JOURNAL OF ENGINEERING AND EARTH SCIENCES
JEES ISSN: 1897-8680
JEES 2022
VOLUME 15 ISSUE NO 1
PAGE 36 - 43

DEVELOPMENT OF A ROTARY SAND SIEVING MACHINE

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ABSTRACT

This paper presents the design, fabrication, and testing of a rotary sand sieving device for sieving suitable grain sand size 0.1mm for moulding activities in the foundry workshop. Unlike the conventional reciprocating sieving sand, the rotary sieving machine employs the principle of rotating systems and transmits the centrifugal force to the sand that breaks the lumps of sand and sieve it through the provided net. 10kg of lumped sands were loaded into the drum and operated for five minutes to evaluate the machine performance. It was observed that all the lumped moulding sands were broken to the smaller particles and passed through the mesh size of the net; it remains only solid particles that are either scraps from the cast or inclusive bigger grains of sand that were accidentally included during moulding process. Efficiency of the machine was based on the percentage of the sand recovered. The machine efficiency is 99% while the throughput is 50kg/hr. The device performs were highly satisfactory.

KEYWORDS: Fabrication; Grain; Sand; Sieving; Centrifugal

INTRODUCTION

Moulding sands are granular materials composed of finely divided rock and mineral particles. They are described as sizes being finer than gravels and coarser than silts. They are also referred to as a textural class of soil that contain more than 85% small sand-sized particles by mass. They are produced from the fragments that result when rock is broken down by wind or rain (weathering). Generally, sands start as larger fragments (gravels) but broken down as river carries them down the stream; the finer the particle, the further they traveled. In other words, large bits of gravel are deposited at the banks closed to the head of a river. As the gravels travel downstream, they become finer into cobbles, pebbles, granules that are eventually turned into sand that finally flow into the ocean, where these sediments deposit (National Geographic, 2021).

The composition of sand varies, depending on the local rock sources and conditions, but the most common constituents of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz. The second most common type of sand is calcium carbonate, for example, aragonite, which has mostly been created, by various forms of life, like coral and shellfish shells and other hard parts precipitated out of the ocean water by marine organisms (Aldo et al., 2018).

In the separation of these others minerals from sand, the process of sieving the sand needs to be carried out. Sieving of sand is carried out using a mesh net which is either inclined or straight depends on the method used in sieving.

In the modern days, sand sieving is carried out by taken, the sample sand, subjected to parallel movement when sieving; generating relative motion between the particles and the sieve's mesh net. Some of the sands pass through the sieve mesh while others are retained on the sieve surface depending on the sizes of the particles of sands and the mesh net. Various types of machines and method have been developed for sieving processes. An example of the common locally made sieving devices are as shown in Figures 1.1 and 1.2.

MATERIALS AND METHOD

The aim of this study is to design and fabricate a power-driven sand sieving equipment that is capable to break solid sand into pebbles and separate the unbreakable with simple operation using local materials.

A number of components were fabricated and assembled, such as a rectangular base and stand produced from angle bars and sheet metals, three 12milimeters twisted rod rings for support of mesh metal skeleton, drum- shaped net mesh of size 0.1mm made of constantan wire.

The Structural Components' Description

Rectangular Base Frame

The rectangular base comprises of four rectangular steel plates attached to four angular bars as leg stands welded together as shown in Plate 2.1. It is made from mild steel, and designed to withstand the tension and compressive load of its components.

Column rings

It is to supports the drum-shaped net mesh. It is fixed to the center shaft that is attached to the pulley. It is of strong welding and high compressive strength. It is made of mild steel of 12 millimeters rod bent to form rings. It is as shown in Plate 2.2.

i. **Shaft:** The shaft is 120millimeter long rod of 25mm diameter made of mild steel. It is the column structure on which the net mesh rings are attached as shown in Plate 2.2.
ii. **Net mesh**: This is wire mesh of 0.10millimeters. It is made of constantan wire and rolled round the rod- rings produced to form the drum as shown in Plate 2.3.
iii. **The hopper:** It is the mouth piece of the sieve through which the sand is loaded into the sieve. It is made from sheet mild steel of 3 millimeters thickness to form a box shaped as it is as shown in Plate2.4
iv. **Electric motor:** The driven power is supplied by 0.75 kilowatt (I horse power), 3 phase electric motor that is shown in Plate 2.5.

