Imam Khomeini International University
Vol. 7, No. 1, Spring 2022, pp. 30-34

نشریه مهندسی منابع معدنی
Journal of Mineral Resources Engineering
(JMRE)

DOI: 10.30479/JMRE.2021.13751.1427

Research Paper

Investigation of Relationship Between Residence Time Distribution and Size Distribution of Solid Particles in Tank Leaching Modelling

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(Received: 14 Jul. 2020, Accepted: 05 Oct. 2020)

Abstract: While many studies have confirmed the effect of particle size distribution on the residence time in a reactor, the most employed models of continuous tank leaching process consider the residence time and particle size distributions as independent variables. In minerals processing field, no systematic study has been conducted on this issue yet. In this research, the relationship between the particles size and their residence time in a mixing tank has been studied. An empirical method for the determination of the residence time distribution function based on the inflow particles size distribution has been proposed. The relationship between the average size of one size fraction of particles and its residence time was obtained by mean residence time and parameter (an empirical coefficient). Results showed that increasing the particle sizes resulted in a 50% increase in the mean residence time while decreased from 0.95 to 0.3. Using the evaluated values of the residence time distribution function of the inflow stream was determined. Including this function in the segregated flow model, the effect of the variations of the value on the leaching performance was evaluated. Results showed that smaller values of resulted in higher conversion value.

Keywords: Leaching, Residence time distribution, Particle size distribution, Conversion.

INTRODUCTION

Residence time and particles size distribution are two important characteristics of the continuous leaching systems which could be used as the input data for some leaching models such as segregated flow model presented in Equation 1 [1]:

$$1-X_B=\int_0^{\infty}\int_0^{\infty}[1-X_B(L,t)]f(L)E(t)dLdt \tag{1}$$

where:

$f(L)$: particle size distribution function

$E(t)$: residence time distribution function

$1-X_B$ is the unreacted part of the particles in the reactor.

Many researchers have studied the relationship between particle size and residence time in a chemical reactor. Oldeshuo [2] showed that when pulp stream containing particles with a specified size distribution is fed to continuous reactor, the distribution of sizes in the reactor is not the same as the feed. Also Murphy [3] investigated the relationship between particle size and its residence time in a reactor. However, he could not predict the variation of the residence time distribution by changing the feed particles size distribution.

While many studies have confirmed the effect of particle size distribution on the residence time in a reactor, the most employed models of continuous tank leaching process consider the residence time and particle size distributions as the independent variables. In this study, the relationship between the particles size and their residence time in a mixing tank has been studied. An empirical method for the determination of the residence time distribution function based on the inflow particles size distribution has been proposed.

METHODS

Tracer experiments were done by zinc powder using the wash-out method. Determined amount of the tracer was injected to a 100 L agitating reactor. Sampling was done from the outlet stream. The experimental average residence time ($\tau_{\exp}$) and residence time distribution ($E(t)_{\exp}$) were calculated using Equations 2 and 3 [4]:

$$\tau_{\exp}=\frac{\int_0^\infty tC_{t\exp}\,dt}{\int_0^\infty C_{t\exp}\,dt}\cong\frac{\sum_i t_iC_{t\exp}\,\Delta t_i}{\sum_i t_i\,\Delta t_i} \tag{2}$$

$$E(t)_{\exp}=\frac{C_{t\exp}}{\int_0^\infty C_{t\exp}dt} \tag{3}$$

where:

$C_{t\exp}$ is the tracer concentration at time t.

Three sets of experiments were run. Firstly the mean residence time of each size fraction of the zinc powder was measured. Secondly, the main sample (mix of fractions) was fed to the reactor and the outlet stream was sampled in three time intervals to analyze the particles size distribution. Finally, the possibility of the prediction of the mean residence time of a synthetized feed and the deviation from the ideal mixing was evaluated. The parameter α is the slope of a diagram horizontal axes is ($\frac{t}{\tau}$) and its vertical axes is $Ln\left(\frac{C_{out}}{C_0}\right)$ [3], Where C_{out} is the outlet solid concentration and C_0 is the initial concentration of solid. The value of τ is theoretical mean residence time of liquid in the reactor.

The relationship between output solid concentration, α and τ can be written as Equation 4.

$$C_{out}=C_0\exp\left(\frac{-\alpha t}{\tau}\right) \tag{4}$$

For predicting the value of α for a sample with distribution of particle sizes (α_m), the Equation 5 was used:

$$\alpha_m = \frac{\sum_{i=1}^{n} \alpha_i m_i}{\sum_{i=1}^{n} m_i} \qquad (5)$$

where:

α_i: related to the size fraction i

m_i is the remained mass fraction on the sieve i.

FINDINGS AND ARGUMENT

Table 1 showes the results of the first set of the experiments using various size fractions. According to the results, the mean residence time is larger for coarse particles. Increaseing the particles size from -38 micron to +125 -150 micron resulted in a 50% increase in the mean residence time.

