Development of a Mechanical Sand Sieving Machine with an Automatic Vibrator

A thesis

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Gratitude takes three forms: a feeling from heart, an expression in words and giving a return. We take this opportunity to express our heartfelt feelings.

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ABSTRACT

This study focuses on the development of a mechanical sieving machine with an integrated automatic vibrator system.

It is a device that can be used to sieve granulated materials such as sand for industrial purposes and food for agricultural and domestic purposes to obtain the required grain sizes. Sieving, either for industrial, agricultural, or domestic purposes can be done either manually (manual labor) or mechanically by using an appropriate machine (sieving machine).

The manual sieve takes longer hours and is tedious while mechanical sieving takes shorter time with just an operator overseeing the smooth running of the machine. In industrial operations where sand is required such as for aggregate mixing in construction or molds for casting in foundry operations, the grain size of the sand for the particular purpose is very important.

Using a sieving machine will enhance the work and make the sieving faster either for construction or for foundry. The machine uses an electric motor connected to a reciprocating sieve screen through a connecting rod.

There is a switch that controls the speed of the motor which in turn increases or reduces the vibration of the screen. Overall, this article provides an overview of the mechanical sand sieving machine with an automatic vibrator, its working principle, design, and operation.

It also highlights the challenges faced in the construction of the machine and makes recommendations to improve its efficiency.

Table of Contents

ACKNOWLEDGEMENT i
ABSTRACT ii

CHAPTER 1 1
INTRODUCTION 1
1.2 Objectives 2-4
CHAPTER 2 5
METHODOLOGY 5
2.1 Materials 5
2.1.1 Electric motor: 5
2.1.2 Pulleys: 6
2.1.3 Shaft: 7
2.1.4 Squire Bar: 8
2.1.5 Tension Belt: 9
2.1.6 Block Bearings: 10
2.1.7 Sieve Screen: 11
2.2 Methods: 13
2.3 Design Calculations 14
2.3.1 Power Calculation: 14
2.3.2 Torque Calculation: 15
2.3.3 Machine Energy Consumption: 15
2.3.4 RPM: 16
2.3.5 Torsional force in shaft: 16
2.3.6 Belt length: 16
CHAPTER 3 17
Experimental Setup 17
CHAPTER 4 18
RESULT AND DISCUSSIONS 18
TABLE: SAND SOIL 19
CHAPTER 5 20
CONCLUSION 20
REFERENCES 21

CHAPTER 1

INTRODUCTION

1.1 General:

The general-purpose sieve is used to separate the required grains from the unwanted materials, and then it is used to characterize the grains according to the required size of the sample allocation. A sieve is used to separate and break up particles of dry materials such as sand, flour, etc. Sieving is a simple practice for sorting particles of different sizes. Very fine holes are used on the sieve to sift the particles. Fine coarse particles are separated or broken up by grinding together. The quality of sand is one of the most important things in the industrial world. Today, the industry needs treated base sand as a sand product. Base sand is mixed with many other ingredients such as dirt and metal [1]. Different types of sieves are used to separate industrial waste such as bolts, washers, nuts, and nails of different sizes. The way to collect sand still is to use conversion methods such as manual or machine sieving. And human energy is needed to make the process happen. So, to make the process more efficient, technology is needed to help increase productivity which can reduce the manpower and also reduce the cost of the process. Mechanical sand sieving machines have been in use for centuries. The earliest designs were manual and involved the use of screens made from woven materials, such as silk, plant or wool. These early designs were relatively simple and inefficient, but they paved the way for more sophisticated machines [2], [3], [4]. During the 19th century, mechanical sand sieving machines began to appear that were powered by steam engines. These machines were larger and more complex than their manual counterparts, but they were also more efficient. By the early 20th century, electric motors had become widely available, and sand sieving machines were adapted to use this new power source [5]. Today, mechanical sand sieving machines are available in a wide variety of designs, from simple hand-operated models to sophisticated automated machines. The basic principle of operation is to pass the sand through a series of screens or sieves that are designed to remove unwanted materials [6]. Some of the modern designs of mechanical sand sieving machines include vibratory sieves, rotary sieves, and reciprocating sieves. Vibratory sieves use high-frequency vibrations to separate the sand from unwanted materials, while rotary sieves use a rotating drum to accomplish the same task. Reciprocating sieves use a

