A Review of Some Welding Parameters and their Effects on the Heat-Affected Zone of Mild Steel Plate

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Abstract

Welding is one of the most important processes in manufacturing and construction industries. Various categories of welding exist and there are many welding processes available from which and industrial engineers can select for a particular application. The fusion category include the arc welding processes, resistance welding and gas welding methods; the non-fusion or solid state include cold welding, forge welding, ultrasonic welding, friction welding, friction stir welding, resistance welding, diffusion bonding, and explosion welding. The high energy densities/low dilution welding method in this category are pulse arc welding (PAW), laser beam welding and electron beam welding. The choice of a welding process and the welding input parameters are determined by some factors. This review highlights the categories of welding, factors influencing the choice of a particular welding process for a given application, Various areas of application of these categories of welding were discussed and it also address the effect of some of these welding input parameters on the integrity and quality of weld joints. The goal is to achieve high-quality welded joints with desired bead geometry and performance while minimizing detrimental internal stress and distortion and the corrosion rate characteristics of these regions, are all demonstrably influenced by the selected welding parameters. In essence, this review underscores the critical role of precise process control in achieving optimal weld quality and mitigating potential drawbacks in the welding industry.

KEYWORDS: Welding Parameters, Fusion welding, Non-fusion welding, Welding Processes,

1.0 Introduction

Joining two or more materials - typically metal to achieve coalescence is the process of welding in manufacturing or construction activities. To do this, the work piece must be merged under heat or pressure, usually with filler material added to create a pool of molten material that will later solidify to form the junction for the weld. Various welding techniques use either heat or pressure alone, heat and pressure combined, or pressure alone without the need for external heat (Owolabi, 2014; Kumar and Gandhinathan, 2020;). Different parts, structures, and pieces of equipment are joined together using these kinds of techniques.

The most appropriate welding technique depends on the significant functions of the part, structures, and equipment, as well as the application area's sensitivity (Wang *et al*., 2020). The welding techniques can be categorised into (i) fusion welding, (ii) non-fusion/solid state welding processes and (iii) low dilution welding method (Chaudhari *et al*., 2020).

1.1 Fusion Welding Processes

This essentially uses the phenomena of melting metal surfaces at high temperatures for joining. Fusion welding processes are widely employed for industrial applications; they include the arc welding, resistance welding and gas welding techniques (Kumar *et al.*, 2019). The arc welding include the welding processes such as gas welding also known as chemical welding process, Shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), gas tungsten arc welding (GTAW), plasma arc welding (PAW), submerged arc welding (SAW) among others (Murugan and Gunaraj, 2005; Hussain *et al.*, 2010; Abbasi *et al.*, 2011; Biwas *et al.,* 2011)., resistance welding process involves welding processes like Resistance seam welding, resistance spot welding, Flash Welding and Projection welding while gas welding comprises of oxy-acetylene gas welding, air-acetylene gas welding and oxy-hydrogen gas welding (Kumar *et al.*, 2019).

1.2 Non-Fusion/Solid State Welding Processes

Solid-state welding also known as non-fusion welding describes the joining techniques where heat and pressure are applied in combination or alone, causing coalescence. In the event that heat is applied, the process temperature is lower than the melting point of the metals being welded. Non-fusion welding/Solid-state welding techniques include cold welding, forge welding, ultrasonic welding, friction welding, friction stir welding, resistance welding, diffusion bonding, and explosion welding (Guo, 2015).

1.3 High-Energy Density/Low Dilution Welding Method

Welding techniques with high energy density concentrate the required welding energy into a tiny region. This permits minimal total heat input to the work piece, leading to a reduced residual stress, distortion, and Material deterioration (Hui-Chi *et al*., 2014). Rapid welding speeds are possible. When there is little to no alloying between the joining metals, diffusion welding is utilised in specific applications. The three main techniques recognised for achieving high energy densities in this category are pulse arc welding (PAW), laser beam welding and electron beam welding abbreviated as LBW and EBW, respectively (Chaudhari *et al*., 2020).

