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A Complete Review on 3D Printing

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ABSTRACT: The 3D printing technology is the process of fabricating the graphically designed structure into a real object by its layer-to-layer operation. It is one of the fastest emerging technologies which has its applications in all the fields. The graphically designed data is first sliced into several 2D structures and each structure is built one above the other to make the desired complete object. Any complex structure and design can be achieved using 3D printing. Our main contribution in this paper is compiling the history, trends, types, application and its pros and cons of 3D printing technology. Our work will be useful for the readers to select the perfect method which is preferred by them for their respective application and getting a much better output with all the information given.

KEY WORDS: Additive manufacturing, 3D Printing, Classifications of 3D Printing, Trends in 3D Printing, Applications of 3D Printing

I. INTRODUCTION

Additive manufacturing is employed to manufacture 3D objects by adding multiple layers of materials such as plastic, wood, concrete or metal. In the year 1950, the general concept and procedure used in 3D printing was first made by Raymond Jones in his work and referred to it as a "molecular spray" and in the later year of 1987, additive manufacturing was developed with stereo lithography. SLA-1 was the first commercially available AM system in the world after the SLA 250 machine. [1] Basically it uses a 3D modelling software, layering equipment and layering material to create the 3D outputs. First the output is modelled to a 3D modelling software which makes suitable codes which are readable by a printer. After this the 3D printer extrudes the material layer by layer to get the final desired 3D model. It is used in various industries to produce physical prototypes as well as end use parts. [4]

Circumstances such as usable material, material properties and design constraints differ depending on the AM technique chosen. Layer by layer is the most common method used for manufacturing. These are various classifications of AM processes according to the: (i) base material, such as polymers, ceramics, and metals (ii) indirect and direct processes depending on the bonding method (iii) state of the raw material input, such as liquid, molten, powder, and solid layer process

In the construction, field architectural models are created using this method for more than a decade. The research on printing of building components has increased in the past years using the AM process. This method is an alternative to the conventional method used in which the materials is formed in moulds by milling. Hence it is making the works of the architects even easier. The aerospace industry also uses this method of additive manufacturing to manufacture lighter structure [3],[5],[2]

II. TRENDS IN 3D PRINTING

3D printing is an emerging technology in the past years until now. It was originally developed for industrial purposes but in recent years it has become a very promising and reliable technology. John McEleney, one of the long-time board members of Stratasys, had written about the future of 3D printing in his article. In the article 5 items were briefed in which the first was materials development and the second one was the affordability of metal 3D printers. Though it is impossible for a company to compete with the money spent on the technology by the consumer. For this to happen the company must innovate on any of the aspects of the technology to make an edge over the company to win over the consumer. It has also improved outputs in the structural integrity and the expectation on the applications of the technology will go further beyond the actual typical prototyping. The next trend would be the demand and the development of new design tools which would eliminate the middleman in the near future as the process of conversion of the 3D model into the codes which is readable by the printer to make the 3D object can be reduced to printing it directly from the computer to the 3D printer. A recent survey conducted by Jabil showed that from the years 2017 to 2019 the use of the 3D printing technology has increased drastically in many fields. According to the survey the increase rate is 27% to 52% in production of parts, 23% to 39% in bridge production, 14% to 38% in repair in



maintenance, and 30% to 37% in jigs, fixtures and tooling.[22]In the Philippines, the Department of Science and Technology fully supports the changes which were brought by the disruptive technologies and it also publicly announced the first Additive Manufacturing Centre (AMC) in the Philippines. The department has researched the varied materials such as ceramics, polymers, nonmaterial etc. Their ultimate motto is to uplift the technology to the peak for the maximum application of it and also its great advantages of high-speed production, reduce of wastage will make it furthermore to be adopted by various industries,

In the pharmaceutical industry 3D printing has played a major role in the manufacturing process of drug products and enabled non-digitized medical products to turn into digital 3D content. The main reason for the use of printing technology in the field of drug delivery is due to its adaptability to create novel oral dosage forms. Even in construction field architectural models are created using this method for more than a decade. The research on printing of building components has increased in the past years using the AM process. This method is an alternative to the conventional method used in which the material is formed in moulds by milling. Hence it is making the works of the architects even easier. The aerospace industry also uses this method of additive manufacturing to manufacture lighter structure.[23]

III. CLASSIFICATION

Additive Manufacturing Processes ASTM International categorizes the AM processes into seven main categories, according to the adhesion and bonding method. They are

- (i) Binder Jetting
- (ii) Direct Energy Deposition
- (iii) Material Extrusion
- (iv) Material Jetting
- (v) Powder Bed Fusion
- (vi) Sheet Lamination
- (vii) Vat Polymerization.

