A SEMINAR REPORT

ON

"3D PRINTING – Analysis of Different Types of Methods"

B.TECH- IV (ELECTRONICS & COMMUNICATION)

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ABSTRACT

3D printing is a form of additive manufacturing technology whereby a three dimensional object is created by laying down successive layers of a material. It is also known as rapid prototyping. It is a mechanized method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing blueprints for the object. This revolutionary concept for creating 3D models, with the use of methods like Selective Laser Sintering (SLS), Stereolithography (SLA) etc. saves time and cost by eliminating the need to design, print and glue together separate model parts. One can create a complete model in a single process using 3D printing. It is used in a variety of industries that include jewellery, footwear, industrial design, architecture, engineering and construction, automotive, aerospace, dental and medical industries, education and consumer products. Given its technological advances, 3D printing has a promising future.

ACKNOWLEDGEMENT

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Last but not the least I would like to thank my beloved parent, friends for their support and warm wishes throughout this work.

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CERTIFICATE

This is to certify that candidate **Mr. Sowmit Suryadevara** bearing **Roll No: U11EC123** of **B.TECH IV, 7TH Semester** has successfully and satisfactorily presented seminar & submitted the Report on the topic entitled "**3D Printing – Analysis of Different Types of Methods**" for the partial fulfillment of the degree of Bachelor of Technology (B.Tech) in **Nov. 2014**.

Guide: ______________

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Chapter – 1 INTRODUCTION

3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layers of material. It is also known as rapid prototyping, is a mechanized method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing blueprints for the object. The 3D printing concept of custom manufacturing is exciting to nearly everyone. This revolutionary method for creating 3D models with the use of inkjet technology saves time and cost by eliminating the need to design; print and glue together separate model parts [1]. Now, you can create a complete model in a single process using 3D printing. The basic principles include materials cartridges, flexibility of output, and translation of code into a visible pattern.

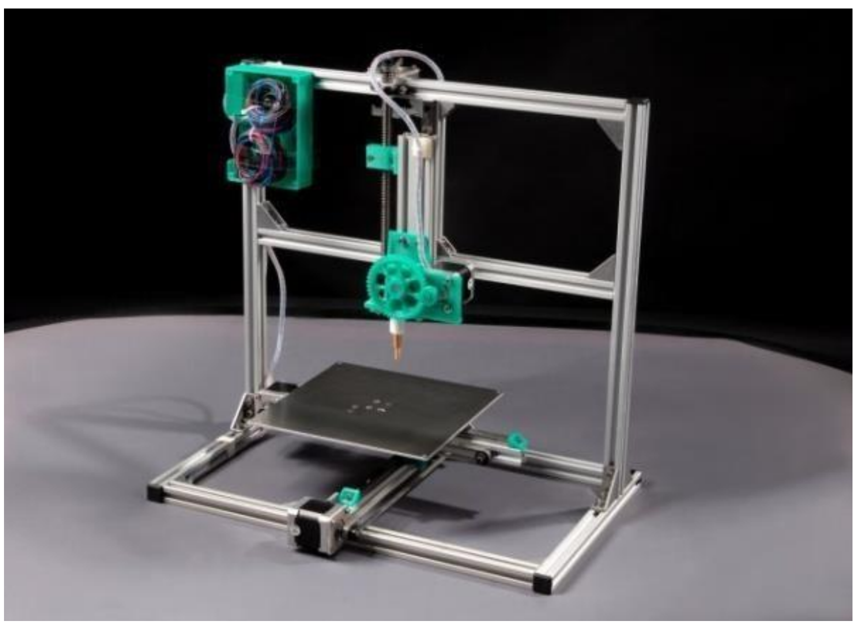

Figure 1: 3D Printer

(Courtesy: http://www.3ders.org/images/)

3D Printers are machines that produce physical 3D models from digital data by printing layer by layer. It can make physical models of objects either designed with a CAD program or scanned with a 3D Scanner. It is used in a variety of industries including jewellery, footwear, industrial design, architecture, engineering and construction, automotive, aerospace, dental and medical industries, education and consumer products.

1.1 History of 3D Printing

The technology for printing physical 3D objects from digital data was first developed by Charles Hull in 1984. He named the technique as Stereo lithography and obtained a patent for the technique in 1986.

While Stereo lithography systems had become popular by the end of 1980s, other similar technologies such as Fused Deposition Modelling (FDM) and Selective Laser Sintering (SLS) were introduced.

In 1993, Massachusetts Institute of Technology (MIT) patented another technology, named "3 Dimensional Printing techniques", which is similar to the inkjet technology used in 2D Printers.

In 1996, three major products, "Genisys" from Stratasys, "Actua 2100" from 3D Systems and "Z402" from Z Corporation, were introduced.

In 2005, Z Corp. launched a breakthrough product, named Spectrum Z510, which was the first high definition colour 3D Printer in the market.

Another breakthrough in 3D Printing occurred in 2006 with the initiation of an open source project, named Reprap, which was aimed at developing a self-replicating 3D printer [2].