Design Calculation

Determination of Sieve Train Volume

The maximum volume that the sieve train can accommodate at a time, is the volume of the cylindrical sieve as calculated using Equation 1 below as given by Khurmi and Gupta (2005).

$$V = \pi r^2 l \tag{1}$$

Where, V is the volume of the sieve, r is the radius of the sieve and l is the length of the mesh drum.

Determination of Mass of Sieving Sand in the Sieve Train

Since, the sieve train is the required volume of sieve sand; the mass of the sand in the sieve train is determined using the Equation 2 as given by Hall et al., (1988).

$$M_s = \rho_s * V_s \tag{2}$$

Where, M_s is the mass of dry Sand, ρ_s is the density of dry Sand (1602 kg/m^3 for aerated silica sand. (Density of cement and aggregate) as given by Shigley and Mischke (2001).

Determination Speed of the Shaft

The speed of the shaft is determined, using Equation 3 as given by Khurmi and Gupta (2005).

$$\frac{N_1}{N_2} = \frac{D}{d} \quad (3)$$

Where N_1, is the speed of the machine pulley, (Larger Pulley), N_2 is the speed of the electric motor, (Smaller Pulley), d is the diameter of the electric motor pulley and D is the diameter of the sieve train pulley.

Determination of Torque Transmit on the Motor

The torque required transmitted from the shaft to the electric motor is determined, using Equation 4 as given by Khurmi and Gupta (2005).

$$T_S = \frac{60P}{2\pi N_2} \quad (4)$$

Where; T_S is the torque of the motor, P, is the power of the motor, N_2 is the speed of the motor and pi = 3.142

Determination of the Tension on the Belt

The tension on the belt on sieve sand machine is determined by using Equation 5 as given by Khurmi and Gupta (2005).

$$T_s = (T_1 - T_2)\frac{D_2}{2} \quad (5)$$

Where T_s = is the torque on the belt, T_1 is the tension on the tight side of the belt, T_2 is tension on the slack side of the belt, D_2 is the diameter of the smaller pulley.

NOTE: $\frac{T_1}{T_2} = 4$

$Therefore, \quad T_1 = 4T_2$

Determination of Power Transmit on the Machine

The power transmit on the machine can be determined by using equation as given by Khurmi and Gupta (2005).

$$P_t = (T'_1 - T'_2)V_b \quad (6)$$

Where; P_t = Power transmitted to the shaft, T_1 = tension on the tight side, $T_2 =$ tension on the slack side and $V_b =$ Velocity of the belt

Determination of Efficiency on Belt Drive

The efficiency of the machine belt drive sieving was estimated using the Equation 7 given by Khurmi and Gulpta (2005) and Spolt, (1998).

$$\text{Efficiency} = \frac{output}{input} * 100\% \quad (7)$$

Output = Weight of the sand after sieving.

Input = Weight of the sand before sieving.

Centre to Centre distance between the Pulleys

From Figure 3.1, α_1 and α_2 are angles wrap (rad) of the driving and driven pulleys respectively, β is the angle of inclination of the belt, T_1 and T_2 are the effective tensions on the tight and slacks sides of the belt respectively as in Equation 8 and 9 respectively (Khurmi & Gupta 2005).

$$\alpha_1 = 180 - 2\, sin^{-1}\left[\frac{(D-d)}{2C}\right] \quad (8)$$

$$\alpha_1 = 180 + 2\, sin^{-1}\left[\frac{(D-d)}{2C}\right] \quad (9)$$

Determination of Belt Length

For V-belt; Length, L,

$$L = 2C + \left(\frac{\pi}{2}\right)(D + d) + \frac{(D-d)^2}{4C} \quad (10)$$

Where L is pitch length of the belt, D is the diameter of the bigger pulley, d is the diameter of the smaller pulley, C is the center-to-center distance. The density of belt is of $1250 kg/m^3$, allowable stress is 2.50 MPa and friction coefficient of 0.35.

CONCLUSIONS AND RECOMMENDATIONS

Design, fabrication, and testing of a rotary sand sieving have been successfully carried out. The device is much easier to use and requires less force to operate when compared with the locally made devices. The sieving type which is using centrifugal forces enable the solid particles to disintegrate into smaller particles thereby serve more as breaking device which is much safer to use and technically more reliable than the old labor-intensive way of sieving.

