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TWO WAY ARC WELDING FOR DEEPER AND NARROWER PENETRATION

Sambhav Jain, Nisarg Shah

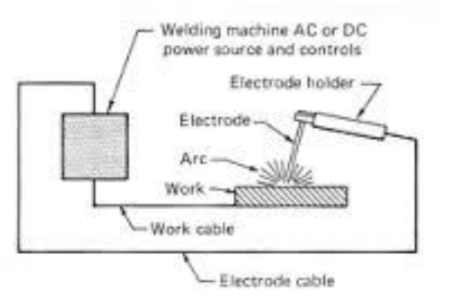
Abstract— **The Welding process can be defined as a method to join material usually metals and thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. Thus Cost reduction and productivity improvement in welding operation can therefore generate considerable impacts on competitiveness of various manufacturing industries. The other factors which plays a major role in determination of weld quality is welding time, depth of penetration, heat, surrounding conditions. The other methods used to perform the deep penetration processes are energy beam methods such as laser beam welding and electron beam welding. The primary disadvantages are their very high equipment costs (though these are decreasing) and a susceptibility to thermal cracking. Also these energy beam methods are very expensive and thus does not suits for many applications. This paper presents an inexpensive welding process with much smaller weld joint and good depth of penetration. This work thus focuses on improving weld penetration without substantial cost increase. Instead of using another welding process, arc welding process will be performed in a novel method. These processes use a welding power supply to create and maintain an electric arc between an electrode and the base material to melt metals at the welding point. They use either direct or alternating current, and consumable or non-consumable electrodes. The welding region is sometimes protected by some type of inert or semi-inert gas, known as a shielding gas, and filler material is sometimes used as well. Common types of arc welding process are submerged metal arc welding, gas metal arc welding, flux core arc welding, tungsten gas welding and submerged arc welding.**

Index Terms—**two way arc welding, modern technologies, penetration, welding**

I. Introduction

It is known that arc welding can achieve deeper penetration than other arc welding because of its more concentrated arc and plasma jet. However, the majority of the welding current in arc welding earths through the top surface of the base metal. This earthling of current leads to low weld penetration, thus only the plasma jet which has been ionized and heated by the arc, rather than the arc itself, can directly penetrate into the keyhole. If the arc can directly penetrate into the keyhole, the penetration will be significantly increased. Hence, this paper proposes increasing the penetration by placing a second electrode on the opposite side of the work piece. The two torches are directly connected to the two terminals of the power supply. Thus this completes arc and the hence the current flows. The resultant welding current loop becomes power supply-torch-work-torch-power supply instead of the conventional power supply-torch-work-power-supply loop.

As a result, the welding current, thus the arc, is guided into the joint. Another method to improve penetration in arc welding is to improve the energy density of the arc because energy density is the primary factor responsible for the penetration difference between laser/electron beam welding and arc welding. Hence, this study explores another method to improve arc concentration and arc energy density to improve penetration with arc welding.



II. Working Principle

The basic working principle of the process is to place the second torch in opposite direction to the first torch referred as primary torch, welding current flows through the keyhole, instead of earthing through the work surface, in the proposed process. Thus, the plasma arc is guided into the joint and it becomes more concentrated. Hence, the penetration capability is increased to a great extent. It is apparent that the welding current must flow through the work during DSAW. Thus, the process proposed above, of arc welding in improving penetration provides a better weld joint.

In case of plasma arc welding the gas gets ionized after passage of electric current through it and it becomes a conductor of electricity. In ionized state atoms break into electrons (-) and ions (+) and the system contains a mixture of ions, electrons and highly exited atoms. The degree of ionization may be between 1% and greater than 100%.

Thus the whole process is divided in two stages viz. electropositive and electronegative periods. The major difference that is the arc is more concentrated in electronegative period and the penetration is primarily due to electronegative period.

