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A REVIEW OF 3D PRINTING TECHNIQUES

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Abstract: This study paper examines 3D printing, the many materials used for it, and their qualities, a hot topic in contemporary technology. Applications of 3D printing in manufacturing play a significant role in our daily lives. Different advanced manufacturing technologies have evolved throughout time.

Recently, additive manufacturing, commonly referred to as three-dimensional (3D) printing, has been applied in a wide range of industries. Comparatively speaking, 3D printing takes less time than conventional manufacturing methods. Using raw materials, components are built up layer by layer in this process. These days, many items are manufactured and constructed using this approach.

Keywords: 3D printing, Stereo-lithography (SLA); Fused Deposition Modelling (FDM); Selective Laser Sintering; Laminated Object Manufacturing;

I. INTRODUCTION

3D printing or additive manufacturing is a process of making three-dimensional solid objects from a digital file. Utilizing additive methods, 3D-printed objects are produced. In an additive process, an object is made by adding layers of material one after another until the product is made. It is possible to think of each of these levels as a finely sliced cross-section of the object.

The Nagoya Municipal Industrial Research Institute's Dr. Hideo Kodama provided information on a "rapid prototyping" method in May 1981. The layer-by-layer approach essential to 3D printing was initially described in this paper. In his research, photopolymers were printed using an approach that predated stereolithography. He also discussed cross-sectional slices of the layers that were stacked to create the 3D object.

Chuck Hull, however, produced the first 3D printer ever in 1983. Charles Hull was a pioneer of the stereolithography solid imaging method and the STL (stereolithographic) file format while he was employed by the business known as 3D Systems Corp. STL (stereolithographic) is still the most extensively utilized format used today in 3D printer

Rapid prototyping is now used widely in a variety of human endeavours, including research, engineering, the medical sector, the military, the building and construction industry, fashion, education, and the computer industry, among many others. Rapid prototyping is the process of using 3D printers for these needs. Using 3D computer-aided design (CAD), rapid prototyping is the quick creation of a physical part, model, or assembly.

Typically, additive manufacturing, sometimes referred to as 3D printing, is used to create the item, model, or assembly. quick manufacturing is another application for 3D printing in addition to quick prototyping. A new manufacturing process called rapid manufacturing involves using 3D printers for small- and short-run production.[1]

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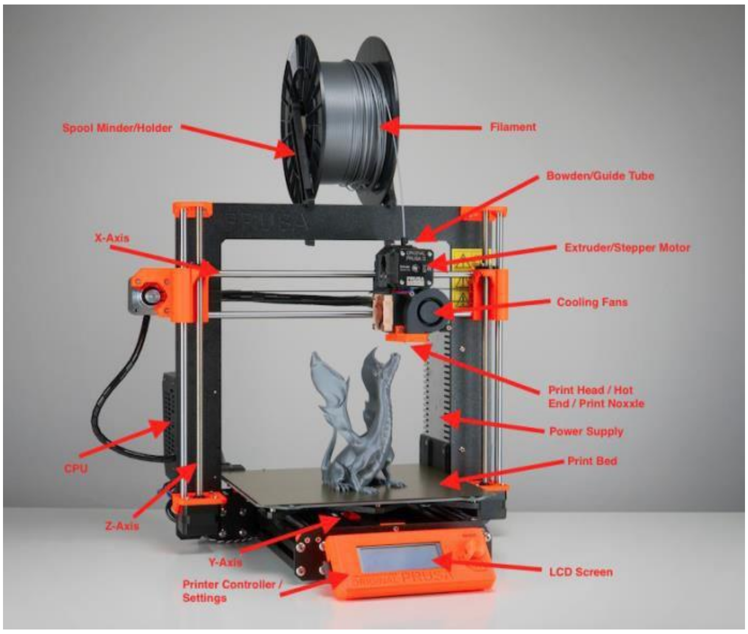

II. WORKING PRINCIPLES

A. Modelling

Models for 3D printing can be produced using 3D scanners or CAD design software. Similar to sculpting, the hand modelling procedure prepares geometric data for 3D computer graphics. Analysing and gathering information about an object's form and appearance is the process of 3D modelling.

