Shielding gas: the GMAW solution optimiser

***African Fusion* talks to Afrox's Johann Pieterse and Arnold Meyer about shielding gas choices: the ultimate differentiator when optimising gas metal arc (GMAW) and flux-cored arc welding (FCAW) processes using Afrox's 360° welding solutions service.**

Afrox's 360° welding solutions offering, according to Pieterse, is about identifying challenges in industry and packaging whole solutions so as to optimally resolve them. "An optimised solution offers quality, productivity, reduced costs and the safest environment possible," he says.

"With respect to welding applications solutions involving shielding gases – GMAW, FCAW and GTAW, for example, there are numerous aspects and parameters that have to be optimised to best suit the application: consumable wires; welding processes; machine choices; machine settings; welding technique; and, most importantly, the skill and careful attention of the welder," he continues.

"All these must be carefully chosen and controlled in order to achieve the best possible outcome and our 360° applications solutions focus on optimising all these interconnected aspects," Pieterse explains.

"Consumable suppliers talk about their wire and coating quality as a differentiator. We simply say a quality wire is absolutely essential. A bad quality wire with an inconsistent thickness and coating will change the resistance continually, which means the current, burn-off rate and voltage are inconsistent making it very hard for a welder to produce a quality outcome," he argues.

"But there are many quality wire options that offer equally consistent weldability and ASME-accredited metallurgy. In addition, there are many good welding machines, which we know how to set up to give optimal performance.

"We often find, however, that the shielding gas choice is assumed to be unimportant. We can routinely demonstrate to people that by optimising the shielding gas mix to match the welding application, the shielding gas becomes the difference between a problematic welding application and a fully optimised solution," Pieterse tells *African Fusion*.

The effects of shielding gas constituents

At the starting point of many GMAW/FCAW gas-shielding mixtures is pure argon, which promotes spray transfer and deep penetration. "However, the penetration profile of pure argon is very narrow, which can lead to a lack of side wall fusion if the weld is not very accurately placed," says Meyer.

"The reason for this is that argon has a relatively low ionisation potential and low heat conductivity, which tend to concentrate the arc and its associated heat down a narrow column in the centre of the arc. This gives the arc its characteristic 'needle' penetration profile," he tells *African Fusion*.

In spite of this, arc striking is very easy and argon promotes open-arc spray transfer at relatively low current levels, which promotes a stable arc with low spatter levels and high deposition rates. "But the narrow penetration and fusion zone makes it unsuitable in applications where penetration and sidewall fusion have to be balanced. That is why we have developed mixed gases, which are used to modify the width of the arc column and the shape of the penetration zone," he says.

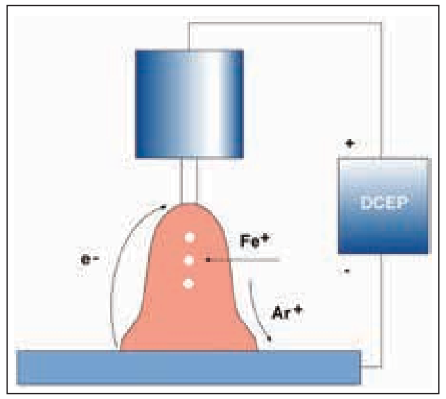
The most common additional constituent is carbon dioxide (CO_2), which is relatively cheap. CO_2 dissociates inside the arc to give carbon monoxide (CO) and oxygen (O_2). These give a more even distribution of heat inside the arc and a lower differential between the core arc temperature and the periphery of the arc. The net effect on the weld is a lower depth of penetration but a wider and larger fusion zone with a broader weld bead, all of which can help to overcome sidewall fusion problems.

