ABSTRACT AND REFERENCES

APPLIED PHYSICS. MATERIALS SCIENCE

RESEARCH INTO RHEOLOGICAL TRANSFORMATIONS IN A PIEZOCERAMIC ULTRASONIC SENSOR OF FLUID LEVEL CONTROL (p. 4-11)

Iosiph Stencel, Konstantin Litvinov

It was established that in the piezoceramic transducers of electric excitation pulse into ultrasonic signal that are used for measuring control of level of fluids and gas volumetric rate, similar electromagnetic processes occur. The effect of change in parameters of piezoceramic element on the formation of ultrasonic pulse was studied. It was shown that to create the pulse, the electric field intensity of this element is converted to electrodynamic force, which causes elastic deformation of a membrane unit. It was shown that the elastic deformation of a membrane unit causes electromotive force, which creates current in a piezoceramic element. The latter causes a secondary electrodynamic force, which is braking for a mechanical unit that leads to the deformation of mechanical ultrasonic oscillations. Physical models of irreversible rheological transformations are given and it is shown that the following processes occur in the piezoceramic transducers: conversion of electric exciting momentum to mechanical motion of a membrane of transducer, the latter to mechanical ultrasonic oscillations, and these oscillations to electromotive force of a piezoceramic element. The processes of irreversible rheological transformations are presented by the integrated pulse Dirac delta function. It was shown that such transformations are described by nonlinear differential equations, the right part of which characterizes the rate of decrease (flow) of electrical or mechanical energy, and these equations are the core of the integrated pulse Dirac delta function. Analytical solution of nonlinear differential equations of transfer of energy, mass and momentum by a zero gradient was obtained.

A mechanism of the effect of temperature of heating of a piezoceramic element on the ultrasonic pulse form was determined.

The essence of the impact is the fact that as a result of the heating of this element by electric current of excitation pulse and secondary electromotive force, its linear dimensions, resistance and density of the material change, leading to a phase shift of the ultrasonic pulse.

Keywords: piezoceramic, ultrasound, pulse, rheology, natural gas, fluid, membrane, pulse, intensity.

References

1. Zhmylev, A. B., Titov, S. V., Toom, K. E., Topunov, A. V. (2002). Patent 2195635 Rossijskaya Federaciya, MPK G01F23/28. Sposob izmereniya urovnya zhidkih i sypuchih sred. Zayavitel' i patentoobladatel' zakrytoe akcionernoe obshhestvo «Vzlet». № 2002104724/28; declared: 21.02.02; published: 27.12.02, Byul. № 19, 3.
2. Subhash, N. N., Balasubramaniam, K. (2014). Fluid level sensing using ultrasonic waveguides. Insight – Non-Destructive Testing and Condition Monitoring, 56 (11), 607–612. doi: 10.1784/insi.2014.56.11.607
3. Moore, P. I., Brown, G. J., Stimpson, B. P. (2000). Ultrasonic transit-time flowmeters modelled with theoretical velocity profiles: methodology. Measurement Science and Technology, 11 (12), 1802–1811. doi: 10.1088/0957-0233/11/12/321
4. Zheng, X. M., Hu, J., Chen, Y. S. (2014). The Development of an Automatic Ultrasonic Non-Destructive Testing System. Applied Mechanics and Materials, 599-601, 1120–1123. doi: 10.4028/www.scientific.net/amm.599-601.1120
5. Ultrasonic level measurement (2002). Level: Technical Information/ Endress+Hauser GmbH+Co.KG. Endress+Hauser GmbH+Co.KG,.
6. Lagoda, D. P., Myetolkin, M. I., Pososhko, V. N., Uvarov, A. Ya. (2008). Patent 82594 Ukrayina, MPK G01S15/00, G01F23/28. Sposib vymiryuvannya rivnya ridkyx seredovyshh i ultrazvukovyj rivnemir. Zayavnyk i patentovlasnyk tovarystvo z obmezhenoyu vidpovidalnistyu Naukovo-vyrobnyche pidpryyemstvo «Mikroterm». #a200608554; declared: 31.07.06; published: 25.04.08. Byul. # 8, 3.
7. Piezoelectric ceramic sensors (Piezotite): Catalog №P19E6. Murata Manufacturing Co., Ltd., 33.
8. International Organization for Standardization (2010). ISO 17989-1: Measurement of fluid flow in closed conduits Ultrasonic meters for gas. Part 1: Meters for custody transfer and allocation measurement. Geneva, Switzerland: ISO.
9. Ultrasonic level measurement (2002). Level: Technical Information/Endress+Hauser GmbH+Co.KG. Endress+Hauser GmbH+Co.KG.
10. Froysa, K-E., Lunde, P. (2001). A ray theory approach to investigate the influence of flow velocity profiles on transit times in ultrasonic flow meters for gas and liquid. Paper presented at the 24 Scandinavian Symposium on Physical Acoustics, Ustaoset.
11. Stencel, J. I., Tomson, A. V., Shapovalov, O. I., Litvinov, K. A., Ryabichenko, A. V. (2012). Patent 74227 Ukrayina, MPK G01F 23/28 (2006/01). Ultrazvukovyj prystrij dlya vymiryuvannya rivnya seredovyshh z nerivnomirnoyu poverxneyu. Zayavnyk i patentovlasnyk Sxidnoukrayinskyj nacionalnyj universytet im. V. Dalya. # u201203182; declared: 19.03.2012; published: 25.10.2012. Byul. # 20, 3.
12. Yoder, J. (2013). Part II: The Role of Oil & Naturel Gas. Flow Control, 2, 26–31.
13. Stencel, J. I., Tomson, A. V.; Elyseev, V. V. (Ed.) (2006). Elektrodeformacijni procesy v p'yezoelektrychnyx peretvoryuvachax. Systemi kontrolya y upravlenyya texnologycheskymy processamy. Sbornyk nauchnix statej. Lugansk: Svitlycya, 144–149.
14. Stencel, J. I., Litvinov, K. A., Ryabichenko, A. V. (2015). Patent 110220 Ukrayina, MPK G01F 23/296 (2006/01). Ultrazvukovyj prystrij dlya kontrolyu rivnya ridynnyx seredovyshh. Zayavnyk i patentovlasnyk Sxidnoukrayinskyj nacionalnyj universytet im. V. Dalya. # a201305151; declared: 22.04.2013; published: 10.12.2015. Byul. # 23, 3.
15. Stencel, Y. Y., Tomson, A. V. (2007). Matematycheskye modely ultrazvukovyx datchykov urovnya veshhestv, Voprosy xymyy y xymycheskoj texnologyy, 5, 182–185.
16. Stencel, J. I. (1992). Fotokolorymetrychni gazoanalizatory. Kyiv: NMK VO, 124.
17. Urovnemery ul'trazvukovye MTM900. Rukovodstvo po ekspluatacii: AALU.407632.000 (2007). Severodonec'k: TOV NVP «Mikroterm», 71.

