OBTAINING SINTERED PARTS OF BASALT POWDER

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ABSTRACT*: Unconventional materials such as composite, ceramic and mineral materials can be used, along with other technical materials, in various fields of technology. The most diverse processes and technologies can be applied to them in order to obtain finished parts, thus reducing the consumption of expensive and deficient materials. Basalt, which belongs to the category of mineral materials, can be processed by melting and recrystallization, sintering or basaltization. As a result of these processes and processing technologies, basalt improves its main mechanical, physical and chemical characteristics, becoming resistant to temperatures between 4000 ... 6000C, mechanical shocks and corrosion. Under these conditions, basalt can also be used advantageously in the construction of the resistance structures of certain engines, especially for combustion chambers and nozzles, along with other materials already used.*

KEY WORDS: sintered, cast, fiber, mass loss, granular material.

1. INTRODUCTION

One of the major, topical problems of the contemporary world, in the context of the global crisis of raw materials and materials, is that of saving ferrous and non-ferrous metal as well as other deficient and expensive materials (composite materials). This action also includes concerns for the introduction and expansion of the use of basalt, a material that is found in large quantities in nature, accessible and inexpensive.

Basalt is presented in the form of black and gray rock, finely crystallized, with porous structure, weakly visible microscopically and chemically having a complex composition (Table 1) [3].

Table 1 – Compoziţia chimică a bazaltului

Silice [%]	TiO_2 [%]	Al_2O_3 [%]	Fe_2O_3 [%]	FeO [%]	Mg [%]	CaO [%]	K_2O [%]
43 - 50	1 - 3	12 - 16	1 - 4	7 - 9	7 - 9	2 - 4	0,4 - 2

In terms of physical properties, basalt is characterized by: compressive strength between 250 and 300 MPa; shock resistance of 1.5 to 5 MJ/m^2; wear resistance between 0.05 and 1.5 g/cm^2; density 2.5 to 3.2 g/cm^3; melting temperature 1170 ... 1350 ^oC; water absorption, porosity, permeability and sensitivity to temperature variations are almost zero. Basalt can be used: in its natural state, in the field of ordinary constructions or processed by formation in order to obtain aggregates with high compactness for the protection of nuclear reactors; cast in metal forms in the form of tubes, pipes or other categories of parts resistant to wear and the action of chemical agents; in sintered state at temperatures of 2500 ... 2800 ^oC and pressures of 50 - 80 GPa, in the form of bushings, sealing rings and other types of parts used in the construction of cars, automobiles, fine mechanics, aviation[4].

Products obtained by melting basalt and casting it into metal or ground and sintered molds are five times more durable, three times lighter and twice as cheap as the same products made of steel or cast iron. The main physical and mechanical characteristics of the basalt of interest are: density, maximum use temperature, as well as a series of mechanical and electrical properties, properties that are presented in table 2 [3].

Table 2 – Physico-mechanical properties of basalt

Characteristic	U/M	Natural basalt	Melted basalt	Sintered basalt
Color	-	gray-black	gray-black	reddish-brown
Density	g/cm^3	2,9	2,8...3	2,7...2,9
Total porosity	%	5,39	0,5...5	2,0...6,0
Stability of H_2SO_4 at room temperature	-	-	98...99	98...99
Thermal shock resistance for the temperature of 150 ^oC	no. cycles	-	4	6
Maximum operating temperature	^0C	400	400	600
Thermal conductivity	W	-	1,391	1,391
MOHS hardness	-	-	7,4...8	7,4...8

Known technologies allow the processing of basalt by:
- casting (melting and recrystallization);
- sintering;
- basaltization (basalt coating - thermal spraying of basalt).

The main advantages of molten basalt, which conditions its use in a number of industrial fields, are:
a) resistance to abrasive wear of hard materials;
b) stability in aggressive, corrosive environments of acidic or basic nature (at high temperatures) and stability against atmospheric influences;
c) pressure resistance;
d) exceptional hardness and strength of the coating;
e) thermal and sound insulating character (in the form of cotton wool).

