Faculty of Engineering

EFFECT OF VARIOUS CONDITIONS ON ADHESIVELY BONDED GFRP

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Dedicated especially to Ivan, Ivy, Ian, Alvin & Laura

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ABSTRAK

Kebolehan dan ketahanan “adhesive joint” merupakan antara prasyarat terpenting ketika proses “adhesive bonding”. Ini adalah kerana dalam jangka hayat sendi gam ataupun “adhesive joint”, ianya didedahkan kepada persekitaran yang mampu melemahkan sendi tersebut, seperti kelembapan, suhu yang melampau, karat, impak yang kuat dan juga persekitaran yang menghakis seperti asid dan alkali. Oleh itu, adalah amat penting untuk kita mengetahui sejauh manakah persekitaran tersebut mampu melemahkan sendi gam yang direka. Selain itu, pemilihan gam adalah amat penting kerana setiap gam tersebut mempunyai sifat tersendiri yang membolehkan ianya menahan persekitaran yang sesuai dengan sifat kimianya. Tujuan projek tahun akhir ini adalah untuk menyiasat dan mengkaji kesan empat jenis persekitaran terhadap sendi gam yang digunakan untuk melekat komposit GFRP-GFRP yang telah direka. Empat jenis persekitaran tersebut adalah suhu bilik, air laut, persekitaran luar dan juga suhu panas. Dua jenis gam digunakan untuk melekat komposit-komposit tersebut, iaitu epoxy yang telah dikuatkan (toughened epoxy) dan epoxy ketahanan kimia (chemical resistance). Jangka masa untuk mendedahkan spesimen kepada persekitaran yang dikaji adalah 3 – 6 minggu untuk persekitaran suhu bilik, air laut dan persekitaran luar. Bagi suhu panas, spesimen didedahkan untuk jangkamasa 24 – 48 jam. Keputusan akan diuji dengan menggunakan mesin Shimadzu Autograph dan akan diplotkan pada graf dan dibandingkan.

ABSTRACT

Durability of the adhesive joint is one of the most important requirements in adhesive bonding. This is because in real life service, adhesive bonding is subjected to aggressive environments such as humidity, heat, corrosive, impact and chemical environments. Therefore, it is important to know the extend of degradation that these environments can do to the adhesive joint. Adhesive selection is also important because each adhesive have its own properties that make it suitable for different types of environments. The purpose of this project is to investigate four different types of environmental effect on the adhesive joints of GFRP-GFRP (composite) plate using two types of adhesives; one is of toughened epoxy and another one is of chemical resistance epoxy adhesives. The duration for the tests is 3 weeks and 6 weeks for three environments (room temperature, seawater and outside). For the heat test, the duration of the exposure is 1 days and 2 days respectively. The result of the environmental test is found using Shimadzu Autograph machine and graphs for the specimens will be tested and compared.

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LIST OF ABBREVIATIONS

GFRP	-	Glass Fiber Reinforced Plastic
CSM	-	Chopped Mat Strand
FRP	-	Fiber Reinforced Plastic
Ksi	-	Kilo psi (1 Ksi = 1000 psi)
ABS	-	Acrylonitrile Butadiene Styrene
Tg	-	Transition Temperature
MEKP	-	Methyl Ethyl Ketone Peroxide
FE	-	Finite Element
ASTM	-	American Society for Testing and Material
MN/m^2	-	Mega Newton (10^6) / meter square (m^2)
UNIMAS	-	Universiti Malaysia Sarawak

CHAPTER 1

INTRODUCTION

1.1 Background

Glass Fiber Reinforced Plastic (GFRP) had been used extensively in commercial composite application due to its excellent comprehensive performances, which has high heat resistance and high intensity with mechanics after been reinforced with glass fiber. It was one of the world's most widely used engineering plastic before been substituted by carbon fiber which is stronger both by volume and weight.

Among the application of GFRP is in the automotive and aircraft industry, where GFRP is been used to make some of their body parts using adhesive bonding technique. Figure 1.1 shows the application of GFRP in making the body parts of aircraft such as tip fairings and wings. GFRP is also used in telecommunications industry for shrouding the visual appearance of antennas, due to its radio frequency permeability and low signal attenuation properties [1].

