History and impact of additive manufacturing

In the recent years, technology has been evolving at an exponential rate, due to important breakthroughs in research and development of new ways to produce efficient materials and structures. One of the most important technological step forward was the implementation of the extended use of Additive Manufacturing Machines, also known as 3D Printers. This revolutionary concept of Additive Manufacturing (AM) describes the technologies that build 3D objects by adding layer-upon-layer of material, whether the material is plastic, metal, concrete or maybe one day…. human tissue?

1. The history of AM Manufacturing:

The first additive manufacturing equipment and materials were developed by Charles Hull in the early 1980s, and he called the process “ stereolithography,” (Jane Bird – 2012). Hull, who has a bachelor’s degree in engineering physics, was working on making plastic objects from photopolymers at the company Ultra Violet Products in California. Stereolithography uses an *. stl* file format to interpret the data in a CAD file, allowing these instructions to be communicated electronically to the 3D printer. Along with shape, the instructions in the *. stl* file may also include information such as the color, texture, and thickness of the object to be printed.(Gross BC, Erkal JL, Lockwood SY, Chen C, Spence DM -2014) By the early 2010s, the terms 3D printing and additive manufacturing evolvedsensesin which they were alternate umbrella terms for AM technologies, one being used in popular vernacular by consumer – maker communities and the media, and the other used officially by industrial AM end use part producers, AM machine manufacturers, and global technical

standards organizations.(Ishengoma, Fredrick R.; Mtaho, Adam B.-2014) Many other companies have since developed 3D printers for commercial applications. Hull’s work, as well as advances made by other researchers, has revolutionized manufacturing, and is poised to do the same in many other fields-including medicine. (Gross BC, Erkal JL, Lockwood SY, Chen C, Spence DM -2014)

2. The types of AM Processes

Although the term “ 3D Printing” is used as a synonym for all Additive Manufacturing processes, there are actually lots of individual processes which vary in their method of layer manufacturing. Individual processes will differ depending on the material and machine technology used. Hence, in 2010, the American Society for Testing and Materials (ASTM) group “ ASTM F42 – Additive Manufacturing”, formulated a set of standards that classify the range of Additive Manufacturing processes into 7 categories (Standard Terminology for Additive Manufacturing Technologies -2012). These categories are: VAT Photopolymerisationwhich refers to using a vat of liquid photopolymer resin, out of which the model is constructed layer by layer; Material Jetting, which is used to create objects in a similar method to a two-dimensional ink jet printer. Material is jetted onto a build platform using either a continuous or Drop on Demand approach; Binder Jetting, which uses two materials; a powder based material and a binder. The binder is usually in liquid form and the build material in powder form. A print head moves horizontally along the x and y axes of the machine and deposits alternating layers of the build material and the binding material. Material Extrusion; Fuse deposition modelling is a common material extrusion process. Material is

drawn through a nozzle, where it is heated and is then deposited layer by layer. The nozzle can move horizontally and a platform moves up and down vertically after each new layer is deposited. Inkjet Printingis a “ noncontact” technique that uses thermal, electromagnetic, or piezoelectric technology to deposit tiny droplets of “ ink” (actual ink or other materials) onto a substrate according to digital instructions. Sheet Laminationprocesses that include ultrasonic additive manufacturing and laminated object manufacturing. Directed Energy Depositionwhich covers a range of terminology: ‘ Laser engineered net shaping, directed light fabrication, direct metal deposition, 3D laser cladding’ It is a more complex printing process commonly used to repair or add additional material to existing components.

3. Description of the way Thermal Inkjet Printing AM Machines work

As mentioned above, TIJprinters use a technique that uses thermal, electromagnetic, or piezoelectric technology to deposit tiny droplets of “ ink” (actual ink or other materials) onto a substrate according to digital instructions. In inkjet printing, droplet deposition is usually done by using heat or mechanical compression to eject the ink drops. In TIJ printers, heating the print head creates small air bubbles that collapse, creating pressure pulses that eject ink drops from nozzles in volumes as small as 10 to 150 picolitres. Droplet size can be varied by adjusting the applied temperature gradient, pulse frequency, and ink viscosity. TIJ printers are particularly promising for use in tissue engineering and regenerative medicine. Because of their digital precision, control, versatility, and benign effect on mammalian cells, this technology is already being applied to print

simple 2D and 3D tissues and organs (also known as bioprinting). (Cui X, Boland T, D'Lima DD, Lotz MK -2012)

4. The benefits of AM Machines in Medical Industry

The strengths of Additive Manufacturing lie in those areas where conventional manufacturing reaches its limitations. The technology is of interest where a new approach to design and manufacturing is required so as to come up with solutions to complex and complicated situations. It enables a design-driven manufacturing process – where design determines production and not the other way around. What is more, AM allows for highly complex structures which can still be extremely light and stable, which is a particularly important characteristic for medical bio-engineering. It provides a high degree of design freedom, the optimization and integration of functional features, the manufacture of small batch sizes at reasonable unit costs and a high degree of product customization even in serial production, thus providing the possibility of adapting every AM designed apparatus to every patient needs. (S. V Murphy, A. Atala -2014) For example, 3D printing has been considered as a method of implanting stem cells capable of generating new tissues and organs in living humans. With their ability to transform into any other kind of cell in the human body, stem cells offer huge potential in 3D bio-printing. (3D Masterminds – 7 Ways 3D Printing Is Disrupting the Medical Industry"-2015) Many medical devices, such as hearing aids, dental crowns, and surgical implants are relatively small in size and therefore suitable for the production available through common AM systems. According to a new research report from Albany, NY based Transparency Market Research, the global market for 3D printing in medical

application was valued $354. 5 million in 2012 and is expected to grow at a compound annual growth rate (CAGR) of 15. 4 percent from 2013 to 2019 to reach $965. 5 million by 2019. (Wohlers Associates – 2014)

5. Conclusion

3D printing has become a useful and potentially transformative tool in a number of different fields, including medicine. As printer performance, resolution, and available materials have increased, so have the applications. Researchers continue to improve existing medical applications that use 3D printing technology and to explore new ones. The medical advances that have been made using 3D printing are already significant and exciting, but some of the more revolutionary applications, such as organ printing, will need time to evolve, but still, taking into account the way technology evolves today, this kind of application may soon be accessible.

6. References

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