Optimal design of Silo for bulk storage of Rice

A PROJECT REPORT

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

BACHELOR OF ENGINEERING

IN

COMPUTER SCIENCE WITH SPECIALIZATION ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

CHANDIGARH UNIVERSITY, GHARUAN, MOHALI - 140413,

PUNJAB November,2023

BONAFIDE CERTIFICATE

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Abstract

The ideal design of rice silos for bulk storage is a significant undertaking that combines engineering precision, agricultural understanding, and technology innovation. This research aims to address the critical need forefficient rice storage, which is critical for maintaining food security and minimising post-harvest losses. Rice, b eing a critical staple for worldwide populations, necessitates specialised storage strategies in order to retain nutritional quality, flavour, and market value.

The study goes into the various aspects required for building silos that maintain rice integrity over long periods of time. Temperature and humidity control, pest management, loading and unloading systems, structural integrity, energy efficiency, and adherence to regulatory standards are all factorsto consider. The study looks into different silo designs, such as flat-bottom, hopper-bottom, and cone-bottom designs, and assesses their suitability for rice storage.

Temperature and humidity changes have a substantial impact on rice quality, thus optimising silo design for climate management is a major concern. Integrating ventilation and aeration systems maintains consistent indoor conditions, preventing mould growth, pest infestations, and moisture-related degradation. Furthermore, cutting-edge technologies like IoTsensors and automation play a critical role in real-time monitoring and controlof storage settings.

Finally, a simulation study checks the performance of the approximations, first with the Fisher Information matrix, then with thelinearization of the function to be estimated. The results are useful forexperimenting in a laboratory and then translating the results to a real scenario.

Abbreviation

Table-1

S. No.	Abbreviation	Full Form
1.	PC&YC	Partial-Chalky and Yellow-Colored
2.	MC&YC	Mass-Chalky and Yellow-Colored
3.	BR&YC	Broken and Yellow-Colored
4.	PC&SP	PartialChalky and Spotted
5.	MC&SP	Mass-Chalky and Spotted
6.	BR&SP	Broken and Spotted(BR&SP).

Introduction

Silos and hoppers are indispensable components in various industrial sectors, acting as pivotal storage units for a diverse array of solids and liquids. Their primary function is to serve as intermediate storage, bridging gaps between different industrial processes. Industries such as power generation, steelmaking, quarrying, plastics production, food processing, mining, farming, and agriculture heavily rely on these structures. The versatility of silos is evident in their accommodation of materials ranging from micron-sized fine powders to larger entities such as agricultural grains, pellets, minerals, and crushed rocks.

Constructing silos demands meticulous attention to structural intricacies to ensure their reliability. While numerous codes and standards provide guidelines for construction, challenges persist. The paramount objective is to guarantee the consistent, steady, and complete discharge of solids from the silo. Challenges arise in the form of flow obstructions, commonly caused by the formation of cylindrical pipes or stable arch-shaped obstacles over the silo outlet. These obstructions can lead to blockages or jams, emphasizing the need for precise determination of the critical size of the outlet during the design phase.

Two significant challenges hinder the optimization of silo design and performance. Firstly, there is a critical knowledge gap regarding the properties of stored materials, such as biomass particles or granular materials. This lack of understanding can impede the establishment of reliable criteria for construction. Issues like jam formation and the intricacies of non-linear heteroscedastic modeling further complicate the design process. Secondly, the nature of bulk solids is subject to change over time due to various factors, including storage duration, moisture content, temperature variations, aeration, silo degradation, and prevailing climate conditions. These changes can significantly impact the performance of the silo.

Constructing silos demands meticulous attention to structural intricacies to ensure their reliability and functionality. While numerous codes and standards provide guidelines for silo construction, challenges persist, particularly in guaranteeing the consistent, steady, and complete discharge of solids from the silo.

One of the primary challenges in silo design is flow obstruction. Flow obstructions commonly occur due to the formation of cylindrical pipes or stable arch-shaped obstacles over the silo outlet. These obstructions can lead to blockages or jams, emphasizing the need for precise determination of the critical size of the outlet during the design phase.

Optimizing silo design and performance is hindered by two significant challenges: the critical knowledge gap regarding the properties of stored materials and the dynamic nature of bulk solids. The lack of understanding of material properties, such as those of biomass particles or granular materials, impedes the establishment of reliable criteria for silo construction. Issues like jam formation and the complexities of non-linear heteroscedastic modeling further complicate the design process.

Furthermore, the nature of bulk solids is subject to change over time due to various factors, including storage duration, moisture content, temperature variations, aeration, silo degradation, and prevailing climate conditions. These changes can significantly impact the performance of the silo, potentially leading to malfunctions or structural failures.

Direct experimentation in silo design poses substantial challenges, primarily due to the scale involved and the potential risks associated with handling large quantities of stored materials. The expense and difficulty in replicating experiments make computational simulation a more viable solution. By utilizing physical models of the dynamics of stored materials and employing statistical experimental designs, researchers and engineers can explore numerous scenarios in a controlled and cost-effective manner. This approach allows for a nuanced understanding of how varying conditions affect silo behavior, facilitating the optimization of design parameters to minimize the risk of failures.

Direct experimentation in silo design poses substantial challenges, primarily due to the scale involved and the potential risks associated with handling large quantities of stored materials. The expense and difficulty in replicating experiments make computational simulation a more viable solution.

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In summary, the intricacies of silo construction and the dynamic nature of stored materials necessitate an integrated approach. This involves combining theoretical insights, empirical data, and computational simulations to achieve optimal design and reliable performance in industrial settings. By addressing challenges in understanding material properties and adapting to changing conditions, engineers can enhance the efficiency and safety of silos, ensuring their crucial role in industrial processes remains uninterrupted.

1.1 Identification of Client and Need of Project

The client for a silo design project could be any organization or individual that needs to store rice in bulk. This could include rice farmers, rice millers, rice traders, or government agencies responsible for food security.

Rice is one of the most important staple foods in the world, and its storage is critical for ensuring food security. Silos are the most common type of storage structure for rice, and the optimal design of silos can have a significant impact on the quality and quantity of rice that can be stored.

There are many factors to consider when designing a silo for rice storage, including the type of rice, the storage capacity required, the climate, and the budget. However, some general principles can be applied to optimize silo design for rice storage.

