**Test Report**

**Filament Recycler**

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Course: GE-498

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Report Submitted on April 27, 2021

**Abstract:**

Five tests were performed on the filament recycler to ensure it meets all the system design requirements that were agreed upon with the customer in the beginning of the last semester. The filament recycler was able to pass most of the tests. The system failed to meet the requirements 2.1.1.1, 2.1.1.2 and 2.4.1.1 of the test plan. Requirements 2.1.1.1 and 2.4.1.1 were brought up to the customer in customer meetings and were approved by him as they were not important for the functioning of the system and he could easily fix them later on if he desires. Requirement 2.1.1.2 deals with the tolerance of the filament diameter which could not be achieved.

**Filament Test:**

**Procedure:**

The goal is to test the normal functioning of the machine. At the First the hopper should be filled and the recycler should be turned on. We will run the system for 1 hour. Every 10 minutes barrel nozzle temperature reading will be taken using a thermocouple and will be compared with the expected value. Using a micrometer, diameter of the output filament will be measured every 10 minutes as well and will be compared to the expected diameter of 1.75 ± 0.05 mm. Also confirm that the measured diameter is the same as the in house diameter sensor. Weight of the spool will be measured every 10 minutes and from the weight extrusion rate will be calculated and compared to the desired rate of 0.2 kg per hour.

**Requirements Tested:**

SDRD 3.1 The barrel nozzle shall maintain a temperature accuracy of ± 2.5 degrees Celsius from the set value.

SDRD 3.2 The output filament diameter shall be 1.75 ± 0.05 mm.

SDRD 3.3 The filament shall be extruded onto a nominally 1 kg spool.

SDRD 3.5 The system shall be capable of extrusion at a rate of at least 0.2 kg per hour.

**Results:**

The temperature of the nozzle and barrel was maintained within ±2.5 degrees Celsius throughout the 60 minutes run. The system was unable to extrude and keep the filament within the required tolerance of 1.75 ± 0.05 mm. The caliper and dial indicator were reading the same value for the diameter. The system was able to extrude at the rate of 0.26 kg per hour which is higher than the required rate. The system was able to spool extruded filament on a nominal 1 kg spool. The recorded values for the test can be seen in Table 1.

**Table 1.** Readings for filament test recorded every 10 minute

|  |  |  |  |
| --- | --- | --- | --- |
| Time (min) | Nozzle Temp (C) | Barrel Temp (C) | Diameter (mm) |
| 10 | 197.5 | 200.2 | 1.5 |
| 20 | 201.4 | 199.6 | 1.55 |
| 30 | 199.8 | 200.2 | 1.43 |
| 40 | 200.4 | 200 | 1.31 |
| 50 | 198.0 | 199.7 | 1.4 |
| 60 | 201.2 | 200 | 1.37 |

**Dimension Test:**

**Procedure**:

The system’s length, width, and height will be recorded at the points where the measurements are greatest and compared to the dimensions given. Additionally, a guard-opening scale will be attempted to be inserted into hazardous areas of the system to ensure compliance with OSHA standards. Furthermore, we will attempt to process plastic chips with dimensions averaging 7mm

**Requirements Tested:**

SDRD 2.1 The system shall fit in a cuboid with dimensions of 82 inches by 50 inches by 46 inches.

SDRD 3.4 The system shall accept shredded plastic with no dimension exceeding 7 mm.

SDRD 4.4 Any opening of the system shall comply with Table O-10 of OSHA 29 CFR 1910.217(c)(2)(i)(a) and 1910.217(c)(2)(i)(b).

**Results:**

The system had a height of 17.5 inches, a length of 48 inches, and a width of 10.5 inches. The hopper allows for particles to fit through holes of 7mm square sections. After inspection the device complies with the OSHA guideline.

**UI Test**

**Procedure:**

The user interface(s) will be able to allow the user to change the recycler’s active temperature freely between 130 and 180 degrees celsius with the temperature value correctly displayed. There will also be an option for the user to control the speed from 0.1kg of plastic per hour to at least 0.2kg per hour.

