



OUTSOURCE OF 3D PRINTING TECHNOLOGY

Engineering

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ABSTRACT

From the past few decades' many inventions and research are going on in the field of Additive Manufacturing (AM) technologies, Rapid Prototyping (RP) and fabrication machines which use various additive manufacturing techniques especially 3D printers which use different printing techniques for modeling of the designed product. Some of the techniques used by these 3D printers are Fused Deposition Modelling (FDM) techniques, Fused Filament Fabrication (FFF) techniques, extrusion techniques, Multi-Jet Modeling (MJM) techniques, and Selective Laser Sintering (SLS) techniques. The designed models are fabricated by implementing any of the additive manufacturing techniques. Not only to print the desired model with high precision and accuracy these technologies are also used for achieving highly sustainability products which can withstand optimum operating conditions. Many advancements took place in this 3D printing technologies since their first invention. This paper comprehends and reviews the various advancements, case studies, and experimental studies conducted by the various novel researchers. This paper also discusses the various fields in which 3D printing technologies are used.

Synopsis: This paper reviews about the 3D printing technologies such as FDM techniques, FFF techniques, extrusion techniques, MJM techniques, SLM techniques and SLS techniques in various fields like aerospace and aeronautical sectors, tissue engineering, cell cultivation sectors, food sector, pharmaceutical and drug delivery technologies and production engineering sectors. This paper also comprehends the present challenges faced by the 3D Printing technologies and their scope for the 3D Printing technologies in the upcoming future.

KEYWORDS

Additive Manufacturing (AM), Fused Deposition Modelling (FDM), Multi-Jet Modeling (MJM), Selective Laser Sintering (SLS), Inkjet Printer, Rapid Prototyping (RP)

1.1 In the review paper [1] by authors Wang, Jiang, Zuwan, Jihua, David gives an overview on 3D printing techniques of composite materials which uses polymer as a matrix material and evaluated properties of 3D printed composite parts and performance parameters of 3D printed composite parts. Also, they comprehended the 3D technologies and their potential applications in the fields of electronics, biomedical, and aerospace applications.

They discussed the 3D printing techniques such as stereolithography, SLS techniques, FDM techniques, 3D inkjet printing, and 3D plotting. They emphasized the performance and formation methodology of the particle-reinforced polymer composites, fiber-reinforced polymer composites, and nanomaterial-reinforced polymer composites.

The existing limitations of polymer composites 3D printing technologies are identified with evidence of the mentioned publications in their paper. They also reviewed the ongoing research for exploring a new application of 3D printing technologies with new materials of polymer composites.

Their paper aimed to be a base platform on which further researchers will progress. Finally, in their review, important limitations were identified in order to motivate the 3D printing future research.

1.2 Upadhyay, Tharmalingam, Mohamed Mansori paper [2] researched on 3D printed sand molds which can replace the old casting molds and can be used for multiplemumbers of times. Their research aimed to be a better value for the casting industry which is more than 5000 years old by providing a vital role in producing a quality and economic 3D printed sand moulds by using binder jetting technology for rapid prototyping.

A functional mold is manufactured with the required strength, characteristics to absorb heat, gas permeability, ensuring a high success rate for the quality castings with weight reduced and optimized design which overcame many of the limitations in traditional casting technique mold design with a very limited number of parts in the assembled mold.

A wide variety of powders, materials for bonding, of different sized or shaped particles are used to change the physical and thermal properties of the mold. Research by them provided wide range possibilities for casting of alloys.

1.3 In the paper [3] by Jeffrey Stansbury, Mike Idacavage, discussed the objectives of 3D printing technologies, their significance, the results of the advanced 3D printing techniques and their significance in the production industries are discussed.

The Additive Manufacturing (AM) techniques using polymer matrices such as SLA – Stereolithography apparatus, DLP, CLIP, SLS, SHS, BAAM, FFF/FDM - Fused filament fabrication/fused deposition modelling, LOM - Laminated object manufacturing techniques and their significance in the production industries are discussed.

The role taken by these technologies in the field of medicine especially in dental implants and Ortho-implants are also discussed. They signified the 3D printing technology as the next industrial revolution due to their vast utilization in many fields engineering and also in medicine.