2.0 Factors influencing the choice of welding process for a particular application

Though welding is one of the most widely employed joining processes in virtually all the sectors involved in manufacturing and production, there are many welding processes available for several applications in the industry; however the choice of a welding process is determined by many factors (Ravisankar *et al*., 2006). Some of these factors include:

(i) Type of materials to be welded
(ii) Thickness of the materials
(iii) Welding position
(iv) Desired weld quality and aesthetics
(v) Service requirements of joints
(vi) Economic consideration
(vii) Volume of Production
(viii) Welders skills and level of experience

2.1 Type of materials to be welded

Choosing the right welding process depends heavily on the kind of metal being welded. Certain materials, such as titanium, steel, and aluminium, have special qualities that make them more appropriate for some welding techniques than others. Metal inert gas (MIG) welding is preferable for thicker steel materials, but tungsten inert gas (TIG) welding is typically more effective with thin aluminium alloys (Chaturvedi *et al*., 2021).

2.2 Thickness of the materials

When choosing a welding procedure, material thickness is an important consideration. Stick or flux-cored arc welding, which offers more heat control capabilities, may be more advantageous for thicker materials than thinner materials, which require precise heat control techniques like TIG welding to prevent warping or burning through.

2.3 Welding Position

There are several positions from which welding can be done, including flat, horizontal, vertical, and overhead (Hu *et al*., 2021). Generally speaking, MIG welding can be applied more successfully in all of these positions than TIG welding.

2.4 Desired weld quality and aesthetics

Some methods of welding provide welds that are of better quality and require far less spatter. TIG welding is notable for its ability to produce visually appealing welds with minimal spatter (Radhakrishnan, 2005).

2.5 Service requirements of joints

The specific function and environment where the weld joint is to operate also determine which welding process should be employed. Given that local stress raisers like stiffeners, holes, and notches might cause different areas within the structure to experience differing loads, a design engineer must describe the quality requirements in the pertinent regions of the structure (Chaturvedi *et al*., 2021). The type of welding process required in the aviation is different from the type required in marine equipment fabrication (Crouch, 2016). These are also different those welding processes required in chemical industries, construction industries as well as automobile industries.

2.6 Economic consideration

It is necessary that the welding process used for any application should yield the best weld quality at a minimum cost. Cost implications should always be taken into account, such as costs of labour, materials, and equipment. An effective selection strategy should have a dynamic knowledge base and an open database containing all information about welding products, materials, and techniques. The latter's contents facilitate defining, identifying, and storing the precise welding problem variables (Omar and Soltan, 2020).

2.7 Volume of production

Consideration of the quantity of work or productivity needed to justify the expense of welding equipment is very important when selecting a particular welding process for a given application. Another welding process might be sought to help reduce the costs if the job volume for a particular

welding process is insufficient. A method like flux-cored welding or MIG, with its high deposition rates and efficiency, may be preferred for large quantities of production (Singh, 2020). Even though TIG welding is slower, it may be the best option for very precise and clean welds.

2.8 Welders skills and level of experience

Take into account the welding operator's experience and skill level. It might be wise to go with a method that is simpler to understand and use successfully if the operator has less experience. For certain procedures to produce the best outcomes, more experience and training may be needed. For instance, TIG welding demands a high level of accuracy and aesthetics; a skilled welder is required to handle the intricate welding process.

The success, effectiveness, and quality of a project are all greatly impacted by the choice of welding procedure. Making the most appropriate choice requires comprehending the intricate details of each welding procedure, taking into account a variety of influencing factors, and adhering to a well-organized decision-making process. Omar and Soltan (2020) gave more details on some of these factors as presented in Figure 1.

3.0 Areas of Applications for various categories of welding

Various categories of welding have been utilised in some unique environment due to their peculiarity. The fusion welding processes are predominately employed in most of the manufacturing and construction industries. This is due to some of its numerous advantages which include cost effectiveness, simplicity, ease of operation, compatibility among others. Non-fusion welding processes also known as solid state welding processes, though not widely utilised like the fusion welding, it is required for some specific application or operation. The third category of welding which is the high-energy density/low dilution welding method is specialise modern welding technique for some unique applications.

3.1 Area of application of fusion welding

According to Young *et al*. (2020), the industrial fabrication and repair procedure using fusion welding is and will remain significant. Fusion welding procedures are suitable for use in both traditional and cutting-edge nuclear power plants due to the advantageous qualities of the results and their wide range of applications. It is widely utilised for a range of welding tasks, from light duty welding at the roadside to heavy duty welding in the shipbuilding and metal structure industries (Vimal et al., 2015). It is also widely used by the aviation, spaceflight, shipbuilding, automobile, equipment, and construction industries, among others. Its benefits include robustness when applied to a range of metallic materials, ferrous and nonferrous, good joint strength, high performance and automation, cost-effectiveness and consistent performance, simplicity in multidimensional welding, and increased productivity (Baloyi et al., 2020; Odiaka, et al., 2020; Zhao et al., 2021).