Rice silo design project aims to create a storage structure that safely and efficiently stores rice in bulk. This is crucial for several reasons:

- Preventing rice damage from pests, rodents, and weather: Silos safeguard rice from external factors that can cause spoilage and loss.
- Protecting rice from moisture and temperature fluctuations: Silos maintain stable environmental conditions, preventing moisture-induced mold growth and temperature-related rice quality deterioration.
- Minimizing the risk of foodborne illness: By properly storing rice, the risk of contamination and subsequent foodborne illnesses is significantly reduced.
- Improving the efficiency of rice handling and transportation: Silos facilitate efficient rice handling and movement, streamlining the entire supply chain

1.2 Identification Of Problem

Rice preservation is a critical concern, given its status as a staple food for a significant portion of the global population. The challenge lies in maintaining the quality and nutritional value of rice over extended periods. Unfortunately, the current lack of efficient and specialized silo designs tailored for rice storage exacerbates these difficulties, leading to implications for food security and economic sustainability.

Traditional storage methods often prove inadequate in protecting rice from various threats, including temperature variations, humidity, pests, and mechanical damage. These vulnerabilities result in diminished rice quality, financial losses, and potential health hazards for consumers. Inefficient silo designs further compound the problem, hindering loading and unloading processes, causing additional breakage, and introducing distribution inefficiencies.

In response to these challenges, the adoption of silo tanks emerges as a promising alternative to traditional storage practices. Silo tanks, when properly designed, not only replace conventional storage godowns but also alleviate the physical burden on small farmers associated with arranging storage using materials like golden fiber (jute bags). The continuous airflow and controlled humidity within the silo tanks contribute to maintaining a dry environment, essential for preserving rice quality.

The transition to silo tanks brings about several advantages over traditional methods. One notable benefit is the elimination of the labor-intensive process of arranging storage using materials like jute bags. This not only reduces the physical burden on small farmers but also addresses concerns related to post-harvest losses and low selling prices due to damaged or compromised rice quality.

Traditional storage methods frequently fail to provide enough protection against these threats, resulting in decreased rice quality, economic losses, and significant health hazards for consumers. Inadequate silo designs impede efficient loading and unloading procedures, resulting in additional rice breakage and distribution inefficiencies.

By using silo tanks we are replacing the storage godown’s. The human power requires a lot to arrange the storage using golden fiber that is jute bags. The processto carry inside the coldstorages and while removing from them it is very burden for small farmers, So it will make them to sell for the low price. Here the silo tanks will be storing them and remove the moisture we will be continuously air flow and the area should be dry .We will be planning to remove the husk and rice separate from it .

Moreover, silo tanks facilitate moisture removal through continuous airflow, creating an environment conducive to preserving rice quality. The plan to separate husk and rice within the silo adds another layer of efficiency to the storage process. This meticulous design consideration contributes to maintaining the nutritional value and safety of rice, ensuring that it meets the standards required for consumption.

The choice of material for constructing silo tanks, whether steel or concrete, plays a crucial role in ensuring durability and longevity. The height-to-diameter ratio of cylindrical tanks is another design consideration that impacts space utilization efficiency and the overall quality of stored rice.

Efficient rice preservation through silo tanks requires careful attention to various design parameters. The volume of each tank directly influences the total storage capacity, impacting the quantity of rice that can be preserved at any given time. Determining the optimal number of tanks in the silo is crucial for meeting storage demands and ensuring a continuous supply.

The material chosen for constructing the tanks influences factors such as durability, maintenance requirements, and overall cost. Steel and concrete are common choices, each with its advantages and considerations. The height-to-diameter ratio of cylindrical tanks is a critical factor influencing the efficiency of space utilization within the silo.

Cost considerations encompass both construction and maintenance expenses, making it imperative to strike a balance between upfront investments and long-term operational efficiency. Evaluating the overall cost-effectiveness of silo tank adoption involves assessing the benefits in terms of reduced labor, minimized post-harvest losses, and enhanced rice quality.

1.3 Task Identification

Rice, the staple food for over half of the world's population, plays a crucial role in ensuring global food security. However, the post-harvest storage of rice poses significant challenges, leading to substantial losses in quality, nutritional value, and economic value.

Rice is highly susceptible to external factors such as temperature fluctuations, humidity levels, and pest infestations. Traditional storage methods, often relying on simple structures and limited monitoring, fail to adequately protect rice from these threats. As a result, rice undergoes significant deterioration, losing its desirable qualities and becoming susceptible to spoilage.

The deterioration of rice quality during storage not only affects consumer satisfaction but also leads to economic losses for producers and distributors. Consumers are faced with rice that has lost its aroma, texture, and nutritional value, diminishing their overall experience and potentially leading to health concerns. Additionally, producers and distributors incur financial losses due to reduced marketability of the rice and increased costs associated with spoilage and waste management.

Inefficient storage practices not only contribute to the loss of rice but also raise environmental concerns. The lack of climate control systems and advanced technologies leads to wasteful resource usage and carbon emissions. Improper storage conditions can increase energy consumption for cooling or heating, while also contributing to food waste through spoilage and pest damage.

The moisture content of rice grains is a critical factor in maintaining quality and ensuring safe storage. Ideal moisture levels vary depending on the type of rice and the storage conditions. Table 1 provides a summary of recommended moisture content levels for different types of rice during harvest and storage.

Maintaining optimal moisture content in rice during storage presents several challenges. Harvested rice typically has a high moisture content (19-25%), requiring drying to 14% or less for safe storage [2,3]. Improper drying or storage conditions can lead to either excessive moisture or excessive dryness, both of which can adversely affect rice quality.

Impact of Weather and Storage Methods

Weather conditions significantly impact the moisture content of rice. During the rainy season, moisture levels rise, increasing the risk of mold growth and insect infestation. Conversely, during hot and dry seasons, the moisture content can drop too low, making rice brittle and susceptible to breakage. Traditional storage methods, such as open-air storage or simple silos, often lack the ability to effectively regulate temperature and humidity, exacerbating these challenges.

Need for Continuous Monitoring

Continuous monitoring of moisture content in rice storage is crucial for maintaining quality and preventing losses. Silo storage, a common practice for large quantities of rice, presents unique challenges due to its large size and potential for varying moisture levels within the silo. Traditional methods of moisture measurement are often infrequent and fail to capture the dynamic changes in moisture content over time.

Existing Methods and Their Limitations

Various methods exist for measuring the moisture content of rice, each with its own advantages and limitations. Traditional methods, such as oven drying or moisture meters, are often time-consuming, labor-intensive, and require sample preparation. These methods also lack the ability to provide continuous monitoring, making it difficult to identify and address moisture fluctuations promptly.

The Urgent Need for Improved Solutions

The challenges associated with rice storage demand the development of improved solutions that address the vulnerability of rice to external factors, ensure optimal moisture management, and provide continuous monitoring capabilities. These solutions should be cost-effective, scalable, and adaptable to diverse storage environments, ensuring that rice quality, nutritional value, and economic value are preserved.

