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Importance and Utilization of 3D Printing in Various Applications

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ABSTRACT : 3D printing is one of the most important technological advancement in Additive manufacturing which has been Implemented and recognized as a part of modern industry as it has many advantages over conventional approach of which one of the most important factor which is time. Generally in Fused Deposition modeling the component is manufactured using the concept of rapid prototyping and Layer by layer deposition of the material which is done by sending the data into the software of the machine using a Stereo lithography (.STL) file format made by using Modeling software (CAD). In today's world of Mechanical Engineering the applications of 3D Printing are very useful for Research and Development of various components ranging from simple structures used in everyday life to complicated Components in aerospace applications, 3D printing Provides many advantages few are Simplicity, Reliability and Precision etc this makes it one of the most widely used for making components which can be used as concept. Components.3D printing is the most widely used additive manufacturing processes in the current industry not only limited to Engineering. This paper presents an overview of Additive Manufacturing and Various applications o f engineering.

Keywords: *Rapid Prototyping, Fused Deposition Modeling, 3D Printing, Applications.*

I. INTRODUCTION

3D Printing is a rapidly growing field in multiple disciplines of which few are Mechanical, Medical, and Civil, Electrical etc. It is a part of Rapid prototyping Methods which uses the concept of additive manufacturing. The concept of Additive manufacturing was utilized in the development of 3D printing which is the deposition of liquid material layer by layer to get the final component according to given design. In today's manufacturing industry 3D printing is a very important part because of its simplicity and reliability to produce very complex and precise components.3D printing has broken many barriers of which one of its implementation in outer space components like its use in the mars rover. This paper consists of few applications of 3D printing in various applications.

II. OVERVIEW OF 3D PRINTING, FDM AND RAPID PROTOTYPING

Rapid Prototyping (RP) has become one of the fastest growing new technologies. Prototypes are Building in just a few hours, from a CAD file in which the geometry of the model is defined in 3D. It gives the designer possibility of verifying the shapes of the product, validate if it fits into the assembly with the desired functions. It cuts down the required time to design a product. It has been used in Mechanical design, aerospace medical application, arts, and architecture and it is a potential tool for the mechanical field [1]. Additive manufacturing processes are employed to create physical models from three-dimensional (3D) Computer aided design (CAD) models. Fused deposition modeling (FDM) is an additive fabrication Process that builds a product from thin layers of extruded filaments of a semi-melted thermoplastic. The parts Mechanical properties depend mainly on variable factors such as the material's depositing orientation, the Filament's flow rate, the raster's separation, and the extrusion temperatures. These parameters control the Part's mesostructure (when the extruded fibers' scale approximate to 0.1 mm) characteristics and influence the fiber-to-fiber bonding. The dependence of the FDM material's properties provides the designer the ability to optimize the mechanical performance while modifying the part's meso and macro structures. The two Main FDM manufacturing strategies (solid and shell) may be used indistinctively; however, there are Applications where the solid build strategy may not be necessary and even problematic. When there is a Thick wall - thin wall blend, this configuration may lead to distortion [2].

3D printing (3DP) is becoming a research and development focus in many fields including biomedicine and biology as it can quickly and accurately fabricate any desired 3D model of any size. As one of the rapid prototyping (RP) technologies for directly digital manufacturing that provides capabilities for creating a wide range of object geometries in a broad variety of materials. The fabrication in micro and nano level may change the performance of biomaterials and devices compared with the traditional technologies [3].

III. UTILITY OF 3D PRINTING

3D printing has major applications in fields of mechanical engineering and Aerospace Industry. This has made Research and Development in these Industries along with its use in manufacture.3D printing has the added advantage of making the process simpler to make any component as it has only three parts for its output, which are DESIGN, ANALYSIS, PRINTING of the final component using the 3D printer.