1.2 Manufacturing a Model with 3D Printer

The model to be manufactured is built up a layer at a time. A layer of powder is automatically deposited in the model tray. The print head then applies resin in the shape of the model. The layer dries solid almost immediately. The model tray then moves down the distance of a layer and another layer of power is deposited in position, in the model tray. The print head again applies resin in the shape of the model, binding it to the first layer. This sequence occurs one layer at a time until the model is complete.

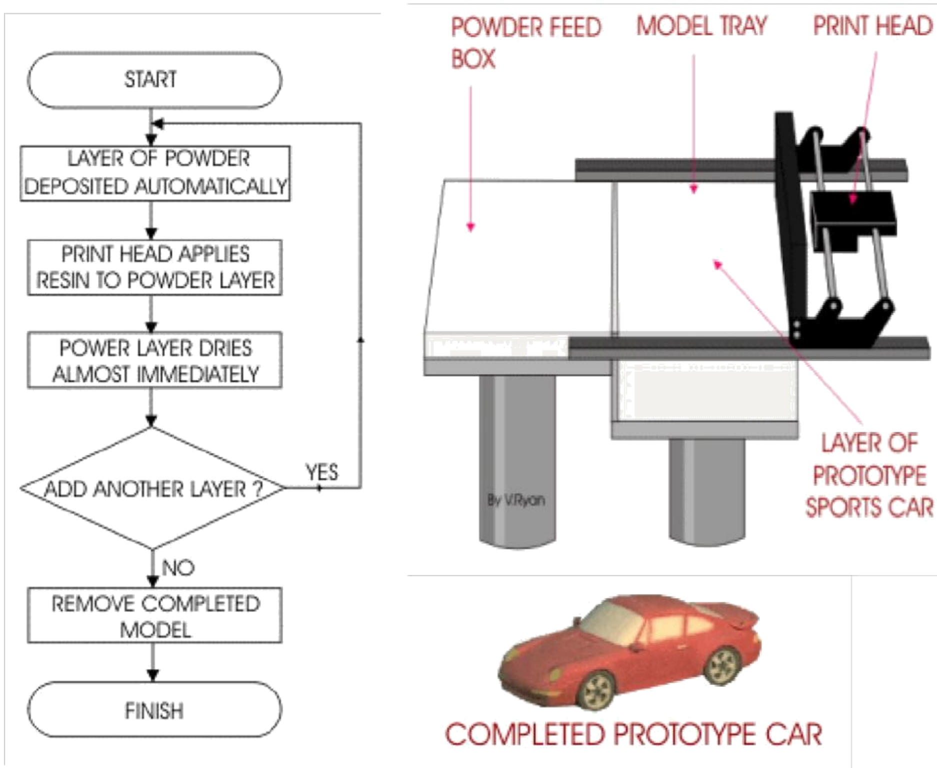

Figure 2 : 3D Printing Manufacturing Process [2]

1.3 Current 3D Printing Technologies

Stereolithography - Stereolithographic 3D printers (known as SLAs or **s**tereolithography **a**pparatus) position a perforated platform just below the surface of a vat of liquid photo curable polymer. A UV laser beam then traces the first slice of an object on the surface of this liquid, causing a very thin layer of photopolymer to harden. The perforated platform is then lowered very slightly and another slice is traced out and hardened by the laser. Another slice is then created, and then another, until a complete object has been printed and can be removed from the vat of photopolymer, drained of excess liquid, and cured.

Fused deposition modelling - Here a hot thermoplastic is extruded from a temperature controlled print head to produce fairly robust objects to a high degree of accuracy.

Selective laser sintering (SLS) - This builds objects by using a laser to selectively fuse together successive layers of a cocktail of powdered wax, ceramic, metal, nylon or one of a range of other materials [3].

Three Dimensional Printing (3DP) – This is a process developed at MIT for the rapid and flexible production of prototype parts, end-use parts, and tools directly from a CAD model. Three Dimensional Printing has unprecedented flexibility [4].

1.4 3D Saves time and Cost

Creating complete models in a single process using 3D printing has great benefits. This innovative technology has been proven to save companies time, manpower and money. Companies providing 3D printing solutions have brought to life an efficient and competent technological product.

Chapter – 2 METHODS OF 3D PRINTING

2.1 Fused deposition Modelling

Fused deposition modelling (FDM) is an additive manufacturing technology commonly used for modelling, prototyping, and production applications. This technology was developed by S. Scott Crump in the late 1980s. FDM works on an "additive" principle by laying down material in layers; a plastic filament or metal wire is molten, unwound from a coil and laid down in layers to produce a part. This is the most seen 3d printing method, as most inexpensive machines use this method [5].

2.1.1 Working

A plastic filament, approximately 1/16 inch in diameter, is unwound from a coil and supplies material to an extrusion nozzle. Some configurations of the machinery have used plastic pellets fed from a hopper rather than a filament. The nozzle is heated to melt the plastic and has a mechanism which allows the flow of the melted plastic to be controlled. The nozzle is mounted to a mechanical stage which can be moved in both horizontal and vertical directions. Some manufacturers take an opposite approach and move the table instead.

