Application of additive manufacturing techniques on replacement components - Case Study Navigator

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Abstract:

Nowadays, additive manufacturing is an area with high industrial interest, with applications in several industries. This technology, characterized by the production of layer by layer parts, encompasses a variety of processes that allow the use of a variety of materials, as well as some advantages such as reducing manufacturing time, warehouse costs and improving the quality of the manufactured part when compared to conventional manufacturing (subtractive manufacturing).

In this context, the work developed aims to study the application of additive manufacturing as a support for obtaining parts of industrial equipment. A part was selected for study in The Navigator Company factory unit replacement component chain - a company dedicated to the manufacture and marketing of paper in Portugal - and mechanically characterized to obtain an optimized part, produced by additive manufacturing. For this, reverse engineering processes and topology optimization processes were used to obtain the CAD model. In order to characterize the part economically regarding cost, data presented in purchase orders was collected. Finally, the pieces were printed and an experimental validation proposal was defined.

This work concludes with a proposal for a general procedure, based on the experience of this case study, which encompasses the approaches used for each phase and allows their use in other cases.

Keywords:

Additive Manufacturing, Maintenance, Reverse Engineering, Topology Optimization

1 Introduction

In the industrial environment, due to the importance of competitivity, companies want to maintain a high level of productivity, with a high efficiency that meets the needs of the market. Therefore, there is a relationship between meeting customer needs and keeping components in good condition and good performance.

One of the most challenging goals is to increase the flexibility of Maintenance, Repair and Overhaul (MRO) to ensure that the production chain meets market needs.

Additive manufacturing (AM), developed in the 1980s, is a technology that allows parts to be created by overlapping layers to achieve the desired final geometry, with the advantage of optimizing the part for its weight, since this optimization is done by removing "unnecessary" parts from the part topology, maintaining functionality, particularly when making small series [1]. These processes have several applications, such as prosthesis manufacturing, automotive and aerospace components. In the area of maintenance there is a high interest in applying such technologies, given their advantages [1].

It is interesting to study the applicability of additive manufacturing in maintenance, to verify if it becomes competitive with conventional processes.

This work aims to study and analyse the application of additive manufacturing techniques in spare components and, based on this case study, to define a methodology that can be applied to other cases.

It focuses on a case study of the company Navigator, where a spare part was chosen in the area of transformation, more precisely the packaging area. According to some parameters considerered important such as lifetime, lack of knowledge about the component, it was made a study and characterization of the piece from a mechanical and economical point of view, to exemplify the use of additive manufacturing in maintenance components, thus contributing to analyze the potential cost reduction of the company.

To achieve the main goals of this work, it was used reverse engineering and topology optimization techniques, projecting a component that fulfils the stipulated requirements, according to the original.

Achieving the objectives will allow the reduction of the amount of warehouse maintenance parts, reducing costs, and the possibility of producing a replacement component only when necessary.

2 Bibliographic Revision

The following chapter is divided in three sub-chapters. The first presents AM technology, the processes, materials, characteristics and applications. In the second sub-chapter the area of MRO is introduced and the third and final one explains Reverse Engineering and its methodology.

2.1 AM technology

The term AM was defined by American Society for Testing and Materials and is the generic term used to describe the manufacturing process through which several tools operate, such as the one that was later known as "3D Printing". It is a mechanical process in which layers of material are progressively on top of each other in order to form an object, based on a digital model [2].

AM processes can be categorized by the type of material used, the deposition technique or by the way the material is fused or solidified. In table 2.1 is shown the different categories, the materials, processes, strengths/downsides and typical applications.

2.2 Maintenance

With the increasing complexity of machines and systems by users and operators, the need for MRO services increases.

MRO may include spare parts, equipment such as pumps and valves, consumables such as cleaning supplies, plant upkeep supplies such as lubricants, and activities completed to restore or maintain the functioning of needed equipment. Anything used in the manufacturing of, but not employed in, a final product may be considered MRO [3].

In [1], a process scheme is presented that allows users to take advantage of using AM in MRO. Following these strategies, it is possible to redesign components to the desired specifications to make the replacement process more flexible before manufacturing, as shown in the following figure.

