# Design and Fabrication of an Automatic Optimized Hammer Mill Machine for Pharmaceutical Applications.

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Thesis submitted for the undergraduate degree in Mechanical Engineering

at the

University of Central Punjab


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**Session 2019-2023**


**Department of Mechanical Engineering,**

**University of Central Punjab, Lahore Pakistan**

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**Internal Examiner:**

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**External Examiners:**

Signature: ________________________________

Signature: ________________________________

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Session 2018-2022

Faculty of Engineering,

University of Central Punjab, Lahore Pakistan

# ABSTRACT

The purpose of this research is to design an improved programmed factory machine who is going to introduced in pharmaceutical industry by crushing and grinding the material. Same Smashes must utilize for a hard, fragile material (require seriously pulverizing force), and a while later it will use to pound different material simply by controlling the speed by controller. This will save time and made the machine more useful. Moreover, right currently hammer plant isn't utilized for pounding tacky material so one of the point is to propose a material (hard yet elusive) having the property which will make a smasher non-stick.

This report covers all the activities being carried out on this project during the year 2022-2023. Reducing appropriate size processes is the first step in densification. A Hammer Mill machine is generally utilized in the Drugs and Food enterprises to cutting Materials into little sections or little pieces

Lastly, the introduction of a hammer mill machine is there along with its design, which is going to be presented and discussed.

# DEDICATION

All the gratitude and thankfulness belong to Allah Almighty. The dedication of this project thesis to the supervisor, parents, teachers, and friends because all that is achieved would not be possible without their prayers and support.

## ACKNOWLEDGEMENT

We sincerely appreciate the sincere efforts and valuable time of our project advisor (Prof Sadaf Zeeshan) gave us the golden opportunity to do this brilliant project. His valuable guidance and feedback have helped us a lot. We also want to acknowledge UCP for providing us with the facilities especially regarded for our project.

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# CHAPTER ONE: INTRODUCTION

## 1. INTRODUCTION

This chapter focuses on introducing the project and outlining its objectives. The aim is to provide an understanding of the hammer mill machine, including its basic terminology, usage, and types. It is essential to familiarize oneself with the main components that constitute the hammer mill machine.

### *1.1. Aim of the project*

The purpose of the project is to build a special machine for factories. This machine can change its speed depending on the materials it’s working with. This helps it crush both hard and delicate materials more efficiently. It saves time and makes the machine more useful for different tasks.

Besides right currently hammer plant isn't utilized for pulverizing tacky material so one of the point is to propose a material (hard yet dangerous) having the property which will make a smasher non-stick.

### *1.2. History of hammer mill machine*

The history of hammer mills dates back to ancient times, with evidence of its existence found in writings from various cultures. The fundamental concept of a hammer mill is the same as it is today: a machine that reduces materials into smaller pieces through repeated blows of small hammers. Here's a brief overview of the historical development of the hammer mill machine:

Prehistoric Origins: The concept of using hammers to crush and grind materials can be traced back to prehistoric times when early humans used stones as primitive hammers to break up grains and other food items for consumption.

Ancient Cultures: Various ancient cultures, such as the Egyptians, Greeks, and Romans, utilized similar principles for grinding grains and other substances. Water-powered mills, driven by simple waterwheels, were used in some cases to perform milling tasks.

Medieval Period: During the medieval period, more advanced water-driven mills emerged, and the technology for grinding grain and other materials continued to improve. The cam principle, used in some of these early mills, would eventually be incorporated into the design of hammer mills.

Industrial Revolution: The late 18th century saw the start of the Industrial Revolution, which saw substantial improvements in manufacturing and machinery. The first true hammer mill machine was created during this period. It was developed to crush or pulverize coal for use as fuel in steam engines.

Modern Developments: The hammer mill machine's design continued to evolve over the years, with improvements in materials, manufacturing techniques, and the introduction of electric motors. This led to increased efficiency and versatility in various industries, such as agriculture, food processing, and mining.

Today, hammer mill machines are widely used in various industries for size reduction purposes. They are used to crush, grind, or shred a wide range of materials, including grains, wood, biomass, minerals, and more. The design and construction of hammer mills have become highly specialized, catering to specific applications and ensuring optimal performance for various materials and production requirements.

## *1.3. Components of hammer mill machine*

The hammer mill consists of various components that synergistically collaborate to fulfil its intended purpose. Following are some main components.

### 1.3.1. *The feeding mechanism of pulverize hammer:*

The feeding process in a hammer mill refers to how particles enter the crushing chamber. There are two common methods: gravity feeding and metered feeding. In metered feeding, a system is used to ensure a consistent and controlled feed of particles. This is important for maintaining consistent product quality. An example of a metered feeding system is a pneumatic rotary valve, which regulates the flow of particles from the feeding container to the crushing chamber. In contrast, in a gravity feeding system, the force of gravity is relied upon to feed particles into the crushing chamber. Gravity helps move the particles into the chamber, ensuring a steady and uniform feed.

### 1.3.2. *Control box of pulveriser hammer:*

A hammer mill's control box resembles the "brain" of the device. All of the actions that take place inside the mill are supervised and regulated by it. It serves as a link between the user and the device, enabling smooth communication and control. The control box can have different designs and settings to suit specific needs. Through this panel, the operator can adjust the mill's crushing speed to optimize the process. The control box also has a display that shows real-time information about the mill's performance, allowing the operator to monitor and make necessary adjustments.

### 1.3.3. *Crushing hammers/knives:*

The crushing hammers in a hammer mill are responsible for crushing the material. They rotate at high speeds, which can be adjusted using the mill's control panel. The hammers are typically mounted on horizontal shafts, allowing them to rotate in either a clockwise or anticlockwise direction. The rotor's motion determines the direction of rotation. The revolving shaft attached to an electric motor is called the rotor. Different styles and shapes of hammers are available for specific crushing tasks. The hammer mill tools can be connected directly to an engine or driven by a belt. Using belts provides protection to the engine from sudden shocks and allows for precise speed adjustments when needed.

### 1.3.4. *Hammer mill pulveriser screens:*

The raw materials are crushed in a hammer mill and then fed through screens for separation and filtering. The screens help achieve the desired particle sizes and ensure that the crushed material meets the required standards. This step prepares the material for further processing or use.

## *1.4. Characteristics*

The hammer mill machines serve several important purposes as part of the manufacturing process. Some of the primary aims and functions of hammer mill machines in the pharmaceutical industry include:

1. Size reduction of pharmaceutical ingredients: One of the main purposes of a hammer mill machine in pharmaceutical manufacturing is to reduce the particle size of active pharmaceutical ingredients (APIs) and other materials used in drug formulation. The machine uses high-speed rotating hammers to break down larger particles into smaller, more uniform sizes, making it easier to mix and process these materials.
2. Homogenization and blending: Hammer mills can also be used to homogenize and blend different pharmaceutical ingredients or drug formulations. By processing the materials through the hammer mill, the particles can be evenly mixed, ensuring uniformity in the final drug product.

A screen is installed at the base of the mill to separate the crushed material. The screen prevents completed items from passing through while keeping coarse materials in place. This guarantees that the desired particle size is obtained and that the finished product complies with the necessary requirements.

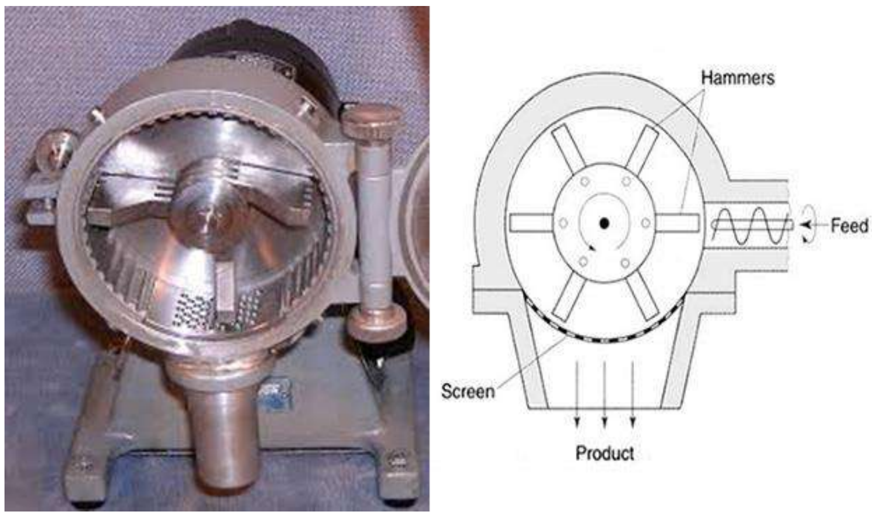



*Figure 1-1: Hammer mill machine[1]*

## *1.5. Types of hammer mill machine*

There are many types of hammer mill machine, some of which are,

**1.** Full Circle Screen Hammer Mills
**2.** Gravity Discharge Industrial Hammer Mills
**3.** Pneumatic Discharge Hammer Mills
**4.** Horizontal In-feed Hammer Mills
**5.** Lump Breakers

The choice of appropriate hammer mill type depends on the specific applications, material characteristics, desired particle size and capacity requirements. Different industries such as agriculture, food processing, wood processing, mining, and recycling, may utilize specific types of hammer mill machines to suit their needs.

### 1.5.1. *Full circle screen hammer mill:*

The hammer mills I mentioned earlier are called Full Circle Screen Hammer Mills. They have a rotating screen that helps improve efficiency. These mills are used for processing lightweight components that don't require initial grinding. They are commonly used for grinding spices, grasses, and similar materials. The rotating screen allows for efficient particle size reduction and ensures the final product meets desired specifications. These mills are suitable for various industries and tasks where a finer particle size is not needed initially.