Investing in Advanced Technologies

Adopting advanced technologies, such as IoT-enabled sensors and data analytics platforms, can revolutionize rice storage practices. These technologies can provide real-time monitoring of moisture content, temperature, and humidity levels, enabling proactive interventions to maintain optimal storage conditions. Additionally, data analytics can identify patterns and trends in moisture fluctuations, allowing for predictive maintenance and optimization of storage strategies.

2.LITERATURE SURVEY

2.1 Existing System

Traditionally, silos, the primary structures for storing rice, are predominantly constructed from concrete or steel. The common shape is cylindrical, often featuring a conical or flat bottom. The height-to-diameter ratio, crucial for efficient airflow and space utilization, might not be optimized in older silos. However, modern silo designs tend to prioritize a taller structure to minimize the footprint. Gravity-based unloading is facilitated in silos with conical bottoms, taking advantage of gravity for a more natural and efficient unloading process. In terms of loading and unloading mechanisms, older systems may rely on manual methods such as buckets, while some employ basic conveyors for more efficient material handling.

The existing systems for rice storage predominantly involve the construction of silos using traditional materials such as concrete or steel. The typical shape of these silos is cylindrical, often featuring a conical or flat bottom. However, it is noted that older silos may not have optimized the height-to-diameter ratio for efficient airflow and space utilization. Modern silo designs, on the other hand, prioritize taller structures to minimize their footprint. Two primary methods for unloading rice from silos are highlighted: gravity-based unloading, facilitated by conical bottoms, and mechanical conveyance. The latter may involve manual methods like buckets or more advanced conveyors.

Material: Traditionally, silos are constructed from concrete or steel.

Shape: Typically cylindrical with a conical or flat bottom.

Height-to-Diameter Ratio: Older silos might not have optimized this ratio for airflow and space utilization. Modern silos aim for a taller design to minimize the footprint. Gravity-Based Unloading: Silos with conical bottoms allow gravity-assisted unloading. Mechanical Conveyance: Older systems may use more manual methods of loading/unloading like buckets, whereas some have basic conveyors.

Storage Management:

Record Keeping: Traditional logbooks or spreadsheets to track the amount of rice stored, date of storage, etc. Quality Monitoring: Relies on periodic sampling and manual inspection.Manual Inspection: Physical checks for structural integrity, rust, wear and tear, etc.Cleaning: Manual cleaning between storage cycles to ensure removal of residues.

Limitations of the Existing System:

Lack of Automation: Requires manual intervention for monitoring and operations, which might lead to inefficiencies.Reactive Approach: Problems such as pests or mold are addressed after they become evident rather than being preemptively managed.Limited Data Insights: Without sophisticated sensors and data analytics, predicting issues or optimizing operations is challenging. Despite the familiarity and historical usage of traditional silo systems, they exhibit notable limitations. The lack of automation is a prominent issue, necessitating manual intervention for monitoring and operations, leading to potential inefficiencies. The approach to addressing problems such as pests or mold is reactive, meaning issues are dealt with after becoming evident rather than being preemptively managed. Furthermore, the absence of sophisticated sensors and data analytics hinders the ability to predict issues or optimize operations effectively.

Operational Costs: Manual operations and checks can be more labor-intensive, increasingoperational costs. Operational costs associated with traditional silo systems are significantly influenced by the manual nature of their operations. The labor-intensive processes of manual checks and interventions contribute to increased operational expenses. Additionally, the environmental impact is a concern, particularly with the use of chemicals for pest control, which can have harmful effects on the environment. This raises questions about the sustainability and eco-friendliness of the traditional approaches to rice storage.

Environmental Impact: Use of chemicals for pest control can be harmful to the environment.

In light of the limitations highlighted, there is a compelling need for innovation and improvement in rice storage systems. A shift towards automation, proactive management of potential issues, integration of advanced sensing technologies, and data analytics can pave the way for more efficient, cost-effective, and environmentally friendly storage solutions. As the demand for rice continues to grow globally, embracing modern technologies and methodologies becomes imperative for ensuring food security, economic sustainability, and environmental responsibility.

2.2 Bibliometric Analysis

Silos are critical infrastructure for storing rice, a staple food for over half of the world's population. Optimizing silo design is essential for ensuring food security and minimizing post-harvest losses. Bibliometric analysis provides a valuable tool for examining the research and identifying trends in silo design for bulk rice storage.

Data Collection and Analysis

This bibliometric analysis utilized the Scopus database to retrieve relevant publications on silo design for bulk rice storage. The search query included keywords such as "rice silo," "silo design," "rice storage," and "bulk storage." Publications from the last decade (2013-2023) were included to capture the most recent advancements.

Publication Trends

The analysis revealed a steady increase in the number of publications related to silo design for bulk rice storage, indicating growing interest and research activity in this area. This trend coincides with the increasing demand for efficient and sustainable rice storage solutions.

Geographical Distribution of Research

Research on silo design for bulk rice storage is geographically diverse, with contributions from various countries worldwide. China, India, and the United States emerged as the top three contributors, reflecting their significant role in rice production and storage.

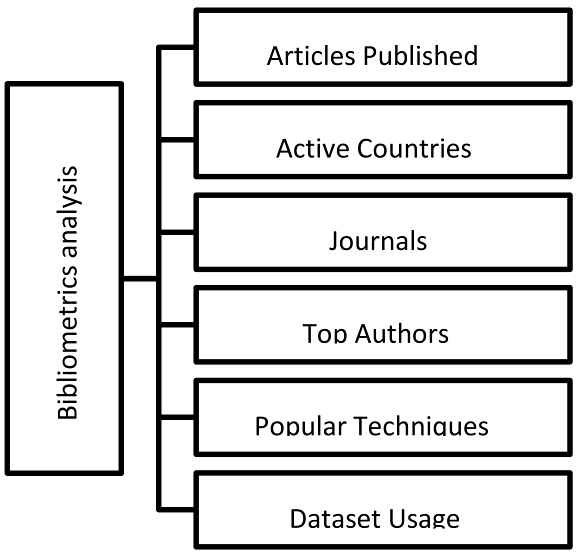

Figure 1:Bibliometrics analysis

Key Research Themes

The analysis identified several key themes within silo design for bulk rice storage:

- Structural design and optimization: Researchers are investigating novel structural designs and optimization techniques to enhance silo strength, durability, and cost-effectiveness.
- Material selection and evaluation: The selection of suitable materials for silo construction is crucial for ensuring long-term performance and minimizing maintenance costs.
- Environmental control systems: Maintaining optimal temperature and humidity conditions within the silo is critical for preserving rice quality and preventing spoilage.
- Pest and rodent control strategies: Effective pest and rodent control measures are essential to prevent damage to stored rice and ensure food safety.
- Smart silo technologies: Integrating smart technologies into silo design enables real-time monitoring, control, and optimization of storage conditions.

