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Comparative analysis of the electroseparation results for the Aghires quartz sand in order to enrich it, using two types of active electrodes

C Plesa, R Morar and M L Vadan
Tehnical University of Cluj Napoca, Electrotechnics and Measurements Department, Baritiu str., no. 26, Cluj Napoca, Romania
E-mail: calin.plesa64@yahoo.com

Abstract. The paper presents the laboratory researches results regarding the Aghires quartz sand electroseparation, in two configurations for the ILES laboratory installation. The first studied configuration used a performant electrode (multi needles) from the endowment of the Intense Electric Field Laboratory from UTCN, while in the second analyzed configuration, the authors use an original multithreaded electrode, for which they have obtained an OSIM patent. The sand sample preparation for the electroseparation was made according to an original technological flow, proposed by the authors. The comparative analysis of the electroseparation results for the two configurations were made with the help of the statistical analysis program MODDE.5.

The comparative study reveals the fact that from the quantitative point of view the multi needles electrode type is preferred, while, in the case in which a superior enrichment is needed for the quartz sand, the multithreaded electrode is preferred. The enriched through electroseparation quartz sand, respectively with low content of Fe₂O₃, is an essential raw material in the porcelain industry.

1. Introduction
The Aghires quartz sand represents an important raw material in the processing porcelain industry [1]. One of the quality and aspect threatening factors for the porcelain objects, is the content of metallic oxides, especially of Fe₂O₃.

Considering, according to the physicochemical analysis of the sand samples taken from the dump, that its main components are SiO₂-94.73%; Fe₂O₃-0.34%; raising the SiO₂ content and decreasing the Fe₂O₃ content to minimum values was imposed.

Since the two essential elements of the quartz sand have different electrical conductivities, the authors proposed the use of the charging with electrical charge principle, through the corona phenomenon, of the granular mixture, followed by an electroseparation process [2], [3], after which a separation in three fractions is performed, namely: nonconductive fraction(NC)-SiO₂--; mixed fraction(M); conductive fraction(C) Fe₂O₃ and others.

The essential element of the electroseparation installation is considered to be the active electrode, fed in high voltage, producing a corona discharge field between the active electrode and the grounded rotating cylindrical electrode [4].
2. Constructive aspect presentation of the two types of electrodes

The multineedles electrode from Figure 1 has as active elements a number of 150 metallic needles with the length of 28mm and a section of 2mm², placed on 15 rows of 10 needles each on a cylindrical surface from textolit with the thickness of 0.6mm. The radius of this surface can be adjusted with the help of M4 screws screwed in a plexiglas holder with the dimensions of 160x100mm, which can be fixed in the electrode holder with the help of a bridle from single pickled sheet.

![Figure 1. Multineedles electrode](image1)

The active elements of the multithreaded electrode are three conductive wolfram wires, with the thickness of 0.3mm. These are parallel between them and are attached on the threaded ends of some steel cylindrical support. The cylindrical support has an exterior diameter of 10 mm, on a length of 24mm, having at one end a threaded part with M4 in a length of 6mm (total 30mm), and at the other end a clogged threaded hole with M4, on a depth of 8 mm. At the base of the threaded part through holes were made perpendicular to the cylindrical support shaft, through which the two ends of the wolfram conductor are inserted, are prestressed, after which is fixed and stretched with the help of some threaded plugs from an isolating material, namely teflon (Figure 2).

![Figure 2. Frontal view of the multithreaded electrode](image2)
3. Technological process proposed by the authors in order to prepare the quartz sand samples for the electroseparation

The technological process proposed for the sand preparation for the electroseparation process is presented in Figure 3.

![Diagram of the technological process](image)

**Figure 3.** Technological process proposed by the authors in order to prepare the quartz sand samples for the electroseparation

4. Main factors which influence the quartz sand electroseparation

Following the preliminary laboratory researches, by varying some factors that influence the electroseparation [5] and by performing a large number of measurements, it was determined that the main influencing factors in the Aghires quartz sand electroseparation are [6]:

- the configuration and the active electrodes type;
- the supply voltage of the active electrodes $U$, variable between $(15-40)$ [kV];
- speed of the rotating cylinder $n$, variable between $(20-60)$ [rpm];
- placement angle to the vertical of the active electrodes $\alpha$, variable between $(45-70)$ [$^\circ$].
It has to be mentioned that throughout the entire experimental plan two parameters were maintained constant: the distance \( S \) between the active electrode and the rotating cylinder surface, and also the granular mixture flow introduced by the vibrotransportor in the active area of the electroseparator.

