3D Filament Recycler

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Abstract

With increased popularity in Fused Deposition Modeling (FDM) 3D printers, research was conducted to design and build a machine that can recycle the waste material created. Although 3D printing can create virtually any geometry, it can also produce waste from failed prints, rafts, brims, or supports required for the print. The team's key focus in developing a 3D filament recycler consists of three sub-functions: shredding, extruding, and spooling. The shredder crushes the waste into smaller pieces to easily melt and extrude the plastic into filament (at the standard 1.75 millimeters in diameter), which then will be neatly organized onto a standard one-kilogram spool. Polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) are two popular materials used in 3D printing due to their thermoplastic properties. Thermoplastics can be melted and printed repeatedly without compromising the integrity of its structure. Recycling filament will lower the cost of production and decrease the carbon footprint that is created by using these 3D printers. The filament produced will be benchmarked against other commercial filaments that are currently on the market to produce a usable and reliable product.

Background

- Project Goals
  - Design & build a machine that recycles 3D filament
  - Customer requirements (in order of importance):
    - Safety
    - Extruded filament has 1.75 mm diameter
    - Extrudes PLA and ABS
    - Reliability
    - Durability
    - Shreds, extrudes, and spools filament
    - Compact Size
    - Aesthetically Pleasing
- 3D Filament Recycler has three main components:
  - **Shredder** - Breaks up failed 3D prints to prepare for melting and extruding.
  - **Extruder** - Melts and extrudes PLA and ABS filament with diameter of 1.75 mm (see Table 1 for material properties).
  - **Spooler** - Rotates to collect and organize the extruded filament.

Table 1: Filament Material Properties

	PLA	ABS
Melting Temperature	164°C	221°C
Maximum Tensile Strength (Standard infill 3D prints)	46.8 MPa	34 MPa
Maximum Tensile Strength (100% infill 3D prints)	65.7 MPa	38.1 MPa
Density	1.25 Mg/m³	1.01–1.21 Mg/m³

