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MEMS 411: Thresher

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SP21 MEMS 411 Mechanical Engineering Design Project

THRESHER

This project and assignment was brought to our attention by Dr. Potter and Dr. Natalie Mueller. Dr. Mueller is an archaeologist and a paleoethnobotanist who specializes in the historical ecology of north America and the origins of agriculture. She is currently undergoing research on domestication of plants and subsequent evolution of agrobiodiversity since the ice age. The seeds are extremely small as well are the batches of seeds. In order to orchestrate research on these seeds, the seeds go through a process of threshing and winnowing. Dr. Mueller already had a design and prototype built for the winnowing process so when given the option, the decision to make a thresher occurred. Threshing is separating grain from a plant. For example, think about taking the seed off of a sunflower seed. In Dr. Mueller's case, these seeds are around the size of a poppy seed. Originally in order to thresh the seeds, they were rubbed against metal mesh with sandpaper. This was an exhausting and long process. The idea was to make it an easier, more efficiency, and quicker process. The following report shows the growth of ideas and concepts that lead to a prototype and a final product. The final product reduced the time, energy and effort needed to thresh the seeds with the barrel method. Due to busy 3D printers, our final 3D design was not able to be prepared by the final deadline but the final product works well enough. With more adjustments and the 3D printed design, the thresher will allow for Dr. Mueller to cut her threshing time by 1/5.

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1 Introduction

The definition of threshing is to separate a grain from a plant. Grains and small seeds must be threshed prior to being winnowed. Winnowing is the process of removing the chaff from the seed. [1].

Natalie Mueller currently manually threshes her current seeds and requests a device that automatically threshes her seeds for it. Manually threshing is a very time consuming process that is important to the harvesting process.

2 Problem Understanding

2.1 Existing Devices

The following existing devices have the closest existing designs to the device we are creating. Two of the existing designs are currently larger scale than what is requested for, and one is largely focused on grains instead of seeds.

2.1.1 Existing Device #1: Single Head Lab Thresher

Figure 1: Single Head Lab Thresher (Source: Seedburo Equipment Company)

Link: https://seedburo.com/products/single-head-lab-thresher
Description: The Single Head Lab Thresher is a combination thresher and winnower that is used for small scale, lab environment threshing. It is used for smaller seeds, such as vegetables and grains. It is powered by a 1/2 HP motor that rotates the wheel in the center, thereby threshing the input. The speed of the motor is fully adjustable via a touch pad at the front of the device. The device itself is powered by a 110 V power supply. The winnowing aspect is taken over by an air fan (0-32000 RPM) which is also controlled by the touch pad. This allows the user to efficiently and safely input grains and output clean, chaff free seeds. The device is small and lightweight but comes at a cost of over $10,000.

2.1.2 Existing Device #2: LD 180 Laboratory Thresher

Figure 2: LD 180 Laboratory Thresher (Source: Wintersteiger)

Link: https://www.wintersteiger.com/us/Plant-Breeding-and-Research/Products/Product-Range/Laboratory-preparation/70-LD-180-laboratory-thresher
Description: LD 180 Laboratory Thresher combines threshing and winnowing. It is used for grains bundles up to 18 cm. The thresher portion of the device is fully adjustable for different types of grains via the speed of the motor. A fan removes the chaff and stems from the seeds during the winnowing portion of the process. A pedal system allows the user to open up a "garbage" bucket and empty the chaff and stems between each use. This device is very simple and intuitive to use, as

it uses single step processes to alter the turbine and fan speeds. The device is portable, as it uses a wheelbarrow approach with wheels on two of its four standing legs.

2.1.3 Existing Device #3: Gode Minibatt Wheat Laboratory Thresher

Figure 3: Gode Minibatt Wheat Laboratory Thresher (Source: Agri Expo)

Link: https://www.agriexpo.online/prod/gode-minibatt/product-175315-63253.html
Description: The Gode Minibatt Wheat Laboratory Thresher is a stationary wheat thresher with a simplistic design. While this device is primarily used for larger grains, its intuitive and inexpensive design makes it a valuable comparison to the more expensive devices on the market. This machine is not a combination thresher and winnower, instead focusing solely on removing the seeds from the stems. A rake near the top of the funnel helps initially separate seeds from the larger stems, and a manual hand crank in the tub spins the grains around. While this device does not have any electric power or necessarily modern technology, it is sturdy and reliable, making it a perfect foil to the other two designs.

2.2 Patents

2.2.1 Threshing Machine (CN102845187A)

This patent outlines a threshing machine that consists of a spinning roller with large spokes that fits snugly inside a cover resting above a collection bucket. The roller is cylindrical with a long length in order to maximize surface area contact between the rotating spokes and the chaff to be threshed or roughed up. The upper roller cover has minimal clearance from the roller spokes so that no chaff can escape threshing. Also, at the bottom of the threshing compartment, there is a semi-cylindrical grate which makes sure large chunks of chaff will not fall into the collection box and also provides an additional rough surface to help break up the chaff. The roller is turned by a belt connected to a powered motor.

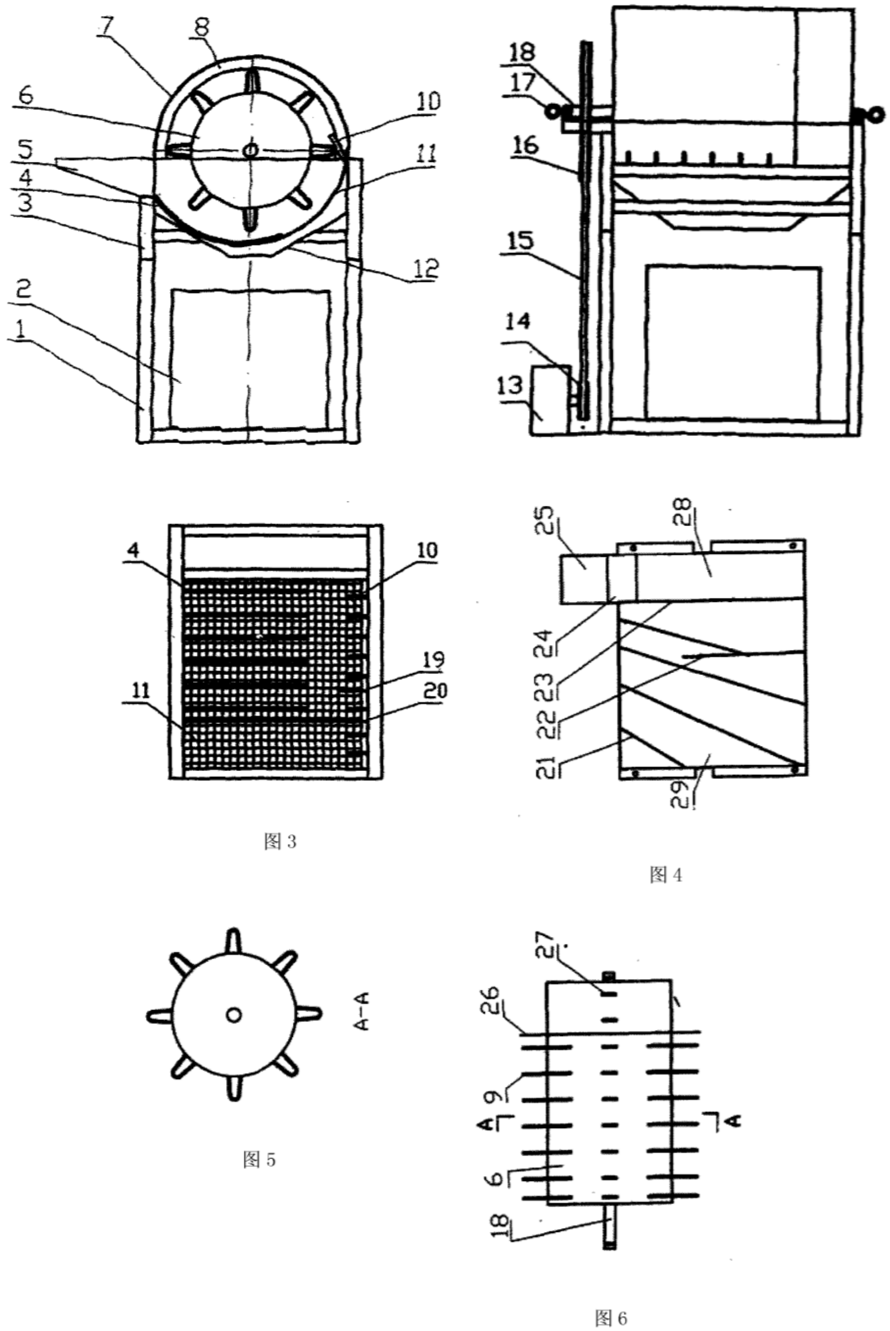


Figure 4: Patent Images for Threshing Machine

2.2.2 Novel Threshing Machine (CN102845188A)

This patent describes a threshing machine very similar to the last; It consists mostly of a large roller with spokes that is driven via a belt connected to a motor in order to rough up the chaff. The main difference between this thresher and the last is that this is a larger thresher designed to handle greater volumes of chaff. As such, every component is larger, including the motor and belt drive, as well as both the threshing and collecting compartments. Another difference is that there is much greater clearance inside the threshing compartment, which makes this machine less efficient because some pieces of chaff will be able to sit out of reach of the roller spokes during the threshing process, and consequently will not get broken up.