RESEARCH OF THERMAL CONDUCTIVITY OF THE CONDENSED MASS OF THE WHOLE WASTE TIRES AND DETERMINATION OF THEIR OPTIMUM ARRANGEMENT IN THE PYROLYSIS REACTOR (p. 12-19)

Serhiy Ryzhkov, Nikolay Rudyuk, Liudmyla Markina

The theoretical study of the total thermal conductivity of three selected anisotropic structures of binary cells proved that the asymmetric arrangement of whole tires in the pyrolysis reactor, which provides the maximum thermal conductivity of the mass

of whole tires in the reactor is the closest to realistic conditions. With the asymmetrical arrangement of tires in the reactor, in the process of consolidation, bead rings overlap, creating a metal lattice with thermal conductivity of 57 W/(m·K) characteristic of metal in the mass of thermoplastic rubber, which increases the total thermal conductivity of the mass in the reactor by up to 70 times to 12.7 W/(m·K) due to the introduction of high thermal conductivity of metal bead rings. The resulting values of thermal conductivity of the mass of whole tires in the pyrolysis reactor at the optimum arrangement of raw materials and coefficient of filling about 98 % allow optimizing the structural characteristics of the pyrolysis equipment, thus confirming the prospects of the proposed modern technology of whole tire pyrolysis under the action of two factors – temperature and mechanical compression.

The development of high-performance series industrial equipment for thermal recycling of tires with full process automation and production of alternative liquid fuels according to this technology is planned.

Keywords: pyrolysis reactor, thermal conductivity of condensed body mass of tire rubber with bead rings, whole waste tires, thermal resistance.

References

1. Markina, L. M., Ryzhkov, S. S., Rudiuk, M. V., Kryva, M. S. (2016). Patent of Ukraine for the invention C. F23G5/24, F23G5/027, C08J11/04, C10G1/10, C10B53/07. Universal automated installation of continuous pyrolysis whole worn car tires. No. 110678, declared: 06.10.2014; published: 25.01 2016, № 2.
2. Bekhiti, M., Trouzine, H., Asroun, A. (2014). Properties of Waste Tire Rubber Powder. Engineering, Technology & Applied Science Research, 4 (4), 669–672.
3. Singh, B., Sharma, N. (2008). Mechanistic implications of plastic degradation. Polymer Degradation and Stability, 93 (3), 561–584. doi: 10.1016/j.polymdegradstab.2007.11.008
4. Skoromnii, A. L. (2008). Snizenie energozatrat na utilizatsiyu iznoshennyh avtomobilnyh shin metodom termohimicheskoj destruktsii [Reduced energy consumption for recycling of used tires by thermochemical destruction]. Ecology and industry, 4, 68–71.
5. Kim, K. K., Karpova, I. M. (2007). Novij metod utilizatsii avtomobilnyh shin s metolokordom [A new method for recycling automobile tires with metal cord]. Life safety, 7, 24–27.
6. Vovk, O. A., Nikitchenko, J. S. (2009). Environmental safety technology on scrap tires treatment. Proceedings of National Aviation University, 41 (4), 94–99. doi: 10.18372/2306-1472.41.1805
7. Koc, A. (2013). Studying the Utilization of Plastic Waste by Chemical Recycling Method. Open Journal of Applied Sciences, 3 (7), 413–420. doi: 10.4236/ojapps.2013.37051
8. Hujuri, U., Ghoshal, A. K., Gumma, S. (2008). Modeling pyrolysis kinetics of plastic mixtures. Polymer Degradation and Stability, 93 (10), 1832–1837. doi: 10.1016/j.polymdegradstab.2008.07.006
9. Stalinsky, D. V., Scoromnyi, A. L., Sinozacky, A. M. (2011). Modelirovanie temperaturnogo sostojanija termohimicheskoj destruktsii iznoshennyh avtomobilnyh shin [Modelling of the temperature condition of the reactor thermochemical destruction for the worn out automobile tires]. Integrated technologies and energy efficiency, 1, 58–66.
10. Development and model operation of installation for a heat treatment of combustible slates. Available at : http://discollection.ru/article/27072009_kosova_ol_ga_jur_evna_93707/
11. Sposib pererobky polimernyh skladovyh znoshenyh avtomobil'nyh shyn. Available at: http://findpatent.com.ua/patent/240/2402591.html
12. Ryzhkov, S. S., Markina, L. N., Rudyuk N. V., Zabolotnaya Yu. V. (2014). Otrabotka piroliznoy tekhnologii utilizatsii organicheskikh otkhodov dlya morekhozyaystvennogo kompleksa – sistemy podachi otkhodov v piroliznyy reaktor [Working off of pyrolysis technology of utilization of an organic wastage for a morekhozyaystvenny complex – system of giving of a wastage in the pyrolysis reactor]. Shipbuilding and marine infrastructure, 2 (2), 131–143.
13. Kirpichev, M. V., Mikheev, M. A. (1936). Modelirovanie teplovykh ustroystv [Simulation of thermal devices]. Moscow: USSR Academy of Sciences Publishing House, 255.
14. Tyabin, N. V. (1974). Teploobmen. [Heat exchange]. Soviet researches. Moscow: Science, 195–198.
15. Dulnev, G. N., Zarichnyak, Yu. P. (1974). Teploprovodnost smesey i kompozitsionnykh materialov [Heat conductivity of mixes and composites. the reference book]. Moscow: Energy, 264.

