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Review of Developments in arc welding of metals by gas mixtures

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Abstract:
In this review paper we review the developments in the technology of electrical arc welding methods of metals via different types of gas mixtures. The paper is divided into four sections based on process inputs, outputs, control systems and diverse advances in the GMAW process. Section 1 describes advances in powersources,wireelectrodetypes,wirefeedingandshieldinggases.Section 2includes a review of process analysis, sensing, monitoring and control.Section 3 reviews miscellaneousGMAW-relatedimprovedprocessessuchashybridlaser-GMAW, tandem GMAW welding, narrow groove GMAW welding.

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I. INTRODUCTION

The arc welding industry is one of the most ancient industries . However it has been improving both rapidly and increasingly . this caused the creation of more job opportunities in the field of the arcwelding industry for the professional arc welders and arc investigators. Even with the economical fluctuations , the arc welding industry has proved it self in the industrial markets . this was a result for the growth of the request for the products created by using the arc welding .the industrial markets always needs labors for all kinds of arc welding industries , starting from small local shops to huge production factories .

Welding is the most important and the favorite way to join metals to each other permanently and it is also a unique way to fusion of two or more than to pieces to be like one piece .

We can notice that the welding industry represent a very god percentage of the economy of most industrialized countries , furthermore the half of the economy of the USA relies on different kinds of welding process specially the various metal industries.

There are a variety of ways of arc welding technique , some of welding technique creates spark and other don’t require over – heating . Welding processes can be done anywhere . It can be operated outdoors , indoor . under water and even in the space in order to build station or to maintain space ships .

II. ADVANCES IN GMAW TECHNOLOGIES:

1.1 Power mains

Usually, the electrical power supplies used in arc welding are Direct Current. The DC voltage and current are controllable via the rate of wire feeding of the electrodes. Figure 1 depicts the welding system.

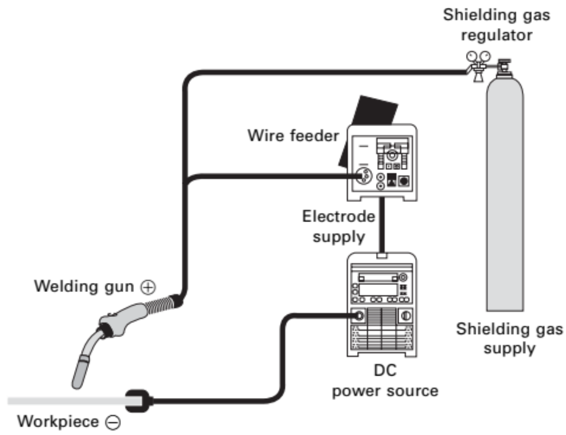

Figure 1. System for GMAW with its main parts.

To improve the efficiency of the power transformer, high frequency AC current is used instead of the DC; this reduces the dimensions of the iron core of the transformer and hence the losses are minimized. With the new digital technologies, more control options could be achieved: remote programmable control capabilities and hence the parameters of the welding processes could be adjusted remotely.

1.2 Feed wires

Traditional wire feeding techniques suffer from major drawbacks, like friction forces between the wires. This force increases dramatically when bents are encountered (Padilla *et al*., 2003). To reduce the friction force, a push–pull torch is used as depicted in figure 2. It should be pointed out that we may use some reduced-size spools attached to the welding torch as shown on figure 3, (Nadzam,2003).

Figure 2. A traditional welding system that incorporate an additive feed wire motor in the handle.

Figure 3. Reduced-size wire spools attached to the welding system.

According to these modifications, the radiated heat energy from the welding arc are concentrated in the contact tip as

