DESIGN AND DEVELOPMENT OF A GRAIN DISPENSING SYSTEM

M.Tech. Thesis

By

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DISCIPLINE OF MECHANICAL ENGINEERING

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Submitted in partial fulfillment of the requirements for the award of the degree

of

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **Design and Development of A Grain Dispensing System** in the partial fulfillment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY** and submitted in the **DISCIPLINE OF MECHANICAL ENGINEERING, Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the time period from July 2022 to May 2024 under the supervision of Prof. Pavan Kumar Kankar.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

Arbaaz Shaikh
24/04/2024

Signature of the student with date
Arbaaz Hamid Shaikh

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

24/02/2024

Signature of Supervisor of M.Tech. thesis
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Arbaaz Hamid Shaikh has successfully given his/her M.Tech. Oral Examination held on **30 May 2024**.

Signature of Supervisor of M.Tech. thesis
Prof. Pavan Kumar Kankar
Date: 31/05/2024

Convener,DPGC
Date: 31-05-2024

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- Arbaaz Hamid Shaikh

ABSTRACT

Rice plays an important role in the global diet and its demand is increasing continuously. This has led to an increase in the production of rice worldwide. This increase in production has brought forth quality-related issues in rice. To tackle this issue there are several traditional methods available. However, these methods are subjective and time-consuming. flatbed scanners, SORTEX machines, and lab-based are objective methods that can overcome these disadvantages. However, these methods are not accessible to the majority of the audience as they are expensive and not easily available. Thus there is a need for a fast, reliable, and user-friendly system for quality assessment of the rice grain.

The project aims to design and develop a portable grain dispensing system This novel grain dispensing system will be used in a grain sorting system. The developed prototype shows great grain dispensing abilities with a grain flow rate of 200 grains per minute. The prototype exhibits a modular design with a linear dispenser, rotary drum, and optical system being the crucial parts of the system. The linear dispenser utilizes the longitudinal vibration to dispense grain one grain at a time. The optical sensing system controls the grain dispensing rate of the system. The dispensing system shows randomization capabilities that can be effectively used in sample and dataset generation. Experimental results demonstrate the effectiveness of the prototype in achieving its objectives. This shows the way for future enhancements and applications in the field of grain sorting and quality assessment.

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NOMENCLATURE

a	: Half of Major Axis of The Ellipsoid
b	: Half of Minor Axis of The Ellipsoid
d	: Distance Between Two Spheres
k	: Subscript Denoting Sub-Spheres
x_k	: Co-ordinate of Center of kth Sphere
R_k	: Radius of k Sphere
R	: Internal Radius of The Rotary Drum
L	: Radial Length of the vane
μ	: Coefficient of friction between vane and rice grain
g	: Acceleration Due To Gravity
s	: Displacement of The Grain From The Initial Position
v	: Instantaneous Velocity of Grain
a	: Instantaneous Acceleration of Grain
m	: Average Mass of Individual Rice Grain
θ	: Angular Displacement of The Vanes Starting From Horizontal
ω	: Angular Speed of The Drum

ACRONYMS

NIRS : Near Infrared Spectroscopy
DEM : Discrete Element Method
CAD : Computer Aided Drawing
DFB : Double Folded Beam
DC : Direct Current
Dpi : Dots Per Inch
FDM : Fused Deposition Modeling
PLA : Polylactic Acid
RPM : Revolution Per Minute
std : Standard Deviation
mm : Minutes
ss : Seconds
ms : Miliseconds
IR : Infrared

CHAPTER 1: INTRODUCTION

Rice is a primary food source for around half of the world's population, particularly in Asia and Africa. It is derived from the grass species *Oryza sativa* (Asian Rice) or less frequently, *Oglaberrima* (African Rice). India is the second-largest producer and leading exporter of rice in the world. In FY2023, India's rice production reached an estimated volume of over 135 million metric tons, indicating a consistent annual increase of 3-4% since 2017 [1]. In the following decades, as developing countries achieved self-reliance and developed the ability to export surplus rice, consumers became more selective in their preferences. This has led to increased attention being paid to the quality of the grain by rice consumers, food industries, farmers, and seed producers. Farmers have started using advanced techniques and technologies to produce high-quality rice cultivars that have a better taste, nutritional value, and texture. Food industries are also investing heavily in research and development to meet the rising demand worldwide. Additionally, there is a growing demand for high-quality rice varieties worldwide due to improvements in living standards. People are now more conscious of their health and are opting for rice that is high in nutritional value and free from harmful chemicals.

Grain size and quality play a key role in determining the market price of the rice. In the market, various quality evaluation methods and tools are used to determine the quality of rice [2]. The traditional approach to evaluating quality involves human decision making which is time-consuming and subjective, resulting in an expensive, inaccurate, and slow process. Efforts have been made to create an objective quality evaluation tool, such as flat-bed scanners. However, they typically operate at low image resolutions (less than 1200 dpi), resulting in low classification accuracy. Moreover, color Sortex machines, which are binary grain classification devices used in various industries, are highly expensive and not feasible for small enterprises. An effective way to determine the quality of rice is by testing it in the lab using techniques such as NIR spectroscopy and DNA fingerprinting. Although these methods are highly precise, they can be costly, difficult to manage, and time-consuming. Thus it is essential to develop an objective, fast, and reliable tool to evaluate rice quality, considering the inaccessibility, inaccuracy, and cost of existing methods [3].

This project aims to develop a prototype of a dispensing system that might be used in a milled rice grain sorter based on visual inspection. The objective of the project is to build a portable, modular device. This device should be capable of randomly selecting and dispensing grains for precise imaging.

After extensive research, design, and experimentation a unique grain dispenser has been developed. Its overall dimensions are approximately 150mm x 150mm x 100mm. The device utilizes physicochemical parameters and mechanical vibration to dispense one grain at a time. It has a dispensing speed of 200 grains per minute at frequency and amplitude of 100 Hz and 0.0752 mm respectively, making it a fast and reliable tool for grain dispensing system which is considered a great achievement for this project.

CHAPTER 2: REVIEW OF PAST WORK AND PROBLEM FORMULATION

2.1 Literature Review

2.1.1 Quality Evaluation of Grains

The Grain quality is a sophisticated and complex subject. It depends on various factors such as the species, genotype, environment, and their interactions. The quality assessment methods for the grains heavily dependents on the ultimate use of the grain. Quality is determined by a wide range of properties and factors. This factors include physical, sanitary, and nutritional quality. Morever, grain quality can also be connected to process-related parametrs. Since it is known that many genes are involved in regulating each aspect of grain quality [2]. Therefore, when evaluating the quality of rice grain, it is reliable to use laboratory-based testing methods. This method includes DNA fingerprinting and NIR spectroscopy.

2.1.1.1 DNA Fingerprinting

The term "DNA fingerprinting" was coined by Jeffery in 1985. It was used to describe the bar-code-like patterns of DNA fragments produced by multi-locus probes. These codes are produced after the electrophoretic separation of genomic DNA fragments. The distinctive patterns that emerge during analysis. These patterns are considered the ultimate tool for the biological individualization of the analyzed individual. These unique features are currently viewed as the most effective way to identify and distinguish individuals [4]. DNA fingerprinting uses the fundamental coding of the genome to identify different varieties and damages. It extracts DNA from a field sample. These DNA samples are compared with a reference library of genetic profiles from known healthy and damaged grains. The sample is then categorized based on its closest match to the data in the reference library. At the time of writing, the cost of genotyping technologies per sample ranges from $7 to $2,500. The cost is dependent on the precision of the genotype or genetic profile developed and the extent of genome coverage. Also creating and maintaining such comprehensive reference libraries can be a daunting task. It needs a large capital of time and resources. Additionally, such huge and sophisticated libraries are not a one-time project. They must be continuously updated and managed over time. Along with that, it is important to ensure that they are available to the intended targets. At the same time respecting any relevant intellectual property rights [5]. DNA fingerprinting is a highly precise method for grain classification. However, it is not a practical or cost-effective approach for assessing the quality of grain.

2.1.1.2 Near-Infrared (NIR) Spectroscopy

NIR spectroscopy is a method that uses the near-infrared part of the electromagnetic spectrum (700 - 2500 nanometers). This method is a non-destructive method of determining the properties of a material. It measures the light that is scattered off and through the sample. NIR reflectance spectra can be obtained to provide valuable information about the material being analyzed. This information can help optimize various processes [6]. It is a high-speed, dependable, precise, and cost-effective method of grain assessment[7]. It is non-destructive, rapid, and needs almost no sample preparation. This led to making it famous for grain quality evaluation. Additionally, it allows for the estimation of multiple parameters simultaneously. The scope of NIR's application in grain quality analysis is extensive which includes the Classification of bulk cereals, Identification of damaged grain, Moisture content determination, Chemical composition analysis, Virtuousness determination, Hardness measurement, Grain color classification, Detection of insects and mites infestation, Detection of mycotoxins, etc. [8].

Although NIR spectroscopy offers several benefits for the assessment and control of grain quality, it also presents some challenges for the analysis and prediction of grain product quality. The accuracy of the NIR model heavily depends on the reference method and a representative sample set used to develop and test the predictive models. Therefore, it is necessary to calibrate and validate the data, which is an expensive and time-consuming process. In addition, the model is sensitive to external factors such as temperature, humidity, or light, so it is important to control or correct these factors to avoid errors or deviations in the spectral outcomes.

While laboratory-based testing methods for quality evaluation serve as an accurate, versatile, and reliable option, these methods can be costly, burdensome, and time-consuming. In addition, the availability of these tests relies on how near labs are, which usually results in longer waiting times for results. Several earlier studies [9-13] have shown that the physical characteristics of raw rice grains, such as their size, shape, surface texture, chalkiness, discoloration, surface irregularities, markings (i.e. stains and watermarks), and areas of increased darkness indicating heat damage, can be efficiently employed for identifying damage. Therefore, visual inspection offers an optimal approach to resolving this issue. It provides a rapid, non-intrusive, and cost-effective method to identify the type and extent of damage by observing visual symptoms.

The conventional visual inspection method for grain assessment involves experts visually examining grains to detect irregularity or defects, using their expertise to identify visual symptoms such as shape, size, color, and texture. However, this method is inherently subjective and relies on the skill level of the inspector, leading to potential inconsistencies and subjective judgments in grain quality evaluation. While this traditional method remains valuable, modern approaches utilize machine vision technologies, including optical sorting machines, grain color sorters, and near-infrared (NIR) grain sorters, X-ray Sorting Machines, to enhance efficiency and accuracy in grain inspection processes. Among these technologies, renowned devices like the flatbed scanner and color SORTEX are widely used in the market for their effectiveness in quality assessment.

2.1.1.3 Flatbed Scanner

Flatbed scanners are a type of optical scanner that utilizes a flat surface for scanning objects. These types of scanners are capable of capturing all elements present in the objects without requiring the object to be moved during the scanning process. When using a flatbed scanner to image rice, the rice is placed on the glass plate in reflection mode (Figure 2.1). Usually, scanners utilize either a cold-cathode fluorescent lamp or a Xenon gas discharge lamp as their light source. The sensor in the scanner picks up the amount of light reflected by the rice and converts it to a voltage proportional to the light intensity [14].

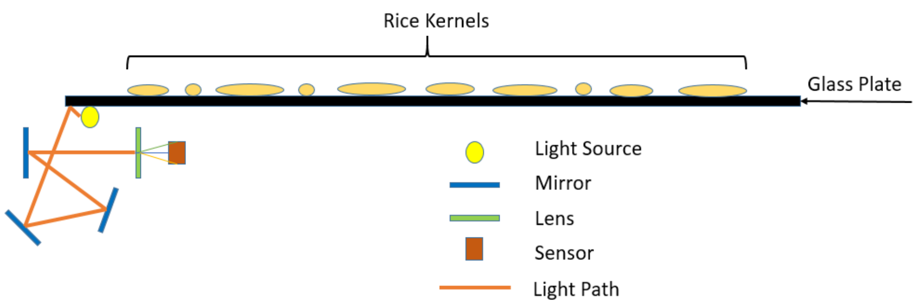

Figure 2.1: Cross Section of a Flatbed Scanner Used for Scanning Rice Kernels

Overall, flatbed scanners are fast, versatile, easy to use, and relatively inexpensive. However, a major drawback of flatbed scanners is that most models on the market offer optical resolutions of 600, 1200, or 2400 dpi, resulting in poor image quality that can negatively impact the overall reliability and accuracy of grain quality evaluation. Additionally, some flatbed scanners may have limited compatibility with certain operating systems, and their large size can be a disadvantage for users with limited desk space.

