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Study of the Mixer Performance under Different Mixing Conditions

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Abstract

In the present work, the performance of a laboratory vertical mixer at different operating conditions has been studied for the mixing of the iron ore concentrate and water. Three discharge valves have been mounted on a mixer wall at different heights.The mixer desired performance occurs when the solid particle contents for three discharge valves are approximately in the same levels. The operating parameters which influence the mixer performance have been studied here including main shaft speed, impeller angle, single or double impeller set and baffle or no-baffle cases.Results show that all mentioned parameters have undeniable role in appropriate mixer performance but the most influencing ones, listed here from most to least, are baffle existence, impeller angle, shaft speed and impeller set.

Keywords: Laboratory mixer, Impeller speed, Impeller angle, Baffle.

1. Introduction

One way of transferring of tiny grains in the mineral industries is by mixing them in water and using vertical cylindrical mixers. The optimum mixing depends on appropriate selection of the mixer performance parameters. These parameters include the impeller rotational speed, impeller dimensions, impeller angle, the position and number of impeller sets and existence or ignoring the baffle in the internal face of cylinder wall. The optimum performance means semi-homogenous slurry to be easily handled and no settlement. The acceptable mixing depends also on the particle properties. The particle cohesiveness, shape, mass, density and etc. may affect the mixer performance. There are complicated relations in computational fluid dynamics (CFD) for prediction of the flow behavior. Commercial CFD software provides the way to have the acceptable solutions for a wide range of engineering problems. However, the experimental observations by laboratory equipment give the reliable data in simple and fast modes in some cases.

Some researches aimed to study the design parameters in order to determine the fluid forces [1, 2]. Hobbs and Muzzio [3] studied the effect on Reynolds number on the laminar mixing. Their results showed that in Reynolds lower than 10 the mixing is independent on Reynolds number. Tanguy et al. [4]investigated experimentally and numerically the mixing performance of a dual impeller mixer and derived a generalized power curve. Effect of the shaft speed and impeller design on the optimum performance of a ribbon mixer was analyzed by discrete element method by Halidan et al. [5]. Gijon and Tecante [6] determined the mixing time which was required to achieve 92% homogeneity. The turbulent flow field generated in a baffled stirred tank was numerically studied by solving the unsteady Navier–Stokes equations by Zamiri and Chung [7]. The Predicted velocity evaluated numerically was compared with experimental measurements. The laminar mixing performance in a cylindrical vessel agitated by a plate impeller was investigated by KC Ng and EYK Ng [8]. They considered several mixing enhancement strategies including the baffling. They observed low radial mixing in an unbaffled vessel. Busciglio et al. [9] provided experimental information by usingthe planar laser induced fluorescence (PLIF) technique on mixing rates in an unbaffled vessel. Torotwa [10] studied the performance of three different types of mixing impeller by Fluent simulation and experimentally. In the present work, the effect of influencing parameters on mixing performance is studied experimentally by a laboratory mixer. The aim is to determine the positive effect of baffle in mixer body and the number of impellers. The optimum impeller angle is determined and the effect of main shaft speed is shown.

2. Laboratory mixer

The present experimental apparatus is a low scale radial-flow mixer which is illustrated in Fig. 1. It is a cylinder with an electrical motor on the upper head. The

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impellers are flat-blade type including three blades on each impeller fixed on a vertical shaft at the specified height (bottom of shaft, 10cm and 20cm from bottom of shaft). The impeller angleθ can be changed from 0^o to 90^o by the screw connection between impeller and shaft. Bafflescanbe mounted on the interior of the vessel body. Baffles are 500×30×10mm Teflon plates. The slurry is a combination of water and iron Pellet-powder whose composition is given in table 1. The mixer body is made of carbon steel and the impellers are cut of Teflon plate same as the baffles. The electrical motor and speed controller are mounted on the top of the main body of mixer. The main shaft end is 10cm above the mixer bottom and the distance between impellers is 15cm. Four baffles mounted around the main body of mixer in 90^o distances.

Table 1. Composition of Pellet- powder

Fe%	Feo%	P%	S%	Sio2%	Cao%	Mgo%	Al2o3%
65.51	1.38	0.04	0.008	3.36	0.745	2.2	0.64

The impellers have end-threads tightened on the main shaft and enables controlling the impeller angle. The impellers can be disassembled to have one, two or three impeller sets. The laboratorymixer dimensions are given in table 2 and test parameters for the present experiments are given in table 3.