back-and-forth motion to separate the sand. In addition to their use in the construction industry, mechanical sand sieving machines are also used in other industries, such as agriculture and mining. In agriculture, they are used to separate seeds from soil and other materials. In mining, they are used to separate valuable minerals from other materials. Numerous research studies have been conducted on mechanical sand sieving machines over the years. These studies have focused on various aspects of the machines, such as their design, performance, and efficiency [6] designed and fabricated a sieving machine, and noted that in designing a sieving machine, the body structure of the machine, the mechanical systems as well as some other criteria such as strength, safety, and ergonomic design needs to be put into consideration. Duriraj & Manikandan developed a sieving machine to separate screws, nuts & bolts and dust depending upon their sizes with different size of mesh [7]. A crank was fixed to a vibrating table to vibrate the tray to act as a separator. The power is provided by a DC electric motor. Khan, et. al., a fully automatic sand-sieving machine that separates waste particles to overcome the human effort involved in the sand-filtering process during construction and also to make the machine simpler [8]. It works on the principle of the slider crank mechanism. The project concentrated more on safety and its ergonomic design. Ramrao, et. al., a fully automated sand filtering and separator system that automatically filters sand poured on it [9]. A motorized shaft that is mounted horizontally using mounts was connected to the shaft is which was in turn connected to a filter frame with mesh below and an enclosing frame on the sides with a frame to hold the filter frame in place while ensuring proper horizontal motion at the same time. When the motor controller circuit is switched on, the system allows the motor to operate which allows the sand filter motion for appropriate sieving and sand filtering needs. Tigadikar, et al., and fabricated a semi automated solar powered sand sieving system in which the rotational motion of an electric motor was converted to reciprocating motion of a sieve box by using Scotch Yoke Mechanism [10]. Gajbhiye, et. al., and fabricated a low-cost and simple motor-operated sand filter machine to reduce the human effort during construction works [11]. Adhapure, et. al., presented the concept of the design and fabrication of a multi-purpose sieving machine [12]. The conceptual model of a machine capable of performing different operations simultaneously was presented and was developed easily. In this machine, the main shaft is driven using a motor to which the slider-crank mechanism is directly attached; the slider-crank mechanism is used for sawing. The table is fixed with the crank which moves the tray to vibrate it and act as a separator with the help of a DC motor. And the motor shaft

(main/driven shaft) is mounted to a pulley-type mechanism. Thus, the design and fabrication of the Sieving Machine is to help the industrial people and farmers. The advantage of this machine is to obtain the easy separation of things according to mesh and reduction in cost associated with power usage, increase in productivity rate and produce less space, etc. Hasan and Sourov introduced a mechanical device that can sieve and move granular and powder material at the same time [13]. This device is recommended for construction sites. Sand can be sieved with this machine as sand is both known as powder and granular according to the diameter of sand particles. This device was designed for the building construction laborers with the construction theme of Screw Conveyor. The materials of this device have been selected under the consideration of monetary value. This fabricated sieving machine is a prototype of the actual product. Krishnan and Alrisi discussed the various mechanisms for designing and manufacturing sand sieving machine [14]. Ten different design and manufacturing ways of sand sieving machines were studied. These methods vary between using the engine and electricity and the primitive manual method. After performing several tests and evaluation of the process, it was found that the engine speed affected the energy consumed to sieve the sand. Meshram, et. al., presented the design and fabrication of a sand sieving machine with multiple sieves that can be changed according to the usage of the work [15]. At many construction sites, sand is sieved by old hand-operated (mesh sieving) machines. This technique is noted to be time-consuming and for fine sand filtration, it will adequately take a much longer time to sieve. In the design, two sieve plates are kept one aside from the other which is hung by the chain, on end is fixed with the main body. [16] proposed a solar-powered sand sieving machine with a heterogeneous bridge inverter (a combination of two MOSFETs and two diodes) and a SEPIC converter is proposed. This system reduced the turn-on losses with the help of a freewheeling diode which is faster than IGBT and also reduces the turn-off losses with the MOSFET switch. Lucena, et. al., constructed an electric sand sieving machine and determined its effectiveness in sieving sand and reducing the burden of workers at the construction sites [17]. The difference between the electric sand sieving machine and the manual were tested. It was observed that there was significant difference between the electric sand sieving machine and the manual type. The differences were observed in speed to complete the task and the output capacity of the two. It was concluded that the electric sand sieving machine demonstrated higher efficiency and usability. The objective of this paper is to develop a mechanical

sieving machine with an automatic vibrator that is powered by an electric motor to sieve particles into different sizes and grades in accordance with the sieve mesh screen used.