As the nozzle is moved over the table in the required geometry, it deposits a thin bead of extruded plastic to form each layer. The plastic cools and hardens immediately after being squirted from the nozzle and bonds to the layer below. In professional-level systems, to prevent warping of parts the entire mechanism is contained within a chamber which is held at a temperature just below the melting point of the plastic. Thus, only a small amount of additional thermal energy needs to be supplied by the extrusion nozzle to cause the plastic to melt. This provides much better control of the process. Basic machines may simply use a heated table.

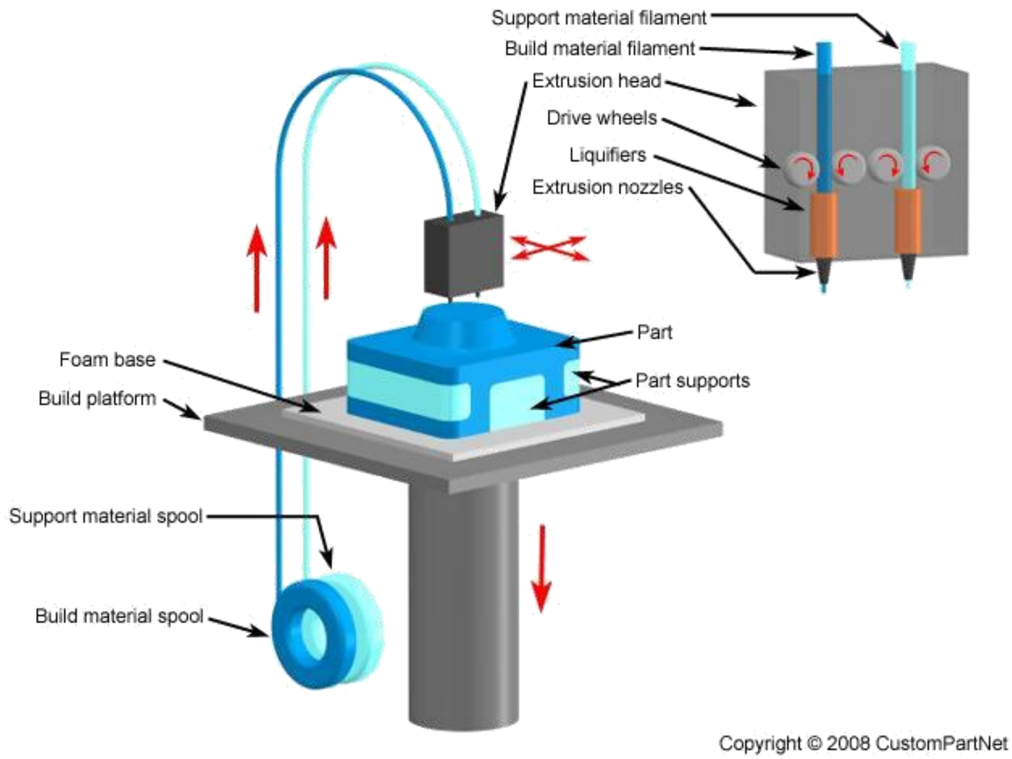

Figure 3 : Fused Deposition Modelling

(Courtesy: http://www.custompartnet.com/wu/images/)

2.1.2 The Positives

Thermoplastic extrusion methods are office-friendly, quiet, reliable, and can produce useable parts in a good selection of materials. Professional-level machines are available for as little as US$10,000 and fairly capable. Accuracy, detail and finishes are fair to good.

2.1.3 The Negatives

The process can be excruciatingly slow for some part geometries. Parts may have poor layer to layer adhesion and may not be watertight for applications that come in contact with liquids. While dozens of low-cost hobbyist machines are available both as kits and assembled form, it can be a lengthy and troublesome learning experience to get useful output from them.

2.1.4 Materials

Several materials are available for the process including ABS and investment casting wax. ABS offers good strength, while polycarbonate and polyphenyl sulfone materials have been introduced which extend the capabilities of the method further in terms of strength and temperature range. Ceramic and metallic materials have been experimented with, but are not available commercially [6].

2.1.5 Comparison with other methods

The finish of parts produced with the method have been greatly improved over the years, but aren't quite on a par with stereolithography. The closest technology competitor to the thermoplastic extrusion process for concept modelling applications is three dimensional printing (3DP), originally developed at MIT. However, the method offers greater strength and a wider range of materials than 3DP, although that technology offers full colour output. The 3DP technology offers excellent speed when compared to Fused Deposition Modelling (FDM). Accuracy and surface finish are more or less the same for both the methods but FDM is an expensive method of the two.

2.2 Three Dimensional Printing

Three Dimensional Printing is a process developed at MIT for the rapid and flexible production of prototype parts, end-use parts, and tools directly from a CAD model. Three Dimensional Printing has unprecedented flexibility. It can create parts of any geometry, and out of any material, including ceramics, metals, polymers and composites. Furthermore, it can exercise local control over the material composition, microstructure, and surface texture.

2.2.1 Working

The method is very reminiscent of laser sintering, except that the laser is replaced by an inkjet head. The multi-channel jetting head deposits a liquid adhesive compound onto the top layer of a bed of powder object material. The particles of the powder become bonded in the areas where the adhesive is deposited.

