Jupiter Publications Consortium

Vol. 2 Iss.3, pp. 16-21, 30th Nov, 2016
ISSN Print : 2454-1435 © 2016 IJRMMAE
ISSN Online : 2454-1443 © 2016 IJRMMAE
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International Journal of Research in Mechanical, Mechatronics and Automobile Engineering (IJRMMAE)

Additive Manufacturing – Challenges Ahead

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Received 25, November 2016 | Accepted 30, November 2016

Abstract : This article explores the development and application of additive manufacturing. Additive manufacturing is a breakthrough technology that represents the third largest industrial revolution in the current scenario. Additive manufacturing is being driven by the need for increased manufacturing efficiency of many engineering structures. This is a promising technology, which can provide many advantages over conventional subtractive methods due to its increased flexible design, dimensional accuracy, better product performance, lower manufacturing cost, less material waste and extended product life.

Keywords: Additive Manufacturing (AM), Stereolithography (SLA), Rapid Prototyping, Computer Aided Design (CAD, Fused Deposition Modeling (FDM)

1. Introduction

Additive manufacturing in the global market has great potential for use in the manufacturing of components with high geometric complexity and mechanical properties. Currently, this process is seen by manufacturers in several sectors, such as aeronautics, energy and biomedicine as a revolution in the manufacture of various components. Additive manufacturing involves the layered or layer-by-layer design of a component and subsequent welding deposition of the multilayer structure to produce parts without the need of moulds or other tools [1].

This technique is an evolution of rapid prototyping in the sense that it creates a physical product from a digital file, however its use goes beyond the production of prototypes. It is viewed as a transformative advancement because it enables distributed manufacturing and the production of parts on demand. The process begins with digital data that is created either on a Computer Aided Design (CAD) system or from 3D scanning an existing part. The digital data describes the geometric shape of the desired part. Then a software program is used to slice the design data into layers from which a tool path is produced that provides motion coordinates to the printer to produce the object.

2. 3D Printing

3D Printing creates physical products from a digital design file by joining or forming input substrate materials using a layer-upon-layer printing method as shown below in Fig.1. The use of 3D Printing is expected in the global market for hardware, suppliers and services [2] are given in Fig.2.

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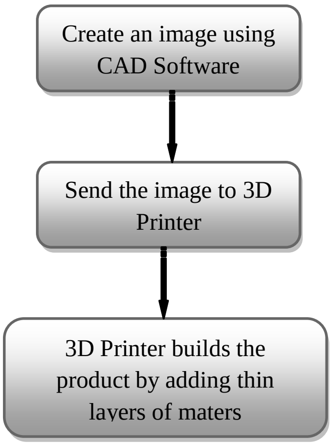

Fig.1 3D Printing

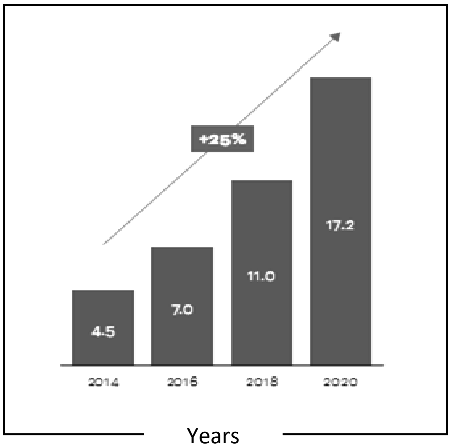

Fig.2 Expected use of 3D Printing

3. Stereolithography

Additive manufacturing technology first emerged in 1980s and mainly used to print plastic objects with a technique known as Stereolithography (SLA). This process shown in Fig. 3 is one of the most widely used rapid prototyping techniques for making plastic SLA models and begins with STL files created from a 3D CAD design.