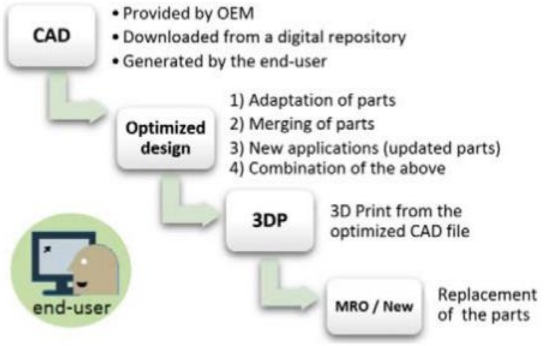

Figure 2.1 - Scheme of strategies for using AM in MRO [1].

The first step consists on getting the CAD model (through the original fabricant, a digital repository or generated by the end-user). Another and probably more efficient way to generate the 3D file is by 3D scanning the original part.

The second step consists on the adaptation of the desired part to specific end-user needs.

Finally, the last step is to 3D print the optimized component from the CAD model and replace the component.

Through this strategy, it is possible to conclude that AM processes enable the production of customized parts, reducing the cost of manufacturing and applying to MRO components.

Table 2.1 - AM processes and its characteristics. Adapted from [4], [5].

Categories	State of Starting Materials	Technologies	Typical Materials	Strengths/Downsides	Applications
Binder Jetting	Liquid/Powder	3D Printing Ink Jet S – Print	Polymer, Metal, Ceramic and others	Full-color objects printing Wide material selection High porosity on finished parts	Prototypes, casting shells, tooling
Directed Energy Deposition	Powder	Direct Metal Deposition Laser Deposition Laser Consolidation	Metal	Repair of damaged/worn parts Functionally graded material printing Require post processing machine	Tooling, metal part repair, functional parts
Material Extrusion	Filament/Paste	Fused Deposition Modeling	Thermoplastics	Inexpensive extrusion machine Multi-material jetting Limited part resolution Poor surface finish	Prototypes, casting patterns
Material Jetting	Liquid	Polyjet Ink – Jetting Thermojet	Fotopolymers, waxes	Multi-material jetting High surface finish Low-strength material	Prototypes, molds
Powder Bed Fusion	Powder	Selective laser Sintering Selective Laser Melting Electron Beam Melting	Metals mostly	High accuracy and detail Fully dense parts Powder handling	Tooling, functional parts
Sheet Lamination	Sheet	Ultrasonic Consolidation Laminated Object Manufacture	Paper, Plastic and Metal	High surface finish Low material machine and process cost Decubing issues	Prototypes, casting models
Vat Photopolymerization	Liquid	Stereolithography Digital Light Processing	Fotopolymers	High building speed Good part resolution High cost for supplies and materials	Functional parts

2.3 Reverse Engineering

Reverse engineering is the process of obtaining a geometric CAD model from measurements acquired by contact or non-contact scanning techniques (e.g. three-dimensional position digitization) of an existing physical model [6], [7].

The typical procedure of reverse engineering is shown in figure 2.2.

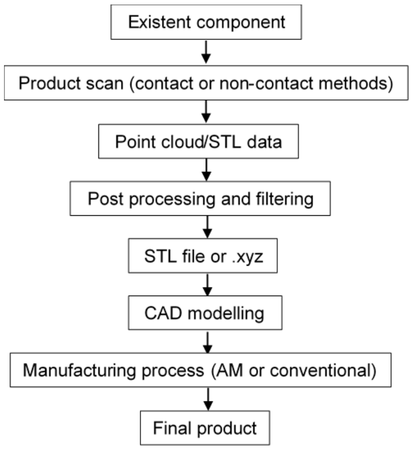

Figure 2.2 - Flowchart of the reverse engineering process [6].

It consists in the following steps: data acquisition, post-processing, application of CAD tools (to create a solid body), manufacturing of the component and obtaining the final product [6].

3 Approach

A methodology was developed and it is represented in figure 3.1.

The procedure begins with the collection of all existing information about the component, such as technical and economic information.

The next step is to replicate the part in a 3D modelling software with a 3D Scanner, because the geometry is complex and there is a spline that requires precision.

With the geometry replicated in the modelling software, a structural analysis simulation is performed to understand the stress and displacement conditions to formulate the problem.

With these two parameters, the problem is formulated and the optimization method to be used is defined as well as the value of the variables to choose, such as the number of iterations.

