

# Study on Pulp Grade of Iron Ore Concentrate by Monte Carlo

Jie Xu, Jiawen Fan, Changming Wang, Yujie Qiao

Chengdu University of Technology, Chengdu, China

Email: 1461997902@qq.com

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## Abstract

When energy distribution X-ray fluorescence analysis method (EDXRF) is used to measure the pulp grade of iron concentrate, the parameters such as the location of radioactive source, detector, the particle size of the iron concentrate, and the concentration of the iron concentrate slurry, etc. have a greater influence on the measurement results. In order to more accurately measure the grade of iron ore pulp, the Monte Carlo method was used to study the different pulp grades of samples of the iron ore concentrate under different conditions such as the location of radioactive source, detector, the particle size of the iron concentrate, and the concentration of the iron concentrate slurry. By studying the relationship between different influencing factors and counting rate, the error of the actual measurement time and the pulp grade of iron concentrate can be reduced. The pulp grade of iron concentrate is improved, and the *in-situ* EDXRF analysis of iron concentrate slurry is more in line with the actual grade.

## Keywords

Pulp Grade, Particle Size, Monte Carlo, EDXRF

## 1. Introduction

The grade of pulp is an important indicator in the process of beneficiation. *In-situ* EDXRF [1] [2] [3] technology is one of the important technical means to improve the stability of pulp quality. In 2000, Panzhihua Iron and Steel Plant (hereinafter referred to as Pangang) adopted an analysis system based on *in-situ* EDXRF technology in 2000 [4], which increased from  $52.50\% \pm 1.00\%$  to  $54.50\% \pm 0.50\%$  in the analysis [5]. However, during the measurement process, it was found that the parameters such as the position of the radioactive source, the position of the detector, the particle size of the iron concentrate, and the concen-

tration of the iron concentrate slurry have a greater influence on the measurement results. In order to make the measurement more accurate, the Monte Carlo method [6] was used to study the different pulp grade samples of the iron ore concentrate under different conditions such as the position of the radioactive source, the position of the detector, the particle size of the iron concentrate, and the concentration of the iron concentrate pulp, etc. So as to obtain the counting rate of pulp sample under different conditions, and then through the analysis of the counting rate, to achieve the purpose of accurate determination of pulp grade of iron concentrate.

## 2. Simulation Model

The simulation model is shown in **Figure 1**. The container size is  $10 \times 10 \times 10 \text{ cm}^3$ , and the detector is a gold-silicon barrier detector. The iron concentrate ore pulp after magnetic separation was selected as the simulation object. Its parameters are as follows:

1) The grade of iron fine powder is 64.5% - 66.5%, and its main component is  $\text{Fe}_3\text{O}_4$ , the impurity is mainly quartz, and the density is  $2.2 \text{ g/cm}^3$  -  $2.4 \text{ g/cm}^3$  when the moisture is 7%. If the main component of iron concentrate is  $\text{Fe}_3\text{O}_4$  with 65% and  $\text{SiO}_2$  with 35% impurities, the density is  $2.3 \text{ g/cm}^3$ .

2) Production capacity: The concentrator produces about 16,000 tons of iron ore concentrate per day.

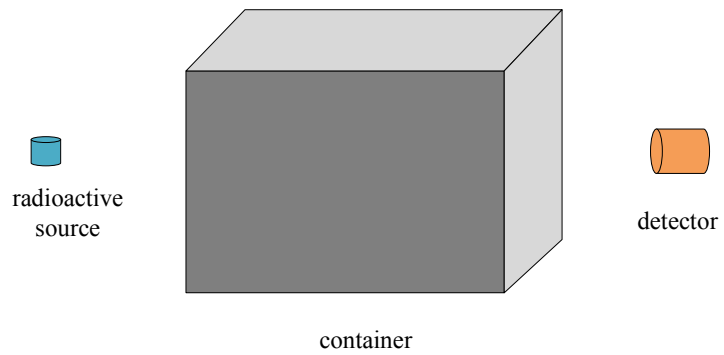
The radioactive source used  $^{238}\text{Pu}$  (5mCi) photon source. Normalization is used in the simulation to facilitate data processing.

