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MEMS 411: Dressmaker Pin Dispenser

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Washington University in St. Louis

JAMES MCKELVEY SCHOOL OF ENGINEERING

SP21 MEMS 411 Mechanical Engineering Design Project

THE MIGHTY CYLINDER PIN DISPENSER

The goal of this project was to design, manufacture, and test a machine which takes in a disorganized jumble of dressmaker pins and outputs them in a consistent orientation where the user can easily, and safely remove them one at a time. The purpose of the machine is to increase the efficiency and safety of sewers who may use dressmaker pins daily. This report covers research into similar designs, evaluation of the specific design challenge at hand, generation of unique concepts, and the process of taking the concepts from paper to 3D printer, to prototype.

Three prototypes were created, all which used the selected concept (the mighty cylinder) to dispense pins. Briefly here is how the design works. Pins are inserted into the machine in a jumble, and they move down a ramp due to gravity, then rest against a cylinder with several pin-sized slots in it. A torque is applied to the cylinder by a DC motor which rotates the cylinder. As the slots pass by the jumble of pins, a pin is nestled into a slot and is lifted from the jumble. This now individuated pin is dumped by the cylinder onto a uniquely-built ramp, which uses gravity to orient the pin parallel to the ramp. Once the pin is oriented parallel, it will slide perfectly into a rail that feeds out to the user. The result is a pin, dangling by its head, and its body freely hanging to grab.

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1 Introduction

This report is a complete design and manufacturing walk through for the appropriately named *Mighty Cylinder Pin Dispenser*. The dispenser's function is to untangle dressmaker pins from a jumble, into an easy pickup line. The device solves two problems: the danger of the pins' sharp points and the lag in work speed from the pins' awkward shape. This project's launch pad was an initial interview with the end customer, Melanie Heckman.

Melanie is an avid sewer. In her craft she uses many dressmaker pins to hold materials together before stitching them. Her current process of grabbing the dressmaker pins is inefficient. Melanie dumps the pins onto the table and picks them up one at a time. She sometimes gathers multiple pins and holds them in her mouth for speed. This is an issue for her because she pokes her fingers with the pins too often, and this current process of picking up pins is too slow. There are existing pin dispensers available, however they can not process dressmaker pins. Therefore, the goal of this project is to design and manufacture a pin sorting and dispensing machine that will make the use of dressmaker pins more efficient and safer for Melanie to use while sewing.

2 Problem Understanding

2.1 Existing Devices

Initial research into similar devices was critical to start the design process in an advantageous position.

The following are three devices which share some common elements to the pin dispenser we are aiming to make. All devices below also have characteristics which are not consistent with our customer's needs.

2.1.1 Existing Device #1: Vibration Bowl Feeder

Figure 1: Rover FluorCam (Source: Feda Machinery Industry Co)

Link: http://www.szfeda.com/vibration-bowl-feeder/fd-vb.html

Figure 2: Rover FluorCam (Source: Feda Machinery Industry Co)

Link: https://www.youtube.com/watch?v=3sXW7W0jlPo
Description: The Feda vibration bowl feeder uses vibrations produced from electromagnets to move components along the track. The track is narrow enough that components must remain in an orientation parallel to the track to keep from falling off. Once they reach the outlet, they slide down a ramp into a rotating cylinder with slots along its diameter. As the cylinder rotates, the components fall into these slots and then fall out into the outlet tray. In this tray, they are aligned in parallel with each other but not necessarily pointing the same direction.

2.1.2 Existing Device #2: Pintastic

Figure 3: Picture of pin dispenser (Source: June Tailor, INC.)

Link: https://www.junetailor.com/notions-pintastic-and-pins

Figure 4: Picture of pin dispenser with user's hand (Source: June Tailor, INC.)

Link: https://www.youtube.com/watch?v=DTNR2LctY84

Description: The Pintastic automatic pin dispenser utilizes rotating cylinder powered by four AA batteries to shake the tangled pins inside, which will make pins eventually reach to the narrow gap. Only the sharp sides of the glass head pins can get into the gap. Once the pins are aligned by the gap, through the slope, the pins move until they reach below the button. During this whole process, a lid is closed, which will protect the user from getting hit by the pins. When a user needs a pin, user can press button, and the button picks up the pins while going back. After being picked up by the button, the pin is ready to be picked up by the user's two fingers.

2.1.3 Existing Device #3: Crave Naturals Glide Thru Detangling Brush

Figure 5: Picture of the back of the comb (Source: Crave Naturals)

Figure 6: Picture of the side of the comb (Source: Crave Naturals)

Link: https://www.cravenaturals.com/collections/all/products/copy-of-glide-thru-detangler-3
Description: This brush is made of smooth and streamlined head and handle with hundreds of smooth, stiff, and flexible teeth all of which make this comb effective for untangling the tangled hair without damage. Head and handle are smooth and are integrated into one body without any sharp or rough sides, which will minimize the damage caused on hair. The teeth are stiff, smooth, and flexible. The stiffness of the teeth enables the teeth to get into the tangled hairs. The smoothness of the teeth minimizes the damage on hair. The flexibility of the teeth enables the teeth to be bent when meeting hair too tangled, rather than unnecessarily pulling the hair too much in one brush. All of these factors enable the user to untangle the tangled hair with minimized damage in several brushes.

2.2 Patents

2.2.1 1. Bowling pin orientation device for orientating falling bowling pins in a bowling pin conveyor system (US4410177A)

A bowling pin orientation device for orienting to a single axial orientation. Bowling pins have a relatively heavy base portion and a relatively light neck portion. This device includes an arm disposed beneath a horizontal shelf from which bowling pins fall, tipping differently depending on whether base-first or neck-first. An arm pushes the pins so that they are not pushed out of the revolving wheel until the base contacts the arm. Thus the pins will always exit the machine heavy-side first.

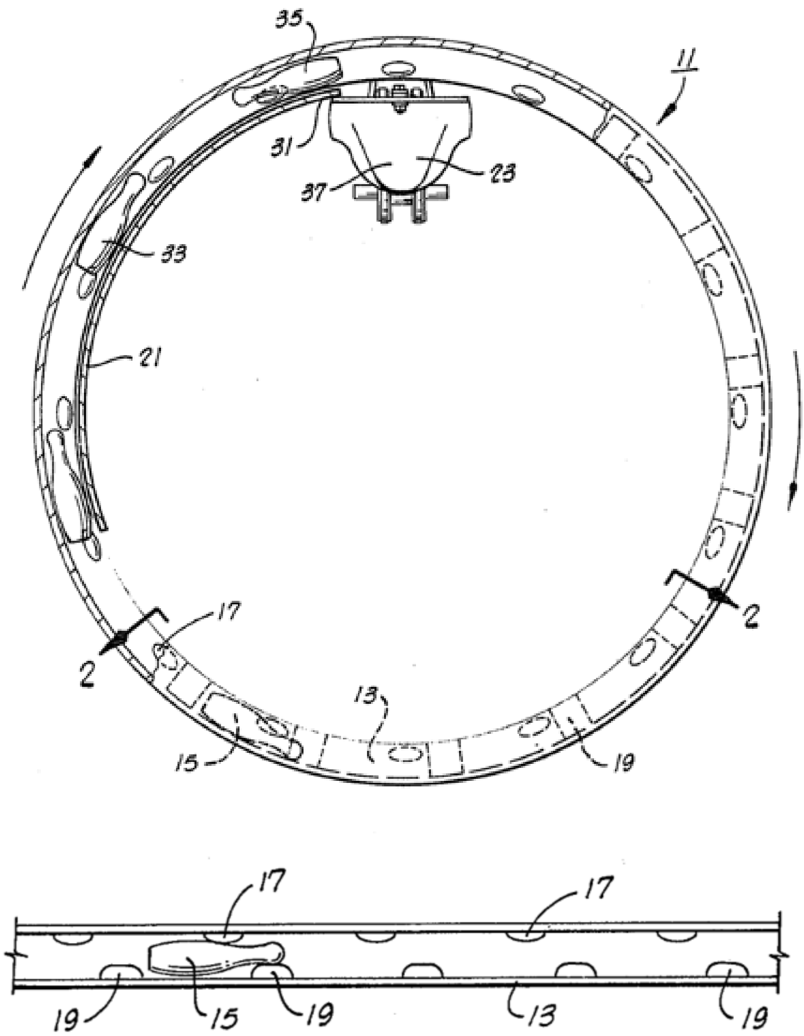


Figure 7: Patent Images for bowling pin orientation device

2.2.2 2. Conveyor for a preparation machine used to orient objects (US20090166153)

This is an invention which uses a conveyor to orient various round objects, among the listed ones are caps, lids, and covers. Objects are moved by air jets or by gravity through a conveyor channel and sorted by vibration or a belt. Objects that are detected to face the wrong way after the sorting process are ejected back into the starting pile, for another run through the sorting.

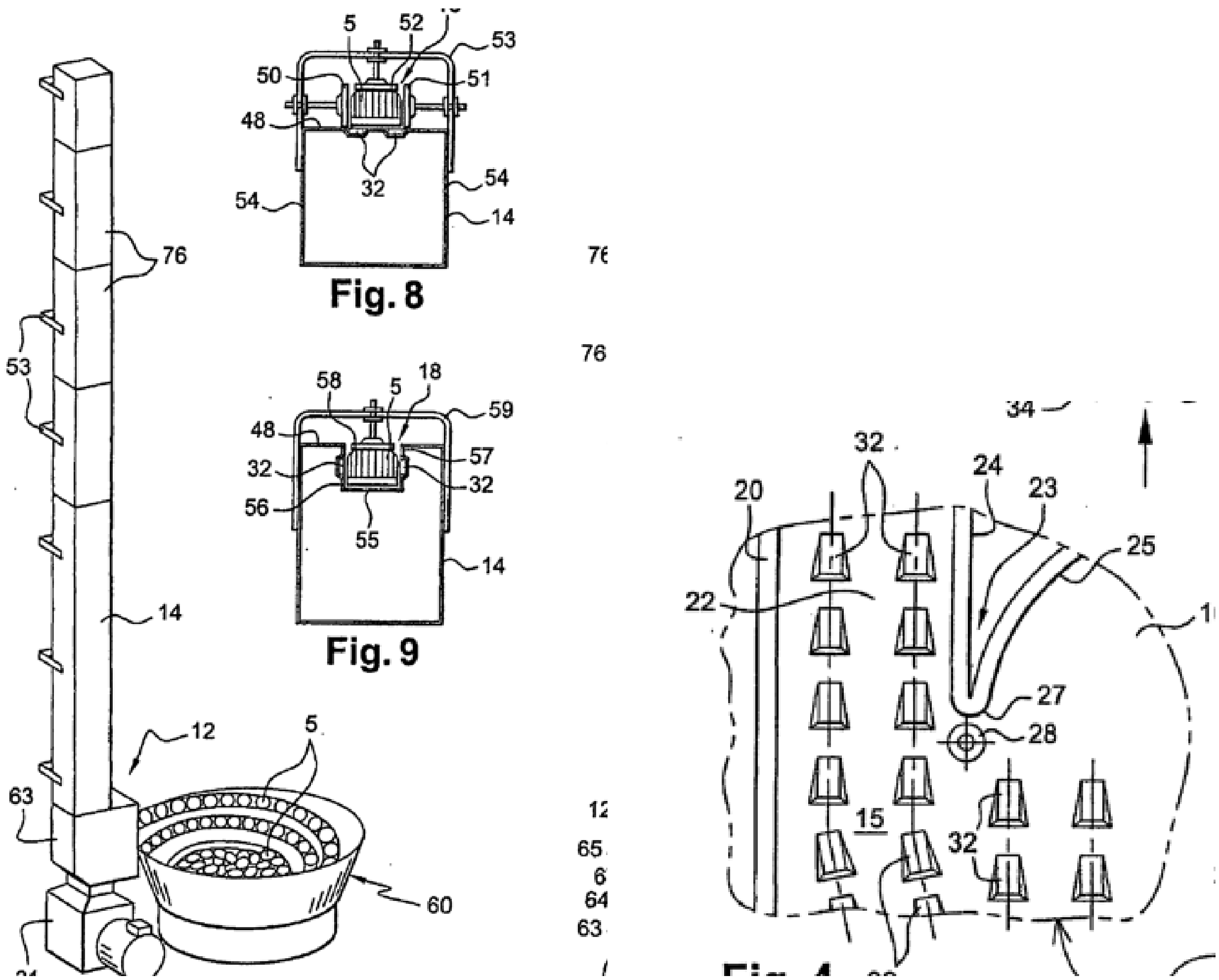


Figure 8: Patent Images for conveyor orienting machine

2.3 Codes & Standards

2.3.1 Standard Test Methods for Bend Testing of Metallic Flat Materials for Spring Applications Involving Static Loading (ASTM E855)

This ASTM standard lays out three methods and procedures for testing bending strength and modulus of elasticity tests in metal materials. This standard is relevant to our design because sewing pins are thin, ductile and easily bent. A pin dispenser would not be effective if it damaged the pins put into it by bending them.

2.3.2 Guarding - Protecting the User. (OSHA 1926.300(b))

This OSHA standard protects power tool users from physical danger the machine may cause. In specific, this rule mandates that a physical guard must be in place on the machine in areas that might cause threats to the user or those nearby, whether the threat is from something sparking, something sharp, something rotating, etc. In specific to this design, it is absolutely necessary to place proper guarding on a pin dispenser which is handling hundreds of razor sharp metal pins at high speeds.

2.4 User Needs

2.4.1 Customer Interview

Interviewee: Melanie Heckman
Location: Zoom
Date: February 2nd, 2021
Setting: We asked questions about the users wants, needs and preferences towards the device. We also asked specifics about the types of pins she uses and how she functions while working. The zoom conference was recorded and took 25 minutes and 31 seconds. Interview notes are paraphrasing Melanie's responses.

Interview Notes:
Would you like pins to dispense automatically one after the other without any new input?

- Yes, and I pick them up head up. To have them come out sideways, straight up, or diagonal works as long as the head is up.

Are there various pin sizes or just one size that the machine will need to handle?

- I use dressmaker pins, which always have small heads, are slightly bendy, and mine range between 1 to 1.5 inches in length. My typical pin is one and a quarter inch. I can use one size if necessary for the machine. I use Dritz dressmaker pins from Joan Fabrics.

How fast would the pins need to feed out?

- Optimally one per second.

How much noise can the machine make?

- As loud as a sewing machine. Engine noise level is too loud.

Do you have concerns about the machine being too heavy?

- No, as long as it doesn't damage the table its on. I would suggest rubber feet, like sewing machines have. I'll also suggest a 50 lb limit.

How many pins will be dumped into the machine at once?

- My boxes come with 350 pins, but it doesn't necessarily need to be able to handle that many.

Do you anticipate any non-pin debris getting into the machine?

- Yes, its hard to sift out little pieces of fabric from the mass of pins. Some thread, dust, and fuzz will get into the machine.

2.4.2 Interpreted User Needs

The customers needs were compiled into a list after the interview. Each need was given an importance value from 1 to 5 with 5 being the most important.

Table 1: Interpreted Customer Needs

Need Number	Need	Importance
1	Dispenses pins head up consistently	5
2	Easy to unclog and fix if jammed	5
3	Can handle some non pin debris	4
4	Pins are dispensed quickly	4
5	Machine neither slides on table nor damages the table	3
6	Machine can handle multiple pins at once	4
7	Machine is portable	2
8	Machine neither dulls nor bends pins	3
9	Machine should be automated	3
10	Size should be no larger than a typical sewing machine	3
11	Machine is quieter than a normal sewing machine	3
12	Machine can handle brass pins	4
13	Machine is sleek and modern	1
14	Machine can handle multiple pin sizes	2

The table shows that the most important customer need is for the pins to be dispensed with the heads available to grab. The functionality of the machine is the most important while the customer does not care about the aesthetics of the machine.

2.5 Design Metrics

Based on the customer interview and the user needs, each customer need has been given a specific target specification and been compiled into Table 2 below. This table provides quantifiable goals for our device which we will be able to test against during the design refinement and final prototyping stages.

Table 2: Target Specifications

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal
1	7	Total weight	lb	< 50	< 20
2	10	Footprint area	in^2	< 200	< 170
3	1	Frequency of improperly oriented pins	pins	$< 4 per 150$	$< 2 per 150$
4	3	Amount of thread machine can handle per 150 pins without jamming	in	< 1	< 5
5	8,12	Runs through the machine before a pin is dulled or bent	integer	> 10	> 50
6	6	Average time to unjam machine if jammed	minutes	10	0.5
7	4,9	Time to dispense a pin after one is taken	seconds	< 1.5	< 1
8	14	Length of pins machine can handle	in	1.25	$1 - 1.5$
9	6	Quantity of pins machine can intake	integer	> 75	> 350

3 Concept Generation

3.1 Mockup Prototype

Here are three photos of a mock up prototype, which illustrates the key principle, orienting the pins from a clump to an orderly arrangement. This is done by using a metal cone to make pins mostly parallel, a track (ruler in this case) to orient them completely parallel, and then a more restrictive improvised metal track on which only pins facing head up will be able to ride. The mock up doesn't fully work, but it successfully illustrates a single solution to the main problem of orienting pins.

