ASHESI UNIVERSITY

DESIGN AND FABRICATION OF A MULTIDECK GARI SIEVING MACHINE

CAPSTONE PROJECT

B.Sc. Mechanical Engineering

Nene Dornu Abayateye

2020

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CAPSTONE PROJECT

Capstone Project submitted to the Department of Engineering, Ashesi University in partial fulfilment of the requirements for the award of Bachelor of Science degree in Mechanical Engineering.

Nene Abayateye

2020

DECLARATION

I hereby declare that this capstone is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

……………………………………………………………………………………………

Candidate's Name:

……………MENE DORKU ABAYATEYE……………………………………

Date: ……29TH MAY 2020………………………………………………………

I hereby declare that preparation and presentation of this capstone were supervised in accordance with the guidelines on supervision of capstone laid down by Ashesi University.

Supervisor's Signature:

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Supervisor's Name:

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Date: ……………………………………………………………………………………………

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Final thanks go to my parents, Martin and Grace Abayateye who have supported me since the beginning of my life and continue to do so relentlessly.

Abstract

Gari is a very important staple food made from cassava and is eaten in many parts of Africa. Gari has a granular nature and may contain different sizes of grains ranging from as small as 1 mm to as large as 6 mm. Depending on where and how gari is going to be eaten, specific particle sizes are desirable. The market value of gari is therefore reduced if a given sample to be bought has different grain sizes mixed together. To correct this, gari is often sieved into varying particle sizes using manual methods and this is often slow and laborious. As such, there arises the need for a machine to sieve gari particles into various sizes which can fit into an existing production setup and is less expensive than already existing ones on the market. This paper discusses all parameters which were considered to design a machine to automatically perform this sieving of the food into 3 distinct grades. A full conceptual design of the machine was developed and was ready for fabrication. Static and vibration simulations were carried out on parts of the machine most susceptible to failure and factors of safety between 1.4 and 5 were obtained for all these parts. Fabrication of the device was started but due to the onset of the COVID-19 pandemic, the fabrication could not be completed.

Table of Contents

List of Figures

1. Chapter 1: Introduction

1.1. Introduction

Gari, as shown in Figure 1.1 is one of the most common staple foods in Africa, eaten by over 80 million people collectively[1]. Gari is a granular flour-like food made from cassava which is first mashed into pulp. Most of the moisture is then drained from this pulp over a period of 3 – 4 days. This dewatered pulp contains fibrous matter and is then removed from the pulp. The remaining mass is roasted in a pot over a fire and this results in the granular product [2]. One of the reasons this food is so common is that it does not go bad easily. Gari is also one of the cheapest foods in a lot of African countries and can be eaten in a lot of ways with soups, stews and sauces. It can also be mixed with water, sugar and milk and eaten as a snack. Gari has great potential for export to other parts of the world, this potential has not yet been achieved due to manual methods of its production and processing.

Figure 1.1. Bowl of Gari

1.2. Problem Statement

After gari has been roasted and is ready for consumption, the granules are typically of different sizes, and these sizes may be as small as 1 mm to as large as 6 mm in diameter. Gari has been classified into grades according to extra fine, fine, coarse and extra course [3]. The various grades and their size ranges are as follows:

Extra fine: <2 mm

Fine: 2 mm – 3 mm

Coarse: 3 mm – 5 mm

Extra coarse: > 5 mm

These grades of gari have different uses in different cultures on the African continent. Fine and extra fine grains can be mixed with sugar, water and milk to make a snack. For this snack, a number of people in some parts of Africa find the coarse granules unpleasant to chew, and as such there is the need to separate larger grains from the finer ones to increase its market value [2]. Some users also have special purposes for coarse and extra coarse grains of gari and it is further important to separate grains according to the different needs of different people. This problem is also a major factor in the reason why the gains from export are also very low. Consumers in other parts of Africa are very sensitive to the inconsistency in the gari. A manual method of correcting this inconsistency problem is for humans to use sieves to separate coarse grains from finer ones. This activity is very laborious and time consuming which ends up in a lot of the gari being lost as waste to the surroundings of the person doing the sieving. Due to this problem, there is the need to design innovative solutions to this problem and improve upon existing ones to maximise the potential gains which can be obtained from the sale of gari in different parts of Africa.

1.3. Conceptual Framework

This project harnesses the natural phenomena of mechanical vibrations and gravity to achieve a goal, which is to separate gari grains into distinct grades. These naturally occurring phenomena are exploited to build a machine while taking into consideration the relevant principles of mechanical machine design.

1.4. Project Scope

This project involves the design and fabrication of a two-grade (including a third collection point for extra fine particles) gari sieving machine to meet the requirements of the machine as obtained from interaction with stakeholders in the Ghanaian market.

1.5. Project Objectives

This project seeks to:

i. Study existing designs of granular food sieving machines and identify their drawbacks.

ii. Identify the relevant components of a sieving machine and size these components appropriately to solve the shortcomings in existing machines.

iii. Develop conceptual designs of a machine to separate gari grains into 3 distinct grades.

iv. Generate Computer Aided Design (CAD) models of this machine.

v. Carry out static and vibrational analysis to ensure that all parts of the machine function properly.

vi. Fabricate the gari sieving machine.

2. Chapter 2 – Literature Review

2.1. Literature Review

In the past, gari was sieved through an entirely manual process[1]. In this process, an operator would pour mixed grains of gari onto a sieve (as shown in Figure 2.1) and manually shake the sieve to separate the grains. This process was slow and tedious and as a result, innovations were introduced to solve this problem. A number of these innovations are explored in this section with their advantages and disadvantages analysed.

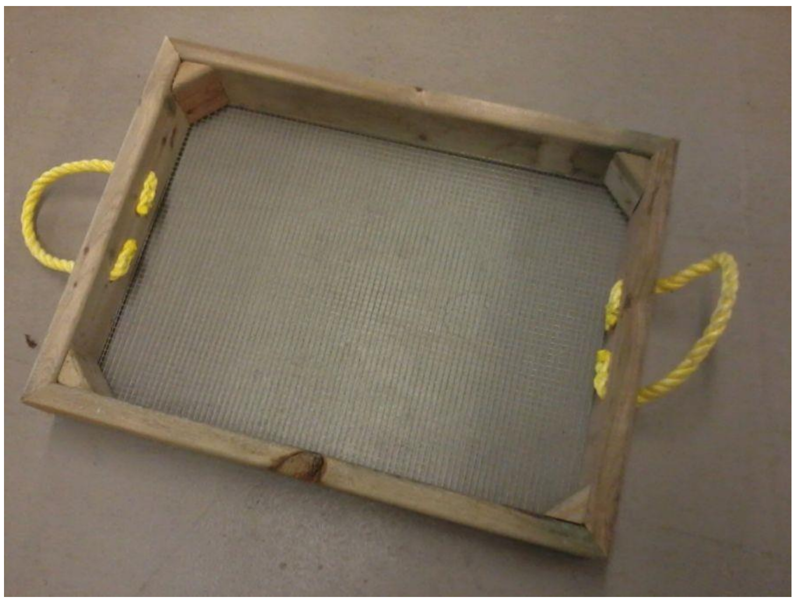

Figure 2.1. Manual wooden mesh.

One of the most common grain sieving machines in the food industry in recent times is the rotatory vibratory sieve in Figure 2.2 which uses a vibratory mechanism to excite particles. The food to be separated passes through a number of sieves which have gradually reducing mesh sizes. As the food passes through a particular sieve, grains larger than that mesh size are trapped and those smaller are able to pass through to the next sieve. These sieves also come in a variety of sizes and have different volume output capacities. These machines, though efficient, present a limitation due to their circular design. It is difficult to fit these rotatory sieves in a production floor with a moving assembly line.

Figure 2.2. Rotary vibratory sieve

A device which works on the same principles but in a slightly different manner is the quarry vibrating screen shown in Figure 2.3. This is a relatively larger device used in the mineral processing industry to separate aggregates into varying sizes [4]. These quarry vibrating screens for the quarry industry normally have a downward sloping rectangular design as opposed to the circular design used in food processing sieves. This rectangular design is making its way into the food industry because of the range of applications it can be made to fit in.

Figure 2.3. Quarry Vibrating Screen

Rice destoners [5] are also machines which work on a similar principle to this vibratory sieve, but do not use a vibration motor to achieve its separation. The device separates rice from impurities such as stones and gravels by passing feed (a mixture of rice and gravels) through a series of sieving trays. A traditional induction motor is attached to an exciter which rocks these sieving trays back and forth to achieve a vibratory effect. This is one of the most cost-effective ways to build such a machine. However, this mechanism has a flaw which makes it unfavourable for certain applications. Due to the number of moving parts and complexities involved in a design such as this, it is easily susceptible to breakdowns. One way to improve upon the design of this machine is to decrease the number of moving parts and find alternative ways to achieve the vibratory effect.

Other gari sieving machines exist which separate grains into two distinct grades. One of such machines was built by [2] and designed to be more robust than most other sieves present at the time. The design is laudable since it reduced the mechanisms involved in the sieving process. The machine could also be transported easily. One main flaw of this device however is that it has only one level of sieving; that is it separates feed into only two separate grades. According to [6], people in different parts of the African continent traditionally are accustomed to different grades and as such there is the need to further separate these grains into their respective sizes to increase its market value in different parts of the continent.

An important area to consider in the development of such a machine is the vibrating effect of the whole device. Vibrations are needed to ensure that the grains separate properly, and the volume of output and efficiency needed within a certain time is achieved. However, in as much as vibrations are important to this application, it is also essential to note that vibrations can lead to the failure of other parts of the machine which are not aiding in the actual sieving of the gari particles. The summary of this challenge is that enough vibration is needed to cause the gari to separate properly but can destroy other parts of the machine. Due to this, the vibrations need to be isolated from other parts of the machine. According to [7], springs are traditionally used to isolate these vibrations in such devices. These vibrations also need to be isolated to reduce the noise of the machine as a whole[8].

2.2. Ethnographic Research

After existing literature on this subject was consulted to gain understanding and become abreast with the topic, ethnographic research was then conducted to understand the problem in a local context. To build a solution that addresses the needs of the immediate environment (Ghana), a local gari processing factory was visited. Praise Exports Ltd is the name of this factory situated at Pokuase in Accra. This factory processes local foods for export and gari is one of the foods the company processes. This factory receives gari from suppliers which it packages and exports based on orders from clients all over the world. The factory expressed the need for such a device because these suppliers usually do not sieve the gari (though as per contract, they are supposed to) before delivering it to them. As such, Praise Exports is forced to employ laborers to sieve the gari using manual methods as described above. A device to do this sieving would be greatly appreciated in such an environment. The main problem with buying an already existing rotary sieve (the commonest for this application) was that the circular design did not fit into their already existing setup and as such a rectangular design of specific measurements was what they needed the most. Management of the company however did mention that currently, only one grade of sieved gari is useful to them as their current clients simply need one particular grade (fine grains). Nonetheless, the prospects of a larger African market to sell different grades of gari to is an opportunity management of the factory was very excited about.

A device such as this aims to massively speed up the time it takes to sieve granules, thereby increasing productivity of such a company and boosting the country’s economy in the long run.

3. Chapter 3 – Requirements & Options Evaluation

3.1. Requirements

From a review of existing literature and information gathered through ethnographic research, some requirements for the proposed machine were obtained. These requirements informed other design choices and decisions. These requirements are as follows:

- The machine should have the capacity to sieve 25 kg of gari per minute.
- The machine should be able to separate this 25 kg of gari into three distinct grades namely fine (<2 mm), coarse (2 mm – 3 mm) and extra coarse (> 3 mm).
- The machine should have a long lifespan (At least 10 years).
- The machine should require the very least maintenance (at most once in 3 months).
- The machine should cost less than GHC 2000.
- The machine should be easy to assemble, disassemble and transport.
- The machine should consume the least electrical power to achieve its purpose. This means the electrical motor must be appropriately sized to sieve 25 kg per minute.

3.2. Options Evaluation

This machine has vibrations as the core of its functionality. There are many forms of achieving this vibration and as such, there was need to compare some common methods of vibration and then define a criterion to select one of these methods. Two of the most popular methods are the linear vibration system and the vibration motor.

