WELDING OF NON-FERROUS METALS BY THE ARGON ARC AND ARGONAUT PROCESSES

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Abstract

The paper deals with the latest inert-gas arc method of welding of non-ferrous metals.

DURING recent years an unprecedented increase in the use of aluminium, magnesium and their alloys in all branches of the engineering field has emphasized the need for a welding process capable of producing sound defectless welds. In conventional methods of welding a highly reactive flux has to be employed to counteract the refractory oxides formed by atmospheric action during welding. Therefore, a time-consuming costly post-weld treatment has to be given to remove all traces of flux from the weld area to prevent corrosion. This, moreover, imposed limitations on the design of the joints.

Metals such as copper, nickel and their alloys like monel and chrome nickel have also become increasingly popular in recent years. To weld these, a process providing maximum heat concentration at the weld zone and minimum thermal disturbance of the rest of the plates is most desirable.

The argon arc process has provided a solution to both these problems. For, this process eliminates the use of flux and provides a heat source of sufficient intensity to concentrate the heat to a narrow zone. In this process an arc is struck between the work and a refractory electrode preferably tungsten. This forms the source of intense heat. The arc, the electrode and the weld area are shrouded from the injurious effects of atmospheric oxygen and nitrogen by a stream of inert argon gas passed through a nozzle-shaped shield surrounding the electrode. The function of this chemically inactive gas is to prevent the formation of oxides and harmful nitrides. The necessity for flux is, therefore, eliminated. A filler rod is added into the molten pool just as in gas welding.

Tungsten, having a m.p. of $>3350°C.$, is virtually non-consumable under good welding conditions. But some loss is inevitable due to gradual disintegration and faulty techniques. Chemically pure tungsten is preferred, although recent experiments have proved that the presence of thoria helps to keep the electrode cool when carrying large currents.

Any inert gas can be used as an inert shroud. But helium, neon, krypton and xenon are present in the atmosphere in very low concentrations. Therefore, in the U.K. and India argon is used. Argon is present in the atmosphere to an extent of 0·94 per cent by volume and is extracted by fractional evaporation of liquid air and purified. It is stored in cylinders at 130 atmospheres. A regulator is used to reduce this pressure to the working range and a flow meter indicates the rate of flow in cu.ft./hr.

In America, where helium is present to the extent of 2 per cent in the natural crude gas wells, it is cheaper to use helium, and they call this process Heliarc. Argon, however, has certain advantages such as higher density, lower excitation and ionization voltages which make its use more economical and more stable with A.C. equipment.

A.C. or D.C. can be used with argon arc equipment depending on the material to be welded. D.C. is unsuitable for aluminium, magnesium and their alloys. These light alloys have an oxide film which gets disrupted only if the electrode is connected to the positive pole. Welds made with negative polarity are contaminated with oxides and are poor in quality. But when positive polarity is used, two-thirds of the heat is generated at the electrode and the small mass of electrode material gets rapidly overheated. The plates to be welded do not fuse properly due to lack of heat, while the electrode melts and falls off contaminating the weld. However, copper, nickel and other metals which have no refractory oxides to interfere with welding can be welded most satisfactorily with D.C., the electrode being connected to the negative pole. With such polarity the same size of electrode can carry four times the current with positive polarity without overheating.

Therefore, A.C. was tried for welding light alloys. However, it was found that current got rectified due to the action of the arc operating between dissimilar metals. The essential positive half cycles got suppressed, current flowing only during the negative half. The oxides got disrupted due to the purging action of the positive half cycles and hence welds were found to be contaminated and unsatisfactory, similar to the ones obtained with D.C. negative polarity. Also, due to the D.C. component formed, huge stresses developed between the coils of the transformer which got damaged. This phenomenon limits the use of transformers to 150 amps. for welding copper, nickel and their alloys. Thicknesses over $\frac{1}{8}$ in., therefore, have to be welded with D.C.

In order to get rid of this current rectification the standard method followed is to incorporate in series with the welding current a bank of electrolytic condensers of very large capacitance. Condensers offer high impedance to D.C. but very low impedance to A.C., thereby effectively suppressing the D.C. component. This bank of condensers is called the D.C. suppressor unit.

Another equipment needed for argon arc welding is a high-frequency unit. Tungsten gets contaminated if the arc is started in the normal way by contact. In order to establish the arc at a distance of about $\frac{1}{4}$ in. from the plate, a high-frequency high-voltage current is superimposed. A simple oscillating circuit of the spark gap type is used to step up the frequency to about 500 kc/s to 3 mc/s and pressure of about 3000 V. are used to start the arc. The H.F. currents are safe even at this voltage due to the skin effect and jump across the gap before the electrode makes contact, ionizing the atmosphere and establishing the low-voltage welding current.

