European Journal of Applied Engineering and Scientific Research
Short Communication
2020
Vol. 8, Iss. 2

3D Printing 2020- Cellular Structures Design and Optimization for Additive Manufacturing: A Review

Aamer Nazir[1] and **Jeng-Ywan Jeng**[1,2]

[1]High Speed 3D Printing Research Center, National Taiwan University of Science and Technology, No. 43, Section 4, Keelung Road, Taipei 106, Taiwan, ROC
[2]Department of Mechanical Engineering, National Taiwan University of Science and Technology, No. 43, Section 4, Keelung Road, Taipei 106, Taiwan, ROC

Cellular structures are largely found in nature such as wood, bones, cork, honeycomb etc., due to excellent properties, for example excellent energy absorption, high strength-to-weight-ratio, and lightweight. Cellular structures are made up of an interconnected network of plates (closed- cell structures), solid struts (open-cell structures) or small unit cells (periodic structures). When compared with traditional manufacturing processes, Additive Manufacturing (AM) has enabled the designers and engineers to fabricate intricate geometries having cellular structures for various applications in automotive, aerospace, biomedical, and footwear industries. All major industries have been exploiting the benefits of cellular structures due to their prevalence over a wide range of research fields. In this study, authors aim to present a comprehensive review of design, optimization, and AM of various cellular structure morphologies investigated by different researchers. In addition, the applications and properties of 3D printed structures, and the major challenges are presented. Furthermore, major gaps, limitations and new areas that needs to be investigated in cellular structures for AM area of research. This review would provide a more precise understanding and the state-of-the-art of AM with the cellular structures for engineers and researchers in both academia and industrial applications.

Introduction: The demands for lighter, stronger, and more customizable parts have necessitated the research and development of new technologies, tools, and methodologies that can satisfy the new demands of the modern world. In this regard, the advent and continual improvement of one technology, additive manufacturing, has dramatically changed the way engineers pursue design and manufacturing. Additive manufacturing, once referred to as Rapid Prototyping (RP), has been used in many diverse field of industry for verifying the concepts (concept modeling) prior to production. However, with advancement of material science, this new and promising technology has eliminated many barriers to manufacturing and has allowed designers to achieve a level of complexity and customizability that is infeasible using traditional machining processes. As a result, most of the industries like Siemens, Phonak, Widex, Boeing and Airbus are now using this technology for producing their functional parts that are used in the final products. One such application of this technology is for manufacturing of customized, lightweight cellular structures. They have several advantages such as high strength-to-weight ratio and strong thermal and acoustic insulation properties. These types of structures are suitable for any weight-critical applications, particularly in the aerospace and automotive industries. This research will present a method for the design of these cellular structures for mold making application.

Additive Manufacturing: Additive manufacturing (AM) is an additive fabrication process where a three-dimensional part is produced by stacking layers of thin 2-D cross sectional slices of materials one over another without use of tooling and human intervention. The process begins with a solid model CAD drawing of the object. The CAD model is then converted in to .STL file format and sent to an AM machine for prototype building [1]. The whole process of design to physical model through various intermediate interfacing stages . These steps are common to most AM systems but the mechanisms by which the individual layers are created depend on the specific system.

Currently, many technologies exist that into the broad definition of AM. These technologies are supported by various distinct process categories. These are: photopolymerization, powder bed fusion, extrusionbased systems, printing, sheet lamination, beam deposition, and direct write technologies [2,3]. Each of these processes has its own distinct set of advantages and disadvantages regarding characteristics such as surface finish, manufacturing speed and layer resolution. Of these different processes, three technologies are most commonly used: fused deposition modeling (FDM), stereolithography (SLA) and selective laser sintering (SLS). These three processes will

Note: This work is partly presented at 3rd international conference on 3dprinting and additive manufacturing (May 22, 2020 Paris, France)

be briefly outlined in the following sections.

