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Research Article

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Design and Development of a Foundry Sand Mixer

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Abstract A simple foundry sand mixer capable of mixing foundry sand was designed, developed in this research work. The sand mixer components consist of the machine frame, mixing chamber, auger screw, ball bearings, auger housing, motor support, gearbox speed reducer, shaft, discharge door and mixing blades. The machine was fabricated and used to mix sand. The dry sand was gently poured on the auger screw via the hopper top. Water was gradually added and bidders at the required quantities. The handle was turned clockwise as the mixture rapidly mixes the material whilst keeping the body of the sand fluffy and light all in one simple action. The mixer test results show that the average mixing time of the sand mixer to mix 15.6 kg of sand was 15.2 minutes. The time of mixing was short, thus the machine performance is satisfactory.

Keywords Design, development, foundry sand mixer, mixing time, performance

1. Introduction

The chief components of foundry sand are high quality silica sand with uniform physical characteristics. It is a byproduct of ferrous and nonferrous metal casting industries, where sand has been used for centuries as a moulding material because of its thermal conductivity [1]. At first, the sand is clean before casting, but after casting, it will be rich in ferrous content of about 95% of its own volume. The major production of foundry sand is by automotive industry and by casting of generator parts. The metal casting industry uses projected 100 million tons of foundry sand yearly for production [2]. The appropriate blending of these materials enhances desirable properties for moulding. Thus, the techniques of mixing sand is a process of kneading and working sand for the purpose of ingredients (additives) into a homogenous mixture [3]. The physical and chemical characteristics of foundry sand mainly depend on the type of casting process and the industry sector from which it originates [4].

In current foundry practice, sand is typically recycled and reused through many production cycles. Industrial estimation show that approximately 100 million tons of sand are used in annual production of 6 - 10 million tons which are discarded annually and are available to be recycled into other products and in industry [1]. In this line, the automotive industries and its parts are the major generators of foundry sand [1]. Foundries purchase high quality size-specific silica sands for use in their molding and casting operations. However, the raw sand is normally of a higher quality than the typical bank run or natural sands used in fill construction sites. Generally, two types of binder systems are used in metal casting depending on their classification such as (Green sand) and chemically bonded systems [5]. The green sand owning the 90% of the about ingredients is used in large scale. In United State of America (USA), green sand moulds are used to produce about 90% of casting volume [6]. Green sand comprises of naturally occurring materials which are mixed together; high quality silica sand (85-95%), bentonite clay (4-10%) as a binder, a carbonaceous additive (2-10%) to improve the casting surface finish and water (2-5%) [7]. Green sand is the most commonly used recycled foundry sand for beneficial reuse. It is black in colour, due to carbon content in it, has a clay content that results in percentage of material that passes a 200 sieve and adheres together due to clay and water. On the other hand, the chemically bonded sands are used both in core making where high strengths are required especially to withstand the heat of molten metal, and in mould making. Large percentage of chemical binder systems consist of an organic binder that is activated by a catalyst even though some systems use inorganic binders. Chemically bonded sands are usually light in colour and in texture than clay bonded sands [8].

There is an ever-present trend to increase the tonnage of prepared sand from sand preparation units. This has caused the time for mixing to be shortened to such an extent that the quality of the sands have suffered materially [9-10]. Sand mixture can sometimes be done manually especially in small foundry shops. However, most foundry sands can prove very difficult to mix and could lead to fatigue of the foundry man [10]. Even when mixed by hand, the mix is nowhere as good when compared to when mixed with machine. Foundry sand mixture machine available in Nigeria market are bulky expensive and need a lot of energy to run leading to shovel mixing which is not only ineffective but tedious and unreliable. Hence, there is need to design and develop a foundry sand mixer from locally available materials in Nigeria.

