3D Printing Technologies: Comparisons and Impact on Society

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Abstract- *3D printing is a procedure of making a three-dimensional shape from a computerized display. 3D printing is accomplished utilizing an additive process, where progressive layers of material are set down in various shapes. 3D printing is additionally viewed as different from conventional machining strategies, which for the most part depend on the removal of material by techniques, for example, cutting or boring. Recent Developments in materials and electronics technology have opened up a scope to massively reduce the development, running and maintenance costs of 3D printers, thereby exposing the technology to a much wider audience. In this paper, we present the existing 3d printing solutions, and propose a cost-effective system based on open source technologies.*

Keywords- 3-D printing technology, costs, impact, Selective Laser Sintering (SLS), Computer Aided Design (CAD), Computer Aided Manufacturing (CAM)

I. INTRODUCTION

While 3D printing innovation has been around since the 1980s, it wasn't until the mid-2010s that the printers turned out to be broadly accessible monetarily. Since the beginning of the 21st century there has been a huge development in the offers of these machines. The market for 3D printers was worth $2.2 billion worldwide in 2012, up 29% from 2011. The 3D printing innovation is utilized for both prototyping and dispersed assembling with applications in engineering, development, industrial design, cars, aviation, military, building, structural designing, dental and therapeutic enterprises, biotech, footwear, adornments, eyewear, training, geographic data frameworks, food, and numerous different fields. Similarly as it occurred in the previous decades with the PCs and Internet, the effect of 3-D printing will continuously increment later on, prompting critical changes, redefining our everyday life, economy and society.

The 3D printing innovation comprises of three principle stages - the modeling, the printing and the completing of the item:

- In the modeling stage, keeping in mind the end goal to get the printed model, the machine utilizes virtual diagrams of the object and processes them in a progression of thin cross-sections that are being processed progressively. The virtual model is indistinguishable to the physical one.
- In the printing stage, the 3D printer reads the design (comprising of cross-sections) and stores the layers of material, keeping in mind the end goal to construct the item. Each layer, essentially a virtual cross section, joins with the past ones and, at last, subsequent to printing every one of these layers, the desired object has been developed. Through this method, one can make distinctive objects of different shapes, worked from an assortment of materials (thermoplastic, metal, powder, earthenware, paper, photopolymer, fluid).
- The last stage comprises in the completing of the item. By and large, keeping in mind the end goal to get the proper exactness, it is more invaluable to print the object at a larger size than desired, and to remove the supplementary material utilizing a subtractive procedure at a higher resolution.

Depending upon the utilized manufacturing system, 3D printing could offer extra improvements. In this way, in the printing procedure, one can use numerous materials in manufacturing diverse parts of a similar object or one can use different hues.

II. LITERATURE SURVEY

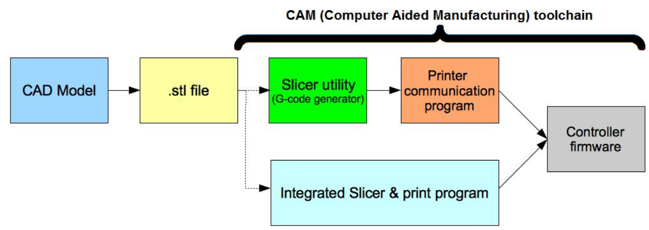
2.1 ADDITIVE MANUFACTURING AND THE MATERIALS USED IN RAPID PROTOTYPING

The current 3D printers utilize an extensive variety of innovations and materials keeping in mind the end goal to print objects beginning from a computerized outline. The main 3D printing technologies and materials are:

- The inkjet head and the powder bed 3D printers sprinkle an underlying slight layer of powder with fine cover beads. At that point, a roller is utilized to spread and distribute a new layer of powder. In the end, an object consisting in powder layers bound together is obtained. On the off chance that it is vital, the powder could be colored to acquire a colored object. After the printing, one can likewise utilize treatments for enhancing the material's quality (with super glue) or for reducing the colour fading (with UV protectants) [1]. The final object is produced using more various constituent materials, having diverse substance and physical properties, in this way being a composite material.