Table 2. Dimensions of laboratory mixer

Dimension	Value
Box diameter	410mm
Box length	540mm
Box thickness	2mm
Shaft diameter	12mm
Impeller diameter	350mm
Impeller width	25mm
Impeller thickness	10mm

Table 3. Test parameters

Parameter	Value
Impeller face angle (Deg)	0, 15, 30, 45
Number of impeller sets	1, 2
Number of baffles Without baffle	With baffles,
Impeller speed (Rpm)	90, 120, 150

The governing parameter which guaranties the appropriate mixing is the Reynolds number which is evaluated as follow:

$$R = \frac{ND^2\rho}{\mu} \quad (1)$$

In which *N* is the main shaft speed in *rev/s*, *D* is the impeller diameter in meter, ρ is the flow density in kg/m^3 and μ is the viscosity in *Pa.s.*

The slurry physical properties including density and viscosity are evaluated by the following relations: [11].

$$\rho_m = \frac{100}{\frac{C_W}{\rho_S} + \frac{100-C_W}{\rho_L}} \quad (2)$$

Where ρ_m is the density of slurry in kg/m^3, C_w is the solids concentration by weight%, ρ_s is the density of solidin $kg/m^3$and ρ_L is the density of liquid inkg/m^3. The viscosity of slurry is evaluated by the following relation [11]:

$$\mu_m = \mu_L(1 + 2.5\emptyset) \quad (3)$$

In which μ_m is the viscosity of slurry,μ_L is the viscosity of liquid and Φ is the volume fraction of particles. The slurry parameters for the present work are given in table 4.

Table 4. Mixture parameters

C_w	8.3%
ρ_s	4200kg/m^3
ρ_L	1000kg/m^3
$\emptyset$	0.02
μ_L	8.9e-4 Pa.s

According to the given parameters in tables 3 and 4, the slurry density ρ_m and viscosity μ_m are respectively *1075* kg/m^3 and $9.34 \times 10^{-4} Pa.s$

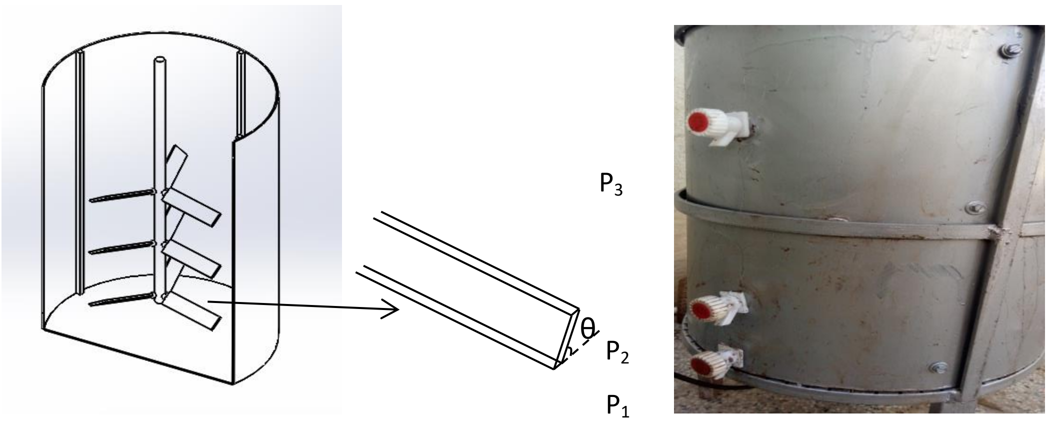

Figure 1. Schematic of the mixer box, baffle and impellers, impeller angle and discharge valve positions

3. Experimental procedure

The main body of mixer is washed completely and dried to be cleaned of particles before each test. The slurry was provided by mixing *2.5kg* magnetite concentrate in *30Liter* of water and the particles were allowed to be settled in 30 minutes. After the particles settled in the bottom of the mixer box, the motor was turned on and experiments start. After *2 minutes*, the discharge valves were opened simultaneously and *250cc* of slurry was taken in glass cups. Discharge valves which their position on mixer body is illustrated in Fig 1., are positioned at the bottom of main box (P_1), *100mm* from the bottom (P_2) and *250mm* from the bottom (P_3). The taken slurry has been dried in laboratory furnace and remained particles have been weighed accurately. The particle content in obtained slurry is considered as the value of the particles at the corresponding position in the main box during the mixing.

