FEASIBILTY STUDY OF DISSILMILAR METAL WELDING BETWEEN GALVANIZED STEEL AND ALLUMINIUM ALLOYS USING METAL INERT GAS WELDING(MIG)

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ABSTRACT

An experimental project to combine different metals (aluminum alloy to galvanized steel) welded using metal inert gas welding or MIG. The reason of this experimental project is done is to examine the effect of the MIG weld towards the combination of different metals. The research's objective is to optimize the parameter and investigate the effect of welding parameter on tensile strength and hardness based on Taguchi method. The used of Taguchi method is to guide the experimental number. The parameter chosen for this project is welding current, voltage, speed and bevel angle on galvanized steel. The Minitab statistical software was used to create and suitable orthogonal arrays for run the experiment. This MIG welding will be using the automatic table with the help aluminum 5356 filler wire. Type of welding joint that has chosen is butt joint. The argon is used for shielding gas and the constant of torch distance was setup to be 1mm from the specimen. The gas flow rate was constant at 15L/m. The size of every material has a dimension of length x width x thickness (70 mm x 50 mm x 2mm) and will be held onto the automatic welding table with steel jig during the welding process. The sample for lab testing was cut into small size for mounting of hardness test and ASTM E8-04 was used to cut the specimen for tensile test after welding done. Tests that will conducted after the welding are, mechanical test as tensile test by using Instron Tensile machine and Vickers hardness test by using Microhardness machine The finding from this research project is achieving the objective that is aluminum alloy and galvanized steel can merged together using chosen filler metal and getting value reading of tensile strength and hardness for every joint following a determined parameter setup by Taguhi method was obtain. The maximum tensile strength reaches 90Mpa and maximum hardness at the heat affected zone of aluminum alloy is improved by using Taguchi method.

ABSTRAK

Satu projek percubaan untuk menggabungkan logam berlainan (aloi aluminium untuk keluli tergalvani) dikimpal dengan menggunakan kimpalan gas lengai logam atau MIG. Objektif penyelidikan ini adalah untuk mengoptimumkan parameter dan mengkaji kesan parameter kimpalan kepada kekuatan tegangan dan kekerasan berdasarkan kaedah Taguchi. Yang digunakan kaedah Taguchi adalah untuk membimbing bilangan eksperimen. Parameter yang dipilih untuk projek ini adalah kimpalan arus, voltan, kelajuan dan sudut serong pada keluli tergalvani. Perisian Minitab statistik telah digunakan untuk mencipta dan array ortogon sesuai untuk menjalankan eksperimen. Ini kimpalan MIG akan menggunakan jadual automatik dengan aluminium bantuan 5356 dawai pengisi. Jenis sendi kimpalan yang telah dipilih adalah sendi punggung. The argon digunakan untuk melindungi dan gas berterusan jarak obor adalah persediaan untuk 1mm daripada contoh yang. Kadar aliran gas adalah tetap di 15L / m. Saiz setiap bahan mempunyai dimensi panjang x lebar x tebal (70 mm x 50 mm x 2mm) dan akan diadakan ke atas meja kimpalan automatik dengan besi jig semasa proses kimpalan. Sampel untuk ujian makmal telah dipotong menjadi saiz yang kecil untuk pemasangan kekerasan ujian dan ASTM E8-04 telah digunakan untuk memotong spesimen untuk ujian tegangan selepas kimpalan dilakukan. Ujian yang akan dijalankan selepas kimpalan adalah, ujian mekanikal ujian tegangan dengan menggunakan mesin tegangan Instron dan ujian kekerasan Vickers dengan menggunakan mesin Microhardness Hasil daripada projek kajian ini mencapai objektif yang aloi aluminium dan keluli tergalvani boleh digabungkan bersama-sama menggunakan pengisi dipilih logam dan mendapatkan bacaan nilai kekuatan tegangan dan kekerasan untuk setiap sendi berikutan persediaan parameter ditentukan oleh kaedah Taguhi adalah mendapatkan. Kekuatan tegangan maksimum mencapai kekerasan 90Mpa dan maksimum di zon panas terjejas aloi aluminium bertambah baik dengan menggunakan kaedah Taguchi.

