3D Printing Methods and Potential Applications

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Abstract- The term 3D printing from newscasters and journalists has astonished many of us at what they've witnessed. It's a machine which can create objects out of plastic, metal, nylon, and over a hundred other materials. Additive manufacturing, or 3D printing, is the process of turning digital designs into three-dimensional objects. It can be used to print manufacturing prototypes, end user products, quasi-legal guns, aircraft engine parts and even human organs. This paper particularly aims at putting forth the detailed ideas of the fast emerging 3D printing technology and elaborates in depth about a variety of 3D models used for designing, the different 3D printing technologies commonly used, the various printing materials used and finally its applications.

Keywords:- Models, Stereo Lithography, Fused Deposition Modeling (FDM), Selective LASER Sintering, Multi-Jet Modeling

I. INTRODUCTION

We live in an age of Third Industrial Revolution. 3D printing, more professionally called additive moves us away from the era of mass production to a new reality of customizable, one-off production. In the 2D world, a sheet of printed paper output from a printer was "designed" on the computer in a program such as Microsoft Word. Similarly, 3D printer also needs a file - a Computer Aided Design (CAD) file, created using necessary software's that is sent to the 3D printer. Along the way, software slices the design into hundreds, or more likely thousands, of horizontal layers. These layers will be printed one a top the other until the 3D object is done. It's much like printing in two dimensions on a sheet of paper, but with an added third dimension: UP - the Z-axis.

II. 3D MODELING

3D modeling is the process of developing a mathematical representation of any three dimensional surface of an object via specialized software. There are 3 Types of 3D models that can be basically generated. They are 1) Wire frame 2) Surface Model and 3) Solid Model.

A wireframe model is built up using a series of connected lines to produce a 3D object. It is created by specifying each edge of the physical object where two mathematically continuous smooth surfaces meet. The term wire frame comes from designers using metal wire to represent the three-dimensional shape of solid objects. The figure below shows the wire frame model of various shapes.

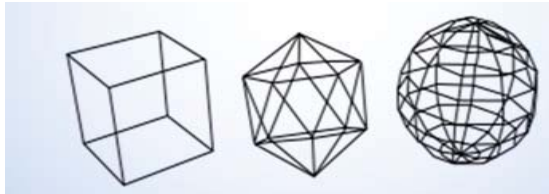

Figure 1 Wire frame model of various shapes

The surface model is built up by drawing the surfaces of an object, like adding the canvass onto the frame of a tent. Surface modeling is a more complex method for representing objects than wireframe modeling, but not as sophisticated as solid modeling. Surface modeling is widely used in CAD (computer-aided design) for illustrations and architectural renderings. It is also used in 3D animation for games and other presentations. Although surface and solid models appear the same on screen, they are quite different. Surface models cannot be sliced open as can solid models.

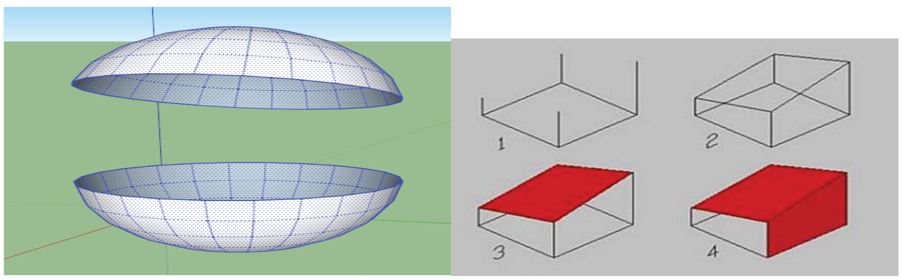

Figure 2 Surface models

The solid model is built up by using simple geometric forms or extrusions - such as cuboids, cylinders & prisms. These can be added or subtracted to produce complex 3D models. Solid modeling is a consistent set of principles for mathematical and computer modeling of three-dimensional solids. Solid modeling is distinguished from related areas of geometric modeling and computer graphics by its emphasis on physical fidelity. Together, the principles of geometric and solid modeling form the foundation of CAD and in general support the creation, exchange, visualization, animation, interrogation, and annotation of digital models of physical objects.