Molten basalt is not a simple substitute for defective metals, but is a new material that, due to its high resistance to wear and corrosion, will penetrate where, due to these phenomena, thousands of tons of defective metals are lost annually. Its importance lies in the long service life of molten basalt castings, as well as its abundance in the natural state. Castings have a lower tensile and bending strength and a greater fragility than metals and cannot replace mechanical components of machines, installations or some metal constructions without special treatment, in cases where they are subjected to mechanical and thermal shocks [1].

These products are obtained by casting basalt melts into metal molds, in forming mixtures or by centrifugal casting, the melting casting process being chosen according to the desired size and configuration of the parts. The casting operation is followed by a suitable heat treatment which aims to regain the initial crystalline structure of the rock from which the melt and the formation of mineralogical constituents were obtained, values that give the basalt parts some remarkable properties. From molten basalt are obtained: tubes of molten basalt; basalt tiles covering the walls of various tanks; use of basalt in the production of mortar materials; lining tanks for limestone, clinker and others; basalt lining of mills; basalt pipes for the pneumatic transport of coal dust from mills or tanks to burners; use of basalt in the manufacture of cement. Basalt cotton wool production. This fiber, in combination with asbestos fiber, was used as a filler and as a thermal and acoustic insulation product with better physical properties compared to glass and slag fibers [1].

Basalt fibers are an effective reinforcing material for the use of reinforced plastics for various constructions. The value of the modulus of elasticity is very high compared to glass fibers (678.000 Kg / cm^2 for basalt fibers and 500.000 Kg / cm^2 for glass fibers) so the strength indicators are much higher (Table 3 - characteristics of basalt fibers) [3].

Table 3 - Characteristics of basalt fibers

Nr. crt.	Characteristic	U.M.	Value
1.	Fiber diameter	μm	7-15
2	Density	kg/dm^3	2,85
3	Tensile strength	daN/mm^2	220-250
4	Stretching modulus	daN/mm^2	9000-10000
5	Working temperature range	^oC	250-600

2. TECHNOLOGIES FOR OBTAINING PARTS FROM MOLDED AND SINTERED BASALT

Obtaining finished basalt products raises a number of special issues in terms of processing technology and in establishing processing technologies. Basalt products can be obtained by casting, followed by a recrystallization heat treatment or by the powder sintering method, also known as powder metallurgy. Natural basalt rock, of volcanic origin, crystalline, compact, formed from a mixture of silicates is the raw material for obtaining the parts and is represented by:

A) Tectosilicates - plagioclase feldspars (bleached, anorthite), formed in three-dimensional networks with structures that allow cleavage and maclation, crystallize in the triclinic system. In less than 20% they have a favorable effect on the crystallization process.

B) Mesosilicates - olivines, isomorphic compounds, consisting of forsterite and fayalite with island structure, which allow cleavage and crystallize in the rhombic system. The presence in large quantities of finished products is undesirable.

C) Inosilicates - pyroxenes (metasilicates of Mg, Fe, Mn, Ca, Al) with simple chain structure, have a fibrous appearance and cleave easily, crystallize in the monoclinic and rhombic system. Pyroxenes are the main phase of basalt and are found in amounts between 34% and 80%. Pyroxenes give finished products good chemical and mechanical properties, in mineralogical components with a content below 60%, and a content below 10% magnetite and olivine favor the crystallization process [1].

2.1. Cast basalt technology

The molten basalt can be poured into various metal forms or forming mixtures, obtaining parts with multiple uses in various industrial fields, including machine construction. Metal forms are less used for this purpose, as cooling is rapid, and an amorphous layer appears on the surface of the castings. The crystallization of this layer, through subsequent treatments, requires high temperatures as a result of which the cast changes its characteristics. The molten material does not crystallize completely during the casting and cooling process, leaving about 15-25% amorphous situations. By the casting method the basalt products obtained are, in general, of simpler geometric shapes and with large dimensional deviations.

The cast basalt products are continuously produced in tunnel melting furnaces at 1280 °C and then the melt is poured at a temperature of 1200 °C into metal or sand molds. The melt is cast either gravimetrically or centrifugally in rotating molds. After crystallization (curing) the products are quickly detached from the molds and stored in the cooling tunnels in which they move until cooling (18 ÷ 21 hours).Numai după un astfel de proces bazaltul turnat are rezistenţă mare la uzură şi coroziune.