3.2.1. Mechanical Vibration System

In this system, an induction motor is attached via belt and sheave to circular unbalanced mass. The rotation of the motor rotates this unbalanced mass and set it in a back and forth motion happening many times per second. This produces the vibratory effect and rocks whatever machine the unbalanced masses are attached to. The biggest advantage of this system is its price. The induction motor, masses and belt collectively cost less than the cost of a vibratory motor [8]. The different components of this system can also be serviced individually, and problems are more easily detected and resolved. The main drawback of this system however is the number of parts which must be assembled. According to [9], machines with more moving parts pose a greater health risk to their operators. From [9] as well, the higher the moving parts a machine has, the lower its efficiency tends to be.

3.2.2. Vibration Motor

An electric vibration motor is a standard induction motor with unbalanced masses attached to its shaft not through their centres but at an offset. When these masses are spun by the motor, the whole motor vibrates and then vibrates whatever device it is attached to. This system is very similar to that of the mechanical vibration system in Section 3.2.1 but does not have all the components being separated. The main advantage of this motor is its simplicity and compactness. Due to this, maintenance cost is greatly reduced. The main drawback of this motor however is its initial cost which is far above an induction motor. From price comparisons on online trading websites Alibaba and AliExpress, it was observed that vibration motors are 60 to 70% more expensive than induction motors of the same power ratings. These two websites were selected because they are the two main sites from which engineering spare parts are shipped to Ghana.

A Pugh chart comparing these two modes of achieving vibration is shown in Table 3.1.

Table 3.1. Pugh chart comparing Vibration Systems

		Baseline	Option 1
Criteria	Weight	Mechanical Vibration System	Vibration Motor
Initial Cost	3	3	0
Operational Cost	3	0	3
Efficiency	4	0	4
Durability	2	0	2
Ease of Maintenance	5	0	5
Total		3	14

From Table 3.1, it was concluded that the best way to obtain the vibration required for this machine was with a vibration motor.

4. Chapter 4 – Methodology

After the requirements of the machine were obtained, the next phase of the project involved calculations to size and select various components of this machine.

4.1. Sieve Pore Sizes

The sieves are the main means by which larger grains of gari are separated from the finer ones. This device performs two layers of sieving. One of these sieves has pore openings of 2 mm and the other has 3 mm openings. Gari particles greater than 3 mm are trapped by the first sieve and those with sizes between 2 mm and 3 mm are trapped by the second sieve. All extra fine particles less than 2 mm are collected from the bottom of the machine. These sieves were made from galvanized steel, because of its cost effectiveness. A sample sieve is shown in Figure 4.1.

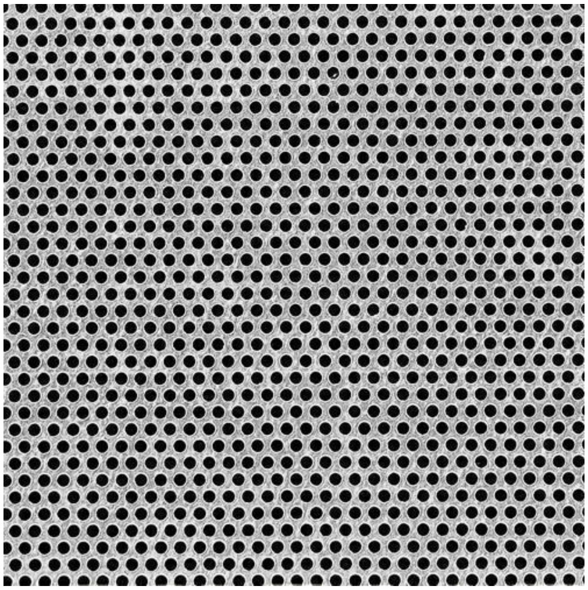

Figure 4.1. Sample of sieve

4.2. Tray

The tray houses the two sieves and is the part of the device to which a vibration motor is attached. From [4], the tray is inclined at an angle of 14° to the horizontal. This angle of inclination coupled with the excitation of the motor causes all grains to move downward along the length of the sieves. Particles smaller than the respective sizes of sieve fall through to the next level.

4.3. Vibration Motor

This motor is shown below in Figure 4.2. Like other induction motors on the market, these motors come in various power capacities and from the requirements of the device to be met, a 0.75 kW (1 hp) single phase motor running at 1400 rpm [2] was selected. This motor also has a mass of 15 kg.

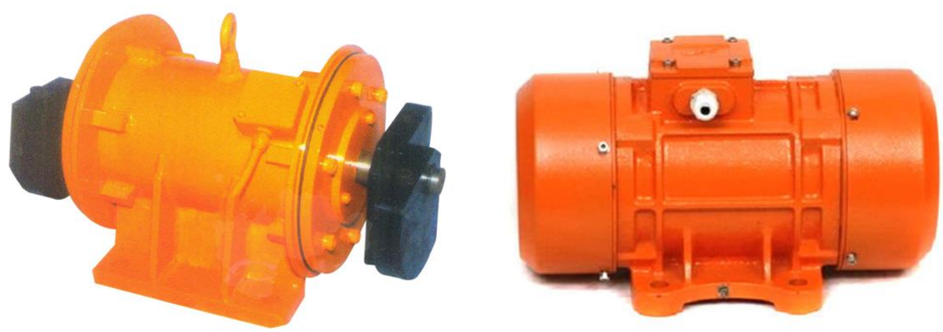

Figure 4.2. A vibration motor showing masses attached (left) and fully enclosed (right)

4.4. Springs for Vibration Isolation.

In such a machine, it is necessary to isolate vibrations at the body from reaching the support members of the device. It is important for a distinction to be made between vibration dampening and vibration isolation. While these two terms may sound very similar, there is an important difference in their technical definitions. Vibration damping is the process of absorbing or changing vibration energy to reduce the amount of energy transmitted to the equipment or machinery, while vibration isolation prevents energy from entering machinery[10]. In this case, the aim is to prevent vibrations from entering the supports, and as such isolation is the goal here and springs are the simplest means of achieving this[7]. The springs chosen must be a good fit for this application, because a spring which is too stiff (high spring constant) would transfer all the vibrations down to the support and defeat the whole purpose of the spring. A spring which is too lose (low spring constant) would compress entirely under the weight of the body alone even before the machine begins vibrating and this is also unfavourable. A model to be used for initial analysis of this machine can be found in Figure 4.3

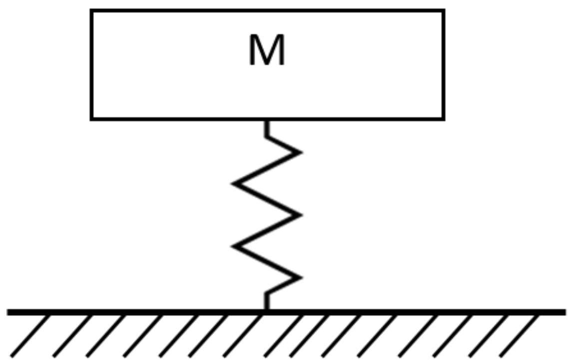

Figure 4.3. Model of Machine

4.4.1. Theoretical Spring Selection Analysis

The mass, M in Figure 4.3 is the lumped mass of the gari grains, vibration motor, tray and any other metal parts.

From Section 3.1, the mass of gari = 25 kg

From Section 4.3, the mass of the vibration motor = 15 kg

The assumed mass of all tray, sieves and all other members = 20 kg

The total mass,

$$m = 25 + 15 + 20 = 60 \text{ kg}$$

It is assumed that there is no damping, with all vibrations being isolated such that the damping coefficient, $\zeta = 0$

From section 4.3, speed of chosen motor = 1400 revs/min.

Converting this speed to the motor's excitation frequency,

$$\Omega = 1400 \frac{rev}{min} \text{ x } \frac{2\pi\ rad}{rev} \text{ x } \frac{1\ min}{60s} = 146.6 \text{ rad/s}$$

From [11], this system is assumed to have a vibration isolation of 90% = 0.9

From [11], the transmissibility, T is given by

$$T = \frac{\sqrt{1+(2\zeta r)^2}}{\sqrt{(1-r^2)^2+(2\zeta r)^2}}, \qquad \ldots \text{ (Eqn 4.1)}$$

where r is the frequency ratio.

Since there is no damping in this system,

$$T = \frac{1}{\sqrt{(1-r^2)^2}} \qquad \ldots \text{ (Eqn 4.2)}$$

$$T = 1 - 0.9 = 0.1 = \frac{1}{\sqrt{(1-r^2)^2}}$$

Solving for the frequency ratio r, $r = \sqrt{11}$.

From [11], the stiffness or spring constant k, required can be calculated using the relation

$$r = \frac{\Omega}{\omega}, \text{ but } \omega = \sqrt{\frac{k}{m}} \qquad \ldots \text{ (Eqn 4.3)}$$

Rearranging this equation and solving for k,

$$k = 60\left(\frac{146.6}{\sqrt{11}}\right)$$

$$k = 117{,}227\ \frac{\mathrm{N}}{\mathrm{m}} \approx 117.227\ \mathrm{kN/m}$$

4.4.2. Experimental values of potential spring constants

After the spring constant was obtained from theoretical analysis, some springs already available in the Ashesi environment were considered to determine if they would be suitable for this application. The spring constants of these springs were not known, and as such experiments were carried out to determine their springs constants. To perform this experiment, the springs were placed between the two jaws of an MTS Tensile Testing Machine as shown in Figure 4.4.

Figure 4.4. Spring during Tests

The tensile testing machine compressed the spring while recording the force needed to do so against the compression (negative extension). The graph in Figure 4.5 was obtained from this experiment and the spring constant of this spring was found to be k = 102.202 kN/m. This spring constant was suitably close to the theoretical value of 117.227 kN/m to be used for the machine.

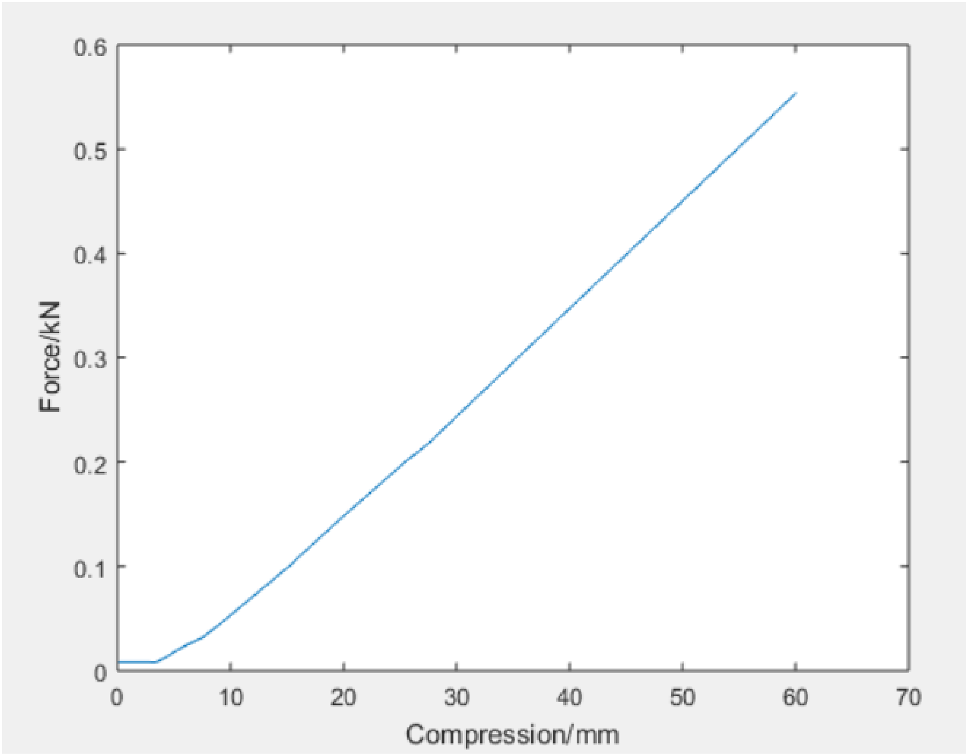

Figure 4.5. Graph of force (kN) against compression (mm)

4.5. Conceptual Development of Designs

This section of the report entails different design concepts which were considered. The advantages and disadvantages of each of these designs are analysed and then one was selected to for further studies.

4.5.1. Concept 1

Figure 4.6 shows an initial proposed concept of this machine which satisfies all requirements and calculations as shown above. This model was designed with a 3 mm thick body (shown in Figure 4.6) in which two sloping sieves would be inserted to sieve the gari grains. The proposed material was stainless steel because the food grains are in direct contact with the body of the device. The proposed material for the stands of this concept was 4 cm square galvanised steel bars with springs in between the body and the stands for vibration isolation.

