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# An Overview of Metal Additive Manufacturing Technologies

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**Abstract**

The possibility of production of complex parts with least material loss makes additive manufacturing attractive over traditional manufacturing practices. Additive Manufacturing enables producing complex objects with intricate shapes with light weight and improved functionality.

## 1. Introduction

The possibility of production of complex parts with least material loss makes additive manufacturing attractive over traditional manufacturing practices. Additive Manufacturing enables producing complex objects with intricate shapes with light weight and improved functionality [1]. Additive Manufacturing applications are renovated from rapid prototyping to producing functional parts. The applications of additive manufacturing spreads over different sectors like automobile industry, civil construction, aerospace, and bio-medical field [2].

The six steps of the metal additive manufacturing process consist of:

1. 3D Digital Model or CAD Model
2. STL File Conversion
3. Preprocessing machine calibration
4. Layer by Layer part building
5. Build Object Removal
6. Post-Processing

**Figure. 1. Demonstrate the workflow of additive manufacturing process [3].**

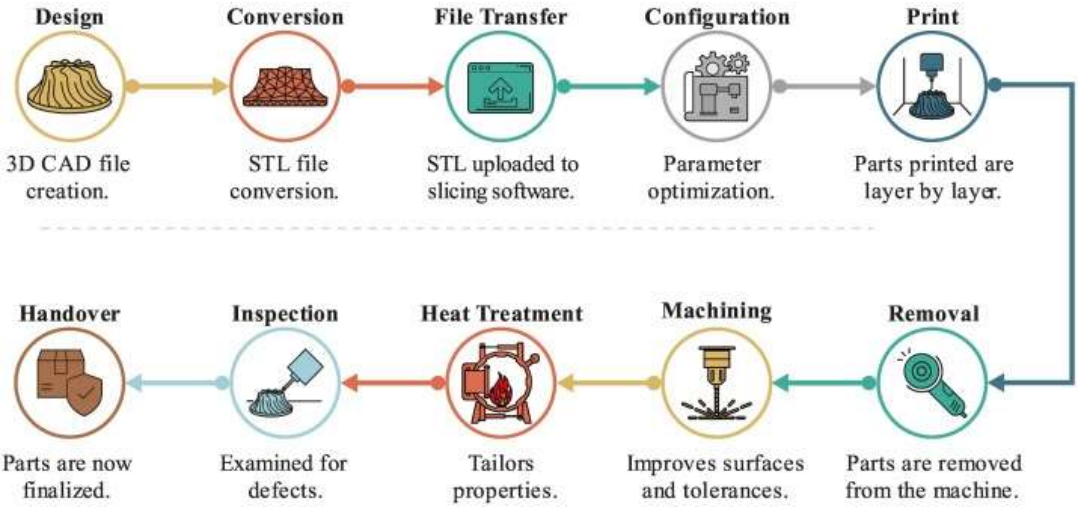


Figure (1) : Metal Additive manufacturing Process Flow

## 2. Metal Additive Manufacturing Methods

The ASTM classification of Additive Manufacturing systems suitable includes Powder Bed Fusion, Metal Extrusion, Material Jetting, Directed Energy deposition, Laminated Object Manufacturing and Metal Powder Binder Jetting, The classification of metal additive manufacturing methods based on feedstock form, Heat Source and Consolidation of material Fig(2).

