EFFECT OF HUMIDITY ON THE MECHANICAL PERFORMANCE OF JOINTS BONDED WITH ELECTRICALLY CONDUCTIVE ADHESIVE

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in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project report entitled "Effect of Humidity on The Mechanical Performance of Joints Bonded With Electrically Conductive Adhesive" is the result of my own work except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Mechanical Engineering with Honours.

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATION

To my beloved parents and my respected supervisor

ABSTRACT

The research describes about the effect of humidity on the mechanical properties of joints bonded with electrically conductive adhesive. Through the background of the study, the applications of adhesive bonding with electrically conductive adhesive were described together with the advantages and limitations of the adhesive joints. The aim of this research is to investigate the mechanical properties of adhesive joints under various humidity conditions and to examine the surface profiling of adhesive bonding taken under 3D Non-Contact Surface Profilometer. The research covers on the design and fabrication of adhesive joints bonded with electrically conductive adhesive. Apart from that, the methodology used in this research includes the design of jig, preparations of specimens and test joints, and also experimental set up to obtain the analysis of mechanical properties and characterization of surface profiling tested through various humidity conditions. The results shows that the humidity factor will lead to higher shear strength depends on the type of adhesive used together with the effect of surface roughness. In comparison between high and low humidity condition, higher lap shear strength were obtained at low humidity condition as compared to high humidity condition. Besides, from the analysis of surface profiling, it can be analyzed that humidity factor will result in different surface textures depends on the shear strength developed from the mechanical properties of adhesive itself. In this research, the shear strength obtained from the humidity test will depends on the height distributions of the surface profile. For future works, it is recommended to improve the effect of surface roughness by using different techniques instead of mechanical abrasion method in order to enhance the strength of the adhesive joints. Besides, in terms of formulated adhesive as prepared in this project, the future research is recommended to identify the composition ratio of the adhesive with different mix ratio to get variation of results in the mechanical performance of joints bonded with electrically conductive adhesive.

ABSTRAK

Penyelidikan ini menerangkan tentang kesan kelembapan pada sifat mekanik sendi yang terikat dengan pelekat konduktif elektrik. Melalui latar belakang kajian ini, aplikasi ikatan pelekat dengan pelekat konduktif elektrik digambarkan bersama dengan kelebihan dan batasan sendi pelekat. Tujuan penyelidikan ini adalah untuk mengkaji sifat-sifat mekanik sendi pelekat melalui pelbagai keadaan kelembapan dan untuk mengkaji profil permukaan pelekat ikatan yang diambil di bawah Profilometer permukaan tanpa sentuh 3D. Kajian ini merangkumi reka bentuk dan fabrikasi sendi pelekat yang terikat dengan pelekat konduktif elektrik. Selain itu, metodologi yang digunakan dalam penyelidikan ini termasuk reka bentuk jig, persediaan spesimen dan sendi ujian, dan juga eksperimen yang dijalankan untuk mendapatkan analisis sifat-sifat mekanik dan pencirian profil permukaan yang diuji melalui pelbagai keadaan kelembapan. Keputusan menunjukkan bahawa faktor kelembapan akan membawa kepada kekuatan ricih yang lebih tinggi bergantung pada jenis pelekat yang digunakan bersama-sama dengan kesan kekasaran permukaan. Sebagai perbandingan antara keadaan kelembapan yang tinggi dan rendah, kekuatan ricih pusingan yang lebih tinggi didapati pada keadaan kelembapan yang rendah berbanding keadaan kelembapan yang tinggi. Selain itu, dari analisis profil permukaan, dapat dianalisis bahawa faktor kelembapan akan menghasilkan tekstur permukaan yang berbeza bergantung pada kekuatan ricih yang dihasilkan dari sifat mekanik pelekat itu sendiri. Dalam kajian ini, kekuatan ricih yang diperoleh daripada ujian kelembapan bergantung kepada ketinggian profil profil permukaan. Untuk kerja-kerja masa hadapan, adalah disyorkan untuk meningkatkan kesan kekasaran permukaan dengan menggunakan teknik yang berbeza dan bukan kaedah lelasan mekanikal untuk meningkatkan kekuatan sendi pelekat. Selain itu, dari segi pelekat yang dirumuskan seperti yang disediakan dalam projek ini, penyelidikan masa depan adalah disyorkan untuk mengenal pasti nisbah komposisi pelekat dengan nisbah campuran yang berbeza untuk mendapatkan variasi keputusan dalam prestasi mekanikal sendi yang terikat dengan pelekat konduktif elektrik.

