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ADVANCED MANUFACTURING TECHNOLOGY

Raja Vamsi Chidella
Middle Tennessee State University
Affiliated by Association of Public and Land-Grant Universities and
Oak Ridge Associated Universities

S.Rama Rao
Associate Professor, Narasaraopeta Engineering College
Narasaraopet, A.P, India

Abstract:

Mechanical engineers have traditionally designed parts by setting selecting a material with best known properties based on how it was processed and heat treated and they create the shape they want. With additive manufacturing, the process is reversed. They print the shape they want and then relieve stress, heat treat, and age or anneal the part until they get the material they want. The process sounds simple but not. The thermal cycling that 3-D printed metallic parts see during the layer-by-layer melting and fusion process, be it by laser or electronic beam, has a huge influence on the micro structure, which in turn affects the material properties. So, the engineers had designed and engineered for specific strength and mechanical properties is not necessarily the part or it may be, depending on how it was made and post-processed. Companies are currently treating each part as a "one-off," which equates to extensive testing and verification for each part made by additive manufacturing, which is neither cost effective nor an efficient use of resources. The 3-D printing of metals would be easy as Advanced Manufacturing (AM) is rewriting the rules of how to design, make, and quality parts, and 3-D metal printing needs all the help it can get from Mechanical engineers. Production of high variety of products introduces complexities in the quality processes involved in a manufacturing system. Previous methods of quality assurance and control are not sufficient to manage the quality characteristics that are significant to each customer. This paper seeks to a method of holistically managing product quality in a manufacturing environment with high customer input and product variety. The development of a reconfigurable inspection apparatus is discussed as a technological requirement for performing the quality control aspect of the management system. In this paper the findings of the design/ methodology approach, research limitations/implications, and practical implications are discussed.

Introduction

Additive manufacturing processes take the information from a computer-aided design (CAD) file that is later converted to a stereo lithography (STL) file. In this process, the drawing made in the CAD software is approximated by triangles and sliced containing the information of each layer that is going to be printed. It is transforming the practice of medicine and making work easier for architects. In this paper, I will go through different advanced additive manufacturing processes like 3-D printing systems such as rapid prototyping, stereo lithography, STL file, 3DP, fused deposition modelling, prometal, selective laser sintering, electron beam melting, laser engineered net shaping, laminated object manufacturing, and polyjet. Coming to the quality management system, the required flow of information for an advanced quality management system was proposed and compared to the information flow in a traditional quality management system. There is a shift in previous production strategies due to customers' products and service without having to pay the full cost currently associated with customisation.

Manufacturers now have to satisfy a wide spectrum of smaller niche markets as opposed to satisfying a single broad market, which requires manufacturers to produce a higher bandwidth products in an advanced manufacturing environment (AME). The manufacturing of a product has always involved consideration of the quality requirements of that product. 3-D printing of metals is a process full of unknowns, mechanical engineers can fill in many of the gaps. 3-D printing metals supports anchoring the part to build plate must be removed by cutting, grinding, and other labour-intensive processes. Polymer 3D printing systems can use supports to counteract gravity and to ensure a successful build, but polymer supports are water soluble and easy to remove.

Rapid Prototyping:

The first form of creating layer by layer a three dimensional object using computer aided design was rapid prototyping, developed in 1980's fro creating models and prototype parts. It allows for the creation of printed parts, not just models. Among the major advances this process presented to product development are the time and cost reduction, human interaction and consequently the product development cycle [1], also the possibility to create almost any shape that could be very difficult to machine. The steps involved in product development using rapid prototyping are shown in Figure 1.

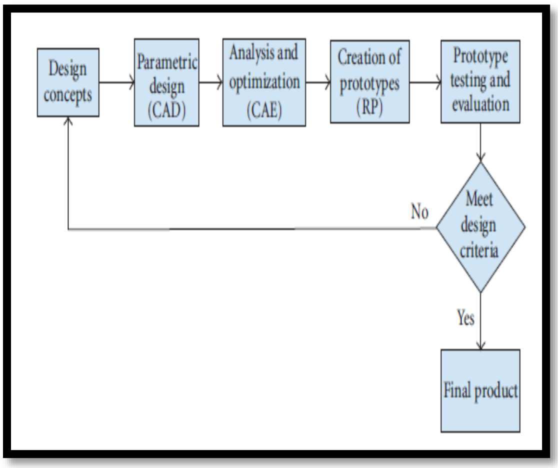

FIGURE 1: Product development cycle

Here, it can be seen that creating models faster save a lot of time and there is the possibility of testing more models. With rapid prototyping, scientists and students can rapidly build and analyse models for theoretical comprehension and studies. At present time, the technologies of rapid prototyping are not just used for creating models, with the advantages in plastic materials it has been possible to create finished products, of course at the beginning they were developed to expand the situations tested in the prototyping process. Now a days, these technologies have names like 3-D printing, and so forth, but all have the origins of rapid prototyping.

