Role of 3D Printing in Digital Supply Chain

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Abstract

The advent of 3D printing technology has truly transformed the whole world. Owing to the advantages which the technology offers, today it is widely adopted and is used in various sectors such as manufacturing, aerospace, robotics, medical industry and the list just keeps going on. The entire world was taken by storm when scientists unveiled an artificial 3D printed heart which could be implanted in human beings, though at present it is not fully functional however such a discovery creates optimism amongst the people regarding the future of the technology. Medical industry is not the sole area where this technology is surprising people, today small sized yachts are created using 3D printing, and even SpaceX is manufacturing parts of its starship using 3D printing. To some things up 3D printing is a disruptive technology. The use of 3D printing in Logistics and Supply Chain Management is a true game changer that has the potential to change the face of the entire supply chain. There are many 3D printing solutions in the market many of which are being used in Logistics and Supply Chain; however each one of the methods is having its own benefits and limitations. In this paper some of the commonly used 3D printing methods will be explored along with its use case in Logistics and Supply Chain industry.

Keywords: *Fused Deposition Modeling, Thermoplastic Polymers, Stereolithography, Resins, Selective LASER Sintering, Subtractive Manufacturing, Digital Supply Chain*

1. 3 D Printing Techniques

Some of the most commonly used 3D printing methods that are currently deployed in industries are as follows:

1.1. FDM (Fused Deposition Modeling)

Fused Deposition Modeling commonly referred to as FDM is a 3D printing method that is used to make durable objects. FDM printers are the most widely used printer because they are easy to work with and are inexpensive.FDM 3D printing is bottom-up additive manufacturing process where an item is created by depositing the melted thermoplastic layer by layer. To make the objects industry grade plastic and thermoplastic polymers are used. To create the object the design model of the object is created using AutoCAD or similar design software and then the file is converted into a format compatible with the FDM 3D printer like. stl or .obj. The FDM printer takes a spool of thermoplastic polymer material from which the object is made, melts the polymer at its melting points and extrudes it on a bed platform layer by layer to build the object bottom up as depicted in Figure 1 (https://gronkwena.wordpress.com).

The obvious advantage offered by FDM is that the articles made with the help of this technique are very affordable. However, this method comes with its own flaws, 3D printed objects developed using this method have rigid edges because of layering process involved, so objects require finishing touches which is time consuming and adds on to the cost.

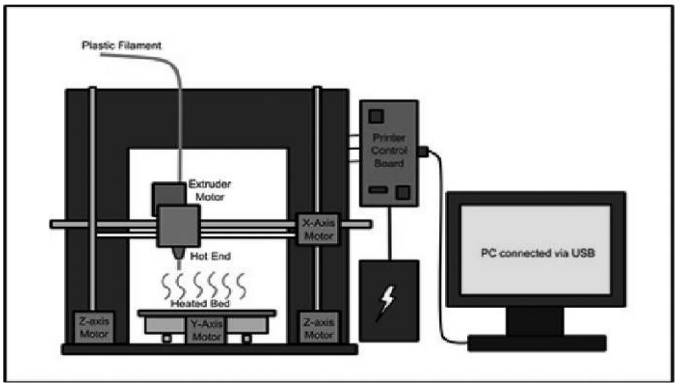

Figure 1: Fused Deposition Modeling

1.2. SLA (Stereo lithography)

Stereo lithography is a form of 3-D printing technology used for creating models, prototypes, patterns in a layer-by-layer fashion using photo polymerization, a process by which light causes chains of molecules to link together, forming polymers (**Dongkeon Lee et.al, 2006**). This method was first explained theoretically in 1970s however it was in 1980s when it was deployed practically to manufacture 3D printed objects. It uses UV light or high-powered LASER to cure liquid resin. The resins used in this method are photosensitive that means these liquid resins have the tendency to harden when exposed to light of certain wavelength. Just like FDM method, the computer modeled design is fed into the SLA machine. In the SLA machine, the resin is dispensed into resin tank from the cartridge and a build platform is lowered into the resin. At the beginning of the process, a beam of LASER is passed into the tank thereby drawing the first layer of print. Each layer is only a few microns thick. Because of the photosensitive nature of the resin, it solidifies when it comes in contact with the LASER. Computer controlled mirrors are used to direct the LASER in accordance to the design coordinates. Once the first layer is made, the build platform is raised, thereby allowing resin liquid to flow in to make further layers. In this way the whole object is made layer by layer from bottom up. A schematic diagram of SLA machine is shown in Figure 2.The object produced using this technique is very precise however it takes more time to produce the article when compared with the time taken to produce the same object using FDM. The other disadvantage of this method is the fact that resins used in this technique are brittle in nature hence the final products are not very durable.