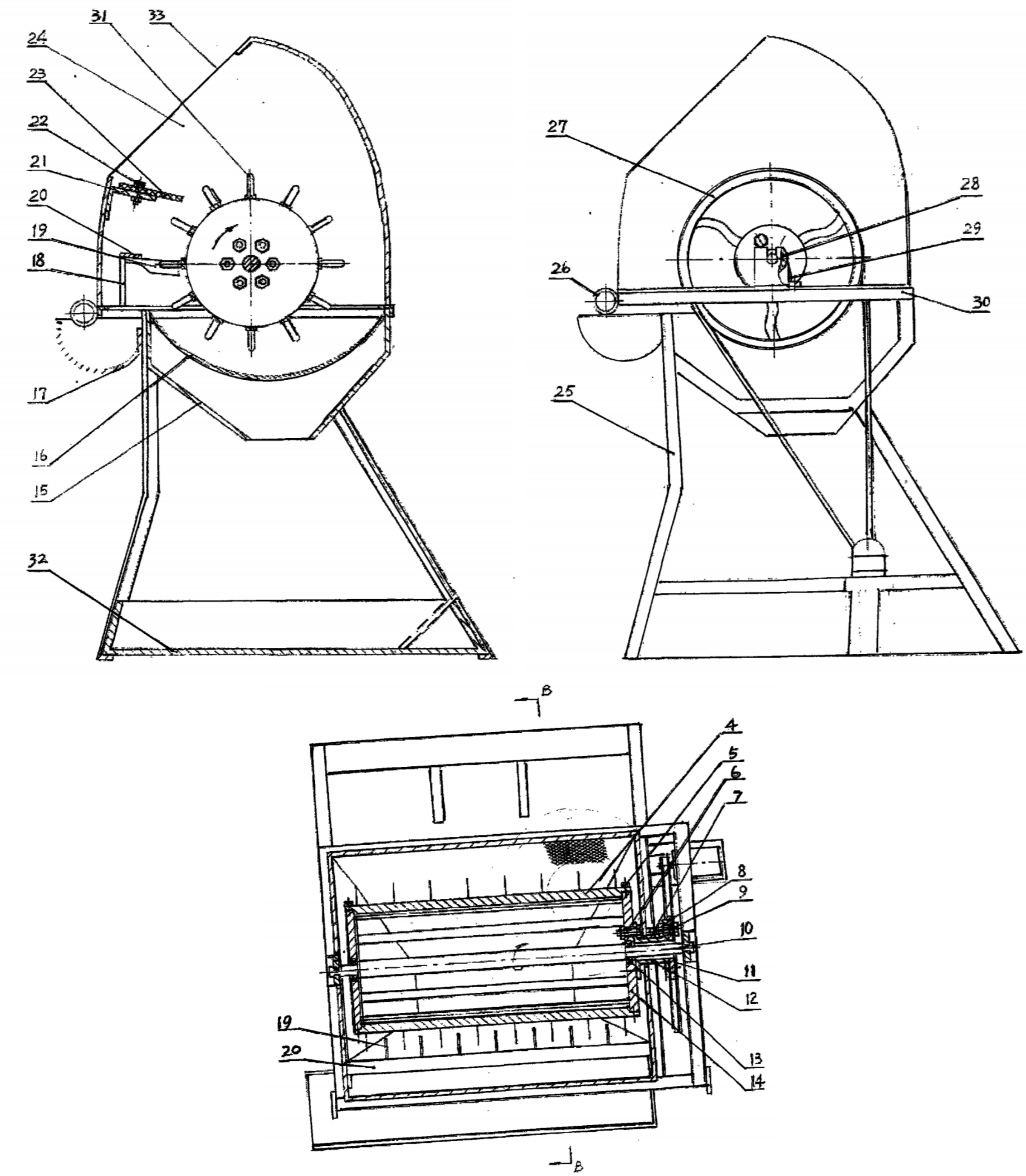


Figure 5: Patent Images for Novel Threshing Machine

2.3 Codes & Standards

2.3.1 Agricultural machinery : safety. Pt. 1. (ISO 4254-1:2013/DAM 1:2019(E))

These standards give detail about what is acceptable and not acceptable when it comes to machinery used for agricultural purposes. We will be heavily referring to said standards when going through our design and build stages.

2.3.2 Standard for food equipment : food equipment materials (NSF/ANSI 51-2017)

These standards go into detail about what health and safety standards are necessary when building something for food resources. We will be referring to these standards often when it our design and building stages.

2.4 User Needs

The following user needs were determined from the customer interview. Within the interview, we determined that an automatic thresher would be the best use of time and be the most efficient addition to Winnower that is already designed. The current thresher process is manual so the user needs are to make it an easier and more efficient process by making it automated.

2.4.1 Customer Interview

Interviewee: Natalie Mueller, Megan Belcher
Location: Remote, zoom
Date: February 5^{th}, 2021
Setting: We were given details of how the winnower is used as well as the better ways to update the device. When going through the ways to make the winnower better, the threshing process was mentioned and explained to be a difficult part of the process which is where we decided to create a thresher to make the process quicker and more efficient. The whole interview was conducted over zoom, and took ∼30 min.

Interview Notes:
How are the seeds currently being threshed right now?

- The seeds are being threshed by hand and it is a very long process. It is done by rubbing the harvest between the hands to break down the chaff and the seeds to prepare it for the winnower.

What type of seeds will be used in the machine

- The seeds are: chenopodium berlandieri, iva annua, polygonum erectum. These are their latin names. The seeds go from 0.04-0.1g in weight and 1mm-5mm in length.

How often is the tool used?

- It is used about three to five times a week. Some weeks more frequently than others and mostly during the summer after the harvest.

Are there any known materials or designs that damage the seeds?

- Threshing can cause damage to the seeds and must be designed to the size of the seed.

2.4.2 Interpreted User Needs

The following table is determined from the interview and interpreting the customers needs and then giving a priority list of their importance to the needs. As of right now, threshing is currently a manual process so there are not many known needs other than making it an automated process and adjustable to different sizes of seeds.

Table 1: Interpreted Customer Needs

Need Number	Need	Importance
1	Adjustable to specified seed	5
2	Easy to transport	4
3	Easy to use	3
4	Sturdy and long-lasting	3
5	Able to open and clean out	4
6	Automated and efficient	5
7	Does not damage seeds	5
8	Safe entrance and exit of device	4

2.5 Design Metrics

Below gives the target specifications table for the threshing device. The specifications included are very general and will be changed throughout the process of research and building.

Table 2: Target Specifications

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal
1	1	Adjustable to specified seed	No. of settings	3-4	5
2	1	Easy to transport (weight + handles)	lbs	25	10-15
3	2	Efficiency	No. of uses required	2	1
4	2,4	Sturdy and long lasting	Material	Plastic	Metal
5	5	Number of dials and switches	Integer	< 5	< 3
6	6	Number of seeds lost in use	Percentage	< 20	< 10

3 Concept Generation

3.1 Mockup Prototype

The following figures are different views of the mockup prototype. As you can see in the following Figure 9, there is an open and sloped entry point, which allows gravity to take over as the seed mixture is pulled towards the conveyor belt.

Figure 6: Annotated Mockup view 1

The seeds then enter the next section of the device which has them ride along a conveyor belt below a stationary sandpaper section. The height of this sandpaper can be adjusted, allowing for a variety of different sized seeds to be properly threshed. The lighter stocks attached to the seeds are then held back by the coarseness of the sandpaper, while the seeds continue and are dropped into a bucket or bowl at the end of the device.

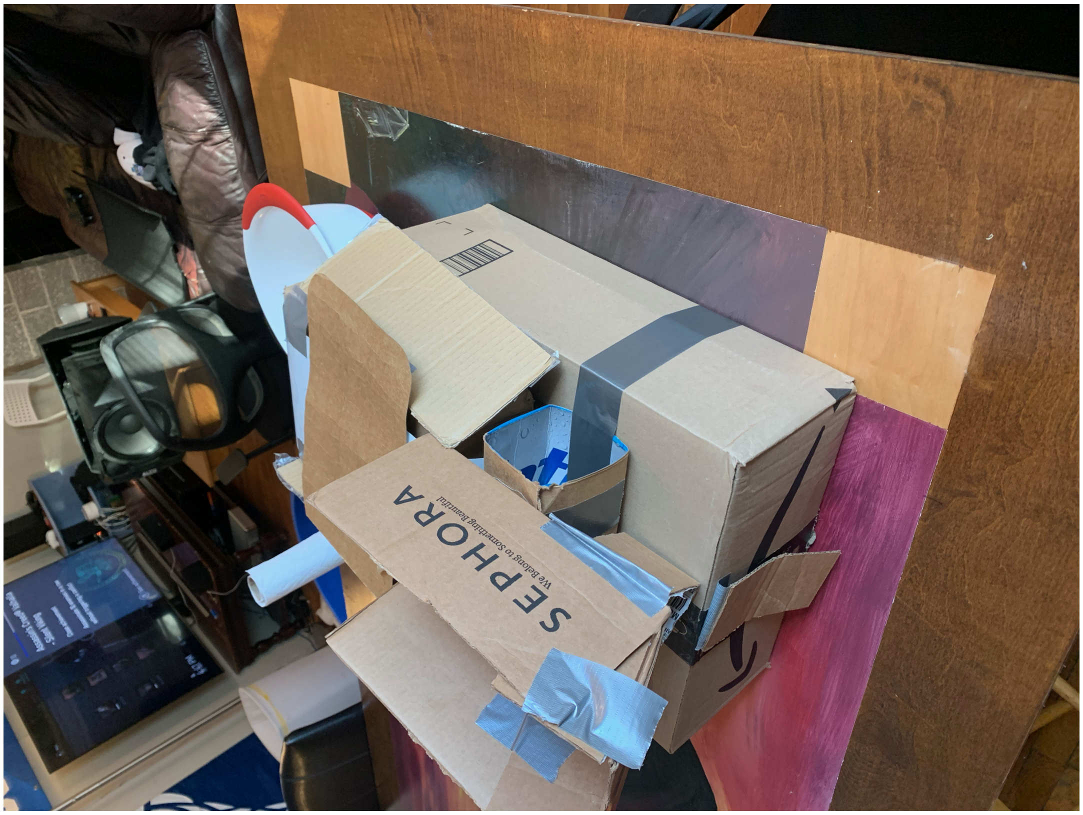


Figure 7: Mockup view 2

The sandpaper section can then be lifted and removed for easy replacement and cleaning.

Figure 8: Mockup view 3

While this mock-up is not foolproof, given the limited information we currently have on the exact type of threshing being performed by Dr. Mueller, this design is simple to use, clean, and modify if need be.

Building the mock-up itself demonstrated to us how many moving parts will be necessary for the final version of this device. Not only do we have to build a functioning conveyor belt, but we also have to make the speed adjustable as well as the height and coarseness of sandpaper fully modifiable. This design will require a lot more research into the size, shape, and durability of the seeds being threshed. Without this information, there is no way to tell if the mock-up concept is even viable, or if it will cause too much damage to the seeds being worked on.

3.2 Functional Decomposition

The following figure shows the function tree that describes the necessary attributes that are requested and required with the thresher. These attributes will then be broken down to help create a morphological chart and concept drawings.

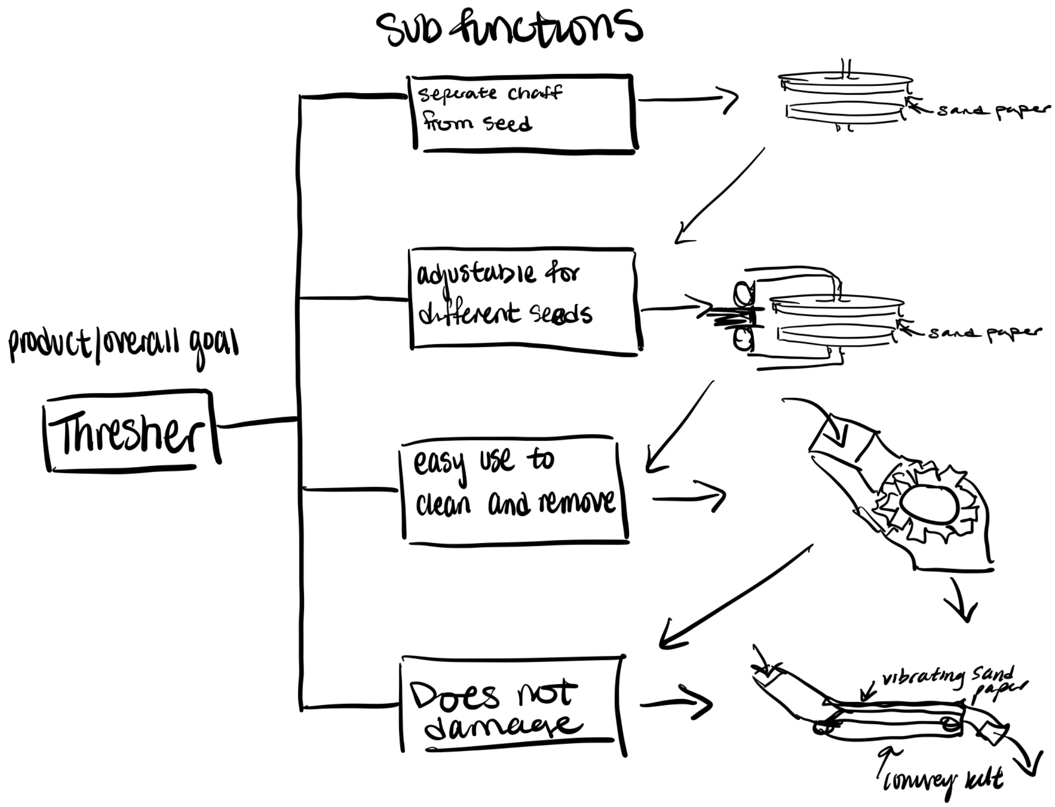


Figure 9: Function tree for Thresher

3.3 Morphological Chart

The following figure shows the morphological chart that breaks down each of the subsections determined in the function chart. This is then followed by quick hand sketches that may satisfy that subsection with a different design idea.

