3D Printing: Technology Innovation, Advancement and Future Scope

Vishal Kumar Jaiswal
M.Tech (Production & Industrial Engineering),
Department of Mechanical Engineering, RKDF University, Bhopal

***Abstract*—** In this paper, we have talked about the technological development related to 3D printing. In which we have explained how 3D printing works and how it will affect our lives in the future. As we all know that 3D printing is going to be involved gradually in our everyday life. Therefore, we must bring new ideas about 3D printing for the benefit of society. As seen, 3D printing makes many of our tasks much easier, and we will be able to use it on a smaller scale, even in our homes in future. As we all know that there are always some flaws in technology in the initial stages. However, we are always on the path of making those techniques best by removing those imperfections. If seen, 3D printing is not a new technology, work has been going on for many years. However, the way we are now seeing the possibility. From this it seems that in future it will be used much more. In the coming time, most everyday items will be able to be made according to their requirement in a short time with the help of 3D printing. This will be a technique and a new way of advancement in technology.

***Keywords*—** 3d printing, technology, innovation, future scope, advancement, application.

1. INTRODUCTION

- Where a normal printer can only print in 2D, a 3D printer is advanced by this and can print three-dimensional things just like a real object.
- With this, you can design the object as you imagine. This ease and accessibility make the 3D printer available to you.
- 3D printing or additive manufacturing is a procedure in which three dimensional solid objects are made from a digital file. Additive processes are used to create a 3D printed object.
- To create an object in this additive process, the material is placed one on top in successive layers until that object is created.
- In this, you can see each of the layers at the end of a thinly sliced horizontal cross-section of the eventual object that you want to create at the end.
- 3D printing is completely the opposite of subtractive manufacturing where an object is gradually cut into small pieces using a milling machine.

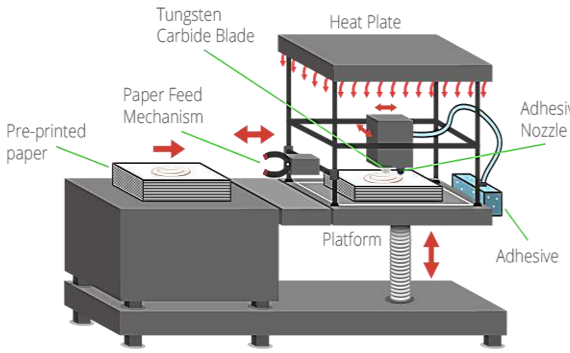

Fig.1: Block diagram of 3D printer.

Image source: https://3dprintingindustry.com

3D printing enables you to prepare very complex (functional) shapes, which is very easy to do with traditional manufacturing methods. Simultaneously, few things are required for this.[1]

HISTORY

If you look at the history of manufacturing itself, subtractive methods are used first. In the empire of the whole machining (in which exact shapes are prepared with high precision) subtractive methods are given more importance, in which filing and turning are predominant by milling and grinding. Additive manufacturing applications have been ranked last in the entire manufacturing spectrum.

For example, rapid prototyping was one of the initial additive alternatives and its mission was to decrease the lead time and price when prototypes of new parts and devices are being advanced, to do this first by subtractive tool room methods (which is were typically slow and expensive).

However, as advancement in technology started, additive methods were used an increasing amount of manufacturing. At one time, where only subtractive methods were used, now profit is being made by using additive methods.

Whereas if we talk about real integration of new additive technologies in commercial production then subtractive methods should be used on a complementing basis with subtractive methods rather than completely erasing them. If talking about the future of commercial manufacturing, then manufacturing firms need all available technologies of flexible, ever-improving users if they want to remain competitive.[2]

LITERATURE REVIEW

[Jee, H. J., and E. Sachs, 2000] The proposed procedure furnishes surface planners with a significant device for collaborations between the virtual and genuine world and understands a manufactural plan with the least cycle by considering the full creation measure rules of 3D printing. The surface is a bizarre strong calculation that can scarcely be acknowledged by the innovation, 3D printing, and planning surface surfaces is troublesome because of the complex large-scale structure of the minuscule surface maths as it must be viable with the non-conventional assembling technique for 3D printing. With the annualised visual re-enactment apparatus proposed in this paper, architects can sort out an approximated visual picture of the actual model in the epitome of surface plan without creating it. It fuses fundamental mathematical credits of actual wonders of the 3D printing measure and consequently furnishes fashioned measures with an important device for confirming the concealed creation capacity of the current prototyping machine. Significant actual printing measure rules of the 3DP machine from 3DP form document, consequently, are considered in making the outwardly re-enacted models. [3]