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INTRODUCTION

1.1 RESEARCH BACKGROUND

World Statistical shows that the demand of ferrous and nonferrous metals is significant in industries such as manufacturing, construction, aerospace, automotive and others. Nowadays, the important use of metal that can reduce the weight and cost like aluminium alloys is increasing. As we know, the material use in industries must be enough strength in term of tensile strength, ductility, hardness and other mechanical properties. So, the high expectation of product is need including lower cost, good strength and light weight. Because of it, the combination like welding is needed.

The combination of dissimilar metal becomes a huge research and use in industry in order to make a product that can reduce the cost and improve the quality in term of strength and ductility. In the automotive industry, there are many parts that use the combination of different metal to reduce fuel consumption and control the pollution by using the material that have light weight and good corrosion resistance like stainless steel and aluminum alloys. The combination of dissimilar metal has also become a new style of assembling for aerospace field. From other research that have been done, the combination between aluminum alloys and galvanized steel shown that there are still having a problem making them well combine because of the presence of brittle intermetallic compound layer. But the combination able to joint with good quality if the parameter use is suitable. The skills and technique also play as a main role. It’s also depends on the filler metal that use during the welding. The filler metal is also depends on the base metal. From past research, the presence of Si in the filler metal can promote a good weldability to perform a good joint. Tungsten Inert Gas (TIG) or Gas Tungsten Gas Arc Welding (GTAW) and Metal Inert Gas (MIG) are a new arc welding technique of combining dissimilar thin sheet metal (Rattana Borrisutthekul 2010).

The purpose of this combination project is to determine how the effect of the parameter can improve the quality of the weld part in term of hardness, toughness, tensile strength and also observe the microstructure of different metal. Can the dissimilar metal weld each other or not. The demand and usage of galvanized steel in the automotive industries and other field is slightly increased because of its physical properties which is lightweight, high strength, low cost and multiple usages. That is also in the case of aluminum alloys, the usage of aluminum alloys in the industry is annually increased because of the high corrosion resistance, excellent machining properties, lightweight, high thermal conductivity/electricity and high ductility/easily definable. Figure 1.1 shows the example application of dissimilar joint.

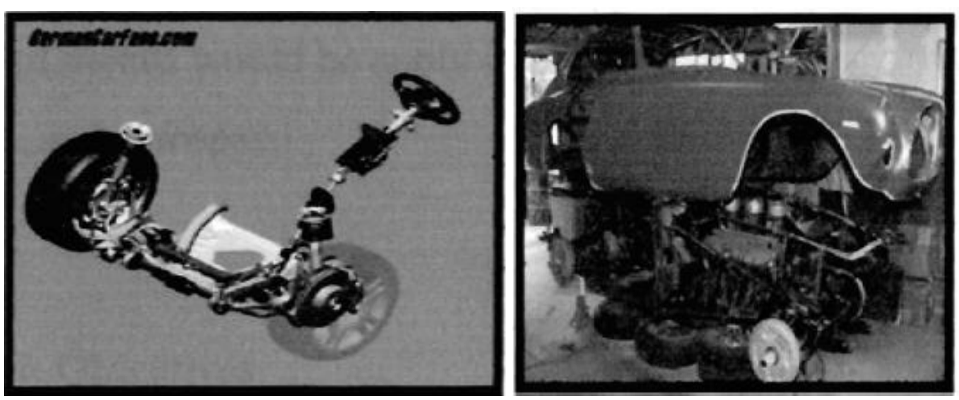


Figure 1.1 Example of application of combination.

