UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Study of the Epoxy Resin Bonding Process of Aluminum Alloy : Chemical Pickling Process (Sulphuric Acid)

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering in (Manufacturing Process) with Honours.

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process). The members of the supervisory committee are as follow:

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DECLARATION

I hereby, declared this report entitled "Study of the Epoxy Resin Bonding Process of Aluminum Alloy : Chemical Pickling Process (Sulphuric Acid)" is the results of my own research except as citied in references.

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ABSTRACT

Metal bonding is a process adhesive or epoxy resin that used to bond thin material lap joints. This process as an alternative method to change others joint method such as spot welding and riveting. Hence, the purpose of this report is to study of the epoxy resin bonding process of aluminum alloy through several process. Before the process is operated, the surface of aluminum alloy will be rough and be pre-treated using sulphuric acid. Then the test sample will be tested using Universal Testing Machine for tensile strength test. The project will analyze difference concentration and immersion time of pickling chemical and from the result we can determine the best Al-Al bonding technique. Type of material that we use in this study is Aluminum Alloy 2014/2024 T3, epoxy resin and sulphuric acid. Machine that involve in this study Universal Testing Machine model Shimadzu, AG-100kNI in Material Lab Faculty of Manufacturing Engineering UTeM and SEM microscope. The purpose of this study also to find the best aluminum-aluminum joint method. Other joint method that we can compare is riveting and spot welding.

ABSTRAK

‘Metal Bonding’ adalah satu bahan pelekat atau bahan epoksi yang digunakan untuk melekatkan bahan yang nipis untuk cantuman bertindih. Proses ini sebagai satu kaedah alternatif untuk menukar lain-lain kaedah pengikat seperti kimpalan bintik dan ‘rivet’. Oleh itu, tujuan laporan ini adalah untuk mengkaji pelekatan aluminium aloi menggunakan bahan epoksi melalui beberapa proses sampingan. Sebelum proses dikendalikan, permukaan aluminum aloi akan dikasarkan sebelum ditindakbalaskan menggunakan asid sulfurik. Kemudian sampel ujian akan di uji menggunakan ‘Universal Testing Machine’ untuk ujian ketegangan. Projek ini juga akan menganalisis tahap asid dan masa rendaman aluminium aloi ke dalam asid sulfurik dan daripada hasil itu kami dapat menentukan teknik pelekat terbaik untuk aluminium aloi- aluminium aloi. Jenis bahan yang kami gunakan dalam kajian ini adalah Aluminum Alloy 2014/2024 T3, bahan epoksi dan asid sulfurik. Mesin yang terlibat dalam projek ini adalah ‘Universal Testing Machine model Shimadzu AG-100kNI yang terdapat dalam Makmal Kejuruteraan Bahan Fakulti Kejuruteraan Pembuatan UTeM dan mikroskop SEM. Tujuan kajian ini juga untuk mencari kaedah terbaik pelekatan antara aluminum aluminum. Kaedah pelekatan lain yang kami boleh bandingkan adalah rivet dan kimpalan bintik.

DEDICATION

This thesis gratefully dedicated to my beloved mother, father, brother, sister and my friend. Thank you for your continuous support.

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LIST OF ABBREAVIATION, SYMBOLS, SPECIALIZED NOMENCLATURE

A	-	Area
Al	-	Aluminium
ANSI	-	American National Standards Institutes
ASTM	-	American Standard for Testing and Materials
CO_2	-	Carbon Dioxide
DIN	-	Deutsches Intitut für Normung (German Institues for Standardization)
F	-	Force
g	-	Gram
H_2SO_4	-	Sulphuric Acid
ISO	-	International Standard Organization
M	-	Mass
Nd : YAG	-	Neodymium : yttrium-aluminium-garnet
Nd	-	Glass, ruby
RH	-	Relative Humidity
UTM	-	Universal Testing Machine
Vs	-	Versus
%	-	Percentage
^oC	-	Degrees Celsius

CHAPTER 1
INTRODUCTION

1.1 Background of the research

Metal bonding is a process in which structural adhesives are primarily used to bond thin material lap joints, replacing rivets or spot welds that are commonly used in these applications. Metal bonding adhesives also eliminate gaps, bulges, and protruding fasteners on aircraft exterior surfaces, thereby reducing drag forces on the aircraft. As an aircraft design consideration, metal bonding via adhesives is an important factor in facilitating sonic dampening and extending the fatigue life of aircraft components.

Adhesive bonding has gained increased acceptance in manufacturing ever since its use on a large scale: the assembly of load-bearing component in aircraft during World War II (1939-1945). Adhesive are available in various forms: liquid, paste, solution, emulsion, powder, tape, and film. When applied, adhesives typically are about 0.1 mm thick.

1.2 Problem Statement

Aluminum Alloy 2018 sheet metal are pre-treated using the chemical pickling process before being bonded using epoxy resin. The test sample are then tested for tensile strength using the Universal Testing Machine (UTM). The project will analyze different concentration level and immersion period of pickling chemical.

