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Cloth Folding Machine

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Executive Summary

This project introduces the design process and design results of a cloth folding machine. Since clothes folding is always a tedious process for most people, it is a good idea to produce a machine that can reduce the work and time of folding clothes. The cloth folding machine is designed and produced by a group of three engineering students. The final product is designed for household use and is intended to compete against similar existing products. The design process includes research in background information and relevant standards, needs specification, concept generation and selection, and engineering analysis. The prototype was built based on calculations and simulations in Solidworks. The design uses several combinations of gears and cranks to flip the boards and thus fold the clothes that is put on the platform by the user. The final product achieved several of the performance goals, including completing one cycle in less than 20 seconds, less than 20 pounds, completing ten cycles consecutively without failure and having at least two folding patterns. The major problem of this final product is that it did not fold the clothes in a good shape and it could not switch patterns automatically. Further improvements could still be done.

MEMS 411: Senior Design Project

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1. Introduction and Background Information

1.1. Initial Project Description

The project was designed to meet the needs of folding clothes for college students, housewives or anyone who has trouble folding clothes. Lots of college students are annoyed by spending time folding clothes based on our customer interviews. In addition, most of clothes folding machine in market are either for industry use or too expensive. We are trying to build a portable automatic clothes folding machine at a cheap cost to serve most people. It not only combined the metrics from existing products but also have two folding patterns, which is more convenient and efficient.

1.2. Existing Products

Automatic Folding Machine FX23: Fx23 is an automatic folding platform that can easily fold lots of clothes in a short time. It is really easy to operate with just two buttons. One of its strong merits is that it can stack those folded clothes after. However, it is an industrial product not suited for a household environment.

FoldiMate: FoldiMate Folding Machine is a robotic clothes folding machine which can easily handle most of types of clothes including pants, shirts and towels with its easy clipping function. Moreover, FoldiMate enables internet connection which largely improves user experience. One drawback is that it is not available yet and is costly

1.3. Relevant Patents

US8973792B1

"Fabric article folding machine and method, a invention that folds fabric articles automatically. It uses a rotating rod in combination with a retractable concave/convex tape to create pairs of folds on a fabric article on a horizontal platform. "

US5417641A

"Device for folding articles, a device for folding flexible articles such as shirts, towels, piece goods by comprising a generally flat main member with two side panels foldable attached to the main member. "

1.4. Codes & Standards

ISO 10472-5:1997

"This standard is the safety requirements for industrial laundry machinery, and it is intended to instruct the designer of industrial laundry machinery in a systematic manner regarding the relevant safety requirements and to suggest possible safety solutions. "

1.5. Project Scope

The machine should be programmed to fold, and stack simple clothes. It will operate in a semi-automated process; the customer only need to lay the clothes flat on the platform and the machine takes them in for folding and stacking. It should be connected to a power source. It should have two folding patterns, one for short-sleeve shirts, and the other for pants.

1.6. Project Planning

The project, clothes folding machine, is planned to be designed and assembled in four months from September to December. The final working prototype is planned to have two folding patterns and to fold shirt or pant in less than 20 seconds. The project budget is around $170.

1.7. Realistic Constraints

The project should not exceed $170 in budget ideally. This is the key constraint of the project. We need to keep the design simple and functional to appeal to most customers. We should have a prototype completed by the end of the semester, so about 2 to 3 months for a presentable final prototype. The size of the machine should not be too large so that it would not occupy too much space in the room, but large enough to fold a typical sized piece of clothing.

1.7.1. Functional

The machine will be able for fold one piece of clothing at one time and put it in a stack. It will consist of two folding patterns for shirts and pants.

1.7.2. Safety

Based on the purpose of design, the clothes folding machine is a household appliance. Safety is the first priority to be considered. Both electrical hazard and noise hazard are avoided in the design.

1.7.3. Quality

The machine should work smoothly and stably. The total weight of the machine should be less than 20 pounds.

1.7.4. Manufacturing

For ease of manufacturing, our design consists of several parts that can be easily created and assembled. The final prototype was improved from the rough design such as: Instead of a bottom and top for the casing, the prototype is held by four vertical boards, which can hold the flipping boards on top with ease and are also much easier to be manufactured.

1.7.5. Timing

We used a stepper motor to drive gear combinations to flip boards of two sides. The left boards is to be set to flip first. When left board falls down, the right board goes up. In addition, the stepper motor is set to have a 7 seconds lag between two full cycles. In addition, the whole design, manufacturing, and assembly are finished in time as they were planned on our project Gantt Chart.

1.7.6. Economic

Under the budget of $170, the final expense was successfully controlled to be lower than the budget. We bought cheap boards from HomeDepot and also borrowed the motors from school’s inventory. In addition, most of the parts are cutted by laser cutter from the architecture school.

1.7.7. Ergonomic

To better help users to control the clothes folding machine, there are only two buttons on the machine. One button is the start button. Once the start button is pressed, the clothes folding machine will automatically fold either shirt or pant. The other button is switch button. Once the switch button is pressed, the machine will switch its folding function.

1.7.8. Ecological

Because most of the material used in our final product is recyclable, the clothes folding machine can be easily tear down and its parts can be reused to build other things. In addition, since all the parts are built from woods, the machine is not harmful to the environment.

1.7.9. Aesthetic

The machine uses combinations of gears and a set of mechanism to connect the gear t o the flipping boards. The shape of the parts for connection are designed in aesthetic manners.

1.7.10. Life Cycle

Since we used battery pack of 27 V each to drive two motors installed inside the machine, the running hour is estimated 3 hours. In addition, all the parts have three layers, which have strong stability. The life cycle is estimated to be one year.

1.7.11. Legal

The machine is legal use only and it should not violate any laws.

1.8. Revised Project Description

The project aims to create a household cloth folding machine. It will use several folding on a base unit which can fold clothing in the flipping motion. The final design will have two different patterns to fold pants and shirts, and stack finished clothes afterwards. In addition, the unit will be much lighter and smaller than existing products to fit in a household environment.

2. Customer Needs & Product Specifications

2.1. Customer Interviews

Table 1 Customer interview and interpreted need

Customer Data: Typical student A Address: Washington University in St. Louis Date: September 15th 2017			
Question	**Customer Statement**	**Interpreted Need**	**Importance**

What is the typical usage of the machine?	Fold clothes neatly flatly and quickly Fold different types of clothes	The CFM has good folding patterns It is more effective than folding manually It has multiple folding patterns	4 5 5
What material considerations are present?	Not too hard so it can fit in my house	The material is not too hard or it is covered by soft materials	3
What safety considerations do you have? Are moving parts, electricity an issue?	Machine is family friendly, and should be sturdy enough	The CFM has no sharp edges The CFM is compact for household use	5 4
What other capabilities would you like?	Machine is able to spray some fragrance on the clothes	The CFM has fabric softening function	2
Likes - Current Products	Easy to operate Cheap	The CFM is user friendly The CFM is cost-effective	5 5
Dislikes - Current Products	Does not save too much time	The CFM can fold a piece of clothing quickly	5

2.2. Interpreted Customer Needs

Table 2 Interpreted customer needs

Need Number	Need	Importance
1	The cloth folding machine can be operated in multiple patterns	5

2	The CFM can be operated at home	3
3	The CFM can fold pants or shirts simultaneously	5
4	The CFM can be moved	4
5	The CFM is quiet	4
6	The Cost of CFM is low	4
7	The CFM is time efficient	5
8	The CFM is user friendly	4
9	The CFM is safe to use	5

2.3. Target Specifications

Table 3 Target product specifications for cloth folding machine

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal	Source
1	2,4,6,8	Weight	Kg	10-30	<=20	Customer statement
2	2,4,6,8	Volume	m^3	1-2	<=2	Customer statement
3	2 ,4,6,8	Height	m	0.5-1	<=1	Customer statement
4	1, 7	Efficiency	clothes/min	5-10	20	Customer statement
5	2,4	Size adjustability	Integer	1-5	4	Customer statement
6	5	Sound level while running	dB	< 40-70	< 50	Standard
7	8	Force needed to lift shirt folding platform	N	10-30	10	Customer statement

8	8,9	Voltage needed while running	V	110	110	Standard

3. Concept Generation

3.1. Functional Decomposition

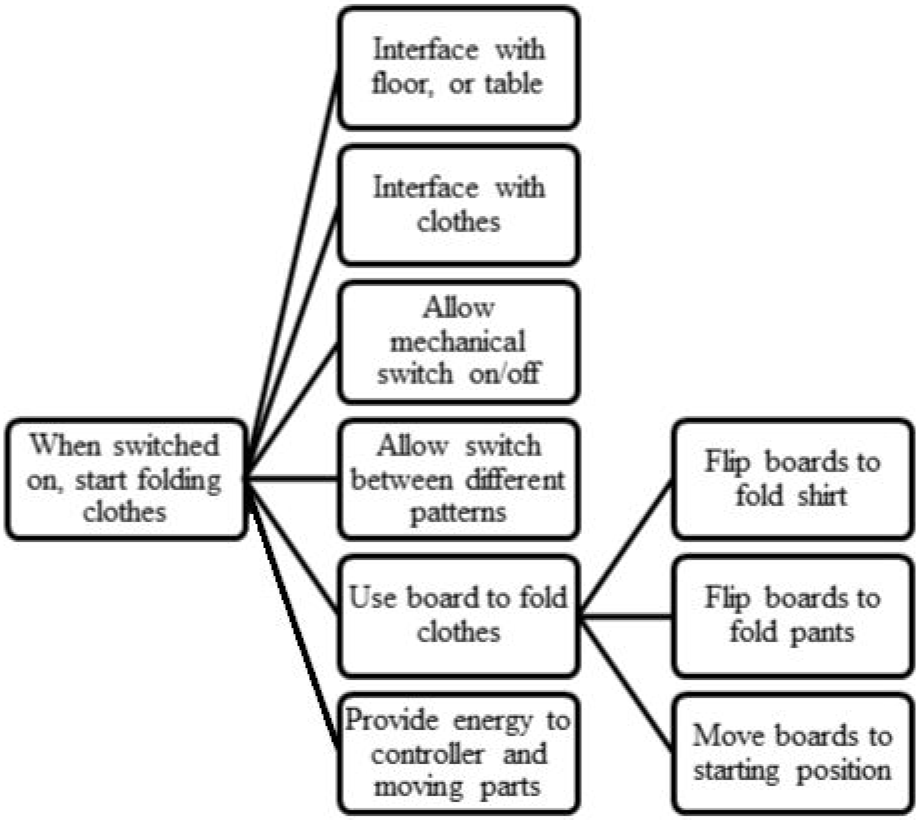
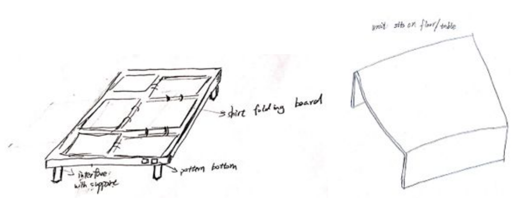
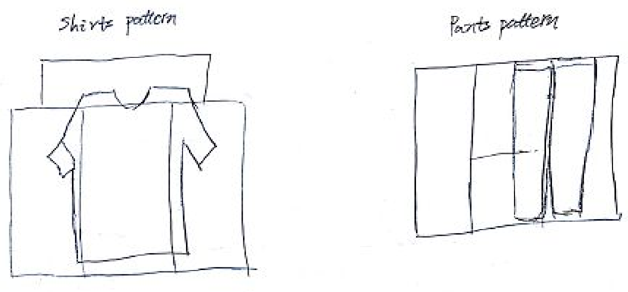
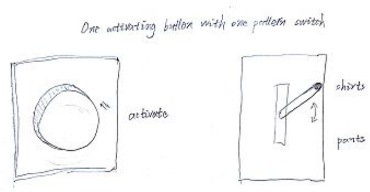
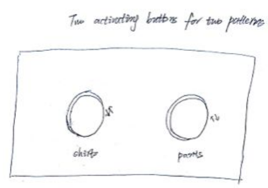
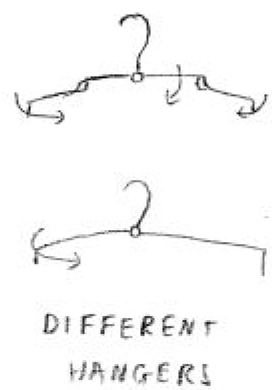