The electroseparated sand was collected and measured (weighed) in three fractions: \( m_1 \)- nonconductive material (boxes 1-3); \( m_2 \)- mixt material (boxes 4-7); \( m_3 \)- conductive material (boxes 8-10).

The used material as raw material in the production process is the one from the \( m_1 \) fraction, requiring a high concentration of SiO\(_2\) and low concentration of Fe\(_2\)O\(_3\).

5. Statistical analysis of the results of the quartz sand electroseparation in the two considered configurations, using MODDE.5 software program

5.1. The principle of the statistical analysis program MODDE.5

According to the program MODDE.5 some process with \( m \) factors and \( n \) answers is considered, as in Figure 4.

![Figure 4](image)

**Figure 4.** Symbolic representation of a process with \( u \) inputs and \( y \) outputs

The \( y \) answers may be expressed as polynomial functions with the variables \( u_i, i=1,2,...,m \) of the following form:

\[
y = c_0 + \sum c_i u_i + \sum c_{ij} u_i u_j + \sum c_{ij} u_i^2, \quad i, j = 1, 2,..., m
\] (1)

The MODDE.5 program allows the graphical representation of the output functions as equipotential surfaces, marked with the resulting values on the contour [7].

5.2. The configuration with multineedle electrode and the statistical analysis of the electroseparation results

The configuration for the multineedle electrode can be observed in Figure 5, while in Table 1 the measurements for this configuration are presented.
In Figure 5 the configuration with corona multineedle electrode for the ILES installation is shown.

Table 1. Measurements in the multineedle electrode configuration – grading 70–400 μm.

| Crt. No. | U [kV] | n [rot/min] | α1 [º] | m1 [g] | m2 [g] | m3 [g] |
|----------|--------|-------------|---------|-------|-------|-------|
| 1        | 20     | 20          | 50      | 85.24 | 13.86 | 0.85  |
| 2        | 20     | 60          | 50      | 92.92 | 5.82  | 0.52  |
| 3        | 40     | 20          | 50      | 94.07 | 5.22  | 0.08  |
| 4        | 40     | 60          | 50      | 95.54 | 3.82  | 0.04  |
| 5        | 20     | 20          | 70      | 87.02 | 12    | 0.62  |
| 6        | 20     | 60          | 70      | 91.1  | 7.84  | 0.26  |
| 7        | 40     | 20          | 70      | 96.3  | 3.04  | 0.18  |
| 8        | 40     | 60          | 70      | 96.3  | 3.14  | 0.26  |
| 9        | 30     | 20          | 60      | 92.28 | 7.21  | 0.21  |
| 10       | 30     | 60          | 60      | 93.15 | 6.12  | 0.17  |
| 11       | 20     | 40          | 60      | 93.42 | 6.25  | 0.42  |
| 12       | 40     | 40          | 60      | 96.34 | 2.63  | 0.14  |
| 13       | 30     | 40          | 50      | 96.16 | 3.18  | 0.11  |
| 14       | 30     | 40          | 70      | 96.76 | 2.27  | 0.12  |
| 15       | 30     | 40          | 60      | 96.69 | 2.14  | 0.39  |
| 16       | 30     | 40          | 60      | 96.62 | 2.52  | 0.42  |
| 17       | 30     | 40          | 60      | 96.56 | 2.68  | 0.36  |

In Figure 6 the allure of the response functions for the functions m1 and m2 can be observed. In the case of m1, the maximum obtained value is in the area represented in red, delimited by the border labeled “98.8”, for a speed of approximately 40 rev/min and a supply voltage of approximately 40kV.
For m2, the same area includes the minimum obtained value, while the maximum appears around the values of 20 rev/min and 20kV.

**Figure 6.** $m_1$ and $m_2$ masses predicted for the experimental plan in the case of the multineedles electrode configuration and grading of 70-400 $\mu$m, represented as equipotential surfaces

For the representation of the $m_3$ mass, we only have one factor, namely the supply voltage of the active electrode. The representation from Figure 7 was chosen, where the program adds the values of a confidence interval, represented by the red and blue curves.

