

Gas shielding critical for duplex welds

African Fusion talks to Rob Lawrence (right), Air Liquide's group international expert, about the important role of shielding gases when welding high-value materials such as duplex stainless steel.



According to Lawrence, people often call on their shielding gas supplier to complain about porosity at the beginning of the weld. "When you pull the trigger on a GMAW welding torch, three things happen. The gas starts to flow, the power comes on and the wire starts to feed. On a well-designed welding machine, the gas should come on first, because as soon as the wire touches the plate the protective atmosphere has to be in place. If it is not, then the weld start will immediately be attacked by the oxygen and nitrogen in the atmosphere, which results in porosity at the start of the weld," he says. "So instead of finding fault with the shielding gas mixture, welders should look at pre- and post-weld gas purging if they want to avoid such problems," he suggests.

"For TIG welding, the problem is more complex, if you strike a TIG arc before the gas shield has been established, then the electrode immediately overheats and is attacked, blackened and contaminated by the oxygen in the atmosphere. As welding progresses, the contaminated electrode then transfers these contaminants to the weld metal, so you end up with discontinuances along the length of the weld bead. Also, at the end of a TIG weld, the gas should run for a further 10 seconds to cool the tungsten electrode. If the electrode remains red-hot for any time in an unshielded environment, it will become contaminated," Lawrence warns, adding that, while modern welding equipment is likely to incorporate pre- and post-weld purging features, older machines do not always have these features, so high quality welding on expensive materials becomes difficult.

"Often we are told that the welding is fine for a while, then it becomes full of porosity, which disappears again. Shielding gases aren't made in layers and any shielding gas contamination will be evident all the time. Intermittent porosity is more probably caused by a gas solenoid problem on the wire feeder. If the voltage signal drops across a gas solenoid, it can begin to 'chatter'. The solution is to repair the wire feeder or its solenoid, yet the fault is attributed to the gas. Most available shielding gases in South Africa are manufactured to ISO 14175 specifications, so the shielding gas composition, assuming the correct gas is being used, is the least likely cause of porosity in

welding," Lawrence explains.

Describing a commonly held myth about shielding gas leaks, he says that welders believe they can compensate for a leak by increasing the shielding gas flow rate. The logic is that the gas is leaking out, so as long as enough gas is flowing through the shroud of the torch, the weld should be adequately shielded. "But this is wrong! If gas is leaking out, then air is always being sucked in at the same time. So any leak will cause porosity problems, and by turning the gas flow up, you make the problem worse, because you are drawing more air into the shielding gas line," he warns.

Turning attention to shielding gases for high value material such as stainless steel and duplex stainless steel, Lawrence advises that, since these materials are often very expensive, it makes much more sense to use the equipment and procedures that give the best possible chance of a flaw-free weld. "There is always enough money for rework," he points out. "I was recently called to a client making rollers for the mining industry, where I observed that the shielding gas was coming on late. When I pointed this out, I was told that this problem was not new and every start had to be repaired after the weld had been completed. The costs of doing ongoing repairs, compared to simply fixing the pre-purging problem, was never evaluated," he suggests.

Duplex stainless and gas shielding

Because of their longer life and better strengths, Lawrence believes that in the chemical industry, particularly in highly corrosive areas, the use of duplex stainless steel is on the rise. "Duplex steels are more expensive than stainless steel alternatives, but their superior corrosion



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resistance and mechanical performance means that these steels can last for over 30 years, so the additional costs can easily be justified," he says.

"I get routine calls asking if pure argon can be used for gas metal arc welding of duplex stainless steels with solid wires. The standard for solid wire duplex welding is to use 2% nitrogen in argon," he says. Air Liquide offers this gas in its ARCAL technical range and the same mixture is also recommended for use in TIG welding.