1.3 Objective

1. To analyze different concentration level and immersion period of pickling chemical between aluminum alloy and H2SO4 before the aluminum will be bonded using epoxy resin.
2. To determine the best concentration level and immersion time of H_2SO_4.
3. Analyzing the UTM test data.

1.4 Scope of Study

The scope of this project is to analyze different concentration level and immersion period of pickling chemical between aluminum alloy and H_2SO_4 before the aluminum will be bonded using epoxy resin. The aluminum alloy grade that will be use in this experiment is Aluminium Alloy sheet 2018 with thickness 0.8mm. After the bonding process, the sample will analyze using Universal Testing Machine (UTM) model Shimadzu, AG-100kNI to make the tensile strength test. The concentration level of H_2SO_4 that used is 5%, 10%, 15%, 20%, and 25% with 5 minutes immersion time. For different immersion time, the period that used is 1 minutes, 2 minutes, 3 minutes, 4 minutes and 5 minutes. Then the result or data can define the best concentration level and immersion time period of pickling chemical. The result also will compare to the test sample without pickling process. It is important to show that there are some changes to the strength of aluminium alloy 2018 before and after pickling process

1.5 Aluminum Alloy

Aluminum alloys are alloys of aluminum, often with copper, zinc, manganese, silicon, or magnesium. They are much lighter and more corrosion resistant than plain carbon steel, but not quite as corrosion resistant as pure aluminum. Bare aluminum alloy surfaces will keep their apparent shine in a dry environment due to the formation of a

clear, protective oxide layer. Galvanic corrosion can be rapid when aluminum alloy is placed in electrical contact with stainless steel, or other metals with a more negative corrosion potential than the aluminum alloy, in a wet environment. Aluminum alloy and stainless steel parts should only be used together in water-containing systems or outdoor installations if provision is made for either electrical or electrolytic isolation between the two metals.

Aluminum alloys with a wide range of properties are used in engineering structures. Alloy systems are classified by a number system (ANSI) or by names indicating their main alloying constituents (DIN and ISO). Selecting the right alloy for a given application entails considerations of strength, ductility, formability, weld ability and corrosion resistance to name a few. Aluminum is used extensively in modern aircraft due to its high strength to weight ratio.

In this experiment, type of aluminum alloy use is 2018. The International Alloy Designation System is the most widely accepted naming scheme for wrought alloys. Each alloy is given a four-digit number, where the first digit indicates the major alloying elements.

1.6 Epoxy Resin

In chemistry, epoxy or polyepoxide is a thermosetting epoxide polymer that cures (polymerizes and crosslinks) when mixed with a catalyzing agent or "hardener". Most common epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A. Epoxy adhesives are a major part of the class of adhesives called "structural adhesives" or "engineering adhesives" (which also includes polyurethane, acrylic, cyanoacrylate, and other chemicals). These high-performance adhesives are used in the construction of aircraft, automobiles, bicycles, boats, golf clubs, skis, snow boards, and other applications where high strength bonds are required. Epoxy adhesives can be developed to suit almost any application. They are exceptional adhesives for wood,

metal, glass, stone, and some plastics. They can be made flexible or rigid, transparent or opaque/colored, fast setting or extremely slow setting. Epoxy adhesives are almost unmatched in heat and chemical resistance among common adhesives.

1.7 Chemical Pickling

Chemical pickling in bonding is the process to pre-treat the surface of material. Pickling is a method of surface cleaning and preparation that is achieved through immersion of metals in dilute acids. Pickling is used in metal working industries to remove scales, tarnish, or oxides. Pickling can be accomplished with a variety of different acids. Acids used for pickling include sulfuric, hydrochloric, nitric, phosphoric and various other mixtures of these.

Pickling is usually carried out by immersing metals into large baths of acid solution but pickling can also involve spraying or flowing the solution over the specimen. The overall goal of pickling is to remove scale from the base metal without loss from dissolving the metal itself. This is usually accomplished through the use of inhibitors in the pickling solution. If the scale could somehow be removed from the surface uniformly acid attack of the base metal wouldn't be a problem as the sample could be removed from the solution as soon as the scale was removed. Since scale is removed faster from some areas an uninhibited acid solution would begin dissolving base metal in those areas before all of the scale is removed.

The pickling process breaks down in the following way. First the metal must be cleaned and prepared for the pickling process. This step includes removing any material from the metal that would prevent contact of the pickling acid with the surface. Generally this involves removing any oils on the surface. This is accomplished by either solvent or alkali cleaning. In this experiment, the ultrasonic bath is use. The next step is the actual pickling process. After pickling the metal is treated in preparation for coating. After pickling the metal is run through a cold clean water rinse to remove the film of pickling

acids and salts that cling to the surface. These actually cause corrosion even under coatings if they are not removed. The film can be difficult to remove if it dries so rinsing must occur immediately. After the cold water rinse the metal undergoes a final hot rinse in boiling weak alkaline solution. This creates an alkaline surface that does not rust rapidly. Prior to painting the surface pH must be adjusted to ensure proper adhesion of the coating to the surface. This is achieved by a phosphoric or chromic acid solution.