1.2 Objectives

(i) To design a sand sieving machine and construct.

(ii) To test the performance of the machine.

CHAPTER 2

METHODOLOGY

2.1 Materials

There were not many materials and machines used in this project. The standard workshop machines, such as drilling, cutting, and welding machines, were in this project. The materials used include:

2.1.1 Electric motor:



An ½ hp AC electric motor was used to power the sieving machine. It was selected based on the design calculations presented in this work. This motor choice was crucial for ensuring optimal performance and efficiency of the sieving operation. The ½ hp rating provided sufficient power to drive the vibrating mechanism while maintaining energy efficiency.

AC motors are known for their reliability and ability to handle continuous operation, making them ideal for industrial applications like sieving machines. The motor's speed and torque characteristics were carefully matched to the sieving requirements, considering factors such as the desired particle separation rate and the expected load variations during operation.

Additionally, this motor size offered a good balance between power output and cost-effectiveness, aligning with the project's budget constraints while meeting the necessary performance criteria. It was selected based on the design calculations presented in this work.

2.1.2 Pulleys:



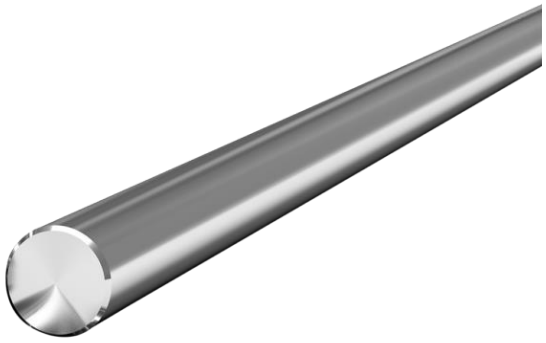
Pulleys were used to connect two power transmitters in the sieving machine design. This pulley system played a crucial role in the power transmission mechanism, effectively transferring rotational energy from the ½ hp AC electric motor to the vibrating components of the sieve.

The use of pulleys allowed for precise control over the speed and torque delivered to the sieving apparatus, enabling optimal vibration frequency and amplitude for efficient particle separation. By incorporating multiple pulleys of varying sizes, the system could achieve the desired gear ratio, effectively reducing or increasing the rotational speed as needed.

This configuration also provided flexibility in the machine's layout, allowing for compact design and efficient use of space. The pulley system offered additional benefits such as shock absorption, reducing wear on the motor and other components, and the ability to adjust tension for maintenance or performance tuning easily.

Furthermore, the use of pulleys contributed to the overall energy efficiency of the machine by minimizing power losses during transmission.

2.1.3 Shaft:



The shaft transmits power from the electric motor to the reciprocating rod, which connects to the automatic vibrator (sieve screen). This critical component serves as the primary link in the sieving machine's power transmission system.

The shaft, typically made of high-strength steel, is designed to withstand the torsional stresses and bending moments generated during operation.

It rotates at a speed determined by the motor and pulley system, converting the motor's rotational motion into the linear reciprocating movement required for effective sieving. The shaft's dimensions and material properties were carefully calculated to ensure optimal performance and durability under continuous operation.

At one end, the shaft is coupled to the motor via a flexible coupling or pulley system, while the other end connects to an eccentric mechanism or cam that drives the reciprocating rod. This rod, in turn, imparts a controlled, oscillatory motion to the sieve screen, creating the vibration necessary for efficient particle separation.

The design of this power transmission system allows for precise control over the vibration frequency and amplitude, which can be adjusted to suit different materials and sieving requirements.

Additionally, the use of a shaft-based system provides advantages in terms of maintenance accessibility and the ability to isolate vibrations from the motor, thereby extending the overall lifespan of the machine components.

2.1.4 Squire Bar:



1" x 1" Square Bar was used to construct the main frame of the machine. This choice of material provided an optimal balance of strength, weight, and cost-effectiveness for the sieving machine's structure. The square profile of the bar offered several advantages over other shapes, including ease of fabrication, superior rigidity, and simplified alignment during assembly.

The 1" x 1" dimensions were carefully selected based on structural calculations to ensure the frame could withstand the vibrations and loads generated during the sieving process without excessive flexing or fatigue.