**Requirements Tested:**

SDRD 5.2 The system shall allow for manual temperature control between 130 and 180 degrees Celsius.

SDRD 5.3 The system shall allow for manual flow rate control between 0.1 kg and 0.2 kg per hour.

SDRD 5.4 The system shall display the current temperatures of the nozzle.

**Results:**

The UI allows for the user to set a desired temperature with the temperature controllers between 0 and 482 degrees celsius. The system displays current temperatures of the system through the temperature controllers for the barrel and nozzle. During our tests, the system can reach flow rates of about 0.26 kg per hour on the highest screw speed.

**External Test:**

**Procedure:**

The system will be connected to a nominally 110 VAC outlet and turned on to see if it is powered. The system will then be connected to a nominally 220VAC outlet and turned on to see if it is powered. Once powered on the system will be turned on to the highest temperature possible and left to reach full temperature for 30 minutes. Once at full temperature a thermocouple probe will be moved throughout the system to verify that all surfaces within reach are less than 49 degrees Celsius.

**Requirements Tested:**

SDRD 4.3. The system shall be built such that external surfaces that can be touched will not exceed temperatures of 49 degrees Celsius.

SDRD 1.1 The system shall be able to use an input between 95-125 VAC or 195-255 VAC at 60 Hz.

**Results:**

The system fails part of this test as the nozzle is exposed at a temperature of above 49 degrees Celsius. However, the system is able to run off of an input between 95-125 VAC at 60 Hz.

**Power Loss Test:**

**Procedure:**

The system shall be run so that it has been outputting filament for at least 3 minutes and the power will be cut off via the emergency stop as well as a simulated power outage by unplugging the machine. Once this is done the power cut off time will be measured for the electronic system, the mechanical system will also be tested by recording the time it takes the moving parts to stop. Then turn the system back on and check for the stored data for temperature control as well as the extrusion speed.

**Requirements Tested:**

SDRD 4.1 The system shall cut off power within 1 second of using the emergency stop.

SDRD 4.2 The system’s mechanical components shall stop within 5 seconds of using the emergency stop.

SDRD 5.1 The system shall maintain storage specified settings even after power loss.

**Results:**

The system does cut power within 1 second of using the emergency stop. And, the system’s mechanical components stop at 1 second of using the emergency stop. After an emergency stop, the settings specified by the user are stored by the system after power loss and remain in place when turned back on.

**Conclusions:**

The system meets most test requirements that were set at the beginning of the project. The requirements that were failed were discussed with the customer and were determined acceptable. This is due to the fact that the requirements that were failed can be easily fixed or implemented with more time and resources.

**Appendices:**

**APPENDIX A: Test Plan**

**Multidisciplinary Senior Design Project**

**GE 497**

**College of Engineering**

**Valparaiso University**

**Valparaiso, Indiana**



**Finalized Test Plan**

**for**

**Filament Recycling**

**Filament Recycling Squad**

**Date: March, 22 2020**

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| Prepared by: | **Filament Recycling Squad** |  |
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**Honor Code Statement**

I have neither given or received, nor have I tolerated other’s use of unauthorized aid.

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# **TEST PROGRAM**

## PROGRAM OBJECTIVE

This test program will verify that the Filament Recycler either satisfies or fails to satisfy its design requirements as identified in Appendix A.

## SCOPE OF EFFORT

The article to be tested is the extrusion machine for filament recycling. There are 15 requirements that will be tested through 5 different tests as laid out in Section 2.

## ADMINISTRATION

* Obtain the shredded plastic from Adam. (Oscar)
* Secure a location for testing. (Munib)
* Acquire correct testing equipment. (Alec and Jon)

# **TEST SUPPORT REQUIREMENTS**

The five tests discussed below will verify if the filament recycler meets the thirteen system design requirements that are stated in the SDRD. These 5 tests are: Filament Test (1), Dimension Test (2), UI Test (3), External Test (4) and Powerloss Test (5).