1.4 In the paper, "Tissue Engineering: Toward a New Era of Medicine," by Ashkan Shafiee and Anthony Atala, [4] discussed the 2D and 3D printing technologies in the medical field since the beginning of the twenty-first century.

2D and 3D printing technologies have been extensively applied ranging from nanoelectronics to renewable energy to tissue engineering and medicine. In drug delivery and personalized medicine 2D and 3D printing technologies became an excellent choice for researchers due to their ability to precisely and accurately deposit different materials on various substrates rendered them.

Sophisticated surgical planning and 3D printed surgical models has enhanced surgical outcomes. Tissue engineers belonging to tissue engineering discipline are using 3D printers to scaffolds, print cells, and cell-laden hydrogels to make biological 3D constructs. Since bioprinting has been accepted as the best fabrication technique, several cell types are being used in the 3D printing of different tissues.

Polyester urethane urea which was used in cardiovascular research is used as a cardiac patch in which human umbilical vein endothelial cells patterned onto human mesenchymal stem cells. In order to test these patches, they were implanted into rats with induced myocardial infarction. These patches showed enhanced heart function and increase in vessel formation. 3D Printing is considered a reliable technique for heart valve fabrication.

Methacrylated gelatin and methacrylated hyaluronic acid were used to develop a hydrogel hybrid to encapsulate valvular interstitial cells for printing heart trileaflet valve conduits. Researchers also employed 3D printing approaches and techniques for tissue vascularization. Sacrificial elements, a glucose/sucrose/dextran combination, were used for casting the 3D vascular design, 3D printed and encapsulated in cells and ECM. The sacrificial elements were dissolved using culture medium by leaving an imprint throughout the tissue model that was lined with endothelial cells perfused with blood.

They outlined the bioprinting techniques in brief and about the 2D and 3D printing technologies in Tissue engineering and medicine.

1.5 The paper "Perspectives on Additive Manufacturing," by David L. Bourell [5] discussed additive manufacturing economics, history, current applications, future, and outlook. Additive manufacturing (AM) has been reached a very top level in public sectors commercially. Their article described the development of Additive manufacturing (AM) field from previously layered manufacturing approaches of topography, photosculpture, and material deposition. Some precursors for modern AM processes are also described briefly. The growth of the field from the last 20 years is pictured. The usage of AM technologies in the conventional system of manufacturing is still evolving. Currently, considerations such as high cost place AM in few applications, complex geometric parts. Future reductions in the cost of AM equipment and feedstock coupled with increased processing speed will expand the usage space for AM.

The development of the field in the course of the most recent 20 years is exhibited. Included is the standard outline of AM advancements into seven general classes. The financial matters of AM partage are considered, and the effects of the financial aspects of application divisions are depicted. Based on current patterns, the future viewpoint will incorporate a merging of AM fabricators, mass-created AM fabricators, empowering of topology enhancement outlines, and specialization in the AM legitimate field. Long haul advancements with gigantic effect are organ printing and volume-based printing.

They recommended that the disparity of top of the line and low-end fabricators in the course of the most recent 20 years will turn around itself, to a great extent because of the diminishing expense of top of the line fabricators and upgrades in the nature of parts created on low-end fabricators. AM gear produce and deals have been grasped by an extensive, multinational hardware organization that will goad social selection of the innovations. AM is an empowering innovation for topology streamlining that will bring about PC composed part geometries with enhanced properties.

The legal communities are beginning to have some expertise in issues specific to AM. Areas of focus incorporate copyright and patent encroachment, item risk, and controls on weapon creation in light of administrative obligations and ensured opportunities. Territories of center incorporate copyright and patent encroachment, item risk, and controls on weapon creation in light of administrative obligations and ensured opportunities. Long haul advancements in AM that will be transformational are organ printing and volume printing.