This size also allowed for efficient welding and bolting of joints, contributing to the overall stability and durability of the machine. The square bar's flat surfaces facilitated the attachment of other components such as the motor mount, sieve screens, and control panels.

Additionally, the use of standardized square bar stock simplified sourcing and potential future repairs or modifications. The frame's design incorporated strategic placement of these bars to create a robust skeleton that effectively distributed forces throughout the structure,

minimizing stress concentrations and enhancing the machine's longevity. The resulting frame provided a

solid foundation for the sieving mechanism, ensuring consistent and reliable performance over extended periods of operation.

2.1.5 Tension Belt: -



Tension Belt is used for transmitting power from the motor shaft to the crankshaft which is attached to the sieving bracket. The length is as calculated in this work. This belt plays a crucial role in the power transmission system of the sieving machine, offering several advantages over direct drive mechanisms.

The tension belt, typically made of durable synthetic materials like polyurethane or reinforced rubber, provides efficient power transfer while also acting as a shock absorber, reducing vibrations transmitted back to the motor. Its length was precisely calculated to ensure optimal tension and minimal slippage, factors critical for maintaining consistent sieving performance.

The use of a belt drive system allows for flexibility in the machine's layout, enabling compact design and easier maintenance access. Additionally, the belt drive can act as a safety mechanism, slipping in case of sudden overloads to protect the motor and other components from damage.

The tension can be adjusted to fine-tune the machine's performance or compensate for belt stretching over time. This belt-driven system also contributes to the machine's overall energy efficiency by minimizing power losses during transmission. The specific material and profile of the belt were selected based on factors such as the expected load, operating speed, and environmental conditions, ensuring long-term reliability and performance of the sieving machine.

2.1.6 Block bearings: -



Block Bearings were used to support the crankshaft and ensure frictionless power transmission in the sieving machine. These specialized bearings, also known as pillow block bearings or Plummer blocks, offer several advantages for this application.

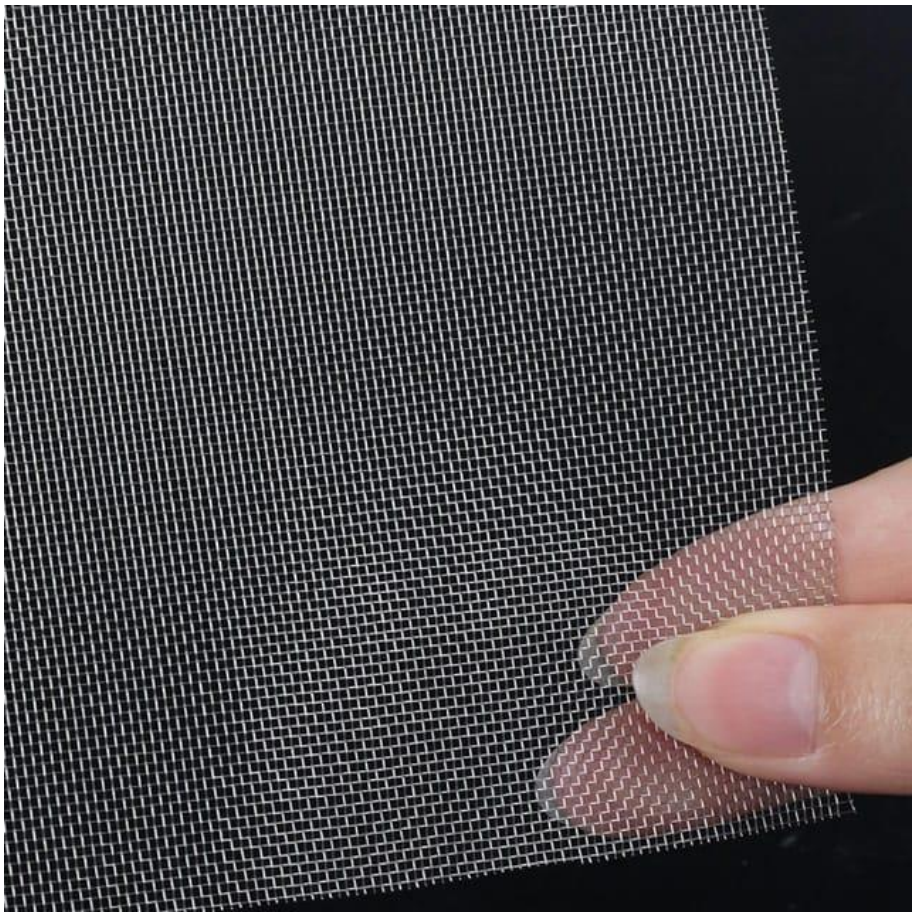
The block housing provides a robust and stable mounting solution, allowing for easy installation and alignment of the crankshaft. This design helps to distribute the load evenly and absorb vibrations, contributing to the overall stability of the sieving mechanism. The bearings inside the block are typically self-aligning, which compensates for minor misalignments and shaft deflections, ensuring smooth operation even under varying loads.