1.2 PROBLEM STATEMENT

From the journal, book and other reference, the combination of dissimilar metal between galvanized steel and aluminum alloys is still a lack of quality by fusion welding and the arc welding such as Tungsten inert Gas and Metal Inert Gas. There are some requirements of combining dissimilar metal because of the differences in thermo physical properties such expansion coefficient, conductivity and specific heat. These will make the defect occur on the weld part such as cracking, spatter and other. The difference in melting point of galvanized steel and aluminum alloys is also the main reason why it has a great challenge in joining. It is also the same goes to other material especially for ferrous to nonferrous metal combination.

The main problem of joining dissimilar metal welding such as follows:

i. The presence of brittle intermetallic compound layer (IMC) form in the welded seam (Rattana Borrisutthekul 2010). This is difficult to control because of the change quickly in heating temperature especially in the aluminum alloy side. The low in melting point will make the material easy to melt.
ii. Nearly zero solid solubility of iron in aluminum.
iii. Need more skills and correct method of joining to make a good quality

1.3 OBJECTIVE

Based on a research project, the potential to weld galvanized steel to aluminum alloys using MIG machine welding is researched and developed. Many literature research and reviews are done to see the matching of galvanized steel and aluminum alloys for combination. This is because it could contribute to the practical applications in the fields of industrial engineering that needs material with high expectations. The research is needed to carry out with the appropriate welding method, the appropriate choosing of filler wire and to apply the right rules of welding. So, hope that the welding that would form will show good strength, high mechanical properties after weld.

Main objective that is set through this research projects such as follows:

i. To investigate the effect of parameter to weld geometry and mechanical properties(tensile and hardness)
ii. To optimize the parameter of dissimilar metal with MIG welding by using Taguchi Method

At the end of the research, with the collecting data and the observation acquired, the conclusion whether galvanized steel is compliable to be combined with aluminum alloys using a MIG flat butt joint technique as groove type will use and using Taguchi method as a guide in designing the experiment. It's also to make sure the parameter optimization of dissimilar metal welding could be obtained.

1.4 RESEARCH SCOPES

To fulfill the objective goals, the welding of the galvanized steel to aluminum alloys will be done by using MIG welding. There are different types of filler wires that can be used as variables such as stainless steel, aluminum and mild steel types but for welding aluminum the best filler to have a sound joint is normally used aluminum type of filler. There are several fillers that normally used in the industry to combine aluminum such as ER4043 that consist of 5% Si, ER4047 that consist of 12% of Si. The addition of Si in filler metal has a great function to prevent the intermetallic compound layer which is brittle structure(J.L. Song 2009). The filler that uses for this welding process is ER5356 which is more addition of magnesium into the aluminum filler. This filler will effect on tensile strength and also corrosion resistance. Before running the experiment, design of the experiment is very important to make an optimization. In this project the theory or method from Genichi Taguchi will use. Then, after the result collected, Taguchi method will be used to see what set of parameter that influencing the combination of aluminum alloy and galvanized steel. By setting certain parameters such as welding speed while welding, power output and voltage while welding, angle of welding, types of joint, types of gas, size and the thickness of every metal used. The preparation of materials such as 1100 aluminum alloy and galvanized steel have length, width and thickness will be used in the weld process. The composition and microstructure of the galvanized steel and aluminum alloys needed to determine first before to weld process to make sure the types of each metal by using emission spectrometry and scanning electron microscope (SEM). The types of joining that will be done are butt joint. While the welding process, the sample will be set on the table using the steel Jig. A few of lab tests will be done to the samples that have been welded; the mechanical properties will be determined by using the tensile test. After that, to determine the hardness of every sample, the Vickers Hardness testing will be done.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This research is about the dissimilar metal welding between galvanized steel and aluminum alloy. From the other research that has been done before and also according book, there are several methods and technique of combining the dissimilar metal such as metal inert gas welding (MIG), tungsten inert gas (TIG welding), fusion welding, spot welding. There has a difficulty to joint dissimilar metal because of differences in mechanical and physical properties like thermal expansion, thermal conductivity, and melting temperature. So, this literature is very important to view the solution of the problem.