The main drawbacks of this model were its extremely high cost and difficult machineability of the 3 mm stainless steel plate the body was to be made from. From discussions with various metal vendors, a 122 cm x 245 cm stainless steel plate of such thickness would cost an estimated GHC2,500. This was before all manufacturing processes were carried out on it to cut and weld it into the finished product. These costs were out of the budget allocated for the completion of this project and was one of the major drawbacks of this conceptual design.

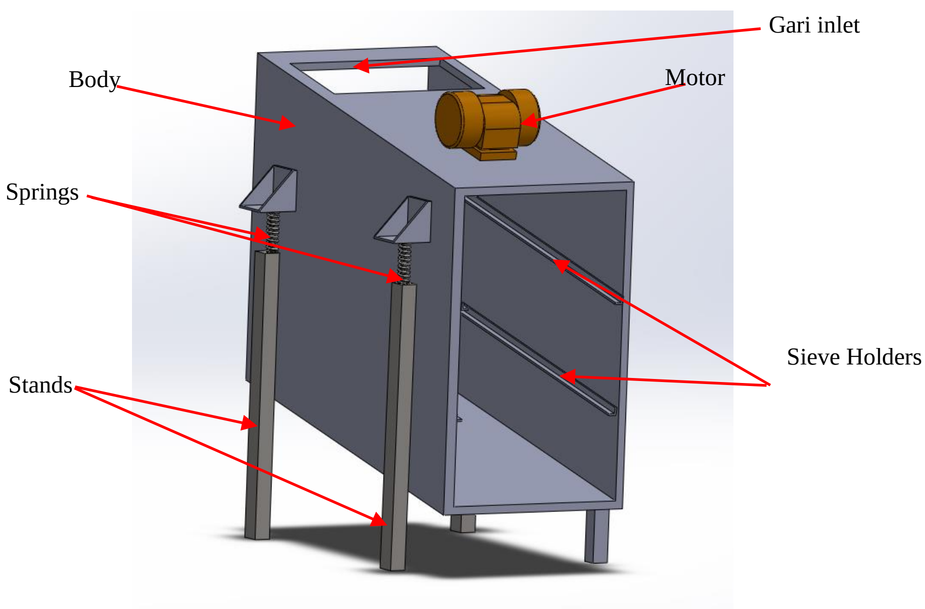

Figure 4.6. 3D Model of Concept 1

4.5.2. Concept 2

This iteration improved upon the challenges and issues on Concept 1 and was to be made with more cost-effective and easily accessible materials. This configuration has a hopper on top of a frame through which gari grains would be poured into the machine. The springs discussed in Section 4.4.1, are placed in between the frame and a tray which contains the sieves. Several improvements were made to this design and is explained into detail in the next chapter.

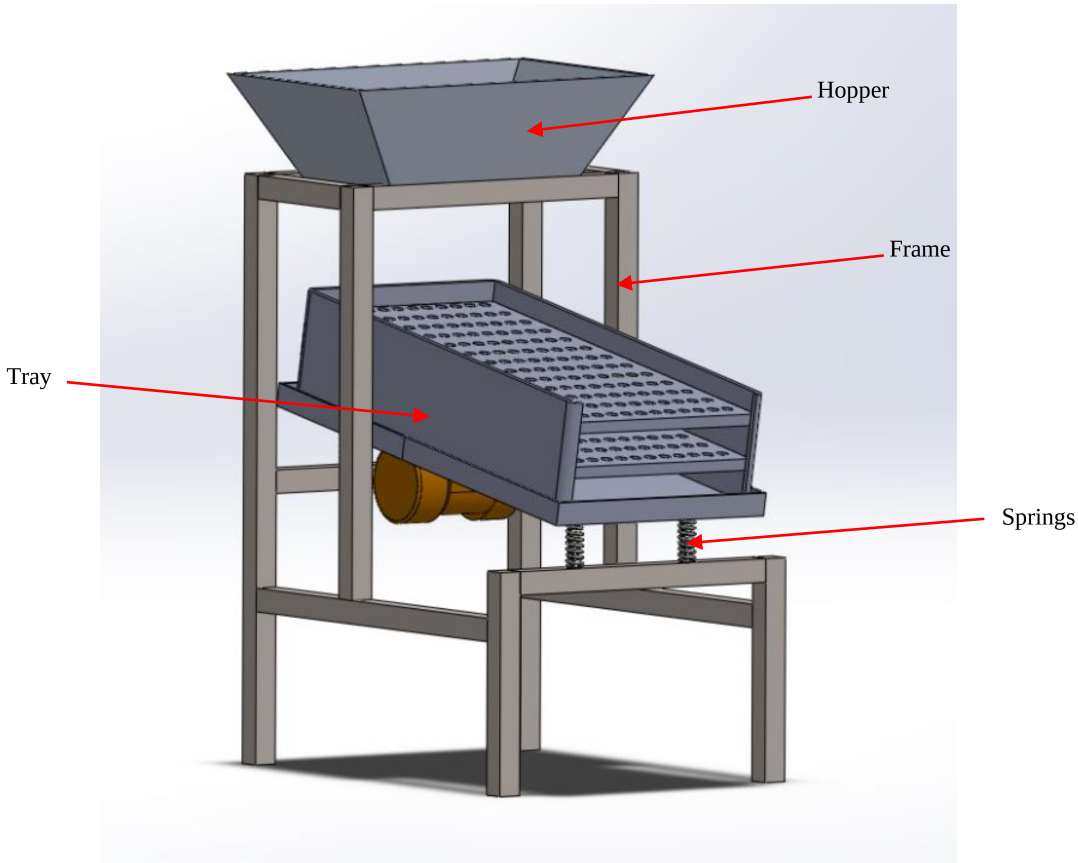

Figure 4.7. 3D Model of Concept 2

5. Chapter 5 – Discussion of Proposed Concept

5.1. Discussion of Main Parts

This section discusses the main components of the proposed concept.

5.1.1. Frame

The frame of this device is the skeleton which holds all the other components of the system (motor, sieving tray, hopper, etc.). This part is designed to be one structure and all its different members connected by welds. In the development of a similar machine, [2] selected mild steel as the material to be used for the frame. A 3D image of the frame is shown in Figure 5.1. There are four cylindrical members on the surface of the front and rear bracing members and can be thought of as supports. These are the points where springs are inserted. The proposed material for these supports is 2.5 cm diameter galvanized steel pipes. They will be welded unto the front and rear bracings.

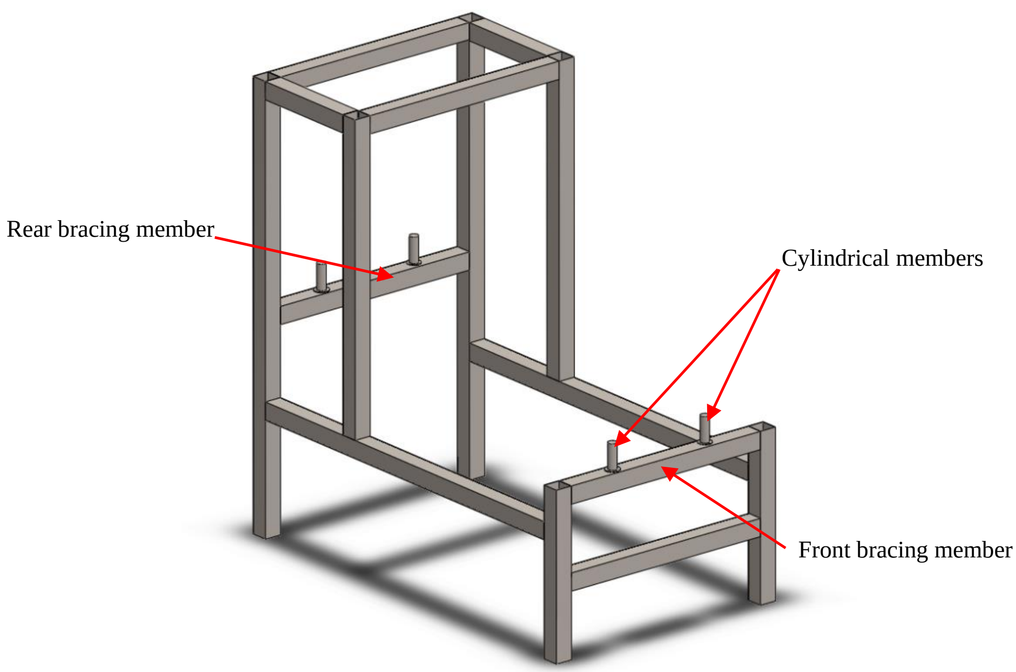

Figure 5.1. 3D Image of Frame

5.1.2. Hopper

The hopper is a funnel-shaped part which the gari grains are poured through. This part directs all grains into the sieving tray for the sieving process to commence. The hopper fits directly into the upper section of the frame and will be welded to members of the lateral bracing members on the frame. It would be impractical for such a device to be taller than the average human, since a human would have to hoist a sack of gari up to the level of hopper to pour it in. The dimensions of the frame and hopper were carefully designed so that they did not exceed reasonable height. The final height of the whole machine was 112 cm, well below the 95th percentile male height of 186 cm [12]. The industry standard material for constructing a part such as this is stainless steel. Due to cost reasons however, the proposed material for this hopper is aluminium sheet metal. Forming operations will be used to obtained the shape shown in Figure 5.2.

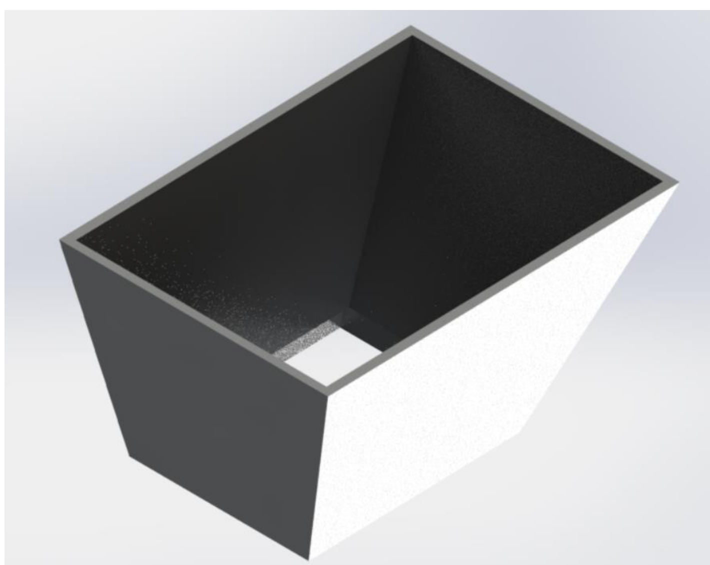

Figure 5.2. Hopper

5.1.3. Sieve tray

The sieve tray is the part of the device which holds the sieves and has outlets for the different grades of separated gari. The two sieves are inserted into aluminium F- profiles fixed to the inner walls of the tray (shown in blue in Figure 5.4). This forms a sliding mechanism and the sieves can be removed for routine cleaning when the machine is not in use. To ensure that gari grains which have just been separated do not end up being collected into the same container again, the outlets for the different grades are pointed in different directions as shown in Figure 5.3B. Coarse grains are collected from an outlet on the right, fine grains from the front of the tray and extra fine grains from below. Due to the high price of the food grade stainless steel required for this part, this tray is to be formed from aluminium sheets which equally works as a proof of concept.

