BREE 495 Engineering Design 3

Department of Bioresource Engineering
McGill University

Automating Grinder Cleaning System to Increase Efficiencies and User Safety

Client: Emile A. Lods Research Centre

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April 14, 2022

Abstract

At the Emile A. Lods Agronomy Research Centre, research from professors and external companies require the grinding and sieving of thousands of plant tissue samples to further analyze their specific findings of the season's harvest. The operation of this grinder requires insertion of tissue through a funnel following the shearing of the plant into a specified sieve depending on the project. The final and most inefficient step is the cleaning and preparation of the grinder for the proceeding sample. The cleaning and preparation unit operation is the most flawed part of the system. It requires as much time as the grinding of the plant tissue which accounts for hourly costs of the operation room as well as the technician's salary. Cleaning is accomplished by opening a heavy door secured by a bolt and thoroughly vacuuming the grinding chamber with a shop vacuum to remove all plant material from the previous sample. The door is the resecured for the next sample. Safety and energy costs are also a detrimental factor to this operation as the use of a hand brush and vacuum is inefficient as well as dangerous maneuvering around heavy shearing blades. The current method of operation also introduces human error into the data collection process. If the operator does not clean the grinding chamber properly it can cause cross contamination between samples. This is a major risk for the research being completed as the grinding is a destructive and non-reversible operation. Preliminary solutions attempt to integrate a vacuum system and/or pressurized air to the ease of cleaning the chamber of plant residues. This project concluded that a redesign of the grinder door with the use of an auxiliary vacuum for residue extraction through a system of ported valves, is the most energy efficient method while being easily adaptable to previous models and ensuring the safety of the laboratory technicians. This report will assess the methodologies, prototypes and final designs used to overcome the efficiencies imbedded in plant grinding operations.

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List of Acronyms and Abbreviations

CAD	Canadian Dollar
CCOHS	Canadian Centre for Occupational Health and Safety
EPA	United states environmental protection agency
GHG	Greenhouse gas
PE	Polyethylene
PETG	Polyethylene terephthalate glycol
PP	Polypropylene
PPE	Personal protective equipment
PVC	Polyvinyl chloride

List of Units

hp	Horsepower
s	Seconds
kW	Kilowatts
kWh	Kilowatt hour
mm	Millimeter

1.0 Introduction

As world populations continue to grow, the demand for agricultural products increases. To keep up, more efficient research methods must be implemented. Sample grinding is a key step in measuring the chemical makeup of the plant tissues and this essential information that cannot be measured without grinding. This process of chopping the whole plant into microscopic fractions is done to ensure homogeneity is every sub-sample. Commonly in laboratory settings, grinders such as the Wiley Laboratory Mill and its competitors, function similarly. A high-power electric motor attached to a central rotor with 4 shearing blades is seated in a chamber lined with 6 more blades with a vertical input at the top, a sieve at the bottom just above the output where the completed homogenous sample is ready for analysis. This method of grinding has proved its efficacy as it has remained in professional and academic laboratories since its release roughly a century ago. This grinder has succeeded from its robustness and very few adjustments have been made to subsequent models. On the other hand, its flaws have followed in its iterations. This design report explores the overarching pitfall of the grinder cleaning operation, how the original design functioned as well as other pupils' attempts at research and innovation. This report will also cover the social, environmental, and economic constraints set by the client and the necessary standards and guides. The design process and proposed iterations are compared, and the most suitable approach is selected as the solution to the grinder cleaning operation.

Vision Statement: Improving efficiencies in plant grinding operations.

Mission Statement: To provide customers with the highest efficiency and improved safety in laboratory plant processing by automating grinding and cleaning processes.

2.0 Literature Review

2.1 Plant Grinding

High accuracy and reliability in plant sample analysis is reliant on one thing: How well a subsample relates to the actual plant itself (Smith et al., 1968). Grinding is the process of reducing the size of larger aggregates. The result is much finer and uniform parts of the original sample (Beke, 1981). Plant grinding is an essential post-harvest operation in labs that research agronomy and plant physiology. Understanding the essential nutrients including nitrogen, potassium, phosphorus, and sulfur are important to compare samples from one another (Day et al., 2003). At different plant maturity levels, certain nutrients can profoundly assess the characteristics of a certain sub sample. In a common laboratory, four plant stages could be examined through a season from the three-leaf stage until full maturity and in between (ECODA, 2021). Depending on the study, hundreds to thousands of plant samples are retrieved from the field and placed into a dryer until moisture content reaches roughly 12% (UNL, 2013). From the dryer, the samples are to be grinded and sieve through a specified sieve diameter, and of the grinded sample only a few grams are to be sealed and labeled for further laboratory processing.

2.2 S. W. Wiley Laboratory Mill

In plant science laboratories, innovation in laboratory mills has not improved much in the last century. The first laboratory mills widely used throughout labs is the S. W. Wiley Laboratory Mill as seen in Figure 1. Patented in 1926, the Wiley Laboratory Mill was the first of its kind to have a central block with flour blades rotating and shearing the plant material with 6 outer blades (Wiley, 1926). This durable and robust design has proven its time as the same design with slight alterations from model to model is still used in professional and academic laboratories such as the Emile A. Lods Agronomy Research Centre on McGill's MacDonald Campus. This grinder is exceptional at reducing the size of the original sample where each analytical aliquot well represents the original sample, although from its debut the grinder the cleaning process has not changed from manually brushing out the remainders of the plant sample (Harrison, 1926). A flaw with this grinder experienced by colleagues at the Emile A. Lods Research Centre is the cleaning operation. A standard 4.5hp Miley Model 3 is currently in use which is like the model 1 featured in Figure 1. This grinder, along with the redesign, will comply with the Preparation of Laboratory Sample official analysis methods from AOAC 922 (2008).

2.2.1 Wiley Cleaning Procedure

After a sample is ground by a 1.5 hp motor and sieved, the door is unlatched and pulled aside. In the open position, and with the motor off, residuals are extracted with a standard 4 hp shop vacuum and a handheld brush. This process is unfavorable due to the energy and time inefficient manual cleaning, the threat of physical harm maneuvering weighted shearing blades and sample contamination due to user fatigue. From independent tests, the results of one cycle of grinding and cleaning of one sample of soybean plant at maturity are listed in table 1. From trials we estimate that the grinding operation requires an average of 63.7 seconds and 0.0149 kWh, the cleaning operation takes 138.7 seconds and 0.086 kWh for a total of 202.4 seconds for grinding and cleaning one full sample and 0.1011 kWh from equation (1). From the cleaning cycle parameters, we estimate that the 138.7 seconds can be attributed to 30 seconds for opening and closing the door and the other 108.7 seconds for extracting the plant samples.

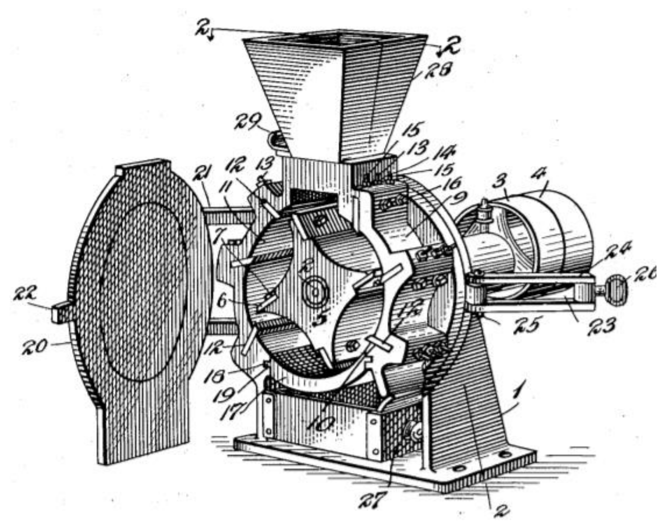


FIGURE 1. S.W. WILEY LABORATORY MILL

Table 1. Baseline Energy and Time Usage for Model 3 Wiley Mill

Operation			Trail 1	Trail 2	Trial 3	Average
Grinding	Time (s)		64	59	68	63.7
	Energy (kWh)	Grinder	0.0149	0.0138	0.0159	0.0149
Cleaning	Time (s)		131	135	150	138.7
	Energy (kWh)	Vacuum	0.0813	0.0840	0.0933	0.0860
Total	Time (s)		195	194	218	**202.4**
	Energy (kWh)		0.0962	0.0978	0.1092	**0.1011**

$$eq.1\ Energy\ Usage\ (kWh) = Power\ (hp) * \frac{0.7457\,kW}{1\,hp} * Time(s) * \frac{1\,hr}{3600\,s} \quad (1)$$

2.3 Previous Redesigns of Laboratory Mills

As previously stated, research and development on advancements to laboratory milling operations has not been thoroughly explored or reported. Due to the robust and reliable system at hand, very similar redesigns and variations of the standard Wiley mill including the Perkin Elmer 3000 series as shown in Figure 2, the Eberbach E3300 Series Mills as well as models 2 through 4 of the Wiley mills. Advancements to these grinders include more updated feeding systems, safety features including magnetic sensors to ensure the motor is not operating when open and more ergonomic operating systems. Although the cleaning process has remained the same throughout the iterations. As stated by Lockman (1977) the possibility of grinding plant samples without completely excreting the previous sample would greatly improve the time and efficiency of the operation. The experimentation of running the grinder without opening the door and removing previous samples would result in a nutrient difference of plus or minus 5% (Lockman et al., 1977). This solution of removing segregation of plant samples would create a medium to high acceptable error, although depending on the research protocol for a specific project, these tolerances and the procedure may not be approved.

FIGURE 2. PERKIN ELMER LAB MILL 3310

2.4 Design Constraints

The Emile A. Lods Agronomy Research Centre demands a high standard of social, economic, and environmental constraints with research facilities due to legacy, prestige and professionalism that McGill University supplies for its workers, research and the environment.

2.4.1 Social Constraints

2.4.1.1 Safety

In every engineering solution, idea or design, safety must be the parameter that overwrites any other criteria including cost. Every employee of the research centre is and must be part of one of the two unions offered to the staff. The two unions offered are AMURE and AMUSE although the one most used for technicians is AMURE. This design project must pertain to article 17 of the collective agreement currently in effect (AMURE, 2018). As well the design will abide by safety standards and protocols as stated in the section 2.61.

2.4.1.2 Adaptability

The Wiley Laboratory Mill platform, used by many labs, is an expensive piece of machinery in the range of $20,000 CAD (Thompson, 2021). This piece of machinery is a substantial cost and as previously stated is a reliable grinder therefore adaptability without too much intervention to the mill is favorable. The client would prefer a component that could easily be installed by the user or manager of the facility.

2.4.1.3 Ergonomics

Throughout the summer season, there are frequent harvests of plant materials. Depending on the ongoing project, there could be thousands of samples to take at a time. About 100 samples may take a single worker 8 hours to complete. At this rate, a single batch would cause a lot of strain and repetition of a mundane cleaning task. The client would prefer a process that is more automated so that the strain on the technician is less and monotony is reduced to avoid processing mistakes or physical injury. The design should also be easy for most technicians to use without a major learning curve.

2.4.2 Environmental Constraints

2.4.2.1 Energy Usage

The current plant grinding operation is very energy intensive including the motor responsible for the shearing, the vacuum and the ventilation unit as shown in table 1. Although the motor and the ventilation units are two energy intensive parts of the system, they will not be changed or edited in any way due to the effectiveness of the shearing mechanism and the essentiality of the ventilation. As mentioned earlier in section 2.3.1, the vacuum is the largest energy hog as it requires the most operation time compared to its power output. Therefore, to reduce the amount of energy required for the cleaning process, a more efficient use of the vacuum is desired.

2.4.2.2 Sustainable Components

Much Like the original design for the Miley Mill, our system is designed to last for many years. In many laboratory settings, equipment is designed for light use and an overall life cycle of 5 years. This is often due to equipment becoming obsolete as new machines come onto the market. The parts that are being replaced on the grinder will be constructed of the same steel as the original.

2.4.3 Economic Constraints

2.4.3.1 Initial Cost

Anyone accustomed to laboratory research is familiar with the reality of expensive machinery. Factors including a niche market, precision, accuracy, durability, and reliability result in the high prices. Often laboratory equipment can be paid for by grants which may unburden the sacrifice over the price. Similarly, the Wiley mill alone retails for $20,000 CAD and accessories such as the blades retail for $600 CAD and the sieves for $1000 CAD. For the design of the automating cleaning system, a budget of $2000 CAD is given for the research and design. This budget is suitable for the cost of machining parts as well as the purchase of an efficient and appropriate vacuum.