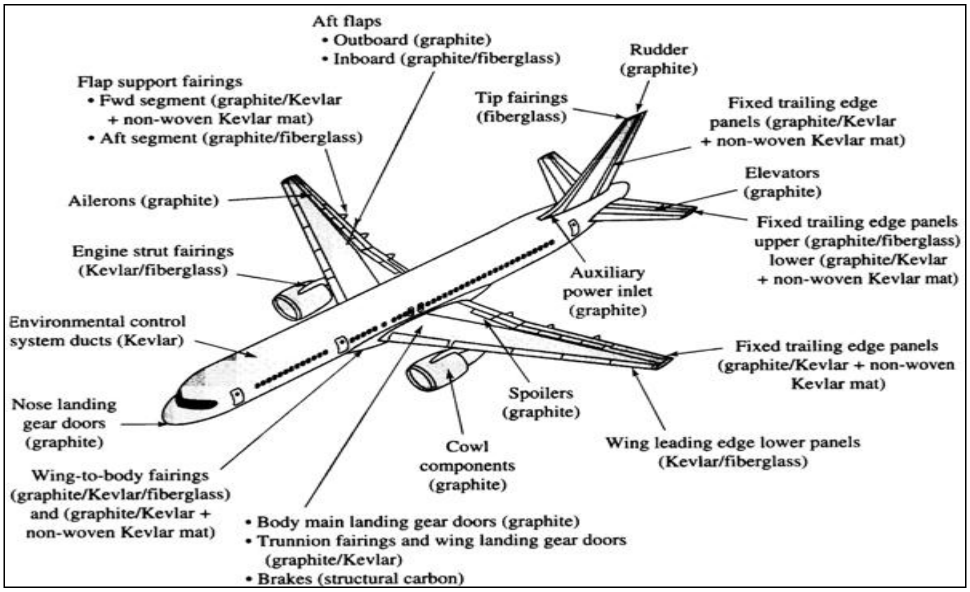

Figure 1.1: The use of Glass Fiber Reinforced Plastic (GFRP) in making body parts of plane, such as tip fairings and wing

The application of adhesively bonded GFRP ranges in different environment, such as high temperature, corrosive and extreme temperature environment [2]. One of the most critical cases is in military and aircraft, especially those operating in tropical or coastal locations. The strength of the adhesive joint that joins the composites must be strong enough to sustain the hostile environment. For example, if the adhesive joint of aircraft failed during its service, the effect will be catastrophic. Therefore, it is important to study the effect of the environment on the adhesive joint of composites because the physical and mechanical properties of both the adhesive and adherend cannot be regarded as constant with time [2].

1.2 Problem Statement

The practical importance of environmental deterioration of adhesive bonds has resulted in extensive research on many aspects of the problem. By far, the largest problem faced by scientists is the long term durability of adhesive bonds exposed to natural environments; weathering [3]. Degradation in mechanical properties of GFRP is also a direct result of exposure to aggressive environments. Therefore, it is important for the user to determine the most suitable adhesive for their specific application to ensure that joint degradation would not cause catastrophic failure of their system.

1.3 Project Objectives

The objectives of this project are to:

i. Study the effect of different environmental condition on the adhesively bonded Glass Fiber Reinforced Plastic (GFRP)

ii. Identify experimentally the shear strength of the adhesively bonded Glass Fiber Reinforced Plastic (GFRP) for both toughened epoxy resin and chemical resistance epoxy resin.

iii. Identify the condition of environment that affects the most the performance of the adhesive joint for both the toughened epoxy and chemical resistance epoxy.

1.4 Scope Of The Study

This project will study the effect of four types of environmental conditions to the strength of the adhesively bonded GFRP, which uses two types of epoxy resin to construct the adhesive joint. The two types of epoxy resin are Araldite 2015 (toughened epoxy) and Araldite 2013 (chemical resistance epoxy). The four types of environmental testing are sea water environment (corrosive), room temperature, elevated temperature (80^{o} C) and outside environment conditions. The period of environmental exposure is three weeks to six weeks (seawater, corrosive and room temperature) and 24-48 hours for the elevated temperature test. After the exposure, each specimen will be tested for its shear strength and to determine which environment affects the most the strength of the adhesive joint.

1.5 Importance Of The Study

This study will compare the effect of various environmental conditions on adhesive joint performance of the Glass Fiber Reinforced Plastic (GFRP) sheet. Comparisons of the results obtained from the experiment can be used to recognize as to which type of environmental condition presents the most severe threat to the performance of the adhesive joint.

CHAPTER 2

LITERATURE REVIEW

2.1 Glass Fiber Reinforced Plastic

The development of Glass Fiber Reinforced Plastic (GFRP) started out in the United Kingdom [1]. It was developed back then as a mean of replacement for the molded plywood used in aircraft radomes. It was chosen as a replacement for its properties of being transparent to microwave. Its first main civilian application however was for the building of boats, where it gained global acceptance in the 1950s.

Glass Fiber Reinforced Plastic (GFRP) is a composite material made of plastic (polymer) and glass fibers as its reinforcement [1]. The plastic is of thermosetting, such as polyester and epoxy. GFRP is usually found to be in the form of chopped mat strand (CSM), where it is a type of non-woven material using emulsion or powder as binder. It consists of glass-fibers that are laid randomly across each other and held by a binder.

Chopped Mat Strand (CSM) fiberglass, which is shown in Figure 2.1 below have the characteristics of all direction reinforcement, nice resin conformability and good formability. It is used to produce FRP items, usually by hand lay-up technique. In this technique, sheets of material are placed in a mold and brushed with resin. The binder, which dissolves in resin, will make the material to conform to different shapes easily when wetted out. After the resin cures, the hardened product can be taken from the mold.

