**Project Proposal: Optimizing print parameters to reduce warpage in fused deposition modeling**

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**Objective**

The purpose of this project is to reduce the occurrence of warpage in 3D printing, specifically in fused deposition modeling, by studying the effects of various printing parameters on the spatiotemporal distribution of temperature and heat flow trajectory throughout the printing process.The outcome is expected to be a collection of parameter combinations, representing the parameters that can produce the greatest reduction in warpage.

**Justification**

This study is vital to future additive manufacturing studies as well as for commercial use. Thermal defects are a widespread problem for 3D printing, and the findings of this project will help lead to solutions. Additionally, this topic has not been studied before and is crucial for understanding the thermodynamic properties of 3D printing, especially for industries that rely heavily on 3D printing, such as aerospace and defense, automotive, and healthcare.

**Description**

The parameters used in this study will include infill type, either rectilinear, triangular, or hexagonal; infill percentage, either 10%, 20%, 30%; layer height, either 2mm or 4mm; and wall thickness, either 0.8mm, or 1.5mm. Therefore, there are 4 independent variables and consequently 36 unique combinations of parameters. Some parameters will be given a “cost” as a weight to be added in the optimization to account for the time and material use. Each combination will be printed twice such that there is a total of 72 trials. For each trial, a 6-inch radius, 0.5 inch thick disc will be printed, and an Arduino connected to 6 thermistors will be embedded during the print. Data will be collected as temperature at a position over time, such that the dependent variable can be found from the spatial temperature data over time as the trajectory of heat flow. If time permits, the discs will be tested for thermal conductivity using a Lees’ Disc Apparatus, and the thermal conductivity will be accounted for in the optimization as well. Both the actual spatiotemporal temperature data and the heat flow trajectory will be compared between all combinations, and the combination with the qualitatively more uniform distribution of heat will be deemed as the optimal combination to reduce warpage.

**Limitations**

The most major limitation of the project is the available time to print 72 discs while embedding thermistors. The print parameters being tested drastically change the time and material required to print each of the objects, making the time factor unpredictable and difficult to control for. Additionally, there are many other factors that play a role in influencing the thermal properties in 3D printing. Due to time, material, and skill constraints, only a select collection of parameters were chosen to be tested in this study by researching the most influential ones. Although this study may be representative of finding the optimal printing parameters, it is certainly not an exhaustive comparison of all parameters.

**Feasibility Study: Optimizing print parameters to reduce warpage in fused deposition modeling**

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**Available Resources**

**Personnel**

* Me
* Research Mentor

**Equipment**

The following equipment is available at the Academies of Loudoun campus:

* 3D printer with at least 6” x 6” bed size (gCreate gMax 1.5 XT+ with Heated Bed)
* Arduino Mega and Breadboard
* Computer with CAD design software and slicing software
* Basic manufacturing equipment (drills, screwdrivers, etc.)
* An 8” x 8” Lee’s Disc Apparatus

**Supplies**

* Electric wire with colored plastic insulation
* Thermistors (approximately 100 in stock)
* PLA filament (approximately 5 spools)

**Knowledge and Skills**

* Basic manufacturing ability
* Understanding of thermodynamics in 3D printing
* 3D printer operation
* CAD design skills
* Arduino programming
* Optimization techniques

**Additional Resources**

**Personnel**

None.

**Equipment**

* Computer with ANSYS simulation software

**Supplies**

* Thermistors (approximately 300 more).
* PLA filament (approximately 10 more spools)
* Electrical wire with colored insulation

**Knowledge and Skills**

* ANSYS operation
* Improved optimization techniques
* Thermistor embedding

**Proposed Budget**

* Thermistors (Part no. 594-NTCLG100E2203JB) cost $132.40 for 400 from Mouser Electronics
* PLA costs $200 for 10 spools from Amazon

Total budget: approximately $250.

**Risk Assessment**

One of the primary safety issues in this project is the risk of being burned while embedding thermistors in the 3D printed discs. This is solved by using caution, wearing safety glasses, and wearing thick gloves when embedding the thermistors and connecting them to the Arduino. The same safety procedures can be followed when operating the 3D printer, as it can cause burns if handled without using caution or without wearing safety glasses and gloves.

**Project Alternatives**

The required electrical wiring can be bought from any electronics store, as it carries limited purpose other than to connect the thermistors to the Arduino. The additional supplies for this project can easily be replaced if they become unable to use. The specific thermistors can be replaced using any other brand and model of thermistors that reach a maximum of 200 degrees Celsius as long as the brand and model of thermistors are kept constant for all prints. The PLA can also be replaced by another manufacturer, but similar to the thermistors, must be kept constant for all prints as manufacturers have varying methods and materials used to create their filaments.