After performing some topological studies, the results are evaluated and their feasibility verified. If the results are satisfactory, a 3D model is build based on the results obtained and then a structural analysis study is performed to verify that the stress and displacement conditions are below the limits initially imposed. Otherwise, the study is repeated by adjusting certain parameters.

Having the geometry optimized, a proposal is presented to the collaborating company, based on research on companies in the field of metal additive manufacturing.

Finally, after being printed and coated, the part is validated *in situ* for a specified period of time, following a planned process, and the results are evaluated.

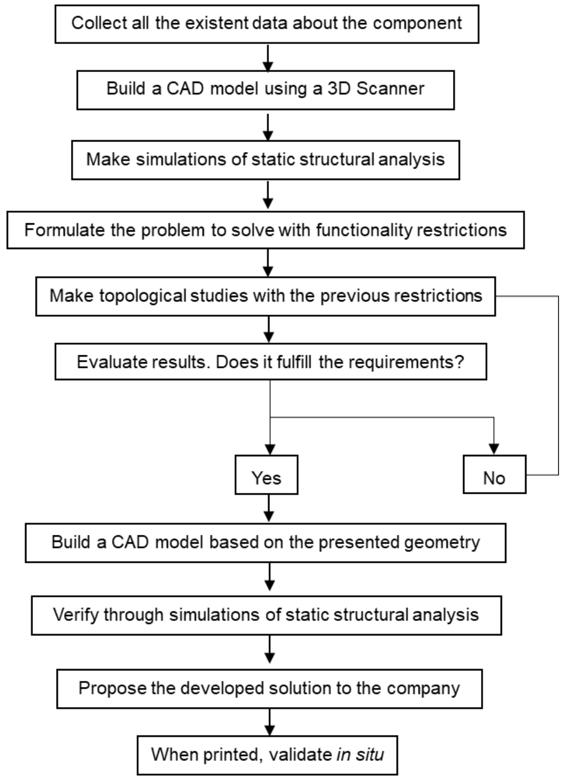

Figure 3.1 - Flowchart of the followed methodology.

4 Case study

This chapter is divided in several sub-chapters: introduction of the company, selection of the case study, gathered data about the component, topology optimization and validation.

4.1 The company

The Navigator Company is one of the strongest entities in Portugal and is dedicated to the manufacture and marketing of paper and other products. This business group consists of four industrial complexes - Cacia, Figueira da Foz, Setúbal and Vila Velha de Rodão [8].

4.2 Selection of the case study

To select the most suitable component, there were some meetings with the company and the criteria applied to choose the right component was based on factors such as:

- Be a part with high wear;
- Have a short replacement time;
- Navigator's lack of knowledge of the component as it is purchased from an external supplier;

Therefore, the selected component is represented in figure 4.1.

Figure 4.1 - Selected component to study.

This part is placed in an equipment, represented in figure 4.2, in the transformation area, that receives the sheets of paper and arranges them on a pallet for later packaging.

Figure 4.2 - Parts arrangement on the equipment.

Initially, the paper and places it on a mat to be cut and turned into sheets of the desired size and weight.

Then, the paper is cut to the desired size. After being cut, the sheets go to the stacking stage where they are placed on top of each other on a pallet until they reach a certain height.

In the stacking phase, the sheets are layered on a pallet until a certain height is reached, at which time the pallet is removed and an empty pallet is entered for re-loading. It is at this stage that the part performs its function.

After this phase, the pallet moves to the area where the reams are wrapped, packaged and palletised.

Given the high production volume, it becomes an interesting component to study as it has a high wear area, presented in figure 4.3, because the paper has a high abrasive effect given its surface roughness.

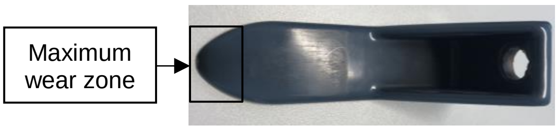

Figure 4.3 - Selected part to represent the high wear.

4.3 Functional and economic data

The propose of this component is to support a zone of the paper as it settles in layers until it reaches a certain height. Then the piece leaves its position and stays still.

Figure 4.4 - Component in real conditions.

The part is purchased from an external supplier and when it needs to be repaired, is coated externally, in TEandM company [9].