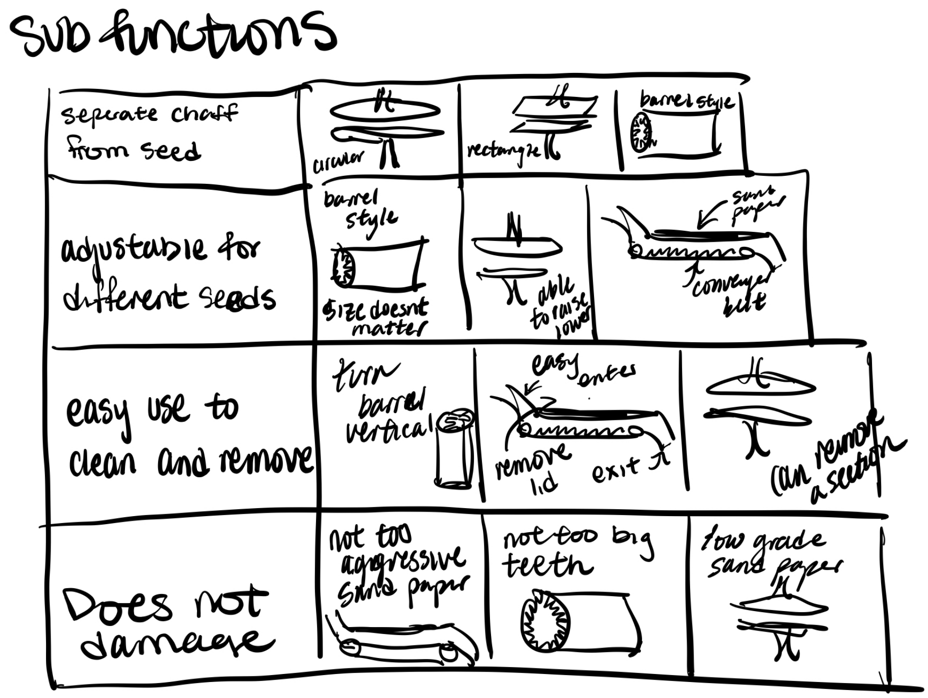


Figure 10: Morphological Chart for Thresher

3.4 Alternative Design Concepts

3.4.1 Concept 1 ()

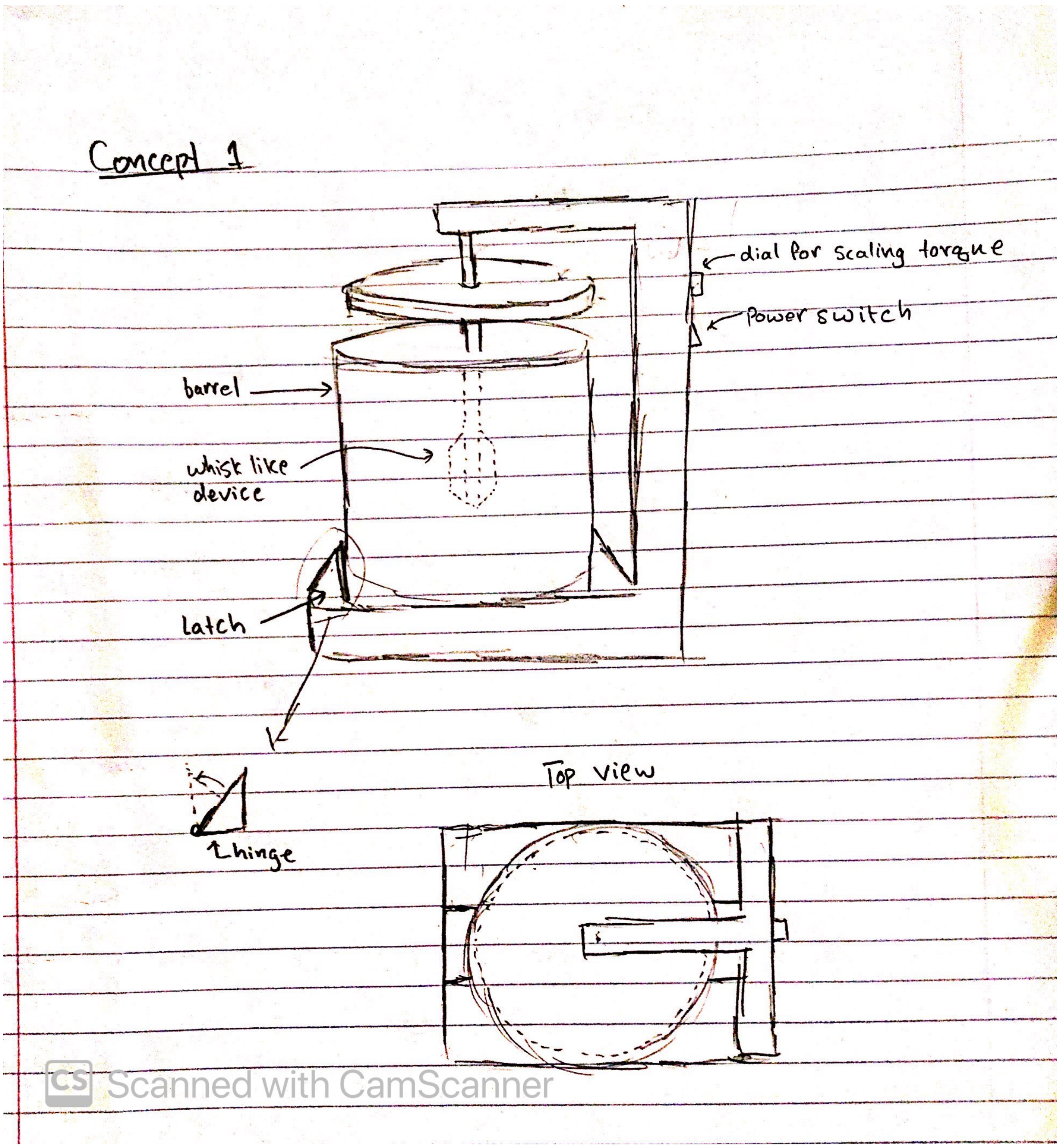


Figure 11: Preliminary sketches of Barrel Thresher

Solutions from morph chart:

1. Sits on a table
2. Adjustable speed of threshing
3. Minimal damage to seeds
4. Removable barrel for easy cleaning

5. Small and relatively portable
6. Powered by outlet

Description: This threshing concept utilizes a barrel and flail combination. The user adds the stocks and seeds to the barrel and then latches the barrel into place. The mechanical flail is then inserted to the barrel. The flail is connected to an electric motor. On the arm connected to the flail are nobs and dials which both power and adjust the speed of the motor. The substance inside the barrel is then threshed for however long the user likes, and then the motor is powered off. Finally, the barrel is unlatched and then removed from the device, thereby allowing the user to gain easy access to the seeds themselves.

3.4.2 Sandy Conveyor ()

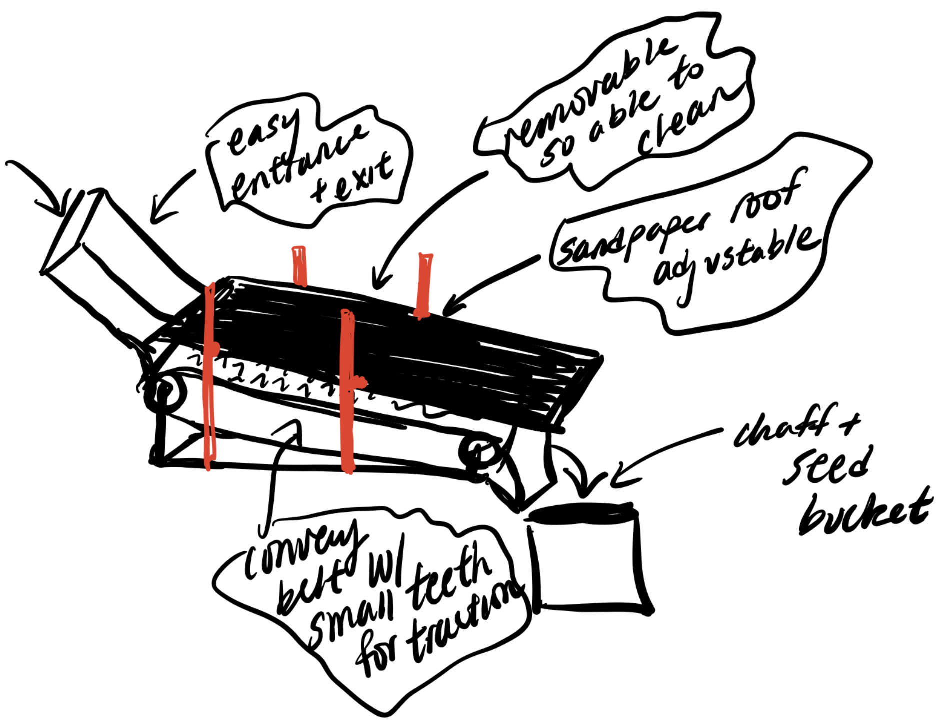


Figure 12: Concept design of thresher conveyor belt

Solutions from morph chart:

1. Easy entrance + exit
2. Removable top for easy clean
3. Adjustable roof component
4. No damage to seeds

5. Separates seed and chaff

6. Sits on table

Description: A motor controls the frictional conveyor belt that catches the stocks and harvest which then goes through a small tunnel where the "roof" is sandpaper. The friction between the conveyor belt and the sandpaper causes the separation of the chaff and the seed which then drops into the bucket at the end. The sandpaper component or "roof" is adjustable for the different type of seeds so as to not damage them.

