Plastic Recycler Project

CSC 490 Initial Report

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Introduction

The purpose of this directed studies course is to design and build a plastic extruder that can recycle 3D printed plastic. This project started from an interesting article written about a plastic filament extruder built by Hugh Lyman, an 83-year old retiree. His project is open sourced and can be accessed by anyone through his Thingiverse page:

http://www.thingiverse.com/thing:34653

Our goal is to create our own plastic extruder that can recycle 3D printed plastic and is designed to be more modular and more inexpensive than Lyman's design. Our aim is to make the majority of our designed mechanical parts to be3D printed so that it can be easily reproduced by anyone.

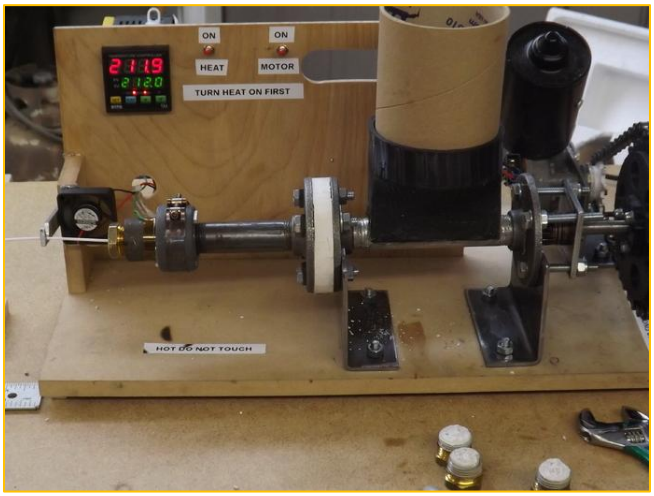

FIGURE 1 - LYMAN EXTRUDER

Interface

The scope of the project is actually quite large and can be broken down into three different parts: the plastic grinder, filament extruder, and the filament winder. The plastic grinder grinds up large plastic pieces of plastic so that it can be fed to the extruder. The extruder then compresses and melts the grinded plastic back into strands of filaments. Finally, the filament winder takes the extruded filament and winds it up into usable rolls. The interface between the components is shown in the figure below.

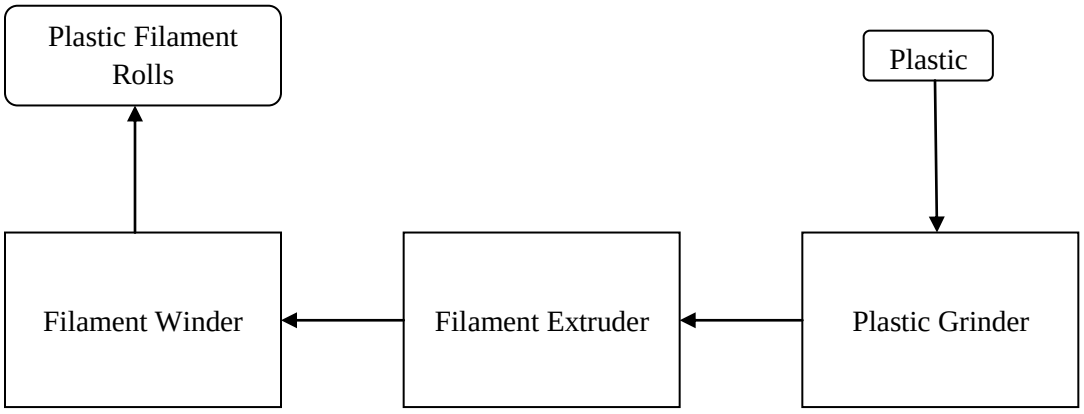

FIGURE 2 - INTERFACE DESIGN

Design Components

The following is a list of components that we need for this project and the thought process behind choosing them.

