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Additive and Subtractive Manufacturing: A Review

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Abstract—*Global competition in manufacturing field, cost saving and new product design has led to need of new technologies to improve business processes.*
Traditional machining processes base on the theme controlled material removal called as subtractive manufacturing. There are some applications in growing world where traditional method of machining become impractical and uneconomical. Rapid prototyping is the emerging nontraditional method of machining. In additive process is the exact reverse process in which materials are manipulated so that they are successfully combined to form the desired product.The rise of rapid prototyping has spurred progress in traditional subtractive methods. High material removal rates translate into shortbuild times. For certain applications, particularly metals, machining will continue to be a useful manufacturing process. Rapid prototyping will not make machining obsolete, but rather complement it. A natural extension of RP is rapid manufacturing directly from the CAD data. RM will never completely replace other manufacturing techniques, especially in large production runs where mass-production is more economical. For short production runs, however, RM is much cheaper, since it does not require tooling.
Additive manufacturing typically does not require large amounts of time to remove unwanted material, so it reduces time and costs, and has the ability to create parts that could not have been produced by subtractive manufacturing processes. Efforts currently are underway to advance additive manufacturing processes into high-volume production methods thereby competing directly with traditional manufacturing processes.
The present paper is an integrated review of different new trend manufacturing technologies. In the broad context of entire industries, their relationship is complementary*. Each method has its own advantages over the other. While additive manufacturing methods can produce very intricate prototype designs impossible to replicate by machining, strength and material selection may be limited. The additive process can be very helpful in design stage.*

1. INTRODUCTION

Global competition in manufacturing field, cost saving and new product design has led to need of new technologies to improve business processes.

Before the industrial revolution of the 18th century, hand tools were used for the production of goods such as cooking utensils. Machine tools came in existence after the advent of the steam engine for producing material from power-driven machines. These were the indispensable innovations that mademass production and interchangeable parts realities in the 19th century. By the end of the 19th century a complete revolution had taken place in the working and shaping of metals that created the basis for mass production and an industrialized society. Numerous refinements of machine tools, such as multiple-point cutters for milling machines, the development of automated operations governed by electronic and fluid-control systems, and nonconventional techniques, such as electrochemical and ultrasonic machining were introduced in 20thcentury [1].

When people hear the word "machining" they generally think of the many processes that have this common theme, controlled material removal using shear as primary method. These are today collectively known as subtractive manufacturing, in which, one starts with a single block of solid material larger than the final size of desired object and portions of the material are removed until the desired shape is reached. These include most of the machining processes CNC, milling, grinding, turning, drilling laser cutting. The category of nontraditional machining covers a broad range of technologies. These machining methods generally have higher energy requirements and slower throughputs than traditional machining, but have been developed for applications where traditional machining methods were uneconomical. Nontraditional machining can be thought of as operations that do not use shear as their primary source of energy. These machine tools were developed primarily to shape the ultra-hard alloys used in heavy industry and ultrathin materials used in such electronic devices as microprocessors [2]. In distinction from processes of controlled material addition, which are known as additive process is the exact reverse process in that the end product is much larger than the material when it started. Materials are manipulated so that they are successfully combined to form the desired product. This includes rapid prototyping technique. Rapid prototyping (RP) has emerged as a time compression technology, with its ability to shorten product design and development time.

The term “Rapid Prototyping” refers to a class of additive technologies that can automatically construct physical models from computer-Aided Design data (CAD)[3].Rapid prototyping has brought a revolution in the manufacturing world in the way manufacturers design and build products. By using faster computers, more complex control systems, and improved materials, RP manufacturers are dramatically reducing build time increasing the speed and accuracy of machining. The rise of rapid prototyping has spurred progress in traditional subtractive methods. Modern CNC machining centers can have spindle speeds of up to 100,000 RPM, with correspondingly fast feed rates. Such high material removal rates translate into short build times. For certain applications, particularly metals, machining will continue to be a useful manufacturing process. Rapid prototyping will not make machining obsolete, but rather complement it. A natural extension of RP is rapid manufacturing directly from the CAD data. RM will never completely replace other manufacturing techniques, especially in large production runs where mass-production is more economical [4].