2.2 WELDING PROCESS

Welding is actually the fastest method to combine the material like metals and alloys including dissimilar or similar to make it functional as one product. The dissimilarity is referring to the metals that have difference in mechanical and physical properties like welding a different type of steel. Some considerations need to make before two materials is combine even on similar metal welding. Welding is also joining process that involve of the use of variables in temperature in order to heat the material. The heat input will produce the fusion of two materials that will use to join. It allows the production of a monolithic structure that is strong in all directions. Nowadays, welding becomes more important in industries. The examples of product from welding are automobiles, airplane, coffee pots, bridges, jet engine, pipelines, water storage tanker and many more. Most of the product used metals normally using a welding to join them to make a piece of product that have good in mechanical and physical properties. The famous trans-Alaskan pipeline is completely welded from end to end. There are many different welding processes, welding type and also the way how to weld but now the popular spark welding is arc welding (Cary ; Abbasi. K 2011; P. Kumari 2011). Welding is a faster way of fabricating compare to riveting and casting and it can reduce time of production and also get a good result .Welding also use in small industry because its efficiency and economical and dependable as means of joining metals (Mr. Parth D Patel Research Scholar, Department of Mechanical Engineering). Normally, some welded products have a defect because of the lack of skills and parameter use. In order to eliminate the defect and make the weld success in term of strength, some requirement need such as the parameter use must suitable for the method and type of welding, remark the physical and mechanical properties like melting point. The joining is considered a success if the output or weld metals is in smooth profile, penetrate not too large and also microstructure (Pal 2010).

Basically, there are many methods of fusion welding that usually use in industries such Friction Stir Welding use in weld the piping system but very high maintenance and cost of production. Its mean that the welding is must have a quality product to ensure no problem will occur such as in construction, if the weld part is poor in strength and ductility, it’s giving some effect to the building itself and also for customers. In industries like manufacturing, costing is one of important thing to make a profit, so the right machine use with a lower cost but high quality is needed. The two most commonly used for weld thin metal types of Gas Metal Arc Welding (GMAW) processes are tungsten inert gas (TIG) and metal inert gas (MIG) (K. Abbasi 2012).

2.3 FUSION WELDING

Fusion welding is a generic term for welding processes that rely upon melting to join materials of similar compositions and melting points. Due to the high-temperature phase transitions inherent to these processes, a heat-affected zone is created in the material (although some techniques, like beam welding, often minimize this effect by introducing comparatively little heat into the workpiece.

2.3.1 Metal Inert Gas Welding (MIG)

The gas metal arc process or also known as Metal Inert Gas (MIG) is a process that use of consumable electrode and weld pool. This type is used without application of pressure. The other types of welding using a consumable electrode are Electrogas Welding, Electroslag Welding, Shielded Metal Arc Welding, Submerged Arc Welding and Flux-Cored Arc Welding. Metal Inert Gas or MIG is an arc welding that uses an arc and continues filler metal electrode. Many researches did before about this welding type to increase the quality of the weld. Figure 1(a) and 1(b) below shows the Gas metal arc welding process, and basic equipment used in gas metal arc welding operations.