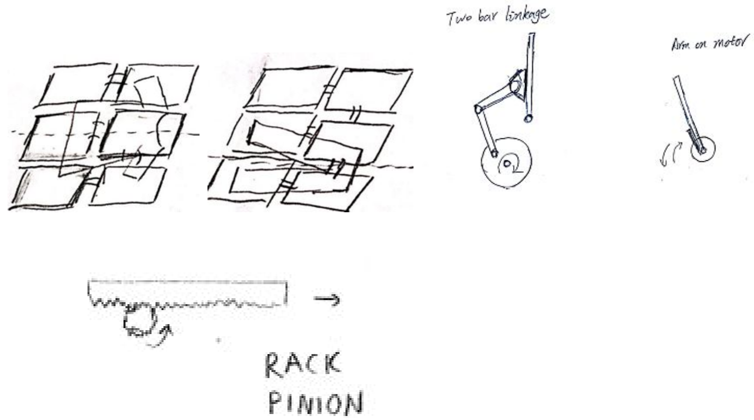
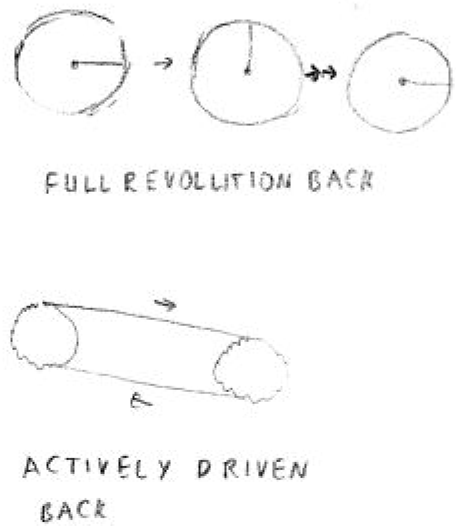
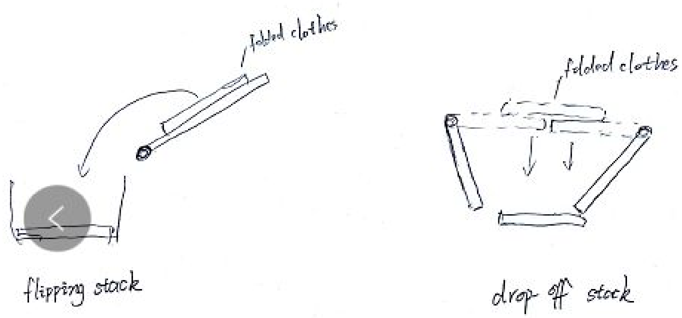
Figure 1 Function tree for cloth folding machine

3.2. Morphological Chart

Table 4 Morphological Chart

Interface with floor, or table	

Interface with clothes	
Allow mechanical switch on/off	
Allow switch between different patterns	  

Flip boards to fold shirts and pants	
Move boards to starting position	
Stack folded clothes	

Provide energy to controller and moving parts	

3.3. Concept #1 – "Cloth folding board"

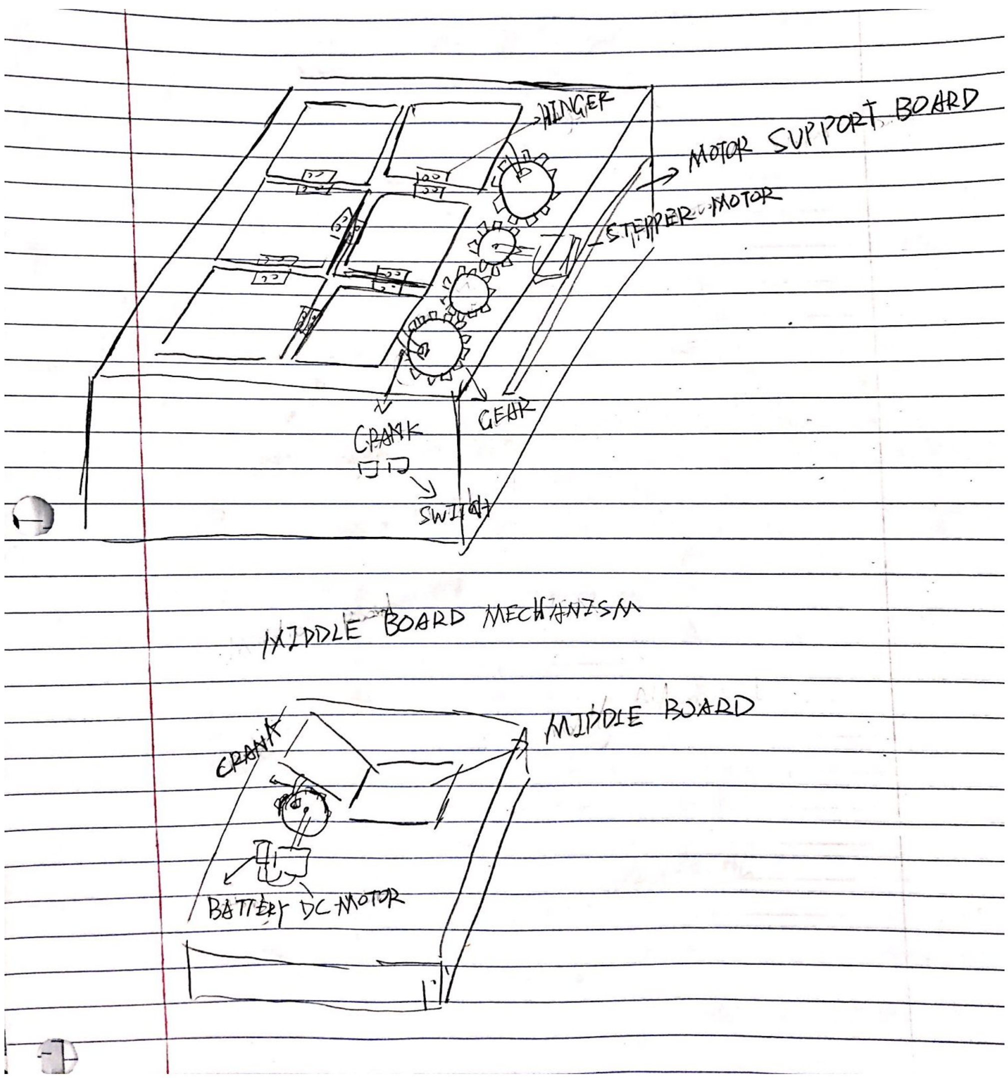


Figure 2 Concept #1 – "Cloth folding board"

When the folding pattern is chosen, each different board would be lifted by spring supporters in sequences, folding the clothes. For Pants, they are put in different position because of its different structure.

3.4. Concept #2 – "Cloth folding hanger"

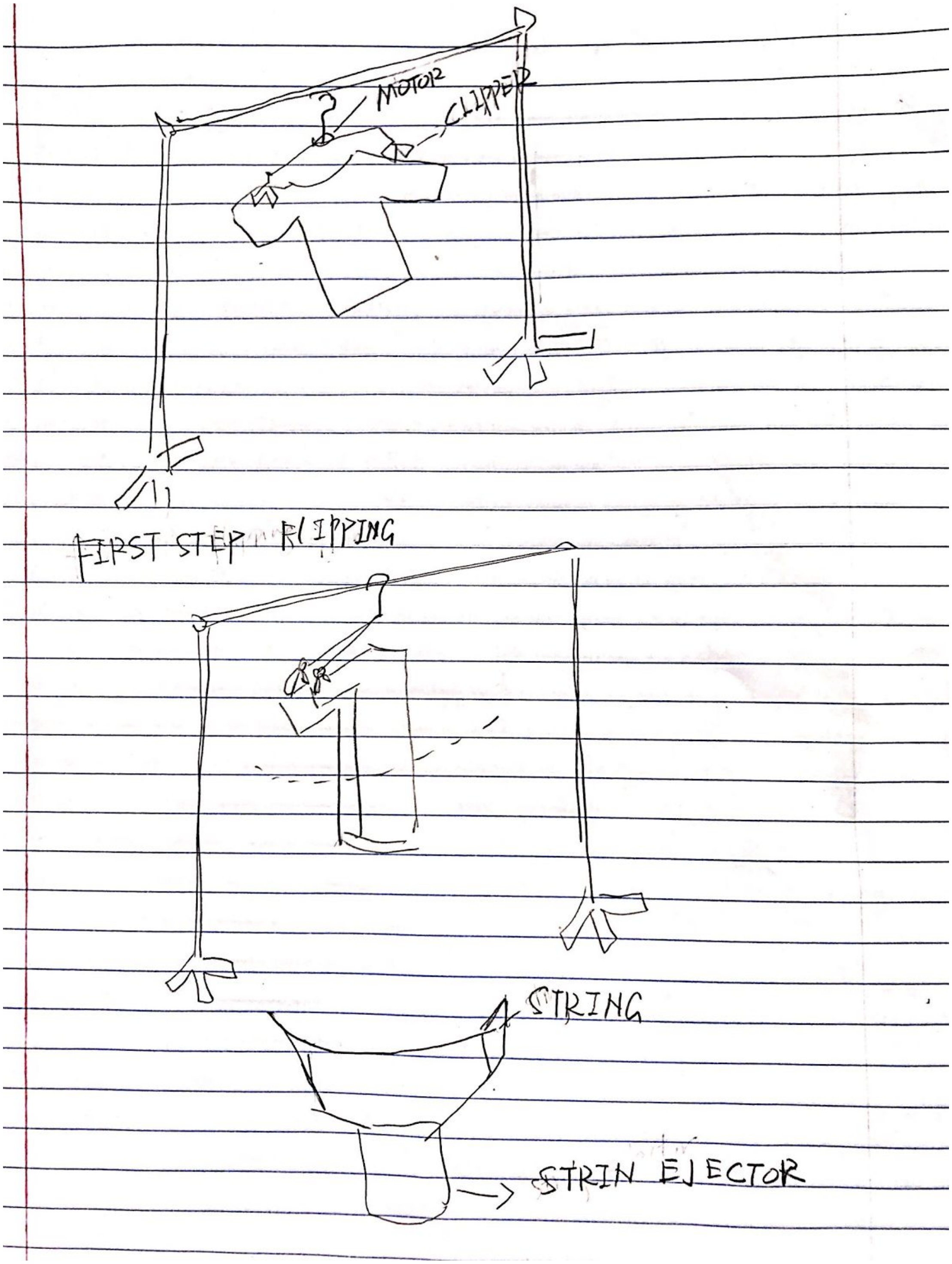


Figure 3 Concept #2 "Folding Hanger"

There are four hangers with grips that can hold clothes. After one fold, the string ejector will eject a sting to the hanging cloth. The ejected string will fold clothes to a further extent. The final step is to take the string out from the folded clothes.

3.5. Concept #3 – "Gear-driven board"

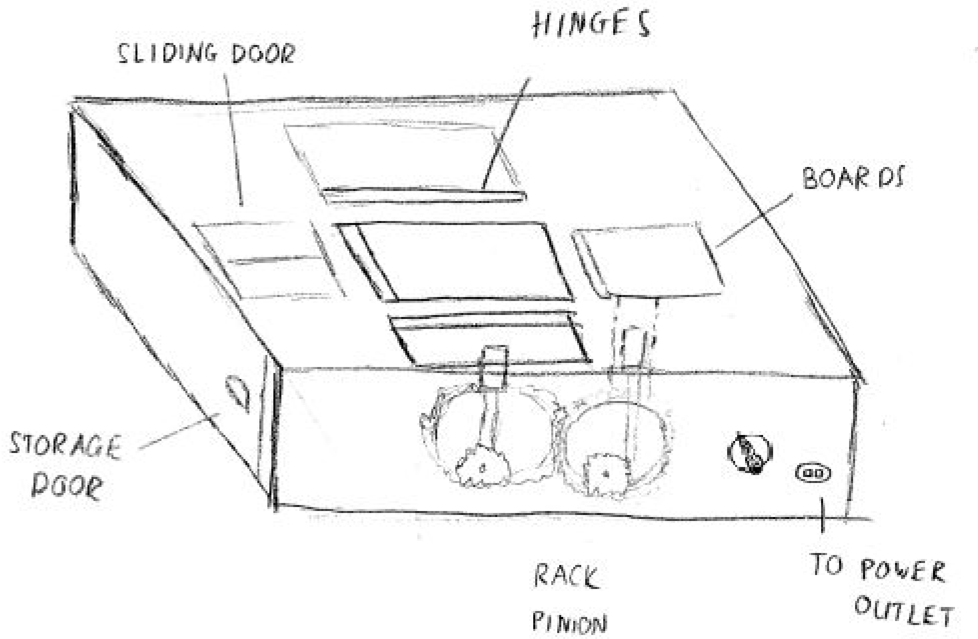


Figure 4 Concept #3 "Gear-driven board"

The four boards are driven by set of gears. The gears consist of different sizes so that they will drive each board at different sequence when power is provided from the power cord. The gears can also be switched for different clothing patterns. The final board in the middle will flip the piece of clothing on top of the sliding door, which opens to a storage inside the machine. The storage can be opened by a door on the side.

3.6. Concept #4 – "Rail Folding machine"

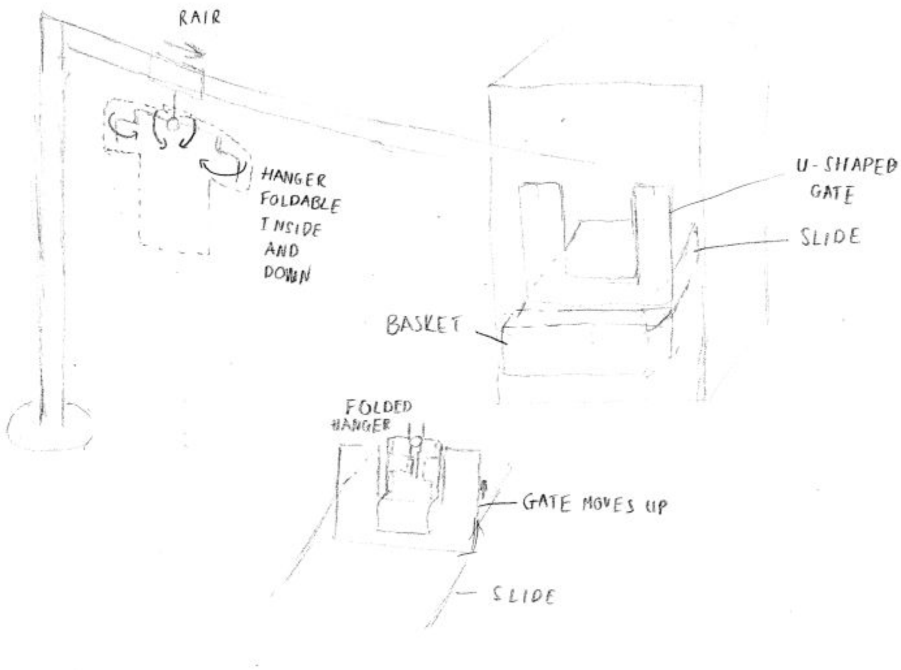


Figure 5 Concept #4 "Rail Folding Machine"

This machine consists of a hanger (or several) which can fold inside and down in the middle and in the parts where the shoulders of the T-shirt are. The hanger can travel along a sloped rail to a U-shaped gate which can move up. The shape of the gate will fold the shirt (and the hanger) widthwise close to the shoulders while the upward motion of the gate will fold the shirt lengthwise. The hanger will now collapse completely, dropping the shirt onto a slide which leads to a basket below.