Figure 9: Pin Dispenser Mockup 1

Figure 10: Pin Dispenser Mockup 2

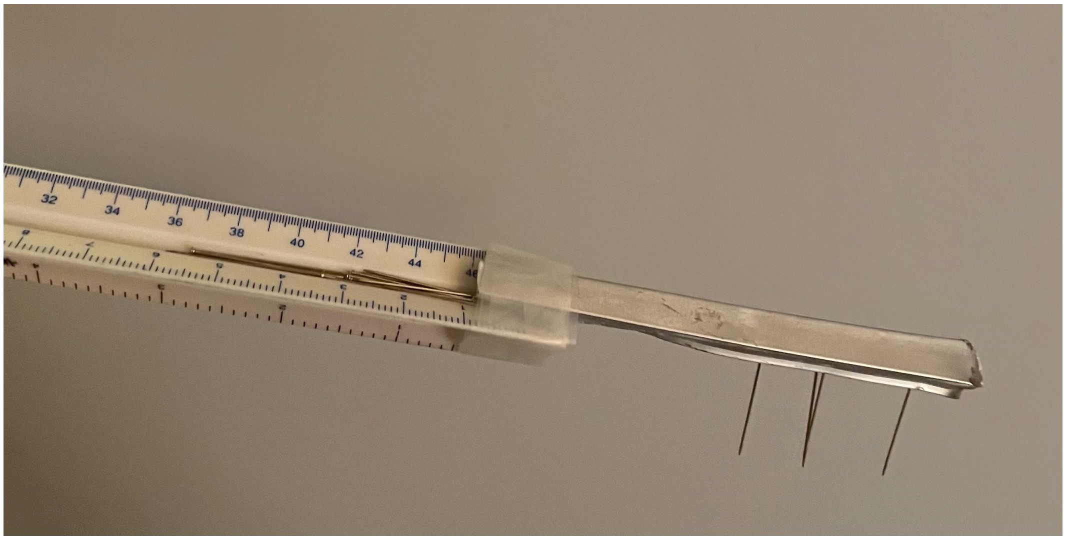


Figure 11: Pin Dispenser Mockup 3

3.2 Functional Decomposition

Here are the two function trees which illustrate the most important design functions of the pin dispenser.

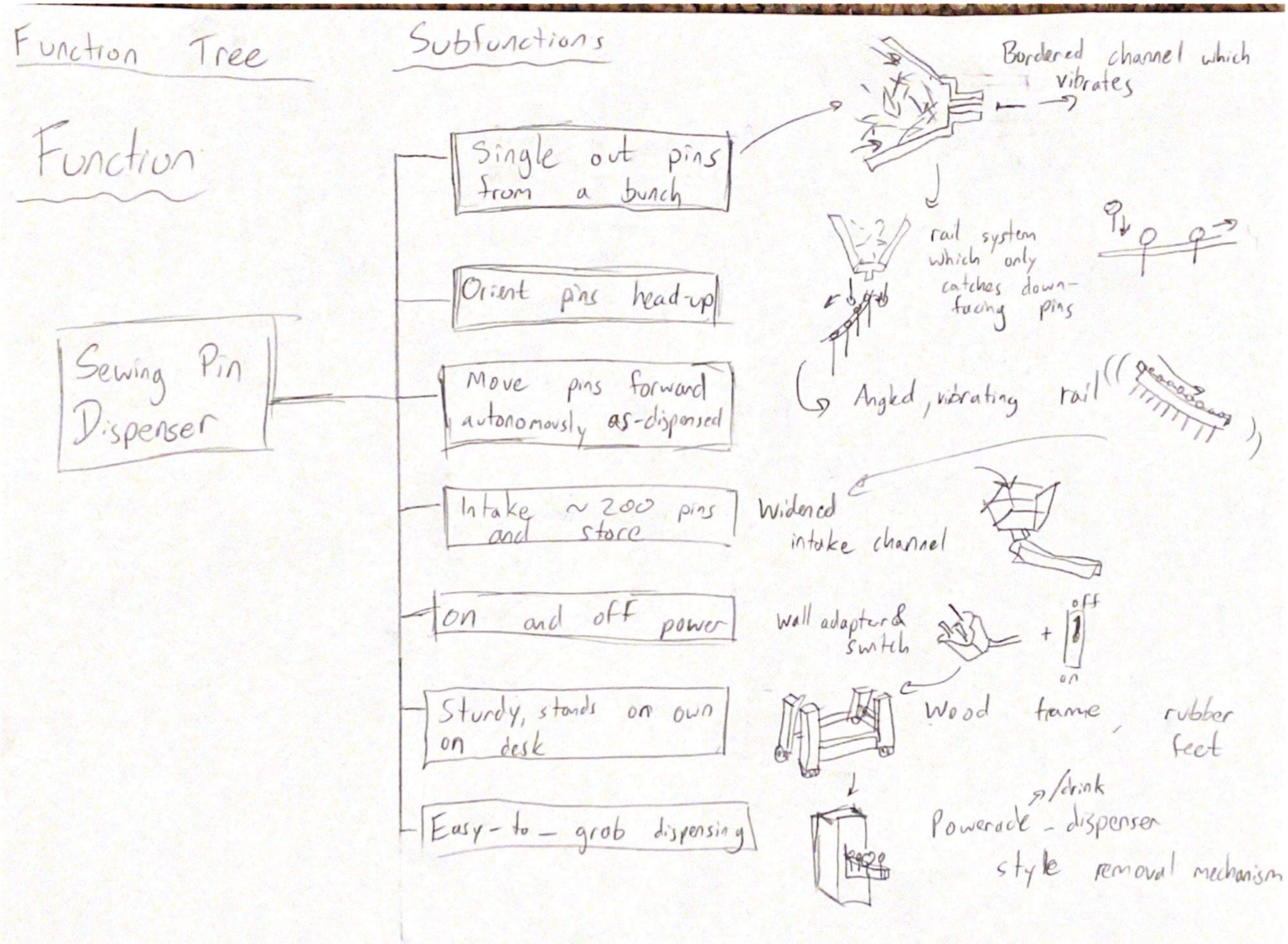


Figure 12: Function tree for Pin Dispenser, hand-drawn and scanned

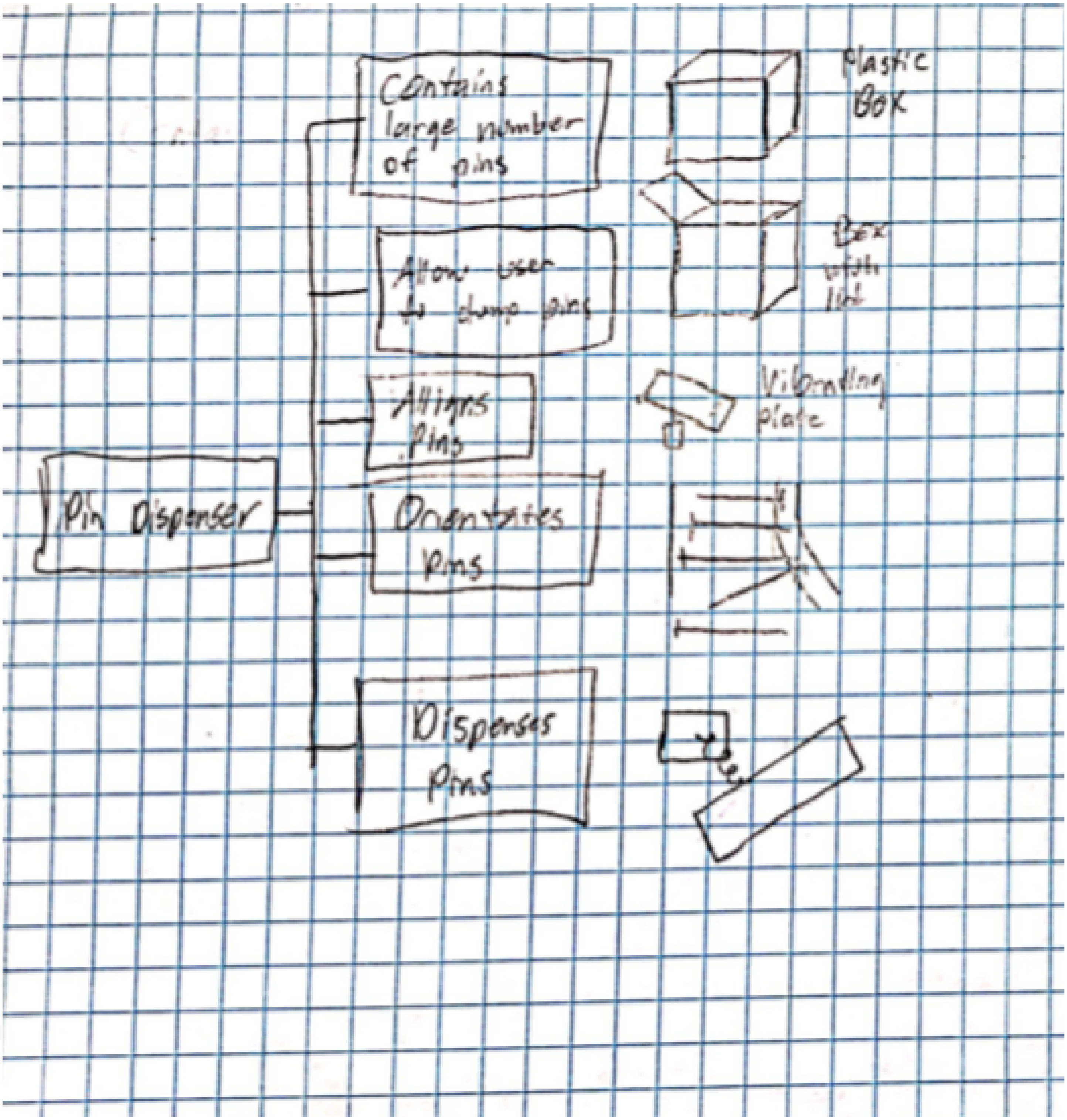


Figure 13: Function tree for Pin Dispenser, hand-drawn and scanned

3.3 Morphological Chart

Below are two morphological charts which illustrate several solutions to each of the proposed sub functions for the pin dispenser. Not all the ideas are actually executable, but they all help flesh out the problem better.

