Method for determining the concentration of ferrosilicon in suspension for dense medium separation process

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Abstract. In Russia, dumps of diamond-bearing deposits are characterized by a high content of secondary modified non-magnetic kimberlite minerals of fine size classes (-0.05 mm), the presence of which negatively affects their processing by methods of dense media separation. In the present work, the possibility of determining the concentration of ferrosilicon in a continuous process of dense medium separation by measuring the magnetic properties of a suspension was investigated. As a result of experimental studies, the dependences of volumetric concentration of ferrosilicon on the magnetic moment of various grades were obtained, which made it possible to measure the concentration of ferrosilicon in a continuous process of dense media separation by measuring the magnetic properties of the suspension.

1. Introduction

At present, the enterprises of the mining, metallurgical, chemical and other industries of the Russian Federation annually generate about 7 billion tons of waste. The country’s dumps have already accumulated about 80 billion tons of solid waste. The use of mining waste for additional extraction of minerals provides not only a significant technical and economic effect, but also reduces the environmental load on the territory, water bodies and air. In this regard, in Russian practice, for a number of years, there has been a tendency to reintroduce overburden and waste dumps into industrial processing. [1, 2].

In diamond fields, overburden rocks are disposed of using standard methods, and refinement tailings represent technogenic deposits that must be enrich in the future. The average granulometric composition of dumps is mainly represented by small size classes containing up to 50% of fine fractions (less 0.05 mm). In terms of mineral composition, the fraction of dumps –2+0.05 mm consists mainly of calcite and dolomite, and the fraction less 0.05 mm of serpentine and carbonate [3]. Based on the foregoing it is clear these dumps are characterized by a high content of secondary modified non-magnetic kimberlite minerals of fine size classes, the presence of which affects their processing [4].

The main methods of diamond extraction in world practice are X-ray separation and dense media separation (DMS) [5]. The process of enrichment in heavy suspensions consists in dividing the ore
material by the density of individual pieces in a gravitational or centrifugal field in a suspension that has an intermediate density between heavy and light fractions.

Heavy suspensions used in diamond enrichment processes are a mechanical suspension of fine particles of ferrosilicon (weighting agent) in water. In Russia, diamond extraction plants use mill ferrosilicon with a density of 6900 kg/m³ with a particle size distribution of 270D [6]. The modern equipment that provides the highest efficiency of dense medium separation is a dense medium cyclone.

The use of dense medium cyclones for enrichment of kimberlites is due to several advantages: high productivity, good separation characteristics of the device, a high concentration ratio [7]. The main disadvantage of the DMS process is a significant deterioration in the separation characteristics during long-term operation of the working suspension, which is due to corrosion of ferrosilicon and clogging of the working suspension with non-magnetic rock slurries. At the same time, there is a significant difference in the densities of the suspension, separated from the light and heavy fractions, reaching 1.2 t/m³, which is unacceptable for the effective conduct of the process of dense medium separation in cyclones [8-11].

Based on the foregoing, the determination of the volumetric concentration of ferrosilicon in the working suspension of a continuous process of dense medium separation is a very urgent task.

2. Materials and methods
In this paper, the possibility of determining the ferrosilicon concentration by measuring the magnetic properties of the suspension was investigated. Since the suppliers of ferrosilicon to diamond mining enterprises have changed quite often in recent years, 3 samples of crushed powder of ferrosilicon of various grades used for enrichment of diamond-bearing kimberlites were selected for the experiment (Figure 1).

Since ferrosilicon samples very often differ in size, the particle size distribution was determined. The granulometric composition of ferrosilicon samples were determined by a laser device for measuring particle size Fritsch Analysette 22 at the ICEMR RAS Analytical Center for the Study of Natural Substances (Figure 2).

By adding a different mass of ferrosilicon samples to a 17.8 cm³ cuvette, a series of suspension samples were obtained to study their magnetic properties. The variation in the volume concentration of ferrosilicon in the suspension was limited to 40-45%, since the denser suspension tends to structure and subsequent settle. Measurements of magnetic properties with different ferrosilicon content of different grades in the suspension were carried out in the Association of subjects of innovative activity in the mining industry «Innovative mining technologies» on the device «Ferrograph» (Figure 3) [12]. This device was used to determine the magnetic properties of iron-bearing ores, which consist mainly
of a mineral - magnetite. Since ferrosilicon is an alloy containing 73-77% iron, its magnetic properties are stronger than magnetite, therefore the use of the «Ferrograph» device is justified.