2.4.3.2 Operating Cost

The operating costs are an important design criterion for the client. The combination of energy usage, hourly cost of machine usage and hourly wage of the technician are three factors that keep the operations cost high. These costs can be reduced by increasing the energy efficiencies of the cleaning cycle along with reducing the time to process one sample. These parameters will be discussed in detail in section 2.13.

2.5 Proposed Designs

2.5.1 Vacuum Flow Parameters

To develop and evaluate the different approaches, the flow of air and particles was analyzed with SOLIDWORKS Flow Simulation. This was done by creating a 3d model of the grinder with the proposed solution. The flow of the vacuum was then applied to the system and the design was evaluated and improved. See appendix 6

2.5.2 Design Process

Gantt chart showing flow of the design process of both BREE490 and BREE495 can be found in appendix 4 and 5.

2.5.3 Suggested Design 1: Vacuum Inlet

The first approach to simplifying the cleaning process was to simply design an adapter so the vacuum nozzle could be attached directly to the grinder inlet. This would back the air up through the screen and around the rotating grinder into the vacuum. The reverse airflow would carry the plant material back up through the grinder leaving the chamber clean and ready for the next sample. This design was very simple and cost effective, requiring no modification to the grinder itself. The components could be 3D printed at very low cost. When put to the test, this system did not provide a reliable cleaning cycle. When light and low oil and resin samples were used it was able to remove the residual plant material. When samples with a higher density and resin/oil content were used, the vacuum inlet was not able to remove residue from behind the cutting knives or from the sides of the screen. This inconsistency does not meet our requirement of a reliable system that can be used on all types of samples that are processed in the grinder.

2.5.4 Suggested Design 2: Compressed Air and Vacuum

This approach uses compressed air to dislodge the plant material then a vacuum to remove it from the chamber. This system uses a 2-stage removal process. This is the most complex design as it uses compressed air as well as vacuum. This dramatically increases the cost of the project by needing an air compressor to be purchased. The main issue with this system was matching the airflow of the compressor to the vacuum. The positive pressure would force the sample out through the grinder inlet and screen. This would cause a large amount of dust to be forced out of the grinder. This created an unnecessarily dangerous working environment for the operator.

2.5.5 Suggested Design 3: Manually Actuated Plunger

This system uses 4 valves placed in the door of the grinding chamber to extract plant residue. Each valve is located between two cutting knives, providing direct suction to the area where residue buildup occurs. This eliminates the need for the supplemental compressed air. When grinding is taking place, the closed valve is level with the surface of the door, providing a smooth area to ensure the sample is not bypassing the knives or getting caught in the ports. The valve then retracts into the housing mounted on the door for the cleaning cycle. The valve is mechanically blocked from entering the grinding chamber as this would cause a collision with the rotor. During the cleaning cycle, each valve is opened individually to provide maximum suction to that area of the chamber. The spinning rotor provides extra turbulence to loosen particles.

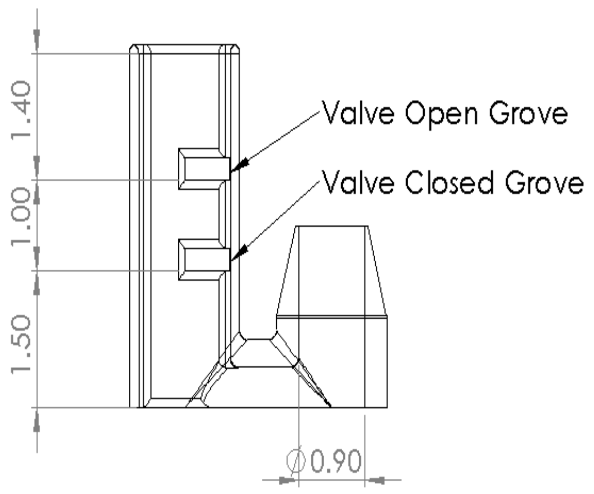


FIGURE 3. PLUNGER HOUSING

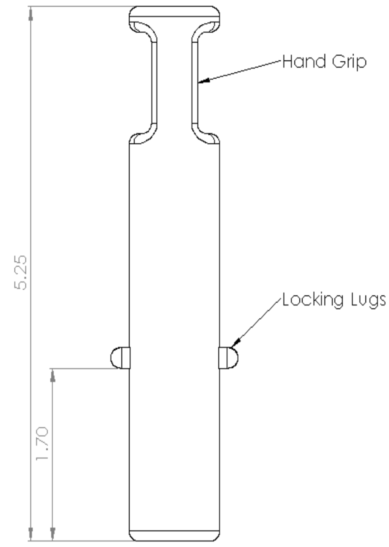


FIGURE 4. PLUNGER

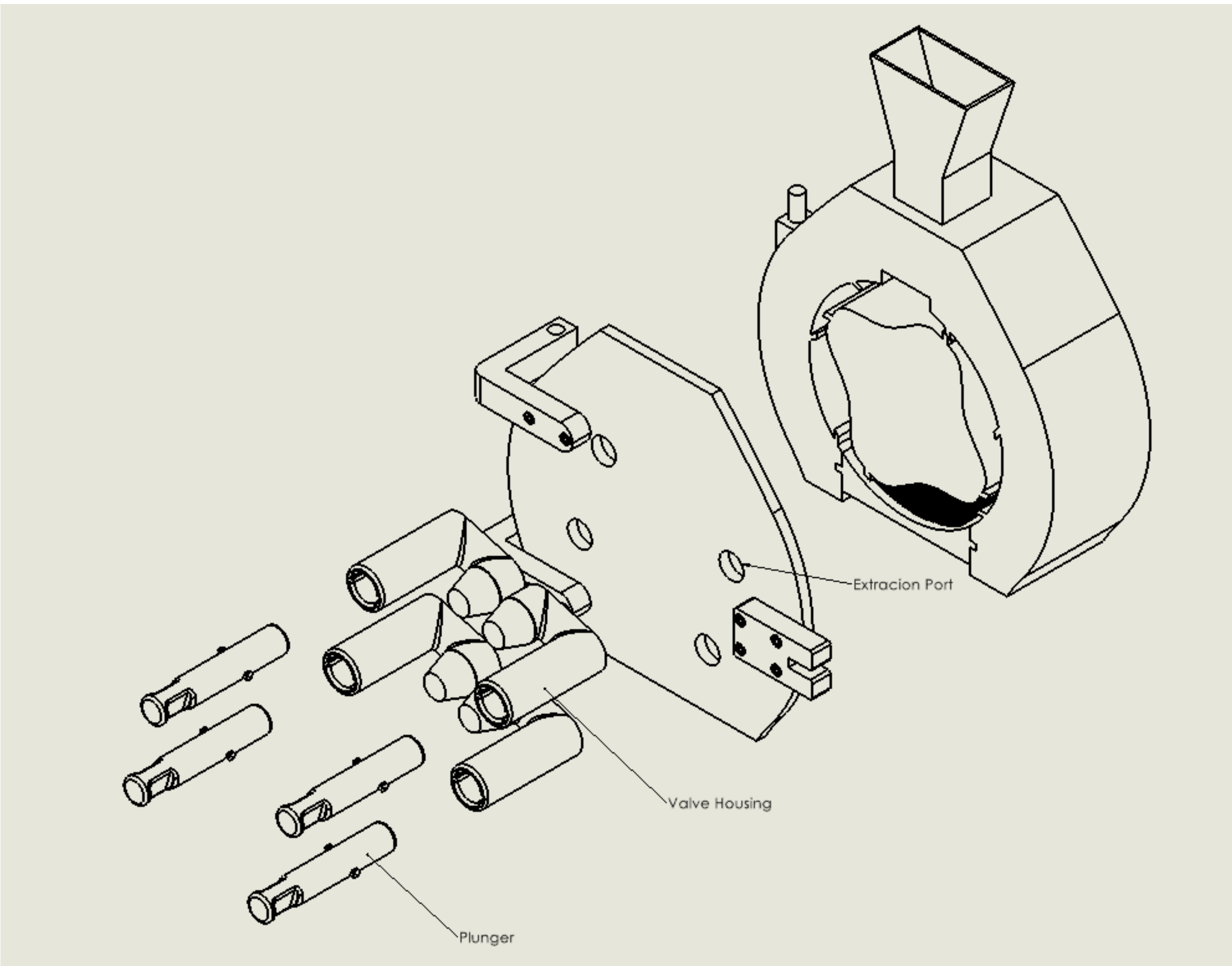


FIGURE 5 PARTS DISPLAY OF GRINDER

2.5.6 Startup Procedure: Suggested Design 3

A startup procedure has been put in place to ensure that the provide the flow of the grinding operation as well as ques on where and when to apply safety measures. This startup procedure can be found in appendix 6.

2.5.7 Alternatives Comparison

In further comparison on the various

Table 2. Pugh Chart

Description		Manual vacuum cleaning		Single Vacuum no valve		Dual air inlet single vacuum		Quad valve actuated vacuum		Electronically actuated quad valve	
Constriaints	Weight	Previous design		Design 1		Design 2		Design 3		Vorte-X M4	
		Rating	Weight	Rating	Weight	Rating	Weight	Rating	Weight	Rating	Weight
Energy savings	3	0	0	1	3	-1	-3	1	3	1	3
Saftey	2	0	0	1	2	1	2	1	2	1	2
Sample contamination	2	0	0	-1	-2	1	2	0	0	1	2
Adaptability	2	0	0	1	2	-1	-2	1	2	1	2
Time efficiency	2	0	0	0	0	0.5	1	0.5	1	1	2
Ergonomics	1	0	0	1	1	1	1	1	1	1	1
Cost	1	0	0	0	0	-1	-1	-1	-1	1	1
Score			0		6		0		8		13

2.6 Final Design: Vorte-X M4

The Vorte-X is the culmination of the 4 previous designed prototypes. This design combines aspects of the manually actuated plunger with a more advanced and sophisticated design. Named the Vorte-X M4, this design integrates the electronically actuated plungers for a off-hand cleaning procedure. This design is considerably the most complex due to the addition of electronics and a complex mounting housing. However, this design is based on the Wiley Grinder Model 4 which, the newer model in the Wiley series, as apposed to the model 3 which the previous designs were based on. Alternatively, this approach combines the vacuum lines from the ports into a centralized universal vacuuming terminal. The Vorte-X M4 is an attachment for the Wiley Model 4 grinder and consists of the components featured below. Further descriptions and diagrams of the functioning components will be listed.

