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A Review on Types of Powder Bed Fusion Process in Additive Manufacturing Technology.

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Abstract— *Powder Bed Fusion (PBF) is a advanced manufacturing technologies that can fabricate three dimensional objects directly from CAD data, on a successive layer-by-layer strategy by using thermal energy, typically from a laser source or electron beam to irradiate and fuse particles within a powder bed. Also, Laser powder bed fusion (PBF) is emerging as the most popular additive manufacturing (AM) method for producing metallic components based on the flexibility in accommodating a wide range of materials with resulting mechanical properties similar to bulk machined counterparts, as well as based on in-class fabrication speed. Additive manufacturing is a topic of considerable ongoing interest, with forecasts predicting it to have major impact on industry in the future In comparison to traditional manufacturing Methods ,powder bed fusion additive manufacturing (AM) has many good properties to overcome the drawbacks of traditional manufacturing methods Powder bed fusion, in which each powder bed layer is selectively fused by using energy source like laser or electron beam, is the most promising additive manufacturing technology that can be used for manufacturing small, low volume, complex metallic parts. This review presents evolution, current status and challenges of powder bed fusion technology. It also compares laser and electron beam based technologies in terms of performance characteristics of each process, advantages/disadvantages, materials and applications.[16]*

Keywords: PBF, SLS, SLM, DMLS, LENS, EBM.

I. INTRODUCTION

Additive manufacturing (AM), also known as 3D printing, is a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. This tool less manufacturing approach can give industry new design flexibility, reduce energy use and shorten time to market . Main applications of additive manufacturing include rapid prototyping, rapid tooling, direct part production and part repairing of plastic, metal, ceramic and composite materials. Recent advancements in computation power of electronics, material & modelling science and advantages offered by AM technology have shifted focus of AM from rapid prototyping to direct part production of metallic parts. The two main parameters of any metal AM process are type of input raw material and energy source used to form the part. Input raw material can be used in the form of metal powder or wire whereas laser/electron beam or arc can be used as energy source. AM machine requires CAD model of the part in the .stl (stereo lithography) file format. Specialized slicing software then slices this model into number of cross sectional layers. AM machine builds these layers one by one to manufacture complete part . Thickness of these layers depends on the type of raw material and the AM process used to manufacture the given part. Every AM manufactured part has inherent stair case like surface finish due to layer by layer build up approach.[16]

All PBF processes share a basic set of characteristics. These include one or more thermal sources for inducing fusion between powder particles, a method for controlling powder fusion to a prescribed region of each layer, and mechanisms for adding and smoothing powder layers. The most common thermal sources for PBF are lasers. PBF processes which utilize lasers are known as laser sintering (LS) machines. Since polymer laser sintering (pLS) machines and metal laser sintering (mLS) machines are significantly different from each other, we will address each separately. In addition, as electron beam and other thermal sources require significantly different machine architectures than laser sintering machines, non-laser thermal sources will be addressed separately from laser sources at the end[10]

In addition to the customization of geometrical features, laser PBF processes have the potential of producing lightweight or weight-optimized lattice structures with suitable mechanical properties and multi-material composition, with minimal material loss. Although the parts produced using laser-based AM approaches tend to have embedded pores, their densities can reach almost 100%, having mechanical properties equaling and at times exceeding those of conventionally manufactured counterparts.

II. LITERATURE SURVEY

Powder bed fusion process

The Powder Bed Fusion process includes the following commonly used printing techniques: Direct metal laser sintering (DMLS), Electron beam melting (EBM), Selective heat sintering (SHS), Selective laser melting (SLM), Selective laser sintering (SLS), and laser engineered net shaping(LENS). Powder bed fusion (PBF) methods use either a laser or electron beam to melt and fuse material powder together. Electron beam melting (EBM), methods require a vacuum but can be used with metals and alloys in the creation of functional parts. All PBF processes involve the spreading of the powder material over previous layers. There are different mechanisms to enable this, including a roller or a blade. A hopper or a reservoir below of aside the bed provides fresh material supply