3.4.3 Concept 3 ()

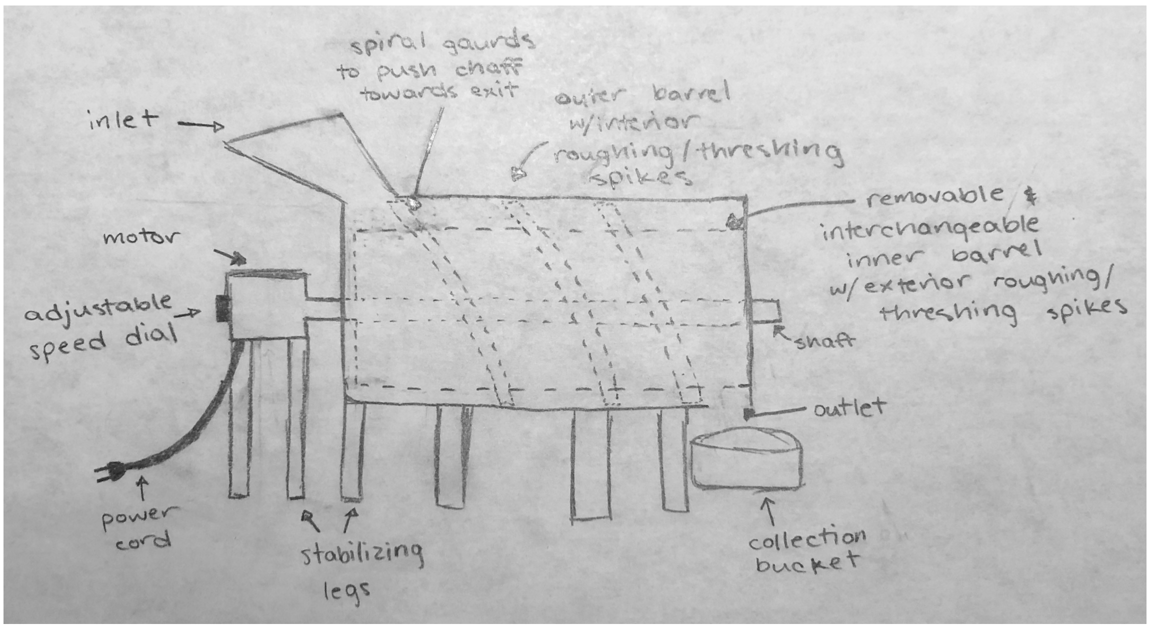


Figure 13: Preliminary sketches of Concept 3

Solutions from morph chart:

1. Adjustable to specified seed

2. Easy to use

3. Sturdy and long-lasting

4. Able to open and clean out

5. Automated and efficient

6. Does not damage seeds

Description: An interior barrel can be horizontally loaded onto the motor shaft inside the outer barrel. The motor is powered from a wall outlet and has an adjustable speed dial. There is an inlet funnel and an outlet hole which dumps into a lightweight bucket. The interior and exterior barrels have interfacing spikes that will rough up/thresh the chaff. The interior barrel also has a spiral guard along it to move the chaff from the inlet side to the exit as it spins. The interior barrel can be removed horizontally so that the contraction can be cleaned and serviced, and also replaced with different size interior barrels to deal with different seeds/chaff.

3.4.4 Concept 4 ()

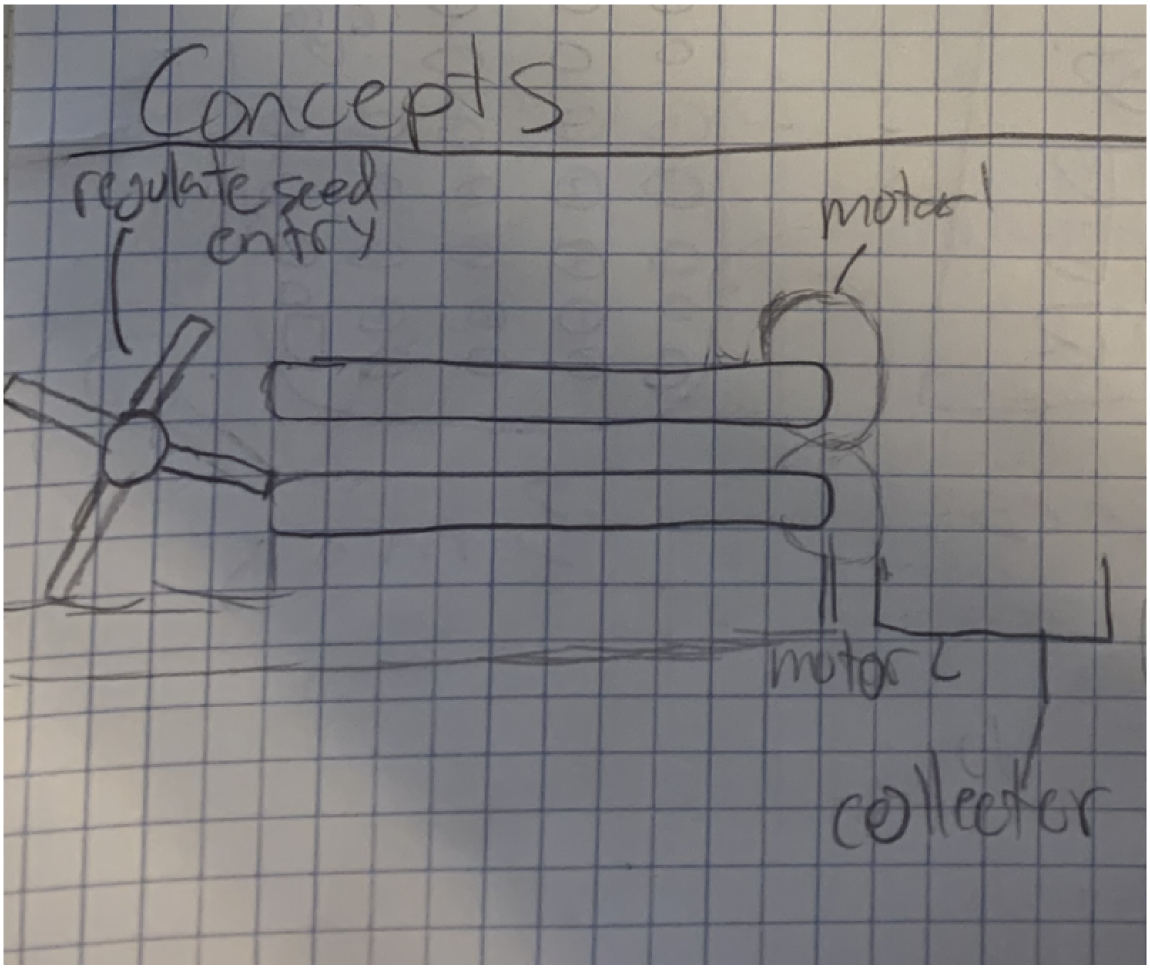


Figure 14: Sketches of Conveyor Belt concept

Solutions from morph chart:

1. Adjustable sift holes for different seeds
2. Sturdy, made of metal/plastic
3. Two conveyor belts separate seeds from te chaff
4. Has a switch to activate motors

Description: A beveled wheel feeds crops into the conveyor belt at a constant velocity. The conveyor belts are set a certain distance apart depending on the size of the seed in question. The tow belts then work in tandem to separate the seed from the chaff. Then there is a plate with holes that are sized in a way so the seed falls into the collector and (most of) the chaff is removed.

4 Concept Selection

4.1 Selection Criteria

We compared five design criteria for the thresher in the table below: efficient, non-damaging to seeds, easy to clean, sturdy, and adjustable to different seeds.

The criteria are compared row to column and the scoring legend is shown below the chart.

	Efficient (separates seeds in one go)	doesn't damage seeds	easy to clean	sturdy/long lasting	adjustable to different seeds	Row Total	Weight Value	Weight (%)
Efficient (separates seeds i	1.00	3.03	3.03	0.33	0.33	7.73	0.19	18.95
doesn't damage seeds	0.33	1.00	0.33	0.20	0.20	2.06	0.05	5.06
easy to clean	0.33	3.00	1.00	1.00	0.33	5.66	0.14	13.89
sturdy/long lasting	3.00	5.00	1.00	1.00	0.33	10.33	0.25	25.33
adjustable to different seed	3.00	5.00	3.00	3.00	1.00	15.00	0.37	36.78
					Column Total:	**40.79**	**1.00**	**100.00**

Row criterion is ________ than/as column criterion

Numerical ratings:
- 9 -- Extremely more important
- 7 -- Very strongly more important
- 5 -- Strongly more important
- 3 -- Moderately more important
- 1 -- Equally important
- 1/3 -- Moderately less important
- 1/5 -- Strongly less important
- 1/7 -- Very strongly less important
- 1/9 -- Extremely less important

Figure 15: Analytic Hierarchy Process (AHP) to determine scoring matrix weights

By filling out the entire bottom left triangle, we compared every design criteria to each other in order to determine the relative importance of each and therefore how heavily to weight each criteria when evaluating a concept model.

4.2 Concept Evaluation

We evaluated the four concept models with respect to the most important criteria in the chart below, taking into account the relative weights of each criteria that were evaluated in the selection criteria section. Each concept was given a rating from 1 (worst) to 5 (best) for how well it accomplishes each of the selection criteria. These scores were then multiplied by the weight or importance of the selection criteria, and the total was added for each concept.

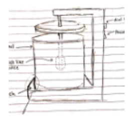
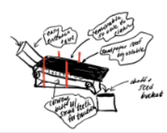
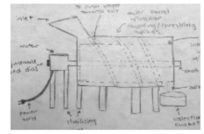
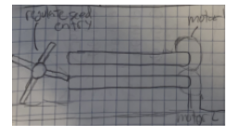
Alternative Deisgn Concepts		**Concept #1**		**Concept #2**		**Concept #3**		**Concept #4**	
									
Selection Criterion	**Weight (%)**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**
Efficient (separates seeds in one go)	18.52	4	0.74	1	0.19	2	0.37	1	0.19
doesn't damage seeds	13.34	5	0.67	5	0.67	5	0.67	5	0.67
easy to clean	22.15	3	0.66	3	0.66	3	0.66	2	0.44
sturdy/long lasting	18.41	5	0.92	5	0.92	5	0.92	4	0.74
adjustable to different seeds	27.59	3	0.83	4	1.10	5	1.38	3	0.83
	Total score	**3.820**		**3.540**		**4.001**		**2.859**	
	Rank	**2**		**3**		**1**		**4**	

Figure 16: Weighted Scoring Matrix (WSM) for choosing between alternative concepts

4.3 Evaluation Results

From the selection criteria chart, we determined that the most important design criteria is for the thresher to be adjustable to different seeds, as it had the highest weight percentage of any of the criteria. Next was that the thresher be sturdy and long-lasting, then efficient so that the user doesn't have to repeat their work, then that it is easy to clean. Finally, the criteria with the lowest score (and therefore lowest importance), was the thresher not damaging the seeds.

From the concept evaluation chart, we determined that concept 3 came out with the highest total score, so we selected it over the other concepts for prototyping. All of the concepts scored a 5 on not damaging the seeds because we learned from speaking with our client that the seeds are actually very durable and it would require a significant amount of force to damage them. All the models were similarly average difficulty to clean. Concept 3 stood out because of its superior adjustability to different seeds, because of the removable inner barrel that can be quickly and easily switched out for a different barrel that is customized for a different type of seed. Concept 3 fell behind some others in efficiency because of the screw shape inside of it which pushes the seeds towards the exit. We decided that this would limit the threshing process to only a small amount of time before the seeds were pushed out the end, and so the seeds might have to be fed back through the thresher more than once. However, we decided that if we removed the screw shape, the client could run the thresher for as long as they want until the seeds are completely clean, and then empty the thresher, eliminating the need to re-insert and run the thresher.