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LIST OF ABBREVIATIONS

ECA	Electrically Conductive Adhesive
ICA	Isotropic Conductive Adhesives
ACA	Anisotropic Conductive Adhesives
LCD	Liquid Crystal Display
3D	3 Dimensional
ISO	International Organization for Standardization
DC	Direct Current
VDC	Volts Direct Current
MPa	Mega Pascal
g	Gram
ml	Milliliter
mm	Millimeter
ASTM	American Society for Testing and Materials
Ra	Arithmetical Mean Roughness
Sn	Tin
Ag	Silver
RH	Relative Humidity
CATIA	Computer Aided Three-Dimensional Interactive Application
ABS	Acrylonitrile Butadiene Styrene
CAD	Computer-Aided Design
STL	Stereolithography
IPA	Isopropyl Alcohol
µm	Micrometer
N	Newton
mm^2	Square millimeter
Rz	Maximum Average Peak-To-Valley Height

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Generally, an adhesive can be defined as a non-metallic substances that have the ability to join materials in terms of surface bonding (adhesion) meanwhile in term of bonding, it can be defined as one of the material joining methods that is capable to joint between a surfaces to another surfaces in terms of identical or antithetical materials. Usually, by using a substance that is made of different materials, it will enable the two adherents to be joined by transporting the forces from one adherents to another adherents [1].

Nowadays, one of the great applications of adhesive bonding is mainly known as electrically conductive adhesive whereby it is actually being developed to be used in electronics applications. This electrically conductive adhesive can be considered as a glue that can hold the electronic components in place while passing the electrical current between them. In general, people used to do soldering as the conventional method to allow the electrical current to flow through the electronic components. Solder joints are usually the best choice in the electronics construction however if there are too much solder on a certain joint, it may cause to poor joints itself. Sometimes, it can have the possibility of failure that will lead to a short circuit if the solder spilled over on another track on printed circuit boards. Besides, in the traditional soldering techniques, different types of solders are used for distinct use. The most common solder that are widely used is generally made of a mixture of tin and lead. However, due to environmental and health issues, lead is no longer available to be used commercially in soldering process.

Therefore, electrically conductive adhesive is being introduced to the electronics constructions by using bonding method instead of soldering process. According to Heindl [2] , there are two types of electrically conductive adhesives which are isotropic conductive adhesives (ICA) and anisotropic conductive adhesives (ACA). Generally, isotropic conductive adhesive is an element that have the capability of conducting electric in all directions as desired whereby it is currently being used in the information technology applications such as chip connection. Meanwhile for anisotropic conductive adhesives, it can be summarized as a material that have an exclusive elements within the μm range whereby it only have the ability of conducting electric in a single direction as compared to previous type of adhesives. Anisotropic conductive adhesives are widely used to adhere various types of complex structures on circuit boards. For example, it is commonly used to connect any flexible components on printed circuit boards as well as to strengthen the liquid crystal display (LCD) connections.

Apart from that, the main advantages of using this electrical conductive adhesives instead of soldering is due to its flexibility and capability to resist vibrations is better than the solder itself. Besides, this electrical conductive adhesives are absolutely a lead-free material that comes in an ideal resolution to produce electrical contacts on any substrates. However, there are certain limitations to the application of the adhesives bonding itself. For example, a few important factors such as sensitivity to the environmental conditions, adhesives temperature, ambient temperature, and condition of materials must be considered during the adhesives bonding process [3]. In terms of ambient temperature, it is actually involves the temperature of the surrounding air that is usually influenced by the humidity range of the surrounding. Brennan [4] stated that relative humidity can be expressed as the amount of moisture contains in the air that are in conjunction to the temperature parameter. Normally, when the relative humidity increases, it is usually occurs due to the temperature

drops while the water vapor remains the same since cool air only need a small amount of moisture to become saturated as compared to warm air. Therefore, it is important to maintain a relevance ambient temperature in order to produce a great adhesive bonding since the ambient temperature will automatically effects the humidity of the surrounding hence it give impacts on the lifespan of the bonds in the finished product.

1.2 Problem Statement

In the material designing and manufacturing process of adhesives bonding, there are several significant things that need to be considered in order to produce great product. In the previous research, it was found that reliability of anisotropic conductive adhesives (ACAs) interconnects is affected by degradation due to moisture absorption [5] . According to this study, ACAs is made of large amount of polymers, therefore water can degrade polymers in several ways that will eventually lead to mechanical degradation since moisture absorption that is affected by relative humidity can cause the interruption of conductivity within the joining of electrodes. This will also contributes to the formation of defects on the electrically adhesive bonding such as cracks and delamination.

1.3 Objectives

The objectives of this study are:

- To identify the characterization and mechanical properties of an adhesive bonding based on various humidity.
- To examine the surface profiling of adhesive bonding taken under 3D Non-Contact Surface Profilometer.

1.4 Scope of Study

The study covers the design and fabrication of specimen of single lap joint according to the ISO standard in order to join between two materials by using an adhesive bonding substrates. Besides, the characterization of mechanical properties were observed and mechanical testing was conducted under various humidity level at certain space. Apart from that, the analysis of surface profiles and characterization of mechanical strengths on the tested specimens also investigated in this research.