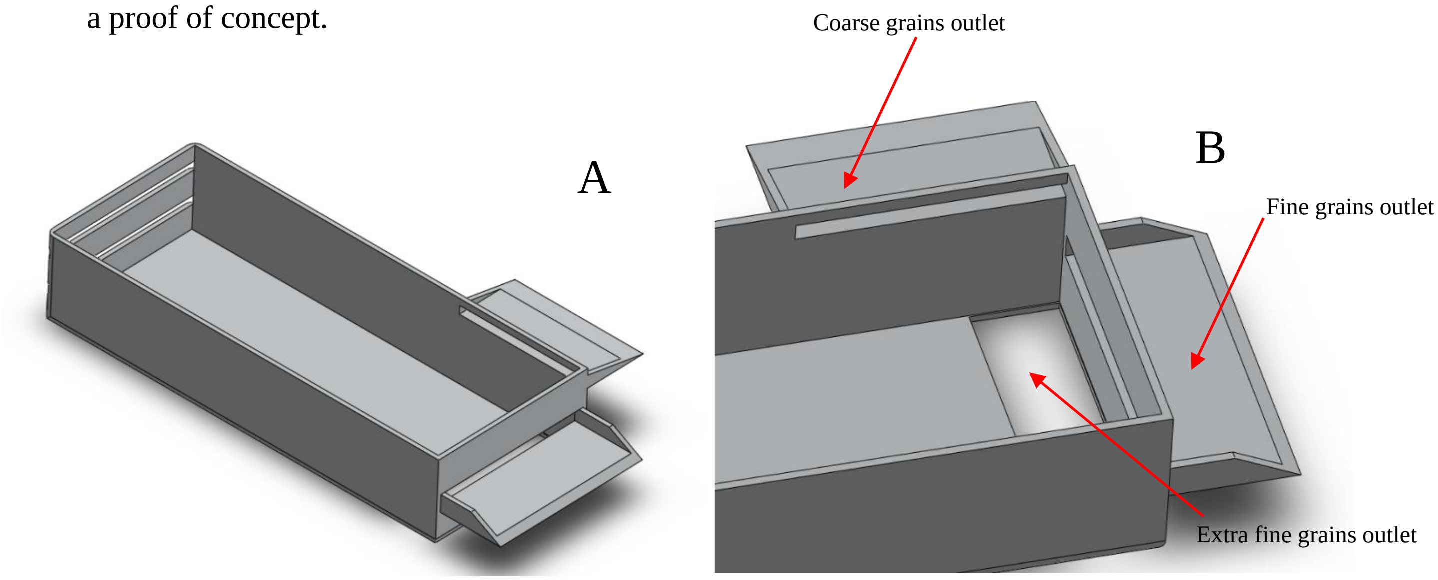

Figure 5.3. Sieve Tray. A - whole part and B – View of front sections showing outlets

Due to the angle of inclination of the tray, the gari grains at the second and third outlets will always pour out without becoming accumulated in the tray. At the first outlet however, the grains may become trapped at the corner opposite the outlet. To prevent this, this sieve is slanted to make sure the grains always move towards the first outlet as shown in Figure 5.4.

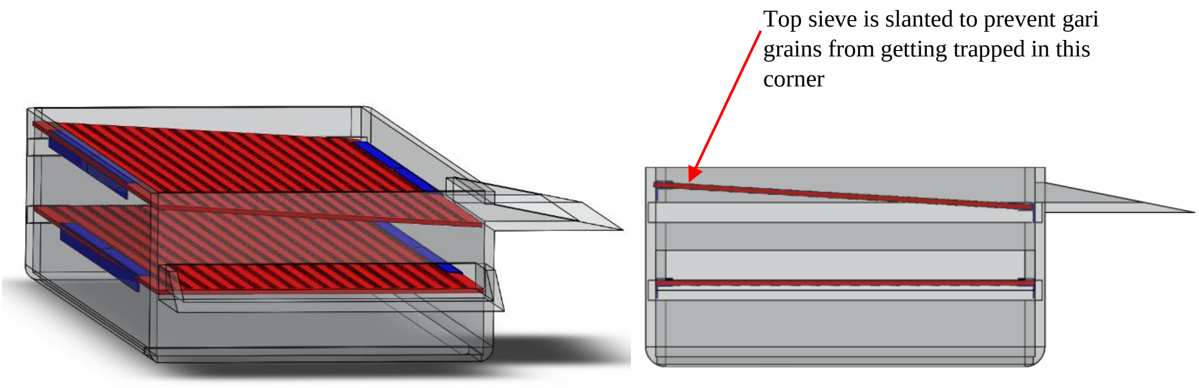

Figure 5.4. Slanted Upper Sieve (Sieves in red for clarity and aluminium profiles in blue)

5.1.4. Sieve tray seat

The tray shown in Figure 5.5 connects the tray to the frame of the machine. The motor is attached to the tray seat using bolts and nuts. The proposed material for this seat is 4 cm iron angle bars because it has high flexural rigidity. The seat also has cylindrical supports similar to those in Figure 5.1 for connecting to the springs.

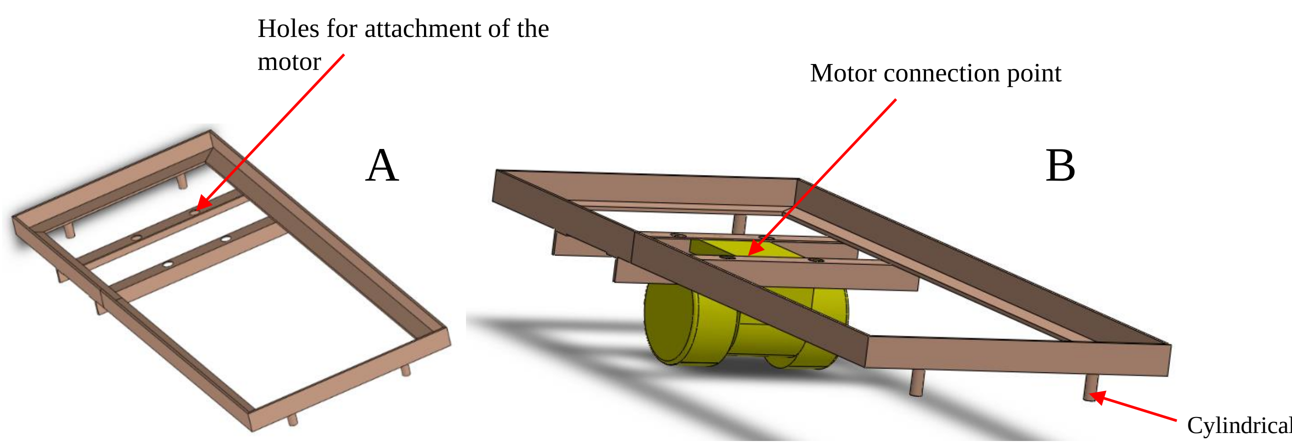

Figure 5.5. Sieve Tray Seat. A – Seat Alone. B- Seat with motor attached

5.1.5. Assembled Machine

Figure 5.6 shows the complete concept of the gari sieving machine with all parts assembled. The complete dimensions of the whole machine and all various parts may be found in the Appendix section. The exploded view of the assembled device is shown in Figure 5.7 with all the different parts labelled.

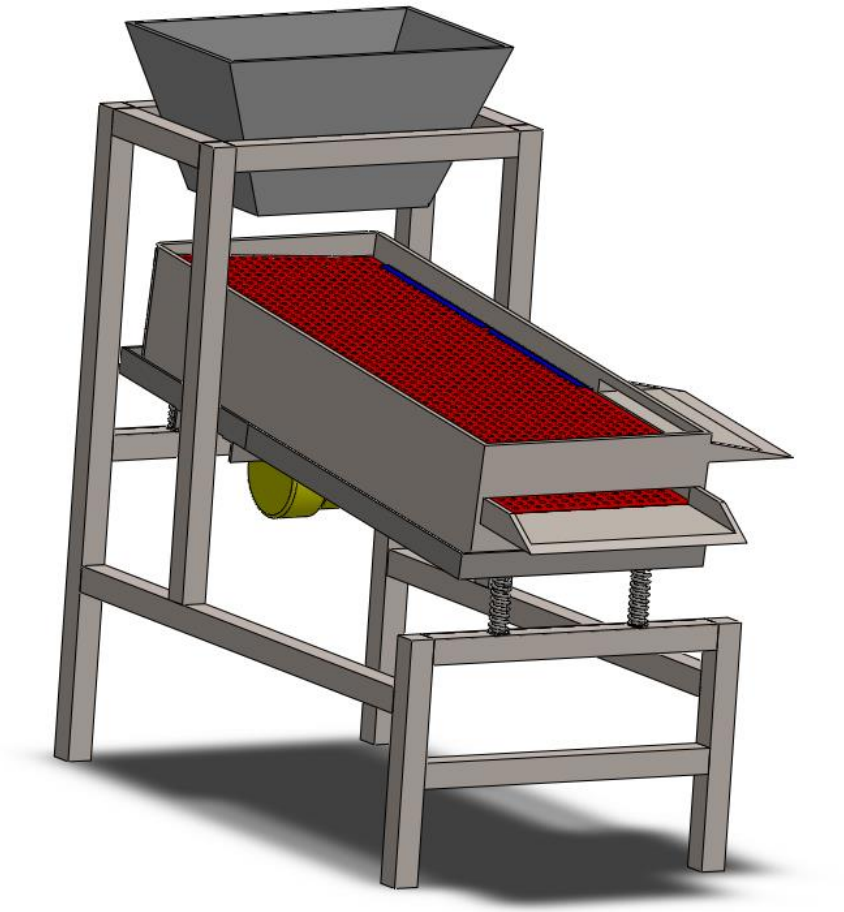

Figure 5.6. Assembled Machine

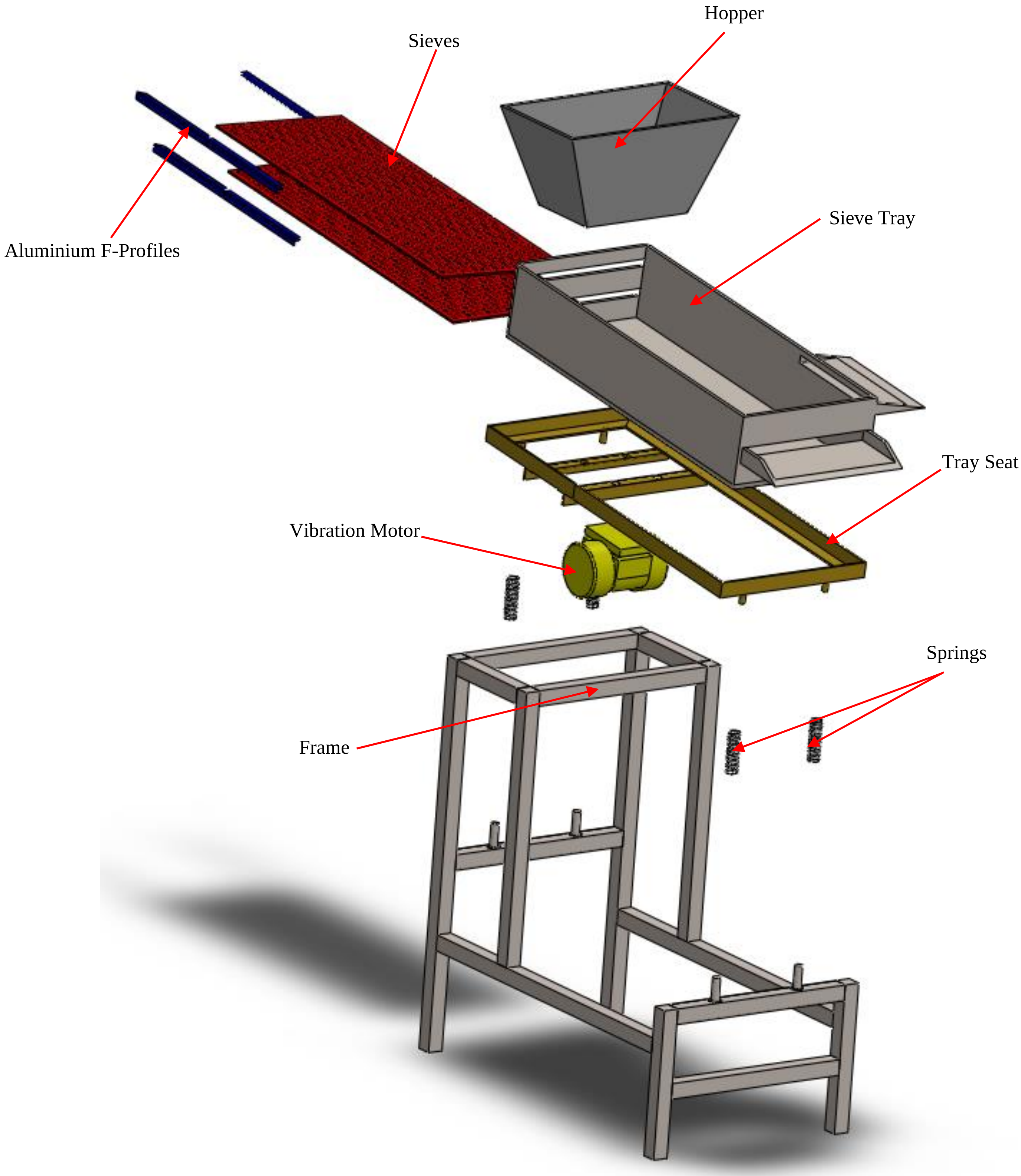

Figure 5.7. Exploded View of Machine

5.2. Static and Vibration Simulation Results

Three parts of this machine are the most susceptible to failure due to their positions and geometries. These include the tray seat, front and rear bracing members and the frame. This section discusses static and vibration analyses which were carried out on these three parts. Static analyses were carried out to ensure that these parts do not fail even before the motor starts vibrating. Vibration analyses were carried out to ensure that the resonant frequencies of these parts are sufficiently far away from the vibration frequency of the motor to prevent damage. Fatigue analyses were not performed on these parts because the machine would not be experiencing conventional cyclic loading. When the machine is in use, the loading can be thought of as static loads. The only change to this static load comes as a result of the vibrations of the motor.

