DELIVERABLE 2.3.1.: CONCLUSIONS OF THE VIABILITY STUDIES

Contenido

INTRODUCTION

The Work Package 2 (WP2) of the ADDISPACE project with Title: *Demonstrative pilot project of additive manufacturing technologies transfer in SMEs of the aerospatial sector* had the aim of developing and fabricating 4 pilots to transfer the AM technologies through SMEs of the aerospace sector in the SUDOE. In the Activity 2.3: *Study of viability in companies,* a SME joined to each of the pilots. The results and developments done in the previous Activity 2.2: *Industrial research phase* were applied in order to show the benefits of metal additive manufacturing applied to their sector and concretely to their company production chain.

OBJECTIVE

The main objective of this document is to provide the **description of the methodology** applied in the development of the viability studies and **the conclusions extracted** about each of them.

DESCRIPTION

This deliverable provides a **general description** and the **main conclusions** obtained during the viability studies.

These studies gathered a deep analysis about the fabrication process with conventional manufacturing and the integration of AM technologies, the technical viability analysis of AM process implantation and a proposal for process redesign, the economic study of that implantation and the environmental impact of the new process and component.

These studies were conducted by the Working Group of each pilot and leaded by the leader of each pilot. A guide was provided by LORTEK to be modified and adapted for the different requirements or opportunities found in each company.

Achieved results are owned by the company however, in the case of deduced conclusions and recommendations were subjected to dissemination and transference in the frame of the last Workshop of ADDISPACE project.

The structure of each study started with a first part of collection of data from the current manufacturing process of the company.

Then in a second stage, **4 different phases** were overcome in order to provide the next content:

- Study of the current fabrication process of the target component and with the implementation of MAM.
- Analysis of the technological viability of the MAM implementation by the adaptation of current systems and proposal of process redesign.
- Economical study of the incorporation of the new process.
- Study of the environmental and technical impact of the new fabrication process of target component.

For the development these studies an open call was launched for the SMEs willing to participate. After that, in order the select the SMEs, a ranking was done to select the most appropriate SME for each pilot. Hence the SMEs selected for each pilot remained as follows:

Pilot	Company
Pilot 1	AEROTECNIC
Pilot 2	UNILASER
Pilot 3	VENTANA
Pilot 4	Egile Mechanics S.L.

VIABILITY STUDIES

Pilot 1

Methodology

AEROTECNIC company participated in the viability study of the pilot 1: **SLMilling.** The research phase of pilot 1 focused in the development of a strategy by AM that includes the positioning, supporting, etc, taking into account the post-processing operations including the machining. This knowledge acquired during the research phase was shared with AEROTECNIC in the viability assessment.

The **main steps** followed in the study were:

- Selection of components
- General study of orientation and positioning of the selected components in the manufacturing plate (manufacturing software)
- Selection of final part for complete study
- Complete study of the selected part:
  - Part preparation through manufacturing software
  - Manufacturing process analysis
  - Economic analysis of the SLM process
  - Analysis of postprocess operations and inspection
- Impact study

Initially, a screening of components was carried out where 12 components were taken into account for a general overview to consider the parts for additive manufacturing, Selective Laser Melting specifically. Among them, a **selection** of three components was undertaken for a **general analysis** through the manufacturing software: orientation and positioning of the selected components in the manufacturing plate.

According to specific considerations, finally a TiAl6V4 part was selected for a more accurate study.

The analysis performed for the selected part included a **first approach** in which the part was analyzed through software considering different manufacturing orientations.

Once the most suitable orientation was identified, considering not only manufacturing through **SLM** but also **machining**, the **complete study of the component** was executed. This included all the stages considered in the **value chain** of the **manufacturing process**, as specified down below:

- Manufacturing software analysis:
    - Positioning
    - Orientation
    - Supporting strategy
- Manufacturing process analysis:
    - Material and layer thickness
    - Material volume and support volume
    - building time
- Economic analysis of the SLM process
    - Material
    - Fungibles
    - Machine time
- Analysis of post-process operations and inspection
    - Thermal Treatment: Annealing
    - Supports removing
    - Manual deburring
    - Thermal Treatment: HIP
    - Surface finishing
    - Interface machining
    - Inspection

Furthermore, the study was executed for a single part and considering few components (**serial production**) in a same manufacturing plate, in order to analyze the possibilities of reducing manufacturing costs.

