Adhesive .

Figure 2.1: Example of Epoxy type Adhesive

2.4 Joint Design

Optimization of joint design is an important consideration when designing adhesive bonding applications. Adhesive joints have no limit in term of geometrical the way as in mechanical fastener. Hence it is free to design specific joint that focus only on the mechanical and chemical stresses behaviour. Particular attention must be pay during the design phase such as the distribution of shear stress due to the non-symmetric external tensile load. Tensile load or tensile strength is the ability of the material to withstand a longitudinal stress. At the overlap end where the inner composite materials has a lower stiffness is where the shear stress at peaks. An understanding behaviour of the joint designs for application is beneficial study in order to get the good bonding joint. Typical joint design and stress development data offers various number of joint design choices. The Figure 2.2 and 2.3 following show the most two widely employed types of joint designs used for two substrate, single lap and double lap respectively.

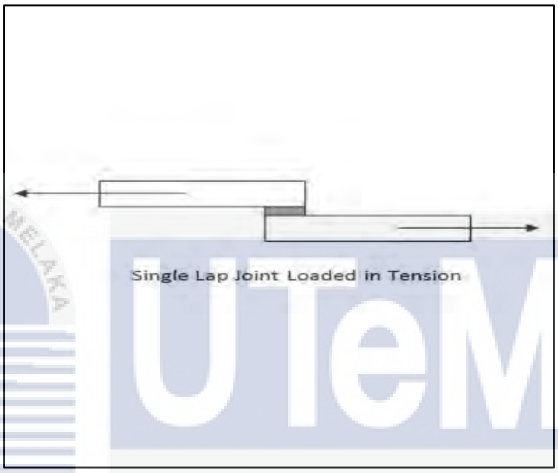


Figure 2.2: Single lap joint (SLJ) (retrieved from www.testresources.net)

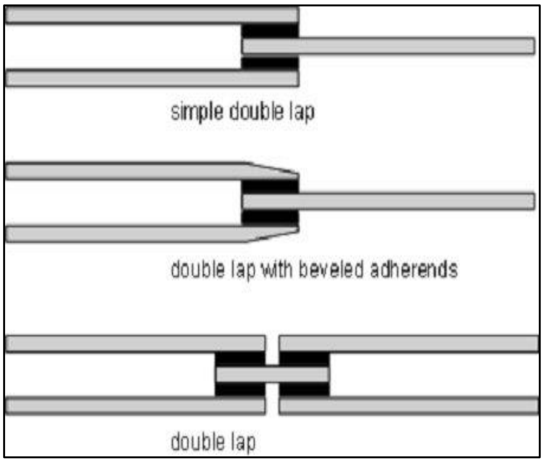


Figure 2.3: Double lap joint (DLJ) (retrieved from www.testresources.net)

Single lap joints are over years the most universal adhesive joints used and have been the subject of major research. Simplicity and service efficiency of the single lap design is exploited for determining the mechanical properties of adhesive joints and the adhesives as well (Diharjo K et al, 2013). The stress is non-uniformly distributed through the bond-line even when relatively low modulus of adhesive are employed. The loads in a single lap joint are not co-linear, what create a bending moment which result the joint to rotate. This produce consequent exposion of the adhesive layer into shear, and peeling stresses. The adherends are similarly at the same time subjected to tension and bending. It is probable that deformation of both of adhesive and adherend may become plastic, typically in the highly stressed regions. The commonly used metallic adherend used in single lap joint tests are often found to have plastic deformation, due to yielding, before failure. (Diharjo K et al, 2013).

2.5 Parametric study on bonding failure (Pressure effect)

For this project aluminium and composite has been used to undergo bonding failure tensile shearing test. There are several parameters that will affect the adhesive bond strength which are overlap length, adhesive thickness, adherend thickness, bonding pressure and temperature. For the adhesive thickness it obviously decreasing the bond strength. Moreover, along adhesive thickness both tensile stress and shear stress are significantly change. Increase of the ratio of the overlap length to adhesive thickness also increase the failure load. From the study of different bonding method effect to the failure mode and strength of composite single-lap bonded joints shows that the failure strength of a composite bonded joint is not always proportional to the adhesion strength of the adhesive.

The investigation is on the influences of bonding pressure on the failure load bonding between composite to aluminium. Increasing the bonding pressure improved the strength of the bonded material. From the figure 2.4, the graph show result of effect bonding pressure (Myeong, S.S. ,2008).Graph shows that at 4 atm and 6 atm the bonding pressure are very close which is 23.6 Mpa and 24 Mpa. At 2 atm the joint strength is 18.5 Mpa while the failure load is 11.6 kN. For 3 atm the joint strength is 20 Mpa and the failure load is 12.6 kN. From the graph can be concluded that the more the bonding pressure the higher the joint strength and failure load.

