Basalts of the Republic of Buryatia and their suitability for obtaining mineral fibres

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Abstract. Mineral wool is one of the most effective and environmentally safe types of heat insulation materials. Basalt is the main raw material for its production. The quality of the fibre produced depends on its chemical composition. The priority task is to assess the suitability of basalts for use in the production by their chemical composition. The main indicator is the acidity index, which reflects the acid-base characteristics of rocks. Basalt deposits of the Republic of Buryatia have been studied. It was found that the basalts of the Ilyushkin Klyuch deposit have a chemical composition which meets the requirements for continuous fibre production, and the basalts of the Selendum and Mukhor-Talinsky deposits – for staple fibre production. The production of continuous fibres for basalts of the Selendum deposit requires additional charging of calcium- or magnesium-containing rocks, and for basalts of Mukhor-Talinsky deposit- an addition of silicon-containing rocks.

1. Introduction

Due to the intensive development of the northern regions of Russia, the demand for heat insulation materials with high physical and mechanical characteristics, including mineral wool, is increasing. The main raw material for its production is gabbro-basalt rocks, mainly basalts and diabases. Basalt fibre is environmentally safe. It has high physical and chemical characteristics at low cost. It can be used in a wide temperature range (from -260 °C to 900 °C) [1-5]. The quality of the obtained fibre and field of its application depend on the chemical and mineralogical composition of the rocks used [6,7]. Therefore, the first stage is a preliminary assessment of the suitability of raw materials according to their chemical and mineralogical composition [8-10]. This is an urgent task, because basalts of various deposits differ in their composition and structure, and local raw materials are not always suitable for obtaining high-quality basalt fibre.

The purpose of this work is to assess the quality of basalt rocks of the Republic of Buryatia and to determine their suitability for fibre production, as well as to compare them with known literature data.

2. Materials and methods

The basalts of the Republic of Buryatia were taken for research. Their chemical analysis was carried out. The obtained values are compared with the composition of basalts of known deposits.
Chemical analysis was performed by methods of atomic absorption spectroscopy using a Unicam spectrophotometer SOLAAR–6M (Thermo Electron, Franklin, Ma, USA) with the suitable software, photocolorimetry using a photocolorimeter PE-5300 (ECRUSCHEM, St. Petersburg, Russia) and gravimetry using an electronic scale VSL–200/0.1A (Nevskiye Vesy, St. Petersburg, Russia).

3. Results and discussion

The raw materials for producing mineral wool must have a certain chemical composition. The requirements for the content of basic oxides are well-founded. The suitability of raw materials for the production of mineral fibres is determined by the physical and mechanical properties of their melts, in particular, the viscosity. These indicators, in turn, are directly depending on the chemical composition of the feedstock. Numerous experimental studies of rocks show that the influence of a particular oxide on the viscosity of the melt is determined not only by its nature, but also by its content \[11,12\]. There are certain requirements for the chemical composition of raw materials for the production of various types of basalt fibre, presented in Table 1 \[13\].

Table 1. Chemical composition of rocks for fiber production.

| Basic oxides     | The content of basic oxides, wt. % |
|------------------|-----------------------------------|
|                  | continuous fiber      | staple fiber       |
| SiO<sub>2</sub>  | 47.0±55.0              | 39.0±51.0          |
| Al<sub>2</sub>O<sub>3</sub> | 14.0±20.0             | 10.0±19.0          |
| FeO+Fe<sub>2</sub>O<sub>3</sub> | 7.0±13.5              | 10.0±18.0          |
| MgO              | 3.0±8.5                | 4.0±12.0           |
| CaO              | 7.0±11.0               | 8.0±13.0           |
| K<sub>2</sub>O+N<sub>2</sub>O<sub>3</sub> | 2.5±7.5               | 2.0±5.0            |
| TiO<sub>2</sub>  | 0.2±2.0                | 2.0±5.0            |
| MnO, no more     | 0.25                   | 0.2±0.3            |
| SO<sub>3</sub>, no more | 0.2             | -                  |
| LOI<sup>a</sup>, no more | 5.0           | 5.0                |

<sup>a</sup>LOI – Losses on ignition.

On the basis of these requirements, the basalts of the Republic of Buryatia were analyzed. The comparative characteristics of the studied rocks and rocks known from literary sources, the chemical composition of which is presented in Table 2, are given.

The acidity index is one of the main widely used parameters and reflects the acid-base characteristics of materials. It is used in production practice as a preliminary assessment of the suitability of raw materials for obtaining mineral fibre and is calculated using the formula \(M_K = (\text{SiO}_2 + \text{Al}_2\text{O}_3) / (\text{CaO} + \text{MgO})\). For melts with good working characteristics it is assumed that \(M_K = 3÷6\). According to literature data, rocks with \(M_K > 1.2\) are suitable for obtaining super-thin and thin staple fibres.

The acidity index of the Mukhor-Talinskoye and Ilyushkin Klyuch deposits basalts (table 2) is within the required limits, which indicates good working characteristics of the melt from them and a normal process of fiberization. The acidity index of the Selendum deposit basalts exceeds these values.