### 1.5.2. *Gravity discharge industrial hammer mills:*

The hammer mills I mentioned earlier are called Gravity Discharge Hammer Mills or Bottom Discharge Hammer Mills. They have swinging hammers that crush materials. The crushed materials are then discharged from the bottom of the mill due to gravity. These mills are commonly used to crush various substances like glass, dry chemicals, and ceramics. The gravity discharge feature makes it easy to collect the crushed material

### 1.5.3. *Horizontal in-feed hammer mills:*

Horizontal In-feed Hammer Mills are a type of hammer mills where the material is inserted from the side. They are designed for heavy particle grinding and are commonly used in industrial settings. These mills are effective for processing trim scrap and grinding pallets. They are strong and efficient, allowing for efficient reduction of particle size and high throughput.

### 1.5.4. *Lump breakers:*

A Lump Breaker is different from traditional hammer mills. It doesn't have swinging hammers but instead features a fixed comb structure. Its main purpose is to break up lumps or clumps in powders or pastes, not to reduce particle size. The material passes through the comb structure, breaking it apart into smaller pieces. Lump Breakers are used in industries where breaking up lumps is needed, such as sugar processing and cement. They ensure smoother processing by handling larger chunks and breaking them down.

### 1.5.5. *Pneumatic discharge hammer mills:*

Pneumatic discharge hammer mills work similarly to gravity discharge mills, crushing materials with hammers and thin walls. They have a plate dashboard that helps reduce particle size. The air evacuation mechanism improves mill efficiency and output. These mills are suitable for lighter materials like paper and biomass. They efficiently process these materials to achieve the desired particle size distribution.

## *1.6. Main parts of hammer mill machine*

A hammer mill is a device that breaks down chunks of solid food.. It operates quietly and efficiently, making it ideal for grinding sensitive ingredients in pharmaceutical processes. Hammer mills come in standard and customized models to meet different needs. They are versatile and widely used in industries like food processing. The main components of a hammer mill are the rotor (which rotates), hammers (that crush the material), the crushing chamber (where the crushing happens), a screen (to control particle size), a feed hopper (where the material is fed), and a motor (which powers the rotation).

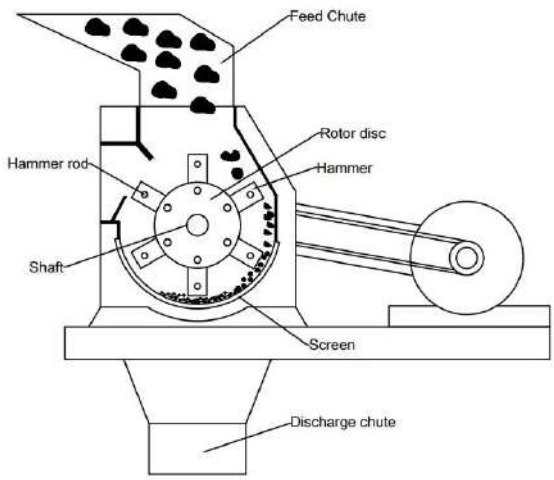



*Figure 1-2: Hammer mill machine with its labeled parts[2]*

### 1.6.1. *Hopper:*

The hopper is the top part of the hammer mill, where raw materials or feedstock are loaded. It provides a reservoir for the materials before they enter the grinding chamber.

### 1.6.2. *Feeding mechanism:*

This is the system responsible for transferring the raw materials from the hopper into the grinding chamber. It may involve gravity feeding, screw conveyors, or other mechanisms to ensure a steady and controlled flow of material.

### 1.6.3. *Grinding chamber:*

The grinding chamber is the central part of the hammer mill where the actual size reduction of the material takes place. It houses the hammers and the screens or perforated metal plates through which the material is processed.

### 1.6.4. *Hammer blades:*

The hammers are the main working tools of the hammer mill. They are typically attached to a rotating shaft and strike the raw materials, causing them to be shredded or crushed into smaller particles.

### 1.6.5. *Screen:*

The screens or sieves are located at the bottom half of the grinding chamber. They help control the particle size of the final product by regulating the size of the openings through which the crushed material exits the mill.

### 1.6.6. *Rotor:*

The rotor is the rotating component that houses the hammers. It provides the necessary force and motion for the hammers to impact the raw materials and initiate the grinding process.

### 1.6.7. *Main drive motor:*

The main drive motor provides the power to rotate the rotor and drive the entire hammer mill system.

### 1.6.8. *Belt or gear transmission:*

In some designs, a belt or gear transmission system is used to transfer the power from the motor to the rotor.

### 1.6.9. *Discharge mechanism:*

The discharge mechanism is responsible for collecting the processed material and directing it to the desired output, such as a collection bin or downstream processing equipment.

## *1.7. Pharmaceutical applications*

Hammer mills are machines used in the food industry to crush and grind agricultural products like corn, oats, barley, and rice. They are important for making powdered feed in the feed industry. These mills break down the raw materials to create finely ground feed with the right size and consistency. Hammer mills are versatile and efficient tools used to process food materials for further use or processing. They play a significant role in converting agricultural products into forms suitable for feeding animals or making flour.

1. Hammer mill machines are extensively used for size reduction. This includes reducing the particle size of active pharmaceutical ingredients (APIs), excipients, and other materials, making them suitable for further processing or formulation.
2. Hammer mills can be used for dry or wet granulation processes, where the machine breaks down the powders and facilitates the formation of uniform granules for tablet compression. Herbal medicines often require size reduction and processing to extract their active components effectively. Hammer mill machines are used to pulverize dried herbs.
3. Hammer mills can be employed for the proper disposal of expired or defective pharmaceutical products to prevent them from re-entering the market. These machines can shred and reduce pharmaceutical waste to facilitate safe disposal and minimize environmental impact.
4. Some pharmaceutical formulations require micronization, where the particle size of the drug is reduced to a very fine level. Hammer mills with suitable screens can achieve micronization, which enhances the dissolution rate and bioavailability of the drug, especially for oral solid dosage forms.

## *1.8. Advantages*

The hammer mill has several advantages:

**1.** It can make the materials the right size without needing extra crushing equipment.
**2.** It can create different sizes without making too much dust.
**3.** It can crush a lot of material and make it smaller.
**4.** It doesn't use too much energy.
**5.** It can break hard materials with its strong hammers.
**6.** It can grind many different things.

### *Concluding Remarks:*

In this chapter, we thoroughly study the Hammer mill machine and their types and learned about the main parts of the hammer mill machine. The hammer mill machine consists of different parts in which we study about their working and detailed discussed about all the part. Applications in pharmaceutical industry and advantages are also discuss in this chapter.

# CHAPTER TWO: LITERATURE REVIEW

# 2. LITERATURE REVIEW

To gather knowledge and information for the project, various articles, journals, and books related to the specific topic are consulted. These sources provide insights into the existing research and studies conducted on the subject matter. Conducting an extensive study is essential before proceeding with the project as it helps to gain a deeper understanding of the topic and informs the project's direction. Research papers are particularly valuable in providing detailed information and findings relevant to the project.

## *2.1. Hammer mill machine: A Brief Review*

A conventional hammer mill is a device consisting of a rotating head with free- swinging hammers, which reduce rock, grains or similarly hard objects to a predetermined size through a perforated screen [Sci-Tech Dictionary, 2003]. A hammer mill machine is a versatile and essential industrial equipment used for particle size reduction in various applications. Its primary function is to crush and grind a wide range of materials into smaller particles, making it suitable for various industries, including pharmaceuticals, food processing, agriculture, and more.

One of the key advantages of the hammer mill machine is its simplicity and robust construction, making it easy to operate and maintain. The machine typically consists of a rotor with hammers or blades that rapidly rotate and impact the material fed into the grinding chamber. The repeated impacts break down the material into smaller particles, achieving the desired size reduction.

The machine's versatility allows it to handle various materials, including soft and fibrous substances, as well as hard and brittle compounds. By adjusting the rotor speed and screen or grate size, operators can control the final particle size distribution, making it suitable for a wide range of applications.

### 2.1.1. *Article-1:*

The article contains the study of hammer mill machine used in agricultural industry. They used a hammer mill machine to crush and grind the corn. A grain size reduction hammer mill for crushing corn (Zea mays L.) was designed depending on variety characteristics and by using computer aided design "ANSYS" software.

The suitability of the manufactured hammer was tested at three hammer rotor speeds (RS) (600, 1000, and 1440 rpm), three screen hole diameters (SD) (2, 4, and 6 mm), and three feeding rates (FR) (60, 90, and 120 kg h-1).The evaluation criteria were geometric mean diameter of crushed maize (dgw), machine productivity (Pm), used energy (CE), and cost (CO).The geometric mean diameter grew as the diameter of the screen holes increased and reduced when the feeding rate and hammer speed increased.

