Deliverable 7: Prototype II & Customer Feedback

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Abstract

Our team (Group 18) has been tasked with designing and building a device meant to retrieve a metal sample from a tube in a CANDU reactor. This sample will then be sent to a lab to test the integrity of the tube. This report delineated the project's design process, “Prototype”. This report details the development of our second prototype, incorporating client and peer feedback, which was used to design elements like collection, functionality, and rotation. Key improvements include adding a rotary support system made of aluminum foil, redesigning the blade of the “grater”, and downsizing the whole mechanism. The prototype revolves around the electronic systems of the device which are prone to fail, especially the motor, which must stop in the upright position no matter the amount of rotations. The project is ready to move onto the “Prototype 3” phase, where more testing must be conducted.

Table of Contents

1. Introduction

- 1.1 Purpose of the Report
    - This report aims to analyze the development of our second prototype. This will incorporate the 2nd bout of client feedback, assessing and analyzing critical elements of our design, and outlining necessary improvements by testing and validating. The prototype seeks to validate the most vulnerable component of our design.
- 1.2 Scope and Objectives
    - This report will cover the prototype's design, methods of testing, and the incorporated feedback. Specifically focusing on precision, rotation, and feasibility of the electronics. This report will be a foundation for the next prototype, which will be a full build of our design.
- 1.3 Overview of the Design Process
    - The design process followed an iterative approach, which incorporated feedback from the client meeting. Our initial concepts are mostly firm, which means we are now able to test specific aspects of our design without worrying about major changes. The purpose of this prototype is to start the physical testing by wiring all of the crucial electrical systems necessary to make a successful collection tool.

2. Client Feedback and Design Improvements

- 2.1 Summary of Client Feedback

The client emphasized the need for a more durable scraping mechanism and a fail-safe feature to prevent the device from jamming inside the tube. They also suggested testing the motorized system to ensure smooth operations.

- 2.2 Key Takeaways from Feedback

Strengthen the scraping mechanism to minimize the wear.

Implement an emergency stop mechanism.

Test motor control for precise rotation and stopping.

- 2.3 Implementation of Feedback in Future Design

These insights led to potential material upgrades still trying to fit within the budget. Enhanced safety features, and an improved motorized scraping mechanism.

3. Prototyping Strategy and Objectives

- 3.1 Purpose of Prototype II
    - To test if our motor system can provide enough torque to scrape the metal tube

- 3.2 Description of the Prototype

    - The prototype was originally designed to be a motor attached to our tubular device however, the motor we ordered was smaller and weaker than expected and an encoder was missing so we decided to test the rotation of the motor with a wooded cork. Rough calculations involving angular velocity and torque were carried out to predict the behavior of our future prototype that will be rescaled to the correct dimensions.

    - The prototype code is designed to automate the power of the device once it is turned on by user input, checking every 15 rotations to see if the collected debris is over or equal to the load limit, stopping the system if it is, to allow for collection, and continuing to function if not. The code is pictured below.

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```c
#include "HX711.h" // Load cell library

#define MOTOR_PIN 9       // Motor control pin
#define START_SWITCH 4    // Switch to start motor
#define ENCA 2            // Encoder A pin
#define ENCB 3            // Encoder B pin
#define LOAD_CELL_DOUT 6  // HX711 data pin
#define LOAD_CELL_SCK 7   // HX711 clock pin

