Production of composite materials using a microwave plasma installation. Research and analysis of the characteristics of the obtained materials.

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Introduction

There are known technologies for the use of high-frequency capacitive (HF) discharge, microwave plasma technologies with the supply of materials by air transport to the processing zone. These technologies for modifying the processing of products have technological limitations: the cyclic type of loading and unloading of products, short plasma exposure time, limitation or inability to work with liquid media, the use of inert gases as a plasma-forming gas [7].

Early studies on the use of basalt fibers in combination with leather, cellulose and textile fibers were unsuccessful, because basalt mineral fibers are difficult to glue with binders and, further, did not allow to obtain a smooth surface of the composite after pressing the studied samples (Fig.1).

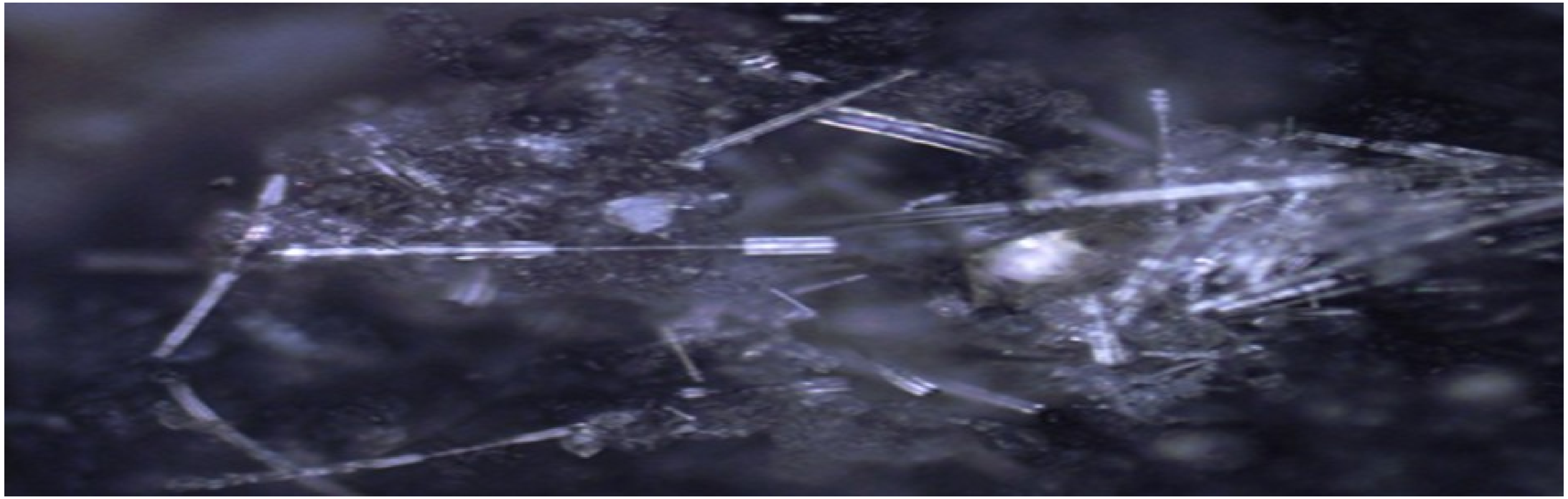

Fig. 1. Micrographs of basalt fibers on the surface of the composite processed in the traditional way (×200).

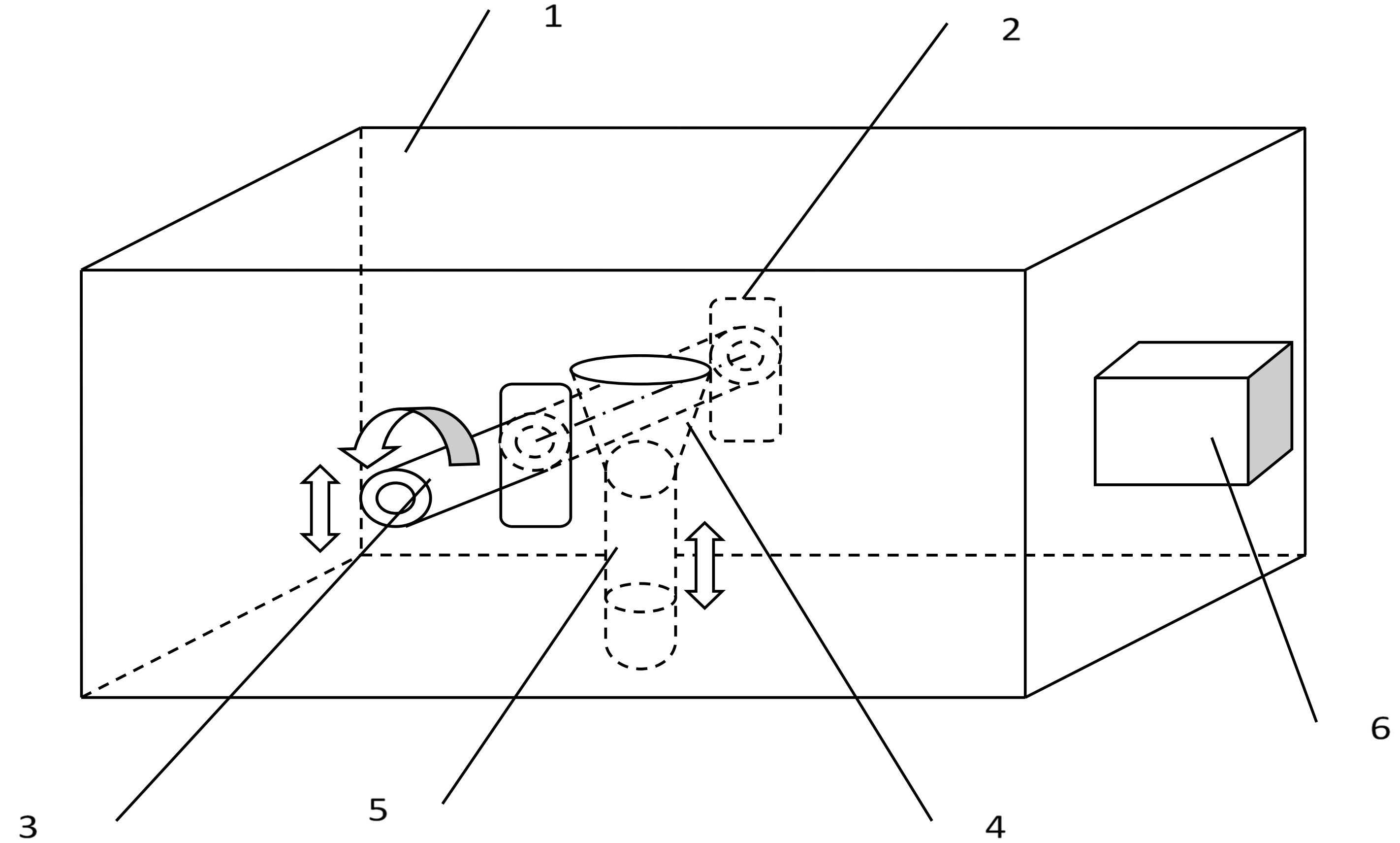

Fig. 2. The design of the developed microwave plasma torch and the experimental scheme. 1- magnetron, 2-feeding guide, 3 – resonator chamber, 4 – plasma transition zone, 5- cone chamber, 6-diverting guide.