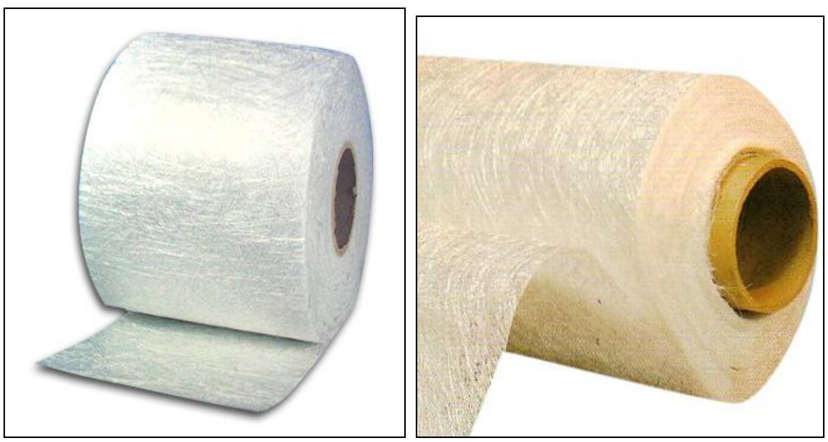

Figure 2.1: Fiberglass in Chopped Mat Strand form [4]

GFRP have a general property of high tensile strength, high impact resistance and good chemical resistance. The combination of the two materials, plastic and glass fiber overcomes the deficit of one another. Whereas plastic is strong in compressive and weak in tensile strength, glass fibers are strong in tension but weak against compression.

2.1.1 Type of Glass Fibers

The three most common glass fibers used in composites are E-Glass, S-2 Glass and Quartz [5]. E-Glass, which is shown in Figure 2.2 is the most common and least expensive of the three, providing good combination of tensile strength (3.4 GN/m^2) and modulus (75 GN/m^2). S-2 Glass is 40% stronger than E-Glass, possessing tensile strength of 4.5 GN/m^2 and modulus strength of 87 GN/m^2. It is also capable of retaining greater percentage of its strength at higher temperature. However, it is more expensive compared to E-Glass. Quartz fiber is an ultra-pure silica glass with low dielectric fiber and is used in demanding electrical applications.

Figure 2.2: E-Glass Fiberglass Roving [6]

2.2 Adhesive

An adhesive is any substance, inorganic or organic, natural of synthetic, that is capable of bonding substances together by surface attachment [2]. The bonding power of the adhesive is a function of its molecular weight or size of molecules. Adhesive with higher molecular weight generally provides stronger bond, provided the bonding process is done properly. It is important to analyze the characteristic of adhesive before it is been chosen to work with adherent. Such efforts may direct towards specific purpose that may focus on structural determination, curing reaction, and process control or failure analysis.

2.3 Types of Adhesives

Adhesives that are used in fiber reinforced plastics are also referred to as polymers, where they composed of long chain molecules consisting of many repeating units. Men made polymers are known as synthetic resins or simply resin. These resins can be classified under two types, thermoplastic and thermosetting [7]; each represents different properties under the effect of heat.

Thermoplastics like metals, melts when heated and hardened again when cooled. This process can be repeated as often as desired without any appreciable effect on the material properties in either state. Typical types of thermoplastics include nylon, polypropylene and ABS, and these materials can be reinforced, usually by using short, chopped fibers such as glass as its reinforcement [2,7].

Thermosetting materials, on the other hand are formed from a chemical reaction in situ, where the resin and hardener are mixed and then undergo a non-reversible chemical reaction to form a hard, infusible product. Thermosets will not become liquid again even though it is heated, although their mechanical properties might change under certain temperature. This temperature is known as the Glass Transition Temperature (T_g), and varies widely among different types of resin. Above the T_g, the molecular structure of the thermoset will change from rigid crystalline polymer to amorphous polymer, which is more flexible. This structure can be reversed back once it is cooled back to temperature below its T_g. Under temperatures higher than T_g, properties of resin modulus such as stiffness will drop sharply, and as a result the compressive and shear strength of the composite will drop too. Although there are many different types of resin in use in the composite industry, the majority of structural parts are made with three main types, namely polyester, vinyl ester and epoxy resin [2], which is the adhesives chosen in this project.

2.3.1 Polyester Resins

Polyesters are the main adhesive of choice when it comes to glass fiber lamination. This is because of the exothermic nature of polyesters, where it is accompanied by a rise in temperature. Since glass fibers are the strongest laminates, they are the preferred form of adherend for polyester resins [2]. Polyester resins such as these are of the 'unsaturated' type. Unsaturated polyester resin is a thermoset, capable of being cured from a liquid or solid state when subject to the right conditions. Unsaturated polyester resin is normally referred as polyester resin or just polyester. There is a whole range of polyesters made from different acids, glycols and monomers, all having varying properties.

Two principle types of polyester resin are used as standard laminating systems in the composites industry; Orthophthalic and Isophthalic [8]. Orthophthalic polyester resin is the standard economic resin used by many people. Isophthalic polyester resins have now become the preferred material in industries because of its superior water resistance properties.

Even though polyester's usage is limited in use for high performance composites, they are used extensively in commercial applications due to their lower cost compared