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A Review on Effects of GTAW Process Parameters on weld

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***Abstract—* Different process parameters of Gas Tungsten Arc Welding (GTAW) affects the weldment quality. Increasing welding current increases the deposition rate and reduces the hardness. Direct current electrode negative (DCEN) polarity provides deep penetration as compared to Direct current electrode positive (DCEP) and Alternating Current (AC) polarity. Increase in welding speed decreases the bead width and depth of penetration. Depth of penetration and deposition rate decreases with increase in welding voltage. At high voltage, arc length increase which results in wider bid width. Different combination of shielding gases shows different effect on arc plasma which mainly depends upon gas properties such as electrical conductivity, molecular weight, ionization temperature etc. Arc velocity, current density and heat flux decreases with increase in tip angle of electrode.**

Keywords— ***GTAW, Hardness, Welding Parameter, Shielding Gas, Marangoni Effect, weld bead geometry***

I. INTRODUCTION

Gas Tungsten Arc Welding (GTAW) also known as Tungsten Inert Gas (TIG) welding was developed in late 1930s when a need to weld magnesium became apparent. The melting temperatures necessary to weld materials in GTAW process is obtained by maintaining an arc between tungsten alloy electrode and a workpiece. An inert gas sustains the arc and protects the molten metal from atmospheric contamination. The inert gas may be argon, carbon dioxide, helium or the mixture of these gases.

Advantages & Disadvantages: This method produces high quality low distortion weld, Free of the spatter, welds almost all metals including dissimilar ones and gives precise control of welding heat.The concentrated nature of a GTAW arc permits pin point control of heat input to the workpiece resulting in a narrow heat affected zone (HAZ). Narrow HAZ is an advantage because this is where the base metal has undergone the change due to superheating of arc and fast cooling rate.

Limitations of this process are low deposition rates, requires slightly more welder coordination than Gas Metal Arc Welding or Shielded Metal Arc Welding [1].

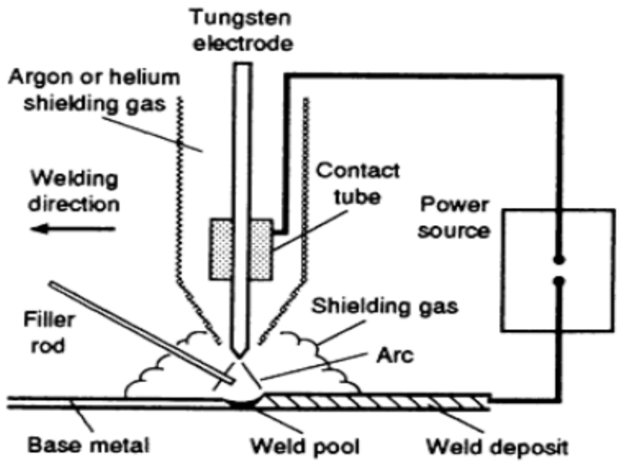

Fig. 1 Schematic of GTAW process [1]

Different welding parameters such as welding current, voltage, polarity, Gas flow rate, Welding speed, electrode tip angle changes the properties of weld produced through GTAW welding. This paper provides the review of literatures provided by different researchers in context to the topic. Figure below shows the Ishikawa diagram for the same.

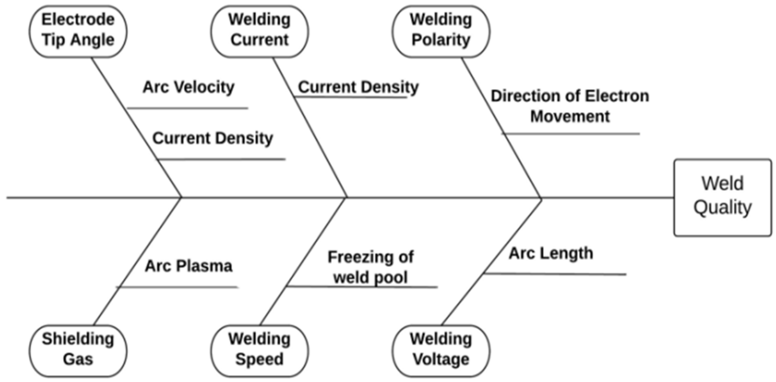

Fig. 2 Ishikawa diagram for GTW process parameters

II. PARAMETRIC EFFECT ON GTAW PROCESS

A. *Welding Current:*

Welding current represents the flow of electrons. GTAW process is classified as a constant current process as voltage is dynamic in nature. Welding current selection is very much governed by the tungsten electrode diameter, gas type and welding polarity.