This is an energizing time for AM. The advancements are incorporating into general society part on a global premise. Innovative work is expanding at a quick pace. Item commercialization is additionally developing and differentiating quickly. The effect of appropriated fabricating can possibly have an effect tantamount to that of disseminated registering, which started over 40 years' prior and was an empowering innovation circulated producing. Expanded perceivability and consideration put on AM will goad and quicken headway on both connected and research planes. The rest of the difficulties have been systematized and defined in various research street mapping ponders beginning with the 2009 Roadmap for Additive Manufacturing.

The situation of AM advances in conventional manufacturing is developing. At present, economic considerations put AM in uses of short-run, complex geometric parts. Future decreases in the cost of AM gear and feedstock combined with expanded preparing pace will extend the application space for AM. They gave a brief spectrum of

Additive Manufacturing and 3D printing technologies in their paper.

1.6 In the paper "3D printing: Printing precision and application in the food sector," by Zhenbin Liu, Min Zhang, Bhesh Bhandari, Yuchuan Wang [6] discussed the 3D printing applications in the food sector. They also discussed the 3D printing technologies printing precision and accuracy to print the consumable and storable food items. They also described the background for the 3D printing technologies in the food industry and the scope for 3D printing technologies in the food industries.

Solid freeform fabrication (SFF) or 3D printing, AM, was introduced first by researchers from Cornell University in food sector by using an extrusion-based 3D printer. The 3D printing technology is characterized by deposition of amaterial layer by layer which is based directly from a pre-designed CAD file.

3D printing technology has numerous potential applications and advantages in the food sector, such as digitalized and personalized nutrition, customized food designs, broadening the available source, simplifying supply chain of food material. Utilizing this technology, fantastic foods with complex designs can be created which cannot be achieved by conventional moldor by manual labor or can be produced based on predetermined data files that comprise artistic skills and culinary knowledge from chefs, food designers, and nutrition experts. It additionally can be utilized to redo candy store shapes and brilliant pictures onto the surface of strong consumable substrates. Likewise, 3D nourishment printing grants to digitize and customize the sustenance and vitality necessities of a distinctive individual as indicated by their physical and nourishment status.

Regular nourishment store network can be improved by 3D sustenance printing. The all-inclusive application this strategy will make the assembling exercises gradually drawing to the spots nearer to the clients and will prompt the diminished transport volume, subsequently decreasing the bundling, circulation and superseding costs. Food printing technology will likewise expand the source of available food materials by utilizing the non-traditional food materials such as high fiber plant-based materials, insects, and animal and plant-based by-products

Currently available 3D printing techniques in the food sector are of four types: selective sintering printing (SLS), extrusion based printing, inkjet 3D printing, and 3D binder jetting. Extrusion-based 3D printing is generally used in the extrusion of soft material such as dough, hot melt chocolate or puree of meat, and pasted potatoes. Researchers from Cornell University studied the fabrication of cake frosting, processed cheese, and sugar cookies using 3D printer which uses extrusion techniques. The 3D printing technology has also been used by TNO, Netherlands to fabricate many kinds of foods using non-traditional ingredients and traditional materials such as insects and algae. Another extrusion based printer (Foodini Printer) was created by Natural Machines to be used for graphical decorations and surface filling. The effect of 3D printing technologies on processed cheese quality was reviewed by Camille.

Compared to the untreated cheese samples (samples that are not 3D printed) the 3D printed cheese shows meltability (21%) degrees very higher and was less hard, by up 68 to 49%. The hot-melt extrusion technique for chocolate, utilizing 3D printing was right off the bat worked utilizing a Fab@home printing framework. They examined the deposition of chocolate and the processing factors influencing the printing precision during chocolate creation.

The chocolate extrusion printing has been popularized by Choc Edge's Choc Creator, ChefJet 3D Systems, Hershey's CokoJet, and Chocabyte. SLS has been used to create complex structures utilizing sugar or sugar-rich powders. Fragile and complex 3D structures have been made by specialists from TNO utilizing sugars and NesQuik powders (Gray, 2010).

Utilizing SLS, CandyFab Project has effectively made different alluring complex structures utilizing sugar powders which couldn't be created by regular ways (CandyFab 2007).