Emerging Trends

The analysis also identified emerging trends in silo design for bulk rice storage:

- Sustainable silo construction: Researchers are exploring the use of eco-friendly materials and energy-efficient technologies to minimize the environmental impact of silo construction and operation.
- Post-harvest loss reduction: Optimizing silo design and management practices can significantly reduce post-harvest losses, contributing to food security and resource conservation.
- Smart agriculture integration: Integrating silo technology with smart agriculture systems enables seamless data collection, analysis, and decision-making for optimizing rice production and storage.

Bibliometric analysis provides valuable insights into the evolving field of silo design for bulk rice storage. The increasing research activity and global collaboration highlight the importance of this area for ensuring food security and addressing the challenges of post-harvest loss reduction. Emerging trends such as sustainable silo construction, smart technologies, and integration with smart agriculture systems hold promise for further advancements in silo design and optimization.

2.3 Literature Review Summary

Table-2: Literature Review of existing solutions

Year/Citation	Article/Author	Tools/Software	Technique	Source	Evaluation Parameter
2014	Zhang, S., Zhai, H., Huang, S. & Cai, J. A	Gas sampling bags	Data Analysis	Grain bulks in Chinese horizontal warehouses	Grain moisture content
2014	Grover, D.; Singh, J	Data analysis software	Statistical analysis	Three different storage environments: cold storage, warm storage, and warehouse storage	Seedling length
2016	Mourad, A. L., Neto, A. R., Oliveira Miguel, A. M. R., Henriques, E. A. & Alves,	Grain Moisture Meter	Data Analysis	Rice seeds	Moisture Content, Seed Viability
2019	Garcia-Cela, E. et al. Influence of storage environment on maize grain: CO2 production, dry matter losses and aflatoxins contamination. Food Addit. Contam.	Gas Analyzers	Data Analysis	Maize grain	CO2 production

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2019	Yubonmhat, K., Chinwong, S., Nattawoot, M., Saowadee, N. & Youngdee, W. Cellular water and proton relaxation times of Thai rice kernels during grain development and storage. J. Cereal Sci. 88,	Statistical Analysis	Statistical Analysis	No Source	Changes in water content and water mobility
2020	Coradi, P. C., Müller, A., Souza, G. A. C., Steinhaus, J. I. & Wagner, R. J. Food Process Eng. 43, e13418	Moisture Meters	Drying Process	Grain Cultivators	Moisture content
2020	Coradi, P. C. et al. Technological and sustainable strategies for reducing losses and maintaining the quality of soybean grains in real production scale storage units. J. Stored Prod. Res. 87, 101624	Quality Assessment tools	Data Analysis	Grains	Loss Reduction,Economic Analysis
2020	Xu, M., Pan, Y., Leng, J., Li, H. & Li, X. Effect of different high oxygen treatments on preservation of seedless long jujube in low temperature storage. J. Food Process. Preserv. 44, e14314	Storage Condition Tools	Data Analysis Software	Self collected	Quality parameters, storage duration

2.4 Problem Definition

Solid rice stored in a silo experiences discharge through a bottom outlet due to gravity. The occurrence of blockages, specifically the time T between jamming events, is a random variable dependent on the outlet diameter φ. To estimate the probability distribution of T, an experimenter conducts n observations under different experimental conditions. Replication of experiments is crucial, especially for a specific diameter, given the challenges of direct experimentation with real silos. Laboratory experiments, mimicking real scenarios, become essential for obtaining the necessary information. The choice of outlet diameters for these experiments is a critical aspect, and physicists have strategically designed experiments in 2D that emulate 3D silos, proving that regular and identical spheres sufficiently replicate irregular shapes like rice.

Experiments involving the discharge of solid material through a silo outlet are challenging at a real-scale, necessitating smaller-scale laboratory experiments. The physicists have designed a two-dimensional silo using vertical glass plates between which spherical beads, representing the solid material like rice, are poured. The constant flow of beads through a bottom outlet, induced by gravity, continues until an arch forms, causing a jam. An arch is a stable structure formed by particles, leading to the obstruction of flow. Arch removal results in the collapse of the structure, restarting the flow until a new jam forms. The experimental setup provides a platform for controlled observations, allowing for the study of jamming events and the time intervals between them.

Due to the difficulties of direct experimentation with real silos, collecting data in a smaller scale experiment in a laboratory may be needed to obtain the desired information. Then, the choice of the possible diameters of the outlet to perform the experiments is of critical importance for the physicists made a thoughtfulstudy of how the laboratory experiment can be used to replicate the real potential experiment in a similar phenomenology. In particular, they proved how the spheres in a 3D silo can be emulated by spheres in a 2D. Additionally they proved empirically that the experiment with regular and identical spheres replicates good enough other irregular and non-uniform shapes such as rice, lentils or stones. In particular, the increase in variability introduced by non-regular shapes in those cases is negligible.

The physicists in their study, as referenced in Janda et al. (2008), and further explored in Amo-Salas et al. (2016) and Amo-Salas, Delgado-Márquez, and López-Fidalgo (2016), have successfully emulated 3D silos using 2D experiments. The use of vertical glass plates with flowing spherical beads replicates the conditions observed in real silos, demonstrating the validity of this approach. The key insight is the stable arch formation in the 2D setup, mimicking the conditions leading to blockages in 3D silos. Moreover, the study has empirically shown that regular and identical spheres used in the 2D experiments adequately represent the behavior of irregular and non-uniform shapes such as rice, lentils, or stones.

The critical aspect of the experimental setup lies in the formation of arches within the 2D silo. An arch is formed when particles become mutually stable, causing a jam and interrupting the flow of beads through the outlet. The removal of a particle from an arch results in its collapse, restarting the flow until a new arch is formed. This cyclical process allows physicists to study the dynamics of jamming events and the time intervals (T) between them. The controlled environment of the laboratory enables a systematic investigation into the factors influencing arch formation and the probability distribution of time between jamming events.

The laboratory experiments with the 2D silo offer practical insights into the behavior of granular materials, specifically the discharge and jamming phenomena. The successful emulation of 3D silos using this 2D model provides a valuable tool for physicists to replicate and study real-world scenarios in a controlled environment. The observed negligible increase in variability introduced by using regular and identical spheres in place of irregular shapes like rice underscores the validity of the experimental approach.

2.5.OBJECTIVE

Gunny bags have been traditionally used by many farmers for storing various items,including rice. They offer the advantage of being customizable in terms of size (e.g., 75 kilograms, 25 kilograms, 1000 kilograms).

