

Recent Development and Applications of Additive Layer Manufacturing Processes for Metal Components Production

ROHIT PANDEY¹, HARDIK B. RAMANI¹

²Department of Mechanical, Engineering, Dr. A. P. J. Abdul Kalam University, Indore 452016, India
Corresponding Author Email: pandeyrohit1988@gmail.com

Abstract—Additive layer manufacturing processes referring to create the dimensional models by layer by layer material deposition. The cost and time saving are the major advantages of additive layer manufacturing/ models can usually be built within hour, and the build materials for important processes are generally inexpensive. Few AM machine are so small and environment friendly so that it can be placed directly into a manufacturing. Additive manufacturing referred to in AM, the basic principle or the standard of this technology is that a model, initially generated using 3D computer aided design (3D CAD) system, can be fabricated directly without the need for process planning. Although this is not simple, additive manufacturing technology certainly simplifies the process of production complex 3D objects directly from CAD data. The key point in additive manufacturing works is that parts are made by adding material in layers, each layer is a thin cross section of the part derived from the original CAD data. In the physical world, each layer must have a finite thickness to it and so the resulting part will be an approximation of the original data.

Index Terms— Additive manufacturing, Polymer, 3D printing, CAD data, modelling, prototyping.

I. INTRODUCTION

With a list of design requirements and constraints established, conceptualization of the design solution may begin. This chapter begins with the identification of the crux of the design task, which is accomplished through a systematic abstraction of the design requirements. The primary and secondary functions of the to-be-designed manufacturing process are then identified through abstraction of the essential tasks that are required for the successful achievement of the listed requirements [1]. Conceptualization of a design solution begins with the ideation of physical principles that can satisfy each sub function of the process. More concrete embodiment of these principles is then provided through the generation of working principles, which are ideated via research and critical analysis of a wide variety of ceramic manufacturing processes [2]. The key to how additive manufacturing works is that parts are made by additive material in layers, each layer is a thin cross section of the part derived from the original CAD data. In the physical layer must have a finite thickness to it and so the resulting part will be an approximation of the original data [3].

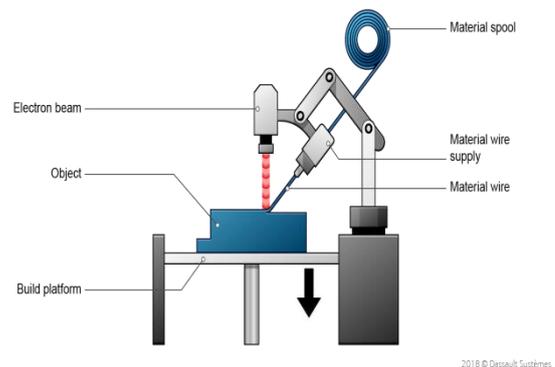


Figure 1: Additive layer manufacturing process [3].

II. ADDITIVE LAYER MANUFACTURING PROCESSES

Additive manufacturing technologies developed into three crucial technological and application areas: concept modelling, prototyping and additive manufacturing. It is evident that these forms of three form fabrication are growing exponentially over time. Even through some techniques can produce parts with reasonable and fair mechanical properties, more uneven materials are necessary for parts that are subjected to actual service conditions [4]. The amount of commercially available metal, composite and ceramic materials is growing rapidly due to worldwide research in labs and universities. Based upon the operations; additive manufacturing is broadly classified as: (1) Material removal additive manufacturing (2) Material addition additive manufacturing. If both are used in one operation, it is called hybrid additive manufacturing. The hybrid prototyping minimises the effect of stair stepping that highly influences the dimensional accuracy of the process. The stair stepping occurs in material addition AM and can be minimised by material removal AM [4-6].

III. THE DESIGN PROCESS OF ADDITIVE LAYER MANUFACTURING

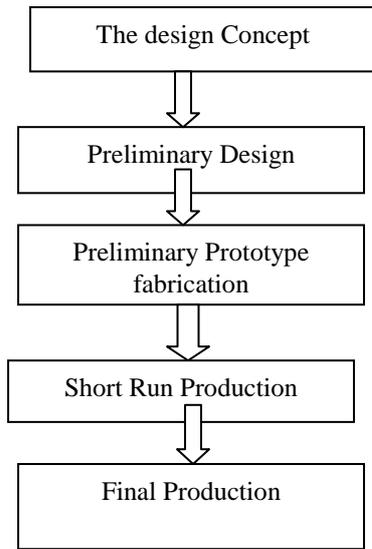


Figure 2: Design process of Additive manufacturing [7].