The block bearing units often incorporate seals or shields to protect against dust and debris, a crucial feature in the dusty environment of a sieving machine. This design also facilitates easier maintenance, as the entire bearing unit can be replaced, if necessary, without disassembling the shaft.

The selection of appropriate block bearings considered factors such as load capacity, rotational speed, and environmental conditions to ensure optimal performance and longevity.

By minimizing friction and maintaining proper shaft alignment, these block bearings contribute significantly to the efficiency and reliability of the power transmission system, ultimately enhancing the overall performance of the sieving machine.

2.1.7 Sieve screen:



Three types of sieve screens (Types A, B & C) were used in this project, each designed to meet specific particle separation requirements. Type A likely features the largest mesh size, suitable for initial coarse separation of larger particles or debris. This screen acts as the first stage in the sieving process, efficiently removing oversized materials and protecting the finer screens from damage.

Type B, with its intermediate mesh size, serves as the second stage, further refining the particle size distribution and capturing medium-sized particles.

Type C, featuring the finest mesh, is used for the most precise separation, capable of isolating very small particles or powders. The use of multiple screen types allows for a graduated sieving process, improving overall efficiency and accuracy of particle size analysis.

Each screen type is likely made from durable materials such as stainless steel or high-grade polymers, chosen for their resistance to wear, corrosion, and ability to maintain consistent mesh openings under vibration. The screens are designed to be easily interchangeable, allowing operators to adapt the machine to different materials or separation requirements.

The combination of these three screen types enables the sieving machine to handle a wide range of materials and achieve precise particle size distributions, making it versatile for various industrial applications such as food processing, pharmaceutical production, or mineral analysis

2.2 METHODS

Figure 1(a) is the automatic vibrator under construction while Figure 1(b) is the completed frame of the sieving machine. An automatic sieving machine is a device that is used to separate particles of different sizes by passing them through a sieve or mesh screen.

The machine typically consists of a frame, a motor, a sieve, and a collection chamber for the sieved materials. To use the sieving machine, the material to be sieved is poured at the top side of the sieve, and the motor is switched on to vibrate the sieve, causing the smaller particles to fall through the sieve mesh and to be collected in a container positioned below, while the larger particles bigger than the diameter of the sieve holes remain on top of the sieve. This process can be repeated with sieves of different mesh sizes to further separate the particles into different size categories.



Fig 1(a): The Reciprocating part Machine



Fig 1(b): The main frame of the automatic sieving

2.3 Design Calculations

The design calculations in this section are carried out according to Adhapure et al. (2021)

2.3.1 Power calculation:

Power = Force × velocity

Force = Weight = mg

where,

m = mass of sand = 3 kg (for this purpose only)

g = 9.81 m/s2 (acceleration due to gravity)

Power = Force x Velocity

=m x g x v

If 25 % margin of safety is proposed then

Power required $\frac{m \times g \times v}{0.75}$ = = 1.33 x mgv

Velocity, v = rω

Where r = radius of the pulley

ω = angular velocity of the pulley

v = 0.025 m x 300 m

= 7.5 m/s

Power, P = 1.33 x 3 x 9.81 x 7.5 W

= 293.56 W

So, it is safe to use ½ hp electric motor because it is more than 1/3 hp (248.4 W)

2.3.2 Torque Calculation:

Torque is calculated from the Power generated by the motor to operate the machine,

Diameter of pulley = 20 cm

Number of revolution (N) = 1500 rpm

Power of the electric motor = ½ hp

= 375 W

Force (F) = m × r × ω2

Where m is the total mass of the rotation chamber = 15 kg,

$$\omega = \frac{2 \times \pi \times 1500}{60}$$

= 157.1 rad/s

Torque (given by motor) = power/ω

= 375/157.1

= 2.387 Nm

2.3.3 Machine Energy Consumption:

Power of motor =375W.

