



WIRE ARC ADDITIVE MANUFACTURING

## Wire Arc Additive Manufacturing – from prototyping to production

### The challenge of demonstrating verifiable repeatability

Making the transition from prototyping to production can be a major challenge for manufacturers. This has proved particularly difficult when using additive manufacturing (AM), because to produce a component again and again, the process needs to demonstrate strong and verifiable repeatability. The challenge for AM - across all of the processes - is that a component's geometry is being produced at the same time as its properties and this makes quality control more challenging. So, is it possible to develop system and process reliability and validation using AM?

Some processes such as Electron Beam Melting (EBM) have achieved productivity and stability using tools such as Statistical Process Control (SPC).<sup>1</sup> SPC - which began life in the mid-1920s with handwritten control charts - has been used to monitor and control many manufacturing processes. Its success is in using statistical tools to detect variability before a sub-standard part can be produced; reducing scrap, downtime, and reworking costs. Decades later, those charts became spreadsheets, and the tools turned digital with the invention of SPC software.<sup>2</sup> Now, SPC has expanded to include real-time data aggregation, analysis and reporting. The question remains however, can WAAM demonstrate verifiable repeatability using a tool such as SPC?



## Statistical Process Control and WAAM

Given the criticality of the components created using WAAM, and the underpinning regulatory framework that needs to be worked within, there is a strong requirement to demonstrate the validity of the process. This is particularly important when checking the conditions used to qualify the procedure.

Until recently, demonstrating strong and verifiable repeatability using the Wire + Arc Additive Manufacturing (WAAM) process was a significant challenge to it being used in production. This was because of the difficulties of measuring independent primary variables, such as power, travel and wire feed speed; and variables that depend on these, such as the voltage, temperature field, geometry, integrity and ultimately the structural integrity of the component that is being printed.

Now however, with the introduction of WAAM3D's RoboWAAM®, the pressing need to demonstrate compliance in a repeatable manner for WAAM printed components has been resolved. Thanks to RoboWAAM's comprehensive sensor suite, the system goes above and beyond when it comes to delivering measurable control and robustness for users.

## RoboWAAM – fully auditable and repeatable compliance

From the point of view of process and control, WAAM3D's RoboWAAM hardware has multiple sensors that are used for both the qualification and production aspects of component creation.

These include:

- Real time interferometric ShapeTech sensor – this innovative proprietary sensor gives live measurement of layer height
- Double-point temperature measurement capability - ensures consistent printing conditions and enables in-process parameters checks
- Electronic wire positioning – allows for increased process stability
- Process camera, combined with CCTV – enables remote melt-pool imaging and safe machine supervision

The accompanying software tool (WAAMCtrl®) records the process data throughout the building of the part, which makes the process fully auditable and exportable should there be any need to access the component's quality trail.

## EU Consortium looks at next level additive productivity

A new academic-industrial partnership, known as LAMM, is aiming to improve WAAM deposition rates and printing efficiency still further. With funding from EIT Manufacturing the aim of the project is to complete the industrialisation of two kinds of end-effectors, tailored for the deposition of Ti64 and steel.

WAAM3D's role is to design, build and test the two new end-effectors and demonstrate the viability of high build rate on several demonstrator parts; and to adapt WAAM3D's proprietary software to embrace the new capabilities.

- 12 months duration
- Overall budget 611,611 euros
- WAAM3D budget 360,000 euros





## Ultimate tracking and recording



WAAMCtrl enables the tracking and recording, point by point, instant by instant, across a whole build. It includes:

- Arc current
- Arc voltage
- Wire feed speed
- Travel speed
- Melt pool position
- Pre-deposition interpass temperature
- Live temperature at the front and rear of the melt-pool
- Wire position, which it also controls with closed-loop
- Layer height, in real time
- Gas flows (process, and shielding)
- Oxygen content (in the deposition environment and in several other places around the system)
- Melt pool video

This data is stored on RoboWAAM's server and displayed to the operator. It can be accessed in real time whilst parts are being made, or conveniently retrieved post-build – from anywhere. It can also be exported in fully auditable templates, for quality control.

### Alerts based on rigorous process control methodology

WAAMCtrl provides an instant-by-instant data sample, giving the machine operator the opportunity to evaluate both the historical and the immediate behaviour of the process. If there is any need to intervene in the process the operator is alerted. This alert is based on a rigorous process control method, based on strict statistical methodology, that looks at what the acceptance tolerance bands are and takes into account the inherent variability in normal machine processes. Therefore the operator can be confident in knowing whether the process is still in control or starting to go outside the control parameters.

Once this alert is activated, a number of closed loop feedback processes have been built into WAAMCtrl, based on WAAM process findings, that the operator can choose to use should they want to:

- The automatic position of the wire – looking at the WAAM process findings, WAAM3D has developed a proprietary way to adjust the wire to an optimal position, relative to the electric arc, to create consistent metal droplet application.
- The interpass temperature – for a lot of materials ensuring consistent thermal conditions during deposition is key to facilitating predictable microstructures and properties within the part. One of the variables that is looked at is the temperature at which a new layer is printed. Thanks to the pyrometer positioned at the front of RoboWAAM's end effector, it is possible to assess when it is time to print a new layer or section, based on the pre-set temperature. The pyrometer at the back of the unit also cross-checks the temperatures behind the melt pool, ensuring that these are consistent with the ones measured during the qualification phase of the printing of the component.
- The real time interferometric ShapeTech sensor – this innovative proprietary sensor gives live measurement of layer height. Powered by interferometric technology it provides real-time geometrical data that is stored on WAAMCtrl's server and shown within WAAMCtrl's process dashboard. Not only is real-time layer height shown, but the full 3D profile of what is being deposited.

Due to these innovative features, WAAM3D has the tools to achieve robustness in large-scale metal additive printing and prove it. RoboWAAM's use of a wide array of sensors to track, record and store the deposition process, parts made using WAAM3D's RoboWAAM system are able to make the demonstration of robustness, validity and compliance more straightforward. The era of large-scale metal additive component production is now here.



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#### Sources:

1. Lungblad, U[ric], Statistical Process Control Applied to Additive Manufacturing Enables Series Production of Orthopedic Implants. Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679, ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
2. <https://www.qualitymag.com/articles/94869-advancements-in-statistical-process-control-spc>



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