[CXF Lam, 2002] In this examination, another way to deal with plan and create frameworks for tissue designing utilising three-dimensional printing (3DP) alongside characteristic polymer and water-based fastener was explored. Platforms were portrayed for their physical and synthetic properties. The examination and tests used in this investigation showed that permeable 3D frameworks made by another mix of materials through 3DP were attainable. A bunch of conceivable creation approach and post-processing strategies for a practical and interconnected framework was additionally inferred. Be that as it may, the biocompatibility of the arrangement of materials utilised should be concentrated later on. The highlights and properties of the present permeable platforms have demonstrated that they may be appropriate for tissue-designing applications. Various frameworks plans can be utilised to create platforms with repeatable 3D maths, exceptionally interconnected permeable organisations and reasonable mechanical properties. [4]

[B Leukers, 2005] In synopsis, cells multiplied well on our planned frameworks in static and dynamic development strategies. Besides, the perfusion framework uncovered that the cells developed profound between the HA granules. HA platforms made by 3D printing are reasonable for bone substitution. Inside and out, the discoveries of this introduced investigation are significant for additional use of 3D printed frameworks for bone tissue designing. Our future work will zero in on the osteogenic separation capacity of mesenchymal undifferentiated cells cultivated on frameworks with profoundly interconnecting channels. [5]

[F Rengier, 2010] Rapid prototyping is an emerging technique with various medical applications, such as surgical planning and training, implant design, biomedical research and medical education. Due to its current limitations, rapid prototyping is not used in everyday clinical practise yet. However, for the enormous potential of the technique, the near future promises growing utilisation and development of new applications in the fields of individual patient care, as well as academic and research activities. [6]

[HN Chia, 2015] Extra advancement for 3D Printing innovations is required for expanding goal without relinquishing shape, quality, and taking care of capacity of frameworks. Anatomical highlights and tissue engineering may have subtleties on the size of many microns (e.g., the villi of the small digestive system with ~500 um measurements). Dissemination utilisation demonstrating has indicated a 200 μm limit in platforms for oxygen transport to cells, bringing about a limit of 400 μm measurement highlights for cell endurance. For the two SLS and 3DP, there is a test with making more grounded structures without expanding measurements. To make little highlights, which endure the creation cycle, powder particles much be bound together firmly. By expanding the quality of the laser for SLS or measure of folio for 3DP, extra powder particles would tie and accordingly increment the measurements. Extra work is expected to move SLS and 3DP to goals under 400–500 μm. Additionally, unbound caught powder is difficult to eliminate from little channels. Future work is expected to make a powder that is effectively removable with conventional strategies for high-pressure air. One technique is to make circular powder particles, which would encourage the expulsion in restricted spaces. While SLA can arrive athigh goals, there are a predetermined number of biodegradable, biocompatible gums. Advances have been made to orchestrate new macromers with biodegradable moieties; in any case, these materials have not been FDA endorsed. FDM, SLS, and 3DP can use polymers, for example, PLGA, PLLA, and PCL without substance alteration, which will help facilitate future FDA endorsement for biomedical gadgets. [7]

[X Wang, 2017] Most printing processes are time-consuming now, and it is difficult to fabricate parts that have a large volume. These inhibit their industry adoption. New printing techniques based on scalable and fast processing of materials should be developed. For example, digital light processing is an efficient improvement of SLA process. A layer of photopolymer is fabricated during the one-time projection, which greatly reduces the processing time. Similar improvements should be done for other techniques. Another area of growth centres on the need for feedback systems. If an error occurs during printing now, the process needs to be suspended, which causes the waste of time and materials. Feedback systems should be built in the printer to have a response to the process change. Additional progress for 3D printers is to increase the printing resolution without extending printing time or sacrificing the geometry complexity of products. [8]

[TD Ngo, 2018] In terms of methods, fused deposition modelling (FDM) is a common 3D printing technology because of low-cost, simplicity and high-speed processing. It was originally used for 3D printing of polymer filaments but has been adapted to many other materials. FDM is mainly used for fast prototyping, and the mechanical properties and quality of the printed parts are lower compared to the powder-bed methods such as selective laser sintering (SLS) and selective laser melting (SLM).