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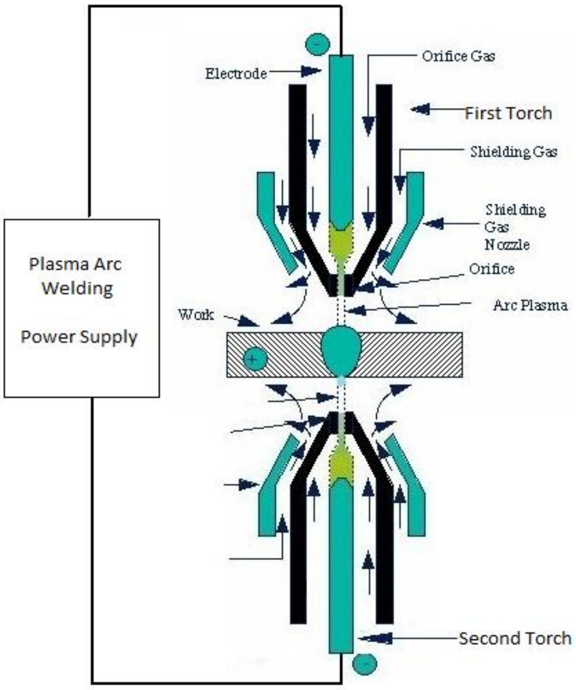
Sambhav Jain, Mechanical Engineering, Jamia Millia Islamia, New Delhi, India, +9654337070.
Nisarg Shah, Mechanical Engineering, Babaria Institute of technology, Gujarat, India, +9409213539



It is known that the PAW torch has a constricting orifice such that electrons emitted from the tungsten electrode flow through the ionized plasma gas and form a highly constricted plasma jet. This plasma jet melts the workpiece and can displace the molten metal to form a keyhole or deep narrow cavity. Therefore, the PAW/GTAW torch combination may generate the keyhole double-sided arcing phenomenon.

The concentration of the plasma arc can be explained by the welding current direction and its induced magnetic field. In The proposed process, the welding current flows approximately normally through the work. Welding current in such a direction generates a magnetic field. Under the effect of this magnetic field, the current lines are driven towards the axis. The welding current is concentrated both in the arcs and in the work. Because of the spatial correlation between the welding current and the arc distribution, the arcs are therefore converged.

A. ANALYSIS OF HEAT AFFECTED ZONE (HAZ)

The heat affected zone is the factor that determines the properties of the weld. For any application the depth of the weld pool is pre determined thus ratio of the depth and the width of the pool play a major role in the determination of HAZ. Thus it is clearly stated that the increase in the penetration can only be achieved by increasing the width of the weld pool. Thus width of the pool becomes the primary factor in determination of the heat affected zone. It is noted that with the increase in the current supply, the depth and width of the pool increases simultaneously and thus the ratio remain unchanged, thus for increasing the depth of penetration, heating is to done from both the sides which primarily increases the depth due to increased depth to width ratio.

B. DEFECTS IN WELDING

The major welding defects are the undercuts, porosity, distortion, incomplete penetration and lamellar tearing, gas inclusion.

This method solves most of the problems associated with the plasma arc welding. In case of convectional plasma arc welding the plasma pressure, gravity results in separation of liquid pool from the welding torch solid material, however the undercut may develop when the force between the solid material and melted material is not sufficient due to which the cross-sectional thickness of the base metal reduces. This defect is however solved in this process because of the simultaneous welding at the bottom of the work piece due to which the gravity serves as the retaining force.

Distortion in welding process occurs due to shrinkage of the heated metal. Since the two way arc welding heats the metal from both the sides, thus thermal distortion is reduced.

III. EXPERIMENTAL SET-UP

For setting up the experiment, we analyzed the material TC4 titanium alloy with following chemical composition:

AL	V	Fe	C	N	O	H	Ti
6.0	4.1	0.05	0.01	.027	0.12	.006	Bal.

The basic dimension selected for the experiment is 120mm*60mm*4.35mm. The work piece was firstly grounded with stainless steel brush and sandpaper to remove the oxide film, and then cleaned with acetone to remove the organism such as oily soil. It is also seen that at high temperature, the welding of tungsten is very difficult due to its high chemical reactivity. Large amount of oxygen, nitrogen and hydrogen is used during the welding. The welding speed was approximately 200 mm/min. The diameter of the nozzle and the electrode was 12 and 3 respectively.

The welding joints were then carefully observed with optical microscope. Tensile tests were carried out on INSTRON series IX auto material test machine at a cross head speed of 1mm/min.