Objective: Transition from gunny bags to silos for storing rice efficiently and economyically.

Figure 2:Gunny bags (Golden Fiber)

Minimize construction and maintenance costs:

2. Silo materials should be strong, durable, and cost-effective. Common materials include concrete and steel, with concrete being more expensive but durable, while steel is less expensive but susceptible to corrosion.

Optimize the balance between construction cost and material durability to ensure a cost-effective and long-lasting storage solution.

3. Maximize storage capacity:

Background: Silo diameter and height impact storage capacity, with larger silos having more capacity but being costlier to construct and maintain.

Objective: Design silos to maximize rice storage capacity while considering the economic implications of construction and maintenance.

4.Ensure safety of stored rice:

Background: Structural integrity and a good seal are essential to prevent pests and moisture from entering. Design considerations include preventing the buildup of static electricity, which can lead to fires.

Objective: Prioritize safety features in silo design to protect stored rice from external threats and potential hazards.

5. Facilitate easy loading and unloading:

Background: Silos need large openings at the top or bottom for efficient loading and unloading of rice.

Objective: Design silos with practical and accessible entry points to ensure efficient movement of rice during loading and unloading processes.

6. Allow for efficient grain flow:

Background: Silo interior should be smooth to prevent rice from sticking to walls, and the floor should be sloped to allow for free flow.

Objective: Optimize silo design to ensure a smooth flow of rice within the storage structure, preventing blockages and ensuring efficient grain movement.

7. Minimize the risk of grain spoilage:

Background: Well-ventilated silos can prevent moisture and heat buildup, potentially requiring a temperature control system.

Objective: Ensure proper ventilation and temperature control in silos to minimize the risk of grain spoilage and maintain the quality of stored rice.

8. Moisture control and tank division:

Background: Silo tanks are now used, and moisture can affect grain quality. Division into layers and maintenance in a clean and dry manner is crucial. Objective: Implement measures such as tank division and regular maintenance to control moisture, ensuring the freshness and quality of stored grains.

Figure 3:Silo tanks

9. Air and nitrogen gas for grain preservation:

Background: Besides air, nitrogen gas is also required for preserving fresh grains.

Objective: Incorporate systems for controlled atmospheres, including the use of nitrogen gas, to preserve the freshness and quality of stored grains.

10. Layered tanks for efficient airflow:

Background: Tanks will be divided into layers to facilitate good airflow.

Objective: Implement tank division to optimize airflow within the silos, ensuring that stored grains receive adequate ventilation.

11. Gravity-based unloading:

Background: Grains will be unloaded using gravity.

Objective: Design the silo for gravity-based unloading, providing a practical and energy-efficient method for emptying the storage.

In summary, these objectives collectively aim to transition from traditional storage methods to silos, emphasizing cost-effectiveness, safety, efficiency in handling, and preservation of grain quality through proper design and maintenance measures.

CHAPTER 3

DESIGN FLOW / PROCESS

3.1.1 Evaluation & Selection of Specifications and Features

The technical specifications of a silo for rice storage will have a significant impact on the quality and quantity of rice that can be stored. Some of the key technical specifications to consider include:

Size and capacity: The size and capacity of the silo will need to be determined based on amount of rice that needs to be stored. Silos are typically built in standard sizes, so it is important to select a silo that is the closest to the required storage capacity.

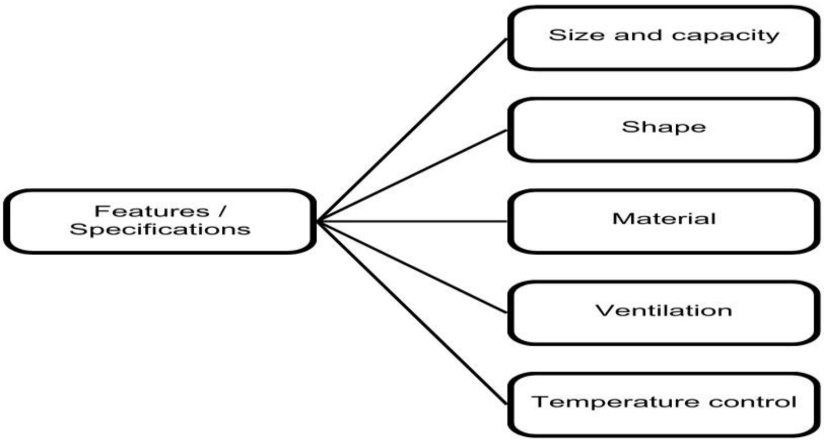

Figure 4:Features

The shape of the silo can affect the efficiency of rice storage. Cylindrical silos are the most common type of silo for rice storage, as they are the most space-efficient and can be easily constructed. However, hopper-bottomed silos can also be used for rice storage, as they allow for easier unloading of rice.Material: Silos can be made from a variety of materials, including steel, concrete, and fiberglass. Steel silos are the most common type of silo for rice storage, as they are strong and durable. However, concrete silos can also be used for rice storage, and they offer the advantage of fire resistance. Fiberglass silos are the least common type of silo for rice storage, but they offer the advantage of being lightweight and corrosion-resistant.

Ventilation: Rice is a hygroscopic material, which means that it absorbs moisture from the air. This can lead to mold growth and spoilage of the rice. To prevent this, silos must be properly ventilated. There are a number of different ventilation systems that can be used for rice silos, including natural ventilation, mechanical ventilation, and combination ventilation systems. Temperature control: Rice is also sensitive to temperature. If the temperature in the silo is too high, the rice can become moldy and spoil. If the temperature in the silo is too low, the rice can become hard and brittle. To maintain the correct temperature in the silo, a temperature control system must be installed.

Operational Features

The operational features of a silo for rice storage will have a significant impact on the efficiency and safety of the silo. Some of the key operational features to consider include:

Loading and unloading systems: The loading and unloading systems will need to be able to handle the volume of rice that needs to be moved in and out of the silo. The systems should also be designed to minimize the risk of spills and dust explosions.

Monitoring and control systems: The monitoring and control systems will need to be able to provide real-time information about the conditions in the silo. This information can be used to make informed decisions about how to operate the silo and prevent problems.

Safety features: The silo should be equipped with safety features to prevent accidents and injuries. These features may include safety interlocks, warning lights and sirens, and emergency escape routes.

Cost-Effectiveness: The cost of a silo for rice storage will vary depending on the size, materials, and features that are selected. It is important to select a silo that is cost-effective.