Cast basalt products have applications mainly to hydraulic transport lines (for sand, ash, acids, alkaline materials, etc.), inclined planes for storage of materials, coal, cement, etc., where strong abrasion is expected.

Cast basalt has good resistance to acids and acidic and alkaline media. It is very useful, where necessary, to have both a high abrasion resistance and a high corrosion resistance. Cast basalt has a coefficient of friction 20% - 30% lower than steel. The more used the cast basalt, the better the sliding characteristics (for example, the coefficient of friction reaches 0.021) [1].

2.2. Sintered basalt technology

To obtain small and medium parts of complex configuration with dimensional deviations of the order of ± 0.1 mm and roughness between 3.2 - 3.7 µm, it is recommended to use the powder sintering method. Forming and sintering operations, which determine the appearance of interatomic bonds between particles, are the essence of the process of obtaining products by aggregating powders.

The aim of the training is to process the powders in intermediate states to facilitate and ensure the obtaining of the prescribed properties. The most used forming process is the pressing in the mold at compaction pressures varying between (2 - 10) x 103 daN / cm^2.

Sintering is an operation of heating the pressed semi-finished products to a temperature at least equal to or higher than the recrystallization temperature, practically the sintering temperature:

$$T_s = (2/3 – 4/5) T_f, \qquad [1]$$

where T_f represents the melting temperature of the main component.

During sintering there is an increase in compactness (more pronounced in the direction of pressing), a phenomenon that decisively influences the mechanical properties of the finished products. The porous structure of sintered products varies between 1… 30% depending on the porosity obtained during the forming operation, as well as the temperature and duration of sintering [1].

3. EXPERIMENTAL STUDIES ON BASALT SINTERIZATION

3.1. Basalt powder preparation method and facilities

For the preparation of the basalt powder, a basalt rock was taken from the Racoş region, Braşov county, presented in figure 1.

Fig.1. The basaltic rock

In order to obtain the basalt powder, the following operations were performed:

1. Basalt washing - performed in a water jet washing installation to remove adherent residues from its surface;
2. Basalt drying - performed in a heat treatment furnace at a temperature of 70^{o}C for 48 hours;
3. Sorting of basalt - performed on a sorting table and consisting in the removal of rocks that have in their mass particles or foreign bodies (limestone, slag, etc.), which have not been removed by washing;
4. Basalt crushing - performed with a crusher. After crushing, the resulting basalt granular material (figure 2a, b) was screened through a 5 mm mesh sieve and then placed in closed containers;

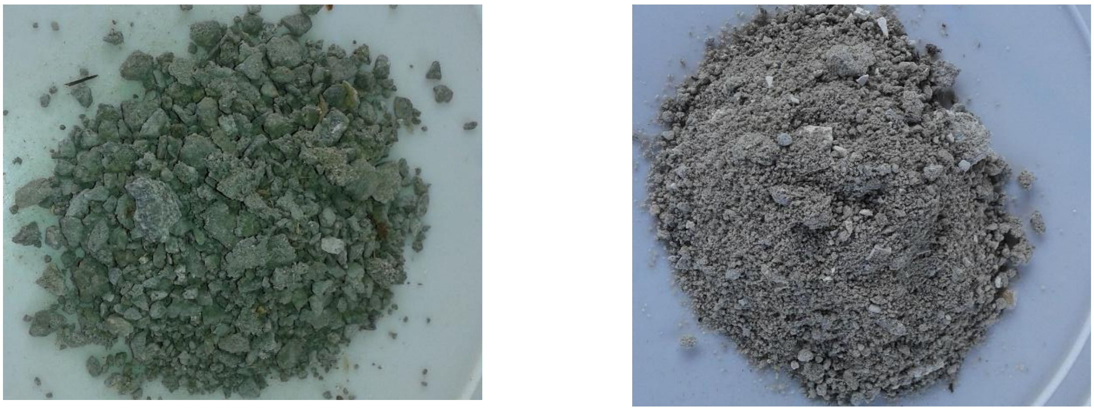


Fig.2. The resulting granular material

5. Basalt grinding - performed in a ball mill in order to obtain equiaxial particles, with an irregular and rough surface having a size of the order of 10 - 103 μm;
6. Screening of basalt powder - was made through a sieve with a mesh size of 1.0 mm, particles that did not pass through the mesh of the sieve being recycled to be recombined;
7. Preparation of the basalt-binder powder mixture performed to ensure the compactness necessary for the formation of the parts. The basalt powder is mixed homogeneously with a gravimetrically dosed binder consisting of aracet, olein and water (figure 3). The homogenization of the basalt-binder powder mixture was performed in a mixer, followed by

the operation of sieving the basalt-binder mixture and keeping it, maximum 24 hours after obtaining, in tightly closed containers.