4. Results

The particle contents of the taken slurry from 3 discharge valves at three impeller speeds *90, 120* and *150rpm* are illustrated in Fig. 2.The results shown in figure 1 are for impeller angle of 0^o; with two impellers and four baffles mount. The Reynolds number is about *211000, 281000* and *351000* at the impeller speeds of *90, 120* and 150rpm respectively. A tangible difference between the particle content of discharges P_1, $P_2$and P_3 is observed at the shaft speed of *90rpm* which is a sign of non-homogenous slurry in main body of mixer. By increasing the speed to *120rpm* the homogeneity tends to be better and the shaft speed of *150rpm* gives appropriate and homogenous slurry in form of nearlyclose value of particle content from three discharge positions.

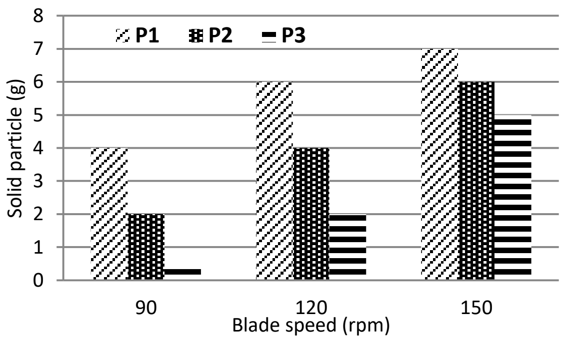

Figure 2. Variation of the solid particle contents at the different positions at three blade speeds

To better illustrate the effect of impeller speed on mixer performance, the variation of particle content by increasing the impeller speed is separately for each valve shown in Fig.3. Vertical axis is the ratio of particle content at the speeds *90, 120* and *150rpm* to the particle content at the speed of *90rpm*. However, as illustrated, by increasing the speed from 90 to 120 rpm the particle content of all three discharge valve increased but there are different graph behaviors. The increment of particle content of P_3 discharge by increasing the impeller speed is evidently higher than the increment for$P_1$and P_2. The particle content of P_3 at the speed of *150rpm* is about *10* times of its content at the speed of *90rpm*.The increment of impeller speed pushes the particles up and increases the particle content from the P_3 discharge valve.

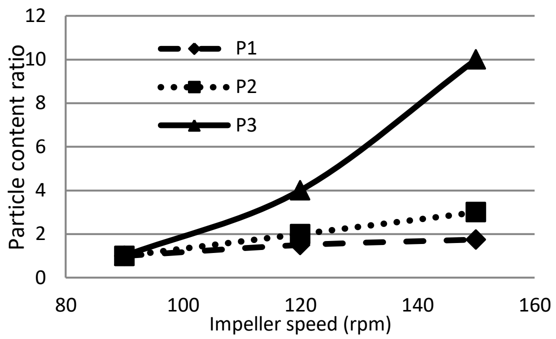

Figure 3. dimensionless Increment of particle content of three discharge positions of mixer by increasing the impeller speed

One of the important parameters which influences the mixer performance is the impeller angle [12]. The effect of impeller angle on the mixing homogeneity can be seen in Fig. 4. The impeller speed is *120rpm* and there are four baffles and two impellers.The zero degree impeller angle behaves like a vertical moving wall pushing the local current which influences the little portion of slurry. Many parts of slurry are not influenced by the impeller-induced current. This means that there will be non-homogeneous current and different particle contents will be achieved from three discharge valves. At the impeller angle of 15^o and 30^o the conditions tend to be better. The impeller angle of 45^o gives the appropriate mixing conditions in form of homogenous slurry in mixer body. The impeller angle of 45^o provides the upward currents in mixer and increases the particle content in P_3 discharge valve.