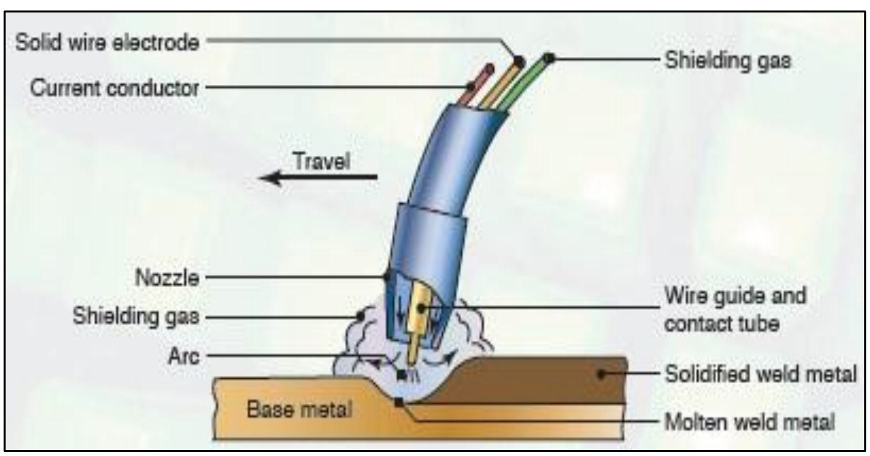


Figure 2.1(a) MIG operation

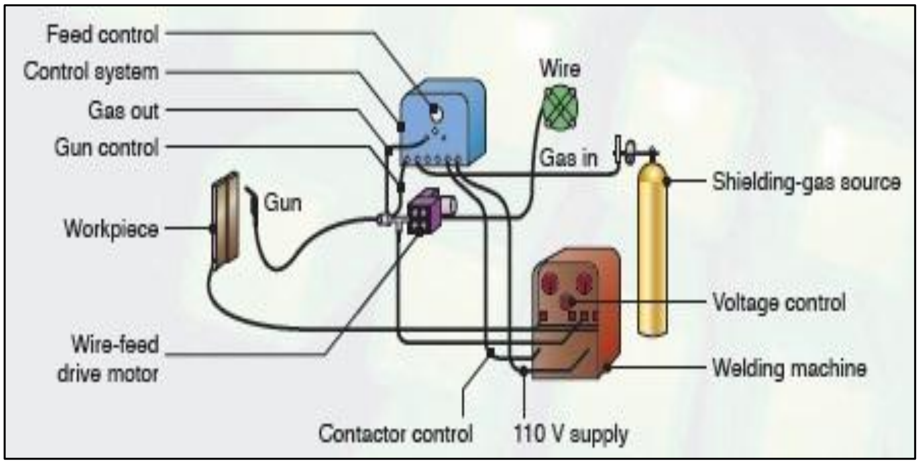


Figure 2.1(b) Basic equipment use in MIG welding

Source: Schmid (2008)

2.3.2 The control parameter of MIG welding

There are many factors that influence the quality of weld. Some parameters that need to optimize like current, speed, voltage also angle of torch, torch distance and others. The size or depth of penetration is important to determine the quality of the weld. The current is highly factored affect the depth of penetration than other factors. When the depth of penetration is too large, the arc will burn the thin material and at the same time will reduce the quality of weld .The input variable or normally call as parameter will affect to their bead shape and the penetration of the weldment (K. Abbasi 2012). Welding current is normally controlling the burn rate of the electrode, fusion depth, and weld geometry. This variable is very important in metal inert gas welding. Another parameter is welding voltages which give effect to the shape of fusion zone and also weld reinforcement height. The welding speed is referring to the rate of travel of workpiece under the electrode. Welding speed also causes of decreasing the heat input per unit length of the weld (al 2005; S. P. Tewari 2010). The heat input of welding is needed to calculate after the other parameter was chosen. The parameters that need to calculate the heat input is voltage, speed and current of welding. The formula to calculate the heat input is voltage in volts time with current in ampere and time with 60 and over the speed in mm/s (S. Alam and M.I.Khan 2011).

2.3.3 Advantages and disadvantages of MIG welding

Basically there are several positions of welding such as flat position. All positions may possibly by using Metal Inert Gas. All metals that are high demand in the industry including ferrous and nonferrous such as steel, nickel can be welded by choosing a good variable such shielding gas, electrode, current, voltage, speed, angle, torch distance and others (M.St. Wêglowski 2008). Metal inert gas welding (MIG) is widely used in industry because of its advantages, which are high deposition rate, high operation factor, high utilization of filler metal, elimination of slag and flux removal, reduction in smoke and fumes, lower skill level in a semi-automatic method of application than that required for manual shielded metal arc welding, possible of automation and extremely versatile with wide and broad application ability (Kumar ; S. V. Sapakal ; P K Palani 2007). However there is still having problem while doing MIG welding which produce the rough of microstructure because of high at the heat affected zone (HAZ) due to the high heat requirement and lower penetration with high reinforcement which is can reduce the weld joint strength ant also the life of product (Kumar). Shielding gas also can influence the result of weld product. Its use to protect the specimen from oxygen and nitrogen in atmosphere. The strength, ductility, toughness and corrosion is also depends on the shielding. From past experimentation, the use of helium can reduce the defect like porosity. The increase amount of oxidation level will decrease the strength and toughness due to increasing of oxygen and carbon dioxide (Jyoti Prakash 2009).