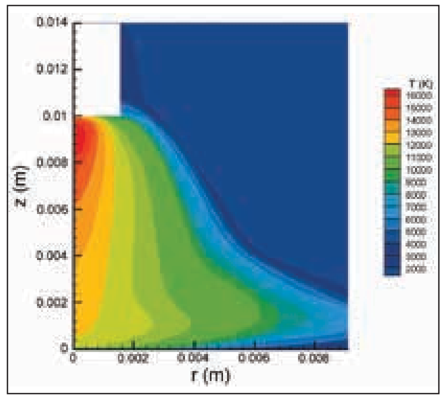
Meyer says there are other gas constituents that can also even out the arc temperature distribution and broaden the fusion zone. These include hydrogen, oxygen and helium. "Metallurgical factors often drive this choice. When welding carbon steels, for example, the inclusion of hydrogen may cause cold- or hydrogen cracking, but if welding a low-carbon austenitic stainless steel, small percentages of hydrogen in an argon gas mix are ideal for this purpose and, because hydrogen is a reducing agent, it produces a clean weld metal and a bright surface finish," he says.

With respect to CO_2, he says that the carbon in CO_2 is undesirable when welding stainless steels. "Carbon in stainless steel weld metal or the heat-affected zone will react with chromium to form carbides. This depletes the amount of chromium available to form the protective chromium rich oxide film on the metal surface and pitting corrosion may occur in these areas," Meyer explains, adding that this phenomenon is known as sensitisation. Most shielding gas mixtures for welding stainless steel, therefore, use oxygen to spread the arc instead, which evens the temperature profile without raising the net heat energy in the arc by much, Meyer notes.

When welding carbon steels, CO_2 in a gas mix can also add unwanted carbon. This tends to increase the strength of the weld metal while reducing its toughness – and this also applies to the heat-affected zone, since carbon from the gas can quickly diffuse into solid metal at these temperatures.

"So, where Charpy impact toughness is critical, you may need to reduce the CO_2 content and use an argon/helium or argon/oxygen mix, for example, suggests Meyer.





Plasma is an ionised (electrically charged) state of the gas and consists of neutral and charged gaseous atoms, electrons and ions; molten metals; slags; and vapour.

Marangoni effect

Since surface tension is generally lower where the temperature is hotter, the temperature gradient from the edge of the fusion zone to the centre causes metal to flow in the weld pool towards the hotter liquid in the centre, that is, from the sides towards the centre. This is called Marangoni flow. "When using pure argon, this amplifies the 'needle' fusion profile. Mixing in an arc spreading gas, however, significantly reduces the temperature and surface tension gradients, which reduces Marangoni flow to give an even penetration and fusion profile," Meyer explains.

A gas for every application

If putting a root into a thick-walled pipe with a gap, penetration and sidewall fusion are both essential, it is not advisable to use pure argon shielding gas. Depending on the weld preparation, a shielding gas with relatively large percentages of CO_2, O_2 or both are commonly used to ensure sidewall fusion.

Thick plate produces a heat-sinking effect, which lowers the energy available for fusion. So, for carbon steel welding, for example, the highest possible percentages of CO_2 and/or O_2 will give the best results. "And on even thicker plate, preheat in the area around the weld to compensate for heat sinking may also need to be applied," Meyer explains.

Turning attention to thinner plate, he says if the arc is too hot on the sides of the weld, distortion or burn through may result, so lower percentages of the 'hotter' additives are necessary, typically in the region of 5.0 to 10% of the total.

"For anyone who works across a wide thickness range, we suggest using different shielding gas mixtures for each thickness range. It is very seldom that the same shielding gas mixture will be best suited to both 5.0 and 50 mm plate thicknesses," he says.