The reaction chamber

is made of refractory clay and has a conical shape for excitation by a microwave wave source – a magnetron with a radiation frequency of **2450 MHz** and the transition of the substances in the plasma state. At the same time, the composition of substances located in the reaction chamber depends on the temperature, amplitude and frequency of radiation waves that affect the processed composite materials.

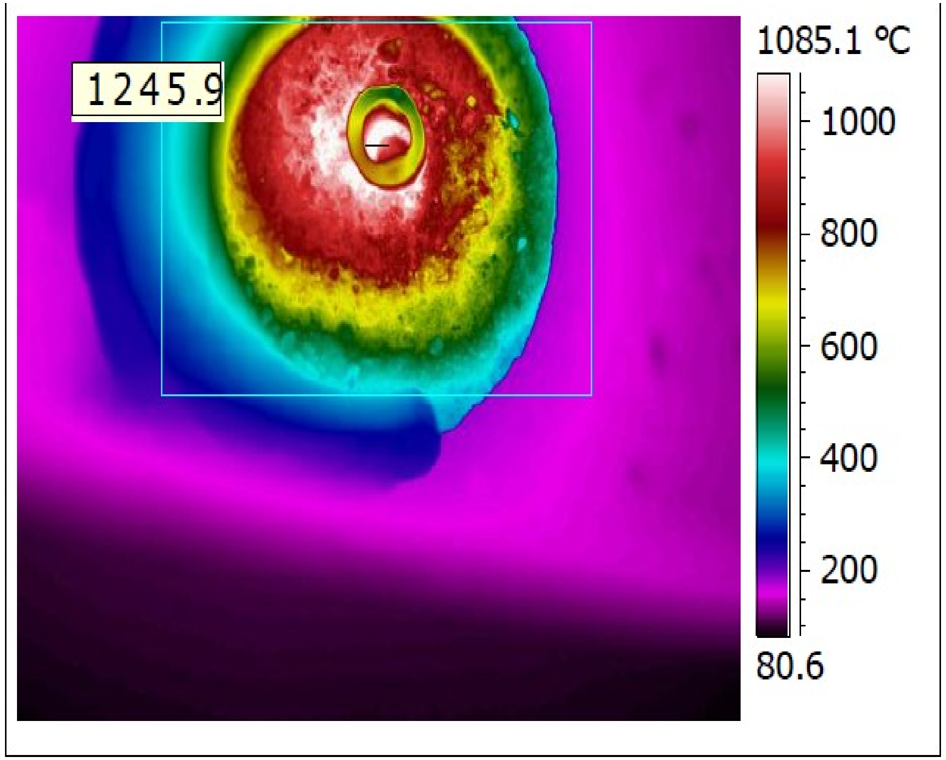

Fig. 3. Forced emissions of a plasma substance consisting of a mixture of charcoal and sand SiO.

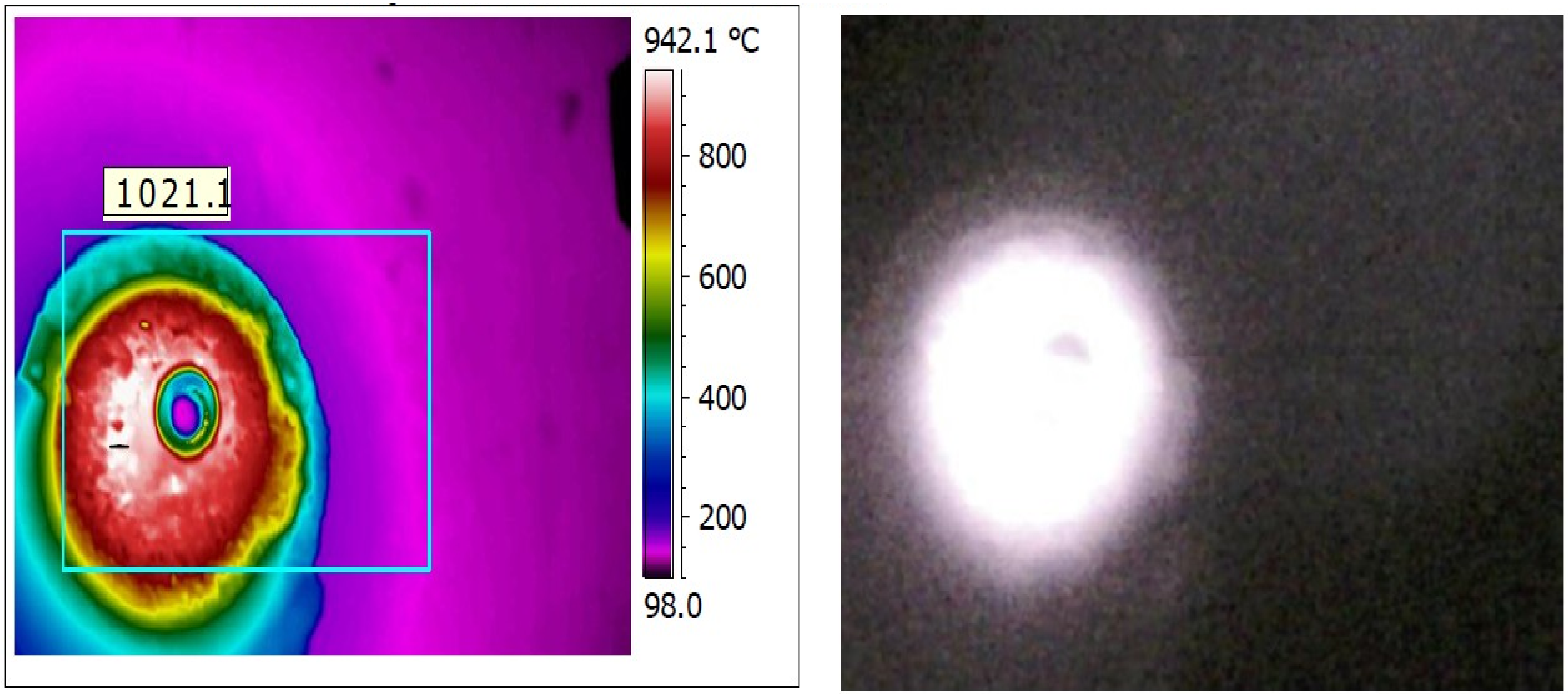

Fig. 4. Forced emissions of plasma matter consisting of brown coal from the Kara Kechinsky Field.