5.2.1. Static Analysis on Front and Rear Bracing Members

The frame of the machine must be able to support the lumped mass of the motor, sieve tray, gari grains and sieves even before any vibrations are considered. From Section 4.4, this mass was found to be 60 kg. The member shown in Figure 5.8 was selected from the whole frame in Figure 5.1 for a static analysis because the lumped mass rests on two of these members.

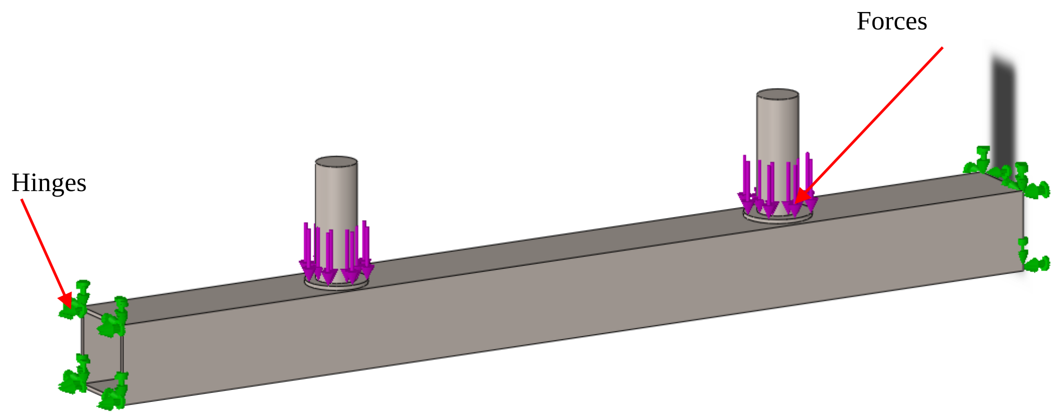

Figure 5.8. Front and Rear Bracing Member

In this simulation in SOLIDWORKS 2018, annealed mild steel with a yield strength of 292 MPa was set as the material to be used. A force of 600 N was applied as indicated by the purple arrows in Figure 5.8. After the simulation was run, the maximum stress was found to be 105 MPa as seen in Figure 5.9. This corresponded with a factor of safety of 2.8 as shown in Figure 5.10. Because of the high cost of mild steel however, galvanised steel was chosen to build the frame because it has similar properties and is more readily available on the Ghanaian market.

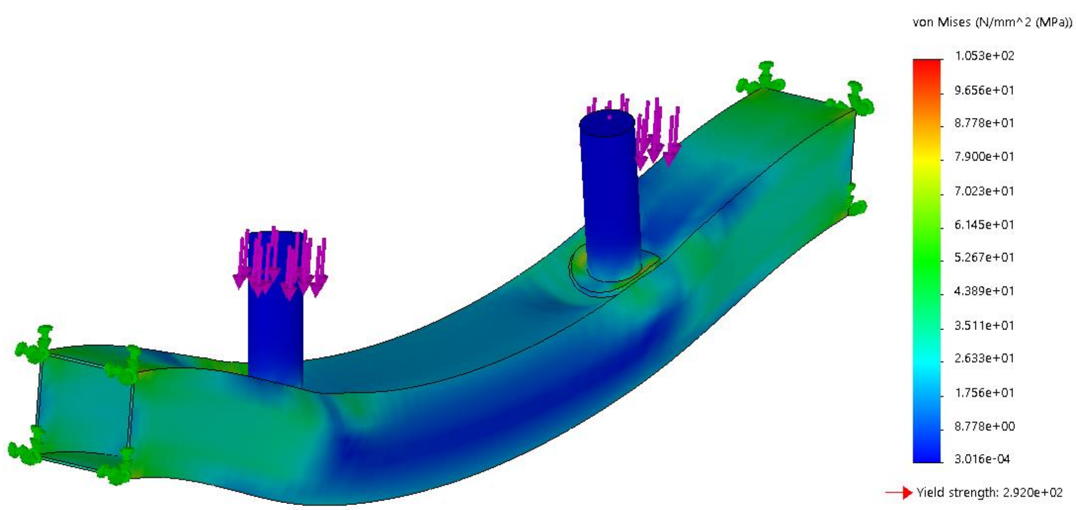

Figure 5.9. Stress Simulation Result

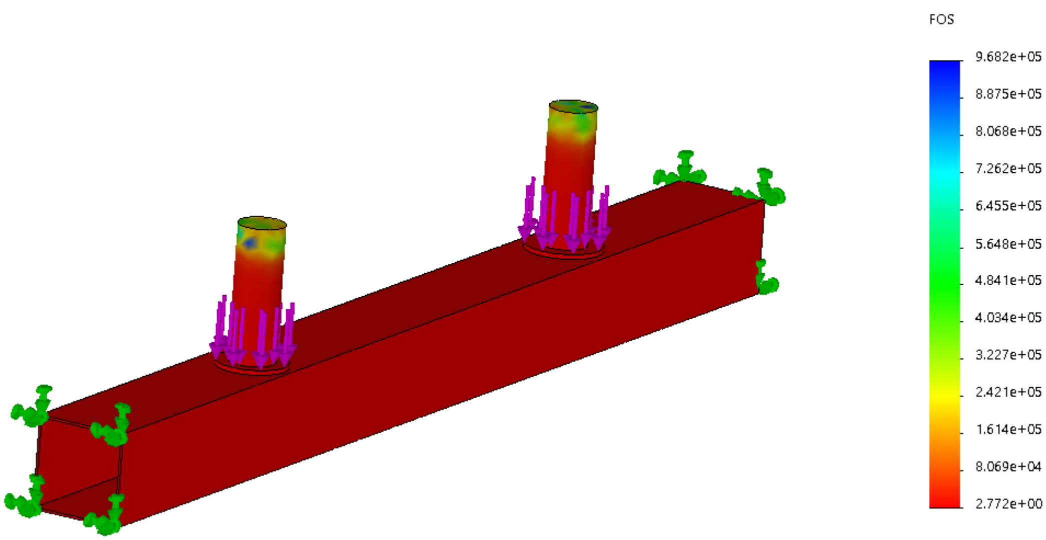

Figure 5.10. Factor of Safety Plot

5.2.2. Static Analysis on Entire Frame

A static analysis on the whole frame assembly was performed. The material applied was mild steel as used in Section 5.2.1. Forces (shown in purple) and fixtures (shown in green) were applied as shown in Figure 5.11.

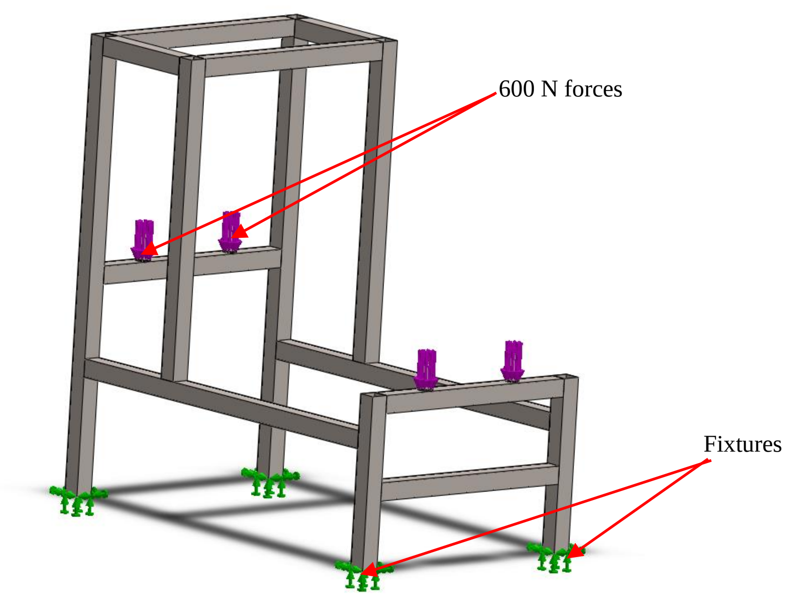

Figure 5.11. Forces and fixtures applied to frame

After the simulation was run, the maximum stress obtained was 69 MPa. This value is well below the stress value of 292 MPa and had a minimum safety factor of 3.8 which was acceptable.

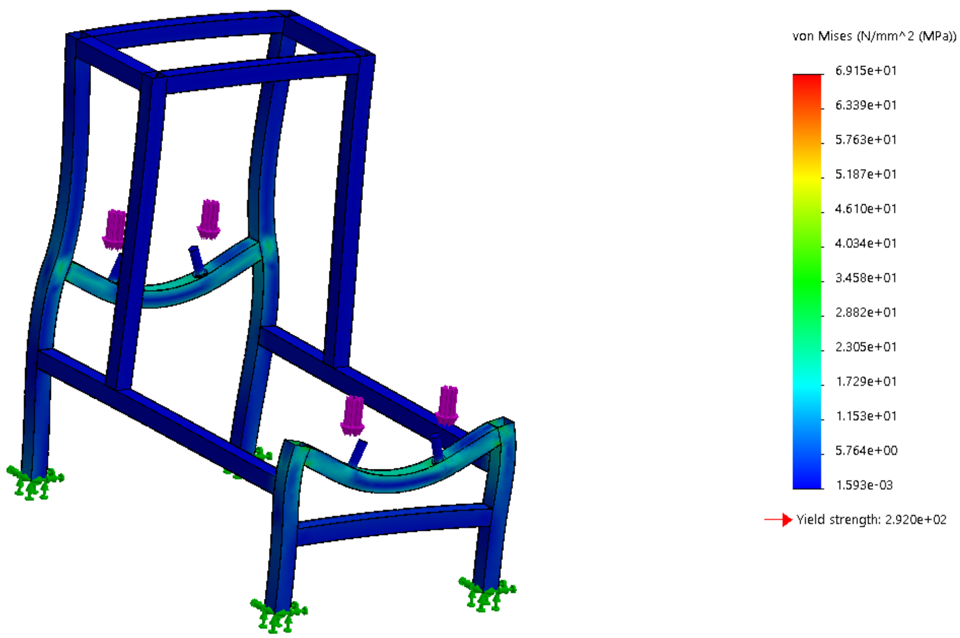

Figure 5.12. Stress simulation of frame

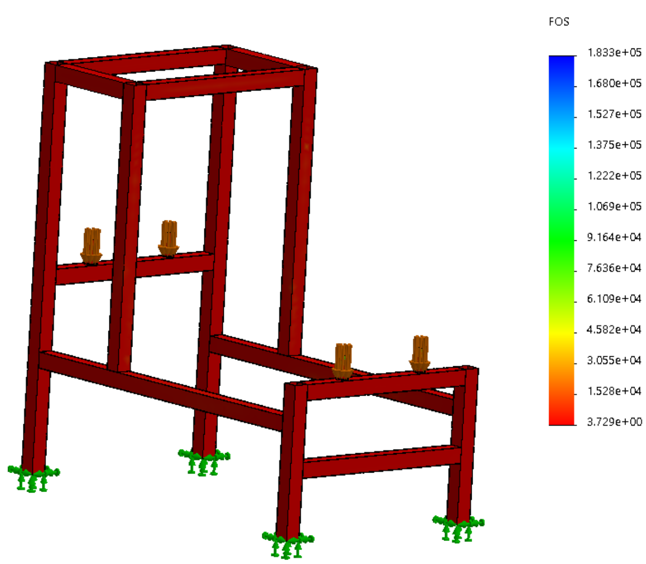

Figure 5.13. Factor of safety of frame

5.2.3. Static Analysis on Tray Seat

In a static analysis on the tray seat, a 150 N force (weight of the vibration motor) was applied to the points of attachment of the motor and a 300 N force (weight of the gari and sieve tray) was applied to the inner horizontal surface of the tray seat. This is shown in Figure 5.14. From [5], cast iron was applied to the part with a yield strength of 241 MPa.