3.2. Sintering of the powder mixture

The molding process in which the gravimetric dosing mixture is placed was used to form and press the basalt parts (figure 4). The mold housings have an increased size of about 15%, depending on the percentage of shrinkage of the mixture [2].

Fig.3. The powder mixture - binder

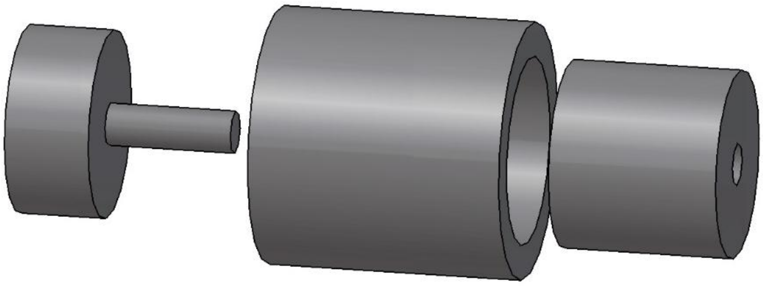


Fig.4. The press and forming mold

The sintering and cooling of the compacted basalt parts was carried out in a Therma heat treatment furnace capable of realizing the sintering temperatures of 1000 °C and 1100 °C, the heating times of 8h and 10h and the maintenance times of 1h and 1.5h, respectively. The pieces obtained are shown in figure 5.

Fig.5. Piese sinterizate şi răcite

3.3. Method and installations for the wear test of sintered basalt

In order to determine the wear resistance, a stand from figure 6 was used. Stand characteristics:

Contact type: plane, linear or punctual.

Sliding motion - sliding speeds between 0.000001 and 0.018 m / s.

Contact pressures: 0.1 MPa… .5 GPa

Testing hard or soft materials and layers at low and very low speeds

Friction regimes: dry, limited and mixed technique.

Use:

- experiments on the tribological passport for any material or layer deposited;
- determining the thickness of the deposited layers and the adhesion to the support material;
- determination of the parameters of the jerky movement (stick-slip phenomenon) [2].

Fig.6. Stand used to determine wear resistance

Table 4 - Measurement values performed to determine the wear of the sintered basalt sample

Nr. crt.	Force [N]	Initial mass M_i [g]	Final mass M_f [g]	Mass loss ΔM [g]	Mass loss ΔM [%]	Sliding speed V_a [m/s]	Time [min]				
							0	15	30	45	60
							ΔM_i [g]				
1	50	16,37	16,13	0,24	1,46	0,01	0	0,08	0,11	0,17	0,24
2	100		16,06	0,31	1,89	0,01	0	0,12	0,15	0,22	0,31
3	150		16,01	0,36	2,19	0,01	0	0,14	0,18	0,26	0,36

In order to perform a comparative analysis, measurements were performed on the same test stand on a sample taken from a brake disc of a car (Table 5).

Table 5 - The values of the measurements carried out in order to determine the wear of the brake disc sample

Nr. crt.	Force [N]	Initial mass M_i [g]	Final mass M_f [g]	Mass loss ΔM [g]	Mass loss ΔM [%]	Sliding speed V_a [m/s]	Time [min]				
							0	15	30	45	60
							ΔM_i [g]				
1	50	146,57	143,90	2,67	1,82	0,01	0	0,87	1,68	2,31	2,67
2	100		143,59	2,98	2,03	0,01	0	0,97	1,73	2,42	2,98
3	150		143,31	3,26	2,22	0,01	0	1,08	1,92	2,78	3,26