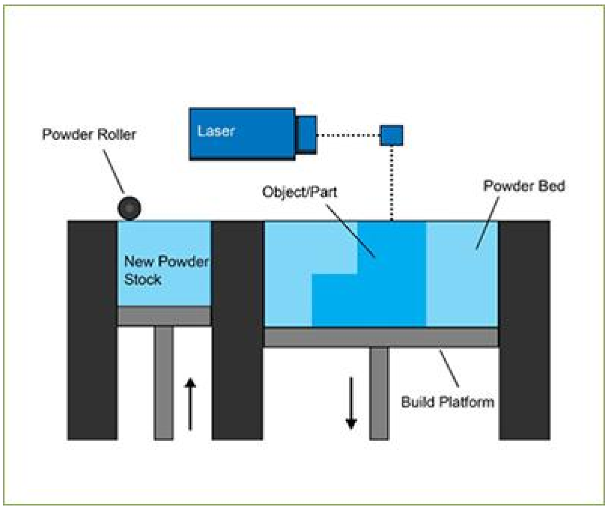


Fig (1)

Direct metal laser sintering (DMLS) is the same as SLS, but with the use of metals and not plastics. The process sinters the powder, layer by layer. Selective Heat Sintering differs from other processes by way of using a heated thermal print head to fuse powder material together. As before, layers are added with a roller in between fusion of layers. A platform lowers the model accordingly.

Selective laser sintering

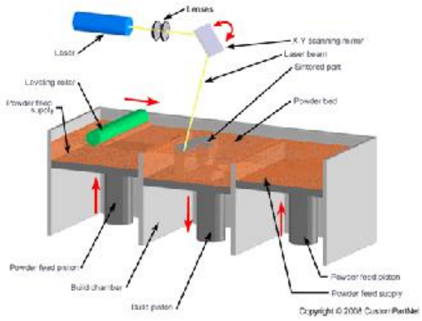
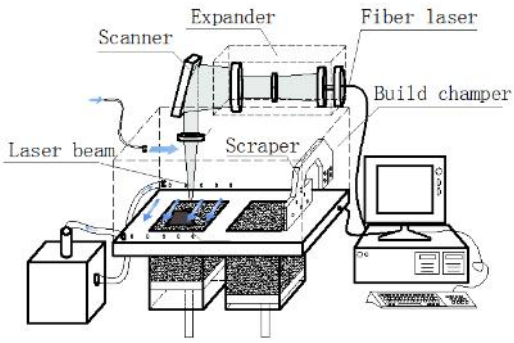


Fig (2)

(SLS) machines are made up of three components [10]: a heat source to fuse the material, a method to control this heat source and a mechanism to add new layers of material over the previous. The SLS process benefits from requiring no additional support structure, as the powder material provides adequate model support throughout the build process. The build platform is within a temperature controlled chamber, where the temperature is usually a few degrees below that of the material melting point, reducing the dependency of the laser to fuse layers together. The chamber is often filled with nitrogen to maximise oxidation and end quality of the model. Models require a cool down period to ensure a high tolerance and quality of fusion. Some machines monitor the temperature layer by layer and adapt the power and wattage of the laser respectively to improve quality.

Selective Laser Melting



Fig(3)

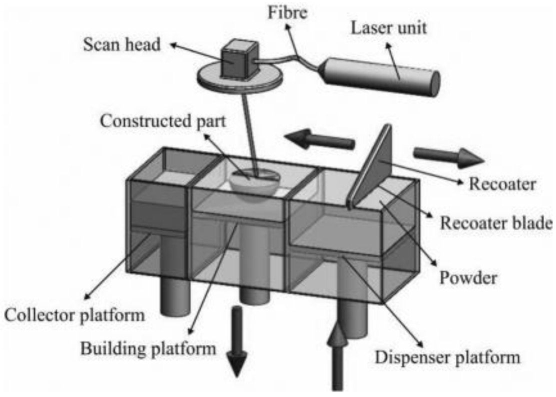
Selective laser melting (SLM) is one kind of additive manufacturing technologies, which makes it possible to manufacture metal components layer by layer according to a 3D-CAD volume model. The laser beam is controlled by industrial computer to melt metal powder. The melting tracks are obtained by moving the laser beam, and the layers are formed by joining the melting tracks. This technology overcomes the design limitations of traditional methods and avoids complex manufacturing process. The manufacturing cycle time of products can be shorten, and the parts with complex geometry can be manufactured rapidly. Compared to the conventional manufacturing methods, finer structures can be observed in the microstructure at very high cooling rate. Excellent mechanical properties can be obtained. Therefore, SLM is widely used in aerospace, automobile, medical treatment and industry applications. However, some of the parts directly manufactured by SLM cannot meet the requirements, so it is necessary to make heat treatment for more excellent comprehensive performance.[17]