Table 1. Mean residence time for different size fractions

Size range (μ)	Mean residence time (min)
-38	59.1
+38-53	71.70
+53-75	74.63
+75-90	85.86
+90-106	83.73
+106-125	88.88
+125-150	92.93
Non classified sample	74.00

Figure 1 showes the results of the second set of the experiments. As could be seen, the size distribution curve has moved to right for longer times. In other words, coarse particles have larger residence time.

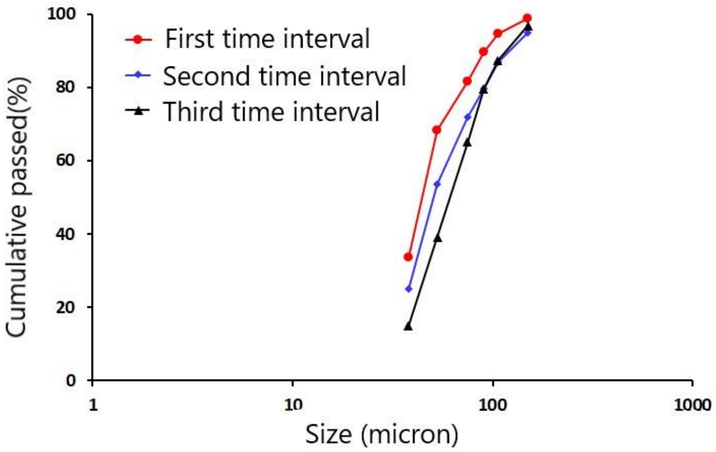
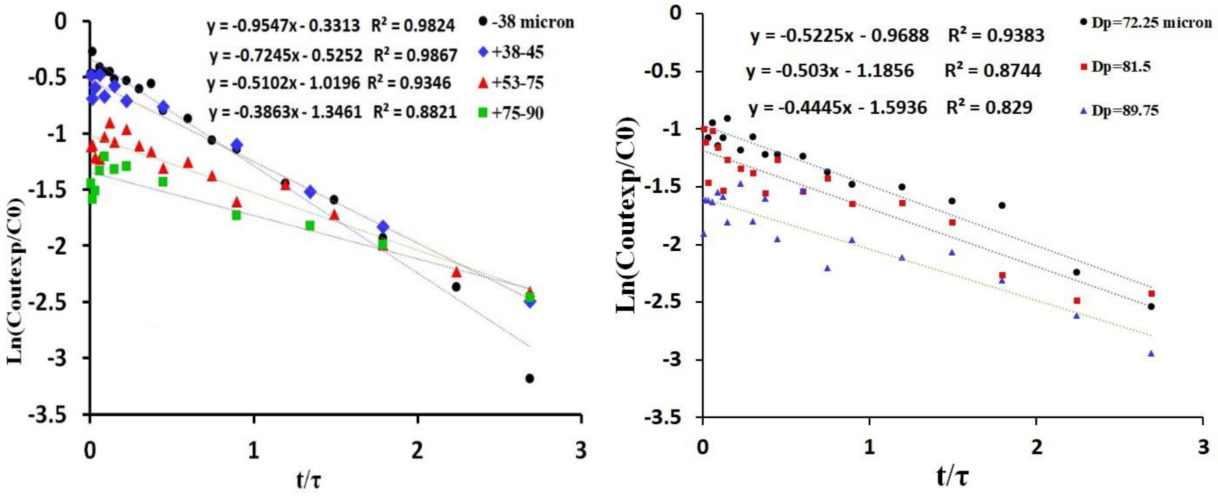


Figure 1. Size distribution of reactor output at 3 different time intervals

Figure 2 shows the results of the third set of experiments. The value of α for each size fraction was evaluated and is shown in Figure 2A. Then α_m for a mix of various size fractions was obtained using the data from Figure 2B and Equation 5. Table 2 compares the results.



A **B**

Figure 2. The values of α with respect to **A:** particle size and **B:** mix of size fractions

Table 1. The experimental and predicted α for various samples

Size (μ)	Experimental α	Predicted α
D_p = 72.25	0.59	0.62
D_p = 81.50	0.57	0.55
D_p = 89.75	0.51	0.53
-38	0.95	0.97
+38-53	0.72	0.68
+53-75	0.51	0.53
+75-90	0.39	0.42
+90-106	0.34	0.36
+106-125	0.32	0.32
+125-150	0.3	0.33

With including this data in the segregated flow model, the effect of the variations of the α value on the leaching performance was evaluated. Results showed that smaller values of α results in higher conversion value.

CONCLUSIONS

In this paper, the relationship between particles size and their residence time in a mixing tank was studied. An empirical method for the determination of the residence time distribution function based on the inflow particles size distribution was proposed. The relationship between the average size of one size fraction of particles and its residence time was obtained by mean residence time and parameter α (an empirical coefficient). Using the evaluated values of α for each size fraction, the residence time distribution function of the inflow stream (α_m) was predicted and compared with the values of α_m obtained from the experimental data. Results showed that the value of α_m for the feeds with various size distributions could be evaluated and used in the leaching model.

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