3.7. Concept #5 – "Drop-off stack"

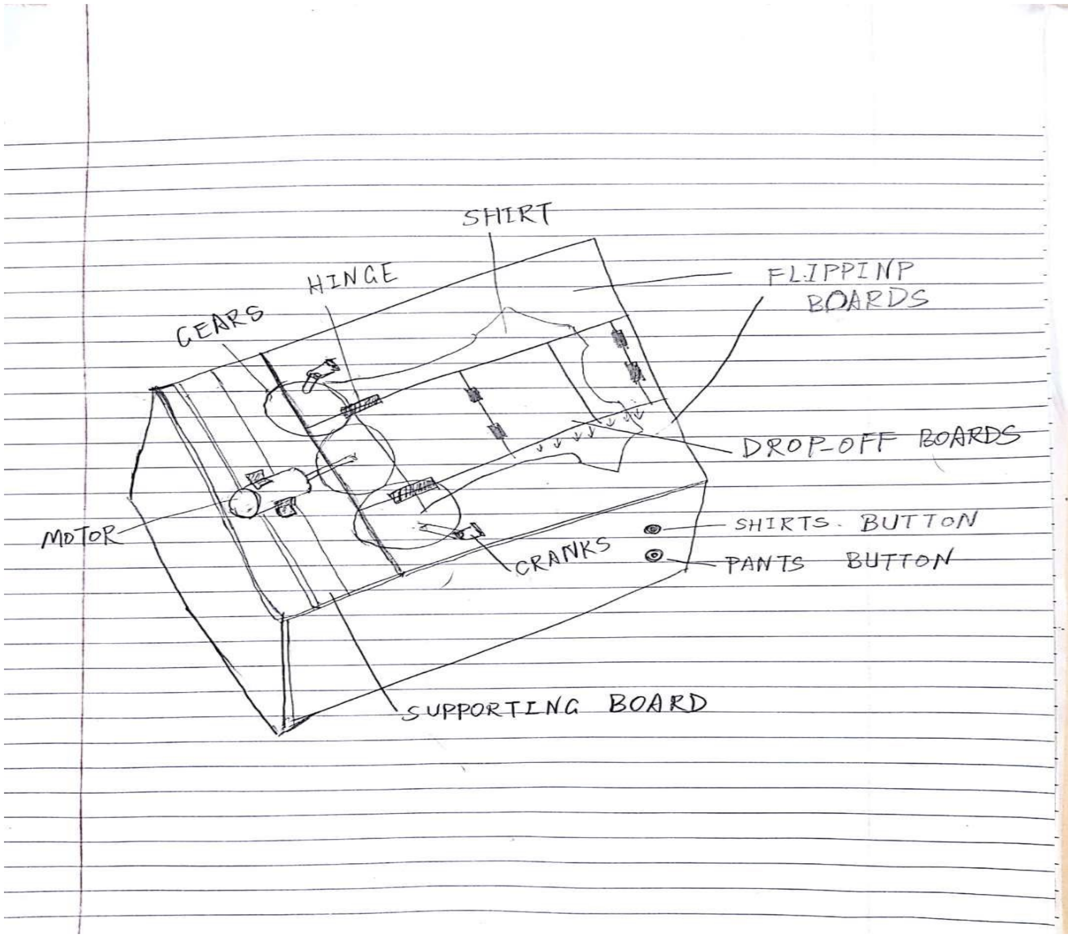


Figure 6 Concept #5 "Drop-off Stack"

An electrical control unit (ECU) controls three motors to rotate a certain degree and then rotate to the original position to finish the motion for three folding boards. One other motor to control the stacking mechanism to open so that the folded clothes fall down to the stack.

3.8. CONCEPT #6 – "FLIPPING STACK"

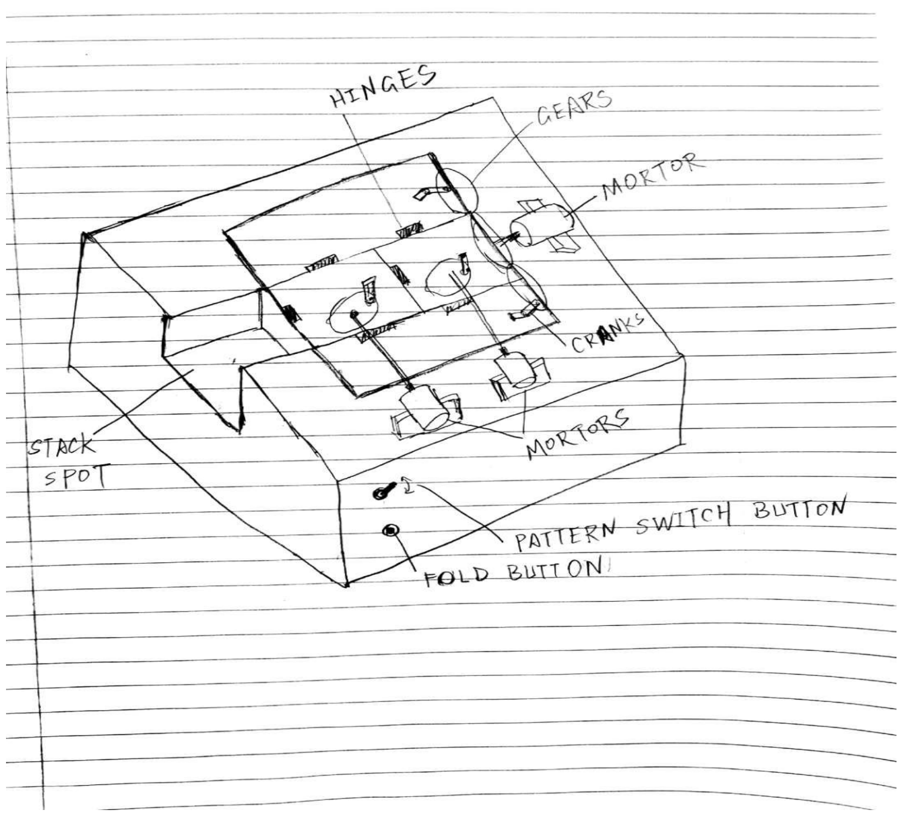


Figure 7 Concept #6 "Flipping Stack"
An electrical control unit (ECU) controls one motor to rotate in one or several cycles to flip the folding boards in a certain sequence and then flip the stacking board to stack the clothes.

4. Concept Selection

4.1. Concept Scoring Matrix

Table 5 Weighted Score Matrix

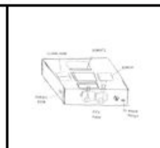
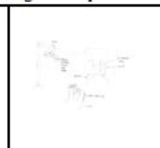
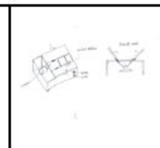
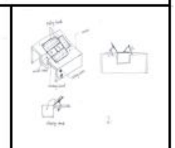
		Alternative Deisgn Concepts											
													
Selection Criterion	Weight (%)	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted
Mechanical safety	21.45	3	0.64	2	0.43	4	0.86	1	0.21	4	0.86	5	1.07
Cost of components	8.81	3	0.26	3	0.26	5	0.44	5	0.44	1	0.09	5	0.44
Volume	5.25	3	0.16	2	0.11	3	0.16	3	0.16	3	0.16	3	0.16
Noise	5.4	3	0.16	3	0.16	3	0.16	3	0.16	3	0.16	3	0.16
Reassembling	1.84	3	0.06	4	0.07	3	0.06	3	0.06	3	0.06	3	0.06
Weight	4.69	3	0.14	3	0.14	3	0.14	3	0.14	3	0.14	3	0.14
Time efficiency	15.58	3	0.47	3	0.47	4	0.62	3	0.47	4	0.62	4	0.62
Size adjustability	2.1	3	0.06	4	0.08	3	0.06	3	0.06	3	0.06	3	0.06
Pattern switch	1.85	3	0.06	3	0.06	3	0.06	3	0.06	3	0.06	3	0.06
Customer friendliness	11.57	3	0.35	2	0.23	3	0.35	2	0.23	3	0.35	5	0.58
Electrical safety	21.45	3	0.64	2	0.43	3	0.64	3	0.64	3	0.64	3	0.64
	Total score	3.000		2.442		3.546		2.631		3.194		3.992	
	Rank	**4**		**6**		**2**		**5**		**3**		**1**	

Table 5 Analytic Hierarchy Process

	Mechanical Safety	Cost of components	Volume	Noise	Reassembling	Weight	Time efficiency	Size adjustability	Pattern switch	Customer friendliness	Electrical safety	Row Total	Weight Value	Weight (%)
Mechanical safety	1.00	5.00	7.00	7.00	7.00	5.00	5.00	7.00	7.00	5.00	1.00	57.00	0.21	21.45%
Cost of components	0.20	1.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	0.20	23.40	0.09	8.81%
Volume	0.14	0.33	1.00	3.00	3.00	1.00	0.33	1.00	3.00	1.00	0.14	13.95	0.05	5.25%
Noise	0.14	0.33	0.33	1.00	3.00	3.00	0.20	3.00	3.00	0.20	0.14	14.35	0.05	5.40%
Reassembling	0.14	0.33	0.33	0.33	1.00	0.33	0.14	1.00	1.00	0.14	0.14	4.89	0.02	1.84%
Weight	0.20	0.33	1.00	0.33	3.00	1.00	0.20	3.00	3.00	0.20	0.20	12.46	0.05	4.69%
Time efficiency	0.20	1.00	3.00	5.00	7.00	5.00	1.00	9.00	9.00	1.00	0.20	41.40	0.16	15.58%
Size adjustability	0.14	0.33	1.00	0.33	1.00	0.33	0.11	1.00	1.00	0.20	0.14	5.59	0.02	2.10%
Pattern switch	0.14	0.33	0.33	0.33	1.00	0.33	0.11	1.00	1.00	0.20	0.14	4.92	0.02	1.85%
Customer friendliness	0.20	0.33	1.00	5.00	7.00	5.00	1.00	5.00	5.00	1.00	0.20	30.73	0.12	11.57%
Electrical safety	1.00	5.00	7.00	7.00	7.00	5.00	5.00	7.00	7.00	5.00	1.00	57.00	0.21	21.45%
											Column Total:	**265.70**	**1.00**	**100%**

4.2. Explanation of Winning Concept Scores

AD 6 (alternative design #6) successfully combined metrics from AD1 and AD 3. AD 6 uses a gear combination controlled by an electrical control unit (ECU). AD6 only uses two motors which save a lot of space and components cost. Two motors are connecting gear combinations and gears rotate in one or several cycles to flip the folding boards in a certain sequence and then flip the stacking board to stack the clothes. AD6 uses a better gear structure than AD3 which is safer and much more efficient. In conclusion, AD6 is the most ideal design. With only two motors and two sets of gear combinations, this design will cause less noise and is also lighter than the other alternative design.

4.3. Explanation of Second-Place Concept Scores

The four boards are driven by set of gears. The gears consist of different sizes so that they will drive each board at different sequence when power is provided from the power cord. The gears can also be switched for different clothing patterns. The final board in the middle will flip the piece of clothing on top of the sliding door, which opens to a storage inside the machine. The storage can be opened by a door on the side. This design needs a larger space for the storage and cannot solve the problem of how to drive two sets of boards in two different directions since it can only drive the boards in one direction with the gear combination shown. However, it provides a general idea of how to drive the boards.

4.4. Explanation of Third-Place Concept Scores

AD5 uses spring support and crank structure to either lift or pull shirt folding board back. Generally, AD5 still use similar structure as AD6 and AD3 with a hollow base. However, AD5 need use 4 motors to drive each different board, which is time consuming and costy. In addition, 4 motors may cause more electrical hazards and louder noise. Based on the safety-first rule, AD5 cannot be our optimal design.

4.5. Summary of Evaluation Results

We have 12 selection criteria including mechanical safety, cost of components, volume, noise, resembling, weight, time efficiency, size adjustability, pattern switch, customer friendliness and electrical safety. In deciding weight for each of those above selection criterion, we used analytic hierarchy process. We followed the principle of our ideal final design and safety-first rule. Because our ideal final design aims to be home-use cloth folding machine that can help to increase time efficiency and decrease human work, safety, time efficiency and customer friendliness are top influential factors.