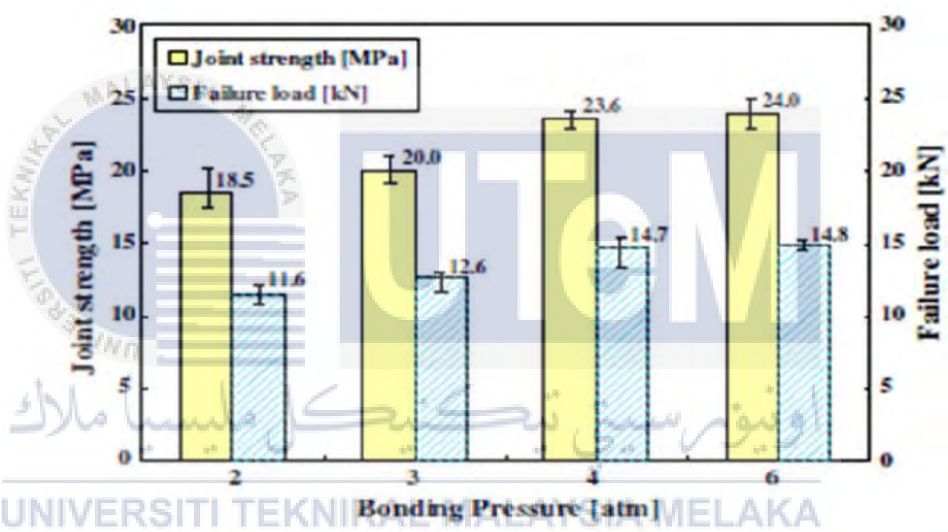


Figure 2.4: Failure loads and strengths of bonded joints with different bonding pressures to the adhesion strength of the adhesive (Myeong, S.S. ,2008)

2.6 Failure Analysis :Static Tensile Shearing stress

To evaluate shear strength values adhesive bonded composite is investigated under the effect of pressure. The tensile shear test conduct according to ASTM D1002. The amount of shear area measure in square inches or square centimetre. The each end of the specimen in the tensile grips be loaded and force at a controlled rate to the specimen is applied until it breaks and record the maximum force and type of joint failure. ASTM D1002 specifies a load control rate of 1,200 to 1,400 psi/minute. A cross head control rate of 0.05 inch/minute approximates the loading rate and also is an acceptable mode of control.

The test report include the maximum force recorded, maximum shear stress and the type of failure for each specimen. Maximum shear stress is found by dividing the maximum force by the shear area and is reported in units of kilogram/square centimeter or psi. Failure types include cohesion in the adhesive or metal substrate or adhesion.The Figure 2.5 and 2.6 show Schematic test specimen Tensile testing equipment test respectively and Tensile testing equipment test.

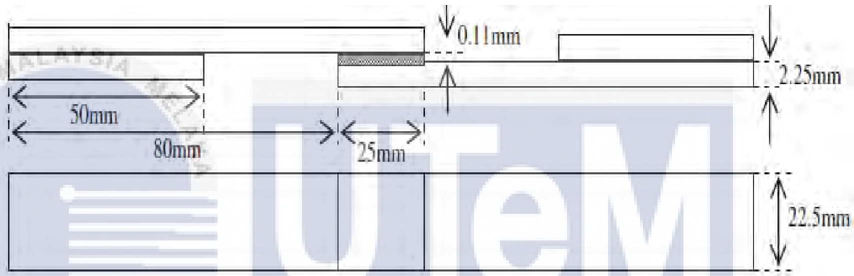


Figure 2.5 : Schematic test specimen (Onur et al, 2013).

Figure 2.6 : Experiment set up for Tensile test

CHAPTER 3

METHODOLOGY

3.1 Introduction

Generally, this project is divided into two part which is understanding the theories and analyze the effect of pressure on the bonding of aluminum-composite. Part one of this project is to understand the theories, the properties and characteristic of test piece which is aluminum and composite including the properties and characteristic. The objective of this project, project scope and problem statements are also included in part one of this project. Part two of this project is to study the effect of pressure on bonding by conduct a Static Tensile test on aluminum-composite bonding. The tensile shear strength of each specimen will be tested by using different compressing pressure. Moreover, the flow process in figure 3.1 and Gantt chart in 3.2 has been made to identify all work for this project.