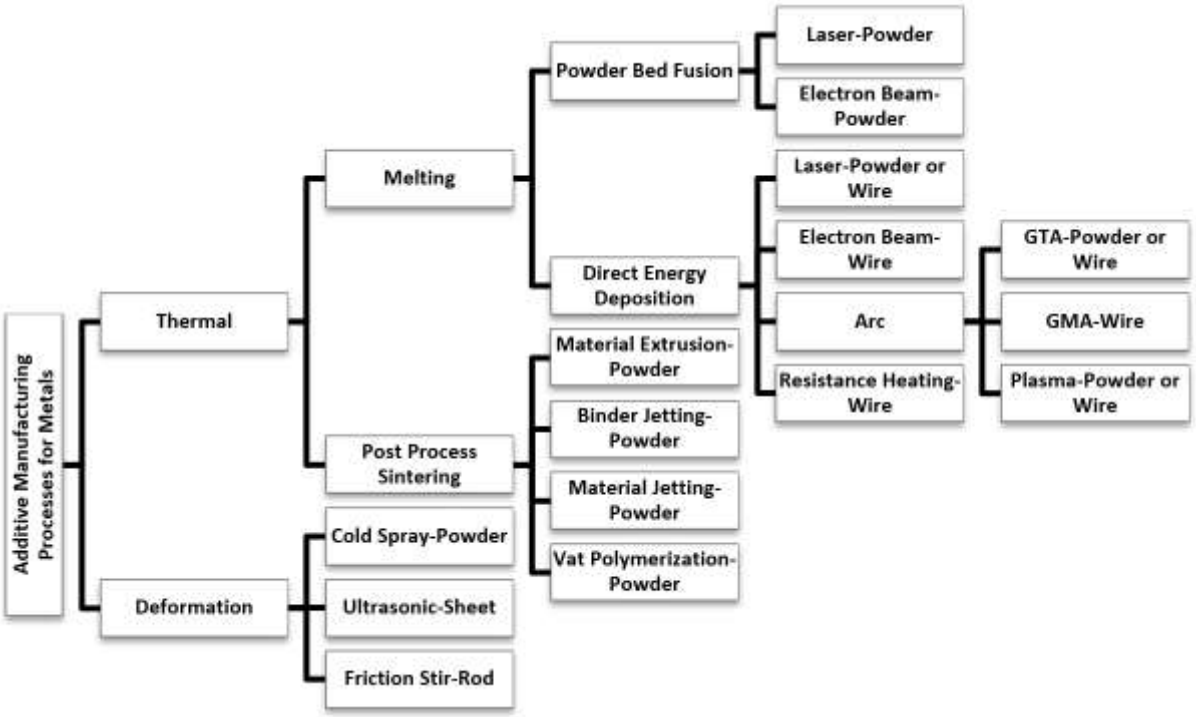


**Figure 2: Metal additive manufacturing processes**

### 2.1. Powder Bed Fusion

Based on the processes and material used additive manufacturing has 7 different methods. Among 7 methods, Powder bed fusion (PBF) is most prominent and useful method in Additive Manufacturing paradigm. In the powder bed fusion technique, heat source is used to melt the focused area of interest of metal powder. Metallic powder is completely or partially melt in different layers to form a 3D part [5]. Following Fig.3 shows the process of powder bed fusion:

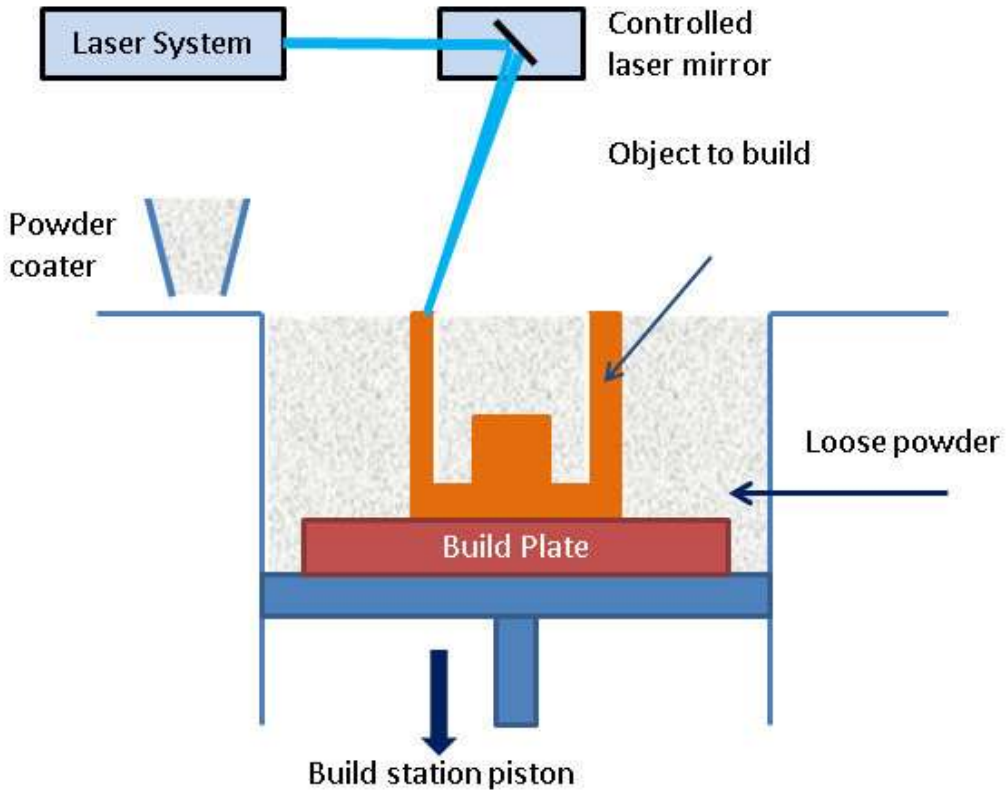


**Figure 3: Powder Bed Fusion Process**

### 2.2. Binder jetting

Binder jetting is an AM technique in which metallic powder material is spread in the form of a layer and selectively combined into the required layer form with a binder [6]. As the build advancements, the layers of the build part are joined together and form 3D shape of the desired part geometry. A diagram depicted the working of binder jet AM method is shown in Fig. 4.

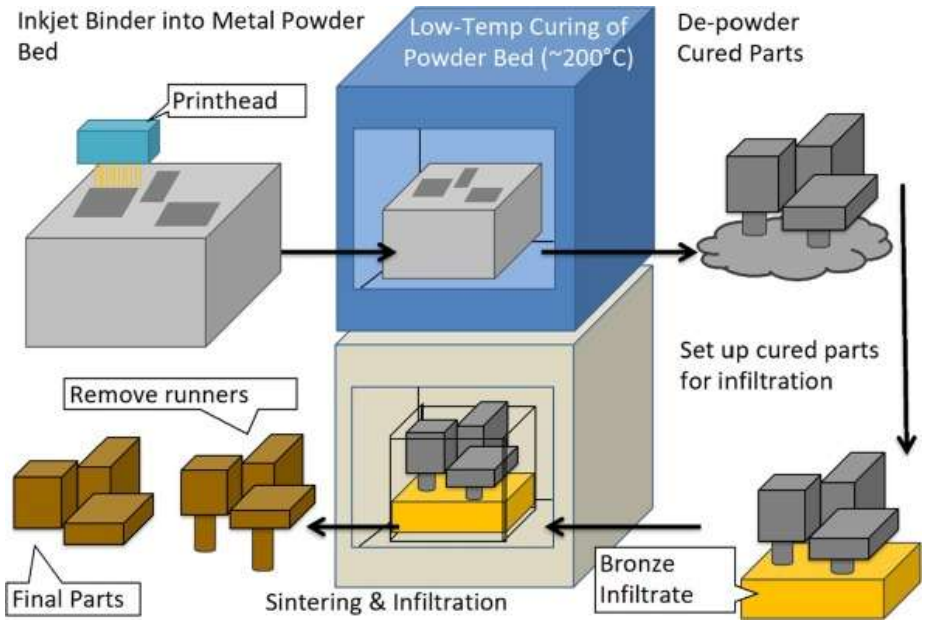


**Fig. 4. Illustration of binder jet 3D printing process**

### 2. 3. Directed energy deposition.

Direct Energy Deposition is an Additive Manufacturing technique that is vastly adapted for printing of various metal material like different grades of steels, Cobalt and nickel-based alloys, aluminium alloys, different composites, and functionally graded materials (FGMs) [7]. Direct Energy Deposition Process usages a high energy heat source pointed on the substrate, creating a melt pool, and at the same time melting the feedstock carried into the melt pool in wire or powder form(Fig. 5).

