# Additive Manufacturing

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***Abstract:*** Additive manufacturing refers to a process by which 3D CAD data is used to construct an object in layers by depositing material. It may be regarded as a process whereby solid objects are constructed using additive techniques to lay down successive layers of a material until the object is completely made. It is the industrial version of 3-D printing, and it is growing at an incredible pace due to its potentially lower cost and flexibility.

This paper provides a brief introduction to additive manufacturing.

***Keywords:*** *Additive Manufacturing, 3D Printing, Rapid Prototyping, Direct Digital Manufacturing, Manufacturing Technology*

## I. INTRODUCTION

Today we are witnessing a trend towards miniaturization. As a result, there is an ever-increasing demand for miniaturized components. Additive manufacturing (AM) has emerged as a prototyping method. It is a new technology to automatically produce three dimensional (3D) objects by printing successive layering of material. It goes by other names such as free form fabrication, rapid prototyping (RP), 3D-printing, or direct digital manufacturing. It describes the technologies for building 3D objects by adding layer-upon-layer of material, and the material could be plastic, metal, concrete or. human tissue.

Additive manufacturing technology first emerged in the 1980s and was used to print plastic objects along with stereolithography (SLA). It enables cost efficient, rapid fabrication of complex components from material. The material could be supplied in the form of a powder or wire into a laser or electron beam, melted and then deposited selectively. Figure 1 illustrates additive manufacturing mapped on the four modern industry revolutions of production [1].

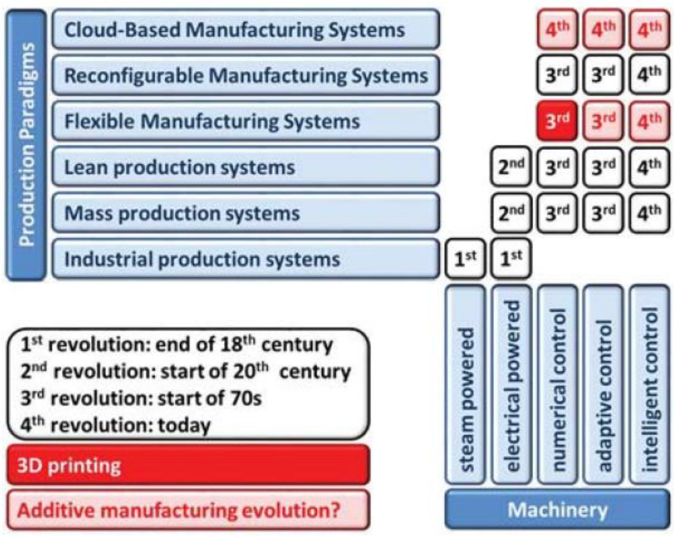


Figure 1 Additive manufacturing mapped on the evolution of production [1].

## II. HOW AM WORKS

AM technologies typically include a computer, 3D modeling software (Computer Aided Design or CAD), a machine and material. The AM machine reads in data from the CAD file and develops successive layers of the material in a layer-upon-layer manner to fabricate the desired 3D object. The process involves using a computer and CAD software to relay messages to the printer so that it "prints" in the desired object.

AM is a digitally driven manufacturing process. The AM technology consists of the following 5-step approach [2]: (1) spray forming, using spraying equipment which is similar to the ink jet printer; (2) laminated object manufacturing, which consists of a computer, raw materials stored and fed mechanism; (3) photosensitive polymer curing molding, which projects each layer image onto the liquid photosensitive polymer surface and solidifies every layer instantly; (4) materials extrusion molding, which builds the three-dimensional structure by means of accumulation, point to point line by line and layer by layer; and (5) laser powder sintering molding, which forms the required shape by bonding or fusing the powder material through thermal energy.

## III. APPLICATIONS

AM application is limitless. AM technologies have wide applications in industries such as automotive, aerospace, medical, food, and electronics [2],

- *Aerospace:* The automotive and aerospace industries are the two main beneficiaries of AM. AM technology is popular in aerospace/aviation industry because it can easily produce the lightweight and long-life components. In aerospace field, the rapid additive manufacturing of composites is currently the norm.
- *Medicine:* The main applications of AM technology in medicine include orthopedics, plastic surgery, tissue engineering, and regenerative medicine. AM is used for fabrication of orthopedic implants, biomaterials, tissues, and organs. AM can construct patient-matched implants. Advances in printable biomaterial and AM technologies allow the fabrication of vascularized tissue constructs.
- *Food Industry:* AM is being used in food industry for squeezing out food, layer by layer, into three-dimensional objects. This applies to a variety of foods such as candy, crackers, pasta, and pizza.
- *Electronics:* Aadditive manufacturing has been applied in fabricating active electronic components such as transistors, light-emitting diodes (LEDs), batteries, and operational amplifiers. (Transistors are important electronic components used in virtually all electronic devices.) These components usually require highly elaborate fabrication processes due to their complex functionalities [3]. Today AM is used for mass production of consumer electronics devices.