Once a layer is completed the piston moves down by the thickness of a layer. As in laser sintering, the powder supply system is similar in function to the build cylinder In this case the piston moves upward incrementally to supply powder for the process and the roller spreads and compresses the powder on the top of the build cylinder. The process is repeated until the entire object is completed within the powder bed [4].

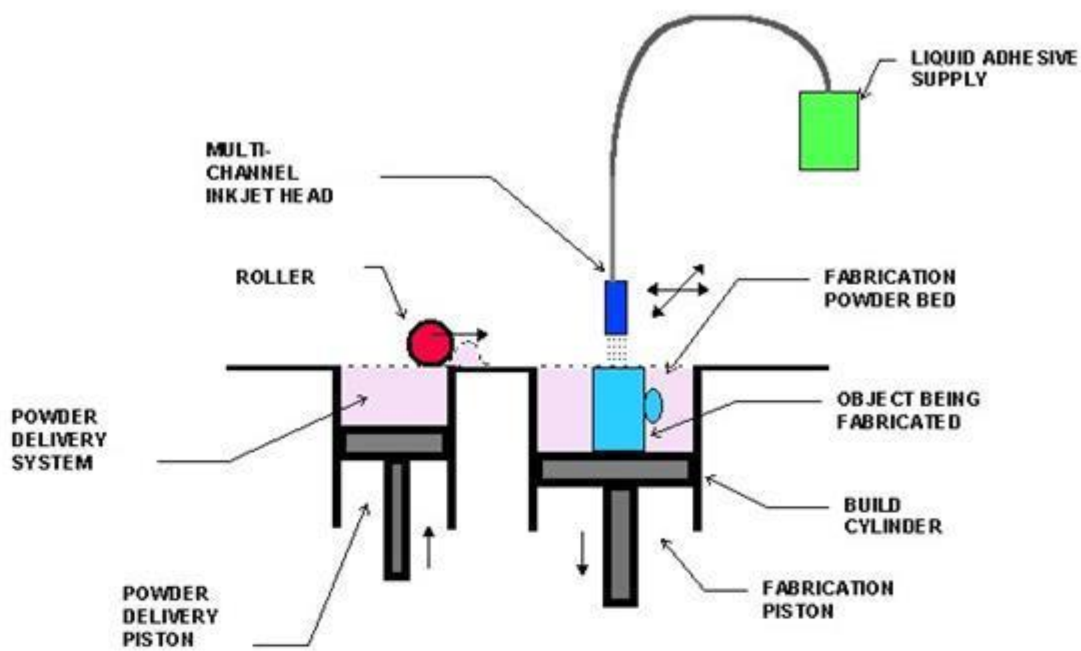

Figure 4 : Three Dimensional Printing [7]

After completion the object is elevated and the extra powder brushed away leaving a "green" object. Parts must usually be infiltrated with a hardener before they can be handled without much risk of damage. No external supports are required during fabrication since the powder bed supports overhangs.

2.2.2 The Positives

Three dimensional printing offers the advantages of speedy fabrication and low materials cost. Overall, it's the fastest of all additive methods. It is also the only technology for which full colour output is available. This makes it an excellent choice for industrial design, scientific visualization and architectural modelling applications.

2.2.3 The Negatives

The technology suffers from limitations on resolution, surface finish and part fragility. The number of available materials is very limited and parts must usually be infiltrated with an adhesive before they can be safely handled.

2.2.4 Materials

The materials used in Three Dimensional Printing (3DP) are exactly similar to those mentioned in section 2.4.4 under Selective Laser Sintering.

2.2.5 Comparison with other methods

The closest competitor to this process in terms of applications is probably Stereolithography (SLA). Three Dimensional Printing (3DP) has an excellent speed of production when compared to that of Stereolithography (SLA). On the other hand, accuracy and surface finish of the objects produced from SLA are very detailed and proper while 3DP is used for limited functions where low accuracy and average surface finish is acceptable. 3DP can be used to make coloured products but the materials and size of the product are limited as compared to SLA.

2.3 Stereolithography

Stereo lithography is an additive manufacturing or 3D printing technology used for producing models, prototypes, patterns, and production parts up one layer at a time by curing a photo-reactive resin with a UV laser or another similar power source. It makes for great surface quality and build accuracy.

2.3.1 Working

A moveable table, or elevator, is placed initially at a position just below the surface of a vat filled with liquid photopolymer resin. This material has the property that when light of the correct colour strikes it, it very quickly turns from a liquid into a solid. The most common photopolymer materials used require an ultraviolet light, but resins that work with visible light are also available. Most stereolithography systems are sealed to prevent the escape of vapour from the resin as indicated by the dashed line. The vapour is potentially harmful and there is also typically some odour associated with the resin.