2. Materials and Methods

2.1. Design Calculation

2.1.1. Capacity of the Hopper

The capacity of the hopper is given by Eq. (2.1)

$$V_C = \frac{\pi h}{12}(D^2 + Dd + d^2) \tag{2.1}$$

where,

D = Outer diameter (m)

d = Inner diameter

H= Height (m)

2.1.2. Mass of Moulding Sand

The mass of the moulding sand is given by Eq. (2.2)

$$M_S = \rho_S \times V_C \tag{2.2}$$

where,

Ms = Mass of moulding sand (kg)

Ps = Bulk density of moulding sand (kg/m^3)

2.1.3. Shaft Design

$$T_d = \frac{60PK_L}{2\pi N} \tag{2.3}$$

T_D= Design torque

K_L= Load factor=1.75 for line shaft

Thus, for diameter of shaft

$$d^3 = \frac{16}{\pi S_S}\sqrt{(K_b M)^2 + (K_t T_d)^2} \tag{2.4}$$

where,

M=Bending moment

For suddenly applied load (heavy shock), the following values are recommended for K_b and K_t

K_b= 2 to 3

K_t= 1.5 to 3

Selecting material of shaft SAE 1030

S_{ut}= 527MPa

S_{yt}=296MPa

$\tau_{max} \leq 0.30 S_{yt}$

$\tau_{max} \leq 0.18 S_{ut}$

Where,

S_{ut}= Ultimate yield strength

2.1.4. Speed of the Shaft

Using gear speed ratio, the speed (N) of the shaft in rpm is given by Eq. (2.5)

$$\frac{N_1}{N_2} = \frac{20}{1} \quad (2.5)$$

where,

N_1=Rotational speed of the electric motor (rpm)

N_2 =Rotational speed of the shaft (rpm)

2.1.5. Angular Velocity of the Shaft

The angular velocity of the shaft is given by Eq. (2.6)

$$\omega_s = \frac{2\pi N_2}{60} \quad (2.6)$$

where,

ω_s = Angular velocity

2.1.6. Force acting on the Shaft

The force acting on the shaft, F_s was determined using Eq. (2.8)

$$F_s = M_S \times g \quad (2.7)$$

where,

M_s = mass of moulding sand (kg)

g = Acceleration due to gravity

2.1.7. Required Torque

The torque required is given by Eq. (2.8)

$$T = F_w \times r \quad (2.8)$$

2.2. Fabrication

2.2.1. Frame of the Machine

The machine frame was fabricated from low carbon steel. The key prerequisite in the design of the frame of the machine is that it maintains the proper relatives position of the units and parts mounted on it over a long period of service condition. The choice of low carbon steel was mainly on strengthand and workability.

2.2.2. Mixing Chamber

The mixing chamberis cylindrical in shape incorporated into a truncated trapezium hopper with a guide to channel the flowing mixture (sand) out of the mixing chamber. The mixing chamber was fabricated from a low carbon steel material of 6mm thickness.

2.2.3. Trap Door for Discharge

The trap door for discharge is made of galvanized steel which provides a smoother finish than regular steel to allow for free movement of the door. The grove for the door stands at 30mm from the base of the mixing pan and is approximately 120 by 120 in mm. This height is just sufficient enough to effectively discharge the content of the pan. The trap door is of a square shape and slightly curve to enable the door lap properly on the circumference of the drum frame

2.2.4. The Blades and Blade Support

The blades and blade support are made of low carbon steel. It was assembled together by electric arc welding and connected to the shaft through slots on the parts which transmits the motion from the reduction gear box to the blades and blade support.

2.2.5. Shaft

In this design, the shaft was used to support the rotating mixer blades and subjected to torsion and transverse or axial loads, acting singly or in combination. The shaft carries the blade support and the blades, and it is powered by an electric motor through a ball bearing and gear system. The forces acting on the shaft are those acting on the blades which are transmitted to the shaft, these include the reaction due to weight of blades, reactions due to weight of the sand and centrifugal effect on both blades and shaft.

2.2.6. Reduction Gear Box

The purpose of this reduction gear box (speed reduction gearbox) is to reduce the speed (in rpm) of the electric motor. Reduction gear box with gear reduction ratio of 20:1 will be procured to reduced speed of the electric motor.