(SLM) Compared to SLS, SLM is often faster [10], but requires the use of an inert gas, has higher energy costs and typically has a poor energy efficiency of 10 to 20 % [10]. The process uses either a roller or a blade to spread new layers of powder over previous layers. When a blade is sed, it is often vibrated to encourage a more even distribution of powder [10]. A hopper or a reservoir below or aside the bed provides a fresh material supply.

Selective heat sintering :

Selective Heat Sintering (SHS) uses a heated thermal printhead to fuse powder material together. As before, layers are added with a roller in between fusion of layers. The process is used in creating concept prototypes and less so structural components. The use of a thermal print head and not a laser benefits the process by reducing significantly the heat and power levels required. Thermoplastics powders are used and as before act as support material. The 'Blue printer' is a desktop 3D printer that uses the SHS technology, with a build chamber of 200mm x 160mm x 140mm, print speed of 2-3mm/hour and a layer thickness of 0.1mm (Blue Printer SHS , 2014).

Direct Metal Laser Sintering



Fig(4)

(DMLS) uses the same process as SLS, but with the use of metals and not plastic powders. The process sinters the powder, layer by layer and a range of engineering metals are available. In actual, The building process starts with the deposition of a layer of metal powder onto the building platform by means of a recoater blade. The laser beam melts the powder according to the slice geometry tracing the cross-section. Laser irradiation consists of three steps: first, the laser beam traces the contour of the section, then the inner (core) area is melted with parallel scan lines and, lastly, the contour is traced again. After irradiation, the platform is lowered by a vertical distance that is equal to the layer thickness, and the sequence is repeated until the part is completed. After the deposition of each new layer, the direction of the scan lines of the core area is rotated by 67 °. At the end of the building process, the platform with the part is subjected to a thermal treatment to relieve stress and the part is then removed from the platform[11] DMLS has many potential applications, including the production of functional prototypes, short-run component fabrication, and the fabrication of functionally-graded materials. It is particularly attractive for the fabrication of titanium aerospace components because it can greatly reduce the amount of raw materials required to produce a finished part, the lead time for production, and cost.[12]

Electron Beam Melting:

(EBM) Layers are fused using an electron beam to melt metal powders. EBM is another PBF based AM process in which electron beam is used to selectively fuse powder bed layer in vacuum chamber. It was commercialized by ARCAM from Sweden in 1997. Electron beam melting (EBM) process is similar to the SLM with the only

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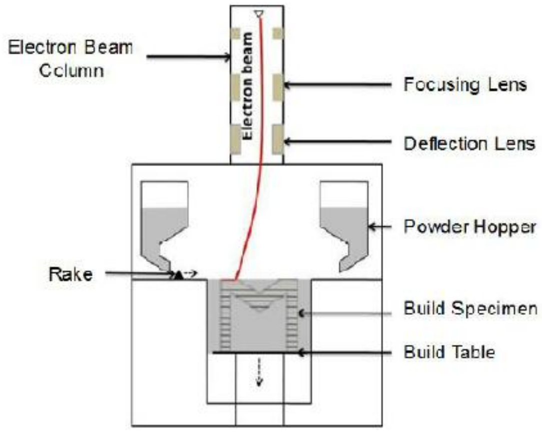
difference being its energy source used to fuse powder bed layers: here an electron beam is used instead of the laser.