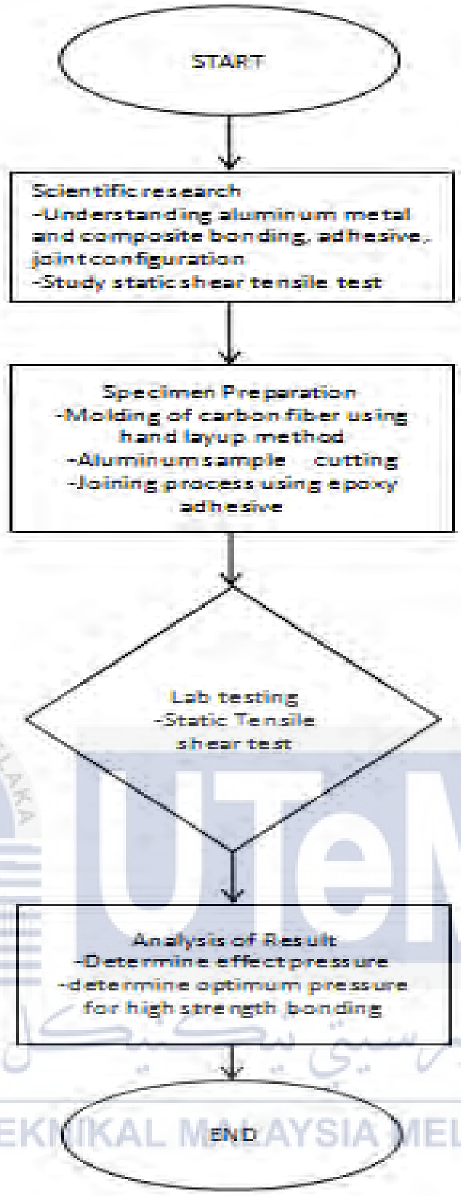


Figure 3.1: Flow process for project

TASK	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY
DATA ANALYSIS -Understanding aluminum and composite bonding, adhesive, joint configuration -Study static shear tensile test					
SAMPLE PREPARATION -Composite Fabrication -Aluminum Cutting -Lab test Design					
DISCUSSION ON THE DATA -Conduct test -Analyze effect pressure on shear strength -Analyze optimum temperature					
SUBMISSION OF THE FINAL DRAFT					

Figure 3.2: Gantt Chart of flow process

3.2 Specimen Preparation

Sample preparation should be taking seriously before conduct the test.For this study, as mention earlier in scope included the process of cutting Aluminum specimen and preparation of composite. Aluminum types is used in this experiment is 2024-T4; 2024-T351 and carbon fibre as composite is used.

3.2.1 Aluminum Cutting

Sample preparation of Aluminum also should be taken into account before conducting the test. The accurate parameter for each specimen is crucial in order to get good bonding joint. The Aluminium sheet 2024-T4; 2024-T351 types is used in this experiment. This process is conducted according to the standard dimension of test specimen and standard test joint as prescribed in ASTM D 3165. The Aluminum plate are cut in size into twelve set with same dimensions by using shearing machine as twelve specimen been tested, representing four different joint with different bonding pressure. The dimension of Aluminum as per figure 3.3.

Figure 3.3: Dimension of Aluminum plate

From the figure, A is width of Aluminium plate = 25 mm, B is thickness of plate = 2.5mm and C is lenght of plate = 101 mm.

3.2.2 Composite Preparation

The hand layup method has been used to fabricate the carbon fibre sheet. This is the simplest method for composite molding that is low costing and fast. The 30cm X 30cm, 2.5 mm thick fibre sheet were made. The resin epoxy and hardener were mixed by following the standard ratio that provided by manufacturer which is 5:2, resin to hardener. The thin glass block are used as mold . Release agent which is wax is first applied to the mold surface to avoid sticking polymer to surface. The first layer of resin applied by spreading it using brush on the intended surface area then followed by manually place the first sheet of reinforcement mat (CSM) carbon fibre. Roller is used to consolidate the laminate, thoroughly wetting the reinforcement and removing excess entrapped air. Roller is moved with a mild pressure on the mat polymer and layer until required layer are stacked. The step repeated until eight layer of carbon fibre mat.The orientation of all sheet of carbon fibre mat are in zero degree. The Perspex sheet are placed on the last layer of resin and rolled mildly. The polymer is cured at room temperature. The composite then is cut as prescribed in standard test joint in ASTM D 3165 by using hand table saw and been prepared similarly with dimension of the Aluminum sample. Figure 3.4 shows example of hand layup technique.