3.2 Area of application for non-fusion/solid state welding

Badavath *et al*. (2022) expressed that over the last ten years, the solid-state welding method has become more significant because of the need to combine various material components, reduce costs, and save energy in a variety of mechanical industries, including automotive, marine, space, aviation, and nuclear. It has mostly been utilised in the aviation sector. There is no use of filler metal in this procedure. Using this technique, dissimilar metals, such as steel and aluminium, can be joined. Solid-state welding can be done under various pressure and temperature conditions. Additionally, they lack any microstructure imperfections. Guo (2015) opined that solid-state techniques typically result in joints devoid of non-metallic inclusions, hot cracking, and gas porosity, among other solidification flaws that could arise during fusion welding procedures. With solid-state welding, no flux, shielding gas, or filler metals are needed. Because most of these techniques don't involve heat-affected zones or flaws, the metal being joined can have mechanical qualities that are just as good as or even better than those of their parent metals.

3.3 Area of application for the high-energy density/low dilution welding method

According to Hui-Chi *et al*. (2014), the high-energy beam welding technique is a type of contactless process that offers increased manufacturing and design freedom. Owing to these exceptional qualities, the high-energy beam welding technique has found use in numerous industrial domains (such as aerospace, automotive, oil and gas, shipbuilding, medical devices, etc.) and is anticipated to maintain its significant influence in the welding industry going forward.

