Product Design and Development Using 3D Technology By Fused Deposition Modelling

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ABSTRACT - 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. 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. 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 jewelry, footwear, industrial design, architecture, engineering and construction, automotive, aerospace, dental and medical industries, education and consumer products.

Key words: Product design, 3D Technology, CAD, Scanner, AM

I. INTRODUCTION

3D printing called as desktop fabrication. It is a rapid prototyping process whereby a real object can be created from a 3D design. A 3D printer machine uses a CAD model for rapid prototyping process. 3D printing is called as desktop fabrication which is a process of prototyping where by a structure is synthesized from its 3d model. The 3d design is stored in as a STL format and after that forwarded to the 3D printer. It can use a wide range of materials such as ABS, PLA, and composites as well.3D printing is one kind of rapidly developing and cost optimized form which is used for rapid prototyping. The 3D printer prints the CAD design layer by layer forming a real object. 3D printing process is derived from inkjet desktop printers in which multiple deposit jets and the printing material, layer by layer derived from the CAD 3D data.3D printing is diversifying and accelerating our life, letting various qualities of products to be synthesized easier and faster. Three-dimensional (3D) printing has the ability to impact the transmission of information in ways similar to the influence of such earlier technologies as photocopying. This identifies sources of information on 3D printing, its technology, required software and applications. Along 3D printing, companies are able to extract and innovate new ideologies and various design replications with no time or tool expense. 3D printing possibly challenges mass production processes in future. 3D printing influences many industries, such as automotive, architecture, education, medical, business and consumer industries.

MOTIVATION FOR THE PRESENT RESEARCH WORK:

Since over a century the visual world of printed scriptures has been dominated by the 2-D printing methods. Be that easy to read or comprehend but when it comes to imaging of definite and real-life models it is sorely outsourced. Any 3-D model cannot be represented and displayed easily in a 2-D workplace. The only thing worth mentioning for likable perception is the rendering of the image. This ushered in the era of the much-needed idea of "3-D" printing.

Basically, the singular purpose for the division of 3-D printer was to prepare 3-D samples directly on the bed of the printer. It has been an effective way of manufacturing since many companies are now opting for this type of method for their production operations.

1.1 OBJECTIVE:

1. To study different methods of 3d printing and their applications.
2. To study the working procedure of each component of a 3d printer and the evolution of 3d printer.
3. To design and fabricate a 3d printer using tool kit.

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1.2 PROCESS OF 3D PRINTING:

3D printing process can be described and defined in the following steps:

CAD Model Creation: Initially, the item to be 3D printed is designed utilizing a Computer- Aided Design (CAD) software. Solid modelers, for example, CATIA, and SOLID WORKS have a tendency to represent 3-D objects more precisely than wire-frame modelers, for example, AutoCAD. This procedure is comparative for the majority of the Rapid Prototyping building methods.

Conversion to STL Format: The different CAD models use different methods to present solid parts. To have consistency, the stereo lithography format has been followed as the standard of the 3D printing industry.

Slice the STL File: A preprocessing computer program is done which readies the STL format going to be built. Numerous programs are there, which permit the user to tweak the model. The preprocessing program cuts the Stereo lithography model into numerous layers from 0.01 mm to 0.7 mm thickness, in view of the building method. The program likewise makes an auxiliary structure to help the model amidst of building. Sophisticated structures are bound to use auxiliary support.

Layer by Layer Construction: The fourth step is the actual construction of the part. Using one of various techniques RP machines build one layer at a time from polymers, or powdered metal.

II. LITERATURE REVIEW

1974:

David E. H. Jones laid out the concept of 3D printing in his regular column Ariadne in the journal New Scientist

1981:

Early additive manufacturing equipment and materials were developed in the 1980s. In 1981, Hideo Kodama of Nagoya Municipal Industrial Research Institute invented two additive methods for fabricating three-dimensional plastic models with photo-hardening thermoset polymer, where the UV exposure area is controlled by a mask pattern or a scanning fibre transmitter.

1984:

On 16 July 1984, Alain Le Méhauté, Olivier de Witte, and Jean Claude André filed their patent for the stereolithography process. The application of the French inventors was abandoned by the French General Electric Company (now Alcatel-Alstom) and CILAS (The Laser Consortium). The claimed reason was "for lack of business perspective".