Folio streaming offers favourable circumstances, for example, quick creation, working of complex structures and low material cost. In view of cover flying, Southerland and Walters researched the creation of

edible builds utilizing sugars and starch blends. Scientists from 3D System have made a folio to create a wide assortment of vivid and flavors palatable items, for example, different sorts of complex sculptural cakes by fluctuating flavor and bright covers. Inkjet printing by and large handle low thickness materials, in this manner it is primarily utilized as a part of the territory of surface filling or picture improvement. Grood and Grood made a drop-on-request inkjet printer to apportion palatable fluids onto sustenance surfaces to make engaging pictures. The FoodJet printer utilizes pneumatic film spout planes to store consumable drops onto a moving article to frame an engaging surface. Willcocks, Shastry, Collins, Camporini, and Suttle made a sort of edible ink to create high resolutions of pictures on edible substrates, for example, cake, biscuit and crackers.

Around the world 3D printing is being used widely. In any case, few examinations have concentrated on the best way to accomplish an exact and exact printing, however it is basic to a fruitful and smooth printing of the sustenance objects. The points of this audit paper are to gather and investigate the data with respect to how to accomplish an exact and precise sustenance printing, and to survey the utilization of, and also to give a few recommendations and give a basic knowledge into the patterns and difficulties looked by 3D food printing.

3D printing is as a rule broadly examined in the food sector. However, few examinations have concentrated on the most proficient method to accomplish a precision and accurate printing, however, it is basic to an effective and smooth printing of the food objects. The points of their research paper is to gather and break down the data in regards to how to accomplish an accurate, exact and precise food printing, also, to study the utilization of 3D printing in a few food regions, and in addition to give a few recommendations and give a basic understanding into the patterns and difficulties looked by 3D food printing.

Their review gave brief details of 3D printing technologies in the food sector and various methods available for 3D printing food items. They also outlined the advancements done by various researchers from various institutions in the 3D Food printing technologies.

1.7 In the research article [7] by Jinah, Young Ju, Gao, Woo Cho discussed printing the human cells and tissues by utilizing 3D printing technologies. They also detailed the current advancements achieved in tissue engineering by utilizing 3D Cell printing technologies by using microfluids and 3D tissue fabrication techniques.

Building human tissues through 3D cell printing technologies have gotten specific consideration because of its procedure adaptability and flexibility. This innovation encourages the summarization of one of a kind highlights of human tissues and the across the board producing process through the outline of savvy and progressed biomaterials and appropriate polymerization strategies. For the ideal building of tissues, a higher-arrange get together of physiological parts, including biomaterials, cells, and biomolecules should meet the basic prerequisites for vascularization and morphogenesis of tissue.

The merging of 3D cell printing with a microfluidic approach was prompted a huge jump in the vascularization of designing tissues. In addition, recent edge innovation in stem cells and genetic engineering can possibly be adjusted to the 3D tissue fabrication system, and it can possibly move the worldview of the investigation of obscure malady components and disease modeling which is required for precision medicine.

Their review gives an overview of the recent developments in 3D cell printing technologies and bioinks. And also provides technical requirements for engineering human cells and human tissues. At last, they proposed suggestions on the development of next-generation diagnostics and therapeutics.

1.8 The research was done by the scientists Sophia N. Economidou, Dimitrios A. Lamprou, Dennis Douroumis [7] on "3D printing applications for transdermal drug delivery," outlined the 3D printed delivery systems for transdermal drug and current regulatory framework associated with it.

The part of two and three-dimensional printing as a manufacturing

technology for advanced transdermal drug delivery systems were investigated in their writing. 3D printing incorporates a group of distinct technologies that utilize a virtual model to convey and create a physical object through numerically controlled mechanical gatherings. The applicability of many printing technologies has been looked into for the direct or indirect printing of microneedle arrays or microneedle clusters or for the modification of their surface through drug-containing coatings. The findings of the particular examinations are also exhibited. The scope of printable materials that are presently utilized or conceivably can be utilized for 3D printing of TDD systems is evaluated. Also, the impact and difficulties of the selection of 3D printing as a manufacturing strategy for drug delivery systems, are surveyed in their research. At long last, their paper traces the current administrative structure related to 3D printed transdermal drug delivery systems

Since its presentation, 3D printing has adjusted the conventional fabrication strategies in various fields including medication and pharmaceuticals, bringing quietly altered treatment a bit nearer to acknowledgment. The advances in the field of TDD are still in a crude stage and they are as of now being investigated yet the outcomes appear to be promising. Inkjet printing has effectively been utilized to specifically deposit 2D films on pre-created microneedle surfaces or smaller molds which are micro natured that were later utilized for microneedle casting. 3D inkjet printed microneedles have additionally been commercialized.