Gharibshahiyan*et al.* [2] during their study reported that increase in welding current led to the grain refinement in welding metal and reduces the hardness. This is considered to be attributed to a reduction in the density of dislocations and microstructural coarsening.

Parvinder Singh*et al.* [3] during their study concluded that increase in current results in increase in deposition rate. It is also practical that in a given time more heat is needed to melt a given amount of metal. According to joule's effect, heat is directly proportional to current and time, given $H = I^2Rt$ (where H is heat, I is current, R is resistance, t is time).

Trivedi *et al.* [4] during their study of weld bead geometry on Aluminium concluded that bead height increases with increase in current where as bead penetration remains constant with increasing current and Bead width decreases with increase in current.

Niles *et al.*[5] characterized the heat energy in to three different parts.

Et as total arc energy input

Ei as energy per unit distance entering the work

Em as energy per unit length required to melt the weld bead

Based on these energies they proposed terms Process Efficiency and Melting Efficiency as

$$\text{Process Efficiency} = Zi = (Ei/Et) \times 100 \quad (1)$$

$$\text{Melting Efficiency} = Zm = (Em/Et) \times 100 \quad (2)$$

And they reported that as current increases the percentage of heat entering the plate (Ei) decreases. This indicates that heat losses from the arc column increases more rapidly with current level than does the percentage of total heat entering the base metal. For the given heat entering into the plate (Ei), melting efficiency (Zm) increases as current increases.

D. Uhrlandt*et al.* [6] during their study of cathode fall voltage of GTAW arcs observed that cathode tip temperature increases as current increases and they found this increase of 700K for current rise from 50Amps to 250Amps.

B. *Welding Polarity:*

There are three different polarities which might be used when using GTAW depending on the power supply being used. The direction that the electron flows is referred to as the polarity. Electron generally flows from a negatively charged body to a positively charged body. If a direct current power supply is used and the workpiece is connected to the positive terminal is called DCEN. On the other hand if the parent material is connected to the negative terminal of the direct power supply is called DCEP. If an alternating current power supply is used the polarity is referred to as AC.

Due to the direction of electron movement 70% of the heat in DCEN is directed to the workpiece and 30% of the heat is directed to the electrode and vice versa when DCEP is used. This results in narrow and deep weld pool in case of DCEN polarity due to high energy in the parent metal. The arc forces the droplets away from the workpiece due to the low rate of electron emission from the negative electrode. For a DCEP, weld pool is shallow. This method can be used to clean the surface of the workpiece by knocking off oxide films by the positive ions of the shielding gas. DCEP produces rapid heating and degradation of electrode tip because

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anode is more heated than cathode. In case of AC polarity 50% of heat is directed towards the workpiece and the other 50% of the heat is directed to electrode. The AC polarity provides reasonably good penetration of the weld pool and oxide cleaning as shown in Figure 3[1].

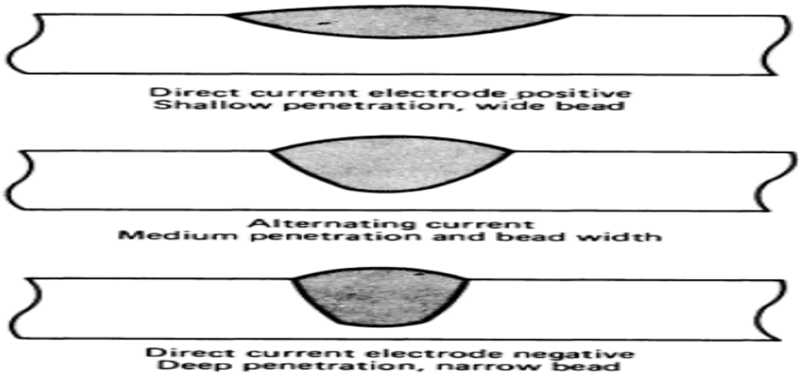

Fig. 3 Bead geometry for different polarities [1]

C. Welding Speed

Speed of welding is defined as the rate of travel of the electrode along the seam or the rate of travel of the work under the electrode along the seam.

Depth of penetration also gets affected by the welding speed. *Tewari etal.* [7] during their study on effect of varying speed on weld geometry found that the depth of penetration increases with increasing welding speed up to the optimum value then starts decreasing with further increase in welding speed for a constant voltage and current conditions.

