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A COMPREHENSIVE REVIEW OF ADDITIVE MANUFACTURING PROCESS

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Abstract

Additive Manufacturing (AM) processes (1) Fused deposition modeling (FDM) (2) Stereo lithography (SLA) (3) Selective laser sintering /melting (SLM) (4) Laminated object Manufacturing (LOM) (5) Inkjet printing facilitate the manufacturing of arbitrary Three dimensional – configuration with exceptional degrees of freedom. Research and development is promptly advancing in this vicinity. Several divisions/sectors are now taking benefit from additive manufacturing to fabricate complex structures and attain the desired purpose for instance enhanced property of material, strength-to-weight ratio, increased utilized products, among others. Additive manufacturing (AM) satisfying demands with low cost and production time. In addition, defects are formed by sudden heating and cooling within additive manufactured components. A several studies have been developed treatments to recover it. Additive manufactured products by metal and their alloy, polymers and ceramics have under study to recognize their functions. In this comprehensive review paper highlights some key topics such as common methods; materials used applications and challenges which are crucial and more attentive. It is a comprehensive review for the purpose of maintaining the inter-relation between the assorted features. It is also demonstrated reliability of attained industrial products and applications.

Keywords: Additive Manufacturing, Materials, Applications and Challenges

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1. Introduction

Additive Manufacturing (AM) process is used for manufacturing complex geometries in 3D form. By using CAD model as input data. In 1986 Charles Hull was invented stereo lithography (SLA), which was useful for further development in additive manufacturing such as powder bed fusion / selective laser sintering (SLS), fused deposition modeling (FDM) and inkjet printing. Carl R. Deckard invented selective laser sintering process in 1989s. In the beginning of three dimensional (3D) printing has been widely used by architects and designers to produce artistic and serviceable prototypes due to its rapid and cost effective prototyping capability. Now a day's 3D printing has fewer applications. It is a consequences of additional expenses incurred in the process of developing a product. Nonetheless, past few years that additive manufacturing (3D printing) has been utilized in various industries from prototypes to products. Product alteration has been confronting for fabricators due to the production costs for the end users. In contrast, additive manufacturing is very useful for producing small quantities of customized three dimensional print products with low cost. It has several advantages over traditional manufacturing shown in fig.1. It is used to fabricate complex geometry without using tool [1]. Additive manufacturing is truly integrated layer-by-layer additive/subtractive process under development with few limitations. Furthermore, some difficult technologies have been developed to produce complex and freeform solid objects which are directly import from computer models (CAD) without part and specific tooling are in progress; these are often labeled "solid freeform fabrication" (SFF) technologies. Solid free form fabrication (SFF) has permitted for the design and production of complex 3D structures. The integration of computer aided design advanced imaging techniques i.e. magnetic resonance imaging and computer tomography [2]. 3D models can be created by 3D CAD software or obtained through CT scan or MRI, and then it is converted to a Standard Triangulation Language (.STL) file [3]. Subsequently, a software package slices the CAD model in the formation of 2D series which is, in number of thin 0.1mm thick cross-sectional layers, creating a computer file thereafter it shows the route to the printer for tracing [4]. As shown in fig.1. It is also known as rapid prototyping (RP) [5]. The four RP techniques are available and mentioned as follow: (a) Fused deposition modeling (FDM), (b) inkjet printing, (c) stereo Lithography (SLA) and (d) selective laser sintering (SLS)/Powder bed fusion. As shown in fig.3. Following are the common parameters for instance layer height; infill orientation, infill density, and extruder temperature (TE) are affected on quality of product. Popescu .D.et.al [6] reviewed rapid prototyping and selective laser sintering process are very useful for development of new composite materials from the different materials such as polymers, ceramics, metal alloys. Additive manufacturing (3D printing) is applicable in medical field to satisfy patients demand Frazier.W. [7] reviewed rapid prototype is solid free form process on functionally graded material which is class of advanced material as well orthopedic applications. Sharma .S.et.al.[8],F.Melchels .et.al. [9] and Coon.C.et.al. [10] Presented framework of stereo lithography to develop heterogeneous object as well as studied application of rapid prototyping in the development of biomaterials, and their challenges. Peltola .S.et.al.[11] and Ngo.T. [12] investigated rapid prototyping process which has potential to manufacture humerus bone, as well as discussed implants, tissue engineering, prosthesis and other cases in medical field. Also reviewed many applications of additive manufacturing (3D printing) such as , fused deposition modeling, organ printing, rapid prototyping, scaffold fabrication, selective laser sintering, stereo lithography, tissue engineering, two-photon polymerization like CAD based tissue engineering, CAD based anatomical modeling, implantation and prototype modeling assisted surgical planning etc. Hence the above survey suggested that, additive manufacturing is a very challenging and broad research area for the researchers now a day. Hence, objective of this paper is to contribute for the same as well as discussed some fundamental points in terms of common methods, materials, applications and challenges in brief.

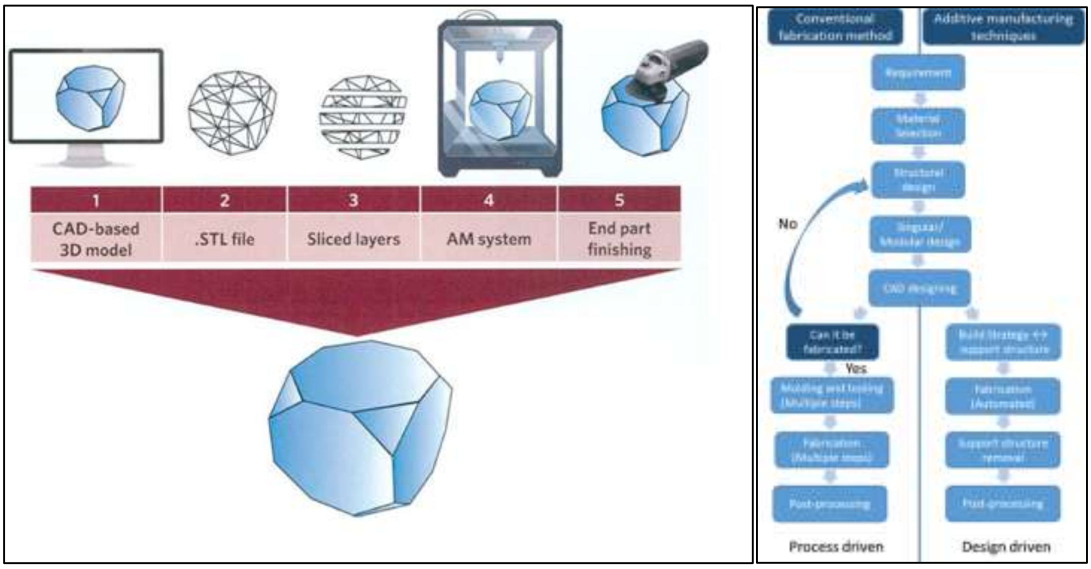


Fig.1.The Additive Manufacturing process flow and comparison between conventional / Additive manufacturing (Courtesy Dizon.J.et.al. [14])

2. Common Methods

Additive manufacturing (AM) or (3D printing) has been accepted as producing defect free complex geometries with excellent resolutions. The common methods of additive manufacturing (3D printing) is fused deposition modeling (FDM), stereo lithography for polymer powders and photopolymers, selective laser sintering (SLS), selective laser melting (SLM) or liquid binding for metal powders, as well as inkjet printing for inks, laminated object manufacturing (LOM) for paper or foil. Following are commonly used methods are explained in comprehensive form.

