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A Fabrication and characterization of sand-casting mold using conventional and additive manufacturing process - A Review

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Abstract: This article compares techniques to manufacturing cast molds by conventional sand-casting and 3-D printing procedures. The techniques were evaluated in terms of lighter weight, tensile strength, hardness, and microstructure. The results demonstrate that there are several advantages to using 3-D printing techniques in mold fabrication. The molds produced by 3-D printing offers a full-size sand saving, tensile strength, hardness, and microstructure.

Keywords: Magnesium alloy; Metal matrix composites (MMC); stir casting; Microstructural investigation.

1. INTRODUCTION

Additive manufacturing use CAD software records or 3D item scanners aimed at hardware to deposit fabric, layer by layer, in distinct geometrical forms. A material is delivered to additive manufacturing in order to produce an object or item. In contrast, when you make an object the conventional technique, it's much often necessary to remove cloth by milling, machining, carving, shaping, or other techniques. Casting is a procedure in which a material is poured directly into a mold, which contains a hollow cavity of the desired form, and then allowed to solidify. A wooden pattern, as well as 3D printed pattern, is used to compare the properties of both the patterns. Common applications include ECS ducting, bespoke beauty aircraft interior components, rocket engine parts, combustor liners, composite tooling, oil tanks and gas tanks, and UAV components.

2. LITERATURE REVIEW

Additive manufacturing is a novel way of producing items by layering them (AM). Before AM processes were categorised, other names were used. Similar applications are referred to as "3D Printing," "Indirect Additive Manufacturing," "Solid Freeform," and other terms in the literature. AM has evolved over three decades. This new generation of manufacturing technology allows for complex geometry and customisation. The methods of selective laser melting (SLM), electron beam melting (EBM), and laser metal deposition (LMD) are highly regarded. These methods are called direct manufacturing. Direct manufacture provides benefits like complicated geometry.

Brant et al. (2015) investigated how cloud-based computing may improve industrial cooperation, save costs, and streamline processes. Because additive manufacturing is a computer-based technology, it can readily connect into the cloud. The cloud-based use of an in-house metal micro fabrication via electrochemical deposition technology was tested. With a personal phone, tablet, or computer, the system was connected to a commercial cloud and email. The cloud enabled remote start, stop, change, and query of the process. Preliminary design (current feedback threshold value) and input parameters (geometry, tool size) were determined.

Graphs representing output performance, time, and current information are returned to the user on demand and saved in the cloud. The cloud may then keep input parameters and their performance history in a cloud-based database. To improve horizontal deposition, an experiment was put up to preserve values in the cloud for future usage. The trial was a success, demonstrating the cloud's advantages in long-term storage, knowledge exchange, and ease. [1]. According to Mun et al. (2015), it has a number of shortcomings, including a restricted product selection, high thermal anxiety, poor area finish, anisotropic properties, and a high cost. Research is still being conducted to enhance such techniques [2].

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3. STATE OF THE ART

Previously, state-of-the-art evaluations on 3D printing procedures were undertaken. This technique works by depositing droplets of binder from the jet nozzle to selectively firm moulding powdered fabric layer, then blowing away the unneeded moulding powdered fabric to obtain sand mould. Patil et al. (2012) shown that the production of complex grip samples using quick prototyping approach, in addition to giving its scope and benefits in contrast to the existing practice. The study's findings demonstrate specific advantages in the fabrication of complicated designs utilising the rapid prototyping approach. These advantages also include lower costs and reduced time consumption with lower material costs [3]. Snelling et al. (2015) examined lightweight metallic cell systems using 3D printed sand moulds. Nowadays, it has been discovered that 3D printing is being used in a variety of casting processes, including investment casting for pattern production. When compared to traditional cast constructions, the durability of the cellular structure was also enhanced [4].

