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LEAD FREE SOLDER TECHNIQUE SOLDER TECHNIQUE FOR AUTOMOTIVE INDUSTRY

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A project report submitted in partial fulfillment of the requirement for the award of the Degree of Bachelor of Mechanical Engineering (Structure & Material)

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October, 2005

"I hereby declare that this thesis is my own work except the ideas and summaries which I have clarified their sources"

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ACKNOWLEDGEMENTS

Thank to Allah, for giving me strength and helping me through out the difficulty that have happen to complete this project.

I am grateful to all who assisted for their attention and in helping sustain focus. Special thanks are due to Encik Ruztamreen bin Jenal, Puan Siti Hajar binti Sheikh Md Fadzullah and Puan Anita Akmar binti Kamarolzaman as my project supervisors and lecturers of Kolej Universiti Teknikal Kebangsaan Malaysia, for their assistance and advices in to write this thesis. They had spent time to guide me and together find solutions for some problem that occurred in this project. Everyone of them are meaningful to me due to their experience in soldering technique and material science that so much helping me in this project.

I also would like to thank all my friends for their support and help during preparation of specimens. Without their ideas and help, it's hard to me to finish the specimens.

Finally, thank a lot to my family for give me support and the motivation in whatever I have done.

ABSTRACT

Lead free solder technique have been an alternative method for joining process for aluminum other than rivet. Soldering can be a very attractive joining method for aluminum with much less heat distortion due to its lower process temperature than brazing and fusion welding. Various aluminum alloys have different solderability; 1xxx, 2xxx, 3xxx, 4xxx and 7xxx are easier to solder than 6xxx series alloys. 5xxx series alloys are the most difficult due to their magnesium content. The aluminum alloy has been chosen as soldered material in automotive industry because of its lower density than commonly used steel, its ability to be recycled, its potential to significantly minimize greenhouse emissions, and to create excellent mechanical and thermal properties, aluminum is a desirable material in automotive industry. This study expected to be the current knowledge to expand the usage of the lead free solder technique especially in the application of aluminum alloy in automotive industry.

ABSTRAK

Kaedah pateri tanpa plumbum adalah satu kaedah alternatif untuk menyambung aluminum selain kaedah rivet. Pateri boleh menjadi kaedah penyambungan yang sangat menarik bagi aluminium kerana sedikit haba yang merebak kerana suhu prosesnya lebih rendah daripada proses kimpalan. Aluminium aloi mempunyai kebolehpaterian yang berbeza, siri 1xxx, 2xxx, 3xxx, 4xxx dan 7xxx lebih mudah dipateri berbanding siri 6xxx. Siri 5xxx adalah yang paling sulit untuk dipateri disebabkan kandungan magnesiumnya. Aluminium aloi dipilih sebagai bahan untuk dipateri dalam industri automotif karenanya ketumpatannya yang lebih rendah berbanding keluli, boleh dikitarsemula dan bagi keguanaan yang memerlukan sifat mekanikal dan sifat haba yang baik. Oleh sebab itu aluminium adalah bahan yang diperlukan dalam industri automotif. Kajian ini yang diharapkan dapat menjadi bahan pengetahuan semasa bagi memperluaskan lagi penggunaan kaedah pateri tanpa plumbum pada aluminium aloi dalam industri automotif.

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SYMBOLS	DEFINITION
S_j	strength of solder joint
S_b	strength of base metal
S_s	strength of solder alloy
σ_b	yield strength of base metal
σ_s	yield strength of solder alloy
A_s	critical area of solder joint
L_j	length of solder joint
β	strength ratio
D	diameter
W	width
H	height

SUBSCRIPTS	DEFINITION
b	base metal
s	solder alloy
j	solder joint

CHAPTER I

INTRODUCTION

1.1 OVERVIEW

Soldering is a process by which two metals or alloys are joined together with a third metal or alloy. The third metal or alloy has a much lower melting point compared to the first two metals. The solder technique also can be defined as the joining of metals using a filler metal of a lower melting point than that of the parent metals to be joined. It is a metallurgical joining method using filler metal (the solder) with a melting point below 450 °C. This method also same as brazing but different the filler metal melting point. The brazing technique use the filler metal that melts over 450 °C). Soldering relies on wetting for bond formation and requires neither diffusion nor intermetallic compound growth in the base metal to achieve bonding.