Motor

The motor assembly takes the main components from a standard 12 volt hand drill. A hand drill was chosen due to the high torque requirements of the plastic extruder. Since each hand drill has a planetary gear in the head, it can convert the high speed dc motor into a lower speed high torque output. The head of the drill also allows for adjustment of the torque and makes mounting the auger bit to the motor extremely easy. Another factor that played a part in choosing to go with the hand drill was cost. A suitable 12v hand drill can be bought for as little as $50 new and they are readily available. Plus the motor and head are a suitable size to mount directly in line with the auger bit.

Extruder

The extruder assembly consists of a ½" copper pipe with a ½" auger bit inserted within the pipe. As the auger bit turns it will move the plastic pellets down the copper tube towards the heating element, where it is melted and forced out the extruder head. The reason a copper pipe was chosen is for its high thermal conductivity. This will allow the heat from the heating element to travel down the tube to begin warming the plastic. Plus it will make cooling the pipe at specific points with the fan much easier. An auger bit was chosen as the way to push the plastic pellets due to its gradual taper and large thread. This allows for a large amount of plastic pellets to be pushed down the extruder to develop a consistent filament output.

Heating Element

In the Lyman extruder design, he used a mica band heater which we find to be too expensive an impractical for our project. We wanted to have better control over the temperature so that the plastic is heated gradually as it moves down the extruder. This cannot be done effectively with the band heater due to its larger size and price per unit. Instead, we choose to use the Nickel-Chrome 60 resistance heating wire for its high heating capabilities (up to 1000 degrees Celsius), and coiling flexibility. The heating wire will be coiled and adhered to the extruder using Kapton (Polyimide) tape. This tape is chosen because of its high resistance properties (up to 400 degrees Celsius) and it acts as a very good electrical insulator. The specification for this heating wire can be found on this manufacturer's site:

FIGURE 3 - NICKEL-CHROME 60 RESISTANCE HEATING WIRE

http://www.omega.com/Temperature/pdf/NI60.pdf

For our application, we want to have around 1to 2 feet of heating wire wrapped around a copper pipe that is powered by a 12 volt power supply. The important current temperature characteristics for different gages of wire are shown in the table below. Since the Kapton tape we are using is rated max at 400 degrees Celsius, our target temperature for the wire should be no more than 425 degrees Celsius (from the table below). The power generated by the wire is voltage multiplied by the current and the amount of heating power we need depends on how fast we are able to extrude the plastic and the volume of space we need to heat up. However, our power supply only allows us approximately 5 amps, or 60Watts of power.

Therefore the most suitable size for our project would be to use a 26 gage wire which will allow us to fit 3 heating elements equally distributed along our pipe.

AWG	Dia. mm (inch)	Ω per ft @ 20°C (68°F)	Current Temperature Characteristics* °C (°F)						Model No.
			425 (800)	550 (1000)	650 (1200)	750 (1400)	875 (1600)	1100 (2000)	
18	1.0 (0.040)	0.4219	7.90	9.75	11.96	14.51	17.37	23.08	NI60-040-(t)
20	0.81 (0.032)	0.6592	5.92	7.25	8.86	10.69	12.72	16.87	NI60-032-(t)
22	0.64 (0.0253)	1.055	4.44	5.40	6.56	7.87	11.63	12.33	NI60-025-(t)
24	0.51 (0.0201)	1.671	3.32	4.01	4.86	5.80	6.82	9.01	NI60-020-(t)
26	0.40 (0.0159)	2.670	2.52	3.00	3.61	4.31	5.06	6.63	NI60-015-(t)
28	0.32 (0.0126)	4.252	1.90	2.28	2.73	3.23	3.77	4.88	NI60-012-(t)
30	0.25 (0.010)	6.750	1.43	1.74	2.06	2.43	2.81	3.59	NI60-010-(t)

Microcontroller & Electronics

For the microcontroller an Arduino mega was chosen. The Arduino platform was chosen due to its low cost and relatively easy programming language. The mega will allow us to track our three temperature sensors and then provide a feedback loop to control the fans and motor speed. As well the Arduino will be used to regulate the heating element depending on the speed of the motor and the required filament output.