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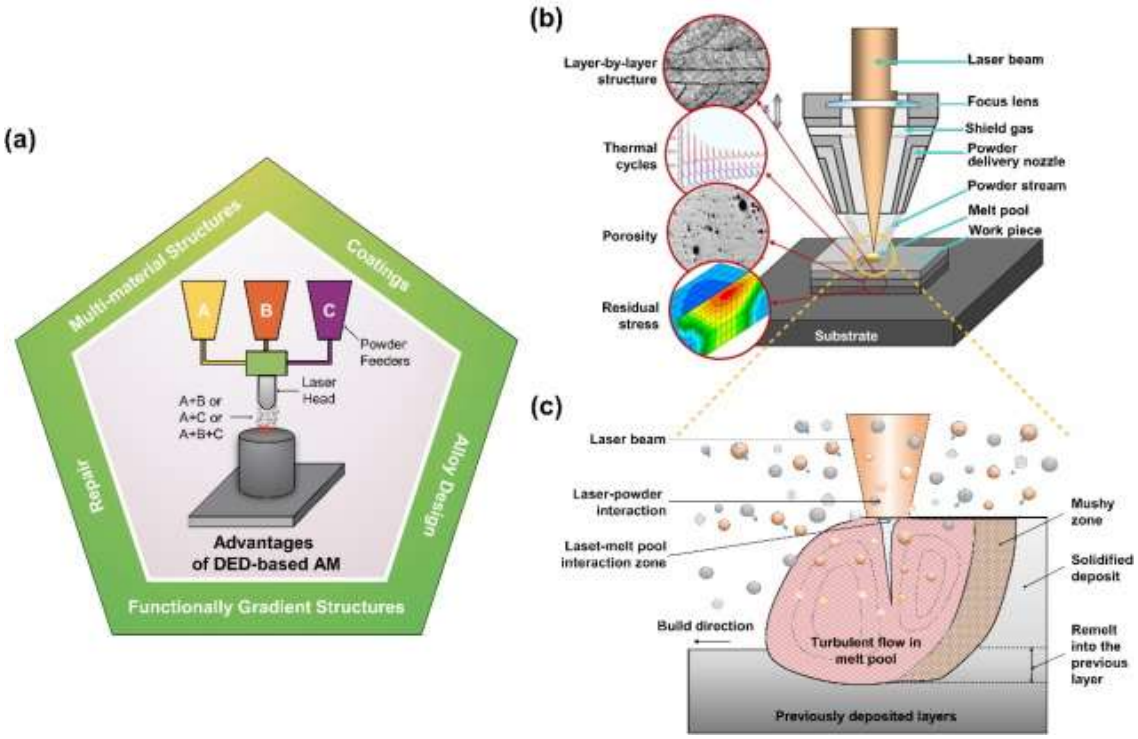


**Figure 5: Direct Energy Deposition**

### 2.4. Laminated object manufacturing (LOM)

The LOM method of additive manufacturing began with a metal sheet combined to a substrate with a roller and cut by a laser or a mechanical cutter as shown in Fig.6.