Fused Deposition Modelling (FDM): Fused Deposition Modelling (FDM) was introduced and commercialized by Stratasys, Minnesota, USA in 1991.FDM process builds prototype by extruding material (normally thermoplastic like ABS) through a nozzle that traverses in X and Y to create each two dimensional layer. As each layer is extruded, it bonds to the previous layer and solidify. The platform is then lowered relative to the nozzle and the next slice of the part is deposited on top of the previous slice. A second nozzle is used to extrude a different material in order to build-up support structures for the part where needed. Once the part is completed, the support structures are broken away from the part [4, 5]. Fig. 2 shows a schematic diagram of FDM Process, where blue color indicates the model material and red color points to the support material.

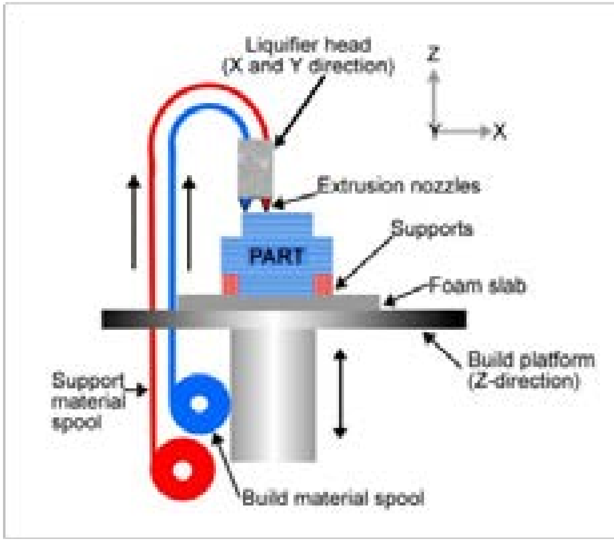

Fig. 2 FDM Process Flow [6]

Stereolithography (SLA)

Stereolithography (SLA) is the first fully commercialized AM process introduced in mid 1980s by 3D systems, California, USA. It fabricates part from a photo curable liquid resin that solidifies when sufficiently exposed to a laser beam that scans across the surface of resin. Once irradiated, the resin undergoes a chemical reaction to become solid called photo polymerization [8]. In SLA, there is a platform in a vat of liquid, photocurable polymer, i.e. epoxy or acrylate resin. After each cross-section is traced, the platform moves down an incremental amount and the laser cures the next cross-section. This process continues until the part is complete. At initial days, SLA was mainly used as a prototyping tool; however, several companies are now using SLA for production manufacturing. For example, Siemens, Phonak, Widex and other hearing aid manufacturers use SLA machines to produce hearing aid shell . Align Technology uses SLA to fabricate molds for producing customized clear braces (Invisalign®).

References:

[1] S. Upcraft and R. Fletcher, “The Rapid Prototyping Technologies,” Assembly Automation, vol. 23(4), pp. 318-330, 2003

[2] C. C. Kai and L. K Fai, “Rapid Prototyping: Principles and Applications in Manufacturing,” John Wiley and Sons, Singapore, 1997

[3] S.S. Mahapatra and B. N. Panda, “Benchmarking of rapid prototyping systems using grey relational analysis,” Int. J. Services and Operations Management, Vol. 16, No. 4, pp.460–477, 2013

[4] R. Noorani, “Rapid Prototyping-Principles and Application,” John Wiley & Sons, New Jersey, USA, 2005

[5] S. H. Masood and W. Q. Song, “Development of New Metal / Polymer Materials for Rapid Tooling using Fused Deposition Modelling,” Materials & Design, vol. 25, pp. 587-594, 2004.

[6] “Image: FDM Process Flow,” ed. http://chuansong.me/n/492448

[7] http://www.stratasys.com/industries/automotive

[8] P. F. Jabobs, “Rapid Prototyping & Manufacturing: Fundamentals of Stereolithography,” TX: Mcgraw-Hill, 1993.

[9] “Image: Siemens hearing aid,” ed. http://www.medical.siemens.com.

Note: This work is partly presented at 3rd international conference on 3dprinting and additive manufacturing (May 22, 2020 Paris, France)