INCREASING ACCURACY OF MEASURING THERMAL CONDUCTIVITY OF LIQUIDS BY USING THE DIRECT HEATING THERMISTOR METHOD (p. 20-30)

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The work is devoted to the research of thermal and physical characteristics of different materials by the nondestructive method. We propose to determine thermal conductivity of liquids by using the method of thermistor direct heating.

Essential disadvantage of many existing methods for determining thermal and physical characteristics (TPC) is the use of the methods of destructive control of materials and products, which significantly complicates measuring and makes it impossible to simultaneously measure a large number of experimental samples, as well as does not allow obtaining the required accuracy of measurement results.

So there exists a task of developing a device, which has high accuracy and can simultaneously measure a large number of thermal and physical characteristics of the studied samples, thereby increasing the efficiency of measurements.

We designed a device for measuring thermal conductivity of liquids, the principle of work of which is based on the method of thermistor direct heating. The results of experimental studies using reference liquids are presented, obtained with the help of the developed device. They demonstrated high accuracy and efficiency of its use in determining thermal conductivity of liquids. The result is achieved by introduction of additional coefficients of proportionality to the calculation formulas for determining thermal conductivity of the studied liquids, which are determined by testing the thermistors with the use of reference liquids with known TPC.

The conducted studies revealed that the value of measurement error per one session of 10 minutes by different probes amounted to not higher than 2 %, while in the course of measuring the same studied fluid by 60 probes simultaneously the error did not exceed 1.5 %.

Using the proposed method of thermistor direct heating, due to the small size of the probe and simple design of the device, allows applying it in various sectors of industry, medicine and biology to determine TPC of different materials with high accuracy of measurements.

Keywords: thermal conductivity of materials, thermistor, thermistor direct heating, device for determining thermal conductivity.

References

1. Zharov, A. V., Savinskiy, N. G., Pavlov, A. A., Evdokimov, A. N. (2014). Eksperimental'nyy metod izmereniya teploprovodnosti nanozhidkosti. Fundamental'nye issledovaniya, 8–6, 1345–1350.
2. Kutsakova, V. E., Frolov, S. V., Filippov, V. I., Danin, V. B. (2007). Kholodil'naya tekhnologiya pishchevykh produktov. Sankt-Peterburg: GIORD, 224.