2.1 Fused Deposition Modeling

Fused Deposition Modeling FDM (shown in fig.2. (a)) was invented in the 1980s by Scott Crump and commercially introduced in 1990. In Fused Deposition Modeling (FDM) process, the feedstock material is heated till the semi-liquid state. Tip of nozzle extrude material in semi-liquid form, nozzle moves in XYZ direction to create 3D object in layer by layer fashion from a digital data to solid object [12]. Several attempts have been made to optimize the process parameters of fused deposition model for good quality product. Mohamed.O.et.al. [13] investigated and optimized following process parameters for instance (1) layer thickness (2) air gap (3) raster angle (4) build orientation and (5) road width. As shown in fig.2

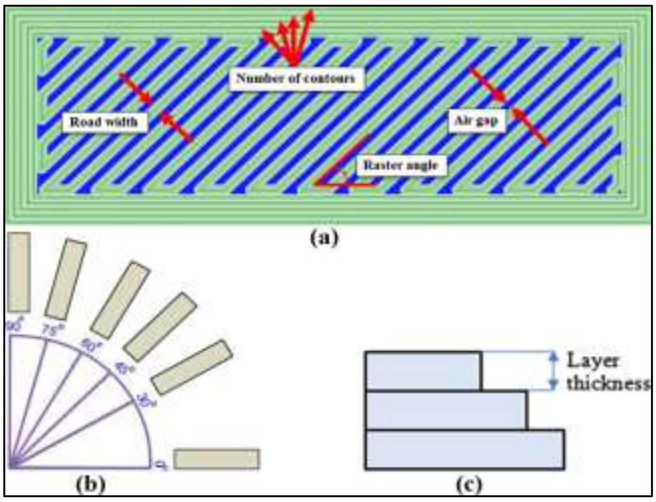


Fig.2. (a) Tool path (b) build orientation (c) layer thickness (Courtesy Mohamed.O.et.al.[13])

Studied I-optimum design and ANOVA analysis tool to establish relation between process parameters and dimensional accuracy. Panda.S.et.al. [14] claimed it is difficult task to establish functional relationship between above mentioned five process parameters and dimensional accuracy, surface roughness combined with strength such as tensile, flexural and impact. Afterwards, result has been validated by analysis of variance (ANOVA) tool. It is claimed higher temperature is responsible for higher strength due to diffusion bonding between adjacent layers. Results shown among five process parameters, air gap, and model temperature with raster orientation have greatest effect on the strength of (FDM) fused deposition component, whereas bead width and color have little effect. Similarly, equal results obtained by Chennakesava .P.et.al. [15] while studying optimization of process parameters of fused deposition modeling. To optimize build (process) time (time required to develop actual part on FDM platform) and material consumption without compromising the dynamic mechanical properties. Build parameters includes orientation, layer thickness, air gap and bond formation with infill temperature are most effective parameters on quality of the product. But on the other hand raster angle and road width are less effective parameters. Due to complex nature of (FDM) fused deposition modeling is very slow process and conflict the said process parameters. Griffiths.C.et.al. [16] Found infill level and layers are responsible for improvement of tensile strength. It is attained by application of design of experiments. Also suggested optimized process parameters had significant effect on mechanical properties such as tensile, flexural and impact test of printed components. Minimum thickness layers and less air gap reduce loss of heat. In particular, temperature plays a significant and efficient role in diffusion and bonding among layers. It improves tensile and flexural strength successfully; but maximum layer thickness enhances impact strength. Additionally, one more attempt has been made on thermal cycle by Rao.R.et.al. [17] and observed tremendous effect on fused deposition model (FDM)-(ABS) of acrylonitrile butadiene styrene material component. Subsequently, suggested the viscosity of the material is very important property for diffusion and bonding within layers. The viscosity of the processing material is depending on their temperature. Optimum temperature was responsible to maintain viscosity for superior bonding and diffusion between polymer molecules caused healthier mechanical strength. Padhi.S.et.al. [18] obtained higher dimensional accuracy by part orientation which is most essential parameter after application of fuzzy interference with taguchi technique. Fused deposition modeling (FDM) is substitute for wax pattern. Wax is usually used in investment casting. Fused deposition modeling (FDM) can develop complex shape. For dimensional accuracy with reduced internal cavity Darbar.R.et.al. [19] Implemented artificial neural network combined with taguchi technique which was another trial. Parameters such as raster (extruded) width, raster angle, extruder temperature, flow rate, feed rate was considered for optimization. Optimum temperature is accountable for moderation of internal cavity as well as precision dimension. Temperature was mentioned 210^0 C among 220^0 C and 230^0 C. Optimum raster width was affects directly on layer thickness and caused to eliminates air gap between rasters, without disturbing flow rate and feed rate values. Feed rate and flow rate also functioning on internal cavity and dimensional accuracy of printed component. Components failed due to increased feed rate. Raster width affected by flow rate. Optimum raster width avoids overlapping as well as internal cavity and endow with better surface finish. Authors also claimed this optimization technique could be useful for available material like ABS (Acrylonitrile butadiene styrene) or PLA (Polylactic acid). Moreover, for lattice structure generation design of experiment is the best technique recommended by Dizon.J.et.al. [20]. the optimal process parameters of the fused deposition modeling (FDM) were used to develop lattice structures. Lattice structures comprise more flexibility to attain a several physical properties such as high stiffness to weight ratio, low thermal expansion coefficient. As a result of these exceptional features of lattice structures adapted in many engineering, biomedical and tissue engineering applications for instance ultra light structures, energy absorbers, low thermal expansion and conformal cooling. Additionally, taguchi technique involves orthogonal arrays to organize the parameters like nozzle temperature, print speed, fan speed and layer height that affecting on the process and their levels at which they should be varied. Lattice structures was created in both types horizontal and inclined, orthogonal array implemented on both types. Results revealed that the most significant process parameter for inclined struts is a fan speed and layer height for horizontal struts it is.

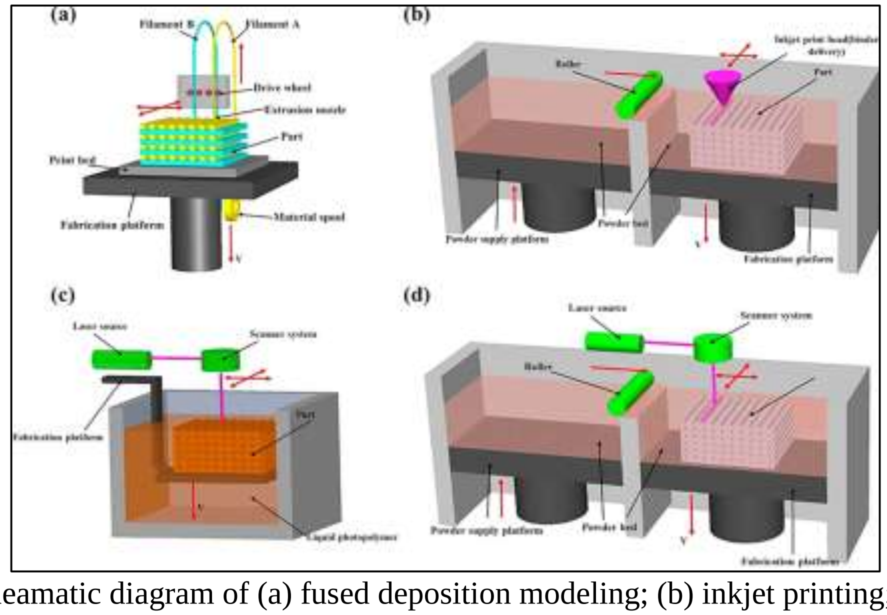


Fig .3.Scheamatic diagram of (a) fused deposition modeling; (b) inkjet printing; (c) stereo lithography; (d) selective laser sintering (Courtesy Ngo.T.[12])

2.2. Stereo lithography

Stereo lithography is a remarkable improvement over the traditional prototyping production in many aspects such as product development. It is invented by Dr. Hideo Kodama in 1981. Then commercially Stereo lithography (SLA) printer was patented in 1986 by Charles W. Hull [21]. It is most popular and widely used additive manufacturing (AM) process. It works on the principle of photo polymerization. Complex part or prototype generates by curing a liquid resin (photosensitive polymer) or monomer solution by means of electron beam or UV rays. In other words irradiation light source supplied the energy which helps in curing action. This curing action of resin is an exothermic polymerization process which possesses chemical cross linking reaction. In addition curing action commenced by introducing an exact amount and form of energy, which is completely depends on activated monomer by UV rays. As a result of curing reaction, an insoluble, infusible and highly cross-linked 3D network is formed. As shown in figure 3(c).