- The powder bed and inkjet head 3D printers are likewise useful in making objects utilizing clay powder. The printed objects are then subjected to warm treatment for drying and coating, in this manner enhancing the material's quality and aspect.
- The stereolitography (SLA) [1] is an added substance fabricating innovation that uses a fluid photopolymer (gum) and a bright laser light, to acquire progressive objects' layers. In order to acquire a layer, the laser draws on the gum in a 2D way, subsequently getting a cross area of the object. The obtained layer is then presented to bright laser light, curing and setting the layer with the past ones. Through this innovation, one can get extremely smooth final objects.
- Selective Laser Sintering (SLS) [2] melts and fuses fine particle layers of powdered materials like plastic (regularly nylon) or metal, utilizing a capable laser beam. The laser traverses a powder surface and after the finishing of a printed layer, the plastic powder is spread over. At the point when the laser traverses this new layer, the powder particles soften, interfusing each other and furthermore with the past layer. The SLS innovation is valuable when printing complex items having fine details.
- The Direct Metal Laser Sintering (DMLS) 3D printing [2] utilizes a laser with a specific end goal to intertwine particles of metal powder (e.g. titanium). This innovation is like the previously mentioned SLS innovation that prints plastic materials. The DMLS has the drawbacks of high expenses and requires particular design rules. The indirect printing strategies are those in light of making models or forms that can be additionally utilized as a part of making metal items, in view of conventional methods.

2.2 SOFTWARE STACK FOR ADDITIVE MANUFACTURING



CAD Modelling

Computer aided design is essentially utilized for detailed building of 3D models and additionally 2D illustrations of physical components, yet it is likewise utilized all through the building procedure from concept planning and formatting of items, through quality and dynamic investigation of assemblies to assembling strategies for components.

STL Files

STL [4] (STereoLithography) is a file format native to the stereolithography CAD software created by 3D Systems. This file format is supported by many other software packages; it is widely used for rapid prototyping, 3D printing and computer-aided manufacturing. STL records depict just the surface geometry of a three-dimensional protest with no portrayal of shading, surface or other regular CAD demonstrated properties.

Slicing

Slicing is the task of analysing the model and creating GCode which is sent to the Firmware as a print Job [4]. It's a standout amongst the most vital undertakings in the 3D print work process as it decides how the printer will really print the final item. Two open-source slicers are being tried and utilized: Slic3r [3] and Cura.

G-Code

G-code [4] (additionally RS-274), is the regular name for the most broadly utilized numerical control (NC) programming dialect. It is utilized predominantly in PC helped assembling to control computerized machine instruments.

G-code is a dialect in which programmersinstruct mechanized instruments how to make something. The "how" is characterized by directions on where to move, how quick to move, and what route to take. The most widely recognized situation is that, inside a machine apparatus, a cutting device is moved by these guidelines through a toolpath and removes material to leave just the completed workpiece. A similar idea additionally stretches out to non-cutting apparatuses, for example, forming or burnishing devices, photo-plotting, additive substance strategies, for example, 3D printing, and measuring instruments.

Controller Firmware

The controller is programmed to receive GCode instructions via a hardware serial connection with a computer. The computer has the compiled GCode file and transmits it line by line to the controller. The instructions are then turned into coordinated mechanical movements that form the design of the part to be printed. The firmware also sends out telemetry data like temperature states, motor positions, etc. to the connected computer.

Additive manufacturing (AM) involves a number of steps that move from the virtualCAD description to the physical part [7]. Regardless ofthe AM machine, the process can be divided into eight keysteps.

- Conceptualization and CAD
- Conversion to STL (triangular representation of the CAD model)
- Transfer and manipulation of the STL file to the AM machine
- Machine setup
- Build
- Part removal and cleanup Post-processing of the part
- Application

2.3 REVIEW OF THE VARIOUS SIGNIFICANT 3D PRINTING TECHNOLOGIES

FUSED DEPOSITION MODELING (FDM)

Created by Scott Crump of Stratasys, FDM is a standout amongst the most generally utilized manufacturing advancements for fast prototyping today. FDM manufactures a 3D model by extruding thermoplastic materials onto a stage layer by layer.

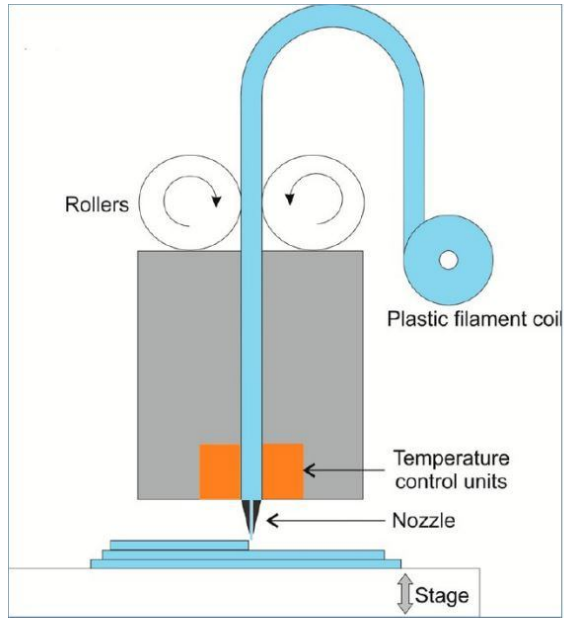


Fig. Fused Deposition Modeling [10]

