RNI: MAHENG/2016/68030 Vol. 4 Issue 2 Mar-Apr. (2019): Page No.08-12 ISSN: 2456-5342 (print)

MGM's JAWAHARLAL NEHRU ENGINEERING COLLEGE

VISTA INTERNATIONAL JOURNAL ON ENERGY, ENVIRONMENT & ENGINEERING

VISTA

Sustainable Product Design and Development: Additive Manufacturing

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ABSTRACT

The additive manufacturing gives various opportunities that provides a large benefit to the designers and supports the sustainability of products. The additive manufacturing technology has removed the various restrictions which were present before. This increased the designer's ability to manufacture a product of their desirability, pleasure and attachment. This has provided a great potential for the customization of the product, which was first wasn't possible. The product design and development will greatly change with the increased advancements in the additive manufacturing. This work narrates the use of Additive Manufacturing as a tool to increase the sustainability of the product in various possible manners.

Keywords : *Sustainable Product Design and Development, Additive Manufacturing*

1.Introduction

The past decade has seen tremendous changes in the product design. With increasing demand in the more complex design of the product, the society urged for the betterment of the environment. This made the designers in the world to look forward to the sustainability of the products. Sustainability is now an important aspect for any product and this will lead to our better future. Sustainable development has been defined in many ways, but the most frequently quoted definition is from Our Common Future, also known as the Brundtland Report. Sustainable Development is a form of development which satisfies the needs of present generation without affecting the capability of future generations to satisfy their needs. The major concepts on which sustainable development is based include: firstly, the vital needs of the global poor populace which should be accorded priority. Secondly the restrictions that are posed by current state of technology and societal organizations on nature to satisfy current and future needs.

A concept of Triple Bottom Line was put forth for more sustainable products by John Elkington in 1994. This concept means the profit or loss for the business houses depending on the considerations of revenue and expenses at a very basic level. The Triple Bottom Line, considers in it the three bottom lines in the categories of Social, Ecological (Environmental) and Financial (Economical) aspects of a product. The concept is being adopted by many industries. The concept also rises the business value to a great extent. India having a population of 130 billion, has a great potential for the growth of Sustainable Product Design and Development. Thus, it becomes necessary for the

companies and designers to go for the sustainability of the products. Moreover, due to the high birth rate, preserving the resources and making the best use of the available resource is a matter of concern.

2. Literature Review

In a paper by Gmelin [1] on the determinants of a sustainable new product development he effectively linked sustainability and a new product development with the help of a conceptual structure which highlighted the linkages between them through a life-cycle and product-oriented approach which was a newly presented concept. This suggests that it is significant to consider life-cycle and product life-cycle management which provide the basis for developing a sustainable new product based on inter-departmental and inter-firm processes, data and staff.

In 2015, Chou[2], in their research paper commented that, "Life Cycle Assessment" (LCA), is no longer the only approach to interpreting the performances of product-service systems. Multiple criteria reflecting productservice quality, customer satisfaction, and the full sustainability concerns would be needed to evaluate the system solutions." Their paper discussed the concept of sustainable product efficiency, that explores the relationship between product-service value and the sustainable impact, can be applied to assess sustainable product-service system.

Salari (2016) [3], in their work on improving the current sustainable product development, argued that the environmental aspects at early stages of the product development can be significantly considered for the environmental performance of the product to be improved. They emphasised on the methods and tools that have developed in order to develop the product in a more ecological way. Their discussion included classification of tools and the limitations and barriers of current tools.

The forthcoming industrial revolution 4.0 has set the stage for product design. Gerlitz[4] in their research paper discussed that concepts of strategy and innovation along with open innovation which include design and 4.0 industry perceptions are associated with practice-orienteddesign integration in new product development. This indicates the manner in which smart digitalization and new technologies initiate innovations driven by design. The role of design is illustrated by interconnected dimensions of information, technology, communication along with societal stakeholders for sharing product or service attributes in an open manner.

3. Additive Manufacturing

In general, the Additive Layer Manufacturing (ALM) is nothing but the opposite of subtractive manufacturing, where material is removed to get desired shape. Basically, the concept of ALM is building 3D parts under computer control. Initially 3D printing was used for rapid prototyping, but the manufacturing units didn't take longer to realize the endless capabilities of this entirely new fabrication process. The use of Additive Manufacturing didn't just make the advanced applications in aerospace and cars components efficient, but also made the creation of complicated ones possible which were not possible before. The most commonly used materials are Inconel 718 and titanium Ti6Al4V.

The additive manufacturing is not like subtractive manufacturing where the material is removed to gain the desired shape, but is the process of joining the material to build 3D structures, adding layer by layer.

3.1.Types of Additive Manufacturing

Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS) and Selective Laser Melting (SLM) are the three most commonly used techniques of Additive Manufacturing.

SLS and DMLS are effectively the same processes, where the particles of the material are merged without reaching the melting point of material. SLS is used to merge the non-metals (Fig.1), while DMLS is used for metals. SLM is slightly different because it involves a full melt, i.e., it reaches the melting point of the metal, so that it is first heated and then cooled to fully consolidate. The final product won't be porous as in DMLS as the metal reaches the melting point.