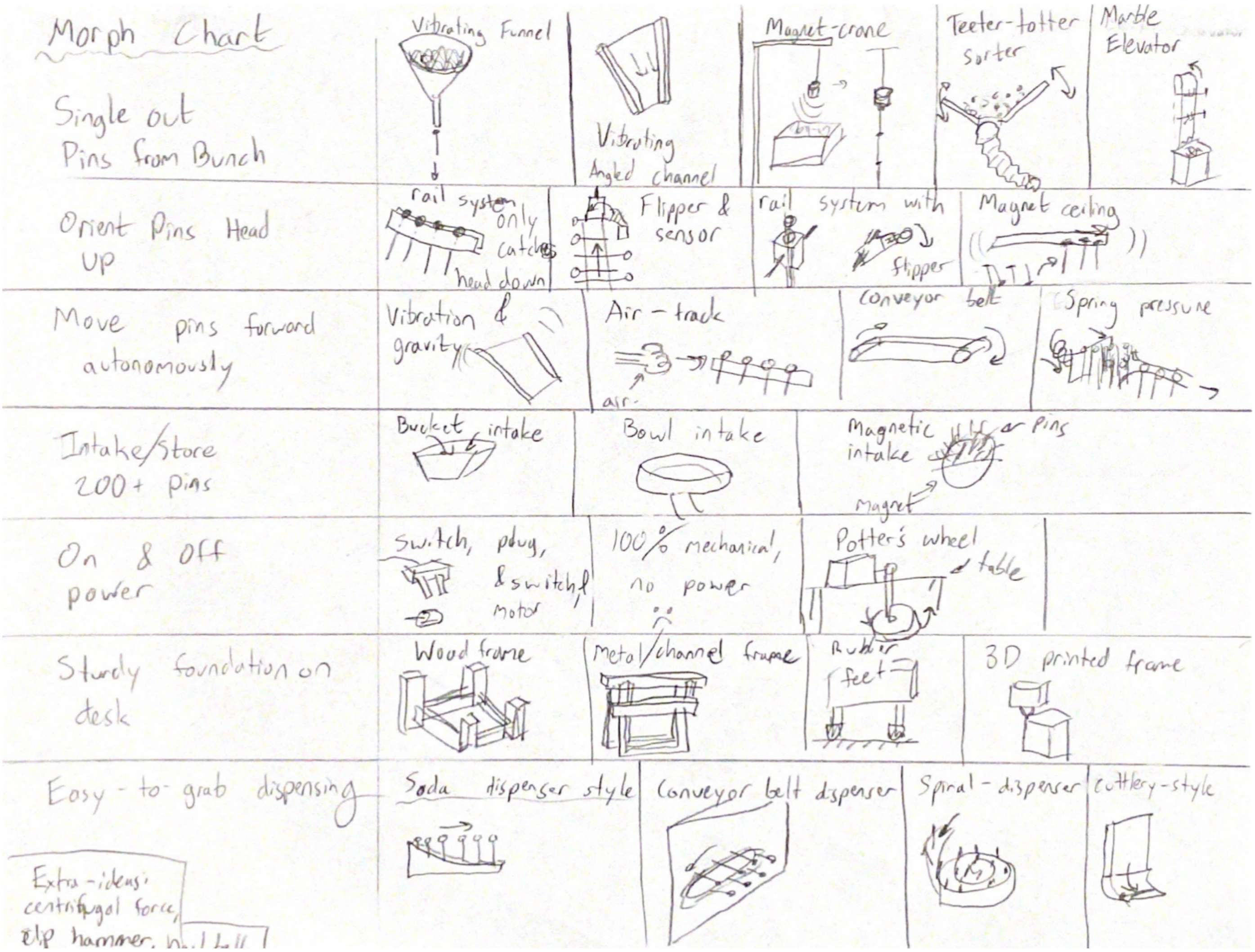


Figure 14: Morphological Chart for Pin Dispenser

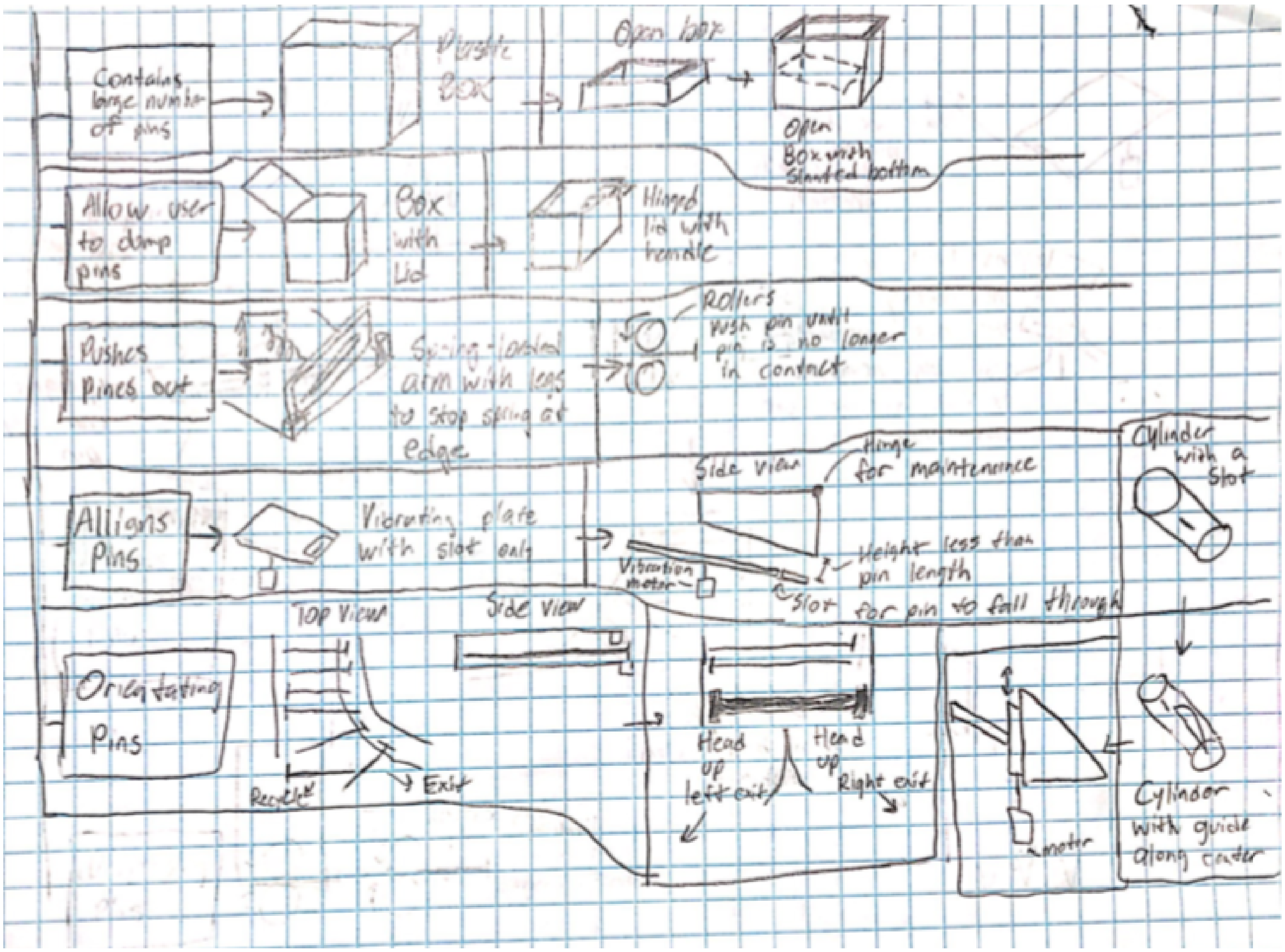


Figure 15: Morphological Chart for Pin Dispenser

3.4 Alternative Design Concepts

3.4.1 Concept 1

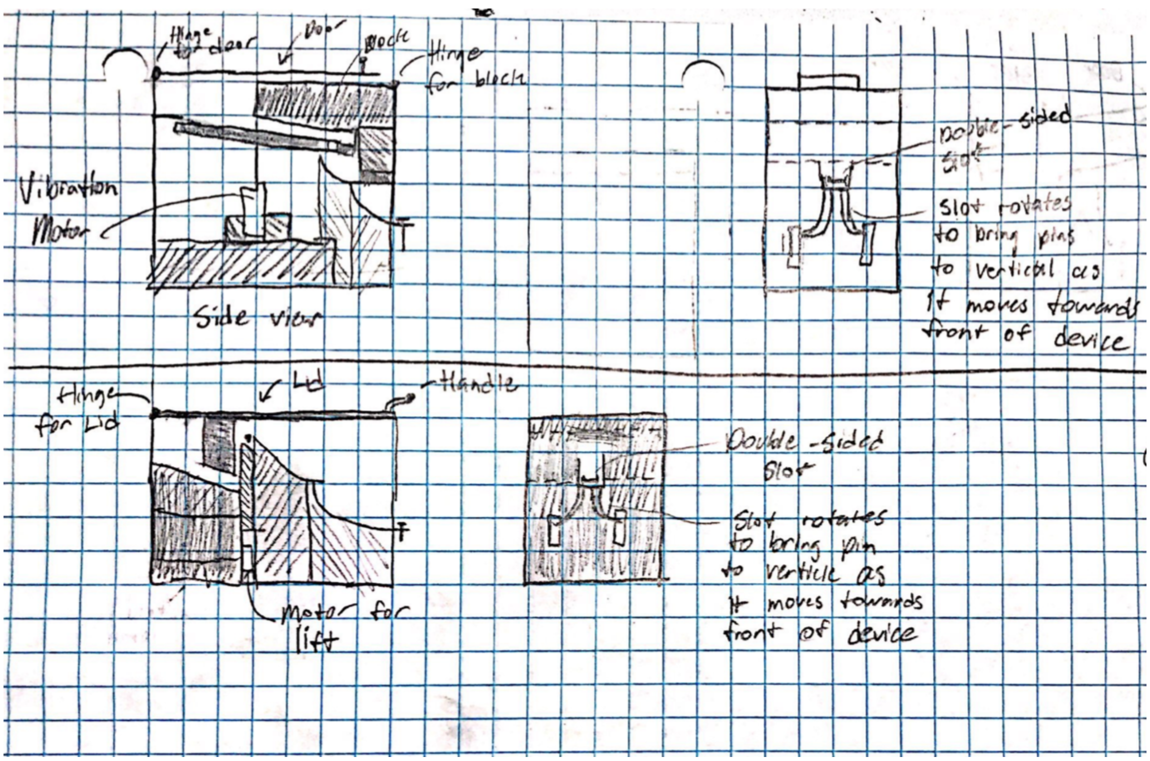


Figure 16: Preliminary sketches of Pin Dispenser concept

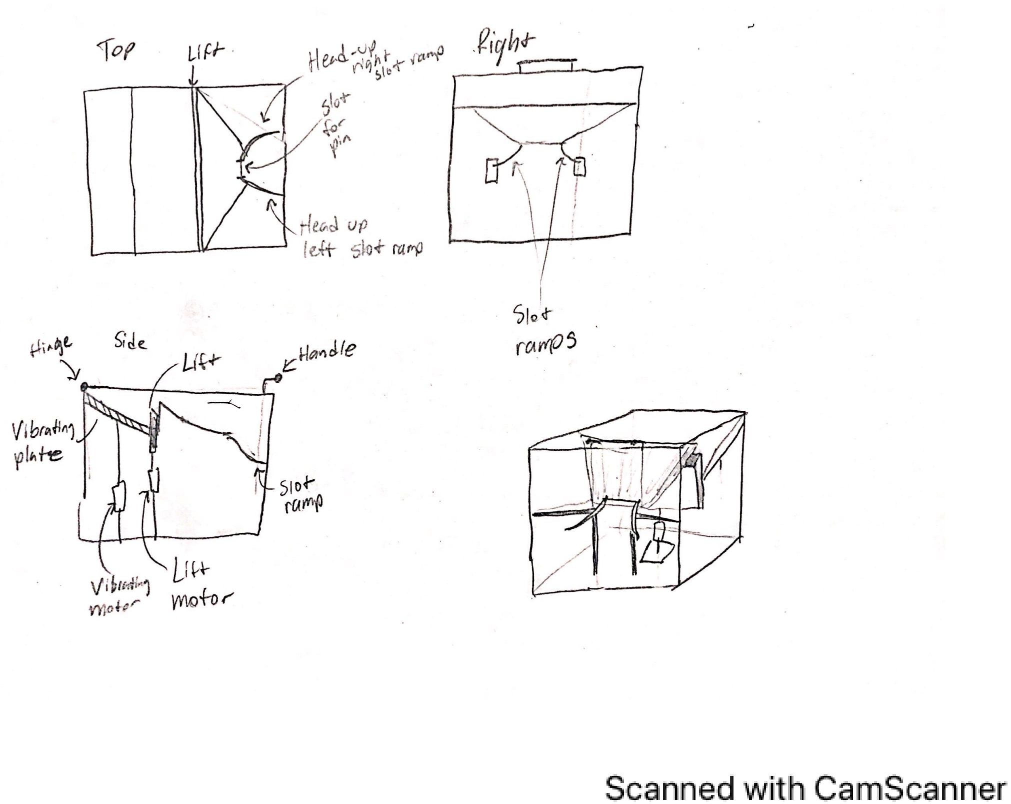


Figure 17: Final sketches of Pin Dispenser concept

Solutions from morph chart:

1. Box with lid and handle on top
2. Vibrating Plate
3. Slanted lifting ledge
4. Narrowing ramp
5. Double-sided slot

Description: A vibrating motor forces pins down plate to a narrow ledge which will continuously raise and lower while the device is running. The ledge is narrow enough that pins which are not parallel to the ledge will fall off as it is raised. Once the pins reach the top, they slide onto another ramp which narrows to about the width of one pin. At which point the pins will fall through a slot which is big enough to accommodate a pin with the head pointing in either direction, but once falling through, the head will catch onto a narrow slot ramps which will guide the pin to either the left or the right.

3.4.2 Concept 2

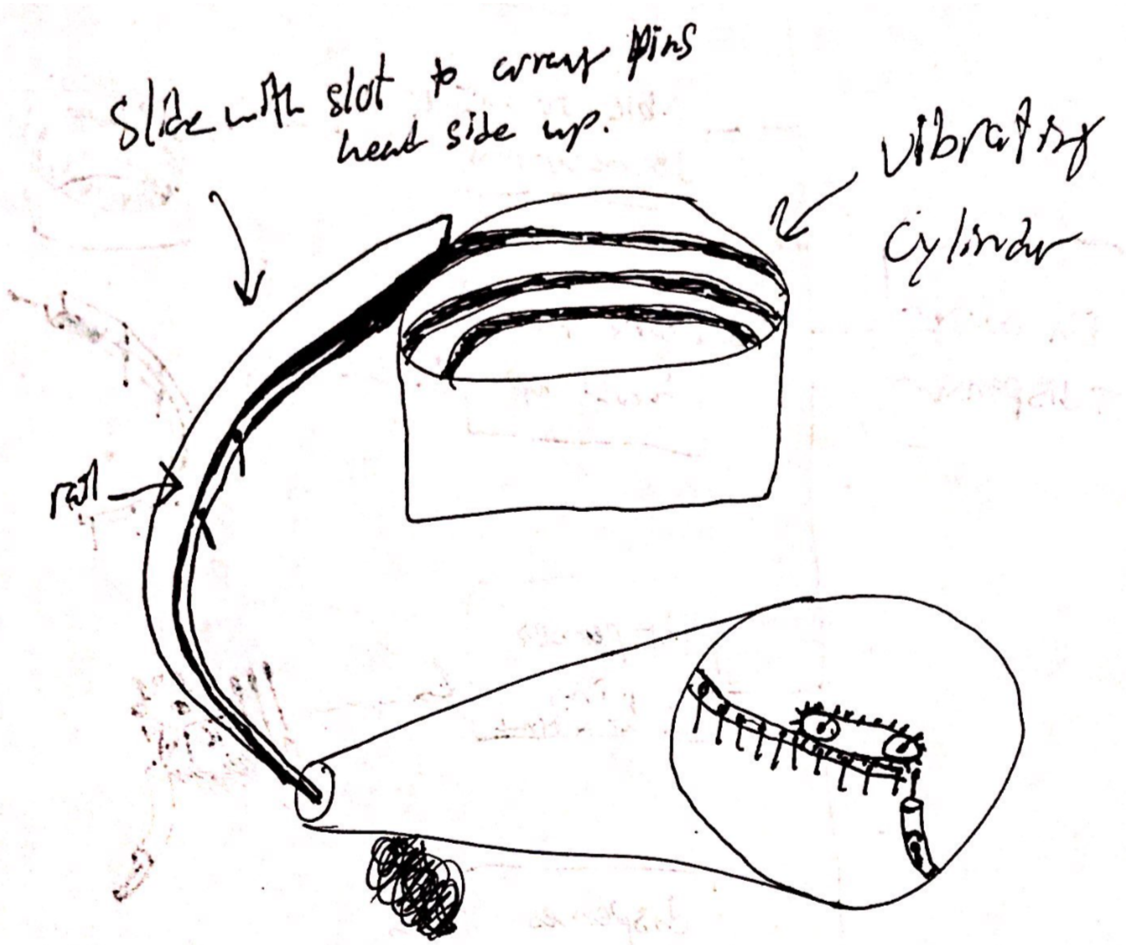


Figure 18: Preliminary sketches of Pin Sorter concept

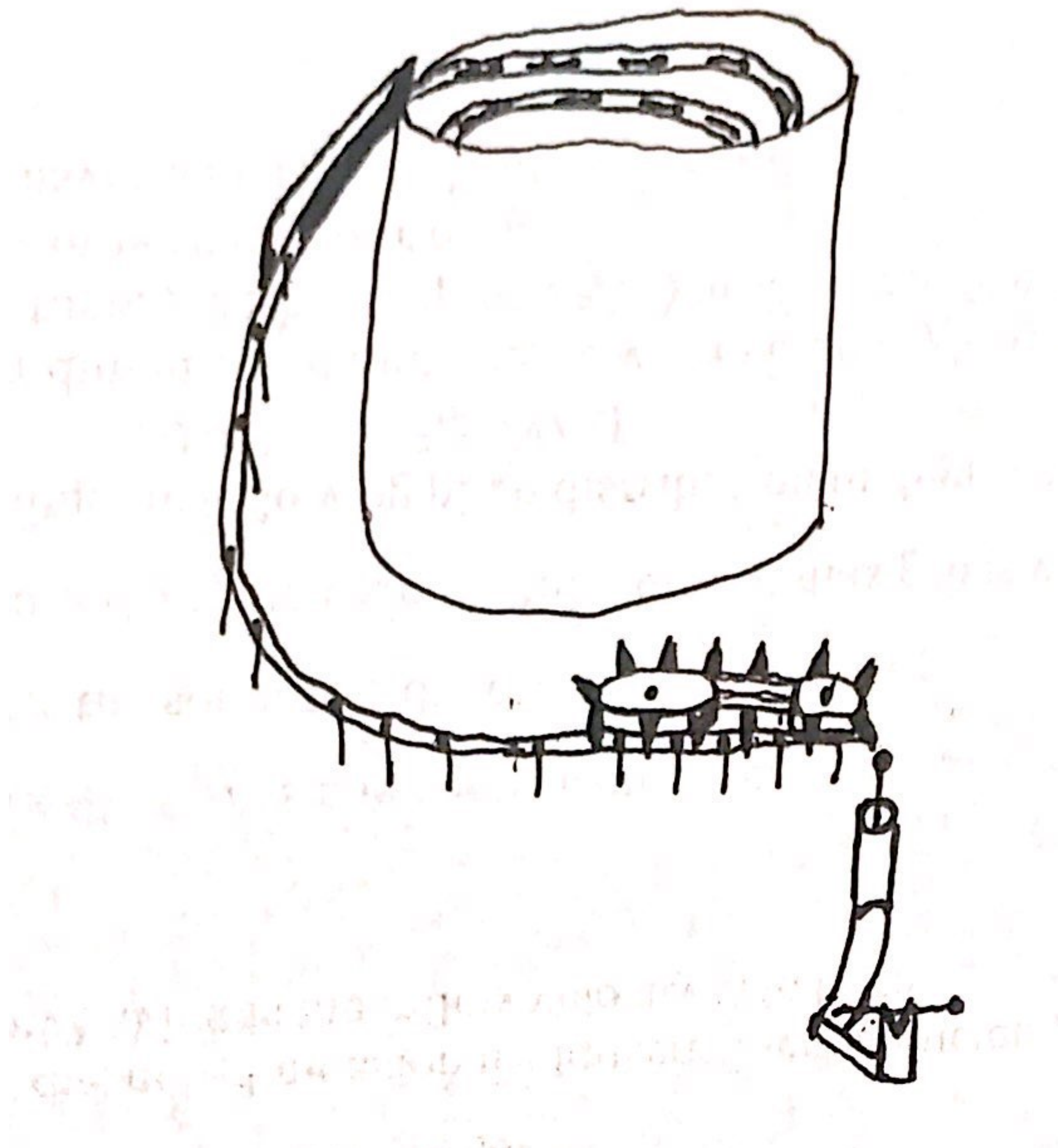


Figure 19: Final sketches of Pin Sorter concept

Solutions from morph chart:

1. Vibrating cylinder to sort pins
2. Slide-rail system to orient pins heads up
3. Motor with track to sort pins individually

Description: A cylinder with a spiral grove will vibrate to sort the pins in a linear arrangement. It will also move the pins vertically up the spiral groves. Once at the top, the pins will move down the slide which will orient the pins heads up. This is achieved by removing the bottom of the slide and creating a rail system. The pins will then be organized individually by a motor with a track that will "grab" each pin one by one.