1.8 Sulphuric Acid

Sulphuric acid is a strong mineral acid with the molecular formula H_2SO_4. It is soluble in water at all concentrations. It was once known as oil of vitriol, coined by the 8th-century alchemist Jabir ibn Hayyan after his discovery of the chemical. The H_2SO_4 that used is bought from the hardware shop.

1.9 Universal Testing Machine (UTM)

A Universal Testing Machine otherwise known as a materials testing machine/ test frame is used to test the tensile and compressive properties of materials. Such machines generally have two columns but single column types are also available. Load cells and extensometers measure the key parameters of force and deformation as the sample is tested. These machines are widely used and would be found in any materials testing laboratory.

A typical testing system is comprised of a materials testing machine/test frame, control and analysis software, and critically, the test fixtures, accessories, parts and devices used to hold and support the test specimen.

CHAPTER 2

LITERATURE REVIEW

2.1 Adhesive Bonding

2.1.1 Introduction

Higgins, A. (2000) said that adhesive bonding has been used in the manufacture of primary aircraft fuselage and wing structures for over 50 years. As such, it is a direct competitor process to riveted structures but not as dominant. Metal bonding is a process in which structural adhesives are primarily used to bond thin material lap joints, replacing rivets or spot welds that are commonly used in these applications. Metal bonding adhesives also eliminate gaps, bulges, and protruding fasteners on aircraft exterior surfaces, thereby reducing drag forces on the aircraft. As an aircraft design consideration, metal bonding via adhesives is an important factor in facilitating sonic dampening and extending the fatigue life of aircraft components.

David, E. and Lazar, A. (2003) states that the bonding process is when adhesive was applied onto the bonding surface. The remaining layer of adhesive was as thin as possible, about 0.05–0.08 mm. As is the case with chemical reactions, rapidity of hardening depends on the ambient temperature or the temperature of the work piece.

Wheeler, M.J. (1987) classify the benefits of adhesive bonding have been demonstrated by a number of car manufacturers in concept cars and low volume niche products, e.g. Jaguar's XJ220, Ford's AIV , Rover's ECV3, the Lotus Elise, and to a

limited extent in Honda's NSX. Not least of these benefits is that adhesive bonding does not distort the components being joined as arc-welding has been shown to do.

2.1.2 The advantages of the process are:

1. Barnes, T.A. and Pashby, I.R. (1998) said adhesive bonding offers improved joint stiffness compared to mechanical fasteners or spot-welds because it produces a continuous bond rather than a localized point contact. This results in a more uniform stress distribution over a larger area.
2. A well designed joint will absorb energy well, and tend to have good noise and vibration damping properties.
3. The smooth joint produced reduces stress concentrations at the joint edges thereby providing good fatigue resistance
4. Adhesive bonds are inherently high strength in shear.
5. Adhesive bonds are inherently high strength in shear ;
6. Adhesive bonding has tended to be regarded as a comparatively low cost process in terms of equipment.
7. Kalpakjian, S. (1992) classify that the adhesive is essentially dual purpose in this type of application as well as providing mechanical strength, the adhesive seals the joint against moisture and debris ingress
8. Kalpakjian, S. (1992) classify that it is possible to join dissimilar and otherwise incompatible materials. Dissimilar metals can be joined in this way, since the adhesive layer prevents intimate contact which could otherwise lead to galvanic corrosion

2.1.3 The limitation of the process are:

1. Barnes, T.A. and Pashby, I.R (1998) said current high performance adhesives are epoxy or solvent based systems, giving rise to considerable environmental concerns. The health and safety hazards involved in the use of these substances implies significant costs in providing adequate fume extraction, protective clothing

and adequate provision for fire protection storage. Given current environmental concerns, there is also the possibility that these substances may eventually be banned from use by future legislation. Alternative adhesives such as Corobond eliminate such issues but exhibit inferior mechanical properties, particularly with regard to impact strength.

2. Structural adhesives require heat curing. The utilization of the body-in-white (BIW) paint bake cycle has been cited as a possible economic solution, obviating the need for an additional processing stage. It is however, important to note that an intent to replace pressed metal body panels with polymeric panels, paint-coated as an integral part of the injection molding process would however invalidate this particular solution.
3. There are also foreseeable difficulties with extensive utilization of adhesive joints in volume production. Adhesives have a limited shelf-life and provision must be made for this by materials control. Despite increasingly sophisticated systems designed to counter problems such as increasing viscosity over time, the adhesive dispensers are still likely to require regular cleaning and therefore planned routine maintenance to prevent problems.
4. Adhesive joints are inherently weak in peel and vehicle design would need to take account of this, particularly with regard to crashworthiness.

2.1.4 Basic Loading condition for adhesive bonded joints

Adderley, C.S (1988) states that in practice, a bonded structure often has to sustain a combination of tensile, compressive, shear, cleavage and peel stresses. Therefore in order to minimize the peel stresses experienced by a joint, thereby substantially increasing its robustness, engineers generally use some form of lap shear joint.