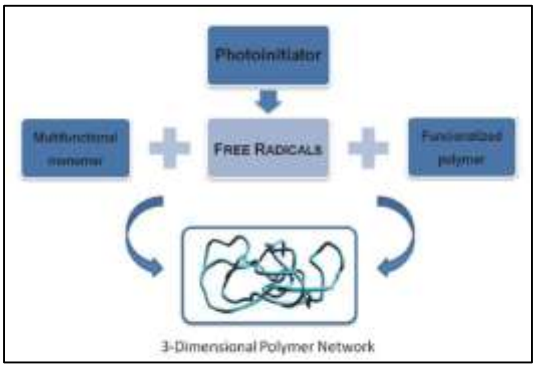


Fig.4. A photo polymerization process (Courtesy Ngo.T.[12])

Computer controlled ultraviolet laser beam adapted in stereo lithography to cure photosensitive resin layer by layer to build prototypes objects having complex shapes. In curing polymer network encompass laser exposure, photo initiation, polymer chain propagation and termination, species diffusion and heat transfer through conduction in the exposed region. Usually Epoxy or acrylate resin is used. A very thin cross sections created by Standard Triangulation Language (STL) in CAD model and then building 3D object with the help of stereo lithography apparatus (SLA) shown in fig.3(C). Furthermore, it includes wavelength of electromagnetic radiation act together on monomers or polymer molecules. However, it involves formation and breakdown of chemical bonds. Short chain of monomer and molar mass are together form longer chains of polymers in the form of three dimensional networks with polymerization process by UV rays shown in fig.4. The photo polymerization reaction mechanism can be described in four phases: initiation, association, propagation and termination.Wang.w.et.al. [22]. Suggests stereo lithography contains exposure, photo initiation, photo polymerization, mass and heat transfer. Due to dimensional accuracy stereo lithography overcomes CNC process. Process parameters of stereo lithography (SLA) are controlled by software for instance Layer thickness (for part building thickness of each slice), Hatch spacing (Centerline distance between parallel hatch vectors), Over cure (It is thickness of layer cured by laser), Blade gap (Vertical separation between two laser cured layer per sweep), Position on the build plane (is the as inner, middle and outer from the center to the edge. Optimal setting of process parameters established minimum dimensional error caused by build hole (vertically square or rectangle), a minimum consequential over cure (extra over cure) and medium layer thickness. For feed material, free radical photo polymerization kinetics is also characterized by differential photo calorimeter (DPC). Various attempts have been made in this manner. Gowda .R.et.al.[23] Applied analysis of variance (ANOVA) with taguchi philosophy. The Taguchi's L_9 orthogonal array was used for optimization of stereo lithography process parameters. Subsequently, analysis of variance (ANOVA) was used for result analysis respectively. Process parameters for instance layer thickness, orientation and hatch spacing is directly affects on tensile, flexural and impact strength of components. Chockalingam.K.et.al [24] was studied design of experiments as statistical tool for optimization and observed strength of the component. Layer thickness, orientation had greatest effect on component strength. Dimensional error has been reduced by layer thickness. In addition grey relational analysis with Taguchi method applied by Chiu.S.et.al. [25] and Raju. B.et.al.[26] for the optimization purpose. It is observed layer thickness; orientation and hatch spacing significantly improve tensile strength. Hatch spacing and over cure effects on flexural strength. Finally, Impact strength enhanced by over cure. Moreover, mechanical properties improved by using layer thickness, orientation and hatch spacing. Dies manufactured by stereo lithography (SLA) process are greater tension, compression and impact factor as a result of to high injection pressure.

2.3. Selective Laser Sintering

In mid 1980s selective laser sintering process has been adapted as rapid prototyping process, invented by Dr Carl Deckard. Selective laser sintering is powder based process, in this process high intensity laser beam partially melts the powder particles Raus A.et.al.[27]. In this additive manufacturing technique a component is manufactured with a series of layers through melting the top surface of a powder bed with a help of high intensity laser. This is followed sliced three dimensional computer aided design (CAD) data. At the top of building platform a thin layers of material powder are spread intricately and stacked. Subsequently a laser beam melts and fuses the layer of that material (metal/plastic) powder which is considering as the generated slice as input data. At the end of this process a build platform lowers down by means of piston for the repetitions of the same. These manufacturing process repetitions continue from bottom to top until the part is completed. As shown in fig.3 (d). It is also known as selective laser melting it includes the laser beam fully melts the powder particles. Thermal conductivity is important property in this process. Heat energy accumulated and extracted in the form of latent heat. This is a phase changing phenomenon from solid to liquid; it needs high amount of latent heat. Local sintering/melting of powder particles used for creating 3D components by adapting laser technology, it is based on CAD data. CAD data is converted in Standard Triangulation Language (STL) form and sliced into layers of 0.05-0.3. Then laser beam moves in X and Y directions for the melting of powder layer. Fine powder spread on the machine bed and scanned by CO_2 laser which leads to surface tension of the grains is conquered and sintered together. Temperature increased due to interaction between laser beam and powder for melting purpose, resulting in bonding particle to form layer. The individual layers are selectively melted and sequentially processed on top of one another. Part bed slowly goes down by one layer thickness to facilitate new powder layer and provides sufficient time for cool down without causing significant internal stresses. It is necessary to understand effects of process parameters on quality of components. Process parameters of selective laser sintering such as build orientation, laser power, scan speed, scan spacing, layer thickness, and preheating temperature plays vital role to obtain better surface finish, dimensional accuracy and hardness as well as to improve mechanical properties in critical sectors. Therefore, it is recommended by Ruban.W.et.al. [28]. the optimum process parameters of selective laser sintering helps to obtain better results like dimensional accuracy with mechanical strength. Though the Hofland .E.et.al [29] concluded scan spacing and layer thickness had greatest effect on tensile strength. Also, mentioned build parameters like Layer thickness and scan spacing improves tensile strength in build orientation, but vertically build sample shows good strength due to preheating temperature. Cooling rate also had effect on crystal structure of material. Fast cooling created low crystallinity, high ductility, and large elongation at break. Slow cooling leads high crystallinity, low ductility, and small elongation at break. The Taguchi technique was adapted by Kumar.N.et.al. [30] to design the process parameters then analyzed dimensional accuracy and hardness of fabricated prototype. Process parameters for instance laser power and Temperature has the significant influence over the dimensional accuracy, where as micro-hardness improved by temperature on 90^0 part orientation. Hence, there is response surface methodology (RSM) approach done by Negi .S.et.al.[31] on process parameters of selective laser sintering. It is mentioned that strength of the sintered parts increased with increased laser power. Strength of the sintered parts decreased by increasing scans speed and scan spacing. Reason behind that, energy has been absorbed by sintered material due to maximum scan speed, consequently inadequate energy distributed. This leads to the reduction in sintered part strength. Stwora .A.et.al.[32] Investigated maximum scan speed had poor effect on density, hardness and compression strength. Laser power had the biggest effect on sintered components. Under laser power following two points are considered such as exposure time and point distance.

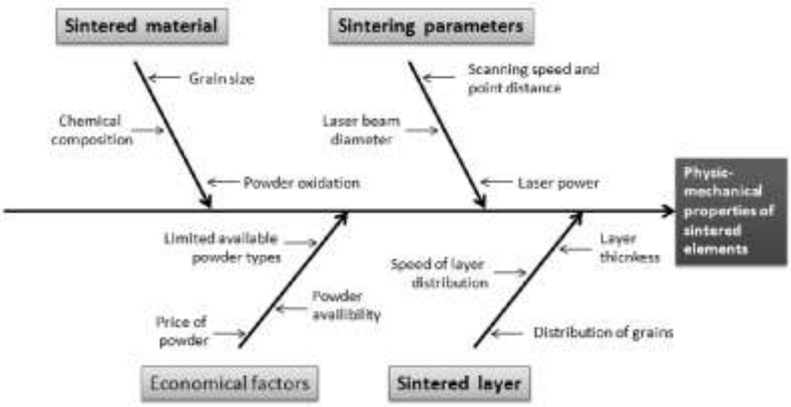


Fig.5. Factors influencing physic-mechanical properties of SLS manufactured elements (Courtesy Sushant Negi [31])

Following are some more recommendations of Pilipovic.A.et.al.[33] Successfully developed mathematical model for selective laser sintering (SLS) process parameters for instance laser power, laser beam speed, and hatch distance. Laser beam diameter and hatch distance improved mechanical properties as well as less manufacturing time required for sintered components. Nancharaiah .T.et.al.[34] and Viramgama.M.et.al. [35] Investigated laser energy by using analysis of variance. It is confirmed slice thickness is inversely proportional to the laser energy. But part orientation on laser energy is dependent on geometrical structure.

2.4. Laminated object Manufacturing

This process is commercially introduced in 1986 by Helisys. They used paper as the raw or processing material, which was feed from roll onto the bed. Prechtl.M.et.al. [36]. In the series of the paper layers, first layer of paper initially attached or tied to the previous layer using a heated roller, which melted the Polyethylene coating on the underneath of the paper. The profiles from inside and external perimeter of the slice are then drawn by laser optics system that is mounted to an X-Y movement (stage). It is additive manufacturing process includes cutting layer in the form of series and lamination of sheets or rolls of materials. Mechanical cutter or laser was adapted for precise cutting after wards it's bonded together or vice versa. The excess material was recycled after cutting. As shown in fig.6. In this type of additive manufacturing process post-heating is a necessary step, which is completely depending on type of materials and their properties. Furthermore, the laminated objective manufacturing contains four steps (1) hot rolling for bonding (2) height measurement for dimensional accuracy (3) laser cutting (4) decubing process. Henceforth, following process parameters such as layer thickness, heater temperature, and platform retract, heater speed, laser speed, feeder speed and platform speed are necessary to study for obtaining good quality of product with dimensional accuracy and strength. Few researchers are studying abovementioned process parameters in various ways. Chryssolouris.G.et.al.[37] studied process parameters of laminated objective manufacturing system with analysis of variance (ANOVA) and concluded layer thickness has improved tensile strength than other process parameters.Park.J.et.al.[38] and Flach.L.et.al [40] investigated thermal and stress analysis by simulation tool. Bonding between layers was shown significant effect on strength.

