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Latest Development of 3D Printing Technology in Bio, Metal, Food (Astronauts), Construction

Ekechi Sixtus Nshirim[1], Urenna Nwagwu[2] & Uzoma Chukwuemeka Henry[3]
[1]Southern Illinois University Edwardsville, **United States**
[2]Wichita State University, **United States**
[3]Imo State, **Nigeria**

Abstract

This project report covers the Latest development of 30 printing tech in biomedical fields, In manufacturing of metals with unique properties, printing of parts and food for astronauts in space and in the construction industry. The flexibility of 30 printing allows industries and manufacturers to easily modify designs and properties of materials to specifically match their desired parts with unique properties that suits the specification needed.

F0M is a more widely used 30 printing technology for buildings by extruding clay or concrete, 30 printed deserts by extruding chocolate, 30 printed organs by extruding live cells in a bio gel. We may assume that if it can be extruded, it can be 30 printed.

The construction industry stands to gain in many ways by adopting 30 technologies as its main component composite material (e.g. Concrete) can be easily extruded and modified.

1. Introduction

1.1 Background

Copier and printer technology has gone a long way since Gutenberg (1436) and while inkjet and laser are not new printing technologies (both have been invented in the 1960s), the industry certainly hasn't stopped moving forward.

Printing can be categorized thus;

- **Mobile printing** - Printers need to be operated from literally anywhere now. Not only is it possible to print any contents in the memory of a smartphone, without having to use any computer in the process, distant printing has become easier than ever.
- **Cloud printing** - Cloud printing means printed or copied files are stored online. There again, the use of a computer to retrieve these files and have them printed is becoming increasingly irrelevant.
- **3D printing -** The popularization of 3D printers mean they may become affordable for any kind of company in just a few years' time. More and more applications useful for any company are being found, such as the printing of furniture for trade shows, models, replacement appliances and machine parts.

These works sometimes are achieved without any cable, such as Wireless printers, accepting Bluetooth, WIFI but also RFID, Contactless, Cloud printing are taking the market by storm. Our study is within the scope of 3D printing.

3D PRINTING

The term 3D simply refers to Three-Dimensions, Hence, 3D Objects refer to objects with more than two surfaces (on a plane), and have a length, breadth and height. They can come in regular forms, Irregular forms or defined forms.

3D printing can be defined as the computer-controlled sequential layering of materials to construct a three-dimensional object from a CAD (Computer Aided Design) model or a digital 3D model. The term "3D printing" can refer to a variety of processes in which material is deposited, joined or solidified under computer control to create a three-dimensional object, with material being added together (such as plastics, metal, rubber, liquids or powder grains being fused together), typically layer by layer.

In the 1980s, 3D printing techniques were considered suitable only to produce functional or aesthetic prototypes, and a more appropriate term for it at the time was **RAPID PROTOTYPING**. As of 2019, the precision, repeatability, and material range of 3D printing have increased to the point that some 3D printing processes are considered viable as an industrial-production technology, whereby the term additive manufacturing can be used synonymously with 3D printing. One of the key advantages of 3D printing is the ability to produce very complex shapes or geometries that would be otherwise impossible to construct by hand, including hollow parts or parts with internal truss structures to reduce weight.

In recent years, Industrial photocopiers and printers are more concerned by new printing technologies such as Digital print technology, with print-on-demand for large projects is more and more replacing offset printing. Some of these recent technologies include.

Hybrid print technologies (such as computer-to-print plate automation) and newer printer industry software are being used to help bridge the gap faster.

Digital Inkjet Printing represents the future of printing technologies. It enables extremely fast inkjet printing, directly onto offset coated stocks if needed, with high-end color printing quality, suitable for projects in the field of fine arts.

Fused deposition modeling (FDM), which uses a continuous filament of a thermoplastic material, is the most common 3D printing process in use as of 2020.

These Recent Technologies will be discussed in details in a later Chapter.

1.2 Problem statement

A Common challenge many newbies in 3D printing face is distinguishing between the different processes, technologies, and materials used in 3D Printing. 3D printing, also commonly referred to as additive manufacturing, is a basic term that encompasses a group of different 3D printing processes. In 2015, the ISO/ASTM 52900 standard was created with the aim to standardize all terminology and classify each of the different types of 3D printers.

1.3 Objectives of Study

The aim of this project is to review and bring to light the latest developments of 3D Printing in high level projects and as well the future of 3D Modelling in changing the world. To achieve this, we will

1. Define 3D printing
2. List the different Processes of 3D printing
3. List the different 3d techniques used in these 3D processes
4. Explain these 3D printing techniques
5. Discuss the latest development 3D printing technology in different industries
6. Discuss further on latest development of 3D printing technology in Construction, hence give an insight in the future of 3D printing in this industry.

1.4 Scope of Work

This study will discuss the success in latest Development of 3D Printing Technology in Bio, Metal, Food (Astronauts) and most importantly Construction in more details. We will discuss what has been done by 3D printers in recent years and also give an insight to the future of 3D printing in construction.

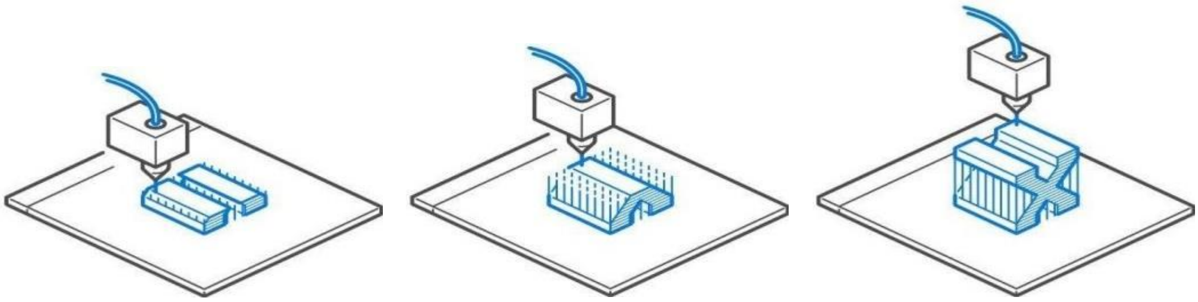
2. Brief Literature Review

2.1 Concepts Of 3D Printing Processes

In total, seven categories of additive manufacturing/3D printing processes have been identified and established so far. These seven 3D printing processes have brought forth many different types of 3D printing technologies that 3D printers use today. This study will explain these 3D printing Processes and techniques used for each process.

