Team 16

Recycled Plastic Shredder

Students: Adriana Watson, Dania Khan, Dominick Civitano, Garrett Lilley, Nicholas Gilbert, Samuel Laird
Mentor: Ralph Munguia Clients: Professor Paul McPherson and Dr. Ragu Athinarayanan

Client Background

Our customer for this project is Professor Paul McPherson, who works for the school of engineering technology at Purdue University. Our goal is to create a machine which can shred recycled plastics for Purdue's SOET department. This project will be implemented in the SOET's Smart Factory, located in the newly built gateway building. This will become the first stage to a recycling process which allows the factory to use plastic items such as water bottles to create the board deck and other portions of the product being developed in the factory.

Problem Statement/ Scope of Work

The task of this problem is to review the open-source plastic shredder CAD design, made by Mandin and provided by the client, and make changes as necessary to ensure that the product will be functional, meets safety requirements, and integrates well with the extrusion machine being developed by Capstone Team 15. Research must be done on plastic types and how they should be processed. This information as well as an SOP must be communicated to the client and end user. This solution will impact our clients and Purdue students interacting with the Smart Factory, both of whom are considered end users of the product.

Requirements Matrix

Table 1: Requirements Matrix

Requirement #	Requirement	Description	Test Type
1	Cost	Less than $5000	Analysis
Rationale	This item should be low cost to improve affordability		
2	Footprint	3' x 6'	Measurement
Rationale	The shredder shouldn't take up much room space.		
3	Safety	Safe for those 18+	Examination
Rationale	Should meet all standards set by Purdue University.		
4	Weight	Less than 90kg	Analysis
Rationale	Should be easy to relocate		
5	Easily sourced	Reproducible parts	Analysis
Rationale	All materials used should be easy to source or produce		
6	Easy to operate	Ages 18+	Analysis
Rationale	A normal college aged student should understand how to operate it		
7	Self-Regulatory	Easy to troubleshot	Examination
Rationale	Simple and easy to repair or detect failures		
8	Modular	Pieces can be hot-swapped	Examination
Rationale	Students should be able to swap components with OTS equivalents		
9	Motor Requirement	Power: ~1 kW Torque: min 300Nm	Measurement
Rationale	To ensure safe and efficient operations based on material selection		
10	Material/Hopper	Type: HDPE, LDPE, PP, PS	Examination
Rationale	The shredder will need to be capable of shredding plastics needed for Team 15's extruder.		

Experimentation and Concepts

Blade Assembly:

After analyzing the initial CAD files supplied by the client, the original design contains 14 blades with 13 disks on one shaft. Based on these factors, (and assuming the material volume going into the design (n) and the shaft revolutions of the crushing chamber(q)) the equation [12] can be used for calculating shredder productive quality.

$Q1=n*1*13*14*qQ1=n*1*13*14*q$
$Q1=n*q*182Q1=n*q*182$

Assuming that the n and q variables stay the same, if the team was to add simply one more blade (and subsequently one more disc), the new Q can be calculated below.
$Q2=n*1*14*15*qQ2=n*1*14*15*q$
$Q2=n*q*210Q2=n*q*210$
With these new modifications that would increase the Q (shredder productive quality), by 15%.

Electrical Design:

The final PCB design for the power supply was done in Altium Designer 21, with board fabrication handled by PCBWay. The design entailed a 500W output at 48V DC with additional 5V rails for controls. With this, a current limit of 12A was set in case of excess current draw from the motor.

The motor selected was a VEVOR electric bicycle motor. The motor's output is rated at 3N*m at 5200RPM and can be driven in both forwards and backwards operation.

