Design & Development of 3D Components Manufacturing System using Waste Paper

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Abstract - *The market for Additive manufacturing is constantly growing in everything from the automotive industry to ceramics. However the biggest part is still in more traditional areas like prototyping using plastics. While 3D printing do bring advantages such as being faster and less wasteful than traditional manufacturing, also making it easier to produce on demand. The problem is that the majority of print material used is still plastic, which is one of the most harmful materials for the environment. This became apparent for us as well, thus we wondered why there isn't more sustainable materials for 3D printing. This has led us to study a method to print with waste paper. The Paper Printer is the 3D printer which uses waste paper to replace plastic. Generally the market of materials is growing and there are other alternative materials you can choose from for your prints. However most of others still hybrid materials using PLA as a base. At the early stage we crossed path with 3D modeling and additive manufacturing. Through this process, we noticed the worrying amount of plastic being used in the process and started searching for a more sustainable material to replace it. As the amount of paper waste per person is at around 80 kg yearly, we decided to study with this wasteful and hugely used material.*

Key Words: Layer, Rapid prototyping, SDL, SLS, STL.

1. INTRODUCTION

3D printers have been with us for decades, routinely turning 3D computer designs into detailed physical objects for product design, education, architecture, healthcare, mapping, historic preservation and other applications. These devices create models in a range of materials, including plastic, plaster, photopolymers, metal and sometimes even food. Each of these materials brings inherent advantages and disadvantages, depending upon your application. There's one more to consider: paper. Additively making parts using ordinary paper as the build material is a bit deceptive. On the one hand, you think such a 3D printed object can't possibly handle the potential wear and tear you might expose it to. On the other hand, with the right binders and sealing materials, you are almost returning ordinary paper to its original form wood, with all the toughness, resiliency, and ruggedness of wood-based products.

1.1 Literature review

[1]Direct Tool Production (DTP) by Laminated Manufacturing techniques such as Selective deposition lamination (SDL) & laminated object manufacturing is extensively studied to exchange conventional tool production techniques. The benefits we get from such techniques are reduction in both production time & cost for production. The major difficulty in this technique is 'staircase' effect arises due to distinct height of laminated sheets. Their work shows experimental study to reduce 'staircase' effect by use of slant cutting & laser cutting. [2]Laminated Manufacturing technique is a rapid prototyping method which constructed part successively from layers of paper. Their work shows the precision and accuracy of the Laminated Manufacturing techniques & the dimensional stability of their objects. The dimensional error was the largest normal to the plane of the paper, intensified by the moisture absorption and successive swelling. The key process parameters were identified and optimized for adequate bonding and cutting accuracy. [3]Their work indicates an analysis of warping occurs in the laminated manufacturing technique. Based on their study of thermal-mechanical behavior of the adhesive and its effect on the laminated materials, the cause of warping, the correlation between temperature and adhesive viscosity, and the adhesive linking intensity is investigated. An optimal combination of the handling parameters may remove the undesired warping effect. [4]Generally manufacturing processes where tool has to travel along recommended path to accomplish machining operation has an excellent application, for this problem found in layered Manufacturing method where the laser traces the profile of a layer by moving along the path while the laser turns on. The path is typically followed by a sequence of curves. For typical paths, extra time may be wasted in the progression of tool in between the end point of one curve to the start point of the next curve along which the laser is turned off. Normally, this non cutting motion generates straight line to minimize the distance. A maximum linear intersection (MLI) algorithm is introduced to solve this problem. [5]In their work the principle of sheet metal Laminated Manufacturing methods is described as well as the process chain of Laminated Object Manufacturing method of metal foil. For each sub-process of metal foil Laminated Manufacturing methods the results of the experimental work for qualifying and optimizing the sub-process are revealed. Finally some examples of possible