Power for one hour = 375W x 1hr.

= 0.375 KWhr

If an average of 8 hours daily usage is assumed, then energy consumption per month

= 0.375 × 8

= 3.0 kWh

If electricity cost N69.26/kWh, the monthly bill to run the machine = 3.0 kWk x N69.26/kWh

= N207. 78/day

An average worker charges N2, 000 – N3, 500 per day.

This machine leads to a great financial savings

2.3.4 RPM:

Motor pulley diameter (outer) = 10 cm

Machine pulley diameter (outer) = 50 cm

Speed ratio = 10/50 = 0.20

For a machine with 1, 500 rpm, the speed of the rotating arm

= 1,500 × 0.20 = 300 rpm

2.3.5 Torsional force in shaft:

Maximum tensile stress of a mild steel = 525 MPa

Maximum shear stress of mild steel = 525/1.73

= 300 MPa

Diameter of shaft (D) = 30 mm = 0.03 m

Torque transmitted by circular shaft = 1589.625 Nm

2.3.6 Belt length:

Diameter of small pulley, d1 = 100 mm = 0.1 m

Diameter of large pulley, d2 = 500 mm = 0.5 m

Distance between center of two pulleys (x) = 400 mm = 0.4 m

Now, Length of pulley$= \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_2 - d_2)^2}{4x} = \frac{\pi}{2}(0.1 + 0.5) + 2(0.4) + \frac{(0.1-0.5)^2}{4(0.4)} = 1.843\ m$

CHAPTER 3

Experimental Setup

The sand sieving machine is shown in Figure 2. The main aim of this machine is to sieve clean sand of particular sizes from impurities such as dirt and pebble stones for foundry purposes. The sieving machine is made up of a main frame, electric motor, reciprocating connecting rod sieving mesh, drive belt for power transmission, and collector. The purpose of the main frame is to support the whole body of the machine and provide a guide for the reciprocating movements of the sieve.

There is no supporting wheel for the sieving machine to move to prevent unwanted movement during the operation of the machine. The sieve mesh used to sieve is interchangeable, to obtain different grain sizes. The electric motor provides the power for the sieving machine. The power is transmitted through the pulley, the connecting belt, the shaft and the connecting rod to the mesh for sieving operation.



Figure 2(a): Automatic Sieve Machine



Figure 2(b): Automatic Sieve Machine in operation

CHAPTER 4

RESULT AND DISCUSSIONS

The development of an automatic mechanical sand sieving machine was carried out successfully, and the machine was tested for its ability to separate sand particles of different sizes. The automatic mechanical sand sieving machine was able to separate sand particles into different size ranges, based on the hole sizes in the mesh screen, but different sieve screen mesh was used. The machine was tested by pouring one kilogram (1 kg) of sand of different sand materials (Sandy and Clay soils) and allowing the machine to work (separate) and the time for complete separation were noted. The reciprocating motion of the sieve screen caused the smaller sand particles to pass through the mesh screen, while the larger particles remained on top of the screen mesh.

The machine was able to separate the sand particles effectively, with the smaller particles passing through the mesh screen and the larger particles remaining on top.

TABLE: SAND SOIL

Type A Sieve

S/N	Time (s)	Weight of sand sieved (g)	Weight of Dirt (g)
1	16.5	930.37	69.63
2	16.31	937	63
3	17.02	940	60
	Type B Sieve		
1	5.67	974	26
2	4.67	977.7	22.3
3	4.55	986.4	13.6
Type C Sieve			
1	1.92	974	26
2	2.51	981.8	18.20
3	2.87	990	10

CHAPTER 5

CONCLUSION

The fabrication of a mechanical sand sieving machine with an automatic vibrator was developed in this article. The machine is designed to vibrate at a specific frequency to ensure that the sand particles are separated based on the size of holes of the screen used at a particular time.

Different sieve screen with different holes sizes can be used on the machine at different time to allow for the separation of sand particles into different size ranges. The mechanical sand sieve is an important tool in construction and foundry projects for filtering and separating sand particles.

The efficiency of the machine, ease of use, and low cost makes it an attractive option for sand separation across many different industries. The machine can scale up for bigger project.

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