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Review on Advent of Additive Manufacturing

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Abstract: Additive manufacturing is the industrial production name for 3D printing, a computer controlled process that creates 3D objects by depositing materials usually in layers. Using computer aided design (CAD) or 3D object scanners, additive manufacturing allows for the creation of objects with precise geometric shapes. Additive manufacturing processes take the information from a computer-aided design (CAD) file that is later converted to a stereo lithography (STL) file. These are built layer by layer which is in contrast to traditional manufacturing that often requires machining or other techniques to remove surplus material. Additive manufacturing has introduced a novel method in design, manufacturing, and distribution to end to end users. This technology has provided great freedom in design for creating complex components, highly customizable products and efficient waste minimization. This paper mainly concentrates on raising the importance of additive manufacturing and how additive manufacturing has advantages over conventional manufacturing process. Additive manufacturing has revolutionized the production industry by providing Freedom of design; less wastage of raw material, the desired product can be manufactured by adding materials of desired properties. The additive manufacturing includes VAT polymerization, powder sintering, hybrid, 3D printing, metal extrusion, Sheet lamination, metal jetting, Direct energy deposition..

Keywords -additive manufacturing, revolutionized in freedom of design, flexibility, feasibility, efficient waste minimization, Sheet lamination, metal jetting, 3D printing, Hybrid, powder sintering, VAT polymerization, direct energy deposition.

I. Introduction

ASTM has defined additive manufacturing (AM) as "a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. This definition is broadly applicable to all classes of materials including metals, ceramics, polymers, composites, and biological systems. While AM has been around as a means of processing materials for, arguably, over two decades, it has only recently begun to emerge as an important commercial manufacturing technology. Additive manufacturing has enabled the designers to increase strength to weight ratio, ductility by adding better raw material.3D printing has enabled to visualize the 3D objects easily. It has established a good understanding level between a designer and a manufacturer. Few years ago there was lot of problems in understanding the design to the manufacturing for the industry to function, for example if the architect has drawn a 2D model for the civil engineer there were chances that the engineer would misunderstand in which plane what comes. 3D printing has resolved that issue. Many products which have complex symmetry within the structure cannot be manufactured by drilling, Milling, boring or any other operations. This paper mainly concentrates on raising the importance of additive manufacturing over traditional manufacturing. Additive manufacturing (AM) is one of the fastest growing and most promising manufacturing technologies, offering significant advantages over conventional manufacturing processes. That is, the geometrical flexibility that leads to increased design freedom is not infinite as the numerous AM processes impose manufacturing limitations. Abiding by these manufacturability rules implies a back propagation of AM knowledge to all design phases for a successful build. A catholic AM-driven design framework is needed to ensure full exploitation of the AM design capabilities. The current framework is based on the definition of the CAD aspects and the AM process parameters. Their dependence, affection to the resulted part, and weight on the total process determines the outcome. The AM-driven design framework prevents manufacturing issues of certain geometries, which can be effortlessly created by conventional manufacturing, and additionally exploits the full design-freedom potentials AM has to offer with a linear design flow reducing design iterations and ultimately achieving first time right AM design process. The electronic components produced with additive manufacturing include sensor arrays RF antennas and amplifiers, multilayer cable assemblies. Also products produced from additive manufacturing have easy maintenance, replacement. The continuous and increasing growth experienced since the early days and the successful results up to the present time allow for optimism that additive manufacturing has a significant place in the future of manufacturing.

THE SEVEN FAMILIES OF ADDITIVE MANUFACTURING:

I. POLYMERIZATION:

- VAT POLYMERIZATION:

Vat polymerization uses a vat of liquid photopolymer resin, out of which the model is constructed layer by layer. An ultraviolet (UV) light is used to cure or harden the resin where required whilst a platform moves the object being made downwards after each new layer is cured. As the process uses liquid to form objects, there is no structural support from the material during the build phase unlike powder based methods where support is given from the unbound material. In this case, support structures will often need to be added.
Resins are cured using a process of photo polymerization (Gibson et al., 2010) or UV light, where the light is directed across the surface of the resin with the use of motor controlled mirrors (Grenada, 2009). Where the resin comes in contact with the light it cures or hardens.

