The effect of generative design and topology optimization on the design and manufacturing of components in additive manufacturing

L’effet de la conception générative et de l’optimisation topologique sur la conception et la fabrication de composants en fabrication additive

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ABSTRACT. Additive manufacturing, has shown great promises, offering unexpectable design freedom and manufacturing flexibility. but traditional design methodologies cannot fully exploit the functionality of am. this study explores the impact of generative design and topology optimization in the design and production of parts in additive production. by using these advanced design tools, we aim to optimize the case study performance, minimize material usage, and unlock design opportunities. The case study is a gripper arm which is part of a robot deputed to the handle meteors is presented to demonstrate the application of these methods. additionally, it offers a useful description of Autodesk’s generative design, a software, used in our case, that uses generative design to generate a series of potential solutions to a static structural design problem. the finding reveal how generative design and topology optimization can significantly enhance component performance, reduce mass, and enable complex geometries that are difficult or impossible when using traditional methods. additionally, the paper highlights the importance of taking manufacturability constraints into account during the design process.

RESUME. La fabrication additive (FA) s’est révélée très prometteuse, offrant une liberté de conception et une flexibilité de fabrication inattendues. Mais les méthodologies de conception traditionnelles ne peuvent pas exploiter pleinement les fonctionnalités de la FA. Cette étude explore l’impact de la conception générative et de l’optimisation topologique dans la conception et la production de pièces en production additive. En utilisant ces outils de conception avancés, nous visons à optimiser les performances de l’étude de cas, à minimiser l’utilisation de matériaux et à débloquer des opportunités de conception. L’étude de cas est un bras de préhension qui fait partie d’un robot délégué à la poignée des météores est présenté pour démontrer l’application de ces méthodes. De plus, il offre une description utile de la conception générative d’Autodesk, un logiciel, utilisé dans notre cas, qui utilise la conception générative pour générer une série de solutions potentielles à un problème de conception structurelle statique. Les résultats révèlent comment la conception générative et l’optimisation topologique peuvent améliorer considérablement les performances des composants, réduire la masse et permettre des géométries complexes qui sont difficiles, voire impossibles, lors de l’utilisation de méthodes traditionnelles. De plus, l’article souligne l’importance de prendre en compte les contraintes de fabrication lors du processus de conception.

KEYWORDS. Additive manufacturing, design for additive manufacturing, topology optimization, generative design.

MOTS-CLÉS. Fabrication additive, conception pour la fabrication additive, optimisation topologique, conception générative.

1. Introduction

Often affirmed as the next industrial revolution, additive manufacturing (AM) is a production technique that allows designers to create very complex geometries and components with remarkable design freedom [BRI 20]. In compared to conventional subtractive manufacturing techniques, additive manufacturing (AM) forms items layer by layer from digital models [LKA 24]. Furthermore, this adaptable technology eliminates the need for tooling or molds and can quickly produce both prototypes and completed parts [GIB 21].

In recent years, with the significant increase of the computing power and hardware, the adoption of this tools, such as generative design and topology optimization, has boosted the capabilities of AM [WAN 23]. Generative Design (GD) has begun in the architectural field [CAE 20] [SHE 05] and it is always expanding. Major sectors like the automotive and aerospace areas are using generative design solutions more frequently, and the number of generative design tools is also growing [WOH 19], and a large CAD tools developer has also created their own generative design program. The term "generative design" (GD) refers to techniques that allow for DfAM results that are nearly impossible for designer to reach, they are a collection of tools that use algorithms and techniques from artificial intelligence to solve a design matters [WAN 23].

Although TO analyses are now considered standard tools [OUC 23] [GRI 22], the potential of GD has not been completely realized [WAN 23], and since the Autodesk's GD (AGD) is a tool that can be used without requiring a significant amount of setup and adjustment. These characteristics made it a good choice for our study case to attend the design objectives.

As a result, this paper provides a useful and effective details of the AGD design workflow and topology optimization. The study was conducted by employing the AGD suite of tools to complete the whole design process and applying AGD to a static structural optimization issue. The case study was chosen from the literature, as will be discussed in the next sections of the article, so that the outcomes could be compared to those that were achieved using more conventional methods. The paper contents are organized as follows: The methodology and materials adopted are described in section 2, section 3 discusses the results obtained for the case study, and it concludes with a conclusion.

2. Materials and methods

In order to accomplish the suggested study objectives, the approach presented in Figure 1, which consists of three main elements, it uses several DfAM methodologies for complicated functional design: Design and analysis of functional features using numerical simulation and AM processing knowledge by evaluating an original CAD design or resulting from a design problem. The final stages consist of integrating several DfAM outcomes for a continuous design model.

