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Process, Types and Applications of 3D Printing Technologies

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***Abstract*— "**Improvement usually means doing something that we have never done before", says Shigeo Shingo, world's leading expert on manufacturing practices. This principle has been followed, consciously or unconsciously, in almost every industry for the development of the self and the society. The manufacturing industry is one of the fastest growing industries ensuing from this doctrine. With the advancements in Science and Technology, better techniques and efficient methods are being developed to minimize the outright efforts for manufacturing a product. Before the coinage of 3D printing(3DP) technologies, one has to depend on classical plots which are less efficient and time-consuming. But now, the implications of 3D printing technologies have changed the fate of the manufacturing industry. Over and above Manufacturing, 3DP has a profound influence on other industries such as Aerospace industry, Consumer goods industry, Medical industry, Education and so on. This paper elaborates various steps and processes involved in manufacturing a product using 3DP, types of 3DP and their boundless applications in various sectors.

***Keywords*—** Aerospace, Industry, Manufacture, Technique, Technology, 3D printing.

I. INTRODUCTION

Engineering is the application of mathematics and physical sciences to the welfare of humanity. In this field, for the past few decades, there has been a tremendous growth in the domains of manufacturing and technology. Each and every day new technologies and methodologies are being formulated. But among them, only those technologies which have quenched the thirst for immense and incessant human needs effectively have sustained in the market of competition. One such technology is 3D printing Technology, which has an imperative role in today's Manufacturing Industry.

3D printing or additive manufacturing is the casting of a three-dimensional solid object, layer by layer, from a digital file. This file is the geometrical representation of the 3D object to be cast. The design of an object may be crafted using Computer Aided Design (CAD) and saved as Stereo-Lithography(.STL) file (or Virtual Reality Modeling Language - VRML file) and then fed into a 3D printer for actual forging. It is possible to 3D print in a wide range of materials which includes thermoplastics, thermoplastic composites, pure metals, metal alloys, and ceramics. 3D printers are classified depending on the materials used and the constructive mechanisms followed during the actual manufacturing. Using 3D printing technologies, designs as simple as a chip clip to as complex as aircraft modules can be designed.

Section I defines and introduces 3DP, Section II overviews the entire manufacturing process, Section III explains the software designing of a 3D model, Section IV explains the types of 3DP and the processes involved in each type, Section V describes the application of 3DP in various fields, Section VI describes the pros and cons of 3DP, Section VII concludes the article.

II. PROCESS OVERVIEW

First, a model is visualized based on the ideas one has. Then the designing of our model can be done using CAD in three-dimensional (3D) space. This aids one to put one's ideas into 3D virtual figures. The resultant of the design phase is an STL file, which is then fed into a slicer to convert the virtual solid model into two-dimensional layers. These layers are treated as a sequence of independent layers and are then exported into a 3D printer for the actual drafting. The 3D printer then lays these layers--based on the commands it receives from the sliced STL file-- one above the other and joins these layers using several techniques. The accuracy, strength, quality and surface clarity of the final product depends upon the number of layers, equipment, materials, and techniques used.

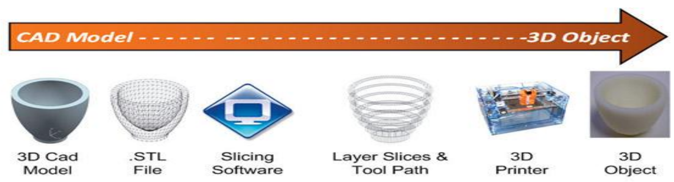

Figure1: The Entire Process

III. SOFTWARE TO DESIGN

The first move in creating an object is making a virtual design of the object destined. This virtual design can be created using either a 3D scanner or a 3D modeling application.

3.1 3D-Scanners

3D scanners aid us to replicate an existing object. Time-of-flight, structured light, volumetric scanning are a few non-contact active technologies which emit radiation or light on to the subject and detects the subject shape based on the reflections and radiations from it.

Time-of-flight 3D laser scanner uses laser light to probe the subject using a time-of-flight laser rangefinder. The laser range finder detects the distance of a surface by calculating the round-trip time t of a pulse of light. A laser is used to emit a pulse of light on the subject and a detector--present adjacent to the laser-- measures the round-trip time t taken by the light of speed c. The distance of the surface is calculated using (c.t)/2.This laser rangefinder detects the distance of only one point in its direction of view at a time and then changes its direction to scan different points.Thus, the entire subject is scanned by varying the position of the laser to obtain the total shape.