This information can be used to create 3D models of the scanned object. For typical consumers, creating 3D-printed models manually or automatically is highly challenging. Because of this, several markets have sprung up globally in recent years. Shape Ways, Pottery, Mining Factory, and Threading are the most well-liked.[4]

B. Printing

Before printing a 3D model. STL file must be processed by a piece of software called a "slicer" which converts the 3D model into a series of thin layers and produces in a G-code file format. STL file containing instructions to a printer. Slicer, KISSlicer, and Cura are three examples of open-source slicer software.

A model is constructed using a succession of cross-sections by the 3D printer by following G-code instructions to lay down successive layers of liquid, powder, or sheet material. The final shape of a model is formed by joining or fusing these layers, which represent the virtual cross sections from the CAD model. The final shape of a model is formed by joining or fusing these layers, which represent the virtual cross sections from the CAD model.

This method's key benefit is that it can produce practically any form or geometric model. Depending on the approach utilized, the size, and the intricacy of the model, building a model might take anywhere from a few hours to days. It varies greatly depending on the type of equipment being used, the size and quantity of models being made, and additive methods may often cut this time to only a few hours.[4]

C. Finishing

Even if the resolution that the printer produces is enough for many applications, printing an object slightly larger than necessary in standard resolution and then deleting material with a higher-resolution method can produce results with greater precision. According to International Manufacturing Technology, various additive manufacturing processes can combine different materials to create pieces.[4]

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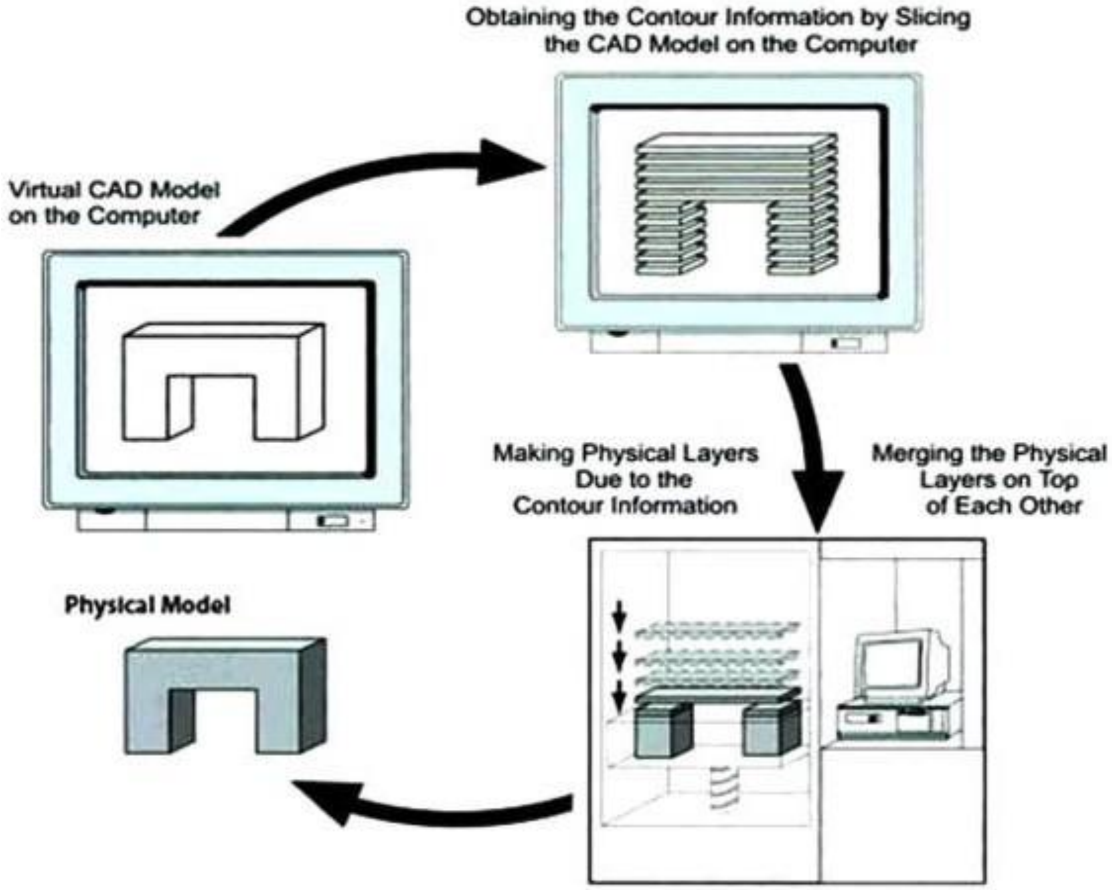