Finally, the main advantages and disadvantages of FA technology in different aspects were presented as an **impact analysis** of the technology.

Conclusions

Within the framework of the ADDISPACE project, a case study of manufacturing via SLM has been developed for AEROTECNIC. From the analysis, a comparative between singular and serial manufacturing of components can be summarized, as presented in Table 1. Unit times and costs may be reduced by the serial approach.

Singular Production		Serial Production (components/batch)	
Manufacturing analysis		**Manufacturing analysis**	
Parameter	**Value**	**Parameter**	**Value**
Material	TiAl6V4	**Material**	TiAl6V4
Layer thickness	60 µm	**Layer thickness**	60 µm
Units of parts	1	**Units of parts**	7
Machine time	8.5 h	**Machine time**	39 h
Component volume	62 cm^3	**Components volume**	435 cm^3
Supports volume	1 cm^3	**Supports volume**	7 cm^3

Table 1. Advantages and drawbacks of SLM (AM technology).

As final conclusions, an overview of the gains and drawbacks of the technology may be addressed: Additive technologies offer benefits in terms of component weight reduction, novel design and delivery times. The collaboration between the Additive Manufacturing and machining experts will be of deep interest for small and medium machining companies, such as AEROTECNIC. Through this project they have been able to evaluate the inclusion of this technology within their manufacturing process to offer the possibility of a finished product in the aerospace sector.

The main advantages and disadvantages of the AM technology (SLM especifically), in different aspects are presented in Table 2.

Feature	Advantages	Disadvantages
Bulk Material	Recyclability - reusability	-
Tooling	Not needed in the SLM process	-
Fungibles	-	Gas for manufacturing – additional fungibles for post-processes
Production waste	Reusability of powder	-
Posprocessing	-	Possible extra post-processing
Weight	Weight reduction – part weight & geometry optimization	-
Personalizing	Geometry adaptation without penalization on tooling and delivery time	
Delivery time	Reduction	-

Table 2. Advantages and drawbacks of SLM (AM technology).

Pilot 2

In this case UNILASER company was selected to implement the results obtained in the previous phase. Unfortunately in this pilot the selected SME did not continue with the interest of participating in the study and due to short notice no viability study could be performed on time.

Pilot 3

Methodology

According to the pilot 3, the company VENTANA has participated to the viability study concerning the study of manufacturing a big part with WAAM technology, originally machined from a big block, with a very high Buy to Fly ratio.

This viability phase focused on a technical study according to the manufacturability of this large part originally made in a material not weldable.

A proposition of 3 solutions of material has been found, and the study explain the way of manufacturing by WAAM processes (way of programming, redesign, value chain to respect, etc.).

Then, an economical study has been performed, in comparison with the original way of manufacturing. The economic study takes into account the manufacturing of the part but also the possibility of an investment on the WAAM or WLAM process, taking into account all the necessary expenses (energy, robot, cell, gas, substrate, human resources, etc.).

To finish, an environmental study has been studied according to the WAAM process, comparing to machining and sand casting. According to these different results, we can estimate that manufacture with WAAM and machine only with finishing phases could have a lower environmental impact, and furthermore, a much smaller amount of waste.

Conclusions

The rise of additive manufacturing technologies has pushed the boundaries of traditional processes. Indeed, the FAM is in full expansion and global turnover keeps increasing: About 501M $ in 2001 to 7300M $ in 2017 with an estimate to 28600M $ in 2023. The benefits of WAAM are relatively obvious: no tools or complex equipment are needed, which translates into low investment costs, for a convincing result.

The metal objects thus formed seduce by their structural integrity and the speed of manufacture. In addition, the ability to produce lightweight parts from expensive materials such as aluminum or titanium, with few wasting metals, makes WAAM technology a very attractive approach for many industries, particularly aerospace, Oil & Gas and automotive. Regarding cost-effectiveness, this process outperforms other additive manufacturing processes such as LMD / P or LBM.