Thermoplastic filaments, the material used to construct 3D models, are moved by two rollers down to the spout tip of the extruder of a print head, where they are heated by temperature control units to a semimolten state. As the print head follows the design of each characterized cross-sectional layer on a level plane, the semimolten materials are expelled out of the extruder and set in the desired positions. The stage at that point moves down and another layer is placed similarly. These steps are repeated to manufacture a 3D structure in a layer-by-layer way. The layout of the part is typically printed to start with, with the interior structures (2D plane) printed layer by layer. Interior imperfections can come about because of heterogeneities in the fiber bolster distance across and thickness, as these can impact how the material is expelled from the printer extruder. An outstanding preferred standpoint of FDM is that it can make objects manufactured from different material composition by printing and subsequently changing the print material, which empowers more client control over model creation for experimental use. Other than regular materials, for example, PC,polystyrene (PS), furthermore, ABS, FDM can likewise print 3D models out of glass strengthened polymers, metal, earthenware and bioresorbable materials.

Lately, 3D printers have become less expensive, better, more valuable and essential with every day that passed [7]. Their developing significance and the features offered have made them popular. From a historical perspective, since the presence of the RepRap 3D printer in 2007, a genuine 3D printer transformation has begun. The RepRap series was trailed by the MakerBot cupcake CNC unit in 2009, Printrbot in 2011 and numerous different devices fulfilling the clients' developing interests.

SELECTIVE LAER SINTERING

Powder bed fusion (PBF) processes were among the primary marketed AM processes. Created at the University of Texas at Austin, USA, Selective Laser Sintering (SLS) was the principal popularized powder bed fusion process. And all other PBF processes change this fundamental approach in at least one approaches to improve machine profitability, empower distinctive materials to be processed, and additionally to dodge particular protected highlights. The SLS process was initially created for delivering plastic models utilizing a point-wise laser scanning method. This approach has been reached out to metal and earthenware powders; more thermal sources have been used; and variations for layer-wise fusion of powdered materials now exist. Subsequently, PBF processes are generally utilized around the world, have a wide scope of materials (counting polymers, metals, earthenware production and composites) which can be used, and are progressively being utilized for coordinate advanced manufacturing of end-utilize items, as the material properties are similar to numerous designing evaluation polymers, metals, and earthenware.

Hardware Illustration: Selective Laser Sintering

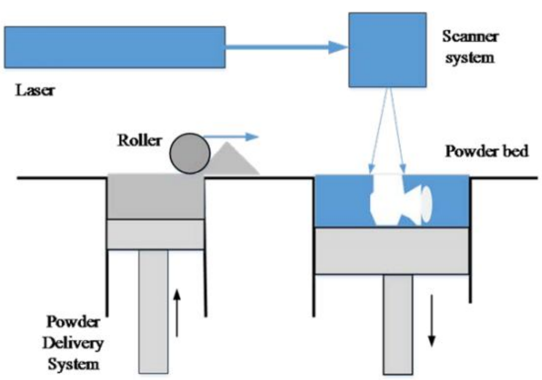


Fig. Selective Laser Sintering

SLS combines thin layers of powder (ordinarily ~0.1 mm thick) which have been spread over the build platform utilizing a counter-rotating powder leveling roller. The part assembling process happens inside an encased chamber loaded with nitrogen gas to limit oxidation and corruption of the powdered material. The powder in the build chamber is kept up at a raised temperature just underneath the melting point and additionally glass transition temperature of the powdered material. Infrared heaters are put over the build platform to keep up a raised temperature around the part being shaped; and additionally, over the bolster cartridges to preheat the powder spreading over the build platform. Sometimes, the build platform is likewise heated utilizing resistive radiators around the build platform. This preheating of powder and maintaining a raised, uniform temperature inside the build chamber is important to limit the laser control Requirements of the process (when pre-warming, less laser Energy is required for fusion) and to avoid distorting of the part amid the work. Once a fitting powder layer has been shaped and Preheated, a focused laser beam is coordinated onto the Powder bed and moved utilizing galvanometers such that it thermally intertwines the material to frame the cut cross segment. the encompassing powder stays free and fills in as support for next layers, in this manner dispensing with the requirement for the optional backings which are vital for photopolymer vat processes. In the wake of finishing a layer, build platform is lowered by one-layer thickness and another layer of powder is laid and leveled using the roller.