Figure 3.4:Hand lay up technique of carbon fibre

3.2.3 Bonding Process

Two substrates that have undergo sample preparation are joined together by using Epoxy type Adhesive. For the joint configuration, single lap is the best for this study as it the simplest joint configuration and common type of joint be used for two substrate. The length of overlap area for both substrate Aluminum and composite is marked as prescribed in test specimens section according to ASTM D 3165. The substrates are joint together by single -step bonding technique which adhesive directly apply to both bonding surfaces without first wetting out the surfaces with neat resin/hardener. Figure 3.5 example of Single lap joint

Figure 3.5: Single lap joint

The process is started by surface area bonding are cleaned by using cloth to remove unnecessary impurities in order to have good contact bonding. Epoxy are applied directly to both marked area bonding surfaces. The adhesive been applied uniformly to the area so that the bonding area is fully covered with adhesive after samples have been pressed together. Clamps is used to hold the components in place and squeeze a small amount of the epoxy from the joint, indicating that the epoxy is making good contact with both mating surfaces . Excess adhesive that squeezes out of the joint as soon as the joint is secured with clamps is removed.

3.2.4 Compression Process

Next step is compressing the bonding area with different pressure bonding by using press machine. This is the critical part in process as pressure is the main variable that be studied in this experiment. The specimen will go through a simple cold press process in an ambient temperature. Different bonding pressure are applied from 3atm, 5atm, 7atm and 9 atm. The parameter been controlled in this process is processing temperature,processing time and cooling time. Figure 3.6 show the press machine used.

Figure 3.6: Press Machine

3.3 Tensile Testing

Test specimen configuration have been prepared as prescribed in ASTM D 3165 .Figure 3.7 shows the configuration of test specimen and their dimensions

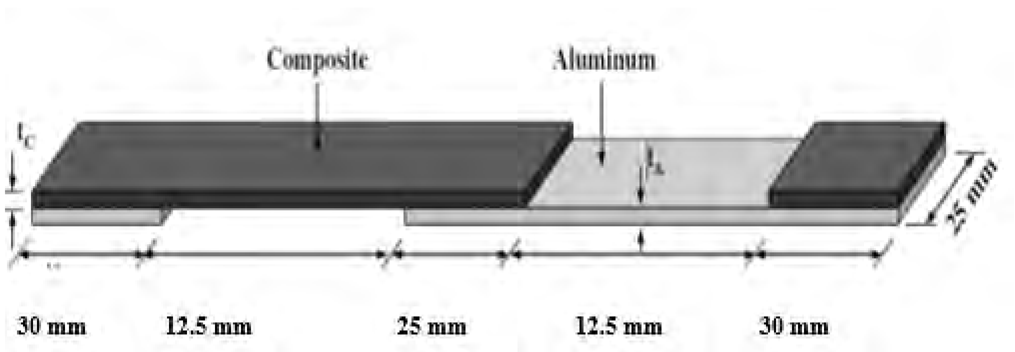
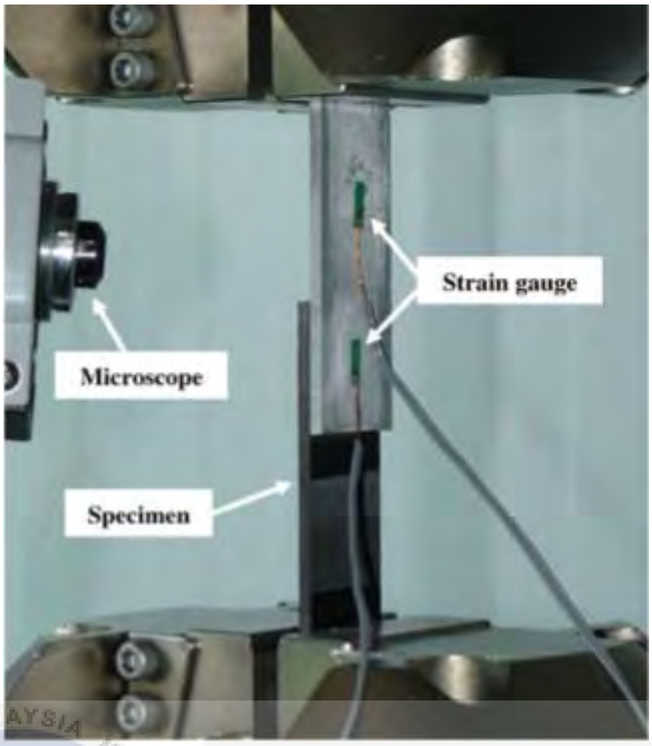