2.1.1.4 Color SORTEX Machine

The color SORTEX machines are binary classification and sorting machines equipped with high-resolution cameras that take high-magnification images of individual grains [15]. These images are then processed using machine learning to detect light or dark defects, allowing for the removal of color defects and foreign materials to ensure consistent quality. These devices are high-speed, dependable, accurate, and versatile. They are made to handle large amounts of grain for continuous operation. However, they can only sort grains into healthy and damaged categories. As a result, they are not suitable for sorting rice grains based on their varieties or determining the type and severity of damage. Furthermore, the price of a SORTEX machine can vary greatly, from $50,000 to more than $650,000 per configuration. They are therefore unfeasible for smaller firms because of their high cost and restricted usefulness [15].

2.1.2 Shape, Size, And Mechanical Properties of Rice Grains

Understanding the shape, size, and mechanical properties of grain is important. These factors help in designing and developing a device for quality evaluation and classification of rice grains. The shape and size of rice grains vary from variety to variety. However, they are generally a long cylindrical shape with two distinct ends. It has one pointed end and another more rounded end. The pointed end is usually called the acrospire. Where as, the more rounded end is known as the basal end [16]. These ends may vary in shape and size based on the particular variety of rice. The overall shape of rice kernels can vary widely among different rice varieties. The kernel lengths varies from 5mm for Japonica rice [17] to 8.5mm for Pusa Basmati rice [18]. For our research project, we have opted to utilize the dimensions of Pusa Basmati rice. This is primarily due to its status as the most widely exported rice variety. The average kernel length of the Pusa Basmati rice is 8.48 mm, with a width of 1.82 mm and a breadth of 1.50 mm. Table 1 outlines the important mechanical properties of rice [19].

Table 2.1: Mechanical and Processing Properties of Rice

Property	Value	Unit
Bulk Density	940	kg/m^3
True density	1290	kg/m^3
Young's Modulus of Elasticity	235	MPa
Modulus of Rigidity	85.45	MPa
Poisson's Ratio	0.375	-

2.2 Research Gap

DNA fingerprinting and NIR spectroscopy are the two most famous laboratory testing methods when it comes to grain qulity evaluation. They are considered the most dependable and precise way of grain quality assessment. However, these methods are linked with few major disadvantages. This includes high costs, complexity, and time consumption. Additionally, their usages is limited by the availability of laboratories, resulting in longer waiting times for results. This had led to making them impractical and expensive for assessing varietal use in farmer's fields. Surface assessment of rice grains acts as a possible alternative to lab testing for rice grain quality evaluation. However, the classification and identification of rice stocks by visual inspection is a complex and time-consuming process. On the one hand, Traditional manual methods are slow, prone to inaccuracies. At the same time, this methods costly due to their reliance on subjective human decision-making. On the other hand, state of the art color SORTEX machines are mainly developed for bulk rice sorting. However, They offer limited functionality in terms of only distinguishing between healthy and damaged rice. As well as their inability to identify damage types and severity is a huge constraint. Moreover, these machines are highly expensive for small-scale enterprises. Portable devices such as flatbed scanners typically operate at low image resolutions. This gives rise to reduced classification accuracy.

Thus, it is necessary to develop a quality assessment tool for rice grain. This tool should overcome the limitations and disadvantages of existing methods. Additionally, it should remain available to a wide range of users. This tool should be capable of classifying grains based on damage type and severity. To accomplish this, the following objectives have been outlined. Firstly, to construct a portable, modular device capable of randomly selecting and dispensing grains for precise imaging. Then, to make a system with the capability of capturing high-magnification images. The image should be focused on one grain at a time. Then, using visual inspection analyze the captured images. The data from the analysis will be used for the identification of the type of damage and its severity. Lastly, to make a subsystem with sorting capabilities with high accuracy. Simultaneously accomplishing all these objectives within a single system presents a complex challenge. Therefore, it is wise to divide the device into subsystems. Each subsystem is dedicated to achieving a specific goal. Our project goal is to achieve the first objective by constructing a portable, modular device capable of randomly selecting and dispensing grains for precise imaging.

CHAPTER 3: METHODOLOGY

The task at hand is to develop a grain dispensing system. This tool should be compact, fast, accurate, reliable, accessible, and user-friendly, capable of dispensing grains one at a time.

The primary objective of the dispensing system is to randomly select and dispense grains. While attending to this goal, it is important to consider some important design and functional aspects of the system. These include ensuring that the system remains compact, does not compromise the quality of grains during dispensing, and incorporates mechanisms for controlling the dispensing rate.

3.1 Concept Generation

Several studies [20-22] have focused on developing dispensing systems for relatively smaller objects For instance Dispensing systems for 'Tablets' and 'Capsules' manufactured in Pharmaceutical industries. However, a major drawback is that these systems are designed for dispensing objects that are identical in shape and size. Since each grain of rice is unique in shape and size, this presents a significant challenge. Moreover, during the milling process, some rice grains may break, and conventional dispensing systems may struggle to handle these fractured grains. Given the limitations of conventional dispensing systems, three concepts have been devised to tackle this task.

Concept 1 Dual Linear Vibratory Feeder

Inspired by a traditional linear vibratory feeder [23], the dual linear vibratory feeder comprises two linear units arranged sequentially, as illustrated in Figure 3.1. Each unit is driven by an eccentric motor located beneath its tray. As rice grains are introduced onto the flat tray of the initial feeder, the eccentric motor generates two-dimensional vibrations, effectively transferring the grains to the V-shaped tray of the subsequent feeder. The unique V-shaped tray serves to align the grains, enabling the dispensing of one grain at a time with precision.

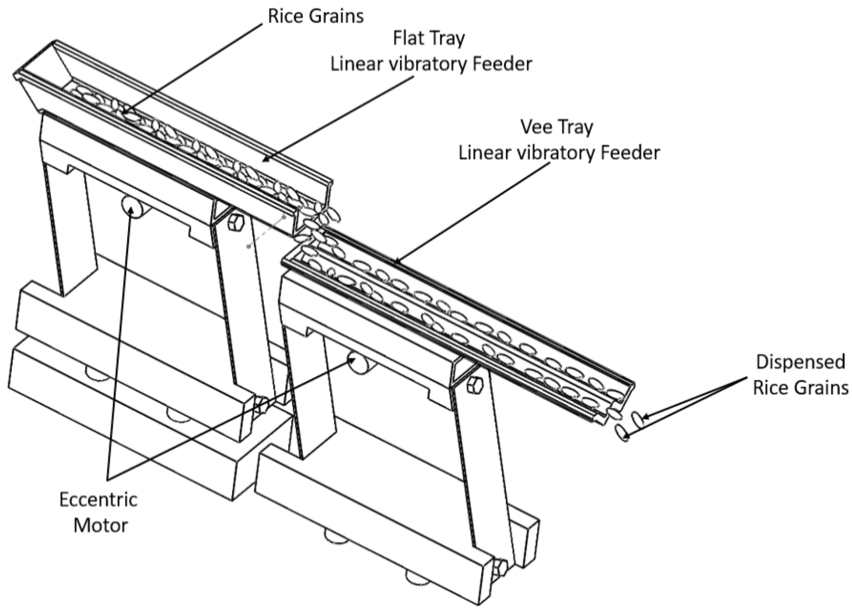

Figure 3.1: Concept Diagram of Dual Linear Vibratory Feeder

Concept 2 Modified Drum Feeder

As shown in Figure 3.2, a modified drum feeder comprises a linear dispenser placed axially inside the drum with multiple radial internal vanes along the circumference.When the drum rotates, the internal vanes guide the rice grains into a specially designed on surface of linear dispenser.

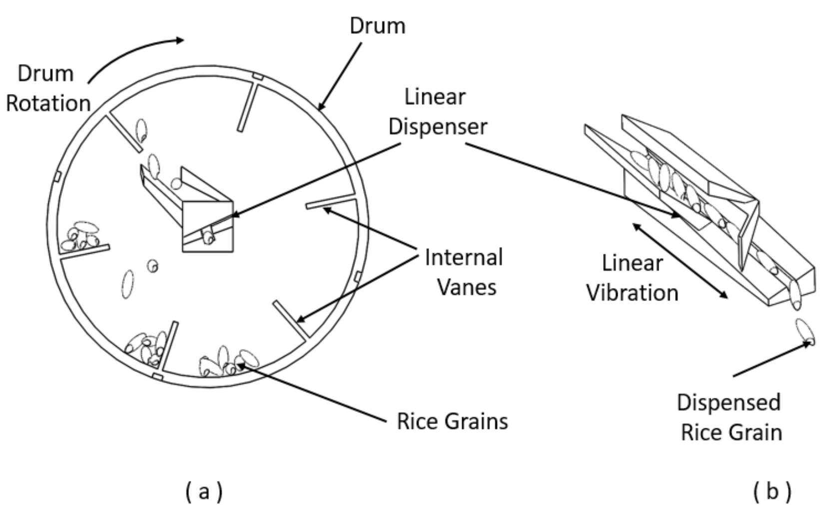

Figure 3.2: Concept Diagram of Modified Drum Feeder

Utilizing longitudinal vibration, the linear dispenser imparts an acceleration to the grains, to overcome the effects of gravity. This acceleration prompts the grains to leap forward along a parabolic trajectory, effectively achieving its dispensing purpose.

Concept 3 Oscillatory Feeder

The oscillatory feeder operates by harnessing centrifugal force and rotational oscillation to dispense grains. As the circular disc undergoes rotational oscillation, the rice grains within it experience the centrifugal force. This force directs the grains into a concentric track carved along the edge of the disc. The oscillation of the disc enables the inertia force to surpass the friction between the surface and the grain, facilitating the dispensing of the grains, as illustrated in Figure 3.3.

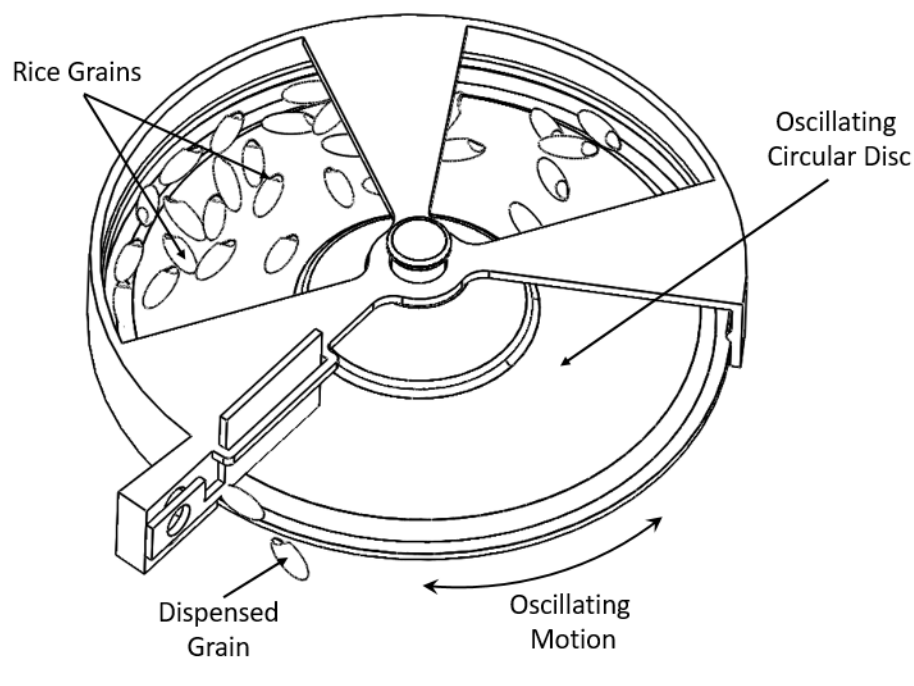

Figure 3.3: Concept Diagram of Oscillatory Feeder

3.2 Concept Selection

In a research project, concept selection is essential post-concept generation to check the feasibility of the concept and to select the most viable ideas for further investigation. For this purpose, analyses are performed using the Discrete Element Method (DEM) on a computer software known as EDEM. It uses the Discrete Element Method (DEM) to efficiently and precisely simulate various materials such as coal, grains, tablets, and others. It gives valuable insights into material behavior under various operational and process conditions. EDEM can be employed independently or integrated with other Computer-Aided Engineering (CAE) tools for comprehensive analysis. While the necessary CAD models for the analysis are designed and imported from CAD software (SOLIDWORKS), to simulate rice grains accurately, a discrete element model of a rice grain must be created within EDEM. Since EDEM only supports spherical elements for modeling, these particles are constructed using spheres of different sizes.

3.2.1 Modelling Of Rice Grain

Assumptions

1. The rice grain is approximated as an ellipsoid.
2. The width and thickness of the rice grain are assumed to be equal.

D. Markauskas et al. (2009) [24] conducted a comprehensive study on the approximation of ellipsoidal particles using a collection of sub-spheres for numerical Discrete Element Method (DEM) simulations. They introduced an algorithm for the adaptive hierarchical multi-sphere (MS) model to construct elliptical particles specifying the positioning and dimensions of each sphere in three-dimensional space. In our research, we are employing a similar methodology to model rice grains as ellipsoidal elements.