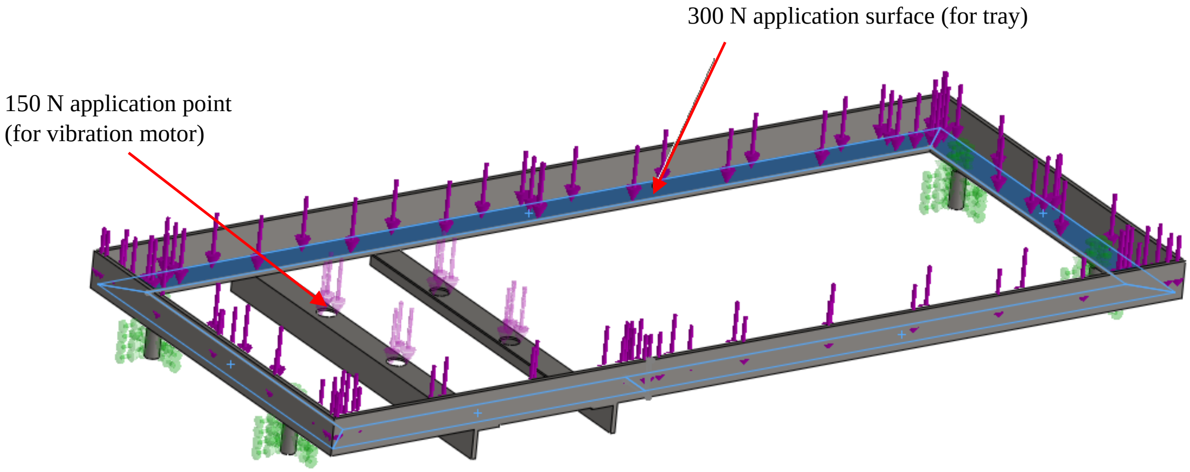

Figure 5.14. Forces on Tray Seat

After the simulation was ran, the maximum stress was 58 MPa as shown in Figure 5.15.

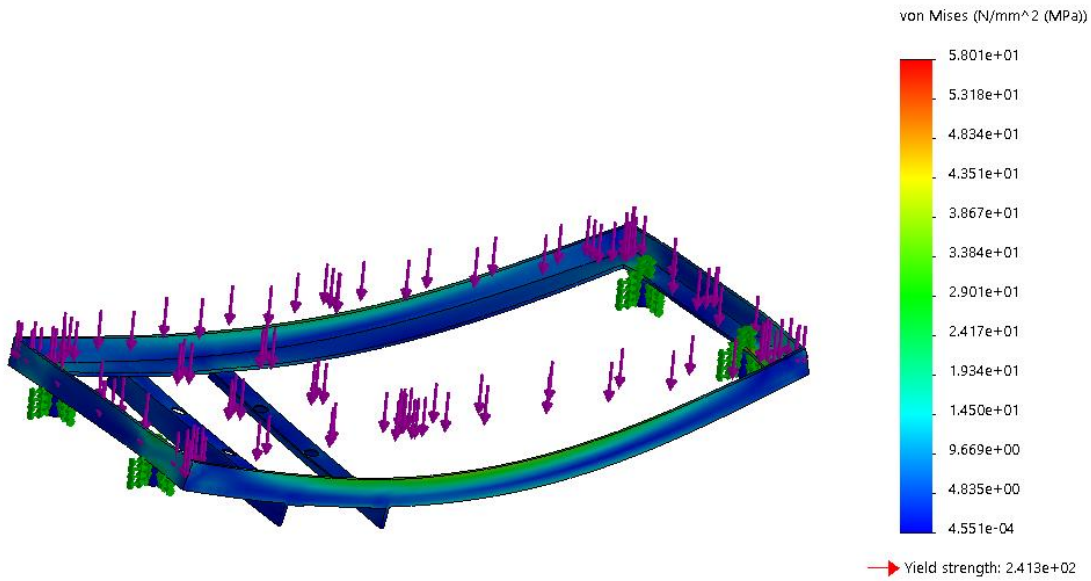

Figure 5.15. Static Simulation Results

The minimum factor of safety obtained was 4.2 as such cast iron is a suitable material for this part.

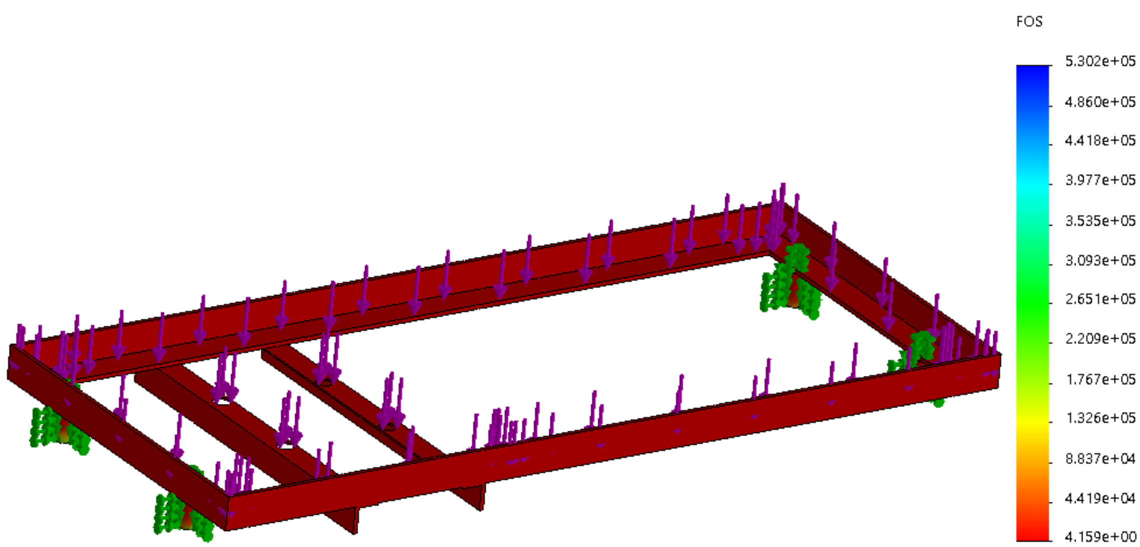

Figure 5.16. FOS of the Tray Seat

5.2.4. Vibration Analysis on Front and Rear Members

The front bracing member was subjected to a vibration analysis to determine its resonant natural frequency. The resonant natural frequency was compared to the frequency of the motor found in Section 4.4.1 to determine if this part fails or not from the motor's vibrations. The first five natural frequencies were used.

The natural frequencies obtained for the front member are shown in Figure 5.17. The minimum natural frequency for this part was found to be 4471.5 rad/s. The motor's excitation frequency of 146 rad/s is far below this value and as such, the member is safe.

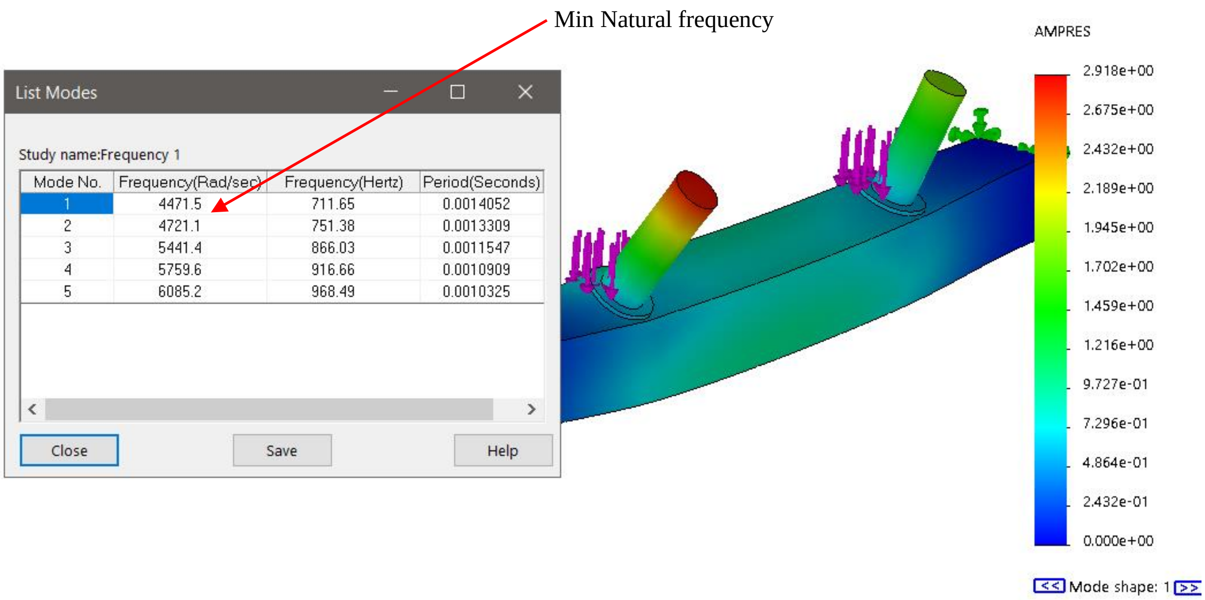

Figure 5.17. Frequencies of front bracing member

5.2.5. Vibration Analysis on Frame

The results of a vibration analysis on the frame are shown in Figure 5.18. The minimum frequency of the members was 209.01 rad/s and this value was quite close to the motor's frequency of 146.6 rad/s, by a factor of 1.42. This factor is low, however is not a problem because the springs are included purposely to isolate the motor vibrations from the frame. This analysis compares the un-isolated frequency of the motor to the resonant frequency of the frame and once they are not equal, the frame will be able to withstand the vibrations.

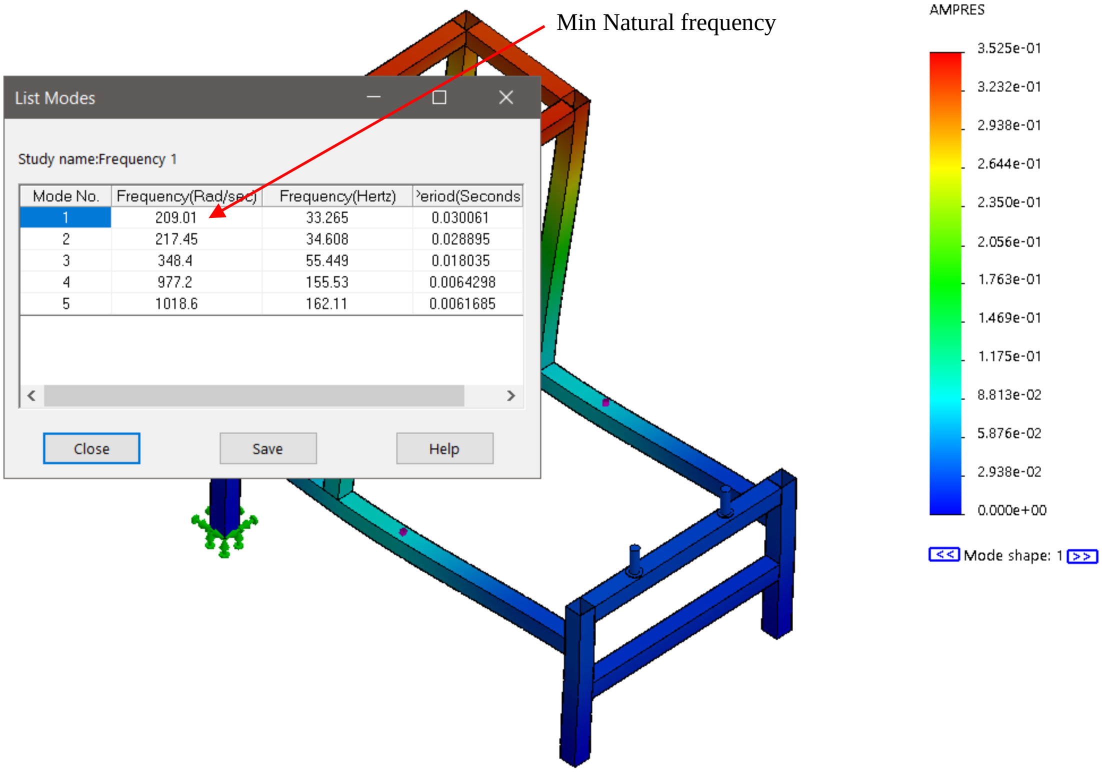

Figure 5.18. Frequencies of Frame

5.2.6. Vibration Analysis on Tray Seat

The first five natural frequencies were obtained for the tray seat as shown in Figure 5.19 and the minimum of these was 393.55 rad/s, still greater than the motor's vibration frequency of 146.6 by a factor of 2.6.