Trivedi *et al.*[4]during their study on weld bid geometry for Aluminum weld concluded that bid width decrease with the increase in welding speed.

Niles *et al*. during their study on weld thermal efficiency of GTAW concluded that, process efficiency and melting efficiency increases with increase in welding speed [5].

D. Welding Voltage

Voltage controls the length of welding arc and resulting width and volume of arc cone. As voltage increases arc length gets longer (and arc cone broader), while as it decreases, the arc length gets shorter (and arc cone narrower). A high initial voltage allows for easy arc initiation and allows for greater range of working tip distance.

Depth of penetration decreases as voltage increases. In GTAW welding process filler feeding or Filler melt off rate should be kept constant since it is manual process. If not welder has to increase the feed rate of filler as progresses which is tedious and not possible. Voltage is a controlling variable in manual processes because in manual process it is very difficult to consistently maintain the same arc length. Hence GTAW is constant current (CC) output method.

Prabhaharan *et al.*[8] as a result of their study concluded that welding voltage has inverse effect on weld deposit area. Accordingly increase in welding voltage decreases the deposition rate.

Lakshmansinghe*t al.* during their study on aluminium alloy concluded that increased arc voltage increases the arc length which results in wider bid width [9].

E. Shielding Gas

Less electrical conductivity of helium than that of argon reduces the diameter of current channel and leads to the current constriction. Current constriction results in higher peak of heat intensity. Due to higher peak of heat intensity, temperature on anode surface is approximately twice of that with the use of Argon gas. Heat transportation from electrons is therefore concentrated near arc axis.

CO_2 welding provides higher temperature on anode surface than that of Helium gas. Since the molecular weight and hence mole specific heat of CO2 is higher than He, current constriction near cathode is more in case of CO_2 which in turns results in higher plasma temperature. This phenomenon is explained through modelling by A. Moarrefzadeh[10] as shown in figure.4

Thermal conductivity of Argon shielded arc plasma can be increased by addition of hydrogen in Argon. Lowke*et al.*[11] reported constricted arc plasma due to 10% addition of hydrogen in to argon.

Argon ionization energy is much lower than the He ionization energy due to which ignition can be achieved at higher (up to 13 mm) tip to work distance, if combination of He and Ar is used. As the percent of Ar in He increases, spark can be achieved at higher distance between tip and work [12].

Shanping Lu *et al.* [12]further concluded that addition of small amount of oxygen (0.2%) in helium argon mixture increases the depth of penetration and hence depth/width ratio. This is attributed to marangoni convection mode. Generally the surface tension decreases with the increasing temperature. In the weld pool surface tension is higher in relatively cooler part of the pool edge than that in the pool center under the arc and hence the fluid flows from the pool centre to the edge. The heat flux is easily transferred to the edge and the weld shape is relatively wide and narrow. Addition of minor element such as oxygen changes the direction of fluid flow and Marangoni convection on the pool surface changed from an outward to inward direction which results in deep and narrow weld shape.

Addition of hydrogen to argon increases the melting efficiency of arc plasma which results in increased depth of penetration, bead width and reduced hardness of weldment as well as deterioration in mechanical properties [13].

F. Electrode Tip Geometry:

During their experimentation, Abid *et al.*[14] found that arc temperature near the electrode tip is the maximum for the sharp tip and decreases as the electrode tip angle increases. It is because sharper electrodes have hotter tips due to the reduced cross section as compared to the blunt tips. Electrode tip angle does not produce any prominent effect on the arc temperature just above the surface of the work piece. Arc velocity gets affected by tip angle. It is found that the arc velocity decreases as the tip angle increases. Current density also shows the same characteristics i.e. inverse nature with respect to the tip angle. Current density at cathode decreases with increase in tip angle. This decrease is due to the lower electrical potential in the arc with large tip angles. Distribution of current density on the anode surface remains almost the same with tip angles.Heat flux due to conduction and convection is more sensitive to the electrode tip angle and decreases with increase in tip angle. However the heat flux due to electronic contribution (which is major part of total heat flux) remains unchanged.