The geometric mean diameter grew as the diameter of the screen holes increased and reduced when the feeding rate and hammer speed increased. The amount of energy consumed reduced as the feeding rate, screen hole diameter, and hammer speed increased. The lowest geometric mean diameter values were found at (RS) 1440. The crushing machine cost 76 to 283.3 L.E kg/ton, with hammer rotor speeds ranging from 600 to 1440 rpm, screen hole diameters ranging from 2 to 6 mm, and feeding rates ranging from 60 to 120 kg/h. The lowest machine cost values were achieved at (RS) 1440 rpm, (SD) 6 mm, and (FR) 120 kg/h, whereas the highest machine cost values were obtained at (RS) 600 rpm, (SD) 2 mm, and (FR) 60 kg/h. [2]

### 2.1.2. *Article-2:*

Based on numerous sets of experimental data, the study in the following article is a first attempt to optimise the parameters of the working regime of hammer mills used to crush plant, agricultural, and forestry biomass. It can serve as the foundation for the creation and implementation of additional optimisation models in the sector. The topic of optimising the hammer mill operating process for milling energetic biomass (Miscanthus Giganteus and Salix Viminalis) is presented in this study. The functional and structural aspects of the hammer mill were considered for the study in order to lower the specific energy consumption. The analysis focused on the energy consumption reliance on the mill rotor spinning frequency and sieve orifices in use, as well as the material feeding flow, in connection to the vegetal biomass milling degree. The hammer mill was outfitted with four distinct types of hammers to grind the energetic biomass, which had a specified humidity content and an initial degree of reduction ratio of the material. Twelve parameters were developed in order to begin the optimisation process of the hammer mill working process.

The aim functions were created to minimise hammer mill energy consumption and maximise milled material % with a particular granulation. The findings can be used to select the best working, structural, and functional parameters for hammer mills in this field, as well as to improve the design of future hammer mills.

The results showed that if the mill was equipped with a 25 mm orifice sieve, we could achieve average particle sizes of 19.1 mm when using one or two step hammers, 22 mm when using three step hammers, and 23.8 mm when using triangle edge hammers, with feeding flows ranging from 0.15 to 0.2 kg/s and hammer rotor speeds ranging from 40 to 50 Hz.

In this regard, the specific energy consumption was even 17-18% lower when using one step hammers compared to the next levels, which were provided by two step hammers, or with approximately 20% towards the three step hammers, when grinding Miscanthus Giganteus stems. Using the same feeding flows and the same array of rotor speeds, if the mill was equipped with the 10 mm orifice sieve, the average material particles which pass through had values of 9.2 mm for one step hammers, 9.4 mm for two step hammers, 9.8 mm for three step hammers, and even 10 mm for triangle angle hammers. In the case of grinding willow chips, grinded particle dimensions were significantly reduced, compared to the case of Miscanthus Giganteus. Thus, if using a 16 mm orifice sieve, the average dimensions of the grinded material are of 10.3 mm, both for one step hammers, as well as for two step hammers. If using a 10 mm orifice sieve, the average grinded material particles had values of 7.9 mm for the one step hammers, respectively 17.6 for two step hammers, but with a 5–15% higher energy consumption, which does not justify their use, more so since the two-step hammer wearing degree is greater. Thus, if using a 16 mm orifice sieve, the average dimensions of the grinded material are of 10.3 mm, both for one step hammers, as well as for two step hammers. If using a 10 mm orifice sieve, the average grinded material particles had values of 7.9 mm for the one step hammers, respectively 17.6 for two step hammers, but with a 5–15% higher energy consumption, which does not justify their use, more so since the two-step hammer wearing degree is greater.[3]

## *2.2. Hammer mill features*

The following features are written from the (Maitra, G.M.; and Prasad, L.V. 1985. *Handbook of Mechanical Design, pp. 89- 108. McGraw Hill, New Delhi, India.)* It describes the following features:

**1.** Impact from free-swinging bar hammers reduces material.
**2.** The finished product size is determined by grates or screen sizes.
**3.** Materials can be rapidly reduced to granular powder.
**4.** Strong cast-iron or carbon steel construction.
**5.** Available in either right-hand or left-hand operation.
**6.** Simple maintenance and screen/grate replacement.
**7.** Large and consistent capacity
**8.** A high level of availability
**9.** Long lifespan
**10.** A high reduction ratio
**11.** Wide range of applications
**12.** Easy replacement of wear and spare parts (Maitra, G.M.; and Prasad, L.V. 1985. *Handbook of Mechanical Design, pp. 89- 108. McGraw Hill, New Delhi, India.) [4]*

## *2.3. Description of hammer mill machine*

Conventional hammer mills work on the impact and pulverisation principles. A hammer mill is made up of a number of steel hammers that are radially and axially spaced on a steel shaft or rotor that rotates at a high speed inside a robust housing (often composed of thick steel sheets). The hammers smash the material with considerable force and swiftly pulverise it when it is fed into the mill from a feed hopper. A screen or sieve is located near the tip of the hammers on the bottom of the housing. Fine particles of pulverised materials pass through the sieve and are collected. The fineness of the particles is controlled by the use of sieves with varying mesh sizes. A hammer mill machine is a versatile and essential industrial equipment used for particle size reduction in various applications. It operates on the principle of impact, where a high-speed rotor, equipped with hammers or blades, rapidly strikes the material fed into the milling chamber. The force of the rotating hammers shatters the material into smaller particles, achieving the desired size reduction. *(Ebunilo.P.O.et al. / International Journal of Engineering Science and Technology.)*

## *2.4. Principle of operation*

The electric motor spins quickly and transfers its power to the shaft through pulleys, belts, and bearings. The hammers, positioned between the spacing discs, stand upright and move rapidly during operation. The tight space between the casing walls and the hammers ensures that all incoming materials are thoroughly crushed before falling onto the sieve. The fast rotation of the hammers breaks the materials into small particles that pass through the sieve holes and exit through the outlet. The machine's slight vibration helps move the materials, making the process automatic. The crushed materials are collected in a receiver or collection area. *(Mbanefo, C. & Akunne, C (2018).*

## *2.5. Advantages*

Hammer mill machines offer several advantages, making them widely used in various industries for size reduction and processing applications. Some of the key advantages of hammer mill machines include:

1. Versatility: Hammer mills can process a wide range of materials, including grains, wood, biomass, fibrous materials, minerals, and more. This versatility makes them suitable for use in various industries, such as agriculture, food processing, pharmaceuticals, and mining.
2. Efficient Size Reduction: Hammer mills efficiently reduce the size of particles through repeated impact and attrition. The hammers rotating at high speed deliver powerful blows to the material, breaking it into smaller pieces.
3. Control over Particle Size: Hammer mills offer precise control over the final particle size of the processed material. By adjusting the screen size and hammer configuration, the operator can achieve the desired particle size distribution.
4. High Throughput: Depending on the size and design of the hammer mill, they can process large quantities of material in a short time, making them suitable for high-capacity applications.
5. Size Reduction and Homogenization: Hammer mills not only reduce the particle size but also help homogenize the material, ensuring a consistent and uniform end product.
6. Low Heat Generation: Hammer mills generate less heat during the grinding process compared to some other milling equipment. This is beneficial for heat-sensitive materials that may undergo undesirable chemical changes at elevated temperatures.
7. Low Energy Consumption: Hammer mills can be operated efficiently with relatively low energy consumption, contributing to cost savings in industrial operations.
8. Particle Size Adjustment: As mentioned earlier, hammer mills allow for easy adjustment of particle size by changing the screen size or hammer configuration. This adaptability is valuable in various applications.

9. Simple Maintenance: Hammer mills have a straightforward design, which makes maintenance and cleaning relatively easy. Regular maintenance helps ensure their longevity and consistent performance.

### ***Concluding Remarks:***

Without having an extensive study, we cannot further proceed with the project, for this purpose, we study different research papers. We have studied the hammer mill machine in which we deal with its application.

# CHAPTER THREE: RESEARCH DESIGN

## 3. RESEARCH DESIGN

### *3.1. Basic structure*

The basic structure of a hammer mill machine consists of several components that work together to facilitate the size reduction and processing of various materials. While the specific design may vary depending on the manufacturer and the intended application, the fundamental elements remain relatively consistent. Here are the key components of a typical hammer mill machine:

Housing, rotors, hammers, screens or grates, feed inlet, discharge outlet, drive system, control panel.

The fundamental design of a hammer mill machine is intended to effectively smash materials and grind a wide range of materials through the repeated impact of hammers, controlling the final particle size through the use of screens or grates.

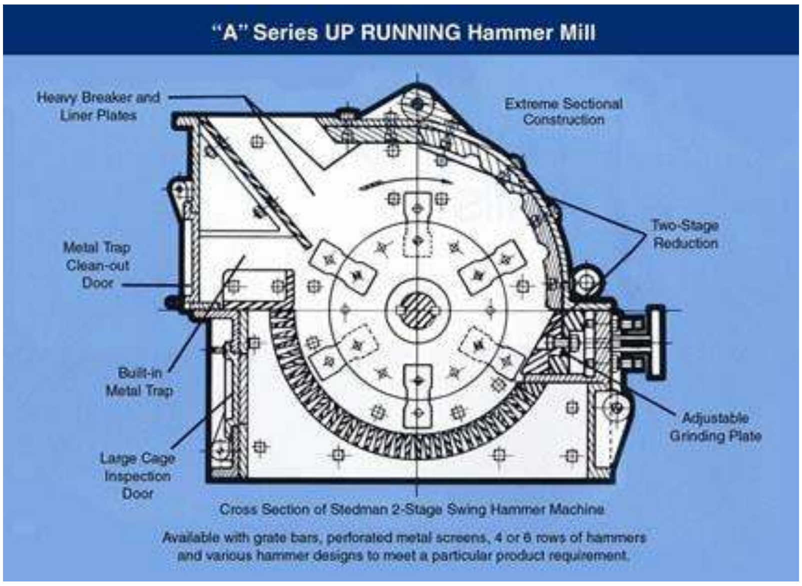



*Figure 3-1: Hammer mill machine general design[3]*

## *3.2. Market Survey*

This includes the material information. The market survey includes following markets; Brandreth road market, Liaqatabad bazar, Ghazi Road market, Township Market, Dill Mohammad road and flemming road Lahore. This market survey helps us to find and select the material for the rods, shaft and the motor as well as the outer case material. Fabrication is also done wisely by market survey and some parts are finished in mechanical department workshops.