- PHOTO POLYMERIZATION*:*

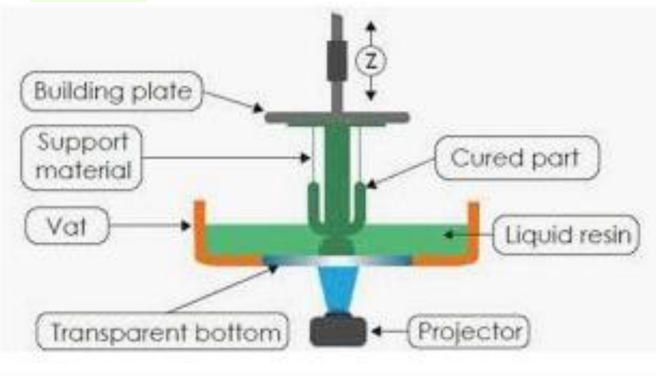
1. The build platform is lowered from the top of the resin vat downwards by the layer thickness.
2. A UV light cures the resin layer by layer. The platform continues to move downwards and additional layers are built on top of the previous.
3. Some machines use a blade which moves between layers in order to provide a smooth resin base to build the next layer on.
4. After completion, the vat is drained of resin and the object is removed.

- POWER SINTERING:

Powder sintering is the process of compacting and forming a solid mass of material by heat or pressure without melting it to the point of liquefaction. Sintering happens naturally in mineral deposits or as a manufacturing process used with metals, ceramics, plastics, and other materials. It is performed in order to provide structural integrity and strength in a work material. The temperature of the powder sintering is kept below the melting point of the major constituent of the powder metallurgy. Before performing powder sintering there are certain precursor to be done they are

1. Removal of the pressing lubricant by evaporation and burning of the vapors
2. Reduction of the surface oxides from the powder particles in the compact

In case of VAT Polymerization, it is exposed to light which initiates and converts the exposed areas into solid part, when light is induced to the material it imparts properties such as toughness stiffness etc. VAT Polymerization has more accuracy and smooth surface finish when compared to powder bed fusion. Additive manufacturing has been performed in various methods as materials possess different properties for example UV Curable photopolymer resins strengthen when it is exposed to light where as plastics ceramic materials are melted and then exposed to light. 3D printer works on adding materials which are available in the form of liquid at room temperature for example 3D printing of iron cannot be performed as it is not a liquid at room temperature in that case powder metallurgy is adopted. Hence there are different types of additive manufacturing depending upon the type of raw material selected for manufacturing process. In case of VAT Polymerization it is exposed to light which initiates and converts the exposed areas into solid part when light is induced to the material it imparts properties such as toughness stiffness etc. VAT Polymerization has more accuracy and smooth surface finish when compared to powder bed fusion. Additive manufacturing has been performed in various methods as materials possess different properties for example UV Curable photopolymer resins strengthen when it is exposed to light where as plastics ceramic materials are melted and then exposed to light. 3D printer works on adding materials which are available in the form of liquid at room temperature for example 3D printing of iron cannot be performed as it is not a liquid at room temperature in that case powder metallurgy is adopted. Hence there are different types of additive manufacturing depending upon the type of raw material selected for manufacturing process.



VAT POLYMERIZATION

II. Powder Bed Fusion:

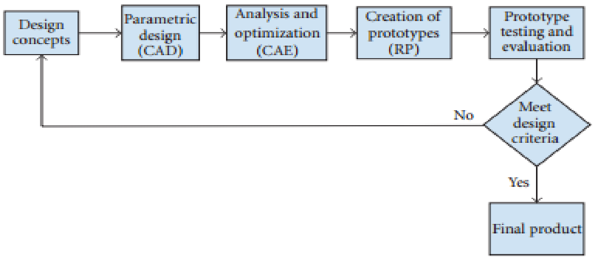
Powder bed fusion is also known as SLS–Selective Laser Sintering Misdirect Metal Laser Sintering SLM- Selective Laser Melting EBM- Electron Beam Melting.
1) Powdered materials is selectively consolidated by melting it together using a heat source such as a laser or electron beam. High level of complexity powder acts as a supporting material wide range of materials can be manufactured.
a)Binder Jetting - Liquid bonding agents are selectively applied onto thin layers of powdered material to built up parts layer by layer. The binders include the organic and inorganic materials. Metal or ceramic powdered parts are typically fired in furnace.
b) Material Jetting-It is also known as poly jet SCP- smooth curvatures printing MJM Multi jet- jet modeling. Droplets of material are

deposited layer by layer to make parts. Common varieties include jetting a procurable resin and curing it with UV light , as well as jetting thermally molten materials that solidify in ambient temperatures.