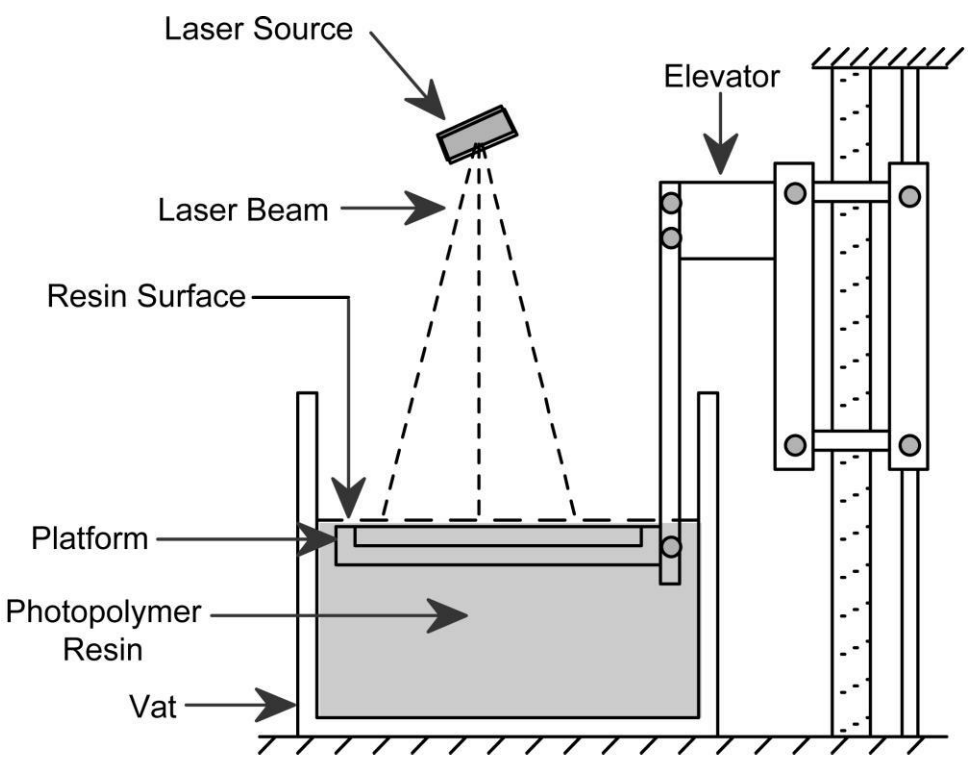

Figure 5 : Stereolithography

(Courtesy: http://www.solidsmack.com/)

A laser beam is moved over the surface of the liquid photopolymer to trace the geometry of the cross-section of the object. This causes the resin to harden in areas where the laser strikes.

The laser beam is moved in the *X-Y* directions by a scanner system. These are very fast and highly-controllable motors which drive mirrors that paint the laser beam over the surface. A laser isn't the only way to expose and harden a photopolymer. An increasingly popular way to do that is by using a conventional light source, such as an arc lamp, in conjunction with a liquid crystal display panel or a deformable mirror device (DMD). These so-called spatial light modulators expose an entire layer of photopolymer at one time [8]. A typical machine based on this method exposes the photopolymer from below through a transparent window, enabling the fabricated part to literally be pulled out of the vat.

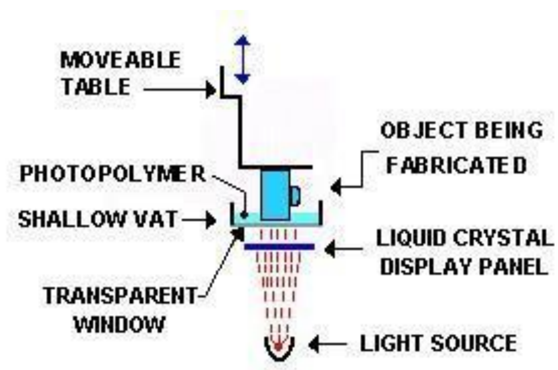

Figure 6 : Stereolithography using Spatial Light Modulators [8]

The motors are guided by information from the CAD data that describes the cross section of the object that's being made. The exact pattern that the laser traces is a combination of this basic geometric information and added information from the machine's internal software that optimizes the accuracy of the fabricated object by compensating for errors, such as shrinkage. A great deal of work over the years has gone into optimizing this exposure technique.

After the layer is completely traced and for the most part hardened by the laser beam, the table is lowered into the vat by a distance equal to the thickness of one layer. To speed this process of recoating, early stereolithography systems drew a knife edge (E) over the surface to smooth it. Pump-driven recoating systems are used in commercial equipment today for faster and more reliable operation. The tracing and recoating steps are repeated until the object is completely fabricated and sits on the table within the vat, as shown.

Some objects have overhangs or undercuts. For example, the handle on the cup pictured would be an overhang. These must be supported during the fabrication process. Support structures may be manually added during the design process, but are usually added automatically by the system's software.

After the fabrication process is complete, the object is elevated from the vat and allowed to drain. Excess resin is swabbed manually from the surfaces and may be cleaned away using alcohol. The object is often given a final cure by bathing it in intense light in a box resembling an oven called a Post-Curing Apparatus (PCA). Some resins and types of stereolithography equipment don't require this operation. After final cure, the support structures are cut off the object and surfaces are sanded or otherwise finished.

2.3.2 The Positives

Stereolithography generally is considered to provide the greatest accuracy and best surface finish of any additive technology. Over the years, materials with properties mimicking those of several engineering thermoplastics have been developed, however choices are still quite limited. One or two selectively color changing materials for biomedical and other applications are available, and ceramic materials have been developed for special applications. The technology is also notable for the large object sizes that are possible.