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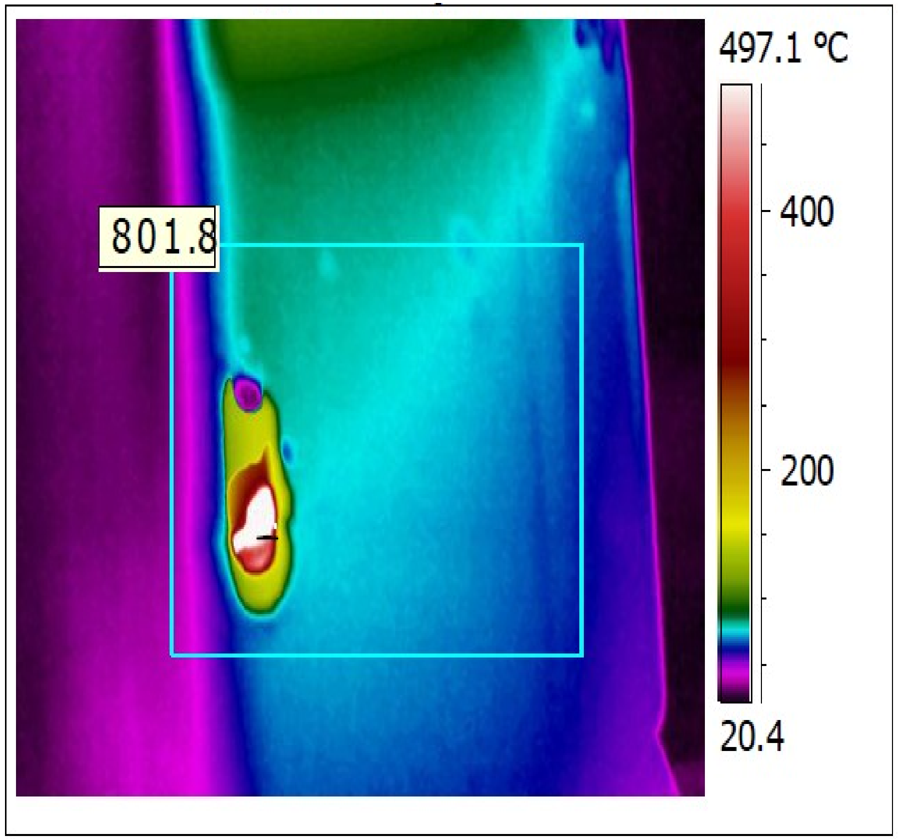


Fig. 5. Forced radiation of a plasma substance consisting of charcoal.

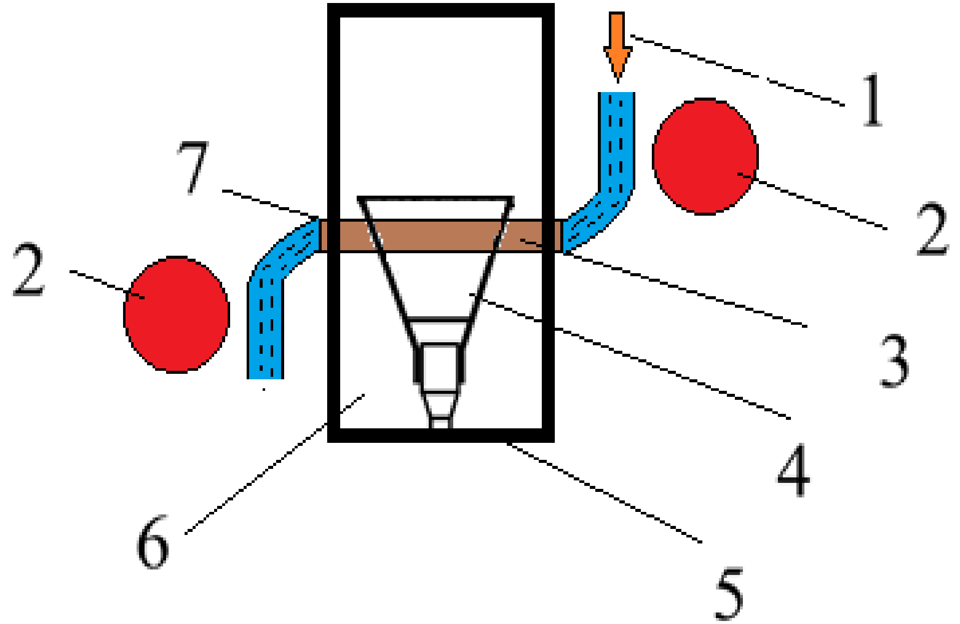


Fig.6. Diagram of a laboratory microwave plasma unit for processing the crushed fraction in a liquid medium:

1-crushed fraction, 2- thermometer at the feed inlet, 3-ceramic tube, 4 - reaction chamber, 5 - resonator chamber, 6- microwave energy generator (magnetron), 7- rubber tubes.

Scheme of interaction of crushed basalt fiber with a microwave plasmatron.

The crushed fraction of basalt, pre-mixed with water, is fed into the upper part of the rubber tube 1 enters the ceramic tube 3 and is exposed to radiation from the plasma substance located in the reaction chamber 4 and exits continuously from the ceramic tube into the rubber tube 7 and is collected in a container. **The inlet temperature** shows **the room data** of the liquid medium. **At the outlet**, the temperature varies from **400 C to 800 C**, depending on the conditions of the experiment.