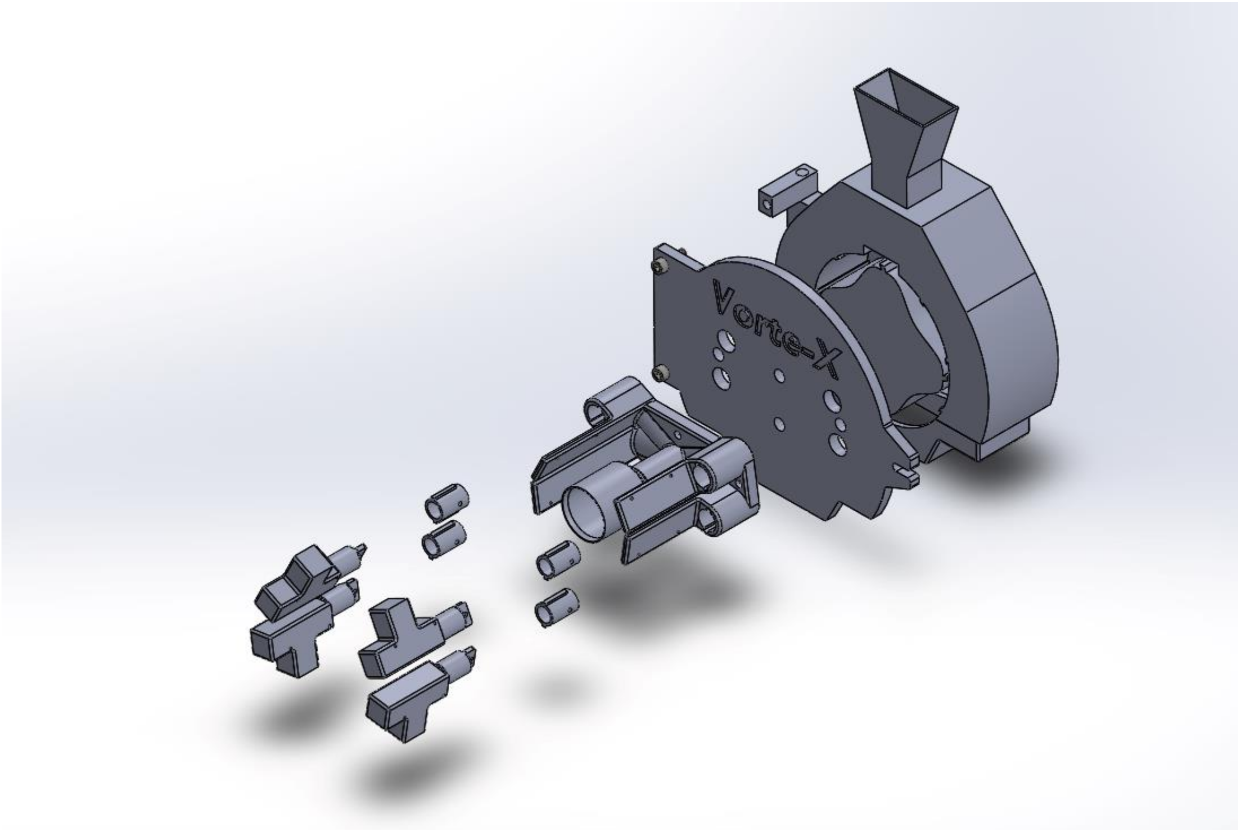


FIGURE 6 VORTE-X GRINDER CLEANING SYSTEM DIAGRAM

2.6.1 Components

2.6.1.1 Vorte-X M4 Door

As previously mentioned, the Vorte-X M4 is based on the Wiley model 4 grinder. The door made of ½" hot rolled pickled and Oiled (HRPO) steel and has been similarly modified to include the port holes for particulate extraction. The door plate is fabricated using a Thermal Dynamics 60i 3-phase plasma cutter torch integrated onto a Fab-Cut ProSteel Auto-Fab CNC machine. The machine must be set to 100 psi of air pressure along with 60 amps and using a 60-amp cutting tip. Etching of the Vorte-X logo is completed through the etching service provided by Fab-Cut CAD software. As well four M10-1.5 x 35mm internal hex bolts are welded to the face of the plate as seen in figure to guild and install the M4 Housing-X. Two M10-1.5 x 35mm internal hex and two M10 flat washers (ISO 7089) were used for the installation of the door to the grinding face as seen in the left side of the door. Specs on material and industry standards of fabrication will be specified further as well the dimensioned diagrams in appendix 14.

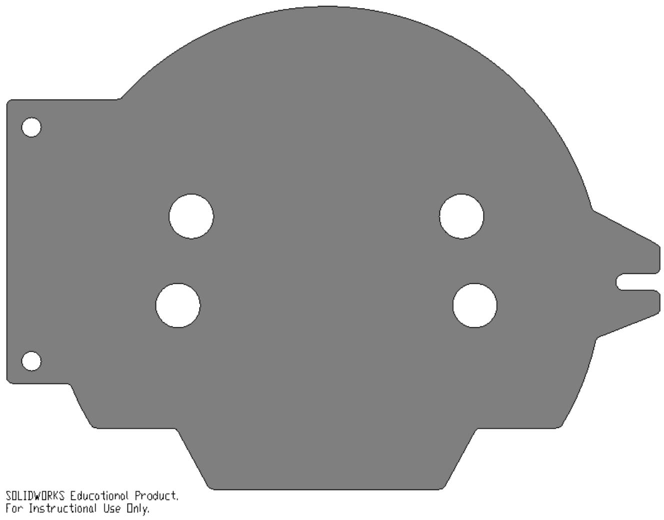


FIGURE 7 GRINDER DOOR

FIGURE 8 GRINDER DOOR WITH MOUNTING BOLTS

2.6.1.2 M4 Housing-X

The M4 Housing-X is a complete redesign of the previous design's particulate collection unit. The complete overhaul was an essential step in the move to automation. The first modification is the addition of mounting points for the linear actuators. Four extended plates are aligned with the port holes and the actuators can be mounted by the two supplied self-tapping screws. Another design change is attributed to the central retrieving vacuum mount. This redesign centralizes the flow from the four ports into a singular 1″ column that expands to a standard 2 ½″ push-fit vacuum fitting. This method reduces complexity of the locking mechanism of the M4 Valve-X while increasing complexity of the flow travel. Four mounting holes are located at the bottom edge of the housing and secured by M10-1.5mm hex locking nuts. The housing is made from PETG (Polyethylene terephthalate glycol) and was 3D printed by a Creality Ender-3 V2 3D printer. Properties and reasons for 3D printing with PETG will be explored later.

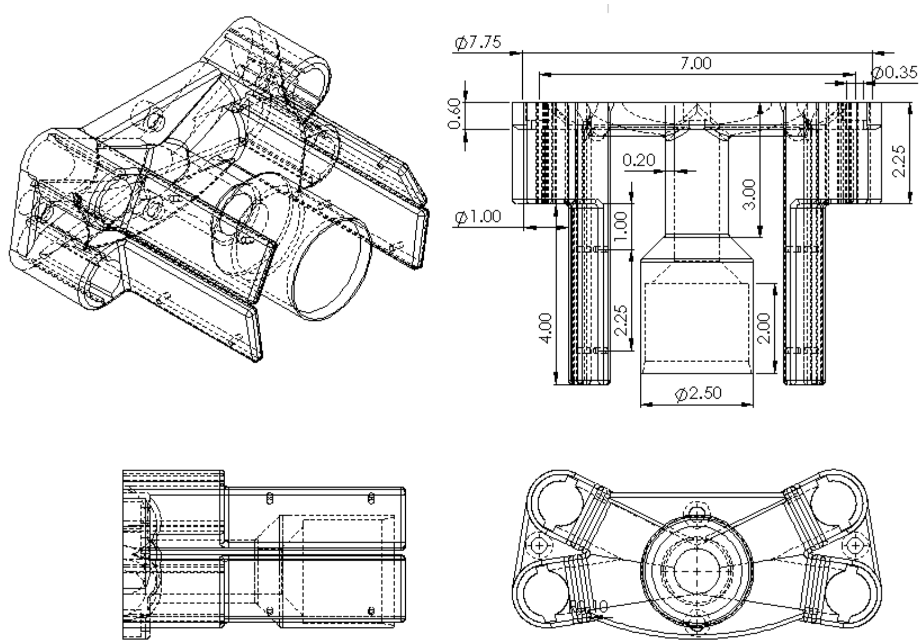


FIGURE 9. M4 HOUSING-X DIAGRAM

2.6.1.3 M4 Valve-X

The M4 Valve-X is the replacement of the previous manually actuated plunger design. Four of these valves used to cap off the port holes of the door. They are attached to the linear actuators by a locking pin and have linear guides to slide in and out of the housing. Unlike the previous design, the valve is not twist and lock. Instead, they are held in place by the full erection of the actuators. Similarly, these components are made from the same PETG as the housing.

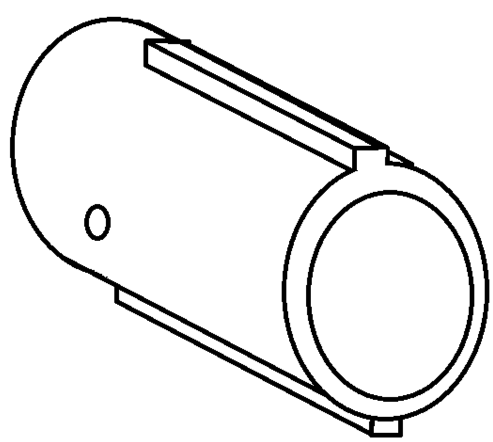


FIGURE 10. M4 VALVE-X DIAGRAM

2.6.1.4 M4 Act-X

The M4 Act-X actuators are 12V linear actuators from InstallGear model IGDLA-2. They are conventionally used as car door lock actuators. The actuating system functions by being positioned and mounted at the port holes of the door. At full open lock, the actuator is fully extended along with the attached valve into port hole with roughly 5lbs of force. A .041 GA x 3/8 in. x 1-1/8 in. spring is positioned over the protective flex seal to ensure the actuator is fully depressed. The spring also serves as a bumper for unlogged debris in the grinding chamber and helps with shock absorbance of any of the impacts.

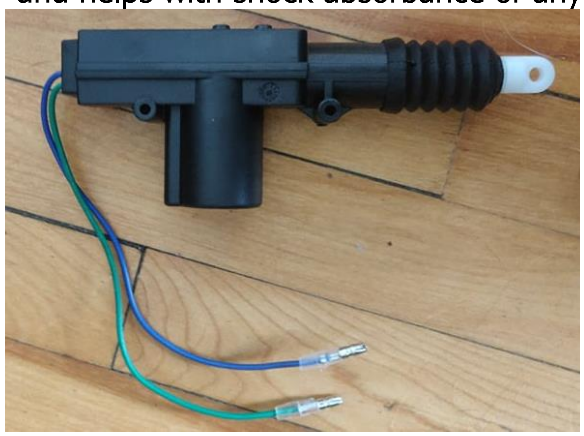


FIGURE 11. M4 ACT-X ACTUATORS

2.6.1.5 Power Converter

A power converter is essential to this design as the actuators run at 12V DC and the main power source of the grinding motor is at 110V AC. A simple 2-amp 120W converter is powerful enough to activate the actuators as well as the Arduino Uno.

FIGURE 12. 110V TO 12V AC/DC CONVERTER (WALMART, 2022)

2.6.1.6 Arduino Uno R3

To operate the automating grinding operation and keeping simplicity operation simple for the technician, an Arduino Uno microcontroller is essential. This controller runs at 12V which is in line with the voltage specifications for the actuators. A simple code was based on an open-source code written by Shamshiri (2019) which uses two push buttons to open and close the actuators. The code can be seen in the appendix 16.

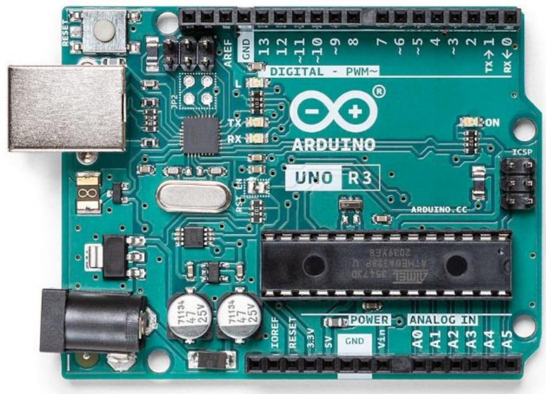


FIGURE 13. ARDUINO UNO R3 MICRO CONTROLLER (ARDUINO, 2022).

2.6.1.7 AR22 Non-Illuminated Pushbuttons

Two pushbuttons installed on the side plate labelled "in" and "out" are wired to the Arduino. These two buttons will actuate the valves inward when on when "in" button is depressed and the valves will move retract into vacuuming position when "out" is depressed.

FIGURE 14. AR22 NON-ILLUMINATED PUSHBUTTONS (FUJI, 2022)

2.6.2 Construction and Refurbishment

Upon retrieval of the donor grinding machine, it was evident that before testing of the automated cleaning design the grinder would need some repairs and refurbishment.

Primarily, the grinder central rotor was installed incorrectly which may have damage the existing blades which can be seen in figure 15. To remove the rotor, all the blades and set screws were removed and a custom mount was fabricated to press off the rotor from the shaft. To ensure smooth rotations of the rotor, the two pillow block bearings were regreased, and the driving belt was replaced. Rewiring of the power cord along with attachment of a 15-amp 125V AC quick grip plug was essential as the previous wiring to the 1.5 hp motor were considerably damaged. Some rust was also removed from the blades as well as plant material and dirt in the enclosure.

FIGURE 15. ROTOR PLACE INCORRECTLY IN LEFT PHOTO.