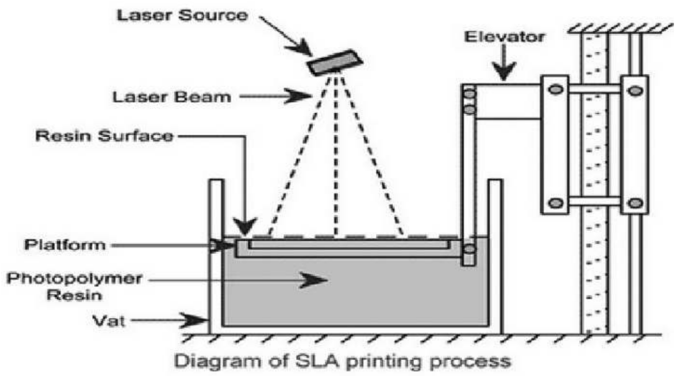

Figure 2: SLA Machine Layouts

Figure 3: SLA Machine

1.3. Selective LASER Sintering (SLS)

Selective LASER Sintering (SLS) is another most commonly used 3D manufacturing technique that turns the object modeled from CAD data into real 3D objects in matter of hours. In this process tiny particles of plastic, ceramic or glass are joined by heat from a high-powered LASER beam to form a solid **(Shiwpursad Jasveer, & XueJianbin, 2018**). These days even Nylon 11 or Nylon 12 are being used as base material. These materials are in their powered form and are placed in a power bed. The CAD data fed into the machine is used to determine the dimensions and coordinates of the object and the LASER beam hits the power bed in accordance to the CAD input file. When this high-powered LASER hits the powered object, the power heats up and solidifies thereby forming the first layer of the object. Once this first layer is made, the power bed is lowered to make room for the next layer and the same process of firing LASER at the power bed is repeated to make further layers. A schematic diagram of SLS process is depicted in Figure 4. SLS 3D printing doesn't require any support material during its manufacturing; hence this method can be deployed to produce complex designs.

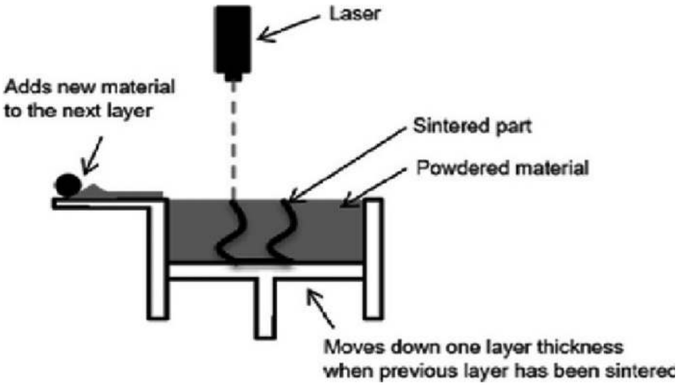

Figure 4: Selective Laser Sintering

3. 3D printing in Logistics and Supply Chain Management

The traditional way of manufacturing articles is a subtractive manufacturing technique, wherein the finished object is made by successively cutting the raw material. The logistics involved in carrying materials carved out using subtractive manufacturing is quite complex and significant cost is incurred by the company to ensure that there is smooth delivery of products in the market or the docking hub or warehouse. Again, to store these materials the industries have to rely on warehouses with large capacities, and these large capacity warehouses cost industries significantly. Apart from the complex logistics, subtractive manufacturing is quite complex process in itself generating huge amount of scrap and waste. The advent of 3D manufacturing which is an additive manufacturing technique has disrupted the way materials are transported and are stored in warehouses. Following are the advantages of 3D printing in Logistics and Supply Chain:

3.1. Decentralized production

3D printing technology is portable in nature. The portable nature of the machinery used in production fosters and promotes decentralization when it comes to manufacturing the commodity. As a result of this there could be an increase in local production hubs, which will not only help in decentralization but will also serve as a catalyst to widen the reach of the commodity far and wide. This local production model is very sustainable and will create tons of job opportunities locally in the area where the component production facility is setup.

3.2. Low carbon footprint during manufacturing

It is no brainer that a huge amount of waste is generated during the production of a commodity. The industrial production waste ranges from e-wastes, scrap, metal, oil, screws, sawdust and the list is a never ending one. Industries and factories in partnership with local government authorities try their level best to recycle the wastes generated, but the problem is the fact that not all the waste generated is recyclable and some wastes generated are toxic in nature which pollutes air, water and soil. The waste generated in 3D printing is negligible and the 3D printing machinery consumes less power than the traditional production machines. This makes 3D printing ecologically safe and sustainable.

3.3. Improves productivity in manufacturing facility

3D printing is faster when compared to traditional manufacturing options. The entire 3D printing process is automated with minimal manual intervention, the worker/product designer just needs to feed the CAD data designed by him/her and feed the raw material and that's it. Because of this automated nature of 3D print manufacturing, the chance of human error is minimal. Workspaces deploying 3D printing are very organized with optimal inventory. All these factors combined together improve the productivity in the manufacturing facility.