Three weeks later in 1984, Chuck Hull of 3D Systems Corporation[18] filed his own patent for a stereolithography fabrication system, in which layers are added by curing photopolymers with ultraviolet light lasers. Hull defined the process as a "system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed," Hull's contribution was the STL (Stereolithography) file format and the digital slicing and infill strategies common to many processes today.

1988:

The technology used by most 3D printers to date—especially hobbyist and consumer-oriented models—is fused deposition modelling, a special application of plastic extrusion, developed in 1988 by S. Scott Crump and commercialized by his company Stratasys, which marketed its first FDM machine in 1992.

1993:

The term 3D printing originally referred to a powder bed process employing standard and custom inkjet print heads, developed at MIT by Emanuel Sachs in 1993 and commercialized by Soligen Technologies, Extrude Hone Corporation, and Z Corporation.

The year 1993 also saw the start of a company called Solidscape, introducing a high-precision polymer jet fabrication system with soluble support structures.

1995:

In 1995 the Fraunhofer Institute developed the selective laser melting process.

2009:

Fused Deposition Modelling (FDM) printing process patents expired in 2009.

2010:

were the first decade in which metal end use parts such as engine brackets and large nuts would be grown in job production rather than obligately being machined from bar stock or plate. It is still the case that casting, fabrication, stamping, and machining are more prevalent than additive manufacturing in metalworking, but AM is now beginning to make significant inroads, and with the advantages of design for additive manufacturing, it is clear to engineers that much more is to come.

As technology matured, several authors had begun to speculate that 3D printing could aid in sustainable development in the developing world.

2012:

Filabot develops a system for closing the loop with plastic and allows for any FDM or FFF 3D printer to be able to print with a wider range of plastics.

2014:

Georgia Institute of Technology Dr. Benjamin S. Cook, and Dr. Manos M. Tentzeris demonstrate the first multi-material, vertically integrated printed electronics additive manufacturing platform (VIPRE) which enabled 3D printing of functional electronics operating up to 40 GHz.

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III. DESIGNING OF ARBOR

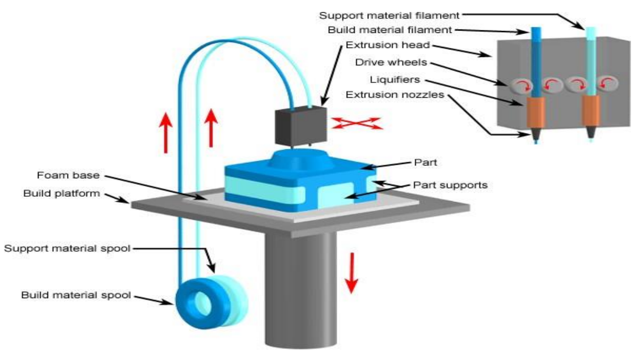
Alter Inspire –

Altair Inspire is a software platform that enable designers and design engineers to generate the most efficient concepts with focus on performance and manufacturability. This leads to reduced costs, shortened product development time, minimal material consumption and lightweight design.

PRINTING METHODS:

4.1 FUSED DEPOSITION MODELLING:

In this process the thermoplastics; which constitute ABS (Acrylonitrile butadiene styrene), wax and nylon were utilized. The introductory venture of the FDM procedure were to warmth up the thermoplastic constituent until it is at an intertwined state .Then, the 3D printer uses advanced demonstrating information from a CAD record to create the 3D item layer by layer, The printers join a much weaker bolster composite. The bolster material goes about as framework to the test item. This is valuable amid the building procedure when parts have overhangs that could not bolster it. The thermoplastic for the most part has a filamentous structure which benefits warmth exchange and serves to move with a print head that navigates in the x and y bearings. After every layer is printed, a cylinder navigates the stage beneath (z-hub) the separation of thickness of printed layer. There are numerous benefits of FDM innovation; it is anything but difficult to control, use, and fix. The expense of the machine and material are generally low.



IV. BASIC METHOD OF FDM TECHNOLOGY

4.2 GRANULAR MATERIAL BINDING (USING HEAT/ ENERGY):

The joining of granular materials involves specifically fusing powder, layer by layer. The elemental constitution of the powder and binding process relies on the machine.

