DESIGN AND ANALYSIS OF 3D PRINTED FOUNDRY PATTERN

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ABSTRACT

This study presents a comprehensive exploration into the design and analysis of 3D-printed foundry patterns, aiming to enhance the efficiency and precision of metal casting processes. The research encompasses the careful selection of suitable materials, the utilization of advanced design algorithms, and the optimization of printing parameters to achieve patterns tailored for intricate and complex metal components. Through an in-depth examination of various post-processing techniques, the study seeks to refine the 3D-printed patterns, ensuring they meet stringent quality standards for foundry applications. The investigation also delves into the integration of Industry.

Keywords: 3D-printing, Additive manufacturing, Foundry Pattern

I. INTRODUCTION

A foundry pattern is a tool used in casting processes to create a replica of a part or object. Traditionally, foundry patterns were made of wood, metal, or plastic. However, with advancements in technology, 3D printing has revolutionized the way foundry patterns are created.

3D printed foundry patterns offer many advantages over traditional patterns. They can be designed and produced quickly with high accuracy. The design process is also much easier as it can be done digitally, allowing for modifications and adjustments before printing.

Another advantage of 3D printed foundry patterns is that they can be printed in a variety of materials including sand, plastic, and wax. This flexibility allows for the creation of complex shapes and intricate designs that would be difficult or impossible to create with traditional patterns.

Overall, 3D printed foundry patterns provide an efficient, cost-effective, and flexible solution for the creation of high-quality castings. As technology continues to advance, it is likely that 3D printing will become even more prevalent in the foundry industry.

II. METHODS AND MATERIAL

3D printing, also known as additive manufacturing, is a transformative technology that has revolutionized the way objects are designed, prototyped, and manufactured. Unlike traditional subtractive manufacturing methods that involve cutting, drilling, or milling away material from a solid block, 3D printing builds objects layer by layer from digital 3D models, offering unprecedented flexibility, efficiency, and customization capabilities.10

At its core, 3D printing works by slicing a digital 3D model into thin horizontal layers, which are then sequentially printed one on top of the other using a variety of materials such as thermoplastics, metals, ceramics, and even biomaterials. This layer-by-layer approach allows for the creation of complex geometries, intricate designs, and customized products that would be challenging or impossible to produce using traditional manufacturing methods.

One of the key advantages of 3D printing is its versatility, as it can be used across a wide range of industries and applications, including aerospace, automotive, healthcare, architecture, education, and consumer goods. In aerospace and automotive industries, 3D printing is used to create lightweight yet durable components, optimize designs, and reduce manufacturing costs. In healthcare, it enables the production of patient-specific implants, prosthetics, and medical devices tailored to individual needs. In architecture, 3D printing facilitates the rapid prototyping of building models and the fabrication of intricate structures with complex geometries.

TYPES

FUSED DEPOSITION MODELING (FDM):

FDM is one of the most widely used 3d printing technologies. It works by extruding thermoplastic filament through a heated nozzle, which then deposits layers of material onto a build platform. As each layer cools and solidifies, the platform moves down, and a new layer is added. Popular FDM printers include those from ultimaker, makerbot, and prusa.

STEREOLITHOGRAPHY (SLA):

Sla is a resin-based 3d printing process that uses a uv laser to solidify liquid photopolymer resin layer by layer. The build platform is submerged in a tank of liquid resin, and the laser selectively cures the resin according to the 3d model's cross-sections. After each layer is cured, the platform moves up, and a new layer of resin is added. Sla printers can produce high-resolution, detailed prints and are commonly used for prototyping and jewelry making.

SELECTIVE LASER SINTERING (SLS):

SLS is a powder-based 3d printing process that uses a high-power laser to sinter (fuse) powdered material, typically nylon or other thermoplastics, into solid layers. The build platform lowers with each layer, and a recoating mechanism spreads a new layer of powder over the previous one. SLS can produce parts with complex geometries and is often used in aerospace, automotive, and medical industries.

DIGITAL LIGHT PROCESSING (DLP):

DLP is similar to SLA but uses a digital light projector to selectively cure liquid photopolymer resin layer by layer. DLP printers typically have faster print speeds than SLA printers but may have slightly lower resolution. DLP printers are popular in industries requiring rapid prototyping and high-detail prints.

BINDER JETTING:

Binder Jetting involves depositing a binding agent onto a powder bed, selectively bonding the powder particles together to form each layer of the object. After printing, the part is removed from the powder bed and undergoes post-processing, such as curing and infiltrating with additional materials. Binder jetting is used for producing metal, ceramic, and composite parts with complex geometries.