3.4. Products manufactured are highly customizable

All companies aim to give their customers a wide variety of products. However, if the industry is manufacturing the product in mass, the degree of customization it is able to offer is little. In contrast to this if the company focuses on customization, it will have some difficulty in mass producing the commodity. Additive manufacturing used in 3D printing unlocks new customizable possibilities because it does not require expensive tooling changes based on individual specifications. This simply means using digital manufacturing methods like 3 D printing opens the door for mass customization. This also helps the consumers because they will be able to buy tailor made products without shelling out extra cash, this is because the entire manufacturing and logistics cost will go down with 3D printing.

3.5. 3D printing significantly reduces the inventory levels

With 3D printing, "built-to-order" model can be implemented with greater ease and flexibility and that could change the dynamics of the entire logistics and supply chain process involved. Today, majority of the industries rely on physical inventories to store the products or parts needed to manufacture the final product like in case of automobile industry. This greatly increases the physical footprint as large facilities are required to store the material. On top of it, industries always have to maintain their inventories in accordance with the demand and market conditions. Any fluctuation in demand of the commodity due to unpredictable nature of human behavior or market fluctuations can put the industry in trouble. This calls for the need to implement digital warehousing wherein new technologies like RFID tags and 3D printing can play a significant role. Industries deploying 3D printing have recorded significantly reduced inventory levels to meet the demands this is because 3D printing is based on "built-to-order" model.

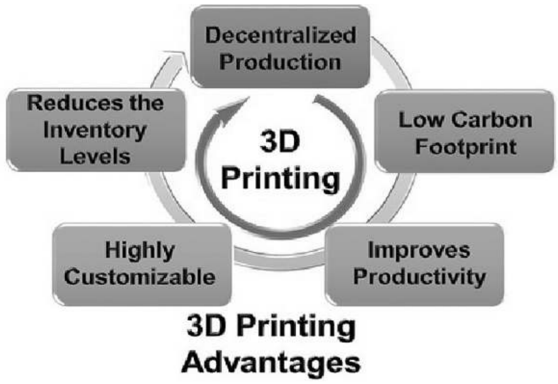

Figure 5: Advantages of 3D Printing

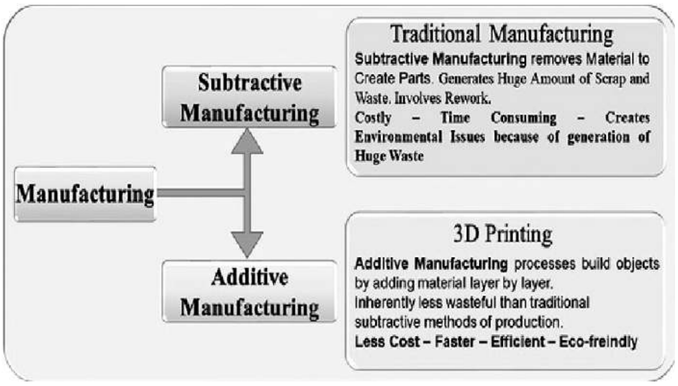

Figure 6: Additive and Subtractive Manufacturing

Though the technology appears to be a game changer it has its share of limitations as well.

Following are some of the limitations of 3D printing:

i. 3D printed objects are made of thermoplastics, resins, metals and few other materials. So, we do not have an extensive list of materials that can be 3D printed to make finished goods. This is one of the serious limitations of 3D printing.

ii. With 3D printing becoming more and more affordable anyone can take a scan of article/object created by someone else or by some other company and can take a 3D print of it. And above all this may happen without the consent of the person/ company that had manufactured the original product. This is a serious violation of copyright and infringement of Intellectual Property (IP).

iii. As of today, the technology is not fully evolved to create complex materials at a reasonable price.

iv. 3D printed materials have a serious size constrain. As an example, FDM which is the cheapest of all 3D printing technologies can only create medium sized objects and it struggles to create small objects with precision. The same goes with SLS which can produce small sized objects with greater accuracy but is time consuming when creating large sized commercial objects thereby making it infeasible in certain manufacturing techniques.

3D printing is gaining significant ground and the limitations posed by the technology should not refrain industries from adopting it as scientists and tech companies are trying out their level best to iron out the flaws of 3D printing.

4. Conclusion

Encouraged by the possibilities of greater personalization, distributed manufacturing and delivery model and less waste generation, more and more businesses across the globe are showing interest towards 3D printing model of manufacturing. This new age digital model has reduced the time and cost of production significantly. This technology also helps in decentralizing the production hubs wherein parts of the same object/material can be manufactured in different places and later on can be assembled. This also helps to drive product customization which is a key for the manufacturers to attract consumers. In terms of inventory and logistics, the objects can be printed on demand that means there is no need to have finished products stacked on shelves or stacked in warehouses (Kubáè, Lukáš & Kodym, Oldøich, 2017). To wrap things in a nutshell, it could be easily said that the 3D printing technology is improving by leaps and bounds and what we are seeing today is just the tip of the iceberg. The technology is also increasingly gaining recognition. It's only a matter of time when majority of the stakeholders in Logistics and Supply Chain Management will adopt the technology and that could benefit both the production houses and the consumers alike.

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