An introduction to welding

Welding can be defined as a permanent joining process that produces coalescence of materials by heating them to the welding temperature, with or without the application of pressure or by the application of pressure alone, and with or without the use of filler metal [8]. Ibrahim [10] defined welding as a process of permanent joining two materials usually metals through localised coalescence resulting from suitable combination of temperature, pressure and metallurgical conditions. Most welding processes use heat to join parts together and the equipment used to generate the required varies, depending on the welding process.

Welding is used extensively for the manufacture and repair of farm equipment, construction of boilers, mining and refinery equipment, furnaces and railway cars. In addition, construction of bridges and ships also commonly requires welding. The application of welding process depends on the requirements of the weld, accessibility of the weld area, economic considerations and available welding equipment [9]. The strength and the integrity of a weld depend on the material properties of the metal being welded, as well as on a great many other factors. These factors include the shape of the weld, temperature of the heat sources, the amount of heat produced by the source and even the type of power source used.

Overview of Flux Cored Arc Welding (FCAW)

In recent years, pressure to increase productivity and reduce costs by the manufacturers has been the main driving force behind the adoption of flux cored wires. Productivity, quality and ease of use are the three main factors on which the increasing popularity of FCAW.

FCAW is an arc welding process that uses an arc between a continuous filler metal electrode and the weld pool [8]. The flux is used as a protection for molten metal from the atmosphere contaminations during welding operation. It will improve strength through chemical reactions and produce excellent weld shape. FCAW is very similar to GMAW in principle of operation and equipment used. In FCAW, weld metal is transferred as in GMAW globular or spray transfer. However, FCAW can achieve greater weld metal deposition and deeper penetration than GMAW short circuiting transfer [9]. The effects of electrode extension, nozzle angle, welding directions, welding speed and other welding manipulations are similar as GMAW.

The FCAW are welding process introduced in early 1950s with the development of an electrode that contained a core of flux material. However, an external shielding gas was required even with the flux cored electrode. After that, the flux cored electrode that did not require an external shielding gas was developed in 1959. Shielding gas is important in FCAW-G process for increased penetration and filler metal deposition [9]. FCAW can be applied automatically or semi-automatic. Most FCAW process is semi-automatic, which is the wire feeder continuously feeds the electrode wire and the welder must manually positions the torch into the weld. However, it can transform to fully automatically with a computer driven robot manipulating the torch along a preset path. FCAW is widely used for welding large sections and with materials of great thicknesses and lengths, especially in the flat position.

FCAW actually comprises two welding processes. The two variations for applying FCAW are self-shielded flux cored arc welding (FCAW-S) and gas-shielded flux cored arc welding (FCAW-G). The difference in the two is due to different fluxing agents in the consumables, which provide different benefits to the user. FCAW-S is a variation of FCAW in which the shielding gas is provided solely by the flux material within the electrode. The heat of the welding arc causes the flux to melt, creating a gaseous shield around the arc and weld pool. FCAW-S is also called Innershield and it is a flux cored arc welding process developed by Lincoln Electric Manufacturing Company [9]. On the other hand, shielding in FCAW-G is obtained from both the CO2 gas flowing from the gas nozzle and from the flux core of the electrode. FCAW-G is widely performed in flat and horizontal position. However, FCAW-G also can be performed for vertical and overhead position by using small diameter electrodes.

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Figure 2. 1: Self-Shielded Flux Cored Arc Welding (FCAW-S). [11]

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Figure 2. 2: Gas-Shielded Flux Cored Arc Welding (FCAW-G). [11]

FCAW requires more electrode extension than GMAW. It is because electrode extension will affect the vapour-forming ingredients to generate enough arc vapour for adequate shielding [11]. Inadequate arc vapour will cause porosity in the weld. Besides that, the deposition rates and current density in FCAW are also higher than GMAW. The increased current density occurs due flux cored electrodes are tubular rather than solid, and the flux core has less density and current-carrying capacity than metal [11]. FCAW has a wide range of applications in industry. FCAW combines the production efficiency of GMAW and the penetration and deposition rates of SMAW. FCAW also has the ability to weld metals as thin as that used in vehicle bodies and as thick as heavy structural members of high rise buildings. The most common application of FCAW is in structural fabrication. High deposition rates achieved in single pass make FCAW more popular in the railroad, shipbuilding and automotive industries.

Advantages of FCAW

FCAW has many advantages over the manual shielded metal arc welding. It is more flexible and acceptable in varies industry compared to other welding operation such as gas metal arc welding, submerged arc welding and oxyacetylene welding. These advantages of FCAW [9, 10] are as follows:

High quality weld metal deposit

Produces smooth and uniform beads with an excellent weld appearance

Produce less distortion than SMAW

Welds a variety of steels over a wide thickness range

High operating factor

High deposition rate with high current density

Economical engineering joint design

Limitations of FCAW

The limitations of FCAW regarding its applicability [12] are as follows:

Confined to ferrous metals which is primary steels

Removal of post weld slag requires another production step

Electrode wire is more expensive on a weight basis than solid electrode wires

Equipment is more expensive and complex than required for SMAW

Ventilation system need to be increased to handle added volume of smoke and fume

Robotic Welding Technology

Nowadays, most of welding processes could be done in automated applications. With these automated applications, the welding process then called as robotic welding. Robot welding is the use of mechanized programmable tools, which completely automate a welding process by both performing the weld and handling the part.