### 3.2.1. *Material:*

The material used in this project has selected by considering some factors, which include cheap material, high strength, good machinability, low notch sensitivity factor. The design is based on the process of hammering salt through the strong and durable material of a hammer mill. Thus, the result is that the salt is broken down, which can be described as a fragmentation process. The process usually takes place in a closed chamber called a crushing chamber.

### 3.2.2. *Crushing material :*

The material to be crushed in Sodium Chloride NaCl (salt). Sodium chloride is frequently used to make isotonic arrangements in several pharmaceutical products. It is used in commonly used intravenous lock flush procedures, nasal saline showers, and eye washes or setups. It is also used to adjust the pH of medications, to dissolve active ingredients, and to increase the solubility of certain drugs. Sodium chloride is also used in the production of intravenous (IV) solutions, eye drops, and nasal sprays.

*Figure 3-2: Pink Salt Rock NaCl [4]*

### 3.2.3. *Shaft material:*

Material going to use for rods and rotor disc is AISI-1060 Carbon Steel. Whose Tensile strength is 620MPa, Hardness, Brinell is 204 and density 7.86 g/cm³.The material was forged from wasted train wheel to shaft and then undergoes turning and facing in mechanical workshop.

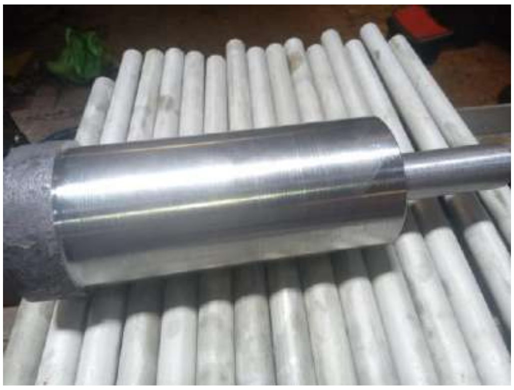


*Figure 3-3: AISI-1060 Shaft [5]*

### 3.2.4. *Rods material:*

Material going to use for rods and rotor disc is AISI-1060 Carbon Steel. Which is a train wheel material, the train wheel that are defected and wasted; it is then forged and transformed to a desired shape to sell out in the market. This material has selected due to its factors like strength for grinding and good machinability.

*Figure 3-4: AISI-1060 Carbon Steel Rod [6]*

### 3.2.5. ***Rotor material:***

Material going to use for rotor plate is AISI-1060 Carbon Steel. Which is a train wheel material, the train wheel that are deserted and squandered; it is then produced and changed to an ideal shape. This material has chosen because of its elements like strength for crushing and great machinability because it is going to hold the rods.

*Figure 3-5-: AISI-1060 Rotor Disc [7]*

### 3.2.6. ***Base material:***

For external base case, the steel angle of 1.15/1.15 is used. In the formation of base case 19 kilo of steel angle is used.

*Figure 3-6: Steel Angle [8]*

### 3.2.7. *Outer case material:*

For external case, stainless steel sheets having thickness of 18 gauges measure are utilized and molded to want external packaging as displayed in design segment.

*Figure 3-7: Steel Sheet [9]*

### 3.2.8. *AC motor:*

According to the design calculations below, the electric engine with a single stage 220 Volts, 0.5 hp of power at 1000 rpm, was used as a power hotspot for the hammer plant.

*Figure 3-8: AC Motor [10]*

### 3.2.9. *Brackets and bearings:*

In order to hold the shaft with the base frame, 2 brackets are used. These brackets are UCP brackets having outer diameter of 99mm. Tapered roller bearing (series-2) ISO 2ED45 are used in this project, having bore diameter of 45mm and OD of 95mm.Bearings are fitted in UCP brackets and fixed with shaft by countering it from 4 ends.

*Figure 3-9: Brackets and bearings [11]*

### 3.2.10. *Belt:*

V-Belt (B Section) is used of 73 inches in this project. The belt is mounted at both ends of the pulleys.

### 3.2.11. *Nuts and Bolts:*

The nut and bolt sizes used for this project are 0.5", 0.75" and 1", and the front retaining nut is 2.5".

### 3.2.12. Bush:

Four space bushes are used under motor to compensate the distance between two pulleys. The space bush is also used between the rotor discs.

### *3.3. Design: Parameters*

**1.** Force Parameters ;

Centrifugal Force, Force because of weight.

**2.** Power Required

**3.** Torque

### *3.4. Design*

Designing has the main role in this project as this project is based on design. An instrument used to crush or shred materials into smaller bits is a hammer mill machine. A hammer mill machine's fundamental construction comprises of a spinning shaft and hammers that can swing freely from the shaft. As the material is fed through the machine, it is struck by the hammers as it enters from the top. The material is then forced through a screen at the bottom of the machine, where it is then collected. The design of the hammer mill is just articulated on solid works and is going to be fabricated through. Moving forward the design of the existing model is improved to crush different material only by controlling the speed by controller. The design is shown separately of each part and the design is shown on A3(ISO) page on solid works in the form of drawings (front view, top view and side view) and an isometric view with smart dimensions. The design of a hammer mill machine consists of several elements that are necessary to keep in mind while designing a hammer mill machine, because hammer mill design is so complex, expertise in machine design and mechanics is essential. Additionally crucial are the kind of materials employed and their characteristics. Materials having qualities appropriate for the working conditions should be used to make machine parts, according to Khumi and Gupta (2010). Physical, mechanical, and financial features are some of the things to take into account while choosing materials for a hammer mill. Operator security was taken into consideration during design. The design also accounts for the hammer's deflection when it is in use. Therefore, when the hammer strikes material that would not shatter at initial impact, an oscillating hammer is used to prevent the rotor or hammer from jamming. The dimensions of the constructed prototype as measured by actual measurements were utilised in the design calculations and are listed below:

### 3.4.1. *Designing software:*

The design of this project is modelled on Solid works 2018.

### 3.4.2. *Rotor Disc:*

Rotor disc is one of the main part of the hammer mill machine. It is mounted on a shaft and holds the hammer rod with nuts and bolts. In this design 2 rotor discs are attached with nuts and bolts having hammer rod in between them.

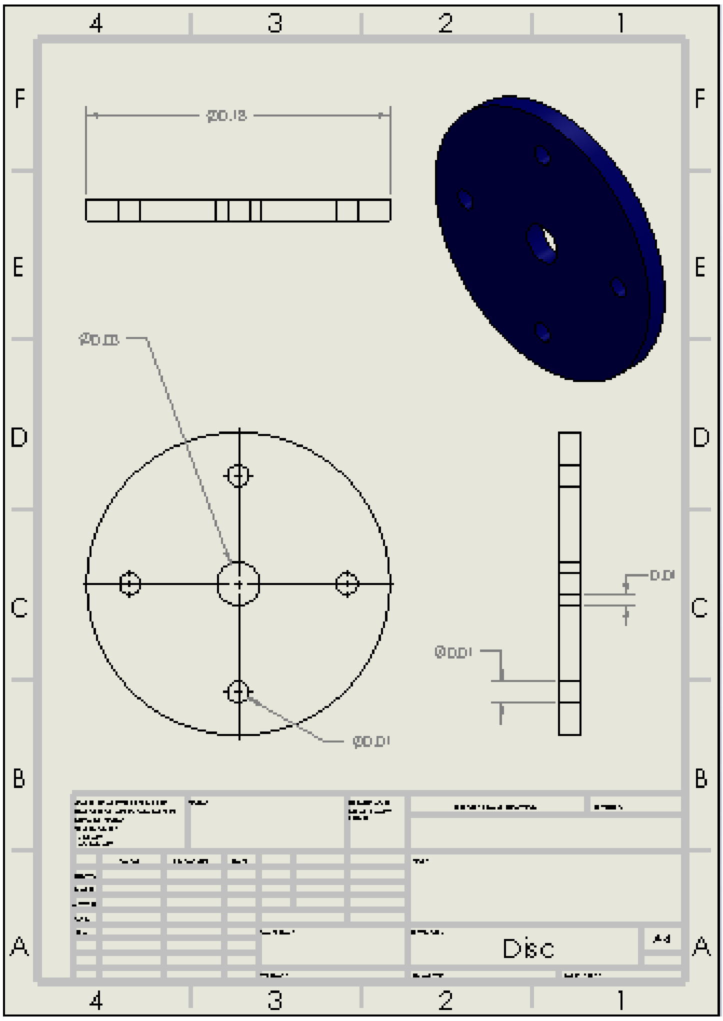



*Figure 3-10: Rotor Disc Design [12]*

### 3.4.3. *Shaft Design:*

This part plays an important role in hammer mill machine, as shaft transmits the power from motor to rotor disc. The shaft rotates at high speed, and the particle size is reduced by hitting with a hammer. Additionally, particle-on-particle contact can also cause size reduction or contact in the grinding chamber with the breaker plate.