III. TYPES OF 3D PRINTING TECHNOLOGIES

A. Selective Laser Sintering

Under the assistance of DARPA, Dr. Carl Deckard and his academic advisor Dr. Joe Beaman at the University of Texas created and patented selective laser sintering (SLS) in the middle of the 1980s. Deckard was a part of the start-up business that was created as a result, DTM, to create selective laser sintering equipment.

The largest rival of DTM, 3D Systems, purchased DTM in 2001. The most current selective laser sintering patent from Deckard was granted in January 1997 and expired in January 2014. Selective laser sintering is a 3D printing technology that employs a laser as the power source to fuse powdered material (mainly metal) by directing the laser at specific locations in space that are identified by a 3D model.

The resulting solid structure is then formed from the sintering of the material**.** Similar principles are used in selective laser melting (SLM), but instead of being sintered, the material is entirely melted in SLM, resulting in distinct properties (crystal structure, porosity). SLS is a relatively new technique that has thus far been mostly utilized for low-volume item production and additive manufacturing. As the commercialization of additive manufacturing technology advances, production positions are expanding. [1,4]

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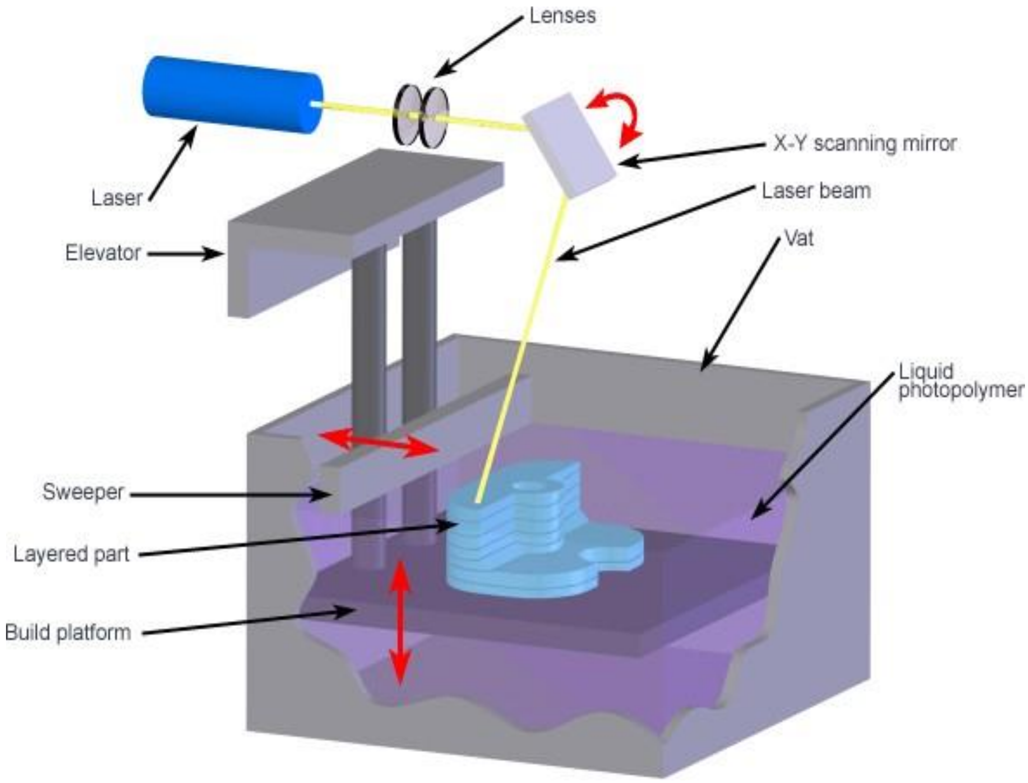

