Development of platform for mixing and extruding multi-material in 3D printing

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Abstract. This paper describes the building of a functional multi material extrusion machine that allows to print on a large scale using non-conventional materials. Large 3D printer was utilized as a ready start up platform to build an additional extrusion mechanism. The study focuses on the control system for mixing and extruding multi materials with the printer, thus leaving the chemistry discussion of two component materials to a minimal side.

Introduction

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. 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].

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]. 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].

While the conventional extrusion-based 3D printing involves melting of solid material for extrusion, this project is focused on creating system for extrusion and mixing of two viscous material(s) without external heat source, which is the most common way of curing epoxies [10]. These materials are suitable for 3D printing because of high adhesion strength and good process ability. The uncured epoxy resins have 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].

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 to 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 platform for a system that allows for a mixing and extruding different two component materials 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].

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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.

System description, key components and measured values

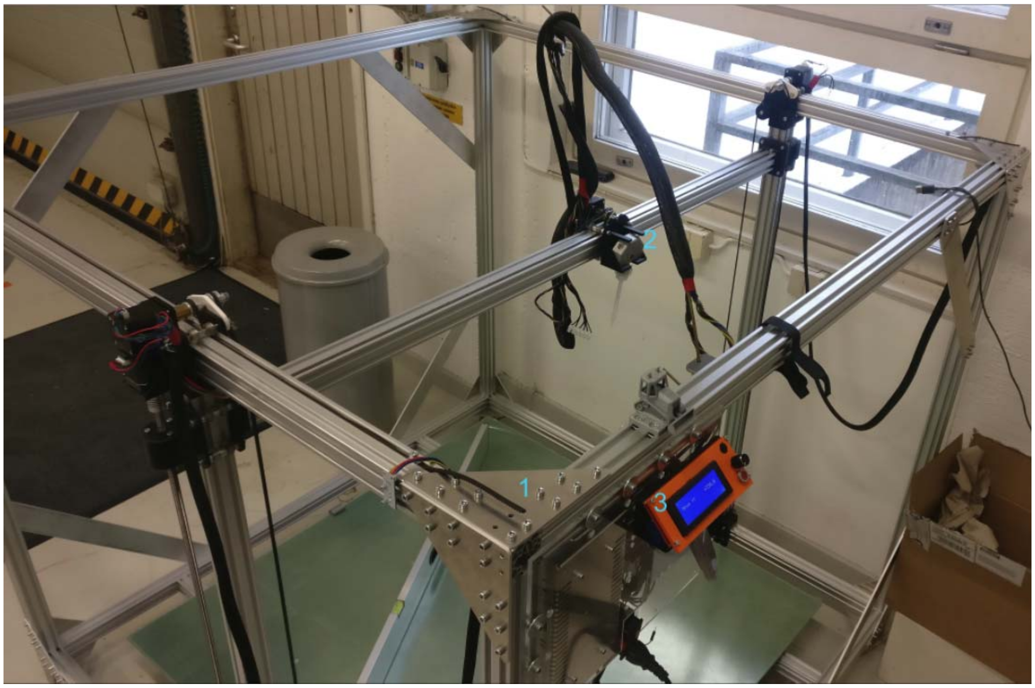

Figure 1 Picture of printer setup (will be better in the future, with more parts!!) 1. Printer frame, 2. Mixer-head, 3. Control unit

Table 1 Table for listing the components including the specs and limitations

S.N.	Component id	Description	Specification	Qty
1	DLA-24-40-A-200-POT-IP65	Linear actuator	24 V, 200mm stroke length, 1000N dynamic force	1
2	Mixer	Casted aluminum mixer	2x ¼ thread into bayonet nozzle attachment	1
3	Mounting for cartridges	Mounting and fastening of the cartridges to the existent frame	3D printed (ABS)	1

Extruding two different materials need a plunging mechanism and mixing them before extrusion. The two materials are plunged through two cartridges using a linear actuator, keeping the materials separated before the mixing head. The designs for this project was based on the extrusion of using two 185mm long cartridges. Size of the cartridge restrict the size of the printable object and sizing of the tubes restrict the maximum material flow. The plunging system was modular designed as seen in figure (x), for it to be used for different lengths of cartridge. Increasing the stroke length of actuator and the length of the plunger allows to extrude materials through longer cartridges. The speed of the actuator movement was controlled to have desired rate of extrusion of the materials. To avoid the additional weight and its resulting effect on the beam where the printing nozzle of the extrusion exists and the complexity of the mount design, the actuator, plunging system and the cartridge were not directly mounted on that beam. They were mounted on the other beam in the frame of the 3D printer and connected to the nozzle through tube and mixing interface. This location further allowed the variability option of the cartridge length depending on the need of the printing size.

The cartridges were intended for single use only. Once the print or the material in them gets finished, they must be manually removed and replaced again for the next print. This means that their placement and removal from the structure is a process that will take place often, so an easy access and a simple replacement solution was provided. It had been chosen a system of two separate cartridges, however they were mounted next to each other placed in parallel. This allowed greater play and flexibility in design, as they must have been integrated with the plunging mechanism. It was designed two cylindrical cavities, with the outer dimensions of the cartridges, lying horizontally and placed by the outer beam in where the two individual cartridges would be inserted. These were two through-holes, which allow the coupling of the tubes, formed from two aligned bodies attached and secured to the outer beam with enough rigidity to withstand the forces created during the plunging movement.

The mixer allows for two material feeds to be joined and start mixing to initialize the chemical reaction between the hardener and the resin. Further mixing was aided by using replaceable static mixers that have mixing elements inside, which causes the flowing material to blend together while flowing through. The mixer must be removable and must withstand chemicals, allowing to clean it through after each print. To aid the cleaning within the mixer, a check hatch is in the section where the resin and the hardener start to blend together.

Testing parameters. For the extrusion, we should know how much the extrusion mechanism extrudes with certain parameters. We should be able to set datapoints with different feed speeds and have a linear graph that shows the behaving of certain materials in our extrusion system. The material is extruded to containers where it is easily measured and datapoints taken from that.

Control system implementation. What control system was used, why and how.

Control system parameters. What kind of values were used for testing and presenting the final values.

Reserved section for time of flight sensor. Insert stuff regarding the time of flight sensor if made possible

Summary

If you follow the "checklist", your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

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