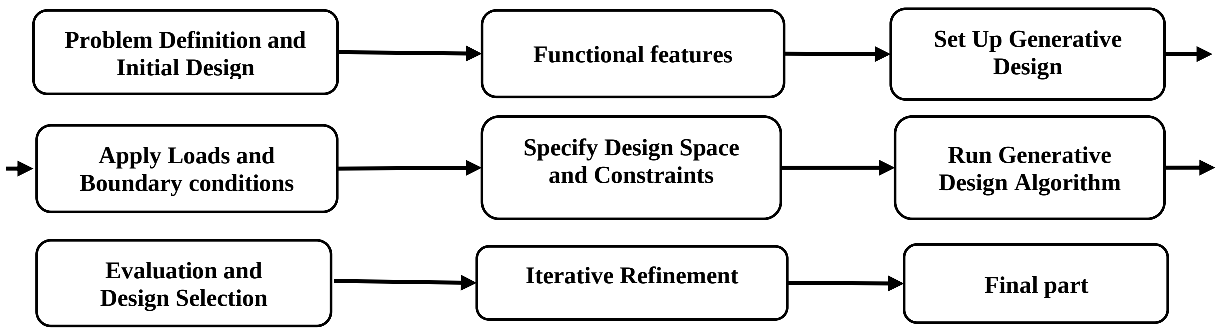


Figure 1. *A workflow of the methodology adopted*

3. Case study

The case study used to evaluate the proposed methodology is a robot's gripper arm that is assigned to handle objects. The Figure 2 assigns and shows the part's general form and constraints, the red highlights indicate the sections that need to be kept intact. The general objective is to reduce the component's weight within the constraints set by the design specifications indicated in Table 1. A static force of 20000 N is applied orthogonally to the gripping surface as in Figure 2, as the gripper arm is limited by two cylinder surfaces that link with the robot's other components. With a safety factor of 3, a maximum deviation of 8 mm is permitted.

Parameter	Value
Material	ASTM A36
Max deflection	8mm
Safety factor	>3
Force applied	20000 N

Table 1. *Design specifications*

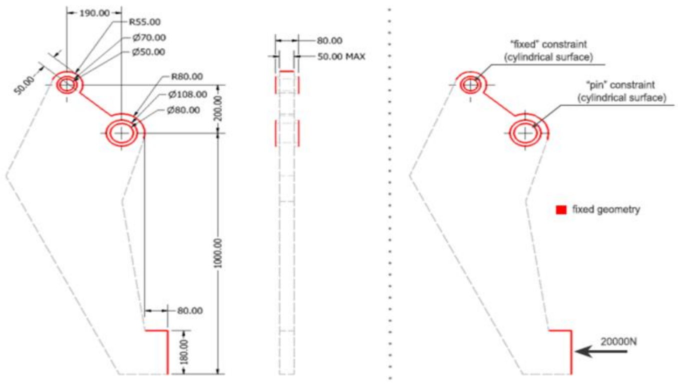


Figure 2. *Part's design constraints*

The software used to analyze the part is Autodesk's Generative Design (AGD), hosted in Fusion 360 and the steps making up the AGD's framework are given in Figure 3.

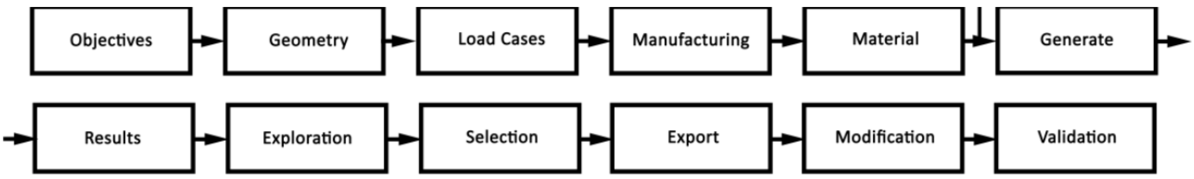


Figure 3. The Generative Design Framework for Autodesk

In parallel with the analysis executed in Fusion 360, an optimization study is performed using ANSYS software with the same parameters and the Figure 4 presented the results for the static structural and the topology optimization results.