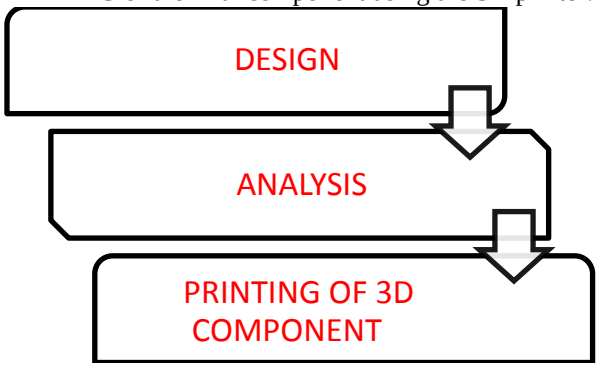

Fig. 1

3D printing has many utilities in manufacturing industry few of which to be explored are
i. Mass Customization of products.
ii. On Demand Component production.
iii. Provision of making the physical component which can be utilized to verify and make corrections.

i .Mass Customization of products:

Mass customization is distinct from the strategy of delivering as many product variants as possible. More specifically, it concerns delivering the desired product - on a mass scale - after the expression of needs taken place [4].
Mass production is one of the most used methods to manufacture in order to keep up with the growing demands in today industry.
This has made 3D printing one of the forerunners in the mass production industry.
The search for balance between the product's price and the degree of its adaptation to individual customers is a permanent dilemma for manufacturers. On the one hand, mass production means low costs. On the other hand, a better adaptation of the product's characteristics and its functions to the buyer's needs means the possibility of obtaining a higher price. That is why, for example, a luxurious product which is usually characterized by a high degree of adaptation to requirements and an adequate price cannot be a mass product. Mass customization is supposed to reconcile these extremes, namely make it possible to provide the customer product with high degree of adaptation and a price comparable to a mass product [5].
By using this idea we can get an understanding what 3D printing as a manufacturing resource for mass customization will be having as to that of the concept of mass production by Henry ford which if implemented rightly creates an entire different market scenario.
In the future, we should expect a further development and diffusion of mass customization in subsequent trade. This will be fostered not only by factors which have so far resulted in its creation and evolution. In the case of production, an increasing role will be played by fully robotized systems with ever greater flexibility.
The 3D printing technology seems to be very promising in this aspect. On the other hand, regarding the identification of the customer's requirements, IT systems gathering information from numerous distributed sources and then analyzing them and searching for patterns in the behavior of particular customers will play an increasing role.
The above demonstrates the need of customized mass production industry which only 3D printing can provide.

ii. On Demand Component Production:

On Demand Component Production is the process of making the component then and there depending on the customer needs specifications and requirements.

This can be done either by using the component directly to the application or using the component as we make pattern for use in casting either in Metal casting or molding.
Component in direct application where the 3D printed part is directly used as part in the machinery.
Recent advances in 3D printing have made it possible to make components which are precise and to make them in direct use in the parts of working of machinery.
With over 2,500 FDM components, the Kaveri jet engine prototype may be the most complex rapid-prototype assembly ever created. It took GTRE only 30 days to produce all these components from ABS plastic using Two FDM-based Fortus (earlier FDM TITAN) machines. It took another 10 days to assemble the engine. The total cost to produce the FDM assembly was about $20,000[6].
This showcases the latest trend where the 3D Printing was used in a practical application. Although many Components can be made for use in daily life 3D printing has a disadvantage over injection casting where the constant is time although this can be useful in scenario where customization is one of the key impacts point of the research and development.
Component in direct application where the 3D printed part is made as a pattern and used to make the cast where it can be used as a regular casting or investment casting depending on the need:
In this scenario the component printed and then it is used as the pattern this has shown various advantages over conventional casting methods, this was done experimentally by Vinay Pramod et.al in 2015 in their study
Feasibility Study on 3D Printed Patterns in casting [7].
This experiment has proved that casting made using 3D casting patterns using PLA material and was compared with a traditional wooden pattern both of them were investigated under a Scanning Electron Microscope with Magnifications of 250 and 1000; although they both have similar surface finish the 3D printed pattern based casting has exhibited a better finish over the wooden pattern based casting.
Investment Castings (IC) is used for making metallic components which are difficult or complex to make using traditional methods.
In an study done by Sivadasan M et.al on topic of Use of fused deposition modeling process in investment precision casting - a viable rapid tooling they have concluded the following which show cases the utility of 3D printing as investment casting option.
The study explored the applicability of FDM and pattern worthiness of ABS in IC. The results indicate that burning ABS generate non-Sticky, loose & brittle- minimal residue around 1.5% and is can be remedied by suitable process variations -post cleaning of the shells [8].
This study was done by 3D printing and using ABS (Acrylonitrile Butadiene Styrene) as the pattern it is first tested for its worthiness, type of ash and burnout, Test of thermal decomposition, Test for replicas of precision patterns and testing casting through IC route although there is ash residue it can be reduced cleaning of the shells after casting.

