Plastic Extruder and Dies

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Project Description and Justification

The purpose of this Capstone project was to design a Plastic Extruder and Dies which means it is a recycling process for 3D printed materials that have either been left over or exist from failed prints. The overall design was to have two die shapes with one being a regular 1.75mm extrusion tip which would be able to extruded material at that width because of its standard size of the 3D printing industry. The second die design was geometrical and in the shape of a rectangle. The rectangular shape was chosen because it was the best choice especially since this shape was going to be used in the Solid Mechanics Course on campus for the Bridge assignment which happens to be their final project. This project is justified because it helps conserve both cost and material when 3D printing. Certain parts, when printed, require supports and it is just leftover material that nobody is going to use ever again. This project was designed to take those supports and failed prints and save on cost of buying new material as well as keeping a better carbon footprint. The student group assigned to this project had designed the final project in SolidWorks and had put a lot of resources into this project. Unfortunately it remains incomplete due to unfortunate circumstances. This group hopes that it can be completed one day so that students and faculty alike can have a cheaper printing process and a better experience altogether.

Functional Requirements and Specifications

Requirement	Source	Validation Measurement
5 meters of extrusion with no defects	Given functional requirement	Bubble count less than 10 per foot
1.75mm diameter filament	Given functional requirement	Diameter within 0.1mm of desired value
Not necessary to pre-grind plastic	Given functional requirement	Hopper melts 10 grams of plastic in 10 minutes
Dies can be swapped out	Given functional requirement	Demonstrable with final prototype
Compatible with PLA and ABS	Customer feedback	Ultimate tensile strength of filament within 10% of theoretical values
Compatible with MakerBot printers	Customer feedback	New melting point within 5 degrees of typical filament
Compact design	Customer feedback	Total volume less than 5 cubic feet Product weight less than 50 pounds Fits through standard GCU lab door FIts under standard GCU lab hood

Engineering Standards

ASTM D618-13 Standard Practice for Conditioning Plastics for Testing

Used to set up verification tests for validation

ISO 2577 Plastics - Thermosetting Moulding Materials - Determination of Shrinkage

Used to calculate proper die sizes to account for shrinkage during cooling

OSHA 1910.333 Electrical Selection and Use of Work Practices

Used to determine safety and training requirements for users

OSHA Best Practices: Weight of Objects

Used to determine maximum weight allowed for one person to lift safely

Validation Testing Plan

The following 6 tests were planned to determine whether validation measurements were met to satisfy functional requirements:

1. **Visual Inspection**

The trial was conducted twice with two different people on the same pieces of filament to see and make sure that there's proper consideration of what makes a 'bubble' and make sure bubble" count less than 10/foot.

2. **Extrude and Measure Filament**

Using the caliper to measure the new filmanet. The diameter should be 1.75mm ± 0.1mm.

3. **Melting Point of New Filament**

Hiring a professional company to measure the melting point of new filament because this test need the accuracy.

4. **Melting Time in Hopper**

Using timer to know how long the PLA or ABS material is meltdown completely.

5. **Filament Tensile Test**

Each of the materials will be tested on the tensile test machine and the data will be recorded on the computer connected to the testing machine.The results of all the samples will be compared to the Makerbot PLA samples to determine if the recycled filament has the same or similar properties.

6. **Compact Design Measurements**

The volume test will be measured, calculated and compared to the goal of the project. The weight test will be conducted using a scale to determine whether or not the machine is under 50 lbs(OSHA standard). The clearance tests will be conducted using a standard door and workstation on campus