1.5 Organization

The report is divided into several chapters and all of these chapters will explain about the details information of the study. The organization of this report will follows the details as follows; chapter 1, the introduction covers the background of the study, problem statement, objectives of the study, scope of the study, and also general methodology of the study. Next, chapter 2 consists of literature review that will covers on the previous study or research that are related to this project. Then, chapter 3 is a details description on the methodology that are being used for further analysis. After that, the result and discussions of this project are then discussed in the chapter 4. Finally, chapter 5 will include the conclusion and recommendations for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Adhesives are greatly being used in joining or reconstruction of any parts in certain materials. Due to high durability of the adhesive, it has replaced the usage of rivet joints in bonding or repairing process because adhesive bonding have minor concentration stress and less potential of having leakage and deterioration. Besides, it will results in less shape change on the repaired structure [6]. Mainly, in an adhesive joint, any adhesive that is applied between two plates can be defined as adherent. In the bonding process, adhesives are being used widely to grip and strengthen the bond between two bodies when the adhesive elements infiltrate into the adherent component. Besides, in order to form a durable bond, long polymeric chain will diffuse into the adherent body from the adhesive element itself. Then, the bonding between two bodies will occurs due to the electrostatic force that are generated along the bonding process. Normally, there are a few types of adhesive joints that are being used in this cases such as single lap joint, double lap joint, scarf joint and others.

As stated by Lempke [7] , single lap joints have been identified as one of the best methods to join between two materials through the application of overlying bond. This method are widely-used due to its respective strength and also the way it is being assembled which is much simpler than the traditional bonding techniques. Besides, the ability of adhesive to adhere between two contradictory materials has developed the behavior of single lap joint itself.

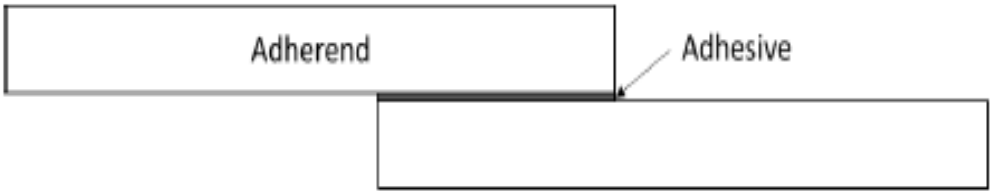

Figure 2.1: Single lap (unsupported) joint [7]

A full single lap joints as illustrated in Figure 2.1, can be defined as a bonding of adherents through an overlapping process with the help of adhesive, whereby there will be no substances is removed at the bond. In other words, no adherent material is being modified along the full overlap of the joint. According to Yan [8], a great fatigue resistance can be obtained by a smooth joint without any stress concentration. Besides, to absorb impact strength as well as to reduce any external disturbance such as noise and vibration, it is very important in to produce a good joint by using the adhesive bonding applications. To investigate the stress distribution and strength of single lap joints, there are several parameters that need to be considered when designing the lap joints [7]. The parameters include type of adhesive and its properties, substrate materials, surface preparations, overlap length, adhesive thickness and environment on the adhesive joints strength, and so on.

2.2 Application of Electrically Conductive Adhesive in Single Lap Joints

In previous century, soldering methods have been used widely in the electronic manufacturing as a standard interconnection technologies. However, this processes are slowly being dismantle through the worldwide because the usage of tin or lead during the soldering processes have been identified as an environmentally harmful material by the European Union, thus it is very important make sure that any solder process need to be lead-free by that respective year [7]. Therefore, a study on alternative method to replace the

conventional soldering techniques has been conducted that eventually leads to the investigation on electrically conductive adhesives (ECAs) which have developed and became as one of the important applications of adhesive bonding. In this case, the ECAs are generally made from composites of insulating polymer matrix and conductive fillers. These two main criterions are very important in designing the ECAs because the characteristics of polymer matrix itself would enable the adhesive to bond and resist the mechanical stresses. Meanwhile, the electrical conductivity of the adhesive would depends particularly on the fillers [5].

Generally, the application of single lap joints are the most used type of joints in the industry because they are much simpler to be fabricated. Therefore, the most efficient type of loading for the adhesive is shear since adhesive is normally loaded in shear [9]. In order to minimize the stress concentrations and increase the joint strength, it was identified that mixing of adhesive joints using a strong adhesive in the middle of overlap will contribute to a more uniform distribution of stresses and enhance the joint strength. Epoxy-based ICAs would improve the adhesion strength as compared to polyimide and silicone-based ICAs [10]. Thus, mixing technique can be applied by mixing the ECA with epoxy adhesive to increase the lap-joints strength. There are numerous type of adhesives that can be used in the application of single lap joints such as Araldite® Rapid (Huntsman, Basel, Switzerland). The properties of this adhesive is shown in the Table 2.1 below.