2.2 Types of 3D Printing Processes

1. <u>Material Extrusion</u>

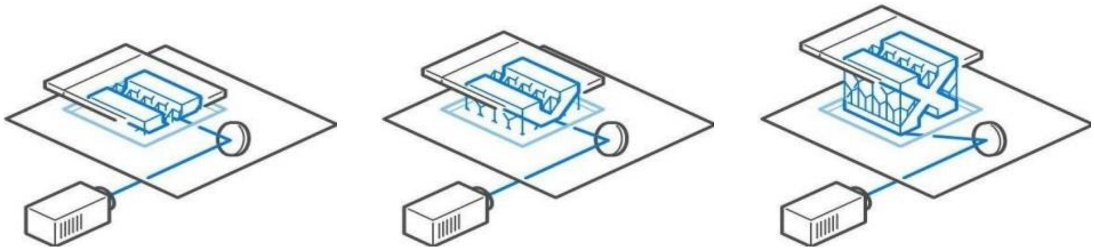


Material extrusion is exactly what it sounds like: material being extruded through a nozzle. Most of the time that material is a plastic filament pushed through a heated nozzle, melting it in the process. The printer deposits the material on a build platform along a predetermined path, where the filament then cools and solidifies to form a solid object. You can also extrude metal paste, biogels, concrete, chocolate, and a wide range of other materials, but plastics are the most common.

- **Types of 3D Printing Technology:** Fused deposition modeling (FDM), sometimes called fused filament fabrication (FFF)

- **Materials:** Plastic filament (PLA, ABS, PET, PETG, TPU, Nylon, ASA, PC, HIPS, Carbon Fiber, and many more.) and other material
- **Dimensional Accuracy:** ±0.5% (lower limit ±0.5 mm)
- **Common Applications:** Electrical housings, form and fit testings, figs and fixtures, investment casting patterns, etc.
- **Strengths:** Lowest cost 3D printing method, wide range of materials

2. Vat polymerization



Vat Polymerization using a laser

Vat polymerization is a 3D printing process where a light source selectively cures a photopolymer resin in a vat. In other words, light is precisely directed to a specific point on a thin layer of liquid plastic to harden it. This process is repeated layer by layer until the 3D part is formed.

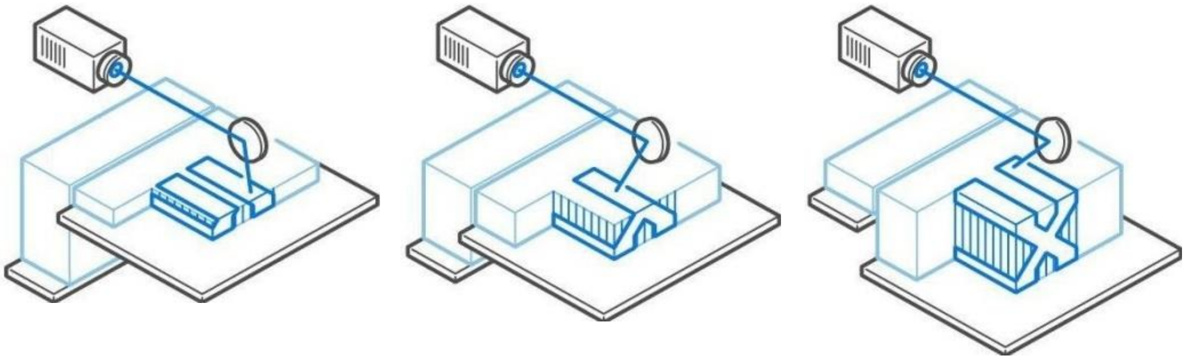
Three common forms of vat polymerization are stereolithography (SLA), digital light processing (DLP), and masked stereolithography (MSLA). The fundamental difference between these types of 3D printing technology is the light source they use to cure the resin and we detail each method below.

- **Types of 3D Printing Technology:** Stereolithography (SLA), masked stereolithography (MSLA), micro stereolithography (µSLA), and more.
- **Materials:** Photopolymer resins (castable, transparent, industrial, bio-compatible, etc.)
- **Dimensional Accuracy:** ±0.5% (lower limit ±0.15 mm or 5 nanometres with µSLA)
- **Common Applications:** Injection Mold-like polymer prototypes; jewellery casting; dental applications
- **Strengths:** Smooth surface finish, fine feature details

There are more technologies used in the Vat Polymerization process particularly in professional circles. The are listed thus;

- Programmable Photopolymerization (P3)
- High Area Rapid Printing (HARP)
- Lithography-based Metal Manufacturing (LMM)
- Light Enabled Additive Production (LEAP)
- Projection Micro Stereolithography (PµSL)
- Digital Composite Manufacturing (DCM)

3. Powder bed fusion



Powder bed fusion is a 3D printing process where a thermal energy source selectively induces fusion between powder particles (plastic, metal, or ceramic) inside a build area to create a solid object.

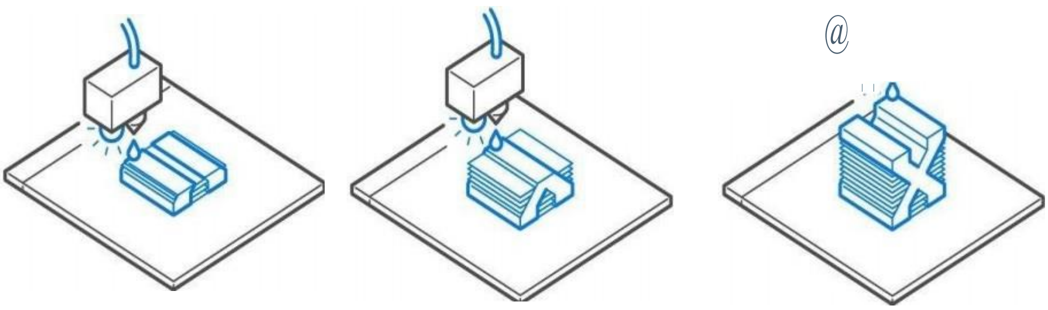
Many powders bed fusion devices also employ a mechanism for applying and smoothing powder simultaneous to an object being fabricated. The final item is encased and supported in unused powder.