MATERIAL JETTING:

Material Jetting works similarly to inkjet printing but uses multiple print heads to deposit droplets of photopolymer resin onto a build platform. Each layer is cured with uv light immediately after deposition, resulting in high-resolution prints with fine details and smooth surfaces. Material jetting is used for prototyping, dental applications, and creating investment casting patterns.

DIRECT METAL LASER SINTERING (DMLS):

DMLS is a metal 3d printing process that uses a high-power laser to selectively sinter metal powder, such as stainless steel, titanium, or aluminum, into solid layers. DMLS can produce functional metal parts with complex geometries and is widely used in aerospace, automotive, and medical industries for producing end-use parts and prototypes.

These are just a few examples of the many types of 3d printing technologies available, each with its own strengths, limitations, and applications. As 3d printing continues to evolve, new technologies and processes are being developed, expanding the possibilities for manufacturing, prototyping, and customization.

MATERIALS:

PLA:

Out of all the raw materials for 3D printing in use today, PLA is the most common. PLA is one of the most diverse materials for 3D-printed toys and household fixtures. Products made with this technique include desk utensils, vases, and action figures. Available in transparent form as well as bright colors, plastic filaments are sold on spools and can have either a matte or shiny texture.

MATERIAL	ACRILONYTRILE BUTADIENE STYRENE-CARBON FIBER (20%)
DIAMETER	1.75 mm
ULTIMATE TENSILE STRENGTH	46 MPa
DENSITY	1.11 g/cm^3
EXTRUDER TEMPERATURE	220–240 °C
MAX SERVICE TEMPERATURE	80 °C

With its firmness, flexibility, smoothness and bright range of color options, the appeal of PLA is easy to understand. As a relatively affordable option, PLA is generally light on the pocketbooks of creators and consumers alike.

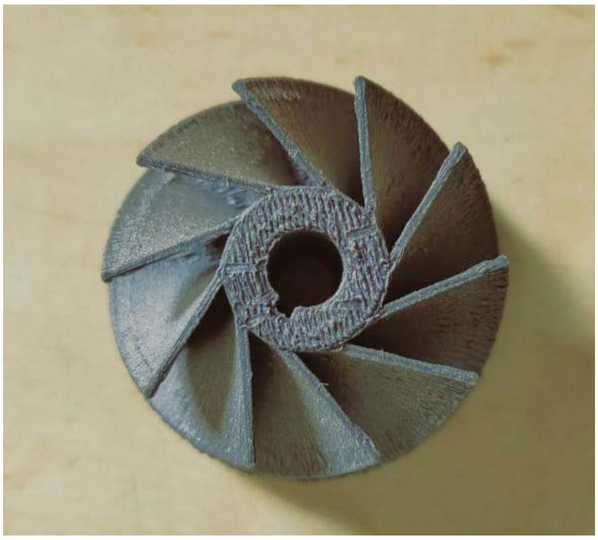
PLA are generally made with FDM printers, in which thermoplastic filaments are melted and molded into shape, layer by layer.

ABS-CF:

MATERIAL	POLY LACTIC ACID
DIAMETER	1.75 mm
ULTIMATE TENSILE STRENGTH	65 MPa
DENSITY	1.24 g/cm^3
EXTRUDER TEMPERATURE	190–220 °C
MAX SERVICE TEMPERATURE	52 °C

ABS CF (Acrylonitrile Butadiene Styrene with Carbon Fiber) filament is a composite material that combines ABS plastic with carbon fiber reinforcement. This combination results in enhanced mechanical properties compared to standard ABS filament.

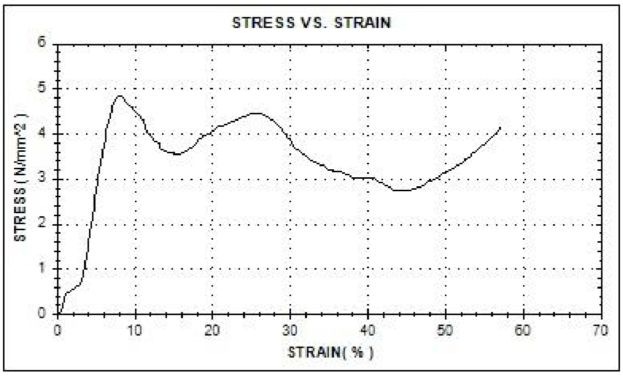
PRINTING PARAMETER:



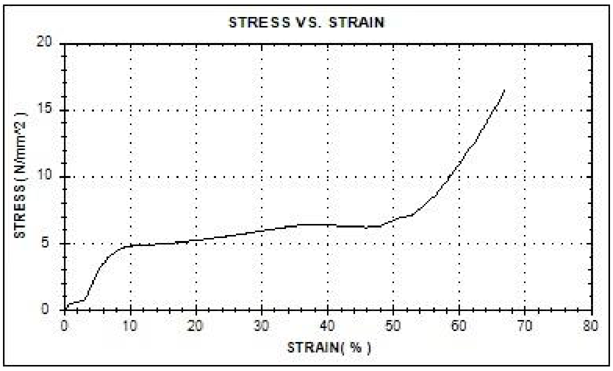
III. RESULTS AND DISCUSSION

Tensile testing also known as tension testing, is a fundamental materials science and engineering testing which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation, and reduction in area measurement the following properties can also be determined: young modulus poison's ratio, yield strength and strain hardening characteristics. Uni axial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. Some materials use bi axial tensile testing Tensile test is used to find how strong material is and also how much it can be stretched before it breaks. This test method used to determine yield strength, ultimate tensile test, ductility, strain hardening characteristic.

STRESS VS STRAIN

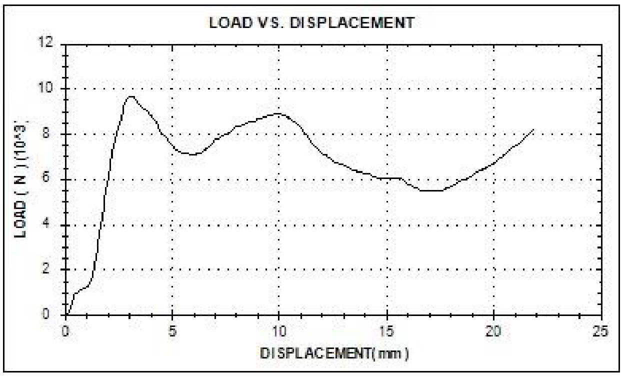


PLA

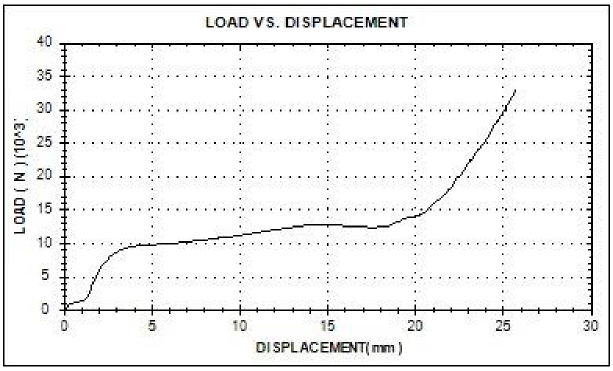


ABS-CF

LOAD VS DISPLACEMENT



PLA



ABS-CF

Test Name	C-PLA
Intial Area (mm2)	1997.41
Ultimate Load in N	9650.32
Ultimate Stress in N/mm^2	4.83
Breaking Load in N	8259.46
Max. Displacement in mm	21.9
Final Gauge Length in mm	17.57
Final Dimension (D X L) in mm	55.86 X 17.57
Final Diameter in mm	55.86
% of Reduction of Area	-22.69
Load Unit	N
Displacement Unit	mm
Time Unit	sec

Test Name	C-ABS
Initial Area (mm2)	1997.41
Ultimate Load in N	32791.27
Ultimate Stress in N/mm^2	16.42
Breaking Load in N	33172.7
Max. Displacement in mm	25.71
Final Gauge Length in mm	16.91
Final Dimension (D X L) in mm	63.60 X 16.91
Final Diameter in mm	63.6
% of Reduction of Area	-59.05

Load Unit	N
Displacement Unit	mm
Time Unit	sec

COMPRESSION TEST RESULT

Sample I.D	Compressive strength, Mpa
PLA	4.83
ABS-Carbon fiber	16.42

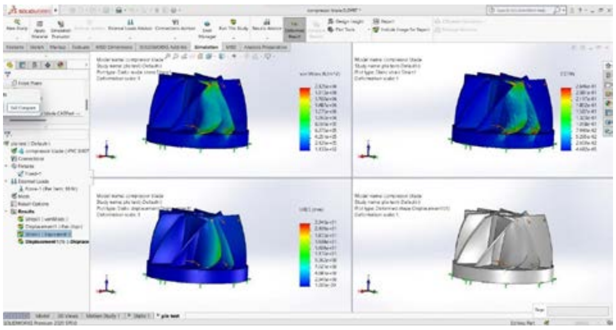
Hardness Test results:
Method: Shore “D”