On the other hand, although the WAAM offers definite advantages, it has been seen in this deliverable that there was a major constraint to take into account: The weldability of the material.

Likewise, the WAAM or LMD / W (WLAM) processes can prove to be very interesting economically for parts with a very high Buy to Fly ratio, saving on tooling and time programming of roughing passes, generated waste, etc.

In the same way, by generating less waste, being a faster process, and by drastically reducing this Buy to Fly ratio, the WAAM process has a slightly lower impact than its CNC Milling and Sand-Casting counterparts.

Additive Manufacturing by wire deposition can therefore be easily envisaged, under certain conditions of size and weldability of the materials, as an interesting alternative or hybridization with conventional methods.

Pilot 4

Methodology

In this case **Egile Mechanics S.L.** participated in the viability study of the pilot 4: **Opti-lattice.** The research phase of pilot 4 focused in the new designs that combine topological optimization and lattice structures with the aim of reducing weight but at the same time providing new functionalities to the part. This knowledge was implemented into a design of a part proposed by Egile Mechanics S.L. for the viability assessment.

The **main steps** followed in the study were:

- Implementation study of reticular structures combined with bulk zones in an optimized topology.
- Calculations of strength and displacements to verify the fulfillment of requirements.
- Study of the position and supporting of the part in the chamber.
- Calculation of the processing times and weight.

Firstly, a **selection** of the part was done from a set of 27 parts of similar shapes. These parts are not optimal for machining, however they are completely solid. **Distribution and values of the loads** were defined to be applied to the selected representative part.

In a first approach, 5 different cases were studied attending to the next criteria:

- Bulk zones fixation
- Topological optimization of bulk zones
- Selection of lattice structures

In the second approach, a **skin** was applied to the best resulting configuration of the first approach. Different cases were studied attending to:

- Thickness of the skin as finer as possible
- Thickness of the skin adapted to the requirements of strength

Along the study the methodology applied was the next:

At the beginning calculation were done about:

- Loads in the volume of the part
- Maximum displacement

Finally, parts that met with the imposed requirements have been calculated:

- Weight of the part
- Weight of the supports
- Processing time

Other study was conducted attending to a conventional topology optimisation including a skin.

Another approach that contemplates the position of the part in the chamber during the processing was performed. In this case, the goal was focused on the avoidance of distortions.

Finally, a study about the simultaneous fabrication in the chamber of 14 parts was done in order to obtain the cost of serial production.

In order to compare the costs and time savings, as reference, the original part used.

Conclusions

In the value chain of additive manufacturing by SLM technology, the part that is applied in this pilot, covers the gap between the design and the program prepared for the manufacturing machine including: design, space for design, rough optimization, first redesign, strength and displacement calculations, various iterations until the achievement of the final design and preparation for the machine.

The main advantages obtained from SLM manufacturing are applied to this part, which are the reduction of weight and the obtaining of complex geometries that allows other functionalizations.

New software make possible the combination of complex geometries and topological optimization.

From the calculations done taking into account the price of 316L stainless steel in powder (40 €/kg), the saving on material are:

- Original part cost: 32.88 €.
- Optimised part: 25.4 € → savings of 7.48 € per part (reducing the weight of the part in 189 grams).
- Cost in serial production: 355.6 €

Due to the non-expensive price of stainless steel, no big savings are overseen in this case.

According to the savings in processing times:

- Original part: 851 min
- Optimised part: 821 min (savings of 30 min).
- Time in serial production: 6218 min (savings of 444 min per part → savings of 407 min (6 h, 47') per part).

Clearly **savings in processing time are the main advantage** that this new design offers.

According to the distortions, the use of higher amount of supports due to the position of the part in the chamber was preferred in order to meet with the tolerances.

Regarding the impact in the environment, the new design proposed have several advantages and disadvantages that are described in the Table 3.

Table 3 Advantages and disadvantages associated to the redesign obtained by the combination of lattice structures and bulk zones.

Aspect	Advantages	Disadvantages
Weight	It is reduced	-
Material	It is reduced	-
Processing time	It is reduced	-
Post processing	A lower stiffness provided by lattice structures can be helpful in the assembly	The non-consolidated powder has to be extracted from the inner side
Personalisation	High	-

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