Figure 3.7 :Test specimen configuration

Tensile testing is conduct according to ASTM D 3165 on test specimens that have been prepared previously. The test piece is fixed in a gripper of testing machine so that the outer is 25.4 mm of each end are in contact with the jaws and the long axis of the test specimen is coincide with the direction of applied pull through the centre line of the grip assembly. The loading at rate 8.3 to 9.7 Mpa of shear test speed 1.27mm/min (0.05 inch/min) is applied immediately. The load is applied continuously until the joint gets disintegrated and failure happen. Total 12 tests were carried out represent 4 different joints with different bonding pressure. The load at the nature failure and values of failure of each specimen is recorded. Joint strengths, reported in units of shear stress, were calculated as as follows:

$$\text{Joint Strength} = \frac{\text{Failure load}}{\text{Adhesive area}}$$



Figue 3.8: Experimental set up of specimen tensile lap-shear test (Myeong SS, 2008)

Data analysis process in this project is analyzing the effect of pressure on the bonding of Aluminum-Composite. The analysis of test piece by using shear tensile test will lead this project to determine shear strength aluminum and composite bonding due to difference in pressure. All the result of failings loads is expressed in kilo Pascal. The load when failure happen as a result from changing the pressure is determined. However,there are several parameter that will affect the bonding which are adhesive bondline thickness, overlap length, test temperature. Hence, it is important to make sure all these parameter are in control variable which is fixed value for all specimen so that it will not affect the study of behaviour of strength bonding under different bonding pressure.

CHAPTER 4

RESULT

4.1 Experimental Results

Shear testing has been used to study the shear strength of the bonding of Aluminium and Composite. The test is performed on the bonding that have been applied different bonding pressure which is 3 atm, 5 atm,7 atm, 9 atm. The pressure applied are pressure of hydraulic system of Press Machine. The experimental result obtained from the Tensile Testing and The adhesive area of bonding are shown in Table 4.1 and Table 4.2 respectively.

Table 4.1 : The experimental result of pressure with maximum load

Pressure(atm)	Maximum Load (N)			Average (N)
	1	2	3	
3	924.6073	619.1223	1719.0673	1087.5990
5	512.9291	676.7978	268.6175	486.1148
7	822.9991	617.1854	607.4716	682.5520
9	1345.7826	1171.6812	664.0450	1060.5029

Table 4.2 : The adhesive area of bonding

Pressure(atm)	Adhesive Area (mm)			Average(mm)
	1	2	3	
3	6.5	6.25	6.5	6.41
5	6.75	2.75	6.25	5.25
7	6.13	6.12	4.75	5.67
9	6.5	6.38	6.5	6.46

The value of the shear stress has been calculated by taking consideration of maximum load with area of adhesive of composite and aluminium:

$$\text{Shear stress} = \frac{\text{Maximum load area}}{\text{Shear stress}}$$

For 3 atm pressure level, the adhesive area of first specimen is 6.5 mm with maximum load 924.6073 N resulting shear stress 142.2472 kPa.The maximum load for the second specimen is smaller which is 619.1223 N with the adhesive area 6.25 mm give 97.1172 kPa of shear stress.The second specimen can bear the largest load which is 1719.0673 N with 6.5 mm bonding area resulting 264.471 kPa of shear stress. The average shear stress obtained at 3 atm level pressure is 167.95 kPa

For 5 atm pressure level, the maximum load for the first sample is 512.9291 N with 6.75 mm of adhesive area give the value of shear stress, 82.068 kPa.For second sample the epoxy wet only 2.75 mm of area bonding give the result of maximum load 676.7978 N resulting 246.1083 kPa of shear stress. For sample 3, failure happened when the applied load reach 268.6175 N and has 6.25 mm of adhesive area. The average of shear stress for 5 atm level pressure is 123.72 kPa.

For 7 atm pressure level, the first sample can stand until 822.9991 N load with bonding area 6.125 mm resulting shear stress, 134.3673 kpa. For Second sample the maximum load is 617.1854, with bonding area 6.12 mm and shear stress 100.7650 kpa. Third sample can bear 607.4716 N of load, with bonding area 4.75 mm, resulting shear stress 127.8887 kpa. It gives average shear stress for 7 atm is 121.007 kpa.

For 9 atm pressure level, the first sample can sustain load until 1345.7826 N load with adhesive area 6.5 mm and Shear stress 207.0434 kpa. Second sample failed at 1171.6812 N, with adhesive area 6.38mm, shear stress 183.7931 kpa. Third sample maximum load rise up to 664.0450, with 6.5 mm bonding area, shear stress of 102.1608 kpa. Average Shear is 164.33kPa.

Figure 4.1 show that the relationship between shear stress (atm) and pressure level (kPa). The graph shows that the relationship between shear stress (Kpa) and pressure level (atm) where at 3 atm the shear stress is 167.95 kPa which is the optimum value or the highest value of shear stress. At 5 atm pressure level shows that the shear stress is 123.72 kPa while for 7 atm pressure level the shear stress is 121kPa. At pressure level 9 atm the shear stress appeared is 164.33kPa. The graph shows decreased and increased trend that show the optimum value of shear stress.