Adjacent powders are fused, melted or bonded together by using an auxiliary adhesive in Powder-bed methods, which result in finer resolutions but incur higher costs and are slower processes.

The direct energy deposition (DED) uses a source of energy (laser or electron beam) to melt metal powders, but no powder bed is used compared to SLM and the feedstock is melted before deposition in a layer-by-layer fashion similar to FDM but with an extremely high amount of energy for melting metals. Inkjet printing is quick and is used for 3D printing of ceramic suspensions but requires post-processing heat treatments.

Contour crafting, which relies on the extrusion of materials (concrete), is used to print larger structures such as buildings. Stereolithography is one of the pioneering methods of 3D printing mainly used for photopolymers that can produce parts at a fine resolution. However, it is a slow and complex procedure that is restricted by a limited number of materials. Finally, laminated object manufacturing (LOM) is based on layer-by-layer cutting and lamination of sheets or rolls of materials. [9]

3D MODELING SOFTWARE

3D modeling in 3D computer graphics is called the process by which the mathematical representation of the surface of an object is made in three dimensions by specialized software. The product that is prepared in this is called 3D Model and the people who work on these 3D models are called 3D Artists.

3D modeling software is a class of 3D Computer Graphics Software that is used to create a 3D model. Individual programs in this class are called modeling applications or modelers. 3D modeling software is always made keeping in mind the needs of the user industry. Such as aerospace, transportation, furniture designs, fabrics. Now that we have a 3D model Method, now the next step is to prepare it so that it can be made 3D printable.

WORKING PROCESS

According to the types of 3D printer, 3D printer is working Normal 3D printer which is cheap and easily available in the market.

In their working, I am telling you that the first object we need to make is Auto CAD or any Let's design in 3D modelling software and save this file and import into 3D printer support software.

Or a 3D scanner which scans 3D image of an object and then removes the direct print from that file, we will understand 3D scanner in Detail in upcoming posts. Like CURA Software which is easily available for PC, the print command is given in it.

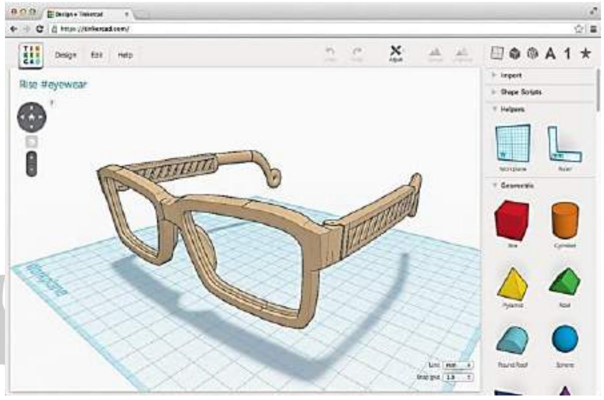

Fig.2: Image of 3D modelling.

Image Source: https://3dprinting.com/

The 3D Printer consists of a Filament that separates different materials such as Carbon fibre 3D Printer filament, ABS 3D Printer Filament, PLA 3D Printer Filament, Wood, Metal etc.

The main role is of this, it is attached to the Filament Drive, the Filament Drive pulls the filament and moves it to the hot end, from which it melts out the material filament and forms the layer of the object on the print board.

Now some Stepper Motors control this Bed and Arms to design it and in some 3D printers move the Hot end in 3 dimension.

These Stepper Motors are controlled with a Micro Computer. We can buy 3D printer from any 3D printer store or Dealer or online you can buy them also.

3D printers are also of large scale that makes big things. It is useful for the production department if you buy a 3D printer. Here further we will learn about all these seven 3D Printing Processes.

1. Vat Photopolymerisation

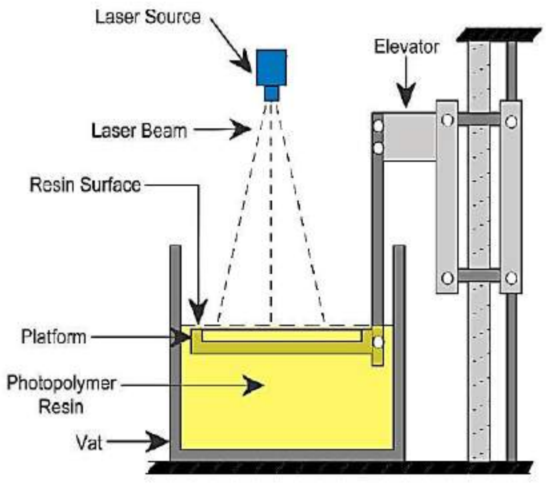

Fig. 3: Diagram of SLD Printing process

Image source: https://www.engineersgarage.com/

A 3D printer is based on the Vat Photopolymerisation method in which a container is filled with photopolymer resin and it is then hardened by a UV light source. [10]

1.1 Stereolithography (SLA)

The most commonly used technology in this is Stereolithography (SLA).