3. Filippov, V. I. (2015). Primenenie metodov regulyarnogo teplovogo rezhima dlya opredeleniya teplofizicheskikh kharakteristik pishchevykh produktov. Nauchn. zhurn. NIU ITMO. Seriya «Protsessy i apparaty pishchevykh proizvodstv», 3, 22–30.
4. Puhlyk, B. M., Zajkov, S. V., Lojanych, O. M. (1995). Patent Ukrai'ny No. 7178 A. MPK A61B 5/145 (2006.01), A61B 10/00,G01N 33/48 (2006.01), G01N 33/49(2006.01). Prystrij dlja rejestracii' alergichnyh reakcij. No. 94011978; declareted: 31.03.1994; published: 30.06.1995, Byul. № 2, 2.
5. Gladkyh, Ju. V., Zajkov, S. V., Puhlyk, B. M., Lojanych, O. M., Gladkyh, V. Ju., Lobynceva, G. S. (2004). Patent Ukrai'ny No. 63844 A. MPK A61B 5/00, G01K 7/16 (2006.01), G01N 27/08 (2006.01), G01N 33/48 (2006.01),G01N 33/483 (2006.01), G01N 33/487(2006.01), G01N 33/49 (2006.01), G01N 35/02 (2006.01), G01N 35/10 (2006.01),G05D 23/20 (2006.01), G05D 23/30(2006.01). Prystrij dlja rejestracii' procesiv u biologichnyh probah. No. 2003098744; declareted: 25.09.2003; published: 15.01.2004, Byul. № 1, 3.
6. Lyubimova, D. A., Ponomarev, S. V., Divin, A. G. (2014). Izmerenie teplofizicheskikh svoystv teploizolyatsionnykh materialov metodom regulyarnogo rezhima tret'ego roda. Tambov: Izd-vo FGBOU VPO «TGTU», 79.
7. Lipaev, A. A. (2010). Primenenie metoda periodicheskogo nagreva v eksperimental'noy teplofizike. Sovremennye metody i sredstva issledovaniy teplofizicheskikh svoystv veshchestv. Sankt-Peterburg: SPbGUNiPT, 182–195.
8. Ivliev, A. D. (2010). Primenenie metoda temperaturnykh voln dlya issledovaniya teplofizicheskikh svoystv kondensirovannykh veshchestv. Sovremennye metody i sredstva issledovaniy teplofizicheskikh svoystv veshchestv. Sankt-Peterburg: SPbGUNiPT, 65–74.
9. Klyuev, V. V. (Ed.) (2004). Nerazrushayushchiy kontrol'. Moscow: Mashinostroenie, 679.
10. Kuttner, H., Urban, G., Jachimowicz, A., Kohl, F., Olcaytug, F., Goiser, P. (1991). Microminiaturized thermistor arrays for temperature gradient, flow and perfusion measurements. Sensors and Actuators A: Physical, 27 (1-3), 641–645. doi: 10.1016/0924-4247(91)87064-a
11. Ould-Lahoucine, C., Sakashita, H., Kumada, T. (2003). A method for measuring thermal conductivity of liquids and powders with a thermistor probe. International Communications in Heat and Mass Transfer, 30 (4), 445–454. doi: 10.1016/s0735-1933(03)00073-3
12. Zhang, H., He, L., Zhao, G., Cheng, S., Gao, D. (2003). Approaches to extract thermal properties from dual-thermistor heat pulse experimental data. Measurement Science and Technology, 15 (1), 221–226. doi: 10.1088/0957-0233/15/1/031
13. Dekusha, L. V., Grishchenko, T. G., Mendeleeva, T. V., Vorob'ev, L. I., Dekusha, O. L. (2005). Dekusha Influence of the determining factors on the measurement results of thermal conductivity by local thermal effects. Prom. Teplotekhnika, 27 (3), 74–79.
14. Churikov, A. A., Senkevich, A. Y. (2002). The multi-stage method, information and measuring system non-destructive testing of thermal properties. Transactions of TGTU, 8 (1), 62–69.
15. Dekusha, L. V., Mendeleeva, T. V., Vorob'ev, L. I., Dekusha, O. L. (2004). Features rapid measurement thermal conductivity of a sample finite thickness instrument IT-8. Promteplotekhnika, 26 (5), 76–81.
16. Zotov, V. (2007). Principy postroenija sistem temperaturnogo kontrolja na NTC–termistorah kompanii Epcos. Komponenty i tehnologii, 71, 32–38.
17. Mitsubishi chip thermistors. Mitsubishi materials. Available at: http://www.mmc.co.jp/adv/dev/english/contents/thermistor/
18. SAW Components (2002). EPCOS AG. Availabe at: http://www.mouser.com/ds/2/136/B3574-50177.pdf
19. Gabitov, F. R., Juzmuhametov, F. D., Tarzimanov, A. A., Zajnullin, I. M., Sattarov, I. R. (1999). Patent na A.S. No. 2139528. RF, MKI4 G01N25/18. Ustrojstvo i sposob dlja izmerenija teplofizicheskih svojstv zhidkostej i gazov. No. 98100282; declareted: 05.01.1998; published: 10.10.1999, Byul. № 28, 7.
20. Kharalkar, N. M., Hayes, L. J., Valvano, J. W. (2008). Pulse-power integrated-decay technique for the measurement of thermal conductivity. Measurement Science and Technology, 19 (7), 075104. doi: 10.1088/0957-0233/19/7/075104
21. Akulenko, D. V., Agapov, A. N., Procenko, I. G. (2012). Izmerenie kojefficienta teploprovodnosti sredy s ispol'zovaniem termistora prjamogo podogreva. Problemy tehnogennoj bezopasnosti i ustojchivogo razvitija, III, 49–52.
22. Matvienko, S., Vysloukh, S., Matvienko, A., Martynchyk, A. (2016). Determination thermal and physical characteristics of liquids using pulse heating thermistor method. International Journal of Engineering Research & Science, 2 (5), 250–258.
23. Vargaftik, N. B., Filippov, L. P., Tarzimanov, A. A., Tockij, E. E. (1990). Spravochnik po teploprovodnosti zhidkostej i gazov. Moscow: Jenergoatomizdat, 352.

TECHNOLOGY OF RECYCLING RADIOACTIVELY CONTAMINATED METAL BY THE METHOD OF MELTING (p. 31-37)

Valeriy Balakin, Viktor Mashinistov, Oleg Galkin, Kostiantyn Bilan

A technology is proposed of recycling radioactively contaminated metal by the method of melting, based on the effect of self deactivation. In accordance with this technology, radioactively contaminated metal is loaded into a melting furnace without the operation of preliminary decontamination. In the process of melting, the radionuclides located on its surface pass into molten metal and are distributed evenly in its volume. Beyond the limits of products made of this metal is the gamma-radiation of a small part of the radionuclides contained by them.

Gamma radiation of the remaining radionuclides, as well as alpha-radiation and beta-radiation of radionuclides, is completely absorbed in the volume of metal. As a result, the process of melting led to a considerable decrease in the power of ionizing radiation on the surface of metal. That is why this effect can be named the self deactivation of metal during its melting. At the same time, some radionuclides evaporate while a part of them passes to slag, further purifying metal. As a result, the conditions are created for obtaining the metal that is safe as far as the radiation is concerned.

The ratios are presented, which make it possible to calculate the amount of gamma-emitting radionuclides that can be loaded to a melting furnace in order to ensure a required level of the power of gamma radiation on the surface of the smelted metal.

