PRODUCTION AND SURFACE RESEARCH OF A NEW MATERIAL WITH THE ADDITION OF DIATOMITE FOR POTENTIAL FILTRATION APPLICATIONS

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Abstract. This work is dedicated to the research and study of the possibility of using Natural minerals such as Diatomaceous Earth (diatoms) for filtering various environments. The extraordinary progress and prospects of diatomaceous earth (DE) as a biomatrix material for creating porous materials are relevant and interesting. The unique structures of DE, including its mesoporosity and large surface area, have made it a key material for the filtration process. Its biotemplating ability can initiate the creation of highly efficient porous permeable materials. Its sufficient natural abundance and ecological properties are consistent with the increasing emphasis on sustainability in environmental solutions. Its complex structures and biotemplating capabilities will pave a compelling path in the future for the advancement of sustainable, highly efficient solutions for filtering environments, marking a significant step towards a more ecological and efficient future for humanity.
This research paper explores the potential of DE as a bio-matrix material for creating a permeable material without delving into the complex filtration processes. Previous studies have shown that the use of Diatomaceous Earth with titanium powder in various proportions allows us to talk about the possibility of creating highly efficient porous permeable materials with branched porosity even for drinking water filtration.

Keywords: Diatomaceous Earth, porous permeable materials, pressing, sintering, profilogram

1 Introduction

Filtration - the process of separating suspensions or aerosols using filter partitions that pass liquid or gas, but retain solid particles, is carried out in special devices - filters.

The effectiveness of filter production in the world in modern economic conditions depends significantly on the rational selection of cheap materials and the use of resource-saving technologies. The competitiveness of industrial corporations, enterprises, factories, and firms is formed by regulating the cost of production and using the latest technologies. Modern technological innovations allow considering natural materials as an additional source of raw materials.

In materials science, new ideas often arise from inspiration and study of natural design works. Structured surfaces are an integral part of many fields of science, including materials science, namely chemistry, microelectronics, optics, photonics, filtration, etc. A key innovation here is the use of bio-templated materials, in particular those made from Diatomaceous Earth.

Natural minerals such as Diatomaceous Earth (diatoms) are widely used in many areas of the national economy, are used in various industries, namely in filtering for various types of water. The use of this material will help to solve a number of problems related to the filtration and purification of wastewater and drinking water, as Diatomaceous Earth has high operational properties due to the uniqueness of its structure.

In modern water purification technology, when drinking water is consumed, the use of natural and artificial materials is expected to solve the problems. Basically, sorption processes are implemented using activated carbon or their analogues - graphite mineral sorbents, for the same purposes saponites, zeolites, clinoptilolites, etc. are used as filter material or contact loading.

Diatomaceous earth filtration is a process that uses diatoms, or diatomaceous earth, the skeletal remains of small single-celled organisms, as a filter medium. This type of diatoms filtration relies on a layer of diatomaceous earth placed on top of a filter element or baffle [1, 2].

This filtering process is expensive, difficult to use and not always economically beneficial.

Powder metallurgy with each newly developed technological process demonstrates advantages that allow obtaining materials with better or completely new properties, or manufacturing products in the most economically beneficial way.

Therefore, the creation of new filters using Diatomaceous Earth by powder metallurgy methods is relevant at the current stage of industrial development.

2 Literature Review

Due to the growing need to find alternative raw materials for filtration, the demandfor natural resources has increased in recent years [3].

To solve these problems, in recent years there has been a growing interest in finding solutions that aim to urgently reduce the negative impact associated with environmental pollution, which, in turn, is one of the biggest challenges facing modern society.

The importance of porous ceramics cannot be underestimated, as its unique properties such as high melting point, high corrosion resistance, high wear resistance, low density, low thermal conductivity and low dielectric constant are extremely important for the filtration process.

In particular, porous ceramic materials are possible materials for creating porous filter ceramics. The driving force behind the development of porous ceramic filters with a higher level of thermal and chemical stability is the availability of high-quality starting ceramic material [4].

In general, the most important aspects of porous ceramic filters are their permeability. Therefore, it is important to control the average and largest pore size while maintaining the degree of permeability [5].