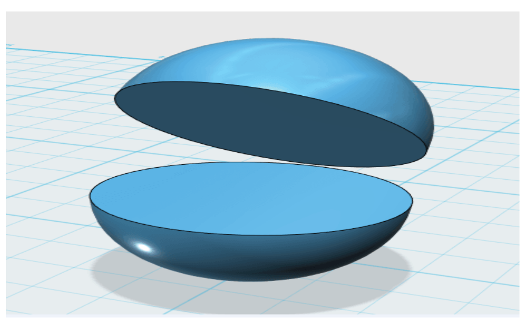

Figure3 Solid models

III. 3D MODELLING SOFTWARE's

3D modeling software is a class of 3D computer graphics software used to produce 3D models. Some of the 3D printing software's available as free wares are Google Sketch Up, 3DCrafter , 3Dtin , Anim8or, Art of Illusion , Blender, BRL-CAD , Creo Elements/Direct , DrawPlus , tarter Edition , FreeCAD, GLC Player, LeoCAD - Netfabb Studio Basic, K-3D ,OpenSCAD , Tinkercad , Wings 3D and commercial 3D softwares available inludes: 3DS Max , Alibre , AC3D, AutoCAD, AutoQ3D, Cheetah3D, Cloud9 , FormZ , Maya, Magics, NetFabb, Rhino3D, Solidworks, ZBrush. The other type of software required to convert the digital 3D model into printing instructions for your printer is slic3r. This generates the G-code from 3D CAD files (STL, OBJ). It cuts the model into horizontal slices (layers), generates tool paths to fill them and calculates the amount of material to be extruded.

IV. 3D TECHNOLOGIES

There are four Printing Technologies currently in use, they are

1) Stereo Lithography (STL)
2) Fused Deposition Modeling (FDM)
3) Selective LASER Sintering (SLS)
4) Multi-Jet Modeling (MJM)

1. Stereo Lithography

Stereo Lithography is an additive manufacturing process that works by focusing an ultraviolet (UV) laser on to a vat of photopolymer resin. With the help of computer aided manufacturing or computer aided design software (CAM/CAD), the UV laser is used to draw a pre-programmed design or shape on to the surface of the photopolymer vat. Because photopolymers are photosensitive under ultraviolet light, the resin is solidified and forms a single layer of the desired 3D object. This process is repeated for each layer of the design until the 3D object is complete.

Designs are then immersed in a chemical bath in order to remove any excess resin and cured in an ultraviolet oven. Stereo lithography requires the use of supporting structure to hold cross sections in place in order to resist lateral pressure from the resin-filled blade. Supports are created automatically during the preparation of 3D Computer Aided Design models and can also be made manually. One of the advantages of this is its speed; functional parts can be manufactured within a day. Although STL can be used to produce virtual any synthetic design, it is often costly; the cost of photopolymer resin ranges from $80 to $210 per liter.

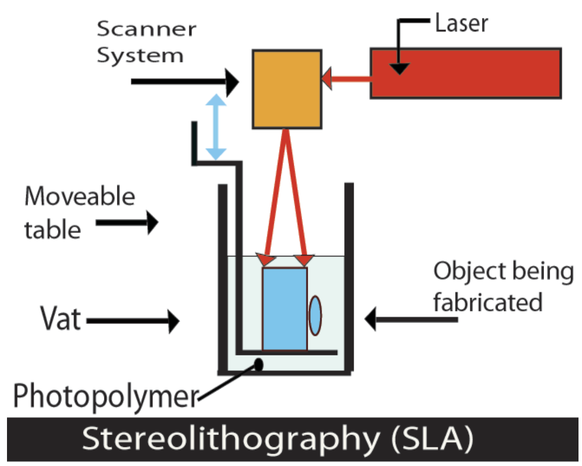

Figure 4 Stereo Lithography Modeling

2. Fused deposition modeling (FDM)

FDM works on an "additive" principle by laying down material in layers. It is also sometimes called Plastic Jet Printing (PJP). 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. There is typically a worm-drive that pushes the filament into the nozzle at a controlled rate. The nozzle is heated to melt the material. The thermoplastics are heated past their glass transition temperature and are then deposited by an extrusion head.

The plastic hardens immediately after flowing from the nozzle and bonds to the layer below. Once a layer is built, the platform lowers, and the extrusion nozzle deposits another layer. The layer thickness and vertical dimensional accuracy is determined by the extruder die diameter, which ranges from 0.013 to 0.005 inches. In the X-Y plane, 0.001 inch resolution is achievable. The nozzle can be moved in both horizontal and vertical directions by a numerically controlled mechanism. Stepper or servo motors are typically employed to move the extrusion head. A range of materials are available including ABS, polyamide, polycarbonate, polyethylene, polypropylene, and investment casting wax.