5. Embodiment & Fabrication plan

5.1. Isometric Drawing with Bill of Materials

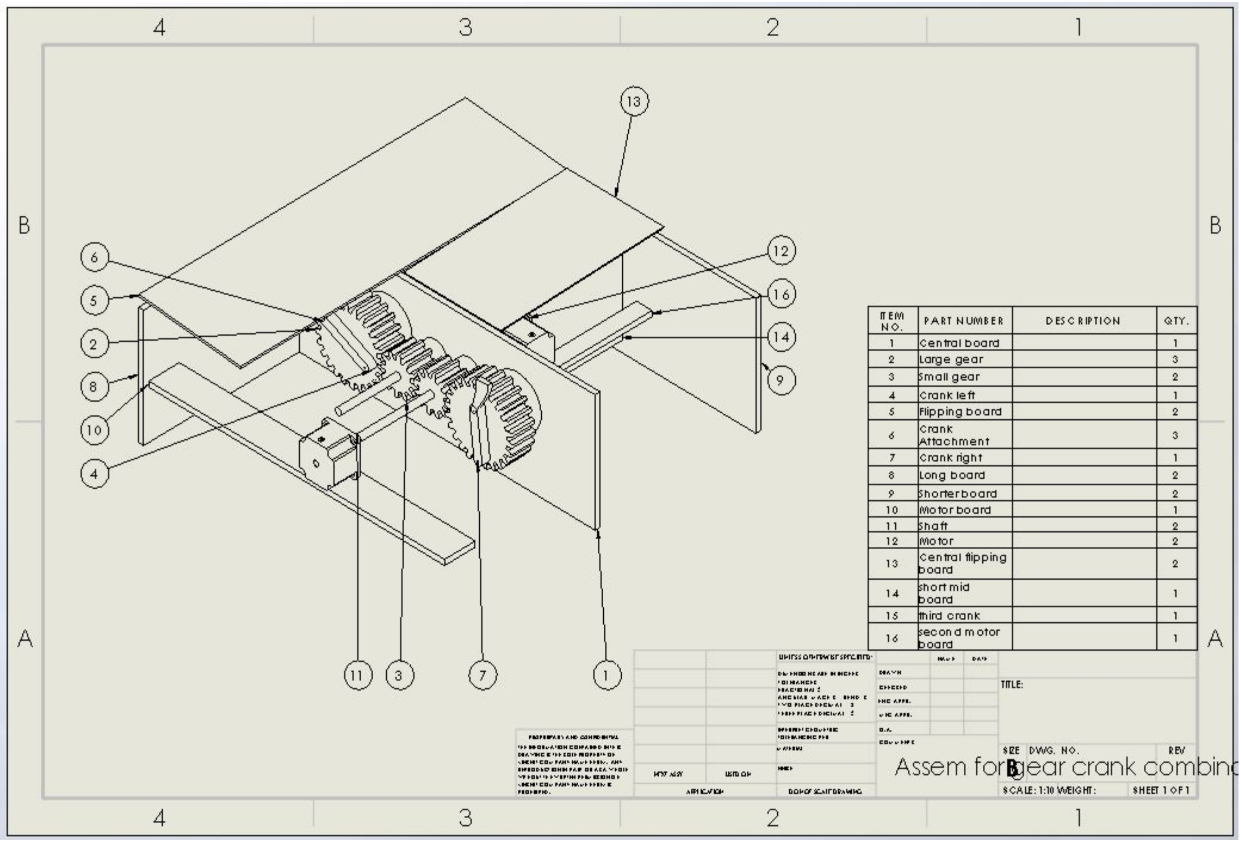


Figure 8 **Isometric drawing with bill of material of the clothes folding machine.**

5.2. Exploded View

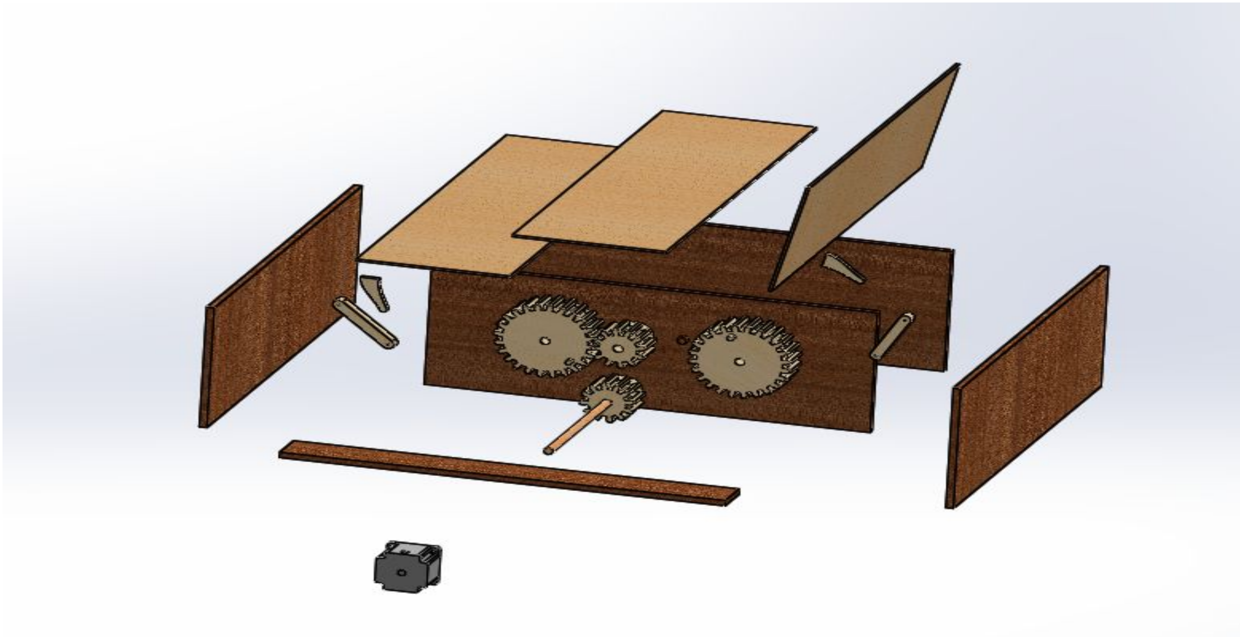


Figure 9 Exploded view of the clothes folding machine.

5.3. Additional Views

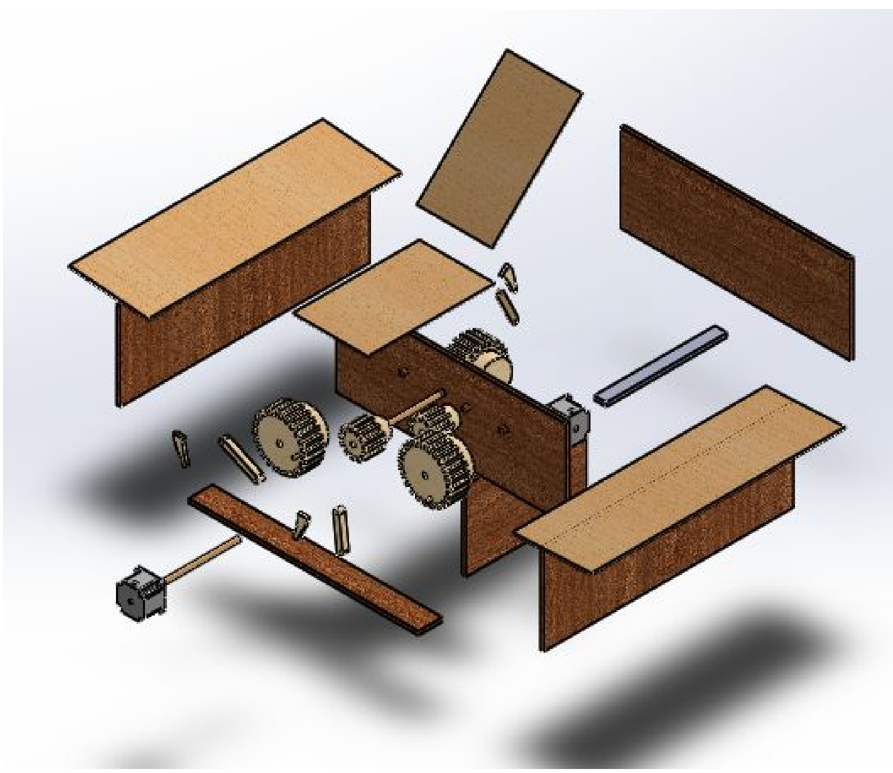


Figure 10 Additional exploded view of the folding machine.

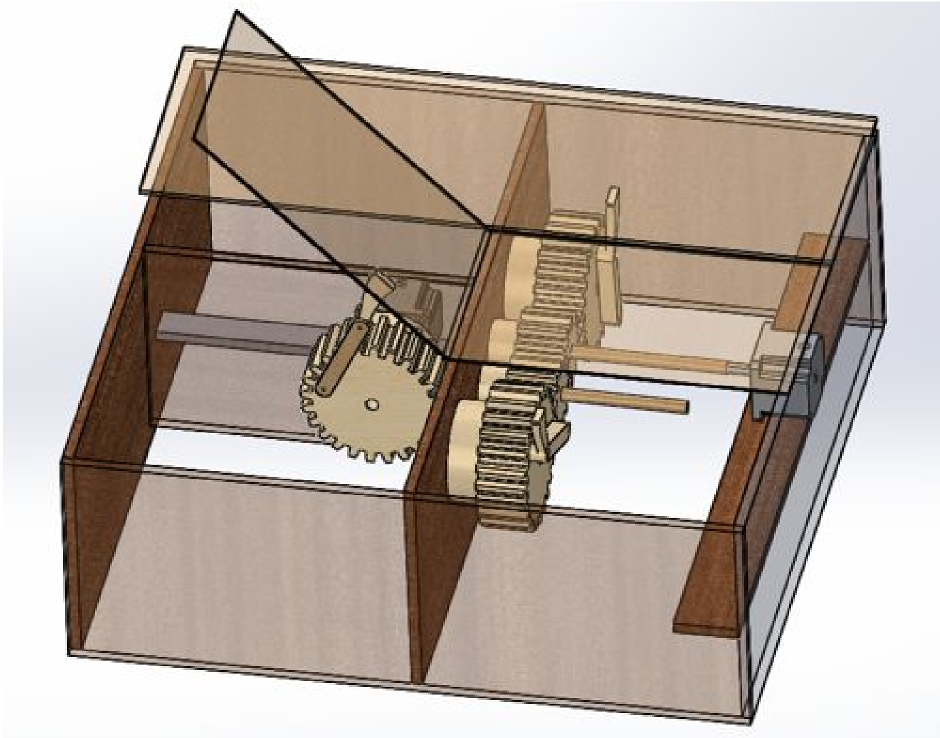


Figure 11 Additional view of the machine.

6. Engineering Analysis

6.1. Engineering Analysis Results

6.1.1. Motivation

Clause 5 Section 3 Electrical Hazards ISO 10472-5:1997

Clause 5 Section 5 Hazards generated by noise

These standards indicates the limit on noise and electrical hazard for industrial cloth folding machines. However, we think they are still a good indications of how our design should be in a household environment. As a result, we will use a DC power supply to drive our stepper motor, which generates less noise at a lower voltage than an AC power supply. Therefore, our supply will have lower electrical hazard.

To make our design work, we need the exact dimensions of the parts we are using or otherwise there will be harmful interfaces among them.

6.1.2. Summary Statement of the Analysis

We used Solidworks Motion to test if we have any clashing parts. The main working mechanism of our design is a combination of gears and cranks. We created the models of them in Solidworks and used motion simulation to determine the proper dimensions. We simulated the motion of the mechanism by adding a motor and plotted the torque of the motor.

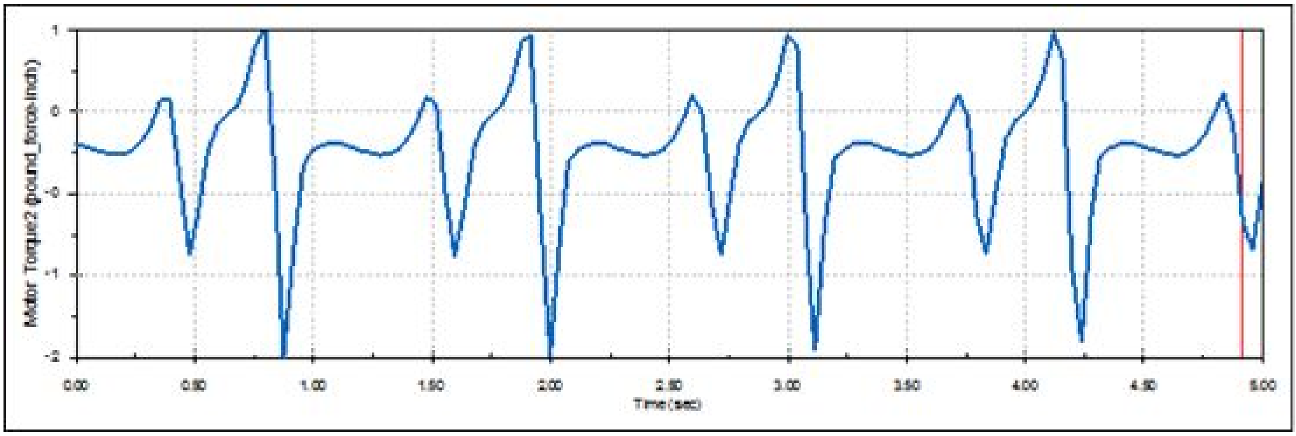


Figure 12 Torque driven by the motor.

