Design and development of control system for mixing and extruding multi-material in 3D printing

Design and development of control system for mixing and extruding multi-material in 3D printing
of epoxy

Design and development of control system for mixing and extruding multi-material of epoxy and integration in 3D printing

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***Abstract*—This paper will consist of building a functional multi material extrusion machine that will allow to build on a large scale using non-conventional materials. Large 3D printer will be utilized as a ready start up platform to build an additional extrusion mechanism. The study will focus on the mechatronics and development of the machine, thus leaving the chemistry discussion of two component materials to a minimal side. (*Abstract*)**

***Keywords*—multi-material, extrusion, 3D printing, epoxy, two components, mechatronics**

I. Introduction

3D printing as an additive manufacturing process, making objects from 3D model data [1], was strongly established with the use of plastic materials in the form of solid filament windings, known as Fused Filament Fabrication (FFF) [2]. There is a large knowledge base collected on the mechanical properties of the most common filaments used [3]. The tensile strength and elastic modulus of printed components using realistic environmental conditions for a selection of open-source 3D printers find an average tensile strength of 28.5 MPa for ABS and 56.6 MPa for PLA with average elastic moduli of 1807 MPa for ABS and 3368 MPa for PLA [4].

The availability of different scale printers and wide selection of materials offer great benefits of rapid prototyping and creating models that were previously impossible to manufacture using traditional manufacturing methods. One example is printing of epoxy structures that have a fiber as reinforcement. Young's modulus of these materials exceeds up to 10 times higher values compared using commercially available 3D-printed polymers, while maintaining comparable strength values [5]. Two component materials combined with complex geometry enabled by 3D printing offer great mechanical properties and reduced weight of the product against components that are made by using traditional manufacturing methods [6].

As of July 2018, the most used 3D printing method is by far the FFF (also known as FDM) with share of 69 percent. This is then followed by Stereolithography & Digital light processing, Selective laser sintering, Material Jetting and Metal Sintering [7]. However, a new additive method emerges with great present and future projection. This 3D printing method is called multi-material extrusion and is currently applied for different purposes such as tissue engineering/ multi-colored surgical parts in medical field, reducing environmental impact on pollution [8].

This paper is focused on multi-material extrusion involving Epoxies, field which is not very widely developed and offers great opportunities. The method used is going to utilize two components consisting of hardener and resin, which are mixed together, and then cured by the chemical reaction [9]. Since this process is going under development, this project will aid in the further development of this type of layered manufacturing.

While the conventional extrusion-based 3D printing involves melting of solid material for extrusion, this project is focused on extrusion of viscous material(s). The purpose of this project is to develop a system to mix and extrude two component material(s) and to control the process in 3D printing. The most common way of cure an epoxy in 3D-printing systems is to use external heat source [10]. The motivation behind multi-material extrusion in this project is to develop a starting point for a system that allows for a mixing and extruding different biomaterials without external heat source. While separate research is being done for the biomaterials, two component mixtures such as epoxies are used in this project as an experiment of extruding different materials. Epoxy was used because of its highly beneficial properties such as high adhesion strength and good process ability. The uncured epoxy resins have only poor mechanical, chemical and heat resistance; by reacting the linear epoxy resin with suitable curatives, three-dimensional cross-linked thermoset structures can be obtained. This is ideal for the mechanical and thermal properties, resulting in high modulus, failure strength and great bonding for many industrial applications [11].

The paper will go through in detail how to build a separate mechanism that can be inserted to an open source 3D printer. The mechanical portion of the build includes of building the feeding mechanism from the containers to the printer nozzle including the mixer, material medium routing, construction of the extrusion mechanism attached to the containers and mounting of both systems.

All the used hardware will be introduced that is needed to achieve multi material extrusion. This will include all the different electrical equipment needed such as stepper motors, controller boards and power supplies. The key focus will be to use existing hardware of the open source 3D printer and make a removable extrusion system that is hardware independent of the existing printer's circuitry.

The control system section will consist of used software that will be utilized to control the extrusion based on the movement of the printer. Additional effort in the end is put towards implementing a time of flight sensor system that will allow a better precision on large scale printing.

II. Containers,routing and mixing

First the material must get from the containers to the nozzle of the printer, this part will tell about how we will implement that system.

A. *Designing the routing and mixing elements*

This section would contain the conceptual ideas, advantages and disadvantages that need to be taken into an account, thoughts about manufacturing the parts and how much sourcing for the parts can be utilized, part specifications and the outcome.

B. *Implementation*

In this part the feeding system can be tested manually weather it is working or not. Thoughts are given about scalability and further improvement of the system. Could give some thoughts about replenishing the resin and curing containers.

III. Extrusion mechanism

Now that the material can get all the way from the containers to the printer nozzle, the extrusion mechanism can be explained here. This will include both hardware and mechanical designing of the product

A. *Selection of suitable hardware*

Here a little bit talking about how the material will behave, because that will impact the design of the extruder, aka forces etc. The hardware should be selected here and be justified

B. *Designing the mechanical components*

The mechanical side should be described here, how the hardware was implemented and what kind of accessories were needed to mount the system to the containers

C. *Implementation*

Some talk about how it was assembled and attached to the machine

IV. Control system

Now all the mechanical and hardware side should be completed from previous sections. Here should be writing about how we are going to control the system based on the existing hardware and software

A. *Control system implementation*

What control system was used, why and how.

B. *Control system paramenters*

What kind of values were used for testing and presenting the final values

C. *Reserved section for time of flight sensoring*

Insert stuff regarding time of flight sensor if made possible

V. Results

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VI. Discussion

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Acknowledgment

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