Granular material binding

GRANULAR MATERIAL BINDING (USING BINDING AGENT):

This methodology utilized fluid binding material for the binding procedure of the powder together, instead of a laser. Zcorp, has a copyright of this innovation around the world. 3D printing is also called fundamental inkjet printing procedures. As opposed to utilizing paper like as a part of the instance of a 2D printer, a 3D printer moves the print heads over a bed of powder whereupon it printed information sent from the product. The fluid binding materials here utilized is much the same as super glue. Composite material or mortar is utilized as powder here.

Illustration of granular material

4.3 SELECTIVE LASER SINTERING (SLS):

One of the sorts of binding processes is Selective Laser Sintering, or SLS. It utilizes a high- powered laser to sinter the powder. Once the first layer is made, the whole granular plate, in which the powder (and the "print") is found, is cut down. As seen in Figure 6, this procedure is supplemented by the vertical development of a cylinder. Moreover, cylinders are additionally utilized as a part of a few printers to send the coupling powder up so that the moving instrument would continue working adequately and the sintering can proceed. A mirror is integrated to control the laser bar into the foreordained "cut" of the CAD model. When the greater part of the layers is appropriately sintered, the item is removed from the build chamber.

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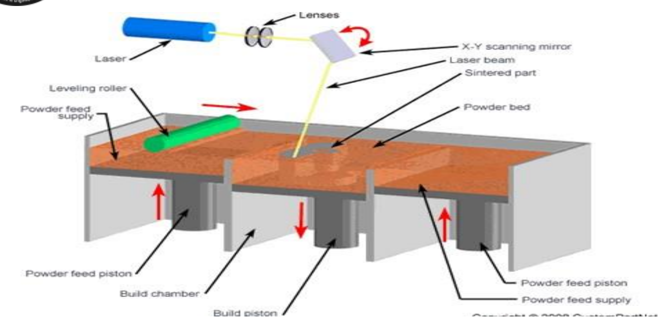


Selective Laser Sintering Citation Process

4.4 SELECTIVE HEAT SINTERING:

SHS is indistinguishable to SLS. Selective Heat Sintering utilized a thermal print head. This new strategy uses concentrated heat to fuse the binding powder.

Illustration of a Blue Printer Citation

A model created by Blue Print Citation

4.5 SELECTIVE LASER MELTING (SLM):

SLM is almost as same as SLS. A more powerful laser is generally used. It required more energy for the metal to be melted.

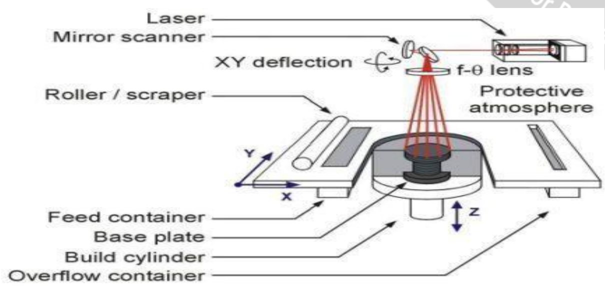


Illustration of selective laser sintering method

Selective laser sintering in action

4.6 Electron Beam Melting (EBM):

Electron Beam Melting is some cases similar to SLM; an electron beam was used to melt the powder. Unlike models produced by SLM, EBM models are fully accurate, void-less, and extremely powerful.

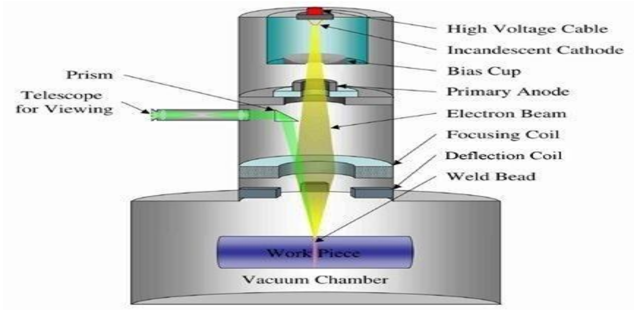


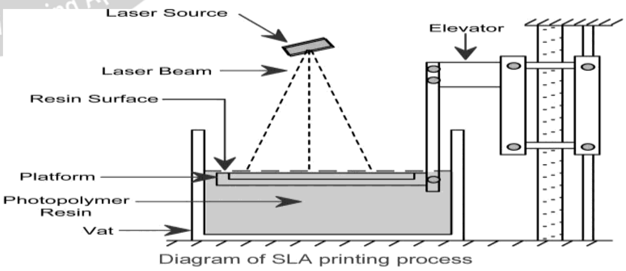
Photo Polymerization:

This is an additive manufacturing process. This methodology utilizes UV light for the hardening of the photograph polymer. There are diverse sorts of photopolymers which are accessible today. Photograph polymerization is really same as FDM and Granular Material binding process. The fundamental contrasts are the material sand the system utilized for the printing systems.