PID Controlled Devices

Two power supply cooling fans will be used to control the cooling temperatures of the device. One of the fans is used to cool and help solidify the hot filament as it comes out of the device. The other one is used to monitor the temperature of the extruder and cooling it down if it gets too hot. The temperature of the entire system will be monitored by three temperature sensing thermocouples. Each set will be controlled by a separate PID controller managed by the Arduino microprocessor to maintain the correct temperatures. In addition to temperature control, the back pressure from the melting plastic must also be monitored by a PID. Since pressure sensors are expensive and difficult to install, the pressure will be measured indirectly by measuring the speed of the motor and the PWM input required to drive it at that speed. The rotational speed of the motor can easily be measured using an optical sensor that gets triggered by reflective tape.

Power Supply

This system requires at least a 12V power 20 amp supply to support the power hungry drill motor and heating elements. Under torque a drill motor can draw up to 10 or more amps and the heating elements are designed to draw up to 5 amps. This leaves 5 amps to spare for the microcontroller and fan motors. Therefore it would be ideal to source a power supply that can provide more power. Our final decision was to purchase a 12V 30 amp power supply, even though it's slightly more expensive.

Design Sketches

The following figure below show some of the sketches of our proposed plastic extruder.

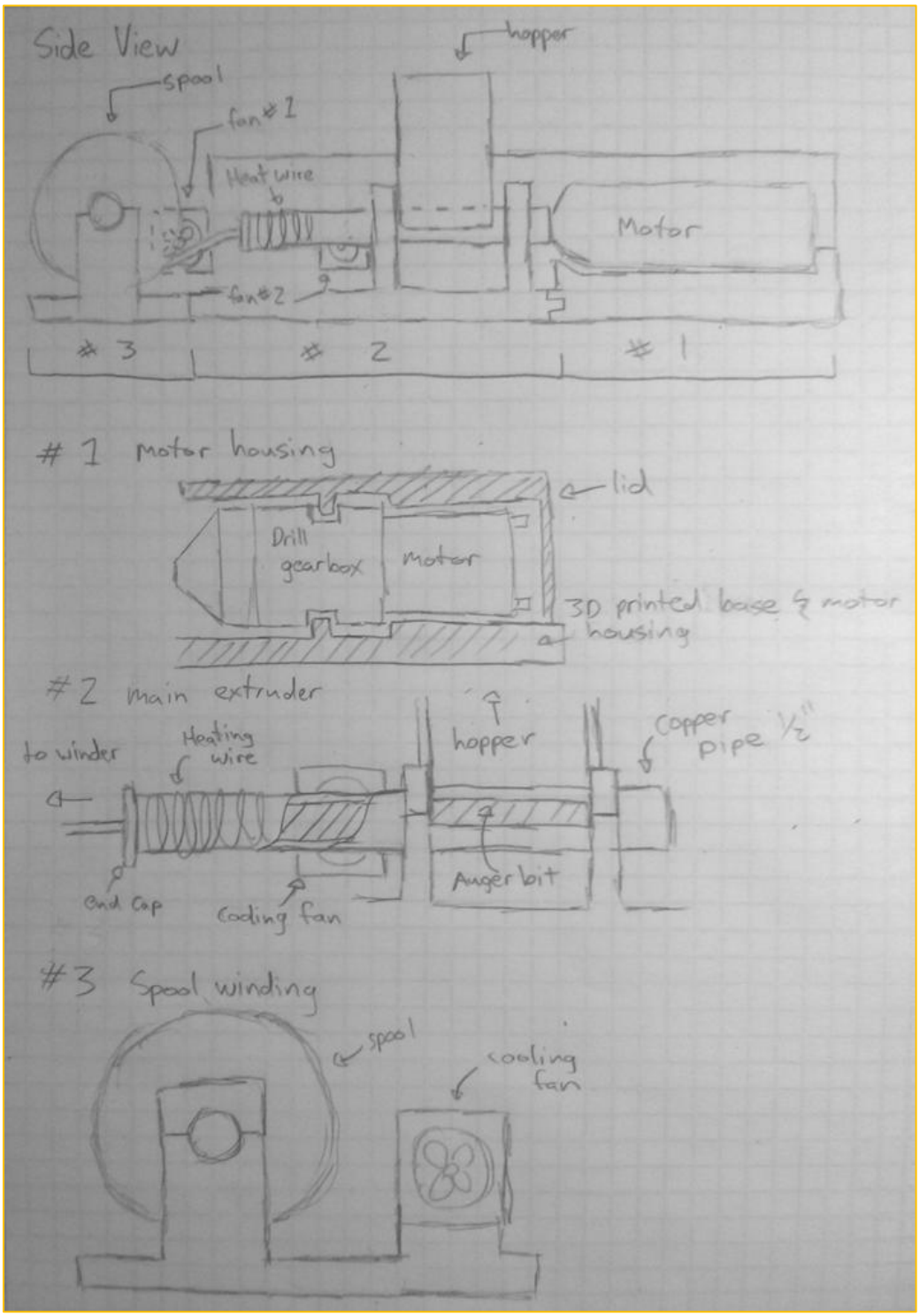

FIGURE 4- DESIGN SKETCHES OF THE PLASTIC EXTRUDER.

Bill of Materials