2.3.3 The Negatives

Working with liquid materials can be messy and parts often require post-curing for complete cure. Some are suspected carcinogens and need to be handled carefully. The long-term stability of materials is also a matter for concern and needs to be taken into consideration for any end-use application. The equipment is also expensive, typically selling for many tens of thousands of dollars. This is mainly because the method requires the use of expensive components such as the laser and scanning system.

2.3.4 Materials

Stereolithography machines use liquid photopolymer resin for additive manufacturing. This material has the property that when light of the correct color strikes it, it very quickly turns from a liquid into a solid. These liquid photopolymer resins are made up of epoxy polymers, either rigid or flexible.

2.3.5 Comparison

Stereolithography generally is considered to provide the greatest accuracy and best surface finish of any additive technology. SLA is also notable for the large object sizes that are possible compared to all other technologies but has limited materials usage as compared to Selective Laser Sintering. The post processing requirement in SLA adds up to its weakness when compared to other technologies. Also, it is an expensive technology when compared to FDM and 3DP.

2.4 Selective Laser Sintering

Selective Laser Sintering (SLS) is an additive manufacturing technique that uses a laser as the power source to sinter powdered material (typically metal), aiming the laser automatically at points in space defined by a 3D model, binding the material together to create a solid structure. When a layer is finished, the build platform moves down and an automated roller adds a new layer of material which is sintered to form the next cross section of the object. Repeating this process builds up the object one layer at a time. SLS includes sintering of both thermoplastic and metal powders. SLS is a relatively new technology that so far has mainly been used for rapid prototyping and for low-volume production of component parts. SLS is both a cost and time effective technology, making it ideal for prototyping and end use manufacturing [5].

2.4.1 Working

In Selective Laser Sintering (SLS), a laser beam is traced over the surface of a tightly compacted powder made of thermoplastic material. The powder is usually spread by a counter-rotating roller over the surface of a build cylinder, although other methods are also used. A piston moves down one object layer thickness to accommodate the layer of powder.

The powder supply system is similar in function to the build cylinder. It also consists of a cylinder and piston. In this case, the piston moves upward incrementally to supply just enough powder for one layer in the build process. In some configurations, excess powder is swept by the roller into another powder supply cylinder located on the other side of the build cylinder (not shown), and the powder feed cycle is alternated between the two material supply sources.

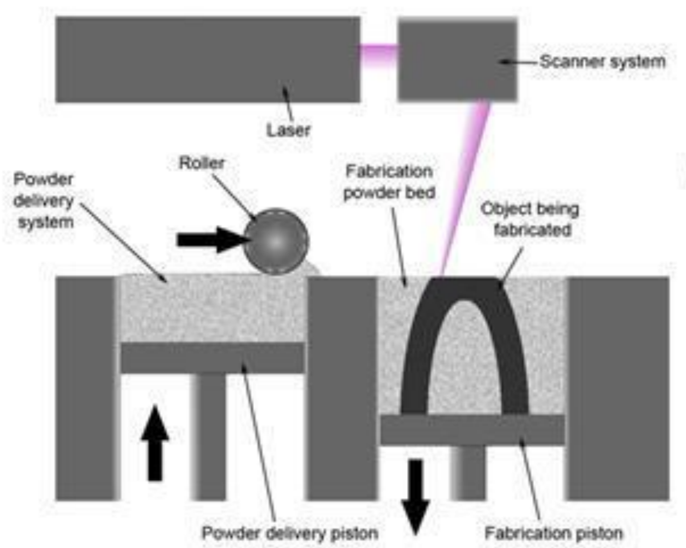

Figure 7 : Selective Laser Sintering

(Courtesy: http://media.treehugger.com/)

The laser beam is moved in the *X-Y* directions by a scanner system. These are very fast and highly-controllable motors which drive mirrors that paint the laser beam over the surface of the compacted powder in the build chamber. The laser selectively fuses the powder in the form of the cross section of the object [9].

The motors are guided by information from the CAD data that describes the cross section of the object that's being made. The exact pattern that the laser traces is a combination of this basic geometric information and added information from the machine's internal software that optimizes the accuracy of the fabricated object by compensating for errors, such as shrinkage and curl. A great deal of work over the years has gone into optimizing this exposure technique, called a build style. Build styles are optimized depending on the particular machines and the usage of specific materials.

The laser used provides a concentrated infrared heating beam. The entire fabrication chamber is sealed and maintained at a temperature just below the melting point of the plastic powder. Thus, heat from the laser need only elevate the temperature slightly to cause sintering, greatly speeding the process. A nitrogen atmosphere is also maintained in the fabrication chamber which prevents the possibility of explosion in the handling of large quantities of powder.

After the object is fully formed, the piston is raised to elevate the object. Excess powder is simply brushed away and final manual finishing may be carried out. That’s not the complete story, though. It may take a considerable time before the part cools down enough to be removed from the machine. Large parts with thin sections may require as much as two days of cooling time.

No supports are required with this method since overhangs and undercuts are supported by the solid powder bed. This saves some finishing time com. However, surface finishes are not as good and this may increase the time. No final curing is required, but since the objects are sintered they are at least somewhat porous. It may sometimes be necessary to infiltrate the object with another material to improve mechanical characteristics depending on the application.

