A Methodology of Additive Manufacturing Technology in Ceramic Field

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Summary:

The application of design ideas determines whether they are creative or not. Creativity is about finding a solution to a problem or a new idea and its appropriate application or tendency to be an innovation. It is not a skill to create ideal ideas greater than the ability of human beings, but the skill is to find creative applicable ideas, which is enabled now by additive manufacturing technology, its new trends in the design process and its various advantages as precision with complex details and speed of achieving the idea in virtual model which was not possible before using AM technologies in production and application of different ideas in design.

It is important to know that additive manufacturing comprises much more than just design and methodology. It is a complete process in which every building block has an essential role to play. Before getting started with the part-printing process. Ceramists have to work with a design that appropriately considers the requirements, the production technology and the material, and they must have a clear understanding of the possibilities, challenges and potential added value of additive manufacturing technology.

AS additive Manufacturing development has a significant impact in ceramic field, AM opened up new horizons in design trends, so this research attempts to shed light on the development of this type of technology and its effect on the design methodology through analyzing of ceramic artistic examples.

The research presents a general methodology aimed at covering all AM technologies in general, taking into account that AM manufacturing includes many different techniques and materials, ranging from polymers, ceramics and metals and therefore each technology and materials will have their own characteristics and requirements, but this methodology is a good starting point adapted to the requirements of ceramics in particular.

Keywords:

Ceramic – Design – Methodology.

Research problem:

With the great development ‘of additive manufacturing technology as a creative technology, now ceramic designers are able to transform the impossible creative idea into real applied

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design, so it is necessary to study the AM design methodology to improve ceramic design process.

Research Objective:

- Emphasizing the importance of AM technologies in creating new ideas.
- Highlight the role of Additive manufacturing technology in ceramic field.
- Present a simplified stages for AM design methodology.

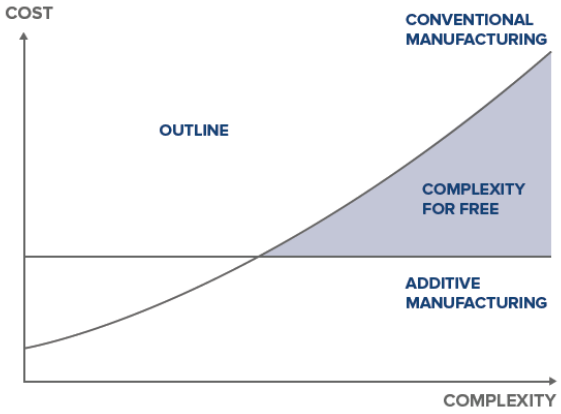
1- Additive Manufacturing as a Creative technology:

The means of applying ideas in applied arts is one of the most important factors for the success and demonstration of design, and by Additive manufacturing technology specially in ceramic field, additive manufacturing technology is classified as one of creative technologies in a variety of disciplines combining computer, design, art and humanities, this type of technology aims to develop new innovative products designed for everyday use.

Creative technology interferes with number of design fields: industrial, advertising and interactive graphic, as some believe that "creativity has the potential to revolutionize technology", and others prove that creative technology fields pushed to develop creative ideas in more integrated and realistic experience. (3)

2- Additive manufacturing and Design process:

Since the beginning of the first industrial revolution and technological development of the 19th century, engineers and manufacturers have faced limitations in new manufacturing technology of what they can produce and how to produce it. Today, at the beginning of the digital manufacturing revolution, with the advent of 3D printing and AM techniques in ceramics, the Methods and machines have evolved considerably and has grown faster and have approached the speeds of traditional manufacturing methods then became more accurate and fast as shown in graph (1), resulting in increasing numbers of companies to adopt 3D printing as manufacturing method.



Graph (1) shows the complexity of products in traditional manufacturing and AM technology VS cost.

AM's possibilities provide ceramists and designers with a new freedom to create innovative designs in comparison with traditional manufacturing processes, allowing creation of complex geometric shapes that were unimaginable before AM such as: lightweight structures, more specialized functional products and more creative artwork. The key to the full use of AM's capabilities is through the design phase before the implementation process. This is not just a

process based on the imagination of the designer, the skills and tools he uses, but the designers and engineers who use 3D ceramic printing today must be taught a different way of thinking not according to the possibilities of traditional manufacturing methods, but according to the infinite possibilities offered by this type of technology.

Designers must learn how to use fast and flexible design tools such as 3D CAD software, not just thinking in the details of programs that can take a long time to create a 3D model in high-quality dimensions and forget about the design as all and how successful it is by using traditional modeling programs that often lead to lose focus on the actual intent of the design.

Today, specialized design programs are available to Design for Additive Manufacturing (DfAM: a manufactural design that applies AM manufacturing process), these programs take into account product life-cycle considerations: manufacturing capability, accuracy and cost, according to the potential of AM techniques. "(2)

This type of software provides tools to improve structural engineering resulting in exceptional organic forms. It creates an ideal model based on specific materials and constraints. By analyzing the process several times to achieve the optimum results.

