Issue 9 vol 3 ISSN: 2321-8134

IJFEAT

INTERNATIONAL JOURNAL FOR ENGINEERING APPLICATIONS AND TECHNOLOGY

INNOVATIONS AND FUTURE SCOPE FOR ADDITIVE MANUFACTURING

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Abstract

Additive Manufacturing (AM) has demonstrated great potential to advance product design and manufacturing, and has showed higher flexibility than conventional manufacturing techniques for the production of small volume, complex and customized components. In an economy focused on the need to develop customized and hi-tech products, there is increasing interest in establishing AM technologies as a more efficient production approach for high value products such as aerospace and biomedical products. Nevertheless, the use of AM processes, for even small to medium volume production faces a number of issues in the current state of the technology. AM production is normally used for making parts with complex geometry which implicates the assessment of numerous processing options or choices; the wrong choice of process parameters can result in poor surface quality, onerous manufacturing time and energy waste, and thus increased production costs and resources. A few commonly used AM processes require the presence of cellular support structures for the production of overhanging parts. Depending on the object complexity their removal can be impossible or very time consuming .Currently, there is a lack of tools to advise the AM operator on the optimal choice of process parameters. This prevents the diffusion of AM as an efficient production process for enterprises, and as affordable access to democratic product development for individual users. Research in literature has focused mainly on the optimization of single criteria for AM production. An integrated predictive modeling and optimization technique has not yet been well established for identifying an efficient process set up for complicated 4 products which often involve critical building requirements. For instance, there are no robust methods for the optimal design of complex cellular support structures, and most of the software commercially available today does not provide adequate guidance on how to optimally orientate the part into the machine bed, or which particular combination of cellular structures need to be used as support.

Index Terms: *Additive manufacturing, 3D printing, STL format, etc.*

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1. INTRODUCTION

Additive Manufacturing (AM) allows the automatic construction of physical objects using solid freeform fabrication, by sequential "layer by layer" deposition of material utilising focused energy, often a laser. This technology has demonstrated great potential to advance design and manufacture and has demonstrated higher flexibility than conventional manufacturing techniques for the production of purpose made and customised parts. AM provides a more flexible way to produce objects. Starting from a sketch design, a CAD model of the object is then built through the use of a computer package, and sent to the AM platform to produce the artefacts in a few hours. This method, in comparison with conventional manufacturing techniques, enables a lot of amount of time to be saved in the design development cycle, since the production of prototypes enhances the assessment of object quality and characteristics in a quicker and more efficient way, than if only a drawing was used. Additive manufacturing technology was traditionally used for prototyping purposes, but recently there has been a trend to use AM technology for the production of parts. Following, an overview of the common features of AM is presented, from the initial design step to aspects related to part fabrication.

2. TECHNICAL ASPECTS OF ADDITIVE MANUFACTURING

The AM production of parts starts with a definition of the part geometry in a CAD model, afterwards converted into a compatible data format for the AM machine software as for example the STL (Standard Tessellation Language) format. This data format is used to create a mesh of the internal and external surfaces of the piece using basic geometrical elements like triangles. Some problems can arise with the STL file format as it does not contain topological data and many CAD vendors use tessellation algorithms that are not robust.

The STL file is then sent to the machine for the next operations such as orientation selection, support generation and slicing. Orientation allows choosing the optimal "growing" direction for the piece, which affects geometrical accuracy, surface finish, anisotropic properties, and time and costs of production. Some AM technologies (such as Selective Laser Melting (SLM), Electron Beam Melting (EBM) and Stereolithography (SL) require the presence of support structure to sustain overhanging parts. After the object is built, the supports are sacrificed, thus they represent a waste of material, time and energy. Manufacturing costs of parts made by high-value metal alloys, such as titanium, can be reduced by minimizing the volume of the supports.

Also, the presence of support structures influences directly the complexity of post manufacturing operations; minimizing the volume of support can shorten this operation, thus improving process efficiency. Slicing is a critical stage; it can produce constant thickness layers, or adaptive thickness layers depending on the surface curvature. Adaptive slicing is most used in order to reduce the staircase effect of the surface as well as part fabrication time.