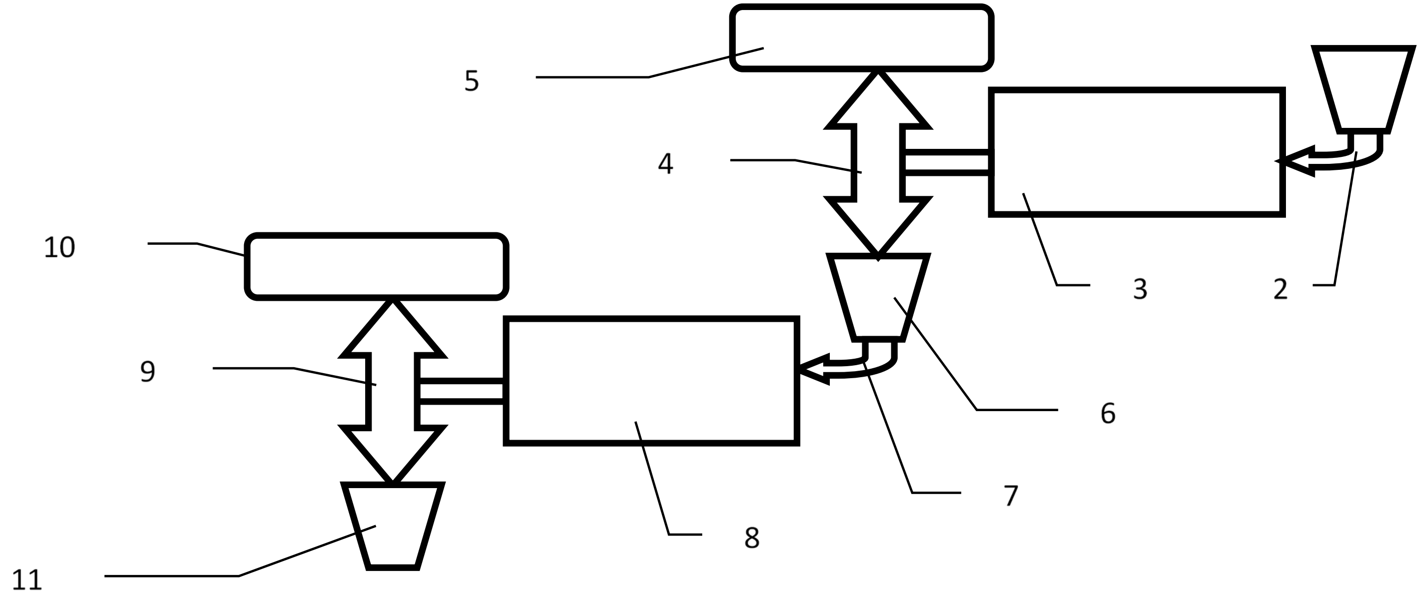
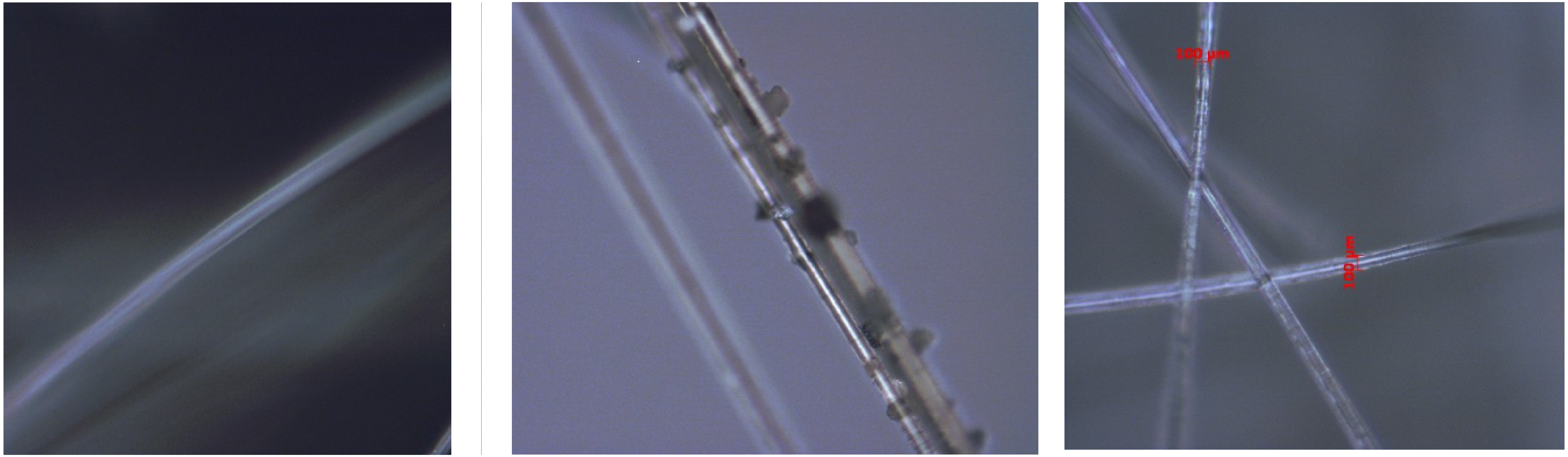


Fig. 7. The scheme of organization of multi-stage processing.

According to this scheme, from Bunker 2, liquid with materials is fed into the microwave plasma treatment zone 3 and at outlet 4, gaseous processing products are collected into a container 5 and liquid substances are further fed into the next hopper 6 to feed 7 into the second microwave plasma treatment zone and then identically divided into 9 into a gaseous part 10 and liquid 11.

Research of the obtained composite materials

The basalt fibers obtained in this way have the following appearance (Fig. 8,9,10). Microscopic examination shows that basalt fiber has a smooth surface before processing on a microwave plasma installation (Fig.8a), after plasma exposure, changes in the surface of the fibers were traced. Significant changes were observed at the ends of the basalt fiber in the form of sintering and a modified, perforated fiber surface along its entire length (Fig.8 b, 9 a, b, c), which increased its functionality, improving the adhesive properties to sizing materials and obtaining basalt fibers with improved properties.