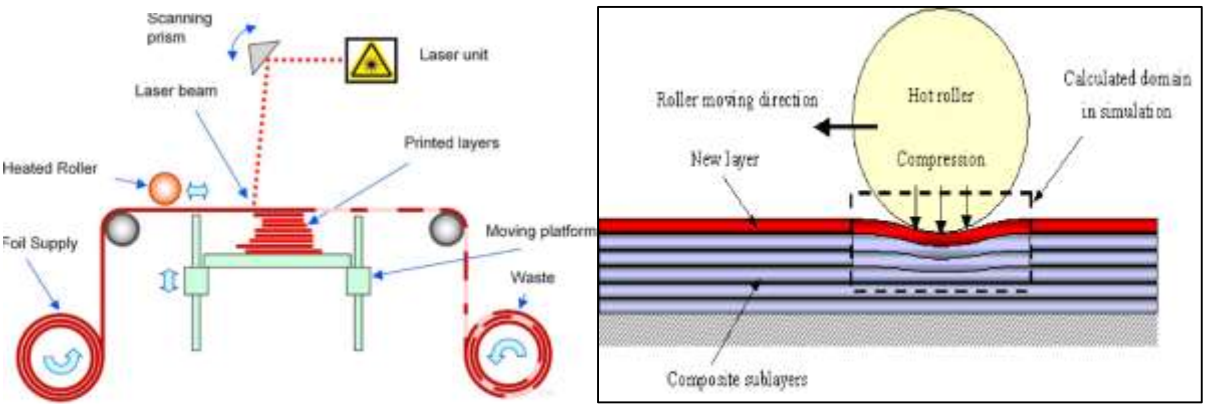


Fig. 6. The schematic diagram of a laminated object manufacturing system (LOM) (Courtesy Chryssolouris .G.et.al. [37])

The ultrasonic additive manufacturing (UAM) is Friel.R.et.al. [39] (fig.7.) a new subclass of laminated objective manufacturing (LOM). It is ultrasonic metal seam welding. In addition, Precht.M.[41]concluded building parameters like the laser parameters and the cutting velocity are responsible, to improve mechanical properties. Park.J.et.al.[42] studied precision dimensional as well as bonding and cutting accuracy. Concluded crosshatch size, either side (left-right) heater margin, speed of the heater and temperature, and laser power with speed are responsible for the same.

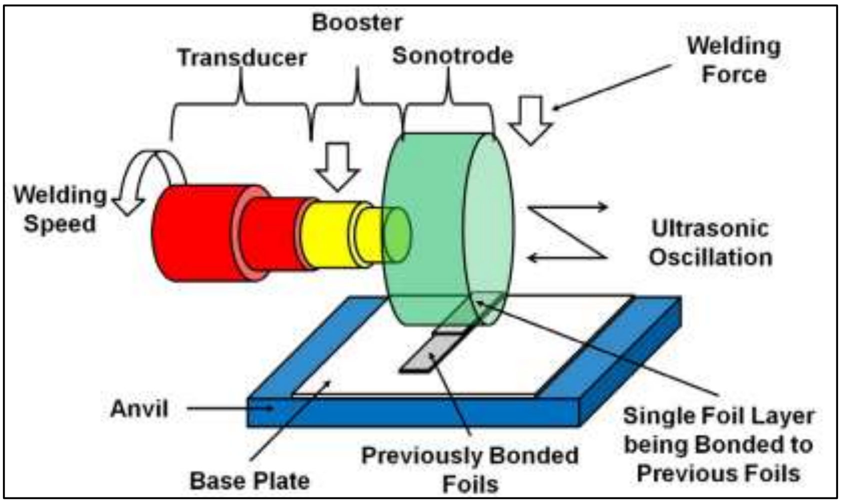


Fig.7. Schematic representation of the Ultrasonic Consolidation material deposition equipment (Courtesy Friel.R.et.al.[39])

2.5. Contour crafting and Inkjet printing

Counter crafting technology is a printing technique particularly for ceramics materials, which comes under the additive manufacturing. As shown in fig. 8. Initially it is used and researched by Behrokh Khoshnevis for printing complex ceramic structures such as building and construction.Tay.Y.et.al.[43].

Additionally, in 1965, Dr Sweet of Stanford University had been invented continuous inkjet printers (fig.9.) Lau.G.[49] which is inspired to develop the first inkjet printer. Then it is commercialized by IBM. It is used water mixed zirconium oxide powder for deposition purpose in the form of droplets via nozzle onto the substrate Cummins.G.et.al.[44]. For uniform size and spacing of droplets excess pressure needed to be applied on the jet. Few droplets are energized due to passing through an electric field and some of them uncharged for channel recirculation on the substrate to form printed image. Furthermore, viscosity of the ink and their surface tension plays very important role in the design of a printer. The droplet consist of viscous flow, surface tension and kinetic energy all are responsible for ejection of energy from the droplets. Following both parameters for instance viscosity and surface tension are responsible for holding the ink inside the nozzle without dripping. Major problem is found initially i.e. First droplet which is clogging at the nozzle this is caused by partially dried ink. Factors has to be considered in inkjet printing such as extrusion rate, nozzle size, speed of printing, distribution of substrate material and viscosity of the ink with solid content. Calvert.P.[45]. Very few researchers studied these parameters. Fauzia.V.et.al. [46] studied and optimizing printing parameters, such as pulse voltages, drop spacing and waveform setting for obtaining the high quality droplets and printed film for organic solar cell application. Lee .A.et.al [47] predicted jettability of zinc oxide (ZnO) particulate considering following factors i.e. viscous forces to inertia and surface tension .These are sufficient for structural formation of Newtonian fluid or polymer solution. Also studied flow velocity and nozzle diameter. From processing and design perspective view clogging can be reduced by higher driving voltage which increase flow rate. In other words exposure time of the ink to the elongation flow field is reduced. Abu-

Khalaf.J.et.al.[48]. applied response surface methodology and investigated electromechanical properties of the printed circuit .

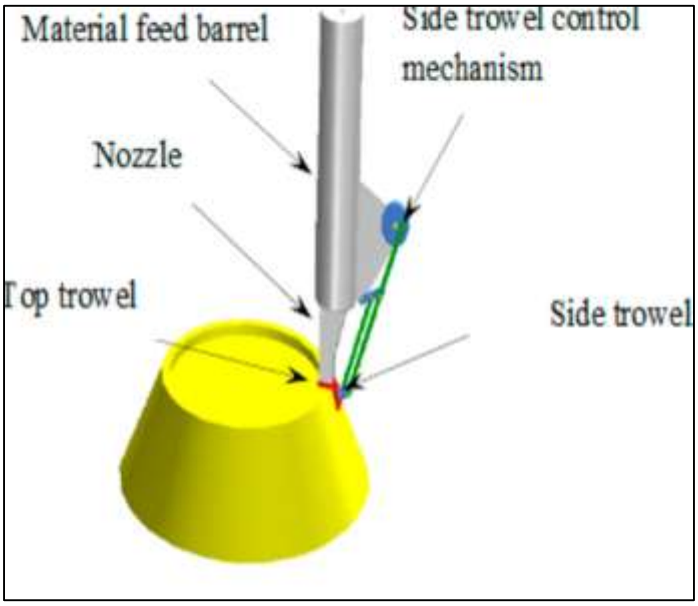


Fig. 8.Contour crafting process (Courtesy Tay.Y.et.al. [43])