## FILAMENT TEST

* + 1. Design Requirements Tested
       1. SDRD 3.1 The barrel nozzle shall maintain a temperature accuracy of ± 2.5 degrees Celsius from the set value.
       2. SDRD 3.2 The output filament diameter shall be 1.75 ± 0.05 mm.
       3. SDRD 3.3 The filament shall be extruded onto a nominally 1 kg spool.
       4. SDRD 3.5 The system shall be capable of extrusion at a rate of at least 0.2 kg per hour.
    2. Description of Test
       1. The goal is to test the normal functioning of the machine. At the First the hopper should be filled and the recycler should be turned on. We will run the system for 1 hour. Every 10 minutes barrel nozzle temperature reading will be taken using a thermocouple and will be compared with the expected value. Using a micrometer, diameter of the output filament will be measured every 10 minutes as well and will be compared to the expected diameter of 1.75 ± 0.05 mm. Also confirm that the measured diameter is the same as the in house diameter sensor. Weight of the spool will be measured every 10 minutes and from the weight extrusion rate will be calculated and compared to the desired rate of 0.2 kg per hour.
    3. Resources Required
       1. Mechanical Requirements
          1. A thermocouple is required to measure up to 180 degrees. This will be used to test the barrel temperature.
          2. Micrometer is needed to measure the diameter of the output filament.
          3. Recycled Filaments will be mixed in hopper, melted and extruded in the barrel inorder to produce new usable filament.
          4. Virgin Filament will be mixed in hopper, melted and extruded in the barrel inorder to produce new usable filament.
       2. Video Requirements
          1. A video camera to record the demonstration.
    4. Justification
       1. SDRD 3.1 This test will show that the barrel nozzle will remain within 2.5 degrees Celsius by measuring the temperature over the length of the test.
       2. SDRD 3.2 This test will observe the diameter of the output filament and record the average. This will show if the diameter is between 1.75 ± 0.05 mm.
       3. SDRD 3.3 This test will show that the recycler can be loaded with a nominally 1 kg spool.
       4. SDRD 3.5 This test will record the rate of output to show that the system is capable of extrusion at a rate of at least 0.2 kg per hour.
       5. SDRD 2.2 This test will show that the inhouse sensor that was designed is functioning correctly.

## DIMENSION TEST

* + 1. Design Requirements Tested
       1. SDRD 2.1 The system shall fit in a cuboid with dimensions of 82 inches by 50 inches by 46 inches.
       2. SDRD 3.4 The system shall accept shredded plastic with no dimension exceeding 7 mm.
       3. SDRD 4.4 Any opening of the system shall comply with Table O-10 of OSHA 29 CFR 1910.217(c)(2)(i)(a) and 1910.217(c)(2)(i)(b).
    2. Description of Test
       1. The system’s length, width, and height will be recorded at the points where the measurements are greatest and compared to the dimensions given. Additionally, a guard-opening scale will be attempted to be inserted into hazardous areas of the system to ensure compliance with OSHA standards. Furthermore, we will attempt to process plastic chips with dimensions averaging 7mm.
    3. Resources Required
       1. Mechanical Requirements
          1. Shredded plastic to ensure that the system can properly handle plastic measuring 7mm in any dimension.
          2. Tape measure to measure the dimensions of the system.
          3. Guard-Opening Scale to ensure that objects cannot be inserted into the system’s hazardous areas.
    4. Justification
       1. SDRD 2.1 This test shall prove that the system does not exceed the given specifications.
       2. SDRD 3.4 The test shall prove that objects with certain dimensions will not be able to come into contact with hazardous parts of the system.
       3. SDRD 4.4 The test shall prove that the system can accept plastic with dimensions up to 7mm.