3. Results discussion
Mathematical processing of experimental data revealed a correlation between the volume concentration of ferrosilicon in the suspension and the magnetic moment of ferrosilicon particles of ferrosilicon samples from various manufacturers. The coefficient of determination for all samples was more than 99.8% (Figure 4).

By a reverse recalculation, the error of the method for determining the volumetric concentration of ferrosilicon in the process of dense medium separation (Table 1). As can be seen from table 1, the average absolute error was 0.4-0.59, and the average relative error was 1.81-2.26%.
Figure 4. The established dependences of the volume concentration of ferrosilicon of various grades on the magnetic moment.

Table 1. Calculation of the error in volumetric concentration of ferrosilicon from the revealed dependence.

| Ferrosilicon №1 | Experiment, % | Calculation, % | Error, % | Ferrosilicon №2 | Experiment, % | Calculation, % | Error, % | Ferrosilicon №3 | Experiment, % | Calculation, % | Error, % |
|-----------------|---------------|----------------|---------|-----------------|---------------|----------------|---------|-----------------|---------------|----------------|---------|
| 8.29            | 8.01          | 3.33           | 9.61    | 9.31            | 3.07          | 10.04          | 10.31   | 2.71            |
| 16.49           | 16.21         | 1.70           | 19.98   | 20.54           | 2.78          | 20.27          | 20.91   | 3.14            |
| 22.00           | 21.58         | 1.91           | 25.47   | 25.17           | 1.17          | 23.35          | 23.09   | 1.12            |
| 28.73           | 28.44         | 1.00           | 30.54   | 29.99           | 1.80          | 29.73          | 28.67   | 3.57            |
| 37.00           | 36.07         | 2.52           | 35.71   | 35.02           | 1.93          | 34.08          | 33.94   | 0.40            |
| 43.74           | 42.40         | 3.07           | 40.53   | 40.49           | 0.10          | 39.57          | 39.77   | 0.50            |
| average error, %| 2.26          | average error, %| 1.81    | average error, %| 1.91          |                 |         |                 |

4. Conclusions
Based on an analysis of the experimental results, the dependences between the volumetric concentration and the magnetic moment of the suspension was obtained for different grades of ferrosilicon.

The revealed dependences make it possible to determine the volumetric concentration of ferrosilicon in a continuous process of dense medium separation by measuring the magnetic properties of a suspension. The method makes it possible to determine the volumetric concentration of ferrosilicon with an average error of 2.26%.
References

[1] Чантурия В А, Козлов А П, Шадрунова И В, Ожогина Е Г 2014 Mining Industry 1 (113) pp 54
[2] Ivannikov A L, Kongar-Syuryun C, Rybak J, Tyulyaeva Y 2019 IOP Conf. Ser.: Earth Environ. Sci. 362(1) 012130
[3] Чантурия В А, Двойченкова Г П, Ковальчук О Е and Тимофеев А С 2014 Ores and metals 4 pp 67-73
[4] Двойченкова Г П, Стегницкий Ю Б, Ковальчук О Е, Тимофеев А С, Подкаменный Ю А 2016 Domestic geology 3 pp 57-66
[5] Verkhoturov M V 2006 Gravity methods of enrichment Textbook for universities (М.: MAXPress) 352 p
[6] Konnova N I and Kilin S V 2013 Theory and practice of modern separation in dense media Modeling the results of heavy-medium enrichment (Monograph - Krasnoyarsk: Sib. Feder. Univ.) 118 p
[7] Goryachev B E 2010 Technology of diamond-bearing ores processing (М: MISiS) 326 p
[8] Timofeev A S 2017 Mining informational and analytical bulletin 5 Special Issue 8 pp 3-11
[9] Williams R A and Kelsall G H 1992 Minerals Engineering 5 1 pp 57-77
[10] Timofeev A S, Dvoichenkova G P, Chernysheva E N, Popadin E G 2020 IOP Conf. Ser.: Earth Environ. Sci. 459 052096
[11] Chanturia V A, Godun K V, Zhelyabovsky Yu G, Goryachev B E 2015 Gornyi Zhurnal 3 pp 67-75
[12] Данилова А А and Ананьев П П 2011 Scientific Bulletin of Moscow State Mining University 6 pp 15-18