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Independent Study of Additive Manufacturing and Casting

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Abstract

This independent study was an investigation into the use of a Stereolithography (SLA) or Resin printer to produce 3-D models intended for the Investment Casting Process. Three-dimensional printing for investment casting has become an increasingly popular method of producing complex castings and is widely used in a variety of industries such as aerospace, medicine, manufacturing, and the defense industry. Using the 3-D printing process allows engineers and designers to iterate faster and quickly produce parts without having to go through traditional, time-consuming mold making processes. Even with the rapid integration of this technology, there are still many factors that need to be improved. Keeping this in mind, the goals of the study were to (1) identify: SLA, and Liquid Crystal Display (LCD) printing technique processes; (2) improvement of the investment casting process using strategies that would be cost effective in small scale production, or for educational institutions; (3) exploring how sprue design and placement impacts the ability to burn out the investment pattern when using traditional jewelry investment mixes; and (2) creating a set of procedures that will allow success in the small-scale creation of 3-D printed models that will be used for investment castings.

SLA, DLP, And LCD Printing Techniques Processes and the Creation of a Set of Procedures that will Allow Success in the Small-Scale Creation of 3-D Printed Models that will be used for Investment Castings.

The stereolithography (SLA) printing process is nuanced in different ways than traditional FDM (fused deposition modeling) printing (Formlabs, 2020). Some of the unique factors that affect SLA print quality include cure times for individual layers, clean optics and surfaces, proper drainage of resin from around the printing part, delamination, part angle, and proper support type and placement (Schodek, Bechthold, Griggs, Kao, & steinberg, 2005, p. 290). All these various quality contributors become especially evident while working with specialty resins. With resins design for the investment casting process, imperfections like improper drainage and layer delamination became much more prevalent. In efforts to improve quality and combat deformation and delamination and overall low-quality prints, it was found through experimentations that there were several factors involved in successful printing which included printer settings, part angle, and support systems.

Improvement of the investment casting process using strategies that would be cost effective in small scale production, or for educational institutions.

Lost wax casting has existed for centuries (Wright, 2005), however, casting using additive manufacturing processes is only a recent development in industry. Using additive manufacturing (Formlabs, 2020) to produce patterns for investment casting opens new doors, although each comes with their own unique set of problems. In the early castings, common defects when following typical wax casting processes included porosity, lost detail, and incomplete casts. Through trial and error and continued research of the available literature, probable causes for each defect were determined. These causes were incomplete burn outs, poor sprueing practices, and turbulence in the molten metal. Incomplete burnouts were addressed by using a high temperature investment, increased oven temperatures, and burnout ovens with increased airflow (formlabs, 2021). These three improvements allowed for full combustion of the 3-D printed parts and ensured that their resulting cavities were free of residual char/plastic.

Exploring how sprue design and placement impacts the ability to burn out the investment pattern when using traditional jewelry investment mixes.

One of the main goals of this project was to simplify sprue design for the casting process using the capabilities of SLA printers. Sprue design and location is a complex topic and incorrect placement and design are one of the most common reasons for casting failures using this process. At first attempts were made to print the sprue system with the parts attached, thus eliminating user error. Unfortunately, this proved to inhibit cast quality and traditional wax sprues and runners were used. This was later found to be because the photopolymer materials do not burn out in the same way that traditional wax sprues do, reducing the efficiency of combustion and preventing a clean burnout. This potentially leaves ash deposits in the casting that can cause rough surface textures, and filled text in the castings (formlabs, 2021). Randomizing the position and size of the gates had mixed results, but all were below the desired quality. The greatest increase in quality of the produced parts came when filleted junctions were added to the body of each piece. This resulted in an evident improvement in the quality and porosity of the parts produced. This was likely due to reduced turbulence as the metal is introduced into the mold cavity (Levon, 1990). (Bovin, 1971) Additionally, it eliminated user error for the sprueing steps making investment casting an easier and more practical process for future students.

Moving Forward

Moving forward there are several areas that warrant more research and several new processes that are worth looking into. One is the addition of boric acid into the investment during the mixing stage. Boric acid can be dissolved into the water that is used when preparing the investment. This has shown to increase the durability of the investment which makes it less likely to fracture during burnout when plastic parts expand (Earnshaw, 1975)(formlabs, 2021). Another promising area to investigate is the effect of wax on the success of plastic burnout cycles. Preliminary testing suggests that wax sprues or additional wax being added to the plastic part may help with eliminating residual char after burnout. Further testing and analysis is required to determine whether or not this is truly the case.

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