Thus, for welding aluminium, magnesium and their alloys, a transformer, a D.C. suppressor and a H.F. unit are needed, besides a source of argon and the torch. A static cored transformer with an open circuit voltage of 100 is suitable for this purpose. Alternatively, a composite power unit which is a compact and portable machine incorporating all these devices can be used.

For welding copper, nickel and their alloys, on the other hand, a D.C. power source is necessary. A motor generator set having a minimum open circuit voltage of 55 is ideal for this purpose. Negative polarity should be used. A H.F. unit to start the arc is also necessary.

Butt, fillet and corner welds are possible. Vertical welding can be done with a little practice. Correct preparation and cleanliness of the joints are important factors to ensure satisfactory welds. Bevelling the edges is recommended for all materials of over $\frac{3}{16}$ in. thickness.

The argon flow required varies according to the material, thickness and the type of joint. Aluminium and magnesium and their alloys require much higher flows than copper and nickel. Thicker sections and outside corner welds require larger flows as these are more exposed.

This process lends itself admirably to mechanization. Fully automatic or semi-automatic machines can be designed to suit individual requirements. Cost of welding can be cut down to a very low level by machine welding as very much higher speeds can be achieved for the same flow of argon.

Various types of torches are available of which the British Oxygen Company's Water-Cooled Mark III designed to carry a continuous current of 300 amp. is the most popular in this country. It can be used to weld up to ½ in. thick aluminium and is supplied with different sizes of electrodes and shields to suit different thicknesses. A master valve is also supplied to economize the costly argon.

The purity of argon plays an important part in this process particularly in welding aluminium and magnesium and their alloys. A minimum purity of 99·6 per cent is necessary for aluminium and 99·9 per cent for alloys containing more than 2·5 per cent Mg. Argon is available in two purities, the AA and the LS, the former being not less than 99·8 per cent and the latter not less than 99·9 per cent.

Magnesium, aluminium and their alloys can be welded easily using filler rods of the same composition as the parent metal. A.C. with a D.C. suppressor is employed.

Deoxidized copper can be welded with Everdur wire. The concentrated heat of the arc ensures very high welding speeds. D.C. with negative polarity is used. Filler rods of pure copper or copper-silver alloy are not satisfactory as they give rise to pinhole porosity. Everdur is the best filler rod where a colour match is not desired and resistance to corrosion is not of primary importance. Commercial copper presents the same difficulty as in gas welding.

Nickel and their alloys can be welded using D.C. negative polarity and similar welding rods, while lead can be welded at very high speeds under the same conditions. Speeds of 100 in./min. have been obtained on 6 lb./sq. ft. lead.

Brasses containing less than 30 per cent zinc can be welded easily. If the zinc content is more, it tends to fume. Standard brass rods give better welds than silicon bronze rods. D.C. negative polarity is preferred.

Although relatively a new process, because of its versatility, this process has been commercially adopted by a number of industries in the U.K., the U.S.A. and India. The chemical industry is likely to be one of its principal users for welding corrosion and heat-resisting alloys. Aluminium bodies for vehicles, fuel tanks and assemblies and heat-resisting exhaust manifolds and jet engine components of aircrafts, copper components in the textile industry are a few of the items that have been welded by this process. Before I conclude this short sketch on argon arc welding, I shall briefly summarize its advantages.

1. This is the only process available for welding of aluminium and magnesium without flux. So no cleaning operations are needed after welding. Designers can choose any type of joint without fear of flux entrapment.
2. Localized heat reduces distortion to a minimum and higher welding speeds reduce risk of cracking.
3. Edge preparation is simple and in most cases involves only cleaning.
4. Penetration is consistent, beads are bright and uniform.
5. There are no operational hazards, the normal protective clothing, gloves and dark glasses being sufficient. No fumes or obnoxious gases are evolved.

The argonaut welding process uses a consumable electrode instead of a tungsten electrode. An electrode of the same composition as the parent metal is fed in through a contact nozzle surrounded by argon. The rate of feed and the current are so adjusted that the burn-off rate obtained just balances the feed-in rate. Thus a steady arc is obtained. The electrode, as in metallic arc welding, fuses with the parent metal resulting in a homogeneous weld.

The outstanding features of this process are: (1) the high current densities used and hence the high welding speeds obtained; (2) the self-adjusting phenomenon of the arc resulting in uniform penetration and ease of operation; and (3) the stiff arc obtained enabling overhead and vertical welding to be done with absolute control of the weld metal.

Metal transfer in the metallic arc, especially in the vertical and overhead position, is a controversial subject. Gravity acts against metal transfer from the electrode to the plate, especially in the overhead position. Of all the theories put forward to explain this phenomenon, the one most accepted is the theory of expanding gases and surface tension. Dissolved gases in the electrode bubble up, expand and explode, and a spray of fine particles is projected on to the molten pool. The surface tension of the pool comes into play as soon as these particles touch the surface which retain them. The theory which was discredited was the theory of pinch effect.