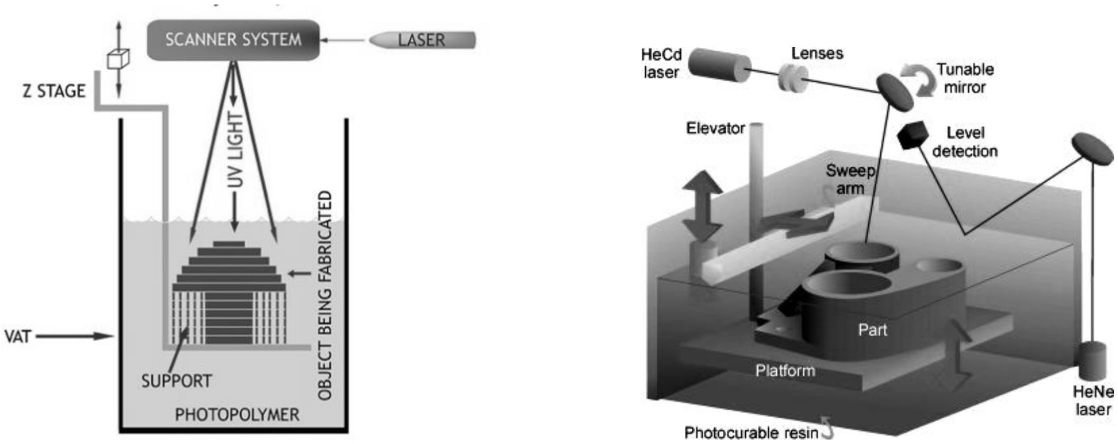

Fig. 3 Stereolithography

The SLA process is more suitable for creating SLA models with good surfaces and fine detailing which can be used to check 3D CAD models and for limited functional testing. The SLA model files are cut into thin horizontal slices and sent to a machine which performs the SLA process. In SLA an ultraviolet light beam is used to selectively cure a photosensitive polymer to build up a part layer by layer.

Later other processes for printing plastic objects emerged such as Fused Deposition Modeling (FDM). In FDM, a thermoplastic filament is extruded from a nozzle and heated to build up an object layer by layer. Laser-based additive manufacturing is another technique used to print metallic objects. The two most commonly known methods available for commercial use today are "*Powder Bed Fusion*" (PBF) and Powder Fed "*Directed Energy Deposition*" (DED) systems. PBF systems use the laser

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beam with a suitable power to selectively melt a bed of metallic powder layer by layer to build up the physical part. After the first layer is spread and sintered, the bed is filled again with a second layer of powder and selectively sintered. This process is repeated until the part is fully formed. The end result is buried in the powder cake and is not visible until the excess powder is removed.

4. Selective Laser Sintering [SLS]

This method uses a high-powered pulse laser to fuse the substrate into 3D shape by scanning across sections generated from a 3D digital description of the design or object. After each cross section is scanned, the powder bed is lowered by one layer of thickness, and then a new layer of material is applied which is shown in Fig.4. This step is repeated until the object is complete.

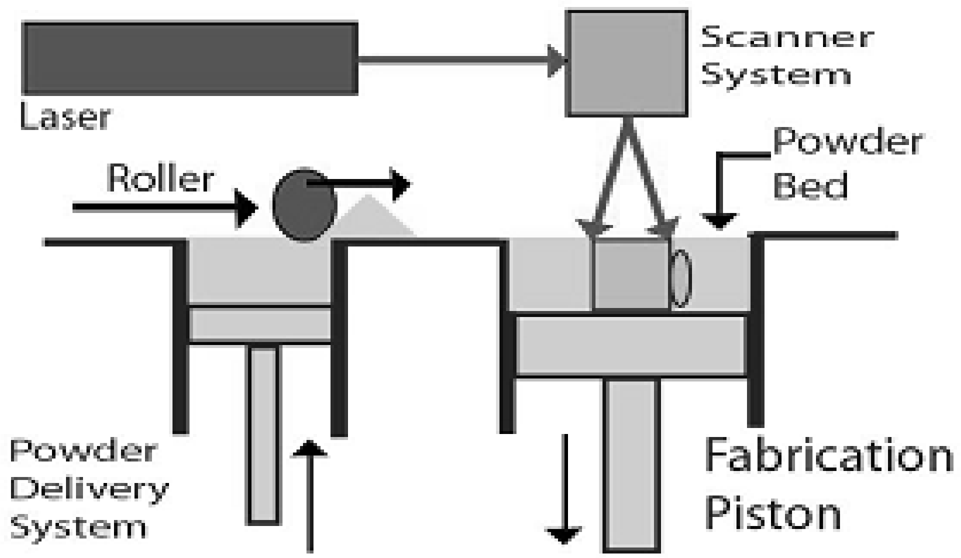

Fig.4 Selective Laser Sintering Process

5. Wire + Arc Additive Manufacturing (WAAM)

The application of welding or joining processes appears as an alternative to increase MA competitiveness. Using feedstock materials in the form of powder or wire also allow greater flexibility in the construction of components with gradient properties, thus allowing a faster evolution of the process. MA procedures are not a mere extrapolation of welding procedures, requiring strict parameter control for the successive deposition of multiple layers. The determination of a correct deposition sequence guarantees the control of the geometry of the component and has an impact on its properties, being in most cases a thermal treatment for the homogenization of the structure. Thus, it is necessary a greater understanding of the phenomena involved by the interaction of different materials in the additive manufacturing processes, in order to map the real possibilities of this process. Using electric arc as heat source and wire as feedstock has been investigated for AM purposes. WAAM hardware currently uses standard welding equipment such as welding power source, torches and wire feeding systems. The wire is the consumable electrode, and its co-axiality with the welding torch results in easier tool path. MIG is perfect for materials such as aluminum and steel and tungsten inert gas or plasma arc welding is currently used for titanium deposition. The simple setup is shown in Fig.5.