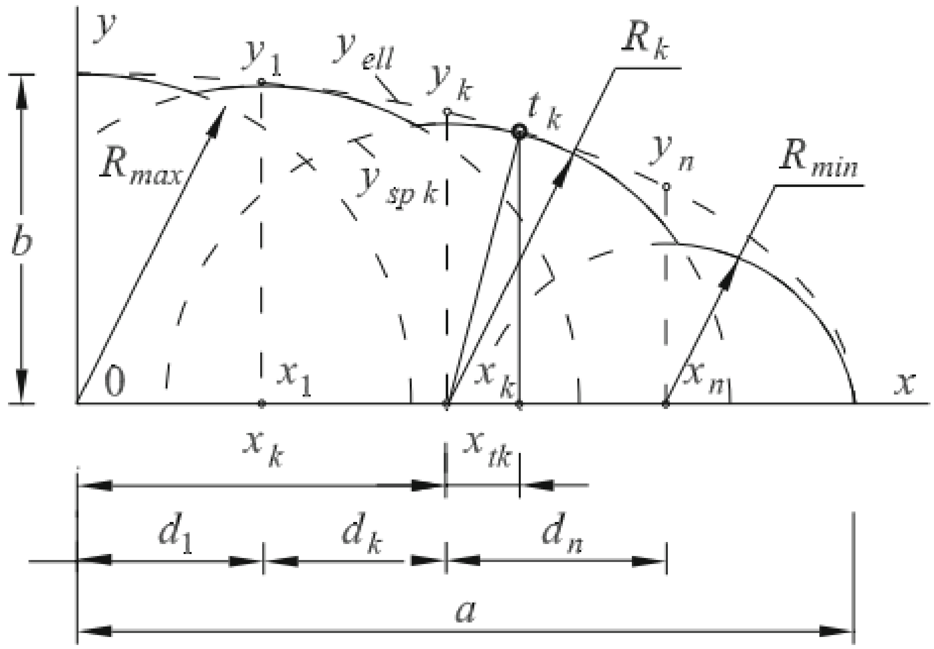

Figure 3.4: Multi-sphere model of ellipsoidal element (section geometry)

Length (2a) = 8.48 mm, Width=breadth (2b) = 1.9 mm

Half of ellipsoid major axis (a) = 4.24 mm

Half of ellipsoid minor axis (b) = 0.85 mm

d - Distance between two spheres

k - Subscript denoting sub-spheres

k = 0 (Represents the central sphere)

x_k - Co-ordinate of center of k sphere

R_k - Radius of k sphere

$$x_{k+1} = x_k + d_{k+1}$$

$$y_k = \sqrt{b^2 \left(1 - \frac{{x_k}^2}{a^2}\right)}$$

$$R_k = \sqrt{\frac{b^2}{(a^2 - b^2)} \left((a^2 - b^2 - {x_k}^2\right)}$$

$$d_{k+1} = d_k \left(\frac{y_k}{y_{k-1}}\right)$$

$$y_0 = b = 0.85\,mm\ ,\ x_0 = \ 4.24\,mm$$

$$Let\ \ d_1 = 0.424\,mm - - - - \left(\frac{1}{10}\right) th\ of\ a$$

$$x_1 = x_0 + d_1$$

$$x_1 = 0.424\,mm$$

$$y_1 = \sqrt{b^2\,(1 - \frac{{x_1}^2}{a^2})}$$

$$y_1 = 0.8457\,mm$$

$$R_1 = \sqrt{\frac{b^2}{(a^2 - b^2)}\,(a^2 - b^2 - {x_1}^2)}$$

$$R_k = \ \ 0.8455\,mm$$

$$d_2 = d_1\,(\frac{y_1}{y_0})$$

$$d_2 = \ \ 0.4218\,mm$$

$$R_{min} = \ \frac{b^2}{a}$$

$$R_{min} = \ \ 0.1788\,mm$$

$$x_n = \ \ a - R_{min} = 4.0696\,mm$$

The process of determining the position and dimensions of each sphere within the ellipsoidal element is iterative. An algorithm that has been developed for this purpose, the flow chart of the algorithm is shown in Figure 3.5.

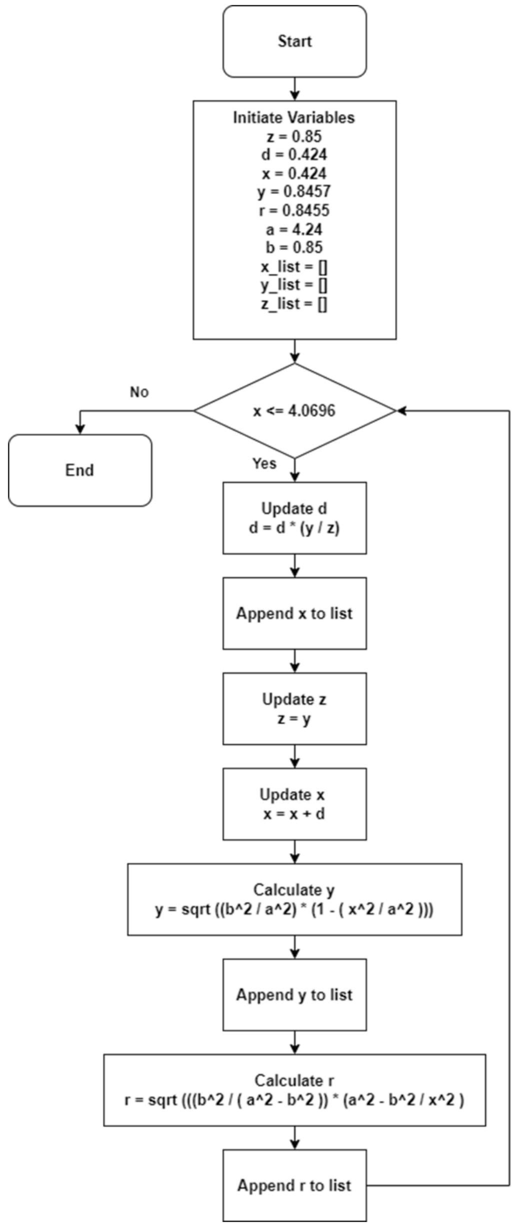

Figure 3.5: Flowchart For determining the position and dimensions of spheres in the ellipsoidal element

When the output of the algorithm is imported into the EDEM particle modeling tool, it produces an ellipsoidal element, as illustrated in Figure 3.6. This closely resembles a rice grain and can be utilized for further simulation of concepts for concept selection.

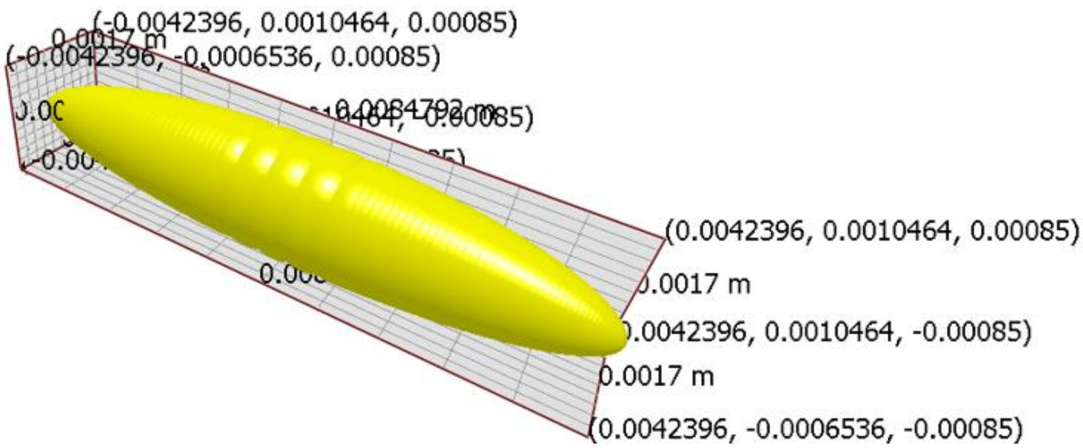

Figure 3.6: EDEM Particle Model of Rice Grain

3.3 Concept Comparison

a. Dual Linear Vibratory Feeder (Concept 1)

- The simulation showed that this concept utilized both longitudinal and transverse vibrations for grain dispensing. However, it faced a challenge due to differing amplitudes between the two vibrations. This inconsistency could complicate the design phase, as it's generally difficult to efficiently vibrate a system in two different directions with varying amplitudes.
- The overall dimensions of the mechanism exceeded 300 mm, potentially compromising the portability of the system.

b. Modified Drum Feeder (Concept 2)

- Concept 2 utilizes one-dimensional longitudinal vibrations to dispense rice grains.
- Concept 2 is relatively smaller in dimension when compared to other concepts making it a viable option from the portability point of view.

c. Oscillatory Feeder (Concept 3)

- From the simulations, it was observed that concept 3 was able to dispense a fraction of grains out of the supplied batch. This can be considered as the failure of the concept leading to its disqualification.

In conclusion, Concept 1 faces problems regarding vibration generation and control. Also, its overall size may impact the portability feature of the system. On the other hand, Concept 2 presents a more promising solution with controlled grain dispensing and its smaller size, making it a favorable choice for further investigation and development.

3.4 Concept Refinement

In the concept comparison section, it was determined that the Modified Drum Feeder is the most suitable mechanism for the dispensing system. However, it is necessary to make a few changes in order to convert this concept into the definitive design for the dispensing system. following areas in the system need refinement:

a) Feeding Mechanism for Rice Grains to Drum: The system needs a feeding system through which the grains can be fed effectively in the drum.

b) Flow Rate Control Mechanism: The system requires a mechanism to precisely regulate the flow rate of grains from the linear dispenser. This mechanism can be as a control system to halt the dispensing for a short interval of time.

c) Support Structure for Drum and Linear Dispenser: The concept of the modified drum feeder does not have any provision for a supporting system of drum and linear dispenser. It is important to build a robust support structure for the drum while allowing its rotational motion. Also, a structure over which the linear dispenser can be affixed.

To implement these refinements, the following design features have been incorporated into the system

a) Installed a hopper (as shown in Figure 3.7) to facilitate the feeding of rice grains into the drum. This hopper ensures a steady and controlled supply of grains. It will also enhance the efficiency and reliability of the feeding process.
b) Implemented an optical sensing system at the dispensing end of the linear dispenser (as shown in Figure 3.7) to accurately monitor the flow of grains. This optical sensing system enables automatic adjustments based on the detected grain flow.
c) Utilized a bearing mounted inside a bearing housing for supporting and facilitating the rotational motion of the drum (as shown in Figure 3.7).
d) Incorporated a rigid metal bracket with a double-folded beam assembly to securely hold the linear dispenser in place (as shown in Figure 3.7).

Integration of these design features ensures the transformation of the Modified Drum Feeder system into a reliable dispensing system.

3.5 Working Principle

The process of dispensing grains begins with feeding them into the rotary drum via the feeding hopper in the dispensing system, as illustrated in Figure 3.7. Once the grains are inside the rotary drum, a DC motor rotates the drum via a gear transmission system at a low rpm for 30 seconds to ensure thorough mixing. After this initial mixing period, the motor's speed is increased past a certain threshold, causing internal vanes on the drum to guide the grains into the linear dispenser. A coin vibrator is attached to the linear dispenser, providing longitudinal vibration that accelerates the grains, counteracting the force of gravity. This acceleration causes the grains to leap forward along a parabolic trajectory, effectively dispensing one grain at a time. When a single grain is dispensed, the sensing system sends a signal to the control system, which then turns off the coin vibrator, pausing the dispensing process until prompted by the control system. Once prompted, the coin vibrator is activated again to continue dispensing. This cycle repeats until all the grains are dispensed.