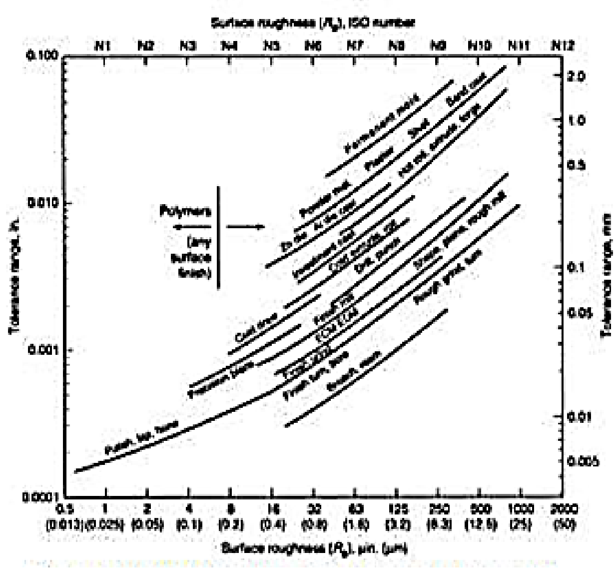

Fig 1: Approximate Value of surface roughness and tolerance on dimensions typically obtained with different Manufacturing processes

Chou et al. (1998) explored the many advantages of fast prototyping procedures. Laser curing is thought to offer a higher potential for enhancing resolution. A combination of several strategies may be utilised to improve rapid prototyping performance by creating the proper component in less time [5]. Kumar et al. (2011) observed that Taguchi's approach of parameter design may increase quality at the lowest potential cost. Before looking at the ANOVA findings for this research, the assumptions of normality, independence, and constant variance have been reviewed. It is also feasible to determine the optimal amounts of signal factors at which the noise factors have the least influence on the response parameters. Using the Taguchi approach, the outcome of this case study is to improve the process parameters of the green sand castings process, resulting in reduced casting defects [6]. Wanlong et al. (2010) stated in their book that with the discovery and commercialization of stereolithography in 1986, a plethora of new and better layered manufacturing techniques were launched to the market. These methods' working materials progressed from laser cured epoxy to wood-like layered paper, engineered polymers, and other forms. Quick prototyping procedures may immediately manufacture patterns and core box tooling with the necessary component, heralding the birth of rapid tooling. While CNC fabrication procedures are precise, they need a significant quantity of working material to get a net tooling form. They are also time demanding, which is frequently a significant variable in a world of short supply chains [7]. It features great flexibility, shorter lead time, reduced cost, process centralization, and no die formation, according to Song et al. (2007) . It is ideal for the creation of complicated shaped castings and small batch manufacturing. Process factors affect the properties and accuracy of sintered samples. With the right laser power, powder ratio, and overlapping, you can increase surface accuracy, dimension precision, interlayer bonding strength, and mechanical strength of the overall component. Post-processing and holding may improve sample strength and uniformity of bonding agents, however the holding temperature cannot exceed 300°C. Reduced slicing thickness and process parameter adjustment may increase sample form accuracy [8]. Zhu et al. (2020) examined the possibility and dimensional accuracy based on 3D printing technology during investment casting of nonvacuum and Bridgman furnaces using a coordinate measuring equipment to compute dimensional tolerances using a systematic method. The study demonstrated that both of the researched RC systems are

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successful at producing cast prototypes in technologically short time and at a cheap cost, with dimensional tolerances that are perfectly compatible with metal casting techniques [9]. To build prototypes from 2D engineering designs, Pham et al. (1998) researched competent model builders. This is a costly and time-consuming operation. Prototypes may now be generated quickly from 3D computer models using modern layer manufacturing and CAD/CAM technology. Rapid prototyping (RP) technologies

come in a variety of varieties. We discuss the pros and disadvantages of the existing technology. In this section, you'll find data on typical process parameters like as layer thickness, system speed, and Unified Taxonomy and Process Selection Guide for Prototypes are also recommended [10].