## UI TEST

* + 1. Design Requirements Tested
       1. SDRD 5.2 The system shall allow for manual temperature control between 130 and 180 degrees Celsius.
       2. SDRD 5.3 The system shall allow for manual flow rate control between 0.1 kg and 0.2 kg per hour.
       3. SDRD 5.4 The system shall display the current temperatures of the nozzle.
    2. Description of Test
       1. The user interface(s) will be able to allow the user to change the recycler’s active temperature freely between 130 and 180 degrees celsius with the temperature value correctly displayed. There will also be an option for the user to control the speed from 0.1kg of plastic per hour to at least 0.2kg per hour.
    3. Resources Required
       1. Mechanical Requirements
          1. Thermocouple probe to measure temperatures of the barrel to check accuracy of user inputs.
          2. Tape Measure to record changes in length of extruded filament.
          3. Time recording device to put length changes in terms of time.
    4. Justification
       1. SDRD 5.2 is tested and verified based on the readings of a thermocouple probe on the heated barrel over an extended period of time.
       2. SDRD 5.3 is tested and verified by measuring the rate at which filament is extruded at different motor speeds.
       3. SDRD 5.4 is tested and verified by the value associated with the user interface matching the thermocouple probe and the desired temperature.

## EXTERNAL TEST

* + 1. Design Requirements Tested
       1. SDRD 4.3. The system shall be built such that external surfaces that can be touched will not exceed temperatures of 49 degrees Celsius.
       2. SDRD 1.1 The system shall be able to use an input between 95-125 VAC or 195-255 VAC at 60Hz.
    2. Description of Test
       1. The system will be connected to a nominally 110 VAC outlet and turned on to see if it is powered. The system will then be connected to a nominally 220VAC outlet and turned on to see if it is powered. Once powered on the system will be turned on to the highest temperature possible and left to reach full temperature for 30 minutes. Once at full temperature a thermocouple probe will be moved throughout the system to verify that all surfaces within reach are less than 49 degrees Celsius.

* + 1. Resources Required
       1. Mechanical Requirements
          1. Thermocouple probe to be used to measure temperatures of the system.
       2. Electrical Requirements
          1. Nominally 110 VAC outlet to power system.
          2. Nominally 220 VAC outlet to power system.
          3. Nominal 220 VAC power cord to plug it in.
    2. Justification
       1. SDRD 1.1 is tested and verified by powering the system off of nominally 110 and 220 VAC to ensure that the extruder can be operated off of both so that the user can plug it in at any location.
       2. SDRD 4.3 is tested and verified by ensuring that the temperature of any surface that can be touched by an operator will be at a temperature that will not cause burns.

## POWER LOSS TEST

* + 1. Design Requirements Tested
       1. SDRD 4.1 The system shall cut off power within 1 second of using the emergency stop.
       2. SDRD 4.2 The system’s mechanical components shall stop within 5 seconds of using the emergency stop.
       3. SDRD 5.1 The system shall maintain storage specified settings even after power loss.
    2. Description of Test
       1. The system shall be run so that it has been outputting filament for at least 3 minutes and the power will be cut off via the emergency stop as well as a simulated power outage by unplugging the machine. Once this is done the power cut off time will be measured for the electronic system, the mechanical system will also be tested by recording the time it takes the moving parts to stop. Then turn the system back on and check for the stored data for temperature control as well as the extrusion speed.
    3. Resources Required.
       1. Mechanical Requirements
          1. Stopwatch to measure stoppage time.
       2. Electrical Requirements
          1. LED for power loss indication.
       3. Video Requirements
          1. Video camera to review stoppage times.
    4. Justification
       1. SDRD 4.1 is tested and verified by the timing of the LED light going off. The timing of the light going off being recorded in the same view as the emergency stop button and power cord being used with give us the amount of time it takes for the system to cut off power
       2. SDRD 4.2 is tested and verified by the timing of the moving parts coming to a complete stop. The time it takes to come to a stop will be recorded with the moving parts in the same view of the stopwatch and the button and power cord being used.
       3. SDRD 5.1 is tested and verified by the system losing power and needing to be turned back on and used again. When the power is cut to the system for the other requirements the system will be turned back on to be tested again and doing so the stored settings will be referenced.