There are many different metals and metal alloys that can be used as solder. The decision to use a particular material is largely based on its properties. The parameters that used to determine which alloy is the most suitable solder are temperature (upper and lower limit), mechanical strength, density, linear coefficient of thermal expansion [2]

By the way, soldering is a better solution than welding to join two different materials, when high heat input would warp the joined elements and the requirement of the joint is suitable in that it permits capillary flow between the elements.

It is better to use soldering when it is imperative to use a lower temperature than base metal melting point for keeping the properties. In addition the size of the assembly is not excessive and the economics of the process are favorable.

Advantages of the process are the use of lower heat input than for welding, with less distortion and metallurgical influence on heat treated materials, the availability of a large range of soldering-alloys, each one adapted to particular base materials and a certain temperature range, the development of adequate strength, dependent on the magnitude of the soldered surfaces, the possibility to use localized or general heat sources as required, and the relatively simpler application process relative to welding.

1.2 OBJECTIVE OF STUDY

The objectives of this study are:

1. To develop a lead free solder technique as a method of joining process for aluminum in automotive industry.
2. To identify the most suitable alloying element of aluminum alloy in automotive industry based on its criteria suit the need of vehicles.
3. To increase the usages of aluminum in automotive industry by expand the soldering technique for aluminum.
4. To test the strength of soldering on aluminum plate.

1.3 SCOPE OF STUDY

The scope of the study is limited to the following:

1. To explore the lead free solder technique by using 6009 series of aluminum alloy.
2. To analyze the strength of aluminum after being joint using solder technique.

CHAPTER II

LEAD FREE SOLDER AND SOLDERING TECHNIQUE

2.1 THE COMPONENTS OF SOLDERING

There are many different processes utilized in soldering, virtually all of them involve four basic elements: base metals, flux, solder, and heat.

A. Base Metals

A base metal is any metal that contacts the solder and forms an intermediate alloy. When attaching electronic components to a printed circuit board, the component's leads or pins and board's metallic circuitry are the base metals that will contact the solder. Many metals, such as copper, bronze, silver, brass, and some steels, readily react with solder to form strong chemical and physical bonds. Other metals, such as aluminum, high alloy steels, cast iron, and titanium, range from very difficult to impossible to solder. [2] The fact that there are metals that do not react with solder is important; these materials are used in the construction of soldering machinery. These metals can also be used as temporary covers for components that are not to be soldered. Also of importance to the electronic industry is the fact that ceramics do not react with solder. This allows a manufacturer to draw liquid solder over a ceramic circuit board and not have any chemical reaction between the solder and the board itself.

There is a direct relationship with the level of surface oxidation on the base metal and how readily solder will react with it. The more oxidation is present, the weaker the solder bond will be. The fact that most metals oxidize at a very accelerated rate when heated creates a particular problem, since the chemical reactions associated with soldering require high temperatures. Flux is the primary material used to overcome problems caused by oxidation. [3]

B. Flux

Flux is often applied as a liquid to the surface of the base metals prior to soldering. Though flux actually has a number of purposes, the first and primary purpose of flux is to stop the base metals from oxidizing while they are being heated to the soldering temperature.

The flux covers the surface to be soldered, shielding it from oxygen and thereby preventing oxidation during heating. Most fluxes also have an acidic element that is used to remove the oxidation already present on the base metal. Using a strong acid, it would be possible to virtually completely clean off the oxidation layer. However, the use of strong acids presents a serious problem. The corrosiveness of acids desirable to remove oxidation layers is not limited to the oxidation layer. Very strong acids can be damaging to electronic components, and even mild acids leave a residue that continues to corrode after the soldering process is complete, leading to future failure. There is a definite trade off between using a flux with a strong acid that removes a lot of oxidation and is very corrosive, and using a flux with a mild acid that is not as corrosive, but does not do as good of a job removing the oxidation layer. In any case, most fluxes in common use are corrosive enough that their residue must be cleaned off after soldering. [2]

When the liquid solder is applied, the flux must readily move out of the way so the solder can come into direct contact with the base metal. During this process some of the flux inevitably combines with the solder. Flux designers typically take advantage of this fact and design the flux to lower the surface tension of the solder upon contact, thereby allowing a more efficient wetting.