IV. INFERENCE FROM EXPERIMENT

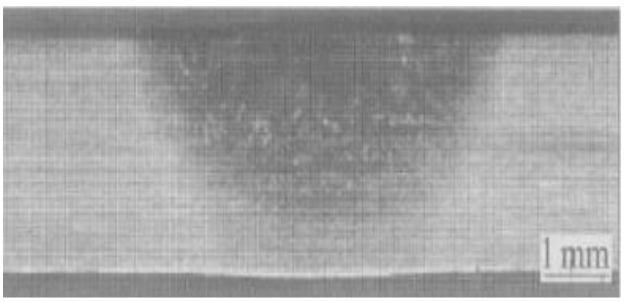
A. Physical Appearance of the Weld

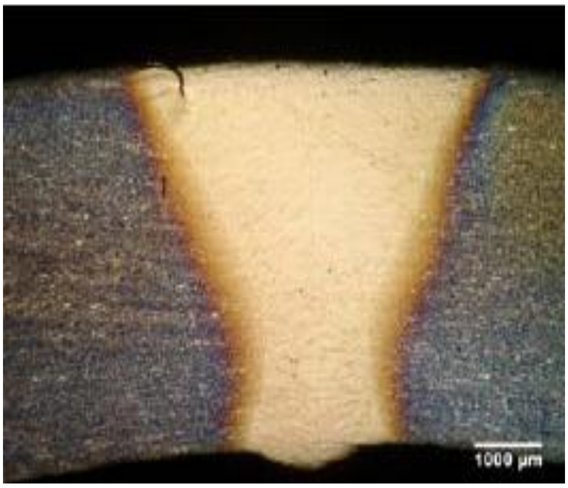
The surface of the weld joint was smooth and fine, when the current of the two torches was 80 A. The weld zones and the heat affected zone are well protected with no defects of deformation. Gas cavities and cracks were also reduced.

B. Macrostructure and Microstructure of welds

The experiments concluded that the two way arc welding was much superior to the convectional arc welding; since the amount of penetration was much more noticed in case of two way arc welding. The figure clearly depicts the arc weld joint in the case of two way arc welding. This not only increases the penetration but reduces heat input and saves energy.

In the case of microstructure of the base metal, the structure





Of heat affected zone was changed and the grains are fine for growing into equiaxed grains during the thermal cycles involving rapid heating and cooling.

C. Tensile Strength

The tensile strength tests were conducted on the work piece. Dimples and polygons contours were observed in fracture photos taken by SEM. Along with this uneven distribution of dimples were observed with clear overlaying of tear ridges. Cavities under dimples were also observed. The large size dimples were seen surrounded by some exiguous one. The coarse columned grains in the fusion zone were rapidly formed and thus leading in harmful elements concentrating of grain boundaries. This results in reduction of binding force of grain boundary and resisting force of fracture of titanium alloy. Thus it shows that the fracture mode of the titanium alloy weld joint is of mixed ductile and brittle characteristics because of dimple and contour faces of grains. But the dimples are the main appearances, thus the fracture is of ductile mode.

V. ARC CONCENTRATION

The arc behaviors for regular Plasma arc welding and TWO WAY ARC WELDING before and after the keyhole is established are very different. First, in comparison with regular plasma arc, the plasma arc in TWO WAY ARC WELDING becomes much more concentrated despite the use of similar welding parameters.

Second, after the weld joint is established, the plasma arc in two way arc welding is further concentrated while the regular plasma arc remains unchanged. During Two way arc welding, current has to flow from one torch to another through the work piece. If the current flows through the work piece instead of the joint, the electrons must exit from the work piece through the cathode on the GTAW side surface of the work piece to the GTAW electrode. Because of the large current needed for welding, the electrons tend to emit from the work piece from an area rather than a small spot. Hence, the work piece cathode is typically much less focused than the anode. As a result, the GTAW arc in DSAW is much broader than the plasma arc.

