

Design Analysis and Testing of Sand Muller for Foundry Application

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Abstract

A Sand Muller was designed, fabricated, and its performance tested by producing standard specimens. They were subjected to green compression strength test. The Sand Muller was designed to help foundry industries in Nigeria as well as small-scale foundries acquire basic foundry equipment to test and control raw materials in order to improve castings quality. In designing the Sand Rammer, systematic design analysis of the basic theories required to make it functional were considered. The Sand Muller was fabricated from locally sourced materials, tested and found to produce sand mix of adequate strength for casting purposes.

Keywords: Sand Muller, mulling, castings, foundry, strength test.

Introduction

The properties of molding materials are very vital to the production of sound dimensionally accurate castings. 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. The bond is not being uniformly blended into the sand, nor is mixing being sufficient to make use of the bond. This certainly does not reflect favorably on the foundry industry where better castings are so important.

Also the accelerated development of the foundry Industry imposes new problems on the sand preparation equipment now available. The progress of the foundry industry has been rapid and marked by enormous casting quality (Troy 2004) improvement together with large productivity per man-hour. These changes require a continued upgrading of prepared foundry sands. Hence, there is a need to provide the foundry with a Muller of ample capacity.

The proper blending of these materials enhances desirable properties for molding. Therefore, Sand Mulling is a process of kneading and working sand for the purpose of

distributing the ingredients (additives) into a homogenous mixture (Beeley 2001).

The objective of sand mulling is to achieve a uniform distribution of sand grains, since this affects permeability and surface fineness. Uniformly mixed sand gives high flowability. The grain size distribution also influences strength properties of bonded mixtures. An inverse relation exists between compression strength and grains size with a uniform bond coating, Heine, *et al.* (1967). Sand with a uniform bond coating and complete absence of uncoated grains will be more thermally stable than poorly mixed sand. Sand mulling reduces mold fracture leading to metal penetration during casting.

Positive sand mulling can be obtained through the use of Muller. There are basically two types of Sand Muller, viz. batch and continuous types.

The batch Muller mixes a given amount of molding materials at a time and discharges it before a fresh one is fed. While the continuous Muller mixes a continuous stream of sand as it passes through the mixing unit. This type of Muller has found an increasing use in the foundry industry as a result of the desire to prepare more sand through a given unit. There are three general designs: Pug mill type, Muller type, and the conveyor roller type (Dietert 1954).

General Features and Principles of Operation of the Sand Muller

The Sand Muller is designed to quickly, uniformly and mechanically manipulate a heterogeneous mass of two or more dry, or wet materials, of varying aggregate sizes, into uniformly blended and bonded homogenous product (E-series Muller Catalogue 1992).

It consists of cylindrical pan, two heavy rollers, which roll in a circular path about a vertical shaft. Two ploughs are also carried with the rollers, which scrape the sand from the sides and bottom of the pan, and place it in the front of the rollers. A discharge door is provided at the bottom of the pan. The rollers are slightly off the true radius so that they move out of center and produce a smearing action on the sand, but are raised about 6 mm from the base of the pan in the lowest position to prevent crushing of sand grains.

The Muller utilizes three way mulling (Bala 1998) actions when sand is placed in it as follows:

- (i) Press and squeeze – to reduce aggregates to uniform particles size;
- (ii) Spread and smear – the wide faced rollers generate a rubbing action in which one material is intimately blended and bonded with another through frictional effects;
- (iii) Turn and fold – the inner and the outer ploughs constantly agitate the mass and progressively move it to the active mixing zone of the mulling surfaces.

Design Theory of Sand Muller

The design theory of the sand Muller considers the geometrical parameters of the Muller, which includes mulling pan, rollers, and shaft and driving mechanisms.

Mulling Pan: The mulling pan is cylindrical in shape, the volume V_p is given by:

$$V_p = \frac{\pi D_p^2 H_p}{4} \text{ ----- 1}$$

Where D_p = diameter of pan (m);
 H_p = height of pan (m).