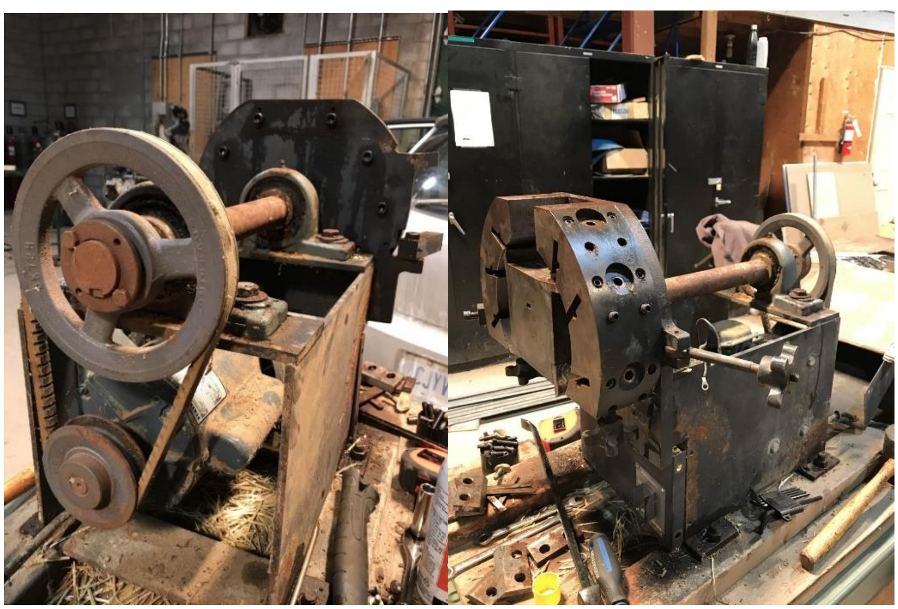


FIGURE 16. DECONSTRUCTION OF GRINDER AND COMPONENTS

2.6.3 Issues and Complications in Fabrication

In fabrication of parts, there were a couple of complications that caused stunts in the feasibility and complexity of the design. Primarily, the parts sold from the authentic retailer are very costly. Any part that needed to be replaced or repaired had to be custom made as the prices were not affordable. Similarly, the parts that were ordered such as the sieve mesh material was delayed due to COVID-19 backup of parts delivered from the U.K.

Plasma cutting of the steel door took several weeks to complete as there were issues with the CNC plasma cutter. To cut the door out, a 4′ x 4′ ½″ steel plate was used. Half of the plate damaged due to the plasma cutter remaining on during transitions of the doors borders and the screw holes. It was at first thought that the Fab-Cut software was corrupted as the table seized to make proper cutouts. Fab-Cut technicians were contacted and assessed that the issue was due to improper installation of the table. The issue address was that the cutting of the ½″ steel was drawing too much current from the plasma cutter and introducing noise to the CNC digital signals. The issue was addressed by keeping the plasma cutting line separated from the digital signal lines of the CNC.

The last issue was attributed to the 3D printing of the main housing. The housing needs to be perfectly flat and must align with the port holes. Any gaps or not flush surface will cause plant material to exit the chamber and render the vacuum lines less effective. When printing the housing, the housing was unsticking from the printing surface roughly 12 hours into 26-hour print. This was due to varied temperature changes in the printing room causing the heated polymer to deform. After another failed trial, we reached out to the M3D club where they were able to print out a more precise and uniform print.

2.6.4 Startup Procedure

A modified startup procedure has been put in place to ensure the flow of the grinding operation as well as ques on where and when to apply safety measures as to the Vorte-X. This startup procedure can be found in appendix 7.

2.7 Standards & Methods

2.7.1 Laboratory Equipment Safety: IEC 61010-1:2010

This standard is applied to the best of its ability to the cleaning apparatus and grinder. IEC 61010 is a standard for safety requirements for electrical equipment in laboratory use (IECEE, 2010). From this standard a requirement for an emergency stop button was installed on the control panel of the grinder with a red button and yellow background. This standard also clarifies that there must be a protection plan against potential electrical fire which is addressed in section 2.7.6. Finally, am important qualification being to ensure that ergonomics is considered in the design of the device. Considering the automation and greater ease of use of the Vorte-X, the capability of safely using the machine has increased due to its simple operation.

2.7.2 Bolts: ASTM A193

All bolts used in the design of the cleaning apparatus conform to ASTM A193 Grade B7 hex bolts. This standard, approved in 1936, is utilized in petroleum and chemical construction operations. It covers alloy and stainless steels for machine bolting in conditions of high pressure, temperature and is used in valves flanges and fittings (Portland Bold, 2022). The rugged and durable bolt standard was chosen as it follows what Wiley Mill already follows and is needed as this lab equipment is susceptible to continuously strained loads.

2.7.3 Safety for Farmstead Equipment: ANSI/ASAE S354.7

This standard is used to provide reasonable degree of personal safety for operators and other persons during normal operation and servicing of farmstead equipment (ANSI/ASAE, 2018). Further explanation of the use of this standard is seen later in this document.

2.7.4 Signage and Warnings: ISO 7010

ISO 7010 is an international standard used for graphical hazardous symbols on hazard and safety signs. It uses a set of colour and principles to make simplify and make the signage understandable with simple pictures or diagrams. Further explanation of the use of this standard is seen later in this document.

2.7.5 Sample Contamination Methods

Standards for contamination methods were not available therefore methods of laboratory procedures were considered. In a 2021 Canola Sulfur Study Protocol, recommends that plant samples must be grinded and sieved through 1mm. Between samples, the grinder must be cleaned and vacuumed with no particulates left in the chamber. Testing results of the Vorte-X grinder cleaner shows that the vacuuming system is sufficient in particulate extraction and avoids sample contamination.

2.8 Workplace Health and Safety

The grinding operation is a complex system with many factors that can affect human health and safety. Below are procedures and implementations in the design that are essential to avoid long term chronic injury or even death. All protocols and safety features must be followed by the user and employer must provide the means for the operation to safely occur.

2.8.1 Grinding Chamber

The grinding chamber contains 4 blades on the central rotating block as well as 6 static blades lining the chamber walls. While grinding, the front door must be fully shut and locked into place before starting. Magnetic security connections between the door and the chamber ensure that the motor cannot operate if the door is not fully shut. To comply with ANSI/ASAE S354.7 (2018) section 11.10.3.2, the inlet of non-uniform material, such as full soybean plant or ear of corn, must be sized appropriately to reasonably fit the sample. A stopper must be kept over the feeding hole when no plant is inserted to avoid unwanted insertions. While operating the grinder, it is adamant that the user must not have any loose clothing, jewelry and any long hair should be tied up. As seen in OSHA (2018) (2019) incident reports, loose hair and clothing has entangled and crushed workers by rotary equipment leading to hospitalized injuries and fatality. Due to the redesign of the cleaning cycle, the door does not need to be opened after each sample which greatly reduced the injuries caused by maneuvering around the shearing blades with a vacuum and brush. Regular maintenance will still require opening of the chamber to inspect oil residues and physical shape of the blades. Under this circumstance caution must be taken and fingers must never be in the path of the rotating blades as the central block is rotated.

2.8.2 Dust and Fine Suspended Particulates

The grinder can grind the sample into small particles as small as 5 microns and potentially some finer particles (Thompson, 2021). Exposure to these fine elements without proper PPE is very dangerous and could lead to chronic health issues. According to the EPA's NAAQS air pollution criteria (2021) recommended maximum exposure to particulates of 10 microns should not exceed 24 hours of exposure once every three years. Unprotected lungs can cause diseases such as fibrosis also known as Farmer's lung through the milling of fine organics (CCOHS, 2021). The redesign of the cleaning system has closed the system and will reduce the open and airborne particulates and concentrate them in the filtered vacuum system. Along with the redesign system, an industrial fan ventilates the drying room and is to be running whenever a technician enters the room.

2.8.2.1 Dust Mask

All users of the grinder machine must have a proper rated mask and the mask along with all other PPE must be provided by the employer which is required by law for the protection of the employee (AMURE, 2018). A half-face mask NIOSH approved must be provided along with the proper P100 cartridges (3M, 2021). Fit testing procedure for the respirators but take place to ensure the seal with the face if impermeable with regular activities (OSHA, 2011). If the user has facial hair, it must have been completely shaved 24 hours before use of facemask.

Figure 17. 3M Filter

2.8.3 Noise Damage

The combination of grinding plant material, a blower fan and a vacuum, the noise level in the confined grinding room ranges from 90-95 dBA. According to the Canadian Centre for Occupational Health and Safety (2020), the maximum allowable working period is 2 to 4 hours a day. To prevent hearing damage, the CCOHS recommends that hearing protection should be provided with decibels above 85. Therefore, users are required to wear hearing protection that is suitable for levels up to 100 dBA (Fisher, 2021).

FIGURE 18. 3M EAR PLUGS

2.8.4 Electrical Shock

In the event of the reparation of electrical components being, the actuation system or the motor for the central block, all components should be removed from power. It is unlikely that the Arduino and actuation device cause electrical shock although the 60Hz 110V motor may, therefore precaution should be paid and any modifications to the power source should be done by a certified electrician.

2.8.5 First Aid and Fire

In the event of injury by laceration, the workplace should provide a first aid kit nearby where the wound could be addressed. Neglect to cleaning out air filters will cause a static flow of the ventilation. An accumulation of fine particulates in static air could be a potential fire hazard. If components or plant tissues catch on fire, similarly a fire extinguisher should be available, and all technicians should be aware of how it operates.

2.8.6 Safety Signs

Safety signs are an important way to convey safety information without a language barrier. The following standard for industrial purposes ISO 7010 (2020) has been used for this design. Prohibition sign P015 as seen in figure 5 will be placed on the inlet feeder. Both mandatory action signs M003 and M016 will be posted upon entry of the grinding room so affirm and set a reminder. A warning sign W012 will be posted on the electronics panel to advise what is behind the panel. A fire extinguisher and first air sign F001 and E003 should be easily visible and make the user know where to reach these areas.

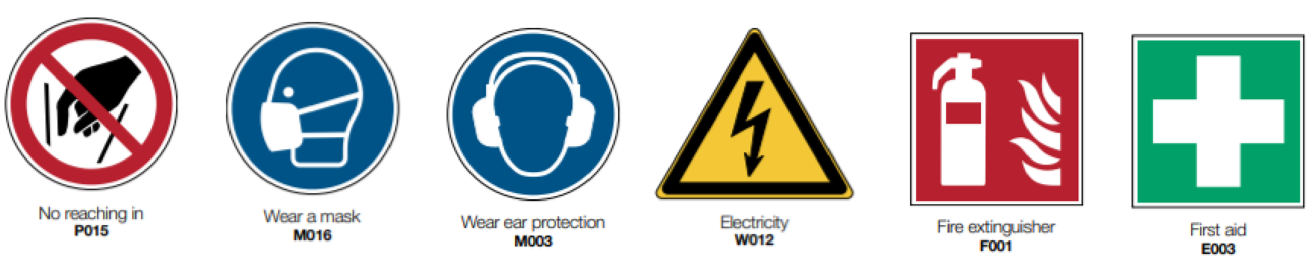


FIGURE 19. ISO 7010 SIGNAGE

2.9 Machinery Failure

FMEA analysis was conducted on the quad valve system. This is a critical step in the design process to ensure operator safety and reliability of the system. This process was essential to determine areas of improvement in the design. The items that FMEA impacted the most were valve and vacuum components. The valve needed a safety to prevent collision with the rotor. A vacuum gauge was added to alert the operator of low suction.

2.9.1 Potential Points of Failure

The valve being the only moving part is the most vulnerable to failure. If it is forced into place while an obstruction is in the path it could cause major damage to the grinder. This has been considered by making the plunger extra robust. There is also a shoulder to prevent the plunger from entering the grinding chamber during failure.

As the design was improved risk of failure was further reduced. The plungers are now held in place by springs. If there is excessive force in the face of the plungers than they will be pushed back into the housing. This eliminates the risk of the plunger braking from the locking lugs.

The implementation of electric actuators for the plungers allows for the plungers to be protected from excessive force to close or open the plunger by the operator. The plunger actuators are fitted with clutches to limit the pressure applied. In the case a plunger does not close or open, the operator must stop the grinder and clean the plunger. Forcing it manually is not an option.

2.9.2 Improper Operation

Negligent use of the grinder including inserting other material than plant tissue or inserting plant tissue that is not fully dried, will cause the blades to dull fast and will jam the moist tissue between the blades. This jamming reduces work efficiency of the grinding operation and could damage the motor.

2.9.3 Failure Due to Maintenance

Failure to abide to the maintenance of the grinder and its parts will lead to faster deterioration of the grinders components as well as may pose risk to the operator. The grinder itself comes with a clear guide for maintenance. The vacuum system addition does not require routine maintenance of components that can result in catastrophic failure.