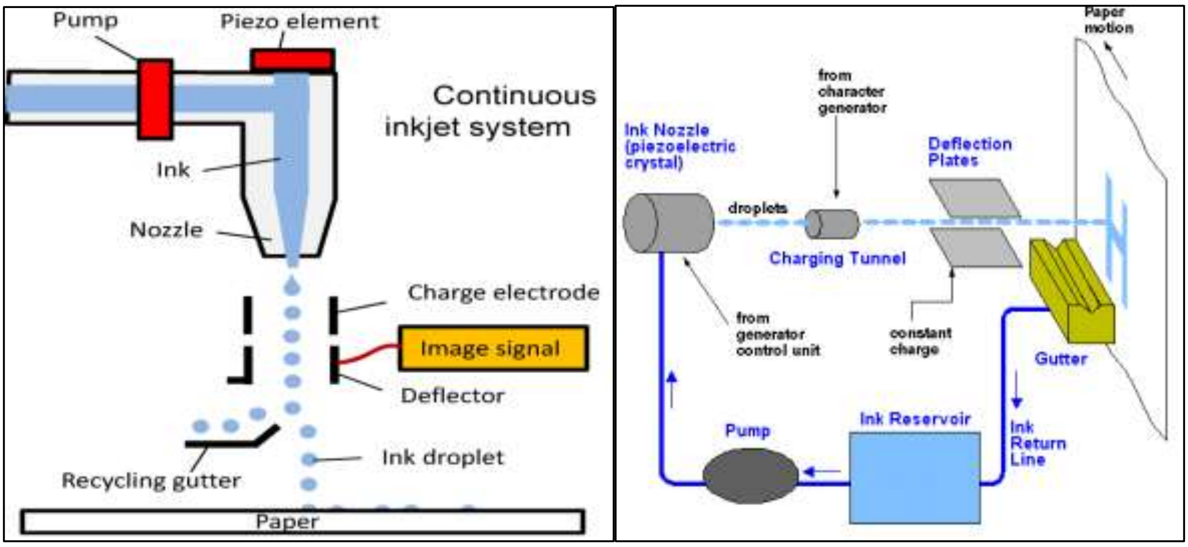


Fig.9. Schematic presentation of Continuous Inkjet printer (Courtesy Lau.G.[49])

3. Materials Used for Additive Manufacturing

3.1. Metals and alloys

In additive manufacturing technique there are two categories for processing metals and alloys such as weldability to avoid cracks during shrinkage of metal pool, and raw materials which is in the form of spherical shape i.e. powders in microns for better density and consistent. There are lots of different alloy compositions which are in the form of powders approximately 50 types. It is adapted in the additive manufacturing process at various technology readiness levels (TRL).Due to sudden cooling and directional shrinkage of the metal pools developed by additive manufacturing. This metal pool contains structures, microstructures and 3D printed architectures which are differ from their cast. Refined grains, anisotropic microstructures with elongated grains generated in the mentioned metal pool.

The surface of the metal pool revealed feature for instance weld tracks, protruding non metlted powder particles or ejected molten droplets and gaps. The mechanical behavior may change in terms of improved strength, defect less and refined grains of additive manufactured component than conventionally processed materials. Henceforth, it is necessary to understand association among powders, metallurgical constraint, and micro-structure. Following are common metals are under use in additive manufacturing technique.

3.1.1 Titanium and alloys (Ti-6Al-4V) (Ti-6Al-4V, Ti-6Al-4V ELI)

Titanium and alloys (Ti-6Al-4V) are used in additive manufacturing due to its mechanical properties (properties normalized by density) and outstanding corrosion behavior. Applications of components created by additive manufacturing are in aerospace, chemical, defense and medical industry. Annealed Titanium and alloys (Ti-6Al-4V) is used as aerospace material. Mechanical properties of wrought and cast materials such as tensile and hardness are equivalent to the additive manufactured titanium component Dutta.B.et.al [50]. It consist fine microstructures during high cooling rates of this process Murat. A. et.al. [51].and Zhang.Yi.[52

(a) (b)

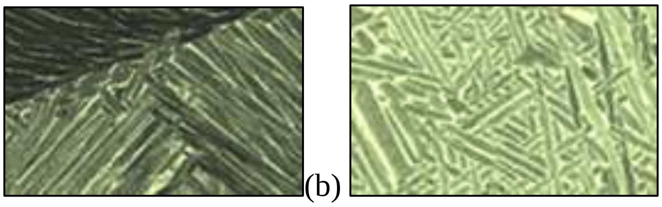


Fig.10. Micro-structure of the additive manufactured titanium alloy component (a) the top, and (b) the central region. (Courtesy Murat. A. et. al. [51]).

3.1.2. Stainless steel (316L and 17–4PH)

Excellent corrosion and oxidation resistance of stainless steel is the reason of attraction by additive manufacturing researcher and industry people. It is used in defense, petroleum, automotive, nuclear and chemical industries. Corrosion property of stainless steel was enhanced by presence of chromium. Zadi-Maad.A.[53]. The thermal cycle in additive manufacturing process induce the grain growth in crystal structure and orientation. In consequence strong crystal structure with plasticity obtained. However, anisotropic tensile properties and evolve the microstructure of the component. Microstructure may vary from columnar grains to equated grains. The grain size was determined by duration and temperature of process. It has been observed hydrogen environment affected on grains. Grains are recrystallized and grow to form strain free equated grains. Isotropic mechanical properties created by uniform arrangement of grains. Gong .H.et.al. [54] (fig.11). A hot-isostatic process (HIP) is responsible to reduce porosity and improve fatigue limit combined with equated grains.

Fig.11.Optical microscopy of additive manufactured stainless steel (Courtesy Gong .H.et.al.[54])

3.1.3. Aluminium alloy and Copper alloy (AlSi9 Cu3, AlSi5Cu3Mg etc.)(CuNiSi(Cr))

In the process of thermal cycle during additive manufacturing organize the micro-structure. The material is subjected to directional heat transfer and high temperature difference during processing. Solidification and re-melting process producing fine microstructure and metastable phase. During shrinkage process Si rejects into the liquid. It increases the Si content in the liquid Aboulkhair.N et.al. [56]. Considering the Al-Si phase diagram shown in fig.12.Solubility of Si in Al is directly proportional to the temperature excluding under high cooling rates, which extend the solubility of Si in Al. Similarly, copper (Cu) and magnesium (Mg) solubility in aluminum alloy (Al) observed Manfredi.D.et.al [55]. Tiberto .D.et.al. [77] attained porous free copper product from copper powder. Content of oxygen is useful impact on the formation of oxides with Si, Mg. Subsequently, cross-contamination elements like aluminium in the alloy is detrimental for the fabrication of the material like reduce wettability and deteriorate its melting behavior.

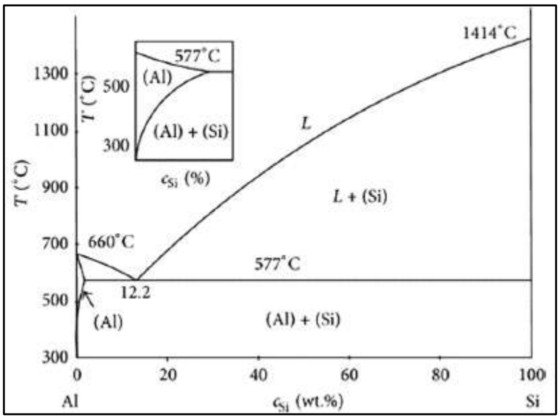


Fig.12.Al-Si phase diagram (Courtesy Aboulkhair.N et.al. [56])

The microstructure of AlSi10Mg powder before additive manufacturing is shown in fig.12 (a). More fine grain formed in melt region shown in fig.12 (b).This is due to high re-melting of boundaries. The columnar structure at the melt boundary due to shrinkage and temperature difference is shown in (fig.14).

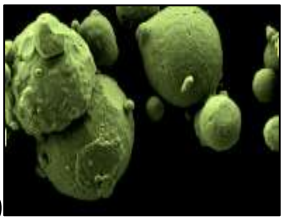
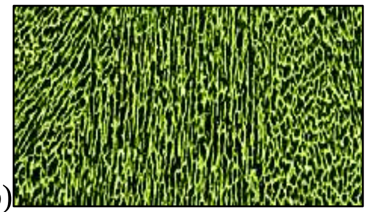
(a)  (b) 

Fig.13.(a) SEM image of AlSi10Mg powder before additive manufacturing process and 13(b) Microstructure of after additive manufactured AlSi10Mg (Courtesy Manfredi.D.et.al [55], Aboulkhair.N et.al. [56])

Fig.14.Columanar structure (Courtesy Aboulkhair.N et.al. [56])

In aluminum alloy an elongated and columnar cells are shown in the fig.14. Equated grains are aligned in the perpendicular (build) direction of the melt pool. Higher temperature of the aluminum allows the precipitation of Si in the columnar Al grains. From fig 12 (b) indicates, equated structure which causes mechanical anisotropy (yield strength and elongation at failure) and crack susceptibility. Shrinkage of melt pool happens in width-to-depth ratio. In this solidification process aluminium alloys, contains dendrites with < 1 0 0 > directions in front stifle less.