## 3. Analysis of Simulation Results

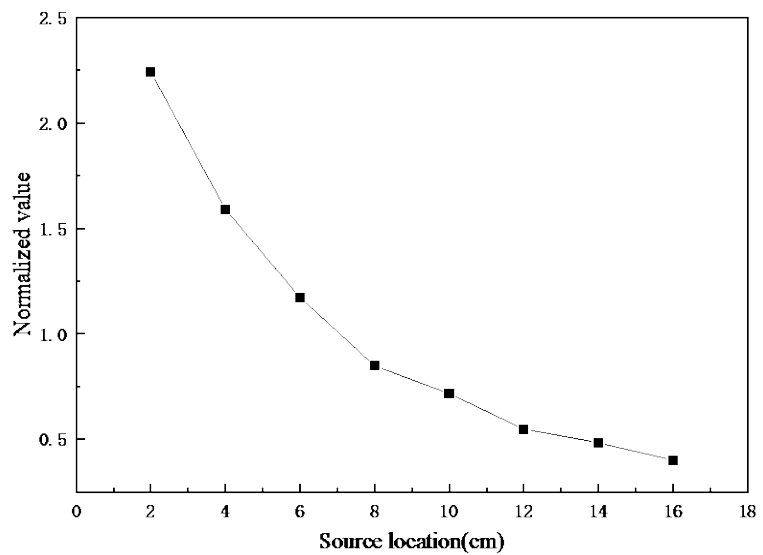
In order to observe the changes of the results intuitively, the simulation results are normalized. In the simulation, the density of the iron ore concentrate is  $2.3 \text{ g/cm}^3$ , and the volume of water is  $500 \text{ cm}^3$ , then the density of the sample is  $1.65 \text{ g/cm}^3$ .

### 3.1. The Effect of Radioactive Source Location on Results

In the actual measurement, different source positions have different measurement results. In order to maximize the measurement efficiency, the relationship between the different distances of the radiation source from the sample and the results is simulated. The change curve of the normalized value of the source position is shown in **Figure 2**. The results show that the influence of the source location on the measurement results accords with the law of exponential decay. On the one hand, the attenuation of the radiation emitted by the radioactive source in the air follows the law of exponential decay. On the other hand, the sample is assumed to be uniformly distributed. When the source distance is 7 cm, the normalized value is 1, and the detector count is optimized. When the distance exceeds and is lower than 7 cm, the detector count is obviously different. Therefore, in the actual operation process, the specified radiation source distance is 7 cm.



**Figure 1.** Simulation model.



**Figure 2.** The effect of source location on the count rate.

### 3.2. The Effect of Detector Location on Results

In the actual measurement, different detector distances have different measurement results. In order to maximize the measurement efficiency, the effects of different detector distances on the measurement results are simulated. Considering the influence of the simulate source distance on the measurement result, when the source distance is 7 cm, the detection efficiency reaches the optimal effect, so the variable of the control source is 7 cm. Detector position-normalized value changes as shown in **Figure 3**. The results show that the overall effect of the detector on the counting rate is small, and the counting rate decreases linearly with the detector distance before 14 mm.

### 3.3. The Effect of Iron Concentrate Particle Size on Results

The source distance is 5 cm and the detector distance is 12 mm. Considering that the particle size of iron concentrate is more difficult for Monte Carlo simulation, it is assumed that the particle size of each sample is uniform, and the particle size of the iron concentrate is changed by the proportion of air. Assuming

that the volume of iron concentrate is  $V_{\text{iron}}$ , the volume of air is  $V_{\text{air}}$ , the volume of water is  $V_{\text{water}}$ , the volume of container is  $V$ , and the iron concentrate is insoluble in water, and without considering the presence of air, the following formula exists:

$$V = V_{\text{iron}} + V_{\text{water}} \tag{3-1}$$

when air is present, the density of air is  $\rho_{\text{air}} : 1.29 \times 10^{-3} \text{ g/cm}^3$  (under standard conditions), and the density of iron concentrate is  $\rho_{\text{iron}}$ . Assuming that the percentage of air in the iron concentrate is  $k$ , the content of iron concentrate is  $1 - k$ , and the density of the iron concentrate containing air is:

$$\rho_{\text{air-containing-iron}} = \rho_{\text{iron}} \cdot (1 - k) + \rho_{\text{air}} \cdot k \tag{3-2}$$

The volume of the above iron concentrate is  $V_{\text{iron}}$ . After adding air, it is assumed that the volume of  $V_{\text{iron}}$  remains the same but the density becomes smaller. It is  $\rho_{\text{air-containing-iron}}$ .