The superior properties of duplex stainless steel are derived from the duplex nature of the material's microstructure, which consists of approximately 50% austenite and 50% ferrite. This microstructure gives them the good corrosion resistance and ductility associated with austenitic stainless steels, but with yield strengths that are significantly higher than both ferritic and austenitic stainless steels. More importantly, though, duplex steels do not suffer from the poor toughness associated with most ferritic stainless steels.

But the duplex properties can be completely destroyed at the welds. Prior to the addition of nitrogen to duplex compositions, the heat affected zone (HAZ) of welded joints became too ferritic and, therefore, too brittle. "Nitrogen is an austenite promoter and it is key to maintaining the austenite-ferrite balance in the HAZ of welds and in weld metal," Lawrence explains. "Imagine a highly alloyed material being welded with a low-alloy wire or with no filler at all," Lawrence suggests. "The nitrogen in the original alloy will be burned out, which affects the austenite, leaving the weld metal and the heat affected zone with low toughness, and lower resistance to corrosion" he explains.

To prevent this from happening, the wire and the shielding gas need to contain nitrogen to compensate for the losses while welding. Reinforcing the role of nitrogen in the shielding gas, Lawrence explains that, while the filler material can compensate for N₂ losses in the weld metal, the HAZ, while heated to above the austenite to ferrite transition temperature, can lose nitrogen without access to replacements. Nitrogen in the shielding gas ensures that nitrogen is replaced to an acceptable level and ensures that the duplex microstructure is retained.

"Nitrogen, along with heat input, has a critical effect on the microstructure

of the HAZ of duplex welds. In particular, nitrogen directly affects the ferrite-austenite balance on which the strength and corrosion resistance of the material depends," says Lawrence.

Touching on the shielding gas requirements for flux-cored welding of duplex steels, Lawrence advises that flux-cored wires are each designed to suit a particular shielding gas and nitrogen in the shielding gas is not usually required. "When using flux-cored wires, fabricators should always use the shielding gas recommended by the manufacturer," he advises.

"Duplex is expensive, so it is imperative that users take the trouble to develop and qualify their welding procedure specifications (WPSs) before launching into a job, and that they keep procedure qualification records (PQR) for every weld," Lawrence insists. "The microstructure of a weld can't be seen, so you need to keep very accurate control of the welding process during welding, in all aspects: amperage; voltage; wire feed speed; heat input, which must be maintained between narrow kJ/mm limits; deposition rates; and interpass temperature – and all of these need to be very tightly controlled to achieve sound duplex welds," he says.

Another neglected issue, according to Lawrence, is cleaning. "People assume, because of the shiny look of high chrome high nickel materials, that cleaning is unnecessary. But the weld area must be cleaned, from the weld preparation to a minimum of 50 mm on either side including the underside, because any hydrocarbon contamination near the weld joint will contaminate the shielding gas and create porosity and other problems," he points out.

As with all other gas shielded welding processes, pre-purging and post-purging also applies. "For full penetration welds, the underside of the weld



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needs to be purged to keep oxygen and hydrogen away from the molten metal, but for duplex, a shielding gas with nitrogen has to be used – again to retain the ferrite-austenite balance," Lawrence tells *African Fusion*. If welding a tube, the inside is flooded with an argon 2% nitrogen mix for purging, otherwise, if welding a plate seam, for example, a welding bench or strip clamp needs to be used, which has a backing bar with gas diffusion ports underneath the surface.

"Full penetration duplex welds are almost always done with a gas shielded process, either TIG or MIG, and, increasingly, the flux-cored processes – due to their higher deposition rates – are ideally suited to the fill and cap passes," Lawrence says.

"Duplex stainless steel is becoming more important in the chemical industry and, globally, in the nuclear industry. Because it performs well at high temperature conditions, it is becoming the material of choice for vessels and heat exchangers that need to carry corrosive media. The new LDX lean duplex, which is now locally manufactured by Columbus Stainless Steel, would be well suited for the R51-billion Metrorail coach contract, won by Gibela and Alstom," he concludes. ■