Stereo lithography:

Stereo lithography (SL), developed by 3-D Systems, Inc., was the first, and is most widely used process of rapid prototyping. This is a liquid based process that consists in the curing or solidification of a photosensitive polymer when an ultraviolet laser makes contact with the resin. The process starts with a model in CAD software and then it is translated to a STL file in which the pieces are "cut in slices" containing the information for each layer. The thickness of each layer as well as the resolution depends on the equipment used. A platform is built to anchor the piece and supporting the overhanging structures. Then the UV laser is applied to the resin solidifying specific locations of each layer. When the layer is finished the platform is lowered and finally when the process is done the excess is drained and can be reused. A newer version of this process has been developed with a higher resolution and is called micro-stereo lithography.

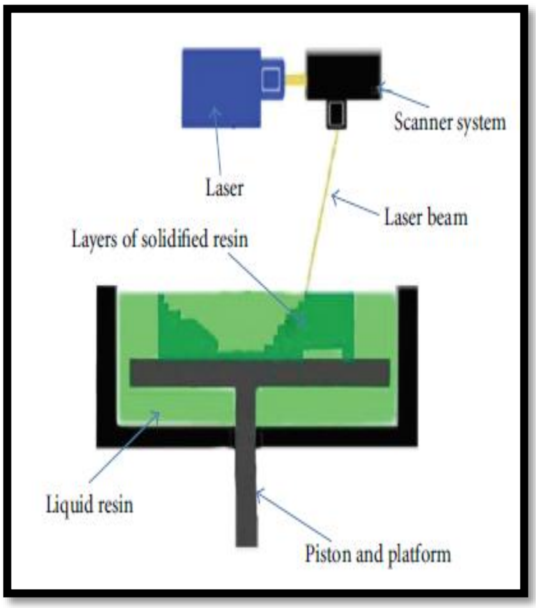

FIGURE 2: Stereo lithography

The basic principle of this process is the photo polymerization, which is the process where a liquid monomer or a polymer converts into a solidified polymer by applying ultraviolet light which acts as a catalyst for the reactions. This process is also called ultraviolet curing.

The STL File:

The STL file was created in 1987 by 3-D Systems Inc. when the stereo lithography was developed first and the STL file stands for this term. It is also called Standard Tessellation Language. The STL file creation process mainly converts the continuous geometry in the CAD file into a header, small triangles, or coordinates of triplet list of (x, y, z) coordinates and the normal vector to the triangles. The data flow in STL file creation is shown in FIGURE 3.

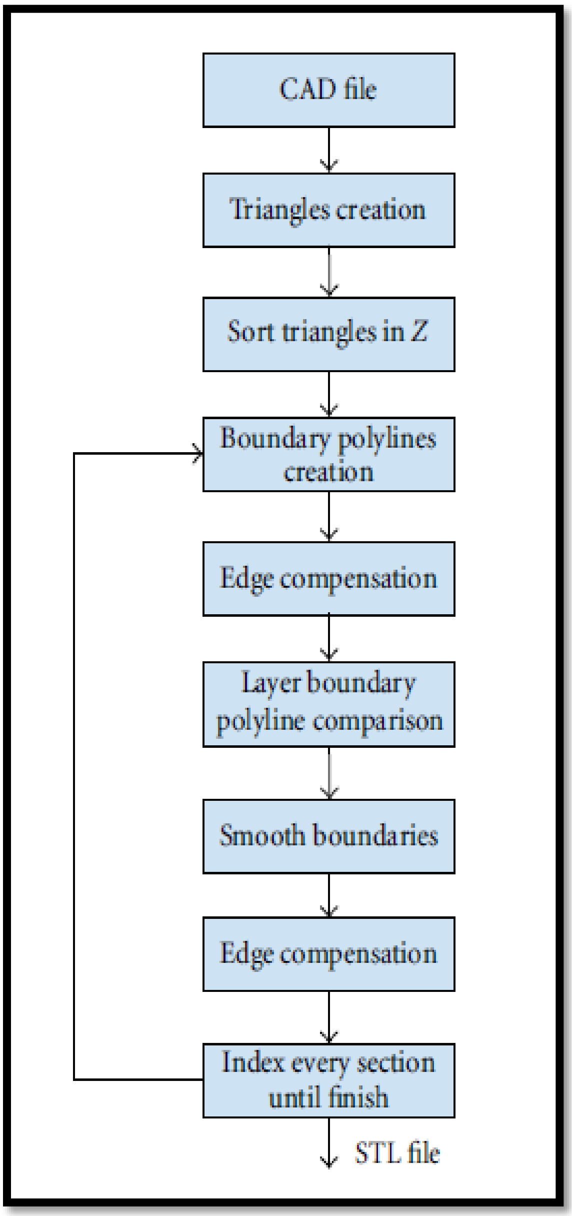

FIGURE 3: Data flow in STL file creation

3DP:

3DP process is a MIT-licensed process in which water-based liquid blinder is supplied in a jet into a starch-based powder to print the data from a CAD drawing. The powder particles lie in a powder bed and they are glued together when the blinder is jetted. This process is called 3DP because of the similarity with the inkjet printing process that is used for two dimensional printing in paper. This process can handle a high variety of polymers.

Fused Deposition Modeling:

Fused deposition modeling (FDM) is an additive manufacturing process in which a thin filament of plastic feeds a machine where a print head melts it and extrude it in a thickness typically of 0.25mm. Materials used in this process are polycarbonate (PC), acrylonitrile butadiene styrene (ABS), polyphenylsulfone (PPSF), PC-ABS blends, and PC-ISO which is a medical grade PC. The main advantages of this process are that no chemical post-processing required, no resins to cure, less expensive machine, and materials resulting in a more cost effective process.

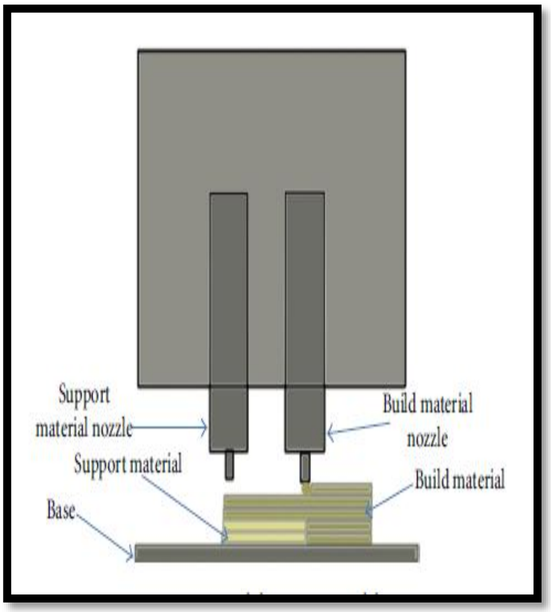

FIGURE 4: Fused deposition modeling

Prometal:

Prometal is a three dimensional printing process to build injection tools and dies. This is a power-based process in which stainless steel is used. The printing process occurs when a liquid blender is spurt out in jets to steel powder. It is located in a powder bed that is controlled by build pistons that lowers the bed when each layer is finished and a feed position that supply the material for each layer. After finishing, the residual powder must be removed. When building a mold no post processing is required. If a functional part is being built, sintering, infiltration, and finishing processes are required.

Selective Laser Sintering:

Selective Laser Sintering is a three dimensional printing process in which a powder is sintered or fuses by the application of a carbon dioxide laser beam. The chamber is heated to almost the melting point of the material. The laser fused powder at a specific location for each layer specified by the design. The particles lie loosely in a bed, which is controlled by a piston, that is lowered the same amount of the layer thickness each time a layer is finished. This process is also called direct metal laser sintering.

Electronic Beam Melting:

A process similar to SLS is electron beam melting (EBM). This process is relatively new but growing rapidly. In this process what melts the powder is an electronic laser beam powered by a high voltage, typically 30 to 60 KV. The process takes place in a high vacuum chamber to avoid oxidation issues because it is intended for building metal parts. One of the future uses of this process is the manufacturing in outer space, since it is all done in a high vacuum chamber.

Laser Engineered Net Shaping:

In this additive manufacturing process, a part is built by melting metal powder that is injected into a specific location. It becomes molten with the use of a high-powered laser beam. The material solidifies when it is cooled down. The process occurs in a closed chamber with an argon atmosphere. This process permits the use of a high variety of metals and combination of them like stainless steel, nickel-based alloys, titanium-6, and so forth. This process is also used to repair parts that by other processes will be impossible or more expensive to do.