Stereolithography (SLA) working

B. Fused Deposition Modelling (FDM)

In Eden Prairie, Minnesota, Stratasys created it. This procedure involves layer-by-layer extrusion of plastic or wax along a nozzle that follows the cross-sectional geometry of the part. After stereo lithography, FDM is the second most used fast prototyping technology [4]. Unwound from a coil, a plastic filament delivers substance to an extrusion nozzle. The plastic is heated in the nozzle to melt it, and it contains a mechanism that lets you control the flow of the melted plastic. There is a second extrusion nozzle for the support material (which is different from the model material), and the nozzle is attached to an X-Y plotter-type device that lines out the part contours. Each layer is formed by the deposition of a thin bead of extruded plastic when the nozzle is moved over the table in the necessary shape. Immediately after being squirted from the nozzle, the plastic hardens and adheres to the layer below. The item is constructed on a mechanical stage that travels layer by layer downward as the portion is created. The complete apparatus is housed in a chamber that is kept at a temperature just below the plastic's melting point. Support structures are automatically generated for overhanging geometries and are later removed by breaking them away from the object. A water-soluble support material is also available for ABS parts. A range of materials are available including ABS, polyamide, polycarbonate, polyethylene, polypropylene, and investment casting wax. [1,5]

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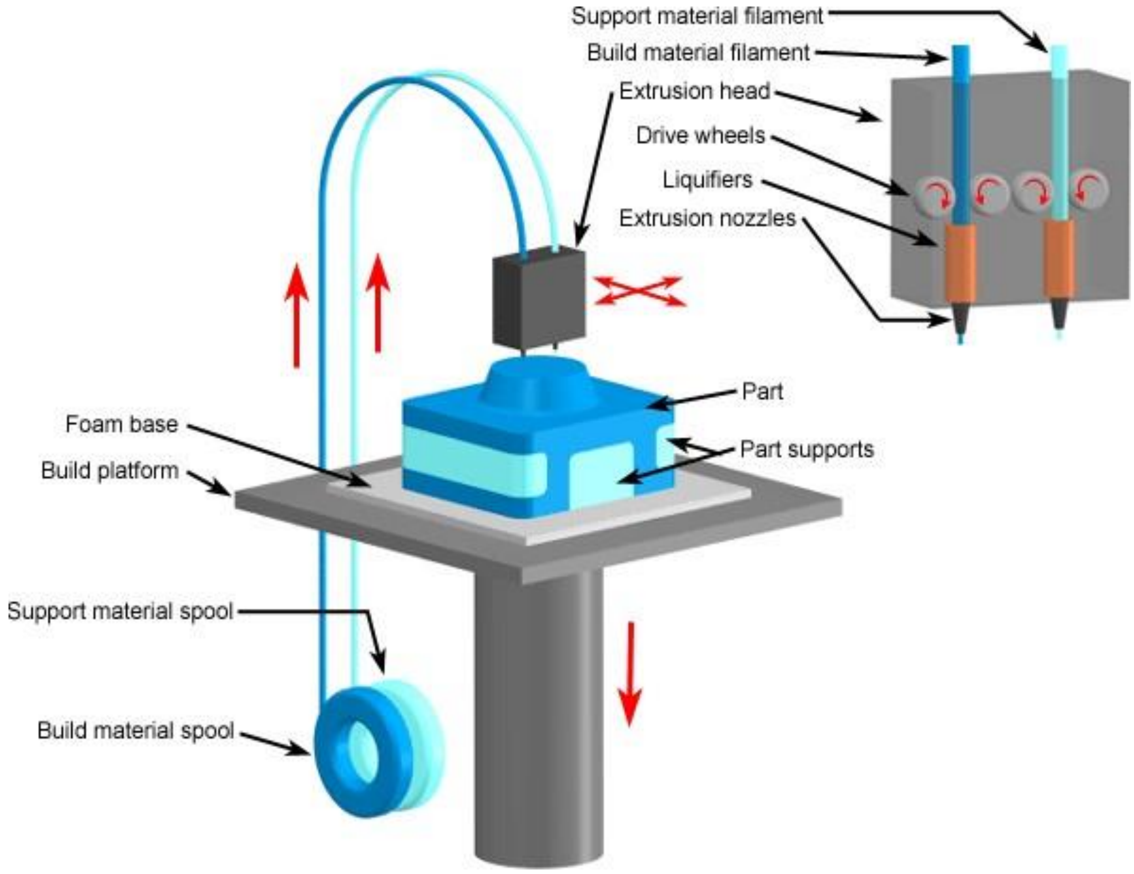