a)before treatment	b)after plasma treatment

Fig. 8. Micrographs of basalt fibers before and after plasma treatment

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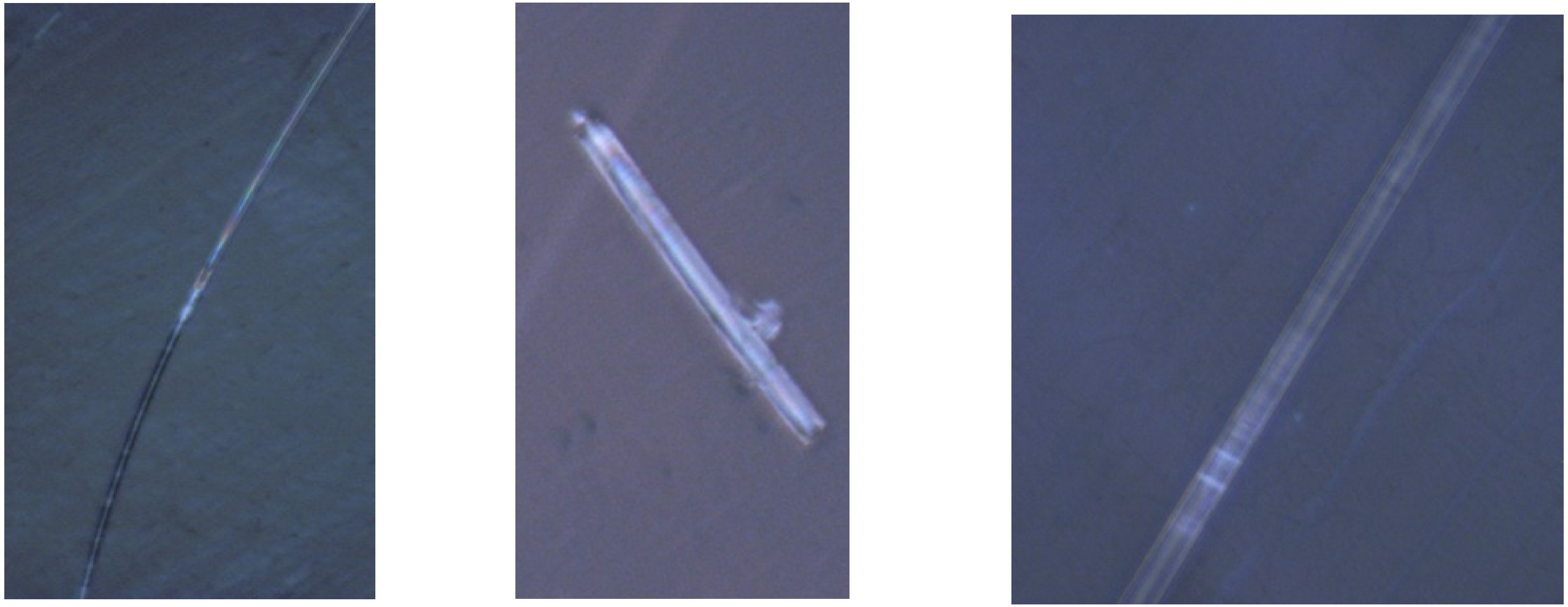

a)	b)	c)

Fig. 9. Micrographs of a microwave treated with plasma exposure to basalt fiber (a, b -×500, c -×1000).

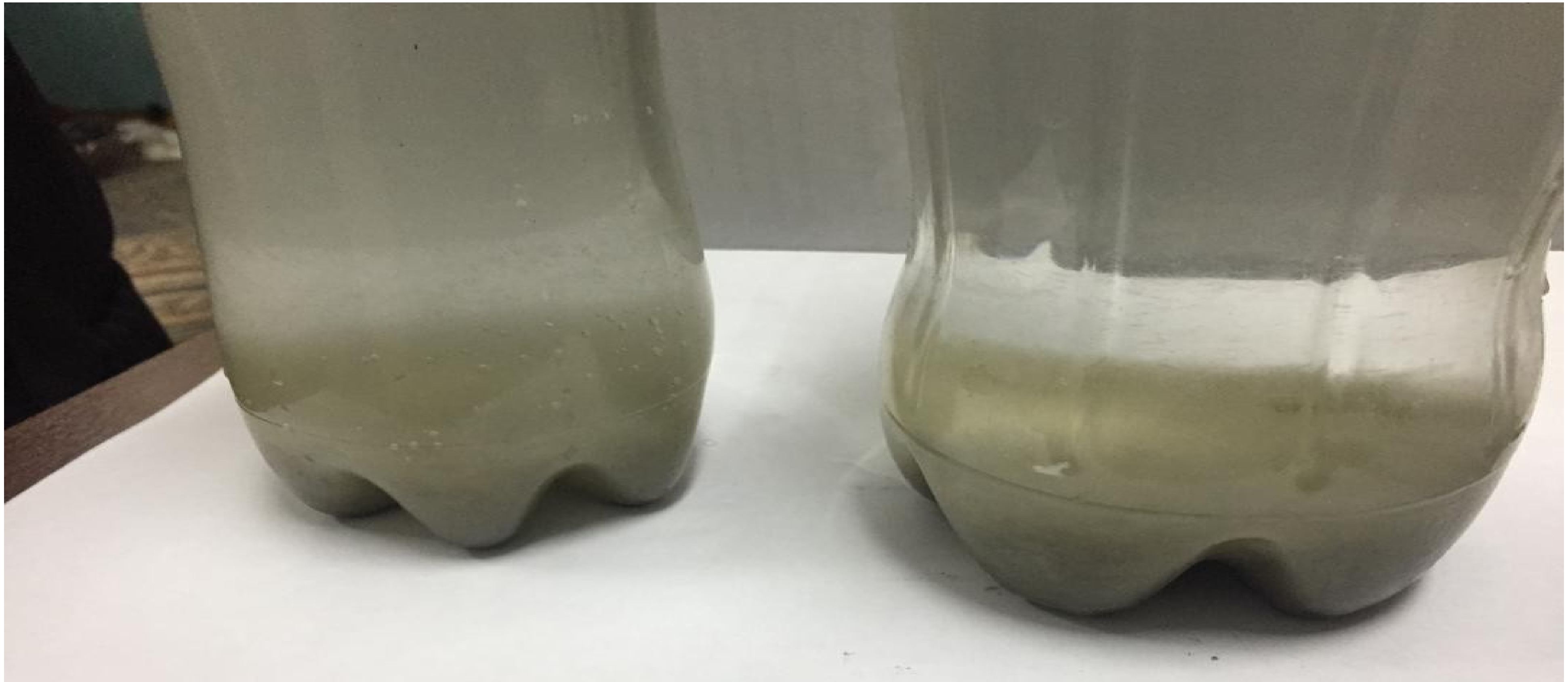

Fig. 10. Photographs of basalt fibers in a water environment. On the left after plasma treatment and on the right without treatment.