- **Types of 3D Printing Technology:** Selective laser sintering (SLS), selective laser melting (SLM), electron beam melting (EBM), multi jet fusion (MJF)
- **Materials:** Thermoplastic powders (Nylon 6, Nylon 11, Nylon 12, etc.), metal powders (steel, titanium, aluminium, cobalt, etc.), ceramics
- **Dimensional Accuracy:** ±0.3% (lower limit ±0.3 mm)
- **Common Applications:** Functional parts, complex ducting (hollow designs), low- run part production
- **Strengths:** Functional parts, excellent mechanical properties, complex geometries

The terms listed below also fall under Powder Bed Fusion technology, but each may have subtle differences or just be named something different for the purpose of marketing.

- Multi Jet Fusion (MJF)
- Selective Heat Sintering (SHS)

4. Material Jetting



Material Jetting is a 3D printing process where droplets of material are selectively deposited and cured on a build plate. Using photopolymers or wax droplets that cure when exposed to light, objects are built up, one layer at a time.

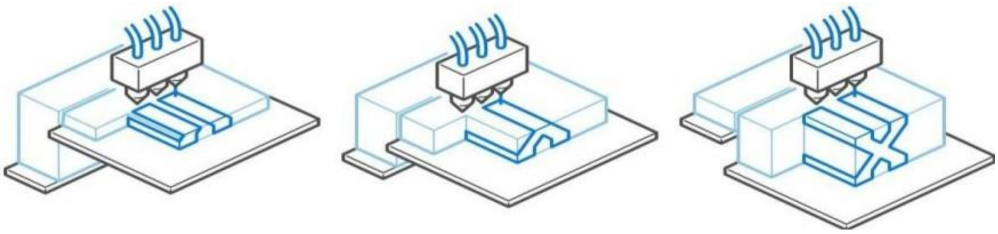
The nature of the Material Jetting process allows for different materials to be printed in the same object. One application for this technique is to fabricate support structures from a different material to the model being produced.

- **Types of 3D Printing Technology:** Material Jetting (MJ), Drop on Demand (DOD)
- **Materials:** Photopolymer resin (Standard, Castable, Transparent, High Temperature)
- **Dimensional Accuracy:** ±0.1 mm
- **Common Applications:** Full-colour product prototypes; Injection Mold-like prototypes; Low run injection Molds; Medical models
- **Strengths:** Best surface finish; Full colour and multi-material available
- **Weaknesses:** Brittle, not suitable for mechanical parts; Higher cost than SLA/DLP for visual purposes

There isn't too much variation in Material Jetting technology, but you may see the technology referred to as one of the following.

- Nano-Particle Jetting (NPJ)
- Colour-Jet Printing (CJP)

5. Binder-Jetting



Binder Jetting is a 3D printing process where a liquid bonding agent selectively binds regions of a powder bed.

Binder Jetting is a similar 3D printing technology to SLS (Selective Laser Sintering), with the requirement for an initial layer of powder on the build platform. But unlike SLS, which uses a laser to sinter powder, Binder Jetting moves a print head over the powder surface depositing binder droplets, which are typically 80 microns in diameter. These droplets bind the powder particles together to produce each layer of the object.

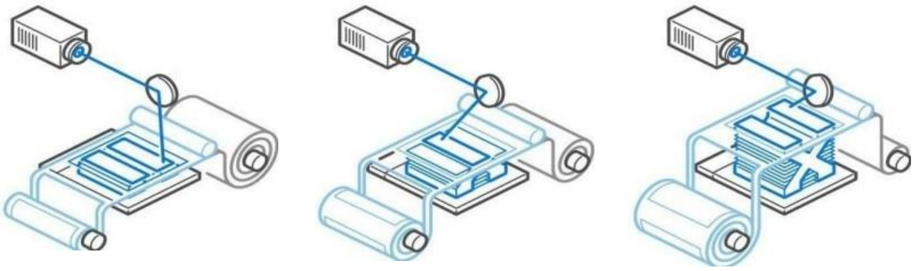
Once a layer has been printed, the powder bed is lowered, and a new layer of powder is spread over the recently printed layer. This process is repeated until a complete object is formed.

The object is then left in the powder to cure and gain strength. Afterward, the object is removed from the powder bed, and any unbound powder is removed using compressed air.

- **Types of 3D Printing Technology:** Binder Jetting (BJ)
- **Materials:** Sand or metal powder: Stainless/ Bronze, Full-color sand, Silicia (sand casting); Ceramic-Metal composites
- **Dimensional Accuracy:** ±0.2 mm (metal) or ±0.3 mm (sand)
- **Common Applications:** Functional metal parts; Full-color models; Sand casting
- **Strengths:** Low-cost; Large build volumes; Functional metal parts

- **Weaknesses:** Mechanical properties not as good as metal powder bed fusion

6. Sheet Lamination



Sheet Lamination is a form of 3D printing that functions by stacking and laminating sheets of very thin material together in order to produce a 3D object. The material layers can be fused together using a variety of methods, with heat and sound commonly used to do so. Which method is most appropriate depends on the material in question, with paper, polymers, and metals all used in sheet lamination.

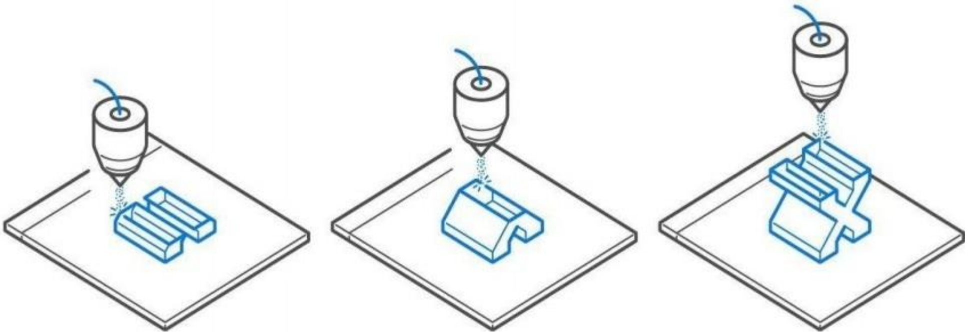
The technology is one of the less accurate 3D printing technologies, with parts produced using this method requiring a lot of post-production finishing. Laser cutters and CNC routers are used as the print progresses to form the print into the desired shape, which can lead to more wastage than in other 3D printing technologies.