Fused Deposition Modelling (FDM)

A WASP Big Delta 3D printing in clay

C. Stereolithography

A pioneering and extensively used 3D printing process is stereolithography. Engineers may now produce prototypes of their designs more quickly and efficiently thanks to the development of 3D printing. As early as 1970, the technology first became available. The present multilayer method of stereolithography was first developed by Dr. Hideo Kodama, a Japanese researcher, who used UV radiation to cure photosensitive polymers. Before Chuck Hull applied for his patent in July 1984, Alain Le Mahout submitted a stereolithography patent The French General Electric Company and CILAS (The Laser Consortium) disregarded the French inventor's patent application. Le Mahouts thinks that France has difficulty with innovation because of abandonment.

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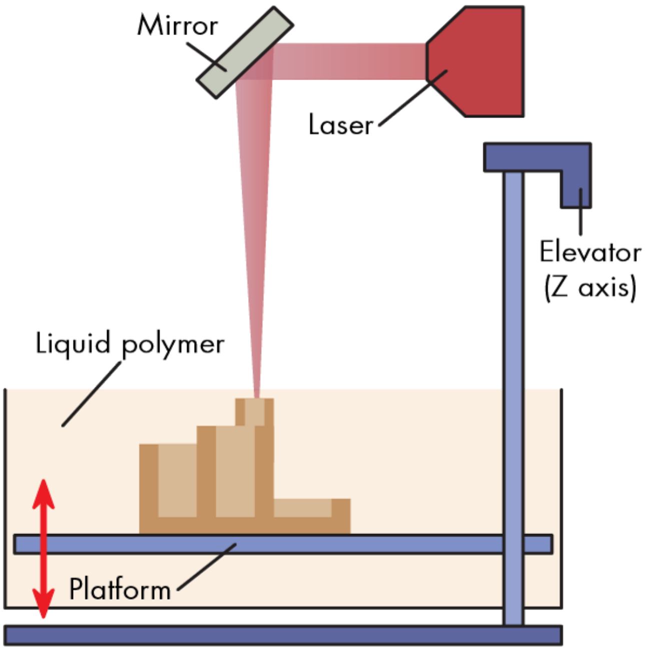
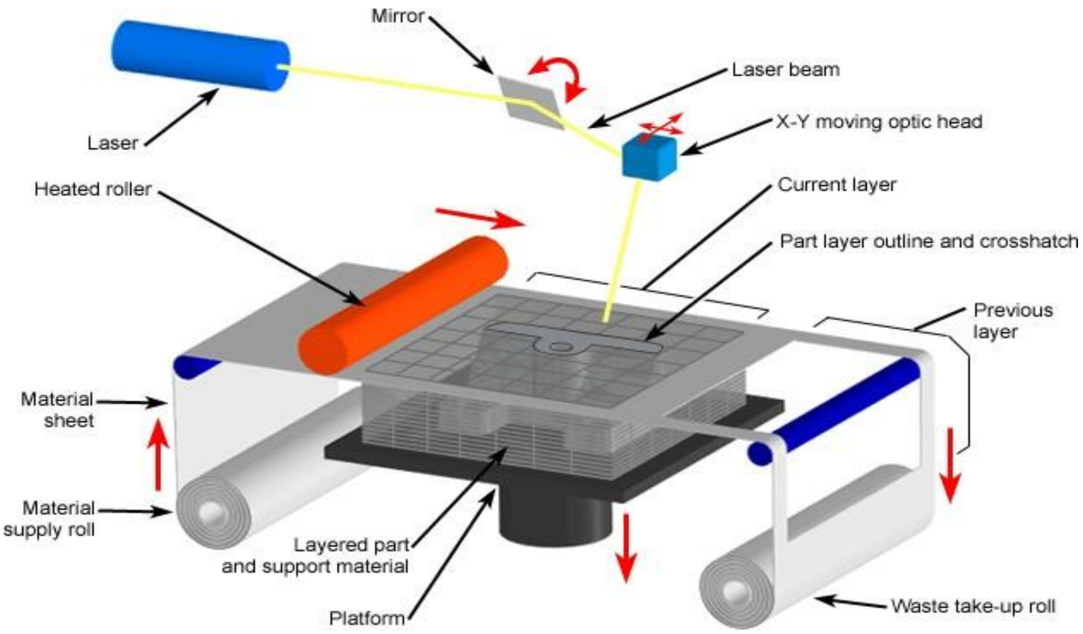
Using photopolymerization, a process by which light causes chains of molecules to link together to produce polymers, stereolithography is a sort of 3-D printing technology used to create models, prototypes, and patterns layer-by-layer.[1] The body of a three-dimensional solid is then constructed from those polymers. Although there had been research in the field in the 1970s, Charles (Chuck) W. Hull invented the name when he patented the method in 1986. He subsequently founded 3D Systems Inc. to make his patent commercially viable. [1,4]