2.4 WELDING PARAMETER

There are some important parameters in the welding which control the quality of the weldment.

2.4.1 Welding wire

Filler wire is commonly supplied on reels that are available in various diameters and varying capacities of wires. The bare steel wire is often coated in copper to improve conductivity, reduce friction at high feed speeds, and to minimize corrosion while in stock (Davies, The Science and Practice of Welding, 1984) (McClure 2011).

2.4.2 Wire size

The wire used in MIG welding is available in differing diameters. Wire size affects the deposition rate, with a smaller diameter wire usually able to carry a larger current rate and deposition rate than a larger wire at the same current. Larger diameter wires have high current capacities and can carry more current and produce higher deposition rates than smaller diameter wire at the same current. Selection of wire size is also dependent on feed rate. When all conditions are kept constant except for wire size, an increase in the wire size will increase the bead width and decrease the penetration and deposition rate (Farhat, 2007) (McClure 2011).

2.4.3 Wire extension (Stick Out).

The current necessary to create an arc reaches the wire at the contact tube within the nozzle of the welding gun. To reach the arc, the current travels a distance from the contact tube to the tip of the wire. This distance is known as the wire stick out, or wire extension, and it adds resistance as the current passes through it. The longer the wire extension, the greater the heat builds up within it. This causes a voltage drop that occurs between the contact tip and the arc, which reduces the penetration (Farhat, 2007) (McClure 2011).

2.4.4 Welding speed

Also known as travel speed, welding speed affects the quality and properties of a weld. It can be used to control the bead size and penetration. Excessive speed can cause a lack of penetration, a lack of fusion, porosity, and an uneven bead shape. Slow speed can result in excessive arc exposures and high heat input that produces a large HAZ (McClure 2011).

2.4.5 Welding voltage

Welding voltage, which controls the arc length, has an important effect on the type of metal transfer desired. “Short arc welding requires relatively low voltages while spray arc requires higher voltage welding current and wire burn off are increased, the welding voltage must also be increased somewhat to maintain stability” (ESAB North America, 2010). The voltage setting directly controls the arc length. A certain range is necessary to maintain arc stability at any welding current level(McClure 2011).

2.4.6 Welding current

The welding current is the electrical amperage in the power system as the weld is being made and determines the rate at which the wire is melted, the amount of parent metal melted, and the depth of penetration (Rossi, 1954). In the MIG welding process, “welding current is directly related to wire-feed speed. As the wire-speed is varied, the welding current will vary in the same direction” (ESAB North America, 2010). If there is an increase, or decrease, in the wire feed rate it will cause an increase, or decrease, in the current(McClure 2011).

2.4.7 Shielding gases

To avoid contamination various gasses and combinations of gasses are used to shield the weld. Argon and helium are inert gasses that are used, and carbon dioxide is also used. Air in the weld zone is displaced by shielding gas in order to prevent contamination. Contamination is caused mainly by nitrogen, oxygen and water vapor present in the atmosphere. Nitrogen in solidified steel reduces the ductility and impact strength of the weld and can cause cracking. In large amounts, nitrogen can also cause weld porosity. Excess oxygen in steel combines with carbon to form carbon monoxide (CO causing porosity. When hydrogen, present in water vapor and oil, combines with iron, porosity will result and under bead‟ weld metal cracking may occur.(McClure 2011).