After talking with the supplier, it was possible to obtain the material base datasheet, with the reference GS – 42CrMo4. Its characteristics are presented in table 4.1.

Table 4.1 - Main characteristics of the material base.

Parameter	**Value**
Yield strength	154 MPa
Extension	56%

The chemical composition is presented on table 4.2.

Table 4.2 - Chemical composition.

Weight fraction (%)	**C**	**Si**	**Mn**	
	0.38-0.45	0.60	0.60-1.00	
	P	**S**	**Cr**	**Mo**
	0.020	0.015	0.80-1.20	0.20-0.30

The purpose of the coating is to improve the surface of the part, thus increasing the abrasion resistance as the part is in contact with the very abrasive paper sheets. At the same time, it was important to make sure that the coating material must endure that abrasion without damaging the sheets.

The technology used for the coating is called *High Velocity Oxi-Fuel*, based on continuous oxygen combustion of a fuel. Combustion gases entering a chamber, where the raw material in powder form injected axially through the flow stream of an inert gas, usually nitrogen [9].

The requirements are the following:

- Material with electrical conductivity to discharge static electricity from paper sheets;
- Low coefficient of friction;
- Recommended thickness between 600 ± 100 µm;

To analyse the component from an economic point of view, it was collected data from purchase orders since 2017. The considered costs are presented in table 4.3.

Table 4.3 - Considered costs.

Considered costs	Description
Acquisition cost	Value obtained annually. The cost per unit is obtained dividing the purchase cost by the number of ordered units
Storage cost	Considered 10% of the average capital invested. The procedure is similar to the previous one.
Labour cost (€/unit)	The indicated value is 15€/hour. The replacement of a unit takes two operators during 3h, making a total of 90€/unit.

The following table, 4.3, shows the data gathered and the total cost per unit.

Table 4.4 - Total cost per unit.

Considered costs	2017	2018	2019
Acquisition cost	19.285,00 €	51.116,00 €	17.038,00 €
Storage cost	1.928,50 €	5.111,60 €	1.703,80 €
Labour cost (€/unit)	90,00 €	90,00 €	90,00 €
Number of ordered units per year	25	66	22
Total cost per unit (rounded)	939 €	942 €	942 €

Therefore, from the data presented above, it is concluded that each component costs approximately 942 €.

4.4 Topology Optimization process

The main steps to do a topology optimization are: obtain the CAD model of the component, identify the applied force and boundary conditions, find the restrictions (which in this case are the stress and displacement), and formulate the problem to do an iterative process in NX Siemens and obtain the optimized solution.

To get the CAD model, a 3D Scanner was used and a point cloud was obtained. The original surface contained 547.313 vertices and 1.094.626 faces. With MeshLab, a software to process and edit 3D triangular meshes, it was possible to reduce it to 68.414 vertices e 136.828 faces [10].

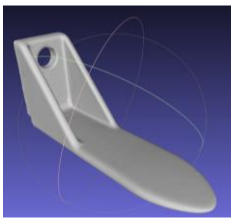

Figure 4.5 - Initial surface.

Using the tools of the ScanTo3D feature available in SolidWorks, it was possible to convert the surface into a solid body, shown in the figure 4.6 [11].

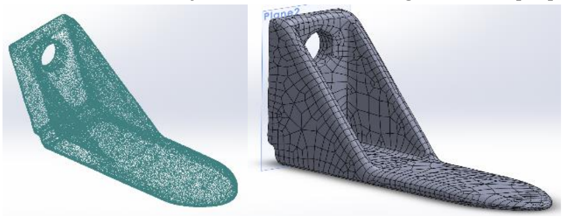

Figure 4.6 - left side: point cloud and right side: solid body.

The component is fixed to the equipment with a M12x30 hexagon socket head cap screw. Figure 4.7 shows the steps to obtain the applied force and the stress and displacement conditions.

