Journal of Mechanical Engineering Advancements, *Volume 1 (Issue 2: May-August, 2024): Pages 1-5*
Published on: October 23, 2024.

ISSN: 3048-5673 (Online)

Journal of Mechanical Engineering Advancements

Contents available at: https://www.swamivivekanandauniversity.ac.in/jmea/

Investment Casting Process - A Study of Additive Manufacturing Technologies in the field of Engineering Design

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Abstract

The aspired of this study was to explain systematically to various casting paths of the most excellent obtainable evidence of Additive manufacturing (AM) technology and how rapid investment casting is revolutionize the meadow of casting. The intention of this methodical review is to explore the capability and usefulness of Additive Manufacturing (AM) to afford a successful solution for production of investment casting. The database which are used for research investigations like Google Scholar, Research Gate, Mendeley & Science Direct, etc. The unadventurous method of Investment Casting should be less effective in conditions of cost and time to develop rather than novel hard tooling wax patterns for low volume production. To conquer this particular problem, we have introduced additive manufacturing for creation patterns of investment casting. The paper reviews the exact applications of rapid prototyping in the meadow of casting. After applying the inclusion criteria this study concluded that using Additive manufacturing in investment casting in place of the unadventurous method is more cost-effective and time-efficient.

Keywords: *Additive Manufacturing, Rapid Investment Casting, Sintering, Rapid Prototyping*

1. Introduction

A. Additive Manufacturing

It is defined by a variety of technologies that are capable of transmitting virtual solid model data into the bodily models in a rapid and simple process. Additive manufacturing technologies manufactures the parts by polymerization, fusing or sintering of materials in predetermined layers with no needs for tools. The model of the ultimate product is then made in CAD Software using then the Computer Aided Design data is converted into a 2D cross-sections of a finite

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thickness. The cross-sections are feed into 3D printers so that they can be collective adding them and make them together in a layer by layer succession to form the corporeal part. The geometry of the part is therefore clearly reproduce in the Additive Manufacturing machine without adjusting a range of parameters for manufacturing processes undercuts, draft angles and so on. This fundamental drives nearly all AM machines with variations in each technology in terms of the techniques used for creating layers and in bonding them together. Further variations include speed, layer thickness, range of materials, accuracy and in factor cost [1].

B. Rapid Investment Casting

The term Rapid Investment Casting represents the utilization of Additive Manufacturing technologies in investment casting. The conniving along with the manufacturing for the growth of master patterns could be made for cost-effective by apply this technology. The completion of AM too results in a lessening of casting time at the same time as providing the similar quality to the final product. It is cost-effective even for small-scale production. A huge number of cost-effective solutions for investment casting of orthopedic implants by means of additive technologies have been reported in the literature. AM which is a fabrication process with lofty potential to improve the conformist manufacturing methods in the future due to its characteristics such as no need for tooling in mass customization, short production time, rather economical for mass production with a complex configuration and able to minimize the material waste produced. The advance of technology impresses some designer and artists too since it can build up their desired ideas precisely with far above the ground levels of complexity. Furthermore, the final product can be done without a large number of skilled craftsmen and longer periods [2]. There are various issues faced by the conventional method among them some of the limitations in mold making using traditional techniques (for ex- machining) include restrictions like limitations on minimum wall thickness, elimination of sharp corners, and undercuts resulting in higher draft angle resulting in increased fabrication costs. This is further amplified within the case of tooling for parts with higher design complexity. The final objective of this work is to analysed the capabilities and effectiveness of Rapid Prototyping to provide an effective solution for investment casting production. In the following section, we review the types, applications, advantages, and limitations of additive manufacturing in the field of metal casting. In the methodology section, we propose a design flowchart for the workflow of this study. Few case studies are provided as evidence. Conclusions and important findings are summarized in the final section [3].

2. Research Methodology

This study of the research papers are selected on the topic by using keywords like Role of Additive manufacturing in casting or Additive Manufacturing in casting or Additive Manufacturing in different casting process or three dimensional printing in casting or three dimensional printing in different casting fields RM in field.

2.1 Research Analytical Questions

The goal of our Systematic Review study is to explain about additive manufacturing and rapid investment casting. The main questions on which our full study is based are stated below:

- ✓ How Rapid Investment casting (RIC) is revolutionizing the field of casting
- ✓ What are the limitations of conventional investment casting process?
- ✓ What are the benefits of introducing additive manufacturing technology in investment casting?

A. Eligibility Criteria

The studies eligible for this systematic review followed the criteria:

- ✓ Studies of Additive Manufacturing
- ✓ Studies of Rapid Investment Casting

- ✓ Studies that evaluate the AM in the field of casting
- ✓ Studies published in English.

B. Search Strategy

An electronic related search was conducted by four independent authors using Google Scholar, Research gate, Science Direct, Mendeley databases to obtain articles published until September 2021 following the eligibility criteria.

C. Data Analysis Process

The research papers selected by all the authors were saved in Mendeley. For extracting data, all the authors used these papers.

2.2 Result analysis

A. Investment Casting

Investment casting (lost-wax casting) is a process supported by molding wax patterns and it is one of the oldest reckoned casting techniques. It is been utilized in various forms for the few decades. It is extremely used because of its ability to provide components with accuracy, versatility, repeatability and integrity in a variety of metals and alloys.

The material is first poured into a cavity in a refractory material.

B. Limitations of Traditional method of Investment Casting

The main Limitations of Traditional method of Investment Casting is the cost especially for low production casting. High costing in investment casting is because of specialized equipment, costly refractories and binders, many operations to make a mold, a lot of labor is needed and occasional minute defects occur.