Conventional and Additive manufacturing processes

Sand-casting is conventional manufacturing process. Due to its low cost, it is the most often employed casting process. This method generates around 70% of all material casting. The initial step of the sand-casting process is patterning. Habits are often made of wood, material, synthetics, and other materials. A design is utilised to build a sand hollow that is a reproduction of the relevant component's model. By pouring molten steel into the hollow cavity, the final material is created. Steel shrinkage during solidification must be accounted for in a design. The shrinkage allowance increases the final cast size. A core placed in the mould chamber determines the interior geometry of the component. To produce a core, which is a replica of the core, a core-box is needed. Casting tools include habits, moulds, and core bins. In addition to the two tooling parts, sand casting requires the creation of core images, a pouring basin, runner and risers, and feed aids. Because the casting component must be removed and the sand mould must be broken, sand casting necessitates production.

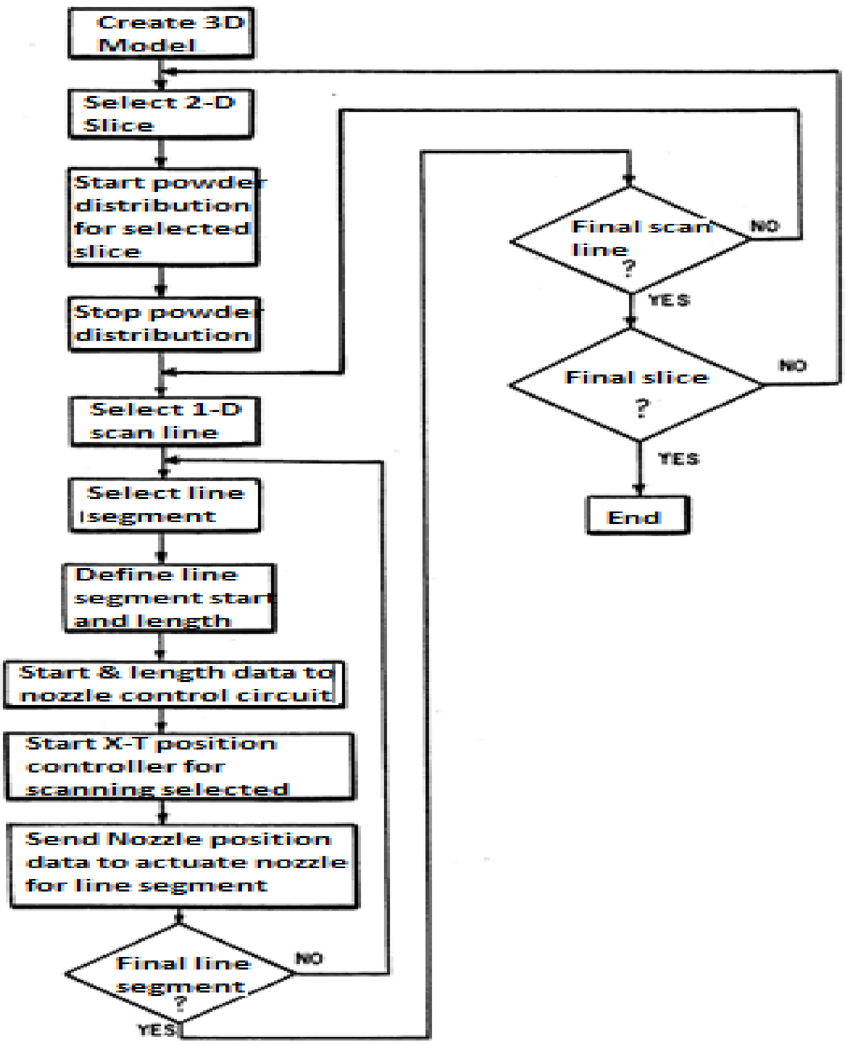

Fig 2: Flow Chart

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In the fabrication of designs, Hawaldar et al. (2018) employed wood, metal, and plastic. Sand casting has used a variety of sands with varying grain sizes. The binder jetting process was used to create the designs. It was discovered that 3D printing saves weight in terms of sand and metal when compared to the typical sand-casting technique. The surface quality of 3D printed sand moulds has also been enhanced. [11].