The content of the main oxides in the studied rocks is within acceptable values. Based on the requirements (table 1), only the basalts of the Ilyushkin Klyuch deposit are suitable for continuous fibre production. The rocks of the Selendum deposit have a reduced content of calcium oxides and an increased content of titanium oxides. The basalts of the Mukhor-Talinsky deposit have a low content of silicon oxide and a high content of iron oxides. Staple fibre can be obtained from the basalts of these deposits.
| Deposit                        | SiO₂  | Al₂O₃ | FeO+Fe₂O₃ | MgO | CaO | K₂O+Na₂O | TiO₂ | LOI | \( Mₖ^{b} \) |
|-------------------------------|-------|-------|-----------|-----|-----|-----------|------|-----|-------------|
| Berestovetskoe (Ukraine) [14] | 49.03 | 12.58 | 14.03     | 5.47| 9.53| 3.00      | 2.85 | 0.75| 4.11        |
| Marneul’skoe (Georgia) [14]  | 50.61 | 16.75 | 10.26     | 4.65| 9.07| 4.88      | 1.81 | 0.31| 4.91        |
| Karatosh (Uzbekistan) [10]   | 48.54 | 14.40 | 11.65     | 7.18| 9.88| 3.99      | 2.14 | 2.36| 3.68        |
| Dubersay (Kazakhstan) [15]   | 43.85 | 15.10 | 10.71     | 5.1 | 17.71| 5.32      | 1.06 | -  | 2.58        |
| Osmansay (Uzbekistan) [16]   | 47.05 | 15.74 | 8.71      | 5.44| 8.45| 4.99      | -    | 7.94| 4.52        |
| Achin (Uzbekistan) [16]      | 44.01 | 6.99  | 19.65     | 6.95| 13.35| -         | -    | 2.15| 2.51        |
| Suluu Terek (Kyrgyzstan) [17]| 44.00 | 14.80 | 10.95     | 6.30| 8.33| 4.84      | 2.30 | 6.79| 4.02        |
| Kuluevskaya (Southern Urals, Russia) [9] | 49.92 | 15.96 | 9.39      | 8.22| 10.52| 2.85      | 0.68 | 2.24| 3.51        |
| Shandong Province (China) [18]| 55.17 | 15.57 | 9.10      | 12.23| 5.89| -         | -    | -  | 5.78        |
| Myandukha (Russia) [14]      | 50.42 | 11.82 | 12.25     | 10.58| 8.84| 2.52      | 1.04 | 0.08| 3.20        |
| Kondopoga (Russia) [14]      | 53.54 | 14.12 | 10.44     | 6.70| 6.60| 4.84      | 1.52 | 0.08| 5.09        |
| Vasil’evka (Yakutiya, Russia) [19]| 51.70 | 17.00 | 12.90     | 5.29 | 7.00| 3.81      | 2.20 | -  | 5.59        |
| Mataram Baru, (Sumatera, Indonesia) [20]| 48.42 | 18.82 | 12.60     | 4.56| 9.76| 3.99      | 1.33 | -  | 4.70        |
| Yanova Dolyna (Ukraine) [21] | 50.60 | 16.00 | 22.90     | 5.10| 9.80| 3.20      | 0.90 | -  | 4.47        |
| Donetsk (Ukraine) [21]        | 47.60 | 17.50 | 24.40     | 5.10| 9.50| 4.70      | 1.50 | -  | 4.46        |
| Uschakivske (Ukraine) [21]   | 48.70 | 15.90 | 20.80     | 5.40| 12.90| 3.50      | 0.80 | -  | 3.53        |
| Suduntuskoie (Trans-Baikal Territory, Russia) | 48.43 | 14.23 | 12.36     | 3.58| 8.58| 5.56      | -    | 1.02| 5.15        |
| Selendum (Republic of Buryatia, Russia) | 48.60 | 16.70 | 11.69     | 4.47| 6.25| 7.40      | 2.12 | -  | 6.09        |
| Mukhor-Talinsky (Republic of Buryatia, Russia) | 44.28 | 15.21 | 13.92     | 8.58| 9.61| 5.24      | 2.08 | -  | 3.27        |
| Ilyushkin Klyuch (Republic of Buryatia, Russia) | 47.98 | 16.04 | 10.60     | 4.82| 7.69| 6.72      | 1.93 | 4.09| 5.10        |

\( ^{b}M_k \) – acidity modulus
The quantity of silica in the rock affects the viscosity of the melt. The content of silicon oxide should be more than 46% [22] for the stability of the fibre formation process. As the value increases, the mechanical characteristics of the fibre improve. In addition, the quality of the material is affected by aluminum oxide [23]. The higher its content, the stronger the fibre is. In the basalt of the Mukhor-Talinsky deposit, the quantity of SiO2 is 44.28%, and the quantity of Al2O3 is 15.21%. Although the acidity index of the rock is equal to 3.27, which indicates the suitability for obtaining fibre, however, the fibre formation process will be unstable, and the formed fibres will have low mechanical indicators.

Iron oxides have a great influence on the quality of the fibres produced [11]. An increase in their content worsens not only its physical and mechanical characteristics, but also increases the number of non-fibrous inclusions of “shots” formed [17]. The smallest number of “shots” will be observed in the material obtained from the basalts of the Ilyushkin Klyuch deposit, and the largest – from the Mukhor-Talinsky deposit.

The acidity index of the Selendum deposit basalts exceeds the boundary value, which is due to the reduced content of calcium and magnesium oxides. Selendum deposit basalts have a minimum content of oxides of calcium, magnesium and a maximum of oxides of potassium and sodium among all submitted basalt deposits. The melt will have an increased viscosity. To eliminate this disadvantage, an addition of dolomites or limestone to the batch is required.

According to the content of silicon, aluminum, iron and titanium oxides, the basalts deposits of Buryatia do not differ from those presented in Table 2. All of them can be used in production, subject to adjustment of the process regimes.

4. Conclusion

Thus, all the basalts of Buryatia deposits can be used to produce mineral fibre. The basalts of the Ilyushkin Klyuch deposit are suitable for the production of continuous fibre. It is possible to obtain staple fibre from basalts of the Selendum and Mukhor-Talin deposits. The production of continuous fibres for basalts of the Selendum deposit requires additional charging of calcium- or magnesium-containing rocks, and for basalts of Mukhor-Talinsky deposit – an addition of silicon-containing rocks.

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