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Plate 2.1. Rectangular Base Frame

Plate. 2.2. Column rings and Shaft

Plate 2.3. Net mesh

Plate 2.4. The Hopper

Plate 2.5. Electric motor

Figure 1.1. *Manual method to sieve the sand* (Source: Ado et al., 2018)

Figure 1.2. Hand sieve stool

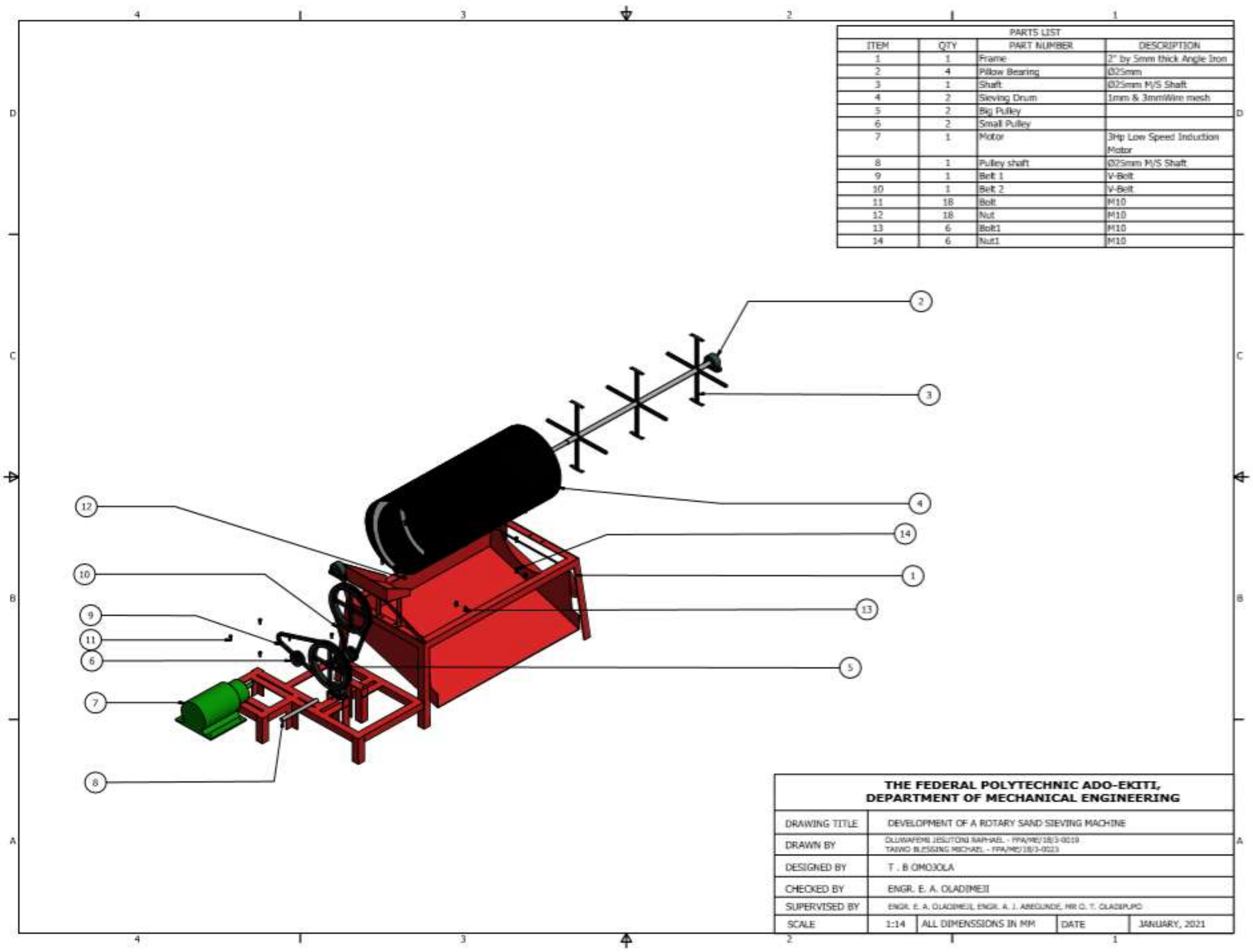

Figure 2: Isometric view of the machine

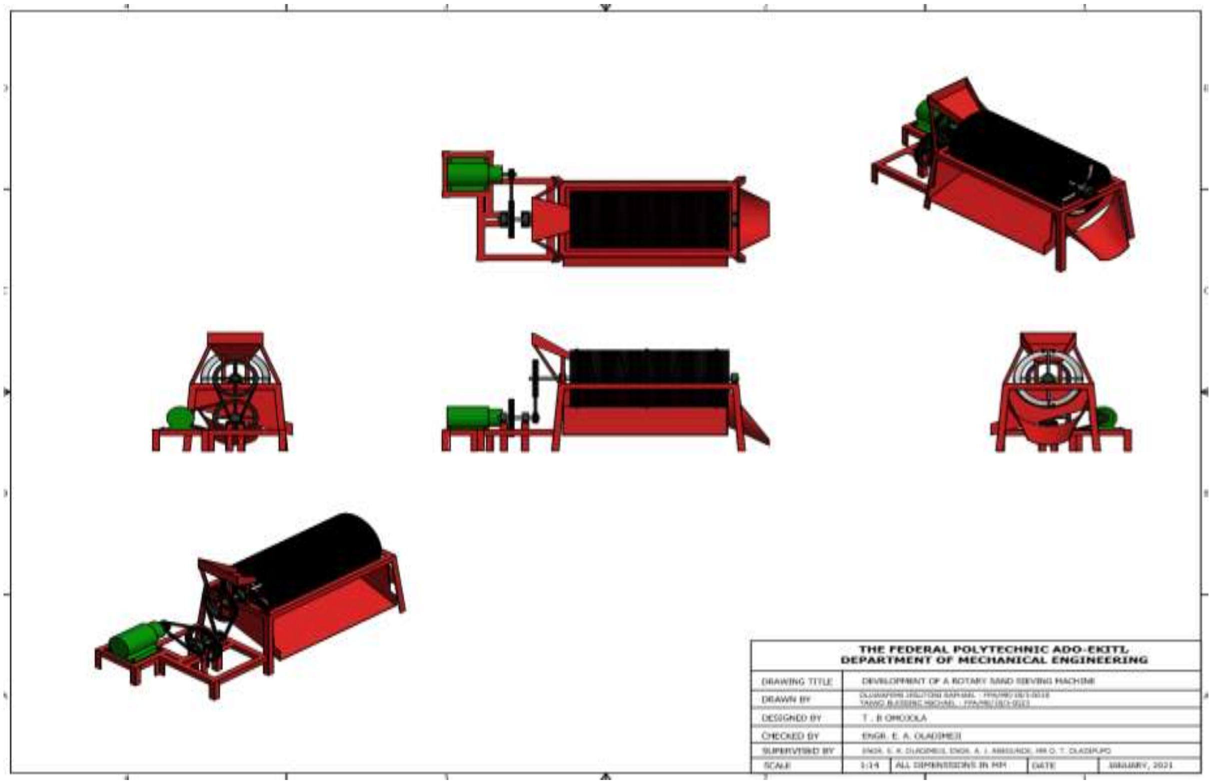

Figure 3. Exploded view of the sieve sand

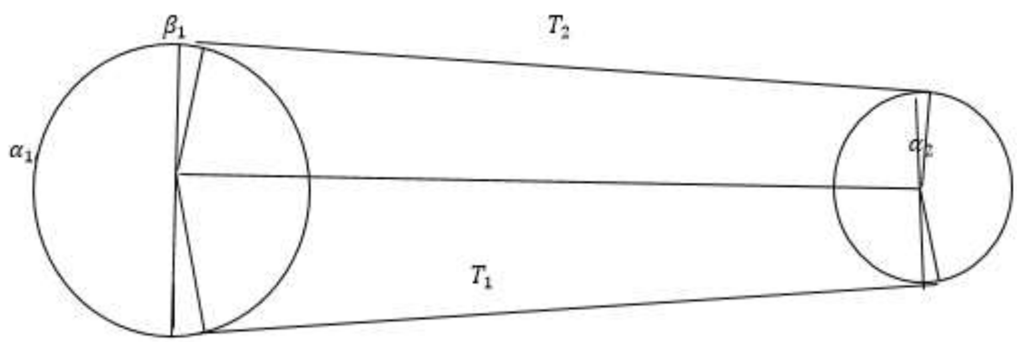

Figure 3.1. Centre to Centre distance between pulleys

Figure 4. Pictorial view of the assembled sand sieving