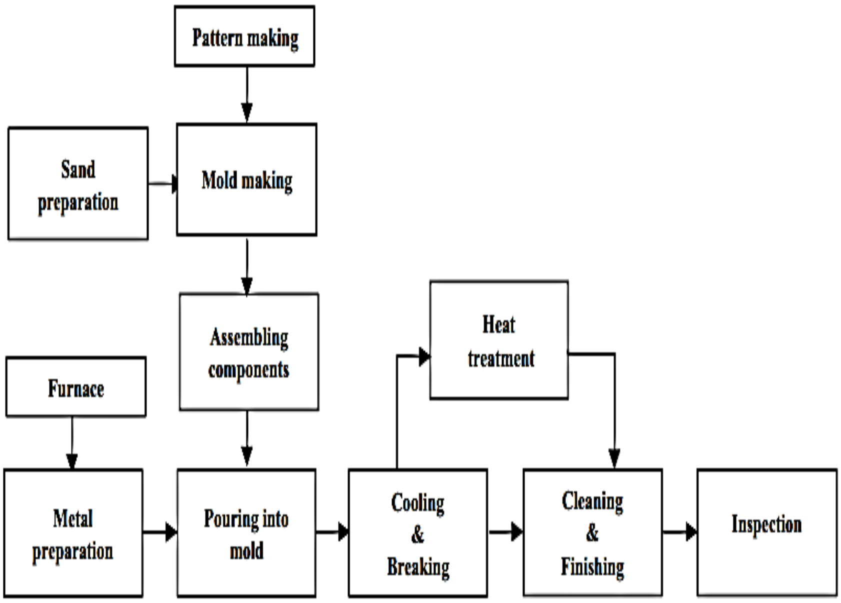

Fig.3. Generalized Steps in Conventional Sand-Casting Process

Sharma et al. (2019) investigated the evolution of 3D printing technology, its deployment, and its important contribution to the worldwide realm of research and medical. The study's findings demonstrate specific advantages in the fabrication of complicated designs utilising the rapid prototyping approach. These advantages also include lower costs and reduced time consumption with lower material costs [12].

A CAD programme, a 3D scanner, or even a camera and photogrammetry software may all be used to create 3D printed designs. Compared to previous technologies, CAD-based 3D printed designs contain fewer flaws. Recognize and correct errors in 3D printable designs before publishing. Manual modelling is similar to sculpting when used to display geometric 3D computer images. 3D scanning is the process of acquiring electronic data about the shape and appearance

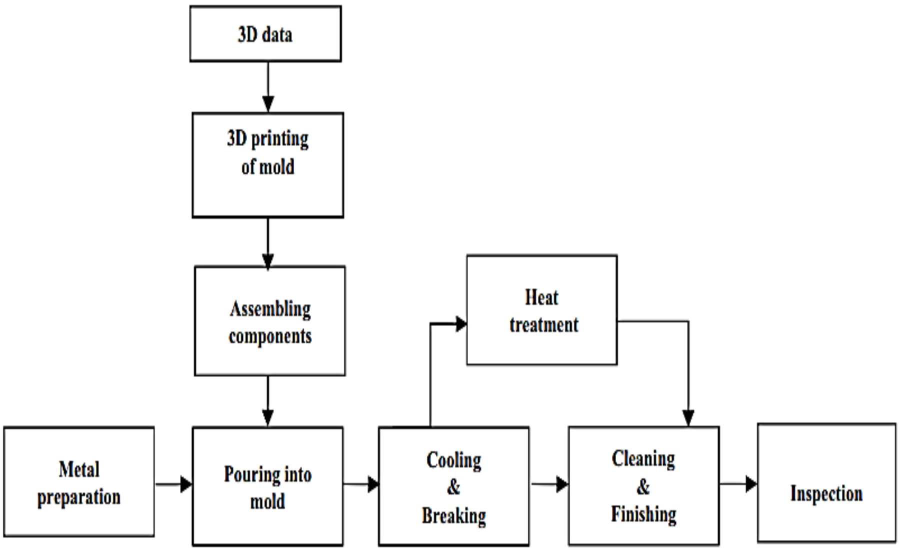

Fig.4 : Generalized Steps in Casting Process using 3D printed molds

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of an item and creating an electronic digital design based on it. Stereolithography (STL) is a de facto format for additive manufacturing that saves information based on area triangulations. STL is not suitable for additive manufacturing because to the large file size of topology optimised pieces and lattice frameworks. The Manufacturing Additive File (AMF) was introduced last year to address this issue. It stores data via curved triangulations.