3.4.3 Concept 3

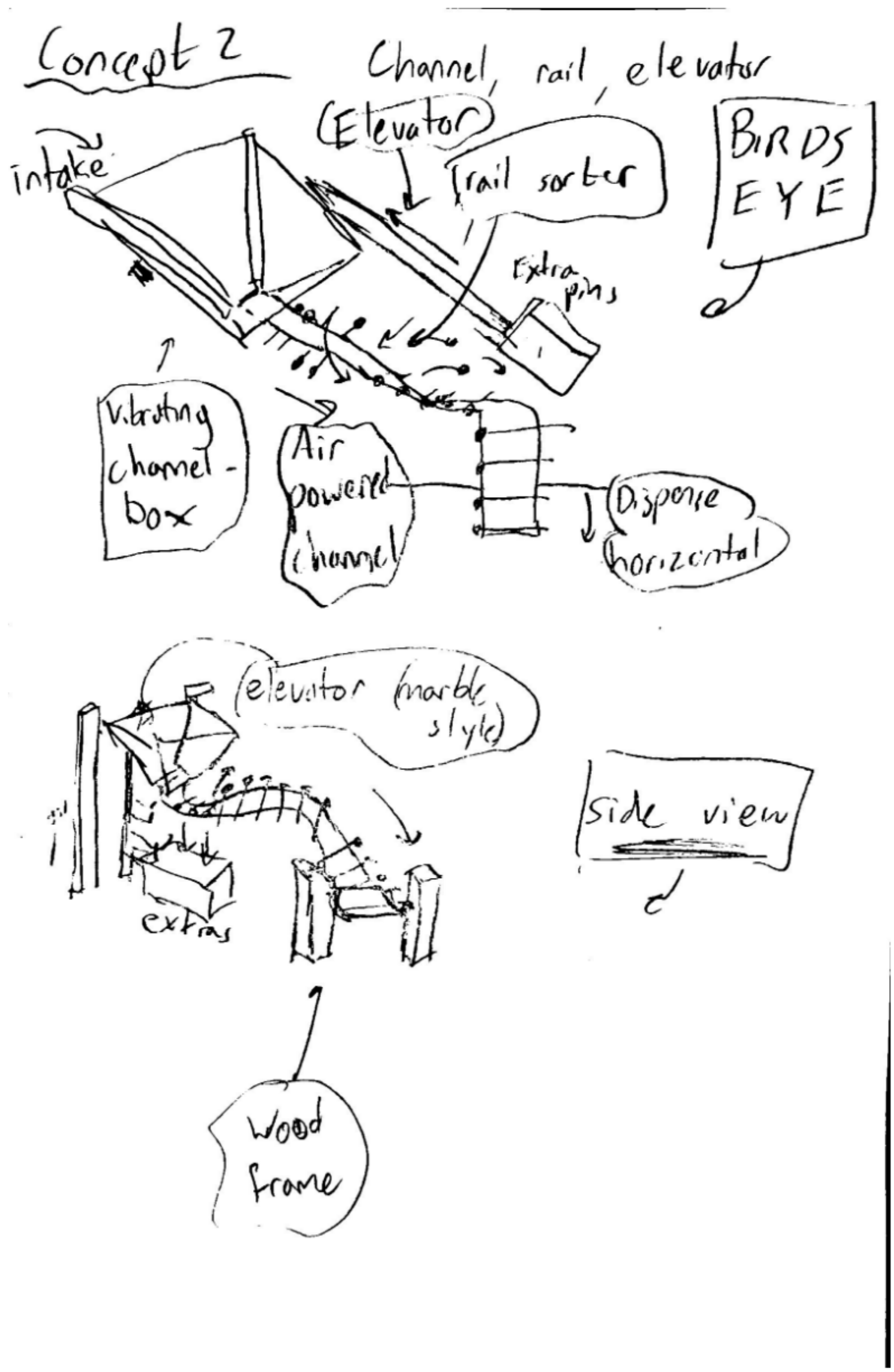


Figure 20: Initial Drawing, Various Views

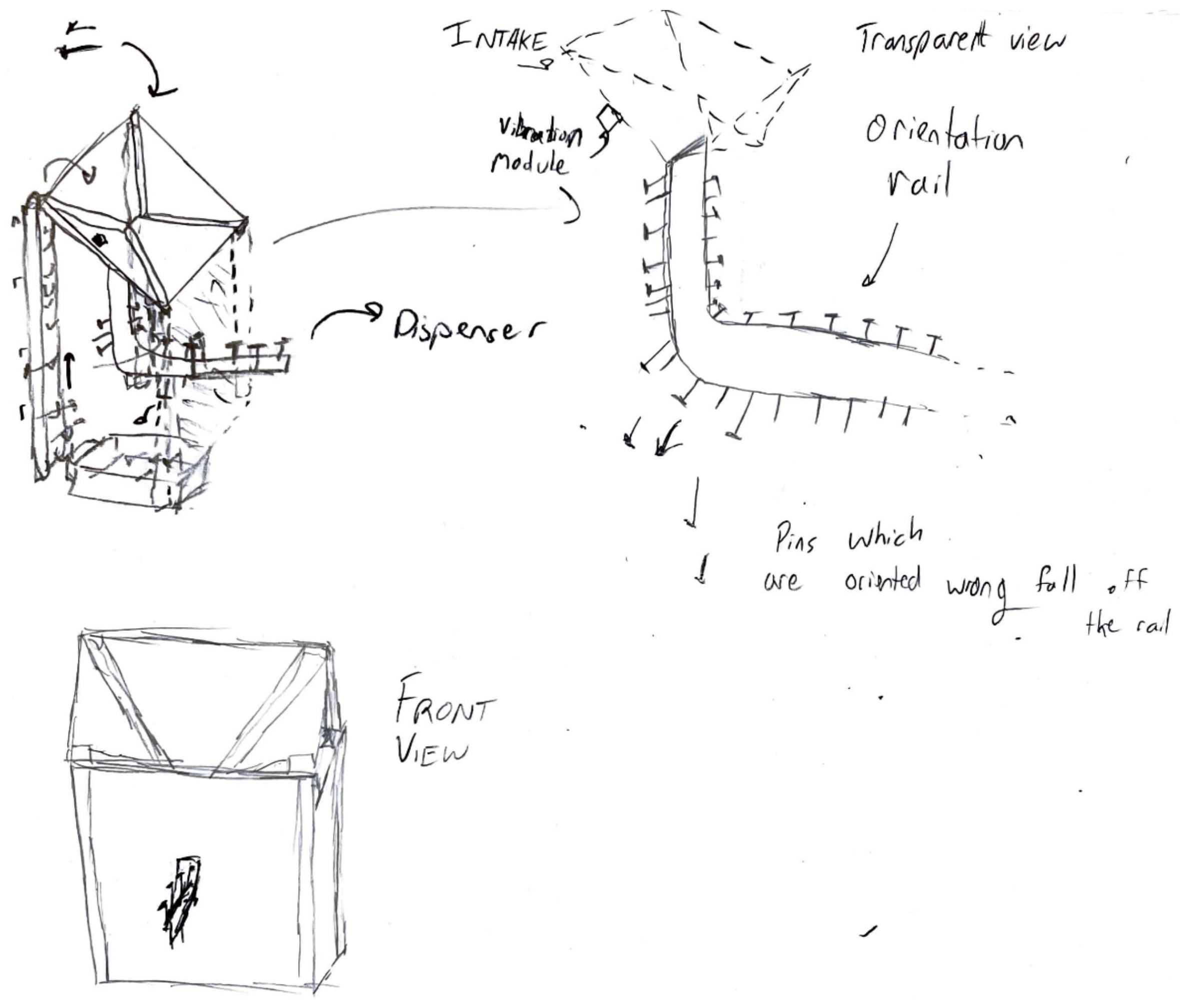


Figure 21: Final Drawing, Various Views

Solutions from morph chart:

1. Slanted, vibrating intake channel which aligns pins
2. Rail to catch correctly oriented pins
3. 'Marble elevator' system to recover dropped pins
4. 'Soda pop' style dispenser rail

Description: This concept uses a vibrating, flat surfaced, trapezoidal prism shaped intake bin, which simultaneously stores pins and orients them parallel to one another. The pins are fed into a rail that moves them by gravity. The rail pitches 90 degrees and dumps out all pins that entered it facing the wrong way. From there, the discarded pins fall into a bin which elevators them up back to the intake. The pins which made through the rail dispense vertically like a Dr. Pepper on the shelf.

3.4.4 Concept 4

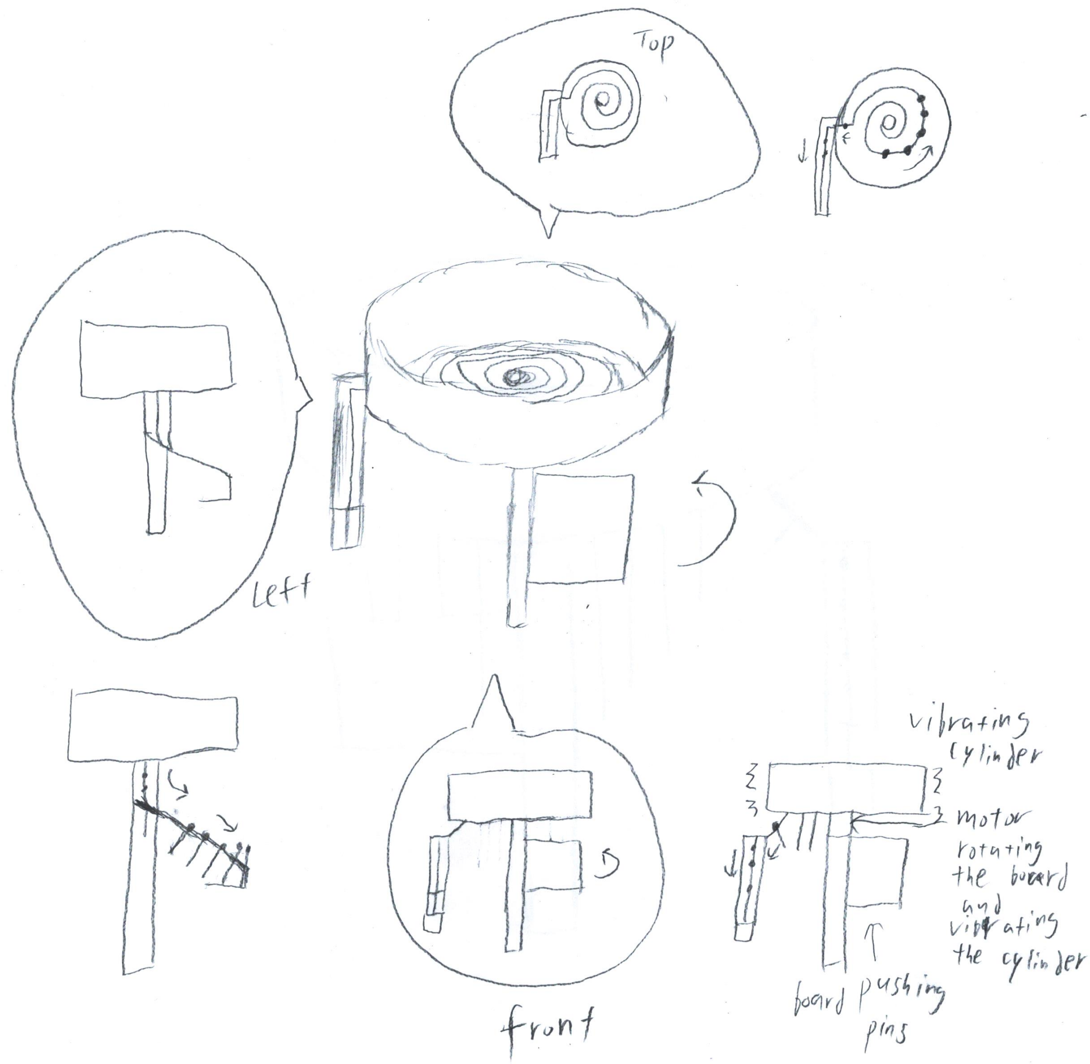


Figure 22: Preliminary sketches of Pin Dispenser concept

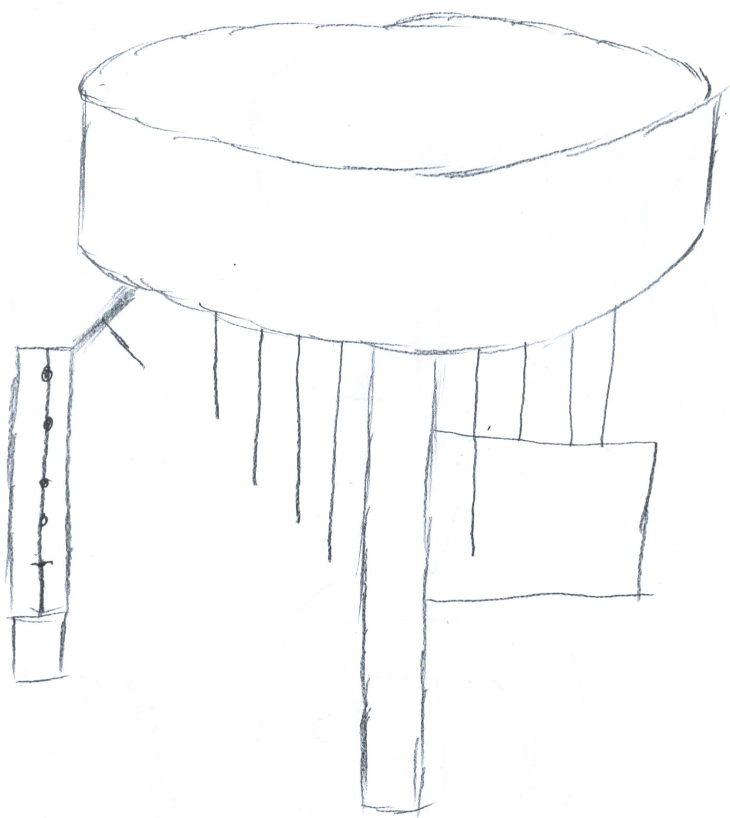


Figure 23: Final sketches of Pin Dispenser concept

Solutions from morph chart:

1. Vibrating cylinder to sort pins
2. Spiral shaped rail to make pins move through
3. Slide-rail system to orient pins heads up
4. Motor to spin the board and vibrate the cylinder
5. Bottom part to stop and to keep the pin away from the rail

Description:This concept uses a spiral shaped rail on a vibrating cylinder to align and move the pins. Being vibrated by the motor, the cylinder align the pins so the tips of the pins fall through to the spiral shaped gap. Then, the board being rotated by the motor moves the pin to the end of the spiral. When the pin reaches to the end, the pin slides out of the cylinder by the slopes. With the momentum from sliding down, the pin goes through the bottom part and stops at the end of the rail, which will make the pin be ready to be picked up by two fingers.

4 Concept Selection

4.1 Selection Criteria

The Analytical Hierarchy Process is used to form a picture of the most important aspects of the design. In the table below, each design criterion is weight against each other criterion to give a total weight value for each. The top three important aspects of the pin dispenser are consistent pin orientation, ease of un-jamming the dispenser in the event of a jam, and ability for the machine to handle a bit of thread without jamming.

	Portable	Reasonable Size	Consistent Orientation	Handles thread without jamming	Doesn't damage pins	Easy to unjam	Dispenses quickly	Handles various pin lengths	Can intake a large number of pins	Row Total	Weight Value	Weight (%)
Portablility	1.00	1.00	0.11	0.14	0.33	0.14	0.14	0.33	0.20	3.41	0.02	2.06
Reasonable Size	1.00	1.00	0.14	0.14	0.20	0.20	0.33	1.00	0.33	4.35	0.03	2.63
Consistent Orientation	9.00	7.00	1.00	5.00	3.00	3.00	3.00	5.00	3.00	39.00	0.24	23.57
Handles thread without jamming	7.00	7.00	1.00	1.00	0.14	1.00	1.00	7.00	3.00	28.14	0.17	17.01
Doesn't damage pins	3.00	5.00	3.00	1.00	1.00	0.33	3.03	5.00	5.00	26.36	0.16	15.93
Easy to unjam	7.00	5.00	3.00	0.33	3.00	1.00	3.00	7.00	0.33	29.66	0.18	17.92
Dispenses quickly	5.00	3.00	1.00	0.14	0.33	0.14	1.00	1.00	1.00	12.62	0.08	7.62
Handles various pin lengths	3.00	1.00	0.20	0.20	0.20	0.14	1.00	1.00	0.33	7.08	0.04	4.28
Can intake a large number of pins	5.00	3.00	1.00	0.33	0.20	0.33	1.00	3.00	1.00	14.86	0.09	8.98

Figure 24: Analytic Hierarchy Process (AHP) to determine scoring matrix weights

4.2 Concept Evaluation

Concept 1 is the winner of the weighted scoring matrix. The criteria and the weighted percentages from the analytical hierarchy process were used in the weighted scoring matrix. Each concept was ranked against each other in order to decide the overall best idea.

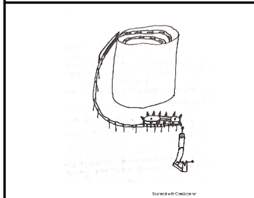
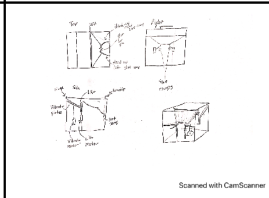
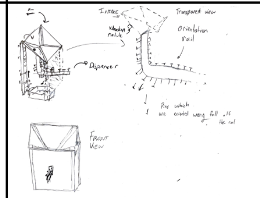
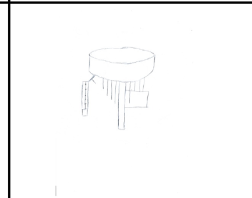
Alternative Deisgn Concepts		**Concept #1**		**Concept #2**		**Concept #3**		**Concept #4**	
									
Selection Criterion	**Weight (%)**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**
Portability	2.06	3	0.06	5	0.10	2	0.04	1	0.02
Reasonable Size	2.63	3	0.08	2	0.05	1	0.03	3	0.08
Consistent Orientation	23.57	5	1.18	5	1.18	5	1.18	5	1.18
Handle Thread w/out Jamming	17.01	5	0.85	5	0.85	5	0.85	5	0.85
Doesn't Damage Pins	15.93	5	0.80	3	0.48	3	0.48	5	0.80
Easy to Unjam	17.92	5	0.90	3	0.54	3	0.54	5	0.90
Dispenses Quickly	7.62	5	0.38	3	0.23	3	0.23	5	0.38
Handles Various Pin Length	4.28	5	0.21	5	0.21	5	0.21	5	0.21
Intake Large Number Of Pins	8.98	5	0.45	5	0.45	5	0.45	5	0.45
	Total score	**4.906**		**4.092**		**4.004**		**4.865**	
	Rank	**1**		**3**		**4**		**2**	

Figure 25: Weighted Scoring Matrix (WSM) for choosing between alternative concepts

4.3 Evaluation Results

Based on our weighted scoring matrix, the average score of concept 1 was highest among all four concepts. It was rated a five out of five on seven of the nine categories. Concept 4 ranked a close second, followed by concepts 2 and 3. The results of our selection criteria prioritized consistent orientations, the ability for the user to fix jams easily, and the ability to handle threads without jamming most highly. Concepts 1 and 2 rated highly because they rely solely on the vibration of the machine to move and orientate the pins. Thus minimizing the chances pin damage. Additionally, their functionality does not rely as much on the geometry of the pin, allowing the user to potentially use different sized pins if needed. The basic idea behind concept 1 and 2 is similar, while concepts 3 and 4 also share many characteristics. Ultimately, the results of our concept evaluation is that there is additional work to be done in this area. The final concept will likely contain some traits of concept 1, while borrowing features from each of the other three.