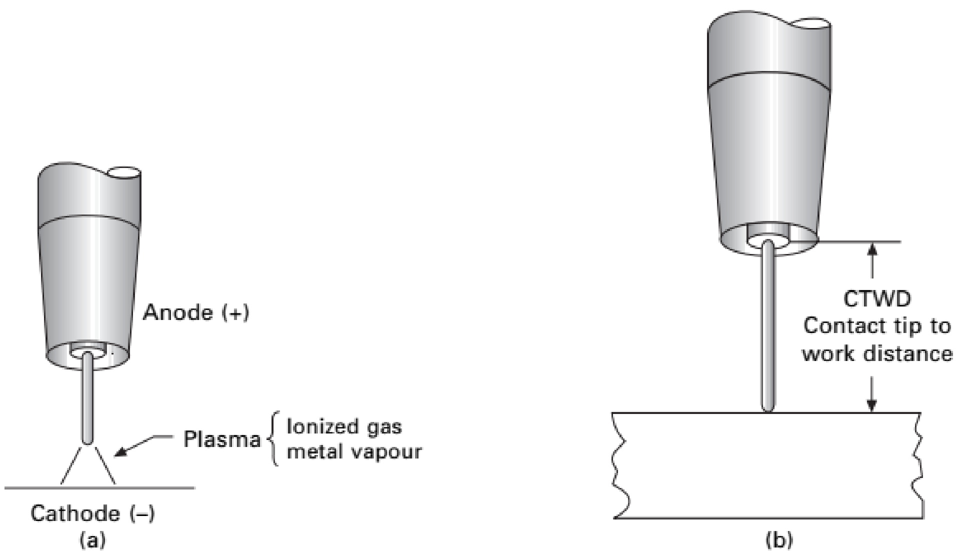

Figure 4. Plasma flow near the tip of the wire electrode (a) and the distance between the contact tip to work object (b).

pointed out by (Adam *et al*., 2001).Thus, the contact tip to work distance in figure 4 has the crucial effect on the overheating of the tip. This emphasizes that the heat radiated from the tip represent the major source of radiated heat energy.

1.3 Configuration of the electrodes

The old-style cylindrical wires are recently replaced by hollow tubular wires with inner core containing flux, thus flexible choices for welding materials. The metallic core is suitable for high usage steels yielding efficient strengthening. On the other hand, wires with large diameters up to almost 3 mm are usable for metal depositing at high rates as mentioned in (Himmelbauer, 2003).

While metallic strips of 0.5 x 4.5 mm rectangular cross-section have a major advantage for higherwirefeedspeedsupto11m/min, thus highdeposition rates are easily achieved as depicted in figure 5.

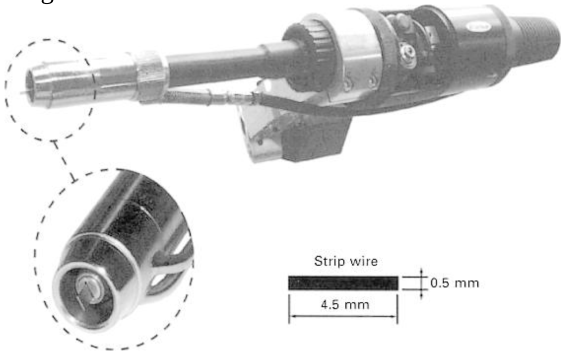

Figure 5. Strip wires of rectangular cross-section in a feeding system.

Generally, strip wires are more appropriate for surface welding.

1.4 GasShielding

There are tow main types of shielding using gases: either by inert gases or by active and reactive types. Standards in Europe use two or three types of mixing gases to optimize the chemical strength of the ionization voltage and the thermal conductivity as emphasized in (Vaidya,2001;Zavodny,2001).

It is worthwhile to note that thesetailored gas mixers should be used cautiously, when Argon and carbon dioxide are mixed in weldingstainless steels, because carbon pickup can occur as pointed out in (Kotecki, 2001).

III. MEASUREMENTANDCONTROL IN GAS WELDING

Thissectionincludesareviewofrecentadvancesin(Gas Metal Arc Welding) GMAWprocessanalysis. Topics include process sensing/monitoring, control, modelling, automation and robotics, droplet transfer modes and fume and spattercontrol.

Droplet transfer modes

One of the major topics in GMAW process analysis has been the molten metal droplet detachment and transfer modes. For given ranges of wire electrodediameter,weldingcurrentandshieldinggas,five modesofdetachment havebeenrecognized(Nadzam,2003):(1)short-circuit,(2)globular,(3)axial spray, (4) pulsed-spray and (5) surface-tension transfer modes (Fig. 6) (Nadzam,2003).

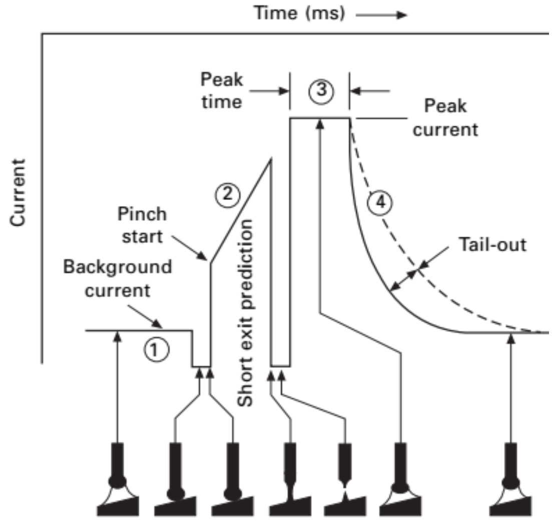

Figure 6. Schematic representation of the surface tension-controlleddroplet transfer mode (STT).