# **SUPPORTING INFORMATION**

## REFERENCED DOCUMENTS

1910.217 - Mechanical power presses. (n.d.). Retrieved August 27, 2020, from https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.217

OSHA Compliant Guard-Opening Scale, Measuring Device. (2020, February 03). Retrieved August 27, 2020, from https://www.rockfordsystems.com/product/osha-guard-opening-scale/

## SYMBOLS AND ABBREVIATIONS

PLA - Polylactic acid is a filament used for 3d printer

SDRD - System Design Requirements Document

VAC - Volts of Alternating Current

UI - User Interface

# **DISTRIBUTION**

(Original) Team Leader  
(1) Advisor

APPENDIX B: System Design Requirements Document (SDRD)

**Multidisciplinary Senior Design Project**

**GE 497**

**College of Engineering**

**Valparaiso University**

**Valparaiso, Indiana**



**System Design Requirements**

**for**

**Filament Recycling**

**Filament Recycling Squad**

**Date: August 30, 2020**

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Connor Cassaro Munib Rashad

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Nicole Pomeroy Jon Bayert

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Alec Rich  *Paul Oscar Benbow*

Alec Rich Oscar Benbow

**Goal Statement**

The open-source filament recycler is a machine that will take ground up plastic and melt it down to extrude it into a usable filament for a 3-D printer to be used as an educational tool for school age children.

**Objectives**

In order to achieve success, the system shall:

1. Be able to move to various locations
2. Have a User Interface to control the system
3. Meet OSHA safety requirements
4. Have documentation for open source
5. Be tested to find optimal settings for different plastics

**System Requirements**

1. Electrical Systems
   1. The system shall be able to use an input between 95-125 VAC or 195-255 VAC at 60Hz.
2. Mechanical System
   1. The system shall fit in a cuboid with dimensions of 82 inches by 50 inches by 46 inches.
   2. The system shall have an in-house sensor to measure the output filament diameter.
3. Filament
   1. The barrel nozzle shall maintain a temperature accuracy of ± 2.5 degrees Celsius from the set value.
   2. The output filament diameter shall be 1.75 ± 0.05 mm.
   3. The filament shall be extruded onto a nominally 1 kg spool.
   4. The system shall accept shredded plastic with no dimension exceeding 7 mm.
   5. The system shall be capable of extrusion at a rate of at least 0.2 kg per hour.
4. Safety

4.1. The system shall cut off power within 1 second of using the emergency stop.

4.2. The system’s mechanical components shall stop within 5 seconds of using the emergency stop.

4.3. The system shall be built such that external surfaces that can be touched will not exceed temperatures of 49 degrees Celsius.

4.4. Any opening of the system shall comply with Table O-10 of OSHA 29 CFR 1910.217(c)(2)(i)(a) and 1910.217(c)(2)(i)(b).

1. User Interface
   1. The system shall maintain storage specified settings even after power loss.
   2. The system shall allow for manual temperature control between 130 and 180 degrees Celsius.
   3. The system shall allow for manual flow rate control between 0.1 kg and 0.2 kg per hour.
   4. The system shall display the current temperatures of the nozzle.
2. Budget
   1. The budget shall not exceed $5,000.
3. Documentation
   1. A bill of materials shall be included in the documentation.
   2. Mechanical drawings shall be included in the documentation.
   3. Electrical schematics shall be included in the documentation.
   4. Wiring diagrams shall be included in the documentation.
   5. Source code shall be included in the documentation.

The estimated cost of meeting the above requirements will be $2000.

1. Reach goals:
   1. For an additional $30 a scale shall be implemented to measure the amount of filament on the spool. The total weight of filament will be displayed on the user interface.
   2. For an additional $20 a distance control option shall be added to the control module. This will allow the control panel to be moved up to 15 feet away from the print but still attached with a cord .
   3. For an additional $20 the hopper size shall be able to hold 1 kg of shredded filament.
   4. Laser Micrometer at exit to determine filament diameter at an additional price of $1500. This will provide the current diameter of the output filament on the user interface in place of the in-house sensor specified in 2.2.