Engineering Design

Final Design

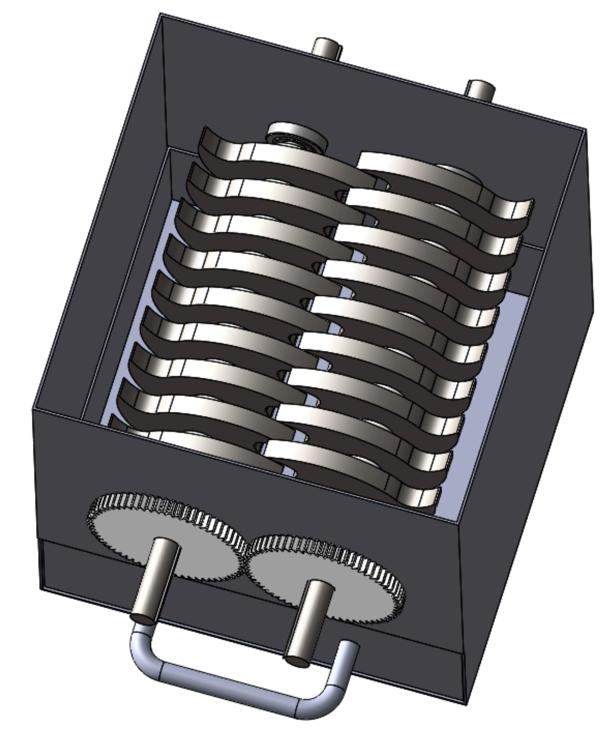

Figure 1: CAD Model of Shredder Internal Components

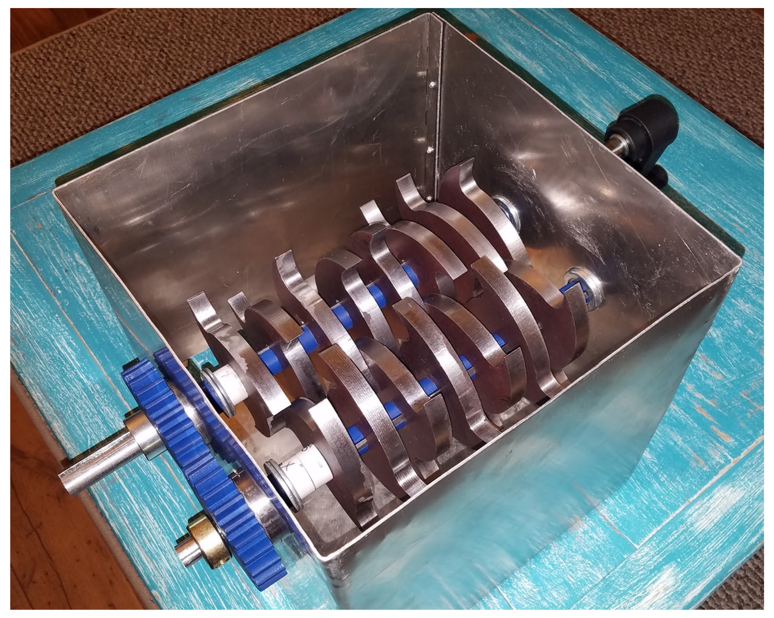

Figure 2: Shredder Internal Components

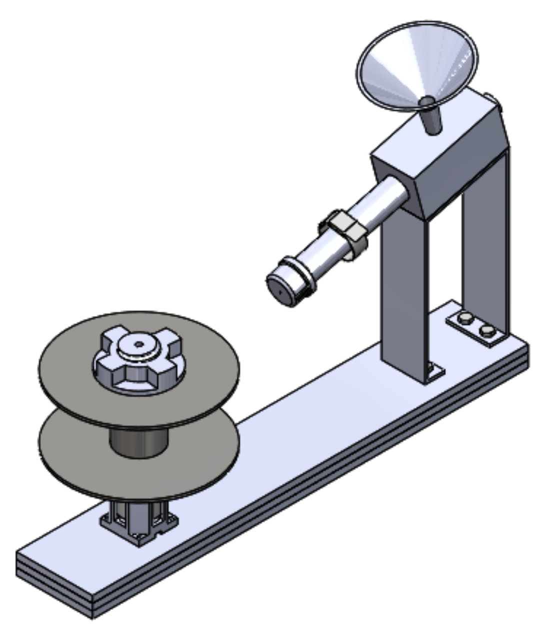

Figure 3: CAD Model of Extruder and Spooler, Isometric View

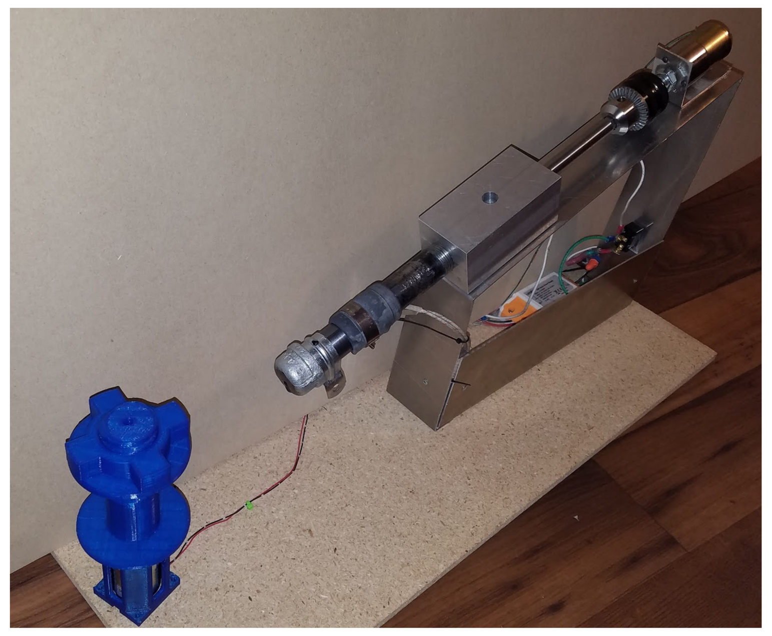

Figure 4: Extruder and Spooler, Isometric View

Major Design Changes

- **Shredder**
  - Resized box for ease of manufacturing
  - Hand crank added instead of motor
- **Extruder:**
  - 3D printed gears for customizable shaft assembly and distances
  - PID controller and toggle switch added instead of programmable controls
- **Spooler**:
  - 3D printed mounting components instead of bent sheet metal
  - Toggle switch added instead of programmable controls

Design & Fabrication

- Design Process
  - Brainstormed concept variants
  - Used Pugh Chart and Decision Matrix to narrow down ideas
  - Designed in SolidWorks (CAD Program)
  - Performed analyses to evaluate performance of components
  - Design Concepts
    - Kept shredder and extruder/spooler separate for better mobility
- Fabrication Process
  - Manufactured Parts
    - Shredder: box, lid, drawer, shafts, blades
    - Extruder: housing, heating chamber, mount
  - 3D Printed Parts
    - Shredder: gears
    - Spooler: housing, shaft, and locking nut

Testing & Analysis

Tooth Stress Analysis

- Finite Element Analysis performed in SolidWorks to determine if A36 steel shredder teeth can withstand forces produced from crushing PLA and ABS
- Analysis performed with PLA specifications as "worst case scenario", see Figure 5 and Table 2 for results