The forces governing the dynamic equilibrium during droplet detachment have been identified. They are: (a) electromagnetic forces associated with theweldingcurrentself-inducedmagneticfield,(b)gravity,(c)surfacetension and (d) cathodic jet forces(Lancaster,1984). Lately, variablepolarity(VP-GMAW)hasbeenshowntobeeffectivealsoincontrollingmetaltransfer and meltingrate.Traditionally, using a CV power source with inductance control proved to be excessively sensitive to arc length variations, responding with large wire speed and current responses. Therefore, feed-forward controls – also known as digital or reactive controls – have been introduced where the current can be modified independently from the wire speed. Advances in process control have been made especially using feed-forward algorithms, as demonstrated bytheirexcellentadaptabilitytostepresponseswhencomparedtothetraditional feed-back control (Adolfsson, 1999). Process control can also be very different in aluminum(AL) alloys when compared to that in steel. For the same wire electrode extension, the Al GMAW was found to be up to 28 times more sensitive to variations in wire feed speed than the mild steel electrode (Quinn, 2002). Because of the higher electrical and thermal conductivity of Al compared to steel, conductive heat transfer dominates the dynamic equilibrium between burn-off and feed rate, compared to convection and resistive heating in steels. For instance, thevoltage drop across the same electrode extension length was one order of magnitude less in Al than it was steels (0.03 V compared to 0.3 V). In most cases, the GMAW process responds in aluminum more dramatically to perturbations in welding current or wire speed setpoints.

IV. GMAWHYBRIDPROCESSESANDOTHE RDEVELOPMENTS

This combination of high penetration laser beam welding (LBW) and good gap bridge ability(GMAW) processes builds on the intelligent combination of the advantages of each process. The resulting welds (Staufer*et al*., 2003) can be made at high speeds, have good penetration and are less sensitive to gapvariations.TheGMAWarcstabilityanddroplettransferarealsoimproved by the intense metal vaporisation caused by LBW. Apparently, the greater amount of ionised metal and electrons in the LBW plasma reduces the need for high ionisation potential and exceeding the electrode work function in the GMAW arc thus provides better arc stability. Disadvantages include: highcapitalcostandtheneedforautomationandprecisebeam/arcalignment. Typical GMAW/LBW heads are expensive and complex, as shown in Fig. 7.

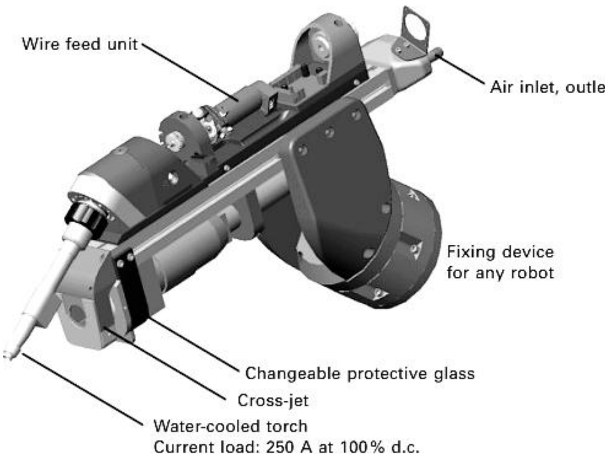

Figure 7. Schematic representation of a laser beam welding/GMAWhybrid welding head.

Using low-melting point electrode wire consumables such as Cu-Si, Cu-Ag, Cu-Al alloys allow for low current GMAW-P deposition without melting of the base metal (i.e. electric brazing). This significant development reduces the width of HAZs and damage to Zn coatings in the automotive sheet and produces minimal distortions (Himmelbauer, 2003). The roof panel joint does not require any post weld processing. Additionally, arc-brazing is also beingaccomplishedusingtraditionalandSTTformsofGMAW-S.GMAWwith a CuAlwireelectrodealsomakespossiblejoiningofdissimilarmaterials with very different melting points such as steel andaluminium.

One disadvantage of GMAW brazing is the low joint strength that can be compensated by using lap joint design. Additional problems have been associated with zinc pickup in the silicon bronze weld and the result is transversecrackingofthewelddeposit.Thisoccursinwel dsofthosemembers where there is a gap. The gap, via capillary action picks up zinc from both surfacesoftheplatedbasematerial.Finally,thepresence ofCuintherecycled car bodies lowers the quality of the scrap and increases cost because of the difficulty of removing Cu which is very detrimental in steel making (solidification crackingsusceptibility).