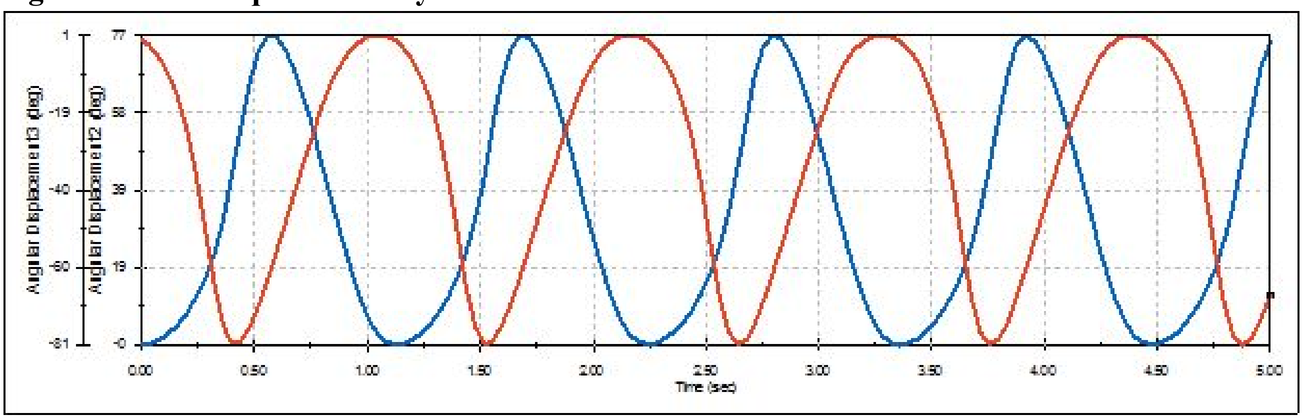


Figure 13 Angular displacement comparison of the two left and right flipping boards.

In addition, figure 15, 17 18 show the mechanism of the working system. A stepper motor is driving the gear combinations to further to make two-sides boards flip. And another DC motor will drive the middle board to flip downward.

6.1.3.Methodology

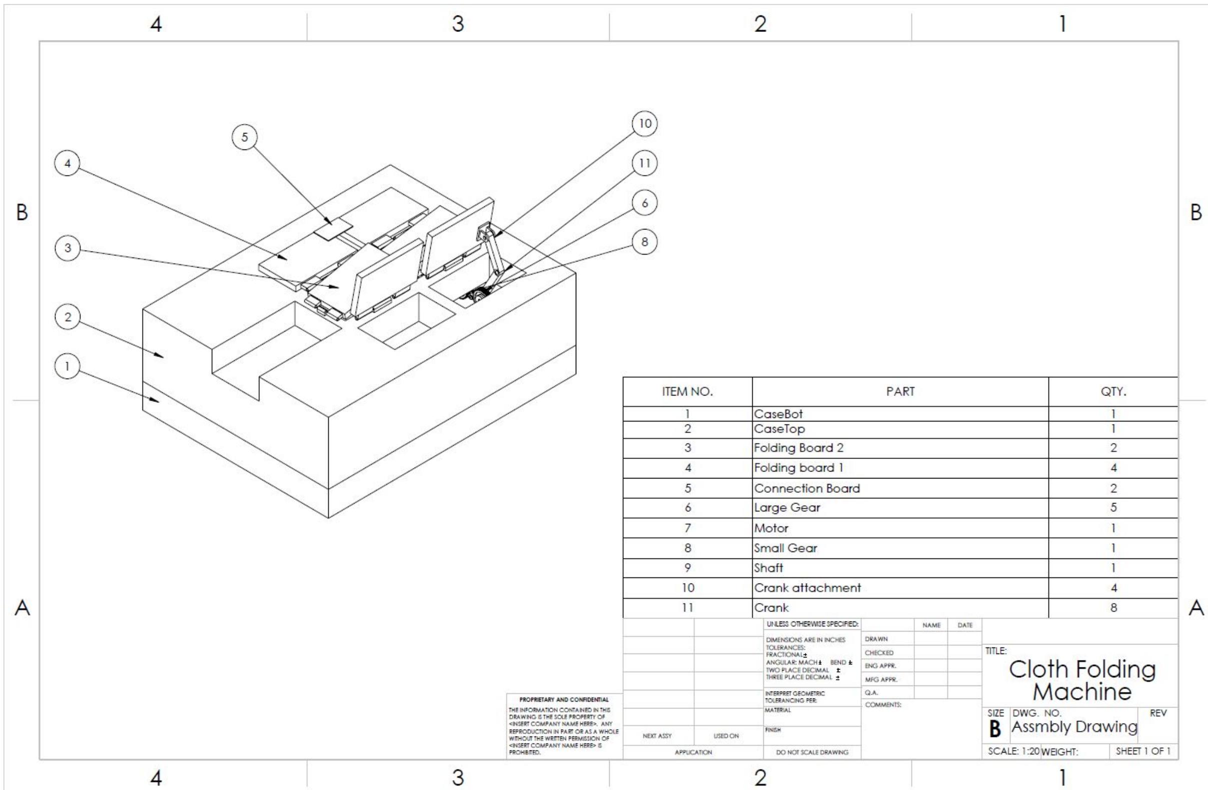
Most of our analyses were done on Solidworks before we build our prototype such as our gears' sizes, their pitch and numbers of teeth. The Solidworks files of the gears were downloaded from Mcmaster, and we tried different combinations on Solidworks to finally determine the best gear models for our design. We also created the models of cranks and crank attachments in Solidworks. We determined the dimension of the cranks and attachments using motion simulations in Solidworks. After our Solidworks design, we laser cut our parts and assembled them for tests. We also tested some of our design using 3D printed parts.

6.1.4.Results

We found that the 3D printed parts were not suitable for our design, mainly because they are unstable and relatively weaker in compression than wood. Additionally, the first pair of gears we used had a very large number of teeth and this made it too hard for the gears to engage smoothly. Thus we reduced our pitch while keeping the same pitch diameters to reduce the numbers of teeth. This can also reduce the torque needed for the motor. Also, using Solidworks, we were able to determine the dimensions and positions of our parts to make our machine function properly and smoothly.

6.1.5. Significance

The final prototype is based on the analysis of the results because dimensions of cranks and crank attachments determines if flipping boards can work. Our analysis results helped us determine the proper dimensions and made our design finally work as a prototype. The material of the shafts were changed from plastic to wood because our analysis showed that the plastic shafts were not strong enough. The analysis significantly benefited our design.



ITEM NO.	PART	QTY.
1	CaseBot	1
2	CaseTop	1
3	Folding Board 2	2
4	Folding board 1	4
5	Connection Board	2
6	Large Gear	5
7	Motor	1
8	Small Gear	1
9	Shaft	1
10	Crank attachment	4
11	Crank	8

Figure 14 Before analysis Solidworks Design

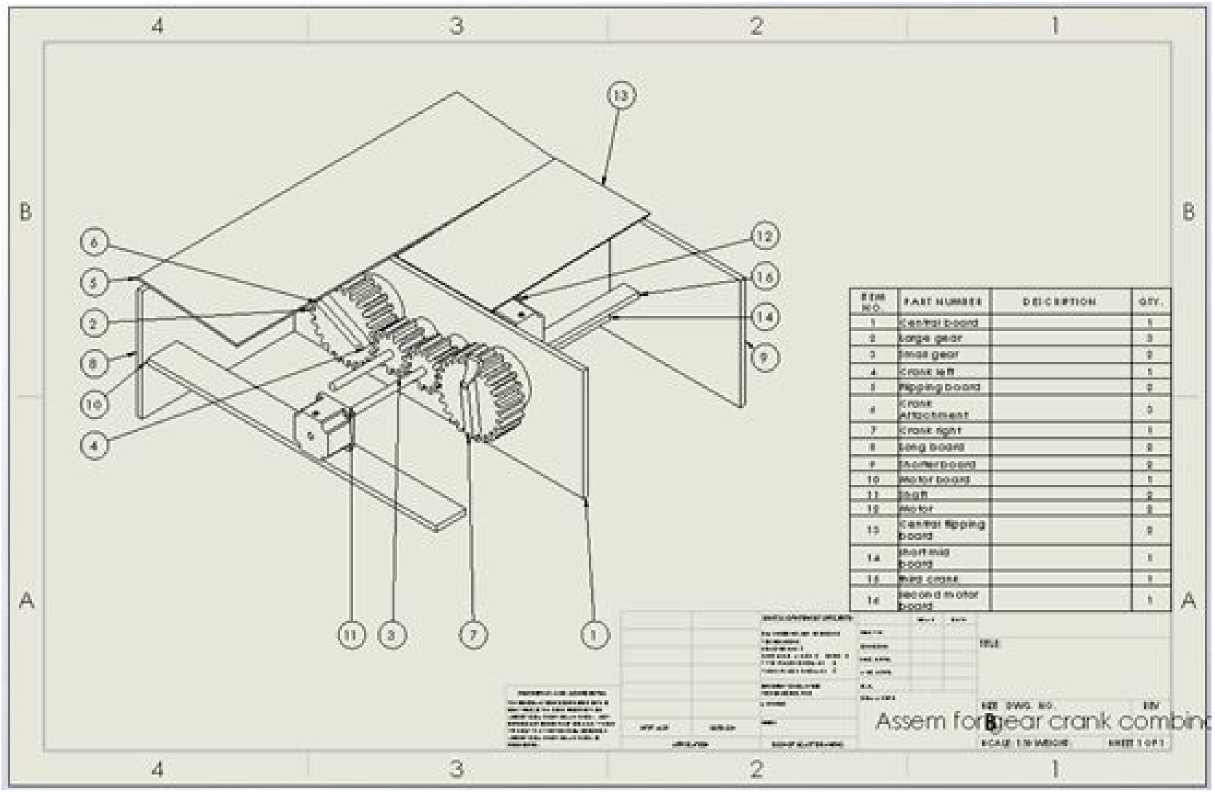


Figure 15 After analysis Solidworks Design

6.2. Product Risk Assessment

6.2.1. Risk Identification

Risk Name: Electric Hazard

Description: According to the safety code, the standard voltage should be around 110V. And in some circumstances such as poor connect and leakage of electricity. During either dry or rainy days, poor connect and leakage of electricity may cause direct contact between people and electricity, result in dangerous situations.

Impact: 4

Likelihood: 2

Risk Name: Noise Hazard

Description: Since ideal cloth folding machine is a household electric appliance, noise of operation must be below the noise standard. Normally, the noise level of cloth folding machine should be way below the standard. However, only if the main shaft is off the link or there is no enough lubricant oil inside the stepper motor, noise of operation could be a hazard.

Impact:2

Likelihood:1

Risk Name: Electromagnetic Radiation Hazard
Description: As other household electric appliance, cloth folding machine still have electromagnetic radiation effects on users or anybody at home to some extent while in operation. Electromagnetic radiation hazard is bad to human's health.
Impact:1
Likelihood:4

Risk Name: Mechanical Risk
Description: In designing the cloth folding machine, it should be a 30X31X11 inch box with shirt folding board. The total weight of the machine should not more that 20lbs. Ideally, all the parts are connected by screws. However, cloth folding machine will fall apart or even crack under crash because the main material is wood.
Impact: 5
Likelihood:1

Risk Name: Operational Risk
Description: Since operation requires all the three boards flip upward and downward, it is kind of dangerous for user to put either shirts or pants on the flipping boards. Users' hands may get clamped during operation, causing injuries.
Impact:3
Likelihood: 2

Risk Name: Quality Risk
Description: Since all the parts are manually made or cutted from huge wood boards. It is likely that the edge of parts are not completely sanded. In that case, small splinters may hurt users.
Impact:2
Likelihood:3

6.2.2. Risk Heat Map

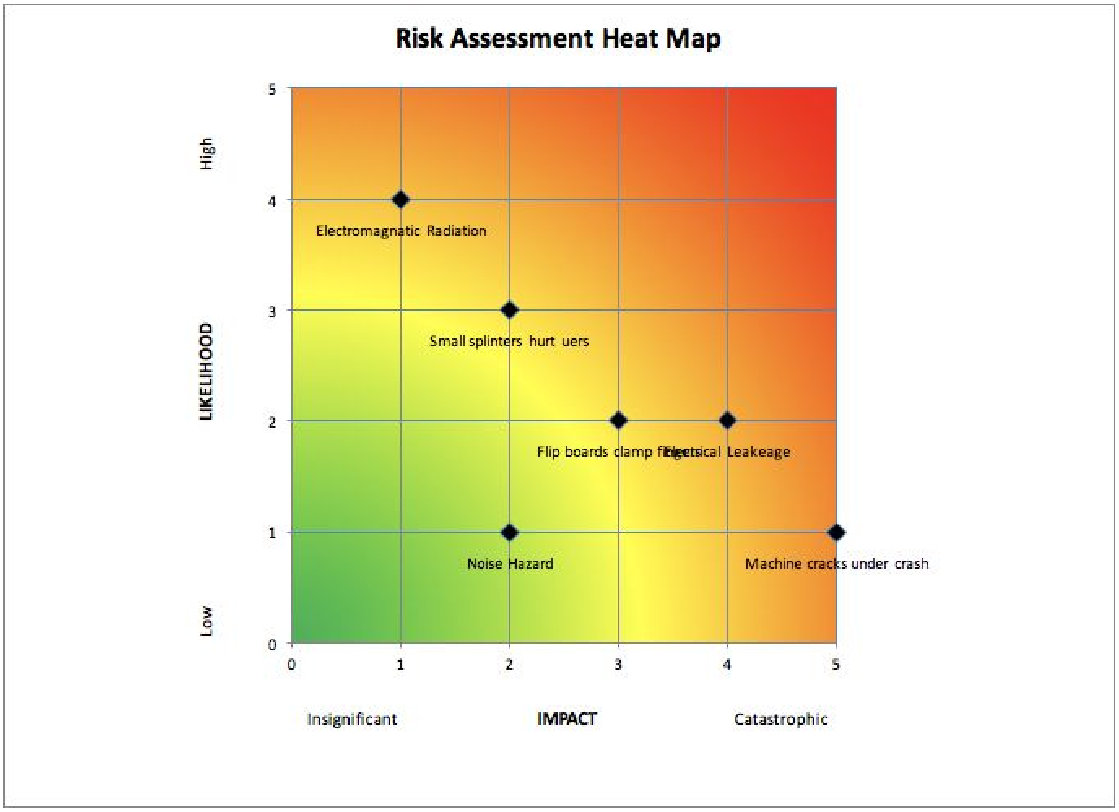


Figure 16 Risk assessment heat map

6.2.3. Risk Prioritization

Rank of risk prioritization: Electrical Leakage > Flip board clamp = Small splinters > Machine cracks > Electromagnetic Radiation > Noise Hazard.
Based on the risk assessment heat map, the first priority of the project is electrical leakage. Flipping board clamp and small splinters have the same weight of risk impact. Machine cracks, electromagnetic radiation and noise hazard have relatively little risks and impacts. Design Documentation

7.1 Design Documentation

7.2 Performance Goals

1. It will complete one switch cycle in less than 20 seconds.

2. It should be portable, i.e. less than 20 pounds.

3. It will complete 10 cycles consecutively without failure.

4. It will have at least 2 folding patterns.

7.3 Working Prototype Demonstration

7.3.1 Performance Evaluation

The final product succeeded in folding half of the shirt. The flipping board on the left worked well and folded the left half of the shirt, while the other half of the shirt was not folded because the flipping board on the right side did not rotate to a large enough degree and the angular velocity did not reach a certain value. The performance can be improved by changing the dimensions and positions of the gear-crank mechanism to rotate the right flipping board by a larger degree.