The characteristics of the pores - depth, tortuosity, closedness and openness - are difficult in the application of ceramic filters [6]. Therefore, the main attention is paid to various approaches that allow controlling the microstructural features of the porous layer of the filter material, which ultimately determine the permeability properties.

Despite the fact that the methods of obtaining porous filter ceramics are widely described in literature sources [7, 8], the relationship between the characteristics of pores and the filter properties of porous permeable materials has not yet been definitively established.

In addition, ceramic filter materials are usually composites consisting of several layers of one or more different ceramic materials or a mixture thereof. Therefore, porous ceramic filters are usually manufactured in several stages.

The application and separation mechanisms of porous ceramic materials correspond to the pore size of the filters. Since it is difficult to create a surface layer of microporous or dense materials due to their low penetration characteristics, it is worth investigating porous ceramic materials consisting of only one layer and a surface layer consisting of the same macroporous material.

Recent developments in porous ceramic materials have increased the need to investigate the surface layer, as the overall permeability and reliability of the pores in the surface layer are critical for the application of porous ceramic filters.

Although various literature sources [9, 10, 11] investigate commonly used materials for ceramic filters, such as Al_2O_3, TiO_2, ZrO_2, SiO_2 and composites of these materials, few scientific studies have been conducted on the application of starting particles for - lack of ceramic porous materials, such as diatomite [12].

Diatomite is a sedimentary rock derived from the siliceous fossilized skeletons of diatoms, which are composed of hard cell walls called frustules. To date, no detailed studies have been published on the use of a surface layer of ceramic porous material made of diatomite or its composite

Diatomaceous earth, or diatomite, fits into this context, since it is a material consisting of 87-91% SiO_2 [13], a large part of which (25-100%) is usually amophous, namely opal silica (opal-A). Due to the high content of amorphous silica and the entire surface of diatomite, it has a high filtration capacity for use in the production of porous cement-based composites [14, 15].

Therefore, the purpose of this research was to create and study the structure of a new material based on diatomite with the prospect of developing new porous permeable materials for drinking water filtration on this basis.

3 Researches Methodology

The analysis of many literary sources shows that promising methods of obtaining filters are methods aimed at creating filters with an anisotropic structure, in which the size and number of pores change in the direction of filtration. In such filters, the fineness of the filtration will be determined by the layer with the minimum pore size, the permeability is an integral value determined by the porous structure of the entire material, and the pollutant during the filtering process is distributed over the entire volume of the filter element, which allows to increase the service life of the filter.

The selection of charge materials is of great importance for obtaining high-quality products [16].

In this work, the basis of the composite components of the charge for obtaining filter partitions was Diatomaceous Earth powder and titanium. Since titanium is characterized by an interesting combination of such properties as high strength, low density, resistance to corrosion and biocompatibility. Therefore, titanium is increasingly used in industries with high requirements, such as the filtration industry, the production of biomedical devices, etc.

The batch composition of the components was determined experimentally.

The ratio of the charge components is summarized in **Table 1.**

Table 1. Ratio of charge components

№ sample	**Diatoms, %**	**Ti, %**
1	70	30
2	60	40
3	50	50

Pressing of the mixture was carried out on a PSU-125 hydraulic press. A single-sided pressing mold made of X12CrNiTi8-10 stainless steel was used to form the samples. Pressing was carried out in the pressure range of 10–20 MPa for 1 min. The samples had a cylindrical shape with a diameter of 20 mm and a height of 6 mm. The appearance of the hydraulic press is presented in **Fig.1.**