4.7 Stereo Lithography:

A stereo lithographic printer is regularly known as a SLA. A perforated platform was put just beneath the surface of a carriage of fluid polymer.

The UV-treatable fluid solidifies quick, shaping the essential layer of the 3D-printed item. Next, the stage was brought down, uncovering another surface layer of the fluid substance. This procedure is rehashed more till the whole question is framed and is completely submerged in the tank. Regularly, the utilization of the UV stove issued for the ensuing cure of the photograph polymer.



4.8 DLP Projecting:

DLP (Digital Light Processing) is one kind of stereo lithographic procedure. It utilizes a projector to solidify a layer of photopolymer at once, as opposed to utilizing a laser for the following of distinctive layers. A mirror was most normally used to position and size the replication precisely onto layer of photopolymer.

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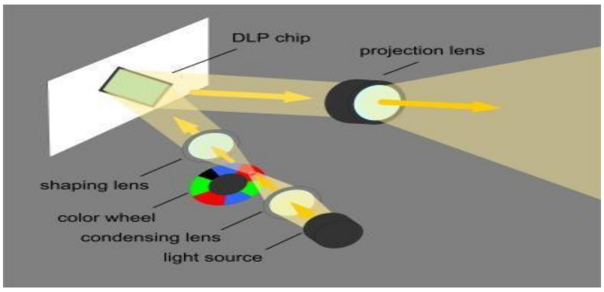


Illustration of DLP Projection

Digital Light Processing is a 3D printing technology known as DLP, used in DLP 3D printers. The object is formed by the solidification of a photo-reactive resin using a digital light projector as the UV light source. The projector used in a DLP 3D printer can be a regular video projector, its resolution will determine the 3D print resolution. DLP 3D printers are gaining traction, notably because of their superior print speed thanks to the light projector which hardens the resin layer by layer and not point by point, as lasers used in SLA 3D printers do.

4.9 Material Jetting:

Material Jetting is much the same as the FDM process, yet it works absolutely in an alternate manner than the basic plastic extrusion system. Layers were made by emanating fluid photopolymer into a specific example. These sorts of printers utilize a bolster material alongside the model material. When every layer is shaped, an UV laser is utilized for the solidification of the photopolymer. The platform is then moved down, and the model is printed layer by layer.

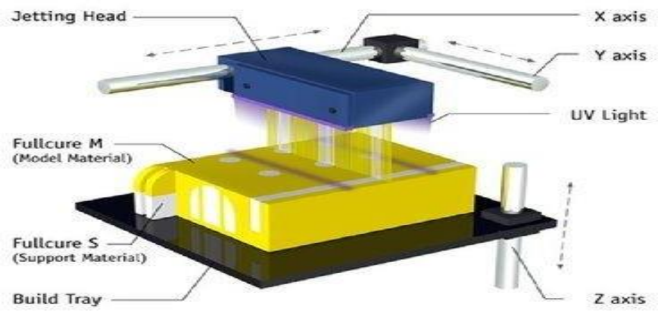
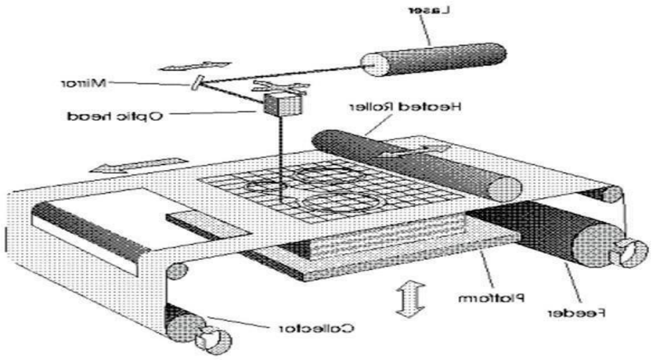


Illustration of material jetting process citation

4.10 Laminated Object Manufacturing (LOM):

Covered article assembling can give great results. Other than the laser (carbon dioxide) that is involved for following the patterns in the material. It is a less prevalent rapid prototyping process yet looks into are continuing for its future actualizes.