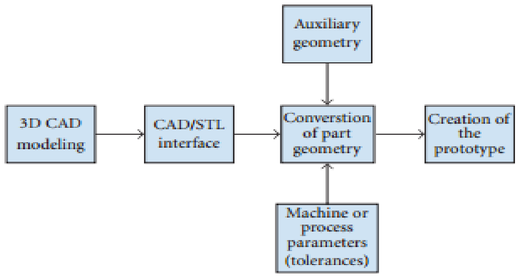
Powder bed fusion

RAPID PROTOTYPING

Rapid prototyping is the fast prototyping techniques to create prototype models. The testing of a fully developed prototype can be effectively carried using rapid prototyping. Doctors can build a model of a damaged body to analyze it and plan better the procedure, market researchers can see what people think of a particular new product, and rapid prototyping makes it easier for artists to explore their creativity. The steps involved in product development using rapid prototyping are shown in Figure 1. Here, it can be seen that creating models faster save a lot of time and there is the possibility of testing more models



Product development cycle using rapid prototype



Data flow in rapid prototyping

Product development cycle starts with design of concepts , create a parametric design using cad tools, analysis and optimization, creation of prototypes, prototype testing and evaluation is done, if it meets the design criteria the product is accepted else the product is rejected.

Data flow in rapid prototyping

The 3D CAD modeling is the first process of creation of drawing to the prototype. In interface it is tested verified if the dimensions are correct. Then there is conversion of part geometry and then the there is creation of prototype.

Stereo lithography

It was the first and most widely used rapid prototyping.

The basic principle of this process is the photo polymerization, which is the process where a liquid monomer or a polymer converts into a solidified polymer by applying ultraviolet light which acts as a catalyst for the reactions; this process is also called ultraviolet curing This is a liquid-based process that consists in the curing or solidification of a photosensitive polymer when an ultraviolet laser makes contact with the resin. The process starts with a model in a CAD software and then it is translated to a STL file in which the pieces are “cut in slices” containing the information for each layer. The thickness of each layer as well as the resolution depend on the equipment used. It is also possible to have powders suspended in the liquid like ceramics.

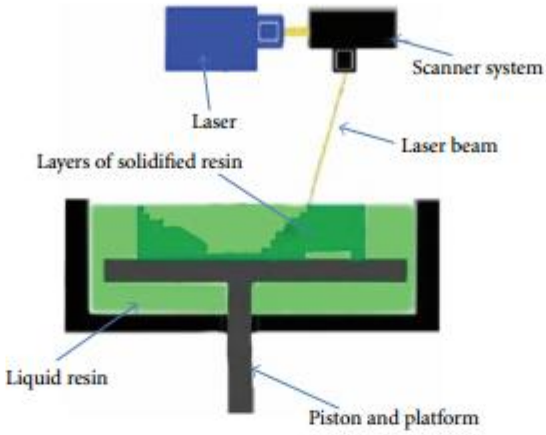
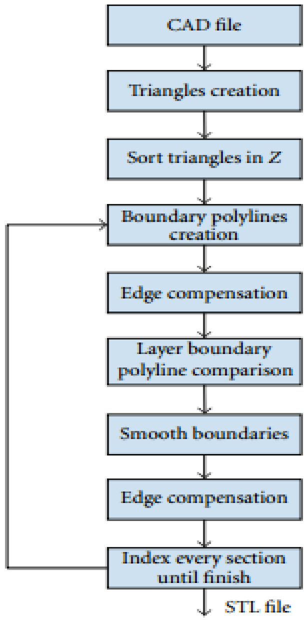
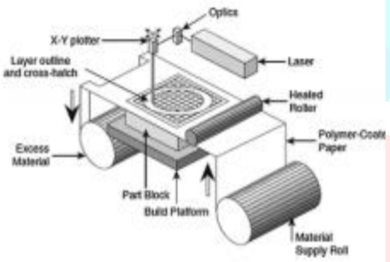


FIGURE 5: Stereolithography.

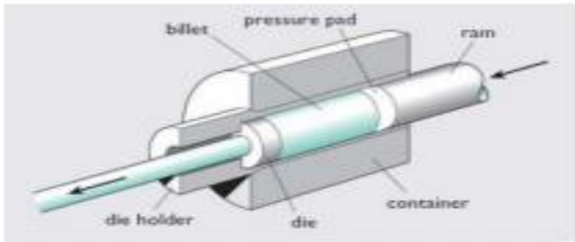


Data flow in stereo lithography

Sheet lamination- It is also known as LOM – laminated Object Manufacture SDL Selective Deposition Lamination UAM-Ultrasonic. Additive Manufacturing Sheets of material are stacked and laminated together to form an object. It contains material supply oil layer outline material where polymer is drawn into thin sheets. Unneeded regions are cut out layer by layer and removed after the object is built.