- **Types of 3D Printing Technology:** Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC)
- **Materials:** Paper, polymer, and metal in sheet forms
- **Dimensional Accuracy:** ±0.1 mm
- **Common Applications:** Non-functional prototypes, multi-color prints, casting molds.
- **Strengths:** Low-cost; quick production possible; composite prints
- **Weaknesses:** Low accuracy; more waste; plenty of post-production work required for parts

There are a few other types of Sheet Lamination technology used today that generally fall under the same category and they are listed thus;

- Selective Lamination Composite Object Manufacturing (SLCOM)
- Plastic Sheet Lamination (PSL)
- Computer-Aided Manufacturing of Laminated Engineering Materials (CAM- LEM)
- Selective Deposition Lamination (SDL)
- Composite Based Additive Manufacturing (CBAM)

7. Direct-Energy-Deposition



DED is a 3D printing process where material is fed and fused by powerful thermal energy simultaneously to when it is deposited. The energy source in question is usually one of three - an electron beam, laser, or plasma. Material is fed in either wire or powder forms for the heat source to melt as it leaves its nozzle, forming complex shapes.

This technology can be used to build up a print layer by layer, but it can also be used 3-dimensionally, moving around an object to create. For this reason, DED is often used as a way to repair high-end metal components, more so than perhaps it is being used to create entirely new printed items.

- **Types of 3D Printing Technology:** Laser Engineered Net Shaping (LENS); Electron Beam Additive Manufacturing (EBAM); Cold Spray
- **Materials:** Metals, in wire and powder form
- **Dimensional Accuracy:** ±0.1 mm
- **Common Applications:** Repair of high-end automotive/aerospace components, functional prototypes, and final parts
- **Strengths:** Support structures rarely required; mixing metals; ability to work in 3 dimensions
- **Weaknesses:** Poor surface finish requires post-processing; expensive

A few other terms have been used to describe DED, with some to differentiate due to marketing purposes and some technically different in execution. However, the below-listed items could all be considered DED.

- Directed Light Fabrication (DLF)
- Direct Metal Deposition (DMD)
- Wire Arc Additive Manufacturing (W AAM)
- Rapid Plasma Deposition (RPD)

It is also worth mentioning that some hybrid 3D printers exist that combine DED technology with CNC milling, one example being DMG Mori's Laser Tec 65 hybrid.

2.3 Types of 3D Printing Technology

1. Fused Deposition Modeling (FDM)

Material Extrusion devices are the most commonly available - and affordable - types of 3D printing technology globally. You might be familiar with them as fused deposition modeling or FDM. They are also sometimes referred to as fused filament fabrication or FFF.

The way it usually works is that a spool of filament is loaded into the 3D printer and fed through to a printer nozzle in the extrusion head. The printer nozzle is heated to the desired temperature, whereupon a motor pushes the filament through the heated nozzle, causing it to melt. The printer then moves the extrusion head along with specified coordinates, laying down the molten material onto the build plate, where it cools down and solidifies. Once a layer is complete, the printer proceeds to lay down another layer. This process of printing cross-sections is repeated, building layer-upon-layer until the object is fully formed.

Depending on the object's geometry, it is sometimes necessary to add support structures, for example, if a model has steep overhanging parts.

2. Stereolithography (SLA)

SLA holds the historical distinction of being the world's first 3D printing technology. Stereolithography was invented by Chuck Hull in 1986, who filed a patent on the technology and founded the company 3D Systems to commercialize it.

An SLA printer uses mirrors, known as galvanometers or galvos, with one positioned on the X-axis and another on the Y-axis. These galvos rapidly aim a laser beam across a vat of resin, selectively curing and solidifying a cross-section of the object inside this building area, building it up layer by layer.

Most SLA printers use a solid-state laser to cure parts. The disadvantage of these types of 3D printing technology using a point laser is that it can take longer to trace the cross-section of an object when compared to our next method (DLP), which hardens an entire layer at once.

3. Digital Light Processing (DLP)

DLP resin 3D printers for Dentistry

Looking at digital light processing machines, these types of 3D printers are almost the same as SLA. The key difference is that DLP uses a digital light projector toflash a single image of each layer all at once (or multiple flashes for larger parts).

Because the projector is a digital screen, the image of each layer is composed of square pixels, resulting in a layer formed from small rectangular blocks called voxels.

Light is projected onto the resin using light-emitting diode (LED) screens or a UV light source (lamp) that is directed to the build surface by a digital micromirror device (DMD).

A DMD is an array of micro-mirrors that control where light is projected and generate the light-pattern on the build surface.

4. Masked Stereolithography (MSLA)

Masked Stereolithography uses an LED array as its light source, shining UV light through an LCD screen displaying a single layer slice as a mask - hence the name.

Like DLP, the LCD photomask is digitally displayed and composed of square pixels. The pixel size of the LCD photomask defines the granularity of a print. Thus, the XY accuracy is fixed and does not depend on how well you can zoom/scale the lens, as is the case with DLP. Another difference between DLP-based printers and MSLA technology is that the latter utilizes an array of hundreds of individual emitters rather than a single-point emitter light source like a laser diode or DLP bulb.

Similar to DLP, MSLA can, under certain conditions, achieve faster print times compared to SLA. That's because an entire layer is exposed at once rather than tracing the cross- sectional area with the point of a laser.

Due to the low cost of LCD units, MSLA has become the go-to technology for the budget desktop resin printer segment.

5. Selective Laser Sintering (SLS)

Creating an object with powder bed fusion technology and polymer powder is generally known as selective laser sintering (SLS). As industrial patents expire, these types of 3D printing technologies are becoming increasingly common and lower cost.