Robot welding is a relatively new application of robotics, even though robots were first introduced into US industry during the 1960s. The use of robots in welding did not take off until the 1980s, when the automotive industry began using robots extensively for spot welding. Since then, both the number of robots used in industry and the number of their applications has grown greatly. Cary and Helzer suggest that, as of 2005, more than 120, 000 robots are used in North American industry, about half of them pertaining to welding. Growth is primarily limited by high equipment costs, and the resulting restriction to high-production applications. Robot arc welding has begun growing quickly just recently, and already it commands about 20% of industrial robot applications.[3]

Major components of robotic welding

The main components of arc welding robots are the manipulator or the mechanical unit and the controller, which acts as the robot's " brain".

The manipulator is what makes the robot move, and the design of these systems can be categorized into several common types, such as the SCARA robot and Cartesian coordinate robot, which use different coordinate systems to direct the arms of the machine. It consists of a vertical mast and a horizontal boom that carries the welding head. They are sometimes referred to as boom and mast or column and boom positioners.

Manipulators are specified by two dimensions:

The maximum height under the arc from the floor.

Maximum reach of the arc from the mast.

The length of travel can be unlimited thus the same welding manipulator can be used for different weldment by moving from one workstation to another.

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In selecting and specifying a welding manipulator, it is important to determine the weight to be carried on the end of the boom and how much deflection can be allowed. The welding torch should move smoothly at travel speed rates compatible with the welding process. The manipulator carriage must also move smoothly at the same speed. Manipulators can be used for straight-line, longitudinal and transverse welds and for circular welds when a rotating device is used. As the diagram below shows, axis 1 and 2 are effectively a shoulder, axis 3 and 4 elbow and forearm and axis 5 and 6 are the wrist of the robot.

Advantages of robotic welding

Improve consistency of quality welds

Difference with manual welding process, robotic welding can produces a consistently high quality of finished product, since there is no risk of tiredness, distraction or other effects from manually performing tedious and repetitive task. Once programmed correctly, robots will give precisely the same welds every time on work pieces of the same dimensions and specifications.

Greater cycle speed

Beside of above repeat ably, robotic welding systems also produce greater cycle speed as robots move from one weld to the next very quickly, making the entire process much faster. Robotic welding systems are able to operate continuously, provided appropriate maintenance procedures are adhered to. Continuous production line interruptions can be minimized with proper robotic system design.

Repeatability

Robot welding system may perform more repeat ably than a manual welder because of the monotony of the task. Robots work well for repetitive tasks or similar pieces that involve welds in more than one axis or where access to the pieces is difficult.

Increase production output rates

With robot welding you can also get an increased output with robots left running overnight and during weekends with little supervision. Robots also produce effectively because they can work inexhaustibly and consistently. As a result, output levels increase and client order deadlines can be met more easily.

Safer workplace

Comply with safety rules and improve workplace health and safety, robots can take overrun pleasant, arduous or health threatening tasks, decreasing the likelihood of accidents caused by employee contact with potentially hazardous fumes machines or processes.

Comfortably

Employees no longer have to work in hot, dusty or hazardous environments, plus they can learn valuable programming skills and be freed up for other work. As the same time, this condition improves quality of work for employees and helps retain them and reduces turnover.

Reduction of costs

Labour costs – with less manual labour, there will be fewer costs related to sickness, accidents and insurance.

Operating costs – Robots can reduce both direct costs and overheads, making a dramatic difference to competitiveness. Automating the torch motions decreases the error potential which means decreased scrap and rework.

Waste material cost – the amount of waste due to poor-quality or inconsistent finishing can be significantly reduced.

Welding Position

Welding must be done in the position in which the part will be used. In this project, the scope is to study and investigate the correlation between welding parameter and bead geometry in 2F position. 2F position indicates welding operation for fillet weld in horizontal position. According to the American Welding Society (AWS), horizontal fillet welding is the position in which welding is performed on the upper side of an approximately horizontal surface and against and approximately vertical surface [8].

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Figure 2. 3: Schematic diagram of horizontal welding 2F position. [8]

The official AWS diagrams for welding positions are precise. They utilize the angle of the axis of the weld which is a line through the length of the weld perpendicular to the cross section at its center of gravity. Figure 2. 4 shows the fillet weld and its limits of the various positions. It is necessary to consider the inclination of the axis of the weld as well as the rotation of the face of the fillet weld [8].

Welding current

Welding current is the most influential variable in arc welding process which controls the electrode burn off rate, the depth of fusion and geometry of the weldments.

Welding voltage

This is the electrical potential difference between the tip of the welding wire and the surface of the molten weld pool. It determines the shape of the fusion zone and weld reinforcement. High welding voltage produces wider, flatter and less deeply penetrating welds than low welding voltages. Depth of penetration is maximum at optimum arc voltage. [15]

Welding speed

Speed of welding is defined as the rate of travel of the electrode along the seam or the rate of the travel of the work under the electrode along the seam. Increasing the speed of travel and maintaining constant arc voltage and current will reduce the width of bead and also increase penetration until an optimum speed is reached at which penetration will be maximum. [15]

The correct weld speed will result in a well formed weld bead that shows good fusion, penetration and a gradual transition of weld metal into the corners of the joint. A weld speed that is too fast results in a thin stringy weld with poor strength. A weld bead that is too slow a speed will result in a heavy weld that has too much convexity.

Increasing the speed beyond this optimum will result in decreasing penetration. [16] In the arc welding process, increase in welding speed causes:

Decrease in the heat input per unit length of the weld.

Decrease in the electrode burn off rate.

Decrease in the weld reinforcement.

If the welding speed decreases beyond a certain point, the penetration also will decrease due to the pressure of the large amount of weld pool beneath the electrode, which will cushion the arc penetrating force. [16]