Structured-light 3D scanners project a pattern of light on the subject and look at the deformation of the pattern on the subject. The pattern is projected onto the subject using either an LCD projector or other stable light sources. A camera, offset slightly from the pattern projector, looks at the shape of the pattern and calculates the distance of every point in the field of view. The advantage of structured-light 3D scanners is speed and precision. Unlike Time-of-flight 3D laser scanner, structured light scanners scan multiple points or the entire field of view at once. Scanning an entire field of view in a fraction of a second reduces or eliminates the problem of distortion from motion.

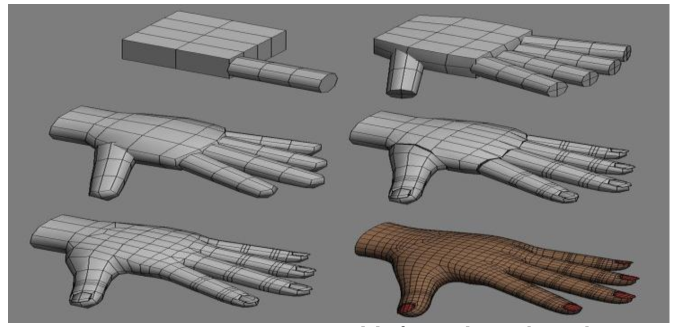

Figure 2: Generating a 3D model of a Hand using basic shapes

3.2 3D-Modeling software

3D modelling software is used to create customized models as needed. Blender, Sketchup, AutoCAD, Rhinoceros , 123 Design, ZBrush are some of the tools that provide an Integrated Development Environment(IDE) to design the models of our choice. These enable us to create photorealistic illustrations and mock-ups that help us craft the blueprints of our models. These modelling tools have been beneficial to increase the speed with which product engineers can generate models.

These tools feature ease to learn and use environment,2D drafting and 3D modelling, collaborating parts, reduced complexity by providing only one file for printing, smooth surfaces, better texture, precise sketches and a lot more. It is to be noted that these features vary among various software tools.

IV. TYPES OF 3D PRINTING TECHNOLOGIES

1. Stereo-lithography (SLA)

Stereo-lithography is one of the most widely used rapid prototyping techniques, first of its kind, to get accurate designs, smooth surfaces, and precise sizes. It is one of the Liquid-based processes which builds plastic parts or objects one layer at a time by tracing a laser beam -based on the commands it receives from the 3D printer- on the surface of liquid photopolymer. Inside this liquid, is a movable platform to support the part being built and can move up and down. As soon as the laser beam strikes the surface of the liquid, it quickly solidifies. The platform is then lowered by a distance equal to the layer thickness, and a subsequent layer is created in the same manner on top of the previously completed layers. Because of the self-adhesive property of the photopolymer, the layers are bound so strong. The resulting three-dimensional object is thus a stack of independent layers bound together. It is also possible to create an object with overhangs or undercuts by using the supports. The objects created using this technique have smooth texture as the size of each layer is at least 0.001 inches. The surfaces are polished and sanded after the overhangs are cutoff.

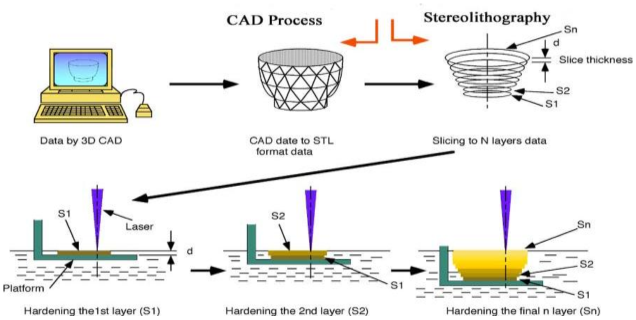

Figure 3: Stereo Lithography Process

2. Fused Deposition Modeling (FDM)

FDM is the second most widely used rapid prototyping technology, after Stereo lithography. It is a solid based process, in which a plastic or wax material is extruded through a nozzle that traces the parts cross sectional geometry layer by layer. The entire process is held at a temperature just below the melting point of the thermoplastic. A filament supplies material to an extrusion nozzle. The nozzle is heated, which indirectly heats the thermoplastic to a semi-liquid state. The nozzle is mounted to an X-Y plotter type mechanism which moves based on the geometry of each layer. The nozzle deposits this semi-liquid in ultra-fine beads along the extrusion path. The thermoplastic hardens immediately and bonds to the bottom layer. A platform moves in the Z direction and facilitates the drafting of the next layer. Support structures are automatically generated for the second nozzle. The objects created using this technique have a bit rough surface, when compared to the object created using Stereo-Lithography, as the size of each layer is at least 0.005 inches.