D. Laminated Object Manufacturing

Helisys Inc. (now known as Cubic Technologies) created the 3D printing technology. It involves the sequential joining and laser-cutting of layers of adhesive-coated paper, plastic, or metal laminates into the desired shape. This method of printing allows for the additional modification of objects by post-print machining. The material feedstock determines the normal layer resolution for this process, which typically has a thickness range from one to multiple copies of a sheet of paper. [1,4]



Laminated Object Manufacturing (LOM)

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Fruit and bowl 3D printed in paper

Component printed using LOM

IV. 3D PRINTER MATERIAL

A. Metal 3D printing Material

Metal Due to the benefits offered by this procedure, 3D printing technology has attracted a lot of attention in the manufacturing, automotive, aerospace, and medical fields. Metal materials can be utilized for complicated production, including printing human organs and aerospace components. Metal materials offer great physical qualities. Alloys made of aluminium, cobalt, nickel, stainless steel, and titanium are a few examples of these materials. A cobalt-based alloy is appropriate for use in dental applications for 3D printing. Its high specific stiffness, robustness, high recovery capacity, elongation, and heat-treated state are the reasons for this. Times New Roman should be used for the entire document. Fonts of type 3 are not permitted. If necessary for certain needs, other font kinds may be utilized.[3] Stainless steel is a material that has numerous advantageous qualities, including great durability, heat resistance, and quick manufacture. As a result, Direct Metal Laser Sintering (DMLS) and other metal 3D printing technologies are employed in a variety of industries, including dental, aerospace, automotive, marine, oil & gas, and even high-end jewellery. [3]

Titanium: Titanium is renowned for being the strongest and lightest 3D-printed metal. This (together with its non-corrosive qualities) makes its use widespread in heavy-duty industries, such as aerospace for wing and airframe structures. Additionally, titanium can be utilized to make smaller components for turbine engines, such as compressor blades and rotors, as well as for orthopaedic devices including spine, hip, and knee implants.. [3]

B. Polymer 3D Printing Material

One of the most widely used materials for 3D printing is BS (Acrylonitrile Butadiene Styrene). Its widespread use can be attributed to factors like its low cost, ease of availability, and strength and durability characteristics. Another material that is used extensively is PLA (Polylactic Acid). Its biodegradability is its key benefit. Additionally, it comes in a variety of colours and even in transparent form. Polymers are utilized in VAT photopolymerization processes such as SLA (Stereolithography), DLP (Digital Light Processing), DLS (Digital Light Synthesis), and even SLS (Selective Laser Sintering) as a liquid material in addition to FDM 3D printing. Polymer materials mainly play a significant role in the production of medical devices and biomaterials. By aiding in the effective operation of the apparatus and by serving as inert materials, many orthopaedic implants are mechanically supported. [3]