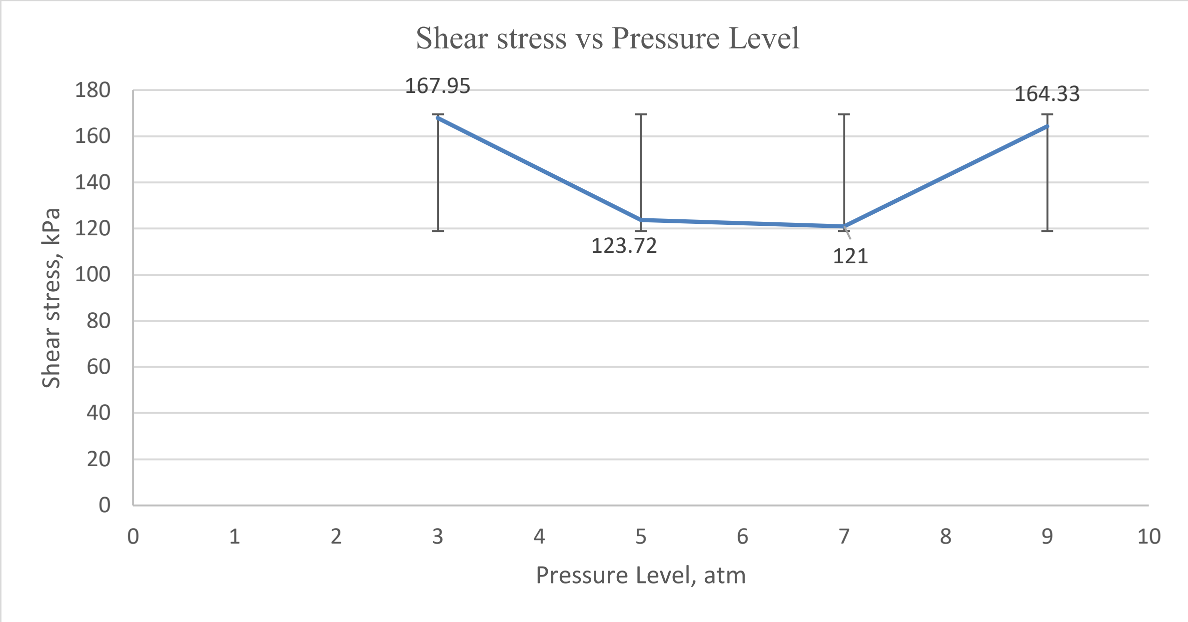


Figure 4.1: Graph of Shear stress (atm) against Pressure level (KPa)

CHAPTER 5

DISCUSSION

5.1 Analysis of Experimental Result

Shear testing is performed to determine the shear strength of a material. The shear testing is used to measures the maximum shear stress that may be sustained before bonding of two materials fail. The highest shear stress is 167.95 kPa at 3 atm pressure level while the lowest shear stress is 121 kPa at 7 atm. The results of the shear strength stress test is showing increasing and decreasing trends. The shear stress at the lowest pressure level which is 3 atm is 167.95 kPa. The shear stress show a decrease trend at pressure level 5 atm and 7 atm which the shear stress is 123.72 kpa and 121 kpa respectively. At pressure level 9 atm the shear stress increase dramatically to 164.33 kPa. The results of the shear strength stress test is showing increasing and decreasing trends.

The trends shows by the shear stress value because of many factors such as the thickness of bonded materials and the adhesive, surface pre-treatment, area of bonding and wettability. The thickness of bonded materials are similar for all specimens but the thickness of the adhesive which is epoxy resins is slightly different from each bonded materials. When different pressure of bonding applied by using cold press method the thickness of adhesive becomes different. For example thickness of adhesive area when 9 atm pressure are applied become smaller compared to thickness of bonded element at 3 atm pressure. Other else, pressure apply during the shear strength test also contributing to the inconsistent of the shear stress value but this factor is not overall affecting the shear stress value.

5.2 Discussion

5.2.1 Wettability

The shear stress value from the shear strength test is being up and down where at 3 atm pressure level the shear stress is high, at 5 atm pressure level the shear stress is falling down followed by 7 atm make it as the lowest shear stress and then at pressure level 9 atm the shear stress value is suddenly increasing dramatically. Theoretically, the value of shear stress should be either low at beginning then increasing and at the end decreasing. The different in shear stress value from previous research result because of many factors such as wettability. Wettability factor played important role to the value of shear stress. Wettability happen when the adhesive exposed too long in the free air where causing the presence of wetting liquids in the adhesive from the atmosphere and lead to decreasing of adhesive strength.

