MANUFACTURING OF A DEMONSTRATOR USING WAAM TECHNOLOGY ON THE ADDILAN V0.1 MACHINE

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ABSTRACT:
Manufacture of a medium-sized demonstrator of the aerospace industry based on WAAM, identifying the key aspects to be considered in the manufacture of this type of parts.
One of the project lines of TKNIKA's area of specialization in Additive Metal Manufacturing is related to the WAAM (''Wire and Arc Additive Manufacturing'') technology. This process is classified into the Directed Energy Deposition (DED) family process and as his description says is based on the deposition of a wire melted under the action of an electric arc. The main objective is the generation of knowledge through practice and experimentation in a network between different VET teachers and schools.
A medium-sized part has been selected, with a simple geometry, which would normally be manufactured from a metal block or a forged preform. In this case, an arc-wire manufacturing process can be a very interesting alternative. The main objective of this practice is to produce a quality preform, identifying the key aspects that allow it to be manufactured, in a controlled manner, on the Addilan WAAM V0.1 manufacturing machine.
The solution has been consisted on manufacturing three-piece series based on previous experiences.

Keywords: WAAM; 3D metal; aeronautics.

INTRODUCTION

The manufacturing industry is constantly evolving, driven by technological advancements that enhance efficiency, productivity, and sustainability. One such technology that has gained significant attention is Wire Arc Additive Manufacturing (WAAM). WAAM enables the creation of complex metal components by depositing material layer by layer using an electric arc. This innovative technique has the potential to revolutionize manufacturing processes and unlock new possibilities for various industries.

The purpose of this research is to explore the application of WAAM technology in the manufacturing of a demonstrator. The demonstrator will serve as a tangible example of the capabilities and potential of WAAM, showcasing its ability to produce intricate, customized, and high-quality metal components.

The projected outcomes of this research hold immense value for the generation of knowledge through practice and experimentation in a network between different Vocational Education and Training (VET) teachers and schools, as well as the industry. By engaging VET teachers and schools in this research, we can foster a collaborative learning environment that promotes the exchange of ideas, expertise, and best practices.

By actively involving VET teachers and schools, we can leverage their knowledge and experience to develop effective teaching methodologies and curricula that incorporate WAAM technology. This will empower students with hands-on experience and practical skills relevant to the evolving manufacturing landscape. Additionally, the collaboration between different schools will create a network that facilitates the sharing of resources, expertise, and research findings, further enhancing the collective knowledge base.

Furthermore, the industry stands to benefit greatly from this research endeavor. By bridging the gap between academia and industry, we can identify industry-specific challenges and requirements that can be addressed through the application of WAAM technology. The outcomes of this research will provide valuable insights and practical solutions that can be implemented to enhance manufacturing processes, reduce costs, and improve product quality.

Additionally, the collaboration between industry and educational institutions will facilitate technology transfer, allowing manufacturers to adopt WAAM technology and capitalize on its potential. This will enable the industry to embrace additive manufacturing as a viable and efficient alternative to traditional manufacturing methods, opening up new avenues for innovation and competitiveness.

In conclusion, the research on manufacturing a demonstrator using WAAM technology holds significant promise for the generation of knowledge through practice and experimentation in a network between different VET teachers and schools, as well as the industry. By leveraging the expertise of VET teachers, sharing resources, and fostering collaboration, we can enhance teaching methodologies and empower students with practical skills. Simultaneously, the industry can benefit from the insights and solutions generated through this research, enabling them to embrace WAAM technology and drive innovation in the manufacturing sector.

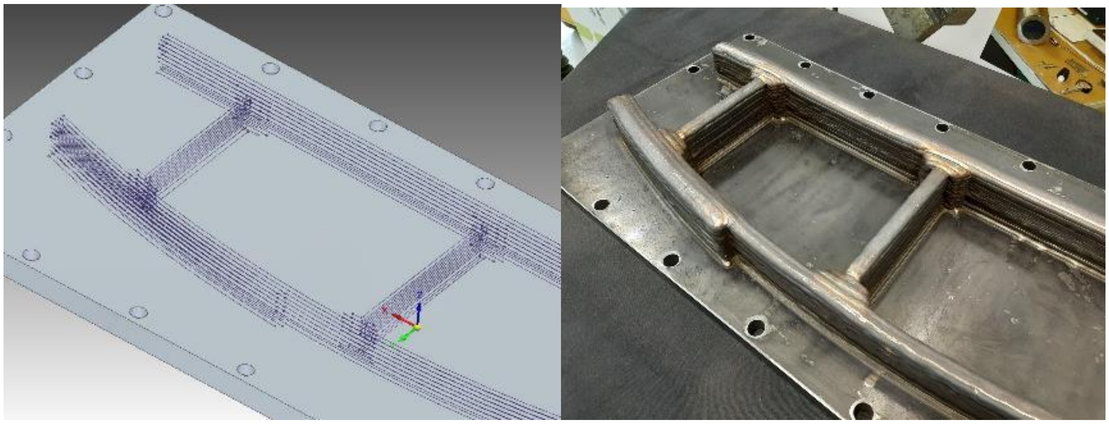

Image1: Demonstrator Model Part. As CADed and as WAAMed.