7.3.2 Working Prototype – Video Link

https://youtu.be/vkcJy7h9Dms

7.3.3 Working Prototype – Additional Photos

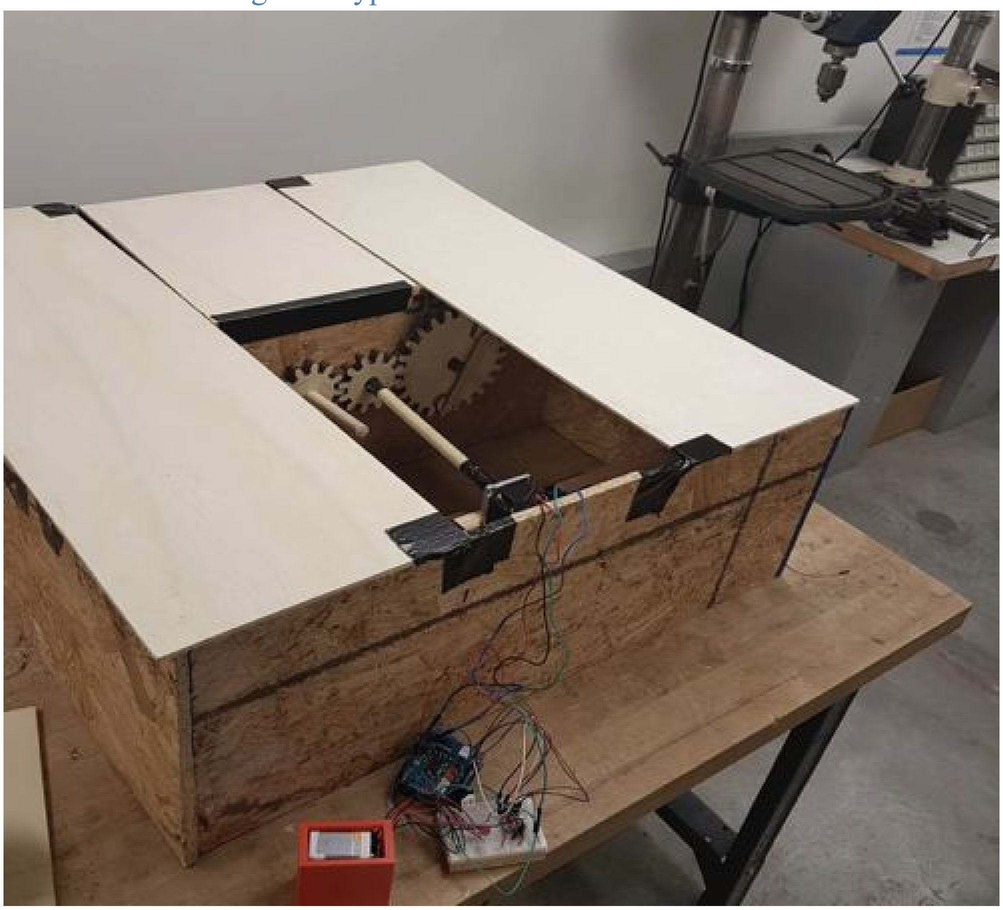


Figure 17 Overview of the working prototype

Figure 18 Gear driven by the DC Motor behind for the top board

7.4 Final Presentation – Video Link

https://youtu.be/OTIuf46fZ0g

8. Discussion

8.1 Design for Manufacturing – Part Redesign for Injection Molding

8.1.1 Draft Analysis Results

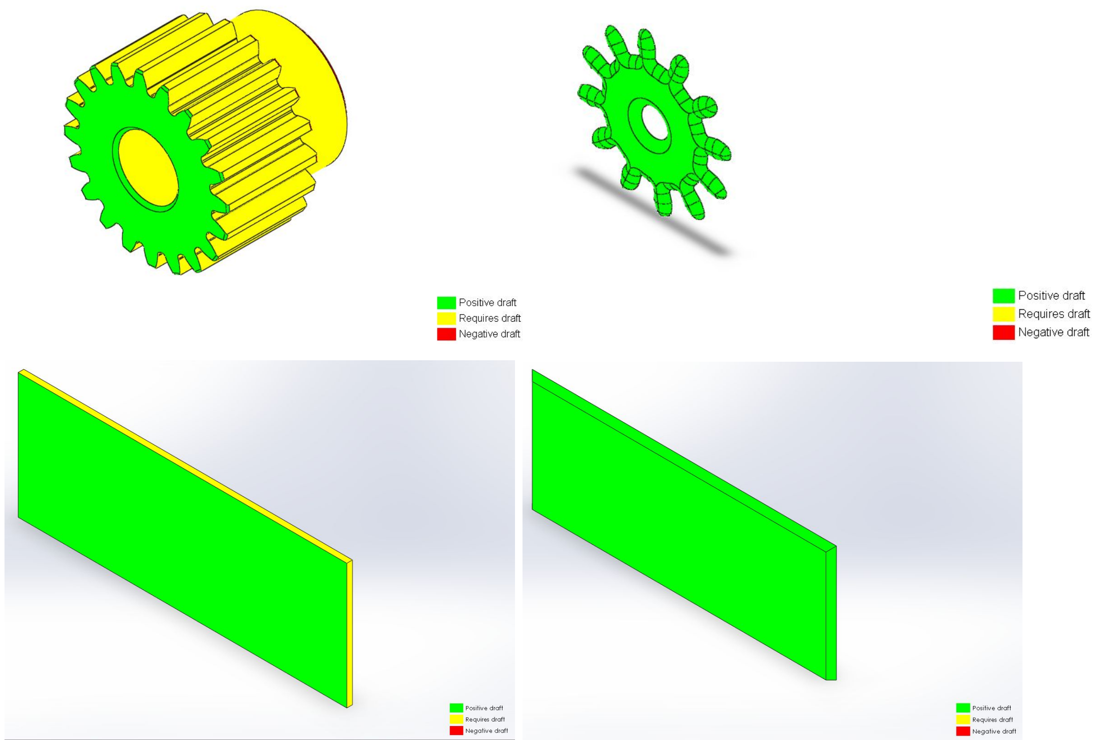


Figure 19 Draft analysis result for injection molding

7.1.2 Explanation of Design Changes

We changed the number of teeth of the gear and the thickness of the gear. As the number of teeth and the thickness reduce, less work would be required for us to laser cut the wooden board. It also helps the gear engage better with each other since there would be more space between every two teeth. It also makes it easier to take the gear out by reducing the contacting area.
We modified the shape of the board for the platform so they can fit better with each other.

8.2 Design for Usability – Effect of Impairments on Usability

8.2.1 Vision

Vision impairment is a common type of disability. At first, we intended to place two stickers with pictures on the buttons in the prototype to show the usage for each button. However, as we take into account the effect of vision impairment on usability, we will 3D print our buttons so that it shows the usage of each button in Braille in addition to the stickers.

8.2.2 Hearing

Our product design would not be influenced by hearing impairment on usability since the usage of our product is not dependent on sound. A hearing impaired customer can operate the machine without fail by following the instructions on the machine. The sound of the machine running may notify the user whether the machine is on or not, as well as whether or not there is any faulty party in the running system. However, all of these can also be detected easily from observing the machine.

8.2.3 Physical

Physical impairment influences our design greatly. We tried to reduce the weight and dimensions of our cloth folding machine while keeping it stable and strong. We may incorporate a wheel system in the final product for ease of moving the machine.

8.2.4 Language

Language barrier has always been an important factor in our design choice. Therefore, we tried to come up with a simple and user friendly design. An example is that we will print stickers with simple step-by-step instructions with images so that users with little or no English can still operate our machine with ease.

8.3 Overall Experience

8.3.1 Does your final project result align with the initial project description?

Our final result achieved our our goal of folding clothes and it has a structure to allow it to switch patterns between folding shirts and folding pants. But we did not make it work perfectly because of some mistakes in part selection and lack of funds. We could not add the switch button to switch the patterns.

8.3.2 Was the project more or less difficult than you had expected?

It was more difficult than we expected. The design of the mechanical part was really difficult. We came up with the working idea early at the beginning, but when we tried to realize it, we found it really difficult to make the dimensions right. A minor imprecision could result in a lot of work to correct the mechanism.

8.3.3 In what ways do you wish your final prototype would have performed better?

We tried to actually fold a shirt with our machine, but it did not work perfectly. We wish the machine can actually fold at least a shirt in a good shape.

8.3.4 Was your group missing any critical information when you evaluated concepts?

We were missing the volume of the prototype and thickness of boards when we evaluated the concepts. The volume of the whole machine is bigger than we expected. And the flipping boards cannot cover the whole case.

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

We did engineering analysis on the motor torque and the angular displacements of our flipping boards. It helped us a lot to design the gears and cranks. We could also have done some analysis on the shaft to improve the performance.

8.3.6 How did you identify your most relevant codes and standards and how they influence revision of the design?

Because we are designing a household appliance, we identify most relevant codes and standards are those apply to home-use appliance. Therefore, we were doing our design under the constraints of relative codes or standard. For example, we are trying to minimize the noise hazard and electrical hazard to follow the rules.

8.3.7 What ethical considerations (from the Engineering Ethics and Design for Environment seminar) are relevant to your device? How could these considerations be addressed?

The relevant considerations include the consumption of energy and the safety of the machine. The machine will be using electricity and the user need to interact with the machine. Since the machine has several electrical and mechanical parts that may cause potential harm to people, it is important to ensure the safety of the machine.

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

We should have spent more time on the switch of patterns and the control of the motors. The circuits part is equivalently important to the mechanical part but we did not spent as much time as we spent on mechanical part. The purchasing of materials and parts required less time.

8.3.9 Was there a task on your Gantt chart that was much harder than expected? Were there any that were much easier?

Actually, most of the tasks on Gantt chart are harder than expected. For example, there is no ideal gears with ideal teeth numbers and sizes in the market. Therefore, we had to build gears by ourselves using laser cutter. In addition, adjusting the crank positions on gears is also harder than expected. It took us countless times to adjust position of the gears, cranks and flipping boards. There are some tasks were much easier like building cases, simulating folding process in solidworks.

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

The gear and cranks were significantly harder than we expected. It required a lot of simulation and adjustment to make the cranks work properly and to avoid interfaces.

8.3.11 If your budget were increased to 10x its original amount, would your approach have changed? If so, in what specific ways?

If our budget were increased to 10 times the original amount, we would use better techniques to fabricate the gear and we will make our circuits more reliable by replacing the parts such as motors, switched and wires. We could also increase the amount of motors to make it easier for the machine to work.

8.3.12 If you were able to take the course again with the same project and group, what would you have done differently the second time around?

If I were able to take the course again, I would do the design process in a more organized way and plan things earlier.

8.3.13 Were your team member's skills complementary?

We made a good team by cooperating properly and contributing equally. Some of us is good at making documents, some of us is good at hands-on work, and some of us is good at electronic work.

8.3.14 Was any needed skill missing from the group?

We needed more skills of doing calculations for machine design. We did not do a lot of math work in the process, but it would have helped us better design the parts. We also need to sharpen the skills to do circuits.

8.3.15 Has the project enhanced your design skills?

The project enhanced my design skills a lot especially in terms of design using solidworks. We used Solidworks to build our theoretical models and assembly, and we used Solidworks to simulate the motion so that we can modify the shapes and dimensions of each part.

8.3.16 Would you now feel more comfortable accepting a design project assignment at a job?

I would feel more comfortable accepting a design project assignment at a job now. I am more used to the process of design and I learned a lot of new skills in designing. I am more confident in design than before.

8.3.17 Are there projects you would attempt now that you would not have attempted before?

We would attempt to make a soccer robot because this project require lots of electrical work, which can be a good practice.