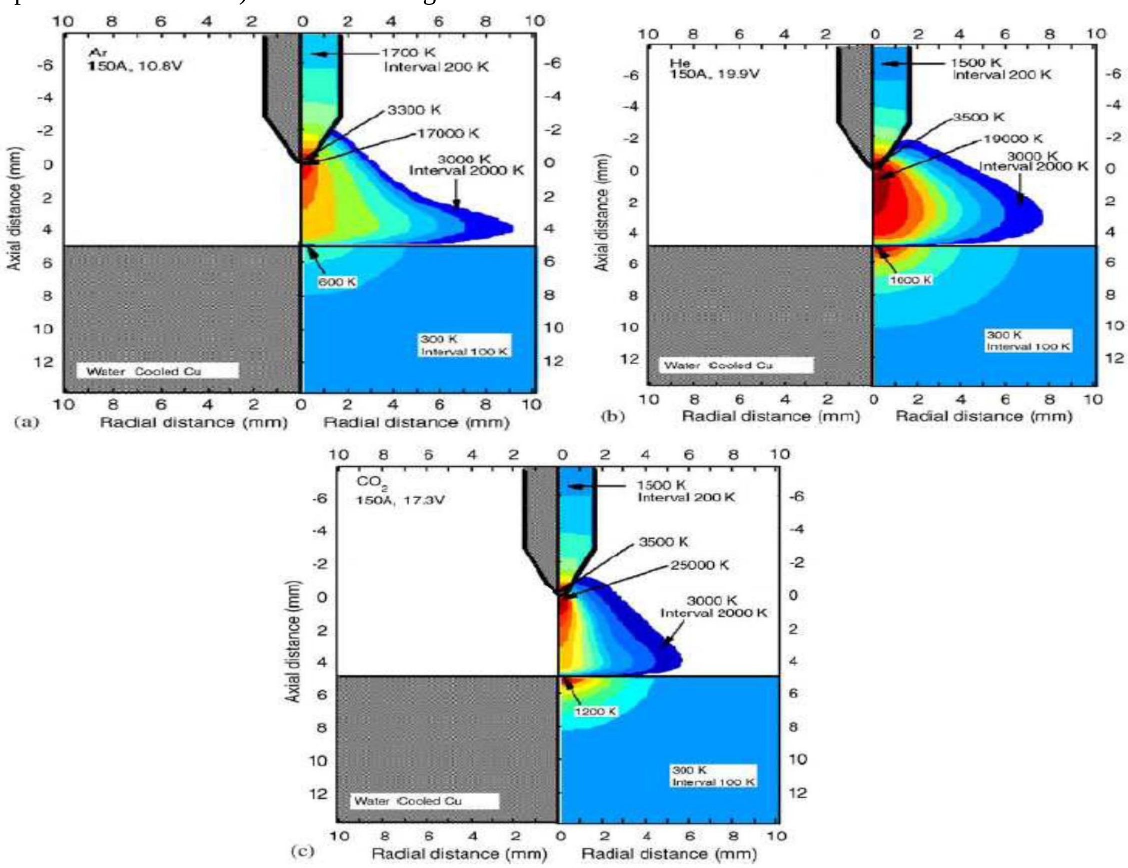

Fig. 4 Distribution of temperature and flow velocity in Argon, Helium and Carbon Dioxide Gas Tungsten Arc at 150AMP arc current.

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III.CONCLUSIONS

Welding current has an effect on heat input and weld bead geometry. Increasing welding current increases the deposition rate and bead height at the same time reduces hardness. Increasing the welding current also increase the melting efficiency however the rate of heat loss to the surrounding is more with increased current.

Welding polarity affects the depth of penetration. DCEN polarity provides deep penetration where as DCEP provides shallow penetration. Degradation of tungsten electrode is more with DCEP polarity as high is directed towards the electrode with DCEP.

Bead geometry gets affected with weld speed. Depth of penetration increases with increasing welding speed up to the optimum value then starts decreasing with further increase in welding speed. Bead width decreases with increase in welding speed. Process efficiency and melting efficiency increases with increase in welding speed.

Depth of penetration and deposition rate decreases with increase in welding voltage. At high voltage arc length increase which results in wider bid width.

Shielding gas protects the molten metal pool, filler rod, HAZ from air contaminations. Shielding gas affects the arc plasma characteristics. CO2 gives highest arc constriction as compared to Argon and Helium gas used individually. Ignition characteristics of argon helps to ignite spark at high work to electrode distance hence argon is mixed in to helium to take advantage of ignition characteristic. Addition of small amount of oxygen in He-Ar mix, increases the depth of penetration.

Arc temperature near sharp electrode tip is more than that with blunt tip. Arc velocity, current densities and heat flux decreases with increase in tip angle. Current densities and heat flux at work surface remains unaffected with respect to varying work tip angle.

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