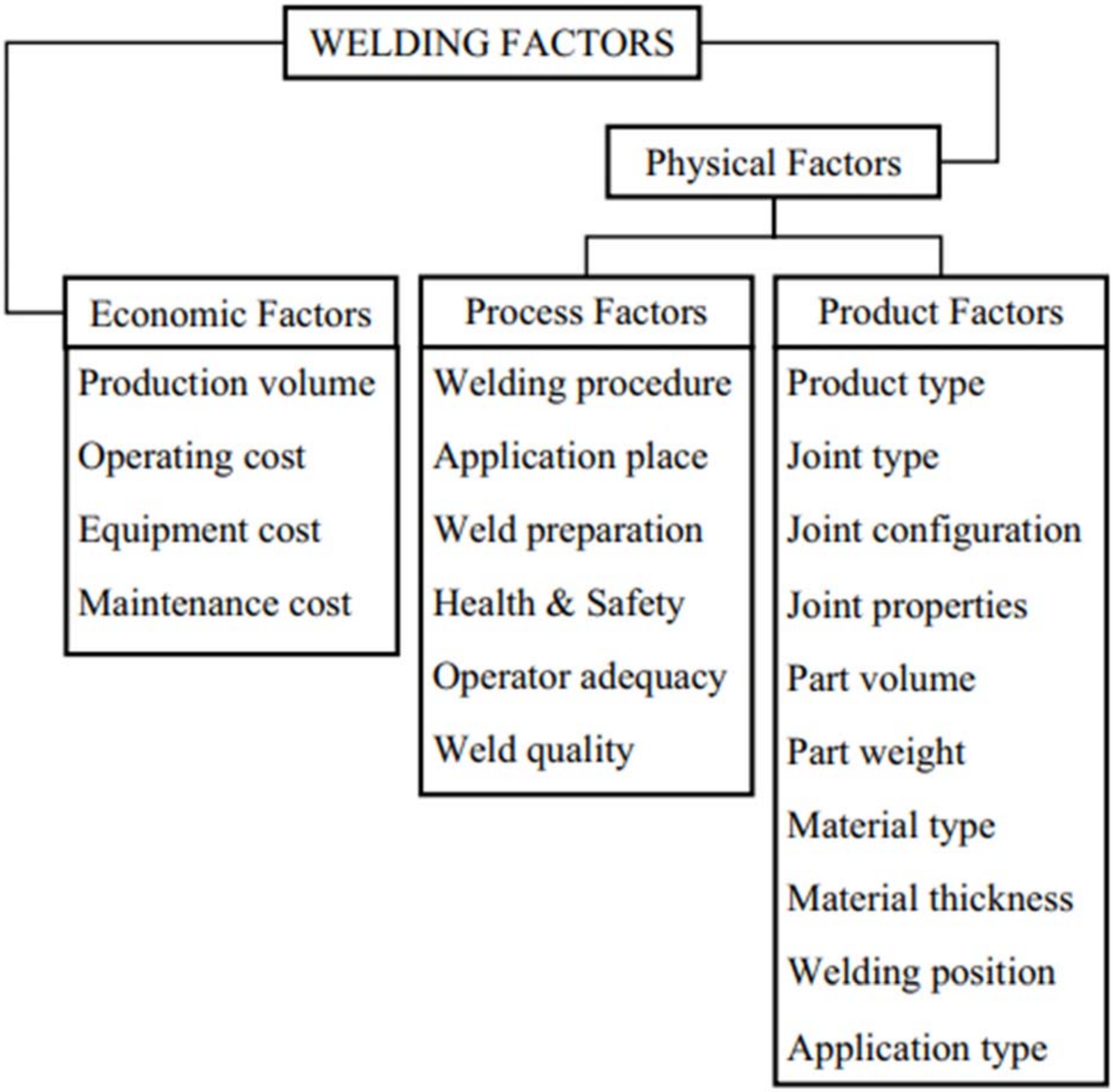

Figure 1: The main welding factors (Omar and Soltan 2020)

4.0 Impacts of Welding Parameters on Welded Joints

To achieve satisfactory weld quality, the right welding parameters should be chosen. Controlling process input variables to produce a suitable metallurgical bond with the proper surface finish and weld strength, with a minimum amount of unfavorable residual stress and distortions, poses the biggest danger to the welding industry (Wang and Wang, 2019; Chaudhari and More, 2014). According to Srivastava *et al.* (2017) using the appropriate welding parameters will increase the likelihood of obtaining welds of an acceptable adequate quality. This was supported by the findings of Kessal *et al.* (2019); Rizvi and Ali (2021) who claimed that process parameters are crucial in influencing the weld quality. Hence the review of the welding parameters will help in understanding the role each welding parameters or variable play in enhancing the quality and strength of welded joints.

Kumar and Vijayakumar *(*2012) noted that there has been improvement in the welding industry with regard to the large number of welding methods that have evolved over the past few years. He came to the conclusion that the development of a variety of welding techniques had made it easier to find techniques that worked for different applications, which led to a decline in the number of reworked and rejected projects.

However, the task of quality maintenance is still challenging due to many variables that must be considered during the welding process. These variables range from those in raw materials such as composition, thickness, internal defects, etc., to other ones like a change of operator, variation in gaps between pieces to be welded, different welding speeds, and different electrodes (Kumar and Vijayakumar 2012).

These factors include welding process variables like welding current, which affects heat input, temperature, voltage used, welding speed, groove angle or edge preparation (joint geometry), root gap, types of materials to be welded, types of filler materials or electrodes, size of electrode diameters, electrode angle, electrode stick-out, arc length, polarity, external magnetic field, welding technique, melting rate, and feed rate (Akbarnejad, 2012).

The processes that use gas as a shield will incorporate the following according to Moshi *et al.* (2016): the kind and makeup of shielding gas, shielding flow rate, and submerged arc welding (SAW) factors such as flux depth and flux basicity index have all been demonstrated to affect the weld quality and strength of the weldment.

4.1 Welding Current

Welding current is regarded as the characteristic with the most significance because of its effect on the frequency at which the filler metals and the base materials melt during the process of arc welding (Kumar, 2011). It establishes the welding heating rate and welding efficiency (Wax *et al.,* 2014). To optimize the heat supply, the welding power can be raised or the welding speed can be lowered. Thus, welding current and welding speed are the two most crucial welding parameter factors that influence the heating rate. It is possible to calculate the heat input by dividing the power (i.e., voltage times current) by the velocity of a source of heat, such as an arc. According to mathematics, the relationship between heat input Q, welding current I, and welding speed v is as follows:

$$Heat\ input\ rate\ Q = \frac{V \times I \times 60}{\nu}\ J/mm$$

(Dhobale and Mishra, 2015).

where, V stands for arc voltage, I for welding current, and ν is the welding speed in millimeters per minute. Therefore, since V = IR, heat input Q is represented below mathematically as

$$Q = I^2Rt$$

where, Q, I, R and t stand for heat input, welding current, the resistance and welding duration respectively.