This technology uses a vat of liquid ultraviolet curable photopolymer resin and an ultraviolet laser individually to create layers of the object. For each layer, the laser beam traces a cross-section of that part pattern on the surface of the liquid resin. [11] With the ultraviolet laser light coming into the exposure, it cures and solidifies the pattern, which is traced to the resin and then joins it with the bottom layer. After the pattern has been traced, the SLA's elevator platform descends by a distance equal to the thickness of a single layer, typically 0.05 mm to 0.15 mm (0.002 ″ to 0.006 ″). Then, a resin-filled blade sweep across the cross-section of that part, which then re-coating the fresh material. On this new liquid surface, the subsequent layer pattern is traced, in which it is joined with the previous layer.

Now this three-dimensional object is completely completed and is ready at the end of this project. Stereolithography requires supporting structures that attach to the part of the elevator platform they must serve and hold the object as it floats in a basin that is filled with liquid resin. They must be manually removed when the object is finally finished. Charles Hull invented this technique in 1986 and found a company called 3D Systems at that time.

1.2 Digital Light Processing (DLP)

DLP Digital Light Processing is a method of printing that uses light and photosensitive polymers. [12] Where it is similar to the stereolithography, the key difference they make is their light-source. DLP uses traditional light-sources such as arc lamps. In most forms of DLP, each layer of that desired structure is projected into a liquid resin work in the vat that is then solidified layer by layer, in which the build plate moves up or down.

As such, this process performs every layer successively so that it is the fastest process in most forms of 3D printing. Envision Tec Ultra, MiiCraft High-Resolution 3D printer, and Lunavast XG2 are examples of DLP printers.

Continuous Liquid Interface Production (CLIP)

The newest and fastest process that uses Vat Photopolymerisation is CLIP, which is the full form of continuous liquid interface production. It was invented by a company called carbon.

Carbon launched three industrial 3D printers:

1. Carbon M1
2. Carbon M2 3D Printer
3. Carbon L1

Digital Light Synthesis technology is the heart of the CLIP process. In this technology, light projects from a custom high performance LED light engine to UV images of a sequence, in which it exposes a cross-section, 3D printed part, which partially cures UV curable resin in a precisely controlled way. Oxygen is passed through the oxygen permeable window to create a thin liquid interface between the window of the uncured resin and the printed part called the dead zone. This dead zone is thin, approximately ten of microns. Within this dead zone, oxygen prohibits curing the light of the resin that remains closest to the window, allowing it to continue under the printed part of the continuous flow liquid. UV projected light upward just above the dead zone causes a cascade such as curing of the part.

Printing only does not allow Carbon's hardware to end-use properties in real-world applications.

Once the light has shaped the part, a second programmable curing process achieves that desired mechanical properties by baking only the 3d printed part in a thermal bath or oven.

Programmed thermal curing sets mechanical properties for which it triggers a secondary chemical reaction, which causes the material to be strengthened and finally by achieving the desired final properties. Parts that are printed with Digital Light Synthesis ™ are mostly injection-moulded. Digital Light Synthesis ™ produces consistent and predictable mechanical properties, creating parts that solidify from the inside.

2. Material jetting

In this process, the material is applied in droplets by a small diameter nozzle, which is similar to the working of a common inkjet paper printer, but it is applied layer-by-layer, allowing a platform so that a 3D object can be created and then hardened. [13]

3. Binder Jetting

Binder jetting uses two materials: a powder base material and a liquid binder.

In the build chamber, the powder is first spread in equal layers and then the binder is applied by jet nozzles which "glue" the powder particles into the shape of a programmed 3D object. [14]

Now the finished object is glued together by the binder remains in that container, using the powder base material. Once the print is finished, then the remaining powder is cleaned and used in the next object in 3D printing. This technology was first developed in the Massachusetts Institute of Technology in 1993 and 1995. Z Corporation acquires its exclusive license.