#	Name	Descrption	Function	Source	Qty	Unit Price	Total
1	Copper pipe	½" by 3' Copper pipe	Extruder barrel for melting the plastic in.	Home Depot	1	$8.79	$8.79
2	Auger bit	½" by 18" bit	Translates the grinded plastic inside the extruder barrel.	Home depot	1	$38.59	$38.59
3	Drill gearbox	Component of a 12V hand drill	Planetary gears that increases the torque of the motor	Used Victoria	1	$8.00	$8.00
4	Drill motor	Component of a 12V hand drill	DC motor to drive the auger bit.				
5	Heating wire	Nickel-Chrome 60 - 26 gage – 50' roll	Heating the extruder barrel	Omega	1	$10.00	$10.00
6	Power supply	12 V 30 amps – Size: 21.5 cm x 11.5 cm x 5cm	Power suppy for the entire system.	AliExpress	1	$25.10	$25.10
7	Thermocoupler interface chip	MAX 6675	Interface chip for the thermocoulper	AliExpress	3	$3.80	$11.40
8	Thermocoupler	Temperature sensor	Used for PID control	AliExpress	3	$0.75	$2.25
9	Optical Sensor	Reflective optical sensor	Measuring motor rotation speed	AliExpress	1	$1.50	$1.50
10	Power supply fan	12V 1.0A fan	Cooling for filament and extruder	Deal Extreme	2	$4.40	$8.80
11	Kapton Tape	Polyimide	Insulating tape for the wire heaters	Amazon	1	$4.50	$4.50
12	Arduino	MCU	Controller for the entire system		1	$15.00	$15.00
13	12V to 5V Step Down	Voltage regulator 7805	Step down the 12V power supply to 5V for MCU and sensors	MiniInTheBox	1	$7.89	$7.89

14	LCD	1602 LCD	Displays information about the device.	AliExpress	1	$2.50	$2.50
15	Mosfets	IRFZ44N IRFZ44 Power MOSFET	Controlling heating wire by turning it on or off electronically	AliExpress	3	$0.30	$0.90
16	Brass Cap	½” Brass Cap	Acts as a breaker plate and die for the extruder	Home Depot	1	$4.76	$4.76
17	Male adapter	½” copper pipe adapter	Adapter for the copper pipe to the brass cap.	Home depot	1	$2.39	$2.39
TOTAL							$152.37