HX711 scale;
volatile int encoderCount = 0;
const int targetRevolutions = 15;
bool motorRunning = false;

void setup() {
    Serial.begin(9600);

    pinMode(MOTOR_PIN, OUTPUT);
    pinMode(START_SWITCH, INPUT_PULLUP); // Internal pull-up resistor
    pinMode(ENCA, INPUT);
    pinMode(ENCB, INPUT);

    attachInterrupt(digitalPinToInterrupt(ENCA), countEncoder, RISING);

    scale.begin(LOAD_CELL_DOUT, LOAD_CELL_SCK);
    scale.set_scale(2280.0); // Adjust calibration factor
    scale.tare(); // Reset weight readings

    digitalWrite(MOTOR_PIN, LOW); // Ensure motor starts off
}

void loop() {
    // Start motor if user inputs 'S' or presses switch
    if (Serial.available() > 0) {
        char command = Serial.read();
        if (command == 'S') {
            startMotor();
        }
    }

    if (digitalRead(START_SWITCH) == LOW) {
```

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```
void loop() {
    if (digitalRead(START_SWITCH) == LOW) {
        startMotor();
    }

    // Stop motor at 15 revolutions and measure weight
    if (motorRunning && encoderCount >= targetRevolutions) {
        stopMotor();
        encoderCount = 0; // Reset encoder count
        delay(1000); // Wait before measuring weight

        float weight = scale.get_units(10); // Take average of 10 readings
        Serial.print("Measured Weight: ");
        Serial.print(weight);
        Serial.println(" mg");

        if (weight < 30) {
            Serial.println("Weight too low, restarting motor...");
            startMotor();
        } else {
            Serial.println("Weight sufficient, stopping machine.");
        }
    }
}

void startMotor() {
    Serial.println("Motor Started");
    encoderCount = 0; // Reset counter
    digitalWrite(MOTOR_PIN, HIGH);
    motorRunning = true;
}

void stopMotor() {
    Serial.println("Motor Stopped");
    digitalWrite(MOTOR_PIN, LOW);
    motorRunning = false;
}

void countEncoder() {
    encoderCount++; // Increase revolution count
```

- Youtube link of our working motor prototype:
  - https://youtube.com/shorts/56DZ8241PBI?si=3PaDj8D0mfbh5hTE

4. Prototyping Test Plan

4.1 Objectives of the Prototype Testing

- Determination of the motor's strength and whether or not it is strong enough to scrape a metallic sample
- Determination of the code's operational status, and debugging.

4.2 Key Performance Metrics and Measurement Criteria

- The motor must be strong enough to provide the required angular velocity and strength to scrape the metal sample
- The motor must uphold the device's weight horizontally
- The program must be able to stop the device every 15 rotations and be able to accurately measure the load limit of the load cell, and stop/continue if the limit is surpassed/not surpassed.

- 4.3 Stopping Criteria for Testing
  - The motor holds its structural integrity under the weight of the device
  - The motor spins the device with minimal vibration
  - The device scrapes the inner wall of the metal tube
  - The program successfully stops the device every 15 rotations, and be able to accurately measure the load limit of the load cell, and stop/continue if the limit is surpassed/not surpassed.
- 4.4 Expected Fidelity Level of the Prototype
  - Due to the changes we had to make, this prototype has a medium-low expected fidelity because it's heavily theoretical.

5. Analysis of Electrical Components and Systems

- 5.1 Identification of Critical Components:
  - Rotary Motor System:
    - Provides required torque for metal scraping.
  - Power System:
    - Supplies consistent energy for stable motor function.
- 5.2 Engineering Analysis:
  - Material Integrity and Durability:
    - If the scaling is correct, the blade and motor will be able to handle the RPM and "hardness" of the sample tube, assuming that it is made out of aluminum.
  - Rotation Stability and Torque Analysis:
    - The blade torque was calculated using friction estimates and a 1.5-inch distance from the origin. The torque was well within safe standards.
- 5.3 Expected Challenges and Risks
  - Ensuring Reliable Rotation and Smooth Operations:
    - A stronger motor must be obtained to sustain the project's cylinder.
  - Minimizing Grater Wear and Maintaining Efficiency:
    - A durable grater must be acquired to avoid switching parts constantly
  - Balancing Cost and Performance for Material Choice:
    - The cost must be carefully managed. Currently, expensive parts include the PVC pipe casing and the load cell.
  - Debugging the Program:

- The program must be run on the full prototype (by March 16th) to ensure no debugging must be done.