Appendix A - Parts List

	Part	Source Link	Supplier Part Number	Color, TPI, other part IDs	Unit price	Tax ($0.00 if tax exemption applied)	Shipping	Quantity	Total price
1	Case Bottom	Machine shop	N	N	$5.00	$0.00	$0.00	1	$5.00
2	Case Top	Machine shop	N	N	$5.00	$0.00	$0.00	1	$5.00
3	Crank	Machine shop	N	N	$2.00	$0.00	$0.00	8	$16.00
4	Crank Attachment	Machine shop	N	N	$2.00	$0.00	$0.00	4	$8.00
5	Folding Boards	Amazon	N	Blue	$9.99	$1.00	$1.00	1	$11.99
6	Motor	McMaster	6142K58	Black	$59.83	$3.00	$5.00	1	$67.83
7	Large gear	McMaster	57655K54	White	$18.27	$1.00	$3.00	5	$95.35
8	Small gear	McMaster	57655K53	White	$6.65	$1.00	$1.00	1	$8.65
9	Shaft	McMaster	1327K3	Silver	$4.28	$1.00	$1.00	1	$6.28
10	Screws and fasteners	McMaster	90930A520	Silver	$4.35	$1.00	$1.00	1	$6.35
Total:									$230.45

Appendix B - CAD Models

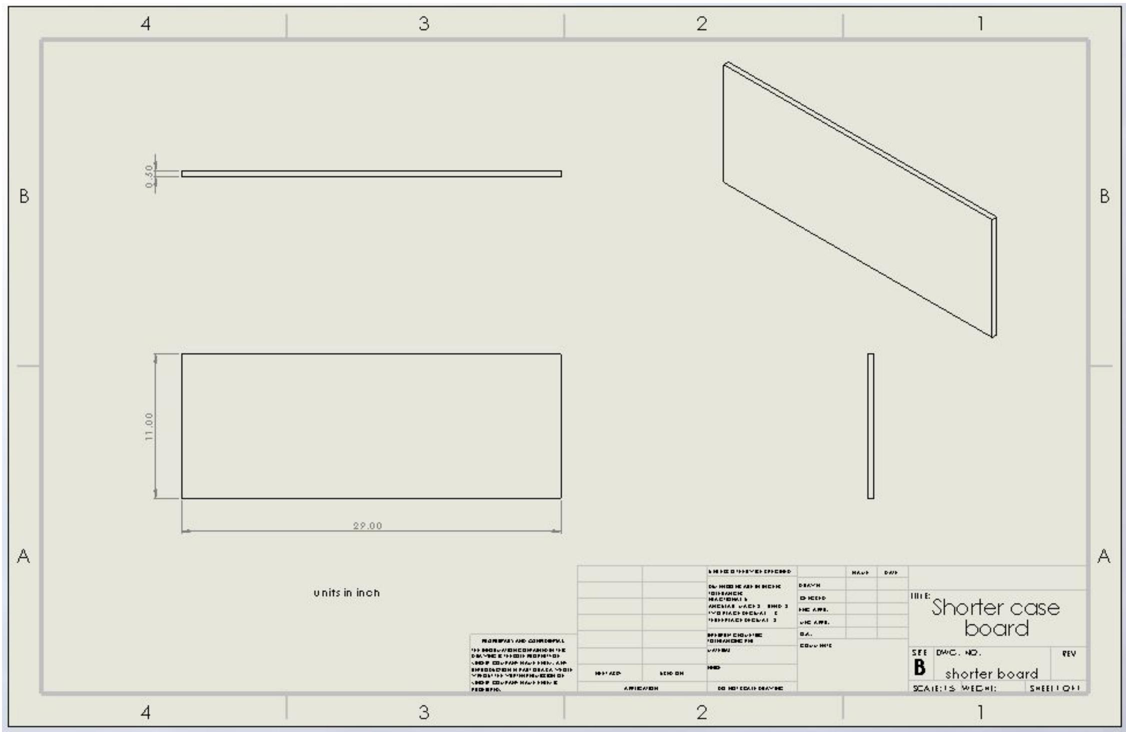


Figure 20 The side boards for the case of the clothes folding machine. The case boards are nailed together.

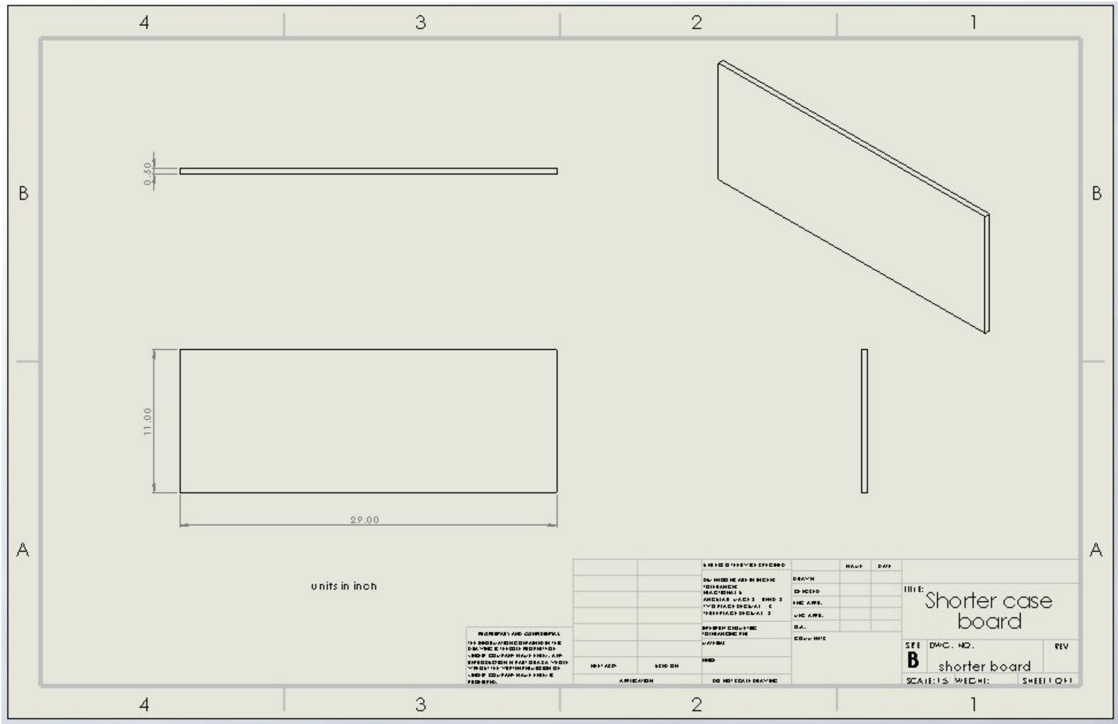


Figure 21 The top and bottom boards for the casing.

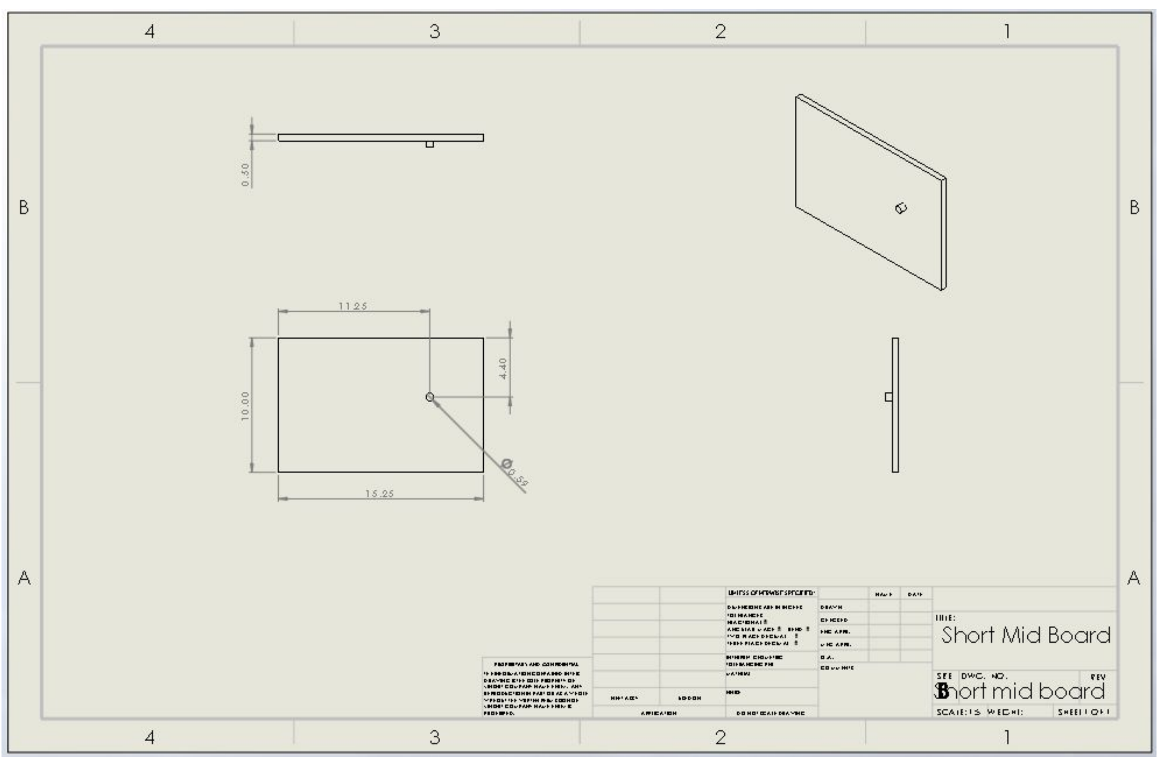


Figure 22 The middle board to holding the set of gears to drive the left and right flipping boards.

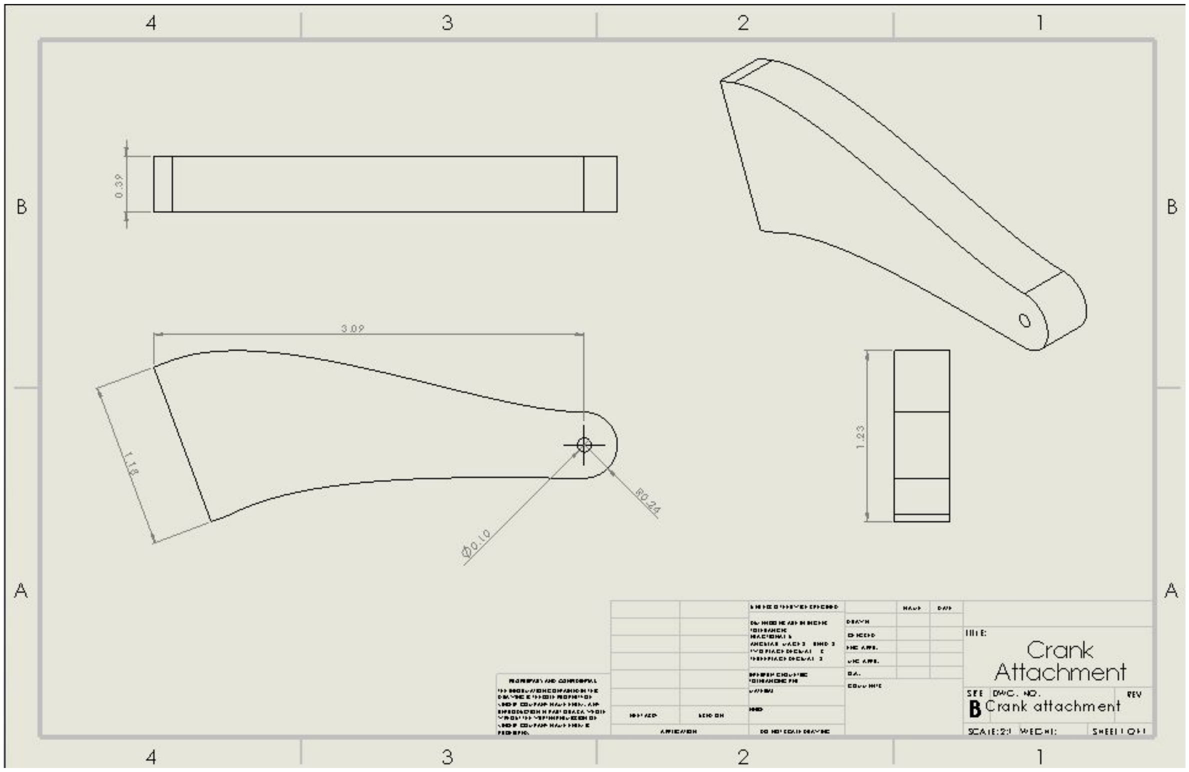


Figure 23 The crank attachment placed between the flipping board and the crank on the gears.