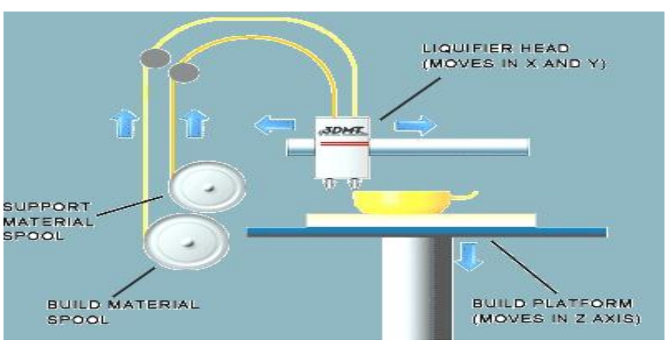

Figure 4: Fused Deposition Modeling Process

Figure 5: FDM vs SLS produced surfaces

3. Selective Laser Sintering (SLS)

Selective Laser Sintering is a Powder-based process which uses very fine granules of Thermoplastic commonly produced by ball milling. This technique uses two pistons .A powder delivery piston supplies a measured quantity of powder required for each layer. The powder is then spread uniformly by a roller over the surface of a build cylinder. A laser beam is then directed over the surface of this tightly compacted powder to selectively melt the surface of the grains and join them together to form a layer of the object. After drafting one layer, the fabrication piston moves down and the entire process repeats. After the object is fully formed, the piston is raised and excess powder is brushed away. The advantage of this technique is that no supports are required as overhangs and undercuts are supported by the solid powder bed. When compared to other methods, SLS can produce parts from a relatively wide range of commercially available powder materials such as polymers, metals including steel, titanium, alloy mixtures, and composites. The objects created using this technique have a bit rough surface, when compared to the object created using Stereo-Lithography, as the size of each layer is at least 0.005 inches.

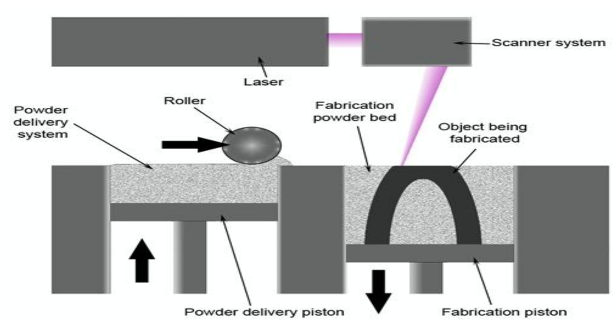

Figure 6: Movement of pistons and supply of powder for each layer by the roller

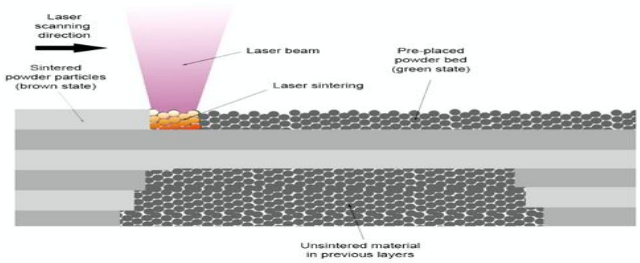

Figure 7: Movement of LASER

4. Laminated Object Manufacturing (LOM)

Laminated Object Manufacturing is a Paper-based process in which paper, metal or plastic sheets are stuck together to build up a solid material. The thickness of each layer is at least one-sixteenth of an inch. Plastic and paper build materials are often coated with an adhesive. A feed roller advances a sheet over a build platform. A heated roller applies pressure to the sheet and melts the adhesive and to bind the sheet to the layer below. A computer-controlled laser or blade then cuts the material into the desired pattern. After each cut, the platform lowers by sheet thickness, and another sheet is advanced on top of the previously deposited layers and then the process repeats. After the complete object is generated, unwanted portions can be cut manually or mechanically. This technique is very cheap as raw materials are readily available. But the dimensional accuracy is slightly less than that of stereo lithography and selective laser sintering.