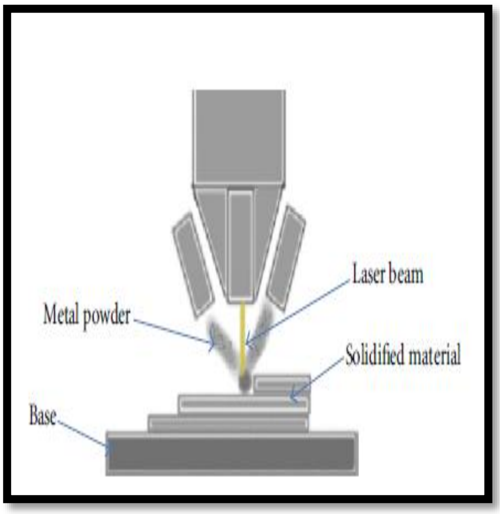

FIGURE 5: Laser engineered net shaping

Laminated Object Manufacturing:

This is a process that combines additive and subtractive techniques to build a part layer by layer. In this process the materials come in sheet form. The layers are bonded together by pressure and heat application and using a thermal adhesive coating. A carbon dioxide laser cuts the material to the shape of each layer given the information of the 3D model from the CAD and STL file. This process can be used for models with papers, composites, and metals.

Polyjet:

This is an additive manufacturing process that uses inkjet technologies to manufacture physical models. The inkjet head moves in the x and y axes depositing a photopolymer which is cured by ultraviolet lamps after each layer is finished. A gel-type polymer is used for supporting the overhang features and after the process is finished this material is water jetted. With this process, parts of multiple colors can be built.

Modern quality requirements:

The mass customization has been researched for more than a decade and is considered, as a manufacturing strategy that aims to satisfy the individual needs of customers at near mass efficiencies. The requirements that have been identified as the consequences of implanting in an advanced manufacturing environment that operates on mass customization and reconfigurable manufacturing systems principles are

- Customers have individual quality requirements of products.
- Customers dictate hierarchy of significant product features.
- Assurance of individualized product functionalities.
- Quality in supply.
- Customized quality at relatively low costs.

The use of a product is considered and is assumed to have a production layout that is comprised of a fixed sequence of reconfigurable machines. The traditional and proposed flows of quality information are shown in FIGURE 6. The process blocks with rounded edges and information blocks coloured in green indicate customer domain and direct consequences of quality information between the two lied in the ability of the customer to dictate product functionalities, constraints and desired outcomes as opposed to generalized product design performed by company employees. The included customer interface lower down the quality information stream on the right awarded the customer more control over the product.

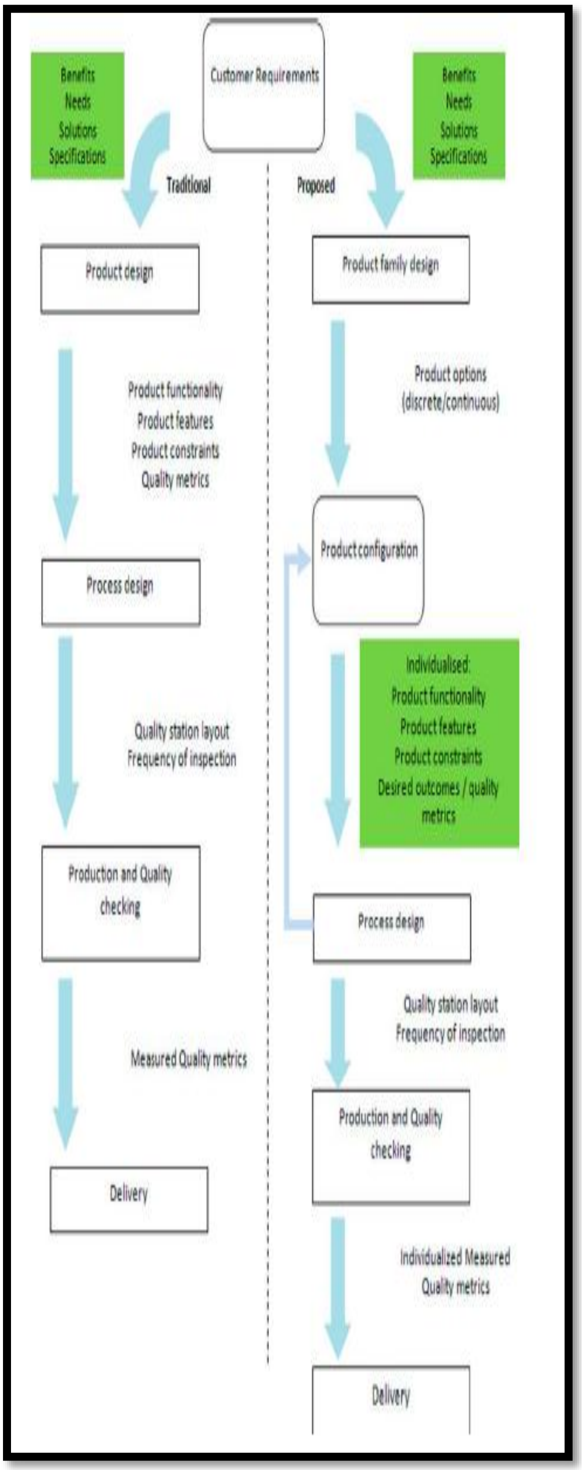

FIGURE 6: Flow of quality information in proposed manufacturing system.