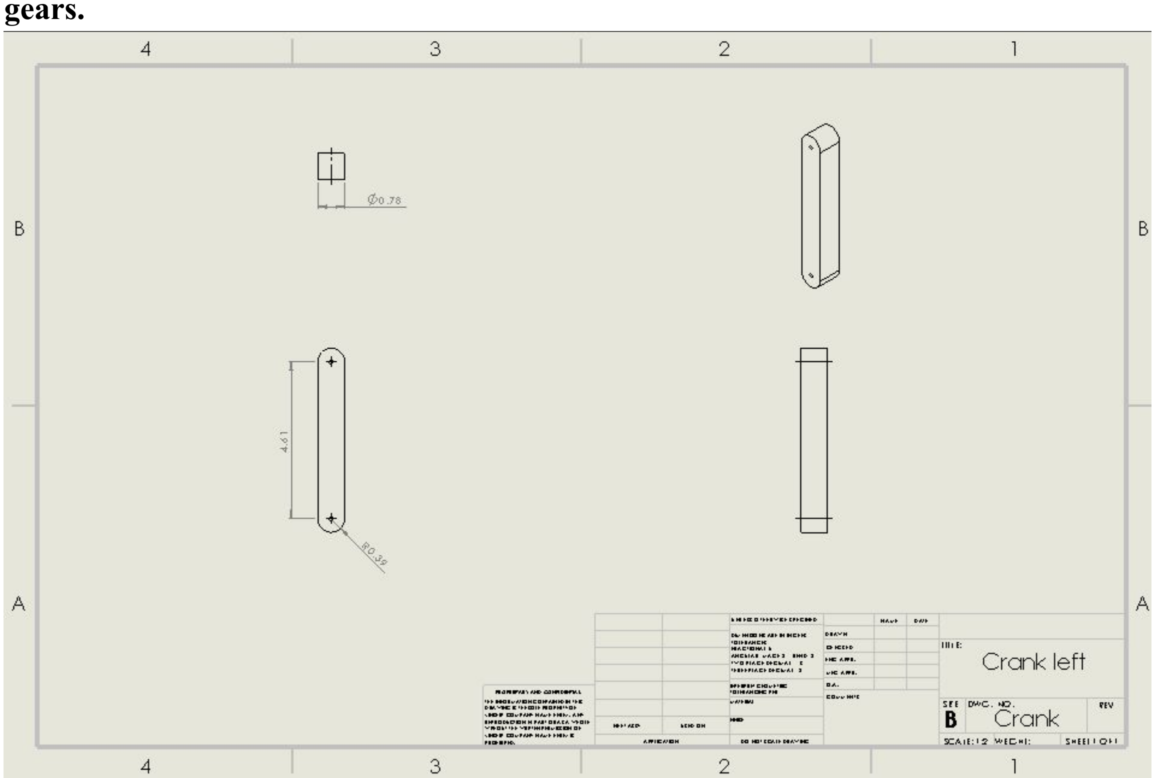


Figure 24 The left crank to drive the left flipping board

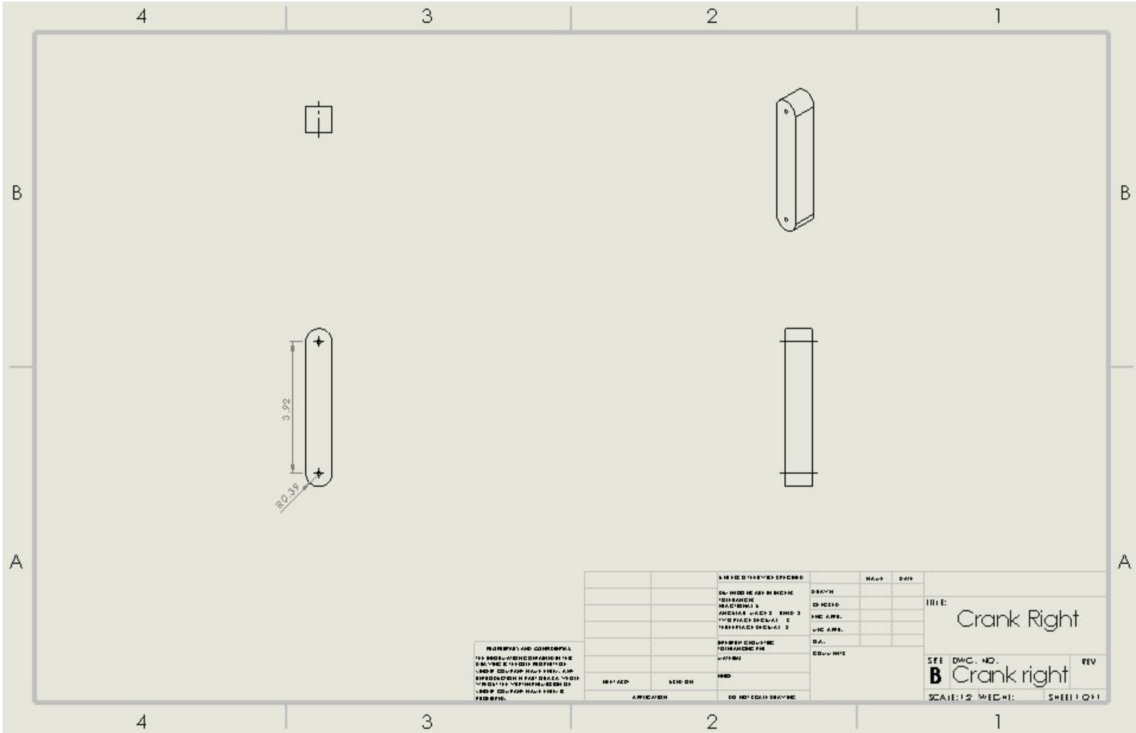


Figure 25 The right crank to drive the right flipping board.

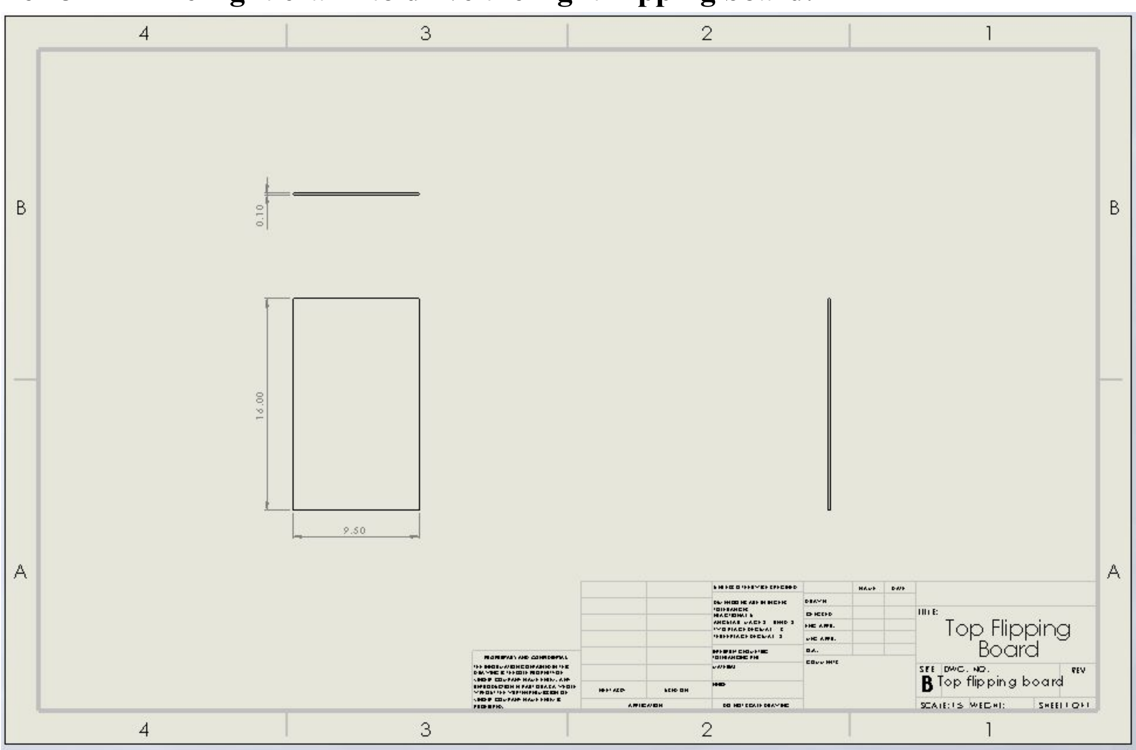


Figure 26 The top flipping board

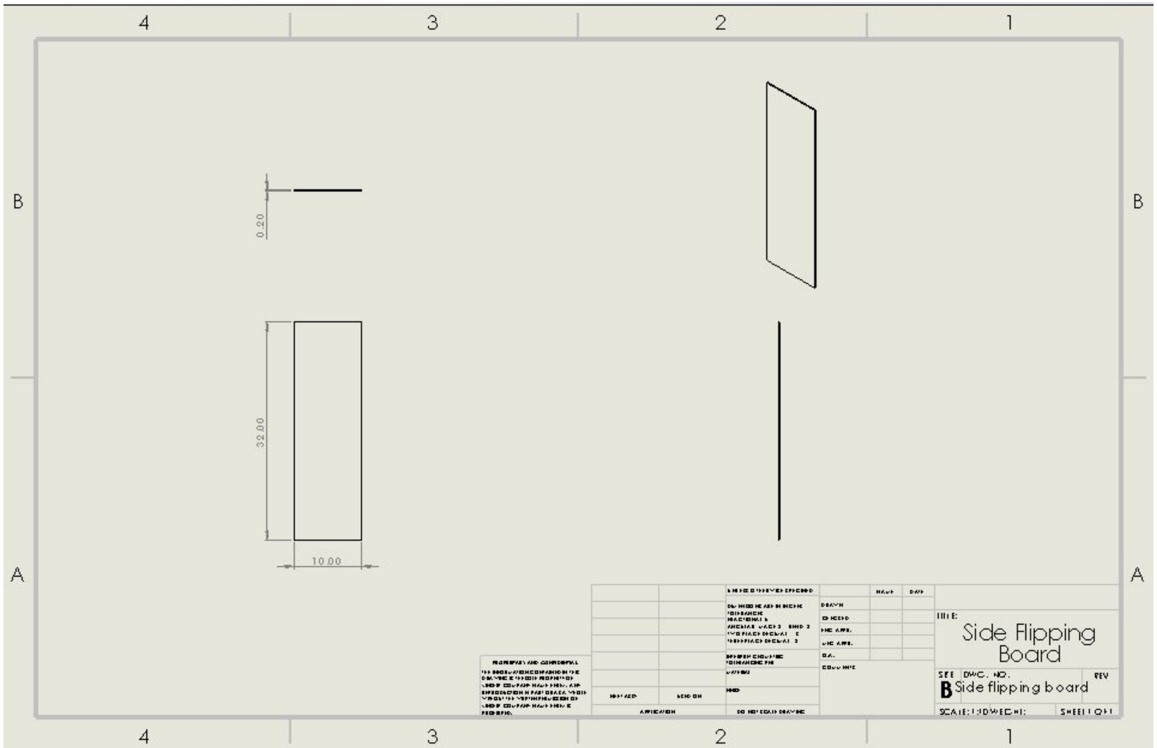


Figure 27 The two flipping boards on the side

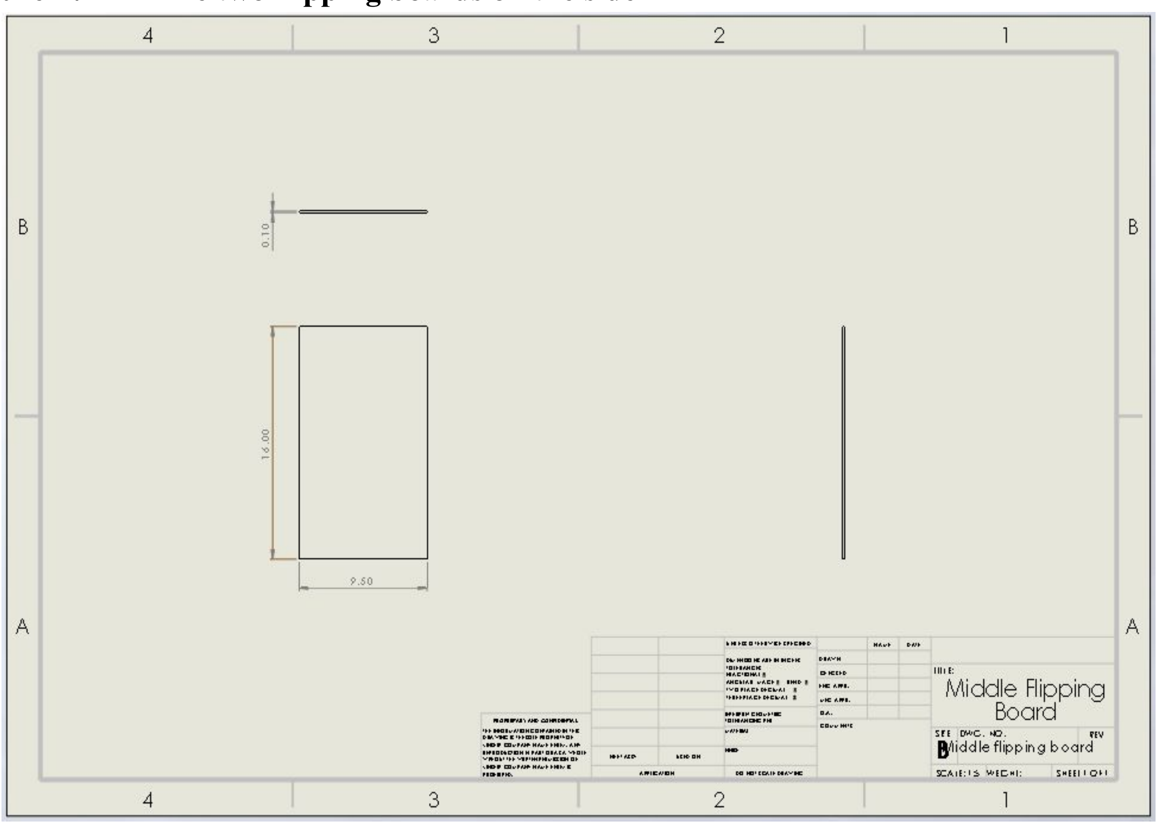


Figure 28 The stationary board below the top flipping board of the folding machine to hold folded clothes

Annotated Bibliography

Selker, Ted, and Gal Rozov. *Fabric article folding machine and method*. 10 Mar. 2015.

"Fabric article folding machine and method, a invention that folds fabric articles automatically. It uses a rotating rod in combination with a retractable concave/convex tape to create pairs of folds on a fabric article on a horizontal platform. "

Warren, James M.*Device for folding articles*. 25 Aug. 1995.

"Device for folding articles, a device for folding flexible articles such as shirts, towels, piece goods by comprising a generally flat main member with two side panels foldable attached to the main member. "

ISO 10472-5
This standard is the safety requirements for industrial laundry machinery, and it is intended to instruct the designer of industrial laundry machinery in a systematic manner regarding the relevant safety requirements and to suggest possible safety solutions.