applications mainly in the field of Rapid Tooling in Rapid Manufacturing method are discussed. [6]A 3D printer is a machine that uses a CAD (Computer Aided Design) model to accomplish rapid prototyping. While old-style 2D printers use ink to print digital information onto paper in two dimensions (x and y axes), 3D printers have the ability to print in three dimensions. (x, y, and z axis) [7] This is a research paper on 3D printing and the various materials used in 3D printing and their properties which become a remarkable topic in technological aspects. They go into the past of 3D printing and study about the process of 3D printing and what materials used in the manufacture of 3D printed objects and choice the best materials among them which are suitable for our 3D printing machine. [8] Adaptation of 3-D printing technology in manufacturing of prototyping is growing rapidly in customized low volume components. 3D printing includes a wide range of additive manufacturing technologies, each of these builds objects in sequential layers that are typically about 0.1 mm thin. The medical application for this technology is a promising and its usefulness with many advantages makes it very near to real time ones. There have several researches carried out in this field but different names have been suggested for close and very analogous technologies. In this review an attempt is made to make out clear classification of the processes among various researches down the history. [9]Subtractive manufacturing methods which usually result in up to 80-90% of the material being wasted, there is rare chance for any wastage of material in 3D printing. The conception of 3D printing has been around for a long time and its technology has grown over the years. Different 3D printers make use of different kind of technologies, printing approaches and also different kinds of materials. This paper gives a general overview to the concept of 3D printing, the different types of printing technologies with their advantages, disadvantages and relates each of them to different criteria such as surface finish, dimensional accuracy, material used, post processing necessities etc. [10]3D printing, also called additive manufacturing (AM), is achieving huge attention from principal manufacturers of the world due its high potential to transform the world. In this report firstly, the term AM is defined and its consequence is discussed. Some historical background of the technology is also underlined here. Then the process of 3D printing and the materials used in the manufacture of 3D printed items are stated. Given the attention around AM, organizations want to recognize if their products should be fabricated using AM. Implications for product development and manufacturing business approaches are discussed. Finally, an assumption is made based on the references studied and future scope of this technology has been underlined. [11]Current Nano patterning methods used for integrated circuit manufacture typically depend on a combination of deposition, lithography, and etch steps. Due to arrangement issues, Nano patterning is becoming very challenging as device dimensions approach sub-5 nm scales. In recent years, area selective atomic layer deposition (ALD) has arisen as substitute, bottom-up approach to nonmanufacturing. By controlling the deposition to specific areas, ALD permits self-aligned fabrication and can decrease the number of processing steps during device manufacturing, such as patterning and chemical mechanical polishing. Since ALD operates in a surface-reaction controlled regime with successive precursor and co-reactant exposures, separated by purge steps, ALD is also characterized by development with precise thickness control and high conformity. [12]This paper explains and investigates the additive manufacturing process from its diversities, types and usage of different programming tools. Printing process need to be selected mainly depend on applications and the materials used for growth. The advantages and limitations of this technology towards the significant development of applications were examined and presented in this paper.

2. GENERAL 3D PRINTING PROCESS

Nowadays, RepRap and Arduino communities have had a growing progress. These terms are defined on the Open Source development model; the designs crafted by these projects are released under the GPL General Public License, which encourages free universal access and distribution of it, allowing an exponential and quick development. RepRap project uses Fused Additive manufacturing technology, term used to refer to processes that make solid items from 3D computer models. In specific, the object is shaped by printing thin layers of fused plastic on top of one another. The objectives of this philosophy are the creation of 3D printers which are capable of self-replicating and use an Open Source software for everyone. Currently, printer's control is recognized by two printed circuit boards (PCB); one board is a microcontroller (Arduino) and the other contains the power electronics. As regards of Arduino, it is an electronic board whose purpose is having an easy-to-use hardware and software.

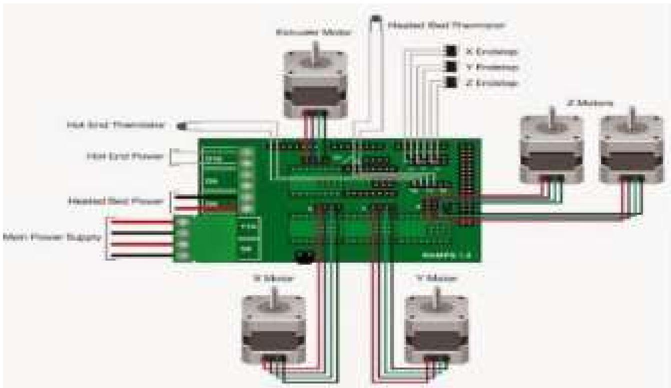


Figure 2.1

Here are 3 main steps in 3D printing.

The first step is the preparation just before printing, when you design a 3D file of the product you want to print. This 3D file can be produced using CAD software, with a 3D scanner. Once you have checked that your 3D file is ready to be printed, you can continue to the second step.

The second step is the real printing process. First, you need to select which material will best attain the specific properties necessary for your object. The range of materials used in 3D printing is very broad. It contains plastics, ceramics, resins, metals, sand, textiles, biomaterials, glass, food and even lunar dust! Most of these materials also allow for plenty of finishing options that allow you to accomplish the precise design result you had in mind, and some others, like glass for example, are still being developed as 3D printing material and are not easily available yet.

The third step is the finishing process. This step needs specific skills and materials. When the part is first printed, often it cannot be directly used or transported until it has been sanded, lacquered or painted to complete it as intended. The material selected for the project will define which printing methods are most suitable.