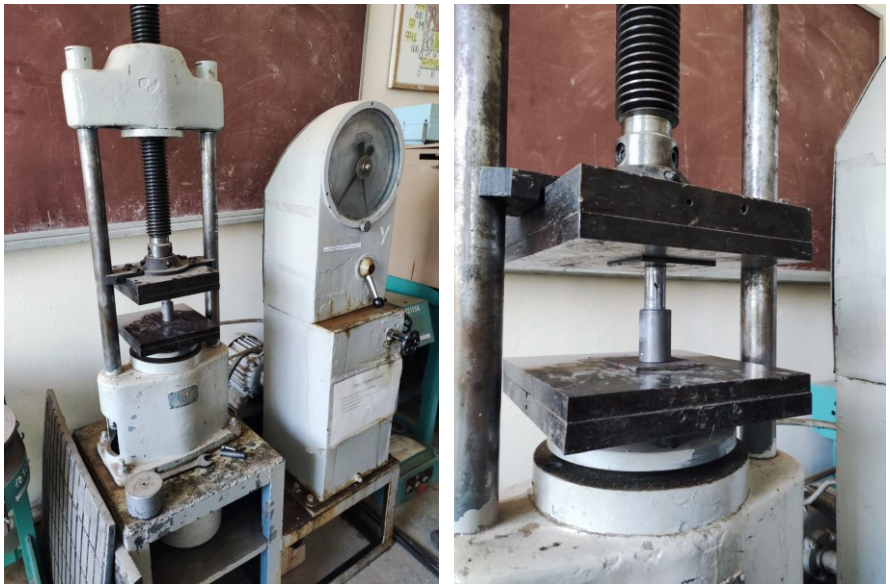


Fig.1. External view of the hydraulic press PSU-125

Sintering of the samples was carried out in a modernized reactor for self-propagating high-temperature synthesis, developed by scientists of the Lutsk National Technical University [17] (**Fig. 2**).



Fig.2. Modernized reactor for sintering in the SHS mode

This reactor design allows obtaining samples with minimal energy consumption at the highest possible productivity. For maximum control over the SHS process, 2 thermocouples are installed in the reactor, above and below the test sample. This arrangement of thermocouples allows controlling the speed of combustion wave propagation and uniformity of sintering at all stages [18].

Sintered samples are presented on **Fig. 3.**



Sample №1 Sample №2 Sample №3

Fig.3. Photo of samples (mixture from the table 1)

The porosity samples, which usually do not have through porosity, is measured by three main methods: hydrostatic weighing, mercury porometry and metallography [19, 20].

In this work, the porosity of the samples was investigated by hydrostatic weighing **(Fig.4).** The results of the obtained data are true density, average density, open porosity and water absorption presented on **Fig.5.**