A. Integration of Additive Manufacturing Systems:

In the outset of AM technology, workstations were used to perform activities of design and manufacturing. Workstations ran and graphics and input/output functions were connected to the computer system. With the advancements in technology, personal computers have become the viable solution for design manipulations [8]. This reduced the production time and increased the productivity. With rich graphics, working with 3D CAD model virtually became easier. Integrate the components of AM systems are attached at operational costs and production time. All the components of AM systems are attached at one place. Integration of components helps in increasing the flexibility and reducing the material consumption [9-11].

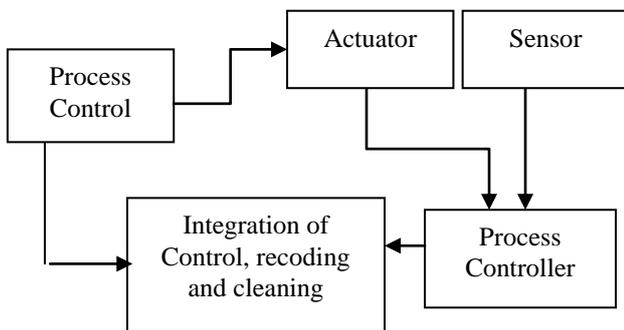


Figure 3: Integration of AM system components [11].

If there is a change in the CAD design, the same design can be modified accordingly without the help of any other systems.

B. Materials Used in Additive manufacturing:

A wide range of thermoplastics, composites, metals and ceramics can be used in this process, therefore providing an

extensive range of function parts to be built. The powders are commonly produced either by ball milting or atomization [11].

Materials used in AM	Properties
Polyamide	<ul style="list-style-type: none"> Can be used as final parts. Highly resistant to chemical and durable. Can be fused at lower temperatures.
Alumide	<ul style="list-style-type: none"> It is a mixture of aluminium and polyamide. Imparts a metal look to the components. Parts are temperature resistant (up to 110°C)
Thermoplastic Elastomer	<ul style="list-style-type: none"> Highly impermeable to water. Imparts good surface finish.
Polycarbonate	<ul style="list-style-type: none"> Needs less laser power to sinter. Mostly used investment and sand casting patterns manufactured by SLS.
Nylon	<ul style="list-style-type: none"> Highly durable thermoplastic materials.
Metals	<ul style="list-style-type: none"> Metals powders are sintered to get final component. Inert reactive metals (Al, Ti and stainless steel)
Ceramics	<ul style="list-style-type: none"> Zircon and silica are widely used.

C. Process Optimization of Additive manufacturing Processes:

The parameters of additive manufacturing can be classified in (1) Nuisance parameters (2) Constant parameters and (3) Control parameters. The functional requirements of any AM process include accuracy, strength, build time and efficiency of the process [12]. Surface accuracy is gaining a greater significance as more parts are used as master pattern for secondary manufacturing process. Build time is very significant in cost estimation and scheduling the work. Layer thickness, hatch space and orientation are the key control parameters for SLA, SLA and FDM. These are required indeed process independent parameters and can be applied to other processes such as LOM, 3D printing etc. support structures are essential for SLA and FDM but they are not needed for LOM and SLA processes [12-14].

$$\lim_{\beta \rightarrow \alpha} \text{mes}(B\beta \setminus B\alpha) \beta - \alpha = k, 0 < k < \infty, \exists \Omega \subset B\beta \setminus B\alpha$$

$$\dim \Omega = \dim B\alpha - 1.$$

$$\forall \alpha < \beta \in I \partial B\beta \in B\alpha,$$

$$C = Rt(e) \sum \gamma e^{-ti\theta} \frac{Ba \exists \pm \sqrt{b^2 - 4ac}}{Ba}$$

A layer wise growing body is a continuous monotone (with respect to inclusion) one-parameter family of manifolds $C = \{Ba\} a \in I, \forall a < \beta \in I Ba \subset B\beta, (1)$ where $I = (a, b) \subset \mathbb{R}$ is an open interval, such that the following property holds: $\forall a \in I \forall X \in Ba \setminus Ba \exists \gamma \in I X \in \partial B\gamma. (2)$

Additive layer manufacturing improved surface quality yields higher precision of dimensions which can facilitate a more accurate test on assembly or functionality of the prototype parts. And surface quality of AM parts depends on the stair stepping effect on inclined planes and the curved surfaces. Build time is an important factor in building a part [15]. If the same model takes different orientations, the build time may vary since it is largely dependent on the height of a part. In the case of SLA, SLS and FDM, build time can differ greatly in terms of the amount of support structures. And build time generally comprises of the three elements: (a) Data preparations (2) part build and (3) post processing time [16].