4.4 Engineering Models/Relationships

4.4.1 Torque of a Moment Arm

As our current prototype design requires a hand powered crank, we must look into the torque equation seen below.

$$\tau = r * F * sin(\theta) \tag{1}$$

Where τ represents the overall torque of the moment arm, r is the radius of the moment arm, F is the force applied to the moment arm, and θ is the angle at which the force is applied to the moment arm. An image of this can be seen in Fig. 25 below.

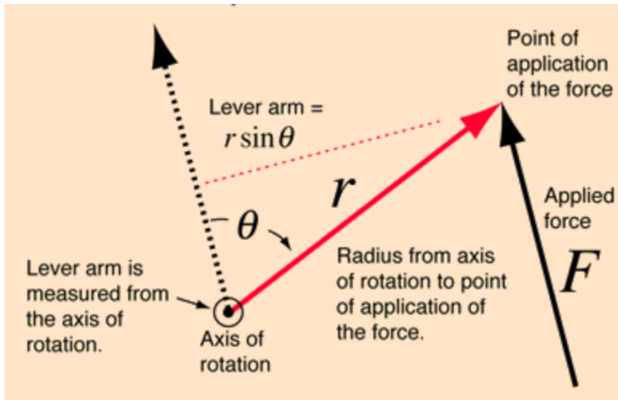


Figure 17: Schematic of Torque Engineering Model
[2]

This engineering model can be used to find the necessary length of the hand crank in the current prototype design. By using the average force found through experimentation, and using a 90 angle of approach, we can determine the length required to generate the appropriate torque to properly thresh the seeds.

4.4.2 Gear Ratio

Once we move beyond the initial human powered prototype design, we must look into more complex ways of increasing torque in the design. To perform this we must use the gear ratio, which can be seen in the equation below.

$$GR = \frac{\omega_1}{\omega_2} = \frac{Z_1}{Z_2} = \frac{T_2}{T_1} \tag{2}$$

Where GR is the gear ratio of the specific gear train, ω_1 and ω_2 are the rotational speeds of gears 1 and 2, Z_1 and Z_2 are the number of teeth each gear possesses, and T_1 and T_2 are the torques of each gear. By using this ratio, we can expand the torque of a small motor to the required amount to successfully thresh the seeds. Likewise we can control the speed, shape, and size of the gears within our train to optimize for efficiency and cost.

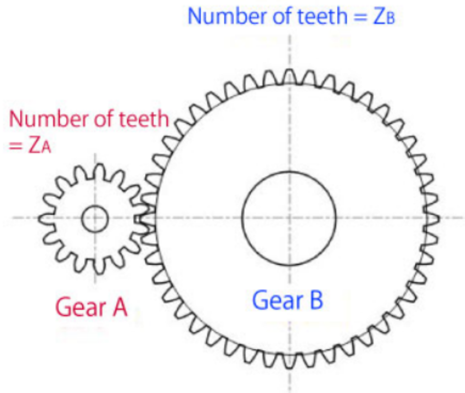


Figure 18: Schematic of Gear Ratio Engineering Model
[3]

4.4.3 Beam Deflection

Based on our current prototype design, we can model our system as two hollow cylindrical cantilever beams, that are fixed with zero degrees of freedom at the origin. By using the model of a cantilever beam we can approximate the deflection at the end of the pipe, so as to see if certain locations are in need of support. The equation for a single fixed end, distributed weight cantilever beam can be seen below.

$$\delta_{max} = \frac{W * L^4}{8 * E * I} \tag{3}$$

Where δ_{max} is the maximum deflection experienced by the beam, W is the weight of the beam, L is the length of the beam, E is the modulus of elasticity of the material, and I is the mass moment of inertia. An approximate image of our model can be seen in Fig. 27.

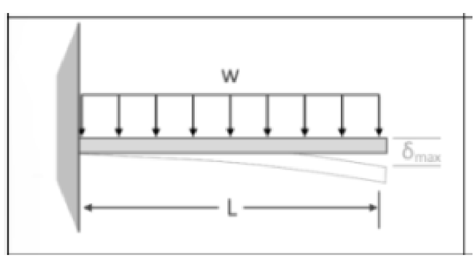


Figure 19: Schematic of Beam Deflection Model
[4]

5 Concept Embodiment

5.1 Initial Embodiment

The following figures show the computer aided design model of the thresher with an isometric view and a bill of materials that correlates to a exploded view. The CAD model was designed using

Inventor.

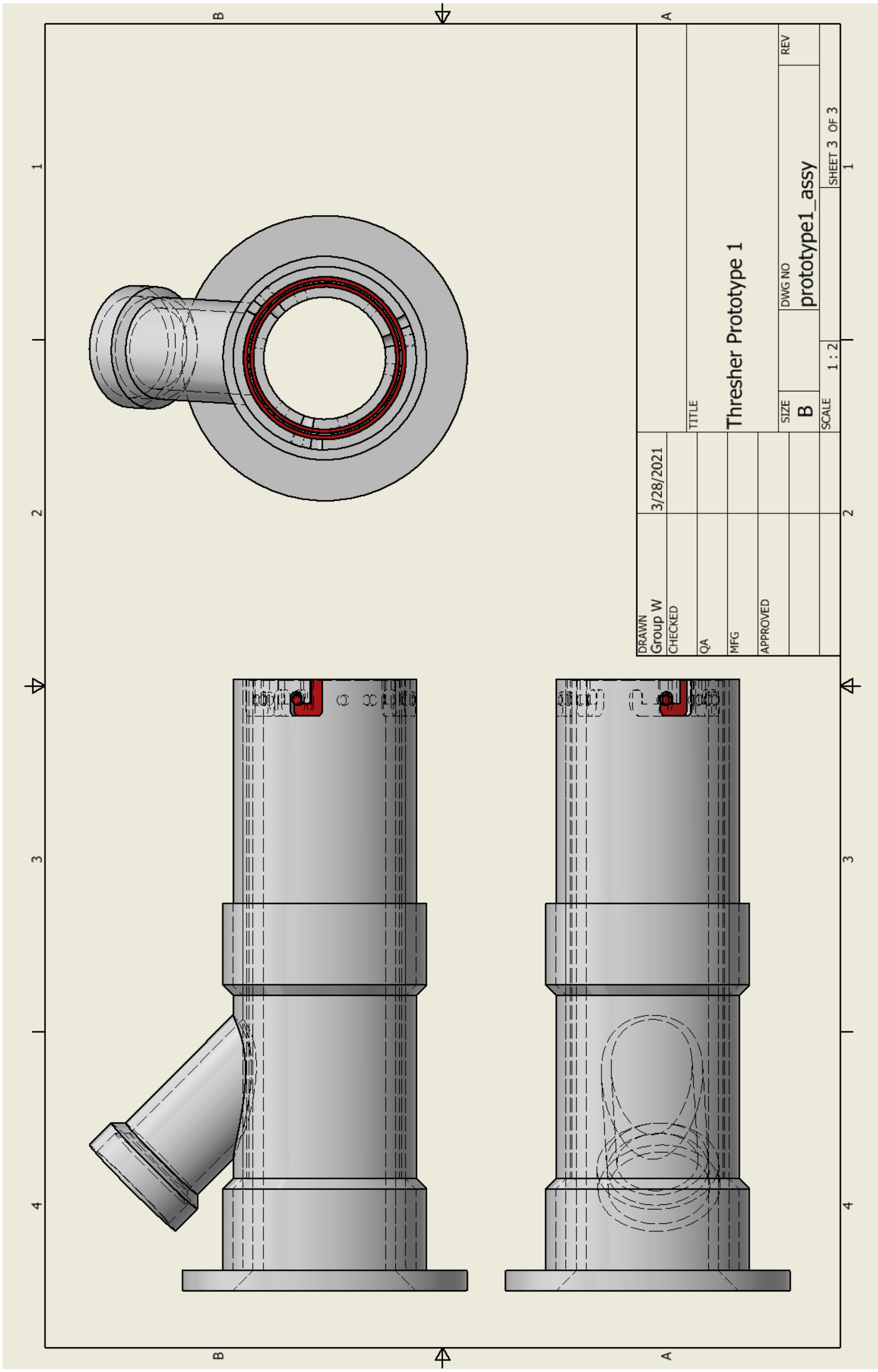


Figure 20: Assembled projected views

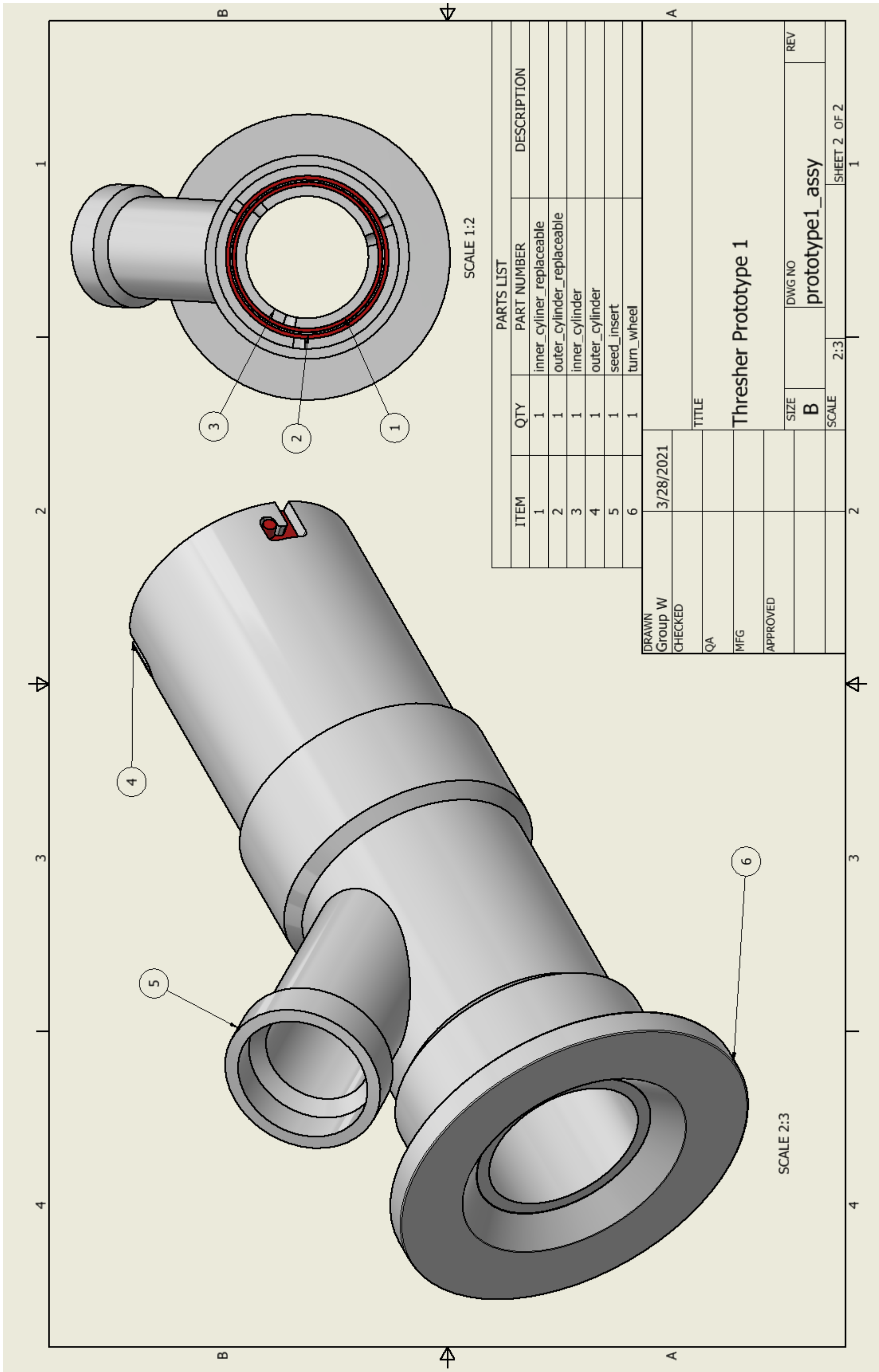


Figure 21: Assembled isometric view with bill of materials (BOM)