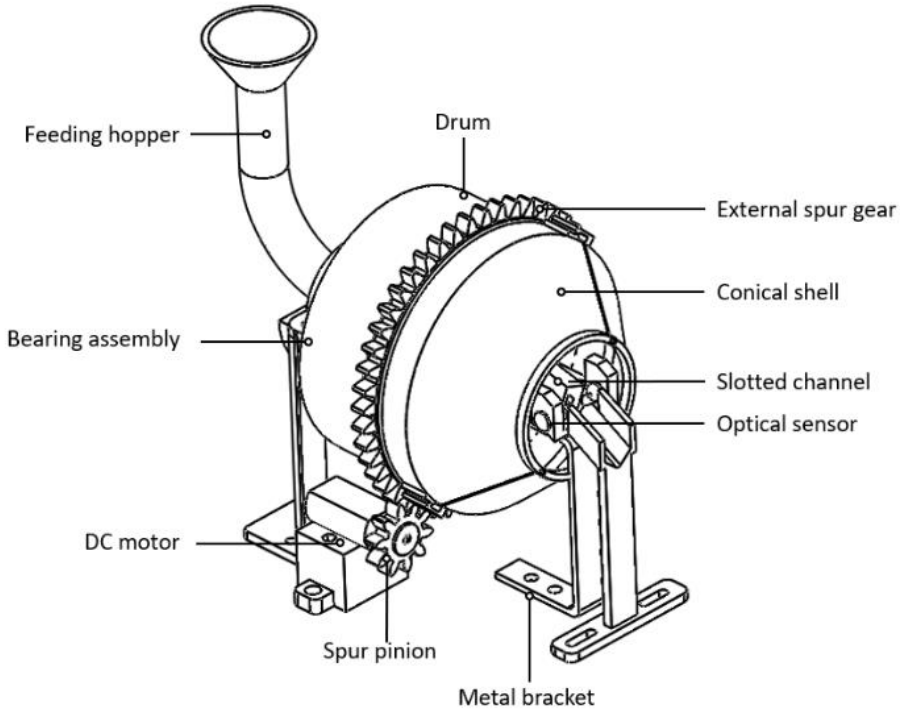

Figure 3.7: Isometric View of Dispensing System

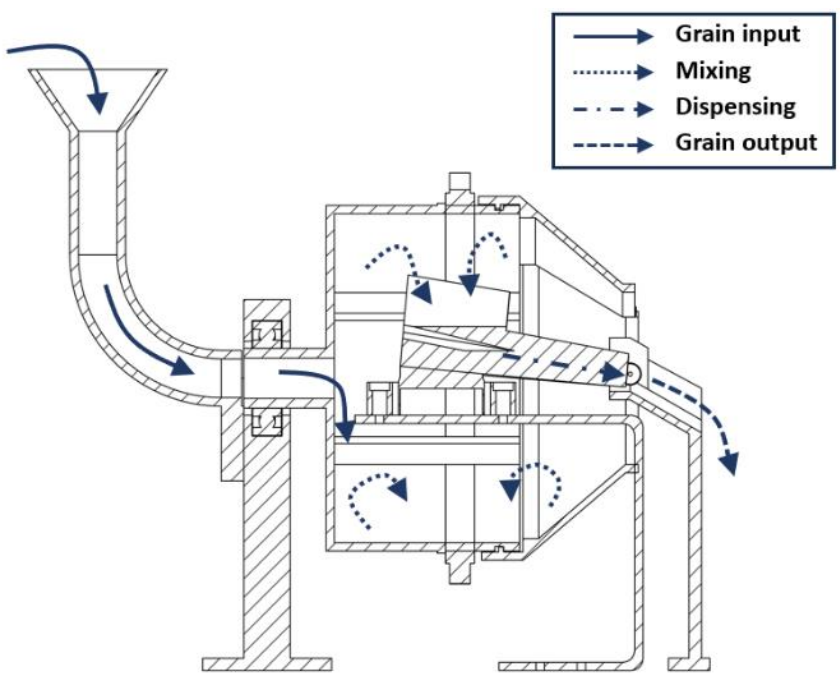

Figure 3.8: Movement of Grains within the Dispensing System

3.6 Detailed Design of Parts and Components

The dispensing system consists of a various compaonent as shown in Figure 3.7. It includes Linear Dispenser, Double-folded beam, Rotary Drum, Bearing Assembly, Feeding Hopper, Gear Transmission, DC motor, and Optical sensing system. The detailed designs and workings of each component are given below.

Linear Dispenser

The linear dispenser serves as the heart of the dispensing system. It is responsible for the precise dispensing of grains. It is located at the center of the rotary drum and affixed to a metal bracket using a double-folded beam assembly. It plays an important role in the operation of the system. It has length of 55mm, approximately six times the average kernel length of a rice grain (8.5mm). Altering the length of the linear dispenser can disrupt grain alignment and lead to inconsistent dispensing. Shortening it may cause discontinuous flow, while extending it beyond the recommended measure can result in excessive transverse vibration. In few case extending the length might result in halting the dispensing mechanism altogether. At the end of the linear dispenser, a 2 mm thick ramp and a vertical shield are provided. The ramp has a length three times that of the average kernel length of rice grain. It is angled at 45 degrees from the horizontal to facilitate smooth grain release by overcoming static friction. The vertical shield has the dimensions simillar to the ramp. Its primary function is prevents grains from bypassing the linear dispenser and directs them onto the ramp for proper guidance.

A unique pathway carved on the linear dispenser enables the grains to move from the ramp to the dispensing end of the linear dispenser, as illustrated in Figure 3.9 and Figure 3.10. As depicted in Figure 3.10, side AB of the dispenser is inclined at an 8-degree angle from the horizontal to prevent the grains from rolling over and falling before reaching the dispensing end. It's worth noting that the angle can be reduced to a minimum of 6 degrees, but any further decrease would result in all the grains falling from the linear dispenser before dispensing. Conversely, the angle can be increased up to 10 degrees while maintaining the proper functioning of the linear dispenser. However, an inclination greater than this may cause multiple grains to dispense simultaneously.

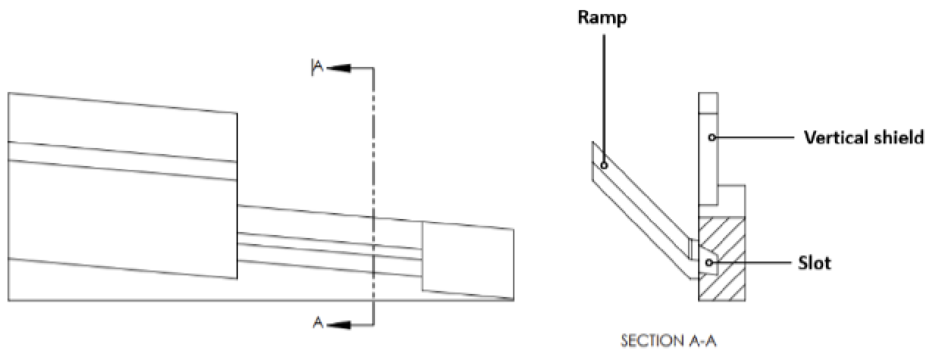

Figure 3.9: Cross-Sectional View of Linear Dispenser

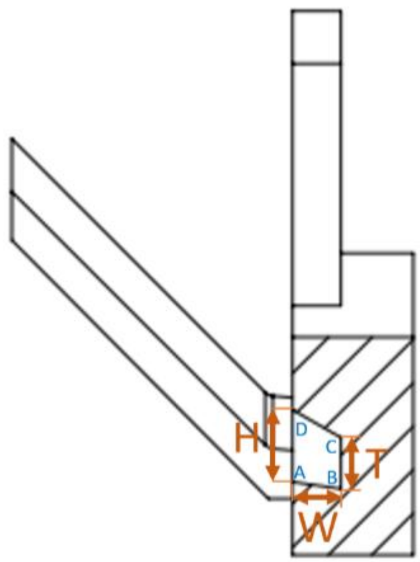

Figure 3.10: Cross-Sectional View of Linear Dispenser Showing Pathway Dimensions

Double-Folded Beam

The design of the double-folded beam draws inspiration from the Double-Folded Beam Flexure System used in the accelerometers [25]. Its purpose is to channel unidirectional longitudinal vibration to the linear dispenser while minimizing vibrations in other directions and isolating this vibration from transmitting to the metal bracket. A custom-designed double-folded beam, attached to the metal bracket, provides support for the linear dispenser while housing the coin vibrator as shown in Figure 3.11. The ends of the double-folded beam are firmly secured to the metal bracket, ensuring the beam's structural integrity during assembling and fastening. While the ideal scenario involves the utilization of purely longitudinal vibrations for the operation of a linear dispenser, achieving and maintaining these conditions in practical settings is challenging. During assembly, even slight misalignments can result in transverse vibrations, causing grains to fall from the dispenser prematurely. To counteract these effects, the upper surface of the beam, where the linear dispenser is fixed, is inclined at a 20-degree angle from the horizontal. This design adjustment helps mitigate the adverse effects of induced transverse vibrations. Its compact and sturdy design facilitates easy integration into the final assembly and minimizes maintenance requirements, ensuring smooth and efficient operation.

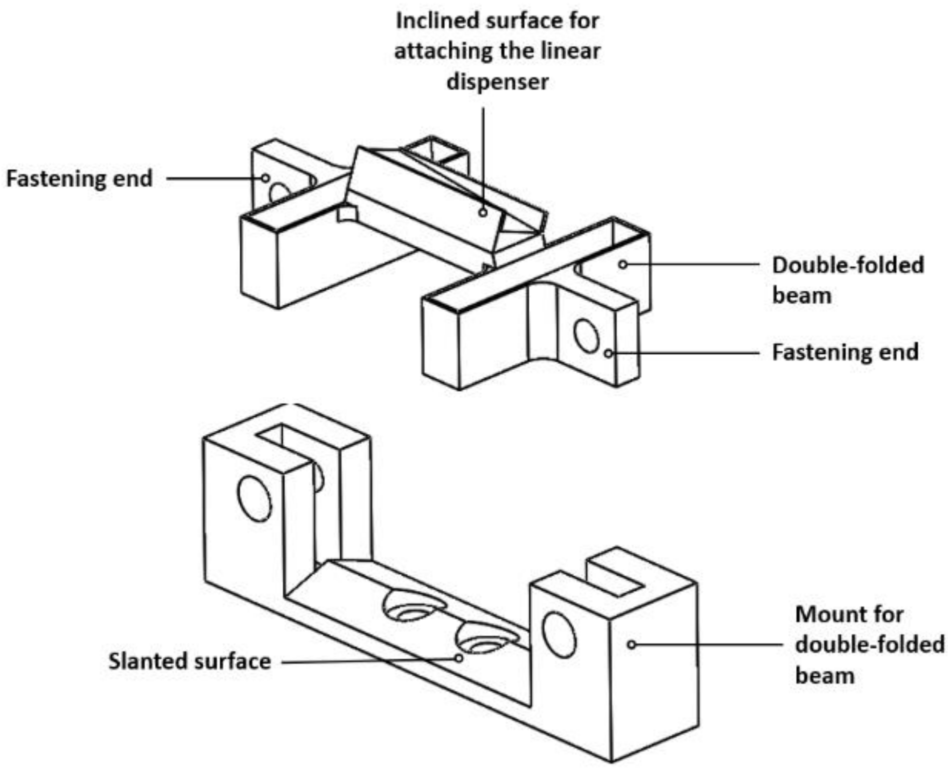

Figure 3.11: Isometric View of Double-Folded Beam

Metal Bracket

To support the linear dispenser attached to the double-folded beam assembly, a metal bracket with a height of 60 mm is used. The ends of the double-folded beam are securely fastened to the metal bracket, ensuring the structural integrity of the beam during assembly and fastening, as depicted in Figure 3.7. Subsequently, the metal bracket is affixed to the base of the system.

Rotary Drum

The rotary drum is a top-open cylinder with an axial length of 47 mm. It has an internal diameter of 80 mm, and a radial thickness of 2 mm. It is positioned horizontally to allow for the central placement of the linear dispenser. It has Six radial vanes, each with a length of 47mm, a height of 10 mm. This vanes are 2mm thick and are evenly positioned around the internal surface of the rotary drum. This configuration is optimal for the drum's operation. Reducing the number of vanes would result in discontinuous grain flow from the linear dispenser while increasing the number of vanes would be redundant. A hollow concentric shaft protrudes from the closed end of the drum, facilitating the loading of grains into the drum.

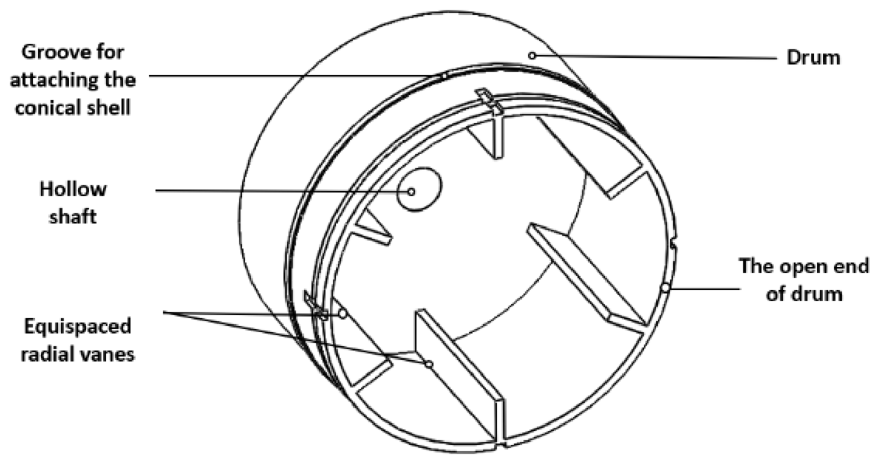

Figure 3.12: Isometric View of Rotary Drum

Bearing Assembly

The assembly includes a bearing and its mounting. For our research project, we utilized a ball bearing with an outer race and inner race measuring 37 mm and 25 mm respectively, with a thickness of 7 mm. The hollow shaft of the rotary drum fits into the inner race of the bearing, enabling the drum to rotate relative to the fixed support. For ease of installation and removal of the bearing, the bearing mount is divided into two parts as shown in Figure 3.13. The bearing assembly is securely attached to the base of the system using bolts.