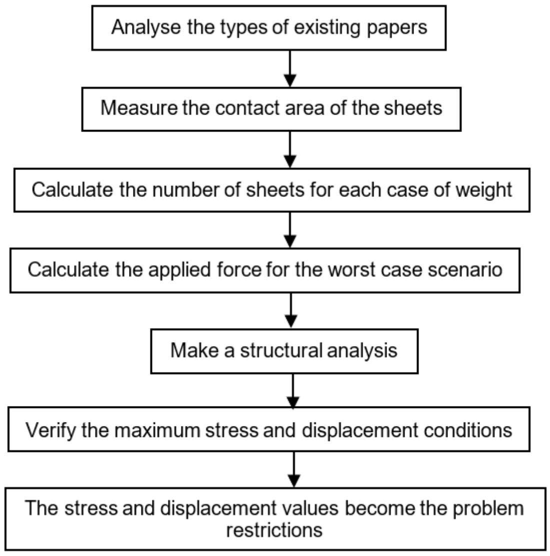

Figure 4.7 - Flowchart of the main steps to obtain the necessary data to formulate the problem.

The types of paper produced by Navigator are 75, 80, 90, 170 and 250 g/m^2. After measuring the necessary data, it was concluded that the applied force is 3.985 Kg.

Before making a structural analysis on NX Siemens to obtain the data for problem formulation, the component was 3D scanned.

After that, a mesh was created in NX Siemens software with 4.15 mm tetrahedral elements and a simulation was done. The results are presented in figure 4.8 and 4.9.

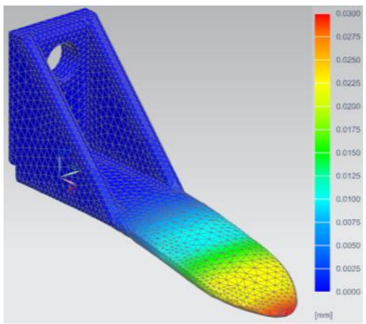

Figure 4.8 - Maximum displacement admissible.

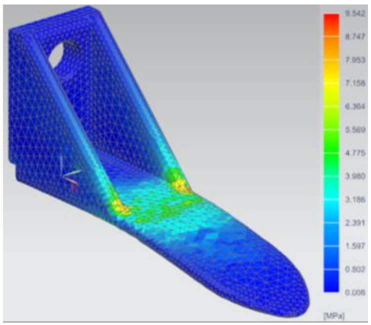

Figure 4.9 - Maximum Von Mises stress admissible.

Observing both figures, it is possible to conclude that the maximum admissible displacement and Von Mises stress are 0.0300 mm and 9.54 MPa, respectively.

In order to obtain the maximum allowable stress, it is necessary to choose an adequate Safety factor, $nproj$. Accordingly to Pugsley's Method, based on n_{sx} and n_{sy} , it was choosen a value of 1.75 and 1.2, respectively. The total value of $nproj$ is 2.1 [13].

The maximum allowable stress is given by:

$$SF = \frac{\sigma_{adm}}{\sigma_{allow}} \Leftrightarrow \sigma_{allow} = \frac{154}{2.1} = 73{,}3(3)\ MPa \qquad (4.1)$$

The next step is to formulate the problem of minimizing the compliance function subjected to the constraint of maximum tension and displacement. The design variable is density, ρ, and the formulation is the following [12]:

$$min_{\rho i \epsilon \mathbb{R}^n} \{u\}^t \{F\}$$
$$s.t. \begin{cases} \rho_{min} < \rho_i \leq 1 \\ \delta max < 0.0300\ mm \\ \sigma max\ <\ 73.3(3)\ \ MPa \end{cases} \qquad (4.2)$$

Where u represents the displacement of finite elements in the mesh, $\boldsymbol{F}$ is the applied force vector, ρ_i is the density of element i in the mesh and ρ_{min} is the minimum density. Regarding the constraints, these were obtained from the simulations presented above where δmax represents the maximum allowable displacement and σmax the maximum allowable stress.

To solve the problem numerically, two software programs were used: NX Siemens and Solidworks. Both use the same method for topology optimization, called SIMP, *Solid Isotropic Material with Penalization* [12].

This process consists of a widely used interpolation method in which the Young modulus of the element, $E_e(\rho_e)$, is given by equation 4.3 and E_e^0 is the Young modulus value of the base material.

$$E_e(\rho_e) = \rho_e^p \times E_e^0\ com\ 0 \leq \rho_{min} \leq \rho_e \leq 1 \qquad (4.3)$$

Where ρ corresponds to the density penalty and it is necessary to enter a minimum density value to have no singularities in the problem.

