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The Study of Sabzevar Chromite Preconcentration with Advanced ore Sorting Techniques

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ABSTRACT: Ore sorting Proposed proposed as an important step in the plant of chromite processing and the reported results in this field bounded. By using this method, substantial energy savings and increasing in production take place in the comminution stage. Ore sorting is done in three stages including entrance to the primary crusher, the output of the primary crusher and entrance to gravity separation which the primary crusher output stage has more favorable results. In this study, for separation with designed device, the identification and characterization of chromite ore is performed. Firstly, minerals imaged with three-dimensional scanner and by creating a cloud of points, the volume of chromite ore achieved and the equivalent diameter of stone pieces are determined. Then ores placed on the device's conveyor and the mass of each pieces are measured by load cell sensor and the density of minerals determined. Finally, according to the size and specified conditions of each fraction, the grade of stone pieces determined and according to the limit specified for the grade of the ore driven to concentrate or tailings. The results showed that Sabzevar chromite with a grade of 26.16 percent with gaunge minerals after ore sorting, produces an initial concentrate with 33.11 and 83.92 percent of the grade and recovery respectively.

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1- Introduction

The energy required to extract valuable metal from an ore and provide concentrate is a significant part of metal production cost. On average, about 44 percent of electricity consumption in the mining industry is devoted to comminution and grinding [1]. In the processing cycle, the dimming operation consumes about 150 kWh of electrical energy individually. The energy required during the comminution and grinding process increases with the invers radical of the product according to the Bond equation [2]. In most metal industries (especially refractory metals), grinding accounts for about 60% of total energy consumption. Reducing the cutoff grade and increasing energy consumption makes the production of metal from ore costly [3]. Removing large amounts of waste before any additional investment costs and operating costs are in the agenda of this approach [4]. In the past centuries, rocks were sort by hand on rocks that were known to be apparent. [5].

In 2011, Bergman categorized a variety of sensors that are used today in sensor-based classifications to optical sensors, near infrared, X-ray transmissions, and electromagnetism. Also, technological improvements in sensors have been taken into account in increasing the capacity of automatic ore sorting equipment and discovering sensor-based classification methods in the mineral industry [6]. Dalm et al. (2014) evaluated the use of automatic ore sorting based on sensor systems and suggested that by eliminating gang minerals, they would reduce the processing costs of large ores [7].

Lizard et al. (2014) found that X-ray transmission, which analyzes the energy transmitted from within a sample, is useful in the classification of rocks. When X-rays pass through a material, they are absorbed, reflected or transmitted; the amount of X-rays transferred from the sample strongly depends on the atomic density of the material [8]. Ballantin et al., in 2015, showed that the capacity of a classifier increases with increasing stone size [9].

In 2015, Steinrand showed that identifying the right spot in a process for the use of rocky devices is very important. Due to the fact that these devices remove waste products, they should be installed at the earliest possible points in order to minimize the cost of energy, chemicals, and capacity, since waste is removed in any other way from the circuit [10].

2- Methodology

Mineral samples were tested from the Sabzevar mine located in South Khorasan province and from the jaw crusher output (primary crusher). The conveyor belt is 40 cm in width, manufactured in Iran by Sahand Co. with Strackchar placed in the South Korean inverter's by LG.

Load cell sensors were used were made in Germany. Also load cell modules and sensors (1-0 kg), analog inputs and Plc data, HMS 4.3 inch kinco, finder24 VDC relay, pneumatic

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valve Air TAK valve, 35/53 power switch, LS fuse, Dugut, Rails, Wire and Rack it was prepared. XRF studies were performed by the Oxford machine (FD2000 constructed in England) and XRD studies by the STOE device (Stidy-mp code and the construction of Germany), the results of XRF and XRD analyzes and compounds of tested minerals are shown in Tables 1 and 2 and Figure 1.