The basic properties of the shielding gasses that affect the performance of the weld are: “Thermal properties at elevated temperatures; Chemical reaction of the gas with the various elements in the base plate and welding wire; Effect of each gas on the mode of metal transfer”(ESAB North America, 2010). The thermal conductivity of the gas at arc temperatures affects the arc voltage required, as well as the temperature delivered to the weld. The selected gas must also be compatible with the wire and base metal. Shielding gasses also affect the depth that the work piece is melted and the mode of metal transfer(McClure 2011).

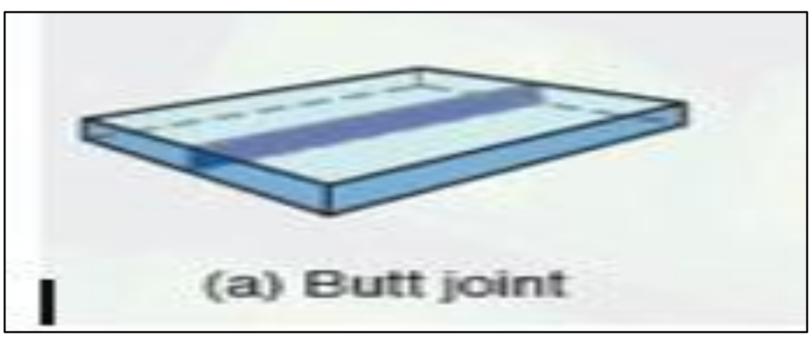
2.4.8 Weld Joint

The size and the shape of the weld joint will influence how the heat is deposited by the source of energy and how it flows and distributes in the weld. The loads in a welded structure are transferred from one member to another through the welds placed on the joints. The type of joint is often determined by the requirements and restrictions on the structure and the type of load. Other factors include the accessibility to the joint for welding and inspection, the welding process required, and cost constraints (Messler R. W., 1999). See Figure 4 for some typical weld joint configurations(McClure 2011).

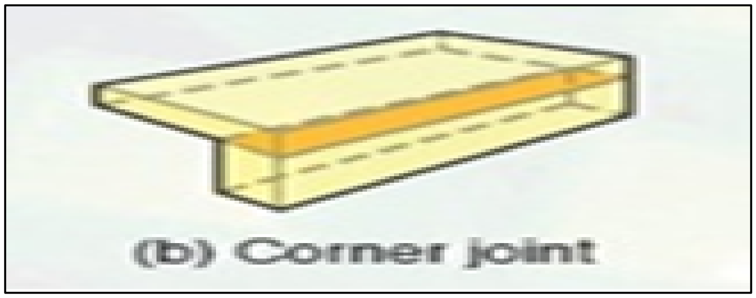
Butt joints, or welds, are also called square butts or straight butts when they are produced from base material that has been prepared before welding with square edges. Such joints do not require filler metal if they fit together tightly. Butt joints can also have other preparations that require filler metal. These joints include single or double-vee, single or double bevel, single or double J, or single or double U(McClure 2011).

Square-groove joints are simple to prepare, economical to use, and provides satisfactory strength, but is limited by joint thickness. For thick joints, the edge of each member of the joint must be prepared to a particular geometry to provide accessibility for welding and to ensure the desired weld soundness and strength… The opening or gap at the root of the joint and the included angle of the groove should be selected to require the least weld metal necessary to give needed access and meet strength requirements. (Messler R.W., 1999) (McClure 2011).