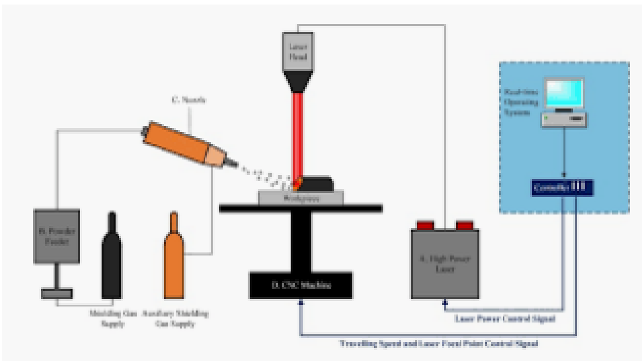
SHEET LAMINATION



METAL EXTRUSION

METAL EXTRUSION-Material is extruded through a nozzle or orifice in tracks or beads, which are then combined into multi-layer models. Common varieties include heated thermoplastic extrusion (similar to a hot glue gun) and syringe dispensing. It is in expensive and parts having good mechanical properties are manufactured.

DIRECT ENERGY DEPOSTION- It is also known as LMD - Laser Metal Deposition LENS- Laser Engineered Net Shaping DMD-Direct Metal Deposition (DM3D) LENS – Laser Engineered Net Shaping DMD – Direct Metal Deposition .Powder or wire is fed into a melt pool which has been generated on the surface of the part where it adheres to the underlying part or layers by using an energy source such as a laser or electron beam. This is essentially a form of automated build-up welding.



DIRECT ENERGY DEPOSITION

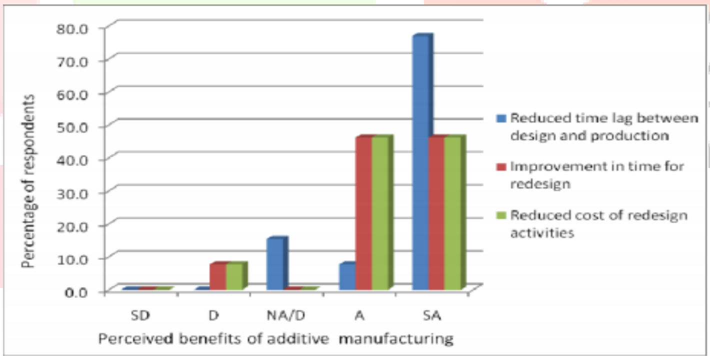
HYBRID

Description: Laser metal deposition (a form of DED) is combined with CNC machining, which allows additive manufacturing and 'subtractive' machining to be performed in a single machine so that parts can utilize the strengths of both processes. The seven families of additive manufacturing has been equipped to manufacture the different kinds of product having different properties for example plastics can be printed as it is liquid at room temperature and in case of iron the powder bed fusion is equipped as iron cannot be maintained as liquid at room temperature.

HYBRID

ADVANTAGES

This freedom to design and innovate on the fly without penalties yields significant rewards: compressed production schedules, better quality products, more product designs and in the end, more products which means more revenue for you. While additive manufacturing does rely on electricity, a relatively small amount is required to produce parts especially when compared to more traditional manufacturing. Additionally, there is also very little waste as only the needed materials are used and the plastics are entirely recyclable. Additive manufacturing is also effective in the light-weighting of vehicles and aircraft, which is an important factor in mitigating harmful fuel emissions. In fact, components produced using additive manufacturing processes allow manufacturing engineers to build solid parts with a semi-hollow honeycomb interior. These parts have an excellent strength to weight ratio that is the equivalent to ratio of a solid part. The main difference, however, is that these components can be as much as 60 percent lighter than traditional, subtractive manufacturing methods, which have tremendous impact on fuel costs of the final product. The additive manufacturing has enabled the design and development of 3D printing to 4D printing where the components change their shape accordingly to external stimuli such as light wind temperature. The 4D printing has the capability to self repair self assembly. Consumer Products -For designers, graphic artists and marketing teams, the time it takes to form an idea and deliver it to the market is everything. Part of that time is simulating the look and feel of the final product during design reviews to prove ideas to key stakeholders. Consumer product manufacturers have embraced 3D printing to help develop iterations and quickly adjust design. 3D printing is great for producing detailed consumer electronics early in the product development life cycle with realistic aesthetics and functionality. Sporting goods have benefited from early iterations delivered quickly and with fine details. Other successful applications include entertainment props and costumes, lightweight models and sets, and finely detailed architectural models. As 3D printing technology advances in speed and build volume, more consumer products may turn to additive manufacturing for their large volume demand. The adoption of additive manufacturing has impacts on a business through the requirement for additional resources and staffing/training as well as value creation through improved turnaround times and positive changes in business-to-business interactions.