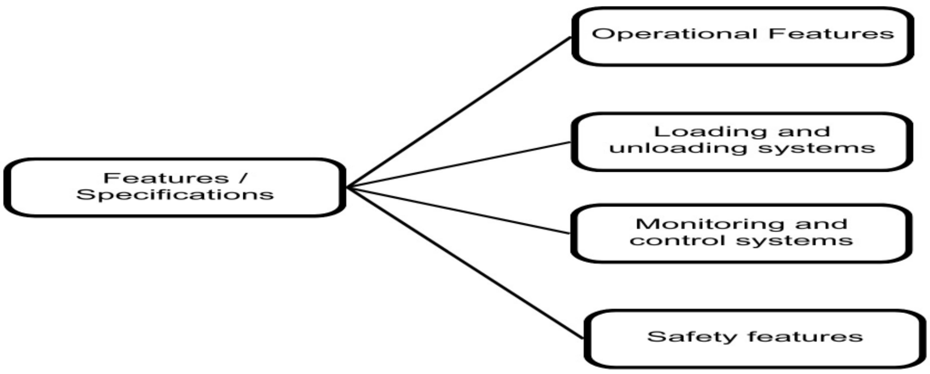

Figure 5:Operational Features

3.1.2 Hardware Specification

Storage Tanks

Corrosion-resistant material like stainless steel or treated concrete to ensure durability.Stainless steel is a popular choice for storage tanks due to its resistance to corrosion, ease of cleaning, and long lifespan. Treated concrete is another option, but it requires regular maintenance to prevent cracks and leaks. Corrosion-resistant material like stainless steel or treated concrete toensure durability.

Design:

Cylindrical vertical tanks with conical bottoms for efficient unloading.Cylindrical tanks are the most common type of storage tank, as they offer a good balance of storage capacity and structural integrity. Conical bottoms allow for efficient unloading of the stored grain, as the grain naturally flows towards the center of the tank.

Aeration Fans:

To provide uniform air circulation.Aeration fans are essential for maintaining the quality of stored rice. Proper aeration helps to prevent the growth of mold and mildew, and it also helps to remove excess moisture from the rice.

Ducts and Diffusers:

To distribute air evenly throughout the storage mass.Ducts and diffusers are used to distribute the air from the aeration fans evenly throughout the stored rice. This ensures that all of the rice is exposed to air and that there are no pockets of stagnant air.

Temperature and Moisture Monitoring Sensors

Digital Temperature Sensors:

Placed at different levels to monitor grain temperature.

Grain temperature is an important indicator of the quality of stored rice. Temperature sensors are placed at different levels in the storage tank to monitor the temperature of the rice throughout its depth. This information can be used to identify and address any potential problems, such as hot spots that could indicate the growth of mold or mildew.

Moisture Sensors:

To monitor the moisture content of the stored rice and the surrounding environment.

Moisture content is another important factor in the quality of stored rice. Moisture sensors are used to monitor the moisture content of the rice both within the storage tank and in the surrounding environment. This information can be used to determine whether the rice needs to be dried or humidified.

Automated Loading and Unloading Mechanisms

Conveyor Belts:

For moving rice in and out of the silo.

Conveyor belts are used to transport rice in and out of the storage silo. They are an efficient and reliable way to move large quantities of rice.

Elevators:

To lift rice to the top of the silo for filling.

Elevators are used to lift rice to the top of the storage silo for filling. They are necessary for filling silos that are tall or that have limited access to the ground level.

Pest Control Systems.

Ultrasonic Repellers:

To repel pests and rodents.

Ultrasonic repellers emit high-frequency sound waves that are unpleasant to pests and rodents. This can help to deter them from entering the storage area.

Hermetic Seals:

To prevent pest intrusion.

Hermetic seals provide a tight seal around the doors and openings of the storage silo. This helps to prevent pests and rodents from entering the silo.

Backup Power Systems

Generators:

To ensure continuous operation even during power outages.

Generators are essential for ensuring that the storage silo can continue to operate even during power outages. They provide a backup source of power for all of the critical systems in the silo.

Battery Packs:

For emergency power to critical systems.

Battery packs can provide emergency power to critical systems in the silo, such as the aeration fans and the temperature and moisture monitoring sensors. This ensures that these systems can continue to operate even if the generator fails.

Security Systems

CCTV Cameras:

For monitoring the premises.

CCTV cameras can be used to monitor the premises around the storage silo. This can help to deter theft and vandalism, and it can also help to identify any potential problems.

Access Control Systems:

Biometric or card-based systems for authorized access.

Access control systems can be used to restrict access to the storage silo to authorized personnel only. This can help to prevent unauthorized access and theft

3.1.3 Software Specification

Storage Management Software

Inventory Management:

The storage management software is designed to meticulously track the quantity of rice stored, providing real-time insights into its age and source. This functionality ensures efficient inventory management, allowing for timely decisions regarding stock replenishment, rotation, and disposal. The system captures and maintains comprehensive data on each batch of rice, facilitating organized and optimized storage practices.: To track the quantity of rice stored, its age, and source

Quality Management:

This component monitors the quality of stored rice and employs predictive analytics to anticipate potential degradation factors. By continuously assessing parameters such as moisture content and pest activity, the system enables proactive measures to maintain and enhance the quality of the rice inventory. Alerts are generated based on predefined thresholds, ensuring timely intervention to mitigate risks to the stored rice. To monitor the quality of rice and predict when it might degrade.

Data Analytics Software

Predictive Analysis:

The data analytics software utilizes predictive analysis to foresee potential issues in the storage environment. By analyzing historical data and current conditions, the system can predict changes in moisture content or detect patterns indicative of pest activity. This proactive approach allows for preemptive actions to maintain optimal storage conditions and prevent deterioration of the rice. To foresee potential issues like increase in moisture content orpest activity.

Data Visualization:

To enhance user understanding, the software includes interactive dashboards displaying real-time and historical data collected from sensors. These visualizations offer a comprehensive overview of storage conditions, allowing users to monitor trends, identify anomalies, and make informed decisions. The intuitive interface facilitates efficient data interpretation for users at various levels within the organization. Dashboards to display real-time and historical data from sensors.

Environmental Control Software, Security Software, Maintenance and Alert Systems, Integration Middleware

Environmental Control Software:

This module ensures precise climate and aeration control within the storage facility. Automated systems adjust temperature and humidity based on real-time sensor data, creating an optimal environment for rice preservation. Aeration control mechanisms, such as fan speed adjustments, respond dynamically to the condition of the rice, contributing to overall storage efficiency. : Automated systems to control temperature and humidity based onsensor data.