First, a bin of polymer powder is heated to a temperature just below the polymer's melting point. Next, a recoating blade or wiper deposits a very thin layer of the powdered material- typically 0.1 mm thick - onto a build platform. A CO2 or fiber laser then begins to scan the surface. The laser selectively sinters the powder and solidify a cross-section of the object. Just like SLA, the laser is focused on the correct location by a pair of galvos.

When the entire cross-section is scanned, the build platform will move down one layer thickness in height. The recoating blade deposits a fresh layer of powder on top of the recently scanned layer, and the laser will sinter the next cross-section of the object onto the previously solidified cross-sections.

These steps are repeated until all objects are entirely manufactured. The powder that hasn't been sintered remains in place to support the object, which reduces and, in some cases, eliminates the need for support structures.

6. Direct Metal Laser Sintering (DMLS) / Selective Laser Melting (SLM)

Both direct metal laser sintering (DMLS) and selective laser melting (SLM) produce objects in a similar fashion to SLS. The main difference is that these types of 3D printing technology are applied to the production of metal parts.

DMLS does not melt the powder but instead heats it to a point so that it can fuse on a molecular level. SLM uses the laser to achieve a full melt of the metal powder forming a homogeneous part. This results in a part that has a single melting temperature (something not produced with an alloy). This is the main difference between DMLS and SLM; the former produces parts from metal alloys, while the latter forms single element materials, such as titanium. Unlike SLS, the DMLS and SLM processes require structural support to limit the possibility of any distortion that may occur (despite the fact that the surrounding powder provides physical support).

DMLS/SLM parts are at risk of warping due to the residual stresses produced during printing because of the high temperatures, yet because DMLS doesn't melt the powder, parts can have less stress. After printing, parts are also typically heat-treated to relieve any stresses in the parts.

7. Electron Beam Melting (EBM)

Distinct from other Powder Bed Fusion techniques, electron beam melting (EBM) uses a high energy beam, or electrons, to induce fusion between the particles of metal powder.

A focused electron beam scans across a thin layer of powder, causing localized melting and solidification over a specific cross-sectional area. These areas are built up to create a solid object.

Compared to SLM and DMLS types of 3D printing technology, EBM generally has a superior build speed because of its higher energy density. However, things like minimum feature size, powder particle size, layer thickness, and surface finish are typically larger.

Also important to note is that EBM parts are fabricated in a vacuum, and the process can only be used with conductive materials.

8. Material Jetting (MJ)

Material Jetting (MJ) works in a similar way to a standard inkjet printer. The key difference is that, instead of printing a single layer of ink, multiple layers are built upon each other to create a solid part.

The print head jets hundreds of tiny droplets of photopolymer and then cures/solidifies them using ultraviolet (UV) light. After one layer has been deposited and cured, the build platform is lowered down one layer thickness, and the process is repeated to build up a 3D object.

MJ is different from other types of 3D printing technology that deposit, sinter, or cure build material using a point-wise deposition. Instead of using a single point to follow a path that outlines the cross-sectional area of a layer, MJ machines deposit build material in a rapid, line-wise fashion.

The advantage of line-wise deposition is that MJ printers can fabricate multiple objects in a single line with no impact on build speed. So long as models are correctly arranged, and the space within each build line is optimized, MJ can produce parts faster than other types of 3D printers.

Objects made with MJ require support, which is printed simultaneously during the build from a dissolvable material that is removed during the post-processing stage. MJ is one of the only types of 3D printing technology to offer objects made from multi-material printing and full-color.

9. Drop on Demand

Drop on Demand (DOD) is a type of 3D printing technology that uses a pair of inkjets. One deposits the build materials, which is typically a wax-like material. The second is used for dissolvable support material. As with typical types of 3D printing technology, DOD printers follow a predetermined path to jet material in a point-wise deposition, creating the cross-sectional area of an object layer-by-layer.

DOD printers also use a fly-cutter that skims the build area after each layer is created, ensuring a perfectly flat surface before commencing the next layer. DOD printers are usually used to create patterns suitable for lost-wax casting or investment casting and other mold-making applications.

10. Sand Binder jetting

With Sand Binder Jetting devices, these are low-cost types of 3D printing technology for producing parts from sand, e.g., sandstone or gypsum.

For full-color models, objects are fabricated using a plaster-based or PMMA powder in conjunction with a liquid binding agent. The printhead first jets the binding agent, while a secondary print head jets in color, allowing full-color models to be printed.

Once parts have fully cured, they are removed from the loose unhanded powder and cleaned. To enhance mechanical properties, parts are often exposed to an infiltrate material.

There are a large number of infiltrates available, each resulting in different properties. Coatings can also be added to improve the vibrancy of colors.

Binder Jetting is also useful for the production of sand cast Molds and cores. The cores and Molds are generally printed with sand, although artificial sand (silica) can be used for special applications.

After printing, the cores and Molds are removed from the build area and cleaned to remove any loose sand. The Molds are typically immediately ready for casting. After casting, the Mold is broken apart, and the final metal component is removed.

The significant advantage of producing sand casting cores and Molds with Binder Jetting is the large, complex geometries the process can produce at relatively low cost. Plus, the process is quite easy to integrate into existing manufacturing or foundry processes without disruption.

11. Metal Binder jetting

Binder Jetting can also be used for the fabrication of metal objects. Metal powder is bound using a polymer binding agent. Producing metal objects using Binder Jetting allows for the production of complex geometries well beyond the capabilities of conventional manufacturing techniques.

Functional metal objects can only be produced via a secondary process like infiltration or sintering, however. The cost and quality of the result generally define which secondary method is the most appropriate for an individual application. Without these additional steps, a part made with metal Binder Jetting will have poor mechanical properties.

The secondary infiltration process works as follows: initially, metal powder particles are bound together using a binding agent to form a "green state" object. Once the objects have fully cured, they are removed from the loose powder and placed in a furnace, where the binder is burnt out. This leaves the object at around 60% density with voids throughout.

Next, bronze is used to infiltrate the voids via capillary action, resulting in an object with around 90% density and greater strength. However, objects made with metal Binder Jetting generally have lower mechanical properties than metal parts made with Powder Bed Fusion.

The sintering secondary process can be applied where metal parts are made without infiltration. After printing is complete, green state objects are cured in an oven. Next, they're sintered in a furnace to a high density of around 97%. However, non-uniform shrinkage can be an issue during sintering and should be accounted for at the design stage.

