Specific features of basalts, its melting and tempering in different environments

Ra'no Rashidova[1*], *Rustam* Yandashev[1], *Abdirahim* Kurbanov[2], and *Buri* Kamolov[3]

[1]Navoi State University of Mining and Technologies, Navoi, 210100, Uzbekistan
[2]Bukhara Engineering and Technology Institute, Bukhara, 200117, Uzbekistan
[3]Karshi Engineering and Economic Institute, Karshi, 180100, Uzbekistan

Abstract. The paper discusses the radical approach to expanding the possibilities of obtaining metals from untapped reserves of natural resources. It presents the results of scientific research dedicated to studying the specific components of the elements contained. The results of the preparation and implementation of smelting works at the basalt deposit 'Asmansay-1' are provided. The analysis of the results of melting basaltic minerals from the 'Asmansay' deposit is presented, along with their annealing in different environments. The aim is to determine the optimal parameters for the melting of basalt and similar ores.

1 Introduction

The study of technological processes at basalt processing enterprises in Uzbekistan has revealed a lack of experience in organizing stone casting and petrourgical production. The reason for this phenomenon can be attributed to insufficient knowledge of basalt melt: the processes of pouring the liquid mass into the mold and the subsequent state of the product related to firing, as well as the lack of information on production costs and payback periods. In connection with this, based on foreign experience, the need for experimental study of the possibility of creating stone casting technology has been identified. Since the differences in the chemical-mineralogical composition of basaltic rock deposits in Uzbekistan and the melting temperature of basalt did not allow for the direct implementation of foreign technology into production, conditions were created in the laboratory for studying the behavior of cast basalt forms after melting and annealing in different environments.

2 Materials and methods

The following types of work were carried out to conduct experimental research:

- the material chosen for the manufacture of the mold of the flask is fire-resistant brick of grade 2XP-3, the holding temperature of which reaches 2500 ^{0}C;

* Corresponding author: rano_nrm.2012@mail.ru

- three holes were drilled on the side of the brick with a diameter of 10; 14 and 16 mm, which was argued by the arbitrariness of the choice of hole sizes depending on the thickness of the walls of the flask
- the flasks are prepared for work; [1].

To prevent the formation of bubbles inside the mold during the heating of the rock and pouring of the liquid mass, three through-holes with a diameter of 3÷5 mm were drilled. These holes serve for the passage of air and removal of gas bubbles from the mass. The channels of the holes were directed upwards at an angle, so that during the pouring of the liquid mass into the mold, gases from impurities could freely pass into the open space.

The laboratory furnace was prepared, and the temperature inside the furnace was measured using an electronic thermometer. When the preliminary heating of the furnace reached a temperature of 1000 °C, the furnace was switched off. The furnace was then cooled to room temperature, and the loading of the mold was carried out using refractory molds.

The process of smelting basalt rock was observed through the window of the furnace door. Three such flasks were made for the purpose of tempering the cast mold in the open air, at room temperature and at high temperature (800÷850 ^{0} C). When the temperature reaches 1550° C, the furnace was turned off, the door was opened and two of the three flasks were removed from the furnace, using traditional metal tongs used in the foundries of the Navoi Machine-Building Plant. [2].

The first flask was left in the furnace with the doors open to temper the molten basalt inside the furnace. The second flask was kept outside in the open air to cool the workpiece to atmospheric temperature. The third flask was kept in laboratory conditions to room temperature. Then the ceramic bands used to separate the flasks were removed and the cooled blanks were taken out.

3 Results and discussion

The results showed that the cooling of the workpiece that was in the furnace was slow. In the other two conditions, the cooling process of the workpieces occurred faster and almost equally, since the ambient temperature was 23 $^{\circ}$C.

It is necessary to note another characteristic feature of cast basalt in a flask, which was kept in a furnace until completely cooled and had an almost smooth outer surface. Bubbles and small cracks were observed on the outer surface of the remaining two workpieces.

It was established that the basalt melt, which was in the flask at a high positive temperature for a relatively longer time, to some extent went through the stage of additional “firing-homogenization”. This similarity of “annealing” can be found in the production of electrical insulators of different potentials.

In general, it was found that cast basalt after annealing will have high hardness and a smooth surface. Parameters such as “time”, “temperature”, “melting rate” and “annealing” are interrelated and product performance largely depends on these parameters. Product quality depends on the annealing temperature, tempering temperature or cooling temperature gradient. [3].

Processing of basalts using the petrurgical method for the manufacture of parts for a fleet of machines for various purposes. In mechanical engineering of any branch of the national economy, an important place is given to strength indicators and technological parameters, which depend on the durability of the materials used. Therefore, when designing machine parts, for example, in the oil and gas industry, special attention is paid to shock loads, operational properties, heat resistance, corrosion resistance, maximum vibration force, etc. This dissertation analyzes the results of a study of the characteristic indicators of metals that are extracted from the basalts of the Asmansay -1 deposit. The study of minerals “Asmansay -1” is argued by the fact that in the rock composition of the bottom deposit, for example, the content of iron oxides reaches up to 15% or more. [4].