Regarding the value to be considered for the penalty p, it must first be greater than 1 in order to cause some penalty and that for *poisson* ratio values of $\nu = \frac{1}{3}$, p must have a value of 3 [12].

In order to make a topological study, several parameters were defined, presented in table 4.5.

Table 4.5 - Parameters used for the topology study.

Parameter	**Value**
Method	SIMP
Penalization	3
Number of iterations	50
Design Objective	Min
Displacement constraint	Displacement - 0.0300 mm

For the first iteration, it was done a mesh in NX with tetrahedral elements with 6 mm. The results obtained from both NX and Solidworks are represented in figure 4.10.

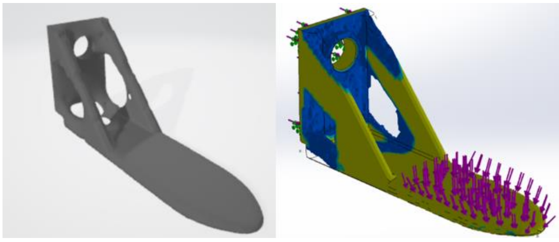

Figure 4.10 - Left side: NX and right side: Solidworks.

Analysing the result obtained, it is observed that material can be removed in the lateral areas (shown in blue), in the base area of the part and in the rear zone.

In order to better understand if material can be introduced in the central zone (in the topology optimization there is no addition) a second study was performed based on the original piece, but with a solid structure.

Using the same procedure and type of elements, the results are shown below, in figure 4.11.

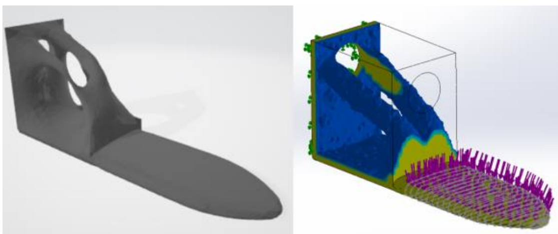

Figure 4.11 - Left side: NX and right side: Solidworks.

Therefore, there is no need to add material and the ribs can be restructured.
Based on the previous results, another study was made with 3.87 tetrahedral elements. Figure 4.12 shows the results.

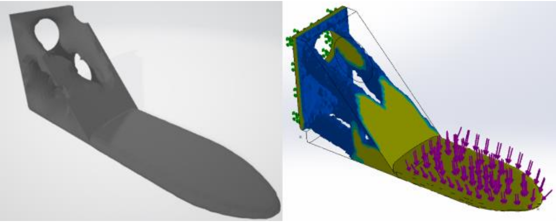

Figure 4.12 - Left side: NX and right side: Solidworks.

Consequently, a new geometry was proposed with 0.280Kg, which means a 18.2% reduction in mass.

Figure 4.13 - Proposed geometry.

To verify if the results fulfilled the requirements, a computational simulation was made and the results are presented below.

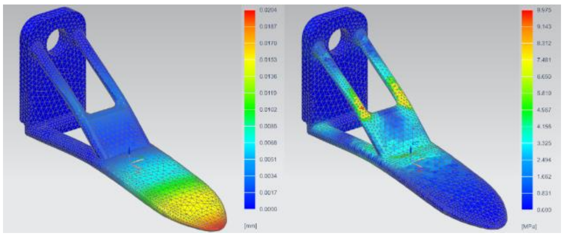

Figure 4.14 - Left side: NX and right side: Solidworks.

In order to remove material from the back zone, a topology study was made considering the “pressure cone” of the screw. The result obtained from the Solidworks program are presented in figure 4.15.

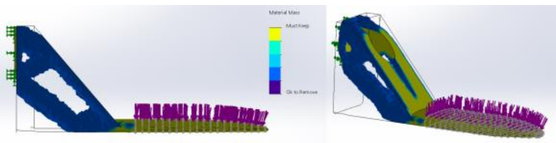

Figure 4.15 - Results obtained from Solidworks.

Based on the previous results, a second geometry was designed with 0.296Kg, reducing the mass by 13.5%.

Figure 4.16 - Proposed geometry

Both geometries were presented in a meeting with the company and a methodology to test them was developed, explained in the next sub-chapter.

4.5 Printing and Validation

After the modelling, one prototype of each geometry was printed in a 3D Printer with PLA to do a dimensional control.