BINDER JETTING: Binder jetting is the 3D printing process which builds the desired products layer-by-layer. The desired shape is designed in CAD software. This CAD design is converted into several layers of 2D structures, which are built one after the other. After printing the first layer the bed moves down according to the height of the first layer. This method comprises two vital components, the first one is the metal which is in the powdered form and the other one is the binder which is in the liquid form. The main role of the binder is to fuse all the powder material (metal, ceramic or any desired component). The UV light is used to dry the components. This method is more cost effective and large components can be printed easily.[6],[7]

DIRECT ENERGY DEPOSITION: In Direct Powder Deposition method an energy source is used to melt the feed material (metal, ceramic or any desired component). The energy source used is mainly laser beams. The feed material is provided in the form of wire or powder. The laser beam continuously melts the feed material and converts into liquid form. Then the melted feed material is applied through the nozzle of the printer in the desired area. The deposition of liquid feed material takes place layer by layer. This method is applicable for both fabricating a new product and also for maintaining the existing product. Even complex structures can be printed easily.[8],[12]

MATERIAL EXTRUSION: The material extrusion type of 3D printing came into operation by the year 1990. This material extrusion process can be classified into two Fused Filament Fabrication (FFF) or Fused Deposition Modelling (FBM) and Direct Ink Writing (DIW). In the first method the melted material comes from the nozzle and fills different layers of the desired component. In the second method a pre melted paste is used directly and this don't require any heating process.[9],[12]

MATERIAL JETTING: This material jetting method has got a great popularity due to its surface finish. This additive manufacturing method is involved in using its characteristic building material mostly in liquid form is poured drop by drop from the nozzle to the building bed. These liquids are photosensitive materials. Then UV light is made to glow to dry the different layers of the product. By using this method one can achieve high dimensional accuracy. The product produced from this method would have a perfect surface finish.[4],[12]



POWER BED FUSION: The power bed fusion process is the most common type of 3D printing process. This method has its application in the field of aerospace, automobile and other key industries. This method uses the energy source which is mainly laser or electron beam. This energy source will melt and fuse the feed material which may be powder, metal or ceramic. The main drawback of this method is its surface finish. The product developed from this method would have less surface finish compared to other methods. So, post machining should be done to get perfect surface finish but in some industries surface roughness is an important criterion, so they use the product without machining it. [17]

SHEET LAMINATION: The sheet lamination or Laminated Object Manufacturing is an additive manufacturing technique which uses metallic sheets as feed material. These sheet materials are fused together by an energy source which is mainly ultrasonic waves. Then the fused sheets are cut accordingly to get the desired 3D object. The fusion of the sheets takes place due to the ultrasonic waves and also the high pressure. This method doesn't require heating. The metallic sheets are placed on the bed; a sonotrode is made to move over the sheets, due to the vibrations the sheets fuse together. Then the fused sheets are removed. Then the products are machined to get a perfect surface finish. [18],[19]

VAT POLYMERISATION: Vat polymerization method has its applications in jewellery making, dental products, sculpturing and in other key industries. In this method the photosensitive resin is used as the feed material. In this process a tank filled with resin is used and when the light source is exposed at the desired area, they fuse together due to the chemical reaction between them. The light which is most commonly used is UV. Like the other methods even in this the product is built layer by layer. Once a layer is done it is sliced off from the resin bed. This can be employed for the production of complex structures. [12],[25]

IV. APPLICATION

Architecture field; Additive manufacturing has a wide scope in the field of architecture. The main setbacks in the field of construction are the low production rate and the safety of the workers. Every year many construction workers die due to the lack of required safety measures in the site. These drawbacks can be overcome by additive manufacturing or 3D printing. The low production rate can be increased by this method and also, they don't produce construction waste. The main advantage of 3D printing over the conventional method is the cost of construction. By using this emerging technology one can cut down the cost drastically. The demand for both physical labour and skilled labour is increasing around the globe, this also contributes to the low production rate, and these can be resolved by using 3D printing. By using 3D printing the architect can design complicated structure which is hard to build manually. [11] There are three methods used in the building construction. They are "COUNTER CRAFTING (CC) METHOD", "D-SHAPE" and "CONCRETE PRINTING". The counter crafting method uses a layer-by-layer process to build up the structure. This method involves the automated building of the entire house including plumbing work, electrical work. The D-shape method is more likely to use a binder jetting method in which the powdered material is hardened by the application of the binder. Each layer is built one above the other according to the thickness of the previous layer. The concrete printing method is likely to use material extrusion process where the concrete comes out of the nozzle at the desired place on the bed according to the design. 3D printing in architecture can be employed to build "emergency buildings" in the place of war, natural calamities or other disasters. This is possible because of its high production rate. The 3D printing enables the person to use the recycled material for constructing the building. This will have a positive impact on the environment. [12]