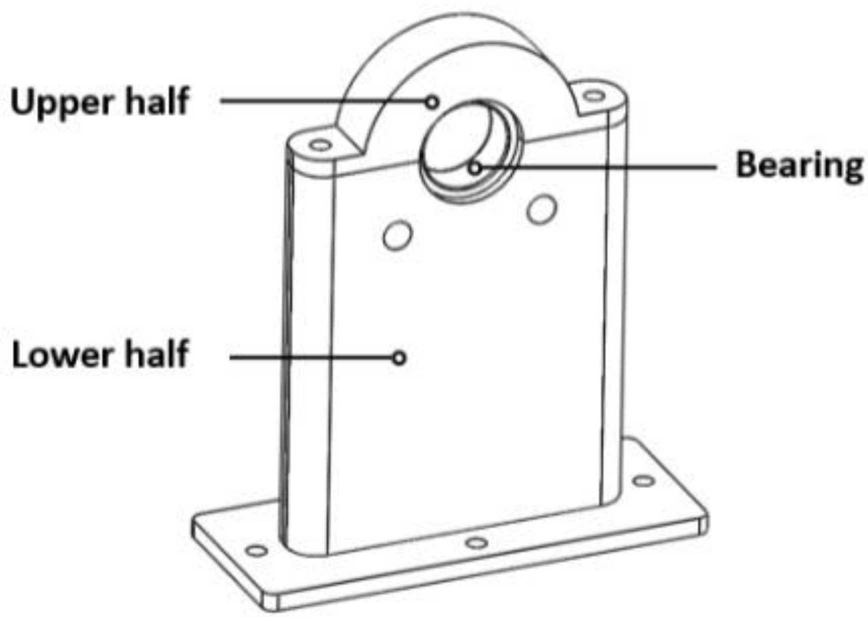

Figure 3.13: Isometric View of Bearing Mounting Assembly

Feeding Hopper

The feeding hopper serves as a gravity-fed chute designed for loading grains into the drum. It features an internal diameter of 21mm with a thickness of 2 mm. Positioned co-axially to the hollow shaft of the rotary drum, the outlet end of the feeding hopper features a 90-degree bend, as depicted in Figure 3.14, to ensure the smooth entry of grains into the drum. The feeding is securely attached to the bearing mounting using the bolts.

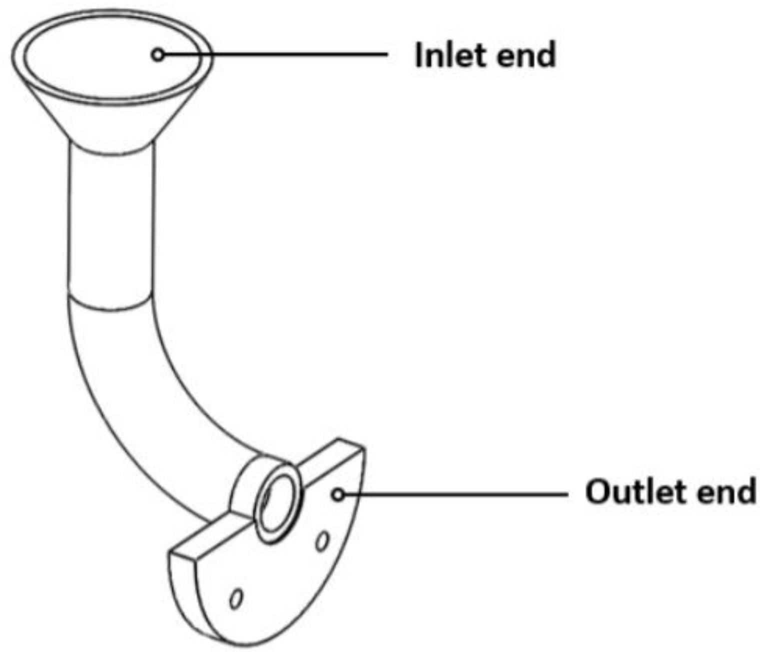

Figure 3.14: Isometric View of Feeding Hopper

Gear Transmission

A pinion is connected to the motor and is responsible for transferring motion to the rotary drum through a mating gear fixed on the drum surface as shown in Figure 3.7. The gear and pinion have a module of 2mm and a pressure angle of 20 degrees, with a pitch circle diameter of 96mm for the gear and 20mm for the pinion, respectively.

Motor

A DC motor is employed to rotate the rotary drum via a gear transmission system as shown in Figure 3.7. However, it is important to select a DC motor capable of operating above the threshold speed. Threshold speed refers to the minimum speed of the motor for which the grains just fall on the ramp and can be guided into the pathway carved in the linear dispenser. Thus it is crucial to determine the threshold speed.

Calculation of Threshold Speed

Assumptions

1. Grains are initially located at the periphery of the drum.
2. The acceleration of grains at the start of the motion is negligible.
3. Grains are slipping without rolling.
4. The trapezoidal rule is applied to determine the area under the curve (integration).

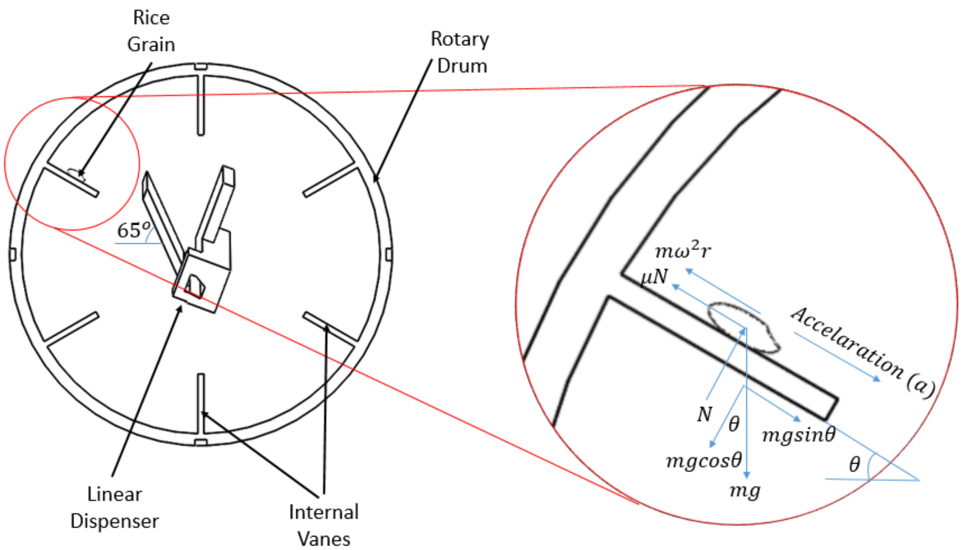

Figure 3.15: Free Body Diagram of A single Rice grain

Internal radius of the rotary drum (R) = 0.04 m

Radial length of the vane (L) = 0.01 m

Coefficient of friction between vane and rice grain = 0.29

Acceleration due to gravity (g) = 9.81 m/s^2

Displacement of the grain from the initial position: s

Instantaneous velocity of grain: v

Instantaneous acceleration of grain: a

Average mass of single rice grain: m

Angular displacement of the vanes starting from horizontal: θ

Let, Angular Speed of the drum (ω) = 2 x π x 1 = 6.28 rad

$$R = 0.04\ m$$

$$r = R - s$$

$$\sum F = ma$$

$$ma = mgsin\theta - mg\cos\theta - m\omega^2 r$$

$$a = gsin\theta - gcos\theta - \omega^2 r$$

At the start of the motion,

$$a = 0$$

$$i.e.\ 0 = gsin\theta - gcos\theta - \omega^2 r$$

$$0 = 9.81 \text{ x } sin\theta - 9.81 \text{ x } cos\theta - 6.282 \text{ x } 0.04$$

$$\theta = 25.057$$

After a small time interval dt = 0.001 sec i.e. 1 millisecond

$$\omega = \frac{d\theta}{dt}$$

$$d\theta = \omega \text{ x } dt$$

$$d\theta = 0.00628\ rad = 0.36$$

$$\theta = \theta + 0.36$$

$$a_2 = gsin\theta - gcos\theta - \omega^2 r$$

$$a_2 = 9.81 * \sin(25.416) - 9.81 * \cos(25.416) - 6.282 * 0.04$$

$$a_2 = 0.0633\ m/s^2$$

$$a = \frac{dv}{dt}$$

Even though the variation of acceleration with time is not linear, within small time intervals considered under the trapezoidal rule, the variation of acceleration with time can be assumed to be linear.

$$v_2 - v_1 = (a_2 - a_1) \text{ x } dt$$

$$a_1 = v_1 = 0 \ -- staring\ from\ rest$$

$$v_2 = 3.169 * 10^{-5}\ m/s$$

$$v = \frac{ds}{dt}$$

Even though the variation of velocity with time is not linear, within small time intervals considered under the trapezoidal rule, the variation of velocity with time can be assumed to be linear

$$s_2 - s_1 = (v_2 - v_1) \text{ x } dt$$

$$s_1 = v_1 = 0 -- staring\ from\ rest$$

$$s_2 = 1.58 * 10^{-8}\ m$$

The process of determining the acceleration, velocity, and displacement of rice grain after each small time interval is iterative. An algorithm is developed for this purpose, the flow chart of the algorithm is shown in Figure 3.16.

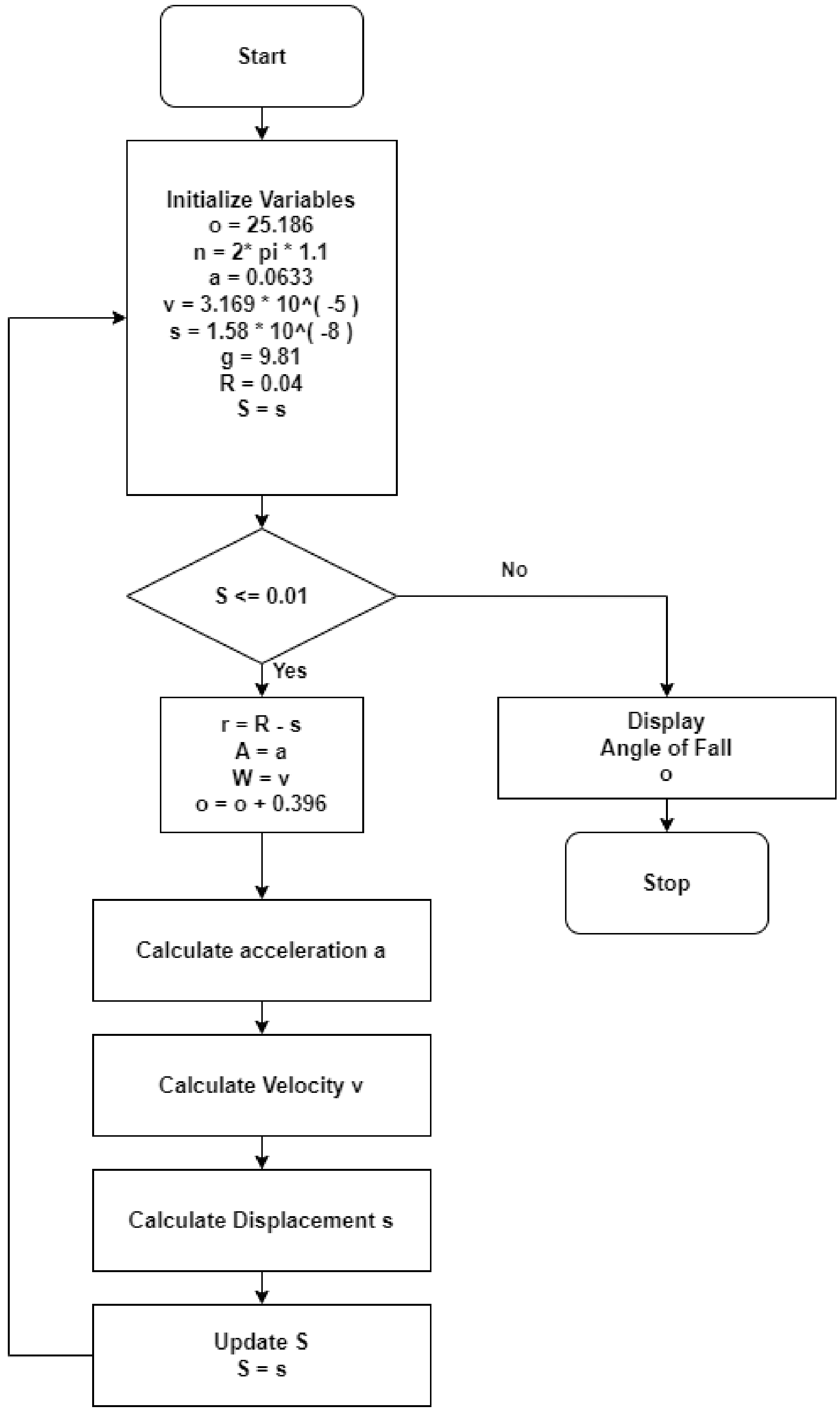

Figure 3.16: Flowchart For Determining the Threshold Speed of Motor

The algorithm's results indicate that for an angular velocity of 6.28 rad/s (equivalent to a frequency of 1 Hz), the angular displacement of the vane from the horizontal, at which the grain falls, is 60.8 degrees. However, it's observed that for the grain to fall on the ramp, the minimum angular displacement must exceed 65 degrees. Hence, it's necessary to increase the speed. For the subsequent calculation, the angular velocity of the drum is assumed to be 6.908 rad/s (corresponding to a frequency of 1.1 Hz). At this speed, the angular displacement of the vane from the horizontal, at which the grain falls, is 65.182 degrees. Therefore, theoretically, the minimum angular velocity of the drum required for the grain to just fall on the ramp and be guided into the pathway carved in the linear dispenser is 6.908 rad/s, equivalent to 1.1 Hz.