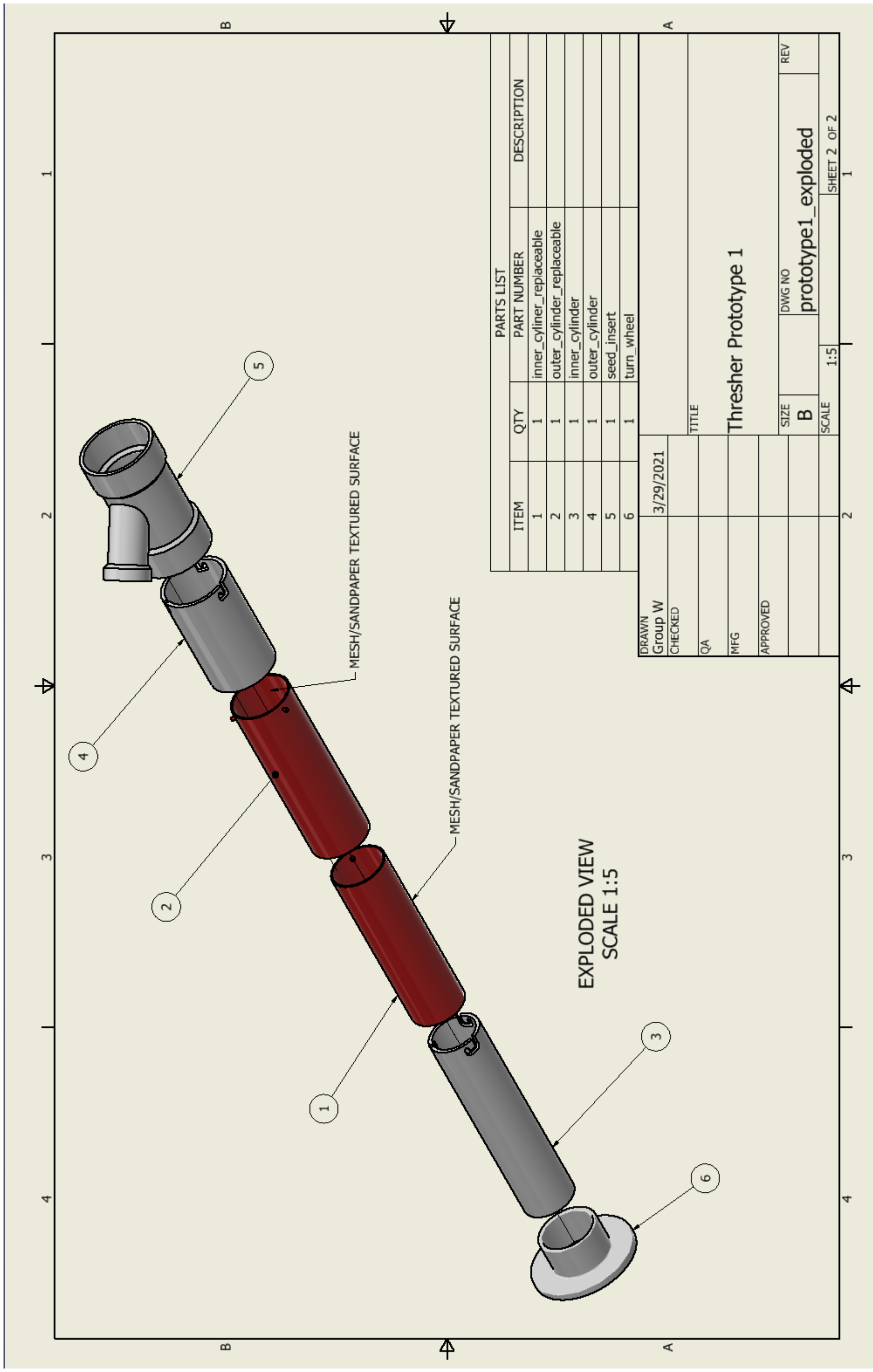


Figure 22: Exploded view with callout to BOM

5.2 Proofs-of-Concept

The following information and calculations are how the CAD model was designed. With the original prototype being made from PVC pipe, we were limited with the sizes so our size was determined by two standard PVC pipes and our design model was made to enhance the PVC pipe.

First, looking at Eq. 3 in the previous section, we can calculate the actual beam deflection of the inner tube to see if this will interfere with the overall threshing process. Modeling this beam as a fixed-free cantilever beam for simplicity, we can calculate the max deflection as seen in the figure below.

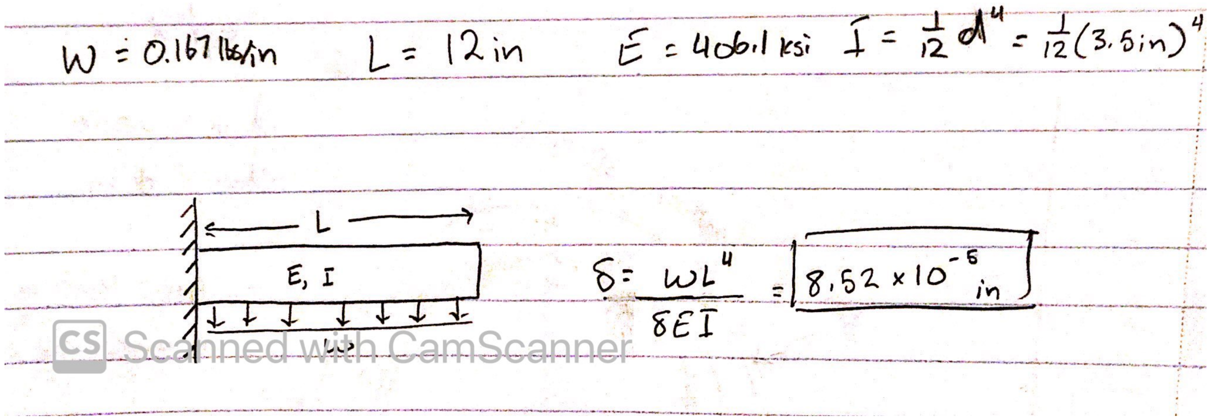


Figure 23: Fixed-Free Beam Deflection Calculations [5]

The max deflection, δ is less than a hundredth of an inch, allowing us to conclude that the deflection is negligible and thereby will not affect our threshing process.

Next, we can analyze the torque required to successfully thresh the seeds. Using Eq. 1 from the previous section we can compare an initial design with that of an updated, optimized prototype. Below is a calculation comparison between an initial design (diameter = 3 in) and a new design (diameter = 3.5 in).

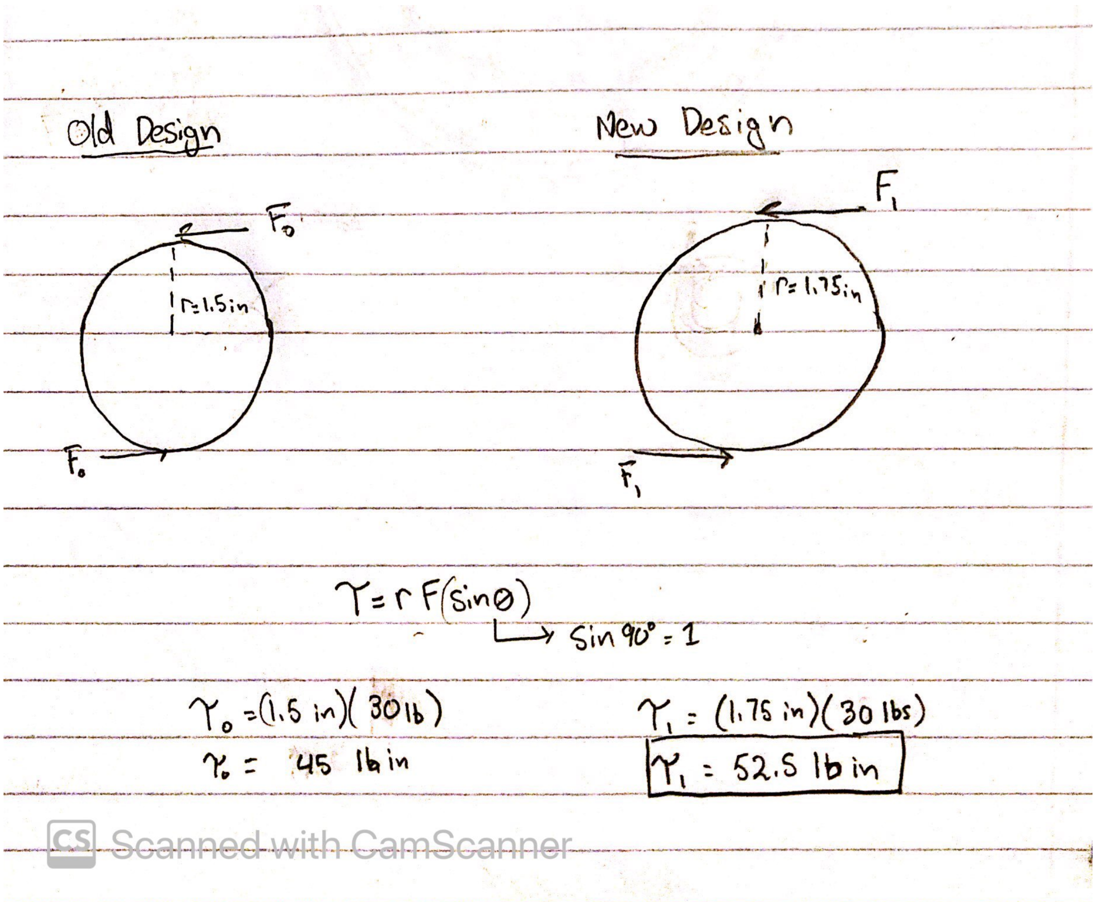


Figure 24: Optimized Torque

By increasing the diameter, we can increase the torque generated by the same amount of force. 15 lbs was used as the force of each arm, because that was found to be the average force required by the current method. In further experimentation, we will lessen force to find an optimal balance between it and the diameter.

6 Design Refinement

6.1 Model-Based Design Decisions

The prototype has remained relatively constant over the course of the design phase, therefore many of the engineering models/relationships will be remarkably similar to those in section 4.4. The thresher still requires a hand-powered crank to operate, therefore the torque of a moment arm is going to be quite relevant once again. The equation for torque is given below.

$$\tau = r * F * sin(\theta) \tag{4}$$

τ represents the overall torque of the moment arm, r is the radius of the moment arm, F is the force applied to the moment arm, and θ is the angle at which the force is applied to the moment arm. An image of this can be seen in Fig. 25 below.

