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# RADICAL DESIGN PRAGMATIC TO AN NOVEL MULTI-PURPOSE APERTURE ACHIEVABLE BY ADDITIVE MANUFACTURING

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## ABSTRACT

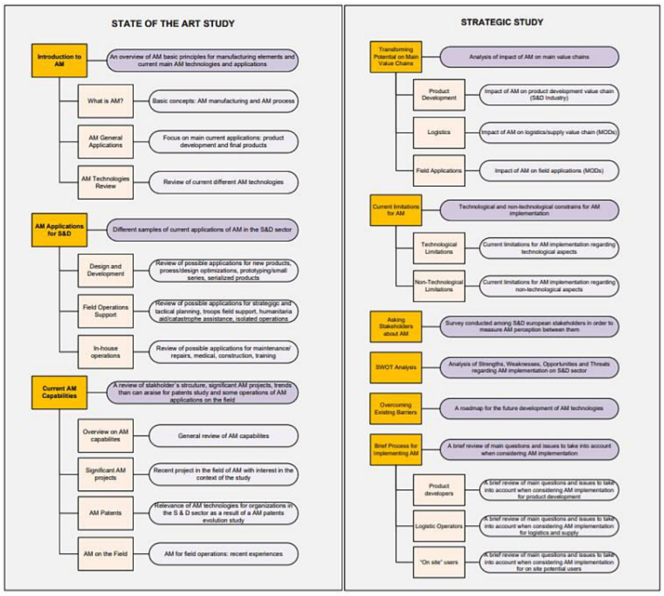
Considering the progressively expansive trade world, "time to market" of productions and goods has turned into a key element for business accomplishment. There are diverse practices that antedate design faults and unveil products on the market in minus time. Among the most used methods in the design and explanation of the necessities, quality function deployment (QFD) and design for Six Sigma (DFSS) can be used. In the prototyping stage, it is probable to address the emergent technology of additive manufacturing. Today, 3D printing is employed as a quick prototyping technique. Nevertheless, the tangible task which industry is fronting is the adoption of these machines for large-scale production of components, which is now possible with new HP multi fusion. The goal of this paper is to illustrate the entire product development process taking advantage of the most modern models and technologies for the final realization of a case study that involves the design and prototyping of an innovative multifunctional fan (lamp, aroma diffuser, and fan) through the multi jet fusion of HP. To begin with, issues related to the DFSS, the QFD and their application to identify the fan requirements are explored. Once the requirements have been defined, the modern CAD design systems and the CAE systems for the validation of the case study will be analyzed and applied. Finally, HP's multi jet fusion methodology and design rules for additive manufacturing will be analyzed in detail, trying to exploit all the positive aspects it offers.

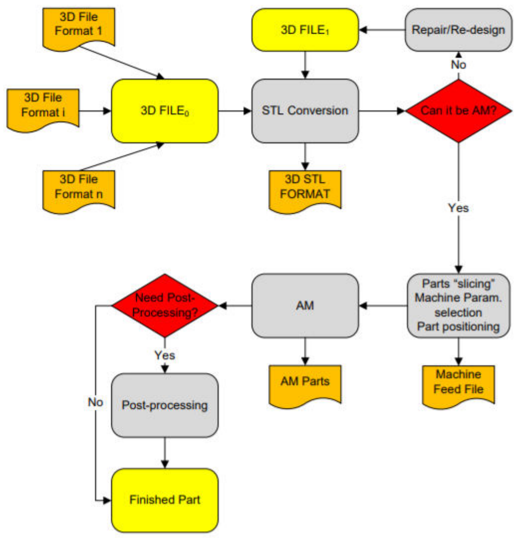
## INTRODUCTION

Design for additive manufacturing (DfAM or DFAM) is design for manufacturability as applied to additive manufacturing (AM). It is a general type of design methods or tools whereby functional performance and/or other key product life-cycle considerations such as manufacturability, reliability, and cost can be optimized subjected to the capabilities of additive manufacturing technologies.