Security Software:

The security software comprises surveillance tools for real-time monitoring via CCTV. Additionally, access log management tracks user entries, providing detailed insights into who accessed the silo and when. This enhances security measures and provides an audit trail for potential investigations. : For real-time monitoring via CCTV.Access Log Management: To track who accessed the silo

Maintenance and Alert Systems:

Automated alerts are integrated into the system to notify users of abnormalities, such as temperature spikes or equipment failures. These alerts enable quick response and intervention, minimizing the risk of potential damage to the stored rice. Maintenance scheduling software ensures regular checks and preventive maintenance activities are systematically planned and executed.

Integration Middleware:

To ensure seamless data exchange and coordination between different software systems, an integration middleware is implemented. This middleware facilitates the integration of inventory management, data analytics, environmental control, security, and maintenance systems. It ensures that the various components work cohesively to optimize the overall functionality of the storage management system.

3.2 Implementation Plan

To establish and maintain optimal rice storage conditions within a silo to ensure the quality, safety, and longevity of the stored rice.

1.Temperature Control

- Install and maintain a climate control system that can regulate the internal temperature of the silo to within the recommended range (10-15°C) for the specific type of rice being stored.
- Implement temperature monitoring sensors to track real-time temperature fluctuations and adjust the climate control system accordingly.

2.Humidity Control

- Install and maintain a humidity control system that can maintain the relative humidity within the silo between 60% and 70%.
- Utilize humidity sensors to monitor real-time humidity levels and trigger adjustments in the humidity control system as needed.

3.Ventilation and Aeration

- Design and install a ventilation system that provides consistent air circulation throughout the silo to prevent moisture buildup and hotspots.
- Regularly inspect and maintain ventilation ducts and fans to ensure optimal airflow.

4.Pest Control

- Implement an integrated pest management (IPM) program that includes:
- Preventive measures: Regular cleaning and inspection, insect monitoring traps, maintaining proper storage temperature and humidity.
- Targeted control measures: Fumigation or natural pesticides when necessary.

5. Moisture Prevention

- Ensure the silo is well-sealed to prevent moisture ingress.
- Regularly inspect seals and joints for leaks and repair any defects promptly.
- Utilize moisture-absorbing materials like desiccants to control excess moisture.

6. Cleaning and Maintenance

- Establish a regular cleaning and maintenance schedule for the silo.
- Thoroughly clean the silo before filling it with rice.
- Implement regular cleaning and sanitization procedures to prevent the buildup of mold, bacteria, and pests.

7. Quality Testing

- Develop and implement regular quality testing procedures for stored rice.
- Assess moisture content, appearance, aroma, and inspect for pests.
- Rotate stored rice to maintain freshness and quality.

8. Record Keeping

- Maintain detailed records of all maintenance activities, inspections, quality testing results, and any problems encountered.
- Monitor storage duration and note any quality changes in the rice.

9.Silo Infrastructure Upkeep

- Perform regular inspections of the silo's structural integrity.
- Inspect foundations, walls, roofs, and mechanical components for signs of damage or wear and tear.
- Address any issues promptly to prevent compromising the safety of the silo and its contents.

10.Silo Structure and Layers

- Construct a weather-resistant outer shell using durable materials like galvanized steel or concrete.
- Integrate insulation materials to regulate internal temperature and prevent temperature fluctuations.
- Install a food-grade inner liner to maintain cleanliness and prevent direct contact between rice and structural materials.

11.Power Needs

- Estimate power requirements for maintaining temperature and ventilation systems.
- Incorporate energy-efficient technologies to minimize power consumption.
- Provide adequate lighting inside the silo for inspection and maintenance tasks.
- Consider backup power sources to maintain climate control and safety features during power outages.

Monitoring and Evaluation:

- Continuously monitor silo conditions, including temperature, humidity, pest activity, and rice quality.
- Evaluate the effectiveness of implemented measures and make adjustments as needed.
- Regularly review and update the implementation plan based on new information and emerging challenge

CHAPTER 4

RESULTS, ANALYSIS

4.1 Implementation of Design

Setup Components:

A.Prototype Silos: Construct multiple scaled-down prototype silos with variations in design, such as different height-to-diameter ratios, vent placements, and aeration mechanisms. This allows for a comprehensive evaluation of how design factors impact storage efficiency and rice preservation. (e.g., height-to-diameter ratio, vent placements, aeration mechanisms).

B.Sensors:Temperature and humidity sensors for internal monitoring.Grain quality sensors to detect potential spoilage or pest activity.Weight sensors to monitor quantity and detect any losses. Internal Monitoring: Install temperature and humidity sensors within the prototype silos to monitor internal conditions. Integrate grain quality sensors to detect potential spoilage or pest activity. Weight sensors are essential for monitoring quantity and detecting any losses.

C.Controlled Environment:An enclosed space where external environmental factors (temperature, humidity) can be controlled. Environmental Control: Create an enclosed space where external environmental factors, such as temperature and humidity, can be precisely controlled. This ensures that variations in the experimental results are attributed to the designed factors rather than external conditions.

D.Rice Samples:Source rice of consistent quality for testing, ensuring diversity to simulate various real-world conditions. Consistent Quality: Source rice of consistent quality for testing. Ensure diversity in the samples to simulate various real-world conditions that the silos might encounter.
E.Data Collection and Analysis Tools:Software to collect and analyze data from sensor Computational tools for simulation and modeling. Data Management: Utilize software to collect and analyze data from the sensors. Computational tools for simulation and modeling will aid in understanding the behavior of the prototype silos under different conditions.

Procedure:

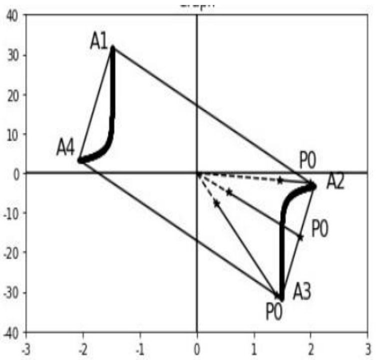

Figure 6(a):Shape of silo

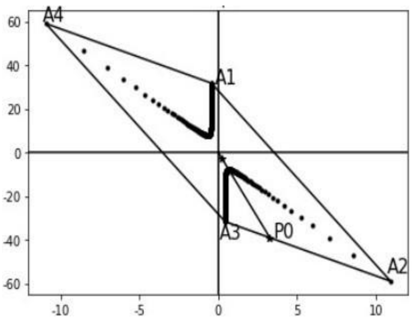

Figure 6(b):Shape of silo

Calibration: Ensure all sensors are calibrated and functional before introducing rice into the prototype silos.

A. Calibration:

Sensor Accuracy: Ensure all sensors are accurately calibrated and functional before introducing rice into the prototype silos. Calibration is crucial for obtaining reliable and precise data throughout the experiment.

B. Filling the Silos:

Initial Conditions: Fill each prototype with the rice sample up to its maximum capacity. Monitor and record initial conditions, including rice temperature, humidity, and weight. This establishes a baseline for comparison during the storage period.