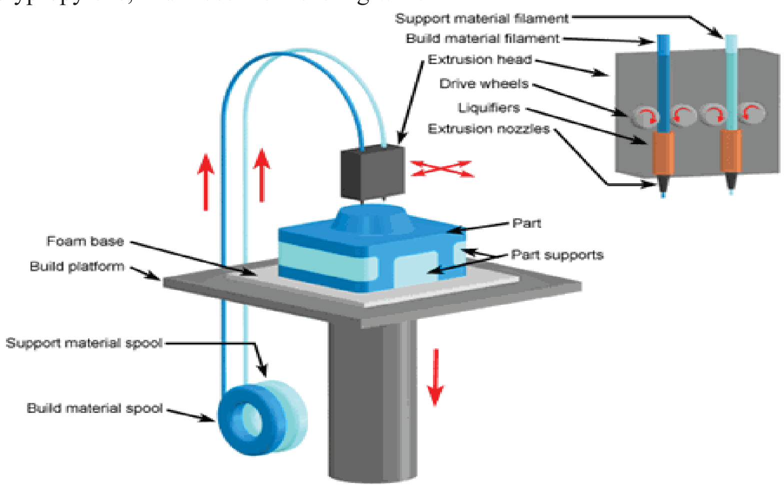

Figure 5 Fused Deposition Modeling

3. Selective Laser Sintering (SLS)

Objects printed with SLS are made with powder materials, most commonly plastics, such as nylon. A high power LASER (for example, a carbon dioxide laser), which is controlled by a computer that tells it what object to "print," pulses down on the platform, tracing a cross-section of the object onto the powder. The laser heats the powder either to just below its boiling point (sintering) or above its boiling point (melting), which fuses the particles in the powder together into a solid form. Once the initial layer is formed, the platform of the SLS machine drops — usually by less than 0.1mm — exposing a new layer of powder for the laser to trace and fuse together. This process continues again and again until the entire object has been printed. When the object is fully formed, it is left to cool in the machine before being removed.

SLS doesn't require the use of additional supports to hold an object together while it is being printed. Such supports are often necessary with other 3D printing methods, such as stereo Lithography or fused deposition modeling, making these methods more time-consuming than SLS. SLS machines can print objects in a variety of materials, such as plastics, glass, and ceramics and even metal (which is a related process known as direct metal laser sintering). This makes it a popular process for creating both prototypes as well as final products. SLS has proved to be particularly useful for industries that need only a small quantity of objects printed in high quality materials. One example of this is the aerospace industry, in which SLS is used to build prototypes for airplane parts.

Using SLS, companies can create prototypes that are stored digitally as .STL files, which they can redesign or reprint as needed. Because SLS machines can print in a range of high-quality materials, from flexible plastic to food-grade ceramic, SLS is also a popular method for 3D printing customized products, such as hearing aids, dental retainers and prosthetics. And because objects printed with SLS don't rely on moulds or require additional tooling, this method of manufacturing is also useful for anyone that wishes to print a highly complex or particularly delicate object.

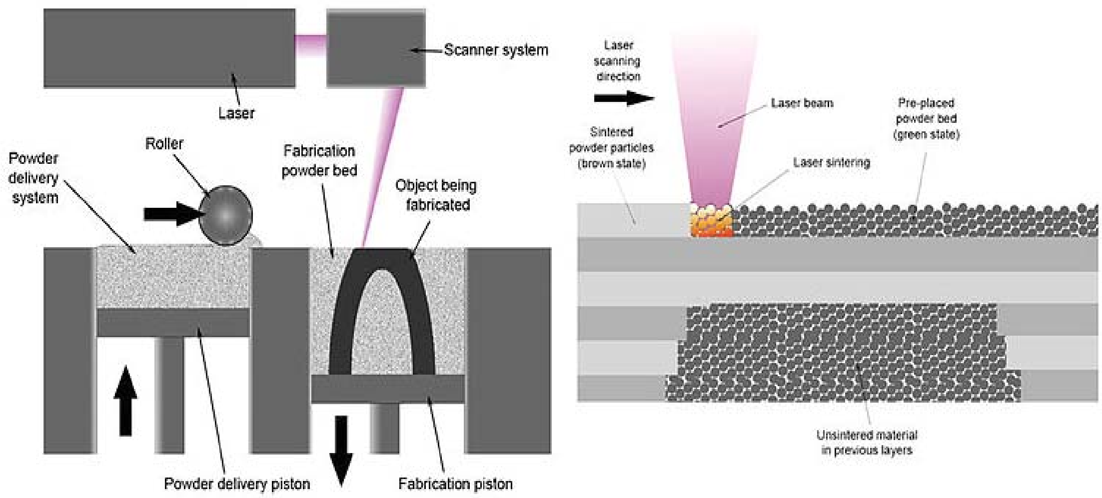

Figure 6 Selective LASER Sintering Modeling

4. Multi-jet modeling

Multi Jet Modeling, also known as *Thermo jet*, generates wax-like plastics models which are less accurate than stereo lithography. The machine uses a wide area head with multiple spray nozzles. These jetting heads spray tiny droplets of melted liquid material which cool and harden on impact to form the solid object. The process is commonly used for creating casting patterns for jewellery industry and other precision casting applications. MJP or Multi Jet Printing is an inkjet printing process that uses piezo print head technology to deposit either photo curable plastic resin or casting wax materials layer by layer. These high-resolution printers are economical to own and operate and use a separate, meltable or dissolvable support material to make post-processing a breeze.