Applications

- With additive manufacturing printing technologies like selective laser sintering or electron beam melting, hollow structures, which are less expensive than a solid one, can be made since less material is used.
- Stereo lithography is a process very suitable for the architectural modeling because of the materials used and the printing resolution.
- Additive manufacturing is a very good tool for dentists because they can easily build a plaster model of patient's mouth or replace te teeth, which have a unique form with process like stereo lithography, selective laser sintering and electron beam melting.

Studies have been made to analyse the properties of the product in each process. The specimens in the building direction and perpendicular to the building direction are tested and found very little influence in building direction in 3DP but an enormous influence in LOM. FIGURE 7 is a comparison of the strength for LOM, Polyjet, SL, SLS, FDM, and 3DP.

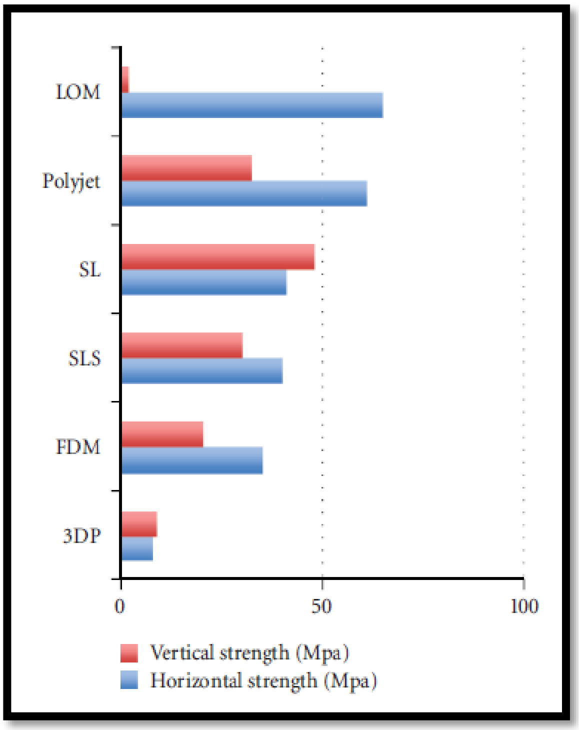

FIGURE 7: Tensile strength of 3-D printing process

Conclusion

The paper discusses the early versions of additive manufacturing for making fast prototypes that was initiated by the necessity of speeding the process in model development and shortening the time between product development and market placement. Additive manufacturing processes take the information from a CAD file that is later converted to an STL file. The continuous and increasing growth experience since the early days and the successful results up to date, there is optimism that additive manufacturing has a

Significant place in the future of manufacturing. Additive manufacturing is transforming the practice of medicine, now it is possible to have a precise model of bone before a surgery and the possibility of creating an accurate transplant, no matter how complex its form is. It is making work easier for architects, who now can print the 3D models of whatever complex shape for a civil project they have in mind. The accuracy needs improvement to eliminate the necessity of a finishing process and to be able to produce parts that require the highest levels of precision.

References

1. Beaman, J., & Lopez, F. (2014). EMERGING NEXUS OF CYBER, MODELING, AND ESTIMATION IN ADVANCED MANUFACTURING: VACUUM ARC REMELTING TO 3D PRINTING. *Mechanical Engineering, 136*(12), S8-S15.
2. Crawford, M. (2015). ADDING UP. *Mechanical Engineering, 137*(7), 22-23.
3. Davrajh, S., & Bright, G. (2013). Advanced quality management system for product families in mass customization and reconfigurable manufacturing. *Assembly Automation, 33*(2), 127-138.
4. Simpson, T. W. (2015). AM needs MEs. *Mechanical Engineering, 137*(8), 30-35.
5. Wong, K. V., & Hernandez, A. (2012). A review of additive manufacturing. *ISRN Mechanical Engineering, 2012*.
6. ADVANCED MANUFACTURING. (2013). *Mechanical Engineering, 135*(9), 82-83.