	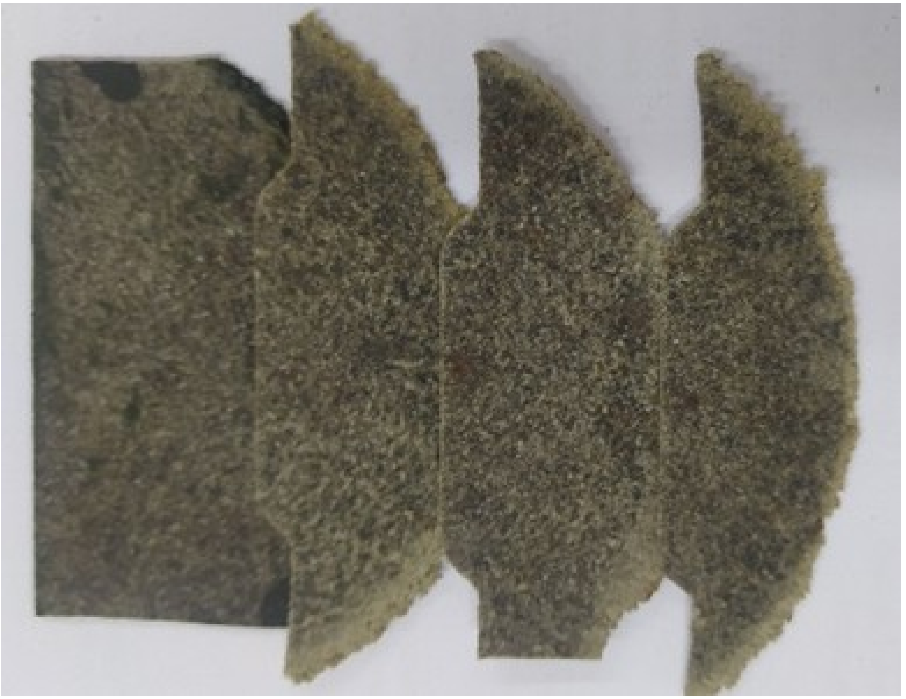
a)	b)

Fig.11. a) Cardboard for the bottom of shoes b) Cardboard for the tops of shoes and leather goods

The tensile strength of the obtained samples such as **cartons for the bottom of shoes**, in which basalt, textile, leather, and cellulose fibers were used, are in the range of **2.5 – 4.5 MPa**, depending on their composition (Fig.12). **The samples obtained on the basis of leather and basalt fibers, as well as collagen and plasticizer dissolution products** (Fig. 11, b), give fullness and flexibility to the materials. **The strength characteristics** of such composites are **up to 10 MPa** and **an elongation of 25-35 mm**, which is typical for genuine leather (Fig. 13). Composite materials using basalt fibers were also studied for thermal conductivity [12], **cartons for the bottom of shoes with lower values (0.049 to 0.088 W/(m•K) thermal conductivity**, with an acceptable 0.1-0.12 W/(m•K)) were obtained, which allows creating favorable thermal protection conditions when wearing shoes **to maintain a good temperature regime inside the shoe in the cold, increase the resistance to getting wet, preventing delamination and maintaining the linear dimensions of the shoe parts, thereby increasing the duration of shoe operation.**

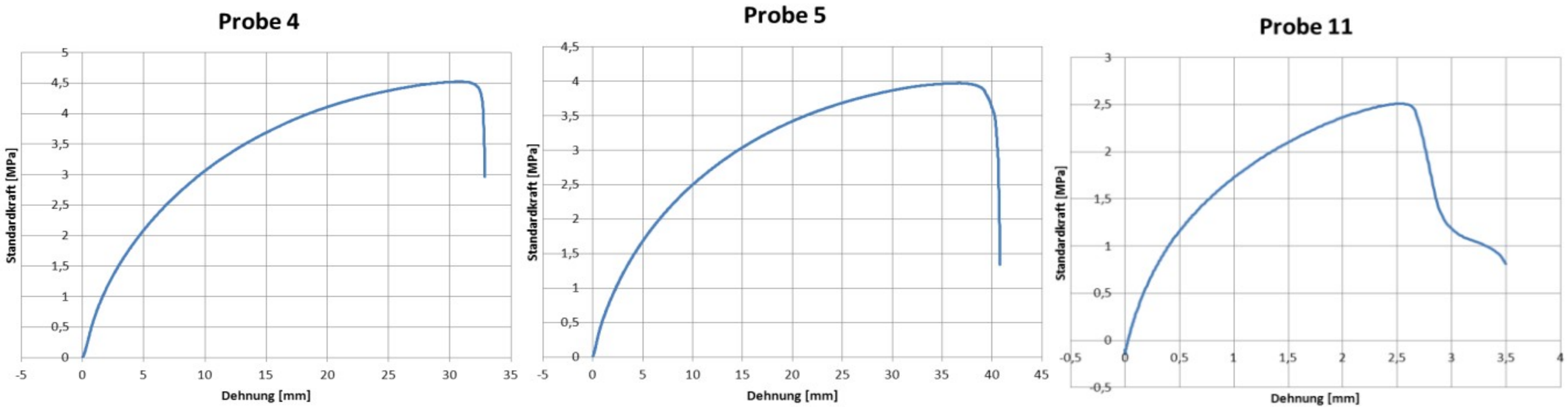

Fig. 12. Tensile strength of samples based on leather, textile, cellulose and basalt fibers