Laser sintering has also been extended to provide direct fabrication of metal and ceramic objects and tools. Metals are handled in a similar way. They can be directly sintered using a much higher power laser than that used with plastics. Alternatively, the metal powder particles can be coated with a thin layer of plastic which enables the use of a lower power laser to bond them into a so-called green part. A green part is very fragile but it can be made into a high strength part by carefully heating it to a high temperature in an oven and infiltrating it with a second metal, often bronze in the case of steel parts.

2.4.2 The Positives

The ability to produce parts in a range of real engineering plastics and metals has enabled laser sintering to compete with less expensive technologies. It's often the method of choice for additively-manufactured parts with critical material properties in fields such as aerospace and medicine. A variety of thermoplastic materials such as nylon, glass-filled nylon, and polystyrene are available. Surface finishes and accuracy are not quite as good as with other available materials, but material properties can be quite close to those of the intrinsic materials.

2.4.3 The Negatives

The method is mechanically more complex and the equipment is larger than most other technologies. It requires expensive components such as the laser and scanner system, leading to very high equipment prices. Materials are also expensive. Even though basic engineering plastics and metals may be used, producers tie their materials to machine warranties and service contracts to prevent users from using less expensive sources.

2.4.4 Materials

Some SLS machines use single-component powder, such as direct metal laser sintering. Powders are commonly produced by ball milling. However, most SLS machines use two component powders, typically either coated powder or a powder mixture. SLS can produce parts from a wide range of powder materials. These include polymers such as nylon (neat, glass-filled, or with other fillers) or polystyrene, metals including steel, titanium, alloy mixtures, and composites and green sand. Depending on the material, up to 100% density can be achieved with material properties comparable to those from conventional manufacturing methods.

2.4.5 Comparison

No supports are required with this method since overhangs and undercuts are supported by the solid powder bed. This saves some finishing time compared to stereolithography. However, surface finishes are not as good and this may increase the time. No final curing is required as in stereolithography. Surface finishes and accuracy are not quite as good as with stereolithography, but material properties can be quite close to those of the intrinsic materials. It's often the method of choice for additively-manufactured parts with critical material properties in fields such as aerospace and medicine [8].

Chapter – 3 COMPARATIVE ANALYSIS

The comparison between different methods of 3D printing is done on the basis of various parameters.

3.1 Speed

It is the time duration in which the end product is obtained.

Table 1 : Comparison on the basis of Speed

	Fused Deposition Modelling (FDM)	Three Dimensional Printing (3DP)	Stereolithography (SLA)	Selective Laser Sintering (SLS)
Speed[8]	Poor	Excellent	Average	Average to Good

- **FDM:** This process is extremely slow for some part geometries i.e. parts with complicated geometries in the product makes the overall speed of the process is poor.
- **3DP:** In this method, the multi-channel jetting head deposits a liquid adhesive compound which helps in bonding different layers at a very fast rate and hence the speed is excellent.
- **SLA:** A laser beam is moved over the surface of the liquid photopolymer to trace the geometry of the cross section of the object even after it is hardened. This extra function for each layer leads to the decreased overall speed.
- **SLS:** The laser beam used to sinter the material takes longer than the adhesion process in 3DP, but is better than SLA.

3.2 Surface Finish

Surface finishing is the degree of visibility of individual layers.

Table 2 : Comparison on the basis of Surface Finishing

	Fused Deposition Modelling (FDM)	Three Dimensional Printing (3DP)	Stereolithography (SLA)	Selective Laser Sintering (SLS)
Surface Finish	Fair	Fair	Very Good	Good

- **FDM & 3DP:** The breakaway support materials in these methods are removed manually by snapping them off and thus the surface finishing is not good.
- **SLA:** The tracing and recoating steps that are repeated until the object is finally fabricated, is the reason for a very good surface finish.
- **SLS:** As the objects are sintered, they are somewhat porous and hence the surface finishing is not as good as SLA.

3.3 Layer Thickness

3D printers make their parts by putting down thin layers of a material to build the part. Each of these layers can vary in size dramatically depending on which type of machine made the part.[10]

Table 3 : Comparison on the basis of Layer Thickness

	Fused Deposition Modelling (FDM)	Three Dimensional Printing (3DP)	Stereolithography (SLA)	Selective Laser Sintering (SLS)
Layer Thickness	Fair	Fair	Good	Very Good

- **FDM:** 0.007in (0.18mm)

- **3DP:** 0.0065in (0.055mm)
- **SLA:** 0.005in (0.128mm)
- **SLS:** 0.002in to 0.004in (0.052mm to 0.104mm)

3.4 Maximum Build Chamber

3D printers largely vary in size. The maximum build area of an object possible varies with the type of machine used.

Table 4 : Comparison on the basis of Maximum Build Chamber

	Fused Deposition Modelling (FDM)	Three Dimensional Printing (3DP)	Stereolithography (SLA)	Selective Laser Sintering (SLS)
Maximum Build Chamber (inches) [8]	24x20x24	20x24x16	20x20x24	27.5x20x23

3.5 Tolerance level

Tolerance is a factor of the materials, cooling and expanding slightly along the walls of parts, resulting in solid sections tending towards the positive tolerance while holes tend towards negative tolerance [12].