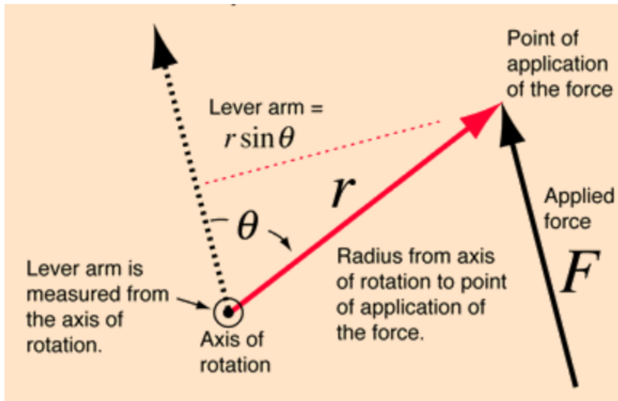


Figure 25: Schematic of Torque Engineering Model
[2]

Assuming a 90 degree angle given the prototypes constraints, a theoretical torque can be calculated for the device. With a diameter of 1.75 inches, and assuming an average force exertion of around 30 lbs, a standard torque for operation would be 52.5 lb•in.

The next engineering relationship that was utilized with our design is the equation for beam deflection. Assuming one end the thresher is anchored, we can then assume a system with two hollow, cylindrical cantilever beams. With this assumption, we can approximate the maximum deflection and ensure the device is capable of withstanding the forces required for use. The equation for maximum deflection is given below.

$$\delta_{max} = \frac{W * L^4}{8 * E * I} \tag{5}$$

δ_{max} is the maximum deflection experienced by the beam, W is the weight of the beam, L is the length of the beam, E is the modulus of elasticity of the material, and I is the mass moment of inertia. An approximate image of our model can be seen in Fig. 27.

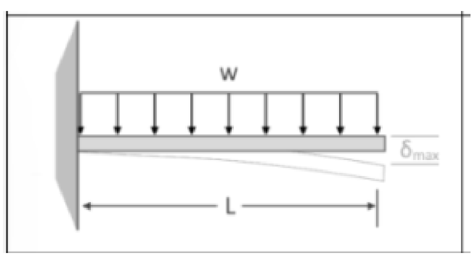


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Figure 26: Schematic of Beam Deflection Model
[4]

Assuming a distributed weight of 0.167 lbs/in, a length of 12 inches, a modulus of elasticity of 406.1 ksi, and a calculated moment of inertia of 12.51 in4, the approximate maximum deflection of the "beam" is 8.52e-6 in.

The final engineering relationship we examined for our device was a potential response associated with adding a locking mechanism at the base of our thresher. Assuming there is only a force response in the longitudinal direction of the cylinders, the response can be modeled as a spring response. This can be done by assuming the interlocking mechanism between the PVC is that of a spring with a very small constant. The formula for spring force is given below.

$$f_k = k * (x - x_o) \tag{6}$$

Where f is the force, k is the spring constant, X is the current position of the displaced material, and Xo is the initial position of the material. This relationship can be further conveyed in the image below.

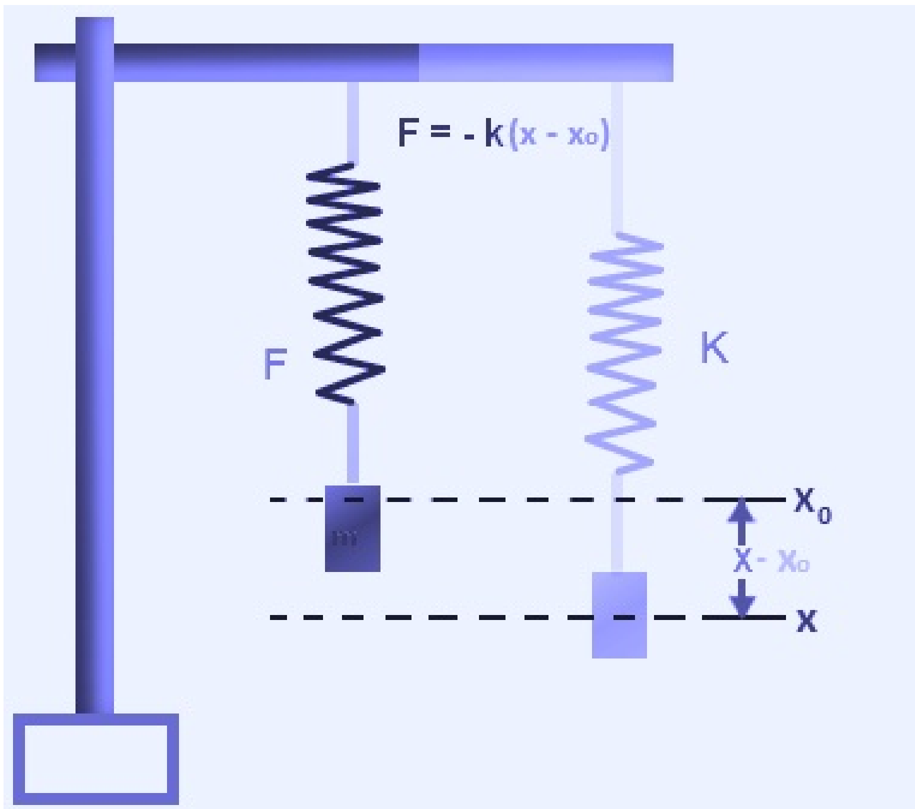

Figure 27: Schematic of Spring Force Model
[4]

6.2 Design for Safety

6.2.1 Risk #1: Skin Irritation

Description: Because the design incorporates sand paper, which, when scraped against human skin, can cause irritation and lacerations. During the process of cleaning, the user has to handle the sandpaper.

Severity: Negligible. The actual damage caused by a sandpaper scrape is minor, and, because the cleaning process occurs outside of any electronic motor, the sandpaper will not be rotating fast enough to cause serious damage.

Probability: Unlikely. This could only possibly occur during the cleaning process and even so, if the user is careful they will not be affected by the courseness of the sandpaper.

Mitigating Steps: The coarseness of the sandpaper is integral to the process of threshing, so this cannot be changed. One way to mitigate the risk would be to suggest that the user wear garden or worker gloves.

6.2.2 Risk #2: Dust Particles Could Cause Eye Irritation

Description: **The threshing process removes the seeds from their outer shell, thereby creating chaff and other dust particles that can exit the device and get into the user's eyes.**
Severity: Marginal. While irritating, the actual damage caused by dust in one's eye is usually minimal. There are obviously extreme cases where the damage is severe, but overwhelmingly, this falls within the category of "irritation"
Probability: Likely. With the current condition of the prototype, particles can escape relatively easily, especially during the removal of the seeds.
Mitigating Steps: To mitigate this issue, we can limit the flow of air into the device. Airflow can cause chaff and other particles to escape before the user is ready, which is a main cause for this issue.

6.2.3 Risk #3: Muscle Fatigue

Description: This device is intended to limit the amount of work required for the user to thresh seeds, but, as with any repeated motion, muscle fatigue can set in. The cranking motion required to power the device can be dangerous when repeated too frequently.
Severity: Critical. Muscle fatigue and other joint issues can cause serious long term deficiencies in a user's body. If taken to an extreme, actions like this can require surgery to correct.
Probability: Occasional. Most likely, the user will get tired and rest before any serious damage is dealt, but the muscle fatigue will still be present after a long session of threshing.
Mitigating Steps: Adding a lever and gears to minimize the amount of user input and increase the device output is an ideal step that will help prevent any serious muscle fatigue.

6.2.4 Risk #4: User Pinches Fingers When Operating the Device

Description: This device is comprised of several moving parts, most of which are connected tightly, which leaves room for potential injury when operating or cleaning it. This would most likely occur when the user reconstructs the device after cleaning.
Severity: Marginal. The most damage caused by such an action would be a minor cut on the user's finger. This, while slightly painful, is not a serious risk.
Probability: Occasional. As stated previously, this would mainly occur after cleaning, when the user pieces the device back together. This action only occurs once every 10-15 uses, so it is limited in probability.
Mitigating Steps: Adding user friendly handholds and tabs to the device would allow the user to safely maneuver each individual piece without putting their fingers at risk.

6.2.5 Risk #5: Seeds Fall out of the Thresher, Causing a Slipping Hazard

Description: Unthreshed seeds, when placed on a tile or hardwood floor, can cause the user to fall. This occurs when the user unknowingly steps on a larger pile of seeds and loses balance, which can lead to serious injury.
Severity: Critical. If the user were to fall on hardwood or tile flooring, they run the risk of serious head trauma or similar severe bodily harm.

Probability: Unlikely. The amount of unthreshed seeds required to make a person slip is large enough that any user would realize the potential issue well before it came to pass. Even if the user were to fall, the likelihood that any serious bodily harm would befall them is next to zero.

Mitigating Steps: Making sure the thresher has no unwanted holes or exit points for the seeds to escape. Increasing the size of the entry hole so that no seeds are dropped before threshing begins.

		Probability that something will go wrong				
	Category	**Frequent** Likely to occur immediately or in a short period of time; expected to occur frequently	**Likely** Quite likely to occur in time	**Occasional** May occur in time	**Seldom** Not likely to occur but possible	**Unlikely** Unlikely to occur
Severity of risk	**Catastrophic**					
	Critical			Muscle Fatigue		Slipping Hazard
	Marginal		Eye Irritation	User Pinches Fingers		
	Negligible hazard presents a minimal threat to safety, health, and well-being of participants; trivial					Skin Irritation

Figure 28: Heat Map of Risk

As can be seen in the heat map above, most of our risks lie within the yellow or green zones, meaning they are not high priorities when thinking about design. The only exclusion to this is the muscle fatigue, which is solidly within the orange. This means that attempting to prevent muscle fatigue in our design should be our number one priority. As stated previously, focusing on levers and ways to minimize the amount of user input into the device look to be a simple, yet effective way to remedy this potential issue. Ergonomically, creating a motion that will not wear away at a particularly important muscle is also important. Our customer has stated on multiple occasions that the act of threshing is tiring and can be painful on certain joints and muscles. This means that our device should at least be able to improve the user experience by minimizing that risk.

6.3 Design for Manufacturing

The current design has 12 parts to it; the outer PVC cylinder, inner PVC cylinder, PVC wheel-turning handle attachment, PVC seed inlet attachment, and the inner and outer 3D printed adjustable grinding attachments, shown in red in the CAD exploded view below. Not included in the CAD model are 6 springs, which are each embedded into the locking cut-outs in the PVC cylinders.