Photopolymerization-based advanced technologies, SLA, DLP, and 2PP have likewise been utilized for the creation of microneedles or miniaturized scale molds for microneedle casting, while FDM has been researched just in one single investigation where nose-shaped devices used for the treatment of skin acne were manufactured. The measure of published work points out attention to that the challenging concept of combining elaborate microneedle array systems with precise, exact, accurate and sophisticated 3D printing techniques that can possibly change the general viewpoints of future and modern drug administration strategies.

To accomplish this, a progression of designing, science, and material-related difficulties must be managed through pertinent interdisciplinary research, with a specific end goal to enlarge the material palette and go around the technical drawbacks. At long last, in spite of the fact that the FDA has made some move in adjusting the current directions on 3D medical devices by distributing rules to enable producers to adapt to quality and process issues, the structure is as yet broad. Tending to administrative issues specifically for 3D printed TDD frameworks is basic with a specific end goal to console the effectiveness and safety of such frameworks. This is a basic condition for 3D printed TDD frameworks to be affirmed and directed to the market.

1.9 In the review article [9] by Lim, Srithar, Alias Noor, Norhayati, Uday reviewed the capabilities of the new 3D printing technology techniques for the fabrication of porous ceramic.

3D printing, close by the quickly progressing specialization of porous ceramics, is rapidly extending the horizon of what will be conceivable later on. In their research paper, 3D printing technologies are assessed for its similarity with porous ceramic materials, because of its focused procedure as far as speed and specific tooling, particularly for good quality fabrication.

Their paper reviews the capacities of these new innovation systems for the fabrication of porous ceramic. The basic technology is the 3D printing techniques and procedures, which are utilized to manufacture permeable green ceramic parts that will be sintered later. Distinctive ceramic materials are assessed and the classification of various powders as per their 3D printing quality and also material perspectives is inspected. The assessment of 3D printing process as far as the powders' physical properties, for example, molecule size, flowability, and wettability are likewise talked about. The connection between the distinctive 3D printing parameters and the final printing result are surveyed.

This examination additionally utilized two advancement strategies to acquire the best 3D printing parameter settings for small porous

structures. At first, a particle swarm optimization algorithm was utilized to acquire the best-aggregated scheme of an artificial neural system (AANN). From that point onward, they actualized the Pareto optimal front to decide the best 3D setting parameters for the scaffold's formation with the required porosity and compressive mechanical strength. They anticipated the porosity and compressive quality of the 3D structure of scaffolds printed on an extensive variety of layer thickness, print orientations and time delays for the deployment of each layer.

With this setting, they could foresee the best mechanical properties and porosity, in view of setting parameters. This approach likewise gives the data to design a porous ceramic structure and survey the effect of leading processing factors. In creating models for porous structures, Zein et al. talked about the compressive properties which rely upon porosity. They exhibited outcomes about the variety of mechanical properties with porosity. Scaffold compressive stiffness E_s and yield quality r diminished quickly as the porosity expanded. These decreases were portrayed utilizing a power law function respectively.

The examination of mechanical properties gave a superior comprehension of the idea of the anisotropic structure of various designs. Generally, it was discovered that the mechanical properties rely upon the porosity and paying little respect to the span of the channel, this being in concurrence with theoretical ideas on the properties and structural connections of porous ceramics production.

1.10 In their review paper "3D printing in orthognathic surgery L Aliterature review," by Lin, Daniel, Lun Lo [10] reviewed and researched the recent advances in 3D technologies in three-dimensional (3D) imaging, simulation and computer-assisted surgical planning and for analysis of craniofacial structures for better prediction of outcomes of surgeries in orthognathic surgery.