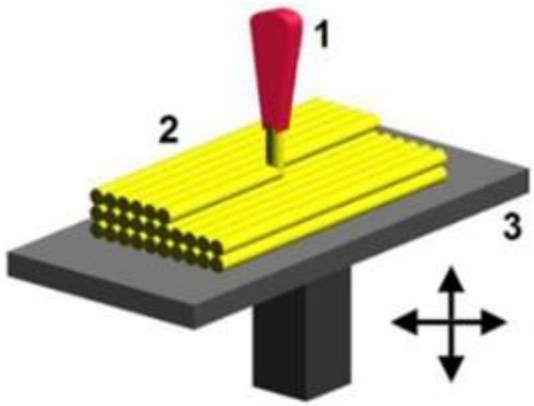

Fig-1: FDM modelling

3. TYPES OF 3D PRINTING

3.1 FDM – Fused Deposition Modeling

Fused Deposition Modeling, is an additive manufacturing technology commonly used for modeling, prototyping, and production applications.

FDM works on an "additive" principle by laying down material in layers. A plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle which can turn the flow on and off. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism, directly controlled by a computer-aided manufacturing (CAM) software package. The model or part is produced by extruding small beads of thermoplastic material to form layers as the material hardens immediately after extrusion from the nozzle. Stepper motors or servo motors are typically employed to move the extrusion head.

FDM, a prominent form of rapid prototyping, is used for prototyping and rapid manufacturing. Rapid prototyping facilitates iterative testing, and for very short runs, rapid manufacturing can be a relatively inexpensive alternative.

Advantages: Cheaper since uses plastic, more expensive models use a different (water soluble) material to remove supports completely. Even cheap 3D printers have enough resolution for many applications.

Disadvantages: Supports leave marks that require removing and sanding. Warping, limited testing allowed due to Thermo plastic material.

3.2 SLA – Stereolithography

Stereolithography is an additive manufacturing process which employs a vat of liquid ultraviolet curable photopolymer "resin" and an ultraviolet laser to build parts' layers one at a time. For each layer, the laser beam traces a cross-section of the part pattern on the surface of the liquid resin. Exposure to the ultraviolet laser light cures and solidifies the pattern traced on the resin and joins it to the layer below.

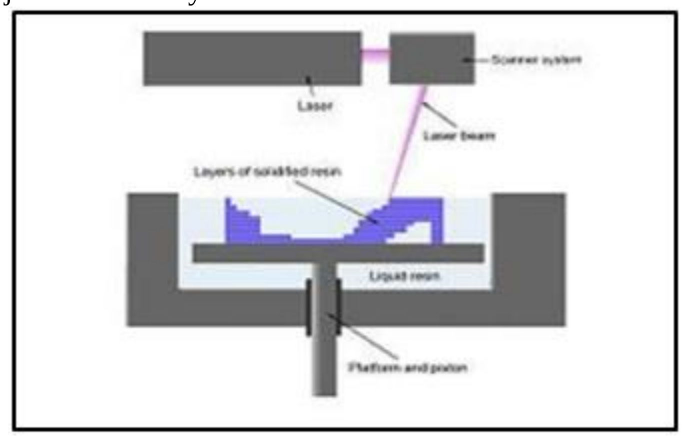

Fig- 4: Mechanism of Stereolithography (STL) printing.

After the pattern has been traced, the SLA's elevator platform descends by a distance equal to the thickness of a single layer, typically 0.05 mm to 0.15 mm. Then, a resin-filled blade sweeps across the cross section of the part, re-coating it with fresh material. On this new liquid surface, the subsequent layer pattern is traced, joining the previous layer. A complete 3-D part is formed by this process. After being built, parts are immersed in a chemical bath in order to be cleaned of excess resin and are subsequently cured in an ultraviolet oven.