2.10 Testing

For testing of the Vorte-X system, left over plant material from a study of pulse leaves were dried for four hours until the moisture was virtually removed. The 300g sample of pulse leaves were inserted in the chamber and grinded as it regularly functions. After the sample was fully grinded the vacuum was switched on and then each actuator was connected to a lead to open the cavities to allow suction. After the actuators were opened for roughly 1 second each, the vacuum was switched off as well as the motor. The door was opened to examine residue where none was found besides light dusting. Video of the first testing of the Vorte-X can be seen here:
https://www.youtube.com/watch?v=ihhaEoW0uWI.

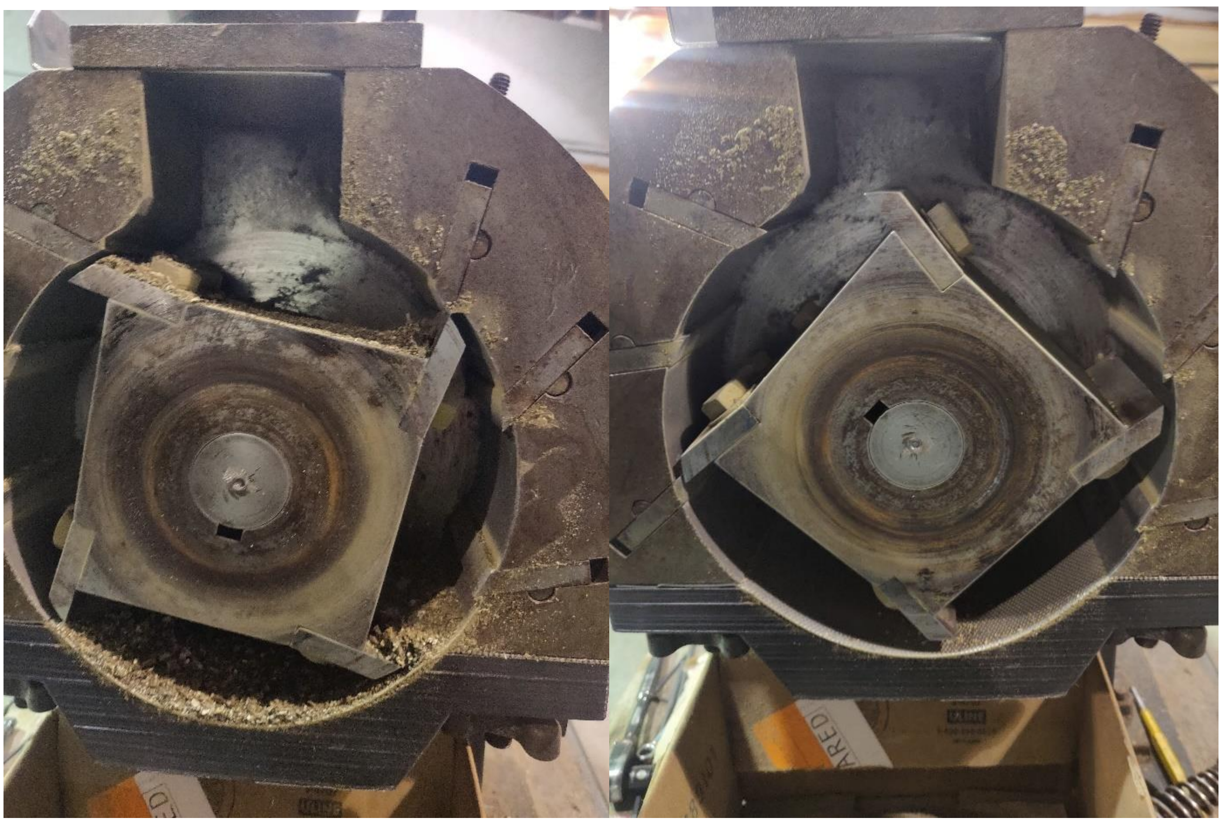


FIGURE 21. FIGURE ON LEFT IS AFTER GRINDING, FIGURE ON RIGHT IS AFTER CLEANING CYCLE

2.11 Results

Table 3. Results From Testing

Description			Trial 1	Trial 2	Trial 3	average
Grinding	Time (s)		62	66	61	62.7
	Energy (kWh)	Grinder	0.0144	0.0154	0.0142	0.0147
Cleaning	Time (s)		4	5	4	4.3
	Energy (kWh)	Vacuum	0.0051	0.0061	0.0051	0.0053
Total	Time (s)		66	71	65	**67.3**
	Energy (kWh)		0.0195	0.0215	0.0193	**0.02**

$$eq1.\ Energy\ grinder\ (kWh) = motor\ power * load\ efficiency * time$$

$$eq2.\ Energy\ vacuum\ (kWh) = vacuum\ power * load\ efficiency * time$$

$$eq3.\ Energy\ cleaning\ (kWh) = Energy\ grinder + Energy\ cleaning$$
(Due to grinder and vacuum operated at simultaneously)

$$eq4.\ Energy\ total = Energy\ grinder + Energy\ cleaning$$

The grinding time is the same as previous tests as expected. The grinding mechanisms were unchanged as the design was focused on the cleaning device. In testing, the cleaning process was undoubtably game changing. The cleaning time was roughly 134 seconds faster. Previous results from conventional manual cleaning were averaged at roughly 139 seconds. The new cleaning time was almost instantaneous as the vacuum full extracted the particulates as the ports were opened. The cleaning method was therefore over 30 times faster. The total grinding and cleaning time and energy consumption were roughly three times faster. These results were very promising and the environmental, economic, and social implications of the faster and more efficient system will be delved in further.

2.12 Maintenance

Maintenance for the grinder operation is described in detail below and the maintenance checklist found in appendix 2 should be displayed near the grinder to ensure proper maintenance has been completed.

2.12.1 Shearing blades

The shearing blades, 4 on the rotor block and the 6 lining the inside of the chamber, must be assessed every month, during the heavy use period. These periods would range from June to November while post-harvest processes are in full swing. Heavy use of the grinder, especially with samples that may have more inorganics such as small rocks or stones, will wear out the blades faster and require replacement. Signs of upcoming replacement of blades will be evident as the grinder will increase time to pulverize samples as well as jamming of the motor may be more frequent. The 4 blades on the rotor block are available in either steel or stainless steel. Depending on the corrosive nature of the samples and proper cleaning maintenance, the choice of either blades can be used. The same applies to the 6 chamber blades although consensus must be made for both blade materials. Blade installation from Thomas Scientific (2021) is found in appendix 11 and should last a study year and be replaced preventatively at the end of spring before seeding. Failure and/or improper replacement blades when wear occurs will cause damage to the motor and rotor. Jammed samples between dull blades will cause stress to the motor and may be permanently damaged.

2.12.2 Door

Although the door is made from heavy steel, wear will still occur from the pressure and rubbing of the rotor and blades. Inspection should be done along with the blades every month during heavy use periods. Normal wear is acceptable although divots deeper than 1 mm will intrude particulates between the door and rotor which are not removable with vacuum pressure itself and may cause sample contamination. The screw that holds the door in place may wear out over time and be difficult to tighten. Applying lithium grease to the threads will reduce the stress on the threads (Thomas Scientific, 2021).

2.12.3 Fan Filter

The fan filter should similarly be inspected every month during the high-use periods. The filters should simply be vacuumed and inspected for tears or holes. Failure to regularly clean filters, will cause a lack of proper ventilation in the grinding room and will lead to quicker use of the disposable face mask cartridges.

2.12.4 Vacuum Filter

The vacuum filter, located on the inner portion, accumulates a lot quicker than with regular vacuum use. Due to the process of grinding plant tissue into fine particles, the filter quickly builds up. It is evident when the filter is clogged as the vacuum pressure greatly decreases and the fan's electric motor reduces rpm, or a bypass valve completely reduces the pressure on the motor and relieves strain. The filter should be cleaned after every day of usage by brushing off the particles. Failure to keep the filter clean will reduce time and energy efficiency of the cleaning process and will damage the vacuum's motor if there is no bypass valve.

2.12.5 Cleaning Valve Housing and Plunger

After every day of grinder usage, the valve housing and plunger area should be thoroughly cleaned. Oil residues from the plant tissue may remain on the walls of the housing and plunger. It is essential to clean these pathways to ensure the plunger seats well within the door and the air passage towards the vacuum is not disturbed. This area should be cleaned with standard household pipe cleaners. Failure to maintain these measures will reduce the efficacy of the vacuum and a poorly seated plunger may damage overtime.

2.13 Economics

2.13.1 Previous Model

Operating the grinding machine is a costly procedure considering the number of samples that must go through the machine. Firstly, the energy required to operate the machine assuming that hydroelectricity is at the rate of 8.39 Canadian cents per kWh (Hydro Quebec, 2021), one plant sample would cost 0.44 Canadian cents per sample. The hourly laboratory fee to use the grinder is $15 CAD and the technician's salary would be roughly $16 per hour. Due to the low cost of the energy, the hourly cost of operating the machine would be 31$ per hour. For 100 samples it is estimated to take 5 hours and 37 minutes and would cost roughly $174.22.

2.13.2 Design Cost

A grant of $2000 CAD has been given for the design and prototype of this project and it is estimated that with this budget the prototype as well as a vacuum will be suitable. When more manufacturing will begin, a clearer price point will be generated at future prototyping. Assuming a price point of $2000 CAD

With any new development, there are risks. Our project is relatively low risk, as the materials used for prototyping are low cost. The other items, such as the vacuum can be repurposed in the case that the project fails. To minimize the risk of destroying samples to projects during testing, we have been using excess plant matter from the field. Samples for research will only be used once the machine is proven reliable.

2.13.3 Proposed Solution: M4 Vorte-X

The proposed solution was shown to take considerably less time for grinding and cleaning process. It was concluded that the grinding process should remain the same as the grinding operation was not redesigned or modified. Although the cleaning process was concluded to take roughly 4 seconds. This significantly decreases the combined grinding and cleaning operation to 67 seconds. Therefore for 100 samples it would take 1 hour and 52 seconds which would cost $57.66. This is roughly 3 times faster therefore saves 3 times as much money.

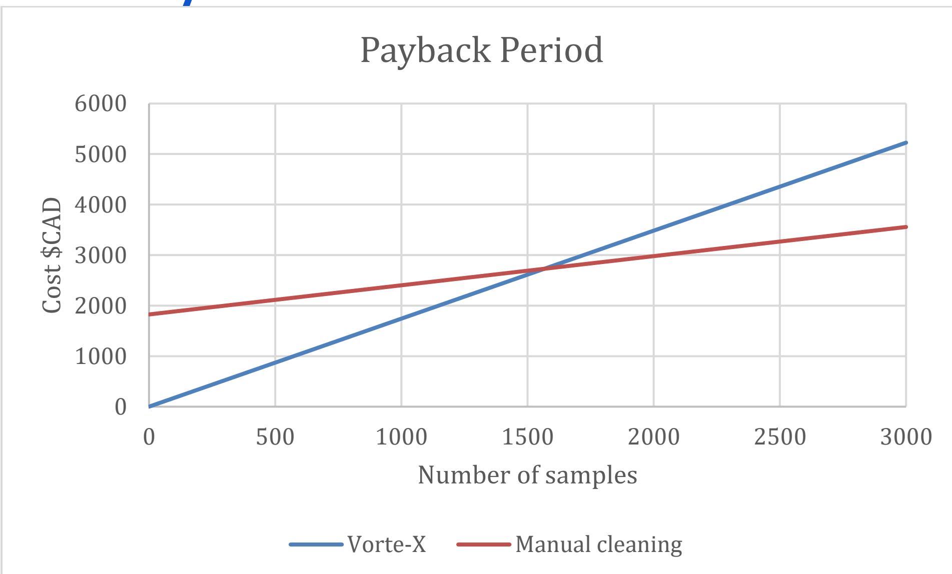
2.13.4 Cost Analysis

Table 4. Pricing of Vorte-X M4

Part	Quantity	Retail Price ($CAD)	
M10-1.5 x 35mm	6	$	6.18
M10-1.5 locking nut	4	$	1.68
M10 flat washer	2	$	0.38
Spring .041 GA x 3/8 in. x 1-1/8 in.	4	$	2.90
Voltage Converter 110V A/C to 12V DC	1	$	28.90
Non-Illuminated Push Buttons AR22	2	$	20.00
Arduino Uno R3	1	$	30.74
Vorte-X M4 Door	1	$	125.00
M4 Housing-X	1	$	43.60
M4 Valve-X	4	$	23.84
M4 Act-X	4	$	35.60
Total cost parts		$	318.82
Markup	300%		
Sale Price		$	1,275.28
Profit		**$**	**956.46**
Gross Margin			**75%**
Installation cost	2.5 hrs	$	312.50
Total cost w/ installation b4 tax		$	1,587.78
Total cost w/ installation after tax	GST 5.000%	$	79.39
	QST 9.975%	$	158.38
	GST+QST	**$**	**1,825.55**

Based on the pricing of components distributed by Thomas Scientific it is estimated that they have a markup of over 420% on material and labor costs. This is based on the pricing of the sieves bought from a third party rather than from Thomas Scientific. The prices of the parts and labor included above were estimated based on local hardware retailers in smaller quantities. From the total costs, a markup of 300% was added due to similar markup of Thomas Scientific as well as development costs and time. The sale price of the Vorte-X M4 was estimated at $1275.28 before tax with a profit margin of $956.46. Installation services were quoted at $125 per hour at two hours of installation services. Total costs including tax were estimated to $1825.55 if the laboratory has the recommended 4hp vacuum as well as the correct 2.5" attachment.