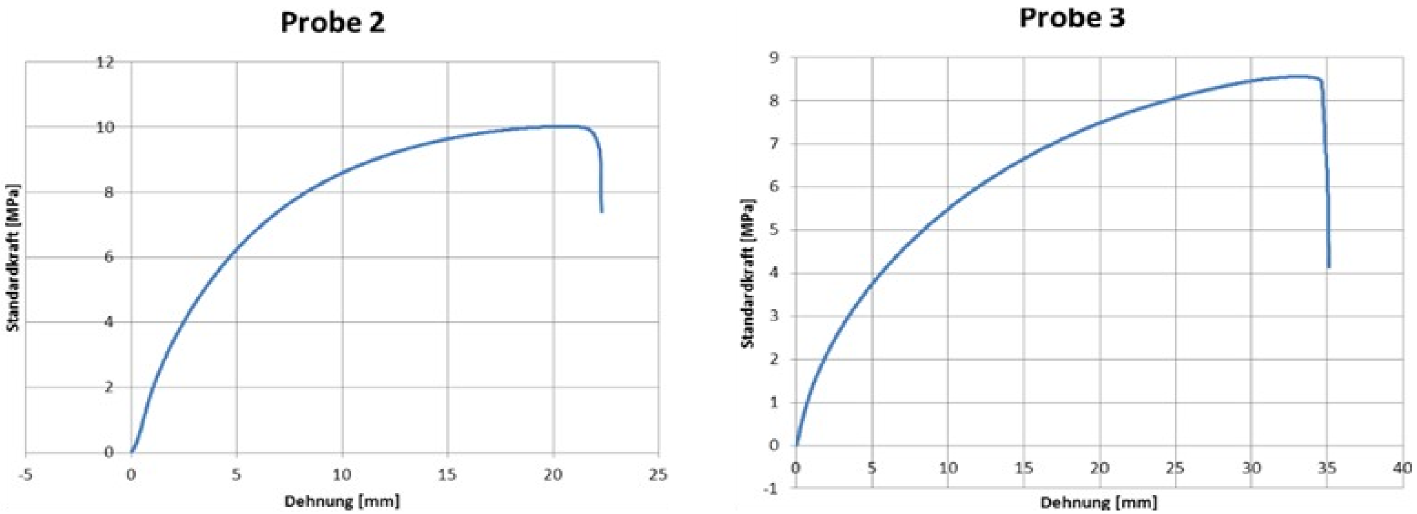

Fig. 13. Tensile strength of samples based on leather and basalt fibers

The measurement results of 32 samples with different binders and the composition of fibrous materials, as well as their calculations, are shown in **Table 1**. The range of specific **thermal conductivity** of experimental samples is **from 0.04 to 0.1. With an increase in the number of cellulose and textile fibers, thermal conductivity increases** regardless of the processing of basalt fibers. Among the samples where leather fibers have a shorter length and basalt fibers with different treatments are used, the PVA sizing material has the greatest effect on thermal conductivity. **When using longer leather fibers, the thermal conductivity increases** – because the surface of these fibers has a larger number of active groups and high adhesion, which gives strength to the obtained samples, this is also facilitated by the presence of cellulose and textile fibers, which also have good activity to the binder.

Table 1. Results of thermal conductivity determination

Sample №	Sample thickness, mm	Weight sample, g	Heater temperature, ^0C	Refrigerator temperature, ^0C	Temperature difference, ^0C	Heater voltage,, V	Heater power, W	Thermal resistance, W/(m2·K)	Specific thermal conductivity, W/(m·K)
1	2,5	13,96	39,25	18,25	21,0	8,9	3,9605	26,0851	0,065213
2	2,8	14,49	39,375	17,625	21,75	8,78	3,8544	24,5110	0,068631
3	3,8	20,10	39,5	17,06	22,44	7,3	2,6645	16,4231	0,062408
4	3,4	23,00	39,5	18,19	21,31	8,94	3,9962	25,9372	0,088187
18	4,3	22,24	39,5	17,75	21,75	8,12	3,2967	20,9645	0,090147
19	4,1	20,53	39,25	18,375	20,875	8,7	3,7845	25,0752	0,102808
20	3,4	19,05	39,375	17,25	22,125	7,71	2,9722	18,5805	0,063174
21	3,5	13,92	40,0	16,56	23,44	6,9	2,3805	14,0466	0,049163
22	4,7	22,98	39,625	16,44	23,185	6,81	2,3188	13,8331	0,065015
23	4,1	17,11	39,5	16,875	22,625	7,71	2,9722	18,1699	0,074496
24	3,5	13,26	40,0	16,25	23,75	6,95	2,4151	14,0650	0,049227
25	4,5	22,56	40,0	17,0	23,0	7,03	2,4711	14,8599	0,066869
26	4,0	18,46	39,375	17,25	22,125	7,51	2,8200	17,6290	0,070516
27	4,5	19,46	40,0	17,375	22,625	7,01	2,4570	15,0203	0,067591
28	4,3	21,03	40,0	17,25	22,75	7,56	1,5456	9,3972	0,040408
29	5,5	21,75	39,625	16,5	23,125	6,51	2,1190	12,6740	0,069707
30	4,2	22,67	40,0	17,25	22,75	7,62	2,9032	17,6506	0,074133
31	4,0	20,94	39,5	16,81	22,69	7,52	2,8275	17,2359	0,068943
32	5,5	23,28	39,25	16,875	22,375	6,88	2,3667	14,6300	0,080465

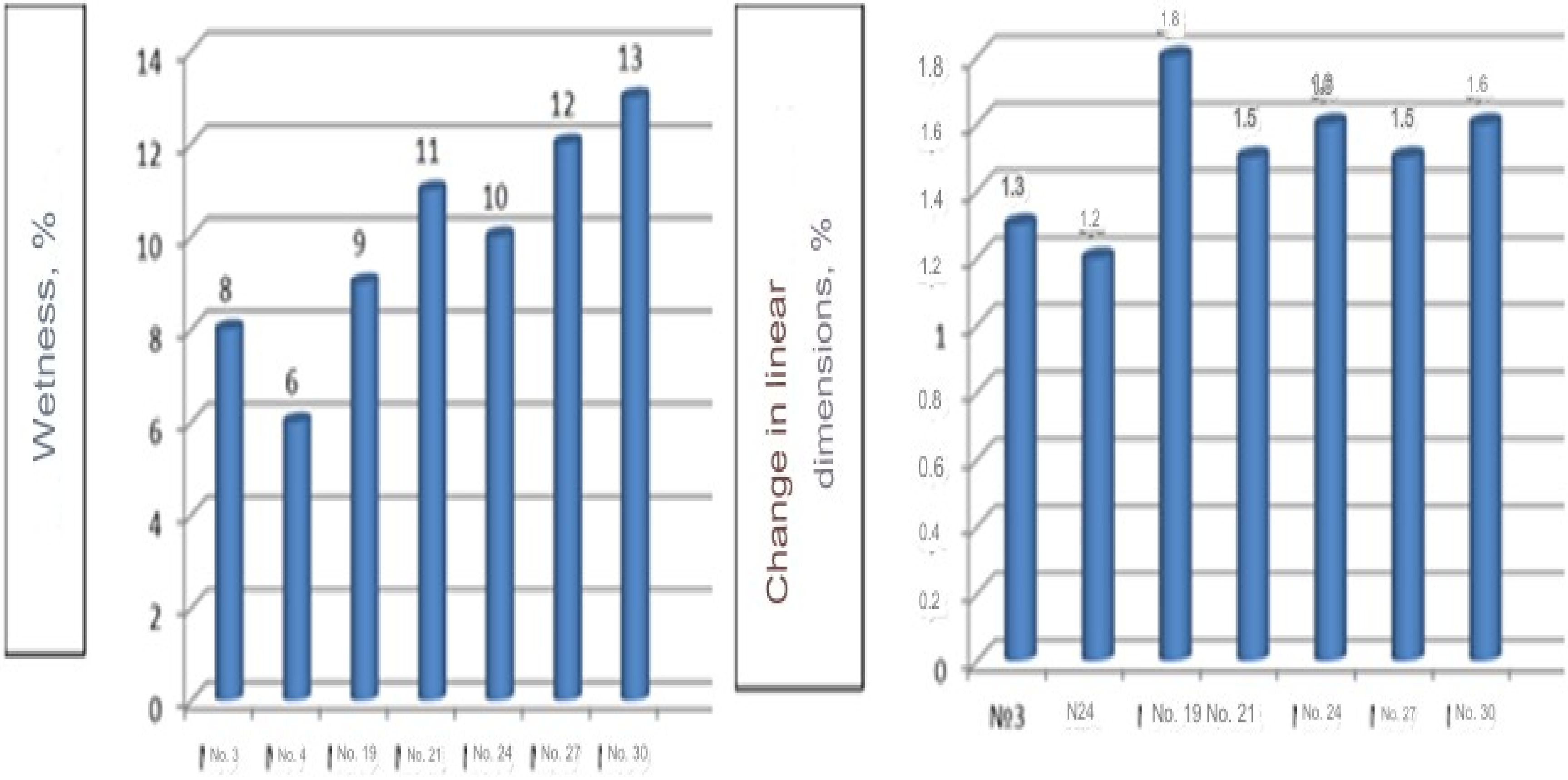

Fig. 14. Indicators of wetness and change in linear dimensions

By including basalt fibers in composite materials, we increase their hydrophobicity, reduce wetness, while maintaining the linear dimensions of the samples.