It was demonstrated that the criterion of evaluation of radiation safety of metal is the power of gamma radiation on its surface.

In the implementation of this approach, both the known technologies of melting metals and the equipment of melting furnaces are not in fact complicated. This makes it possible to considerably increase technical and economic indicators of the process of recycling radioactively contaminated metal and to decrease substantially the volumes of accumulated radioactive wastes.

Keywords: technology of recycling radioactively contaminated metal, radionuclides, self deactivation, melting.

References

1. Ampelogova, N. I., Trapeznikov, A. A. (1982). Dezaktivaciya v yadernoj energetike. Moscow: Energoizdat, 256.

2. Lampard, D., Hillis, K. (2007). Pereplavka radioaktivnogo metalloloma. Atomnaya tehnika za rubezhom, 3, 27–30.
3. Copeland, Y. I. (1981). Decontamination of TRU – Contaminated metal Waste by Smelt. Refing. Trans.Nucl.Soc., 38, 193–195.
4. Nakamura, H., Kanasawa, K., Fujiki, K. (1995). R&D on Melting of Radioactive Metal Wastes at JAERI. Proceedings 3rd JSME/ASME Joint International Conference On Nuclear Engineering (ICONE–3), 4, 1785–1789.
5. Menon, S. (1999). Decommissioning of Nuclear Submarines: Waste Minimization by Recycling, Analysis of Risks Associated with Nuclear Submarine Decommissioning, Dismantling and Disposal, NATO. Dordrecht, Kluwer Academic Publishers, 129–136.
6. Berezhko, B. I. (1995). Utilizacija radioaktivnyh metallicheskih othodov metodom pereplava. Voprosy materialovedeniya, 2, 74–77.
7. Copeland, Y. L. (1978). Volume reduction of lomlevel contaminated metal Waste by Smelting. Trans. Amer. Nucl. Soc, 30, 285–286. doi: 10.2172/6809639
8. Gudim, Yu. A. (2008). Toplivokislorodnyj plavilnyj agregat nepreryvnogo dejstviya, ego primenenie v metallurgii i dlya utilizacii othodov. Vestnik Yuzhno-Uralskogo gosudarstvennogo universiteta. Seriya: Metallurgiya, 24 (124), 16–23.
9. Kompleksnaya pererabotka tverdyh radioaktivnyh othodov metodom plavleniya. Available at: http://www.nkj.ru/open/23369/ (Last accessed: 15.05.2016).
10. Cheremisin, P. I. (2008). Obrashhenie s metallicheskimi othodami, zagryaznennymi radioaktivnymi veshhestvami. Recikling othodov, 2 (14), 2–5.
11. Gasik, M. I., Koval, A. V., Gavrilov, V. A. (1999). Prirodnaya radioaktivnost shihtovyh materialov i produktov plavki ferrosplavov. Aktual'nye problemy i perspektivy elektrometallurgicheskogo proizvodstva, 427.
12. Zlobinskii, B. M., Nemtsov, N. S. (1963). Radioaktivnye izotopy v domennom proizvodstve: metodika primeneniya i voprosy bezopasnosti. Moscow: Metallurgizdat, 96.
13. Mashinistov, V. Ye., Galkin, O. F. (2015). Tehnologiya utilizacii radioaktivno zagryaznennogo metalla na metallurgicheskih predpriyatiyah. Dnepropetrovsk. Available at: http://metaljournal.com.ua/Utilization-technology-of-radioactively-contaminated-metals-from-smelters/ (Last accessed: 15.05.2016).
14. Mashinistov, V. Ye., Galkin, O. F. (2015). Ocenka radiacionnoj obstanovki pri utilizacii radioaktivno zagryaznennogo metalla s ispolzovaniem effekta samodezaktivacii. Dnepropetrovsk. Available at: http://metaljournal.com.ua/Assessment-of-the-radiation-situation-in-the-disposal-of-radioactively-contaminated-metal-using-self-deactivation-effect/ (Last accessed: 15.05.2016).
15. Balakin, V. F., Mashinistov, V. Ye., Galkin, O. F. (2015). Prakticheskie aspekty utilizacii radioaktivno zagryaznennogo metalla na metallurgicheskih predpriyatiyah. Dnepropetrovsk. Available at: http://www.metaljournal.com.ua/Practical-aspects-of-the-utilization-of-radioactively-contaminated-metals-from-smelters/ (Last accessed: 15.05.2016).
16. Kimel, L. R., Mashkovich, V. P. (1972). Zashhita ot ioniziruyushhih izluchenij. Moscow: Atomizdat, 312.
17. Maksimov, M. T., Oyagov, G. O. (1989). Radioaktivnye zagryazneniya i ih izmerenie. Moscow: Energoatomisdat, 304.
18. Pro zatverdzhennya derzhavnyh sanitarnyh pravyl «Osnovni sanitarni pravyla zabezpechennya radiacijnoi bezpeky Ukrainy». Nakaz Ministerstva ohorony zdorovya Ukrainy vid 02.02.2005 (2005). Ofic. visn. Ukrainy, 197.
19. European Commission (1988). Recommended radiological protection criteria for the recycling of metals from the dismantling of nuclear installations. Radiation Protection, 89, 42.