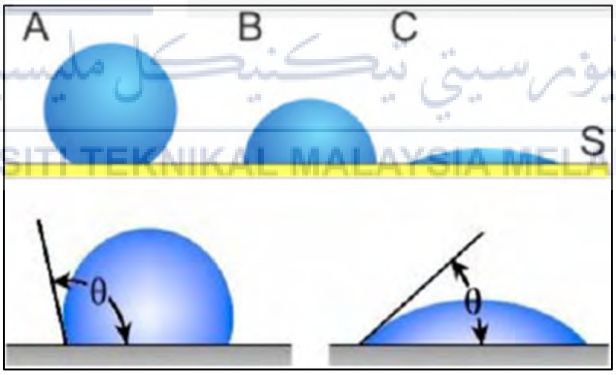


Figure 5.1: wetting liquid on the surface of adhesive
(retrieved from www.academia.edu)

5.2.2 Area of Bonding

One factor that will lead to inconsistent value is bonding area. The inconsistent in shear stress value because of factors of the bonding area.The shear stress can be obtain from the formula which is:

$$\tau = F/A$$

τ = shear stress

F = force

A = cross sectional area

In this experiment bonding area for all specimen have been set constant as 6.25 mm but due to wettability factor, the area of bonding set are not fully wetting . This can be seen from a sample one of sample specimen for pressure at 5 atm, the adhesive only wet 2.75 mm of area bonding compared to another two sample that have a larger area of adhesive. The non-constant of area bonding can also been seen from sample at 7 atm pressure, the area of bonding one of the sample is 4.75 mm. Theoretically, based on the formula of shear stress force and cross sectional area, area of bonding play an important role to decide the shear stress value. When the force is higher the shear stress is higher but when the area is wider the shear stress will be lower, the formula of the shear stress shows the relationship between cross sectional area and force toward shear stress. This factor will affect the value of average shear stress thus lead to inconsistent result of shear stress. The figure of 5.2 below show the relationship of force, overlap length and shear stress.

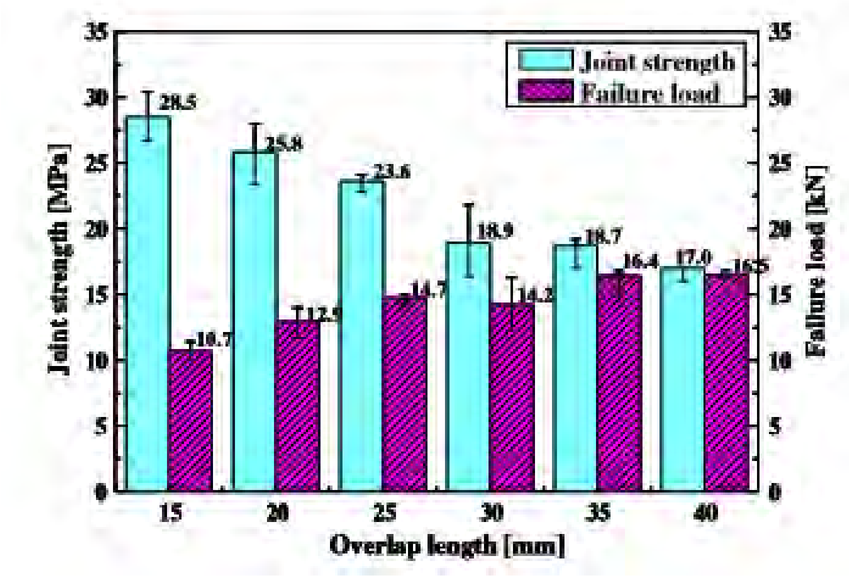


Figure 5.2: Failure load and strength of bonded joint with different overlap length (Myeong SS, (2008)

5.2.3 Surface of Bonding

Another factor that will affect wettability are the good and clean surface of bonding materials. Hence, surface pre–treatment is important thing must be doing to produce a good bonding material. In this experiment, the surface preparation are not taking into consideration hence the the presence of impurities on the surface of bonding might affect the wetting process of adhesive to surface of materials. What been regard is, in reality, often aluminum coated with an oxide. The surface of untreated aluminum is often made up of magnesium oxides. In its turn, this surface may be coated with grease, dirt, adsorbed molecules from gases and liquids or the products of chemical reactions between the material and its surroundings. Hence it will produce weak link in the chain of bonding. In other word, surface treatment can affect the chemical and structural properties of the surface layer of bonded materials thus effect wettability.