For example, lattice design is used to design lightweight parts while maintaining a high level of performance. It creates lattice structures can be applied to shapes. (٩)

The current generation of AI CAD (Artificial Intelligence) software tools as Topology Optimization support the design process, where the designer has a set of objectives, constraints and work standards, then software algorithms explore the optimal design solutions for these constraints and standard, this means the actual modeling function will be implemented by the program and not the designer, and the designers will be able to explore a number of different solutions to a single problem in a shorter time frame, as shown in pic.1 these design tools allow producing highly complex geometrical parts with high precision, lighter weight, and better-performing parts exactly the contrary of using traditional manufacturing techniques as shown in Pic 1 . (4)

Pic. 1 shows a set of ceramic parts: filters and machine parts with lower weights and better performance printed by Canon with Selective Laser Melting (SLM)

Technology of alumina and zirconia.(٥)

3- Design considerations for additive manufacturing:

There must be a special methodology for AM technology with considerations: the function, manufacturing and post-processing, as shown in diagram 1.

3.1 Design for function:

Because of fabrication method of additive manufacturing technology which is building shapes by layers, it is possible to create very complex parts either very small or large sizes, which

increases the functional value, producing complex internal undercuts and integrate multiple parts into One part to reduce assembly time and cost.

3.2 Design for Manufacturing:

To know all the design considerations of AM technology which involves too many technologies is difficult. There are many things must be considered between different processes and materials for manufacturing, but there are general considerations:

• Reduce using materials amount and support structures.
• Remove excess material and support media.
• 3D printer size and available printing space.
• Design small details according to printer specifications.
• Mechanical properties may vary due to different processes and technology.

In general, the design rules for manufacturing technology should be more specific, depending on the type of technology, materials and printer used. (1)

3.3 Post processing:

Although the printing process is almost automatic, post-processing involves a lot of manual work, including removal of the extra material, supports, finishing, etc., and the more manual work required the higher final cost. Post-treatment must be determined in design requirements and materials. There special materials with high tensile strength, compression and durability have a proper treatment such as ceramics have to be carefully and slowly in post processing to reduce the risk of subsequent damage. In general, such decisions should be considered when designing and producing parts with AM technology. (٦)

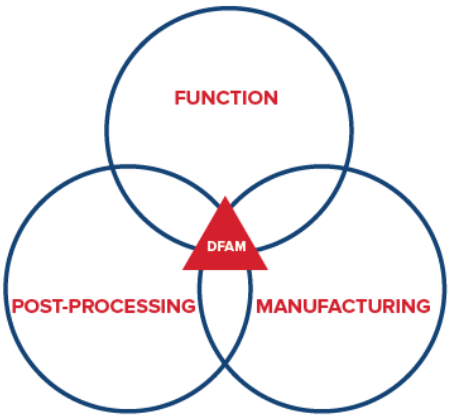


Diagram 1 shown Design considerations for additive manufacturing

4- Additive manufacturing design methodology:

AM design methodology consisting of 6 different stages as follows:

4.1 Analyzing specification:

Before starting the actual design, we need to get as much information as possible about product requirements, by putting all the questions related to the design requirements, often the previous designs help in answering all questions and analyzing the required specifications correctly to reach a concept and preliminary idea. (1)

4.2 Idea and concept generation:

In AM as well as in traditional design processes the second stage is the generation of new ideas and concepts, but in AM parts, they can be built with high degree of freedom and

complexity in order to increase the functional value, so during this stage the function and its requirements is very important and by using the new soft wares that help in reconciling the functional requirements with the design, which gives a clear overview of the design loads and its compatibility with the functional requirements and design shape: hardness, weight limits, (Topology Optimization), etc. and of course using the least amount of material can affect 91% of this total cost of production and energy consumption. (٧)

4.3 Concept Reflection and Selection:

At this stage, the concepts and ideas produced from the previous stage are combined with predefined requirements, then some basic questions must be answered:

• Does it meet the requirements? Compare new concepts and specifications and the requirements.

• What material should be used to meet the requirements?

• Do you need post processing? Some AM techniques produce less accurate surface quality, thus requiring further processing that means cost and time.

4.4 Concept optimization:

After selecting the best concept and identifying the general requirements, the concept needs further modification to increase the functionality of the component or design and the possibility of integrating more than one part. Will the design require support structures? Or reducing the production constraints by modifying the design or implementation to reduce time and cost, and once materials are selected, the most suitable production technology should be chosen for the design(١) .

At this stage, the optimal direction of printing must also be determined and depends on a number of factors including: production technology, materials (affect surface quality) and mechanical properties, for example, if the print orientation is horizontal the part will build with great strength and precision, and if the print orientation is vertical it will look better but weak, and if the print orientation is horizontal on one side the printing will be faster.

Design orientation during printing requires maximum communication among engineering departments. (٨)

4.5 Detailed design:

At these last stages of the design methodology, the design details should adjust for manufacturing, applying the design rules of the technology used and post-processing steps.

Since there is such a wide variety of design rules and requirements for to AM techniques, it is almost impossible to establish general rules but there are some design details must be considered.

4.6 Reflection VS Requirements:

Comparing the final design with the requirements initially identified is an important step during the design process, and before finishing the design you should know:

• Parts or functions could be integrated?

• Has the most suitable technology been selected for the application?

• will AM process be as intended?

If yes, you should immediately start adjusting the machine settings to begin the AM process. (1)

Research Summary:

- Additive manufacturing technology led to a significant development in design possibilities rather than thinking of design limitations, new AM design software programs provide a great deal of flexibility in Ceramic designs implementation, and applying the right steps of AM design methodology led to exceptional results and saving a lot of time and effort in design process to the final product.

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