However, it is worth noting that according to Experiment 2, conducted under practical operating conditions, the minimum angular velocity of the drum required for the grain to just fall on the ramp is approximately 7.66 rad/s (equivalent to a frequency of 1.22 Hz). At this speed, the angular displacement of the vane at which the grain falls is measured to be 62.66 degrees.

To transmit motion to the drum, a gear and a pinion with pitch circle diameters of 96 mm and 20 mm, respectively, are utilized. Therefore, the gear ratio is calculated as,

Gear ratio = 96/20 = 4.8 $\approx$ 5

Consequently, the minimum speed at which the motor must operate is determined as,

Threshold speed = 1.1 x 5 x 60 = 330 rpm

Therefore, for our research project, we employed a DC motor with a rated speed of 600 rpm.

Conical Shell

The open end of the rotary drum is enclosed by a conical shell designed to redirect grains that fall from the slot back into the rotary drum. The conical shell features a larger internal diameter of 84 mm and a smaller internal diameter of 42 mm, with an axial length of 38 mm. The conical shell is split into two identical halves, which can be easily assembled back together using a snap-fit mechanism, simplifying installation onto the rotary drum. These two halves snugly fit into the slot provided on the drum, with an alignment ridge ensuring proper alignment and secure attachment of the conical shell onto the drum, as illustrated in Figure 3.17.

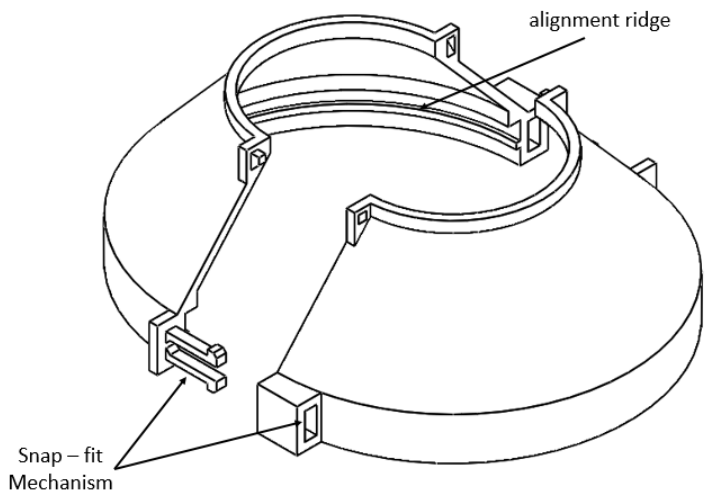

Figure 3.17: Isometric View of Conical Shell

Optical Sensing System

A laser sensor is positioned at the dispensing end of the linear dispenser. As a grain traverses the space between the transmitter and the receiver of the laser sensor, positioned opposite to each other as depicted in Figure 3.18, it initiates a signal to the control system. Subsequently, the control system monitors the dispensed grain count and controls the vibration of the linear dispenser accordingly. For our research project, we employed a Laser module as a transmitter and a laser Sensor as a receiver.

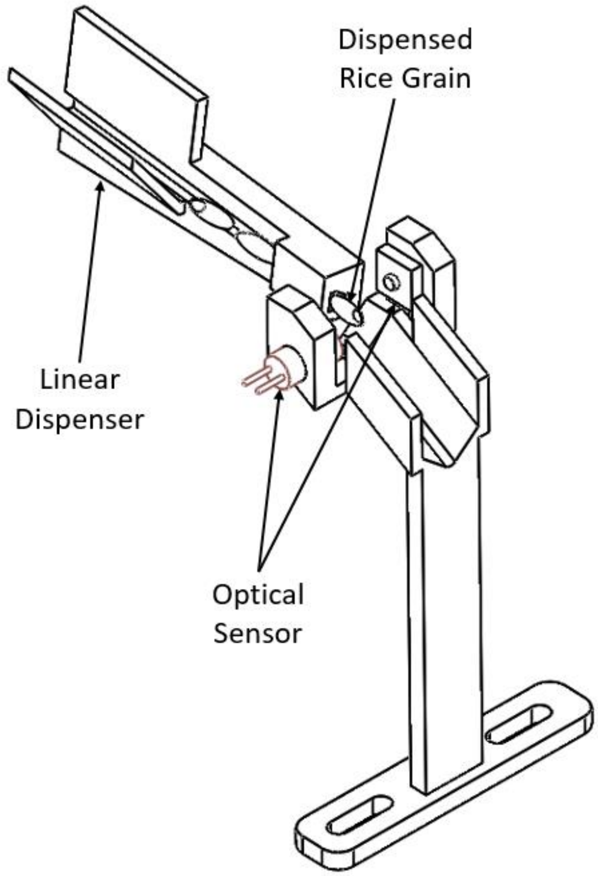

Figure 3.18: Working of Sensing System

CHAPTER 4: PROTOTYPE

Prototypes are important as they are required for they are important for validating the concept and design. They enable an iterative process through which flaws can be detected easily. Overall prototype plays an important part in the development of a new system. Many parts of the dispensing system are custom-designed. It will be wise to 3D printing techniques in the manufacturing process.

for our research project, we utilized Fused Deposition Modeling 3D printing Technology to fabricate important parts. It is used for making various parts including feeding hopper, bearing mounting assembly, rotary drum, conical shells, gear, pinion, double folded beam, linear dispenser, and optical sensor stand. Our prototyping efforts are supported by Snapmaker 2.0 (A350T). Snapmaker 2.0 (A350T) is an FDM 3D printer famous for its versatility and reliability. It has a large build size of 3200 x 350 x 330 mm. We used PLA + as print material developed by eSUN 3D Printing Co.Ltd due to its favorable properties. The PLA+ offers enhanced strength and flexibility when compared to general PLA. These enhanced properties make the PLA+ the most suitable material for our application and end use.

The properties of PLA+ are tabulated below:

Table 4.1: Mechanical Properties of PLA+ material

Property	**Value**	**Unit**
Print Temperature	205-225	°C
Bed Temperature	60-80	°C
Density	1.24	kg/cm^3
Tensile Strength	65	MPa
Elongation at Break	12	%
Flexural Strength	75	MPa
Flexural Modulus	2102	MPa
IZOD Impact Strength	8.5	KJ/m^2

To drive the drum we used an N20 12V DC motor with a rated speed of 600 RPM. It provides the necessary rotational motion. The Coin Vibrator-1638 from POLOLU Robotics and Electronics impart longitudinal vibration onto the linear dispenser. A DC-DC Buck Converter Step Down Module LM2596 is utilized to regulate the frequency and amplitude of vibration. This module provides precise control over voltage levels. Tuning the voltage enables accurate adjustment of the coin vibrator's vibration parameters.

The sensing system of the device comprises a 650nm 5V Laser module serving as the transmitter and a Laser non-modulator Tub sensor module acting as the receiver. This configuration enables the device to detect the presence or absence of grains as they pass through the sensing area.

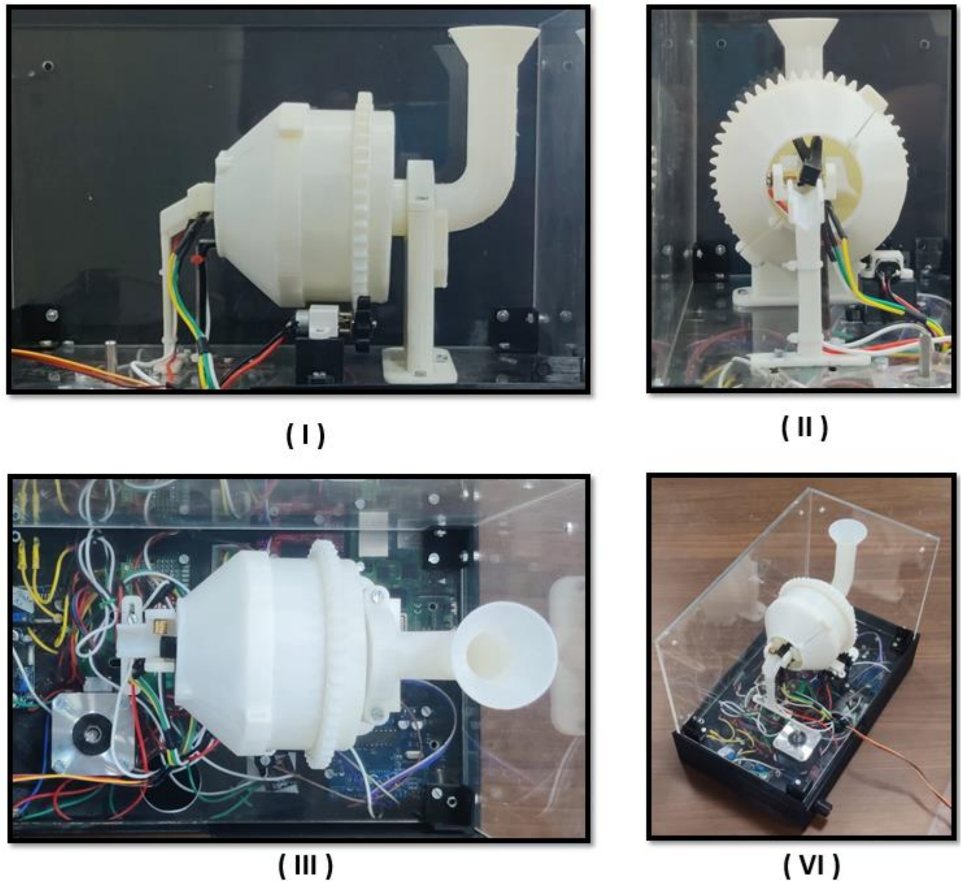

Figure 4.1: (I) Front View (II) Side View (III) Top View (IV) Isometric View of Prototype

Figure 4.2: (I) Rotary Drum (II) Conical Shell (III) Double Folded Beam (VI) Bearing Assembly (V) Gear (VI) Pinion (VII) Linear Dispenser (VIII) Feeding Hopper (XI) Optical Sensor Mounting (X) Laser Sensor Module (XI) Coin Vibrator (XII) Metal Bracket (XIII) Uno Arduino (XVI) DC Motor Driver (XV) DC Motor

CHAPTER 5: EXPERIMENTS AND RESULTS

The theoretical calculations and simulation results establish initial operational parameters. These parameters include the amplitude and frequency of linear dispenser vibration and the angle of fall of rice grain from the vanes of the drum. However, practical validation is essential for these parameters. Also, it is important to confirm certain assumptions and evaluate the performance of the prototype and subsystems. To achieve these objectives, a series of experiments are conducted as follows.

5.1 Experiment 1

Experiment Title: Experimental Validation of Vibration Parameters for Optimal Grain Dispensation in a Linear Dispenser Assembly

Aim: To determine the frequency and amplitude of vibration of the linear dispenser using a data acquisition system and a tri-axial accelerometer.

Theory: The linear dispenser assembly comprises several components. It includes the linear dispenser, the coin vibrator, the double-folded beam, the beam support, and the metal bracket. Initially, grains enter the linear dispenser from the drum's vane. The attached coin vibrator generates longitudinal vibration. This vibration causes the grain to accelerate. The acceleration of grains counteracts gravity causing them to move along a parabolic trajectory. This motion results in facilitating the dispensing process. The double-folded beam plays a crucial role in the dispensing process. It directs unidirectional longitudinal vibration to the linear dispenser while minimizing vibrations in other directions This prevents transmission to the metal bracket.

The Discrete Element Method analysis conducted using EDEM software revealed that in order to accelerate the grains sufficiently to overcome gravity and effectively dispense them, the linear dispenser needs to experience longitudinal vibration with an amplitude of 0.1 mm and a frequency of 100 Hz. It was determined that under these conditions, the linear dispenser can ideally dispense approximately 250 grains per minute.

Procedure

1. Begin by fine-tuning the coin vibrator by the trial and error method until the linear dispenser effectively dispenses grains.