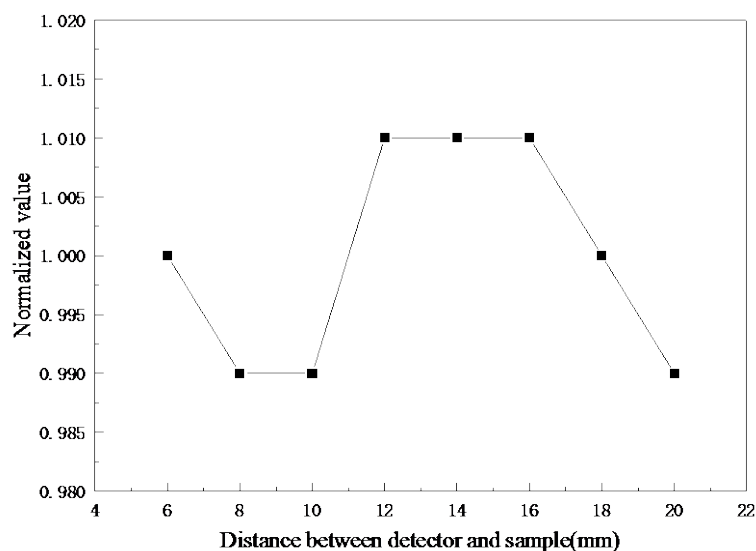
If the volume of air-containing iron concentrate is  $V_{\text{air-containing-air}} = V - V_{\text{water}}$ , the overall density of the sample is:

$$\rho_{\text{sample}} = \rho_{\text{air-containing-iron}} \cdot \frac{V_{\text{air-containing-iron}}}{V_{\text{sample}}} + \rho_{\text{water}} \cdot \frac{V_{\text{water}}}{V_{\text{sample}}} \tag{3-3}$$

Assuming that the proportion of air in the iron concentrate is 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%.  $V$  is  $1000 \text{ cm}^3$ ,  $V_{\text{air-containing-iron}}$  is  $500 \text{ cm}^3$ , for the sample with 1% air, the density is:

$$\begin{aligned} \rho_{\text{air-containing-iron}} &= 2.3 \text{ g/cm}^3 \times (1 - 0.01) + 1.29 \times 10^{-3} \text{ g/cm}^3 \times 0.01 = 2.277 \text{ g/cm}^3 \\ \rho_{\text{sample}} &= 2.277 \text{ g/cm}^3 \times \frac{1}{2} + 1 \text{ g/cm}^3 \times \frac{1}{2} = 1.6385 \text{ g/cm}^3 \end{aligned} \tag{3-4}$$

Similarly, according to the above formula, the sample density of different air proportions is obtained, as shown in **Table 1** below.



**Figure 3.** The effect of detector distance on counting rate.

**Table 1.** Sample density of different air proportions.

Sample volume (cm <sup>3</sup> ) 1000	Volume of iron powder (cm <sup>3</sup> ) 500	Volume of water (cm <sup>3</sup> ) 500
Air proportions (%)	Density of air-containing-iron (g/cm <sup>3</sup> )	Sample density (g/cm <sup>3</sup> )
1	2.277	1.6385
2	2.254	1.627
3	2.231	1.6155
4	2.208	1.604
5	2.185	1.5925
6	2.162	1.581
7	2.139	1.5695
8	2.116	1.558
9	2.093	1.5465
10	2.07	1.535

**Figure 4** shows the variation curve of the normalized value with the particle size. When the particle size is 7%, the normalized value of the count rate tends to be flat. For iron concentrates with a particle size of 7%, the size of the iron concentrate cannot be distinguished by the counting rate. Before the particle size is 7%, the particle size shows a linear growth trend with the change of the normalized value.

### 3.4. The Effect of Iron Concentrate Pulp Concentration on Results

Because the concentration plant has more than 10,000 tons of beneficiation tasks every day, the influence of ore quantity and ball mill and other factors makes the concentration of the sample different, so the simulated sample concentration is of great significance to the actual operation. In the simulation process, it is assumed that the iron concentrate has no air and the volume of water is a variable, then  $V_{iron} = V - V_{water}$ , the density of the simulated sample:

$$\rho_{sample} = \rho_{iron} \cdot \frac{V_{iron}}{V} + \rho_{water} \cdot \frac{V_{water}}{V}$$
. The source distance is 6 cm and the detector distance is 12 mm.