C. Ceramic 3D Printing Materials

The first thing that comes to mind when someone mentions ceramics is conventional pottery ceramics, in which pots are created from clay and sand mixed with a liquid (often water). Or perhaps porcelain, a form of ceramic, comes to mind because of its function as an electrical insulator. However, the development of various ceramic composites for use in technological applications that are significantly more sophisticated has since broadened the field of ceramics. These contemporary industrial ceramics can be developed into materials with strength equal to that of the hardest metals, superconductors, or porous architectures for membrane and filter technologies. Technical, advanced, industrial, or engineering ceramics are names for these materials. They are specialized ceramics utilized in a variety of specialized applications across numerous industries. spanning the automotive, aerospace, aviation, electronics, energy, and medicinal fields. [3]

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D. **S**mart Materials

Smart materials are those that have the capacity to change an object's geometry and shape in response to environmental factors like heat and moisture. Self-evolving structures and soft robotic systems are examples of 3D-printed items made with intelligent materials. As 4D printing materials, smart materials can also be categorized. Shape-memory alloys and shape-memory polymers are two examples of group smart materials. Applications for some shape-memory alloys, such as nickel-titanium, range from microelectromechanical devices to biomedical implants. The key concerns in the fabrication of 3D-printed nickel-titanium materials are transformation temperatures, reproducibility of microstructure, and density. Shape memory polymer, or SMP for short, is a sort of functional material that reacts to stimuli like light, electricity, heat, certain kinds of chemicals, and so forth. Shape memory polymer's complex shape might be manufactured quickly and easily by employing 3D printing technology. Based on the part density, surface roughness, and dimensional accuracy, this material's quality is assessed. [3]

E. Composite 3D Printing Materials

Composites can be divided into industrial composites and fundamental or general-purpose composites. Wood/polymer or metal/polymer composites are general-purpose composites that are readily available in filament form. The polymer is combined with some metal or wood to create a filament shape. According to the needs of the product, these are typically used. Industrial composite materials are complicated special-purpose materials like carbon fibre and fibreglass that increase the strength and longevity of the goods and are utilized in 3D printing. Although less frequently utilized, these materials are still employed for the intended purposes. [3]

V. APPLICATION OF 3D PRINTING

A. The aeronautics and aerospace sectors push the boundaries of geometric design complexity; the constant growth and advancement of the vehicles necessitate that the components become more accurate and efficient even as the size of the vessels decreases. Design optimization is therefore crucial to the development of the sector. Traditional production methods might make it difficult to optimize a design, which is why the majority of engineers now use 3D printing.[4]

B. The technologies are also used to create patterns for dental crowns that will later be cast in metal, as well as to create the tools that will be used to vacuum-form plastic to create dental aligners, in order to promote the development of new products for the medical and dental sectors.[4]

C. 3D printing has proven to be extremely disruptive for the jewellery industry. Regarding how 3D printing can and will advance this industry, there is a tremendous deal of curiosity and uptake. From the increased design flexibility offered by 3D CAD and 3D printing to the direct 3D printing of jewellery that eliminates many of the conventional procedures to the traditional jewellery production processes themselves being improved. [4]

D. The production of accurate demonstration models of an architect's idea has long been a staple application of 3D printing techniques. Direct production of detailed models from 3D CAD, BIM, or other digital data by 3D printing is a reasonably quick, simple, and financially viable option for architects.[4]

E. A particular business, known for experimentation and absurd claims, has emerged as 3D printing technologies have become more precise and adaptable. Of course, we are discussing fashion. Shoes, headgear, caps, and bags that were 3D printed have all appeared on international catwalks.[4]

VI. CONCLUSION

3D printers have a wide range of potential future applications. Designers and engineers now spend less time conceptualizing, creating, and testing prototypes thanks to new 3D printing methods. However, for 3D printing to catch on in the fast-changing industrial industry, it must be viewed by enterprises as a routine business choice rather than an exciting technology improvement.

Medical applications, custom parts replacement, and customized consumer items are among the most promising fields. Other applications that we can only dream of today will become available as materials improve and costs fall. The medical industry is perhaps the most promising area for 3-D printing growth. As previously said, researchers are only now beginning to experiment with the possibility of producing artificial bones using 3-D printers.

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