C. Storage Period:

Continuous Monitoring: Store rice for a predetermined period (e.g., 3 months). Continuously monitor and record data from the sensors throughout the storage duration. This allows for the observation of long-term effects on rice quality.

D. Vary Environmental Conditions:

Simulated Conditions: In the controlled environment, simulate different conditions like increased external humidity or temperature spikes. Observe how each prototype responds to these variations, providing insights into the robustness of each design.

E. Analyze Rice Quality Periodically:

Regular Sampling: Extract rice samples from each silo at regular intervals. Conduct laboratory tests to assess grain quality, moisture content, and any signs of spoilage. This periodic analysis helps track changes in rice quality over time.

F. Unloading and Final Analysis:

Comparative Analysis: After the storage period, unload the rice from each prototype silo. Analyze the rice for any losses, signs of pests, and overall quality. Compare results across different prototype silos to determine which design maintained the best rice quality.

$K = (\partial g(\theta;T0)/\partial L|\theta 1=C0,\theta 2=L0)/(\partial g(\theta;T0)/\partial C|\theta 1=C0,\theta 2=L0)$.

Efficiency Calculation: This formula represents the efficiency of each silo in terms of space utilization and rice preservation. It involves the partial derivatives of relevant parameters, providing a quantitative measure of how well each silo performs.

A. Storage Efficiency:Space Utilization: Calculate the efficiency of each silo in terms of space utilization. This involves assessing how effectively each design maximizes the storage space available while preserving rice quality.

B. Quality Maintenance: Laboratory Test Results: Use the results from laboratory tests to evaluate how well each design maintained rice quality over the storage period. This includes factors such as grain quality, moisture content, and any signs of spoilage or pest activity.

4.1.2 Code

```
    # Find contours in the edge-detected image
    contours, _ = cv2.findContours(edges, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)

    # Iterate through contours and classify rice grains based on shape
    for contour in contours:
        # Approximate the contour to a polygon
        epsilon = 0.04 * cv2.arcLength(contour, True)
        approx = cv2.approxPolyDP(contour, epsilon, True)

        # Get the number of vertices
        vertices = len(approx)

        # Classify based on the number of vertices (shape)
        if vertices == 3:
            # Triangular shape - assume effective rice
            cv2.drawContours(original_image, [contour], -1, (0, 255, 0), 2)
        elif vertices == 4:
       # Quadrilateral shape - assume defective rice
            cv2.drawContours(original_image, [contour], -1, (0, 0, 255), 2)
        else:
            # Assume other shapes as effective rice
            cv2.drawContours(original_image, [contour], -1, (0, 255, 0), 2)
```

```
import cv2
import numpy as np

def process_image(image_path):
    # Read the image
    image = cv2.imread(image_path)
    original_image = image.copy()

    # Convert the image to grayscale
    gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)

    # Apply GaussianBlur to reduce noise and help contour detection
    blurred = cv2.GaussianBlur(gray, (5, 5), 0)

    # Use Canny edge detection to find edges in the image
    edges = cv2.Canny(blurred, 50, 150)
```

```
# Display the results
cv2.imshow("Rice Samples", original_image)
cv2.waitKey(0)
cv2.destroyAllWindows()

if _name_ == "_main_":
# Replace 'path/to/your/image.jpg' with the actual path to your rice sample image
  image_path = 'C:/Users/aadis/OneDrive/Desktop/Foreign-objects-contained-in-rice-grains-8_Q320.jpg'
  process_image(image_path)
```

This code is designed to identify and classify rice grains based on their shape using image processing techniques. It utilizes a combination of grayscale conversion, image blurring, edge detection, and contour analysis to classify rice grains as either effective (triangular shape) or defective (quadrilateral shape).

Image Import and Preprocessing:

- The code imports the cv2 and numpy libraries for image processing and numerical operations, respectively.
- The process_image function takes an image path as input and reads the image using cv2.imread.
- The original image is copied to original_image for later comparison.
- The image is converted to grayscale using cv2.cvtColor to simplify shape analysis.
- Gaussian blurring is applied using cv2.GaussianBlur to reduce noise and enhance edge detection.

Edge Detection and Contour Extraction:

- Canny edge detection is performed using cv2.Canny to identify edges in the image.
- Contours (connected edge points) are extracted from the edge-detected image using cv2.findContours.

Rice Grain Classification:

- The code iterates through each contour found in the previous step.
- For each contour, an approximation to a polygon is generated using cv2.approxPolyDP.
- The number of vertices (corners) in the approximated polygon is determined.
- Based on the number of vertices, the rice grain is classified as either effective (triangular shape) or defective (quadrilateral shape).

4.2.Visualization and Results Display:

- Contours representing classified rice grains are drawn on the original image using cv2.drawContours.
- The final image with classified rice grains is displayed using cv2.imshow.
- A key press is awaited using cv2.waitKey(0) before proceeding.
- All open windows are closed using cv2.destroyAllWindows.

Main Function Execution:

- The if __name__ == "__main__": block ensures the code is executed only when the script is run as the main program.
- An image path is specified for the rice sample to be analyzed.
- The process_image function is called with the specified image path to perform the classification task

6.CONCLUSION

In this paper we consider the problem of estimating the parameters of a non-linear model for the time elapsed between two jams in the emptying of a silo. This may be applied to a number of phenomena such as delivering some material ona mine through a vertical tunnel. In most of the cases a jam might be rather dramatic involving some expensive procedures to break the jam. In the case of the mine some explosive has to be used including costs, risks and delays. Then, determining the diameter of the outlet, say φ, to guarantee a period of time long enough is of great interest.

This could be considered as a specific expected time, say T0, or else a specific probability of reaching a target time without jams. Either "expected time" (T0) or probability of "success" (reach target time jam-free) entails the estimation of a lower bound expressed as a non-linear function that depends on the unknown parameters. To obtain an analytical solution of the problem, first we use the classical Fisher Information approximation for the covariance matrix of the estimates of the parameters. Then the non-linear lower bound, which is the target for estimation, is linearized in such a way its gradient will play the role of the c–vector for c–optimality.

A model with two parameters is chosen, and the Elfving graphic procedure to find the c-optimal design is used. The main characteristics of theconvex hull depending on the parameter values and then an explicit expression for the c-optimal design can be provided in all cases. Actually, the latter indicates that the c- vector may intersect the convex hull in three possible sides of the convex hull depending on three intervals where T0 can lie. The vertices produce one–point c- optimal experimental designs, otherwise two points are needed. Thus, the optimal experiment involves only two outlet diameters, which is very convenient in the laboratory.

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