Stereolithography requires the use of supporting structures which serve to attach the part to the elevator platform, prevent deflection due to gravity and hold the cross sections in place so that they resist lateral pressure from the re-coater blade. Supports are generated automatically during the preparation of 3D Computer Aided Design models for use on the stereolithography machine, although they may be manipulated manually. Supports must be removed from the finished product manually, unlike in other, less costly, rapid prototyping technologies.

Advantages and Disadvantages:

One of the advantages of stereolithography is its speed; functional parts can be manufactured within a day. The length of time it takes to produce one particular part depends on the size and complexity of the project and can last from a few hours to more than a day. Most stereolithography machines can produce parts with a maximum size of approximately 50×50×60 cm and some, such as the Mammoth stereolithography machine (which has a build platform of 210×70×80 cm), are capable of producing single parts of more than 2m in length. Prototypes made by stereolithography are strong enough to be machined and can be used as master patterns for injection molding, thermoforming, blow molding, and various metal casting processes.

Although stereolithography can produce a wide variety of shapes, it has often been expensive; the cost of photo-curable resin has long ranged from $80 to $210 per liter, and the cost of stereolithography machines has ranged from $100,000 to more than $500,000.

3.3 SLS - Selective laser sintering

Selective laser sintering is an additive manufacturing technique that uses a high power laser (for example, a carbon dioxide laser) to fuse small particles of plastic, metal (direct metal laser sintering), ceramic, or glass powders into a mass that has a desired three-dimensional shape. The laser selectively fuses powdered material by scanning cross-sections generated from a 3-D digital description of the part (for example from a CAD file or scan data) on the surface of a powder bed. After each cross-section is scanned, the powder bed is lowered by one layer thickness, a new layer of material is applied on top, and the process is repeated until the part is completed.

Because finished part density depends on peak laser power, rather than laser duration, a SLS machine typically uses a pulsed laser. The SLS machine preheats the bulk powder material in the powder bed somewhat below its melting point, to make it easier for the laser to raise the temperature of the selected regions the rest of the way to the melting point.

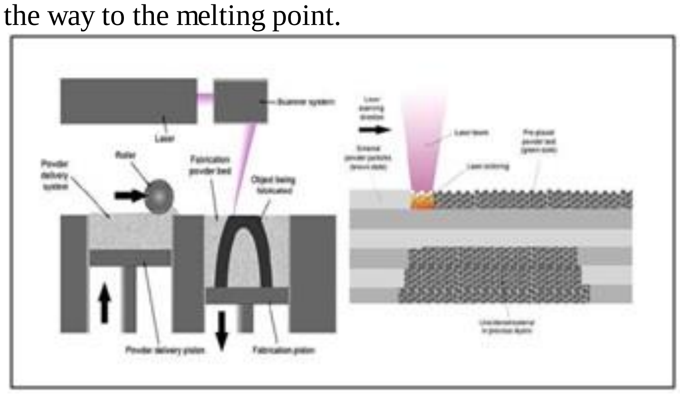

Fig-5: Functional principle of laser- sintering

Some SLS machines use single-component powder, such as direct metal laser sintering. However, most SLS machines use two-component powders, typically either coated powder or a powder mixture. In single-component powders, the laser melts only the outer surface of the particles (surface melting), fusing the solid non-melted cores to each other and to the previous layer.

Compared with other methods of additive manufacturing, SLS can produce parts from a relatively wide range of commercially available powder materials.

Benefits:

SLS has many benefits over traditional manufacturing techniques. Speed is the most obvious because no special tooling is required and parts can be built in a matter of hours. Additionally, SLS allows for more rigorous testing of prototypes. Since SLS can use most alloys, prototypes can now be functional hardware made out of the same material as production components.

SLS is also one of the few additive manufacturing technologies being used in production. Since the components are built layer by layer, it is possible to design internal features and passages that could not be cast or otherwise machined. Complex geometries and assemblies with multiple components can be simplified to fewer parts with a more cost effective assembly. SLS does not require special tooling like castings, so it is convenient for short production runs.