Since, the pan is to contain molding sand; the volume of the pan is also given by:

$$V_p = \frac{M_s}{\rho_s} \text{ ----- 2}$$

Where M_s = mass of molding sand (kg);
 ρ_s = bulk density of molding sand (kg/m³).

For allowance, the volume is doubled, i.e.:

$$4V_p = \frac{\pi D_p^2 H_p}{4} \text{ ----- 3}$$

And for proportion,

$$D_p = 3H_p \text{ ----- 4}$$

Substituting equations 4 and 2 in equation 3

$$H_p = 3 \sqrt{\frac{8M_s}{9\pi\rho_s}} \text{ ----- 5}$$

The Rollers: The sand Muller has two rollers, which are responsible for the rubbing action. The geometric proportion of the rollers is based on an inspection of basic specification of the E-series Muller Catalogue (1992).

$$D_r = 1.1H_p \text{ ----- 6}$$

Where D_r = diameter of rollers (m).

Similarly, width of rollers is:

$$B_r = 0.09D_p \text{ ----- 7}$$

Where B_r = width of rollers.

The material thickness required for rollers is given by:

$$t_r = \frac{2D_r \sigma_o}{[\sigma]} + 0.008 \text{ ----- 8}$$

Where t_r = thickness of roller material (m);

σ_o = stress on rollers due to molding sand (N/m²);

$[\sigma]$ = allowable stress of roller material (N/m²);

(2 is factor of safety).

Roller Arm and Shaft: The shaft carries the rollers and the ploughs, and it is powered by an electric motor through a V-belt pulley system. The forces acting on the shaft are those acting on the rollers which are transmitted to the shaft, these include the reaction due to weight of rollers; reactions due to green

compression strength of molding sand and centrifugal effect on both rollers and shaft.

Now,

$$\omega_s = \frac{r_r \omega_r}{r_a} \quad \text{-----} \quad 9$$

Where ω_s = angular velocity of shaft (rads/sec);

ω_r = angular velocity of roller (rads/sec);
 r_r = external radius of roller (m);
 r_a = radius of roller arm (m).

To determine the diameter of roller arm, the total vertical force on each roller is given as:

$$F_v = N + F_c - W \quad \text{-----} \quad 10$$

Where F_v = total vertical force (N);

N = normal reaction on roller due to centrifugal effect (N);

F_c = force due to green compression strength of molding sand (N);

W = weight of roller (N).

The arm is in bending; therefore, the bending moment is,

$$M_b = F_v r_a$$

Diameter of roller arm is obtained from:

$$d_r = 3 \sqrt{\frac{16M_b}{\pi \sigma_b}} \quad \text{-----} \quad 12$$

Where σ_b = allowable bending stress of material, (for mild steel = 48 x 10⁶ N/m²).

The Shaft Diameter: To determine the shaft diameter, the torque, T_s on shaft is given by:

$$T_s = \frac{P}{\omega_s} \quad \text{-----} \quad 13$$

Where P = power required (W);
 ω_s = angular velocity of shaft (rads/sec).

$$\omega_s = \frac{2\pi N_2}{60} \quad \text{-----} \quad 14$$

Where N_2 = rotational speed of shaft (rpm).

The shaft is under torsion; therefore, the shaft diameter (Hall, *et al.* 1988) is given by:

$$d_s = 3 \sqrt{\frac{16T_s}{\pi S_s}} \quad \text{-----} \quad 15$$

Where d_s = diameter of shaft (m);

T_s = torque on shaft (Nm);

S_s = allowable shear stress of shaft material (N/m²).

Diameter of Driven Pulley: The diameter of the driven (pulley) is obtained from:

$$d_2 = \frac{N_1 d_1}{N_2} \quad \text{-----} \quad 16$$

Where N_1 = speed of electric motor (rpm);

N_2 = speed of driven pulley (rpm);

d_1 = diameter of motor pulley (m);

d_2 = diameter of driven pulley (m).