Final Design

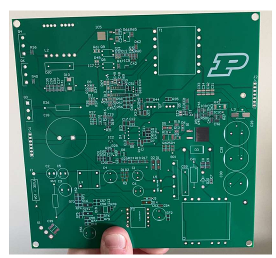

Figure 1: Final PCB design

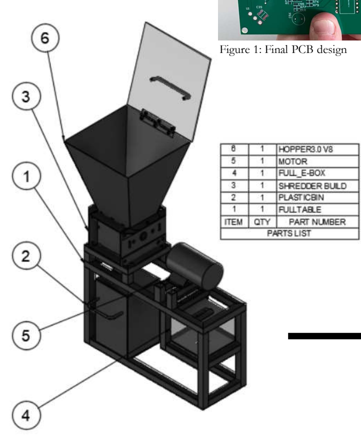

Figure 2: Shredder 3D Render

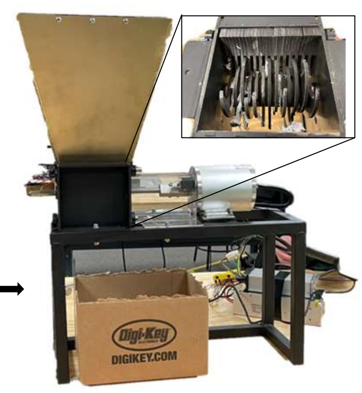

Figure 3: Final actual shredder

FMEA

Table 2: FMEA

FMEA- Failure Modes and Effects Analysis									
Key Process Step	Potential failure mode	Potentail failure effects	SEV	Potential Causes	OCC	Current controls	DET	RPN	Actions taken
Blade condition	Blade(s) break and become a hazard (such as a projectile)	Hazard causes user injury	10	Blade breaks due to inadequate replacement and overuse	3	Visual Inspection	10	300	Review CAD drawings and cut new blades
Bearings	Bearing(s) break and become a hazard (such as a projectile)	Hazard causes user injury	10	Bearings break due to inadequate replacement and overuse	3	Visual Inspection	10	300	Purchase new bearings from the parts list and install them
Counter knife	Counter Knife breaks or becomes misaligned and becomes a hazard (such as a projectile)	Excessive force or friction on the blades. Or Material is not properly shredded	8	Material causes the counter knife to bend or Aged wear and tear of counterknife	3	Visual Inspection	10	240	Review CAD drawings and cut counterknives
Electronics system	Sudden loss of power	No production or limited production of shredded material	4	Blackout, brownout, damage to PCB and its components.	3	System check with a multimeter	1	12	Inspect parts of the circuit with a multimeter and replace components as needed
Electronics system	Overpowering the motor	Damage to motor internals, unsafe operating speeds.	6	Power surge, incorrect source applied	1	System check with a multimeter	1	6	Inspect parts of the circuit with a multimeter and replace components as needed
Electronics system	Electric shock	Hazard causes user injury	8	Improper handling, damage to PCB or its components	1	System check with a multimeter	1	8	Inspect parts of the circuit with a multimeter and replace components as needed

*These are the highlights of the FMEA, meant to show the highest scoring categories in both the mechanical and electrical subsystems

Testing

To test the final design, the team examined the following:

Mechanical Testing

- The mechanical components were tested for general functionality using the hand crank to test the tolerances between the counter knife and blade assembly as well as the shred quality of a small load of plastic.
- All critical dimensions were measured and noted using measuring methods available including calipers, measuring tapes, and micrometers depending on needed precision and overall size limitations.
- The shredded plastic size was tested by Team 15. The team shredded miscellaneous plastics and passed them to Team 15 to be extruded.

Figure 4: Testing shredded parts

Electrical Testing

- Once all electrical components were assembled, they were tested using an oscilloscope and multimeter to ensure that critical components and outputs are consistent with what was expected based on simulations.
- The electrical components were attached to a power source and the motor away from the mechanical components to verify functionality.
- The Electrical components were then integrated with the mechanical components once both had been tested to verify functionality. Current draws were monitored to ensure cohesiveness between the two systems.

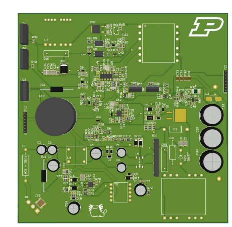

Figure 5: PCB Mockup/Render