Sample I.D	Shore “D”
PLA	73.0, 72.0, 71.0
ABS-Carbon fiber	62.0, 59.0, 59.0

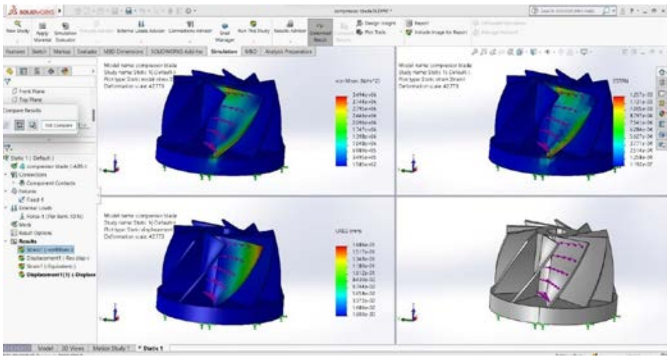
FINITE ELEMENT ANALYSIS TEST

The Finite Element Analysis (FEA) is the simulation of any given physical phenomenon using the numerical technique called the Finite Element Method (FEM). FEA software to reduce the number of physical prototypes and experiments and optimize components in their design phase to develop better products faster while saving on expenses.

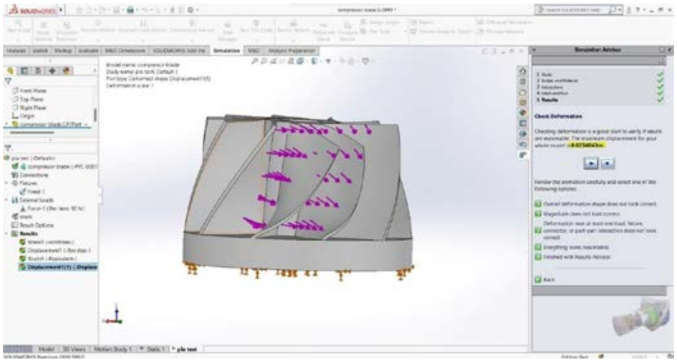
It is necessary to use mathematics to comprehensively understand and quantify any physical phenomena such as structural or fluid behavior, thermal transport, wave propagation, the growth of biological cells, etc. Most of these processes are described using Partial Differential Equations (PDEs). However, for a computer to solve these PDEs, numerical techniques have been developed over the last few decades, and one of the prominent ones, today, is the Finite Element Analysis.



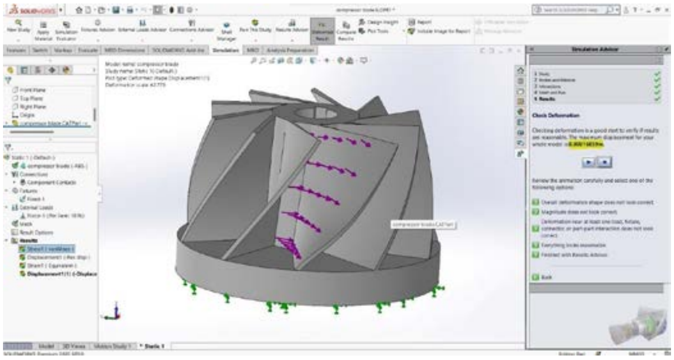
Strain analysis of PLA



Strain analysis of ABS-CF



Displacement analysis of PLA



Displacement analysis of ABS-CF

Clearly the displacement of ABS – CF is less than PLA.

IV. CONCLUSION

In conclusion, the process of 3D printing foundry patterns represents a significant advancement in manufacturing and casting technologies. The careful selection of appropriate materials is to be done and coupled with meticulous design considerations and optimization for 3D printing, lays the foundation for successful pattern creation. Then the post-processing techniques, ranging from support removal to heat treatment, further refine the printed patterns, ensuring they meet the required specifications. The integration of these patterns into the foundry process allows for the production of intricate and complex metal components with precision and efficiency.

Continuous attention to printing parameters, material characteristics, and quality assessment methods is paramount for achieving consistently high-quality foundry patterns. As 3D printing continues to evolve, its role in foundry applications contributes to a more agile and adaptable approach to metal casting, opening new possibilities for design innovation and manufacturing efficiency.

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