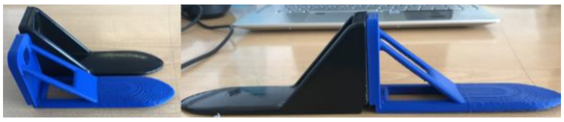

Figure 4.17 - First proposal and original component.

Figure 4.18 - Second proposal and original component.

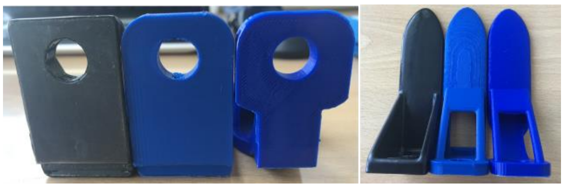

Figure 4.19 - both proposals and original component.

To print the components, two companies were approached, HyperMetal and BBE – Engineering, but the first one was more competitive in terms of price and lead time.
In the table 4.6 are presented the main parameters used for printing.

Table 4.6 - Parameters used in printing.

Parameter	**Value**
Process used	SLM
Printer	Renishaw AM 400
Material used	*Maraging Steel*
Total production time	42h30m

In order to test both components in real conditions, a methodology was defined to evaluate the wear, described in table 4.7.

Week	Action
Week 1	Parts assembly and weight registration, visual analysis
Week 2	Visual inspection, coating condition check
Week 3	Visual inspection, coating condition check
Week 4	Disassembly of the parts, visual and crack analysis

Parts were printed and are presented in figures 4.20 and 4.21.

Figure 4.20 - First proposal and original part.

Figure 4.21 - Second proposal and original part.

5 Methodology

In order to generalize all the procedures used in this case study, a methodology represented in figure 5.1 was defined.

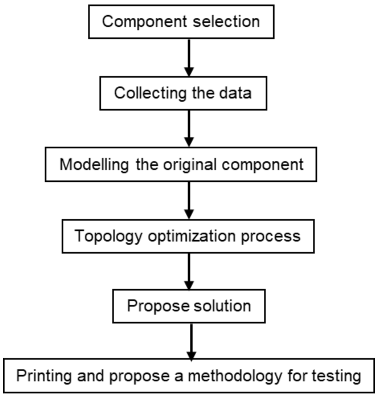

Figure 5.1 - General flowchart.

The definition of the criteria for choosing the part, should take into consideration the following:
• Low replacement time;
• Geometry to ensure print eligibility, given that printing machines have a maximum space limit;
The next step is to review the replacement component inventory to choose a part that fits the defined parameters. After this step, the preliminary cost of the AM produced part should be calculated by contacting a supplier to verify whether AM is viable.

In collecting economic information, all costs associated with the component (by analysing the purchase orders) must be considered. Regarding the collection of technical information, it should include:
• Functional environment - function, constraints, equipment where it is located;
• Forces - which can be calculated based on experimental work;
• Technical drawings - technical drawings and CAD models;
Regarding the material and the coating, this information can be found in the documentation that the company has about the component or, if not available, there may be contact with the company that produces the part, as happened in the case study presented as well as the applied coating.

If there is a model already designed, the next step is, through a finite element program, such as NX, to perform a structural analysis to obtain the data needed to formulate the problem.

Otherwise, the procedure is to digitize the part and, according to figure 2.2, obtain the solid body for structural analysis and proceed to the next phase of the process.

In the scanning phase, there are some details to keep in mind, such as the fact that the surface of the part may be reflective and make the process difficult (one solution might be to use a powder to replicate the part and obtain the point cloud).

Structural analysis requires some intermediate steps such as the construction of a finite element mesh, defined based on parameters such as refinement, and other criteria introduced in the program.

Topology optimization process begins with the formulation of the problem according to the associated requirements and constraints. In this case it was the maximum displacement and tension, but it may be necessary to reduce material from the original part.

Then, to solve the optimization problem, parameters should be defined as the method to be used, the number of iterations (plausible to obtain results, but also not computationally slow), among others depending on the program used.

The results are analysed and if they are satisfactory, the next step is the modelling of the obtained solution. If the results can be improved, the optimization process must be repeated with the adjusted parameters.