Applications:

This technology is used to manufacture direct parts for a variety of industries including aerospace, dental, medical and other industries that have small to medium size, highly complex parts and the tooling industry to make direct tooling inserts. With a build envelop of 250 x 250 x 185 mm, and the ability to 'grow' multiple parts at one time, SLS is a very cost and time effective technology. The technology is used both for rapid prototyping, as it decreases development time for new products, and production manufacturing as a cost saving method to simplify assemblies and complex geometries.

4. CURRENT AND FUTURE APPLICATIONS OF 3D PRINTING

4.1 Biomedical Engineering

In recent years scientists and engineers have already been able to use 3D printing technology to create body parts and parts of organs. The first entire organ created through 3D Printing is expected to be done in the coming years. The process of creating the organ or body part is exactly the same as if you were to create a plastic or metal part, however, instead the raw material used are biological cells created in a lab. By creating the cells specifically for a particular patient, one can be certain that the patient's body will not reject the organ.

Another application of 3D printing in the biomedical field is that of creating limbs and other body parts out of metal or other materials to replace lost or damaged limbs. Prosthetic limbs are required in many parts of the world due to injuries sustained during war or by disease. Currently prosthetic limbs are very expensive and generally are not customized for the patient's needs. 3D printing is being used to design and produce custom prosthetic limbs to meet the patient's exact requirements. By scanning the patient's body and existing bone structure, designers and engineers are able to re-create the lost part of that limb.

4.2 Aerospace and Automobile Manufacturing

High technology companies such as aerospace and automobile manufacturers have been using 3D printing as a prototyping tool for some time now. However, in recently years, with further advancement in 3D printing technology, they have been able to create functional parts that can be used for testing. This process of design and 3D printing has allowed these companies to advance their designs faster than ever before due to the large decrease in the design cycle. From what used to take months between design and the physical prototype, now within hours the design team can have a prototype in their hands for checks and testing.

The future of 3D printing in these industries lies with creating working parts directly from a 3D printer for use in the final product, not just for testing purposes. This process is already underway for future cars and aircraft. The way in which 3D printing works (creating a part layer by layer) allows the designer to create the part exactly the way is needs to be to accomplish the task at hand. Extremely complex geometry can be easily created using a 3D printer, allowing for parts to be lighter, yet stronger than their machined counterparts.

4.3 Construction and Architecture

Architects and city planners have been using 3D printers to create a model of the layout or shape of a building for many years. Now they are looking for ways of employing the 3D printing concept to create entire buildings. There are already prototype printer systems that use concrete and other more specialized materials to create a structure similar to a small house. The goal is the replace many cranes and even construction workers with these printing systems. They would work by using the 3D design model created on CAD software, to create a layer by layer pattern on the building just as a normal 3D printer works today. Most of the innovation in this area will have to come from the creation of the appropriate materials.

4.4 Product Prototyping

The creation of a new product is always one of that involves many iterations of the same design. 3D Printing revolutionized the industry by allows designers to create and the next day see and touch their design. No longer did it take several meetings for everyone to agree on one design to create, and then wait months for the actual part to arrive. Nowadays a version of each idea is created and the next day, all are reviewed together, thus giving the ability to compare and contrast each one's features.

Plastic parts for example require moulds and tooling to be created, these custom parts are expensive to create, therefore one must be certain the part designed meets the requirements. With 3D printing you can create a part that will look and feel exactly like the finished product. Some parts can also be tested just as the real injection moulded part would.

5. CONCLUSION

The following conclusion can be made from this seminar:

1. Additive manufacturing is a revolutionary concept which can be used in various fields to increase productivity.
2. It helps to create and modify almost impossible designs (by traditional manufacturing methods) with more accuracy and core strength.

By 3D printing we can make verity of product range which are not possible by traditional methods of manufacturing.

ACKNOWLEDGEMENT

The making of the paper needed co-operation and guidance of a number of people. I therefore consider it my prime duty to thanks all those who had helped me to this venture. It is my immense pleasure to express my gratitude to my guide who provided me construction and positive feedback during the preparation of this paper.

I will be also thankful to my parent whose best wishes are always with me.

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