Table 1. The amount of elements in the chemical composition of chromite

Compound	Percent
Cr_2O_3	26.01
FeO	15.07
SiO_2	26.31
Al_2O_3	16.49
MgO	7.89
Others	8.23
sum	100

Table 2. The main minerals found in the chromite sample

Mineral	Formula	Percent
Chromite	$(Fe,Mg)Cr_2O_4$	33.9
Kaolinite	$Al_2Si_2O_5(OH)_4$	27.93
Hematite	Fe_2O_3	15.07
Quartz	SiO_2	14.87
sum	-	100

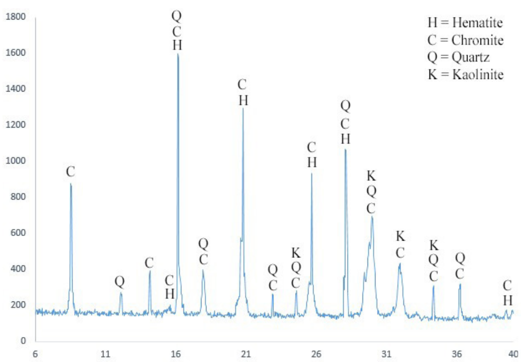

Figure 1. XRD Analysis of the sample

The mineral density was also calculated. Mineral samples were weighed by a digital scale (OHUS OH-PA214C model) and then crushedthen crushed by a jaw crusher (IKH.B1 model and made in Iran). 50% of the crushed sample was graded using a sieve series described below. The results obtained from sieve analysis were categorized and coded in each step in order of weighting and for subsequent experiments. In the next stage and in different fractions, the mineral was first processed by a 3D scanner (nub3d-made in Germany) and draw mineral clouds. The minerals volume was extracted using the CAD program attached to the processor. After this step, the PLC system assigned a code to each of the mineral and record its volume. Then the minerals crossed the conveyor belt in line, and each mass was determined.

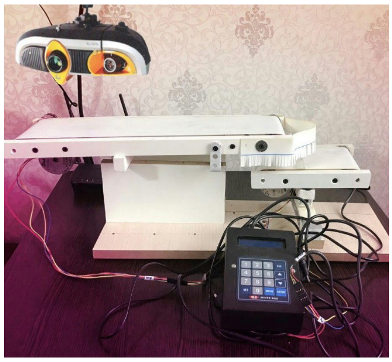

Figure 2. A view of the device and its various parts

At first, the jaw crusher product was classified in different fractions, and according to Figure. 2, after calculating the volume, a three-dimensional scanner was used to determine the diameter of each fraction. Then, in each particle fraction, different densities were analyzed and the percentage of each constituent elements was determined.

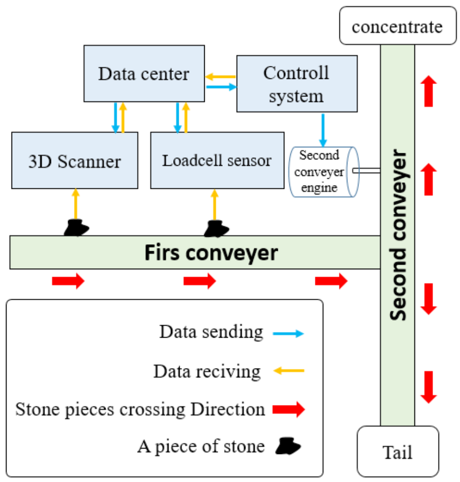

Figure 3. A schematic of how the device works and how it interacts with different parts

Then, by useingusing the calculated percentages in each fraction, the relationship between chromite grade and chromite density was obtained and stored in the database of the device and according to it, the percentages of each chromite ore was determined. Then, by DX10 software, the normality of the samples was verified and the data for each section was analyzed and finally, the mathematical model for each fraction was calculated separately and based on the obtained relationship for each fraction, the content of each stone piece was determined and considering that the grade higher 20 was considered as concentrate and lower 20 as tailings, the sample was divided into waste and concentrate parts, this grade was chosen as the default and performed by experiments. It is possible to determine the best separation to achieve the best grade and recovery.