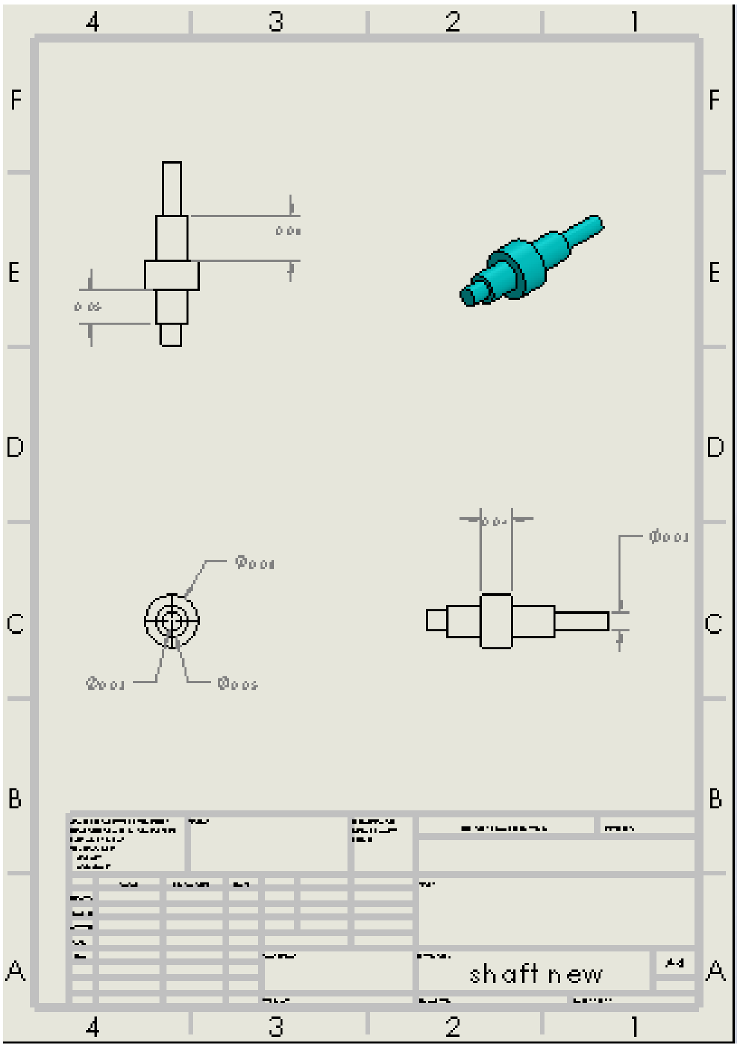



*Figure 3-11: Shaft Design (13]*

### 3.4.4. *Hammer Rod:*

Hammer rod is a part which reduces or crushes the material grains into small pieces. In this design 8 hammer rods are used which are going to attached through nuts and bolts to rotor disc. Hammer rotates as the disc moves in a continuous manner and crushes the material into small pieces. The hammer rods which are used in this design are shape of rectangular bar.

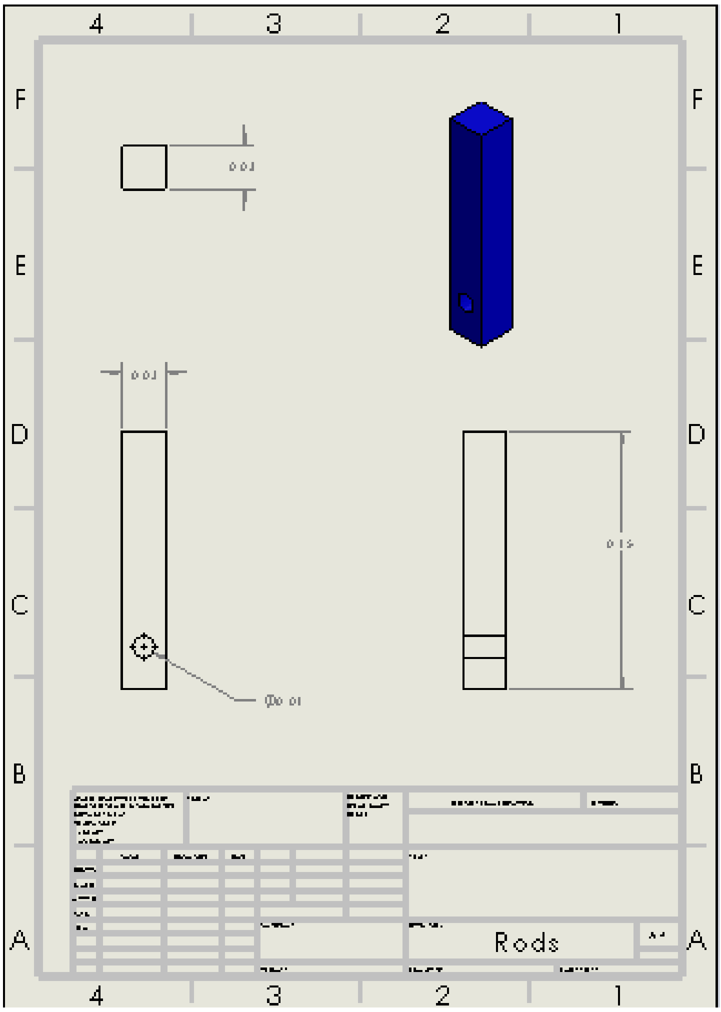



*Figure 3-12 Hammer Rod Design (14]*

### 3.4.5. *Holding Nut:*

Holding nut is a huge nut, used to hold the rotor disc on the shaft. It tightens the rotor disc onto the shaft.

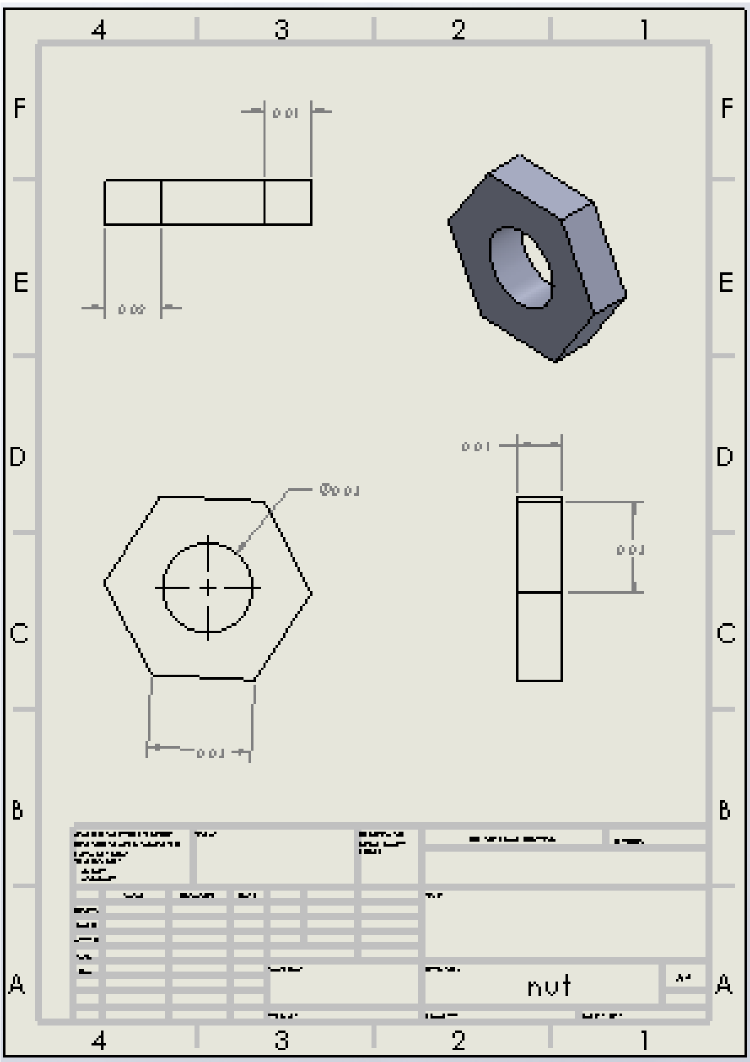



*Figure 3-13: Holding Nut Design (15)*

### 3.4.6. *Final Assembly:*

The final assembly contains the design of all the parts and this final assemble contains only the inside structure of the hammer mill machine.