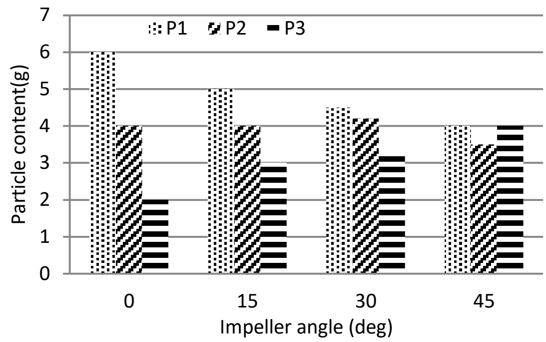

Figure 4. Particle contents at the different impeller angles

Another parameter which has an undeniable influence on the mixer performance is the number of impeller sets on the main shaft. In case of one impeller set at the bottom end of the main shaft, only the slurry around it is influenced. In this case, there is significant content of particles in the P_1 discharge valve and almost no particles inP_2 and P_3. However, by mounting another impeller set *15cm* above the first impeller set on main shaft, a significant improvement in mixing performance is observed as illustrated in Fig. 5. The impeller angle is 30^o, the speed is 120 rpm with four baffles.

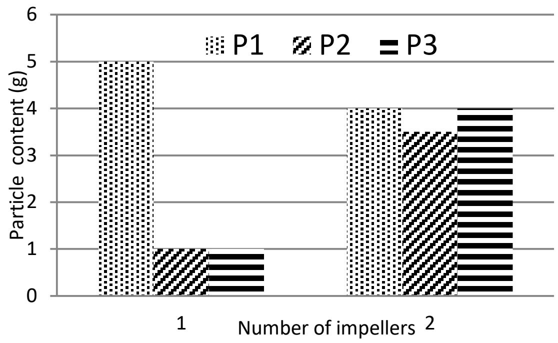

Figure 5. Particle contents discharged from P1, P2 and P3 valves with one and two baffles

Opening the discharge valves at the different times after the start of shaft rotation determines the required time to achieve homogeneity of slurry. It was performed by taking samples from three discharge valves after *60, 120* and *180* seconds after the start of mixer shaft rotation. As illustrated in Fig. 6, the homogeneity observed after 120 seconds.

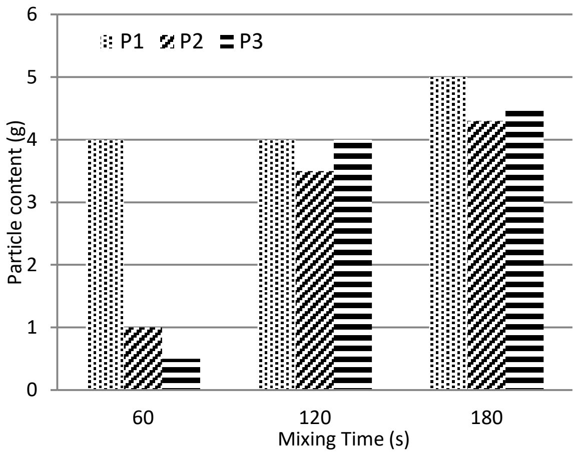

Figure 6. Particle content from discharge valves at the different times after start

The existence of baffle at the interior wall of mixer body has a vital role in mixing performance. As illustrated in Fig. 7, in case of without baffle, the non-homogeneity is clear. By mounting four baffles in mixer wall the significant improvement in mixing performance is observe and clearly homogenous flow is provided in mixer.

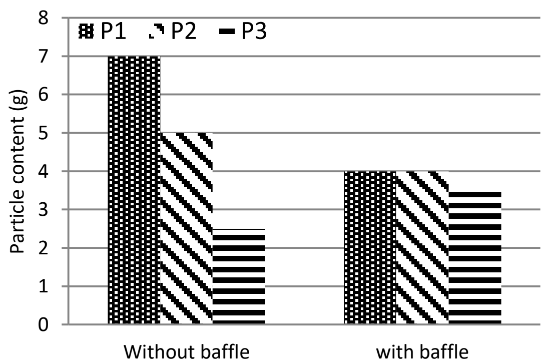

Figure 7. Effect of baffle on mixer performance

5. Conclusions

The mixer performance is important in overall rate of production in mineral complexes. The effect of influencing parameters would help the designers to have appropriate parameter selection for optimal performance. In the present work, a laboratory mixer was designed in which the performance influencing parameters including main shaft speed, number of impeller sets, impeller angle and interior baffles could be altered. Results showed that the low shaft speed provides non-homogenous mixing and by increasing the speed, the improvement was significant however, the more speed increment did not result in higher improvement. The zero impeller angle provided a non-appropriate slurry mix and changing the angle to 30^o or 45^o gavebetter results. The baffles had undeniable positive role in providinghomogenous mixing slurry in mixer. Two impeller sets instead of single impeller set provided turbulent flow in all positions in main body of mixer and helped to provide homogenous flow.

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