2.13.5 Payback Period



With estimated cost of the Vorte-X being $1825.55 and the reduced operating costs, at around 1550 samples the payback period would approach and every sample afterwards would cost roughly 3 times less due to the time efficiency of the unit.

2.14 Sustainability Analysis

2.14.1 Materials

Roughly 21% of the world's house gases emissions are contributed by the industrial sector energy intensive processes required in manufacturing (Gautman et al., 2018). Being that every component fabricated for this design will be manufactured out of steel, there are some factors to consider. Some other materials considered would be aluminum or a type of polymer be it PP (polyethylene), PE (polypropylene) or PVC (polyvinyl chloride). Table 3 compares the carbon dioxide emissions required to produce 1 metric ton of the materials. From the selection, the polymers create the lowest amount of GHGs per ton. Aluminum is way out of the picture as it requires a lot more energy, is generally more expensive and is not as tough as steel. Comparing steel to the polymers in the robust and abusive nature of the grinding and cleaning operation, the polymers do not stand a chance in sense of durability and especially safety of the user. Steel is more energy intensive to produce, although the parts are more tough and could be recycled when ineffective.

As plastics continue to improve future options will allow for a less intense manufacturing process. For our current implementation we will use cast steel to form the housing and plungers. The faces that interact with the surface of the door and plungers will be machined to endure a proper fit. By using steel we will ensure the system will last as long as the grinder it is being used with.

Table 5. Material Carbon Dioxide Emissions

	Steel	Aluminum	PP	PE	PVC	PETG
CO_2 emissions (ton/ton)	1.85 (Carbon Clean, 2021)	11.5 (Clemence, 2019)	1.3 (Narita et al., 2002)	1.4 (Narita et al., 2002)	1.7 (Narita et al., 2002)	1.6 (Narita et al., 2002)

Table 6. Cleaning and Disinfecting for EPA-approved cleaners

	Ethyl Alcohol	Isopropyl Alcohol	Hydrogen Peroxide	Bleach	Ammonium
PETG	PASS (up to 96%)	PASS	PASS (up to 28%)	PASS	PASS (Short usage)

Table 7. PETG Properties

	Ultimate Strength (MPa)	Durability	Cost ($/kg)	Printability	Chemical resistant
PETG	53	8/10	25-65	9/10	10/10

(Simplify3D, 2022).

2.14.2 Energy Savings

Tests have concluded the time therefore energy needed to operate the grinder especially during the cleaning process. Due to the redesign of the cleaning process, the motor will be rotating during the cleaning process as the actuated vacuum extracts the residues. The rotating rotor should cause turbulence to any plant material stuck between the blades as well as the 4 vacuum ports positioned near these areas. Although the time required to grind the plant sample will remain the same due to no modifications in the grinding process, it is estimated that the cleaning cycle will reduce to 4 seconds therefore energy usage will drastically reduce. As stated previously in section 2.2.1, the cleaning operation requires 139 seconds to complete and 0.1149 kWh of energy per sample. The redesign does not require the user to manually open or close the chamber doors with the 4 vacuum housings on the front plate all points of the chamber will be cleaned simultaneously. Therefore, without the maneuvering of the door and with all 6 blade points of the chamber being evacuated at the same time, the cleaning time would reduce to 4 seconds per sample of vacuum operation. In 4 seconds of the 4.0 hp vacuum operation, the energy required would be 0.0053 kWh from equation (1). With the Vorte-X, the grinder will be rotating at full speed during the vacuum extraction therefore the energy required from the 1.5 hp motor during the 4 second period would be 0.00199 kWh per cycle from equation (1) where the energy is required to start the motor is not needed as motor will remain on from the grinding to the cleaning process. The total energy requirements for the cleaning process would be 0.0317 kWh and the total energy required for the grinding and cleaning of one sample would be 0.02 kWh. The new cleaning process would be over

30 times more efficient, and the total grinding and cleaning procedure would be over 3 times more efficient from equation (2).

$$\text{Equaition2.} \quad Percent\ Change = \frac{Final\ Value - Initial\ Value}{Initial\ Value} * 100\% \quad (2)$$

If 15,000 samples are to be analyzed in one year of research at the Emile A. Lods farm, the whole grinding operation would require 1514 kWh of energy and the cleaning process itself would require 1290 kWh for the conventional method. With the Vorte-X, it would only use 303 kWh. A hot water heater of a house or apartment in the city of Montreal consumes roughly the same amount of energy a year for comparison (Hydro Quebec, 2021). According to the Canadian Energy Regulator (2021) Quebec produces more than 95% of its energy from renewable hydroelectricity and has the lowest cost at 8.39 cents per kWh (Hydro Quebec, 2021). Although the energy is relatively cheap and hydroelectricity is renewable, making more energy efficient systems can redirect energy to industries that do not use hydroelectricity and in the meantime make clean energy sources more available.

3.0 Overall Importance of Vorte-X M4 Automating Cleaner

The Vorte-X M4 automating cleaner for the Wiley Mill Model 4 has overall proven to be a revolution in grinder cleaning operations. This easily adaptable system saves much more time, energy, and money as for traditional manual cleaning. Not only does it save time, but it also prevents workplace injury from contact with heavy duty blades. This design will allow for faster grinding operations therefore will speed up research time. The clients at Emile A. Lods Agronomy Research centre are happy with the results of the system and will implement the use for the coming 2022 summer season to increased lab efficiencies and help identify potential points of failure to be adjusted for future designs.

Conclusions

Grinding is an important step in plant research. This design report summarizes and approach to make this process more efficient by reducing the labor, energy and risk required to complete the process. This design will improve the overall throughput of the grinder room at the Emile A. Lods Agronomy Research Centre. This will in turn allow more trials and research to take place, furthering our knowledge of crop production.

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Appendices

1. Blade Replacement

Blade replacement from Thomas Scientific (2021) Blade Maintenance and Replacement Instruction manual.

1. To replace the stationary knives in the cutter head the rotating cutter head must be removed.

2. First, remove the hopper and open the chamber door. Use a 3/16” hex nut driver or wrench to loosen the hex head screw holding the rotating cutter and carefully remove the rotating cutter.

3. Proceed with replacing stationary knives.

4. There is one setscrew associated with each stationary knife. The setscrew, located clockwise from the threaded stud, bears on the knife, holding the knife firmly in position.

5. Loosen the setscrew holding the first stationary knife that is to be replaced. (If replacing the entire set of stationary knives, it does not matter which knife is removed first.)

6. Hold or support the knife and remove the two nuts from the threaded stud. Carefully remove the knife.

7. If all knives are being replaced, remove the remaining knife.

8. Unpack replacement knives. Insert threaded stud into its hole and seat knife in slot. Replace the two nuts and draw the knife up so that there is ample clearance between it and the rotor knives. Repeat this operation for all knives being replaced and also draw up any remaining knives.

9. Replace the rotating cutter head on the shaft with the square key in place on the shaft. Use a 3/16” hex nut driver or wrench to tighten the hex head bolt holding the rotating cutter head in place.

CAUTION: DO NOT OVER TIGHTEN HEX HEAD BOLT HOLDING THE ROTATING CUTTER AS THIS MAY CAUSE THE BOLT TO SNAP

10. Loosen nuts of the first stationary knife to be adjusted. Insert a piece of paper of the necessary thickness (0.002 to 0.003 in.) between the knife and any of the rotor knives, and adjust the clearance by raising or lowering the stationary knife until it pinches the paper but does not sever it.

11. Slightly tighten the two setscrews holding the knife in place. (May require further adjustment later.)

12. Turn rotor to make certain that all rotor knives clear the installed stationary knives. If one rotor knife projects beyond the others, adjust clearance of stationary knife with respect to this rotor knife. Identify this rotor knife and make all stationary knife adjustments with respect to it.

13. Repeat steps 11 and 12 above for the remaining stationary knives. Recheck all clearance and all associated nuts and set screws

2. Maintenance Checklist

Maintenance Schedule 2022 Research Year								
Date	01/05/2022	01/06/2022	01/07/2022	01/08/2022	01/09/2022	01/10/2022	01/11/2022	01/12/2022
Vacuum Filter		daily	daily	daily	daily	daily	daily	daily
Valve Housing and Plunger		daily	daily	daily	daily	daily	daily	daily
Fan Filter		inspect	inspect	inspect	inspect	inspect		inspect
Door		inspect	inspect	inspect	inspect	inspect		inspect
Shearing Blades	inspect and replace		inspect		inspect		inspect	

3. FMEA Chart

Item											Action Results				
Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Cause(s)/Mechanism(s) of Failure	Occurrence	Current Design Controls	Detectability	RPN	Recommended Action(s)	Responsibility and Target Completion Date	Actions Taken	Sev	Occ	Det	RPN
Valve	not closing	sample not ground properly, cross contamination of samples	7	valve jammed by plant residue	5	tolerance of valve in housing	3	105	Test the valve for jamming	Leandro	Create groves for both positions so the operator can lock in place	7	3	2	42
Vacuum	No Suction	sample not being cleared from chamber	8	filter clogged	3	Vacuum supplier standards	5	120	test the vacuum capacity for fine particles	Shamus	Place vacuum gauge on valve housing	8	2	2	32
Valve	stuck closed	cleaning cycle can not be completed	6	residue buildup in valve housing	3	vacuum flow	3	54	NA						0
Actuator	Premature Motor Failure	Fails to actuate valve	7	Excessive current applied while actuator at endpoint	8		2	112	Reduce time power is applied to close valve	Shamus	Changed code to ensure withing safe operating time. Checked for actuator heating	7	2	2	28
Wiring	Connection Failure	Valves not actuating	7	Wire catching on operator or tool	6	Wire placement	4	168	Improve wiring harness	Leandro	Added wire protectors, zip ties to housing	7	2	4	56