4. Material extrusion

This most commonly used technology in this process is called Fused Deposition Modeling (FDM). [15]

4.1 Fused Deposition Modeling (FDM)

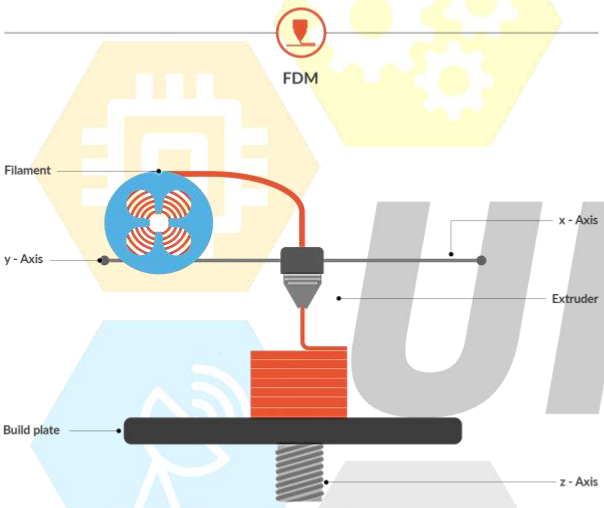

Fig.4 : Diagram of FDM

Image source: https://druckwege.de/

This FDM technology works using a plastic filament or metal wire that is unwound with a coil and the material is supplied to an extrusion nozzle that turns the flow on or off. [16] The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism, which is directly controlled by a computer-aided manufacturing (CAM) software package. through. In this, the object is produced in the form layers of extrude melted material as if the material hardens immediately, as if it is extruse with nozzle. This technology is most commonly used in two plastic 3D printer filament types:

1. ABS (Acrylonitrile Butadiene Styrene) and PLA (Polylactic acid).
2. By the way, there are many other materials available, whose properties range from wood fill to flexible and even conductive materials.
3. FDM was invented by Scott Crump in late 80's. He started a company named Stratasys in 1988 after making it a patent for technology. The term Fused Deposition Modeling and its abbreviation FDM are both trademarked by Stratasys Inc.

4.2 Fused Filament Fabrication (FFF)

Its exactly equivalent term, Fused Filament Fabrication (FFF), was named by members of the RepRap project, who wanted to give it a phrase that would later be used legally unconstrained. That is, it did not face any problem in using it. [17]

By the way, there are many different types of FFF 3D Printer configurations. The most popular arrangements that happen are:

1. Cartesian-XY-Head
2. Cartesian-XZ-Head
3. Delta
4. Core xy

5. Powder Bed Fusion

The most commonly used technology in this is Selective Laser Sintering (SLS).

5. 1 Selective Laser Sintering (SLS)

SLS uses a very high power laser to fuse small particles of plastic, ceramic and glass powders together in a mass that has a desired three-dimensional shape. [18] In this, the laser selectively fuses the powdered material, for which it scans cross-sections (or layers) which are generated by the 3D modelling program in the surface of the powder bed. Once each cross-section is scanned, then the powder bed is lowered to a layer thickness. Then a new layer of material is applied in the top and this process is repeated until the object is completed.

5.2 Direct Metal Laser Sintering (DMLS)

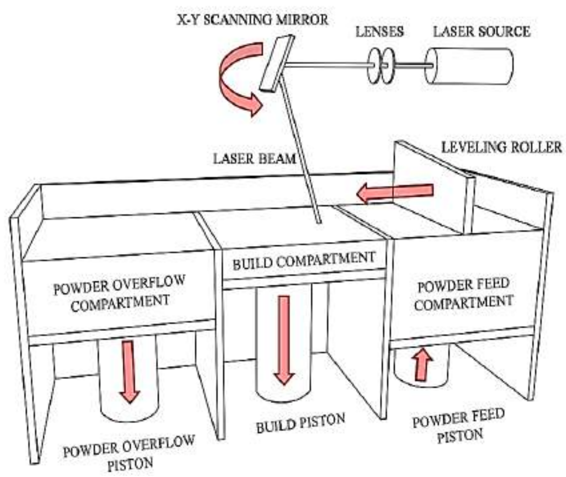

Fig.5: Diagram of DMLS

Image source:https://www.researchgate.net

DMLS is basically the same as SLS, but it uses metal, plastic, ceramic or glass instead. [19] All untouched powder remains in the same way and become a support structure for that object. Therefore, there is no need for any support structure in it, which provides it advantage over SLS and SLA. All unused powder can be used in next print. SLS was developed and patented. They were discovered in the mid-1980s by Carl Deckard, who was from the University of Texas, under the sponsorship of DARPA.