12. Laminated Object Manufacturing (LOM)

LOM is the most common form of Sheet Lamination 3D printing. Sheets of material are layered on top of each other and bonded together using glue. Like many other forms of 3D printing, layers are built up one at a time, but a sheet cannot form a complex shape alone, and in LOM, a knife (or laser, or CNC router) is used to cut the layered object into the correct shape.

The amount of glue applied during this printing process can be varied, with more sticky stuff being applied to areas that will eventually form part of the final print and less being applied to areas that will be removed by the cutter. The cutter works as the print proceeds, cutting a 2D cross-section of the eventual final print.

This printing method has some notable advantages, with prints being quick and affordable to produce and larger objects capable of being produced using this method. There are some downsides too, of course.

More often than not, prints produced using this technology are pretty strong and retain good properties over time, but they require more post-production finishing (and can be altered with drilling or machining) and produce more excess waste than other 3D printing methods.

13. Ultrasonic Consolidation

Ultrasonic Consolidation (UC) is a way to 3D print metal objects that falls under the Sheet Lamination umbrella. You'll sometimes see it referred to as Ultrasonic Additive Manufacturing (UAM).

This 3D printing method uses ultrasonic vibrations and pressure via a sonotrode to fuse thin sheets of metal together at a low temperature. Because of that low temperature, the metal sheets are not melted together but rather bonded together due to the breakdown of oxides on the surface of the metals.

This method does produce heat, but it is far lower than what you would need to join metals together only via temperature, and an advantage of this method is that different types of metal can be bonded together, producing multi-metal parts without the metals intermixing.

Like with other Sheet Lamination printing methods, a cutter is required to cut the 2D cross-section of the 3D printed shape, and with metal parts like this, a CNC router is the most commonly used method. Due to the cutting process, you do get more waste with this method than other metal 3D printing, and the cutter can also be used to produce details and designs as the print is being formed. Post-production finishing is often required, but the high speed of the process and the low temperatures at which metal sheets are bonded give Ultrasonic Consolidation more advantages than disadvantages.

14. Laser Engineered Net Shaping (LENS)

LENS 3D printing happens inside a hermetically sealed chamber, as a metal powder is fed through one or more nozzles and fused specifically via a powerful laser. An object is then built-up layer by layer as the nozzle and laser move around, sometimes in a 3-dimensional manner.

The chamber itself has to be as close to the void of oxygen and moisture as possible to ensure the production of a clean part. For this reason, an inert gas floods the chamber (usually argon) and reduces the amount of oxygen and moisture within it dramatically. Metals commonly used in this process include titanium, stainless steel, aluminium, and copper.

This printing method is often used to repair high-end aerospace and automotive components, such as jet engine blades, but it can also be used to produce entire components. Often, the surface finish of completed parts is not particularly impressive, so a degree of post-production finishing is required in order to deliver a completed component.

15. Electron Beam Additive Manufacturing (EBAM)

With EBAM, we have a pretty similar process to the one described above with LENS, but the main differences between the two are that EBAM uses, unsurprisingly given its name, an electron beam as its energy source and that both powder and wire feedstock can be used.

EBAM is often carried out in a vacuum, reducing the possibility of contaminants tainting the final product and disregarding the need for an inert gas atmosphere, as you'll find with LENS. Layers are built up one by one, with the electron beam creating a melt pool and simply adding the material where its commands tell it to.

Commonly used metals with this procedure include alloys of copper, titanium, cobalt, and nickel, but pure titanium and tantalum are also used. For the most part, an alloy of titanium is the most frequently used material with this printing method, producing parts such as medical implants - such as you' II find in hip replacements.

16. Cold Spray

It could fairly be argued that Cold Spray 3D printing isn't really suitable for falling under the DED banner. It could be argued that it does, though. Instead of using an external energy source such as an electron beam or laser, cold spraying works by the velocity of the molecules of metal alone.

So, it's directed, it has energy, and it deposits, but how it fuses metal together relies on the velocity of the material. Particles of the metal (only powder, in this case) collide with other already expelled particles of the metal and build-up due to the removal of oxygen between the particles, resulting in bonding. In some machines, the particles are expelled by the printer at supersonic speeds.

It might not be surprising to learn that this 3D printing method doesn't produce prints of great surface quality or detail, but the technology doesn't need such high-quality powdered metal to function as other methods do, and there's no need for inert gases or vacuum chambers either.

To finish the prints to a worthwhile standard, often CNC machining is involved, sometimes in connection with the printer, producing a sort of hybrid 3D printer/CNC router. It's a very interesting 3D printing method, best suited to the production of low-cost prototypes.

3. Latest Development of 3D Printing

3.1 Latest development of 3D printing tech: bio, metal, food (astronauts), construction

3D printing requires quality materials that meet specific standards and specifications that satisfy the project to be done. The materials could be in the form of Metals, Polymers, Ceramics, Composites: concrete, Smart materials: food, lunar dust, textile has a vital role to play in what looks set to be the most exciting decade for space exploration since humans first set foot on the Moon. Technology will be pushed beyond today's limits, and we'll see additive manufacturing, including 3D printing, evolve fast to meet growing demands.

The launch systems (rockets), engines, and satellites we send into space are increasingly built using 3D printing and have given rise to the world's largest and most sophisticated additive manufacturing facilities. Once in space, 3D printing has several key roles to play: The "zero-g" environment of space orbit opens doors to print materials not possible under the influence of earthly gravity, parts and spares can be printed on-demand, and structures can be built that wouldn't survive the stresses oflaunch. Even further afield, on the surfaces of the Moon and Mars, structures need to be built using locally sourced materials, and large-scale 3D printing is a key part of that solution, too.

3D printing allows manufacturers to easily modify designs and properties of materials to specifically match a patient's anatomy. In the case of prosthetics, 3D printing produces perfectly fitted devices quickly, while remaining both functional and cost-effective

FDM is a more widely used 3D printing technology for buildings by extruding clay or concrete, 3D printed deserts by extruding chocolate, 3D printed organs by extruding live cells in a bio gel. We may assume that If it can be extruded, it can be 3D printed.

This study will be streamlined to the latest developments of 3D printing technology in Construction.