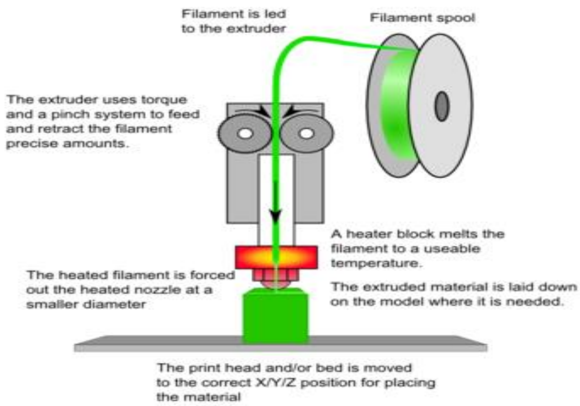


Depiction of Laminated Object Manufacturing process

In this technique the chose printing material is initially covered with a sticky material. The material supply roll turns simply enough with the goal that there is another layer of substance which is prepared to be cut with the assistance of the laser. The warmth and weight from the roller join so that the following layer is safely stuck to the past layer. The laser is being customized in a manner that it cuts the material so that the abundance material is effortlessly expelled from the setup. After the "print" is expelled from the stage, the abundance material and backings are to be uprooted. In this technique at last, regularly there is requirement for devices, for example, etches, to pry the additional parts far from the set up.

FUSED DEPOSITION MODELLING:

In the FDM process, a gantry-robot which is fitted with the extruder head moves in X & Y directions. The table moves in vertical Z-axis. When a layer gets deposited on the table, it goes down according to the layer thickness and the subsequent layers are built in the same way.



Materials used in making FDM parts:

Most of the existing FDM machines use thermoplastic materials which are in a filament form for the extrusion and deposition purpose. Acrylonitrile Butadiene styrene (ABS) and Polylactide (PLA) thermoplastics are predominantly used in the process.

The above-mentioned materials are used in following forms:

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i. Build material: This material is used to obtain actual part.

ii. Support material: This material is used to construct support structures for the actual part. The support material is otherwise called as dissolvable material if it is dissolvable.

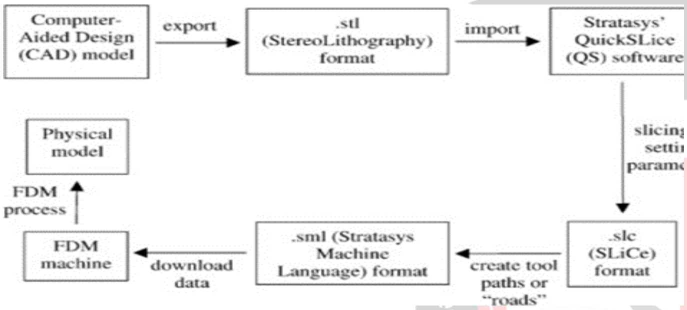
Table 1: Properties of materials

S.No.	Name of the material	Normal melting point	Temperature used in FDM
1	ABS	105ºC	230ºC
2	PLA	65ºC	190-210 ºC

Steps to be carried out to build a model:

Create a CAD model of the product.

1. Save it in the Stereolithography (STL) file format
2. Load the .stl file in to the slicing software or the interface platform between the specific machine and the computer.
3. Upload the sliced file into the FDM machine.
4. Run the machine with required settings.
5. Detach the part from the table after completion.



FDM MANUFACTURERS

With the 3D printing technology gaining popularity day by day, many players are jumping into the manufacturing business of 3D printing machines. The following list contains the names of manufacturers involved in the manufacturing of FDM/3D Printing machines.

i. MakerBot, USA
ii. 3D Systems, USA
iii. Fabbster, Germany
iv. Envision Tec, Germany
v. Aleph Objects, USA
vi. Beijing Tier Time Technology Co.Ltd., China
vii. Beijing Yinhua Laser Rapid Prototype Making and Mould Technology Co. Ltd., China

Vendors selling using open-source technology:

i. Solidoodle
ii. Stratasys Ltd., USA
iii. Tinkerine Studios Ltd., Canada
iv. Ultimaking Ltd. Netherlands

Apart from the above, there are several other companies which provide assembled kits and indigenously manufactured ones. The cost of the machines depends upon the quality of the product that is being obtained with respect to above stated input parameters and the characteristics of the parts.