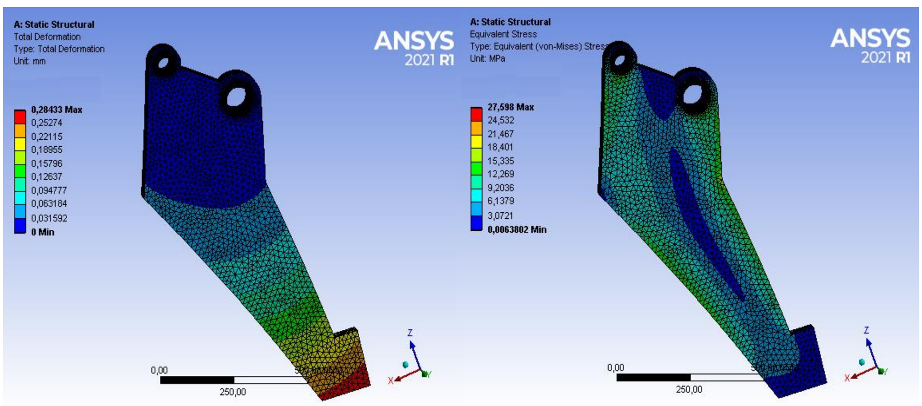
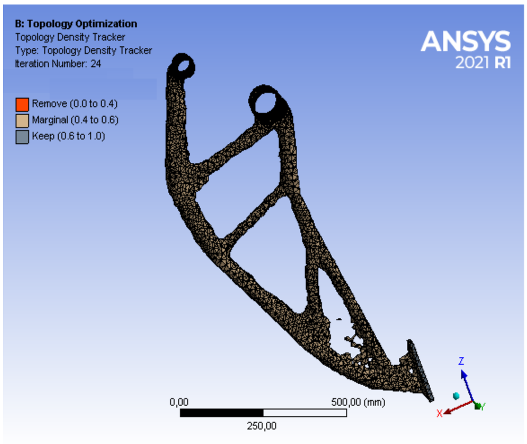


Figure 4. *Total Deformation and equivalent stress of the part*

4. Results and discussion

The Figure 5 shows the topology optimization of our part, which was initially constructed of ASTM A36 steel and exposed to a focused force of 20,000 N, which has effectively produced a notable decrease in material without compromising structural integrity. The optimized part is not just lighter, but also demonstrate an improved stress distribution. The optimization algorithm places material only where it is necessary, while maintaining is performance.



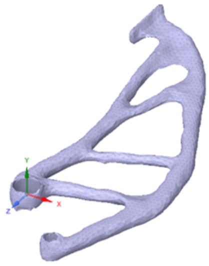
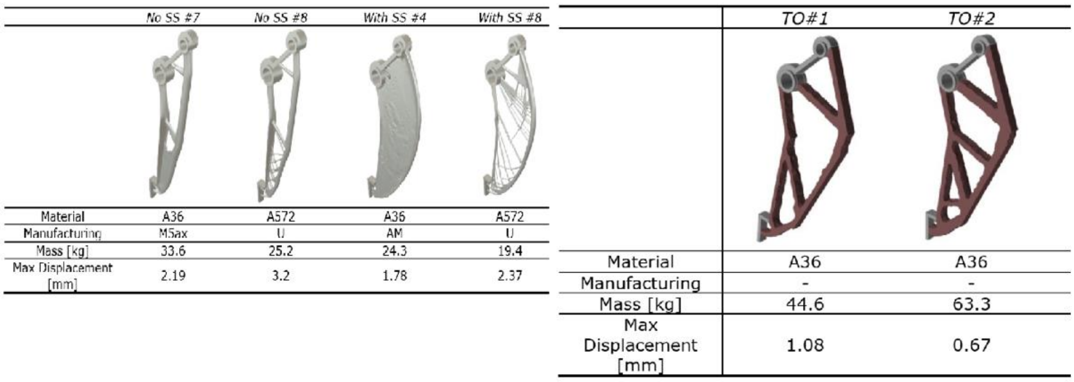


Figure 5. *The topology optimization result's part*

In order to consider as many aspects as possible, Generative design techniques were used to explore a wide range of potential design solutions based on the specified constraints and objectives. The AGD provides the possibility to consider many aspects as possible such as material which can be selected from Fusion 360 library and production technology which introduces some design constraint to allow manufacturing of the part.



	No SS #7	No SS #8	With SS #4	With SS #8
Material	A36	A572	A36	A572
Manufacturing	M5ax	U	AM	U
Mass [kg]	33.6	25.2	24.3	19.4
Max Displacement [mm]	2.19	3.2	1.78	2.37

	TO#1	TO#2
Material	A36	A36
Manufacturing	-	-
Mass [kg]	44.6	63.3
Max Displacement [mm]	1.08	0.67

Figure 6. *Mechanical characteristics of a portion of the AGD-generated data*

5. Conclusions

The transformative effects of topology optimization and generative design on the design and production of components in additive manufacturing techniques are investigated in this work. Improving structural performance with less material consumption and ensuring manufacturability was the main goal. Several alternative geometries that conventional design techniques could not have revealed could have been discovered via the investigation of a variety of creative design options made possible by generative design. These generative designs were further improved by topology optimization, which carefully redistributed material to enhance structural efficiency. Consequently, an optimized component was created that could sustain a focused strain of 20,000 N while achieving a noteworthy weight reduction. In comparison to the original design, the optimized design showed less deformation and better stress distribution, the study shows how important it is to combine topology optimization and generative design into the workflow of additive manufacturing. The next part of this work is to prototype a scaled down ABS part, in order to demonstrate the effectiveness of the methodology and that the optimized design could be effectively manufactured and perform under load, and the use of generative design and optimization tools in the additive manufacturing.

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