III. APPLICATIONS OF ADDITIVE MANUFACTURING PROCESSES

Additive manufacturing is impacting playing a important role in several ways. Possibly, the most obvious applications are as means to design and develop medical devices and instrumentation [17].

A. ADDITIVE MANUFACTURING IN MEDICAL FIELD

This is simply a development of the engineering applications of the technology. Any field where it is vital to decrease product time while simultaneously providing users with function performance feedback, is an excellent prospect for additive manufacturing [17]. It therefore, follows that since human lives depend on the quality and ease of use of numerous medical products, it is very reasonable to use additive technologies in their development. Examples of medical instruments designed using this technology include retractors, scalpels and surgical fasteners. The procedure for making 3D models using AM technologies implies few steps:

- 3D digital image
- Data transfer, processing and segmentation
- Evaluation of design
- AM model production
- AM model validation.

B. ADDITIVE MANUFACTURING IN AUTOMOBILE INDUSTRY

Automotive industry finds the most applications of AM systems. The design constraints currently imposed on the automotive designer owing to tooling, design limitation will be removed. In both high and low volume place market models, the ability to individually customize areas of the car to suit customer's requirements would have a particular

impact in areas such as ergonomics where parts could be manufacturing to make the overall comfort fit of the customer need [18].

C. ADDITIVE MANUFACTURING IN AERONAUTICAL INDUSTRY

The Aeronautical Industry was one of the early adopters of AM with so manufactures and others purchasing equipment in the early 1990s for aeronautical companies, AM began to have a exciting impact on compressing design times and programming costs to the point today where AM is viewed as just the normal way of progressing through a design build. As the technology became key by producing cost effective prototype [19].

D. AM IN INDUSTRIAL PROTOTYPING

Additive manufacturing technologies for industrial applications is a proven technology used by industrial engineers and designers to produce physical, tangible prototypes to work in design and testing [19-20].

- Pump parts and components
- Castings of small body components
- Engine parts and castings
- Mechanical components

IV. CONCLUSION AND DISCUSSION

The roots of AM are actually from the well known and ever growing CAD industry, more specifically, the solid modelling. Solid modelling is the branch of CAD that produces virtual 3D objects in digital format. A solid model has volume and is fully enclosed. This technology can be assigned materials properties such as mass and density. A wireframe is an approximate representation of a 3D object such as one would sketch with appropriate models.

- AM for the production of finished manufactured parts.
- Wood 3D printing
- Growing demand in the medical Industry
- Material advancements
- Micro parts.

Additive manufacturing and rapid prototyping are synonymously used for the ease of reader. It will be noted that, most of the terms introduced and discussed above are interchangeable but different terminology may emphasize the approach used in a particular instance. Additive manufacturing involves a number of steps that move from the virtual CAD description to the physical resultant part. Experiment is conducted on i5 machine, with 8 GB RAM and 256 GB SSD. The experiment is being done using the JUNG Simulator and the entire implementation has been done using java language. The results of the experiment are obtained based on 3 parameters which are time utilization, energy utilization, and residual energy or network lifetime. The results of the experiment are shown in the following graphs:

ACKNOWLEDGEMENTS

Author would like to thank Dr. A.P.J. Abdul Kalam University Indore for giving such a wonderful research facility to perform this work and providing essential facility and also thank to MSME Centre Indore to provide experimental facilities for this research paper work.

V. CONCLUSION

The study presented here is a review of existing literature and researches conducted in the area of traffic engineering. Some of the methods are applicable for traditional network structure whereas some are related to the techniques developed for SDN. The challenges related to the implementation and future enhancement required for the up-gradation of the systems are also discussed. Software Defined Networking is a promising approach in the networking paradigm. It distinguishes the control plane of the network from the plane which is used for data forwarding. It enables and provides the solution for many problems in the traditional network architecture. It reduces the complexity in network management by managing the network centrally. It also presents the network programmability and providing a global view of a network and its state.

ACKNOWLEDGEMENTS

Author would like to thank Dr. A. P. J. Abdul Kalam University Indore for giving such a wonderful research facility to perform this work and providing essential facility and also thank to MSME Centre Indore to provide experimental facilities for this research paper work.