STEREOLITHOGRAPHY (SLA)

Stereolithography is a laser-based innovation that uses an UV-curing fluid resin. An UV laser beam traverses the surface of the resin and specifically solidifies the material corresponding to a cross section of the item, constructing the 3D section from the base to the top. The required backings for overhangs and depressions are created too, and later removed.

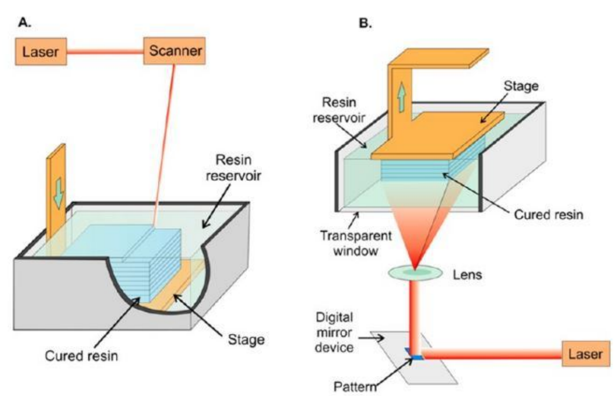


Fig. Stereolithography illustration [10]

Stereolithography is frequently utilized for prototyping parts. At a moderately minimal effort, Stereolithography can create precise models, even of complex shapes. Organizations can utilize those models to evaluate the design of their item or as display for the final product.

One of the benefits of stereolithography is its speed; useful parts can be produced within a day. The time allotment it takes to create a part relies on the complexity of the design and the size. Printing time can be anything from hours to over a day. Numerous 3D printers can create parts with a greatest size of around 50×50×60 cm.

In the two arrangements, a post creation step, utilizing an UV light to ensure every receptive group of the resin is polymerized, is required to reinforce the bonding in the final 3D object. The direct laser writing strategy, while capable to produce point by point 3D objects, is tedious. The mask-based approach utilizes the basics from the previously mentioned coordinate/laser composing, however in a high throughput application where a digital mirror device (DMD) utilizes a great many mirrors that can be controlledat the same time. The particular control of the mirrors enables a whole layer to be cured without delay, significantly reducing layer production time.

	FDM	SLA	SLS
Feed Stock	Plastic filament	Polymer (light sensitive) resin	Metal and polymer powder
Materials and Costs	ABS, PLA, nylon, PC, PVA, woodlike…	Similar to PP to low end ABS	Alumide, stainless steel, ABS, titanium
Precision	25-75 microns	25 microns	150 microns
Part strength	Medium	Low	High
Material Availability	Easily available and cheap	Easily Available but is expensive	Not easily available and is expensive
Price	USD 4000 onwards	USD 4000 onwards	USD 500,000 onwards

Fig. comparison of 3D printing technologies [11]

2.4 IMPACT ON THE ECONOMY AND SOCIETY

To prevail in aggressive worldwide markets, companies always improve their products and plans of action and create capabilities that accumulate when putting resources into innovations like 3D printing. As per numerous onlookers, this innovation can empower "one of the next major innovative revolutions" and have "a tremendous and widespreadeffect on the world". For instance, the 3D printing business is at present evaluated at more than $12 billion and expected to rise to $21 billion by 2020. 3D printing was at first utilized as a part of product development to make models, yet now it is likewise being utilized to make practical items. General Electric, Boeing, and Ford, among others, are as of now utilizing this innovation to fabricate parts for some of their items. 3DP is currently monetarilypractical for assembling an expanding number of finished results.The direct production of these items is the business' fastestgrowing segment with a 60 percent annual development rate.

The formation of about any possible geometry can be made real using CAD programming equipped for delivering .STL documents to be perused and created by a 3D printer.Picking the proper printer type among SLA, inkjet, SLS, FDM, or LOM, relies upon the design, materials, and motivation behind the product. 3D printing has turned into a helpful instrument in various distinctive fields, also, as printer performance, resolution, and printing materials have increased, so too have the applications. While this paper does not present a total offering of what is conceivable with 3D printing, it serves to demonstrate the stage from which future undertakings will launch.

Those creating materials to be used for 3D printing must consider variety, structure, quality, and completing methods keeping in mind the end goal to keep the versatility of the innovation. As of now, the assortment of materials is restricted to the ability of the materials to be powder-based or have low enough viscosities to be expelled from the printing head. Numerous techniques require exclusive materials to be utilized as a part of their 3D printers. This situation has restricted the material pool, and consequently, for 3D printing to proceed to develop, the amount and assorted variety of materials must increase. Research for the improvement of 3D printing materials has a lot of opportunities. Including the combination and discovery of new or blended material creations that are agreeable to printing strategies, new techniques for printing to fast while at the same time achieving higher resolutions, and materials keeping pace with the strengths of materials machined by regular methods.