2.3. Design Procedure and Machine Development

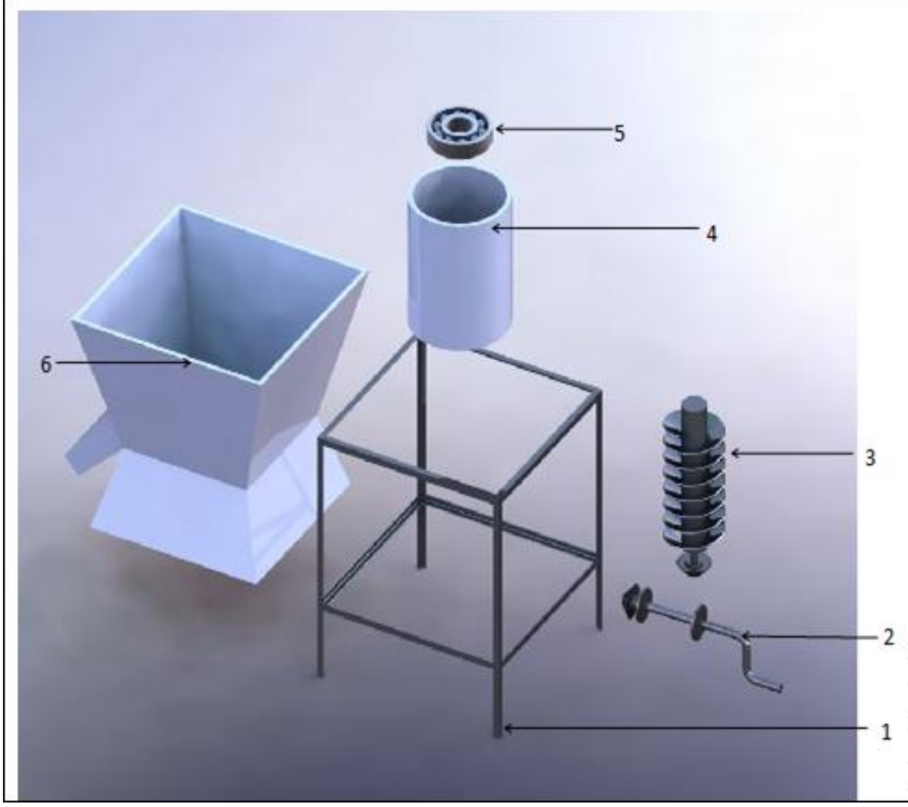
In development of the machine, the geometrical parameters of the mixer, which includes the support frame, mixing chamber, blades, shaft and the driving mechanisms were all considers. Steel which is an alloy of iron and carbon was used for the construction (fabrication) of the sand mixer, the type of steels employed are:

i. Low carbon steel

ii. Galvanized mild stee

Low carbon steel is an alloy of iron which contains 0.1-0.3 percent carbon. The choice of this material was influenced by the good physical and mechanical properties such as strength and its availability. Galvanized mild steel is steel that has gone through a chemical process to prevent it from corroding. The steel gets coated in layers of zinc oxide because this protective metal does not get corrode easily. In the fabrication of the foundry sand mixer, it was used for the fabrication of all parts of the trap door for discharge.

Figure 2.1 shows the exploded view Foundry Sand Mixer



S/N	DESCRIPTION
1	Frame
2	Handle
3	Auger Screw
4	Auger Housing
5	Bearing
6	Hopper