4.4 Engineering Models/Relationships

4.4.1 Model 1: Friction

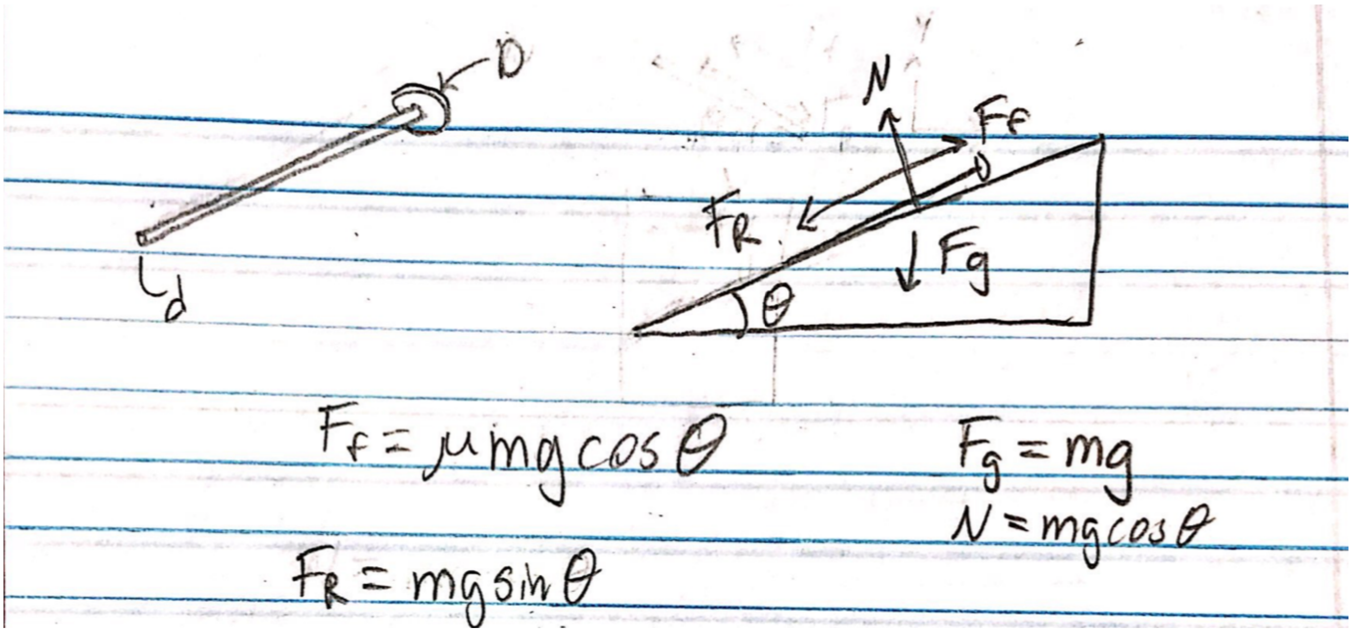


Figure 26: Slip angle equation

Equation 1 and 2 below shows how the plane angle and friction coefficient are related to the frictional force.

$$F_f = \mu mgcos(\theta) \tag{1}$$

$$F_R = mgsin(\theta) \tag{2}$$

Where F_f is the force due to friction (N), F_R is the reaction force of the pin due to gravity. μ is the friction coefficient (unitless), m is the mass of the object (the pin in this case), g is the acceleration due to gravity (m/s^2), and θ is the angle of the plane above horizontal (degrees or radians). This equation is relevant to the pin dispenser because inclined planes are likely to be used in our design and it is necessary to know if pins will slide on the surface of the plane if they are clean, or if they have some sort of debris on them such as a thread or dirt.

4.4.2 Model 2: Magnetism

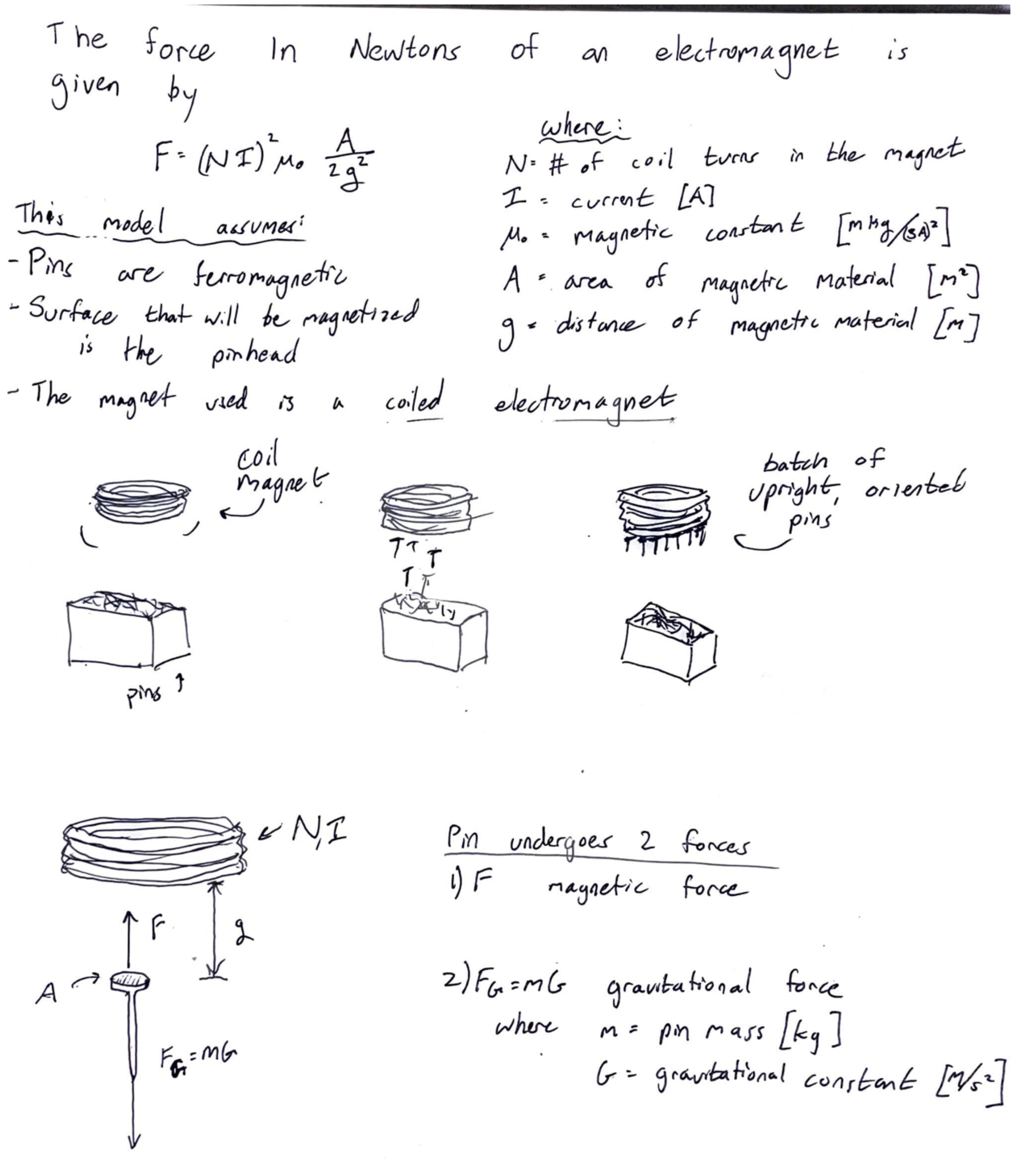


Figure 27: Magnetic model

Shown above is the electromagnetic force on a pin as a function of current, magnetic coil wraps, magnetic constant, area of pin head, and distance of pin from magnet [1]. This equation can be used in conjunction with the gravitational force equation to determine the needed magnetic strength just strong enough to lift a pin. The process of magnetic lifting of pins is multifaceted. Magnets can be used not only to transport the pins from a pile on to a ramp or dispensing channel, but also to sort them head-up.

4.4.3 Model 3: Pin bending

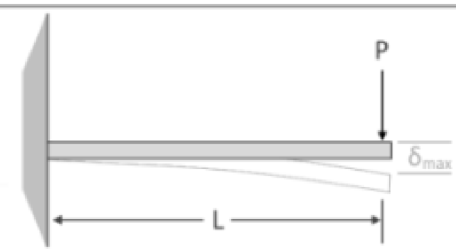
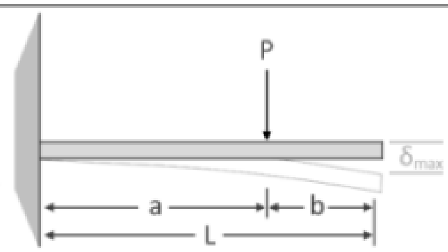
	$\delta_{max} = \frac{PL^3}{3EI}$
	$\delta_{max} = \frac{Pa^2(3L-a)}{6EI}$

Figure 28: Cantilever beam bending equations applied for pin bending

Equation 3 and 4 below shows equation for the bending of the cantilever beam. When applied to the pin, the equations will shows how beam will bend by the load.

$$\delta_{max} = \frac{PL^3}{3EI} \tag{3}$$

$$\delta_{max} = \frac{Pa^2(3L-a)}{6EI} \tag{4}$$

Where δ_{max} is the maximum deflection (m), a is the distance between the head of the pin and the point of the load (m), b is the distance between the tip of the pin and the point of the load (m), P is the point load (N), E is the modulus of elasticity of the material of the pin (Pa), I is moment of inertia based on the inner diameter of the pin (m^4), and L is the length of the pin (m) [2].
To be precise, these are the equations for the bending on the cantilever beams. However, due to extremely small diameters of the pin, the equations will be able to be utilized to figure out the bending of the pins. For the most of the time, it can be considered as that the head of the pin will be hold, and the tip or the middle of the pin will take load. Considering the wall as the head of the pin and the tip of the beam as the tip of the pin, it will be possible to estimate the bending on the pin.

5 Concept Embodiment

5.1 Initial Embodiment

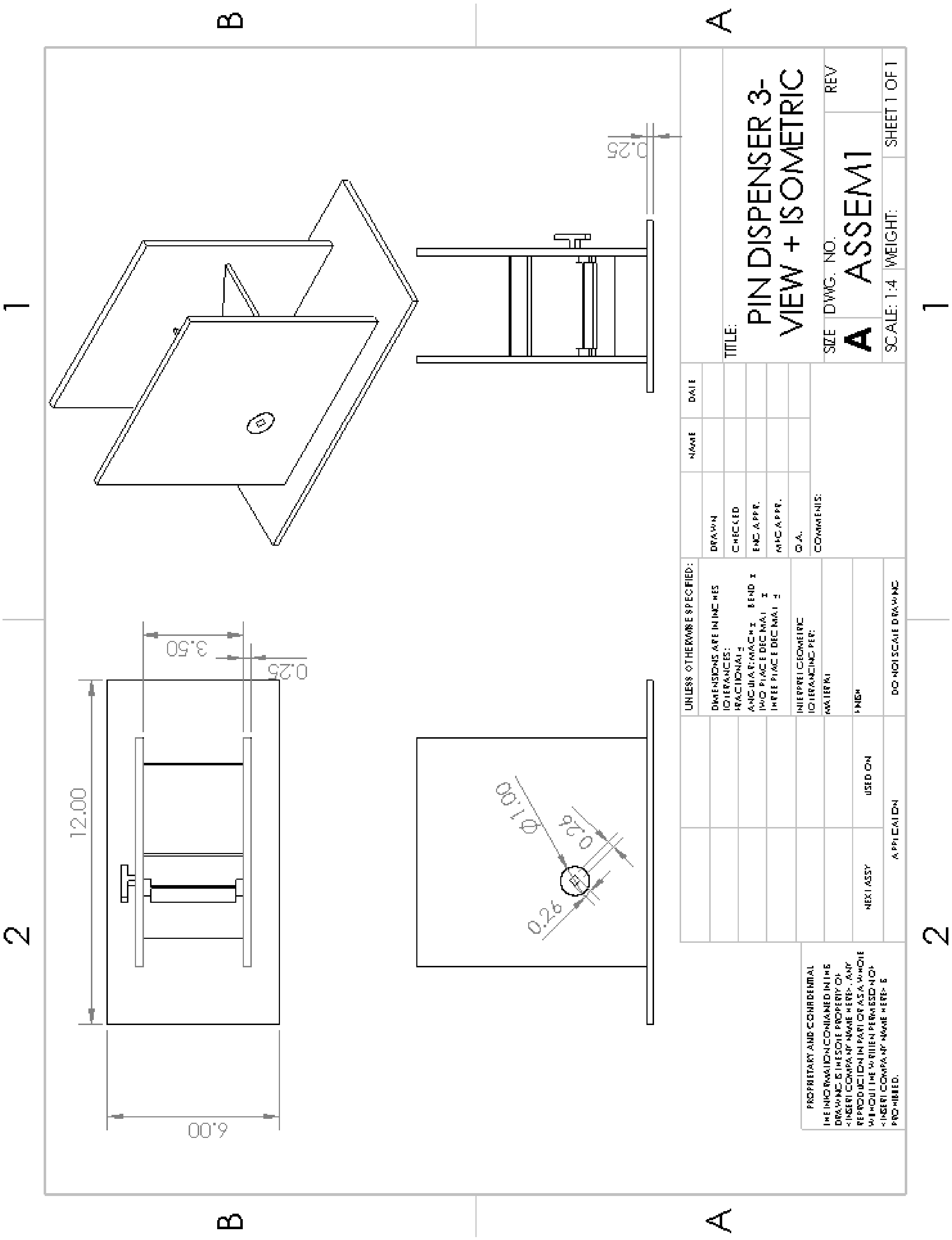
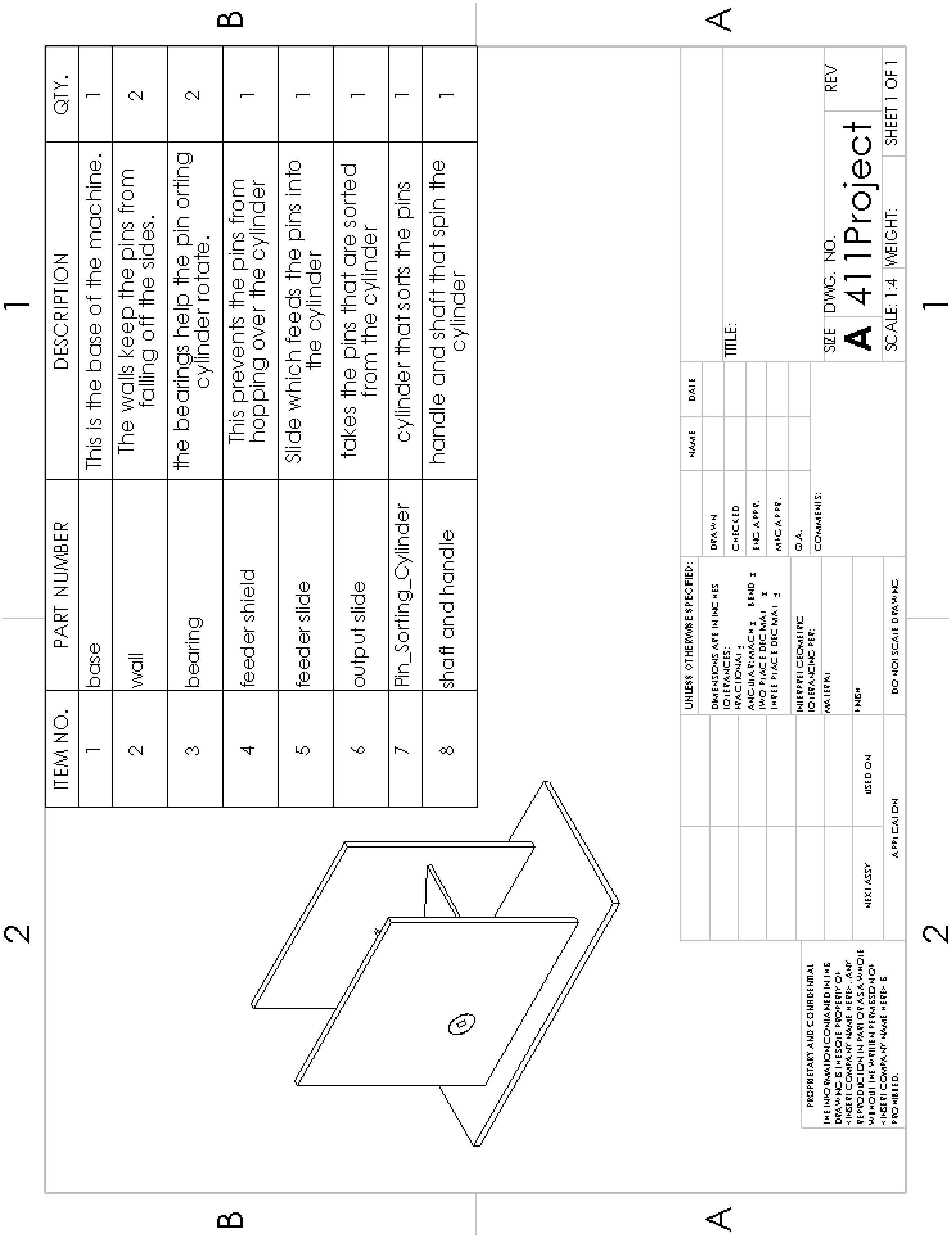