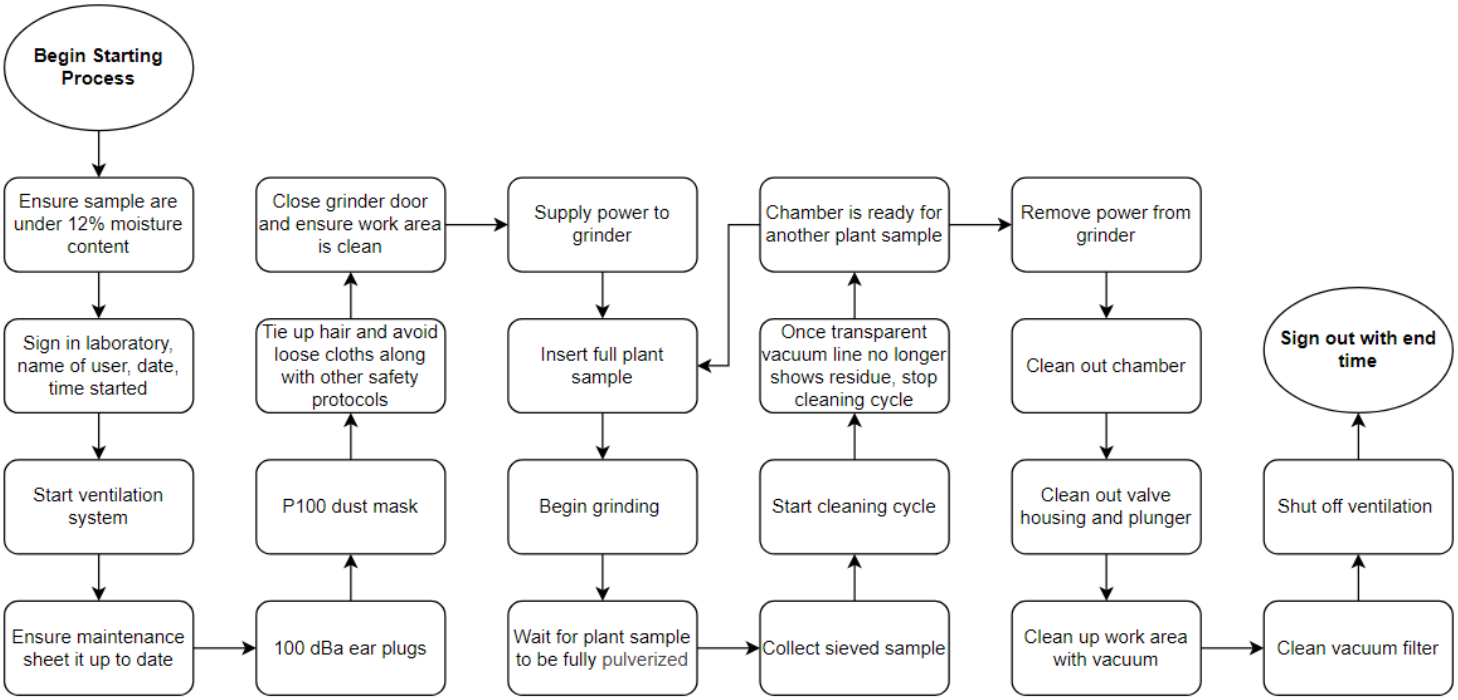
4. Gantt chart: BREE 490

Project and Tasks	Responsibility	Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 5	Wk. 6	Wk. 7	Wk. 8	Wk. 9	Wk. 10	Wk. 11	Wk. 12	Wk. 13
Brainstorming	both													
Preliminary Grinder project	both													
Discussion to join group on composting project	both													
Discussion to join group on mushroom project	both													
Original grinder idea chosen	both													
Decide to complete project as a pare	both													
Accessing problem	both													
Grinder inspected	Shamus													
Contacting client	Shamus													
Pulse breeding lab interested in project	Shamus													
Approximate funding needed	both													
Research	both													
Patent research	Shamus													
Plant material evacuation methods	both													
Develop methods (approach)	both													
1st proposed design (compressed air and vacuum)	Leandro													
1st design CAD	Leandro													
Mission Statement	Leandro													
Vision Statement	Leandro													
2nd proposed design (single vacuum)	Shamus													
Prototype planification	both													
60L 145CFM vacuum acquired	Shamus													
Actuation methods	Shamus													
Instrumentation and control	both													
Grinder safety and PPE	both													
Vacuum gage	Shamus													
Sheet metal	Shamus													
Prototype	both													
3D print value housing & plunger	Shamus													
CNC Plasma front panel	both													

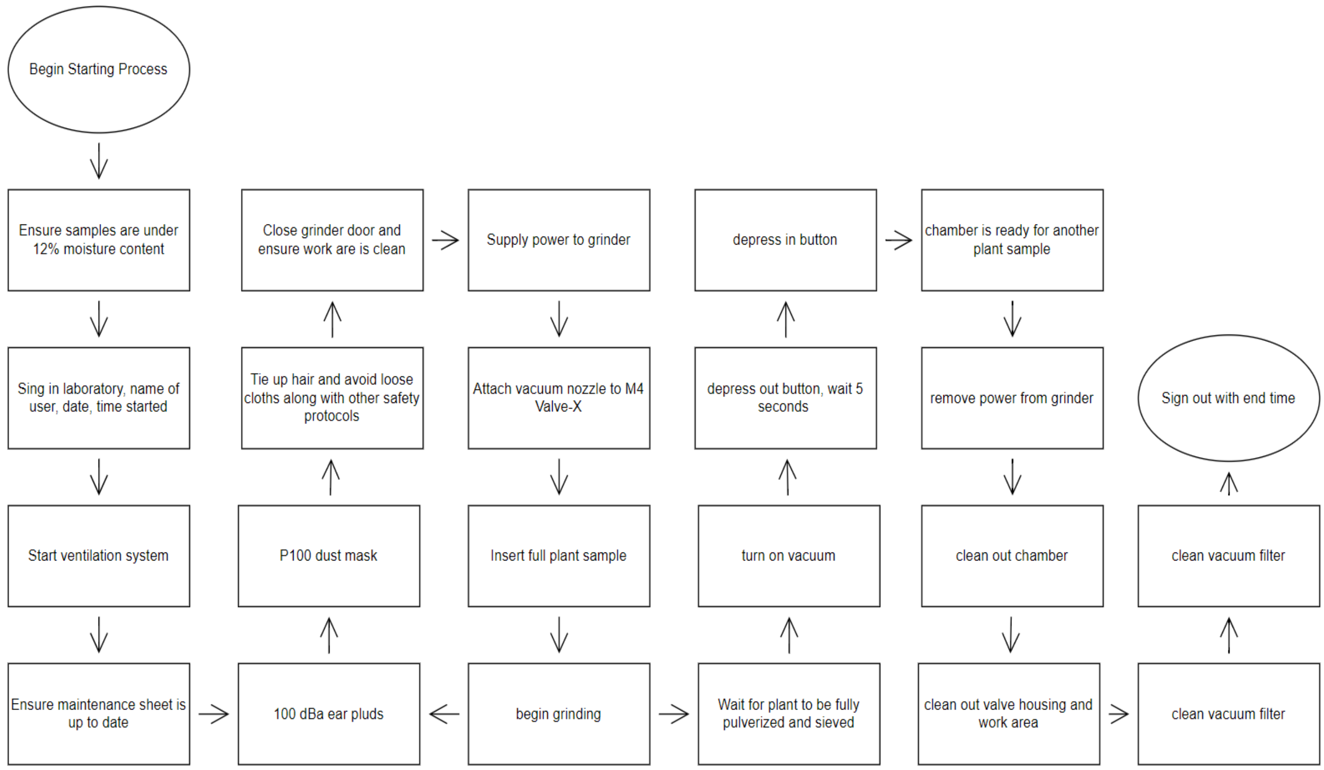
5. Gantt chart: BREE 495

Project and Tasks	**Responsibility**	**Wk.1**	**Wk.2**	**Wk.3**	**Wk.4**	**Wk.5**	**Wk.6**	**Wk.7**	**Wk.8**	**Wk.9**
Prototyping										
Acknowledgement of BREE 490	Leandro									
Bottom grinder receiver	Shamus									
Research ASTM standards	Leandro									
Prototype Door	Shamus									
Printing of prototype 3 housing	Shamus									
Deconstruction of donar grinder	Leandro									
Valve-X Housing designed	Shamus									
Assesing and replacing rotar	Leandro									
Actuators ordered and tested	Leandro									
Parts on domar refurbished and replaced	Both									
All components printed and installed	Both									
Testing	Shamus									

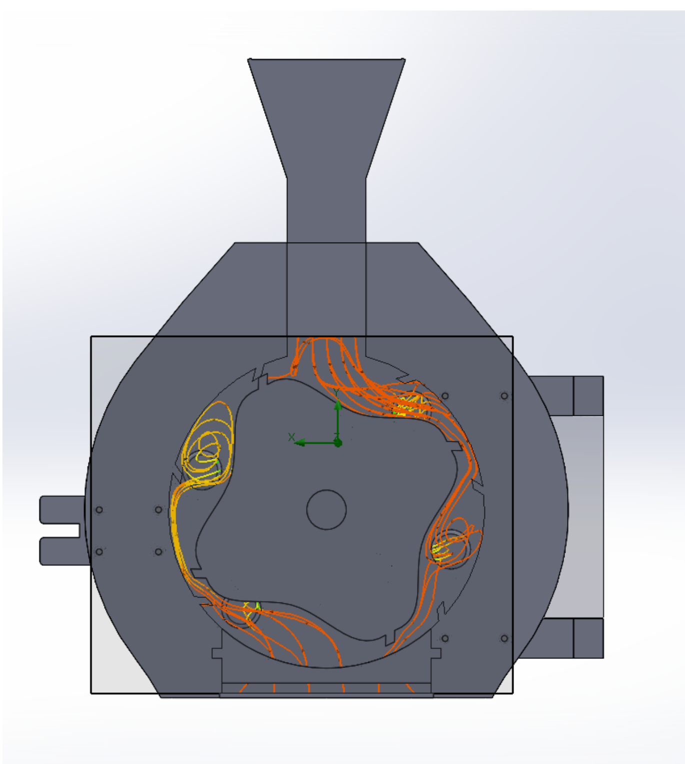
6. Startup Procedure: Suggested Design 3