This concept emerges due to the enormous design freedom provided by AM technologies. To take full advantages of unique capabilities from AM processes, DfAM methods or tools are needed. Typical DfAM methods or tools includes topology optimization, design for multiscale structures (lattice or cellular structures), multi-material design, mass customization, part consolidation, and other design methods which can make use of AM-enabled features.

DfAM is not always separate from broader DFM, as the making of many objects can involve both additive and subtractive steps. Nonetheless, the name "DfAM" has value because it focuses attention on the way that commercializing AM in production roles is not just a matter of figuring out how to switch existing parts from subtractive to additive. Rather, it is about redesigning entire objects (assemblies, subsystems) in view of the newfound availability of advanced AM. That is, it involves redesigning them because their entire earlier design—including even how, why, and at which places they were originally divided into discrete parts—was conceived within the constraints of a world where advanced AM did not yet exist. Thus instead of just modifying an existing part design to allow it to be made additively, full-fledged DfAM involves things like reimagining the overall object such that it has fewer parts or a new set of parts with substantially different boundaries and connections. The object thus may no longer be an assembly at all, or it may be an assembly with many fewer parts. Many examples of such deep-rooted practical impact of DfAM have been emerging in the 2010s, as AM greatly broadens its commercialization. For example, in 2017, GE Aviation revealed that it had used DfAM to create a helicopter engine with 16 parts instead of 900, with great potential impact on reducing the complexity of supply chains. It is this radical rethinking aspect that has led to themes such as that "DfAM requires 'enterprise-level disruption'. In other words, the disruptive innovation that AM can allow can logically extend throughout the enterprise and its supply chain, not just change the layout on a machine shop floor.




The distinguishing feature of additive manufacturing at this stage of product development7 is that, given the freedom of design it provides and the speed and ease with which the technology can be applied, it reduces the technical, time and cost restraints associated with traditional technologies. This allows an increase in the number of design and engineering iterations and a more rational distribution of the cost of demonstrator and prototype manufacture.

The concept of additive manufacture houses a range of different technologies, all sharing the concept of "layer by layer" manufacturing, but each having different characteristics in terms of materials, technical capabilities, constraints, etc. As it will be seen throughout this report, not all additive manufacturing technologies will be suitable for use beyond the manufacture of aesthetic or functional prototypes, and in general the possibility of implementing additive manufacture for the production of final parts/products depends, as with any other technology, on demonstrating that the manufacturing process is adequate (technically speaking) for the intended application.

This means that for a given material, a given technology/machine and a reference or set of manufacturing references, the process must guarantee a reproducible result and the expected quality. Therefore, there is not a unique answer to the previous question, and the suitability of additive manufacturing for producing final parts depends on the desired application and the available technological options. The demonstration of the technical capacity of an additive manufacturing technology for a given product/application is the same as that for any other more traditional technology/process, in order to certify/approve its capacity to produce a product with replicable quality.

It should be borne in mind that traditional precision manufacturing technologies such as CNC machining are generally at least one order of magnitude superior to additive manufacturing technologies8. Even the most well-known and developed of the current AM technologies are not suitable for applications requiring very precise and fixed tolerances, although AM can be combined with other technologies to achieve required precision. However, technical capacity, although of critical importance, is only one aspect to take into account when considering additive manufacturing technology as a means to industrialize a part/product, since the economic aspect is undoubtedly the deciding factor.

In any activity, the cost always tips the balance in the selection of different options. In this respect and given its variability, it is not possible to carry out an overall assessment of all additive manufacturing technologies to produce final parts/products, since important elements such as material cost, energy consumption, processing time, or post-processing activities vary enormously, and it only makes sense to analyse specific cases. Despite this, the concept of additive manufacturing and its global characteristics do make it possible to make a series of general statements

## METHODOLOGY

### Topology optimization

Topology optimization is a type of structural optimization technique which can optimize material layout within a given design space. Compared to other typical structural optimization techniques, such as size optimization or shape optimization, topology optimization can update both shape and topology of a part. However, the complex optimized shapes obtained from topology optimization are always difficult to handle for traditional manufacturing processes such as CNC machining. To solve this issue, additive manufacturing processes can be applied to fabricate topology optimization result. However, it should be noticed, some manufacturing constraints such as minimal feature size also need to be considered during the topology optimization process.[6] Since the topology optimization can help designers to get an optimal complex geometry for additive manufacturing, this technique can be considered one of DfAM methods.

