Achieving Mass Customization Through Additive Manufacturing

R.M. Mahamood and E.T. Akinlabi

Abstract Mass customization aim to achieve customized product at a rate similar to mass production rate. Additive manufacturing (AM), an advanced manufacturing method, is capable of producing customized product, no matter the complexity simply, by adding materials layer after layer and building of the part in one unit. Unlike in traditional manufacturing process where a complex part needs to be broken down to smaller units and then assembled at a later stage, AM produces a complex part directly from the computer aided design (CAD) model of the part by adding materials in layers as against material removal in the traditional manufacturing process. Consumer product is moving from standardized product to customized product. For manufacturing companies to be able to keep up with this demand trend; there is a need for manufacturing process that deliver. This study looks at how AM can be used to achieve customized product with mass production efficiency.

Keywords Additive manufacturing · Advanced manufacturing · Mass customization · Traditional manufacturing

1 Introduction

Consumer demand is greatly moving away from standardized product to highly customized product [1]. The cost of producing customized product is higher when compared to standardized products that are manufactured through mass production. To remain competitive company must be able to meet this demand at competitive price. Mass customization is the answer to this. Mass customization was first

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proposed by Stan Davis [2]. He thought of how customized products could be manufactured at a cost achievable in mass production. This is not only possible but achievable and can also surpass the conventional mass production through the use of new manufacturing and communication technologies while also satisfying the exact requirement of the customer at no additional cost [3]. The main aim of mass customization is to deliver products that are meant to satisfy individual customer's needs while still keeping the near-mass production efficiency [4]. The key feature of mass customization is the capability to integrate the product varieties derived from the individual customer's needs and desire and the efficiency of mass production, so that the product is affordable due to low product cost achievable through mass production. In this competitive manufacturing world, for companies to survive and continue to be able to meet consumers' demands, they must be able to deliver the required product promptly and at competitive price. To be able to achieve this aim, there is need for manufacturing process that is able to produce customized components within short period of time and at lower price too. The candidate manufacturing process is additive manufacturing (AM) technology [5]. Additive manufacturing process is an advanced manufacturing technology that can produce highly complex parts directly from the computer aided design (CAD) model of the required part by adding materials layer after layer until the building of the part is completed [6, 7]. This means that more than one components can be produce simultaneously just by sending the CAD model of the desired parts to the AM machine at the same time.

In this competitive manufacturing world, consumers now demand more customized products and at competitive prices, additive manufacturing is the manufacturing technology that is able to satisfy this demand due to the following advantages offered by this technology: It reduces component lead time, material wastage [8], cost, and above all, energy usage that in turns reduce the carbon footprint [5]. Additively manufactured components are lighter in weight as a result of elimination of additional materials used in fastening, joining and coupling of parts. Light weight parts also consume less energy especially in the automobile and aerospace industry. In addition, AM technology has the potential to enable novel product designs that could be difficult or unable to be fabricated by the traditional manufacturing processes. AM technology can also be used to extend the life of in-service parts through the innovative repair that were prohibitive in the past [9]. The next sections briefly review different types of manufacturing processes and how additive manufacturing technology can be used to produce customized product with mass production efficiency.

2 Traditional Manufacturing Processes

For the purpose of this research work, manufacturing processes are subdivided into three major parts namely: Subtractive manufacturing, formative manufacturing, and additive manufacturing.

2.1 Subtractive Manufacturing Process

Subtractive manufacturing process is a traditional manufacturing process of shaping components that involves material removal [10]. This manufacturing technology starts the manufacturing process with a single block of material that is larger than the final size of the desired part. This block of material is gradually removed using fabrication processes (machining processes) such as milling, turning, drilling, planning, sawing grinding, EDM, laser cutting and water jet cutting until the desired shape is achieved. Different stages are involved in this type of manufacturing process and the products are designed based on the ease of manufacturing.

2.2 Formative Manufacturing Process

Formative manufacturing process is a traditional manufacturing process that shapes component through compression/consolidation process. In this manufacturing process, components are made with application of pressure. These processes include: forging, pressing and bending. This manufacturing process is energy intensive as subtractive manufacturing processes. A lot of material, time and energy are wasted in these traditional manufacturing processes [11]. A large part of these energies are wasted for scrap disposal which makes the overall cost of production to be very high [5]. A major drawback of these traditional manufacturing processes is the high lead time involved in the introduction of new product from concept, prototype, to final introduction of the product to the market. With the increase in demand for customized products, these traditional manufacturing processes cannot deliver on the promise of mass customization. Hence, there is a need for an improved manufacturing process that is able to offset some, if not all of the drawbacks of the traditional manufacturing processes. To remain competitive in this highly dynamic environment, there is need for flexible manufacturing system (FMS) which will be able to cope with the constantly changing consumer demand as well as manufacturing process that will be able to reduce the lead time required for introduction of new product and also keeping the material usage on a low side. The promising manufacturing process is additive manufacturing [12, 13].