Maximum center distance between pulleys is

$$C = 2(d_1 + d_2) \quad \text{-----} \quad 17$$

Angle of wrap for driving and driven pulleys are given as follows:

$$\alpha_1 = 180 - 2\beta \quad \text{-----} \quad 18$$

$$\alpha_2 = 180 + 2\beta \quad \text{-----} \quad 19$$

Where α_1 = angle of wrap of driving pulley (°);

α_2 = angle of wrap of driven pulley (°);

β = half angle of pulley groove (°) and is given by:

$$\beta = \sin^{-1} \left(\frac{d_2 - d_1}{2C} \right) \quad \text{-----} \quad 20$$

Length of belt is obtained from:

$$L = \sqrt{2C^2 - (d_2 - d_1)^2} + \frac{1}{2}(\alpha_2 d_2 + \alpha_1 d_1) \quad \text{-----} \quad 21$$

Fabrication, Testing and Discussion

The Sand Muller was constructed using the calculated values shown in Table 1.

Test specimens of standard size (50 mm by 50 mm) made from locally fabricated sand rammer (Bala 2004) of sand mix of 90.5% silica sand, 6.5% bentonite with varying moisture content after mulling with the fabricated Muller were subjected to green compression test with a view to determining the green compression strength of the mulled molding sand.

Fig. 1 shows the result of the test for different units of mulling efforts for a mulling period of 90 sec. The results obtained are in total agreement with the strength requirements for green moulding sand which is between 30 – 160kPa (Rao 2001).

Table 1. Calculated parameters of Sand Muller

S/no	Symbol	Value	Unit
1	H_s	123.60	mm
2	D_p	370.65	mm
3	D_r	135.91	mm
4	B_r	33.35	mm
5	ω_s	3.142	rad/s
6	ω_r	3.699	rad/s
7	W	22.22	N
8	t_r	8.10	mm
9	F_c	151.34	N
10	d_r	11.33	mm
11	T_s	118.56	N.m
12	d_s	24.71	mm
13	d_2	98.00	mm
14	d_1	60.00	mm
15	C	316.00	mm
16	L	695.70	mm
17	N_1	49	rpm
18	N_2	30	rpm

Conclusion

The designing and fabrication of the Sand Muller presented in this work was to enhance indigenous development of Nigeria foundry industries by providing test equipment at minimal cost as well as enhance sand mulling at higher efficiency.

From the results, it can be concluded that the Muller can be used to provide mulled sand of require green strength for molding purposes. It can therefore, be concluded that the indigen-

ously fabricated Sand Muller is of good standard and can be used for mixing and mulling in the foundry.

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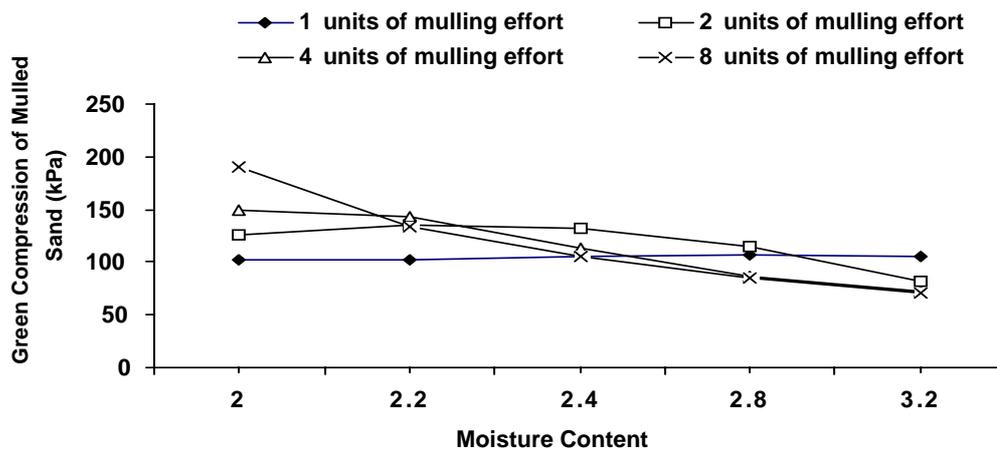


Figure 1: Variation of Green Copression with Moisture Content