Binder jetting and SLS (powder bed fusion) are two of the seven AM technologies that are significant to the manufacturing of sand moulds and cores for the foundry sector. These subjects will be covered in that order in this review. Khandelwal et al. (2015) proposed a novel hybrid approach for the rapid fabrication of metallic components that are advanced and effectively impeller parts. The strategy integrates three indigenous low-cost technologies: three-dimensional plastic printing, rapid prototyping, and rapid prototyping. Every appropriate system is cost-effective. It is particularly well-suited to rapid prototyping and other applications [13]. Kulkarni et al. (1996) devised a strategy to calculate the variable thickness of a parametric item to be made using LM procedures. We looked into two aspects of LM's part correctness. The staircase effect was uniquely investigated and solved. The confinement issue was investigated and solved in certain cases. The approach guaranteed that no tangential spots on the surface were missed when slicing the item. This is crucial since determining tangency sites for arbitrary parametric surfaces is challenging. Their 3D models were created by Stratasys. In layered manufacturing, adaptive slicing definitely outperforms uniform slicing [14]. Gogolewski and colleagues (2020) examined the parameters b ased on results of the tests and quantitative analysis, stated that additive technologies combined with conventional casting with the use of model plastics can be used to create short-run production, particularly prototype models, which can be an alternative to time-consuming and costly conventional technologies [15]. According to Gao et al. (2015), AM is set to revolutionized product design, production, and distribution. This technology's capacity to construct complicated shapes with changeable material characteristics has sparked academic and industrial attention. AM has democratized production and design, inspiring the maker movement. Because of the fast growth of AM technologies, there is a dearth of comprehensive design concepts, production rules, and standardization of best practices [16]. Rosen et al. (2003) have created a novel design-for-manufacturing paradigm termed geometric tailoring (GT) and its related digital interface idea. Conditions for effective technique application are studied. The GT approach is proven for quick prototyping and tooling when prototype components must closely match production attributes. This approach is incorporated in a quick tooling system (RTTB). Research on GT and the RTTB distributed computing environment is presented [17].

Printing

Before printing a 3D model from an STL file, it must be examined for defects. The "repair" step in the STL producing corrects such defects in the design. This is 3D because 3D scanning is often accomplished by point to aim acquisition/mapping, STLs made from a model obtained via scanning. Reconstruction errors are common. To print the STL file, it must be processed by software called a "slicer," which translates it into a file of g-code instructions for a specific printer (FDM printers). This G-code file may be printed using the 3D printing client application (which loads the G-code and uses it to show the 3D printer during the 3D printing process).

Additive manufacturing, in the form of 3-D sand printing, was proposed by Lamoncha et al. (2016). Some dwellings can be printed without sample or core containers using 3-D printers. Currently, 3-D sand printing is done via a binder-jetting additive manufacturing process. According to the element layout compatibility and its connection for different manufacturing extents, it is expected that complicated designed components may have minimum or no influence at the coat per casting in the fabrication of printing [18]. Kang et al. (2017) looked at the impact of 3-D printing technology on casting. The pattern was created with the help of CAD software. In this case, 3-D printing is only utilized to manufacture prototypes, patterns, or centre boxes right away. SLS may be used to quickly make sand moulds or cores using resin-lined sand. It was discovered that eventually leads to the saving of material, time, value, and weight [19]. Voigt et al. (2018) portrayed the impact of 3-D printing technology on the investment casting industry as an untold story. However, one aspect of the story is obvious. Direct 3-D printed steel technology is still in its infancy, with many fundamental technical and cost hurdles to overcome before it can become an industrial success that competes strongly with funding casting in the near future. However, the effect of 3-D printed sand moulds and cores to provide complicated steel shapes provides many opportunities for designers for our foundries to provide casting carrier for published sand components [20].