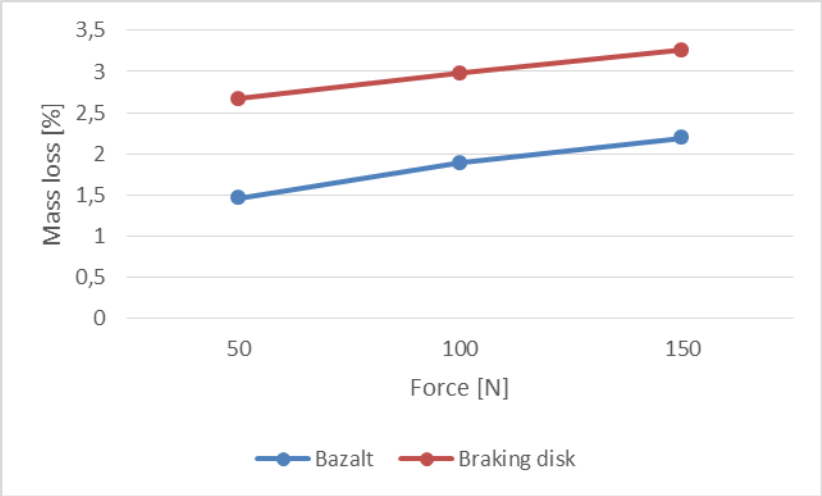
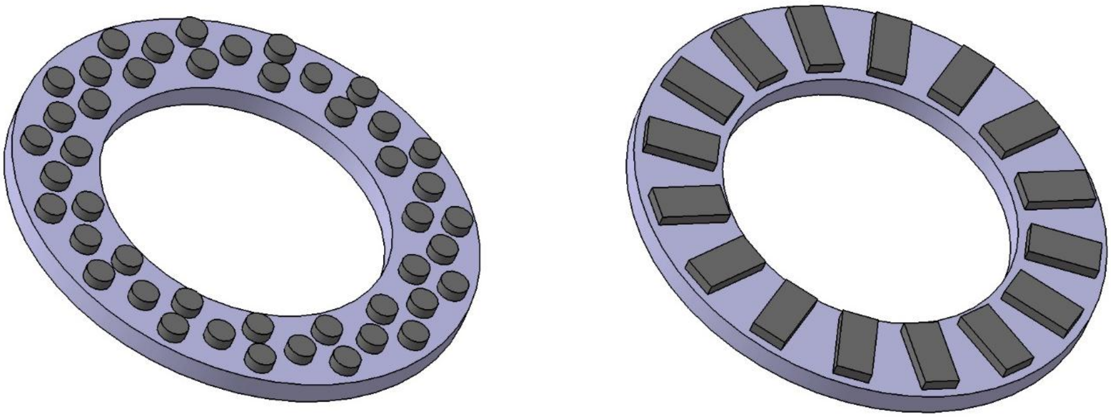


Fig.7. Variation of mass losses of basalt and brake disc parts

Analyzing the results obtained from the experimental determinations, it is found that the use of braking elements in cars, made of basalt powder, significantly increases their service life. Knowing that the sliding friction force does not depend on the area of the contact surface, the brake pads can be redesigned in the form of pads arranged radially on the brake disc of the car (figure 8).



a b

Fig.8. Brake disc design

4. CONCLUSION

One of the most important uses of sintering in the modern era is the manufacture of sintered components from ceramic materials, including basalt, with a high resistance to wear, chemical agents, etc.

The use of basalt products is due to its special mechanical properties: hardness, abrasion resistance, corrosion leading to its use in areas where metallic materials have deficiencies (low strength, high wear, etc.).

From an economic point of view, basalt is used because: in the production of basalt parts the fuel consumption is 6 times lower than in the case of cast iron or high alloy steels, a ton of basalt parts can replace 2.53 tons of laminate, the price delivery of basalt parts is 7 to 10 times lower than those made of alloy steel.

Sintering produces small parts, complexly configured, with dimensional deviations of the order of ± 0.1 mm and roughness between 3.2 ÷ 3.7 µm, values higher than those obtained in the case of molten basalt. The use of basalt pads can lead to the reuse of brake discs as the pads can be replaced (when they have reached maximum wear).

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