Figure 29: Assembled projected views with overall dimensions



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	base	This is the base of the machine.	1
2	wall	The walls keep the pins from falling off the sides.	2
3	bearing	the bearings help the pin orting cylinder rotate.	2
4	feeder shield	This prevents the pins from hopping over the cylinder	1
5	feeder slide	Slide which feeds the pins into the cylinder	1
6	output slide	takes the pins that are sorted from the cylinder	1
7	Pin_Sorting_Cylinder	cylinder that sorts the pins	1
8	shaft and handle	handle and shaft that spin the cylinder	1

Figure 30: Assembled isometric view with bill of materials (BOM)

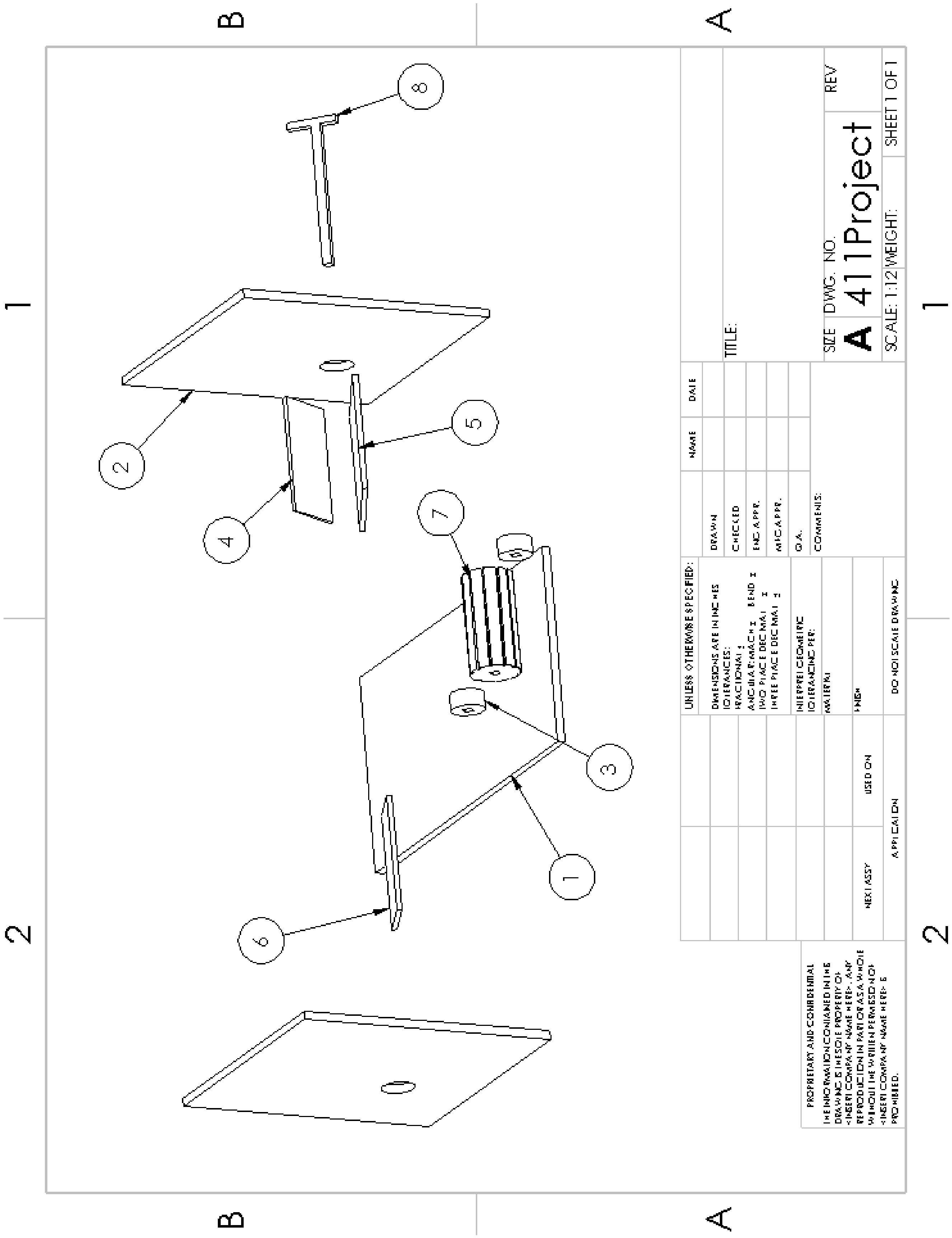


Figure 31: Exploded view with callout to BOM

5.1.1 Prototype Performance Goals

The main goal of this prototype is that it has to automatically sort and realign the pins so that the pins can be picked up by one hand one at a time. The pins to be sorted was the dressmaker pins. Unlike other regular pins whose heads are round or easy to be picked up, they have flat heads, which makes them hard to be picked by just one hand. The length of the pins is 1 1/4". The overall shape of the pins were more like nails. The radius of the needle and the head of the pins were so small that it could not be measured by the equipment provided. So, hundreds of the pins can be easily tangled when stored into a box, and it can damage the user when trying to sort the pins with bare hands. But, customer needed these pins often, which requires many number of pins in long time. Thus, three performance goals were set for this prototype. The first goal is that this device should have more than 90 percent of accuracy. The device should orient 9 pins correctly when dispensing 10 pins. Secondly, the prototype should be able to handle at least 50 pins at the same time. Lastly, the prototype should be able to dispense one pin at most in one second.

5.2 Proofs-of-Concept

.

Differences between concept selection and prototype

The prototype has significant changes from the concept selection. Although the cylindrical sorter system ranked highest in concept selection, it proved difficult to build in the shop. This was mainly because a rail system needs high precision, and the high precision tool available, 3-d printing, was not able to make such a complex and large structure. So our prototype revolves around 3d printing limits. Rather than use a cylinder with rails on the inside like in the concept selection, it was better to use a cylinder with slots cut out on the outside to individuate pins, like a toothpick dispenser.

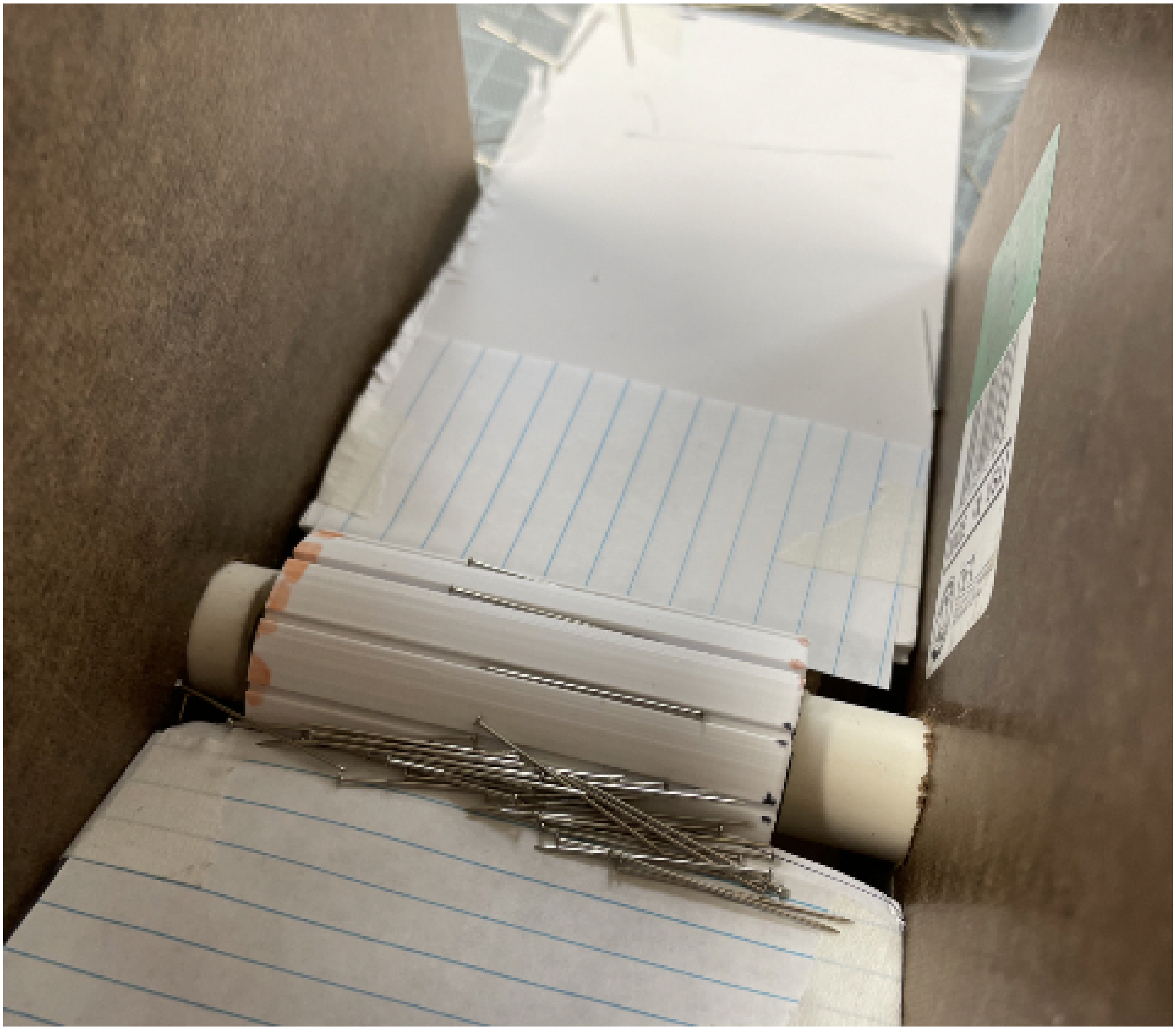


Figure 32: Overhead view of the prototype's cylinder. Look closely to see pins individuated within the cylinder.

Since the design of the pin sorter inherently revolves around the sorting mechanism, the prototype was built out from the toothpick dispenser mechanism. This resulted in the re using of the gravitational feed system from the previous concepts.

6 Design Refinement

6.1 Model-Based Design Decisions

6.1.1 Friction Design Rational

The pin dispenser uses gravitational energy of pins to move them down along the sorting track. In fact, about 90 percent of the pins' travel happens by sliding on an inclined ramp. Therefore, it is important that the friction between the pins and the ramp do not stop the movement under any circumstance.

It is assumed that Melanie's pins are nickel plated steel. PLA is the 3D printed ramp material. PLA on steel has a coefficient of friction of 0.4-0.6 [3], and knowing that nickel has a generally lower coefficient of friction than steel [4], it is assumed that the highest coefficient of friction encountered will be less than $\mu = 0.5$

The component of gravitational force pulling the pin down must be greater than the frictional force or the pin will not slide. Therefore using calculations from equation (1) and (2) from section 3.4.1,

$$F_f = \mu mgcos(\theta), F_R = mgsin(\theta) \tag{5}$$

$$F_f/F_R < 1 \tag{6}$$

$$F_f/F_R = 1 = \mu/tan(\theta) \tag{7}$$

$$\theta > 26.6^\circ \tag{8}$$

26.6° is the minimum angle needed to ensure pin transport. This dimension is partially responsible for the high (8") height of the pin sorting cylinder.

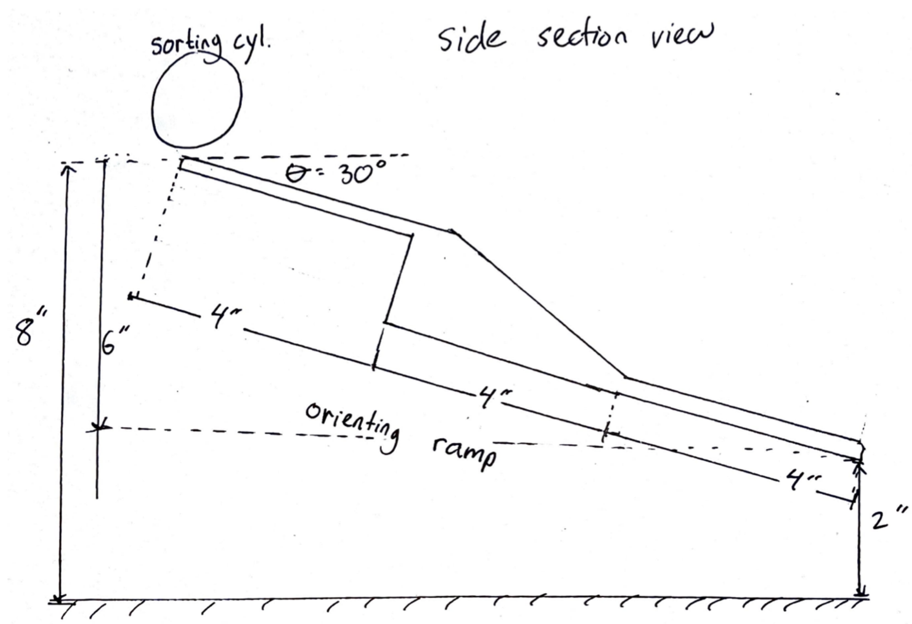


Figure 33: Ramp angle based on engineering model.

Fig.33 shows that our design used an angle of 30°, which works comfortably well and ensures no pins jam as a result of gravity induced friction.

6.1.2 Cylinder Slot Design Rational

The dispenser is designed to not bend or break any pins, because a broken pin would pose an even greater loss in efficiency than not using the machine at all. For this reason, the sorting mechanism utilizes non-forceful means to orient and dispense.

Pins are most vulnerable to damage through bending. Therefore the design intentionally applies little to no bending stress to any pin. To ensure the machine doesn't apply too much force, the highest stress area can be mathematically examined. This area is the dispensing rail, which holds the pin near the head while the user pulls the pin out with their hand.

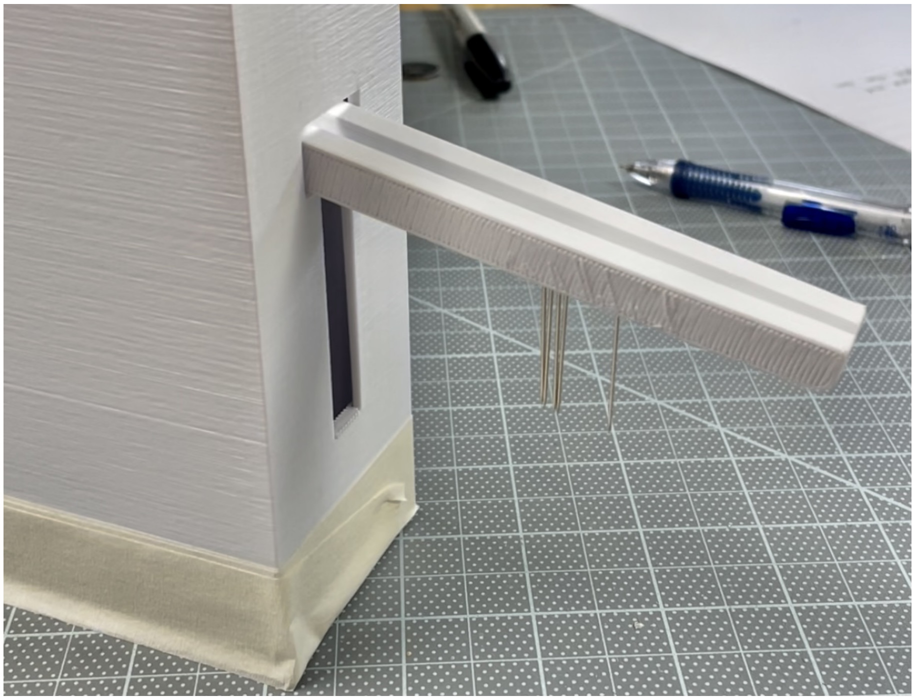


Figure 34: Prototype 2 dispensing rail with 5 pins hanging from it.