INCREASE OF ACCURACY OF DEFINITION OF TEMPERATURE BY SENSORS OF FIRE ALARMS IN REAL CONDITIONS OF FIRE ON OBJECTS (p. 38-44)

Vladimir Andronov, Boris Pospelov, Evgeniy Rybka

The theoretical analysis of the generalised circuit of the thermal sensor has shown that it is a converter of information of the resistive sensitive element into the corresponding voltage, which is carried out by the bridge measuring circuit. The dynamic model of the generalised circuit of the thermal sensor of fire alarm is presented in the form of the differential equations in the state space for the thermoresistive sensitive element in the form of a thin plate is developed on the basis of the generalised circuit of the thermal sensor. The private model of the thermal sensor of the first approximation in the state space is received for values Bi≤1. The given model allows researching the dynamic accuracy of the thermal sensor in various conditions of the fire alarm use taking into account the casual ambient temperature indignations. The influence of parameters of the bridge circuit and also of the sensitive element of the thermal sensor on dynamic accuracy in various conditions is investigated on the basis of this model. The analysis of dependence of the value of the second initial moment of an error on the considered characteristic parameters of the thermal sensor in dynamic conditions in the presence of casual temperature indignations of various intensity has shown that there are minimum values of the second initial moment of an error. Generally the minimum values of the second initial moment of an error depend on the characteristic parameters of the thermal sensor, current time and temperature conditions in the environment, characterised by the fire centre. There are possibilities of maintenance of invariance in time of the second initial moment of an error. The dependences of the optimum value of the characteristic parameter $B_{1,1opt}$ of the thermal sensor on speed of temperature increase caused by the fire centre, and also the intensity of masking casual temperature indignations on the object are received for this case.

The received results allow to predict the expected accuracy for existing thermal sensors in various conditions of use, and also to develop optimum thermal sensors of single fire alarms for the guaranteed detection of low-power fire for real objects' protection.

Keywords: thermal sensor, fire alarm, accuracy, temperature, dynamic conditions, casual indignations.

References

1. Poulsen, A., Jomaas, G. (2011). Experimental Study on the Burning Behavior of Pool Fires in Rooms with Different Wall Linings. Fire Technology, 48 (2), 419–439. doi: 10.1007/s10694-011-0230-0
2. Oppelt, U. (2006). Improvement on fire detectors by using multiple sensors. Fire & Safety. Available at: http://www.securitysa.com/default.aspx?pklissueid=550
3. Pospelov, B. B., Chumachenko, S. N., Urjadnikova, I. V. (2015). Uchet priemlemogo riska pri obosnovanii trebovanij k sistemam kontrolja sostojanija opasnyh ob"ektov. Aktual'ni problemy modeljuvannja ryzykiv i zagroz vynyknennja nadzvychajnyh sytuacij na ob'jektah krytychnoi' infrastruktury. Kyiv: TOV «Instytut matematychnogo modeljuvannja «Fraksim», 139–145.
4. Ding, Q., Peng, Z., Liu, T., Tong, Q. (2014). Multi-Sensor Building Fire Alarm System with Information Fusion Technology Based on D-S Evidence Theory. Algorithms, 7 (4), 523–537. doi: 10.3390/a7040523
5. Cheng, C., Sun, F., Zhou, X. (2011). One fire detection method using neural networks. Tsinghua Science and Technology, 16 (1), 31–35. doi: 10.1016/s1007-0214(11)70005-0
6. Pospelov, B. B., Andronov, V. A. (2015). Improving Efficiency Monitoring Systems for Potentially Dangerous Objects Based on

Optimization of Group Detection Sensors. Civil Engineering and Architecture, 3 (4), 69–72. doi: 10.13189/cea.2015.030401
7. Pospelov, B. B., Shevchenko, R. I., Kolenov, A. N. (2014). Sintez optimal'nogo izmeritelja opasnyh faktorov pozhara s proizvol'noj dinamikoj dlja pozharnyh izveshhatelej. Problemy pozharnoj bezopasnosti, 35, 172–178.
8. Todd, C. (1998). Fire Detection – Overcoming the False Alarm Problem. International Fire and Security Product News, 23 (3), 39–40.
9. Gottuk, D. T., Peatross, M. J., Roby, R. J., Beyler, C. L. (2002). Advanced fire detection using multi-signature alarm algorithms. Fire Safety Journal, 37 (4), 381–394. doi: 10.1016/s0379-7112(01)00057-1
10. Milke, A., Hulcher, M. E., Worrell, C. L., Gottuk, D. T., Williams, F. W. (2003). Investigation of Multi-sensor Algorithms for Fire Detection. Fire Technology, 39 (4), 363–382. doi: 10.1023/a:1025378100781
11. Bowles, J. B., Pelaez, C. E. (1995). Application of fuzzy logic to reliability engineering. Proceedings of the IEEE, 83 (3), 435–449. doi: 10.1109/5.364489
12. Reed, J. (1995). Control and Indicating Equipment for Fire Alarm Systems. International Fire and Security Product News, 20 (5), 41–42.
13. Cestari, L. A., Worrell, C., Milke, J. A. (2005). Advanced fire detection algorithms using data from the home smoke detector project. Fire Safety Journal, 40 (1), 1–28. doi: 10.1016/j.firesaf.2004.07.004
14. Radonja, P., Stankovic, S. (2009). Generalized profile function model based on neural networks. Serbian Journal of Electrical Engineering, 6 (2), 285–298. doi: 10.2298/sjee0902285r
15. Siebel, R. (2006). Test of fire detection algorithms using artificially generated events. Fire Safety Journal, 41 (4), 258–265. doi: 10.1016/j.firesaf.2006.01.004
16. Gurevich, V. (2008). Microprocessor protection devices: The present and the future. Serbian Journal of Electrical Engineering, 5 (2), 325–339. doi: 10.2298/sjee0802325g
17. Tsai, Y. C. (2007). The Design and Implementation of Early Fire Detection and Hierarchical Evacuation Alarm System. Master Thesis, Graduate Institute of Networking and Communication Engineering. Taiwan.
18. Ristic, J., Radosavljevic, D. (2011). Decision algorithms in fire detection systems. Serbian Journal of Electrical Engineering, 8 (2), 155–161. doi: 10.2298/sjee1102155r
19. Willstrand, O., Brandt, J., Svensson, R. (2016). Detection of fires in the toilet compartment and driver sleeping compartment of buses and coaches – Installation considerations based on full scale tests. Case Studies in Fire Safety, 5, 1–10. doi: 10.1016/j.csfs.2015.11.002
20. Zheng, W., Zhang, X., Wang, Z. (2016). Experiment Study of Performances of Fire Detection and Fire Extinguishing Systems in a Subway Train. Procedia Engineering, 135, 393–402. doi: 10.1016/j.proeng.2016.01.147
21. Polishhuk, V. S. (1981). Izmeritel'nye preobrazovateli. Kyiv: Vishha shkola, 296.
22. Kartashov, Je. M. (2001). Analiticheskie metody v teorii teploprovodnosti tverdyh tel. Moscow: Vysshaja shkola, 550.
23. Pugachev, V. S., Kazakov, I. E., Evlanov, L. G. (1974). Osnovy statisticheskoj teorii avtomaticheskih system. Moscow: Mashinostroenie, 400.