REFERENCES

- [1] Agarwala, M., D. Bourell, J. Beaman, H. Marcus and J. Barlow, "Direct Selective Laser Sintering of Metals", *Rapid Prototyping Journal*, Vol. 1, No. 1, pp. 26-36, 1995.
- [2] Agarwala, M. K., V. R. Jamalabad, N. A. Langrana, A. Safari, P. J. Whalen and S. C. Danforth, "Structural Quality of Parts Processed by Fused Deposition", *Rapid Prototyping Journal*, Vol. 2, No. 4, pp. 4-19, 1996.
- [3] Ainsley, C., N. Reis and B. Derby, "Freeform Fabrication by Controlled Droplet Deposition of Powder Filled Melts", *Journal of Materials Science*, Vol. 37, pp. 3155-3161, 2002.
- [4] Grau, J., J. Moon, S. Uhlund, M. J. Cima and E. Sachs, "High Green Density Ceramic Components Fabricated by the Slurry-Based 3DP Process", *Solid Freeform Fabrication Symposium*, Austin, TX., pp. 371-378, 1997.
- [5] Greulich, M., "Rapid Prototyping and Fabrication of Tools and Metal Parts by Laser Sintering of Metal Powders", *Materials Technology*, Vol. 12, No. 5, pp. 155-157, 1997.
- [6] Hattiangadi, A. and A. Bandyopadhyay, "Processing, Characterization and Modeling of Non-Random Porous Ceramic Structures", *Solid Freeform Fabrication Symposium*, Austin, TX, pp. 319-326, 1999.
- [7] Himmer, T., T. Nakagawa and H. Noguchi, "Stereolithography of Ceramics", *Solid Freeform Fabrication Symposium*, Austin, TX., pp. 363-369, 1997.
- [8] Karlsen, R. and J. Reitan, "Metal Printing - Development of a New Rapid Manufacturing Process for Metal and Ceramic Objects", *International Conference on Advanced Research in Virtual and Rapid Prototyping*, Leiria, Portugal, pp. 569-589, 2003.
- [9] Keicher, D. M., "Beyond Rapid Prototyping to Direct Fabrication: Forming Metallic Hardware Directly from a CAD Solid Model", *Materials Technology*, Vol. 13, No. 1, pp. 5-7, 1998.
- [10] Meacham, J. M., M. J. Varady, F. L. Degertekin and A. G. Fedorov, "Droplet Formation and Ejection from a Micromachined Ultrasonic Droplet Generator: Visualization and Scaling", *Physics of Fluids*, Vol. 17, No. 1, pp. 1-8, 2005.
- [11] Reis, N., C. Ainsley and B. Derby, "Viscosity and Acoustic Behavior of Ceramic Suspensions Optimized for Phase-Change Ink-Jet Printing", *Journal of the American Ceramic Society*, Vol. 88, No. 4, pp. 802-808, 2005.
- [12] Sachs, E., M. J. Cima, J. Cornie, D. Brancazio, J. Bredt, A. Curodeau, T. Fan, S. Khanuja, "Three-Dimensional Printing: The Physics and Implications of Additive Manufacturing", *CIRP Annals*, Vol. 42, No. 1, pp. 257-260, 2007.
- [13] Sanders, W. S. and L. J. Gibson, "Mechanics of Hollow Sphere Foams", *Materials Science and Engineering*, Vol. A347, pp.70-85, 2003.
- [14] Smay, J. E., G. M. Gratson, R. F. Shepherd, J. Cesarno and J. A. Lewis, "Directed Colloidal Assembly of 3D Periodic Structures", *Advanced Materials*, Vol. 14, No. 18, pp. 1279-1283, 2002.
- [15] Thomas, H. R., N. Hopkinson and P. Erasenthiran, "High Speed Sintering - Continuing Research into a New Rapid Manufacturing Process", *Solid Freeform Fabrication Symposium*, Austin, TX., pp. 682-691, 2007.
- [16] Teng, W. D., M. J. Edirisinghe and J. R. G. Evans, "Optimization of Dispersion and Viscosity of a Ceramic Jet Printing Ink", *Journal of the American Ceramic Society*, Vol. 80, No. 2, pp. 486-494, 1997.
- [17] Uhlund, S., R. K. Holman, S. Morissette, M. J. Cima and E. M. Sachs, "Strength of Green Ceramics with Low Binder Content", *Journal of the American Ceramic Society*, Vol. 84, No. 12, pp. 2809-2818, 2001.
- [18] Vaidyanathan, R., J. L. Lombardi, J. Walsh, S. Kasichainula, P. Calvert and K. Cooper, "Extrusion Freeform Fabrication of Functional Ceramic Prototypes", *Solid Freeform Fabrication Symposium*, Austin, TX, pp. 327-334, 1999.
- [19] Wang, H. V., S. R. Johnston and D. W. Rosen, "Design of a Graded Cellular Structure for an Acetabular Hip Replacement Component", *17th Solid Freeform Fabrication Symposium*, Austin, TX, pp. 111-123, 2006.
- [20] Yang, S. and J. R. G. Evans, "Acoustic Control of Powder Dispensing in Open Tubes", *Powder Technology*, Vol. 139, pp. 55-60, 2004.