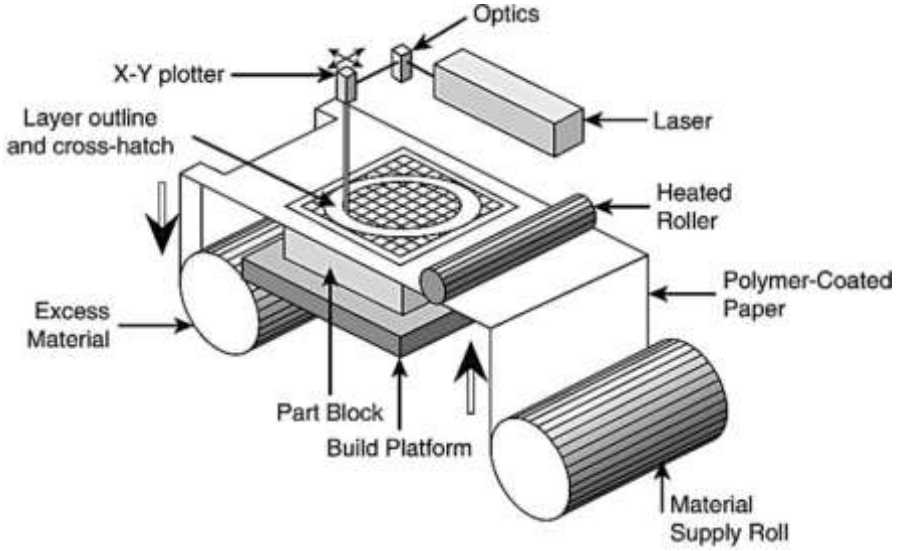


**Figure 6: Laminated Object Manufacturing**

### 2.5. Material Extrusion

In Metal Extrusion process, the material constituting of metal in powder form and binders of polymeric material is heated till the material is softened and can be easily extruded using a small diameter nozzle[9] as dipicted in Figure (7)

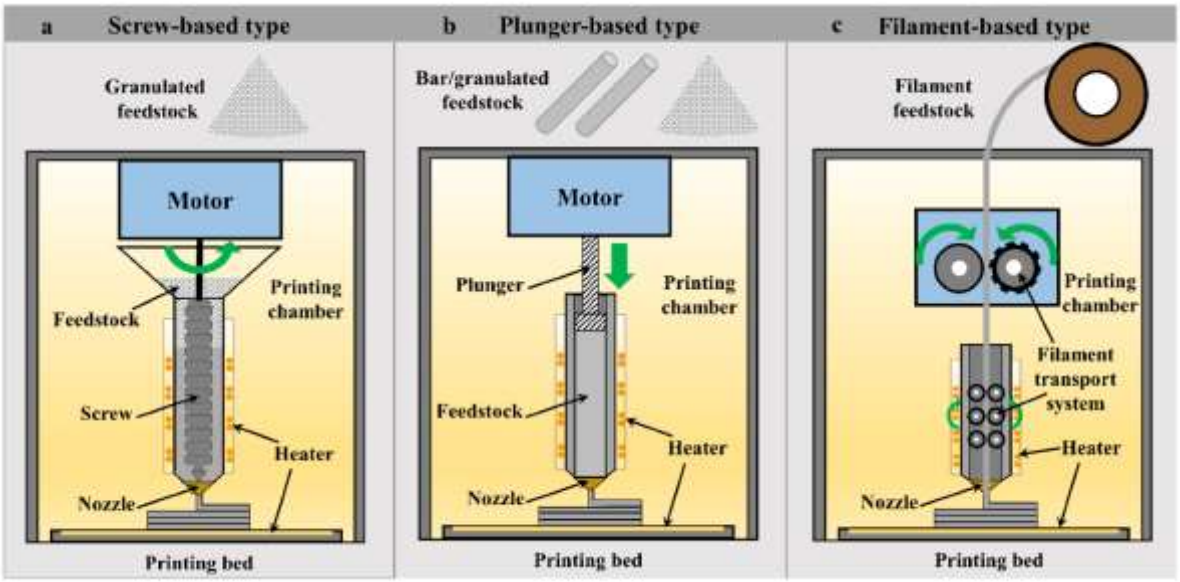


**Figure 7: Material Extrusion Process**

### 3. Applications of Metal additive manufacturing

Following are the main applications of the metal additive manufacturing [10]:

- Structures and Parts are very difficult to Manufactured using conventional Processes.
- Fast Manufacturing of hard materials
- Rapid Manufacturing of Non-Standard Parts
- Repair of Damaged Parts
- Manufacturing of Composite of heterogeneous Materials
- Lightweight Manufacturing Parts with Topology Optimization

### Conclusion

Metal additive manufacturing methods are comparatively new approaches that allow the creation of complex parts. In this review paper, Additive Manufacturing processes were classified based on their deposition techniques. Metal Additive Manufacturing provides substantial benefits over traditional manufacturing processes. However, metal additive manufacturing has limitations, such as high initial cost and defects like porosity.

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