iii. Provision of making the physical component which can be utilized to verify and make corrections:
In industry there is regular need for research and development of products and components. The conventional approach is to develop a new product from scratch (or) Develop the existing product to make a better version, then the product is designed, analyzed, making the product using machining or casting using other traditional methods with lot of skill and time, and checking whether the component is applicable for function with other parts of the component either by dimensionally, shape, profile etc because of today's mechanical components and machine complexity is very complex functionality they need to be perfect in all aspects of physical characteristics like shape, dimensions etc.
Here 3D printing provides an advantage over traditional methods where the component is made once the Design is modeled and Analyzed, it can be made easily with simplicity 3D printing provides in making the component with knowledge and less time, it can be used to check the dimension, shape aspects, physically the product can be checked visually to find out if any design changes need to be made, using the Coordinate Measuring Machine to check the dimensions and shape, using the profile projector to check the profile of the component, then it can be used to check the product as a part in the machine to check it is a good fit etc.
In a study done by Dr. B.Satyanarayana and Kode Jaya Prakash on Component Replication using 3D Printing Technology, they have made a key by using an existing key as a reference, and it was designed with using CATIA software, the key is made using Makerbot replicator machine using ABS filament, finally the key is verified against the original in dimensions by using the profile projector to find the dimensions of the 3D printed key which had proved that the dimensions are very close to the original it was also Checked in assembly with the lock to know whether it is a good fit[9].
Based on the above study we can infer that the component can be checked once in 3D printing before the final part is made using machining or the 3D printed part can be used as the casting saving time in machining and conversely in traditional approach each time there is a problem with the made component in any aspect the component has to be remade each time this is very costly, time consuming and consumption of resources.

Furthermore 3D printing in everyday life can be used in various applications in some situations like Military Zones, Disaster Affected zones and Remote Areas which have one of the most important needs for parts and components which are needed in terms of Medical components, automotive components, and miscellaneous components.

Medical Components:

Components like bones, Prosthetics, Stretchers, and Casts for broken limbs are usually required in these zones which of which some they have the best function if they are customized.

In a study done by Azem Yahamed et.al on Application of 3D printing for Human Bone Replacement, they have investigated the utilization of thermoplastics as a replacement for bone structures and their feasibility they have made the component using 3D printing by Initial Bone geometry scans are done On CT or MRI of actual organs. ABS (Acrylonitrile-Butadiene-Styrene), PVA (Polyvinyl Alcohol), PLA (Polylactic Acid) and Nylon 618 were selected are used for selection of the bone replacement material on the component then these materials were tested for tensile strength. They made use of 3D slicer or OsiriX software to design and convert the bone models. The bone model is created using Osirix and converted into STL file and are cleaned using Mesh Lab Software. They are then sent to the 3D printer to be printed into a bone structure.

They have observed that the MTS Tensile test values of the thermoplastics above were not up to the standards of the manufacturer based on the reason that they used structure filling of only 15% of the component rather than 100%, but these thermoplastics printed by using 3D printing are durable enough to be used as a replacement [10].

IV. APPLICATIONS OF 3D PRINTING

Applications in design:

CAD Model Verification:

The initial objective of designers is the need of physical part to confirm the design created in the CAD system. The parts or products designed are verified whether aesthetic functions are fulfilled or not from the printed parts.

Visualizing Objects:

Designs created on CAD systems need to be easy to visualize amongst designers and to other departments, manufacturing and marketing. Easy visualization of objects helps all those people will be referring to the same object in any communications.

Proof of Concept:

Proof of concept relates to the adaptation, of specific details to an object environment, aesthetic aspects and specific details of the design on the functional performance of a desired task or purpose.