Fluxes can be divided into two basic parts, chemicals and solvents. The chemical portion includes the active components, while the solvent is primarily the carrying medium. The solvent determines the cleaning method that must be employed to remove the flux residue. While some fluxes can be removed with simple water treatments, many require other cleaning agents such as organic solvents, alcohol, and chlorinated fluorocarbons. However, it is no longer legal to use chlorinated fluorocarbons due to environmental concerns. [3]

C. Solder

There are many different metals and metal alloys that can be used as solder. The decision to use a particular material is largely based on its properties. Is it ductile or brittle, how well does it conduct heat, it expansion at high temperatures, electrical resistance, tensile strength, toxicity, what materials will it wet? Although it is by no means the perfect alloy for soldering, the material most commonly used in the electronics industry is a tin-lead alloy. Tin-lead alloys have a relatively low melting point and can be produced at a low cost in comparison with other alloys with similar properties. Lead is a very cheap and abundant metal, so the cost of a tin-lead solder is primarily controlled by the cost of the tin.

When an alloy is heated it typically goes thorough multiple phases. It goes from a solid state to what is known as a pasty stage, sort of halfway between a liquid and a solid, and then to a liquid state. In soldering it is difficult to work with a substance that goes through a pasty stage. Eutectic solder is often used for this reason. A eutectic alloy is one that goes directly from a solid state to a liquid state without a pasty stage. The eutectic tin-lead alloy is made up of 63% tin and 37% lead. Eutectic tin-lead solder can be applied as a liquid just above the melting point, and then as it cools it will transform directly into a solid. This makes it possible to form solid solder joints very quickly. Sometimes a 60% tin and 40% lead alloy is used. This alloy exhibits a nearly eutectic change from solid state to a liquid state and can be produced at a lower cost. [3]

It is very important to keep the solder free of impurities. Not only is it important to produce a pure solder alloy, but it is equally important to use a process that prevents metals from the electronic components or circuitry from entering the solder pot. The presence of even slight concentrations of other metals in a tin-lead alloy results in drastic changes in surface tension. Poor wetting of the base metals leading to a poor solder joint is often the result. In addition, metal impurities often change the melting temperature of the solder. Dust, oil, vapors, and other non-metal impurities tend to weaken solder bonds.

Common forms of solder include chips, bars, and wire (often with a core of flux), each of which has advantages in different soldering processes. A common process called reflow soldering calls for a solder paste. Solder paste is a substance with a cream-like consistency made up of solder, flux, and some carrying medium. While putting the flux and solder together in the same mixture has an obvious advantage when it comes to applying the substance to the base metals, it also presents a problem. Highly corrosive flux cannot be used in solder paste. The flux by nature is acidic and corrosive to the metal solder, which means that solder paste is inherently unstable. [4]

2.2 LEAD SOLDER

The word solder has become synonymous with the tin-lead alloy system. Lead-based solder materials have been used for many decades. The usage of tin, lead and their alloys are due to their low melting temperatures and wide availability, are the most commonly used solder materials. However, as public environmental awareness increases, the toxicity of lead has become increasingly important, and the pressure to eliminate or reduce the industrial use of lead is growing. Lead has been recognized as poisons and harmful to human body. Perhaps could be the strong reasons why we should stop using lead solder alloy. The lead toxicity of lead solder alloy has been a major health concerns to the industry related. Lead poison is retained in the human body and if a person is exposed to lead over a long period, poison builds up and causes damage to the brain and nervous systems. This affect can cause weakness and loss of coordination and mental powers. [2]

Legislation and policies have been proposed in Europe to ban or limit the use of lead in solders, and the United States is very likely to follow this trend. Following this tendency, great efforts have been made in the industry to develop lead-free and environmentally friendly soldering materials to replace lead-based solders. Some of legislations are:

1. Restriction on the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) (Europe, July 2006)
   Bans the use of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs) (Some exceptions
   noted until 2010).
2. Directive on Waste Electrical and Electronic Equipment (WEEE) (Europe, Dec 2006) Mandates reuse and recycling of electrical and electronic equipment
3. Acts of Pollution Control in Electronics Production (China, July 2006) Mirrors WEEE and ROHS legislation.
4. Electronic Waste Recycling Act of 2003 (California, Jan 2007)
   Prohibits electronic devices covered under ROHS from being sold or offered for sale in the state.