The type of materials to be welded, their thickness, the size of the electrode to be used, and the welding location are factors that influence the welding current to be utilized, according to Penkata and Plowas (2014). When the choice of welding current is good, there will be sufficient heat input to properly melt and fuse the materials at the weld joints. Increase in material thickness will require corresponding increase in welding current so as to ensure sufficient heat input for melting, penetration and adequate deposition rate of the electrode and filler materials.

A study carried out by Desai *et al.* (2019) confirmed the assertion that low currents are responsible for the low strength experienced at the welded joints. He experimented with making beads out of mild steel rods that were 250 mm long and 16 mm in diameter by employing different welding variables like welding current, electrode angle and groove angle. According to the investigations, the current varied between 150, 160, and 170 Ampere respectively while electrode angle were 40º, 50º and 60º, the groove angles chosen were 50º, 60º and 70º. The investigation found that the heat input given by the low current supply of 150 Ampere was insufficient to melt the metal as well as the filler metal or electrodes, and that prevented effective fusion from taking place. The strength of the welded junction was enhanced when the current was raised to 160 Ampere.

However, an excessive current of 170 Ampere was found to be detrimental to the welded joint because of the development of void, crack formation, turbulence in the arc which led to spatter and other discontinuities and so he concluded that for an SMAW process, optimization of welding current is a requirement for obtaining good quality welding.

The impacts of three welding parameters on the corrosion resistance, mechanical, and metallurgical properties in FZ and HAZ for a Gas Tungsten Arc Welding (GTAW) of AISI 304L SS cylinders in a butt-joint utilizing AISI 308 SS were examined by other researchers such as Kessal *et al.* (2019). These welding parameters included the welding current, the number of passes, and the rate of flow of argon gas. The welding current and the number of passes were found to have an impact on the mechanical characteristics of HAZ. Peak width is increased and residual stress decreases as the welding current was increased.

In reality, the increased welding current caused plastic deformation and helped to reduce residual stresses (Kessal *et al.,* 2019).

4.2 Welding Speed

The welding speed refers to the rate at which the arc travels along the weld joint in relation to the base metal being welded. According to a mathematical equation, welding speed is also correlated with welding current and arc voltage as given by

$$Heat\ input\ rate\ = \frac{V \times I \times 60}{v}$$

(Dhobale and Mishra, 2015)

where Arc voltage V is expressed in volts, welding current I is expressed in amperes and welding speed v is expressed in millimeters per minute (m/s).

According to Dhobale and Mishra (2015), When the welding speed exceeds what is required, there will be a reduction in the heat input supplied for the welding as well as a reduction in the filler material deposition to the joint, both of which will not be sufficient for the welded joint and will therefore result in less reinforcement of the welded joint.

In addition to the aforementioned problems, undercut arc blow, porosity, and irregular bead shape are examples of welding defects or discontinuities that will be highly evident. On the other hand, when the welding speed is slow, there will be more filler metal being deposited, more weld reinforcement both in size and height, increasing convexity, greater heat input, a big weld pool, a rough weld bead, and a higher likelihood of inclusions.

The focus of a study by Janunkar *et al.* (2017) on the impact of welding speed on the strength of welded joints using the Gas Tungsten Arc Welding (GTAW), also known as the Tungsten Inert Gas (TIG) welding technique, with varied V-groove geometry plate included angles of 30º, 40º, and 50º, as well as varying bevel heights of 1, 1.5, and 2 mm, was on varying welding speed using 0.3, 0.6, 0.9, and 1.2 cm/sec. The materials used for the strength investigation of the V groove butt weld connection were AA6063 and AA5083, where AA6063 was the filler material and AA5083 was the base material.

The analysis revealed that as welding speed increased, the tensile strength decreased. With a welding speed of 0.6 cm/sec, a bevel angle of 40°, and a bevel height of 1.5 mm, a maximum tensile strength of 234 MPa was observed; however, a steady decline in tensile strength was observed for welding speeds of 0.9 and 1.2 cm/sec using the same bevel angle of 40° and bevel height of 1.5 mm; the tensile strengths recorded for the aforementioned welding parameters were 220 and 185 MPa.

4.3 Welding Voltage

There is a differential in electrical potential between the surface of the weld pool and the tip of the welding electrode. The length of the arc between the welding electrode and the molten metal has been stated to affect welding voltage because an increment in arc length normally causes a rise in arc voltage because the extension of the arc exposes the entire arc column to the cool border of the arc (Zhang *et al.,* 2013).