5.2.4 Adhesive Properties

The average value of shear stress obtain in the experiment are smaller compared to previous research. This might be due to properties of adhesive and their strength. The properties of adhesive also one of the main factor that could lead to less strong bonding. Adhesive forces are the attractive forces arising in the interface between two surfaces that are in contact with each other. When bonding aluminum to composite, the surface tension relationship must be taking into consideration. The adhesive must have a lower surface tension than the material that is to be bonded so that spontaneous wetting can occur thus result strong adhesion. In practice, it is important to know about the surface tensions of the material which aluminium and composite. However the surface tension of aluminium is not a problem because all the adhesive(plastic) have lower surface tension than all metal but when bonding adhesive to another plastic in this cases adhesives (epoxy) uses for fabrication carbon fibre were the same adhesive been used as adhesive for bonding. Thus surface tension relationship might be overlooked in this matter. Figure 5.3 and 5.4 show wetting behaviour happen on surface of material.

Figure 5.3: Spontaneous wetting (retrieve from https://www.researchgate.net)

Figure 5.4 : no wetting occur (retrieve from https://www.researchgate.net)

5.2.5 Mechanism of Bonding

The time taken for bonding process also affect the strength of bonding. The time taken for bonding process depends on the curing time for the adhesive .The curing time for an adhesive differ according to their types of adhesive. In this process time taken for bonding process were fixed for 6 hours in ambient temperature. The temperature of bonding also will affect the curing time for adhesive bonding as the temperature increase the curing time for adhesive decrease. However in this experiment both bonding temperature and bonding time are fixed. Thus no significant contribution to the effect of bonding strength from these this parameter in this case.

In this research wettability is the main factor that resulting in inconsistent value of shear stress. It is also major causes that influence area of bonding also important factor for the bonding to have a good and strong bonding. Wetting happen partially in some of the samples in this experiment which might be due to unclean surface bonding and also due to the properties of epoxy that have higher surface tension than composite.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The objective of this project is to determine effect of pressure and time in bonding failure mechanism between Carbon Fibre Reinforced Polymer (CFRP) and Aluminium 2024-T4; 2024-T351. Bonding is the condition where two surfaces of materials are held together by interfacial bond, the bonding failure happen when the interfacial bond is broke down. Many causes which lead to bonding failure and one of the causes is loading stress. There are many factor that affect the bonding strength such as overlap length, bonding thickness, bonding temperature, time taken for bonding and bonding pressure .In this experiment, under difference pressure the result of bonding failure of a structure are difference even though a same materials and same adhesive type been use.

The bonded materials undergo shearing test at different bonding pressure level. Pressure level affecting the value of shear stress where at lower pressure level the shear stress is quiet high and decrease when pressure increase then increase again when at the highest pressure. So, from the result of the research can be concluded bonding pressure is affected the bonding failure between carbon fibre reinforced polymer and aluminium. The optimum strength of bonding is at 3 atm pressure level. In this research wettability factor are the main cause for the lower strength of the bonding and the inconsistent result of shear stress .

6.2 Recommendation

This research are lacked in many aspect especially in findings and information. There are several recommendation in order to improve the quality of this report. More reference materials are needed in this research. This research are lack of reference which lead to some irrelevant information obtained. Reference material is very important to make sure the quality of the researched is preserved. Besides that, because of lack of reference material it is difficult to do the analysis of data for this research. Secondly, lack of information made the research analysis too general. The analysis of data are less precise because of the idea of the research is not clear enough and the information is not enough. For recommendation, a lot of information should be gather in order to make the comprehensive analysis .

Moreover, more discussion is necessary in this research. A details discussion on mechanism of bonding should be cover. It for generation of new idea and deep analysis on the finding. Another recommendation is find another source of information such as consult an experienced researcher. Source of information should not be limited in order to get more idea and information. It is basic skill to obtain information but the way of the person to get the information is more important. Final year project is a very critical subject because it will test student critical thinking skill either in terms of obtaining information, analysis the data and time management.

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APPENDICES

APPENDIX A INSTRON 5582 UNIVERSAL TESTING MACHINE

APPENDIX B1 SAMPLE SPECIMEN OF 3 ATM PRESSURE

APPENDIX B2 SAMPLE SPECIMEN OF 5 ATM PRESSURE

APPENDIX B3 SAMPLE OF SPECIMEN OF 7 ATM PRESSURE

APPENDIX B4 SAMPLE OF SPECIMEN OF 9 ATM PRESSURE

APPENDIX C PRESS MACHINE

APPENDIX D HAND LAY UP PROCESS

APPENDIX E CHOP STRAND MAT(CSM) CARBON FIBRE