6. Sheet Lamination

In the process of sheet lamination, the material of the sheets is bound together with the help of external force. Sheets can be anything, whether it is metal, paper or a form of polymer.

Metal sheets are weld together in layers with ultrasonic welding and then CNC is milled into a proper shape. Paper sheets can also be used, but they stick to each other due to adhesive glue and they are cut later by precise blades in shape. Mcor Technologies is a leading company in this field.

7. Directed Energy Deposition

Most of this process is used in the high-tech metal industry and also in rapid manufacturing applications. It is often attached to a 3D printing apparatus with a multi-axis robotic arm and a nozzle that deposits metal powder or wire above a surface and an energy source (laser, electron beam or plasma arc) That melts it, as well as a solid object at the end. [20]

LIMITATION IN 3D PRINTING

Like with practically some other cycle there are additionally downsides of 3D printing innovation which ought to be considered prior to selecting to utilize this cycle. [21]

1. Limited Materials

While 3D Printing can make things in a choice of plastics and metals the accessible choice of crude materials isn't comprehensive. This is because of the way that not all metals or plastics can be temperature sufficiently controlled to permit 3D printing. What's more, a significant number of these printable materials can't be reused and not many are food safe.

2. Restricted Build Size

3D printers presently have little print chambers, which limit the size of parts that can be printed. Anything greater should be imprinted in isolated parts and combined after creation. This can expand expenses and time for bigger parts because of the printer expecting to print more parts before difficult work is utilised to consolidate the parts.

3. Post Processing

Albeit huge parts require post-processing, as referenced above, most 3D printed parts need some type of tidying up to eliminate uphold material from the manufacture and to smooth the surface to accomplish the necessary completion. Post-processing strategies utilised incorporate waterjetting, sanded, a synthetic douse and wash, air or warmth drying, get together and others. The measure of post-processing required relies upon factors including the size of the part being delivered, the planned application and the sort of 3D printing innovation utilised for creation. Along these lines, while 3D printing considers the quick creation of parts, the speed of production can be eased back by post-processing.

4. Large Volumes

3D printing is a static cost dissimilar to more traditional procedures like infusion shaping, where enormous volumes might be more practical to create. While the underlying speculation for 3D printing might be lower than other assembling techniques, when scaled up to create huge volumes for large-scale manufacturing, the expense per unit does not diminish as it would be with infusion shaping.

5. Part Structure

With 3D printing (otherwise called Additive Manufacturing) parts are delivered layer-by-layer. Although these layers follow together it likewise implies that they can delaminate under specific anxieties or directions.

This issue is more critical while creating things utilising intertwined statement displaying (FDM), while polyjet and multiset parts likewise will be, in general, be more fragile. In specific cases, it very well might be smarter to use an infusion forming as it makes homogenous parts that will not separate and break.

6. Reduction in Manufacturing Jobs

One more of the weaknesses of 3D innovation is the expected decrease in human work since the vast majority of the creation is computerized and done by printers. Notwithstanding, numerous underdeveloped nations depend on low aptitude tasks to keep their economies running, and this innovation could put these blue-collar positions in danger by removing the requirement for creation abroad.

7. Design Inaccuracies

Another possible issue with 3D printing is legitimately identified with the kind of machine or cycle utilized, with certain printers having lower resiliences, implying that last parts may vary from the first plan. This can be fixed in post-handling, yet it must be viewed as that this will additionally expand the time and cost of creation.

8. Copyright Issues

As 3D printing is getting more well-known and available there is a more noteworthy opportunity for individuals to make phony and fake items and it will nearly be difficult to differentiate. This has obvious issues around copyright just as for quality control.

CONCLUSION

While 3D printing may not be assuming control over the whole assembling industry presently, examiners foresee that there will be a lot of development and the market will be worth 32.78 billion USD by 2023.

3D printing is the following enormous thing since it makes you more proficient. As costs keep on dropping, we will see more in the area receiving it to make their models. Try not to fall behind. The models we make with a 3D printer might be the way to helping customers picture your thoughts.