Study and analysis of technical literature and patent sources showed that they do not contain information about the content and extraction of metals from basalt rock. Considering the urgent need of the country's industry for raw materials for the production of metals, it can be assumed that basalt minerals with natural and technical characteristics can be a promising mineral raw material base for the production of metals. For this purpose, an experimental study was organized to determine the content of metals in metal samples. Samples of these metals were removed from unauthorized liquids that were simultaneously released from the furnace, where the process of melting basalt rock and forming crystalline fibers took place.

Afterwards, the metal samples underwent preliminary chemical analysis using a well-established methodology. The results are shown in Table 1. The experiment was carried out on 10 kilograms of basalt minerals “Asmansay -1”, which contains the maximum amount of FeO and Fe_2O_3, up to 18÷ 20%. [5].

Table 1. The results of experimental studies. Chemical composition of the material PF2 and PF3.

Si (in kg)	Mn (in kg)	S (in kg)	P (in kg)	As (in kg)
05 – 0.9	Up to 2	Up to 0.07	0.3 - 2	Up to 0.2

Table 2. Chemical composition of the PF3 material.

Si (in kg)	Mn (in kg)	S (in kg)	P (in kg)	As (in kg)
Up to 05	Up to 2	Up to 0.07	0.3 - 2	Up to 0.2

The tabulated data indicate that the samples of by-product (hereinafter referred to as metal) contain "converter-grade phosphorous pig iron intended for further processing into steel or remelting in foundries during the production of castings." This converter-grade phosphorous pig iron is meant for further processing into steel or remelting in foundries during the production of castings. This suggests that with the development of appropriate technology, there is a promising direction for the production of metals from local basaltic rock.

It has been established that the best natural raw materials for basalt stone casting are igneous rocks, including: diabases, basalts, andesite-basalts, gabbro-diabases, and metamorphic and sedimentary rocks that are close to them in gross chemical composition, such as slates, amphibolites, clays, sands, and others.

In practice, it has been proven that melts with the following chemical composition (in %) exhibit the best casting properties: SiO_2−43.5÷49.0; $A1_2O_3$ −11.0÷20.0; CaO−9.0÷16.0; MgO−5.0÷11.0; FeO −2.0÷7.0; ($Na_2O + K_2O$) 1.2÷5, which proves the acceptability of manufacturing cast products from basalts [6].

Preliminary studies of the chemical and mineralogical composition of basalt rock from the 'Asmansay-1' deposit showed the following average composition of chemical components (in %): SiO_2−43.5÷53.4; $A1_2O_3$−9.2÷15.74; CaO−5.42÷15.8; MgO−1.1÷5.44; FeO−1.16÷8.9; Fe_2O_3−2.89÷7.37; (Na_2O+K_2O) −1.39÷3.5, which are suitable for smelting and extraction of associated metal.

One of the inherent characteristics of extracted products from basalt 'Asmansay-1' is their physico-mechanical properties and the property of cast basalt, which manifest under external loads. In general, the behavior of the extracted cast by-product under load is composed of three sequentially occurring and often mutually overlapping processes: a) reversible or elastic deformation, consisting of a quasi-instantaneous part and elastic aftereffect; b) plastic deformation; and failure.

The state of the by-product metal extracted from cast basalt during transitions is referred to as critical or limit state. Understanding the behavior of basalt cast metal at each stage of deformation, as well as the conditions of transition from one deformation stage to another during the creation of a piece of spontaneously extracted metal, holds significant practical importance. This knowledge enables the prediction of the metal or alloy's behavior under pressure from structures. [6].

The physico-mechanical properties of by-product cast basalt products are divided into deformational, strength, and rheological properties. Deformational properties characterize the behavior of by-product metals under loads that do not exceed critical values and, therefore, do not lead to failure. These properties can be expressed by two pairs of indicators: either by the modulus of deformation and Poisson's ratio, or by the shear and bulk moduli.

The deformational properties of the extracted cast basalt metal are determined under conditions simulating the operation of the considered product among components possibly in the oil and gas industry. The study has shown that deformational properties of metallic samples are most commonly determined under static loading. However, for the design of equipment, such as a drilling rig, the study of the deformational properties of soils will also be conducted under the influence of vibration, variable loads, etc.

Particularly noteworthy is the fact that by-products extracted from basaltic minerals can deform under load during free expansion, whether constrained laterally or without lateral confinement. Experimental research results obtained in research facilities testify to this. The first condition is realized during uniaxial compression of samples, the second during testing in devices for triaxial compression and with the method of trial loads, and the third during compression.