2. Place the accelerometer along the length of the linear dispenser as shown in Figure 5.1 (B).

3. Activate the coin vibrator and collect vibration data using the data acquisition system for 10 seconds, with a sampling frequency of 51.2 KHz.

4. Utilize the Fast Fourier Transform to convert the collected data from the time domain to the frequency domain.

5. Plot a graph illustrating the frequency and amplitude of vibration in the longitudinal direction.

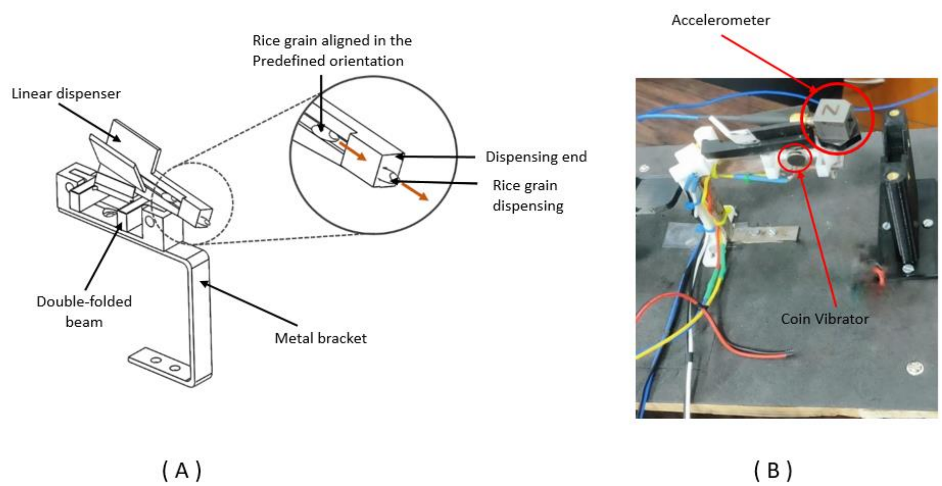

Figure 5.1: Experimental Setup to Determine the Frequency and Amplitude of Vibration of the Linear Dispenser

Observation and Results

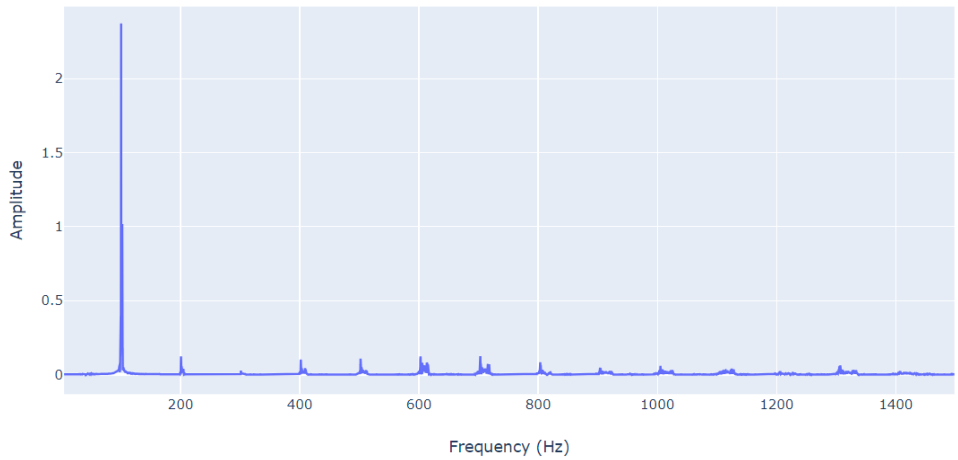

Figure 5.2: Frequency Vs Amplitude Plot for Linear Dispenser

Analysis of Figure 5.2 reveals that for effective grains dispensation during actual operation, the optimal frequency and amplitude of longitudinal vibration should be approximately 100.4 Hz and 0.0752 mm, respectively.

- At this determined frequency and amplitude, the observed grain flow rate is approximately 200 grains per minute.

Conclusion

The comparison between simulation and actual results provides valuable insights into the performance of the linear dispenser assembly. While the simulation predicted an ideal grain flow rate of 250 grains per minute using a frequency of 100 Hz and an amplitude of 0.1 mm, the actual experiment yielded a slightly lower flow rate of approximately 200 grains per minute at a frequency of 100.4 Hz and an amplitude of 0.0752 mm.

5.2 Experiment 2

Experiment Title: Determination of Threshold Speed of the Motor for Grain Dispensation.

Aim: To determine the threshold speed of the motor required for grains to fall onto the ramp of the linear dispenser.

Theory: The threshold speed refers to the minimum speed of the motor at which grains just fall onto the ramp and can be guided into the pathway of the linear dispenser. It is crucial to determine this threshold speed as the motor must operate below this speed during the initial period of operation and above it while dispensing grains. Theoretical threshold speed is calculated to be 330 rpm with an angle of fall of 65.182 degrees.

Procedure

1 Place the linear dispenser at the center of the rotary drum, position the tachometer at an optimal location to continuously monitor the motor speed, and ensure that the slow-motion camera is oriented parallel to the drum's plane of rotation.

2. Introduce a single rice grain into the drum and rotate it using the motor via the gear transmission.

3. Gradually increase the motor speed from 30 rpm to 400 rpm while recording the entire process with the slow-motion camera.

4. Analyze each frame of the recording to determine the exact speed at which the grain falls onto the ramp of the linear dispenser.

5. Repeat the process three times and record the motor speed and corresponding angle of fall for each trial.

Observation and Results

Table 5.1: Experimental Data for Threshold Speed and Corresponding Angle of Fall

Trial	Threshold Speed (rpm)	Angle of Fall (Degrees)
1	363	62
2	375	66
3	359	60

- The average threshold speed for the grain to be dispensed is 366 rpm.
- This threshold speed corresponds to the angle of fall of 62.66 degrees from the horizontal.

Conclusion

The experiment successfully determined the threshold speed of the motor required for grain dispensation. The measured threshold speed of 366 rpm indicates that the motor should operate above this speed during grain dispensation to ensure the effective functionality of the dispensing system.

5.3 Experiment 3

Experiment Title: Validation of Randomization Capability of the Dispensing System

Aim: To assess the ability of the Dispensing System in generetaing representative sample by comparing the average length of rice samples dispensed by the system with manually measured samples.

Theory: It is important to determine the ideal sample size for ensuring the validity of results. Adequate sample size planning is essential for both statistical power and accuracy. Small sample sizes might overlook important effects, whereas overly large ones can lead to resource wastage. Moreover, sample size impacts the study's significance level, its power, and the reliability of research outcomes. Therefore, it is necessary to determine the representative sample size for our experiment.

$$Necessary\ Sample\ size\ (n) = \frac{({z_{score}}^2)\ X\ (std)\ X\ (1 - std)}{(Margin\ of\ error)^2}$$

Confidence Interval = 95% (0.95)

Z-Score (95% Confidence Interval) = 1.96

Margin of error = 1 – Confidence Interval = 1 – 0.95 = 0.05

Standard Deviation (std) = 0.53

$$Necessary\ Sample\ size\ (n) = \frac{({z_{score}}^2)\ X\ (std)\ X\ (1 - std)}{(Margin\ of\ error)^2}$$

$$n = \frac{1.96^2 X(0.53) X(1 - 0.53)}{0.05^2}$$

$$n = 382.15 \approx 383\ grains$$

However, the formula mentioned above is typically used for calculating the size of a representative sample drawn from an infinite population. Given that our population consists of a finite number of 1000 rice grains, a correction factor needs to be applied.

$$n_{corrected} = \frac{n}{1 + \frac{(n-1)}{N}}$$

$$n_{corrected} = \frac{383}{1 + \frac{(383 \ -1)}{1000}}$$

$$n_{corrected} = 278.18 \ \approx 279 \ grains$$

Procedure

1. Measure the length, thickness, and width of 1000 rice grains manually using a digital Vernier Caliper.

2. Load these 1000 grains into the dispensing system. Record the time taken to dispense each sample by the rice dispensing device.

3. Measure the length, thickness, and width of 279 rice grains dispensed by the device for each sample.

4. Calculate the minimum, maximum, and average length of rice samples dispensed by the device.

5. Compare the average length of rice samples dispensed by the device with the manually measured sample.

Observation and Result

Table 5.2: Experimentation Data For Validating the capability of the Dispensing System to produce representative samples

Parameters	Manually Measured	Machine Dispensed Sample -01	Machine Dispensed Sample -02	Machine Dispensed Sample -03
Number of Samples	1000	279	279	279
Time to Dispense sample	_	2 min 58 sec	2 min 25 sec	2 min 57 sec
Minimum Length (mm)	6.95	7.14	7.18	7.01
Maximum Length (mm)	9.77	9.72	9.72	9.64
Average Length (mm)	8.48	8.48	8.49	8.47

- The average lengths of rice samples dispensed through the device are 8.48 mm, 8.49 mm, and 8.47 mm, respectively.
- The average length of 1000 manually measured rice samples is 8.48 mm.

Conclusion

The experiment demonstrates that the dispensing system is capable of producing representative samples, as indicated by the average length of rice samples dispensed, which closely matches the average length of manually measured samples. This validates the randomization capability of the dispensing system in dispensing rice grains.

5.4 Experiment 4

Experiment Title: Time Required to Dispense the Last Grain inside the Dispensing system

Aim: To determine the time required to dispense the last remaining rice grain inside the dispensing system.

Theory: The experiment aims to assess the efficiency of the automated dispensing system in dispensing the last rice grain from the drum. The microcontroller is programmed to shut down the device if the time interval between two rice grains being dispensed exceeds a predetermined threshold value. To determine this threshold the above experiment is conducted

Procedure

1. Introduce a single rice grain into the rotating drum of the dispensing system via the feeding hopper.
2. Observe and record the time taken for the dispensing process to complete for the last remaining rice grain.
3. Repeat the process multiple times to obtain a set of observations.
4. Tabulate the observed times required to dispense the last rice grain.

Observations and Results

Table 5.3: Observation Table for Estimation of Time Required to Dispense the Last Rice Grain

Trial Number	Time to dispense the last rice grain (ss:ms)
1	06:500
2	09:500
3	25:300
4	07:320
5	03:960
6	06:950
7	12:480
8	27:320
9	08:500
10	25:100

- When the last grain is left in the dispensing system it takes variable time interval to be dispensed.
- From the above itration the maximum time duration came out to be 27.36 seconds.

Conclusion

This iterations provides valuable information about performance of the dispensing dispensing. The maximum time duration of 27.36 minutes can be used as reference value when setting the threshold for the dispensing system.

5.5 Experiment 5

Experiment Title: Time Efficiency of Rice Grain Dataset Generation

Aim: To determine the time required to generate a dataset of 50 rice grains using an automated system.

Theory: The experiment aims to compare the time efficiency of generating a dataset of rice grains using an automated system versus manual methods. The automated system comprises two subsystems: a dispensing system and an image acquisition system. Where each grain is dispensed individually onto the movable platform, with high-magnification images captured and stored for each grain.

In contrast, the manual method involves a quartering process, where the sample is placed on a level surface and divided into four roughly equal portions. Any two portions are then combined diagonally. This process is repeated until the desired sample of 50 grains is achieved. Subsequently, each grain is manually placed on the platform, and a high-magnification image of the grain is manually captured. The entire process, from quartering to image capture, takes approximately 1 hour and 15 minutes.

Procedure

1. Introduce a handful quantity of rice grains into the rotating drum via the hopper.
2. Grains are carried by the drum's radial vanes to the linear dispenser for dispensing onto the movable platform.
3. The optical sensor Triggers the camera to capture a high-magnification and high-resolution image of each grain placed on the movable platform.
4. Repeat the process until a dataset comprising images of 50 grains is generated.
5. Record the time required to dispense the first grain and the 51st grain.

Observations and Results

Table 5.4: Observation Table For Dataset Generation of The Rice Grains

Trial Number	Time First Rice Grain Dispensed (mm:ss:ms)	Time 51st Rice Grain Dispensed (mm:ss:ms)
1	00:04:360	03:55:010
2	00:03:270	03:32:540
3	00:02:500	03:39:340
4	00:02:130	03:31:350
5	00:02:320	03:32:000
Average	00:02:916	03:38:048

The experiment yielded an average duration of 3 minutes and 38 seconds to generate a dataset of 50 rice grains using the automated system.

In contrast, manual generation of a similar dataset requires approximately 1 hour and 15 minutes.

The automated system is approximately 20.64 times quicker than the manual process in terms of time efficiency.

Conclusion

The experiment confirms that the automated system consisting of the novel dispensing system and an image acquisition system is substantially more time-efficient than manual methods for generating rice grain datasets.

5.6 Experiment 6

Experiment Title: Verifying the Empirical Relation between Grain Size and Linear Dispenser Dimension

Aim: To experimentally verify the empirical relation between grain size and Linear dispenser dimension.