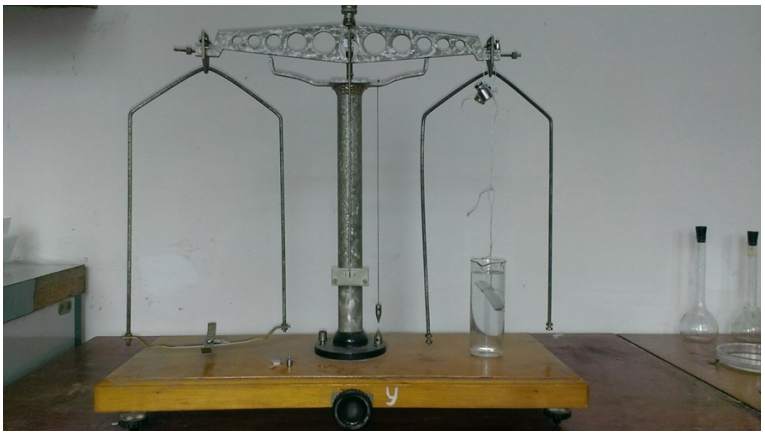


Fig. 4. Hydrostatic weighing

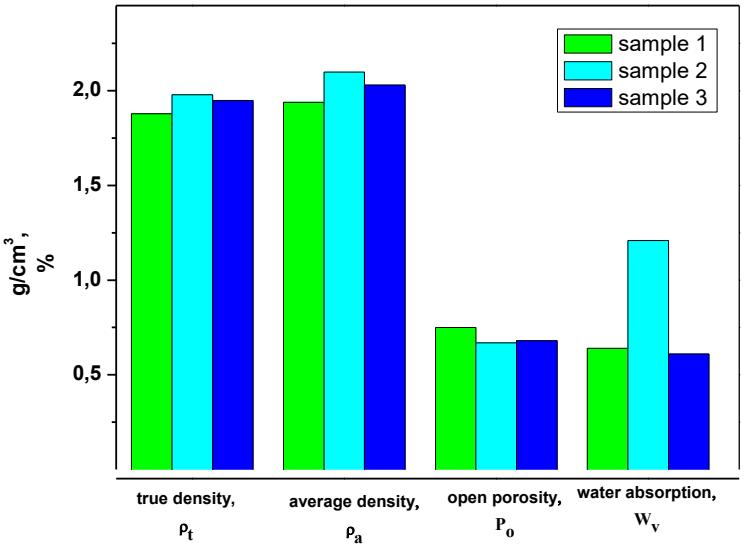


Fig.5. Results of porosity and water absorption determination Sample№1 Sample №2, Sample №3 (diatomite + Ti)

4 Results

The complex structure and high porosity of diatomite make it an excellent basis for modern permeable materials for various filtration.

SEM image of the porous material diatomite + Ti is presented in **Fig.6**. From these images, it can be seen that the biocomposites diatomite + Ti indicate a heterogeneous porous structure with polygonal pores.

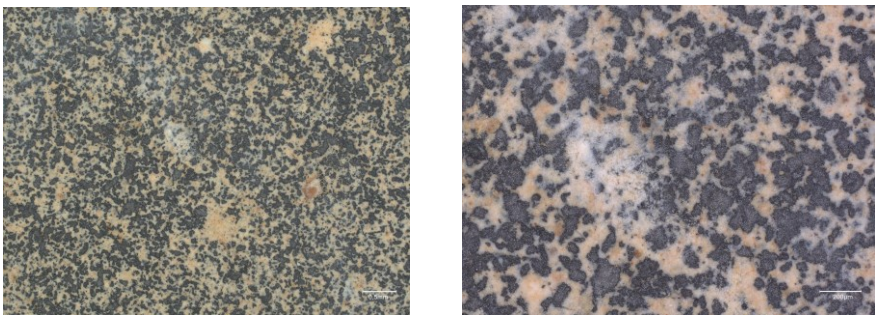


Fig.6. SEM-image of porous material (diatomite + Ti)

To observe the differences in the structure of the porous material diatomite+Ti samples were subjected to profilographic analysis (**Fig.7**). Measurements were performed for four parallel locations on the surface for each sample by method [21].

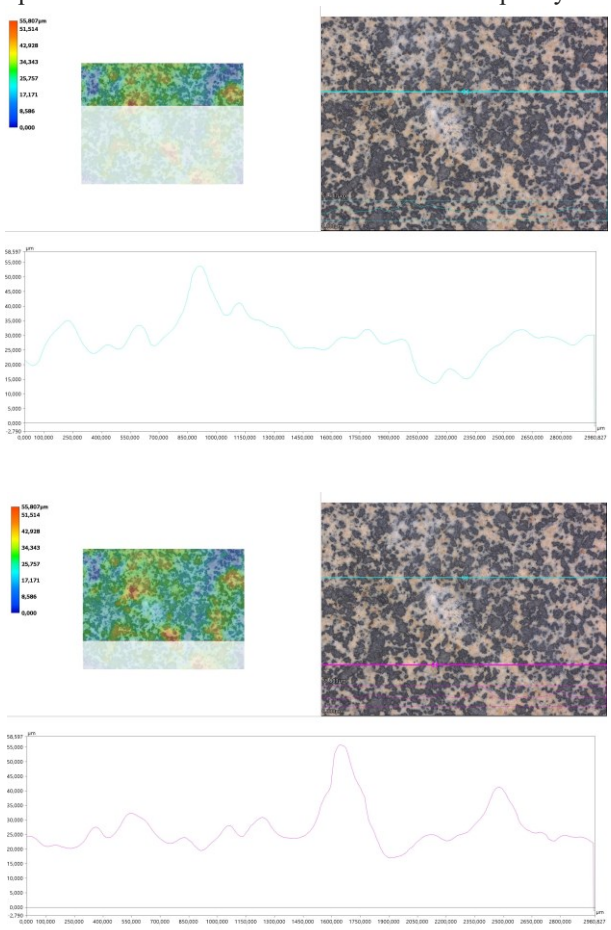


Fig.7. Profile graph for each measured profile Sample №2 (diatomite + Ti)

When creating a new type of filter material with the addition of diatomite, a structure is formed with an outer surface and an average roughness of Rz=75μm, Ra=12.3 μm (Sample №2). With increasing pressure, the surface roughness decreases slightly (**Fig.8**). The average roughness of the product also depends on the roughness of the stamp.