3 Additive Manufacturing Process for Mass Customization

Additive manufacturing process is an additive manufacturing process in which a material is added layer by layer to form the desired object. The objects are produced directly from the digital image of the desired object. AM process is referred to as 3D printing [14] and it promises to change the entire way we design and manufacture products. Additive manufacturing is capable of producing parts with complex geometry and highly sophisticated, at low production cost because there is no need for expensive tooling which make it possible to manufacture part in large quantity without additional cost. The benefit of AM technology include: the ability to shortening the supply chain, the ability to reduce material wastage, the ability to achieve mass customization, short time of production, the ability to redesign product or optimize design even during the production process which is not possible in the traditional manufacturing process. All these benefits contribute to the economy of the AM technology. Additive manufacturing is achieved by simply adding materials layer-upon-layer. The process starts by using three dimensional (3D) Computer Aided Design (CAD) software, to produce a digital image of the desired part. The CAD model of the part is sent to the additive manufacturing machine, where the CAD model is sliced into hundreds of two dimensional (2D) cross sectional geometries depending on the building orientation to be used. After the slicing process, the additive manufacturing machine then follow the paths dictated by this 2D geometries to deposit or fuse the materials along its path. This process is repeated in succession thereby adding the materials layer after layer until the building process is completed [5]. The building process simply follow the 3D model of the path with no mold or tooling required, jigs and fixtures are not required to hold the work in place, and no manual process is required [15]. Any additive machine can produce any CAD data loaded on it so this offer flexibility for designer. That is the part are design based on the desired functionality and not base on the ease of manufacturing which is the practice in the traditional manufacturing process. This will also offer the manufacturer the new opportunities to recreate the CAD model of all the needed customized product as a single CAD file and send to the additive manufacturing machine. The machine will build all the products simultaneously therefore achieving the mass production of these customized products. This unique opportunity will not only make possible the mass customization of products but also simplify the supply chain system. This will undoubtedly revolutionize the manufacturing system as there will be less man contact and less error which will in turn reduce the overall production cost. The competitiveness of AM technology for mass customization cannot be overemphasized, when compared with the traditional manufacturing process, for example, when a new product is to be manufactured using the traditional manufacturing method: new mold needs to be created and for different customized products different mold is required. The mold may become useless after the production of the part since it is one of its kind product. Additive manufacturing process on the other hand does involve the use of molds or tooling to produce different products. It only requires the CAD data of the part to be produced and the machine just build the part by adding materials layer after layer. Mass customization is the ability to create customized products with mass production efficiency, production time and production cost. Additive manufacturing can leave up to this promise because different customized product can be built simultaneously no matter the complexity. Since Consumer are now consistently demanding new, unique, cheap and quality products and customers satisfaction lies with the ability of a manufacturer fulfilling these needs then the candidate manufacturing process that can fulfill these demands is additive manufacturing process. The AM process has the ability to produce each consumer desires at the rate at which standardized product are manufactured. The urge to buy customized cars is on the increase but the cost of these cars is very high when produced using the traditional manufacturing process. The automobile manufacturers can have a competitive advantage by using AM process to manufacture customer unique custom cars. A number of customers can be satisfied within a short period of time because different designs can be built simultaneously which is not possible using the traditional manufacturing route. And the cost of producing this cars will be cheaper because the customizations are achieved at no extra cost, this is because it will not require the new molds thereby, the lowering cost and saving materials. Also in the medical industry where custom medical implants are required (individuals are different). AM is now being used for the creation of these implants e.g. Hearing aids. In the past these hearing aids were produced manually and only one piece can be made at a time by skilled technician. Additive manufacturing can be used to produce a number of hearing aids for different people at the same time thereby reducing the cost of production. It is also possible to mass produce custom dentures using AM process. AM does not require the creation of new molds for various customized products, and items can also be produced where need, then, it reduces the lead time and the cost of production is also greatly reduced. Another important advantage of using AM technology is the weight saving and low material usage achieved during the manufacturing process. Close to the exact raw materials needed are used up and parts can be made in a single piece no matter the complexity. The extra weight gotten from joining or assembly of smaller parts produced through the traditional manufacturing route are absent in the additive manufacturing process. A large amount of material is saved because less material is used, and a higher throughput is [14]. The light weight product achieved through additive manufacturing process also has a great influence on the fuel consumption and carbon footprint in automobile and aerospace industries. Additive manufacturing is the manufacturing process for future products and it will leave up to the expectation in fulfilling the need by the current trend of mass customization.

4 Conclusion

The use of additive manufacturing to achieve mass customization has been presented in the paper. There are many potential benefits that could be achieved using the AM process for mass customization. It can give industries competitive advantage over their counterpart by producing individualized product at mass production rate and cost. The industries that can immediately benefit from this technology include medical, dental, automobile, and aerospace industries. These are industries in which mass customization are needed because of different consumers demanding individualized products, Also light-weight parts are of importance in automobile and aerospace industries because it reduces fuel consumption, this will also shortens the supply chain. The traditional manufacturing technologies cannot compete with AM technology when it comes to one of its kind product which are now being demanded in various forms and in large number because AM does not require molds or tooling to manufacture products. Hence AM can deliver this products at lower prices.

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