2.3 LEAD FREE SOLDER

One alternative to lead-bearing solders is lead-free, low melting temperature metals and metal alloys. The lead free solder technique is just same as other solder technique but vary in the combination of alloying components of the filler metals. The lead free solder does not have Lead (Pb-Plumbum) in their filler metal alloying components. But some limitations still exist in lead-free solder technology, including the relatively high cost or limited availability of some candidate metals, and the requirement for relatively high soldering temperature for some metal and metal alloys. [2]

2.4 ALUMINUM AND ALLOY

Aluminum has advanced from being rarely used metal to the second largest metal used worldwide. However, aluminum in high-purity form is a silvery-white metal, soft and ductile whereas in most commercial uses require greater strength than pure aluminum can afford. This is achieved in aluminum by addition of other element to produce various alloys, which singly or in combination impart strength to the metal. Aluminum alloys with very small amounts of copper, magnesium, silicon, manganese, and other elements have very useful properties. The characteristics and properties which have brought about a dramatic increase in the use of aluminum alloys are its light weight, high strength, resistance to weathering, ease of forming, ability to be treated in variety of finishes and its recyclable. [5]

Aluminum has many characteristics that make it suitable for a variety of automotive applications. There are:

Strong - the entire vehicle body can be aluminum
Durable - good resistance to corrosion and fatigue
Conductive - both thermal and electrical, for efficient engine and electrical components
Nonmagnetic - useful in electronics
Nontoxic - important in any material used in cars
Abundant - adequate supply worldwide
Recyclable - saves energy, benefits the environment
Workable - uses well understood metalworking processes
Available - aluminum's many product forms offer design flexibility and above all, its low density and high strength means that aluminum parts weigh much less than traditional materials such as steel, copper, brass and automotive plastics.

It is the overall value of aluminum that makes it suitable for so many kinds of vehicle applications but it is the weight characteristic that stands out. Fuel use is directly related to weight and over the year's goals for fuel economy have been raised and the auto manufacturers have responded with many innovations to reduce fuel consumption while providing the other characteristics their customers want. Simply making a little car with an anemic engine no longer suffices and the increasing addition of safety features and other improvements have combined to make it necessary to find additional avenues to keep weight in line. Aluminum has come forward as a major solution to the weight problem. In all, a body-in-white structure of aluminum will have a primary weight savings of 45% to 50% over conventional steel construction. [8]

2.5 LEAD FREE SOLDER ON ALUMINUM

As we know the aluminum hard to be weld, there are a few problems that arise when welding aluminum. The porosity is the one of the problems when aluminum tries to be weld. It happens when gas dissolved in the molten weld metal becoming trapped as it solidifies, thus forming bubbles in the solidified weld. That is difficult to produce a porosity-free weld in aluminum. [7]

Therefore, the free lead solder techniques have been chosen to be method of joining aluminum. It is because this method uses a low melting temperature point alloy.

2.6 SOLDERING TECHNIQUE

Precleaning

Any foreign materials on the surfaces from previous machining operations such as chips, cutting oils, and dust are removed to get a repeatable reliable connection.

Flux application

The function of the flux is to remove the oxides and other contaminants, which may form during the heating. The way flux is applied in this soldering technique is by using flux cored solder wire. Here, the flux is contained as a solid, powder, or very heavy paste inside the solder wire. When this wire is applied to the heated surfaces, the flux will flow out, because it has a much lower melting point than the solder. [2]

Heating

The heating step during the soldering fulfills a number of basic needs, some which are identical to preheating. Aluminum is soldered at a minimum 110°C below the solidus temperature of the base metal. Aluminum is heated until temperature rose among 230 °C and 450 °C below the 660 °C aluminum melting temperature. There are some functions of heating during soldering as follows. [2]

1. To fuse the solder alloy, by raising its temperature above the melting point. If there is no sharp melting point such as with eutectic alloy, the metal is considered totally liquefied when it is above its liquidus temperature.