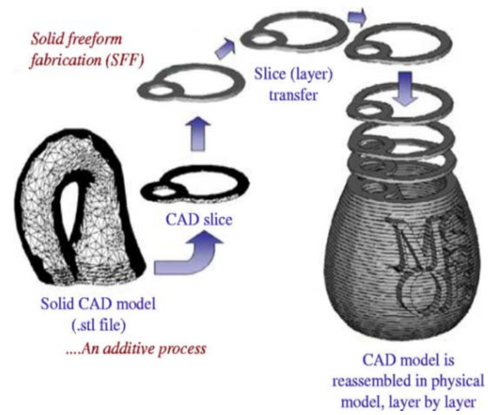
2. ADDITIVE MANUFACTURING: ADVENT STEP

Instead of removing material from a solid block additive manufacturing provides more accurate professional production technique in which components are built by using layer by layer material. Different range of metals, plastics and composite materials may be used. Additive manufacturing is now being used in series production for customer benefits, cost saving potential and the ability to meet sustainability goals. Additive Manufacturing allows for highly complex structures which can still be extremely light and stable. The system starts by applying a thin layer of the powder material to the building platform at exactly the points defined by the CAD data. The platform is then lowered and another layer of powder is applied at the predefined points. Depending on the material used, components can be manufactured using stereo lithography, laser sintering or 3D printing. EOS Additive Manufacturing Technology based on laser sintering has been in existence for over 20 years [5].

The primary applications of additive fabrication are design, fit and function prototyping, and direct part production. Around the world, AM is changing the way organizations design and manufacture products. It can be used to save impressive amounts of time and money by using correct method of additive prototyping. AM has helped to trim time from months to week while avoiding costly errors and enhancing product quality.

According to wohlers 2012 Additive manufacturing will become the most important, most strategic and most used technology ever which led to less material scrap, faster, cheaper and better [6]-[7].

By Stratasys CEO Scott Crump, Electron beam melting (EBM) has been catching on particularly well in the market for medical implant manufacturing.AM provides the tool to stay competitive in manufacturing[8].



By Materialize, Additive manufacturing has been focused in creation of a better and healthier world. Efforts currently are underway to advance direct digital manufacturing processes into high-volume production methods thereby competing directly with traditional manufacturing processes [9].

3. DIFFERENT ADDITIVE TECHNIQUES

Few important processes namely Stereo lithography (SL), Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM), Laminated Object Manufacturing (LOM) and Polyjet are described.

3.1. Stereo lithography

Stereo lithography is an additive manufacturing process which employs a vat of liquid ultraviolet curable photopolymer resinand an ultraviolet laser to build parts layers one at a time and traces a cross-section of the part pattern on each layer and exposure to the ultraviolet laser solidifies the pattern traced on the resin and joins it to the layer below, then SLA's elevator platform descends by a distance equal to the thickness of a single layer, typically 0.05 mm to 0.15 mm.Then, a resin-filled blade sweeps across the cross section of the part, re-coating it with fresh material and three dimensional part is completed by this process. This part is immersed in a chemical bath in order to be cleaned of excess resin and subsequently cured in an ultraviolet oven.

3.2. Selective Laser Sintering

In Selective Laser Sintering (SLS) process, fine polymeric powder like polystyrene, polycarbonate or polyamide etc. is spread on the substrate using a roller. Before starting CO2 laser scanning for sintering of a slice the temperature of the entire bed is raised just below its melting point by infrared heating in order to minimize thermal distortion (curling) and facilitate fusion to the previous layer. The laser is modulated in such a way that only those grains, which are in direct contact with the beam, are affected. Once laser scanning cures a slice, bed is lowered and powder feed chamber is raised so that a covering of powder can be spread evenly over the build area by counter rotating roller. In this process support structures are not required [10].

3.3. Fused Deposition Modeling

FDM begins with a software process mathematically slicing and orienting the model for the build process. If required, support structures may be generated. And part is produced by extruding small beads of thermoplastic material from a coil through heated nozzle at a controlled rate. This process led to form layers as the material hardens immediately after extrusion. Nozzle movement is controlled by CAM (Computer-aided manufacturing) and movement of extrusion head is controlled by stepper motor[11].

3.4. Laminated Object Manufacturing

Laminated Object Manufacture (LOM) cuts the component slices from thin layers of material using a CO_2 laser mounted on a 2D plotter. The system most commonly uses sheets of paper stacked on top of another automatically and bonded together using an adhesive. The parts of the sheet outside the model provide support. These unwanted areas are marked with intersecting lines, which forms cubes that can be broken away from the model once complete. Cheaper materials like paper can be used. Speed is 5-10 times greater than other RP processes. Large amount of scrap is formed. There remains danger of fire hazards and drops of the molten materials formed during the cutting also need to be removed [12].

3.5 Polyjet

Polyjet inkjet technology patented by Materialize-The Factory for 3D printing in 2011.It works by jetting state-of-the-art photopolymer material in ultrathin layers of just 16μ onto a build tray layer by layer until the part is completed and each layer is cured by UV light after material is jetted from the nozzle. Software manages the whole process. The gel like material is used as support material. This technology enables fine details and ultra-thin walls down to 0.6 mm so that they are able to make complex parts and parts made of different materials [13].