MEDICAL APPLICATION

The scope of 3D printing is increasing in modern day medicine. The additive manufacturing exactly provides the designed component in the CAD software. The data for the design is obtained from CT/MRI scan which can be fed in the CAD software and the desired component is obtained. 3D printing has brought a revolutionary change in the medical field. Nowadays the doctors can design the organs of the patient prior to the surgery, this helps them to execute perfect planning which in turn reduces the time and risk involved. Ultimately this reduces the medical cost. [13] The 3D printed organs are more useful in understanding the anatomy and complexity of the human body for the students and researchers. 3D printing provides life changing options for affected people by genetics or accident through prostheses. By providing the exact size through CAD software, a geometrically perfect prostheses which can change the life of affected person [14].

3D printing is employed in the production of human organs which can mimic the function of human organs and it



cannot be transplanted. This method can be used in production of artificial skin which can be used to test cosmetics and other skin care products. Drug delivery can be improved and can be made more personalized by determining the release using 3D printing.[15],[16],[21]

Automobile industry: According to IBIS World, a total of 86 million cars were produced globally in 2013, which increases the maximum possibility for the application of automotive additive manufacturing. Additive manufacturing is also used for the manufacturing of different vehicle part and its demand in the automotive industry is also increasing very much. It also provides small scale producers in the manufacturing of the new parts in a very cost-effective manner. Compared to the traditional types of engineering this process helps in the production of the automotive parts more quickly which enables high production and also changes to the designs can be made easily unlike the other process which has a lengthy design process.

A number of different components which could be produced by this method. Exhausts and emissions Fluid handling [20]

Aeronautics: Additive manufacturing technology is highly used for many fields but the aerospace industry is seen as one of the key growth areas. The ability to create complex shapes within one mould, with intricate internal dimensions and complex geometry, is one of the single biggest benefits.

This technology also is very useful to the engineers as it allows them to copy nature and also the most complicated designs which were not possible before. Engines and turbines work well with this process, as it allows the production of small batches of components at a relatively low cost. Using this method of manufacturing turbine blades, fuel systems and guide vanes or even parts which carry oil and water can also be made. In comparison to the conventional method of manufacturing this method is more flexible, economical and also very quick

V. PROS & CONS

- Customization: With raw materials, a blueprint, and a 3D printer, one will print any style notwithstanding however, advanced it would be.
- Affordability: The initial price for putting in place a 3d printing facility is high; but, it's less expensive compared prices and producing prices whereas victimization is the standard approach.
- Constant Prototyping and accumulated Productivity: It permits fast production with a high variety of prototypes or a small-scale version of the real object in less time than victimization typical ways. This helps designers to boost their prototypes, for any style flaws that will have an effect on the standard of the merchandise.
- Personalization: one in all the foremost engaging benefits is the chance of constructing your garments, objects, products ... this enables you to customize the objects to the exclusive styles.
- Health care: With the rise in technological advancements, a customizable physique and organs will be factory-made with this technology, this technology is termed as bioprinting. Though the technology is in experimental stage the potential is large.
- Employment opportunities: Since there's about to be an enormous demand for 3D printing in the near future, the widespread use of 3D printing technology also will increase the necessity for engineers who are required to style and technicians WHO are specialized in handling, maintenance, designers to style blueprints for products. Hence, providing heaps of job opportunities.
- Affordability: the value for the initial instalment of 3d printing facility is high; but it's cheaper as compared to the labour prices and producing prices whereas victimization the standard approach.
- Limited size: the scale of the objects created with 3D printers is restricted, but in the near future; giant like a building will be created through the 3d printing technology.
- Infringement of copyrights: The replication of proprietary objects is tough to manage. Anyone WHO gets a hold of the blueprint is ready to counterfeit the product simply.
- Malicious uses of technology: With the assistance of this technology anyone will produce objects like firearms, knives, guns, and different unsafe objects which will be created.
- Decrease in producing jobs: With the rise within the production of objects through 3d printing the necessity for the quantity of staff concerned within the producing sector are reduced, thus leading to a decrease in producing jobs.
- Limited raw materials: ancient producing of products has a vast variety of raw materials which will be used. Presently the 3d printing technology uses a restricted variety of stuffs and making the product that use a lot of raw material continues to be underneath development.[24],[26]



V. CONCLUSION

In this review paper the current use of the AM has been taken into account and by considering all the above uses, applications, advantages and also including the disadvantages we can conclude that the additive manufacturing technology is a very rapidly growing technology which is useful in almost every field. It has given high accuracy by decreasing the work within the design process. This review processes the aim of the additive manufacturing process for a better automated design process. It has also shown a new and a very interesting way of manufacturing soft wares with the help of CAD for layer-to-layer construction.

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