The welding current and arc voltage during the GMAW process affected the joints' mechanical features, according to Rao *et al.,* (2016) in their study of a model for selecting GMAW parameters to improve the mechanical qualities of weld joints. In their study of the impact of welding current, arc voltage, and gas flow rate on the depth of penetration during MIG welding of AA2014 plate, Sakthivel *et al.* (2015) noted that while welding variables or parameters like welding voltage, arc current, welding speed, and welding angle have significant effects on the bead geometry, the weld and bead geometry must play a major role in determining the mechanical properties of the weld.

Arc voltage impacts penetration, bead reinforcing, and bead width, according to Sakthivel *et al.* (2015) found this by increasing the arc voltage from 24 to 26 and then to 28 volts, noting that for 24 volts, the penetration, bead width, and bead height were 7.57, 12.20 and 2.20 mm respectively, while for 26 volts, the penetration, bead width, and bead height were 7.56, 12.73 and 2.69 mm, for the 28 volts, they were 7.55, 13.14, and 3.06 mm.

Hence the weld bead width increased with increasing voltage. When the voltage was reduced narrower beads with greater convexity were observed and further reduction in voltage showed some welding defects like porosity and overlapping.

4.4 Shielding gas types and composition

Shielding gases are used to avoid contaminating the weld pool and interacting with additional substances from the air or the welding environment.

According to Kah and Martikainen (2013), shielding gas has an impact on the mechanical properties of the welded junction in addition to protecting the weld pool. This is due to its interactions with the base and filler metals, which change both the way the arc is created during welding as well as the mechanical qualities of the weld joint. These mechanical properties include strength, toughness, corrosion resistance, and hardness.

Therefore, it is thought that one of the major factors in determining the weld joint quality is the shielding gas and that poor choice could lead to welding flaws such as porosity, spatter, inclusions, cracks, etc. that reduce the joint's service life under dynamic loads (Kuk *et al.*, 2004).

Shielding gases are prohibited under the European standard; Welding Consumables - Gases and Gas Mixtures for Fusion Welding and Allied Processes. Helium (He), hydrogen (H_2), carbon dioxide (CO_2), oxygen (O_2), and argon (Ar), as well as several mixtures that can be blended and used as shielding gases, fall under the category of gases specified by this standard.

When shielding gases are used individually without mixing, the various properties such as the resulting welding defects, strength, arc stability, hardness of the welded joint, etc. are impacted in different ways. The same differences are also noted for the welding processes used. When CO_2 is utilized as a shielding gas for some welding procedures, the process is not expensive, but it does result in spatter and oxidation, which lead to material losses.

Argon, on the other hand, is rather expensive when used as a shielding gas in its pure form, and there are issues with arc stability and attaining the necessary weld bead properties (Ebrahimnia *et al.,* 2009). Some gases are therefore combined in different proportions to meet some performance requirements, the combination can be two, three, or even four different types of gases. While some gases, whether in their pure form or when combined, can be employed for certain specific processes, they might not be appropriate for other processes (Mukhopadhyay and Pal, 2006).

The materials to be welded, the welding procedure or method to be used, the quality requirements as well as any tolerance and purity requirements that may be necessary, all affect which gas or gases can be used for a specific process (Lyttle and Stapon, 2005).

4.5 Welding Polarity

In a study on the effect of welding polarity on the mechanical properties, microstructure, and residual stress of gas tungsten arc welded AA5052, Sarmast and Serajzageh (2019) discovered that welding polarity (alternate current AC and direct current electrode negative DCEN) has a significant impact on temperature distribution in weldments, which in turn significantly affects the microstructure, mechanical properties, and residual stress distribution of components.

The distribution of residual stresses and thermal responses were evaluated using a three-dimensional thermo-mechanical model in the study. Tensile tests and hardness measurements were conducted to ascertain the effect of welding polarity on the mechanical properties of the components.

Additionally, optical microscopy was used to make microstructural observations in order to evaluate the microstructural changes. When compared to AC welding, it was shown that DCEN welding had a higher concentration of heat input, smaller weld pools with higher maximum temperatures and faster cooling rates.

As a result, the DCEN weld pool's microstructure of solidification is finer. It was observed that when compared to welding under AC polarity, DCEN polarity welding produced smaller HAZ, which is linked to higher tensile, longitudinal and residual stresses.