C. Types of 3-D Printing

There are various types of 3-D Printing Technology. Few of them are stated below:

1) Fused Filament Fabrication (FFF) or FDM: FFF is a three dimensional printer in which heat is used as a source to melt down the polymer material that came out of the nozzle just in its plastic state. The temperature required for PLA material is 180 to 200°C and that for ABS is 230 to 240°C.This material deposits on the printer bed with the in-sync movement of the XYZ coordinates of the machine. This creates a three dimensional object layer by layer modelling as per the 3D designed model using modelling software [4]

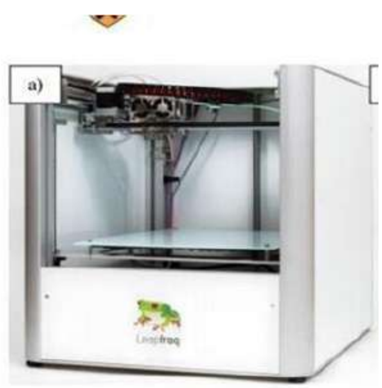

Fig. 1 FDM Printer

2) Multi Jet Printing: Multi Jet Printing is a material jetting printing process that uses the piezo printhead technology to deposit materials layer- by- layer during printing [5]. This technology and silicone rubber moulding both tend to reduce cost as well as lead time required for blade production. According to the results of a dimensional inspection conducted for built patterns by the above two methods, it has been indicated that MJM has higher dimensional accuracy as compared to silicone rubber moulding. The maximum deviation of the built pattern by the thermo jet system was -0.111 mm, while in case of silicone moulding it was +0.298mm. MJM technology has been found to have more ability to make patterns of parts with freeform surfaces such as gas turbine blades [6].

3) Stereolithography: Stereolithography is one of the most popular and extensive techniques in the world of additive manufacturing. It functions using a high-powered laser to harden liquid resin that is held in a reservoir to create the desired shape. In a nutshell, this process converts photosensitive liquid into 3D solid plastics in a layer- by-layer fashion using a low-power laser and photo polymerization world's first SLA apparatus, was created in 1992 by 3D Systems which made it possible to fabricate complex parts, layer by layer, in a fraction of the time. SLA was the first continued to advance itself into a widely used technology to date. Every SLA 3D printer is generally composed of four primary sections:

   a) A vessel filled with the liquid photopolymer: The liquid resin is usually a clear and liquid plastic.

   b) Perforated platform immersed in a tank: The platform is lowered into the tank and can move up and down according to the printing process

   c) High-powered, UV laser

   d) Computer interface that manages both the platform and the laser movements in the process.

4) SLA three dimensional Printing Process: When the printing process starts, the laser "draws" the first layer of the print into the photosensitive resin. Wherever the laser hits, the liquid solidifies. The laser is then directed to the appropriate coordinates by a mirror controlled by a computer. It is a mention- worthy fact that most desktop SLA printers work upside-down. Which is, the laser is pointing up to the build platform, which starts low and is incrementally raised. After the first layer is formed, the platform is raised according to the layer thickness (typically around 0.1 mm), and the additional resin is allowed to flow below the already- printed portion. The laser then solidifies the next cross-section area, and the process is repeated until the whole part is complete. The resin that is not touched by the laser remains back and can be reused.

5) Post-Processing: After finishing the material polymerization, the platform rises out of the tank and the excess resin is drained out. At the termination of the process, the model is removed from the platform, washed off the excess resin, and then placed in a UV oven for final curing. Post-print curing entitles the objects to reach the highest possible strength and become durable [7].

6) Alternative Process: Digital Light Processing: As mentioned before, one scion of SLA is digital light processing (DLP). Unlike SLA, DLP uses a digital projector screen to flash a single profile of each layer across the entire platform. As the projector is a digital screen, every layer will be composed of square pixels. Thus, the resolution of a DLP printer corresponds to the pixel size, whereas in SLA, it's the laser spot size [7, 8]

D. Limitations of additive manufacturing

Additive Manufacturing is material dependent process. Choice of material is limited. Design of components or patterns is constrained to material. Operation cycle time is a limiting factor. Resolution of 3D printing technology is usually at 50 microns. Accuracies obtained depends on the process used currently ranges from 50 to 300 microns based on

Software capabilities & material properties. There is a Temperature limitation for material processing. Operating temperature limitation (typically < 100C for Poly-lactic-acid (PLA) and Acrylonitrile butadiene styrene (ABS)). Size of the component is limited to the size of print bed and related assembly issues. Printing voluminous parts consumes lot of time. 3D printing is usually recommended for prototyping in plastic (PLA or ABS). Unsuitable for volume production. Mechanical properties of product are usually anisotropic before final treatment process [9, 10].

3. Conclusions

Additive manufacturing is a cost-efficient solution for small-batch manufacturing. 3D printing of resin patterns represents a viable alternative for the traditional manufacturing of wax patterns. It has several advantages over conventional technology, mainly faster production, cost-effective, less time-consuming, and precise, having the potential to replace in a few years the conventional technique completely. Studies have shown that resin molds can be used to make intricate products as they provide necessary accuracy. However, conventional metal-mold technology is still better for large-scale manufacturing as metal molds survive longer and have a greater output rate. Additive manufacturing has several potential benefits and may play a significant part in the transition towards a more sustainable industrial system. It has been used successfully in many fields including casting. But the current limitations have restricted usage in specific circumstances. Hence, research in this field might open up new avenues enabling 3D printing to find applications in everyday life.

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