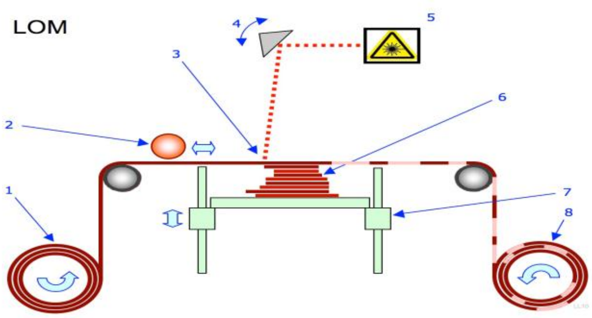

Figure 8: LOM process

V. APPLICATIONS

Fashion: Various designers are using 3D-printing to make eyewear, clothes, and shoes that can fit their clients. New fabrics are being invented which can be used to 3D print customized clothes.

Architecture: Architects make building models before construction is to be started. This helps Clients to better visualize their requirements and can help the architects detect pinpoint potential errors that can be corrected before formal construction begins. Rapid prototyping plays a crucial role in this field.

Aerospace&Automotive: 3D printing is now used to design aircraft, spacecraft,automobile modules independently which can then be assembled.FDM is being used to craft such complex designs.Quick consumables are produced using 3DP so as to meet the consumers' demand.

Food Industry: Chefs achieve precision and accuracy in layering and preparation of a variety of food items making them good looking and also delicious

.**Medicine**: 3DP is emerging as a powerful tool for tissue engineering. In this field, for the fabrication of tissues, blood vessels,heart valves , bones, synthetic skin and organs . Organ models and tumour models are also being designed using 3DP.

Nano-Printing: Printers that create models of few micrometers or nanometre are being invented. Applying 3D printing concepts to nanotechnology could bring some advantages to nano-fabrication such as high speed, less waste, economic viability and also high strength, durability to the product.

Defence: The military finds 3D printing useful in creating improved versions of the defence equipment consisting of arms, suits and vehicles.In U.S.,soldiers are being trained as technicians in 3D printing so as to enable them produce customized parts for unique situations or individuals.

Cloud-based printing: Some developers are employing cloud computing methods together with printing. These methods allow for different parts of a model to be created by different people in various locations as they can access the essential files.

The other areas include Bio-printing, Medical devices, Pills, Industrial applications, Industrial Art and Jewellery, Firearms, Computers and robots, Soft Sensors and Actuators, Art and Jewellery, Communication, Domestic use. Education and research, Environmental use, Dental industry, Jigs, and Fixtures.

Figure 9: 3D food printing

Figure 10: 3D printed replica of human ear

3D printing has got baby siblings viz 4D printing and 5D printing.4D printing involves printing objects that mutate and morph into different shapes-- over time --when exposed to an outside stimulus such as light, water or temperature changes.5D printing refers to the use of five-axis technology to 3D print objects from multiple directions to overcome the weaknesses that occur at the lines of adhesion between layers in 3DP.These infant printing techniques are capable of widening the scope, productivity, and applications of manufacturing further.

VI. PROS AND CONS

In Rapid prototyping, 3D printing gives designers the ability to quickly turn their concepts into 3D models or prototypes. It is a clean process as there is hardly any wastage of material. Complex shapes can be produced easily and no skilled person is needed. Even the people in remote locations can fabricate the objects on their own which are inaccessible to them.

Cost of raw materials is high.The materials that can be used are still limited.3D printers are still expensive as their production is small-scale .3D printing is slow as it uses a vector scan technique where the print head traces each location on a single layer. Components produced using 3DP may not have enough strength. Parts created additively through 3DP are also limited in size.

VII. CONCLUSION

3DP is being used in many industries and is showing its propitious impact on whatever industry it touches.Within a decade, 3D printers will become commonplace in houses just like other home appliances. We can design our clothes and customize almost every daily life product.It is,thus,evident that 3D printing is indeed a game-changer.Every coin has two sides.3DP Technology is never an exemption to this law. Despite its boundless uses, one can misapply it to illegally manufacture arms or any other anti-social activities.The technology is not noxious but the person who uses it can make it so.Whatever,it is apparent that such a technology will change the fate of human race .

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