SOLUTION

The solution is structured in three phases: design, manufacturing and analysis of results, adjustments, and improvements.

In the process design phase, the following are considered:

- Selection of the feed rate and main parameters. From this information we will obtain the weld bead geometry, which will be used as a reference to define the overlapping values between beads and the step value between layers. The feed rate will be 4 m/min, which is equivalent to a total feed rate of 2.0 kg/hour.
- Programming of the paths. Taking the initial trials as a reference, the paths are defined which, in the case of plasma additive processes, are mainly based on longitudinal beads that overlap, depending on the widths of both the long sections and the knots that make up the part. When programming these paths, it is necessary to consider the necessary overlayer to be able to finish the part with machining processes.

In the manufacturing phase, it is essential to consider how the conditions of the part change as it is being formed: on the one hand, the part is acquiring heat and, on the other, the geometry of the part is changing. This makes heat conduction more and more difficult. It is essential to control heat input during the manufacturing process, in the case of this part, it has changed from 12kJ/cm in the first layers to 8,61 kJ/cm in the last part of manufacturing.

In the different tests carried out, the main aspects to be improved have been related to adjustments in the overlapping values between beads, with the programming of the start and end of the bead, and with aspects related to the protection of the molten pool.

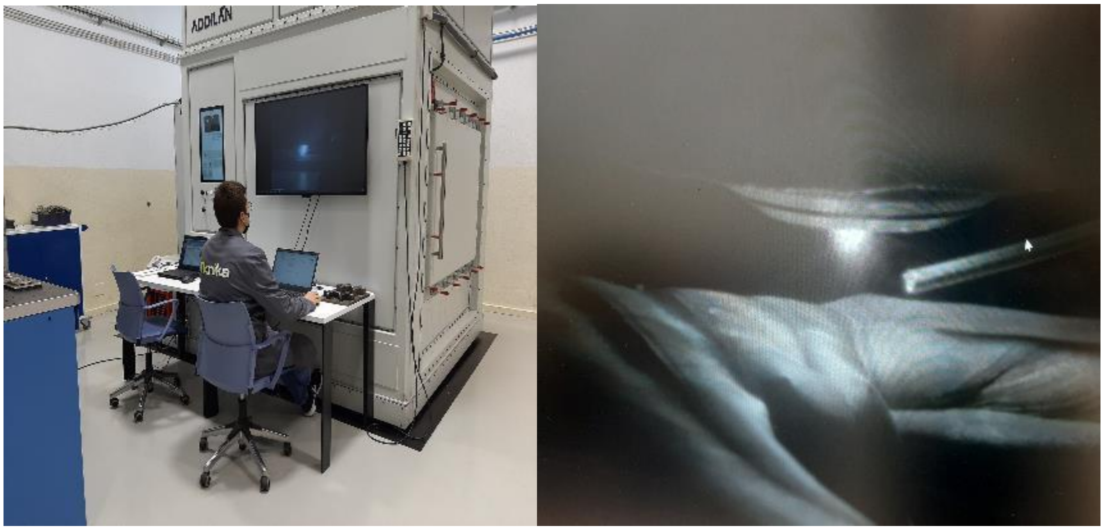

Image 2: Addilan CNC WAAM machines process camera control.

GLOSSARY OF TECHNOLOGIES

For DED (Directe Energi Deposition): CNC machine (Addilan) + Plasma Welding equipment (Fronius).

For Machining: 5 Axel CNC machine.

Verification: X-ray Scannig.

RESULTS AND BENEFITS

The part chosen is based on a manufacturing simulation exercise in the aeronautical sector. For this reason, the part has been subjected to a radiographic X-ray test (SCI Control & Inspección, 2018). It should be noted that this type of non-destructive test is a usual demand in the aerospace industry and is the main reason why this method has been chosen. The objective is to identify the defects generated during the process to locate them in the part and find out the possible cause of its presence without destroying the part. Due to the absence of this equipment in

Tknika's facilities, this work has been subcontracted. The test is validated by the UNE-EN ISO 17636-01 2013 standard. the results obtained are shown below:

Tipo de defecto/Defect Type
Aa Poros-Porosity
Ab Poros vermiculares-Worm holes
Ba Escoria irregular-Slag inclusion
Bb Escoria alineadas-Slag lines
Bc Escorias alternadas-Slag alternates
C Falta de fusion-Lack fusion
D Falta de penetracion-Lack penetration
Ea Grieta longitudinal-Log. crack
F Mordeduras-Undercut
G/H Inclusion Flux/Tungsten-Flux/Tungsten
K Crater-Rechupe-Shrinkages
O Otros defectos-Other defects