The theory of pinch effect says that forces are set up in a conductor carrying current due to electro-magnetic effects, which tend to contract the conductor under a radial pressure. The axial force on the cross-section due to this hydrostatic pressure is $I^2/200$ dynes where I is the current density expressed in amp. per square inch. This force constricts the molten drop until it is severed. This theory was rejected because the force $I^2/200$ dynes was not sufficient to cause metal transfer of small particles at velocities such as 30 ft. per sec. met with in the metallic arc where I is small. But it is easily evident that since the force increases by the square of the current for high current densities, this force due to pinch effect becomes enormous.

It was found that the critical current for $\frac{1}{16}$ in. aluminium was about 145 amp. which is equivalent to 50,000 amp./sq. in. At 120 amp. large droplets were present and fell off at the rate of 3·8 per sec. At 140 amp. the droplets changed abruptly and began to travel at the rate of 34 per sec. At 160 amp. the rate became 49 per sec. and became invisible. The metal transfer took place as a fine spray. This is due to the enormous forces developed at these high current densities on account of pinch effect.

Moreover, it was found that the arc became stiff, that is metal transfer took place in the direction in which the electrode was pointed. Therefore, it could be directed vertically overhead with ease.

The argonaut process has not only a stiff arc but also a self-adjusting arc. The latter phenomenon is due to the drooping characteristics of the motor generator set used.

Since the aim in argonaut welding is to introduce high current densities to get optimum results, D.C. with positive polarity should be used. The positive polarity not only helps to disrupt the oxides but also increases the burn-off rate considerably as two-thirds of the heat is generated at the positive pole. In order to make the argonaut process self-adjusting, this D.C. source should have a drooping characteristic, that is the O.C.V., which is about 70, should fall smoothly to the arc voltage of 25 or 28 immediately the arc is struck.

When the operator withdraws the electrode which is connected to such a D.C. source, he increases the arc length and hence the arc voltage, thereby decreasing the current immediately. As the current decreases, the burn-off rate decreases. Since the rod feed motor is feeding the wire at a constant preset value, this reduced burn-off rate results in lengthening of the electrode from the contact nozzle. The electrode protrudes until the arc length becomes the same as before, and current, and so the burn-off rate, reaches the original value. Should the operator decrease the arc length, the reverse takes place. The arc voltage decreases, the current and burn-off rates increase and the electrode burns back into the nozzle till the original arc length is established. Thus, within certain limits, the arc becomes self-adjusting. The importance of the characteristics of the D.C. source is, therefore, evident.

The Indian Oxygen & Acetylene Company supply the CDR425 rectifier set or the MGH 425 motor generator set as the D.C. power source for this process. Mounted on it are the driving unit for the electrode and the contactor. The wire is fed off a wire reel magazine by a pair of feed rolls driven by a governor controlled motor into a large flexible tube. At the end of this tube our argonaut type 3E gun is attached. Argon is fed off into the flexible tube and passes through a nozzle surrounding the wire in the gun. Current is fed into the gun by a separate cable. Immediately the trigger on the gun is pressed, the argon starts flowing, the rod starts feeding and the current is switched on. The arc is struck and the operator takes the gun forward at welding speeds. The arc is fierce and the molten metal is projected as a fine spray. The rod feed is adjustable to the current setting by referring to a chart attached to the machine corresponding to the current and the diameter of wire used. Roughly for $\frac{1}{16}$ in. aluminium, the speed of feed in in./min. is equal to the current in amp., that is 200 in./min. for 200 amp. setting and so on.

Aluminium and alloys can be welded in all positions readily. It is extremely easy to make a perfect vertical or overhead weld on aluminium. Deoxidized copper can be welded with Everdur wire. But pure copper wire is likely to give rise to porosity. Aluminium bronze can be welded with similar welding wires. This process can be used to weld any thickness above $\frac{1}{8}$ in. Thinner sections and the first pass of thicker gauges require a backing bar of copper.

Besides the advantages mentioned, a high transfer efficiency of 99 per cent can be obtained with this process. Comparatively metallic arc can give only a transfer efficiency of 67 per cent. The balance is lost as flux, stub ends and spatter. Moreover, no losses take place in the alloying elements due to oxidation, even 60 per cent of titanium being transferred intact when welding stabilized stainless steels.

I am aware that within the short time allocated to me, I have not been able to do justice to the subject. Should, however, anyone require further information regarding the processes, the Indian Oxygen & Acetylene Co. Ltd. will be pleased to give him all possible help.