**Figure 7.** $m_3$ mass predicted depending on the $U$ voltage at confidence intervals of 95%

After a number of iterations, the MODDE.5 program optimizer indicates the values outlined in black, as an optimum operating point (Figure 8).
Figure 8. Optimum operating point calculated for the convergence criteria maximum $m_1$, $m_3$, respectively minimum $m_2$.

5.3. The configuration with multithreaded electrode and the statistical analysis of the electroseparation results

The configuration for the multithreaded electrode can be observed in Figure 9, while in Table 2 the measurements for this configuration are presented.

Figure 9. Configuration with corona multithreaded electrode for the ILES installation
Table 2. Measurements in the multithreaded electrode configuration – grading 70-400 μm.

| Crt. No. | U [kV] | n [rot/min] | α1 [º] | m1 [g]   | m2 [g]   | m3 [g]   |
|---------|--------|-------------|--------|----------|----------|----------|
| 1       | 15     | 20          | 45     | 1.15     | 97.87    | 0.62     |
| 2       | 15     | 60          | 45     | 1.69     | 97.64    | 0.44     |
| 3       | 35     | 20          | 45     | 51.41    | 45.43    | 3.98     |
| 4       | 35     | 60          | 45     | 78.47    | 18.28    | 2.89     |
| 5       | 15     | 20          | 65     | 1.2      | 98.13    | 0.11     |
| 6       | 15     | 60          | 65     | 0.76     | 98.59    | 0.18     |
| 7       | 35     | 20          | 65     | 54.8     | 41.12    | 4.43     |
| 8       | 35     | 60          | 65     | 69.21    | 29.47    | 1.24     |
| 9       | 25     | 20          | 55     | 2.79     | 72.89    | 23.61    |
| 10      | 25     | 60          | 55     | 5.67     | 65.26    | 28.12    |
| 11      | 15     | 40          | 55     | 7.89     | 90.65    | 1.32     |
| 12      | 35     | 40          | 55     | 60.84    | 36.22    | 2.15     |
| 13      | 25     | 40          | 45     | 4.62     | 71.27    | 23.86    |
| 14      | 25     | 40          | 65     | 5.55     | 74.21    | 19.89    |
| 15      | 25     | 40          | 55     | 5.23     | 73.16    | 29.58    |
| 16      | 25     | 40          | 55     | 5.14     | 72.82    | 21.86    |
| 17      | 25     | 40          | 55     | 5.48     | 73.11    | 21.37    |

In Figure 10 the allure of the output functions can be seen. In the case of m1, the maximum value at a speed of 50÷60 rev/min and a voltage of the multithreaded electrode over 34 kV. For m2, this is the area with minimum values, the maximum values appearing for a voltage of 15÷18kV, regardless of the speed. The m3 value is maximum for a voltage value of 25÷26kV, for all speed range.

![Figure 10](image_url)

Figure 10. m1, m2 and m3 masses predicted for the experimental plan in the case of the multithreaded electrode configuration and grading of 70-400μm, represented as equipotential surfaces.
After a few iterations, the MODDE.5 program optimizer indicates the values outlined in black, as an optimum operating point for this case as it can be seen in Figure 11.

![Figure 11. Optimum operating point calculated for the convergence criteria maximum m1, m3, respectively minimum m2](image)

6. Conclusions
Aghires quartz sand electroseparation ensures its enrichment, through the increase of SiO₂ content and decrease of the Fe₂O₃ content in the useful fraction m1.

Using MODDE.5 program assured the electroseparation result analysis for a relatively small number of experiments.

From the quantitative point of view, the best results for the m1 fraction were obtained for the multineedle electrode configuration, with a Fe₂O₃ content of 0.17%. The configuration with the original multithreaded corona electrode, ensures a superior quality electroseparation, thus obtaining a smaller amount in the useful fraction m1, but with a higher purity (Fe₂O₃ -0.15%).

The original multithreaded electrode, proposed by the authors, won the OSIM patent no.201500033/19/01/2015. Also, the multithreaded corona electrode, was appreciated at the International Exhibition of Inventions, PRO INVENT, edition XIII 2015, Cluj Napoca, Romania, with excellence diploma and gold medal.

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