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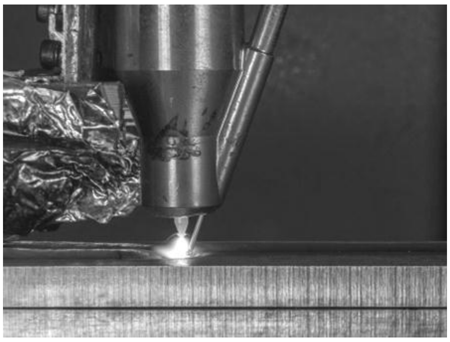

Fig.5 Wire + Arc Additive Manufacturing

4. Fused Deposition Modeling (FDM)

In additive manufacturing, Fused Deposition Modeling (FDM) is widely used with polymeric materials.

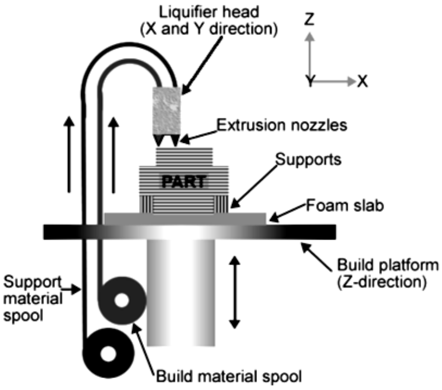

Fig. 6 Fused Deposition Modeling

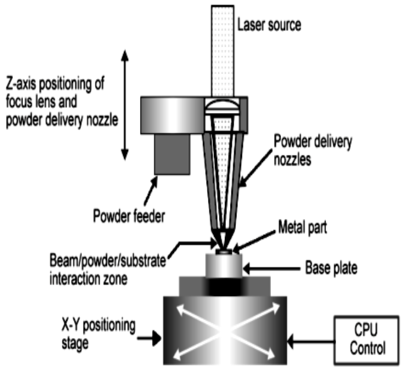

Fig.7 Laser Engineered Net Shaping

In this method, the material is extruded in building a part layer by layer from a CAD file. The FDM schematic is shown in Fig. 6. This technique also gives room for flexibility in design and this is undoubtedly beneficial for implant fabrication because implant size and shape can be tailored leading to the ability to produce patient specific implants.

5. Laser Engineered Net Shaping (LENS)

Laser engineered net shaping or LENS which is a technology developed by Sandia National Laboratories. Similarly to Electron Beam Melting, LENS is used for fabricating metal parts directly from a CAD solid model. The difference is that in LENS, the metal powder is injected into a molten pool which is created by a focused, high-powered laser beam. Fig. 7 is a schematic representation of LENS process [3]. All LENS deposits are metallurgically bonded and exhibit heat-affected zone (HAZ) and dilution zones ranging from 0.005 to 0.025 in. thick. Low heat input and minimal distortion are consistent deposit characteristics. Due to the small melt pool and high travel speeds, the deposits cool very fast (up to 10,000°C/s), which generates very fine grain structures.

6. Future Growth of AM

Technological advancements, newer applications, higher demand and increasing sales are the deciding factors for the future growth of AM [4]. World market for AM is continuously increasing as shown in Fig.8.

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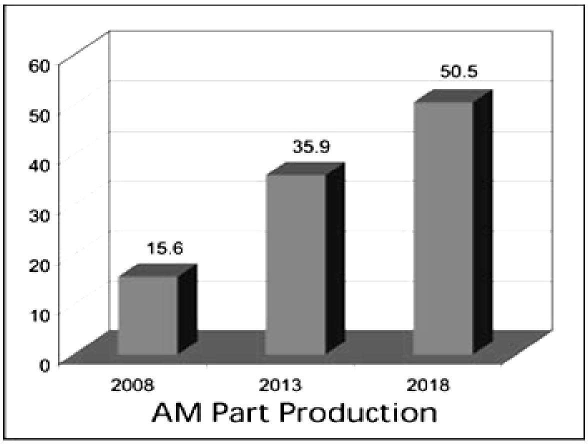

Fig. 8 World market for AM

.7. Benefits of Additive Manufacturing

- Lowers overall production costs by reducing costs of materials and assembly
- Reduces time to market with a digital process – no hard tooling required
- Enables more materials and feature size options
- Can Produce lighter weight structures with internal hidden cavities
- Increases design and manufacturing flexibility, reduces the number of processing steps
- Supports a full range of use models, from prototyping to repair/replacement to full production
- Integrates within traditional production environments
- Reduces environmental impacts

The other areas where AM has gained many advantages in comparison to conventional manufacturing technologies (e. g. milling). By using AM, it is possible to fabricate highly complex parts and hence this benefit can be used to produce customized parts (e. g. bone structures) or tooling inserts with conformal and form-fitting cooling channels. Besides the high geometric complexity, AM allows to assimilate any meltable material, e. g. metals, ceramics or composite powders [5]. Only singular approaches have been taken to make use of this flexibility [6].

Conclusion

- AM has gained a greater potential for the production of complex parts.
- Methods of additive manufacturing are creating new markets for complicated products.
- Parts with more features and accuracy can be manufactured.
- Aeronautical, medical, automobile and many other industries are moving towards additive manufacturing.

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