**Multiscale structure design**

Due to the unique capabilities of AM processes, parts with multiscale complexities can be realized. This provides a great design freedom for designers to use cellular structures or lattice structures on micro or meso-scales for the preferred properties. For example, in the aerospace field, lattice structures fabricated by AM process can be used for weight reduction. In the bio-medical field, bio-implant made of lattice or cellular structures can enhance osseointegration.

**Multi-material design**

Parts with multi-material or complex material distribution can be achieved by additive manufacturing processes. To help designers to take use of this advantage, several design and simulation methods has been proposed to support design a part with multiple materials or Functionally Graded Materials . These design methods also bring a challenge to traditional CAD system. Most of them can only deal with homogeneous materials now.

**Design for mass customization**

Since additive manufacturing can directly fabricate parts from products' digital model, it significantly reduces the cost and leading time of producing customized products. Thus, how to rapidly generate customized parts becomes a central issue for mass customization. Several design methods have been proposed to help designers or users to obtain the customized product in an easy way. These methods or tools can also be considered as the DfAM methods.

**Parts consolidation**

Due to the constraints of traditional manufacturing methods, some complex components are usually separated into several parts for the ease of manufacturing as well as assembly. This situation has been changed by the using of additive manufacturing technologies. Some case studies have been done to shows some parts in the original design can be consolidated into one complex part and fabricated by additive manufacturing processes. This redesigning process can be called as parts consolidation. The research shows parts consolidation will not only reduce part count, it can also improve the product functional performance. The design methods which can guide designers to do part consolidation can also be regarded as a type of DfAM methods.

**Lattice structures**

Lattice structures is a type of cellular structures (i.e. open). These structures were previously difficult to manufacture, hence was not widely used. Thanks to the free-form manufacturing capability of additive manufacturing technology, it is now possible to design and manufacture complex forms. Lattice structures have high strength and low mass mechanical properties and multifunctionality. These structures can be found in parts in the aerospace and biomedical industries. It has been observed that these lattice structures mimic atomic crystal lattice, where the nodes and struts represent atoms and atomic bonds, respectively, and termed as meta-crystals. They obey the metallurgical hardening principles (grain boundary strengthening, precipitate hardening etc.) when undergoing deformation. It has been further reported that the yield strength and ductility of the struts (meta-atomic bonds) can be increased drastically by taking advantage of the non-equilibrium solidification phenomenon in Additive Manufacturing, thus increasing the performance of the bulk structures.

## CONCLUSION

Neglecting labor costs and electricity costs, it can be noted that, simply by adopting the lattice structure, it is possible to reduce production costs by several tens of euros. The most significant component is that linked to the company's service cost (0.20 €/g). However, companies who have purchased this technology are able to allocate fixed costs to higher production volume, thus lowering costs. Nevertheless, production costs remain very high and the real challenge in the next few years is to reduce them considerably to allow for real mass production.

The main advantage of this technology is the ability to reduce costs simply by reducing the amount of printed material. In fact, starting from the basic 3D model, better solutions could be adopted (topology optimization), such as reducing the thickness of the walls or creating pockets in the housings. This, in addition to the lattice structure, would have allowed to further reduce the amount of material required and, therefore, to reduce costs. However, in this article, no further structures or design variants have been developed. In the validation phase, the emerging multi jet fusion technology presented several advantages including:

- Processing speed (six hours).
- Accessible costs for the machines (300.000 €).
- Better quality due to the detail agents.
- Freedom of design, in fact the fan body would have been particularly difficult to achieve with conventional techniques.
- Possibility to reduce costs simply by printing less material. The better the design, the lower the cost

However, it is essential to discuss also the main drawbacks we came across in this case study: to begin with, costs are relatively high if we consider service cost. Moreover, some components were deformed by the cooling process: the fan hole (2 mm) does not fit the motor shaft. Therefore, tolerances are not precise. Furthermore, only few materials were allowed in Multi Jet Fusion, such as PA 12 or PA11.