Applications in engineering, analysis and planning:

Scaling:

Rapid Prototyping technologies allow easy scaling down (or up) of the size of a model by scaling the original CAD model. In a case of designs with different holding capacities, the designer can simply scale the CAD model appropriately for the desired capacities and view the renderings on the CAD software.

Form and Fit:

The sizes and volumes, forms have to be considered from the aesthetics and functional standpoint. How a part fits into a design and its environment are important aspects to be addressed. The model will be used to evaluate how it satisfies both aesthetic and functional requirements. Form and fit models are used in the automotive industries, aerospace, consumer electronic products and appliances.

Flow Analysis:

Designs of components that affect or are affected by air or fluid flow cannot be easily modified if produced by the traditional manufacturing routes. The original 3D design data can be stored in a computer model and any change of object data based on some specific tests can be realized with computer support. Flow analyses are necessary for products manufactured in the aerospace, automotive, biomedical and shipbuilding industries.

Pre-Production Parts:

In cases where mass-production will be introduced once the prototype design has been tested and confirmed, pilot-production runs of ten or more parts are usual. The pilot-production parts are used to confirm tooling design and specifications. Many of the rapid prototyping methods are able to quickly produce pilot-production parts, thus helping to shorten the process development time, thereby accelerating the overall time-to-market process.

Applications in manufacturing and tooling:

Direct Soft Tooling:

This is where the mold tool is produced directly by the rapid prototyping systems. Such tooling can be used for liquid metal sand casting, in which the mold is destroyed after a single cast.

Indirect Soft Tooling:
In this rapid tooling method, a master pattern is first produced using rapid prototyping. From the Master pattern, a mold tooling can be built out of an array of materials such as silicon rubber, Epoxy resin, low melting point metals, and ceramics.
Direct Hard Tooling:
Hard tooling produced by rapid prototyping systems has been a major topic for research in recent years. The advantages of hard tooling produced by rapid prototyping methods are fast turnaround times to create highly complex-shaped mold tooling for high volume production. The fast response to modifications in generic designs can be almost immediate.
Indirect Hard Tooling:
Indirect hard tooling methods using rapid prototyping help in number of ways. Many of these processes remain largely similar in nature except for small differences binder system formulations or type of system used. Processes include the Rapid Solidification Process (RSP). Indirect methods for producing hard tools for plastic injection molding make use of casting of liquid metals or steel powders in a binder system.

Applications in aerospace industry:
Design Verification of an Airline Electrical Generator: The Sundstrand Aerospace manufactures inline Electrical generators decide to verify its design of an integrated drive generator for a large jetliner. Sundstrand assembled the various parts and examined them for form, fit, limit function, clearances and interferences between the housing and the many Sub-assemblies were checked. After the initial inspection, several problematic areas were found and were corrected and incorporated into the CAD Design in some cases new models were made

Applications in automotive industry:
Automotive components which have to be cast into metal if they are damaged or defective are very important in terms of mobility in these zones as they restrict movement unless they are replaced, although many components can be replaced these cannot be replaced easily.
These needs in the above situations can be controlled and improved to prevent lack of parts and components using only technologies like 3D printing where things like Prosthetics, 3D casts, etc for medical applications, Metal casting applications for parts, and many other applications in this field.

Applications in biomedical industry:
Components like Prosthetics, Stretchers, and Casts for broken limbs are usually required in these zones which of which some they have the best function if they are customized [11].
Metallization on FDM Parts Using the Chemical Deposition Technique
Metallization of ABS (acrylonitrile-butadiene-styrene) parts has been studied on flat part surfaces. Electro less copper deposition on ABS parts was performed using two different surface preparation processes, namely ABS parts prepared using chromic acid for etching and ABS parts prepared using a solution mixture of sulphuric acid and hydrogen peroxide (H2SO4/H2O2) for etching [12].

V. CONCLUSION:

3D printing is one of the fastest growing fields in Additive Manufacturing.3D printing being used in multiple disciplines irrespective of their application by personalizing according to the need of their particular discipline. 3D printing is used in applications like medical, civil, electrical etc. 3D printing helps in creating prototypes in short duration of time which can be verified and helps in shortening lead times. This paper has reviewed the importance of 3D printing in various applications in mechanical engineering.

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