3.2 An Insight in the Construction Industry

In the construction world, concrete and asphalt can be classified as composite materials are the two main elements used in today's construction. Fresh concrete are freshly mixed material/composites of concrete which are workable and could be molded into any shape. The relative quantities cement, aggregates and water mixed together control the properties of concrete in the wet state as well as in the hardened state. Concrete consists of cement, aggregate and water. Another type of concrete with extra compressive and tensile strength is called Reinforced concrete.

After mixing, transporting, placing and compacting; finishing of concrete can considerably affect the property of hardened concrete. Below are requirements of fresh concrete according to Gambhir (2005);

i. The mix should be able to produce a homogenous fresh concrete from the constituent materials of the batch under the action of the mixing.
ii. The mix should be stable so that segregation will not take place during transportation and placing operations.
iii. The mix should be sufficiently mobile to be placed in the form.
iv. The mix should conform to proper and thorough compaction into dense compactions concrete with minimum void under the existing facilities of compaction at the state.
v. It should be possible to attain a satisfactory surface finish without honey- comb.

The characteristics systems of fresh concrete which affect full compacting are its workability, mobility, and compatibility.

It is often difficult to attain all the properties expected from a mix design in construction, hence there is need to add a lot of "factors of safety" to ensure that the products/projects do not fail. Also, workability and compatibility tends to be a problem sometimes due to time lag. and lots of environmental factors caused by unforeseen circumstances. These factors of safety and irregularities give rise to waste and poor-quality finished products.

The choice of concrete mix design largely depends on the requirements to be met by the project the concrete is to be used for. The determination of the mix ingredients and their proportions is referred to as mix design. The requirements might be for strength, aesthetics all in relation to local legislation and building codes. There is a procedure to determine the proportions for the constituent elements of concrete with certain properties required by the project the design is to be used. Majid(l974) stated that compressive strength is the most convenient property to measure among the properties of concrete.

3.3 Latest developments of 3D Printing Technology in Construction

In the construction industry, 3D printing can be used to create construction components or to 'print' entire buildings. Construction is well-suited to 3D printing as much of the information necessary to create an item will exist because of the design process, and the industry is already experienced in computer aided manufacturing. The recent emergence of building information modelling (BIM: Building Information Modelling is a very broad term that describes the process of creating and managing digital information about a built asset such as a building, bridge, highway or tunnel) in particular may facilitate greater use of 3D printing.

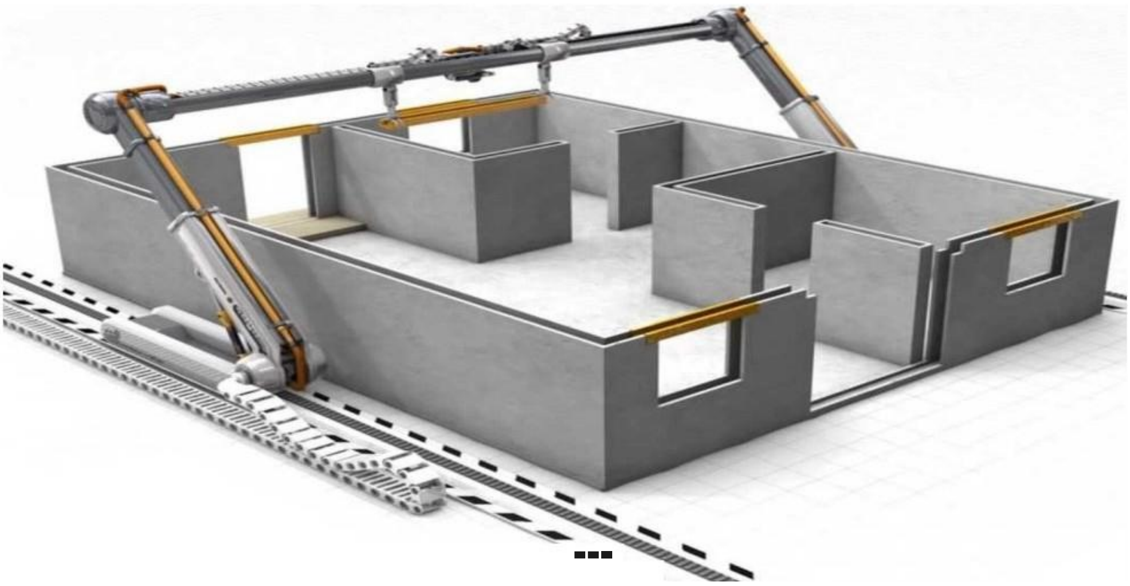


Fig 3.1 Example of a 3D Modelling of a building

Construction with 3D printing may allow, faster and more accurate construction of complex or bespoke items as well as lowering labour costs and producing less waste. It might also enable construction to be undertaken in harsh or dangerous environments not suitable for a human workforce such as in space.

Fid. 3. 3D Printed bridge: In Spain, the first pedestrian bridge printed in 3D in the world (3DBRIDGE) was inaugurated 14th of December of 2016 in the urban park of Castilla-La Mancha in Alcobendas, Madrid.

3.4 Speed & Real-Time Visualization

Printed Architecture is seeing a rapid growth because 3D printing is emerging as a possible solution to some of the challenges currently facing architecture, engineering, and construction (AEC) - it can provide affordable housing, shelters for disaster-hit regions, and an answer to sustainable construction. Alongside these, one of the main advantages is the lower construction costs. It's far easier to calculate the actual volume of construction material required, resulting in less waste. Printed structures are also fabricated much quicker than traditional structures, saving both time and money. Rapid construction speed is a significant benefit and another reason why 3D-printed buildings are on the rise. Californian-based Mighty Buildings, for example, can now print a unit in just 24 hours. Printing at such speed could allow 3D printing to be used to create emergency shelters when needed and help meet the increasing demand for housing.

Fig 3.2 Californian-based Mighty Buildings

3.5 Providing an answer to sustainable architecture

Another advantage that 3D-printed architecture can provide, is a more sustainable way to build. Some specialists are exploring natural and local materials as an alternative to concrete, which comes with a heavy carbon footprint. This is an exciting development for Architecture, Engineering and Construction and of particular interest to architectural firms looking to reduce carbon emissions. Two companies testing alternatives to concrete for 3D printing are WASP and Mario Cucinella Architects. One of their projects, TECLA, has recently been printed m Italy with clay, paving the way for sustainable 3D printing in the future.