3- Results and Discussion and Results

Considering the importance of segmentation accuracy in this method, in order to achieve this goal, we need to perform an analysis on all particles of a fraction. Since the statistical population is very large, therefore, the DX10 software was used to reduce the number of samples, and from each fraction, 10 samples were selected.

Thus, for each fraction of crusher output a model obtained that, the amount of chromite content can be determined using the sample volume and weight. These equations are stored as separation equations in the data base of the device. In this case, by inserting a new sample as feed, the control system, according to the equations stored in the device's databases, is compared about the location of the sample with minimum grade of concentrate and the maximum waste grade. The equations for each fraction and their effect boundaries are given in Table 3.

Table 3. The main minerals found in the chromite sample

fractions	Separation efficiency	Recovery (%)	Concentration grade (%)
1	40.36	83.92	33.11
2	38.21	84.02	31.15
3	36.39	94.37	37.45
4	34.27	79.88	27.82
5	30.57	58.33	30.88
6	23.82	93.29	31.25

For validation of the model, from each fraction, 10 samples were selected once by a percentile and then again determined using a device analysis. In order to divide the samples into two parts, waste and concentrate. 20 grade were stored as default cutoff in the device memory. In this case, the components of grade 20 and above will be driven by the second conveyor to the concentrate section and less than 20 to the waste section.

Table 4. Analysis of Variance Table

Source	Sum of Squares	df	Mean Square	F Value	p Value
Model	1994.03	2	997.31	43.51	0.0001
Mass	8.23	1	8.23	0.36	0.5678
Volume	16.29	1	16.29	0.71	0.4271
Residual	160.45	7	22.92		
Cor Total	2155.07	9			

Finally, to evaluate the separation efficiency of each fraction, Equation 1 was used.

$$SE = \frac{C.m.(c-f)}{F.f.(m-f)} \quad (1)$$

where in:
SE: Separation efficiency
F: feed weight (g)
C: Weight Concentrate (g)
f: feed grade (%)
c: concentrate grade (%)
M: The maximum possible degree of an element in the mineral%

Using the above formula, the separation capability for all fractions was calculated and the results are as follows.

4- Conclusions

According to the obtained results of the analyzes, the separation model was determined for each fraction and finally by using the obtained model, tests were carried out with different densities in each dimensional range and according to the results, obtained in the accuracy of the model was decided. Finally, the separetionseparation efficiency was used to select the best fraction.

There is a direct relationship between the separation efficiency and the dimensions of stone pieces in such a way that the dimensions increase, the separation efficiency is increased, while the use of mechanical tools for conducting rocks reduces the efficiency of the machine for small-sized rocks. While the use of the second conveyor also improves performance in smaller rock fragments.

Table 5. Separation capability of fractions

Modeling relationship for chromite estimation	Upper and lower limit of volume	Upper and lower limit of weight
$Cr(\%)=46.447\rho-177.87$	$27 \le v \le 65$	$121 \le m \le 289$
$Cr(\%)=56.253\rho-222.06$	$9 \le v \le 27$	$43 \le m \le 121$
$Cr(\%)=63.429\rho-255.39$	$3.59 \le v \le 9$	$15.86 \le m \le 43$
$Cr(\%)=53.753\rho-212.8$	$1.02 \le v \le 3.59$	$4.52 \le m \le 15.86$
$Cr(\%)=-62.873\rho^2-619.21\rho-1487$	$0.45 \le v \le 1.02$	$1.98 \le m \le 4.52$
$Cr(\%)=-27.959\rho^2-297.93\rho-741.7$	$0.16 \le v \le 0.45$	$0.69 \le m \le 1.98$

Utilizing this technique, along with other mining methods, such as image processing and the use of infrared waves, which are often used surface as a criterion of separation, can be very useful.

The results showed that the chromite of Sabzevar with 26.16% Cr and gang minerals after ore sorting, the grade of chromite become 33.11% with recovery of 83.92%.

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