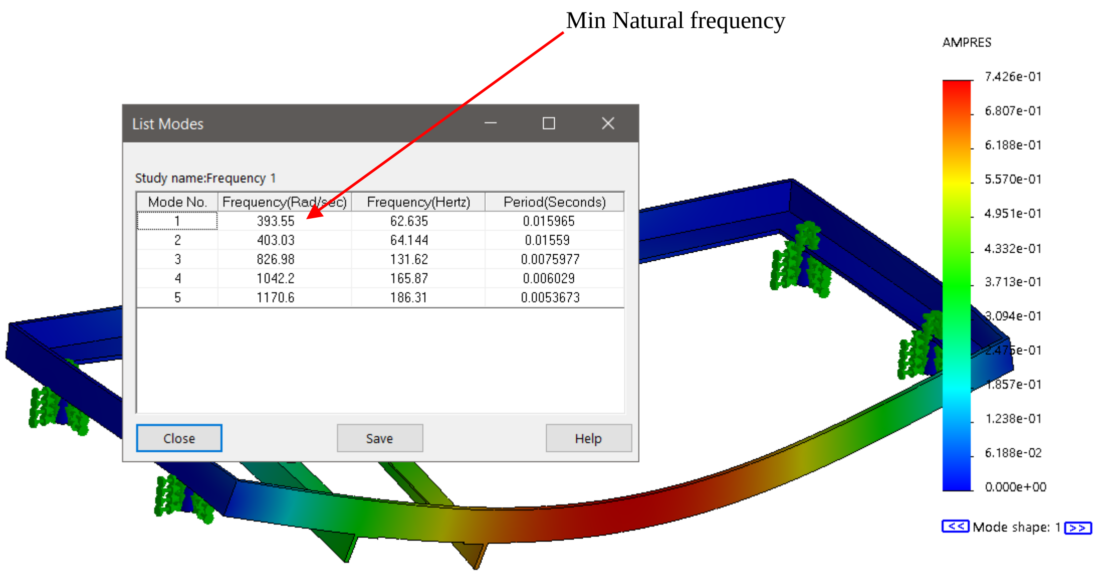

Figure 5.19. Frequency values of the Tray Seat

5.3. Bill of Materials

The next phase of this project was the building of a physical prototype of the machine. Faculty members of the Ashesi engineering department were consulted for guidance on enterprises and organisations which the parts for this project could be procured from and after these consultations, the exhaustive bill of materials for the machine can be found in Table 5.1. A few materials, such as the rivets, iron angle bars, 4 cm square pipes and springs were already present in the Ashesi Mechanical Engineering Workshop. There was no need to buy these parts. They have however been added to this table for documentation purposes.

Table 5.1. Bill of Materials for Gari Sieving Machine

Part Description	**Quantity**	**Source**	**Unit price / GHC**	**Amount / GHC**
100 cm x 300 cm Galvanized Steel Sieves (2 mm pore size)	1	E.O. Enterprise - Timber Market, Accra	275	275
100 cm x 300 cm Galvanized Steel Sieves (3 mm pore size)	1	E.O. Enterprise - Timber Market, Accra	275	275
600 cm long, 4 cm Square Galvanised Steel Pipes (2 mm thickness)	3	Alhaji Gab Moro Ent. - Kwabenya	60	180
Box of Round Rivets	1	Nana K. Gyasi Ent. - Kwabenya	80	80
1 HP Vibration Motor	1	E. O. Enterprise - Timber Market, Accra	400	400
Metal Compression Springs	4	Nana K. Gyasi Ent. - Kwabenya	10	40
Bolts and Nuts	4	Nana K. Gyasi Ent. - Kwabenya	1	4
122 cm x 245 cm Aluminium Sheet	1	Nana K. Gyasi Ent. - Kwabenya	90	90
600 cm long, 4 cm iron angle bars	2	Alhaji Gab Moro Ent. - Kwabenya	50	100
600 cm F - Aluminium Profile	1	Alhaji Gab Moro Ent. - Kwabenya	50	50
			Total	**1494**

6. Chapter 6 – Procurement & Fabrication

After dimensions and design of the final machine were settled upon, materials and parts were then procured and fabrication began in the Ashesi Mechanical Workshop. This section details all manufacturing processes and steps taken to obtain parts needed. Since most of the materials being used were metal, many metalworking processes were used.

6.1. Vibration Motor

The vibration motor shown in Figure 6.1 was already available in Ashesi University, but was originally bought from the source and at the price as listed in the Bill of Materials in Section 5.3.

Figure 6.1. Vibration Motor

6.2. Sieves

The required sieves for this project were obtained from the source listed in Section 5.3. and is shown in Figure 6.2. These were bought at standard dimensions of 100 cm x 300 cm. The sieve in front has 2 mm sized holes and the one behind has 3 mm holes.

Figure 6.2. Procured Sieves

6.3. Fabrication of Frame

The frame was built from 4 cm Square Galvanised Steel Pipes (2 mm thickness) as shown in Figure 6.3. This frame was built according to the dimensions shown in A.1 in the Appendix section.

Figure 6.3. 4 cm Galvanised Steel Pipe

The pipes were first measured to the required lengths and then marked using a scriber and a try Square as shown in Figure 6.4. This was to ensure that all cuts made were straight and none were slanted.

Figure 6.4. Using a Try Square to make Markings

After markings for various members had been made on the pipes, an angle grinder was then used to cut the members to their required length. Great care was also taken in cutting to ensure the smoothest and straightest cuts possible. Some cut members are shown in Figure 6.5.

Figure 6.5. Cut Pieces of Galvanized Steel Pipes

The cut members of the machine were then welded together using shielded metal arc welding. This type of welding was employed because it was the most accessible welding type in the Ashesi Mechanical Workshop. The members were welded together with guidance from the skilful workshop technician, Mr. Peter Larweh. The finished frame is shown in Figure 6.6. After all welding was finished on the frame, all weld beads were ground with a grinding disc to ensure that welded areas flashed with the surface of the metal.

Figure 6.6. Finished Frame of Machine

7. Chapter 7 – Challenges, Recommendations & Conclusion

Various challenges were encountered in the planning and execution of this project and this section details these challenges. Through the whole process, some areas for further research and improvement were also noticed.

7.1. Challenges Encountered & Limitations

The biggest challenge which was encountered in carrying out this project was the onset of the novel coronavirus, COVID-19, due to which all universities in Ghana were instructed to close down immediately by the government of Ghana. On the 15th of March 2020, all students were instructed to go to their respective homes, thus preventing access to the Mechanical Workshop where the fabrication of this device was in progress. This inadvertently spelled an end to the fabrication phase. At the time of closure of campus, the frame had been completed as detailed in Section 6.3. The next parts of the machine to be fabricated were the tray seat and the tray itself; but these could not be completed due to the circumstances.

Another factor which was a limitation to this project was the unavailability of advanced SOLIDWORKS simulation packages to simulate and analyse the gari grains being sieved and separated by the machine. The version of SOLIDWORKS used was an educational version and did not have all the functionality needed for this.

7.2. Recommendations for Future Works

Due to the major challenge explained in the previous section, this machine could not be finished and as such one main area for further studies is the fabrication of the machine and carrying out tests to determine if it met the requirement of sieving 25 kg of gari per minute.

This device is also one machine in the production and processing value chain of gari and there are many other machines which may be developed to speed up the entire process from the harvesting of raw cassava to the packaging of processed gari.

In relation to this machine, the following improvements can be made:

i. Development and addition of a system which hoists gari up to the level of the hopper and feeds it automatically into the machine. This takes away the human labour needed to raise sacks and pour them in.

ii. Development and inclusion of conveyor belt assemblies at the outlets of the sieve to transport the separated gari grains into large vessels for storage.

7.3. Conclusion

In reference to the introductory sections of this document, the problem of manual methods of gari processing has plagued Ghana and the rest of Africa for many years. This project focused on designing and building a gari sieving machine to separate gari grains into three distinct sizes.

First, existing machines which sieve food and aggregates were studied and their problems were noted. Based on these studies and ethnographic research, requirements were set for a new machine to perform this sieving. Possible concepts of this machine were considered and then CAD designs of the chosen concept were developed and the parts most susceptible to failure were subjected to static and vibrational analyses. All parts had factors of safety between 1.4 and 5 and so were safe enough to function for at least 10 years. The outcome of these simulations proved that the device would function without failure if built. The final device met most of its requirements by being easy to disassemble and transport, costing less than GHC 2000 to build and using only a 1 HP motor to operate.

All objectives of the project were reached with the exception of the goal to fabricate the whole machine due to the COVID-19 outbreak which caused the entire Ashesi Campus, and therefore the Mechanical Workshop to be closed down.

This project has been a fruitful experience into mechanical engineering design and product development. It has enabled me appreciate concepts learned across the 4 years of undergraduate studies as a mechanical engineer and I intend to improve these skills in coming years.

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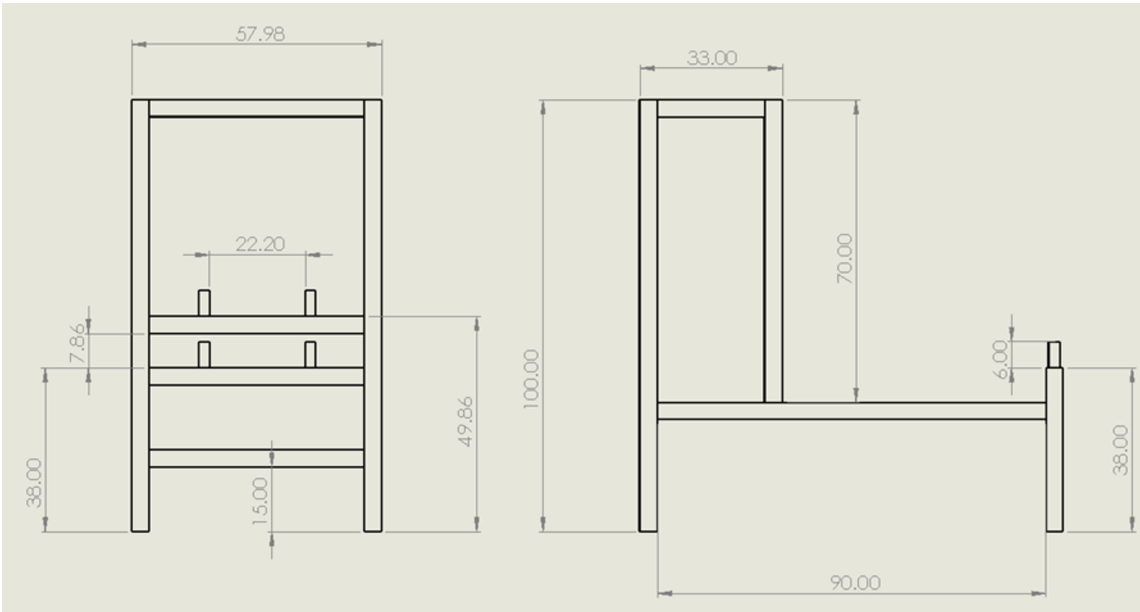
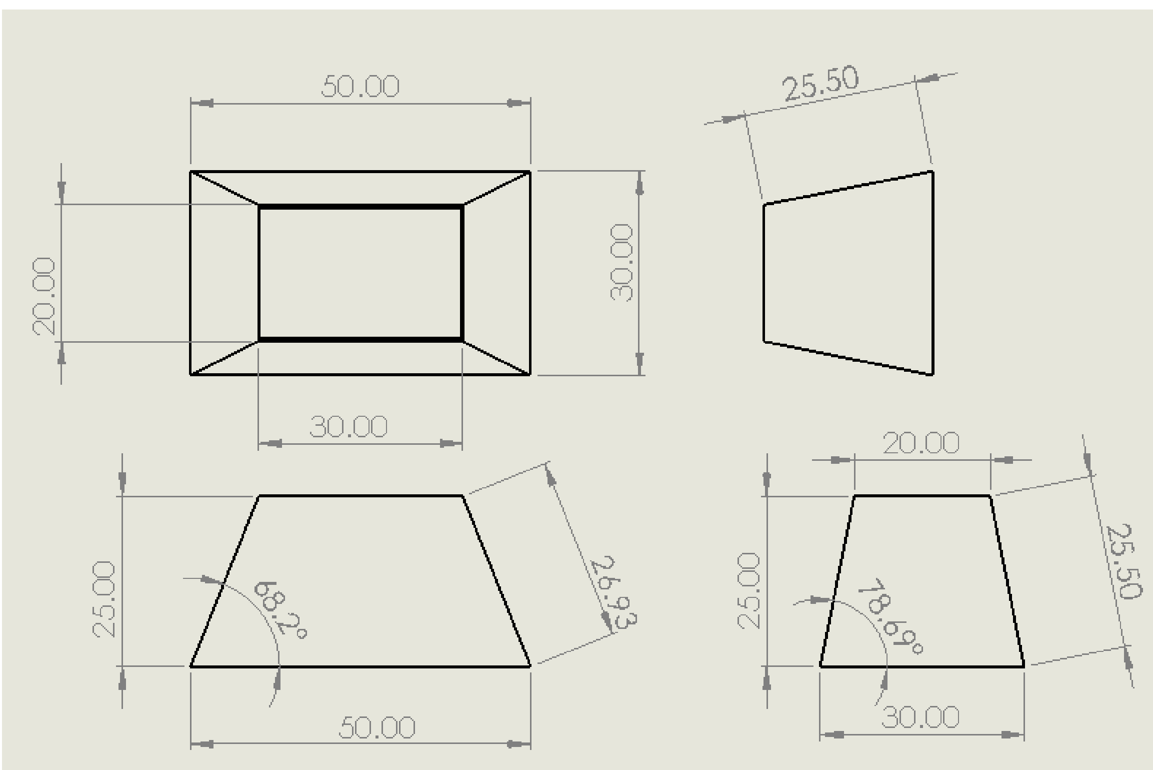
A. Appendix A: Drawings of Machine