Being able to utilize local resources is also important for projects that are literally out of this world. ICON, a US-based developer of advanced construction technologies, is working with NASA to create the first simulated Mars habitat. If or when we support life on Mars, it will be essential to fabricate structures using local materials. 3D construction could be the answer to how we build these structures.

3.6 Aesthetics/Utilizing real-time visualization in Architecture, Engineering, and Construction (AEC)

There are some architectural firms that are already exploring 3D printing, a pioneering method of construction. And some are also making use of revolutionary real-time rendering and visualization technology to elevate their design workflow. When combined, real-time rendering and 3D printing offer architects and stakeholders a fast and efficient way to review desi notions and uickl see them come to life.

These two revolutionary technologies - 3D printing and real-time rendering, provide us with the opportunity to continue advancing both design and architecture. The tools are there to assist professionals to push boundaries and find solutions to today's challenges whilst also preparing for tomorrow. And now is the perfect time to start harnessing them and enjoying the benefits they bring.

4. Conclusion

4.1 The Future with the current trend of 3D Printing technology: in Bio, Metal, Space (Food) and construction

According to a July 2021 report by Grand View Research, the global 3D construction market is set to grow by an incredible 91% between 2021 and 2028. Using 3D printing and multi-material structures in additive manufacturing has allowed for the design and creation of what is called 4D printing. 4D printing is an additive manufacturing process in which the printed object changes shape with time, temperature, or some other type of stimulation. 4D printing allows for the creation of dynamic structures with adjustable shapes, properties or functionality. The smart/stimulus responsive materials that are created using 4D printing can be activated to create calculated responses such as self-assembly, self-repair, multi- functionality, reconfiguration and shape shifting. This allows for customized printing of shape changing and shape-memory materials.

4D printing has the potential to find new applications and uses for materials (plastics, composites, metals, etc.) and will create new alloys and composites that were not viable before. The versatility of this technology and materials can lead to advances in multiple fields of industry, including space, commercial and the medical field. The repeatability, precision, and material range for 4D printing must increase to allow the process to become more practical throughout these industries.

To become a viable industrial production option, there are a couple of challenges that 4D printing must overcome. The challenges of 4D printing include the fact that the microstructures of these printed smart materials must be close to or better than the parts obtained through traditional machining processes. New and customizable materials need to be developed that have the ability to consistently respond to varying external stimuli and change to their desired shape. There is also a need to design new software for the various technique types of 4D printing. The 4D printing software will need to take into consideration the base smart material, printing technique, and structural and geometric requirements of the design.

This Study is streamlined to Latest development of 3D Printing technology in Construction.

4.2 Benefits of latest development of 3D printing technology in construction

In the construction industry the movement is gaining pace and therefore the attention of both the general public and personal sectors. Transparency Market Research predicts that the market size for 3D printing in construction will grow from US$ 29 Mn in 2019 to US$ 280 Mn by 2027.

The Singapore Government - through the Singapore Center for 3D Printing - is investigating the way to build housing project through the utilization of 3D printers while the United Arab Emirates is doubling right down to become a number one player in 3D printing globally. They recently launched a sensible Build ability Index to drive better practices within the 3D construction of buildings and integration of smart components, like connected sensors, for greater functionality and sustainability. Their aim is to use 3D printing technology in 27% of Dubai's buildings by 2030. Considering the competitive nature of the construction industry, 3D printing offers contractors an innovative way to set themselves apart from their competitors.

The construction industry stands to gain in many ways by adopting 3D technology. Here are seven benefits gained by employing a 3D printer in construction projects.

a. Reduced Injury

One of the most important benefits that 3D printers have presented to construction workers may be a reduction in injuries within the field. Considering that building with concrete is difficult---even dangerous-this may be a welcome improvement. Not only do workers have a neater time doing their job, but employers have less worker's compensation paperwork to go through thanks to injuries on the work.

b. Reduced Material Costs

Another improvement may be a considerable reduction of fabric waste. 3D printers use the precise amount of concrete needed for the wall, floor, or whatever it is that you simply want to create. Builders and GCs do not have to order in bulk because they'll know exactly what proportion material they have.

c. Quicker Construction

This is the place solid 3D printers really set themselves apart from conventional development techniques. Where a project may sometimes take weeks-or months-to complete, 3D printers can often finish a project during a matter of hours or days. a whole house was once constructed in 24 hours! this enables contractors to manoeuvre onto other projects sooner and with more orders filled. This means extra money for the contractor.

d. Cheaper Construction Overall,

The utilization of 3D printers' costs less than traditional construction techniques and processes. With the decrease of time, and material cost, organizations will see a sensational increment in their benefits. And while some workers will probably need to be layed off, others will remain, since someone still must be ready to put all of the pieces together. By learning the technology, workers have an opportunity to take care of their job security. They'll earn more, as will the corporate as an entirety.

e. New Markets

Utilizing a 3D printer additionally permits construction organizations to enter into business sectors which may have in any case been blocked off to them previously. And for brand spanking new construction companies, having a 3D printer available could set them aside from companies that are around for a couple of decades and are immune to change. Similarly, traditional and established construction companies could utilize 3D printers to ensure they continue to be relevant within the market. Essentially, 3D printers are often used as a way to enter a replacement market but also to offer an already established company a competitive edge.

f. Better Durability

While testing concrete during the first stages of construction will still be necessary, 3D printers are found to contribute to the sturdiness of the structural elements. this is often due partially to how the materials are made and therefore the manner in which they're assembled. More durable buildings mean fewer repairs have to be made, so construction companies can focus their efforts elsewhere to drive profit. For clients, too, their preferences certainly rest with a building which will last longer.

g. Brand Improvement

Finally, one among the foremost important impacts that the 3D printer has had-and will still have-on the development industry is increased brand awareness. Construction companies are typically thought of to be wasteful and unsustainable. Because it reduces waste, 3D printing is a superb method for a corporation to enhance how they're viewed by those that are concerned about the environmental toll that concrete construction takes on the planet. Contractors that would use a touch help in their branding could had best to acquire and utilize a 3D printer.

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