Layer X–Y and thickness resolution are measured in dots per inch (dpi) or micro-meters (m) in printer resolution. Layer thickness is typically approximately 100 m (250 DPI), many machines can print layers as thin as 16 m. (1,600 DPI). The X–Y resolution is on par with laser printers. The particles (3D dots) possess a diameter of 50 to 100 m (510 to 250 DPI). [requires citation] indicating a response that is mesh of mm and a chord duration of 0.016 mm for that printer quality produces best production that is STL when it comes to design feedback file that is certain. greater resolution configurations end up in larger files without any enhancement on

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the net high quality. Conner et al. (2014) developed the technology of robotic gas metal arc welding that allows additive manufacturing of large-scale parts. Here, welding allows the printing of metal layer by layer. However, this method calls for high-priced postprocessing to attain a high-quality surface finish and remains confined to certain printable forms. To discover the capacity and demanding situations of this technique for architecturally exposed and bespoke solid joints, a chain of joint systems for connecting tubular members were made by students. The know-how gained at some stage in the prototyping section tells the improvement of the mold system continuously [21].

Material

Sand casting is a low-cost, old method of creating metal parts and structures. Quality metal and structures need controlling the structure and features of green sands and cores. A strength web diagram can identify green sand, but the Mohr-Coulomb Criterion (Mohr circle). The low surface of the metallic parts and structures produced by sand casting is one of its major limitations. However, it has great potential, especially for big, heavy and complicated castings. 3D printing and ablation casting are other promising sand-casting processes. Because casting and 3D printing moulding are required to make the highest-quality metal components and structures, ablation casting and 3D printing moulding will become more popular and critical. The materials used in 3D printing are as varied as the final products. Thus, 3D printing allows producers to tailor a product's kind, surface, and power. Moreover, these characteristics may be achieved with fewer steps than required by conventional production processes. Many 3D printing tools may be used to generate these goods. To develop a 3D printing as a final result, a comprehensive image must first be sent to the printer. They are usually supplied in standard triangle language (STL), which specifies the intricacies and proportions of a design and allows 3D computer printers to see it from all angles. An STL design is the digital counterpart of a flat design in a single file.

3D printing and casting materials to make casting moulds and prototypes were discussed by Dzhendov et al. (2016). The authors will also build a casting mould for use in meteorological testing. The linear dimensions of the PJM-casting mould and the Silicone-casting mould vary. They have shrunk to the specified size. The nominated dimensions grew by an average of 5% [22]. Plastic is projected to be the key material driving this market soon. According to a recent SmarTech Markets Publishing report, the 3D printing industry will approach $1.4 billion by 2020. Plastics made from organic components like soybean oil and maize have become more popular as the market grows. Plastics are therefore positioned to become the most eco-friendly 3D printing material. (2020) found that rheo-casting with the cooling pitch plate is an efficient technology for processing and slightly spreading the initial Si, intermetallic Cu_2Al section and riving the massive Al-Fe-Mn-Si section. These temperatures are 710 C for beach soil and 690 C for aluminous earth when using CSP at an inclination angle of sixty with a plate length of five hundred metric linear unit. As a result of the microstructure refinement and blending, the consolidation parcels have been reduced by fifty percent compared to the standard forged sample.

Aluminum LM6

LM6 is a corrosion-resistant aluminium alloy with good ductility and impact strength. LM6 is difficult to manufacture because to its high silicon concentration. LM6 adds simple features (like drilled holes), but more complicated features (such as close tolerance holes). The most bendable aluminium alloy is LM6. Many maritime applications, like as motorboat propellers, need this home to work effectively while remaining malleable. According to the results, inoculating LM6 Al–Si alloy with grain-refiner Al5Ti1B enhances casting technical properties. The product stiffness may be enhanced by 10%, and the ultimate tensile by 39%. Hardness and tensile values are optimal in castings when using 0.5 percent whole grain refiner. Solidification rates of LM6 sand castings improve with whole grain refining. The adoption of finer equiaxed whole grain sizes will be aided by quicker solidification and more heterogeneous nucleation. The results show that LM6 sand castings may be grain refined using Al5Ti1B by introducing the master alloy in club form to the melt just before pouring into the mould. The optimum strong addition for LM6 sand castings is 0.5 wt. %.