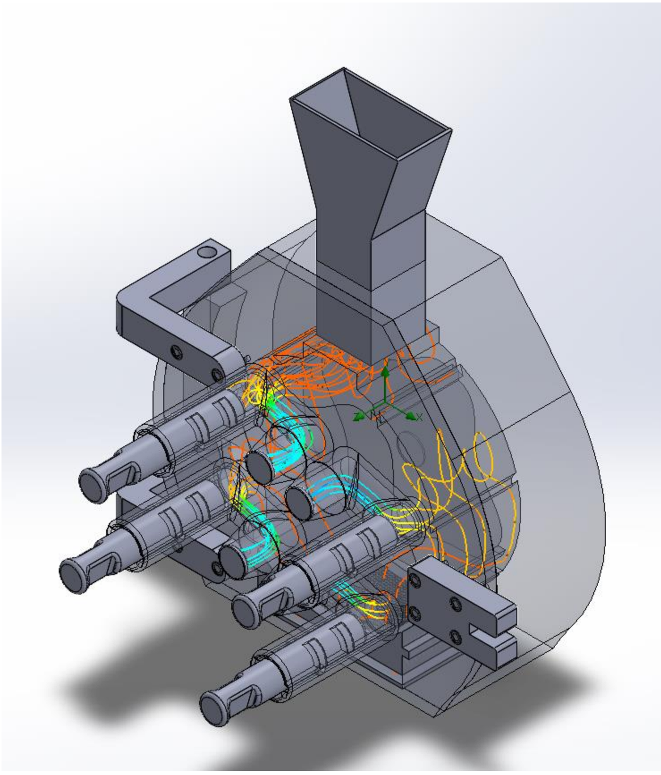
7. Startup Procedure: Vorte-X M4



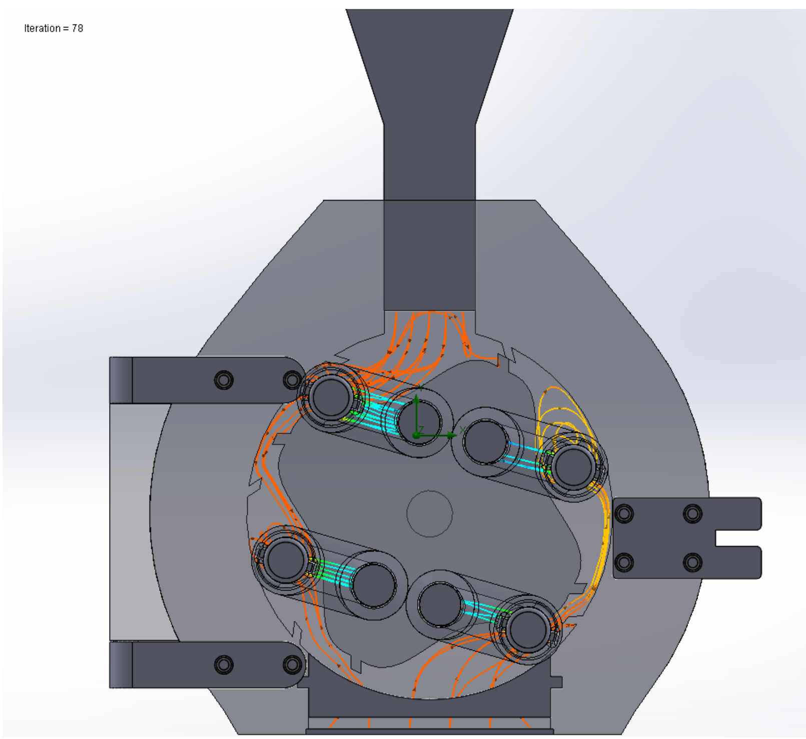
8. Vacuum Air Flow 1



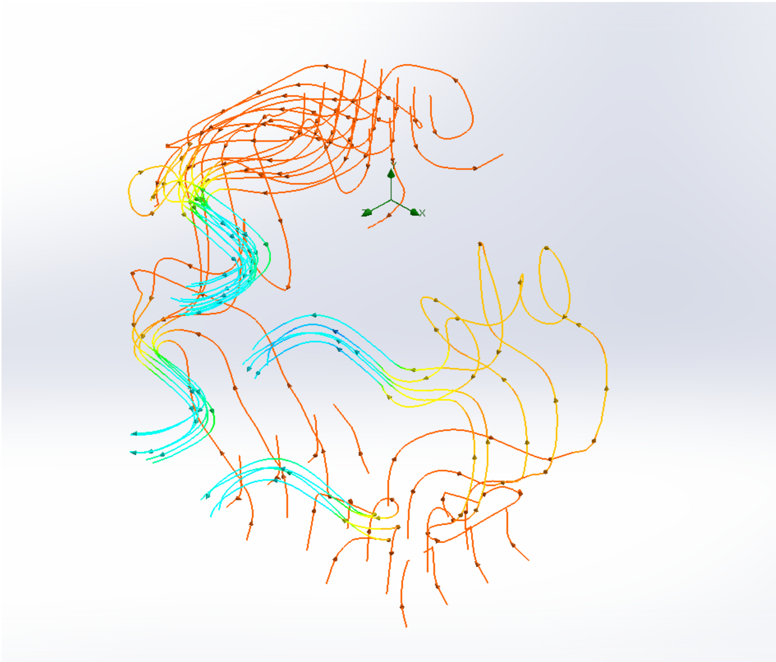
9. Vacuum Air Flow 2



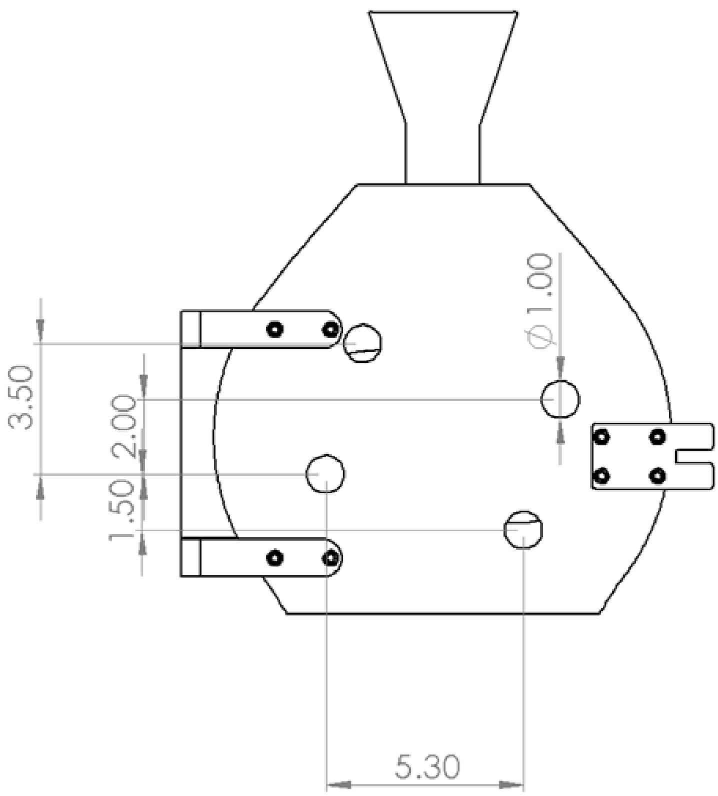
10. Vacuum Air Flow 3



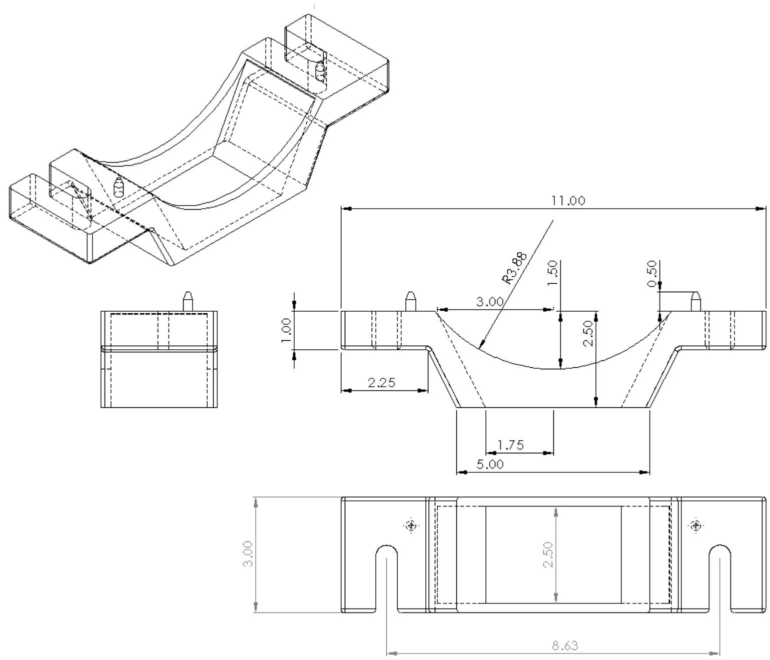
11. Vacuum Air Flow 4



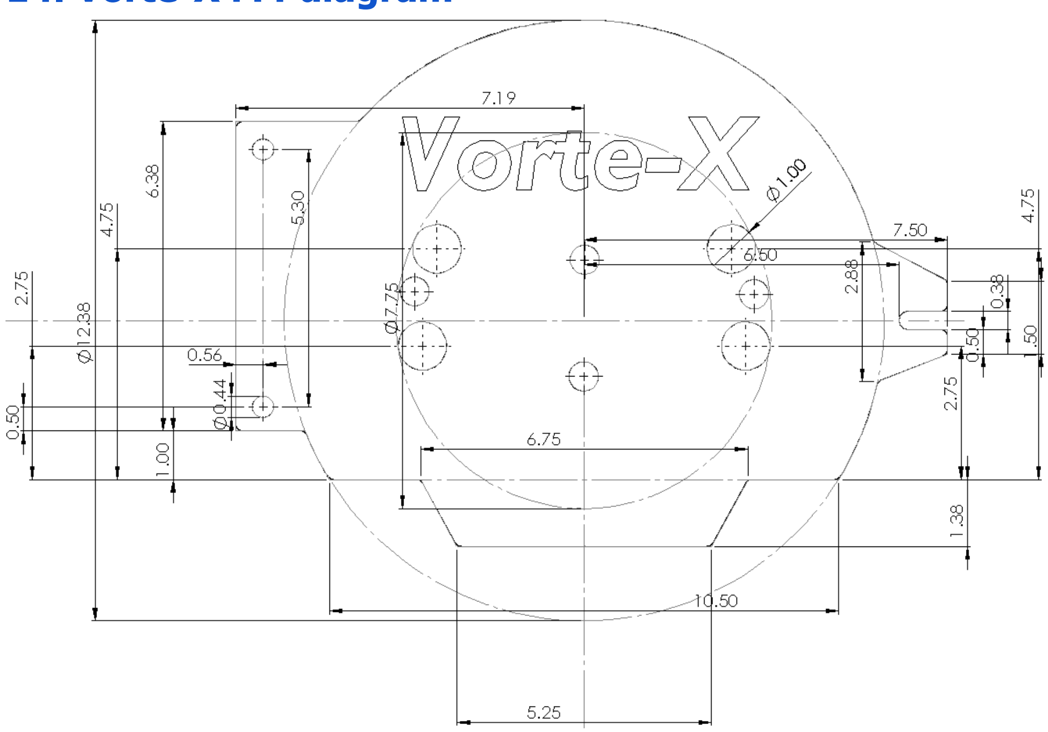
12. Grinder Front Door Dimensions: Design 3



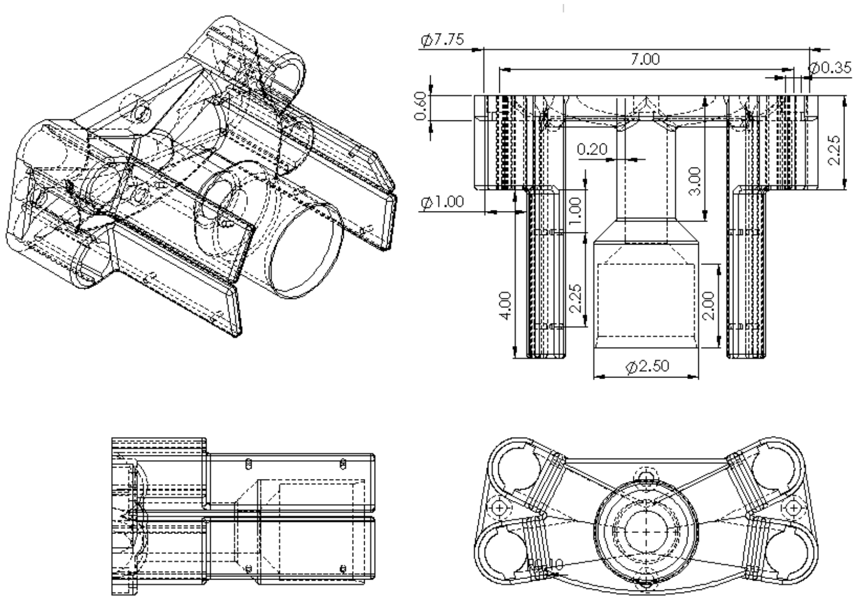
13. Sieve Holder



14. Vorte-X M4 diagram



15. M4 Housing-X Diagram



16. Arduino Code (Shamshiri, 2019)

```
*/

const int relay1 = 2;
const int relay2 = 3;
const int pushButton1=8;
const int pushButton2=9;

void actuatorPull();
void actuatorPush();
void turnOFF();

void setup() {
 // Robojax Actuator code https://youtu.be/_bkNOyPElOo
   pinMode(relay1, OUTPUT);// set pin as output for relay 1
   pinMode(relay2, OUTPUT);// set pin as output for relay 2
   pinMode(pushButton1, INPUT_PULLUP);
   pinMode(pushButton2, INPUT_PULLUP);

   // keep the motor off by keeping both HIGH
   digitalWrite(relay1, HIGH);
   digitalWrite(relay2, HIGH);

  Serial.begin(9600);// initialize serial monitor with 9600 baud
```

```
 Serial.println("Robojax Actuator Control");
 Serial.println("Using 2 Relays");
 delay(2000);
}

void loop() {
  // Robojax Actuator code https://youtu.be/_bkNOyPElOo
 while(digitalRead(pushButton1) ==LOW)
 {
  actuatorPull();
 }

 while(digitalRead(pushButton2) ==LOW)
 {
   actuatorPush();
 }

  turnOFF();

}// loop end

/*
 * pushes the actuator
 * written by Ahmad Shamshiri
 * www.Robojax.com
 * Written on Jan 03, 2019 in Ajax, Ontario, Canada
 */
void actuatorPush()
{
  // Robojax Actuator code https://youtu.be/_bkNOyPElOo
   digitalWrite(relay1, LOW);// turn relay 1 ON
   digitalWrite(relay2, HIGH);// turn relay 2 OFF

}//actuatorPush()

/*
 * pushes the actuator
 * written by Ahmad Shamshiri
 * www.Robojax.com
 * Written on Jan 03, 2019 in Ajax, Ontario, Canada
 */
void actuatorPull()
{
  // Robojax Actuator code https://youtu.be/_bkNOyPElOo
   digitalWrite(relay1, HIGH);// turn relay 1 OFF
   digitalWrite(relay2, LOW);// turn relay 2 ON

}//actuatorPull()
```

```
/*
 * turnOFF the actuator
 * written by Ahmad Shamshiri
 * www.Robojax.com
 * Written on Jan 03, 2019 in Ajax, Ontario, Canada
 */
void turnOFF()
{
  // Robojax Actuator code https://youtu.be/_bkNOyPElOo
   digitalWrite(relay1, HIGH);// turn relay 1 OFF
   digitalWrite(relay2, HIGH);// turn relay 2 OFF

}//turnOFF()
```

17. Wiring Diagram