REFERENCES

[1] Lipson, H. and Kurman, M., 2013. Fabricated: The new world of 3D printing. John Wiley & Sons.

[2] Bradshaw, S., Bowyer, A. and Haufe, P., 2010. The intellectual property implications of low-cost 3D printing. ScriptEd, 7, p.5.

[3] Jee, H.J. and Sachs, E., 2000. A visual simulation technique for 3D printing. Advances in Engineering Software, 31(2), pp.97-106.

[4] Lam, C.X.F., Mo, X.M., Teoh, S.H. and Hutmacher, D.W., 2002. Scaffold development using 3D printing with a starch-based polymer. Materials Science and Engineering: C, 20(1-2), pp.49-56.

[5] Leukers, B., Gülkan, H., Irsen, S.H., Milz, S., Tille, C., Schieker, M. and Seitz, H., 2005. Hydroxyapatite scaffolds for bone tissue engineering made by 3D printing. Journal of Materials Science: Materials in Medicine, 16(12), pp.1121-1124.

[6] Rengier, F., Mehndiratta, A., Von Tengg-Kobligk, H., Zechmann, C.M., Unterhinninghofen, R., Kauczor, H.U. and Giesel, F.L., 2010. 3D printing based on imaging data: review of medical applications. International journal of computer assisted radiology and surgery, 5(4), pp.335-341.

[7] Chia, H.N. and Wu, B.M., 2015. Recent advances in 3D printing of biomaterials. Journal of biological engineering, 9(1), pp.1-14.

[8] Wang, X., Jiang, M., Zhou, Z., Gou, J. and Hui, D., 2017. 3D printing of polymer matrix composites: A review and prospective. Composites Part B: Engineering, 110, pp.442-458.

[9] Ngo, T.D., Kashani, A., Imbalzano, G., Nguyen, K.T. and Hui, D., 2018. Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. Composites Part B: Engineering, 143, pp.172-196.

[10] Gibson, I., Rosen, D. and Stucker, B., 2015. Vat photopolymerization processes. In Additive Manufacturing Technologies (pp. 63-106). Springer, New York, NY.

[11] Wang, J., Goyanes, A., Gaisford, S. and Basit, A.W., 2016. Stereolithographic (SLA) 3D printing of oral modified-release dosage forms. International journal of pharmaceutics, 503(1-2), pp.207-212.

[12] Wagner, T., Werner, C.F., Miyamoto, K.I., Schöning, M.J. and Yoshinobu, T., 2012. Development and characterisation of a compact light-addressable potentiometric sensor (LAPS) based on the digital light processing (DLP) technology for flexible chemical imaging. Sensors and Actuators B: Chemical, 170, pp.34-39.

[13] Yap, Y.L., Wang, C., Sing, S.L., Dikshit, V., Yeong, W.Y. and Wei, J., 2017. Material jetting additive manufacturing: An experimental study using designed metrological benchmarks. Precision engineering, 50, pp.275-285.

[14] Gaytan, S.M., Cadena, M.A., Karim, H., Delfin, D., Lin, Y., Espalin, D., MacDonald, E. and Wicker, R.B., 2015. Fabrication of barium titanate by binder jetting additive manufacturing technology. Ceramics International, 41(5), pp.6610-6619.

[15] Park, S.I., Rosen, D.W., Choi, S.K. and Duty, C.E., 2014. Effective mechanical properties of lattice material fabricated by material extrusion additive manufacturing. Additive Manufacturing, 1, pp.12-23.

[16] Ahn, S.H., Montero, M., Odell, D., Roundy, S. and Wright, P.K., 2002. Anisotropic material properties of fused deposition modeling ABS. Rapid prototyping journal.

[17] Brenken, B., Barocio, E., Favaloro, A., Kunc, V. and Pipes, R.B., 2018. Fused filament fabrication of fiber-reinforced polymers: A review. Additive Manufacturing, 21, pp.1-16.

[18] Johnson, M., 2020. A Review on Selective Laser Sintering. United International Journal for Research & Technology (UIJRT), 2(1), pp.19-21.

[19] Mangano, F., Chambrone, L., Van Noort, R., Miller, C., Hatton, P. and Mangano, C., 2014. Direct metal laser sintering titanium dental implants: a review of the current literature. International journal of biomaterials, 2014.

[20] Duda, T. and Raghavan, L.V., 2016. 3D metal printing technology. IFAC-PapersOnLine, 49(29), pp.103-110.