To resume, only two solutions were developed: a full structure as per design and a lattice structure. By adopting the latter, we managed to reduce the costs by a few tens of euros. Unfortunately, in this article, it was not possible to design a better solution that would optimize costs (by topology optimization). For this reason, it would be interesting to push the design for additive to the limit in a future case study, perhaps creating pockets, reducing the thicknesses to a minimum or generating different topologies thanks to the generative design software and algorithms. Moreover, as a continuation of this project, it would also be interesting to produce another series of parts with a complex design or to produce other design variants to minimize costs and to check their geometry and tolerances with the help of automatic coordinate machines (reverse engineering). It would also be appropriate to consider in the cost analysis:

- Energy consumed
- Operator costs
- Dimensional tolerances and machining tolerances

Comparing their results with existing estimates can be very useful in understanding the real possibilities of these technologies to replace them with traditional processes already existing.

**REFERENCES**

1. Freddi, A. Imparare a Progettare, Principi E Metodi Del Progetto Concettuale per Lo Sviluppo Della Creatività Industriale; Pitagora: Bologna, Italy, 2005; ISBN 88-371-1512-1.
2. Satyanarayana, P. and Subramanyam Pavuluri, D.A., 2013. PARAMETRIC MODELING AND DYNAMIC CHARACTERIZATION FOR STATIC STRENGTH OF STEAM TURBINE MOVING BLADES. International Journal of Innovative Research in Science, Engineering and Technology, 2(7).
3. PAVULURI, S. and KUMAR, D.A.S., 2013. „" Experimental Investigation On Design Of High Pressure Steam Turbine Blade"". International Journal of Innovative Research in Science, Engineering and Technology, 2(5), pp.1469-1476.
4. Sreenivas, P., Kumar, A.S. and Subramanyam Pavuluri, D.A., 2013. Investigations on transient dynamic response of functionally graded materials. a a, 1, p.2.
5. Pavuluri, S., Rajashekar, B. and Damodhar, B., Process of Press Tool Design and its Manufacturing for Blanking Operation.
6. KUMAR, S.S. and SUBRAMANYAM, P., DESIGN AND WEIGHT OPTIMIZATION OF OIL PAN BY FE ANALYSIS.
7. PAVULURI, S. and KUMAR, D.A.S., 2013. „" Experimental Investigation On Design Of High Pressure Steam Turbine Blade"". International Journal of Innovative Research in Science, Engineering and Technology, 2(5), pp.1469-1476.
8. Wenjin, T.; Ming, C.L. Design of lattice structure for additive manufacturing. In Proceedings of the 2016 International Symposium on Flexible Automation (ISFA), Cleveland, OH, USA, 1–3 August 2016.

9. Chirone, E.; Tornincasa, S. Disegno Tecnico Industriale 1; Il capitello: Torino, Italy, 2011.
10. Ogawa, S.; Piller, F. Reducing the risks of new product development. MIT Sloan Manag. Rev. 2006, 47, 65.
11. De Frutos, G.M. Product Development Process for Additive Manufacturing. Master's Thesis, Universidad tecnica de Lisbona, Lisbon, Portugal, 2015.
12. Manuale di Stampa HP4200. Available online: http://www8.hp.com/h20195/v2/GetPDF.aspx/4AA6- 4894ITE.pdf (accessed on 15 December 2018).
13. Hp Website, 3D Printing. Available online: http://www8.hp.com/it/it/printers/3d-printers.html (accessed on 15 December 2018).