6. Prototype Development and Testing

- 6.1 Materials and Construction Process
  - 12V motor
  - Code that controls the number of rotations according to the amount of sample collected in C
- 6.2 Test Setup and Methodology
  - Design of a critical component of the project at a low fidelity. All of the basic code for the Arduino was written.
- 6.3 Experimental Data and Observations
  - The motor concept was proven successful. Future testing must involve the whole final prototype.
  - The current cylinder substitute does not fit 1:1 with the motor shaft, leading to increased vibrations and loss of energy.
- 6.4 Analysis of Test Results
  - The results were satisfactory. The rough calculations showed that under ideal conditions and correct scale, the device would scrap the metal. However, measurement of the mass of the sample and specific prototype conditions must be tested in the final design.

7. Updates to Target Specifications and Design

- 7.1 Updated Detailed Design
  - Refer to the video link and code samples above.
- 7.2 Bill of Materials (BOM) Adjustments
  - Deliverable F - Updated Bill of Materials (BOM)

8. Preparation for the Next Prototype

- 8.1 Key Improvements for Second Prototype
  - To test a stronger motor using the physical casing
  - Once the prototype has been assembled, we can do further testing the determine the functionality of the written code
  - We have to build a prototype of the electrical systems and blades and see how that works first then we can analyze to look for improvement
- 8.2 Next Steps and Timeline

- Prototype 3: Full Functional Model
  - Test 1: Precision of collection; refine the mechanism to ensure maximum precision when collecting debris.
  - Test 2: Precision of rotary motor revolutions; ensure that the motor's rotation always ends with the "grater" facing up, within a small margin of error.
  - Test 3: Friction does not cause any significant wear and tear in any part of the system.

9. Project Timeline and Task Distribution

9.1 Task Breakdown and Team Roles

Currently, the project tasks are allocated as follows:

• **Sam:** Oversee the electrical systems. Find all of the necessary electrical parts for the project with their pricing.

• **Nick:** Find necessary mechanical parts and CAD the design using the remaining budget
- Ahmed: buy the parts

• **Sam, Deba:** Coding and debugging the control program for the prototype. Work on the code and other electrical components.

• **Sam, Nick, Deba:** Work on the CAD design of the prototype.

• **Ahmed:** Responsible for acquiring and preparing the tube for assembly and sourcing any other required materials.

• **Louis:** Tracks the team's completed work, milestones, and overall progress. Build the blade.

• **Louis, Nick, and Sam:** Collaborate on calculations to address theoretical challenges.

★ Note that this task list may be adjusted to ensure efficiency.

9.2 Project Milestones and Deadlines

- Prototype II testing completion:
  - Successes:
    - The prototype was able to chip off a piece of a weaker substance
    - Calculations show that with a stronger motor, the device at real scale would be able to scrape the inner wall of the metallic tube
  - Fails/uncertainties :
    - The motor was not tested with the real casing because it was too weak to provide a strong enough torque

            - The power source used in the experiment did not maximize the motor's potential
            - Calculations still needed to be tested. That will be done and reported in the next deliverable
    - Deliverable Deadlines:
        - Deliverable H - Prototype III and Customer Feedback (3/23/2025)
            - The third and final prototype needs to be tested for functionality, at this point in the development process only small adjustments should be made to either the code or certain small parts related to the electrical or mechanical systems.
        - Deliverable I - Design Day Presentation (3/26/2025)
        - Deliverable J - Project Presentations
        - Deliverable K - User and Product Manual (4/4/2025)

10. Conclusion

10.1 Summary of Findings

- The prototype II process has given us valuable insights into how we should carry out the rest of the project.
- Client input was put into consideration and improved our design.
- The concept of our prototype idea works

10.2 Future Work and Considerations

- Testing the system at the correct scale.
- More research and benchmarking can be done for more inspiration and data.