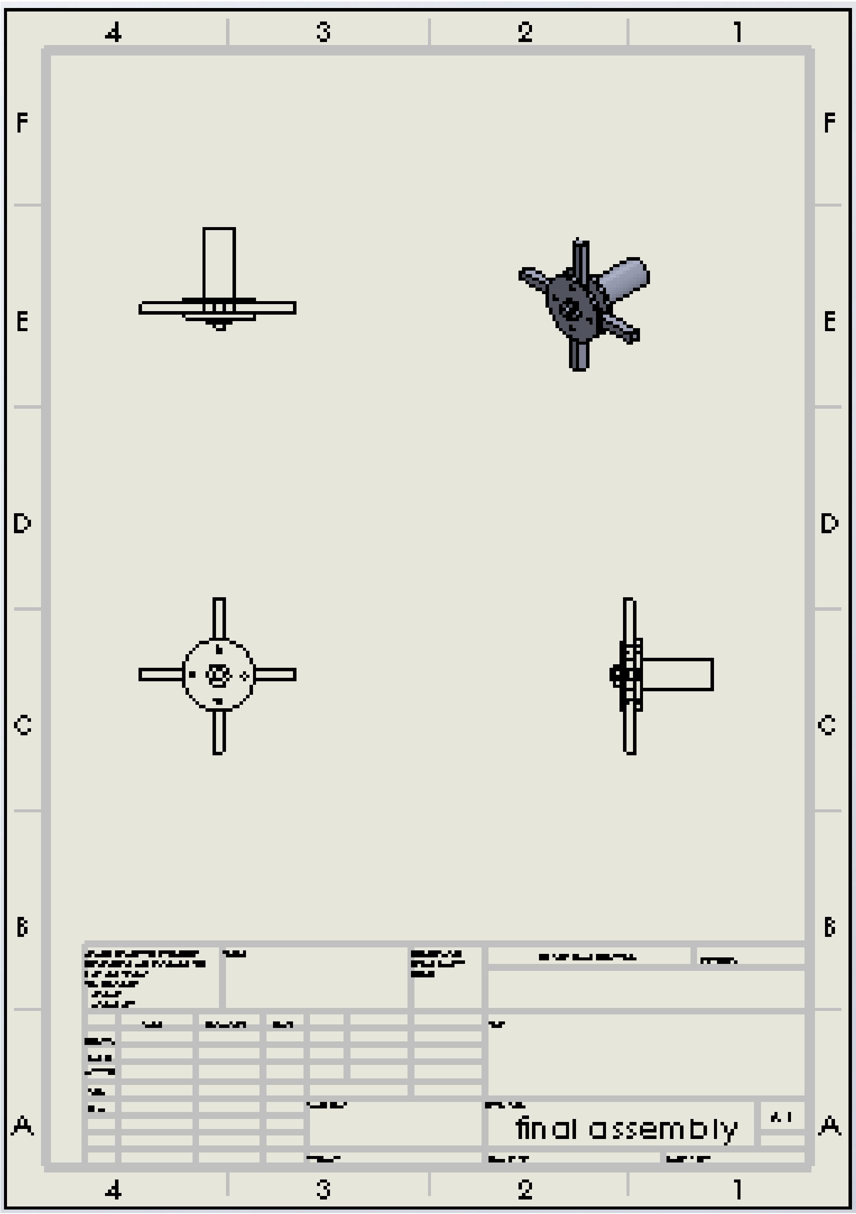



*Figure 3-14 Final Assembly (16)*

### 3.4.7. *Exploded View*

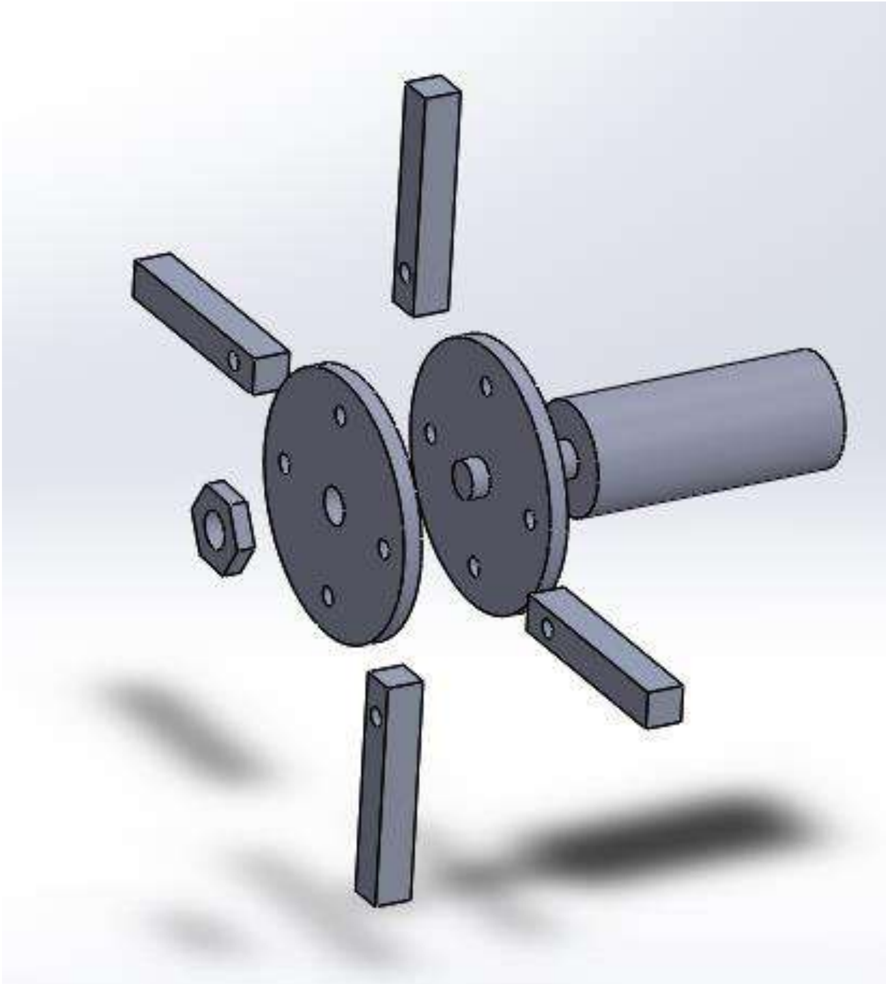


*Figure 3-15: Exploded  View (17)*

### *3.2.8. Final Design:*

*Figure 3-16: Final Design (18)*

## *Concluding Remarks:*

This chapter concludes the basic structure and design of the hammer mill machine. The modification ideas, proposed designs, and the best possible hammer mill machine is presented and described. Design calculations, design methodology, design perimeters and the materials used in the project discuss in this chapter. Cad model with exploded view and final assembly is show in this chapter as well as 2D-Drawing of the project is seen in this chapter.

# CHAPTER FOUR: FINDINGS

# 4. FINDINGS

## *4.1. Design Calculations*

This table consists of some basic values with units and symbols.

| Name | Symbol | Value | Unit |
|---|---|---|---|
| Density | $\rho$ | 7.85 | $g/cm^3$ |
| Width of rod | W | 2.54 | cm |
| Breadth of rod | B | 2.54 | cm |
| Height of rod | H | 15.24 | cm |
| Height of drill hole in rod | h | 2.54 | cm |
| Radius of a rotor | $r$ | 0.0889 | m |
| Diameter of a rotor | R | 0.1778 | m |
| No of hammers | e | 4 | No unit |
| Motors rpm | N | 1000 | rpm |
| rpm of rotor | n | 1000 | rpm |
| Power transmission factor | $\eta$ | 0.85 | No unit |
| factor depending on rim speed of the hammers of the mill | f | 0.044 | No unit |
| Density of belt | d | 1140 | $Kg/m^3$ |

*Table 4-1: Basic Values table [1]*

### 4.1.1. *Speed of shaft:*

$D_1 = 228.6m$, $D_2 = 76.2m$, $N_1 = 1000$ rpm

$$\text{Shaft Speed } \frac{D_1}{D_2} = \frac{N_2}{N_1} \qquad \text{(eq-1)}$$

$N_1$ = Rpms of smaller pulley
$N_2$ = Rpms of larger pulley
$D_1$ = Diameter of smaller pulley
$D_2$ = Diameter of larger pulley

The Dimensions standard for V-belts taken for this design is listed following:

| Type of Belt | Power Ranges in Kw | Minimum Pitch Diameter of pulley (D) mm | Top Width (b) mm | Thickness (t) mm | Weight Per Meter Length in Newton |
|---|---|---|---|---|---|
| A | 0.7-3.5 | 75 | 13 | 8 | 1.06 |
| B | 2-15 | 125 | 17 | 11 | 1.89 |
| C | 7.5 -75 | 200 | 22 | 14 | 3.43 |
| D | 20 -150 | 355 | 32 | 19 | 5.96 |
| E | 30 - 350 | 500 | 38 | 23 | - |

*Table 4-2: Dimension Table [2]*

$$N_2 = \frac{D_1}{D_2} \times N_1$$

$$N_2 = \frac{76.2}{228.6} \times 1000$$

$$N_2 = 333 \text{ rpm}$$

### 4.1.2. *Belt length:*

The length of the belt is determined from the measured diameters of the driving and driven pulleys and the average distance between the driving and driven pulleys. Center distance is 490mm. Use the following conditions (Patton1980).

$$L = 2C + \frac{\pi}{2}(D^1 + D^2) + \left(\frac{D1 - D2}{4C}\right)^2 \qquad \text{(eq-2)}$$

Where,

L= Length of the v-belt

C= Center distance between shaft pulley and motor pulley = 1701 mm (measured on machine as manufactured)

L= $2(1701) + \frac{\pi}{2}(76.2 + 228.6) + (\frac{(76.2)-(228.6)}{4(1701)})^2$

L=73 inch

Belt contact angle (actual benefits of the materials used in development) the place where the belt meets the pulley is known as the belt contact point. (Lobby, Holowenko, and Laughlin 1980) provide the information.

$$\beta = \sin^{-1}(\frac{R-r}{C}) \qquad \text{(eq-3)}$$

Where, R = radius of the smaller pulley and r = radius of the larger pulley,

$$\beta = \sin^{-1}(\frac{38.1 - 114.3}{1701})$$

$$\beta = -2.56°$$

Angles of fold over each pulley:

For smaller pulley, $\alpha_1 = 180 + 2\beta$ (eq-4)

For larger pulley, $\alpha_2 = 180 - 2\beta$ (eq-5)

Where, $\alpha_1$ = degree at which the engine pulley wraps, and $\alpha_2$ = the angle at which the shaft pulley wraps.

$$\alpha_1 = 180 + 2(-2.56) \quad = 174.88°$$

$$\alpha_2 = 180 - 2(-2.56) \quad = 185.12°$$

### 4.1.3. *Weight of hammer:*

Weight of each hammer,

$$W\text{⍰} = m\text{⍰} \times g \qquad \text{(eq-6)}$$

Material = Carbon Steel

$$m\text{⍰} = V \times \rho \qquad \text{(eq-6.1)}$$

Where $\rho = 7.85 \text{g/cm}^3$

For volume, we have a rod, whose perimeters are,

W = 2.54cm, B = 2.54cm, H = 15.24cm

$Vr$ = W×B×H

$Vr$ = 2.54×2.54×15.24

$Vr = 98.32 \text{ cm}^3$

Now as we have a hole in a rod so,

Radius of drill hole is = 0.635cm, h= 2.54 cm

$$Vc = 2\pi r^2 h$$

$$Vc = 2(3.14)(0.635)^2(2.54)$$

$$Vc = 3.215\ \text{cm}^3$$

$$Vt = Vr - Vc$$

$$Vt = 98.32 – 98.32$$

$$Vt = 95.10\ \text{cm}^3$$

$$m□ = 95.10 \times 7.85$$

$$m□ = 751g$$

$$W□ = 0.751 \times 9.81$$

$$W□ = 7.3\ \text{N}$$

It means Force due to weight = 7.3N.