With the current advances in three-dimensional (3D) imaging, computer-assisted simulation of surgeries and planning of surgeries are frequently utilized for investigation of craniofacial structures and enhanced forecast of surgical results in orthognathic surgery. An assortment of patient-specific surgical devices and guides have been designed and manufactured utilizing 3D printing technologies, which quickly increased far-reaching fame to enhance the results.

Their article exhibits a review of 3D printing technologies for best in the class application in orthognathic surgery and examines the effects and patient result. The current accessible writing with respect to the utilization of 3D printing strategies in orthognathic surgery including 3D computer aided manufacturing/computer-aided design, rapid prototyping, additive manufacturing, 3D printed models, 3D printing, custom-made guides, surgical occlusal splints, fixation plates and templates are reviewed. From the review, they presumed that the utilization of 3D printing strategies in orthognathic surgery give the benefit of aesthetic results and optimal functional, understanding fulfillment, an exact interpretation of the treatment design.

Their review uncovered that different patient-specific 3D-printed surgical gadgets are progressively utilized as a part of the orthognathic surgery and presume that it is beneficial to the clinicians and patients. Their research provides data that can be useful to analysts, researchers, and clinicians considering the utilization of 3D printing methods in OGS. A more noteworthy assortment of materials with fluctuating attributes and capacities of 3D printing technologies are being investigated. There are as yet numerous potential applications for future research and clinical application in orthognathic surgery.

Conclusion

The flexibility of configuration, mass-customization and the capacity to print complex structures with least waste are the principle advantages of 3D printing. A complete survey of 3D printing techniques, materials and the present state in drifting applications in applications in various industries was carried out. The fundamental difficulties that are ascribed to the nature of 3D printing were additionally also discussed.

As far as techniques, fused deposition modeling (FDM) is a standout

amongst the most well-known 3D printing technologies due to simplicity, low-cost, and high-speed processing. It is initially utilized for 3D printing of polymer fibers, however, has been adjusted to numerous different materials. FDM is mostly utilized for quick prototyping, and the mechanical properties and nature of the printed parts are bringing down contrasted with the powder-bed strategies, for example, specific laser sintering (SLS) and selective laser melting (SLM).

Adjoining powders are combined, liquefied or reinforced together by utilizing an assistant adhesive in Powder-bed techniques, which result in better resolutions, however, bring about higher expenses and are slower forms. Direct energy deposition (DED) utilizes a source of energy (laser or electron beam) to soften metal powders, however, no powder bed is utilized contrasted with SLM and the feedstock is dissolved before deposition in a layer-by-layer design like FDM yet with an amazing amount of energy for liquefying metals.

A limited selection of alloys and metals which are suitable for 3D printing brought about requests for the adoption of current techniques to a more extensive scope of composite structures and alloys. Ceramics have made a pattern of tailor-designed materials with a high strength-to-weight ratio and encouraged the formation of complex ceramic lattices for some applications such as ceramic scaffolds for tissue engineering. In any case, the principal challenge is the set number of accessible materials for 3D printing of ceramics production with better control over the microstructure and composition of the part.

Additive Manufacturing (AM) significantly added to the research and development for prototyping complex and modified structures with patient-specific necessities. However, it faces difficulties for regulatory issues and limited materials. The avionic business has put resources into AM to create customized parts with higher strength-to-weight ratios, and in addition to quick maintenance of planes and on-demand fabricating. However, the adaptation of AM in the aeronautic trade faces difficulties, for example, restricted materials and high cost, and additionally the inconsistent quality of 3D printed parts. AM innovation is still at its outset in the development business with a limited number of successful projects around the world. The fundamental disadvantages are high cost and diminished mechanical performance contrasted with conventional techniques.

Future Scope:

Regardless of the advantages of 3D printing technologies, there are a couple of downsides that would require additional research to receive this innovation in different businesses. The void arrangement between consequent layers of materials brings about extra porosity amid the assembling procedure, which can reduce mechanical performance because of a decrease in interfacial bonding between printed layers. Anisotropic conduct is another common challenge of 3D printing technologies, which brings about various mechanical behavior under compression or vertical tension compared to that of the horizontal direction

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