In this case study the process was repeated to verify the possibility of improving the results by adding material in the central part area. The fact that the optimization process is subtractive, as no material is added, can make it interesting to adjust the geometry in the iteration to see the program solutions.

The phase of proposing a solution has as steps the modelling of the solution obtained by the program, make structural analysis simulations in which the force and boundary conditions are placed to evaluate if the optimized part meets the initially proposed requirements.

In order to avoid dimensional errors, it is essential to perform dimensional control to validate 3D models. To this end, should the opportunity arise, a prototype must be printed, placed in the service conditions (equipment) and validated.

Once validated, the next step is printing to MAM. In order to perform tests under real service conditions, a testing methodology should be defined that is consistent with the intended study. For example, in the presented component, the objective is to evaluate the wear. Thus, a visual inspection is performed to analyse the wear and a penetrating liquid test to evaluate cracks.

It is concluded that this methodology, when applying topology optimization and reverse engineering techniques to components that have potential in the additive manufacturing area and whose characteristics can be improved, is suitable.

6 Conclusions

This dissertation aimed to understand and study the applicability of additive manufacturing technologies in maintenance, using a component of this area in collaboration with The Navigator Company.

Thus, a characterization of the part was made from two points of view: economic, in order to analyse if the additive manufacturing becomes competitive or not, and mechanical, to obtain the conditions of service, such as forces and boundary conditions To obtain the CAD model of the part, reverse engineering techniques were used, which allowed the model to be constructed from a scanning. One of the limitations found at this stage was the fact that the part had a coating that made the process difficult.

First, a literature review was made. On additive manufacturing, the process, associated technologies, materials used, and all characteristics and its applications. It is concluded that there are a variety of technologies used with different materials, from metal to polymer, which can have several applications, including component repair or custom prosthesis production. Regarding Maintenance, the theme of MRO was explored as well as a strategy for using the AM in this context was presented. Finally, the theme of reverse engineering was developed, in which the typical procedure used and some applications in aviation and medicine were presented.

Having the problem contextualized, an approach to solve it was studied. Following the elaboration of a model to apply in this case, all the information of the part was collected without any constraint and the requests / conditions of service were determined. It was concluded that the methodology was adequate and allowed to formulate the optimization problem, in limit conditions such as displacement and stress.

With the objective of designing an optimized solution, iterative topological studies were made, and analysing the results obtained, two solutions were obtained that allow the functionality to be maintained, reducing the weight and, consequently, the volume of material needed, which influences the cost of the component by AM processes.

All topology optimization process was based on an iterative process in a finite element program, where it was necessary to adjust the mesh and the geometry to study along the iterations, with results production and its critical analysis, leading to two optimized solutions with a significant weight reduction. Another optimization method could have been used, but it would be more computationally time consuming and, for the context of this work, the method used and exposed previously produced quite satisfactory results. These results were computationally validated and the component is expected to support the required force. The wear depends on the coating used, which will be the same applied on the original part.

In order to test the solutions presented, a PLA prototype was printed to validate the design of the CAD models of the solutions presented. With the validated design, the parts were produced and, due to the delivery of this dissertation, it was only possible to define an experimental validation proposal. However, the parts have already been printed and the coating is in progress.

The procedure incorporates steps that may have limitations when applied to other cases such as when considering that the model is built with a 3D scanner. However, there may be technical information of the part and there is no need to scan. Thus, in order to generalize the whole strategy to address a problem similar to the one presented or to study other components, a general strategy was defined in the previous chapter.

This same strategy is distinguished by its versatility in applying to other components and also by its characteristics, make it possible to reduce costs associated with warehouse and inventory and delivery times, peculiarities of additive manufacturing.

Implementing additive manufacturing with techniques such as reverse engineering and topological optimization enables MRO to adapt and become flexible to changes in the production chain as the market demands it, while providing design changes and obtaining component data when there is no information Topological optimization allows to remove material in certain areas where it is not necessary for the function, thus allowing the part to be redrawn, but one of the limitations found is that the program does not "distribute" or "add" material in areas where it would be interesting to add, then requiring a careful analysis of the results.

Due to what was presented and considering the work done, it is concluded that this methodology was adequate for the problem presented, with the application of a case study.

It becomes interesting to apply it to other industries and to analyse its transversality, with the study of other cases and make it more robust.

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