## 4.1.4. *Hammer tip speed:*

$$v = (r\omega□ \qquad \text{(eq-7)}$$

ω = angular velocity of hammer

$$\omega = \frac{2\pi N}{60}\ \text{rad/sec}$$

Here N is assumed as 1000rpms

$$\omega = \frac{2(3.14)(1000)}{60}$$

$$\omega = 104.66\text{rps}$$

$r$ = radius of the rotor = 3.5 inch = 0.0889 m

By using above equation,

$$v = 9.3\ \text{m/s}$$

## 4.1.5. *Centrifugal force exerted by the hammer:*

$$F^c = \frac{m \times v^2}{r} \qquad \text{(eq-8)}$$

v = tip speed of the hammer

m = mass of the hammer

r = radius of the rotor

$$F^c = \frac{0.751 \times (9.3)^2}{0.0889}$$

So, now by putting values above

$$F^c = 730N \ = 0.73KN$$

### 4.1.6. *Tensions on the belt:*

The rubbing guideline is the foundation of how the belt drive operates. The electric engine's driver pulley moves the belt before it is transmitted to the selected pulley. The pressures on the two sides of the belt are not equal because there is friction between the pulley and the belt surfaces. It is crucial to distinguish between the higher strain (tight) and lower pressure (slack) sides in this way.

$$\frac{T_1 - Tc}{T_2 - Tc} = e^{\mu\theta} \qquad \text{(eq-9)}$$

Where,

$$Tc = M\, v^2 \qquad \text{(eq-9.1)}$$

Also,

$$Tc = \frac{T_1}{3} \qquad \text{(eq-9.2)}$$

$T_1$= Pressure on the tight side

$T_2$= Tension on the slack side

μ = coefficient of friction i.e. assumed as 0.3

θ = angle of wrap of the smaller pulley

M = belt mass as per unit length

V = belt velocity

The belt used is a V belt with 0.013 m width and 0.008 mm thickness

The thickness of the belt will be considered as 1140 kg/m$^3$ (Hall, Holowenko, and Laughlin 1980; Khumi and Gupta 2010).

| *Material of belt* | *Mass density in kg / m³* |
|---|---|
| Leather | 1000 |
| Convass | 1220 |
| Rubber | 1140 |
| Balata | 1110 |
| Single woven belt | 1170 |
| Double woven belt | 1250 |

*Table 4-3: Density Table [3]*

$$M = 0.1186 \text{ kg/m}$$

$$Tc = 0.1186\,(9.3)^2$$

$$Tc = 10.25N$$

Now,

$$3\,Tc = T_1$$

$$T_1 = 3(10.25)$$

$$T_1 = 30.25\text{N}$$

Now by using above equation,

$$\frac{(30.25) - (10.25)}{T_2 - (10.25)} = e^{(0.3)(5.48)}$$

$$\frac{20.25}{T_2 - (10.25)} = 5.176$$

$$20.25 = 5.17\,(T_2 - 10.25)$$

$$T_2 = 14\text{N}$$

## 4.1.7. *Power transmitted:*

$$P = (T_1 + T_2) * v \qquad \text{(eq-10)}$$

$$P = (30.25 + 14) * (9.3)$$

$$P = 411 \text{ W} = 0.55\text{hp}$$

## 4.2. Observations

This Table consists of the combined observed values for the hammer mill.

| NAME | SYMBOL | VALUE | UNITS |
|---|---|---|---|
| Weight of hammer | W□ | 7.3 | N |
| Mass of hammer | $m$□ | $751g$ | g |
| Volume of hammer | $Vt$ | 95.10 | $cm^3$ |
| Hammer tip speed | $v$ | 9.3 | m/s |
| Centrifugal force by hammer | $F^c$ | 0.73 | $KN$ |
| Required Power | $N$ | 0.5 | Hp |
| Tension | $T_1$<br>$T_2$ | 30.25<br>14 | $N$<br>$N$ |

*Table 4-4: Observations table [4]*

## 4.3. *Results*

The designed machine was tested with pink salt. Send one kilograms of salt into the crushing chamber of the machine through the hopper. The time required to crush the sample is recorded. Record the weight of the fine samples according to the sieve size below. For samples weighing 0.25 kg, 0.5 kg, and 0.75 kg, respectively, repeat the procedure. Crush the weights in increments of 0.25 kg, 0.5 kg, 0.75 kg, and 1 kg., submit all trials for sieve analysis, and average each weight sample.

### 4.3.1. *Tests results of pink salt:*

| Order Number | Mass of salt before (kg) | Mass of salt after (kg) | Time (s) |
|---|---|---|---|
| 1. | 0.25 | 0.23 | 33 |
| 2. | 0.5 | 0.46 | 41 |
| 3. | 0.75 | 0.73 | 49 |
| 4. | 1.00 | 0.97 | 59 |
| Average | 0.625 | 0.5975 | 45.5 |

*Table 4-5: Test results table [5]*

### 4.3.2. *Determination of milling capacity:*

$$\text{Milling capacity} = \frac{Average\ mass\ of\ milled\ produced}{Average\ time\ taken}$$

$$\text{Milling capacity} = \frac{0.5975}{45.5}$$

$$\text{Milling capacity} = 1.3\times10^{-2}\ \text{kg/s}$$

$$\text{Milling capacity} = 47.2\ \text{kg/hrs.}$$

### 4.3.3. *Determination of milling efficiency:*

$$\text{Milling efficiency}= \frac{Mass\ of\ output\ material}{Mass\ of\ input\ material} \times 100$$