The trajectory of the electrons (current) in the plasma arc column is not affected by the work piece. However, for regular Plasma arc welding, the electrons have a nearly 90-deg transition in direction when they enter the work piece. To realize such a large transition in travel direction, the electrons must change their direction prior to “landing” on the work piece. The arc column in regular plasma arc welding, thus, must be subject to a divergence. Hence, the plasma arc in two way arc welding is much more concentrated than the regular plasma arc. The establishment of the keyhole further enhances the concentration of the plasma arc in two way arc welding. After the keyhole is established, the current may take the keyhole as the path. In this case, the current flows through the keyhole without being affected by the work piece cathode, the diameter of which is much larger than that of the keyhole. The plasma arc can thus be further concentrated. Hence, the density of the plasma arc is at least doubled after the keyhole is established. The GTAW arc is still broad after the keyhole is established. This indicates that; although the electrons can flow through the keyhole to minimize the voltage, part of them actually flows through the work piece, causing a cathode on the work piece. Therefore, during keyhole two way arcs welding, only part of the current goes through the keyhole. The rest of the current flows through the work piece

VI. CHARACTERISTICS OF WELD JOINT

The cross sections of double-sided arc welds are approximately symmetrical and hourglass shaped. Although detailed studies are needed to determine the effectiveness of this shape in thermal distortion and residual stress reduction, it is certain the thermal distortion and residual stress must be reduced.

A. GRAIN STRUCTURE

Generally, the solidification structure is controlled by the solidification parameters— the solidification growth rate R and the thermal gradient in the liquid GL. The ratio of the two parameters GL/R normally changes from a maximum value at the fusion boundary to a minimum along the center of the weld. These changing solidification conditions result in a weld solidification structure changing from planar at the weld boundary to columnar dendrite and then to equiaxed dendrite grain along the weld center. For TWO WAY ARC WELDING process, it was found the fraction and width of the fine equiaxed grain region gradually increases in the weld metal zone along with an increase in the depth of penetration. It is known that when the penetration increases, the amount of molten metal increases. Such an increase in the amount of molten material helps heat the work piece before cooling; hence, the thermal gradient during cooling is reduced. This tends to allow an increase in the amount of fine equiaxed grains produced.

VII. CONCLUSION

Double-sided arcing phenomenon and technique have been used to develop the keyhole TWO WAY ARC WELDING process. Observation and analysis show the through-thickness direction of the current and the establishment of the keyhole both plays significant roles in enhancing arc concentration. Experimental data and analysis suggest at least part of the current flows through the keyhole if the keyhole provides a minimum voltage path. The presence of the current in the keyhole generates an energy compensation not found in other arc welding processes. The keyhole TWO WAY ARC WELDING process has proven capable of achieving deep, narrow joint penetration on square-groove, thick stainless steel plates up to 1⁄2-in. in a single pass. Keyhole TWO WAY ARC WELDING reduces heat input into the work piece by at least 70% in comparison with regular keyhole PAW, which achieves the deepest and narrowest penetration at the least heat input of all existing arc welding processes. In other words, keyhole TWO WAY ARC WELDING requires only 30% of the heat input needed by keyhole PAW. Welds produced by keyhole TWO WAY ARC WELDING are less than 1 mm wider than those produced by the laser process. To penetrate the same thickness of stainless steel plates up to 1⁄2in. thick, the heat input into the work piece by the keyhole TWO WAY ARC WELDING process is approximate five times as much as that input by a high-power (approximately 10-kW)laser. Welds produced by keyhole TWO WAY ARC WELDING are approximately symmetrical and hour glass shaped. Keyhole TWO WAY ARC WELDING tends to increase the amount of the desirable equiaxed grains in the solidified welds. Detailed studies are needed to fully disclose the metallurgical implications and mechanical properties for keyhole TWO WAY ARC WELDING of different materials, including the impact of heat input reduction and symmetrical shape on thermal distortion and residual stress, and to quantitatively analyze the phenomena during double sided arcing and the keyhole two way arc welding process.

Through the experimental set up it can be concluded that the titanium alloy can be successfully welded by two way arc welding at appropriate welding parameters. The welded joint has good surface appearance without obvious deformation and defects of cracks and gas a\cavities.

The two way arc welding process is superior over the regular single side arc welding on the aspect of low heat n\input, decreasing the width and deformation of welds and refining grains. The joints can reach 96.14% tensile strength and 70.85% elongation of the base metal.

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Sambhav Jain is pursuing bachelor of technology in mechanical engineering fro m Jamia Millia Islamia, New Delhi. He has keen interest in manufacturing engineering processes.

Nisarg Shah is a student of mechanical engineering from babaria institute of technology, Gujarat. He has interests in manufacturing engineering.