Another practically and theoretically important parameter is the strength properties that characterize the behavior of cast basalt metal under loads equal to or exceeding critical values and are determined only upon the soil's failure. Shear and rupture are two primary mechanisms of strength loss in a body. Shear occurs under the influence of tangential forces; during shear, one part of the body moves relative to another. Rupture of the body occurs under the influence of normal tensile forces and morphologically manifests as cracks and separation of one part of the body from another. The primary indicator of the strength of cast basalt metal is its shear resistance; rupture resistance is determined significantly less frequently. In the practice of engineering geological surveys, the resistance of soils to uniaxial compression is often determined [7].

Another important factor could be the potential loss of strength in a soil mass due to plastic deformations resembling the flow of viscous metallic liquids. Therefore, cast basalt metals are also characterized by viscosity, allowing the estimation of the magnitude of plastic deformations under a given force over an extended period. For instance, such slow deformations can occur due to centuries-long sedimentation and mineral formation, the movement of metallic components relative to each other during operation, etc. The formation of folds and possible bending of dimensional components are also the result of their flow under prolonged force application [8-10].

The research and analysis of indicators have provided an opportunity to identify the physical mechanism of creep in metals, which is an inherent material characteristic considered highly complex and dependent on numerous factors. In crystals, creep is influenced by the movement of structural defects, twinning, translation, and diffusion. In polycrystalline bodies and dispersive clayey soils, which exhibit creep at lower pressures than crystals, it is characterized by quasi-viscous sliding of particles relative to each other, particle reorientation in the direction normal to the resultant stress, and the development of microcracks. In practice, there is the term "creep kinetics," which depends on pressure and temperature and is complicated by various structural transformations – densification, structural changes, and strengthening of metals during the cooling stage, and dilatant failure during the flow stage of molten metal lava.

4 Conclusion

It has been identified that to compile the obtained data, such as creep data for newly produced metal components, it is necessary to know two quantities - the creep threshold and the effective viscosity coefficient of the metal component's structure, as well as its changes over time. In mechanics, for simplicity of information transfer and discussion, the term "Creep Threshold" (according to N. N. Maslov) has been introduced. It represents the shear stress at which, and above which, creep deformation, which was previously practically negligible in terms of its magnitude and rate, sharply intensifies.

The creep threshold of structural components of metal products depends on the structure and composition of the metal, temperature, pressure, and the rate of pressure application. For dense materials, the creep threshold may be higher than for less dense ones.

The "Creep Threshold" is determined based on prolonged creep tests of identical samples, in this case, by-products that are extracted. The samples undergo testing at various values of shear stress.

Thus, the study and analysis of the research results reveal the specific characteristics of the by-product metallic samples extracted from molten basaltic minerals. It is demonstrated that the natural resources in our country can provide metals from local raw materials.

However, it is practically very important to note that in all sectors of the national economy, the quality of the produced goods and the satisfaction of the demand from both producers and consumers largely depend on the quality of the raw materials used. In our case, basaltic rocks from the "Asmansay-1" deposit are recommended as raw materials. In this context, we have limited the discussion to the extraction of metals and alloys from local basaltic minerals, which holds promising prospects.

References

1. A.A. Kurbanov, Zh. Nurmatov, Technical and production magazine “Mining Bulletin of Uzbekistan” **3**, 55-59 (2020)
2. R.K. Rashidova, J.T. Nurmatov, A.A. Kurbanov, Land Science **1(1)** (2019). https://doi.org/10.30560/ls.v1n1p59
3. Y. Kadirov, O. Boeva, R. Eshqobilov, S. Toshmurodova, D. Abdullaeva, E3S Web of Conferences **414** 05003 (2023)
4. R.K. Rashidova, J.T. Nurmatov, A.A. Kurbanov, O.J. Turdiyeva, J.T. Nurmatov, Land Science **2(2)** (2020)
5. K.S. Sanakulov, A.S. Khasanov, *Recycling of copper production slags* (Tashkent, 2007), p. 248
6. A.A. Kurbanov, S.A. Abdurakhmanov, *Scientific practical basis for the integrated use of different types of basalts in Uzbekistan* (Navoi, 2018), p. 239
7. Z.R. Kadyrova, R.H. Pirmatov, A.A. Eminov, Raw materials **7**, 10-17 (2019)
8. A.S. Pashinkin, Raw materials 1, 46-48 (1984)
9. Sh. Alikulov, Sh. Babayev, M. Alimov, A. Yuldoshev, K. Sharopov, E3S Web of Conferences **417** 01004 (2023)
10. M.A. Askarov, Sh.K. Kurbanov, O.B. Khushvakov, U.Z. Sharafutdinov, N.A. Doniyarov, Gornyi Zhurnal, **2** 61–62 (2002)