Other areas of application include fashion designing, passive microwave components. (Such as waveguides, couplers, power dividers, filters, and antennas), architectural design, weapons development, military, and civil engineering.

## IV. BENEFITS

Additive technologies differ from traditional manufacturing technologies. They have some advantages and disadvantages [4]. They are changing both how and what can be manufactured. Perhaps the most important benefit is their high design flexibility. The greater range of shapes which can be produced. AM enables a design-driven manufacturing process. It provides a high degree of design freedom, the manufacture of small shape sizes at reasonable unit costs.

The mission of additive manufacturing is to reduce the lead time and cost of developing prototypes of new components and devices. AM technology has made it easier and affordable for small companies and individuals to develop a customized prototype. AM enables companies to do what otherwise would be very difficult or impossible.

Additive manufacturing allows one to produce the objects without machining, lathing, milling, grinding, boring, casting or welding. AM has made objects that were very difficult or impossible to make with traditional manufacturing. The process is a faster way to make complex objects because the machines can run 24/7. Conventional methods such as injection molding can be less expensive for manufacturing polymer products, but additive manufacturing can be faster, more flexible, and less expensive.

Other benefits include green manufacturing, reduction in cycle time, speed to market, minimal material waster, enabling personalized manufacturing, decentralized production, capable of building virtually any shape, and mass customization.

## V. CHALLENGES

However, there are issues that need to be addressed in order to make AM technology applicable for large-scale production. From industry viewpoint, the following eighteen barriers have been identified [5]: education, cost, design, software, materials, traceability, machine constraints, in-process monitoring, mechanical properties, repeatability, scalability, validation, standards, quality, inspection, tolerances, finishing and sterilization.

The greatest obstacle in implementing AM is the high price of the equipment. Printing speed, quality, build space, and limitation in raw materials that can be used also resist implementation [6]. AM systems have only become useful for mass production to a limited extent. It is still challenging to use AM on a larger scale. Industrial robots are often used along with AM technologies for producing large components.

AM is a rapidly becoming a multibillion-dollar industry. This makes AM an attractive attack target. There is substantial concern for the security of the storage, transfer and execution of 3-D models across digital networks. As additive manufacturing technology evolves, so will the cyber security risk of tampering and misuse of designs. Security approaches for this emerging technology should be addressed before the technology becomes more widely adopted. This is important for intellectual property of designs [7,8]. The question of ownership and copying of original ideas has sparked considerable debate and interest. AM offers new opportunities for counterfeiting products. For this reason, the government has introduced difficult-to-duplicate materials and designs into currency [9].

The possibility of the rapid replication of highly sophisticated tools could vastly expand the number of persons able to commit violent acts or wage war. AM poses some ethical challenges for militaries and governments who are responsible for keeping war-making tools out of the wrong hands [10]. There is current lack in diversity of materials able to be processed using AM techniques. Other challenges include lack of industry standards, not suitable for mass production, and limited number of materials.

These shortcomings make AM several steps away from replacing current assembly lines of traditional manufacturing. As AM heads towards mass production, it needs to be environment-friendly and energy-efficient in order to be self-sustainable [11].

## CONCLUSION

Additive manufacturing is regarded as a layer-upon-layer manufacturing. Although additive manufacturing is still in its infancy, it has the potential to revolutionize manufacturing. It will take manufacturing to the next level. It will lead to home manufacturing. It has been introduced in many companies worldwide. It is receiving significant global attention. Some regard it as a game changer for the manufacturing industry.

The field of additive manufacturing has a bright future. For more information on the field, one should consult the books in [12-14] and other numerous books available on Amazon.com. One should also consult the following international journals exclusively devoted to additive manufacturing: *Additive Manufacturing, Progress in Additive Manufacturing*, and *Rapid Prototyping Journal*. These journals will help you stay on top of the exploding field of additive manufacturing.

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