The volume of V is 1000 cm<sup>3</sup>, and the volume of water is assumed to be 10%, 15%, 20%, 25%, 30%, 35%, 40%, 50%, 60%, and 70%. The density of the slurry with different concentrations is shown in **Table 2** below.

The volume of different water represents the concentration of slurry under different conditions, and the experiment simulates the counting rate of slurry under different source locations. **Figure 5** shows the change curve of the count rate of different iron concentrate slurry concentration. Before the water volume is 40%, the detector count rate fluctuates less, and after the water volume is 40%, the count rate suddenly increases. When the volume of water increases, iron concentrate pulp concentration decreases, and the count rate measured by the

detector is gradually increased at this time. The increase is mainly due to the reduction of water, the penetration ability of the particles is enhanced, which leads to an increase in the count.

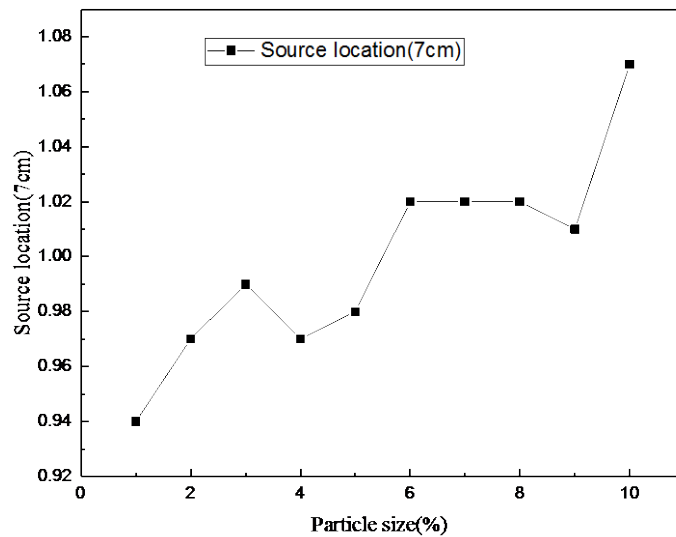


Figure 4. The effect of particle size on counting rate.

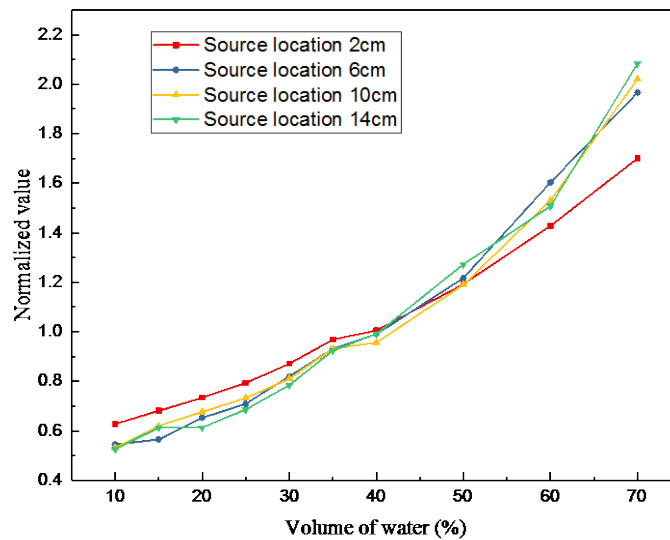


Figure 5. Comparison of samples of different concentrations of slurry.

Table 2. Sample density of different volumes of water.

Water volume ratio (%)	Sample density (g/cm <sup>3</sup> )	Water volume ratio (%)	Sample density (g/cm <sup>3</sup> )
10	2.17	35	1.845
15	2.105	40	1.78
20	2.04	50	1.65
25	1.975	60	1.52
30	1.91	70	1.39

## 4. Conclusion

It is feasible to analyze iron concentrate pulp by the Monte Carlo method, and the grade of iron concentrate pulp can be graded well. The evaluation model requires less subjective data, the method is simple and easy to implement, which is convenient to realize the scientific optimization of improving the grade of iron concentrate pulp by computer simulation. The selection of various evaluation factors, the determination of the evaluation criteria and relative importance can be revised according to the actual pulp level.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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