Ghiaasiaan et al. (2018) examined that the 7 alloy compositions specified in the sounding Al–Zn–Mg–Cu (Al 7000) alloys had been manufactured and effectively cast into net-designed components. The experimental findings of CDS cast components revealed that the behaviour of auxiliary and intermetallic quantities, as well as strengthening precipitates, changed during solidification. The capacity to produce high-quality net-shaped Alv7000 alloy castings via CDS generation and pour gravity casting has been established, and mechanical qualities following suitable heat treatments give high strength equivalent to wrought product counterparts [23]. Lim et al. claim that inoculating LM6 Al–Si alloy with grain refiner Al5Ti1B increased mechanical properties (2005). The maximum tensile strength of this material may be enhanced by 39% while the hardness can be raised by 10%. The optimum grain refiner addition level is 0.5 percent to maximise hardness and ultimate tensile power in the castings. Amounts of LM6 sand castings solidify faster with grain refinement [24].

Polylactic Acid (PLA)

Polylactic acid, often known as poly (lactic acid) or polylactide (PLA), is a thermoplastic polyester having the backbone formula (C3H4O2)n or [–C(CH3) HC(=O) O–]n (hence its title). Ring-opening polymerization may also make lactide [–C(CH3) HC(=O) O–]2, the fundamental device's cyclic dimer. PLA is gaining prominence because of its low-cost manufacture. Despite not being a commodity polymer, PLA was the second most widely used bioplastic in 2010. Several physical and processing issues have impeded its broad adoption. PLA is the most widely used synthetic filament in 3D printing. Despite its frequent usage, "polylactic acid" does not match the IUPAC standard nomenclature of "poly (lactic acid)." PLA is a polyester, not a polyacid (polyelectrolyte), hence the label "polylactic acid" may be misleading.

Traditional and 3-D printing methods were used to fabricate sand-casting moulds by Kumar et al. (2019). CAD software created the stepped pulley. During testing, 3d printed items were made using wooden designs and PLA material. Compared to traditional wooden designs, 3d printed castings had a better surface polish. The experiments also showed that 3D printing may provide precise tolerances [25].

Adhikari et al. (2021) studied the chemistry and properties of pure PLA, as well as its limitations as a 3D printing feedstock. The need and prerequisites for manufacturing PLA composites that will likely be used in 3D printing applications in numerous sectors were studied. In general, 3D-printed PLA composites are made in two steps: first, the materials for the application are mixed with the PLA matrix polymer, and then the PLA composite feedstock filaments are made via melt extrusion (or occasionally solvent precipitation). These filaments are utilised in an FDM-based 3D printer with controlled parameters for raster angle, raster width, layer thickness, polymer flow rate, nozzle temperature, and medium temperature. The adhesion strength between the deposited layers is ultimately defined by the entire technical strength of the object, making 3D printing a sensitive procedure [26]

CONCLUSION:

3D imprinted suggestions that assist save on raw material, length, price, or body weight. It is implied with extending the administration delicacy that is dimensional castings. Intensity will be changed. The 3D stamp is also more generative than the existing beach-casting, in terms of poise delivery along the shore, with entity utilised, drawing allowances, fettling work, and a small quantity of moulds needed. The first machine is tooling-based, subsequently a large number of moulds are built. Also, the present expenses of the 3D writer are better than the previous method. This control's 3D posted face that is earth's executed is better than the workshop alone, along with bettered dimensional delicacy. This is owing to 3D published coast moulds or inner base forbearance, which closes the pattern-making verb in seaside casting.

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