3.1.4. Nickel-Based Super alloys (Inconel 625, Inconel 718 and Hastelloy X)

This alloy concern to the family of face centered cubic structure with various secondary strengthening phases. Diffusion and lattice cohesion is possible at higher temperature. Re-melting of material indicates good cohesion between layers Graybill B.et.al.[57]. The voids were present within the finished product due to the minimum energy density of Ni. Less thermal diffusion influence on the development of comet shaped melt pool but with high diffusivity indicates a spherical shape within melt pool. In the spherically shaped melt pool coloumnar grains are generated due to temperature difference which is similar results observed in aluminium alloy. The complexity in this alloys formed by not only strengthening phase (solid solution hardening depend upon the formation of the γ′ (Ni3(Al,Ti)) and γ″(Ni3Nb) secondary phases within the primary γ matrix) but also secondary phases like Laves, carbides, δ, and σ phases which is generated by temperature differences and local compositions. Temperature difference and cooling of melt pool leads to low G/R ratio. The G/R ratio means growth of columnar v/s equiaxed dendritic microstructures. While G indicates the magnitude of the temperature difference and R indicates cooling rate of the melt pool. The columnar dendrites were developed by temperature difference and lower cooling rates. Lower temperature difference and higher cooling rates both were responsible for equated dendrites. Furthermore, the low value of G/R supports the liquid between grains and isolating the formation of the Laves phase particles. In contrast, high G/R value not able to separate the liquid between them. Therefore, Laves phases particles able to join and form broad strings. Fine grains are randomly oriented in build direction. Furthermore, partially melted and non melted particles with fine Laves particles create dimples within pool. These Laves particles probabilities to develop microvoids while the former defects works as stress concentrators that responsible to crack initiation and failure. The submicron dimples and voids mean ductile failure with superior mechanical properties. However, consequence of the orthorhombic δ phase on microstructure and mechanical properties on nickel alloy through additive manufacturing. The δ phase was achieved in the interdendritic regions due to microsegregation of Nb and Mo during shrinkage. Morphology of the δ phase built in slight elliptical geometry. The material selection is a challenging and limited. Therefore, it is necessary to utilize available material to fabricate critical parts or manufacturing in large volume. It is very crucial part, adapting the various compatible materials, in order to fulfill the gap by means of additive manufacturing which is not possible by conventional casting and forging process.

3.2. Polymers and composites

Polymers are common material for additive manufacturing as filament (fig.15) due to its easy availability in various forms for different three dimensional processes. All polymers are thermoplastic, reactive monomers, resin or powders. Since several years application of polymers and composites are constantly used in three dimensional printing technologies for many sectors such as medical, aerospace, architectural, toy manufacturing. Polymers used in three dimensional printing are acrylates – for free radical photopolymerization, epoxy monomers – for cationic photopolymerization. The thermoplastic filaments are acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), polypropylene (PP) or polyethylene (PE), polyamide (Nylon), polycarbonate (PC), polyetheretherketone (PEEK),polyetherimide (PEI), polyethersulfone (PES) or polyphenylene sulfide (PPS) under processing . Selection of the material is depending upon the final application of the part or product. The epoxies which are photopolymerizable offer good mechanical properties than acrylates. In another hand the acrylate resins epoxy monomers have low volume solidification and perfect dimensional accuracy. Acrylonitrile butadiene styrene is a thermoplastic material which is highly recommended for additive manufacturing due to its low melting temperature and low thermal conductivity. It has the highest impact resistance and hardness but emits unpleasant odor during processing Sagias.V.et.al. [60]. Mechanical properties, dimensional accuracy and texture of polylactic acid graphene sample studied by Caminero.M.et.al.[61]. Uniformly dispersed graphene nanoplatelets embedded in the polymeric PLA matrix. Polylactic graphene had shown a significant decrease of roughness. Vikas.B et.al.[62] investigated higher tensile strength of polylactic acid. Ituarte.I.et.al.[63].observed porous structure within polypropylene specimen with maximum tensile strength and crystallization characteristics. Mercado-Colmenero.J.et.al. [64] investigated compressed uniaxial stress analysis of Polyamide (Nylon) PA-6. Nanoparticles reinforced nylon-6 is substitute of acrylonitrile butadiene styrene (ABS). Reich.M.et.al.[65] studied mechanical properties and applications of recycled polycarbonate (PC). Result indicated high-strength and heat-resistant products at low costs. Haleem.A.et.al [66] studied Poly-ether ether ketone for development of dentistry parts. Jiang . S.et.al [67] analyzes mechanical properties of polyetherimide (PEI), results shown filament orientation and temperature are highly enhanced mechanical strength. In addition, Geng.P.et.al.[68] studied semicrystalline structured polyphenylene sulfide (PPS) and polyvinyledene fluoride (PVDF) are a category of thermoplastic polymer. It consists of thermal stability and chemical resistance. Zhansitov.A.et.al.[69] investigated resilient and strength properties of polyethersulfone (PES) which is increased rigidity and intermolecular interaction within additive manufactured specimen . Subsequently, addition of nanomaterials in three dimensional (3D) printed parts leads to improve mechanical property, advantages and homogeneity of the finished products. Reinforcement of nanomaterial is attracted by various industries due to a several properties like thermal conductivity, improved strength, fire performance and light weight. Micro level composites have been specifically used in the form of micro particles and ceramic powders, fibers or piezoelectric materials. Such that, polymer metal matrix composite which is composition of a mixture of iron micro particles or Fe_3O_4 nanoparticles is reinforced in Polyvinyledene fluoride (PVDF) Sanida.A.et.al. [70]. Young's modulus increased with the concentration of Fe_3O_4. This is filler content in the polymer matrix composite. Additionally, reinforcement of fiber can improve the mechanical properties of polymers. Polylactic acid (PLA) having good properties such as not damaging environment. Polycarbonate (PC) is the higher temperature and particularly for fused deposition modeling method. White polyamide PA2200 powder being the lightest for selective laser sintering (SLS). Water clear ultra 10122 for stereolithography (SLA) and Fullcure 720 – it posses greatest tensile strength , Vero, Tango black plus, Full Cure 980 have similar superior mechanical strength and High-Temperature RGD525 Model Material (RGD 525) for inkjet printing (polyjet) Jasiuk .I.et.al.[58].

Fig.15.Polymer filament for three dimensional printing.(Courtesy Singh.S.et.al.[3])

According to the researcher newly developed thermoplastics material i.e. reinforced metal powder in polymer filament. For instance fiber reinforcement improve significantly polymer matrix composites mechanical perforemance Yasa.E.et.al.[71]. Yakout .M.et.al.[72] reviewed efficient additive manufacturing of polymer matrix composite as well as metal matrix composites such as single-walled carbon nano tube, was adapted as a reinforced material to increase strength of acrylonitrile butadiene styrene (ABS). It had shown improved mechanical properties. Reinforcement is also responsible for reducing porosity of the host material as well as helpful for alteration of rheology.

