WAAM and Fronius' CMT solution

Harald Maringer, Fronius International's key system manager for Wire Arc Additive Manufacturing (WAAM) talks about the advantages of using Fronius' Cold Metal Transfer (CMT) welding process for producing prototypes and high-value small-batch components, as opposed to using more expensive wire- or powder-based metal additive processes.

Additive production methods generate components by building up material layer-by-layer, the most well-known example being 3D printing. WAAM, which is based on the arc welding process, also produces metal parts layer by layer, with the layers formed by melting and fusing a wire electrode. This generative method is particularly advantageous when complex component geometries have to be produced, as the design options are virtually limitless.

In addition, parts can be manufactured at low cost and extremely quickly – which makes WAAM a very attractive option for prototype construction and/or small production batches. In comparison, processing time, tool wear and material loss during traditional machining – especially with the conventional approach of milling out the workpiece from a solid block – all result in significant additional costs.

There are a number of generative production methods for metals. Essentially these can be divided into two fundamental types: powder-based processes and wire-based processes. In powder-based processes, the layers are built up using molten metal powder. The most common method, the powder bed process, produces extremely precise results, but is somewhat slow in production. Wire-based processes, on the other hand, build up the component by melting a wire-based filler metal, using a laser, electron beam, or a welding arc. These processes have a high deposition rate and therefore help to cut production times.

Wire arc additive manufacturing is a wire-based process that uses the gas metal arc welding process (GMAW). WAAM itself offers a number of advantages. First is its high deposition rate (up to 4.0 kg/h with steel materials), and multi-wire solutions could give rise to even higher deposition rates. Equipment and material costs are also important criteria, which is another strength of WAAM: all you need is a suitable welding system. There is no requirement for costly special equipment, such as the vacuum chambers needed for the faster electron beam process.

In comparison to powder-based processes, WAAM benefits from the immediate availability of a range of certified wire types. Since the use of metal powder is a relatively new technology, there are comparatively few powder-based materials to choose from, as it can take years to acquire the necessary certification and to produce data sheets.

A stable welding process and effective heat dissipation are essential for WAAM. The welding process needs to be sufficiently low energy such that when a new layer is applied, the existing layers are not remelted. In other words, the process needs to be as 'cold' as possible. Furthermore, the weld layers need to be continuous, spatter-free, and consistent. If any flaws were to occur, these would be transferred to each subsequent layer.

The CMT GMAW process from Fronius, and its process control variants, meets these requirements. It produces a stable arc and a controlled short circuit with long short circuit times. This means that the heat input is very low and the material transfer is practically spatter-free, which helps to prevent flaws.

Two process control variants of CMT are particularly well suited to WAAM. One is the CMT additive process characteristic, which has been optimised for WAAM. It achieves high deposition rates while transferring very little heat into the component. The CMT Cycle Step variant reduces the arc power even further through the controlled deactivation of the arc during the process phase. However, this particularly 'cold' process does require more time to build up the layers, as the deposition rate is proportionally lower.

Real world WAAM successes

Countless WAAM components have already been produced using welding technology from Fronius in a variety of sectors. These include fan impellers for the electronics industry, which are made from high-grade materials. Milling the workpiece is very expensive owing to the high rate of material consumption, while casting is not always able to meet the critical metallurgical properties required for wall thicknesses of just 1.5 mm. Using WAAM based on Fronius' CMT Cycle Step, the fan impeller blades can be produced from a nickel-based alloy and it is possible to repair these thin components using the process.

Fronius has also implemented an application with a partner in the aviation sector. Titanium is a frequently used material in aircraft construction thanks to its tensile strength, resilience, corrosion resistance, and low weight. The majority of the components are manufactured using subtractive methods, whereby up to 90% of the material is milled away. This results in high costs, long machining times and costly tool wear.

On the other hand, components produced using WAAM need only a final machined skim to produce a smooth surface.

The titanium components produced using the CMT additive process do not exhibit any lack-of-fusion problems and they have impressive metallurgical properties. Tool costs, machining times and wear are significantly reduced, meaning that overall manufacturing costs can be brought down.

This makes WAAM a cost-effective and flexible alternative for component production. The additive process can be adopted with relative ease using welding technology from Fronius and its CMT solution.

With wire arc additive manufacturing (WAAM), components are 'welded up' layer-by-layer before being skimmed into their finished form. In the example shown, the component is being produced from titanium.

Milling thin fan impellers from nickel-based alloys for the electronics industry is an expensive business, while casting is rarely an option. WAAM is an economical alternative.

Key factors determining the quality of a component produced using WAAM are the stability of the welding process and low heat input – the Cold Metal Transfer GMAW process from Fronius fulfils these requirements.

By mechanically retracting the wire electrode used in the CMT welding process, the molten droplet is detached without the need for a high pinch current. This means that less energy is needed and longer short circuit times are achieved, resulting in a 'cold' welding process. It also virtually eliminates weld spatter.