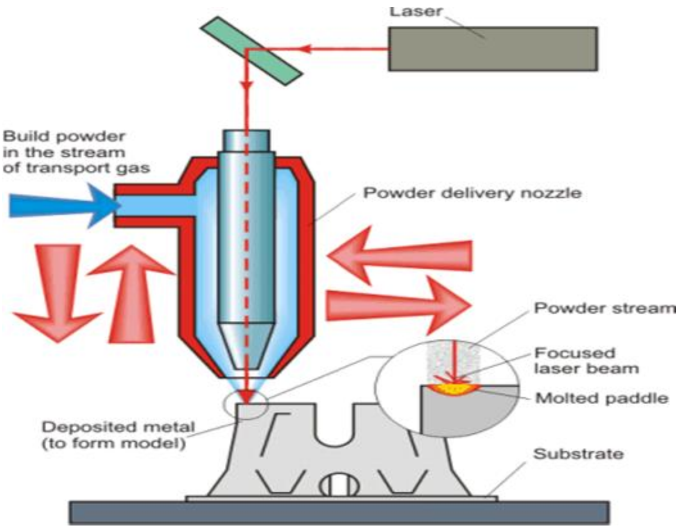


Fig(5)

In EBM, a heated tungsten filament emits electrons at high speed which are then controlled by two magnetic fields, focus coil and deflection coil as shown in Fig.5. Focus coil acts as a magnetic lens and focuses the beam into desired diameter up to 0.1 mm whereas deflection coil deflects the focused beam at required point to scan the layer of powder bed . When high speed electrons hit the powder bed, their kinetic energy gets converted into thermal energy which melts the powder . Each powder bed layer is scanned in two stages, the preheating stage and the melting stage. In preheating stage, a high current beam with a high scanning speed is used to preheat the powder layer (up to 0.4 - 0.6 Tm) in multiple passes. In melting stage, a low current beam with a low scanning speed is used to melt the powder . When scanning of one layer is completed, table is lowered, another powder layer is spread and the process repeats till required component is formed. The entire EBM process takes place under high vacuum of 10-4 to 10-5 mbar. The helium gas supply during the melting further reduces the vacuum pressure which allows part cooling and provides beam stability. It also has multi-beam feature which converts electron beam into several individual beams which can heat, sinter or melt powder bed layer [16]

Post processing requirements include removing excess powder and further cleaning and CNC work. One advantage and common aim of post processing is to increase the density and therefore the structural strength of a part. Liquid phase sintering is a method of melting the metal powder or powder combination in order to achieve homogenisation and a more continuous microstructure throughout the material, however, shrinking during the process must be accounted for Hot isostactic pressing is another method to increase density; a vacuum sealed chamber is used to exert high pressures and temperatures of the material. Although this is an effective technique to improve strength, the trade-off is a longer and more expensive build time.

Laser engineered net shaping:



LENS method can save more time and energy and can produce ceramic parts with higher purity, density, and better mechanical behavior. With properties of high power intensity, excellent stability, and easy controllability, laser is an outstanding heat source in direct deposition processes. Laser additive manufacturing (LAM) is the dominating method for additive manufacturing of ceramic. ceramic structures were manufactured from ZrO2/Al2O3 powders. Net-shaped structures of Al2O3 such as cylindrical and cubic structures are fabricated by LENS.Al2O3-ZrO2 eutectics are also successfully fabricated by LENS. Furthermore, LENS can be applied into coatings and remanufacturing.[11]. LENS produced Ti parts are able to provide properties comparable or even better than those fabricated by conventional methods in order to ensure their performance reliability and to enable the direct replacement of conventionally manufactured parts. As such, comparative studies of Ti materials produced by different additive manufacturing methods and against those manufactured by conventional methods are essential. This will help to understand the commonalities and differences among the various additive manufacturing technologies in terms of the influence of processing parameters and the mechanisms controlling deposition and solidification which are crucial to the production of high quality components.[12]

III CONCLUSION

1] Highest mechanical properties due to its martensitic phase composition and finer microstructure.

2] Melting and solidifying process at a single point happens in A very short periods of time, so stresses generation while solidification is less.

3]Two materials(hybrid) can be used for one object formation.

4] Three out of seven types are laser based so, laser plays important role in additive manufacturing

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