MJP printers ideal for direct investment casting applications in jewellery, dental, medical and aerospace applications where digital workflows provide significant time, labour, quality and cost advantages.

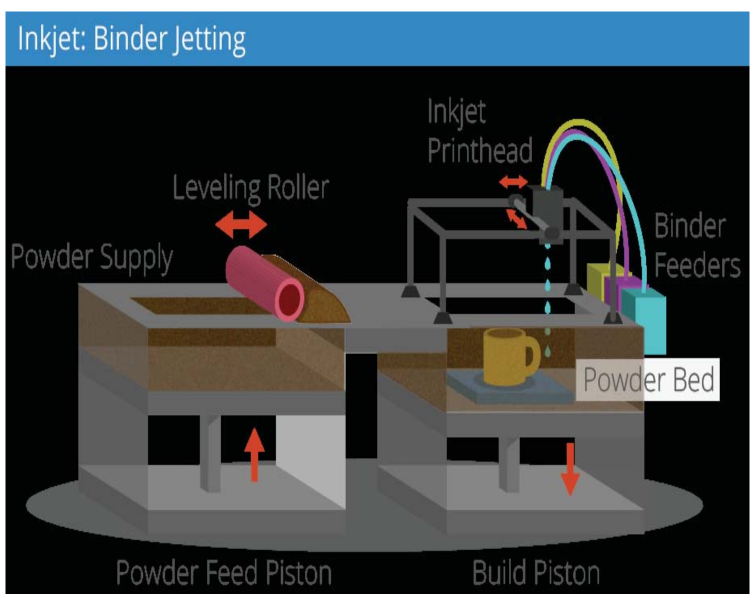

Figure 7 Multi-jet/ Ink-jet Printing

The figure below shows the typical 3D Printer and its parts.

Figure 8 3D Printer and its part

V. 3D PRINTING MATERIALS

The most commonly used materials for 3D Printing are PLA, ABS and PVA. The following comparison table summarizes the key properties as well as the pros and cons of each one of the three filaments types discussed above.

Table 1 Comparison between 3D Printing materials

	ABS	PLA	PVA
Scientific designation	Acrylonitrile butadiene styrene	Polylactic acid or polylactide	Polyvinyl alcohol
Produced from	Petroleum	Plant starch	Petroleum
Properties	Durable Strong Slightly flexible Heat resistant	Tough Strong	Water-soluble Excellent film formation High bonding power Good barrier properties
Extruder temp	210-250°C	160-220°C	190-210°C
Price	14-60$ / kg	19-75$ / kg	80-120$ / kg
Post-processing	Easy sanding Easy glueing Easily soluble in acetone	Sanding possible Limited glueing	Soluble in water
Positive points	Great plastic properties Smooth finish Solidifies quickly Durable and difficult to break Ideal for mechanical parts	Bioplastic – good environmental properties Good smell when heated Nontoxic No heated printbed necessary High print speed and resolution Less warping or shrinking issues Ideal for small parts Hard or soft/flexible variants	Biodegradable Recyclable Non toxic
Negative points	Petroleum-based Non-biodegradable Heated printbed necessary Fumes Deterioration through sunlight	Slow cooling down Low heat resistance Easier to break then ABS Needs thicker walls then ABS	Expensive Deterioration due to air moisture Special storage necessary

VI. APPLICATIONS

3D printers have many promising areas of potential future application. They may, for example, be used to output spare parts for all manner of products.

NASA has already tested a 3D printer on the International Space Station, and recently announced its requirement for a high resolution 3D printer to produce spacecraft parts during deep space missions. The US Army has also experimented with a truck-mounted 3D printer capable of outputting spare tank and other vehicle components in the battlefield.

Like many industries, the aerospace industry is increasingly adopting 3D printing and rapid prototyping technologies to develop aircraft parts in the pursuit of trimming down manufacturing costs.

A team at Loughborough University is working on a 3D concrete printing project that could allow large building components to be 3D printed on-site to any design, and with improved thermal properties.

Another possible future application is in the use of 3D printers to create replacement organs for the human body. This is known as bio printing, and is an area of rapid development.

Using this prototyping technology, students will be able to produce realistic 3 dimensional mini-models.

Nowadays the use of 3D printing in automotives is evolving from relatively simple concept models for fit and finish checks and design verification, to functional parts that are used in test vehicles, engines, and platforms.

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