Figure 2.2

3. SELECTIVE DEPOSITION LAMINATION (SDL)

Selective Deposition Lamination (SDL) or paper 3D printing was invented by Dr. Conor and Fintan MacCormack in 2003. Dr. McCormack first discovered 3D printing in 1986. The technology captured his imagination in the similar way that motorcycles, rockets, computers and space travel already had. Most technologies build replicas from costly plastic or chemically infused powder, SDL 3D printers use normal, affordable paper as the build material. SDL is not to be confused with the old laminated object manufacturing (LOM) technology. LOM uses a laser, laminated paper and glue, so everything was glued together, containing the backing material around the model. Excavating the model was an ordeal, often resulting in 3D part rupture. SDL uses a blade for the cutting and the 3D printer selectively deposits the adhesive only where it's needed. This white paper will explain how a paper-based 3D printer generates a physical 3D model using the SDL process.

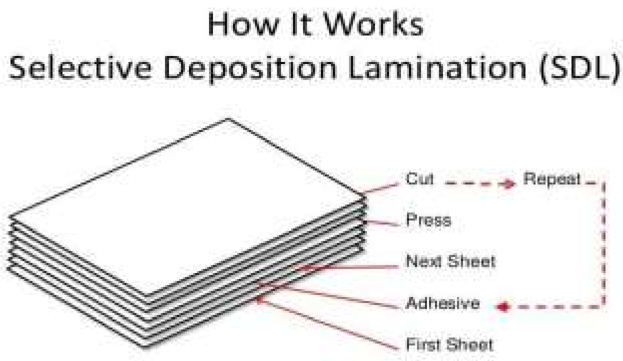


Figure 3.1

3.1 Working of SDL

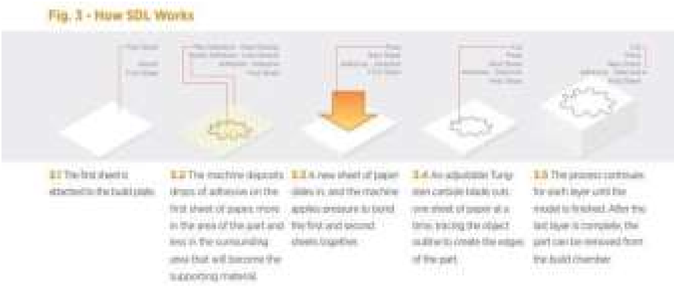
Producing the Digital File 3D printing starts with a 3D data file, SDL 3D printers support the universal industry standard file format for 3D product designs, STL, as well as OBJ and VRML (for color 3D printing). All majority 3D computer-aided design (CAD) software products, including free programs such as Sketch Up, produce STL files. Finished designs offered for download are typically presented in STL, as are files produced by scanning a physical object. SDL 3D printers include control software, called Slice IT. (Fig. 3.1.1) Slice IT reads the digital data and slices the computer model into printable layers same in thickness to the paper. The software also allows you to locate the part, or several parts, within the 3D printer's build chamber. Slice IT works on any standard PC running 64bit Windows (2000, XP, Vista or Windows 7) with a dedicated Ethernet card (speed of 10/100 or better) linked directly to the 3D printer. The SDL printer also comes with an added piece of software, called ColourIT which is used in combination with Slice IT to apply color to the 3D digital files. (Fig. 3.1.2) ColourIT can open numerous file formats: STL, WRL, OBJ, and 3DS, FBX, DAE and PLY. Once the file is within ColourIT it can be checked for integrity to ensure it's a waterproof manifold, however the main function of ColourIT is to apply colors to the digital files prior to slicing in Slice IT. Once the color has been applied, the model is exported as a WRL file which is then imported into Slice IT for preparation for building.

Figure 3.1.1

Figure 3.1.2

Printing the Object

The first sheet is manually attached to the build plate. The placement of the first sheet is not vital, as the first few of pages are attached as a base layer before the real part cutting begins. (Fig. 3.1) Once the blade depth and the adhesive levels are exact, the doors are closed and the machine is ready to accept data from Slice IT. From the PC and within Slice IT, the user picks print and the 3D printer starts to build the part. The first thing that happens is that a layer of adhesive is applied on top of the first manually-placed sheet. The adhesive is applied selectively hence the name SDL "Selective." This means that a much higher density of adhesive is deposited in the area that will become the object, and a much lower density of adhesive is applied in area that will serve as the support. (Fig. 3.2)A next sheet of paper is fed into the printer from the paper feed mechanism and positioned precisely on top of the recently applied adhesive. The build plate is moved up to a heat plate and force is applied. This force ensures a positive bond between the two sheets of paper. (Fig. 3.3) When the build plate returns to the build height, an adjustable Tungsten carbide blade cuts one sheet of paper at a time, tracing the object outline to create the ends of the part. (Fig. 3.4) When this cutting process is complete, the machine starts to deposit the next layer of adhesive and the complete process continues until all the sheets of paper are stuck together and cut and the model is completed. After the last layer is finished, the part can be removed from the build chamber. (Fig. 3.5)