ADVANTAGES

i. To decrease development time -Rapid Prototyping decreases development time by allowing corrections to be made to a product early in the process.

ii. Highly complex geometries-additive manufacturing produces intricate parts that are complicated in traditional processes.

iii. Fabrication for assembly - increased ability to incorporate joints for interlocking assemblies (especially where fabrication size constraints exist)

iv. Reduction of fabrication constraints - reduction in design for fabrication items such as draft angles.

v. Customizing Designs -The most promising benefit of rapid prototyping is the ability to develop customized products as per the individual requirement. It requires no special tools or process to implement design changes in the product. A small change in the CAD model and the entire process remains the same. For manufacturers, this is highly advantageous as it offers a connected experience for the customer with the product they purchase.

vi. Minimizing Design Flaws-The additive manufacturing offers the ability to identify flaws in the design prior to mass production. The risks of faults and usability issues can be identified earlier to avoid problems that might occur later during the manufacturing process.

DISADVANTAGES

1. FDM is a costlier process.
2. The size of the output product is limited to a very small size.
3. Raw material limitations. (No metal-based filaments can be used due to requirement of high temperatures).
4. FDM is a developing process.

APPLICATIONS OF 3D PRINTING:

3-D printing was originally developed for rapid prototyping purposes, making less complicated physical samples. It allowed designers to identify and rectify design flaws quickly and cheaply, thereby speeding up the product development process and minimizing commercial risks. Here are some applications of a 3D printer described below:

Aerospace and Automotive sector

With the help of 3-D-printed components which are used for aircrafts and parts are 70% less weighing but identically tough as conventional parts, indicating cost reduction and carbon reduction and emissions of unwanted particle. It uses less raw constituents and manufactures parts which are less weight, complicated but possess more strength.

Medical

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Medical sector is one of the most promising areas of usage. It is being applied to face many medical situations, and develop medical research, also combining the field of "regenerative medicine". In 2012, using a 3-D printer, engineers and doctors at Hasselt successfully experimented the very first patient-specific instrument of prosthetic jaw transplant.

Rapid manufacturing:

Advancements in Rapid Prototyping have presented materials those are necessary for final manufacturing, leading to the possibility of manufactured finished components and parts.

Mass customization:

Many industries have provided services where people can recreate their desirables implementing simple web-based customizing software. This now enables customers to replicate cases of their mobiles Nokia has displayed the 3D designs of their mobiles so that owners will be able to recreate their own phone case.

a) Aerospace

Air ducts, fixtures or mountings holding specific aeronautic instruments, laser-sintering fits both the needs of commercial and military aerospace

b) Medical

Medical devices are complex, high value products. They have to meet customer requirements exactly. These requirements do not only stem from the operator's personal preferences: legal requirements or norms that differ widely between regions also have to be complied with. This leads to a multitude of varieties and thus small volumes of the variants offered.

c) Anatomical Implants

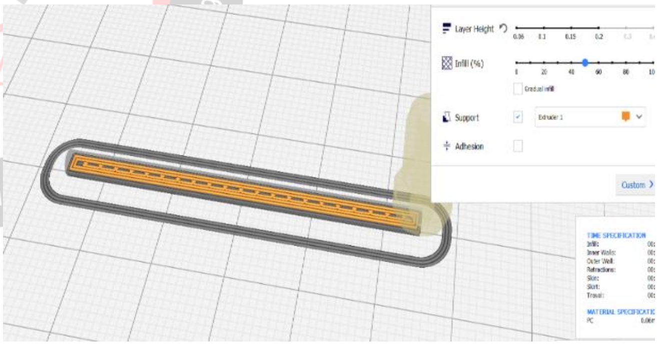
The implant would be made to fit exactly the patient's requirements in terms of shape, performance, and integration into existing structures within the body, using data collected by non-intrusive scans. RP is well suited to produce biomedical implants for bone replacement. 3D printing is an especially appropriate technique to generate complex porous ceramic matrices directly for biomedical applications. Anatomical information obtained from the patient is used to design and optimize the implant for a target defect. The use of RP allows 3D physical model to be created immediately, directly, and automatically from a 3D model. It works by breaking down a 3D model into 2D sections, which are built up layer by layer by high tech machines

d) Food industry:

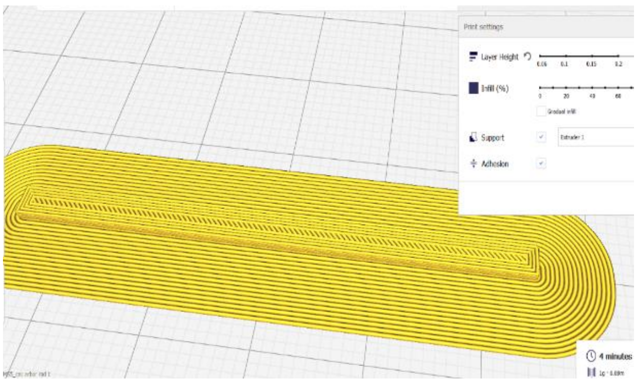
3D printing technology open the doors not only for aerospace industry, but also for food industry. At present, there is a growing demand for the development of customized food for specialized dietary needs, such as athletes, children, pregnant woman, patient and so on which requires a different amount of nutrients by reducing the amount of unnecessary ingredients and enhancing the presence of healthy ingredients. However, the development of customized foods must be conducted in a very detailed and inventive way, which is where the adoption of 3D-food printing appears. Food layer manufacture also known as 3D-food printing fabricated through the deposition of successive layers by layer derived directly from computer-aided design data . By using 3D printing technology, specific materials can be mixed and processes into various complicated structures and shape. Sugar, chocolate, pureed food and flat food such as pasta, pizza and crackers can be used to create new food items with complex and interesting designs and shape. 3D printing technology is a high-energy efficiency technology for food production with environmentally friendly, good quality control and low cost. 3D-food printing can be healthy and give benefit for human because it creates new process for food customization and can adjust with individual preferences and needs. By allowing food preparation and ingredients to be automatically adjusted to the consumer's information, it would be possible to have diets which enforce themselves without need to exercise

V. RESULT

The Paper "PRODUCT DESIGN AND DEVELOPMENT USING 3D PRINTING TECHNOLOGY BY FUSED DEPOSITION MODEELING ". We have learnt how to design a 3d model by using different software's used for 3d printing and also we have learnt about the machines used in 3d printing technology .



CASE 1 -A (ULTIMAKER S5 MATERIAL-PLA)



infill density 100%

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ORIENTATIONS	TIME
Flat(normal condition)	15 mins
30 degrees	15 mins
90 degrees	4 mins

The least time taken to slice is **4 mins** and orientation is **90 degrees**

B (infill density 50%)

ORIENTATIONS	TIME
Flat(normal condition)	17 mins
30 degrees	16 mins
90 degrees	4 mins

The least time taken to slice is **4 mins** and orientation is **90 degrees**

CASE 2 -A (ULTIMAKER S5 MATERIAL-PC)

infill density 100%

ORIENTATIONS	TIME
Flat(normal condition)	13 mins
30 degrees	13 mins
90 degrees	4 mins

The least time taken to slice is **4 mins** and orientation is **90 degrees**

B -infill density 50%

ORIENTATIONS	TIME
Flat(normal condition)	12 mins
30 degrees	12 mins
90 degrees	4 mins

The least time taken to slice is **4 mins** and orientation is **90 degrees**

VI. CONCLUSION

This paper presents brief insight into one of the emerging Rapid-Prototyping technique called Fused Deposition Modeling. It lays emphasis on the working process of the FDM and various parameters involved in it and their effects on physical properties like Dimensional accuracy, surface roughness, strength of the components made through the process. From the study it has been understood that the parameters like orientation, layer thickness, infill and temperature profile are the primary parameters that directly affects the quality of the part. Also, some of the existing methodologies like adaptive slicing, machining, and chemical processing are discussed for the minimization of the problem. Through this paper we developed arbor and sliced with Ultimaker CURA Software and we got printing time as 4 minutes and support material consumption is 0 grams which is consumed 0.06 meters of filament. It can be concluded on the basis of literature review that there is still enough space for the research in order to improve the surface roughness and strength of the parts by optimizing the parameters used in the building of the part. Also, there is a scope for study and optimization of temperature profile during the deposition so that distortion effect and the sliding wear can be reduced with increased mechanical strength. Future work is proposed to be carried out in optimization of overall parameters to manufacture a part to specific level of characteristics.

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