3.3. Ceramics

Ceramics means holding ionic and covalent bonds together for enhancing higher strength and hardness. Ceramics owes outstanding properties. This is obtained from heating of minerals. It consist of following types (1) porcelain, this is very ancient material manufactured from heating kaolin in kiln which are known as clay minerals. Generally it is used for the purpose of insulation and pottery making. (2) Bone china, it contains bone ash. Used for tableware and ornamental applications (3) Earthenware, in this type mineral is not heating at vitrification level. It has translucent and non porous properties also softer than porcelain. For tiles and flower pots applications (4) Stoneware, this classification obtained by heating minerals in between heating temperature of porcelain and earthenware. Both expensive and inexpensive tiles and pottery manufacturing applications (5) Glass ceramics, it is obtained from controlled crystallization and the properties such as strength and durability. It is used for walls, chimney and landscaping. (6) Fired bricks, obtained from sand and clay minerals. In additon, (7) Carbon, itself is a ceramic material. Now a days carbon fibers, nano-tubes, graphenes all are carbon based materials. Consequently, it is wide use in aviation and fabricting sporting equipments. (8) Silicon, all above mentioned ceramics are silicon based. It is very hard and brittle crystalline solid and semiconductor material. (9) Silicon carbide is one of the silicon based ceramic material, it is mixture of silicon and carbon used for semiconductor manufacturing. (10) Titanium carbide, consist extreme hard and heat resistant material with corrosion resistant properties. It is used for fabricating machine parts, drill bits and heat shields. (11) Tungsten carbide, is made up from tungsten and carbon , useful for cutting tools, sports equipment and industry use. (12) Barium titanate, is dielectric material used as piezoelectric material and manufacturing capacitors, transducers, microphones and sensors. (13) Boron carbide, is heat resistant, ionizing radiation and chemicals. Applications such as nozzles, scratch resistance coatings, tools and dies, abrasives, neutrons absorbers and brake linings. (14) Bioceramics, it is biocompatible material and suitable for implantation in human body, which is decompose with time such that they are replaced by human body like artificial hip bone. (15) Ceramic matrix composite, applicable for turbines, furnaces, brakes disks, machine parts like sliding bearings. (16) Ceramic foam, it is designed to be strong and lightweight as well as thermal insulations, acoustic insulation, filtration and absorption of environmental pollution. (17) Ferrite, is manufacturing by heating iron oxide with barium nickel and zinc. Zocca.A.et.al.[73]. The products made from ceramics are in desired shape using mixture of powder with or without binders and other additives. It is manufactured by applying traditional process. Sintering process which includes green parts at elevated temperatures is further process to attain densification. Nonetheless, these conventional process has limitations in terms of long processing times and high expensive. Such as complex geometries and interconnected holes are difficult to produce as moulding is usually included in these process. Therefore, it is very difficult for machining of ceramic component due to its brittle structure. Also it is not possible to attain good surface quality and dimensional accuracy. It includes cutting tools and defects. Considering these difficulties additive manufacturing is a perfect revolutionary solution to overcome abovementioned problems. Additive manufacturing produce ceramic parts with less cracks and without porosity. Commonly used ceramic materials are silicon dioxide (SiO_2), alumina oxide (Al_2O_3), zirconium dioxide (ZrO_2) and silicon carbide (SiC) for the additive manufacturing. Promakhov.V.et.al. [74] observed homogeneous internal structure of aluminium oxide ceramics. Interaction of wave structures such as shock and dynamic waves were determined within the ceramics. It was determined by the processes of elasto plastic deformation and fracture. It is observed during shock comprssion. The shock compression profiles of free surface velocities of the samples were recorded in terms of hugoniot elastic limit (HEL) and critical tensile stress (spall strength). Zhu.S.et.al.

[75] investigated porous free product of silicon based ceramics i.e. silicon carbide (SiC). Sahasrabudhe.H. et.al.[76].studied coatings of zirconium oxide powder on Ti6Al4V alloy substrate. Results shown grains are equiaxed without changing grain size and increased orientation of phases.

4. Applications

4.1. Medical field

Sanadhya.S. [78] reported additive manufactured component such as plastic skull, acrylic polymer based titanium alloy cranium implant, and heel bone is under process and study for implant in human body. Following are the basic areas for instance medical models, surgical implant, guide, external aids and bio-manufacturing. Additive manufacturing also helps in pharmaceutical companies in drug development. There are lots of research challenges in medical field for fabricating complex structure with innovative ideas. It is possible to develop by additive manufacturing only such as biomedical implants, scaffold and tissue engineering as well as organ development and in drug delivery system Aimar.A.et.al. [79]. Due to flexibility in this technology it has lots of probability to develop complex shapes by novel engineering material like semi-crystalline polymeric composites. Specific medical requirement from patient such as drug, artificial organs, customized biomedical products and surgical instruments. It is cost effective process than other traditional process for less production which are typical medical industry. Furthermore, in this technology complex products not required special type of fixtures or second process such as forging , moulding and milling every time. It is faster process than other conventional fabrication process. It is easy to access and supports of any type of CAD files. In addition, bio-printing is used for development of tissues and human body organs. In bio-fabrication living body cells are used in bio-ink as input material/bio material. This biomaterial is combination of bio-molecules and living or dead cell depending upon their application. This is a very helpful for the production of the tissue structure and bio-molecules are guiding them in regeneration of process. Combination of multiple bio-inks and cells are making it possible to construct complex tissues and organs. Autologous cell reduces the risk of the patients from generated organ / tissue. In a production of the bones, aortic valves, vascular trees, bio-resorabable, tracheal splints and the cartilage have been processed within and outside body. Biologically developed models are also used for toxicity tests and disease models as well as study drugs adverse effect. Development of structures with fragile cells has limitations due to low pressure of bio-printing during micro extrusion. Care should be taken not to distort and damage cellular structures. In contrast, high pressure will lower down the number of usable cells. Inkjet bio-printing is the best option to conquer these problems and balance the extrusion and temperature. Selection of bio-ink scaffolds is a one of the big issue. For example, cells needs to attach the scaffolds. Also, assure the protection from mechanical and thermal stresses at same time. Moreover, the utilized material must be cytocompatible, which is not affected on immune and inflammatory response. In a development of the drugs / medicines are under process in pharmaco-genetic profiles due to patients demand. From the demand point of view in terms of age, gender responsible to manufacture the most appropriate medicine. In a single tablet it comprises multiple drugs. On the other hand an unstable drug has been developed by additive manufacturing process with a limited shelf-life. Computational model such as geometrical design, successfully forecasted, it is similar match with release profile of additive manufactured in drug delivery product and it is under investigation. Additive manufacturing is also replacing the face of implant industry.

According to the specific requirements from the patients for implantation is satisfied by additive manufacturing. Computer-aided design (CAD) software is also contributed in image acquisitions and elaboration for the implant design and manufacturing. An additive manufacturing technique is the easiest way to fabricate anatomically complex geometries. It is cost effective and reliable manufacturing process.

4.2. Aerospace

In aerospace industry it consists of many parts, subsequently all of them need at high level inspections and the unpredictable demand. It is directly effects on inventory stage to the limits; therefore regular replacement is only needed with 10% of the spare parts. It is depending on slow moving parts or long term storage parts both are difficult to forecast the exchange times and become expensive. In general inventory control strategies may not be effective in such cases and contribute largely to inventory. Spare parts are classified into four types 'Rotatable', 'Repairable', 'Expendable' and 'Consumable' each of which has a different replenishment policy. Operational structure of the aircraft industry elaborated and consolidated in the form of the block diagram shown in fig.1. It is brief introduction of just-in-time production and supply chain system of the parts Singamneni.S.et.al.[80].

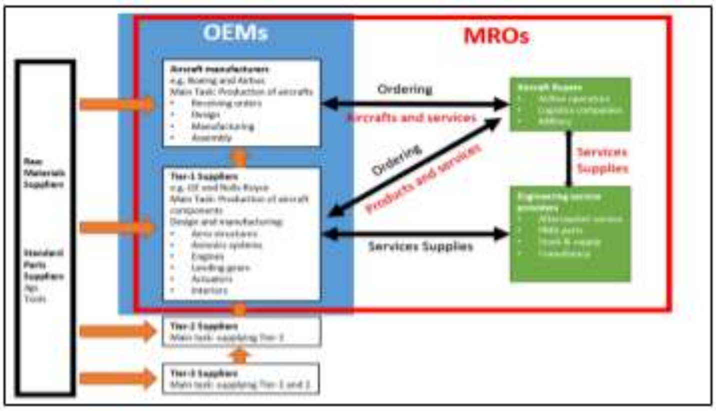


Fig.16. The aircraft production and maintenance models (Courtesy Singamneni.S.et.al.[80]

Complex geometrical shapes are difficult to manufacture and important for integrated functions for instance structural, heat dissipation and air flow. Several aviation companies are manufacturing fan blade edges with optimized air flow. In aircraft manufacturing industry implemented advanced and costly materials like nickel base alloy, titanium alloys and high strength steel alloys as well as ceramics. Machining and processing of this type of material is very costly. It leads to create a large amount of waste materials. Additive manufacturing technique helps to reduces waste and develop required shapes. In customization, it is very helpful to produce parts in a small amount by additive manufacturing than traditional manufacturing process. It is convenient, economical and not expensive and bulky set up like die, moulds. It works on demand manufacturing, in particular parts required for aircraft has a 30 and more than 30 years lifecycle. Therefore, not necessary to upkeep inventory because of additive manufacturing has capability to manufacture just-in-time or on demand. This type of industry needs to create lightweight. It includes both metallic and non-metallic parts for aircraft applications by applying additive manufacturing. For example, aero engine parts, turbine blades and heat exchangers. Nonmetals by additive manufacturing methods such as stereolithography, multijet modeling and fused deposition modeling were used for the rapid prototyped parts.