3.2 Weeding the Object

The key benefit of the SDL process becomes apparent when the deduction of the waste occurs. This process is called "weeding." Because the adhesive is applied selectively, there is a better bond between the layers of paper which establish the model and fewer bonds between the layers building the support material. Also, to aid ease of weeding, the support material is "diced" so that small slices of support material can be removed to confirm that delicate 3D models endure. (Fig.3.2.1) unlike other technologies, SDL 3D printers do not need dipping of parts in toxic chemicals or sharp instruments to eliminate support structures, vacuuming powder, or infiltration. An SDL model will not crumble or shatter. It arises from the 3D printer as a tough, robust model. (Fig.3.2.2) when you consider that it's made of tightly compressed sheets of paper, it essentially is reconstructed wood. As such, it produces a warm, tactile response that is uniquely pleasing to the touch. If you want to make model that can be drilled, threaded, tapped or water resistant, you can give them a fast dip and they're ready to go. The model will also receive a variety of optional common finishes to suit your application needs.


Figure 3.2.1


Figure 3.2.2

3.3 Green, Safe and Easy to Use

Another aspect of accessibility is the capacity to use your 3D printer in non-industrial settings such as schools, medical labs & professional design offices. That means no toxic chemicals, fumes, or dust and no dangerous heat or light. Consequently, SDL liquid materials such as adhesive and ink are water-based and non-toxic. SDL models needs no infiltrates. In addition to being harmless, the SDL process is green: when you're ended using the model, it can go directly into the paper recycling bin.

4. APPLICATIONS

The lost-cost, eco-friendly and full-color capabilities of SDL paper-based 3D printers make them ideally suitable for a wide-ranging of 3D printing and rapid prototyping applications.

Manufacturing: For manufacturers who want to develop superior products faster, SDL concept prototypes help designers rapidly and thoroughly enhance new designs. Concept models also ferret out potential manufacturing issues before they get costly. SDL is also ideal for investment and sand casting, FEA studies, living hinges, packaging development and more.

Education: For educators, who need to securely and affordably improve learning in engineering, architecture, the arts and more, SDL makes 3D printing available at a reasonable cost.

Figure 4.1

Architecture: For architects who want to collaborate closely with clients, 3D printed clean white massing or full-color design models are more accurate than handmade substitutes, and easier, quicker and more affordable to make. As with product designers, architects can make more modifications in a shorter period of time, resulting in better formations.

Medical: For surgeons, dentists and other healthcare specialists, lifelike anatomical 3D models help deliver enhanced outcomes by refining preparation for procedures and fabrication of medical appliances for the specific patient.

Figure 4.2

Geospatial: For rescue squads, law enforcement, developers and the military, detailed, colorful 3D maps make attaining objectives quicker and easier than with traditional paper maps.

Entertainment: For the entertainment industry, full-color 3D printing is a way to bring characters, settings and adventures into the third dimension for maximum influence.

Marketing: For salespeople and marketers who need to show customers and prospects new products before they hit the market, realistic 3D printed prototypes are far additional powerful than brochures. There's more understanding and more impression, when customers can hold a new product in their hands.

Figure 4.3

Service Bureaus: For service bureaus that use 3D printing to make unique toys, jewelry, collectibles and other gifts and household products, in color and at a price point consumers will agree.

Archaeology: For preservationists, 3D printing offers an extensive range of benefits for replicating, repairing and restoring priceless, one of kind artifacts.

5 ADVANTAGES & DISADVANTAGES

5.1 Advantages

1. Parts made are ecofriendly in nature.
2. Low running cost.
3. Does not require infiltration of printed parts.
4. No need for additional support.
5. Reliable process.

5.2 Disadvantages

1. Difficult to fabricate complex thin geometries.
2. Strength part is depends upon adhesive strength of glue.
3. Absorption of water might distort the part.
4. Material trapped in small inner holes is difficult to remove.

6. CONCLUSION AND FUTURE SCOPE

The model can be developed to the level where the waste paper can be used as a printing material instead of using readymade filaments, which is eco-friendly and causes the significant reduction in the environment pollution. The considerable nature of 3D printing, making a part layer by layer, instead of subtractive techniques of manufacturing lend themselves to lower costs in raw material. With so many potential profits of 3D printing, there's no surprise that this technique is making its way through a diverse number of industries and rapidly becoming a preferred tool of progressive marketers. Medicine is perhaps one of the most exciting zones of application. Beyond the use of 3-D printing in making prosthetics and hearing aids, it is being deployed to treat challenging medical situations; the breakthroughs in this zone are quick and awe-inspiring.

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