OBTAINING DYED DECORATIVE ENAMELS FOR PRODUCTS MADE OF GOLD, SILVER AND COPPER (p. 45-51)

Olga Ryzhova, Olga Gurzhyi

The results of developing of colored jewelry enamels on the base of lead-free glass for decorative, artistic and jewelry articles made of gold, silver and copper are presented. The development of enamel coatings of different colors and shades was conducted on one lead-free glass base, which was dyed with ionic dyes during glass founding. The development of colored enamel coatings on the lead-free glass makes it possible to reduce the cost of jewelry enamel and contributes to the solution of ecological problems, connected with the pollution of the environment with lead compounds.

The glass which ensures the smooth enamel coating on copper samples (M1 copper with the thickness of 1 mm) was developed in the system of $Na_2O–B_2O_3–SiO_2–K_2O–BaO–TiO_2–ZnO–TiO_2$.

It was established that the introduction of additives TiO_2, MoO_3 and Fe_2O_3 increases the enamel coatings luster. Adding TiO_2 to 15 mass p. and MoO_3 to 3,0 mass p. makes it possible to increase the luminosity of enamels (CDR) up to 35 %).

Green, mustard, violet, dark-blue and brown enamels were obtained while adding ionic dyes to the composition of the developed glass. In this case, the luster of the obtained enamels is 57–99 %, which indicates a high fusing degree.

The scale of the quality evaluation of different color coating was developed, which makes it possible to classify the defects of enamel layer while applying on gold, silver and copper.

The work shows possibility of obtaining the enamel coatings of different colors and shades for artistic and jewelry applying to the base of the glass of one chemical composition with different dyes. The application of such enamels will make it possible to simplify the technology of obtaining the finished articles and lower the probability of defect forming on the enamel coating.

The developed enamels can be recommended to the tests under production conditions.

Keywords: jewelry enamel, glass coating, hot enamel, artistic enameling, ionic dyeing, glass color.

References

1. Compagnoni, A. M., Rossi, S. (2012). ENAMEL and DESIGN The Potential of enameled materials in design applications. 22rd International Enamellers Congress. Cologne, 200–212.
2. Brepol', E. (1986). Hudozhestvennoe emalirovanie. Leningrad: Mashinostroenie, 127.
3. Sarrazy, K., Aronica, A., Leseur, A. (2015). Low fire enamels for new pre-primed steels. 23rd International Enamellers Congress. Florence, 88–100.
4. Guo, H. Y., Xie, K. F., Liu, H. W. (2012). The Application of Enamel Material in the Jewelry Industry. Advanced Materials Research, 602-604, 2031–2033. doi: 10.4028/www.scientific.net/amr.602-604.2031
5. Previous Congresses. International Enamellers' Congress. The International enamellers institute. Available at: http://www.iei-world.org/pagine/congress_old.asp
6. Technical standars The International enamellers institute. Available at: http://www.iei-world.org/pagine/standards_iso.asp
7. Charles, W. E. (1999). Enamelling on copper and precious metals. The virteous enameller, 50
8. Leveaux, M., Duchamp, V., de Greve, K., Teerlink, S., Patou, D., Junius, Céline, Gombert, J. (2005). Enamels, colour matching modelisation. The virteous enameller, 6, 56
9. Rodtsevich, S. P., Eliseev, S. Y., Lukashevich, G. F. (2001). Jewelry enamels with a decreased content of lead oxide. Glass and ceramics, 58 (7-8), 290–291. doi: 10.1023/a:1012847009417
10. Tsareva, E. V., Spiridonov, Y. A. (2012). Decorative enamels on precious metals. Glass Ceram, 68 (9-10), 308–309. doi: 10.1007/s10717-012-9377-5
11. Pagliuca, S., Faust, W. D. (2011). Porcelain (Vitreous) Enamels and Industrial Enamelling Processes. The Preparation, Application and Properties of Enamels. Third Edition. Tipografia Commercialesrl Via Vittorino da Feltre. Mantova. Italy, 346.