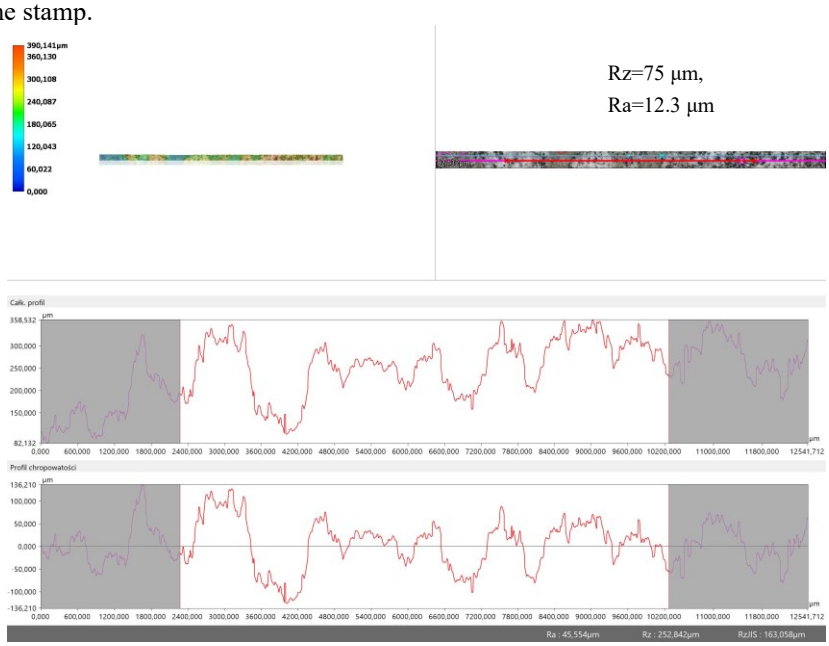


Fig.8. Summarizing profilogram for the measured profile Sample №2 (diatomite + Ti)

Comparative studies of the surface quality of samples made of other materials were conducted, which are listed in **Table 2**.

Table 2. Surface quality of different filtration materials

№	Materials	Ra, μm	Rz, μm
1	Diatomite + Ti	12.3…13.0	75.1…76.2
2	Ti	14.1…15.1	81.1…82.2
3	LH15	17.2…18.1	92.4…93.1

5 Conclusions

By investigating our materials, compressed diatomite + Ti, the article further highlights the versatility of Diatomaceous Earth in accommodating various materials, thereby expanding its application in future filtration technologies. An important aspect of the review is its emphasis on the environmental friendliness of Diatomaceous Earth. The environmentally friendly and biocompatible nature of Diatomaceous Earth distinguishes it from other materials, which often involve hazardous chemicals and complex processes.

The results obtained allow us to show the dependence of diatomite content on roughness. It was found that adding diatomite in a ratio of 60/40 to titanium allows us

to create filter materials with a higher quality surface. Experimental studies have shown that when creating a new type of titanium-based filtering material with the addition of diatomite, the quality of the outer surface with an average roughness of Rz=75μm, Ra=12.3μm is formed.

6 Acknowledgement

Using this template, it can be used as a framework and base for forming the porous structure of the material. This allows you to control the architecture and size of the pores and use these porous membranes as a future framework for creating new products with a well-defined porous structure.

In the future, comprehensive research will be conducted to create full-fledged diatomite filters with a developed surface for better and more productive work. Filters based on diatomite + Ti in further scientific research can be used to filter various types of liquids to eliminate pollutants, including various types of bacteria. If the filter is properly designed in the appropriate proportions, it can be used to remove bacteria up to 100%.

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