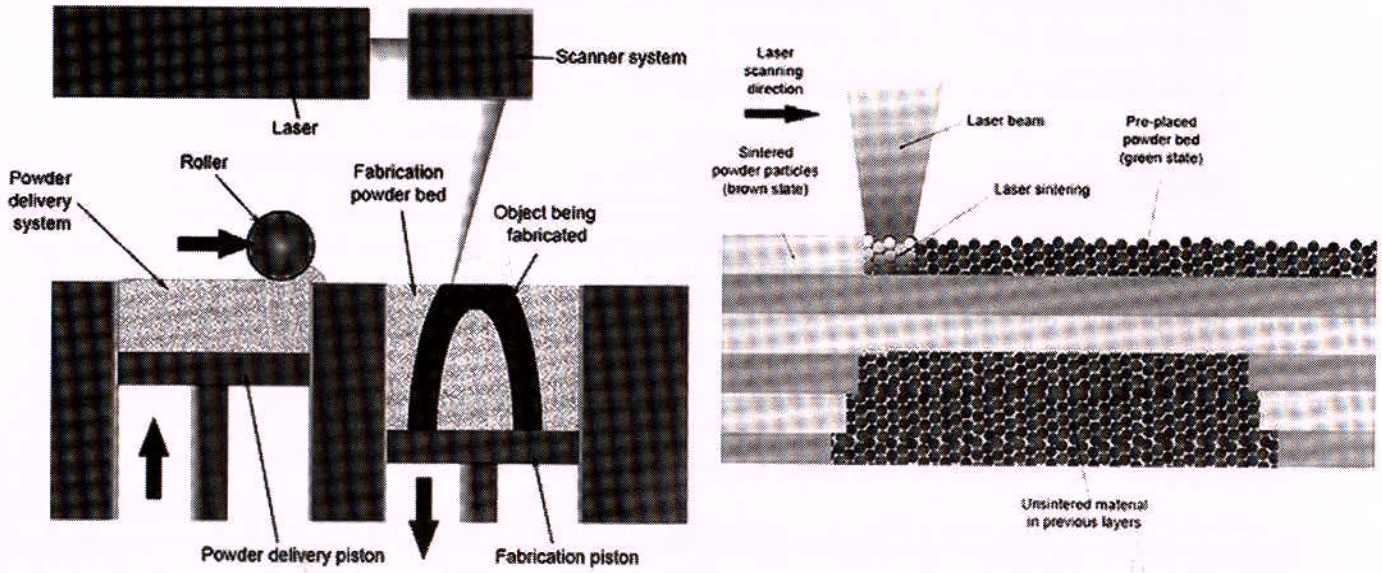

Fig.1 Selektives Laser Sintern (SLS)

3.2.Applications

Additive Manufacturing (AM) has limitless applications and is extremely feasible, as it provides affordable complexity in design. It has got various advantages with design consolidation and function integration as the most significant ones. Having the simplest layer-wise approach of production, its speed, repeatability, quality and material flexibility restrained its uses to rapid prototyping and preproduction visualization models. Now with the upgrading technology, it is now used to produce end-use products in aircraft, dentistry, bioimplants, cars, and even for luxury and fashion products.

Prototyping is one of the applications where experimental and visualization of the product is done before the starting of manufacturing process. Creating highly customized products, production of small units of serial components and rapid casting are other applications of AM.

Today, the additive manufacturing has become very relevant for aerospace industry for production of lighter weight components (and hence improving the efficiency and lowering the fuel consumption) and to consolidate. Also, it brings in the belief of the automotive industry to produce more efficient cars and designs that were thought of to be unconceivable before.