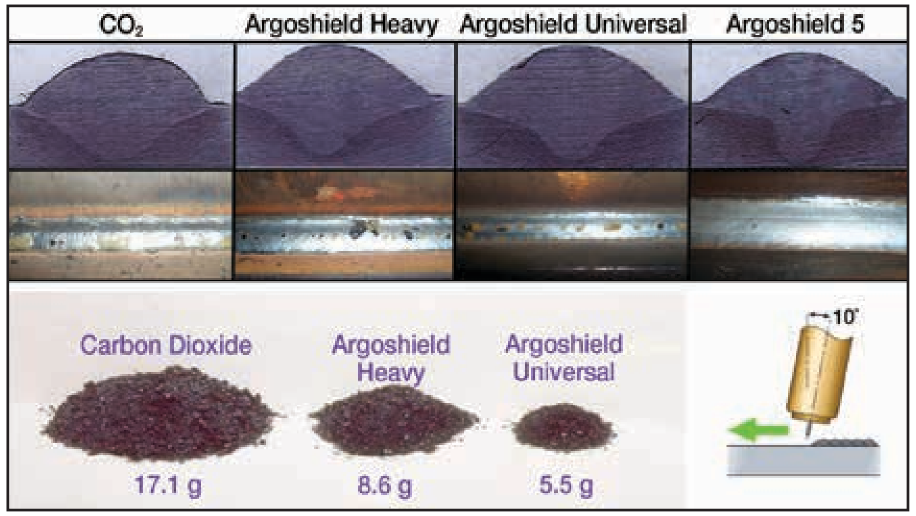
Limiting the amount of CO_2 that can be added to an argon gas mixture, however, is the spray transition current. "With argon/CO_2 gas mixtures, it becomes difficult to get into spray transfer deposition mode at typical welding currents – and at 30% CO_2 or above, the current levels required to spray GMAW wires are unattainably high," Meyer explains, adding that, because flux-cored wires conduct current via thin-sheathed walls at higher current densities, they have a higher tolerance to CO_2 with respect to spray transfer.

"It is very important that all aspects of the welding applications are considered in arriving at a 360° solution," Pieterse reiterates. "The gas mix cannot fix welding technique, machine set up or poor wire quality problems.

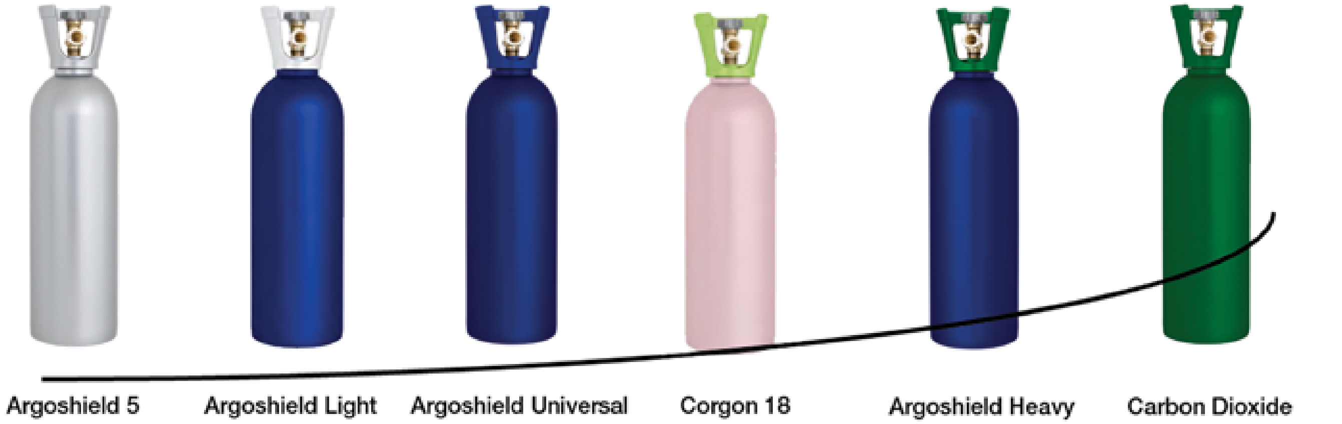
"For GMAW and FCAW, though, where properly developed procedures are being used by properly trained welders using quality machines and consumables, the shielding gas is the differentiator," he says.

"On changing the process to GMAW and optimising the shielding gas used, we have achieved 70% cost savings along with much higher productivity and better weld quality from a 360° intervention," Pieterse reveals.

"Even when optimising existing GMAW processes, we regularly see 10% to 20% savings by optimising the parameters around best-suited shielding gas," concludes Meyer.



A comparison of the results with respect to fusion, weld bead profile and spatter that can be expected from common shielding gases with decreasing CO_2 levels.



The Linde and Afrox shielding gas ranges are suitable across the thickness range. "It is very seldom that the same shielding gas mixture will be best suited to both 5.0 and 50 mm plate thicknesses," says Afrox's Arnold Meyer.