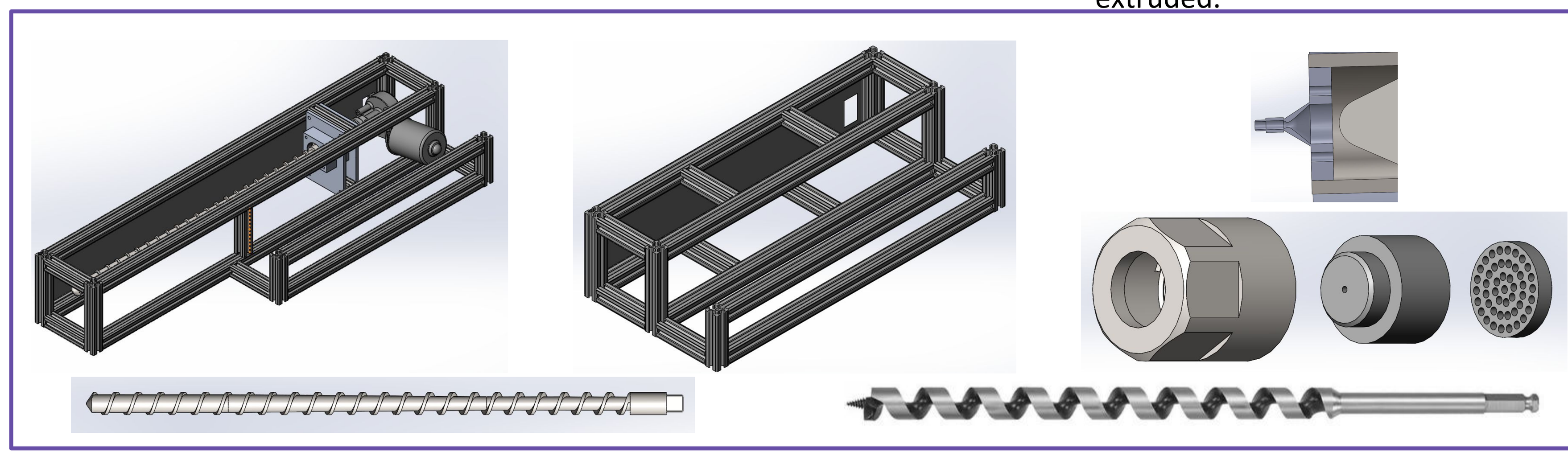
Design Process

Plastic extruders are not a new technology so a lot of research was done on existing technologies to see how we could apply it to our design. The design that was chosen to pursue was a custom compression screw which rotates in a barrel to move material through. This technology is not new and there has been a lot of research surrounding its application which helped tremendously in the development of the project.

The concept of using a rotating screw to move material through the machine did not change for the entirety of the project. However, the design of the screw and everything else on the machine did. The first visualization of what the machine would look like also did not change in concept but a lot of the way those concepts were implemented were changed.

The biggest change was deploying the use of a 1" wood auger bit rather than the custom machined screw. This was due to time and budget constraints. Once this change was implemented the design picked up pace and many new components and electronics were added. The new screw also allowed us to reduce the size of the chassis considerably. A thrust bearing was added to handle the forces generated by the screw, mounting plates for the bearings, barrel, and motor were added and electronics started to populate the main panel. The function of these parts and their construction did not change for the remainder of the project.

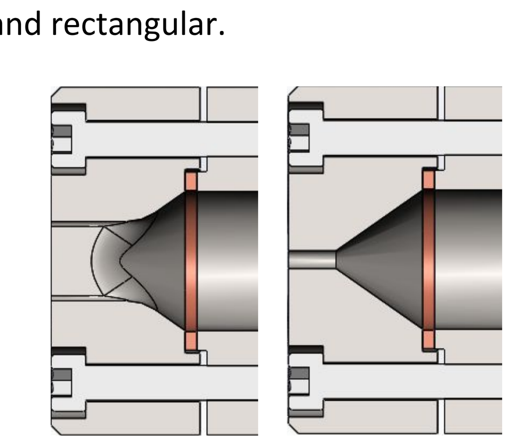
Another part that was changed multiple times was the die assembly. This part had a lot going on with it and had to have many different iterations before a design was settled on. The biggest decision with this design had to be how the die would mount to the barrel and many different methods were considered such as a welded die, threaded die, clamped die, and flange mount die. Ultimately, the flange die was considered the best option and was chosen for the final design. The concepts that were developed from the other designs still stuck with the new die assembly, however. There still needed to be filters to catch debris in the melted plastic, there still needed to be a breaker plate to support the filters, and there still needed to be sufficient tapers to maximize the efficiency of the die. The most important part of the new design was also the ability to swap the die shapes with ease. This allows for many different shapes to be extruded.



Final Design

The final design is contained in a 1" T-slot frame having dimensions of length 23.75", width 13", and height 6.75" without the hopper connected. When the hopper is connected, it adds an additional 10" to the height of the machine. This design features a 1" modified wood auger bit contained in the stainless steel barrel to move plastic material from the hopper, heat it past its melting temperature, and push it out the die. There are three 300 Watt heaters, two located on the barrel and one on the die, and are individually controlled via Proportional-Integral-Derivative (PID) controllers. The PIDs allow for a consistent and repeatable control of the heater temperatures. The heaters are positioned so that there is a consistent temperature along the length of the barrel during operation. The heaters also aid in the startup of the machine by melting material that may have solidified in the barrel from the last operation. The motor used to power the screw is a robust 12 Volt worm geared motor. This motor supplies the screw with the required torque to move material through the barrel. It is controlled using a 12 Volt motor controller to allow it to operate in both the clockwise and counter-clockwise direction. The speed of the motor can be observed on the front panel of the machine using the tachometer display and the speed can be adjusted via a knob located to the left of the display. This allows for repeatable setups once the machine is powered off. The logic of the machine is programmed into an Arduino UNO that controls the motor controller and also monitors temperatures on the barrel. These sensors allow for many software safety features to be implemented such as preventing the motor from functioning if the temperatures are not at a specific temperature.

One of the main design components of this project was swappable dies for different extrusion shapes. This was implemented at the request of one of the customers of the project. The die assembly was designed so that replacing the die shape with a new one would be quick and simple. Two geometries were created for the final design: circular and rectangular.



The circular die was designed using the appropriate diameter to account for the shrinkage of the material as well as other factors in order to extrude a circular filament having a diameter of 1.75mm. The rectangle extrusion shape was designed with the goal of producing a rectangular cross section of 8mm by 3mm. The design of the die assembly also allows for the fabrication of additional die geometries without the need to replace the entire end of the barrel.