1. Rapid Prototyping

rapid prototyping refers to the way of designing a 3D model with computer aided design (CAD), and creating a model, commonly out of plastic, through 3D printing. This model at that point turns into the plan of the final product. Rapid prototyping lessens fabricating costs by enabling the multiple iterations of the design process. This implies thatengineers and designers can outline a more exact model in 3D and audit a scaled, physical object. Clients are at that point ready to assess an idea and give a few rounds ofoutline criticism or alterations. This is different than previous prototyping strategies in 2D.In 2D, creators and specialists would draw, with estimations, a model from a wide range of perspectives on paper or in 2D software. With 3D design and rapid prototyping, organizations are less prone to send inaccurate estimations or flawed specifications into production.

2. Personal Manufacturing

Imagine an economy where consumers have 3D printers in their homes. Whenever a consumer distinguishes or makes an item that can better fit their prerequisites, the consumer plans a model with Computer aided design modelling or 3d scanning. Then, the consumer prints it on their 3D printer at homeor sends it to a 3D printing service for printing [8]. This concept,where consumers are making their own particular items, as opposed to waiting for organizations to tweak item offerings, isknown as "Personal Manufacturing." With Personal Manufacturing, consumers are filling a market requirement on their claim, in this way executing their own particular product improvement cycle. They don't have to wait for an organization to model, produce, amass, circulate, distribute, or retail thenew item.

3. Small Batch Production

3D printing and additive manufacturing may facilitate small production volumes to small global markets. With small batch production, small companies and startupscommit to the development of a product with a very small, niche market. Crowd funding sites like Kickstarter and sharedworking spaces like the Wix Lounge arecontributing to thefeasibility of this business model. For larger companies, highly customized 3D printed products may soon show significant profitability potential [8].

In order to analyse the impact of 3D printing technology on the society and economy, in the following we study its main advantages.

ADVANTAGES OFFERED BY 3D PRINTING

- Additive manufacturing offers the likelihood of making, in a short time, complex 3D objects, with fine subtle elements, from various materials. Through 3D printing, the client has the capability to make complex objects and shapes that are difficult to be made through some other existing manufacturing methods.
- A critical preferred standpoint of making objects utilizing 3D printing innovation rather than conventional manufacturing techniques is the waste reduction. As the development material is included layer after layer, the waste is right around zero and amid the generation, it utilizes exclusively the material required for getting the final object. In the conventional manufacturing processes, in view of subtractive systems, the final object is produced through cutting or penetrating an underlying object, accordingly prompting a significant loss of material.
- The item's design might be sent over the Internet at the client's area, where he can print it.
- Some of the materials utilized as a part of 3D printing have enhanced properties as far as quality and give extensive finishing details, compared to the materials utilized when manufacturing objects through conventional methods.
- As the additive manufacturing is a computer-controlled procedure, it decreases the measure of human intervention and requires a low level of expertise for the administrator. Besides, the process guarantees that the final object takes a flawless form of the 3Ddesign, barring the mistakes that could have showed up when utilizing other existing advances. As the AM lessens the loss in the manufacturing process, it could help taking care of intense issues of mankind, for example, the utilization of the construction materials, energy consumption and environmental protection.
- Using the 3D printing innovation, one can deliver complex designs valuable in different fields: fashion, industry, arts, jewellery, computer industry, media communications, transports and so on. AM has prompted astounding advances in healthcare, being fit for sparing lives, bringing down social insurance costs and enhancing human life quality. For instance, researchers have figured out how to make a 3D printer helpful in making prosthetics, parts of the human body, organs and tissues.

III. CONCLUSION

We have explored the 3D printing innovations to conclude that the use of additive technology will only increase in the coming years and more and more applications will open up to its use. We have studied the various technologies along with their advantages and disadvantages to decide which technology is suitable for what application. Printing a model is generally more reasonable than building one by hand, and surely less expensive than contracting a manufacturer to do it. Especially with low quantities of production, creators can quickly configure, print, and test an item. That cycle can be repeated a few times, at not quite an expense but rather more quickly than a solitary thing produced the customary way. We have indicated how 3d printing is moulding the eventual future of manufacturing, and how it will be a typical pattern sooner rather than later for organizations and people alike. One can infer that the 3-D printing innovation's significance and social impact will only increment step by step for a long time and essentially impact human lives, the economy and present day society.

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