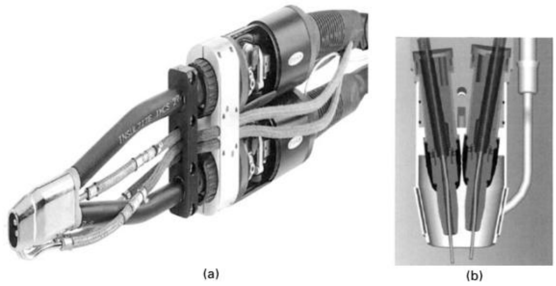

Figure 8. Tandem GMAW torch view (a) and cross-section(b).

As the name implies, two wire electrodes are used in tandem to produce welds. The two wire electrodes are insulated from each other in tandem welding,thusthedroplettransfermodecanbeadjusted independently, in contrast to double-wire welding. Typically, one electrode can work in continuous arc (synergic CV or synergic CC) and the other in pulsed arc mode (also known as 'master' and 'slave' wires or 'lead' and 'trail' wire). Accordingly, the modified process allows for great flexibility, increased travel speed, higher deposition rates, as well as lower spatter. Disadvantages include equipment complexity, as well as the need for automation. Seam tracking may or may not be required (Fig. 8).

The systememploystwopowersources,twowiredrives,anda control.Itisadapted for either repetitive side-beam type applications or is employed with a welding robot.This variant of the gas metal arc welding process is capable of higher travel speeds, 1.5–2.0 times the speed of a single electrode. Some travel speeds may exceed150 in/min (3.81m/min). Deposition rates of42 pounds/h (19.1 kg/h) are achievable for heavier plate welding (Nadzam, 2003).

The modes of metal transfer used for the tandem GMAW are axial spray metal transfer or pulsed spray metal transfer. The combinations of the modes that are popularly employed include:

- Spray + pulse: Axial spray transfer on the lead arc followed by pulsed spray transfer on the trailarc.
- Pulse+pulse:Pulsedspraytransferonboththeleada ndthetrailarc.
- Spray+spray:Axialspraytransferonboththeleadan dthetrailarc.

Thehigherenergyspray+sprayconfigurationi susedforspecialheavyplate welding where deeper penetration is required. Pulse + pulse allows for heavy welding or high-speed sheet metalwelding.

Central to the successful operation of tandem GMAW is proper understanding of the set-up of the special tandem GMAW welding torch. In most cases, the central axis of the torch should be normal to the weld joint. The lead arc has a built in 6 degree lagging electrode angle, and the trail has a built in 6-degree leading electrode angle.

The contact tip to work distance (CTWD) for higher speed sheet metal type applications should be set at 0.625 in (16 mm). The electrode spacing is critical and the shorter CTWD establishes the correct spacing. When the CTWD is held at this position the two arcs become more distinct from one another and shorter arc lengths are used to provide higher travel speeds. Use of tandem GMAW for heavy plate fabrication requires a longer CTWD,1.0 in (25.4 mm). The longer CTWD provides the correct spacing between thetwoarcs,andinthisscenario,thearcstendtomovevery closelytogether. When held at the longer CTWD the arcs lend themselves for use with much higher wire feedspeeds.

Narrow groove GMAWwelding

An excellent application of GMAW is for low heat input welding of thick plate, the resulting welds have often been plagued by occasional lack of sidewall fusion. Wire electrode bending and rotating (twisted wire) have been used in the past to overcome this problem. Korean researchers used electromagnetic arc oscillation to alleviate the same problem in the narrow groove (Khang and Na, 2003).

Futuretrends

The following trends can be anticipated in GMA welding within the next five years. The following areas areimportant:

(1) process simulation andmodelling,
(2) sensing andcontrol,
(3) cost reductionand
(4) newapplications.

- Improvedcomputer*simulations*oftheweldingproc essandimplementation in productionwelding;
- Improved *sensing* and signal acquisition before, during and after welding and inclusion in a comprehensive control system. This effort will

require increased sensitivity to downstream manufacturing practices to improve partfit-up;

- Improved power source technology via digital controls andimprovedcontrol of the welding arcs;
- *Applications*: extension of the process to reduced base metal thickness andhigherdepositionrates.Evenfurtherminiaturization(orMEMS:micro- electro-mechanical systems) can be expected to penetrate the GMAW equipmentworld;
- *Automation*: remote operation (depths, heights, hazardousenvironments);
- In semi-automatic applications: integration of all essential functions in the weldingtorch;
- Deposition rates and cost reductions – more hybrid and newprocessvariants, lower cost filler wires and shielding gases (push toward self-shielded fluxed core arc welding;
- *Controls*: digital networks,qualifications.

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