Table 5 : Comparison on the basis of Tolerance

	Fused Deposition Modelling (FDM)	Three Dimensional Printing (3DP)	Stereolithography (SLA)	Selective Laser Sintering (SLS)
Tolerance Level (inches)[13]	+/- 0.005 +/- 0.010	_	+/-0.002 +/- 0.005	+/- 0.007

3.6 Accuracy

This represents the absolute minimum feature size or the detailing on an object possible. [11]

Table 6 : Comparison on the basis of Accuracy

	Fused Deposition Modelling (FDM)	Three Dimensional Printing (3DP)	Stereolithography (SLA)	Selective Laser Sintering (SLS)
Accuracy	Fair, Detailed enough	Fair, Very less detailed	Very Good, Very Detailed	Good, Slightly less detailed than SLA

3.7 Strength, Weakness and Cost

Table 7 : Comparison on the basis of Strength, Weakness and Cost

	Fused Deposition Modelling (FDM)	Three Dimensional Printing (3DP)	Stereolithography (SLA)	Selective Laser Sintering (SLS)
Strengths	office OK price, materials	speed, office OK, price, colour	large part size, accuracy	accuracy, wide range of materials
Weakness	speed	limited materials, fragile parts, finish	Post processing, messy liquids	size and weight, system price, surface finish
Cost [14]	$10K-300K	$15K-70K	$75K-800K	$200K-1M+

Chapter – 4 FUTURE PROSPECTS

In the recent years parts of the manufacturing world have become very enthusiastic about 3D printing technology. Some people are even talking about a next industrial revolution [15]. Just as computers were once assumed to have no mass market potential, some commentators believe that only a few people will ever need a 3D printer. Even so, there is a speculation that in 10-20 years down the line most people in developed nations will regularly make use of a 3D printer to materialize their design [16].

Some of the future prospects in 3D printing technology which can be very helpful in our daily lives are highlighted below:

4.1 Medical and Educational

Bone models based on 3D printing technology can be used for creating teaching materials for the medical science universities and beyond or even as surgical guides in metal implants. Worldwide, the supply of bodies donated to science and educational purposes has decreased over the last years creating a demand that 3D printing could successfully fill in the near future. High-end machines can print structures in full colour with sections that reveal the important aspects of a body structure, be it a soft tissue organ, or a bone. Furthermore, creating easily accessible structures that mimic the properties of the original, can allow students to practice surgical procedures with ease. Of similar importance, advances in low-cost additive metal manufacturing processes could create new research possibilities in the field of bone implants and prosthetics, making them more affordable while custom designed for each patient's need [1].

4.2 Pharmaceutical

A 3D ice printing technology is a simple and inexpensive bottom-up 3D fabrication method. A prototypical ice printing system can be built up with a modified desktop inkjet printer to validate the technology. Using 3D ice printing structure as a mould, complex microfluidic components can be achieved. With the ice printing technology, a drug solution can be printed as a reservoir and packaged during the fabrication process. This ice printing method has a promising potential for drug delivery applications [17].

4.3 Micro-electromechanical Systems

A method to additively build three-dimensional (3-D) microelectromechanical systems (MEMS) and electrical circuitry by ink-jet printing nanoparticle metal colloids. Fabricating metallic structures from nanoparticles avoids the extreme processing conditions required for standard lithographic fabrication and molten-metal-droplet deposition. Nanoparticles typically measure 1 to 100 nm in diameter and can be sintered at plastic-compatible temperatures as low as 300°C to form material nearly indistinguishable from the bulk material. Multiple ink-jet print heads mounted to a computer-controlled 3-axis gantry deposit the 10% by weight metal colloid ink layer-by-layer onto a heated substrate to make two-dimensional (2-D) and 3-D structures. A high-Q resonant inductive coil, linear and rotary electrostatic-drive motors, and in-plane and vertical electrothermal actuators can be obtained.

The devices can be printed in minutes with a 100 μm feature size, made out of silver and gold material with high conductivity, and feature as many as 400 layers, insulators, 10:1 vertical aspect ratios, and etch-released mechanical structures. These suggest a route to a desktop or large-area MEMS fabrication system characterized by many layers, low cost, and data-driven fabrication for rapid turn-around time, and represent the first use of ink-jet printing to build active MEMS [18].

Chapter – 5 CONCLUSION

The 3D printing concept of custom manufacturing is exciting to nearly everyone. This revolutionary method for creating 3D models saves time and cost by eliminating the need to design; print and glue together separate model parts. In this report, we understood the concept of 3D printing and the important techniques which are used to create a 3D model. Further, the advantages and drawbacks of each method were also discussed. Also, the comparative analysis of different methods was done on factors like size, duration, accuracy, surface finishing etc. Through this analysis we could understand that each technique has its own positives and negatives that determine its usage.

As we head through 2015 and beyond, the speed and variety of 3D Printing Revolution will continue to gather momentum. By then most people in developed nations will regularly make use of a 3D printer to materialize their design. With 66% of industrial manufacturers of a survey [19] using 3D printing for testing, prototyping or production, the concept of 3D printing is intended to have a boom and be a part of our daily life in near future.

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