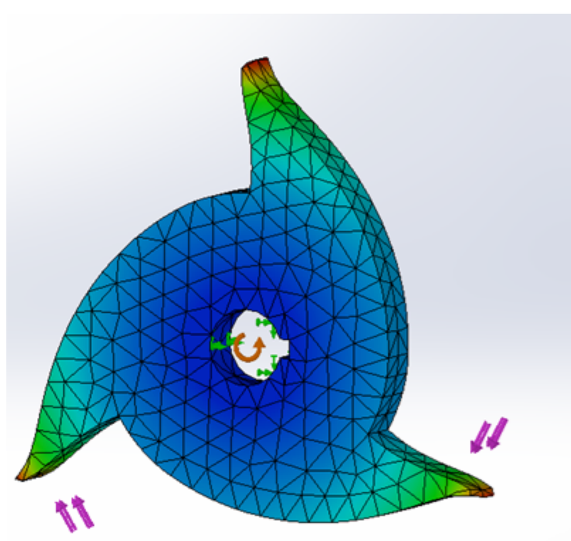

Figure 5: Shredder tooth FEA performed in SolidWorks

Table 2: Shredder tooth FEA Results

Maximum Data from Analysis	
Stress	39,850 psi
Strain	.000928
Deflection	.00369 in

Motor Strength Analysis

- A 12V DC motor is being used for the extruder, analysis was done to figure out the power required to extrude filament
- The motor is rated at 903.5 ft-lb and 30 RPM at max output
- The equation used for this analysis:

$$HP = \frac{D/4 \times IPR \times V_C \times K_C}{3300 \times \eta} \quad (1)$$

- Results can be seen below in Figure 6 and Table 3.

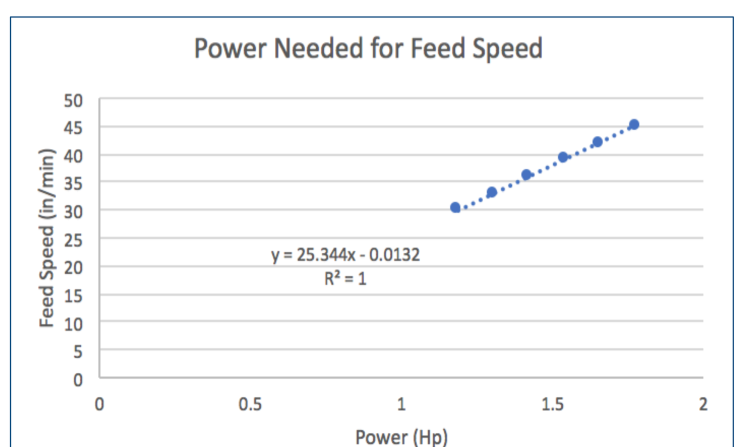

Figure 6: Power required for feed speeds

Table 3: Calculated extrusion power

Torque (RPM)	Feed Rate (in/min)	Power (hp)
30	45	1.776
28	42	1.658
26	39	1.539
24	36	1.421
22	33	1.303
20	30	1.184

Results

- **Shredder shafts**
  - 1:1 gear ratio, hand-cranked
  - Shredder can only break down 3D prints that are printed at standard resolution
- **Heating time for PLA (215°C):** 10 minutes
- **Auger speed**
  - 70%±1% of motor speed, 21 RPM
  - Powered by a 30 RPM 12V DC motor
- **Spooling shaft rate**
  - 70%±1% of motor speed, 21 RPM
  - Powered by a 30 RPM 12V DC motor
- **Filament Size Produced**
  - 1.75 mm ± 5% of diameter

Machine Specifications

- **Shredder:** 11" x 11" x 12"
  - Drawer to catch filament
  - Shredder guard to protect users
  - 1:1 gear ratio, hand-cranked
  - 15 keyed shredder teeth
  - 2 flanged bearings, 2 ball bearings
- **Extruder:** 2.5' x 1' x 0.5'
  - Aluminum housing and mount
  - Steel heating chamber, 1" OD pipe
  - Steel nozzle cap
  - Heating band 1" diameter, 2" width
  - Auger ⅞" diameter, 17" long
  - ½" drill chuck
  - 30 RPM 12V DC motors
- **Spooler**: 2" x 2" x 8"
  - 3D printed mount, shaft, and locking nut
  - 30 RPM 12V DC motors
- **Electrical Components:**
  - PID Controller
  - Speed motor controller with potentiometer
  - 12V DC power supply
  - 8A single pole toggle switch

Acknowledgments

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GORE Creative Technologies Worldwide

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