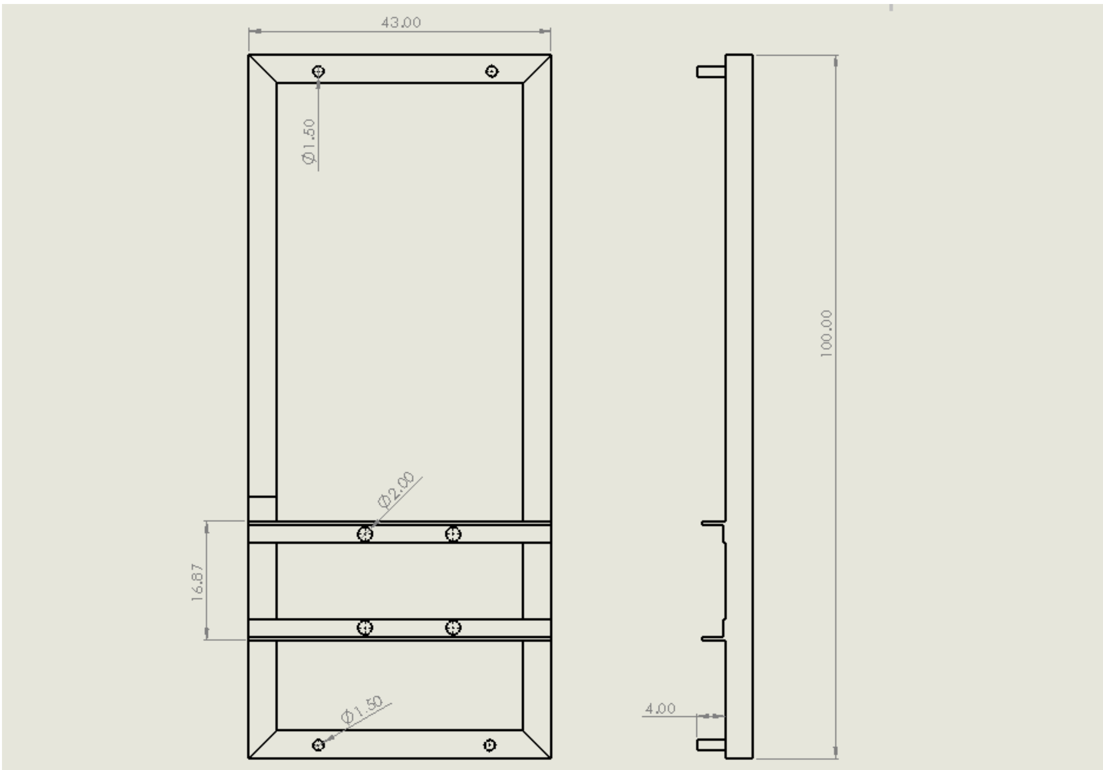
Note: All dimensions are in cm



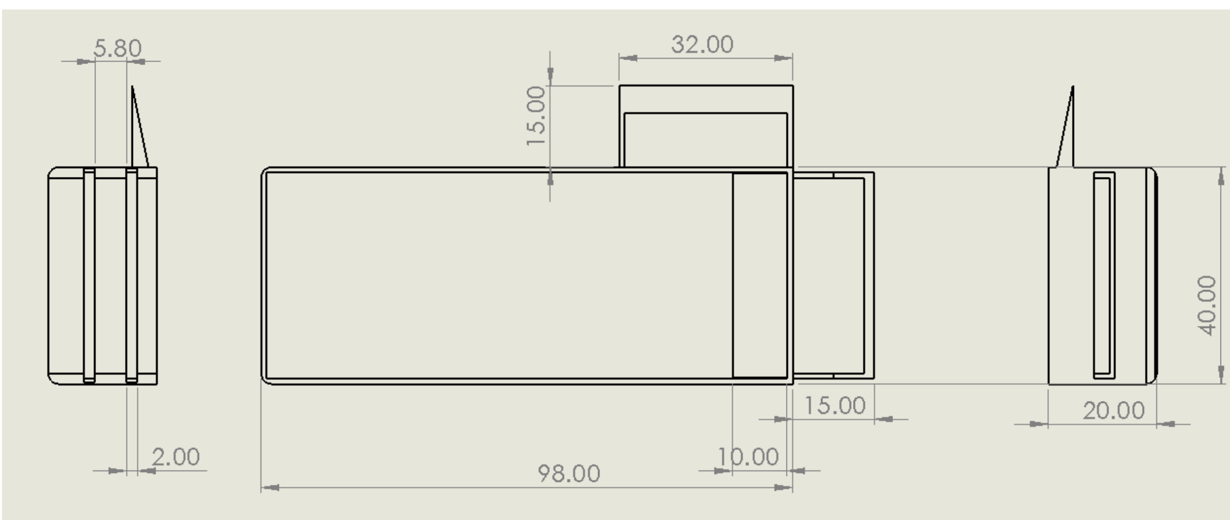
A.1. Drawings of frame



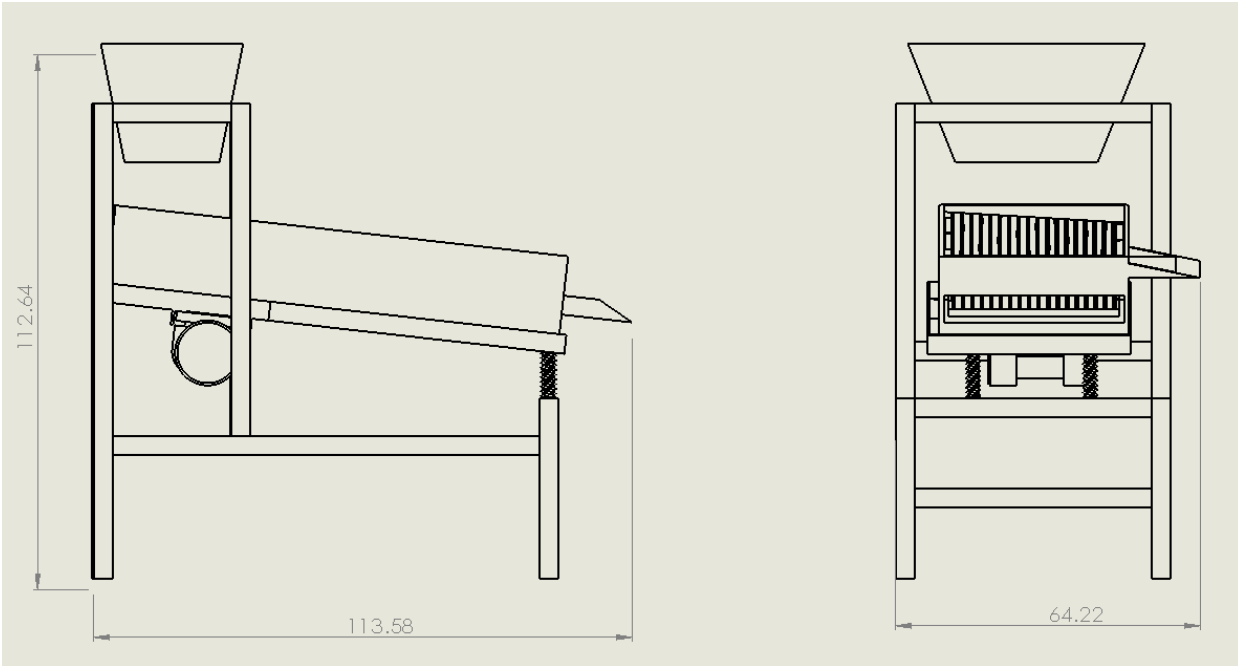
A.2. Drawings of Hopper



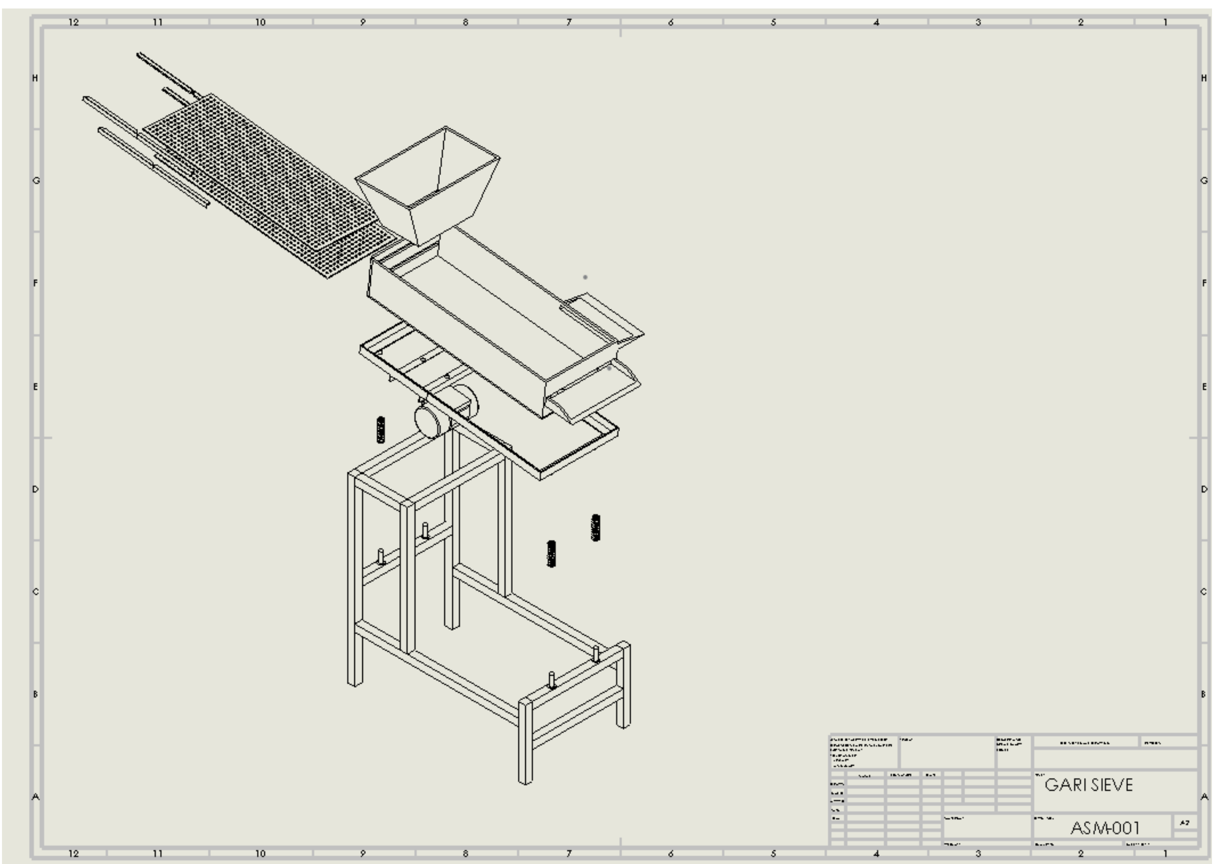
A.3. Drawings of tray seat



A.4. Drawings of Tray



A.5. Drawings of Full Machine



A.6. Drawing of Exploded View