Conclusion

The studied characteristics of cardboard are most important for **special shoes that withstand various aggressive environments, temperature range, radiation, etc.,** where the main requirements are to ensure occupational safety, **protect the foot from harmful industrial factors, protection from special and low temperatures, aggressive environments, exposure to chemicals and radioactive radiation, toxicity, and others .**

Conclusion

1. The conducted research and experimental laboratory experiments show **the prospect of introducing the effects of continuous microwave plasma installations on composite materials.** At the same time, schemes for the supply of composite materials in a liquid medium in a crushed form have been developed. **Two of the main problems have been solved -** mineral fibers were difficult to glue with binders and could not obtain a smooth surface of the composite after pressing the studied samples.

2. Basalt fibers in the details of the bottom of shoes can create favorable conditions for a person's foot when wearing shoes in an atmosphere of low and high temperatures. **The use of basalt fibers, taking into account a wide range of physico-mechanical, physico-chemical properties**, will make it possible to obtain shoe products with improved characteristics and indicators.

Conclusion

3. There are some thoughts how to organize a laser device using the microwave plasma device, described in this report. This will be studied in the future researches.

Literature

1. Abdullin I.S. High-frequency plasma treatment in dynamic vacuum of capillary-porous materials. Theory and practice of application / I.Sh. Abdullin, L.N. Abutalipova, V.S. Zheltukhin, I.V. Krasina. Kazan: KSU – 2004. – 428 p.
2. Rybkin V.V. Low–temperature plasma as a tool for modifying the surface of polymer materials / Chemistry - 2000. – No. 3. – pp.58-63.
3. Kutepov A.M. et al. Plasma modification of textile materials, prospects and problems / Russian Chemical Journal-2002.-No.1. -pp.103-114.
4. Perepelkin K. E. Structure and properties of fibers. — M.: Chemistry. 208p.
5. Sharnina, L.V. Scientific foundations and technologies of finishing textile materials using low-temperature plasma, new drugs and methods of coloring: abstract dissertation / Sharnina Lyubov Viktorovna. Ivanovo, 2006. 36p.
6. Khammatova V.V. Regulation of the molding ability of textile materials using plasma technologies: abstract of the dissertation / Khammatova Venera Vasilovna. – Kazan. 2006. – 32 p.
7. Grishanova I.A. et al. The effect of plasma treatment on the change in the mass of UHMWPE fibers / Bulletin of the Kazan Technological University. - 2010. - No.10. – pp.231-236.
8. Sadova, S.F. The use of STP in the finishing of woolen materials. Encyclopedia of NTP, series B, TI-5, M.: Janus-K, – 2006. – 538p.
9. Samsaliev A.A. Studies on Microwave-Plasma Treatment of Froth Flotation Tailings. Studies on microwave plasma treatment of foam flotation tails. / A.A. Samsaliev, A. Kozhonov, Yu.I. Toporkova, // Solid-state phenomena. 299,1044–1051. https://doi.org/10.4028/www.scientific.net/ssp.299.1044.

Literature

10. Samsaliev A.A. Device and method of regulating plasma effects on the liquid state of substances / A.A. Samsaliev – Bishkek.: Izvestiya KSTU named after I. Razzakov No. 29, 2013 pp. 174-177 https://elibrary.ru/item.asp?id=29214745
11. Tagaeva N.I. On the issue of the use of mineral fibers in fibrous composite materials/ Tagaeva N.I. Bishkek.: Bulletin of the Kyrgyz-Russian Slavic University Volume: 21 No.12, 2021 pp. 126-130. https://www.elibrary.ru/item.asp?id=4804561812 .
12. Tagaeva N.I., Champarov E. Yu. Investigation of the physico-mechanical properties of composite materials based on light industry waste using mineral fibers / Tagaeva N.I., Champarov E.Yu. - Bishkek.: Bulletin of the Kyrgyz-Russian Slavic University Volume: 21, No.12, 2021 pp. 119-125 https://www.elibrary.ru/item.asp?id=48045618
13. Chemistry and technology of polymer film materials and artificial leather [Text] / Edited by G.P. Andrianova, K.A. Polyakova, A.S. Filchikov, and others. 2nd edition, reprint. and additional - M.: Legprombytizdat, 1990. - 304 p.
14. Dzhigiris D.D.. Fundamentals of the production of basalt fibers and products : Monograph / D. D. Dzhigiris, M. F. Makhova. - M. : Teploenergetik, 2002. - 411 p.
15. Samsaliev A.A. Investigation of temperature and spectral changes of substances treated in the reaction chamber of a microwave plasmatron. Problems of risk management in the technosphere. 2023. No. 2 (66). pp. 197-205
16. Samsaliev A.A. Fixation of microwave spectra of a plasma ion source of continuous action. Journal: Scientific research in the Kyrgyz Republic. 2022. No. 3. pp. 20-26.
17. Alif Aiman Zamri, Mei Yin Ong, Saifuddin Nomanbhay, Pau Loke Show // Microwave plasma technology for sustainable energy production and the electromagnetic interaction within the plasma system: A review, Environmental Research, Volume 197, 2021, 111204, ISSN 0013-9351, https://doi.org/10.1016/j.envres.2021.111204.

Literature

18. Javier F de la Fuente, Anton A Kiss, Marilena T Radoiu, Georgios D Stefanidis // Microwave plasma emerging technologies for chemical processes. Journal of Chemical Technology & Biotechnology.Volume92, Issue10, October 2017, Pages 2495-2505, https://doi.org/10.1002/jctb.5205

19. Brandenburg J. E., Kline J., Sullivan D. The Microwave Electro-Thermal (MET) Thruster Using Water Vapor Propellant/ JEEE transactions on plasma science, -2005, - Vol. 33, - No.2, - April, - p.776-781.

Thank you for attention!

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