TIPO DE DEFECTOS (ISO 6520-1)
2011 PORO/PORE
2013 SOPLADURAS AGRUPADAS/CLUSTERED
2014 SOPLADURAS ALINEADAS/LINEAR POROSITY
2015 SOPLADURAS ALARGADAS/ELONGATED CAVITY
2016 SOPLADURAS VERMICULAR/WORM HOLE
100 GRIETAS/CRACK
104 GRIETAS DE CRÁTER/CRATER CRACK
300 INCLUSIÓN SOLIDA/SOLID INCLUSION
304 INCLUSIÓN METÁLICA/METALLIC INCLUSION
2017 PICADURA/SURFACE PORE
401 FALTA DE FUSIÓN/LACK OF FUSION
402 FALTA DE PENETRACIÓN/LACK OF PENETRATION
5011 MORDEDURAS/UNDERCUT
504 EXCESO DE PENETRACIÓN/EXCESSIVE PENETRATION
5041 DESCOLGADURA/LOCAL EXCESSIVE PENETRATION
601 CEBADO DE ARCO/ARC STRIKE
2025 CRATER
O OTROS/OTHERS

Clasificacion-Interpretation
A = Aceptable-Acceptable
R = Rechazable-Rejectable
RF = Rep.radiografia-Repeat film
RO = Rep.observ.-Repeat review

IDENTIFICACION Film Identification	SECTOR	ESPESOR Thickness mm	HILO/TALADRO REQUERIDO Wire/Hole required	HILO/TALADRO OBTENIDO Wire/Hole obtained	DENSIDAD Density	TIPO DEFECTO Defect Type	CALIF. Resul	OBSERVACIONES Remark
PROY WAAM-TKNIKA RT1 R1	1-2	15	W12	W12	2.3	2011-401-O		
PROY WAAM-TKNIKA RT1 R2	1-2	10	W12	W12	2.7	2016		
PROY WAAM-TKNIKA RT1 R3	1-2	15	W12	W12	2.2	401-O		
PROY WAAM-TKNIKA RT1 R4	1-2	15	W12	W12	2.2	2011-401-O		
PROY WAAM-TKNIKA RT1 R5	1-2	15	W12	W12	2.2	2011-401-O		
PROY WAAM-TKNIKA RT1 R6	2-3	7	W13	W13	2.5	401		
PROY WAAM-TKNIKA RT1 R7	1-2	7	W13	W13	2.3	2016-O		
PROY WAAM-TKNIKA RT1 R8	2-3	15	W12	W12	2.3	401-O		

Table 1: Description of the radiographic examination

The test shows the possibility of defects that will have to be specifically researched in the evolution of this project.

The benefits of manufacturing a part of this type using WAAM are those inherent to FA processes, especially the use of both the raw material and the overall energy used in the entire process.

The 620 x 200-part weighs 12.35 kg and its 30 layers are 50 mm high. The cycle time is 25 minutes per layer, of which 17 are feeding time. The effective rate is 68%, i.e., for a total of 1.48 kg/hour.

The material used is AISI 316L stainless steel wire, because the main objective of this production was to learn how to do it, identifying the key aspects of the process. This type of parts, especially those aimed at the aeronautical sector, and depending on their use, can be manufactured with aluminum or titanium alloys. The technology developed by Addilan is especially suited to this type of application and provides both process control and monitoring solutions in real time, as well as optimum protection conditions in an inert chamber.

The next challenge is to fabricate one of these medium or large format parts in one of these materials, applying the methodology and results obtained in the current practice, and adapting them to the new conditions and requirements of these materials.

Another aspect to be worked on is related to the quality of the pieces obtained, both in terms of their metallurgical characteristics and their mechanical properties.

Image 3: Result as Machined VS as WAAMed

CONCLUSIONS

The progress made in WAAM technology is evident in several aspects. First, advancements in process control, such as improved arc stability and wire feed systems, have resulted in enhanced deposition accuracy and quality. This has made WAAM more reliable and consistent, enabling the production of parts with stringent dimensional and structural requirements. Additionally, the development of multi-axis robotic systems and advanced motion planning algorithms has expanded the capabilities of WAAM, allowing the fabrication of complex geometries with minimal post-processing.

However, there are still challenges that need to be addressed for further advancement and wider adoption of WAAM. One of the key challenges is ensuring consistent mechanical properties across the deposited material, as the rapid cooling rates in WAAM can lead to variations in microstructure and potential defects. Research efforts are focused on optimizing process parameters, such as arc characteristics and heat management, to achieve better control over material properties. Furthermore, the integration of in-situ monitoring and control systems is crucial for real-time quality assurance and defect detection during the additive manufacturing process.

WAAM technology also holds promise for vocational learning and teaching. As this technology becomes more prevalent in industrial settings, incorporating WAAM into vocational training programs can equip the workforce with the skills required for future manufacturing jobs. Hands-on training with WAAM systems, coupled with theoretical knowledge, can prepare individuals for careers in additive manufacturing, where there is a growing demand for skilled operators, technicians, and engineers. Furthermore, educational institutions can collaborate with industry partners to develop curricula and certification programs that align with industry needs and ensure a smooth transition from learning to practical application.

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