4. RELATIONSHIP OF SUBTRACTIVE ANDADDITIVE TECHNIQUES

Traditional machining based on controlled material removal rate has been classified in thought as subtractive manufacturing method because of recent propagation in additive manufacturing technologies .In narrow contexts, additive and subtractive methods may compete with each other. In the broad context of entire industries, their relationship is complementary. Each method has its own advantages over the other. While additive manufacturing methods can produce very intricate prototype designs impossible to replicate by machining, strength and material selection may be limited [14].

4.1. How and When to Choose Between Additive and Subtractive Prototyping

Selection criterion of correct method of prototyping techniquebetween rapid prototyping (additive) and (subtractive) CNC can be made by Dan mishek on the basis of product delivery, material ,tolerance ,cost ,quantity of product, and desired needs of product whether its speed, function or a specific material [15]. Different parameters considered by Dan mishek in selection of appropriate technique:

- **Speed**

Additive is best for speed priority. Additive process is not limited to design issues or complexities: SLA, Polyjet1, FDM and SLS technologies can all produce parts consistently between one to four working days depending on the size of part.CNC deliveries typically take seven to 12 working days from releasing CAD data to freed up the machine based on available materials, complex geometries, number of setups and current workload.

- **Function**

Tensile strength, robustness and impact strength are considered for the function priority. In the additive corner, FDM and SLS are the two main contenders offers special material in ABS, PC, PPSF and an ABS/PC blend and GF Nylon powder blend. These materials can be very strong and tested to be proved out for production. These materials will fall a little short compared directly to a subtractive due to the fact that these parts are built layer upon layer, which can create weak points in the material.CNC provides the most function because it is not limited to just ABS or polycarbonate. It can machine Delrin, Peek, Ultem, GF Nylon and metals.

- **Tolerance**

Among the additive processes there are certain processes that are more precise than others. These additive processes can also vary in build layers from .0006" to .010" .The CNC process can really hold any tolerance within reason if print is provided that's not required in SLA or FDM.

- **Budget**

Typically, additive process will be more cost effective for one to five quantities. Initial programming, setup and fixturing require too much cost in machining for small quantities and unit price drops for large quantities. CNC then lends itself to be a more cost-effective process .Budget for technique includes the cost for technology, human programming and material cost.

- **Quantity**

Easier and faster programming and lesser cost for all purpose CNC machining are new emerging factors involved in subtractive world. Due to this CNC world has become more competitive in lower volume as well as in higher volumes.

Additive world having better material, faster machines and dropped unit price.. A new additive machine direct digital manufacturing (DDM)—whose niche is low volume, low cosmetic, functional parts. Multiple materials can be run on a new RP machine without tooling.

5. SUMMARY

This paper provides an integrated view of additive and subtractive manufacturing in broad context of entire industries. It emphasizes on selection of correct method of manufacturing resulting into improved business processes. Classification of different additive techniques and detail of various manufacturing technique has been given since industrial revolution. An attempt has been tried to make by Dan mishek to select correct method between additive and subtractive manufacturing by considering some parameters. Finally, with the waters muddying between additive and subtractive processes, it is wise to be open to both methods. They both can work and both will surely help to revolutionize manufacturing world.

REFERENCES

[1] www.britannica.com/EBchecked/topic/354662/machine-tool
[2] www.engineershandbook.com/MfgMethods/nontraditionalmachining.htm
[3] **Pandey "**Rapid Prototyping Technologies, Applications and Part Deposition Planning"
[4] **D.V. Mahindru, PriyankaMahendru (2013) "**Review of Rapid Prototyping-Technology for the Future" Global Journal of Computer Science and Technology Graphics & Vision.
[5] www.eos.info/additive_manufacturing/for_technology_interested
[6] blog.cafefoundation.org/additive-manufacturing-for-electric-motors
[7] **Chad Duty (2013)** web.ornl.gov/adm/partnerships/events/2013.../6_Duty_2013BTG.**pdf**
[8] americanmachinist.com/technology-trends/additive-manufacturing-advances-another-step
[9] www.materialise.com/glossary/additive-manufacturing
[10] **Chua, C.K., Leong, K.F., Kai, C.C. (1998)"**Rapid Prototyping Principles and Applications in Manufacturing"John Wiley and Sons (New York).
[11] en.wikipedia.org/wiki/Fused_deposition_modeling
[12] www.azom.com/article.aspx?ArticleID=1650
[13] manufacturing.materialise.com/polyjet
[14] en.wikipedia.org/wiki/Machining
[15] **Dan mishek"**How and When to Choose Between Additive and Subtractive Prototyping"