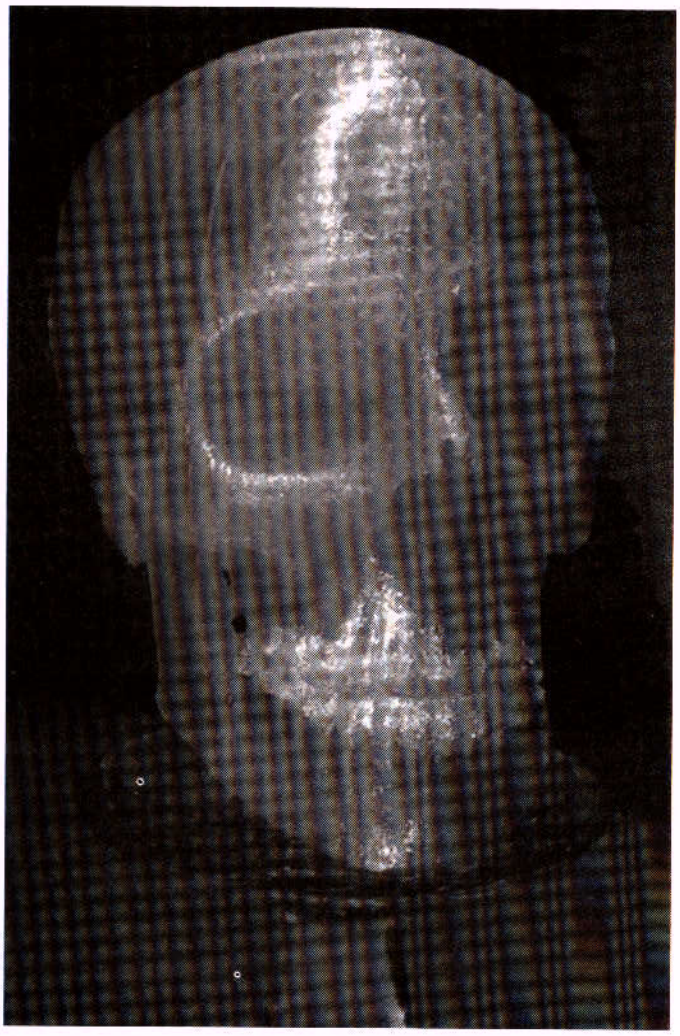

Fig.2 3D Printed Macrognathism

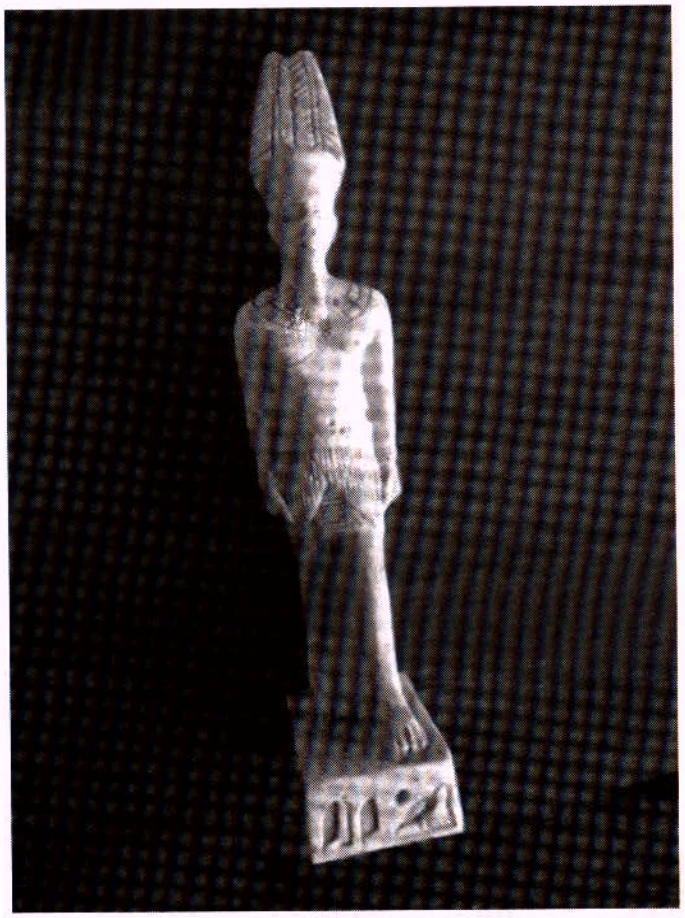

Fig.3 3D Printed Ancient Egyptian Figure

4. Merits and Demerits

The merits and demerits of additive manufacturing are discussed as follows:

4.1 Merits:

- Additive Manufacturing takes production to the next level, even though the traditional manufacturing techniques can be made use of to produce great range of shapes and designs (Fig.2,3).
- The greatest merit of this process is the wider range of shapes that can be produced. Again, the product can be manufactured in a single piece, not like the ones that were built part by part and then assembling into a single through traditional means. Thus, the strength of the product manufactured by means of Additive Manufacturing is greater than the ones made by conventional methods.
- The method being quick, saves time and hence the money. This method just requires the use of the CAD software, and the program can be changed simply by clicking the mouse in case of any changes in the product. The process generally gets completed over a night, which provides flexibility for the companies resulting in the slashing cost of product.
- As just the amount of material required is used, there is very less material wasted.
- The conventional techniques had to rule out their ideas due to unachievable designs. This process significantly overcame this limitation very efficiently.

4.2 Demerits

Even though the additive manufacturing has a greater range of designs for products, it has got limitations using wider range of materials for the production, but with the progress of this technique, day by day various new materials are being add up.

5. Conclusion

Sustainable Product Design and Development is all about efficiently increasing social and financial impact of the product decreasing the harmful effects of it on the environment. Increasing the attachment between product and user helps in the longevity of product and thus leading to the better world with less negative effect on the environment.

Additive Manufacturing provides wider grounds for the design of product and allows large scale customization which provides long lasting product of desired view and of great attachment with the consumers. Various new methodologies can be ruled taking their limitations into account to increase the potential of the process to a greater extent. Tools such as Life Cycle Analysis (LCA) and various frameworks can be used in early stages on the production to increase its longevity. The currents frameworks may be revised with the time to progress in this field of manufacturing.

Additive Manufacturing has unlimited grounds for development. The process can be revised for further improvements. The technique has numerous applications in the fields of medical products such as hearing aids, biological implants, and automotive, aviation and marine industries. Also the textile industry has now started adopting this technology.

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