Materials used in additive manufacturing

There are a variety of materials used for AM, these include bio chemicals, ceramics, metals and thermoplastics. Bio chemicals Bio chemicals used in AM include silicon, calcium phosphate and zinc while bio-inks fabricated from stem cells are also being explored. These materials are generally used for healthcare applications. Ceramics A range of ceramics are used in AM, including alumina, tri calcium phosphate and zircon as well as powdered glass which can be baked together with adhesives to create new types of glass product. Metals A wide variety of metals and metal alloys are used for additive manufacturing, including gold and silver, stainless steels and titanium amongst others. Thermoplastics Thermoplastic polymers are the most commonly used of AM materials and include a variety of types with their own advantages and applications. These include acryl nitrile butadiene styrene (ABS), poly lactic acid (PLA) and polycarbonate (PC) as well as water-soluble polyvinyl alcohol (PVA) which can provide temporary support before being dissolved.

INDUSTRIAL APPLICATIONS OF ADDITIVE MANUFACTURING

1*)* AEROSPACE -Aerospace industry has been using additive manufacturing in production of tanks in UAV ,aircrafts to provide high performance less strength to push forward the innovative design and applications for the world of flight. It has helped to demonstrate the new innovations by helping us to create prototypes. Jet engine, fuel turbo pump valves parts are developed by NASA and GE BY 3D printing technology. Lockheed Martin has printed fuel tank model with 3D printing technology.

2) **MEDICAL-**The artificial bones, kidneys fingers the outer layer of the ear are manufactured by additive manufacturing by precise dimensions and they are successfully equipped to physically disordered human beings. The significant contribution of additive manufacturing in medical field.

1) Improve the strength of impacts of organs.
2) Producing light weight implants of organs.

3) Reconstruction of skull/nose.
4) Reduction of operating time in plastic surgery.
5) Reconstructive surgery and aesthetic surgery.

Medical Implants manufactured by additive manufacturing

3) **Consumer Products** -For designers, graphic artists and marketing teams, the time it takes to form an idea and deliver it to the market is everything. Part of that time is simulating the look and feel of the final product during design reviews to prove ideas to key stakeholders. Consumer product manufacturers have embraced 3D printing to help develop iterations and quickly adjust design. 3D printing is great for producing detailed consumer electronics early in the product development life cycle with realistic aesthetics and functionality. Sporting goods have benefited from early iterations delivered quickly and with fine details. Other successful applications include entertainment props and costumes, lightweight models and sets, and finely detailed architectural models. As 3D printing technology advances in speed and build volume, more consumer products may turn to additive manufacturing for their large volume demands.

Recent advancements in additive manufacturing

1) The evolution from 3D printing to 4D printing which has helped in manufacturing self repairing pipes , helped in manufacturing of self adapting buildings to changes in the surroundings like humidity, temperature.
2) NASA has launched the mini satellite named Kalam sat which will measure radiation in space, it is made of nylon.

Kalam sat

3D printed shell

6) Future satellites are going to be manufactured by 3D printing to save cost of production and crucial weight.
7) General Electric is producing a fuel nozzle for an aircraft engine mini satellite Using 3D printing
8) Tortoise lost its shell during Amazon forest fire humans were able to give an artificial shell by 3D.

9) [9] Tieta had broke her beak humans could replace it by 3D printing.

3D printed beak

STEM CELLS

10) Artificial leg to human being was able to human by 3D printing technology which has high strength and durability.
11) Stem cells produced 3D printing technology artificial leg.
12).Bones cartilage blood vessels and skin have all been successfully created with the technology of additive engineering, thanks to the ultra-fine layers used during the process, each one just a fraction of a millimeter thick.

CONCLUSIONS AND FUTURE SCOPE

In this paper article is discussed the early versions of Additive Manufacturing for making fast prototypes that was initiated by the necessity of speeding the process in model development and shortening the time between product development and market placement.
Automotive- Low volume spares and tooling; new product testing and trialing; spare parts; rapid production of replacement parts for repair shops as well as rapid prototype.
Specialist consumer products -Ability to make unique design apparel without tooling costs; jewellery; many applications some of which are already here: mobile phone cases; shoes and glasses etc.
Tools for assembly purposes Ease of manufacture of tooling without setup costs of traditional manufacturing methods Other Consumer customized products; applications in every industry not just manufacturing

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