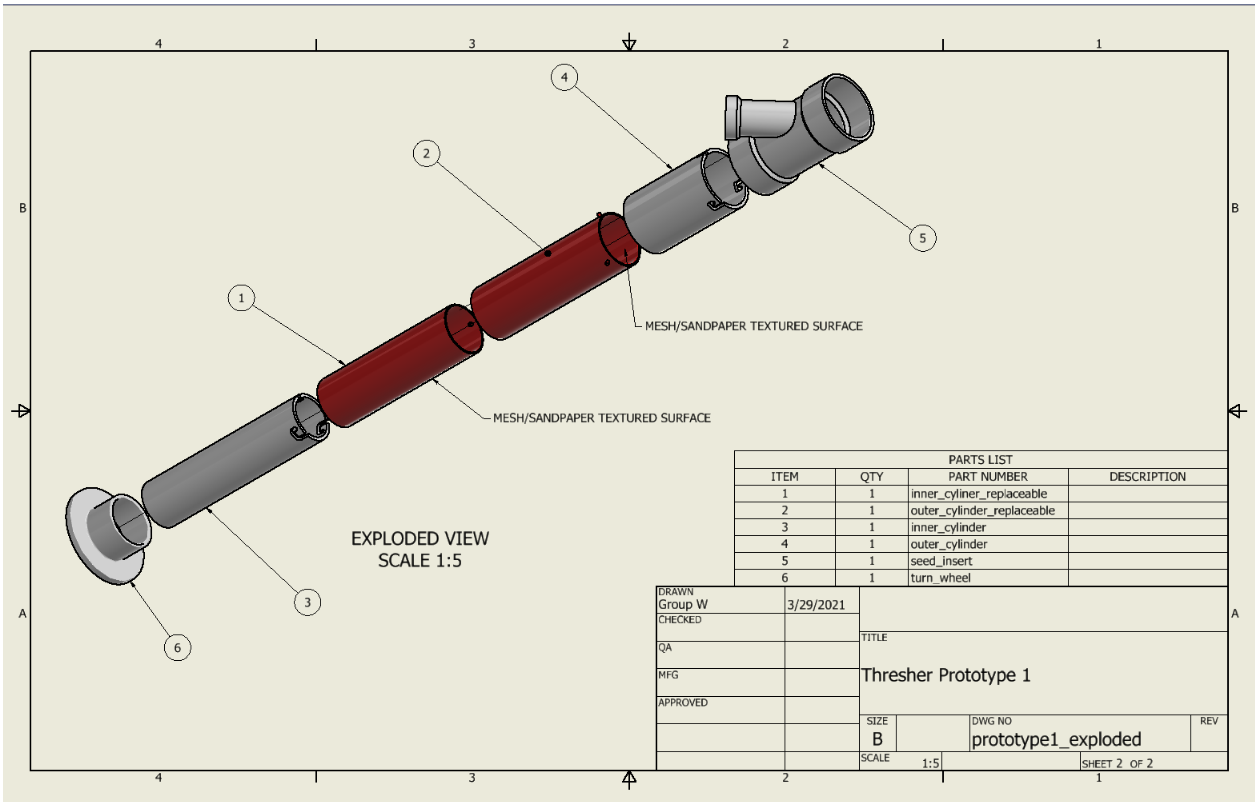

Figure 29: Exploded view with callout to BOM

There are no threaded fasteners in our prototype. All of the connecting PVC pieces are press-fit.

At its most rudimentary, our design concept is very simple, with only two theoretically necessary components. As long as there is an outer cylinder and an inner cylinder with interfacing rough surfaces and an accurate clearance to fit the correct seed sizes, the model will thresh seeds. These components are necessary because, without them, there would be nothing to create the friction on the seeds which removes their husks. These two cylinders must be separate components because they need to spin relative to each other and also need to be detachable from one another for cleaning and inserting/removing seeds.

Hypothetically, every PVC component of our design could be eliminated and the 3D printed cylinders with rough interfacing cylinders could be redesigned to incorporate the useful features of each of the PVC components. The inner 3D printed cylinder could be made thicker to make it more sturdy in order to eliminate the inner PVC cylinder, as well as the 3 springs included to fasten these components together in the current model. Also, the end of the inner 3D printed cylinder could have added geometry to function as a handle, which would replace the PVC wheel piece. The outer 3D printed cylinder could also be thickened to be sturdier, eliminating the need for the outer PVC cylinder and the three springs used to fasten the two components together. Also, the PVC seed inlet piece could be made obsolete by adding similar geometry to the outer 3D printed cylinder piece. A drawing of this model of an entire thresher made of only two 3D printed pieced is shown below.

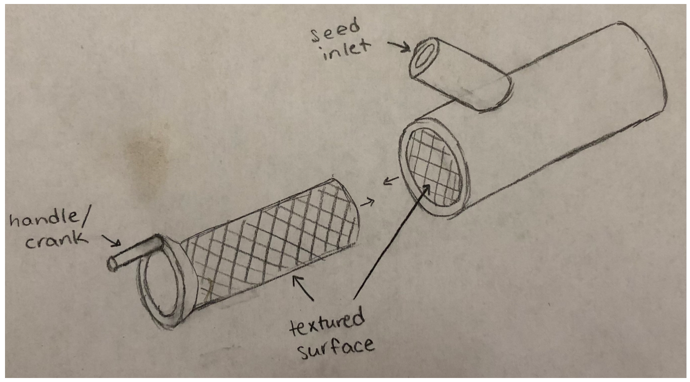

Figure 30: Sketch of simplified model with only 2 theoretically necessary components

6.4 Design for Usability

Vision impairment: A vision impairment such as presbyopia may influence the usability of our device because it may be hard for this user to see whether or not the seeds have been separated from their husks, since they are only 1mm small. The user may be asked to wear appropriate glasses or be provided with some kind of magnifying glass. colorblindness impairment would not affect the usability of this device because no part about it is dependent on color.

Hearing impairment:A hearing impairment such as presbycutia will not influence the usability of our device because the device is manual so they will know when it is running and when it is not running. They will be able to see visual instructions on how to use the device and will know the safety precaution features.

Physical impairment: A physical impairment such as arthritis, muscle weakness, or limb immobilization may influence the usability of our device because the user may have a hard time inserting/removing the inner barrel, picking up the bucket of seeds, or dumping the chaff into the inlet. It would also be physically challenging to continuously turn the crank to create the traction needed to remove the chaff from the seed.

Control impairment:A control impairment such as those caused by distraction, excessive fatigue, intoxication, or medication side effects may influence the usability of our device because they may get tired of using it because it can be a tedious process, although it should not be terrible because it does not take too much force to make the thresher turn with the traction of the sandpaper.

6.5 Overview

Below shows the initial prototype as well as the final prototype. Our main design goals were:

1. The device can process 1 L of seeds $<$ 5x faster and with $<$ 1/5 mechanical work compared to current method
2. The device can thresh 3 types of seeds with acceptable quality, according to Dr. Mueller
3. The device can be cleaned and reset in $<$ 5 minutes

6.6 Documentation

Figure 31: Initial PVC prototype

The initial prototype accomplished threshing 3 types of seeds. It was also able to be cleaned and reset in < 5 minutes. To improve our prototype, we added a stand as well as made two different inner cylinders for the different types of seeds. Two of the seeds are so similar in size that only one cylinder diameter was required. The 3D printed material was not prepared in time for the final prototype, it would have allowed for each cylinder to be more precise. Along with the stand we added a handle to assist in cranking the inner cylinder. Rather than using sandpaper for the internal surface for the external cylinder, we used popcorn paint which was easier to apply than sandpaper.

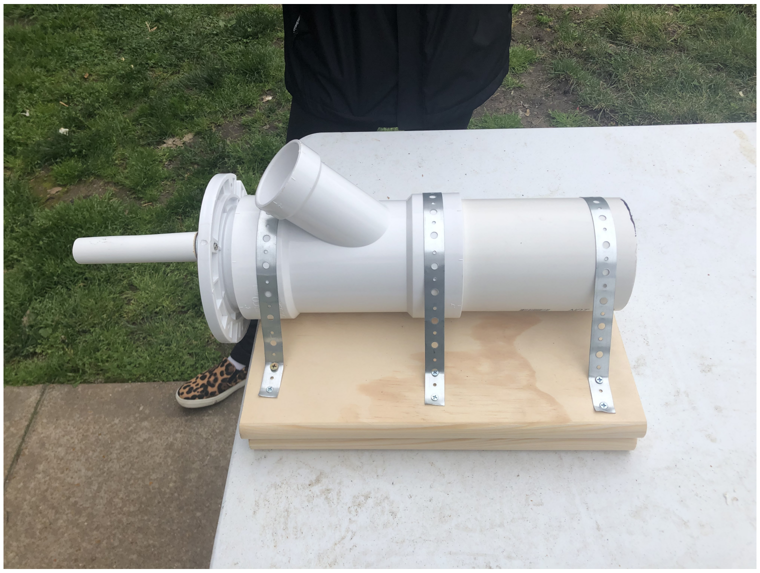

Figure 32: Final PVC prototype resting

Figure 33: Final PVC prototype lifted

The final prototype accomplished threshing the three different types of seeds as well as being able to be cleaned and reset in less than 5 minutes. We were unable to accurately test if the final prototype could thresh a liter of seeds in five times faster and a fifth of the mechanical work because we did not have access to a liter of seeds. We do believe that if we were able to test this goal, we would have been able to accomplish it.

6.7 Project Development and Evolution

Does the final project result align with its initial project description?

- Yes the final project results align with its initial project description. We were given the task to recreate a thresher and we did it.

Was the project more or less difficult than expected?

- The project was more difficult than expected because resources in 3D printed were scarce and assuring that the product would not fall apart was a scare.

On which part(s) of the design process should your group have spent more time? Which parts required less time?

- More time should have been spent on the final product and the prototype. Not enough time was spent on the prototype so the final product went through a series of prototypes and materials before it was done.

Was there a component of the prototype that was significantly easier or harder to make/assemble than expected?

- The idea for prototype came quickly but the aspect of putting a texture inside PVC and having it stay was tricky. The 3D model would have caused this to be a non-issue but because the print was not finished, this was not the case.

In hindsight, was there another design concept that might have been more successful than the chosen concept?

- There would not have been a design concept that would have been more successful. Our original brainstorms were all over the place and the other designs would not have been as successful.

6.8 Design Resources

How did your group decide which codes and standards were most relevant? Did they influence your design concepts?

- There were very few codes and standards that applied to our device because of the nature of the device. With seeds we knew we needed to acknowledge the food code and standard. These codes and standards did not influence our design concepts.

Was your group missing any critical information when it generated and evaluated concepts?

- Our group was not missing any critical information nwhen it generated and evaluated concepts.

Were there additional engineering analyses that could have helped guide your design?

- There were no additional engineering analyses that could have helped guide our design.

If you were able to redo the course, what would you have done differently the second time around?

- If we were able to redo the course, we would have met with the customer more consistenly to assure our product is what they are looking for.

Given more time and money, what upgrades could be made to the working prototype?

- We would 3D print the entire device which allow for more specific measurements as well as able to have more consistent material throughout. This would decrease the loss of seeds and the need to replace the sandpaper.

6.9 Team Organization

Were team members' skills complementary? Are there additional skills that would have benefited this project?

- All of the teams skills were complementary, there is a leader and organizer, a builder, a thinker and a writer! We all worked very well together.

Does this design experience inspire your group to attempt other design projects? If so, what type of projects?

- Yes this inspires us to look at our surroundings and see problems that need solving. Any task in our daily lives that is a bit difficult or inefficient could be one of these projects. There are so many possibilities and now we have the knowledge and process that would allow us to fix one of these problems.

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