To estimate max deflection of the pin body, it is assumed that the pins in this rail can be treated as a two-pin supported rod with a point force and a point moment acting to pull the pin out on the needle side of the pin. The first support on the rod is the dispensing rail which squeezes the pin to hold it in place. The second support on the rod represents the finger of the person grabbing the pin, making the bottom of the dressmaker pin supported even though not by the dispensing machine itself. This is similar but not identical to the model in section 4.4.3.

It is also assumed that only 1 inch of the pin experiences the stress, because a users hand will not grab perfectly at the base of the pin. It is reasonable to assume that no more than *1mm* of deflection should be acceptable. The final assumption is that the pin is pulled out with a 2lb force.

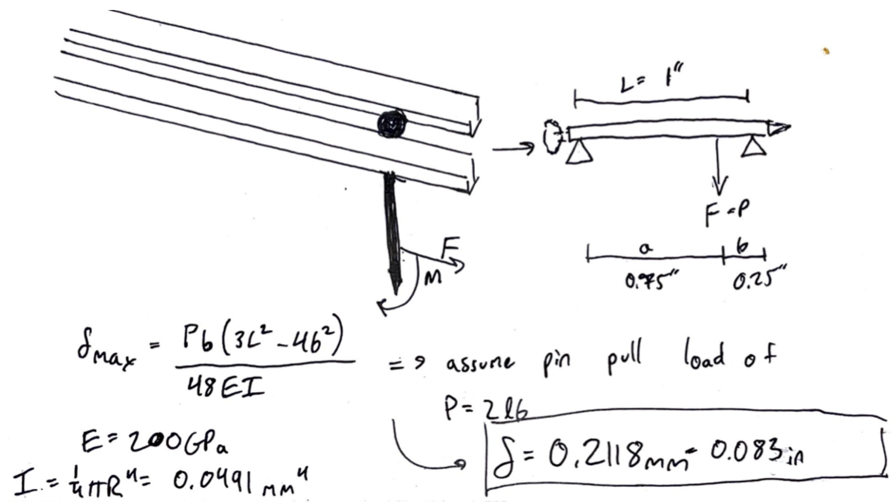


Figure 35: Amount of bending deflection experienced at the highest stress section of the rail.

Based on the shown bending calculation, a pin will bend negligibly under a 2lb force of removal from the dispenser.

6.1.3 Automation System Specification Design Rational

One of the last elements added to the Mighty Cylinder Pin Dispenser was an automation system. A simple DC motor circuit drives a belt to the main sorting device. Assuming 50 percent of work is converted to friction, an electrical and work model is needed to decide if the motor meets the design requirements, and what batteries it needs. Assume that just to spin the cylinder, the motor needs 1ft-lb of torque, which is overshooting for the case of a jam.

A variable speed motor was selected. The motor's rotor is geared such that it spins the sorting cylinder with the same angular velocity. Assume that the sorting cylinder picks up a pin 1/3 of the time a slot passes by the pin jumble.

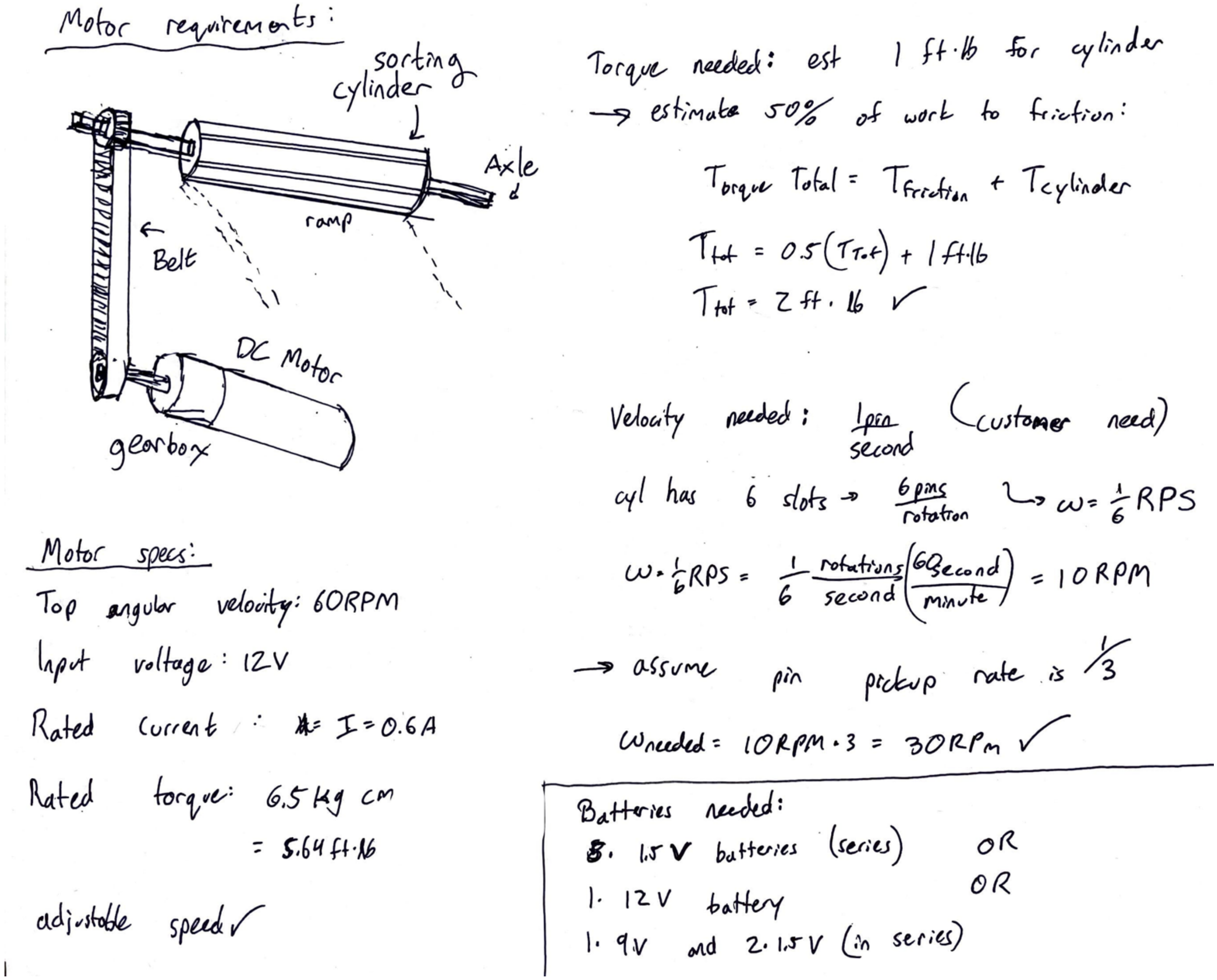


Figure 36: Circuit Development Model

According to this model, the motor is fast enough and powerful enough to meet the requirements of the project by a factor of 2 for both angular velocity and torque. The batteries needed must only supply minimal current (therefore store bought batteries are OK) but must produce at least 12V.

6.2 Design for Safety

For this device, five risks have been identified. Each of the five are listed below, along with a brief description of the risk, their severity should the failure occur, the likelihood of failure occurring, and the steps taken to mitigate the risk.

6.2.1 Risk #1: Stabbed by Pin

Description: Pins which are jammed or dispensed in the incorrect orientation could poke the user and cause pain.
Severity: Marginal
Probability: Likely

Mitigating Steps: Provide redundancies which force the pin to be orientated head down before falling into rail. This ensures that, even if the pin does not correctly fall into the rail, at least the head will be facing towards the user. Also, the rails are designed so that the point of the pin will fall through and the head can not. Thus, either the pin will not fall through at all, or it will be in the correct orientation.

6.2.2 Risk #2: Motor catches fire

Description: A motor which overheats or a wire which is frayed could start a fire or melt part of the dispenser.
Severity: Catastrophic
Probability: Unlikely
Mitigating Steps: Make the container from something non-flammable.

6.2.3 Risk #3: Device falls off table

Description: Vibrations from the motor could gradually push the device off the table which it is sitting on.
Severity: Marginal
Probability: Occasional
Mitigating Steps: Place rubber bumpers on the bottom of the device.

6.2.4 Risk #4: Pins are dispensed but not contained

Description: Pins are released by the dispenser and fall onto the table or floor. These pins are so small it would be extremely difficult to see them on carpet and could easily be stepped on.
Severity: Marginal
Probability: Occasional
Mitigating Steps: Add a tray below the dispensing location to catch any dropped pins.

6.2.5 Risk #5: Damages pin head so that both ends are sharp

Description: During the sorting process, the head of the pin is cut off. That end may or may not be sharp.
Severity: Marginal
Probability: Unlikely
Mitigating Steps: Do not include any processes which apply a force large enough to pull the head of a pin off.

		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**					Motor catches fire
	Critical					
	Marginal		Stabbed by pin	Falls off table Pins are dispensed but not contained		Damages pin head so that both ends are sharp
	Negligible hazard presents a minimal threat to safety, health, and well-being of participants; trivial					

Figure 37: Risk Assessment Heat Map

Based on the results of this heat map, it seems as though the risk of the user being stabbed by a pin, and the risk of the motor catching fire should be prioritized highest. The risk of the user being stabbed by the pin is chosen because of its high likelihood status, meaning that it is is expected to occur frequently during use. The motor catching fire is chosen because of its catastrophic implications. If the device were to catch fire, particularly when used in close proximity to other sewing materials, it is likely that a fire could spread quickly. Below these two highest priorities, the risk of the device falling off a table and the risk of pins being dispensed but not contained should be prioritized next. Both of these may occur occasionally, but the implications of these failures are relatively low. Damages to the pin head so that both ends are sharp should be considered with lowest priority. While this risk has marginal implications, it is unlikely that it would occur.

6.3 Design for Manufacturing

Based on the most recent design, the manufacturing would consist of the following:

Number of Parts: 13
Number of threaded fasteners: 3

The most recent assembly of the prototype contains only nine of the thirteen total parts. These nine parts are labeled in Fig. 38 below.

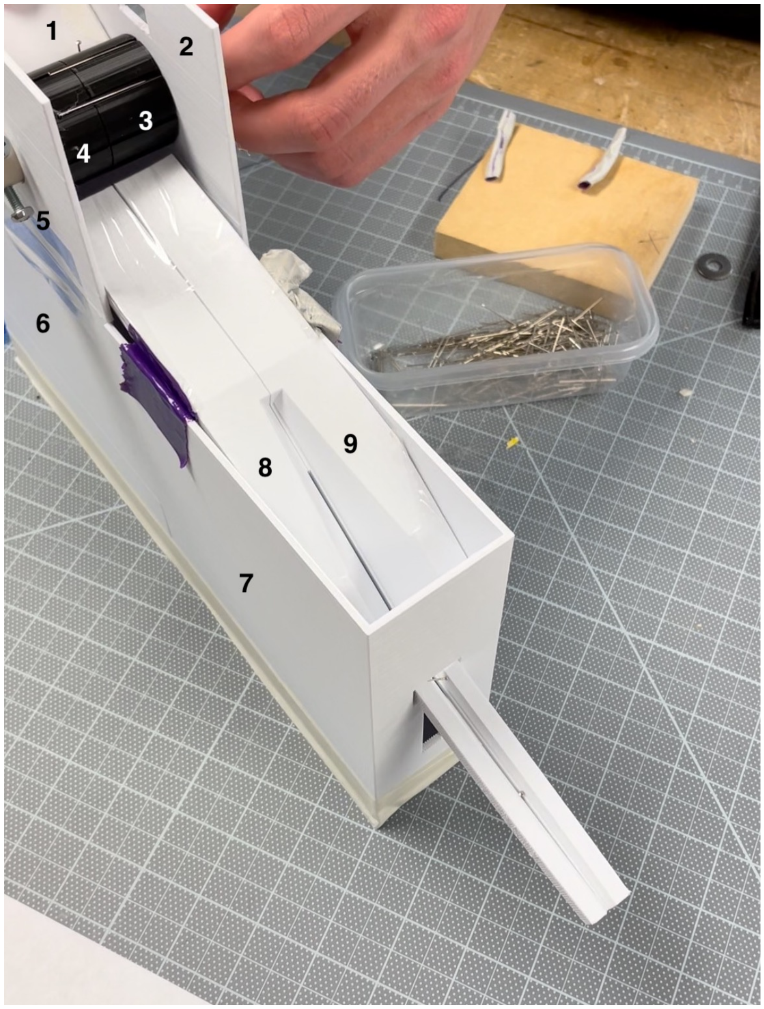


Figure 38: Numbered parts 1-9 of pin dispenser

In this figure, parts 2, 6, and 7 could be combined into one part. They are the body of the device, also called the 'box.' However, when made with a 3D printer, it was necessary to print them as three separate pieces.

The theoretically necessary components (TNC), are as follows:
(following numbers do not correspond with Fig. 38)
1. A box with a ramp at the top for pins to be loaded onto
2. A ramp with a rail at the bottom for pins to be dispensed
3. A precision cylinder which will individualize the pins
4. An axle
5. Two wheel bearings on which the axle will rotate
6. A motor
7. A pedal which will turn the motor on and off
8. Two gears to transfer the power from the motor to the axle.

It is necessary for the cylinder to be separate from the box because it must be able to rotate. Similarly, each wheel bearing must support the cylinder so that it remains at a constant horizontal and lateral position relative to the box but is allowed to rotate freely. The motor must be a separate piece because it will be made out of several different materials than the rest of the device.

Ideally, the main body would be manufactured as a single component. This would reduce assembly time, reduce the total number of components, and limit fitting problems that could result from tolerance stack-up. Theoretically, it would be possible to print the box and both ramps as one piece (labeled parts 1, 2, 6, 7, 8, and 8 above). However, it would likely be easier from a manufacturing perspective, and a maintenance perspective, if they were decoupled into separate pieces. When operating with objects as small as dressmaker pins, it is likely that one will get jammed at some point. If the ramps and the box were manufactured as separate pieces, it would be possible to disassemble the device and fix the jam. The process of fixing a jam may be difficult if the ramps and box were manufactured as a single device.

6.4 Design for Usability

The dispenser is designed to be comfortable to use. The usability of the device depending on the impairments of the user is assessed below.

6.4.1 Impairment #1: Vision Impairment

Most of vision impairments will not be critical for the usability of the device. The color of the device is mostly white or black, so the color blindness will not influence the usability of the device. If the user has extremely low vision or blind, it will be critical for usability, since the user cannot see the pins. However, as long as the user can see the device and pins clearly, regardless of colors, there will be nothing harmful for the usability of the device.

6.4.2 Impairment #2: Hearing Impairment

All of the hearing impairments will not be critical to the usability of the device. Even if the user cannot hear at all, there will be no severe problem with using this device. The only problem is that the user will not be able to check if the device is working well by hearing the motor running and the pins rolling without looking at the device at most.

6.4.3 Impairment #3: Physical Impairment

Most of physical impairments will not be critical to the usability of the device. If the user cannot use their legs, since the pedal is movable, the user can press the pedal by using the arms. If the user cannot use their arms, it will be impossible to pick up the pins. However, if the user is good at using their feet, they may still have enough dexterity for the machine. As long as the user is comfortable sewing, which the Mighty Cylinder Dispenser is meant to assist, there will be no serious problems.

6.4.4 Impairment #4: Control Impairment

Most control impairments will not be critical to the usability of the device because the device is automatic as long as the user pushes the pedal and can drop in a jumble of pins. The device will be usable for most of the situations, regardless of the body conditions of the user. If the user is extremely tired, dizzy, or has hand tremors, there will be only minor problems using the machine.

7 Final Prototype

7.1 Overview

Below is a brief overview of the third and final prototype of the Mighty Cylinder Pin Dispenser. This section will detail new improvements compared to past prototypes, evaluate the success of the final prototype based on a live demonstration during the final presentation, and lastly share some customer insight and feedback.

Below are images of the final prototype with and without the lid on.