Figure 2.1: Exploded View of Foundry Sand Mixer

Figure 2.2 shows the isometric model view of the foundry sand mixer

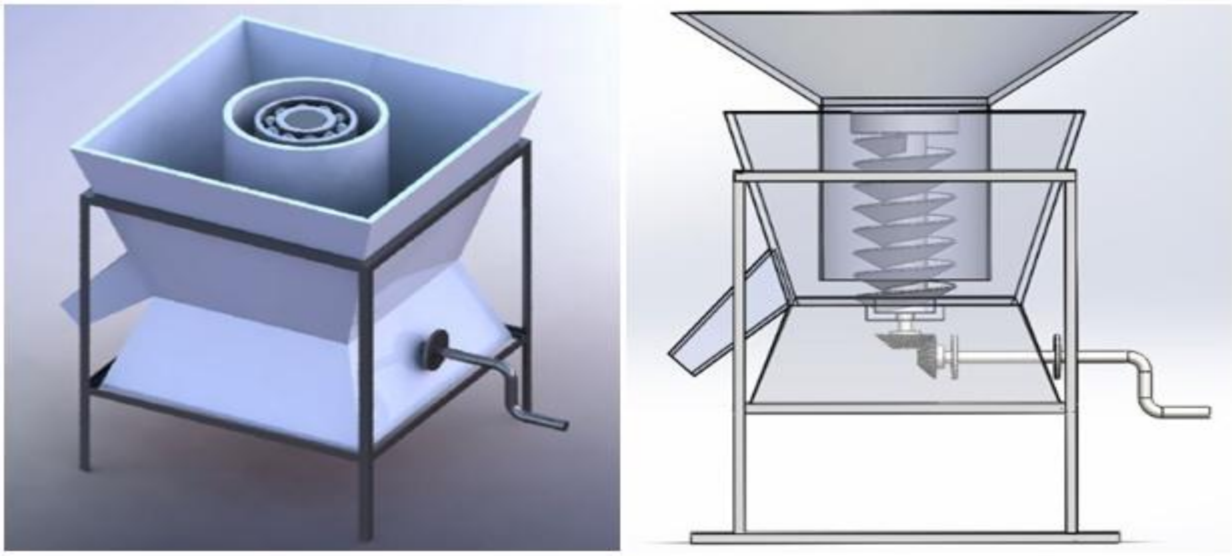


Figure 2.2: Isometric Model View of Foundry Sand Mixer

3. Results and Discussion

The design calculation results obtained is show in Table 3.1. The results obtained from designed calculation show that the capacity of the hopper, mass of moulding sand, shaft diameter, speeds of shaft, angular velocity of shaft, force acting on the shaft and the required torque were 0.024m3, 22.5kg, 30mm, 20rpm, 4.12rad/s, 200.05N and 42.1N respectively. The force calculated for was minimal enough for easy operation of the machine.

Table 3.1: Results of Designed Calculation

S/N	Evaluated Parameters	Value Obtained	Unit
1	Capacity of Hopper	0.024	m^3
2	Mass of Moulding Sand	22.5	kg
3	Shaft Diameter	30	mm
4	Speed of Shaft	20	rpm
5	Angular Velocity of Shaft	4.12	rad/sec
6	Force acting on the shaft	200.05	N
7	Required Torque	42.1	Nm

Moreover, different masses of sand were used to evaluate the machine. The mixing chamber was loaded with sand while the handle is rotated clockwise so that proper mixing can be achieved. At the achievement of a homogeneous mixture, the trap door was opened while the machine is still being operated to allow the sand to be pushed out and collected. This was repeated for five times and the average mixing time recorded as show in Table 3.2.

Table 3.2: Performance Test Results

S/N	Mass of Sand (kg)	Time (minutes)
1	10	13
2	16	15
3	15	14
4	20	18
5	17	16
∑	**78**	**76**
Ave.	**15.6**	**15.2**

The analysis of the performance test results reveal that an average mass of 15.6kg of sand was processed with an average time of 15.2minutes.

4. Conclusion

In this present work, designed and development of a foundry sand mixer was carried out. The comprises of the following major components; machine frame, mixing chamber, ball bearings, gear box speed reducer, shaft, discharge door and mixing blades. Some design parameters such as capacity of the hopper, force, shaft diameter, torque, etc. were calculated for. The outcome of the results revealed that a minimum force and torque is required by the machine. Furthermore, the processing time was minimal, thus the machine can be used for the purpose design for and this will help to solve the problem associated with improper mixing of sand manually.

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