$$\text{Milling efficiency}= \frac{0.5975}{0.625} \times 100$$

Milling efficiency= 0.956 = 95.6 %

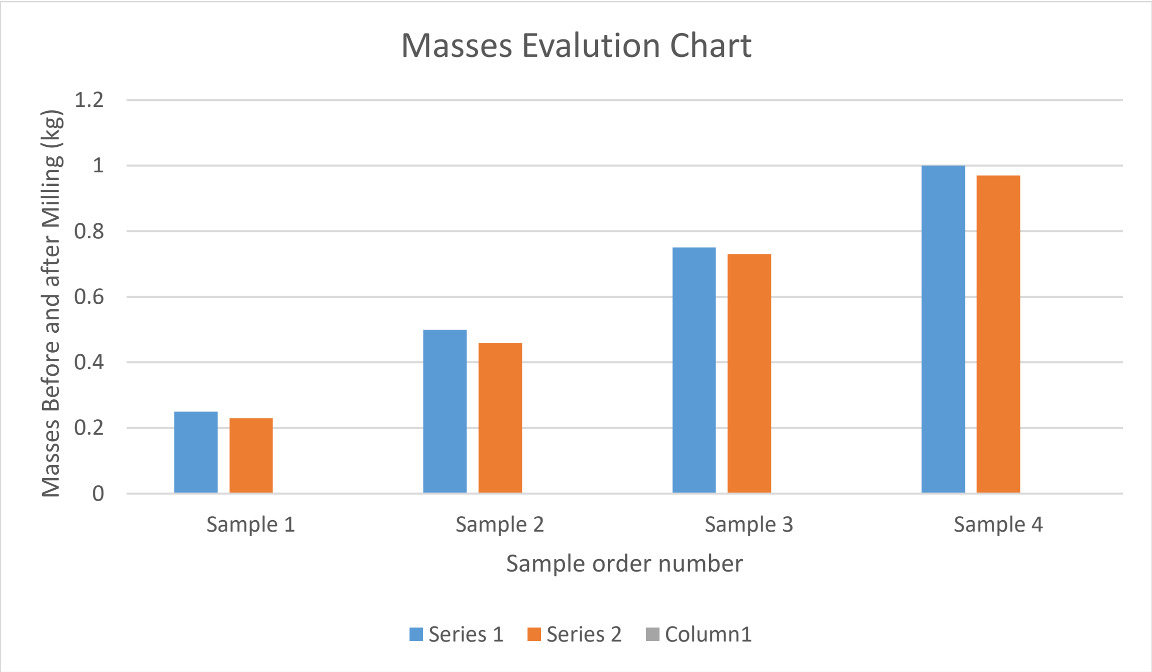
### 4.3.4. *Determination of losses:*

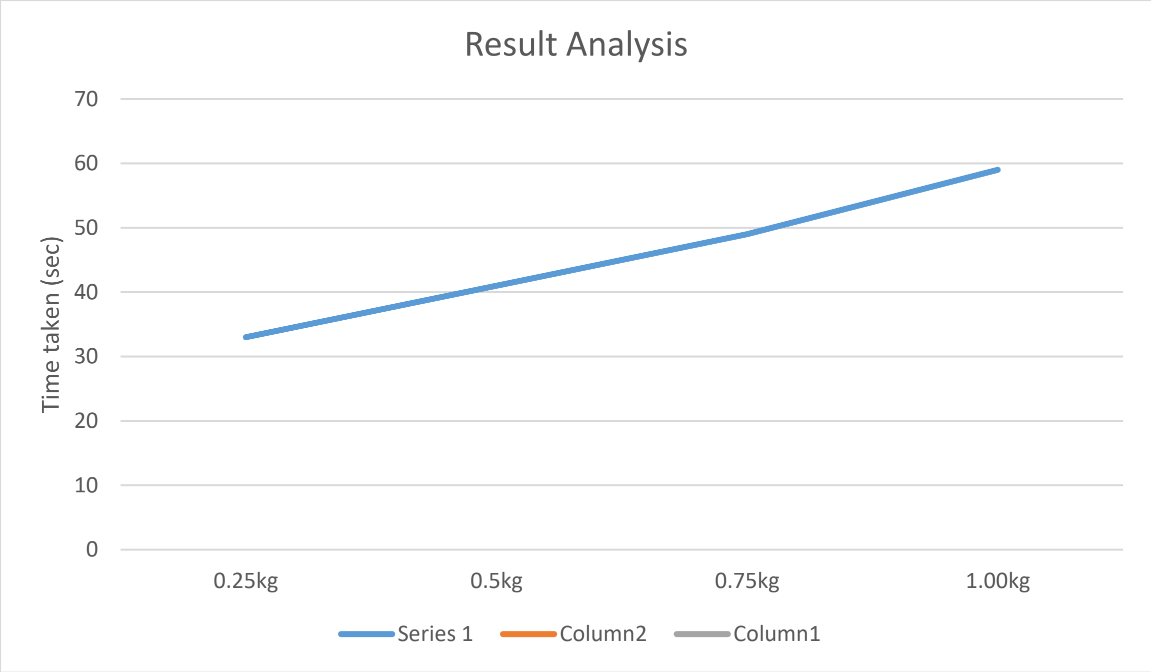
$$Losses = \frac{M_s - M_a}{M_s}$$

Where $M_s$ is the Mass before milling, and $M_a$ is the Mass after milling.

$$Losses = \frac{0.625 - 0.5975}{0.625}$$

Losses = 0.044 = 4.4 %






***Concluding Remarks:***

This chapter includes the findings and results of the project, in which the calculations are the main section of this chapter. This chapter is specifically focused on main results which is discussed in this chapter in the form of table.

# CHAPTER FIVE: DISCUSSION

## 5. DISCUSSION

In the above section we can see that we have repeated the experiment on manufactured milling machine and achieved the desired crushed form of salt. It's essential to consider the limitations and challenges associated with the hammer mill machine, such as dust generation, noise pollution, and potential for overgrinding. Ongoing research and development efforts aim to address these issues and further improve the efficiency and sustainability of hammer mill technology across various industries.

The losses we just get on the material is only 4.4 percent. The experiment has been repeated again and again on different masses in less than 1 minute. At different duration different masses be gathered and the weights are recorded before and after machining.

The scope of application of this machine is not limited to salt, other types of grains can also be ground as long as they are dry. Finally, the manufactured machines are made from locally grown materials and have fewer parts. Therefore, the purchase price of the machine can be kept low comparatively. The reason why this machine is going to be mentioned in pharmaceutical industry is because material known as Metformin is so hard and cannot be crushed easily and used in diabetic medicine i.e. Tegipmet 50/1000mg . This medicine is very expensive and Metformin is so hard that it got hard again after leaving it for few hours in air, so should be used as soon as it is crushed also it can be easily crushed again and again by using hammer mill machine.

# CHAPTER SIX: CONCLUSION

## 6. CONCLUSION

In the dynamic world of pharmaceutical manufacturing, the quest for innovation and efficiency remains a driving force. One crucial aspect of this pursuit is the development of advanced machinery that can enhance the pharmaceutical production process. The hammer mill, a staple in various industrial applications, has now taken centre stage in the pharmaceutical industry due to its versatility and potential to optimize particle size reduction. Till now this project has been a great opportunity to learn modern technologies under the supervision of one of the great scholars. It is not only about completing the final year project or grading but also about living in a third world country it is a contribution of something for the betterment of human lives and society.

This cutting-edge equipment aims to revolutionize the way pharmaceutical powders are processed, leading to enhanced drug formulations, increased bioavailability, and improved therapeutic outcomes. It grinds and crush the salt used in this project which is Sodium Chloride and extracted at the end in the form of small grains. The proposed machine seeks to overcome issues such as inconsistent particle size distribution, cross-contamination, and excessive heat generation during the milling process. Sodium chloride is then used in the pharmaceutical industry as a preservative, a buffering agent, and a source of electrolytes.

This is going to introduced for pharmaceutical application because previously this project is only introduced to grind or crush the stones. In pharmaceutical industry material is crushed by using ball mill but it has some disadvantages of bulky size, running a strong vibration and noise, there must be a solid foundation, low efficiency, energy consumption is relatively large, grinding the friction loss and a great body.

To overcome these disadvantages we apply this idea with scientific knowledge, mathematics, and introduce hammer mill machine for pharmaceutical applications.

The planned mechanical pulverization efficiency is 95.5 %.

The design machine is suitable for laboratory and commercial use. Portability, reliability, safety, and applicability are fully considered in design considerations and analysis. The machine appears to be capable of crushing corn piles and other materials such as straw with a reasonable amount of crushing power. The machines produced are suitable for laboratory and commercial us.

Furthermore, this technological advancement contributes to a more sustainable and efficient pharmaceutical landscape, aligning with the industry's ongoing pursuit of innovation and progress. As the demand for pharmaceutical products continues to grow, the significance of optimizing manufacturing processes cannot be understated, and this machine serves as a crucial step in that direction.

In conclusion, the Automatic Optimized Hammer Mill Machine stands as a testament to the power of engineering and innovation in revolutionizing pharmaceutical manufacturing. By harnessing its capabilities, pharmaceutical companies can redefine the way medicines are produced, ultimately contributing to better healthcare outcomes for individuals worldwide.

## 6.1. Limitations

While an Automatic Optimized Hammer Mill Machine for Pharmaceutical Applications offers numerous advantages, it is essential to acknowledge its limitations to make informed decisions about its implementation and usage. Some of the key limitations include:

1. The size and capacity of the machine may present limitations in terms of scalability for different production volumes. Larger pharmaceutical manufacturing facilities may require custom-designed machines to handle higher throughputs effectively. Moreover not all type of materials can crushed in this machine like sticky materials, acidic material, etc.
2. The operation of hammer mills can generate noise and airborne dust.
3. We can't achieve the zero percentage of losses because when material gets hit with hammer it will scatter in some percentage in air.
4. Some pharmaceutical formulations require precise blending of various components to achieve uniformity. While hammer mills can reduce particle size effectively, additional equipment or processing steps might be necessary for complex formulations
5. Hammer mills generate heat during the milling process, which can potentially degrade heat-sensitive pharmaceutical compounds or lead to alterations in their properties. This limitation may necessitate the incorporation of cooling systems or alternative milling techniques for temperature-sensitive materials.

Despite these limitations, the Automatic Optimized Hammer Mill Machine remains a valuable tool for pharmaceutical applications. Addressing these challenges through ongoing research, engineering improvements, and careful consideration of specific pharmaceutical requirements will enable the machine to fulfil its potential and contribute significantly to pharmaceutical manufacturing processes.

## 6.2. Future Direction

The future direction of an Automatic Optimized Hammer Mill Machine for Pharmaceutical Applications holds immense potential for further advancements and refinements. As technology and research continue to progress, several key areas offer opportunities for development and improvement:

1. Implementing advanced control algorithms can further improve the machine's responsiveness and stability during operation. Adaptive control strategies can account for dynamic changes in raw materials and environmental conditions, ensuring consistent and high-quality output.
2. Developing in-line or integrated particle size characterization techniques will allow the machine to continuously monitor and verify the particle size distribution during the milling process. This data can be fed back into the control system to optimize the process and maintain the desired particle size specifications.
3. Design enhancements that facilitate easier and safer material handling, as well as efficient containment mechanisms, will be crucial in preventing cross-contamination and maintaining aseptic conditions, especially when processing potent or hazardous pharmaceutical compounds.
4. Exploring ways to minimize energy consumption and environmental impact through better heat dissipation, power management, and recycling of waste heat can contribute to a more sustainable and eco-friendly machine design.
5. As the machine demonstrates its efficacy and reliability, efforts should focus on scaling up the design for industrial production. This will involve ensuring robustness and ease of maintenance, factors that are vital for large-scale pharmaceutical manufacturing facilities.
6. Collaborating with pharmaceutical companies, academic institutions, and research organizations can provide valuable insights and feedback for refining the machine's design and validating its performance across various applications.
7. Incorporating data management and connectivity features into the machine will facilitate data tracking, analysis, and process optimization. This integration can lead to a deeper understanding of process parameters and trends, ultimately enhancing productivity and product quality.

In conclusion, the future direction of the Automatic Optimized Hammer Mill Machine for Pharmaceutical Applications lies in pushing the boundaries of automation, control, and adaptability. By continually innovating and addressing industry challenges, this advanced equipment has the potential to revolutionize pharmaceutical powder processing, making drug development and manufacturing more efficient, reliable, and sustainable.

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# 8. APPENDIX