4.3. Automotive

The automotive sector is one of the biggest sectors among the others. The additive manufacturing process is mostly adapted in automobile sectors also, to create detailed and highly précised materials/parts. It is also facilitate to refine the design of certain automobile parts. In automobile industry some of the components of cars like lamps, mirror holders, and dashboard parts in the manufacturing companies required much time and efforts to be finished. The mentioned cost of production incurred through hiring teams of highly skilled persons to develop a single car part, which can be possible by additive manufacturing now a days. This technology is also useful to reduce consumption of time for manufacturing process. It is reduced overall time taken by production and assembly of manufacturing process. Consequently increase the profit and other revenue secured by car manufacturers. Additive manufacturing utilized to the fabricate less weight engine of the truck, for the future development .Bockin.D.et.al.[81]. Electric car built by additive manufacturing, using ABS carbon-fiber material to create parts within 44 hours. Apart from that car battery, suspension and motors were assembled manually. Therefore, in this type of car (electric) is manifestation that the additive manufacturing process can significantly reduce the time consumption required for the workforce needed. This can translate into a bigger cost savings for the automobile manufacturing industries. As per mentioned by all car manufacturer they have already started experimenting with the additive manufacturing in mass production of cars and creation of tools with spare parts of automobiles. It is also facilitate to improve the overall efficiency of the car manufacturing processes. Subsequently in automobile industry required internal channels for cooling purpose, conceal textures, thickness of the walls and their structures as well as curved surfaces. It needs maximum degree of freedom for design concern in small and massive manufacturing purpose in a reasonable cost. Furthermore, production of high quality products tooling plays vital role. It is in the form of jigs, fixtures and other customized tooling equipment by adopting additive manufacturing Sarvankar.S.et.al.[82]. Additive manufacturing also manage to redesigns of components for example lower weight for less fuel consumption in vehicles. During redesigning it combines various components in one component. In results functioning smoothly, less weight, less dismantling while servicing and increase dynamic potential of working. Additive manufacturing is recommended for production of complex geometry and it is very advantageous in saving cost and energy. Therefore, it is not dependent on geometry of parts. Enhance cooling by integration of cooling channels into the structure to increase energy efficiency and performance of the entire component. In contrast, disadvantages of additive manufacturing consume lots of time and energy to develop complex product. This is not applicable in mass production.

Some of the challenges or drawbacks in the additive manufacturing (AM) are discussed below

Apart from fabrication of complex shapes still there are some challenges are under study. It is not possible to manufacture big structure with minimum cost. It is also not useful for mass production as well as inferior and anisotopic mechanical strength. It is time consumable process than other conventional methods for instance casting, extrusion, manufacturing, injection molding. Comparatively selective laser sintering and stereo lithography are more time consumable than inkjet printing and fused deposition modeling. In selective laser sintering higher amount of energy required and material cost due to high in resolution. Although, additive manufacturing is perfect and cost effective for customized products for example scaffold for bone tissue engineering. Additionally, apart from above mentioned problems following are few more challenges. 1) Void formation 2) Anisotropic microstructure and mechanical properties 3) Divergent from design to execution 4) Layer-by-layer appearance.

Void formation, (fig.17) there are lots of probability of porous structures within additive manufactured component. This is caused by less interfacial bonding between printed layers as shown in fig.17. Also, depends upon adapted printing methods and material used. Application of filaments leads to creates void in additive manufacturing which results in low-grade and anisotropic mechanical strength. Void formation will directly affect on the layer to layer bonding which will be reduce product life. Increasing thickness of layer of filament will reduce porosity but deteriorated cohesion within component. Consequently, reduce tensile strength and increase in water uptake. But reduced height of layer will useful for reducing porosity in alumina and glass composites. This is very helpful for the laser penetration when it is passing through the top layer and encourages for diffusion of ceramic powders within layers.

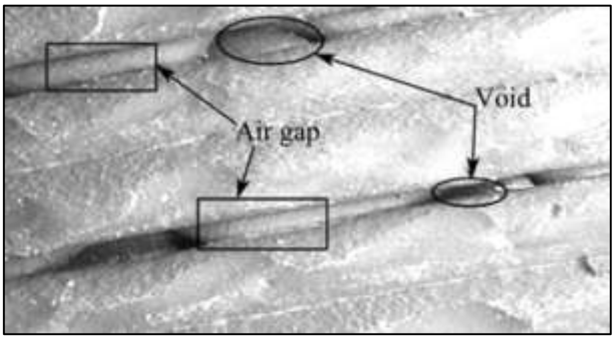


Fig.17. Void formation (Courtesy Padhi.S.[18])

Anisotropic microstructure and mechanical properties, caused due to printing structure and micro-structure of the printed material within each layer. Vertical tension or compression compare to that in the horizontal direction causes anisotropic behavior. In particular, when metallic powder reheated and remolded the boundaries of the layers. It is direct affects on different grain microstructure and anisotropic behavior due to temperature difference. Penetration of heat is a major cause to reduce or control of anisotropic behavior. Maximum tensile strength is in build direction instead of longitudinal direction of additive manufactured component. Sphere shape of grains and orientation are responsible to improve significantly anisotropic behavior for polymers, ceramics and alloys. The controlled properties of the filaments are attained by anisotropic wettability of a surface.

Divergent from design to execution, through the computer aided design (CAD) software parts can be designed and consider as input parameter. There are few defects due to limitations in additive manufacturing. There are inaccurate input data from CAD model to 3D printing particularly curved shapes. It is in the form of tessellation (.STL). The fine tessellation can potentially solve this kind of difficulty at some extent but it is time consuming process. Therefore, post processing is required to eliminate these defects such as post heating, laser, chemical processing or sanding. Also it is necessary to optimize additive manufacturing process parameters for execution of components.

Fig.18.crack between raster (Courtesy Padhi.S.[18])

Series of layer or Layer-by-layer appearance is one more challenge in this technology i.e. additive manufacturing. Cracks are in between raster or layer is shown in fig 18. In some applications such as buildings, aerospace, automotive components and scaffold for tissue engineering are necessary to hide additive manufactured component as well as a required flat surface at the end of the process. Generally at the end of the process in additive manufacturing, components appeared in series of layer form. For that reason post processing viz chemical or physical sintering is helpful to remove these defects but it will effects on time and cost. It is formed mostly in cement and concrete based material work than other material.

5. Conclusions

Additive manufacturing process has capability to develop a complex structures combined with mass customization and less wastage. The main challenges in the additive manufacturing were also argued. Polymer filaments are commonly used in additive manufacturing combined with others such as metals and alloys, ceramics and composites. Fused deposition modeling is commonly used technology in industry applications due to less cost and maximum speed processing. The fused deposition modeling (FDM) is adapted for fast prototyping and enhanced mechanical properties with better quality products than other additive manufacturing processes for example selective laser sintering (SLS). In contrary, selective laser sintering is powder based technology, consists of fusion and melted or bonded particles together by adhesion. Furthermore, inkjet printing technology recognized for quick manufacturing and output of ceramic deferments but it needs post heating. For the processing of photopolymers stereo lithography is the best process to fabricate exceptional tenacity. This is very slow, complex process coupled with applicable only limited materials. Eventually, laminated object manufacturing (LOM) is depending on cutting of layer series as well as lamination of sheets or foil rolls.

Materials are used for additive manufacturing is in the various forms; polymers are in the filaments. Metals and alloys are adapted in the form of powders and wires. Additionally, sheets and inks are also under use. There is selected type of metals and alloys are under demand. Thermoplastic polymers are commonly used in additive manufacturing such as acrylonitrile-butadiene-styrene (ABS) copolymers, polyamide (PA), polycarbonate (PC) and polylactic acid (PLA), thermosetting powders for instance polystyrene, and polyamides and photopolymer resins. The polymer composite materials i.e. fiber and nano-materials reinforced polymers for the purpose of improving the mechanical properties. Ceramics material is also contributed in additive manufacturing because of high strength –to-weight ratio as well as fabrication of complex ceramic lattice structure for scaffolding in tissue engineering. Additive manufacturing is also plays very important role in biomaterials for creating complex and customized shapes according to the patients demand. Subsequently, overcomes lots of challenges and other common issues like limited materials. Moreover, aerospace and automotive industry constantly invested in additive manufacturing to develop customized components with following just-in-time concept due to higher strength to weight ratios. Also, it is benefitted in immediate response and on demand manufacturing.

In both industries aerospace and automotive are faces a major drawbacks for example limitations and maximum cost of materials due to bigger structure and less quality. Despite the abovementioned processing problems following are the substantial drawbacks within components. Void formation among layers which causes porosity during the additively manufacturing process. It is directly affected on mechanical properties due to a less interfacial bonding. Anisotropic behavior is another common challenge which is formed by vertical tension or compression compared to the horizontal direction. During the data transferring it creates inaccuracies and defects particularly in curved surfaces by tessellation (.STL) format of CAD. Moreover, additive manufacturing is not preferable for buildings, toys and aerospace as well as mass production due to maximum cost, time with less speed. Though it is required more research and development compared to other conventional methods.

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