Theory: After extensive observation of grain and linear dispenser dimensions we have formulated a set of empirical formulae. These formulae are as follows.

$$\text{Thickness (T)} = 1.5\times t$$

$$\text{Breadth (W)} = 1.25\times b$$

$$\text{Height (H)} = 1.875\times b$$

$$\text{Length (L)} = 6\times l$$

Where, t = Grain Thickness

b = Grain Breadth

l = Grain Length

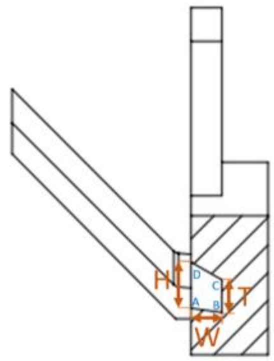

Figure 5.3: Cross-Sectional View of Linear Dispenser Showing Pathway Dimensions

EDEM simulation and experiments are performed on various grain and seed samples, to verify empirical formula derived for the linear dispenser dimensions relative to grain size. These soybean, maize, and sunflower seeds, aiming to validate the formula's universality and applicability across different grain types.

Simulation:

Many studies [26-28] have been done on development of EDEM particles for grains and seeds using multi-sphere particle methods. Using the same method we have developed EDEM particle for Maize, soybean and sunflower seed as shown in Figure 5 4. (I), (II) and (III)

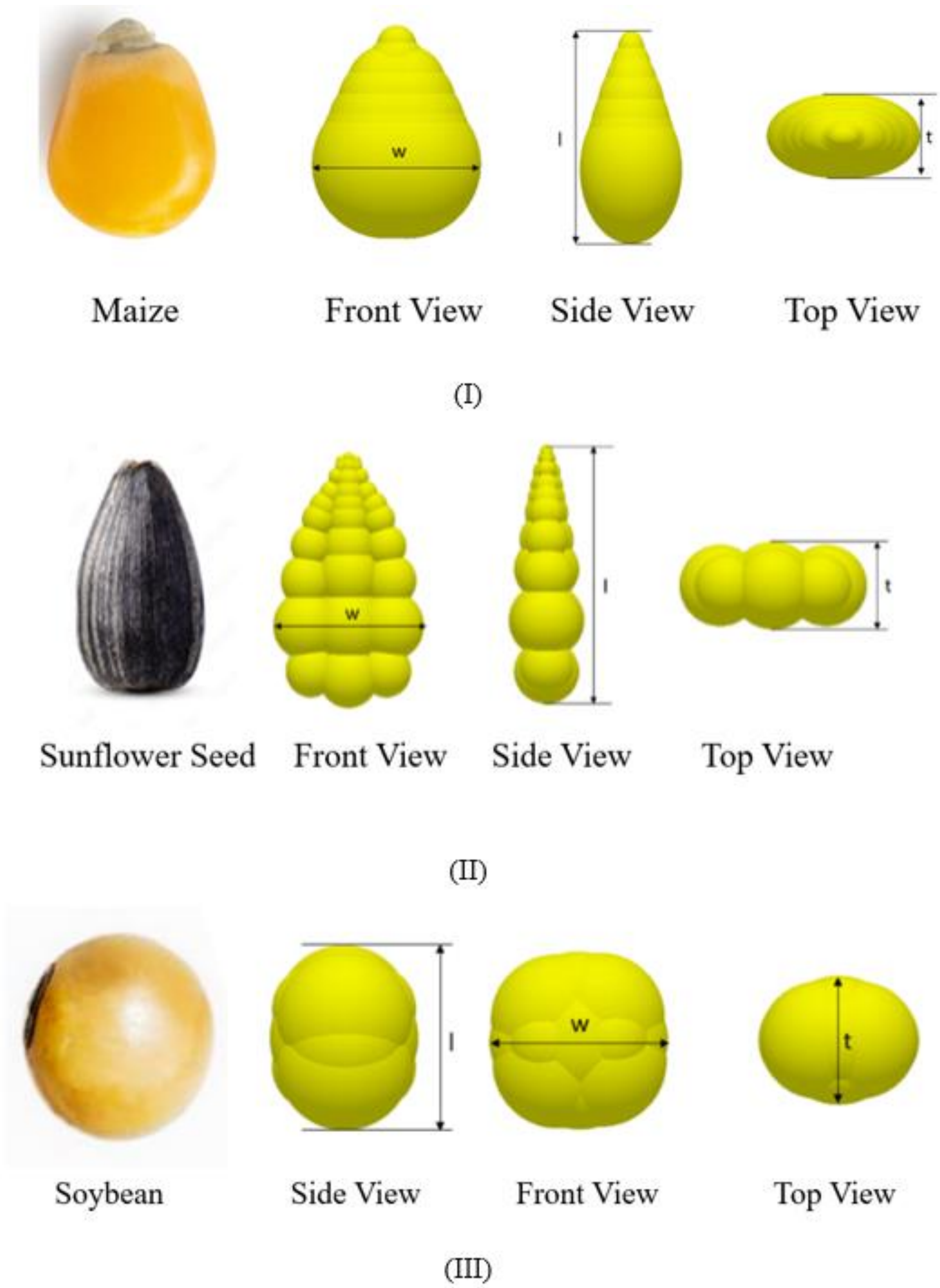

Figure 5.4: DEM model of (I) Maize (II) Sunflower Seed (III) Soybean

Table 5.5: Dimensions of Linear Dispenser Slot for Rice Grain, Soybean, Maize, and Sunflower Seed

Material	Grain Dimensions (mm)			Linear Dispenser Slot Dimensions (mm)			
	l	b	t	L	T	W	H
Rice Grain	8.9	1.6	1.6	54	2.0	2.0	3.0
Soybean	8.2	8.2	6.6	50	10.0	8.25	12.5
Maize	10.8	8.5	7.5	66	10.0	10.0	15.0
Sunflower Seed	9.6	6.0	2.8	60	7.5	3.5	5.5

Using the above dimensions for the slot derived from the empirical relation, CAD models for soybean, maize, and sunflower seeds are constructed and individually imported into the EDEM software to perform simulations. Once the model is imported, boundary conditions are applied to the model. These conditions include oscillating the linear dispenser with a frequency of 100Hz and an amplitude of 0.1 mm in the axial direction. From the observations of the simulations, it was observed that the linear dispenser can dispense the grains and seeds one at a time. From the observations of the simulations, it was observed that the linear dispenser effectively dispenses the grains and seeds one at a time while aligning them linearly. One of the key observations was that in some instances, soybean grains were rolling down the pathway carved on the linear dispenser, resulting in uncontrolled dispensing of the grains due to their near-spherical shape.

Experiments: To conduct the experiments, a linear dispenser for maize is manufactured using a resin printer, while the double-folded beam of corresponding dimensions is produced using an FDM printer. The linear dispenser is secured to the double-folded beam, which in turn is rigidly fixed to the table, as illustrated in Figure 3. To impart longitudinal vibration on the linear dispenser an eccentric motor is used. The motor is attached at the bottom of the double-folded beam as shown in Figure 5.5. Initially, the maize grains are placed on the ramp of the linear dispenser. Then the linear dispenser is actuated using the eccentric motor. The eccentric motor is tuned to induce suitable vibration to the linear dispenser leading to controlled dispensing of the maize grains. This experiment is repeated for soybean and Sunflower seeds and data is collected in multimedia format.

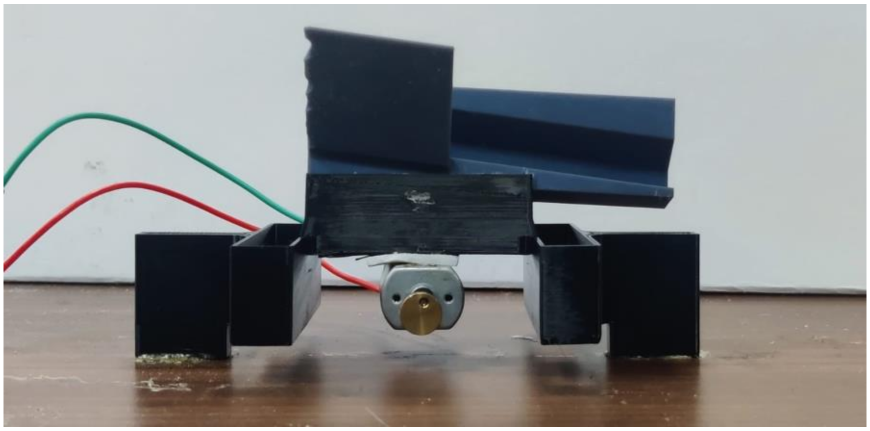

Figure 5.5: Experimental Set-Up for Maize

Observations

1. In the case of maize and sunflower seeds, the linear dispenser successfully dispenses the material in a controlled manner.
2. However, Due to the near-spherical shape of soybeans they tend to roll down the pathway carved on the linear dispenser. This led to uncontrolled dispensing of the soybean seed.

Conclusion

In conclusion, the simulation and experiment have successfully varified the empirical relation between the dimensions of a grain and the linear dispenser. The experiment also points out a potential flaw of linear dispensers in dispensing near-sphere shaped materials.

CHAPTER 6: CONCLUSION

In conclusion, the goal of the project was to design and develop a novel grain dispensing system. Through extensive research and experimentation, we have achieved our primary objective of the project. The developed system is capable of dispensing an average of 200 grains per minute in a controlled manner. The randomization ability of the dispensing system is verified through the experiments. Additionally, the automated system utilizing the dispensing system showed a substantial reduction in the time required for dataset generation compared to the manual technique. the automated system proved to be approximately 20.64 times faster than manual techniques highlighting the efficiency of the system.

Key Findings

To dispense rice grain from the linear dispenser the coin vibrator should impart longitudinal vibrations with a frequency of 100 Hz and amplitude of 0.0735 mm.

The observation has revealed a direct correlation between the dimension of the grain and the linear dispenser. This correlation can be used to manufacture a tailored linear dispenser for dispensing grains and seeds.

The utilization of 3D printing techniques for manufacturing the parts has proven to be effective. Especially while developing the complex parts of the dispensing system. It also helped in taking an iterative approach while designing the parts.

The incorporation of the double-folded beam in the linear dispenser assembly has proven to be effective in constraining vibration in the axial direction. Apart from constraining the vibration DFB effectively isolates the transmission of vibration to other parts of the system. This enhances the system’s stability leading to consistent grain dispensing.

The laser-based optical sensing systems are superior to the IR-based optical systems while working with grains in motion.

Overall, The project shows a significant step forward in the grain dispening system. The accomplished work shows a great potential in the grain classification and sorting industry. We are excited about the opportunities that lie ahead with this work.

CHAPTER 7: FUTURE SCOPE

The developed system is able to dispense rice grain with great accuracy and consistency. However, certain design changes can be made to crucial parts of the system based on applications. This modification can improve the Efficiency and stability of the system.

key areas of improvements are as follows

a) Multipath Linear Dispenser: The developed system utilizes a single-path linear dispenser for grain dispensing. Instead of a single-path dispenser a multi-path dispenser can be used to improve the grain flow rate.
b) Multi-Grain Compatibility: Our prototype can dispense a wide variety of rice grains. However, it can be also used to dispense other grain, seeds, and nuts by developing a linear dispenser according to the empirical relation.
c) Integration with sorting system: The dispensing system can be a part of a grain classification and sorting system. The developed system can act as the feeding system dispensing one grain at a time. The dispensed grain can be sorted based on visual inspection or using some other techniques.

By exploring this modification the system can continue to evolve and adapt to meet the growing needs of agricultural industry.

APPENDIX-A

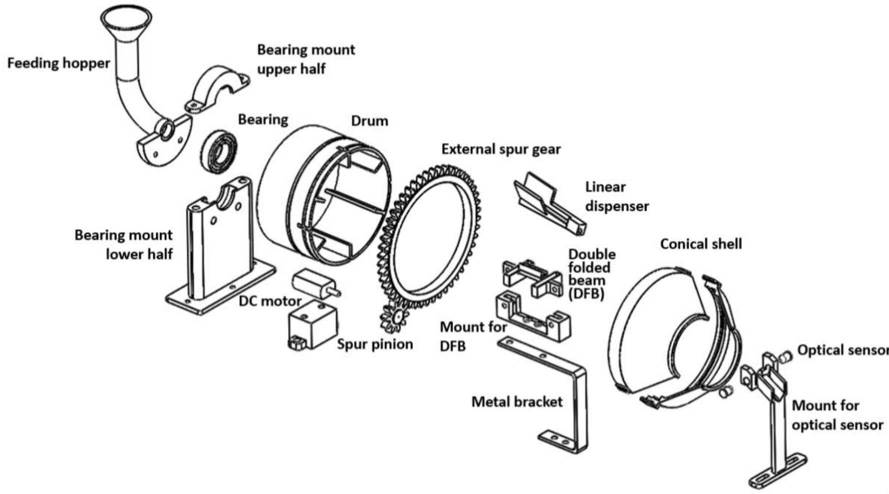

Figure 8.1: Exploded View of Dispensing System

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