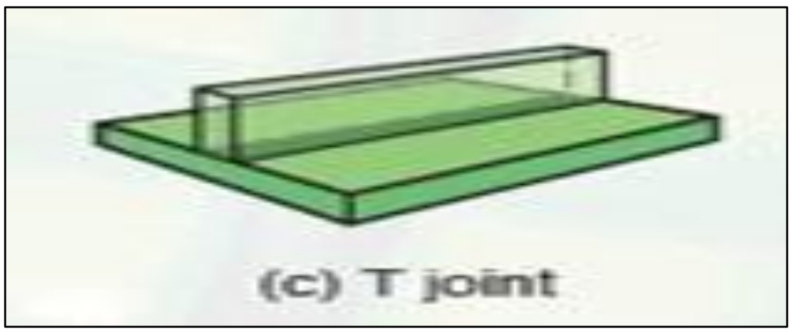
Before welding, preparation is needed to make sure it can good in quality in term of mechanical properties according to the standard. The type of joining also play role to make the product become good in strength after weld and it's depending on the condition of the placement of the product. Figure 2.2 shows the basic welding tip.



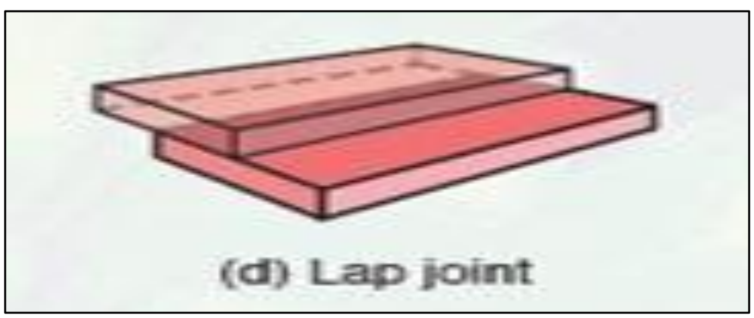
(a) Butt joint



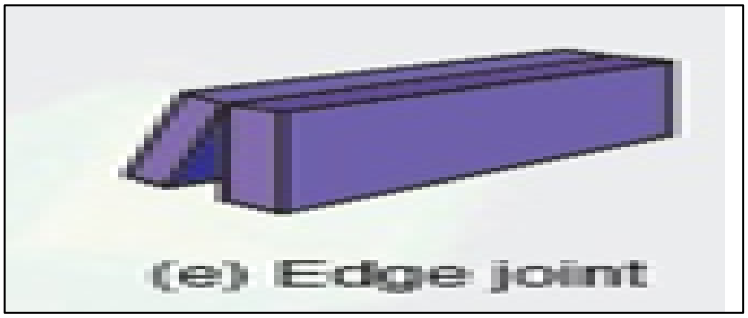
(b) Corner joint



(c) T joint



(d) Lap joint



(e) Edge joint

Figure2.2 (a), (b), (c), (d) and (e) Five basics welding type

Source**:** Kou S (2003)

2.4.9 Effect of Groove Angle

Groove angle is referring to the angle of facing the electrode or torch during the welding and normally use in butt joint. Figure 2.3 shows the configuration groove angle.

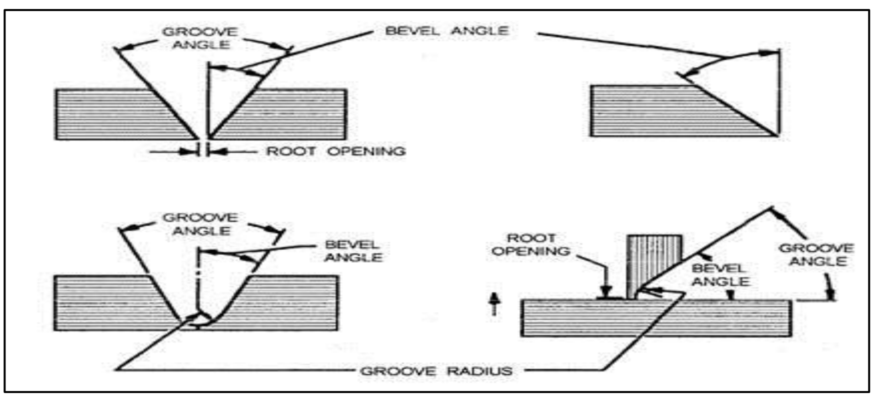


Figure 2.3 Groove angle in butt joint.

Source: Ahmad Khalid Hussain (2010)