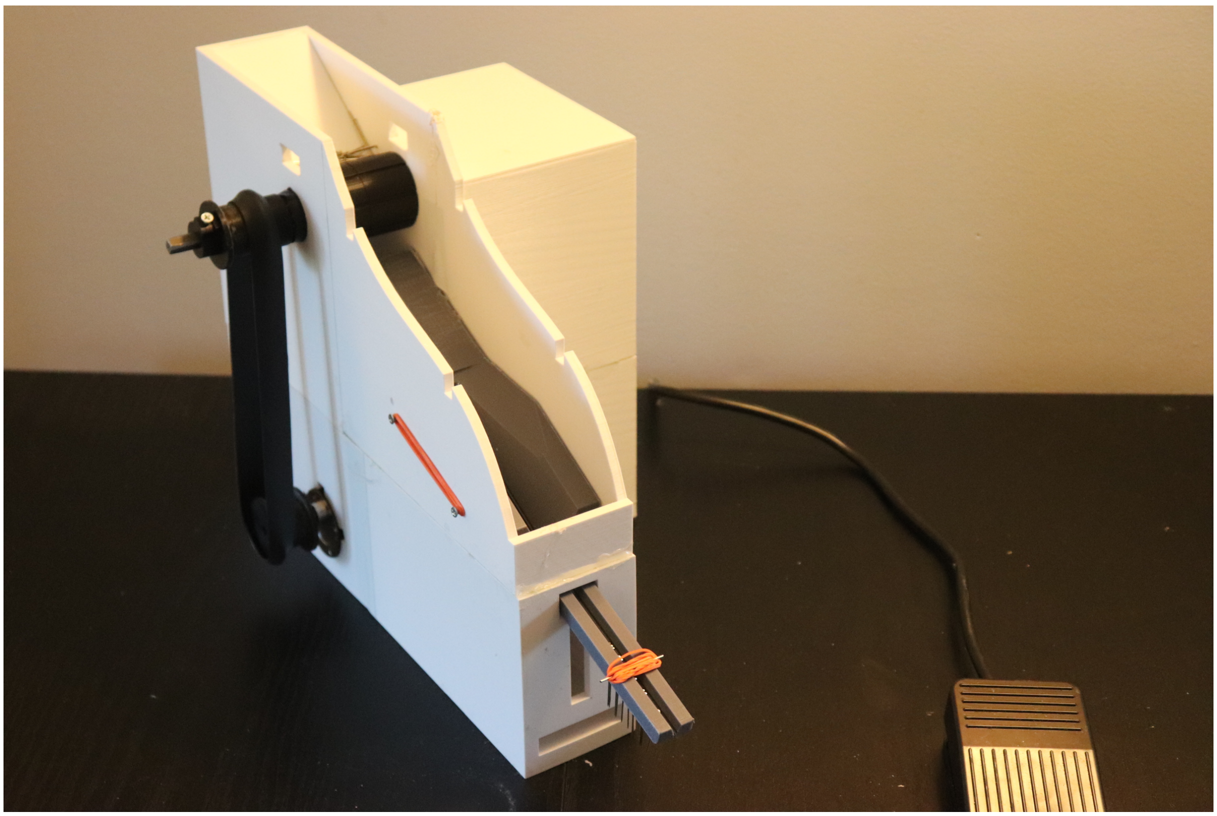


Figure 39: Final assembly with no lid. Dispensed pins are visible on the dispensing rail.

Figure 40: Final assembly with lid on

7.2 Improvements From Past Prototype

Past prototypes used a wide ramp to allow room for pins to slide and re-orientate themselves. They also used paper to keep pins from falling through spaces between the feed ramp and the sorting cylinder. Additionally, there were lots of gaps where the parts fit together, there was no real dispensing mechanism, and the movement of the cylinder was done manually by the user. A CAD drawing and a top view of an early prototype is shown below in Fig. 41 and Fig. 42.

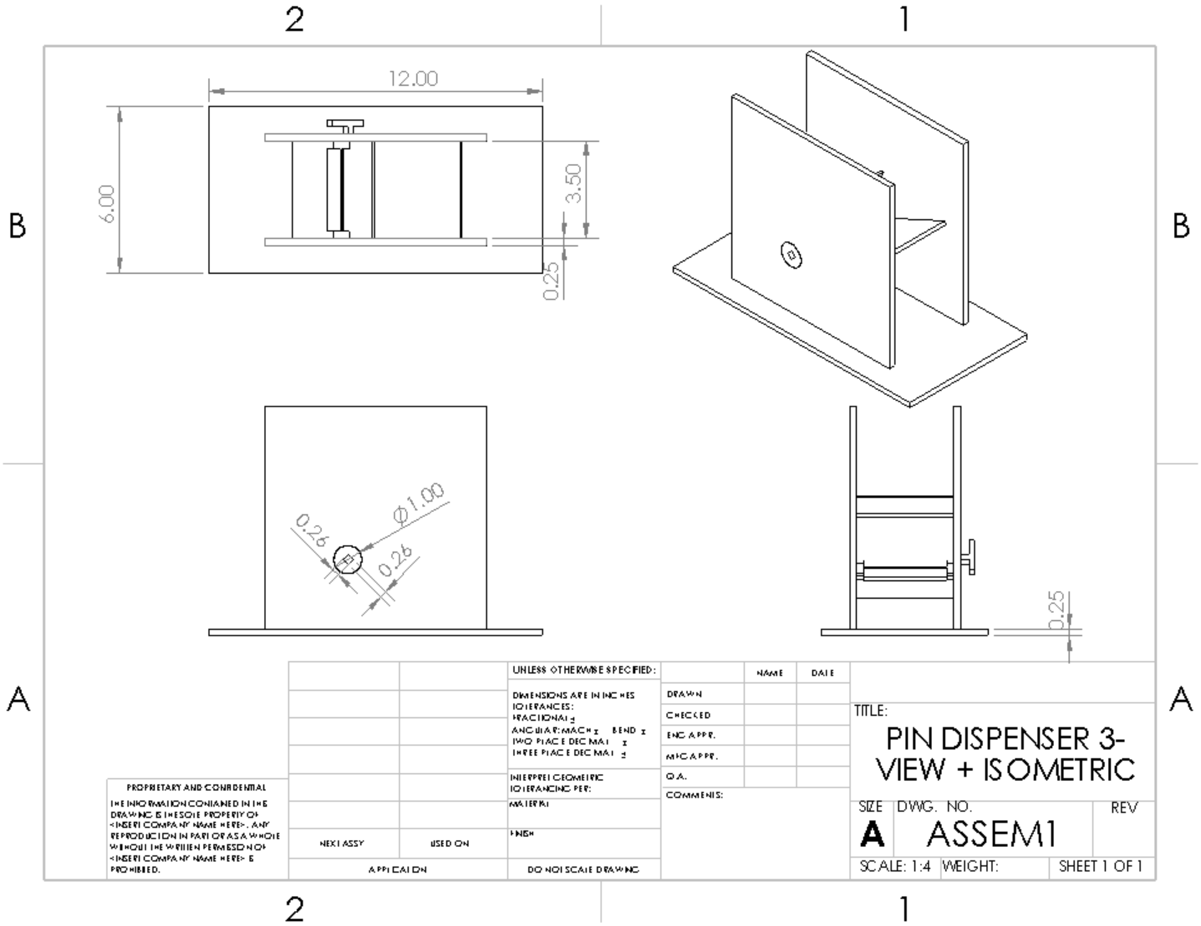


Figure 41: Early Prototype CAD Assembly Drawing

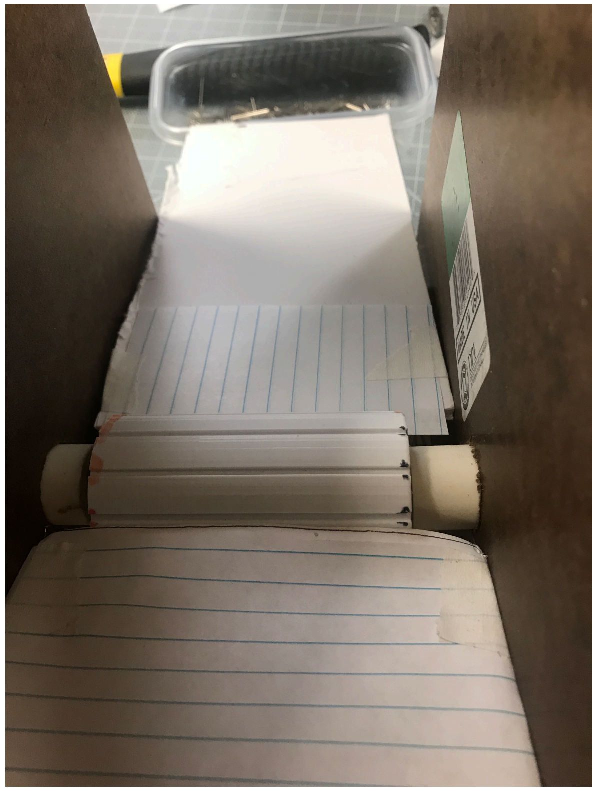


Figure 42: Early Prototype Top View

The final prototype improved upon this early iteration in several ways. Firstly, existing parts were redesigned in CAD to create tighter fittings between parts, allow ramp to orientate pins in a more consistent manner, and dispense them so that the user could more easily remove them from the device. Additionally, spaces were added at the bottom so that the user could easily remove any pins which fell down below the ramp or cylinder. Lastly, a cylindrical cut was made so that a motor could be added and a box was connected to house electrical components. A CAD image of this redesign is shown below in Fig. 43

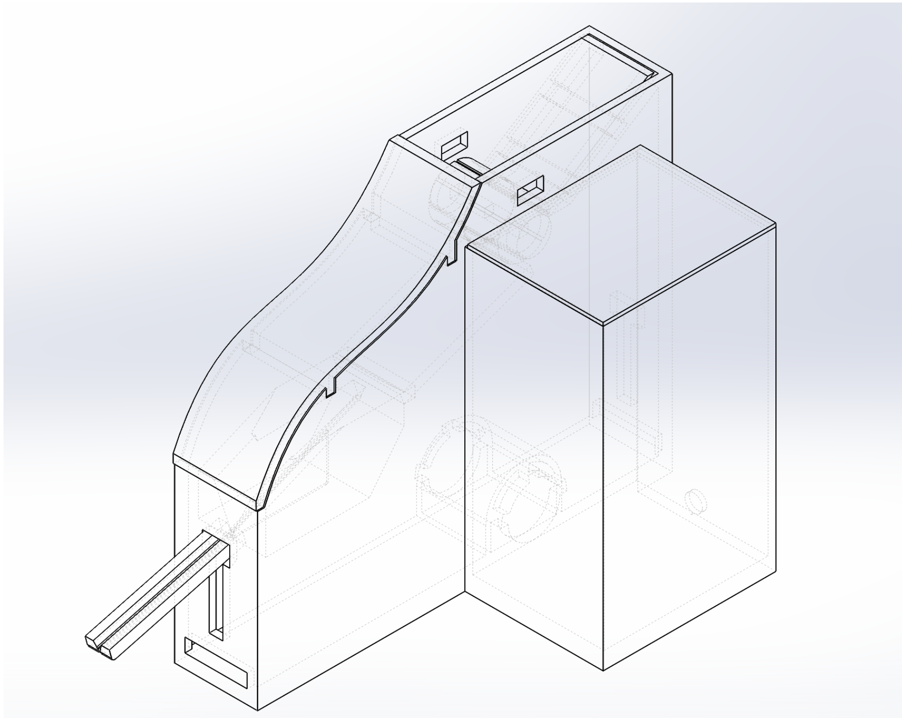


Figure 43: Final CAD Assembly

For the final prototype, most parts were made from PLA using a 3D printer. Printing allowed part fittings to be much more precise than they had been in previous prototypes which were made from a combination of PLA, wood, PVC, paper, and cardstock.

The sorting cylinder of the final prototype is turned by a 12 Volt DC motor which is powered by two A23 batteries in parallel. A foot pedal with an 8' extension switches the motor on and off. The voltage to the motor is dampened with a 12V LED dimmer, which allowed perfect tuning of the angular speed, which is optimally about 40RPM. A tension band was added to the end of the dispensing rail to keep pins from falling off the rail while also allowing the user to easily remove them with one hand.

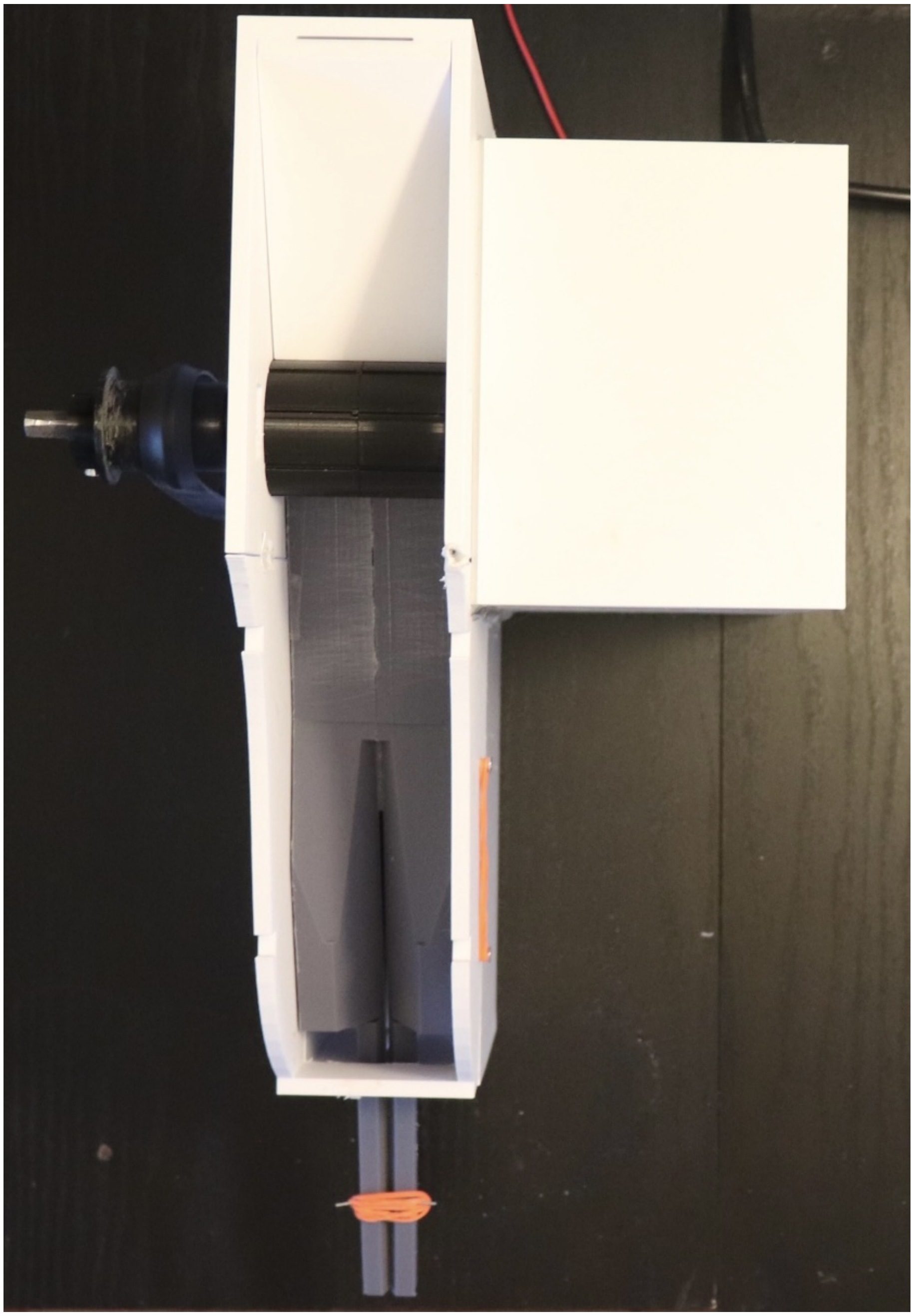


Figure 44: Final Prototype Top View

The changes implemented make the final prototype much easier to use, more reliable, and more hands free than past versions.

7.3 Success Evaluation

During a live demonstration we loaded 101 pins and ran our machine for 21 seconds. We then counted how many pins were correctly and incorrectly oriented. This was done so we could demonstrate whether or not we have reached the goals we set for the machine. Firstly, being able to load 101 pins surpassed our goal of loading 50 pins. There was still plenty of room in the feeding ramp and we estimated that an entire box of 200 pins would easily fit. The total number of pins that was dispensed was 37. This exceeded the goal of dispensing 1 pin every second. Out of those 37 pins, 6 pins were incorrectly oriented. This was the only part of the live demo that failed criteria for the prototype goals.

Consistency is a big part of any successful product, which means that this prototype would need to go through the design process again. One other area of concern would be that the feeding ramp sometimes gets jammed and needs to be shaken to fix it. This did not happen during our live demo but it did happen during our practice sessions. Overall the prototype worked well, the only area that need improvement as of now are the feeding ramp jamming and the consistency of the pins orientation.

7.4 Customer Feedback

Melanie, our customer, saw a video of the final prototype. Her overall thoughts were positive, but there were some improvements needed. Details are below.

Critique comments:

- The pin dispenser can intake many pins at once, (probably up to 200) but Melanie would rather they be able to be dumped in all at once more haphazardly. Currently, a minimal but not negligible amount of effort is needed to delicately insert the pin jumble. A funnel, receptacle or other type of filter was suggested by Melanie to add to the machine.
- The pins are dispensed along a rail that doesn't hold them evenly spaced. It would be better if the spacing between the dispensed pins was even.

Positive comments:

- The dispensing height (3") is comfortable.
- The machine size and noise level is good.
- The foot pedal is a good, familiar actuation method.
- And most importantly, there is virtually no way to stab oneself when grabbing a pin dispensed from this machine, given that the user is familiar with the dispensing action of the device.

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