4.6 Wire Feed Rate

This is measured in either inches per minute (in/min) or meters per minute (m/min) and relates to the rate at which wire filler metal is supplied into the weld. The filler metal's wire feed rate, which is essentially independent of the welding current and is critical for adjusting the Gas Metal Arc Welding Properties, can be used to change the relative degree of fusion between the base metal and filler metal (Palani and Murugan, 2007).

According to Amin (1983), who was cited by Palani and Murugan (2007), there are two fundamental requirements for the GMAW process: In order to maintain a constant arc length, (1) the burn-off rate must be matched with the wire feed speed (W), and (2) there must be a stable transfer of metal from the electrode wire to the weld pool. The rate at which the wire filler material is melted or burnt by the heat energy of the welding arc is referred to as the "burn-off rate" and it is expressed in inches per minute (in/min) or meters per minute (m/min). Good metal transfer conditions are reached when the wire feed rate and the wire melting rate are precisely matched. This results in good arc stability.

To investigate the impact of wire feed rate, John *et al.,* (2020) performed bead-on-plate welding tests using a 7 mm thick Ti-Nb micro-alloyed steel sheet, which has strength of 800 MPa, as the base material. The filler metal utilized was ER70S-6 filler wire, which is readily available and has a strength of 490 MPa. The wire feed rate ranged from 5 m/min to 9 m/min with a step size of 1 m/min, and the welding speed was set at 200 mm/min. The contact tip to workpiece distance (CTWD) was altered between 10 mm and 18 mm during this time. Because it was predicted that pulsed mode would result in the least amount of heat input and lower the heat affected zone (HAZ), it was used during welding.

The width of the bead, penetration, fused base metal area, deposited weld metal area, HAZ breadth, and HAZ area were all observed to rise with an increase in wire feed rate. As the wire feed rate increased, the welding current also increased, raising the amount of heat that was injected into the weld. The reinforcement height was held constant throughout all instances.

The wire feed rate and weld toe angle, on the other hand, exhibited an inverse correlation. The results demonstrated that weld beads with the optimal penetration, bead morphology, reinforcements, dilution, and other characteristics were formed at a wire feed rate of 6 mm/min, therefore, feed rates greater than 8 m/min and those less than 5 m/min were not desired.

According to the literature, the required weld dilution range is between 35 and 40%, and the ideal heat input for the optimal wire feed rate is 1.27 KJ/mm.

As can be seen all the categories of welding are utilised almost in every areas such as aviation, nuclear power plants, automotive, oil and gas, shipbuilding, equipment, and construction industries, among others.

It is therefore necessary that the peculiarity of operation or service as well as function of the component or structure being welded should be well comprehended by the industrial engineers. This understanding will aid the proper selection of the appropriate welding process and the right choice of welding input parameters.

It should be emphasized that there are many welding parameters; hence it is not possible to cover all welding parameters within the scope of this work. As a result, it is advised that additional research be done on the other welding parameters that this work did not cover.

5.0 Conclusions

This review addresses the fusion, non-fusion/solid state categories of welding; it also gave a brief description of high-energy density/low dilution welding method. Some factors influencing the choice of certain welding process for a particular application were discussed. Some welding input parameters that affect weld quality and also have an impact on the welder's potential health hazards. The overall goal is to bring to bear a comprehensive knowledge of the importance of these welding input parameters and how they can lead to production of welds which have minimal defects and have a long service life span during usage. These will also ensure that unnecessary failures of welded structures/components as a result poor choice of welding process and welding input parameters are drastically reduced to the minimum. Based on the numerous parameters examined, some research gaps were found, including:

a) Studies investigating the effects of welding current, welding voltages, and wire feed rate on the heat-affected zone and weld quality of mild steel concerning the bead morphology in terms of bead height, and bead width, as well as visual inspection for different types of welding defects.

b) Evaluation of the impact of these welding variables on the mechanical properties of the mild steel is also necessary.

c) It is also required to conduct a microstructural analysis of the HAZ to determine the effects of changing welding current, welding voltage, and wire feed rate on the microstructure across the welded joint

d) An investigation of the corrosion rate of mild steel should be carried out to determine the effect of these welding variables on it

e) The effects of post-weld heat treatment on the mechanical properties, microstructure, and corrosion rate for the various welding parameters investigated should also be examined.

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