12. Zubekhin, A. P., Yatsenko, E. A., Klimenko, E. B. (2001). Lead-free boron-aluminosilicate enamels for ornamental copper articles. Glass and ceramics, 58 (3-4), 142–143. doi: 10.1023/a:1010972120654
13. The European health report. World Health Organization. Available at: http://www.euro.who.int/__data/assets/pdf_file/0010/98299/E76907R.pdf?ua=1
14. Bragina, L. L.; Bragina, L. L., Zubehina, A. P. (Eds.) (2003). Tehnologiya emali i zashhitnyh pokrytij. Har'kov: NTU «HPI»; Novocherkassk: JuRGTU (NPI), 484.
15. Yatsenko, E. A., Kondiurin, A. M., Rat'kova, V. P., Tkachenko, N. M. (1997). Hudozhestvennye emali dlia medi. Steklo i keramika, 3, 25–27.
16. Turrell, J. (2009). High tech/low tech: The utilization of printmaking techniques in the production of contemporary enamelled jewellery.
17. Ryzhova, O., Khokhlov, M., Goleus, V. (2015). Influence of iron oxides on the properties of unfluoridated enamel frit glass and coatings. Chemistry & Chemical Technology, 3, 343–347.
18. Guloyan, Yu. A. (2007). Complex evaluation of ion dyeing of glass using compounds of transition metals. Glass and ceramics, 5, 7–12.
19. Vargin, V. V. (1940). Proizvodstvo cvetnogo stekla. Leningrad: Gosudarstvennoe izdatel'stvo legkoj promyshlenosti.
20. Kocyk, I. (1983). Okrashivanie stekla. Moscow: Strojizdat, 210.
21. Bleskomer fotometricheskij FB-2 (1984). Tehnicheskoe opisanie i instrukciya po ekspluatacii. Moscow: VNII poligrafiya, 24.
22. Komparator cveta KC-3 (1990). Tehnicheskoe opisanie i instrukciya po ekspluatacii BSh2.850.212TO. Sergiev Posad: PO ZOMZ, 68.
23. Platov, Ju. T., Platova, R. A. (2013). Instrumental'naya specifikaciya cvetovyh harakteristik stroitel'nyh materialov. Stroitel'nye materialy, 4, 66–72.
24. Hohlov, M. A., Rizhova, O. P. (2015). Rozrobka ekonomichno efektivnih emalevih pokrittiv na malovuglecevij stali. HHV Mizhnarodna naukovo-praktichna konferenciya «Ekonomika ta suchasni tehnologii», 15–17.

DEFINITION OF HUE OF DIFFERENT TYPES OF POKOSTIVSKIY GRANODIORITE USING DIGITAL IMAGE PROCESSING (p. 52-57)

Valentyn Korobiichuk, Volodymyr Shamrai, Oksana Iziumova, Oleksandr Tolkach, Ruslan Sobolevskyi

An important task of stone processing enterprises is decorativeness management of natural stone products. Among different ways to change the natural stone decorativeness parameters, stone polishing is the most common.

Classification of the types of Pokostivskiy granodiorite of different hues is based on the characteristics of different types of stone after machining. However, information about the original color characteristics of stone blocks is needed for selecting the polishing technology. In the study of Pokostivskiy granodiorite blocks, the patterns of lightness changes in rough and polished samples of the types of Pokostivskiy granodiorite of different hues depending on the share of white minerals were identified. Before polishing, lightness and average share of white minerals for light, dark and very dark types of Pokostivskiy granodiorite are virtually unchanged. After polishing, lightness of different types of Pokostivskiy granodiorite changes respectively from 59.5 % to 69.4 % – for light types; from 59.0 % to 65.5 % – for dark types; from 58.8 % to 61.2 % – for very dark types.

The developed method of determining the types of Pokostivskiy granodiorite of different hues using digital image processing will allow distinguishing rough blocks, different in lightness and hue, on stone processing enterprises. This will enable stone processing enterprises to select raw materials without prior processing and to choose the polishing technology for standardized products that are made of similar rocks.

Keywords: stone lightness, Pokostivskiy granodiorite, stone color, stone hue, digital image processing.

References

1. Korobiychuk, V. V., Shamrai, V. I. (2014). Influence of grinding-polishing of natural stone on its shine and lightness shades. Eastern-European Journal of Enterprise Technologies, 5 (5 (71)), 56–60. doi: 10.15587/1729-4061.2014.28036
2. Krivoruchko, A. O., Kotenko, V. V., Kamskyh, O. V. (2015). Stability of natural stone in hostile environments. M. Ostrohradskyi Visnyk KrNU, 1 (90), 133–138.
3. Korobiichuk, I., Korobiychuk, V., Nowicki, M., Shamrai, V., Skyba, G., Szewczyk, R. (2016). The study of corrosion resistance of Pokostivskiy granodiorites after processing by various chemical and mechanical methods. Construction & Building Materials, 114, 241–247. doi: 10.1016/j.conbuildmat.2016.03.147
4. EN 1469:2004, IDT. Natural stone products. Slabs for cladding – Requirements.
5. Krivoruchko, A. O. (2006). Substantiation of methods of gabbro beds geometrization on the basis of determination and evaluation of structure and ornamental property. Dnipropetrovs'k: Nacional'nyj girnychyj universytet.
6. Dawei, W., Xianhua, C., Markus, O., Helge, S., Bernhard, S. (2014). Study of micro-texture and skid resistance change of granite slabs during the polishing with the Aachen Polishing Machine. Wear, 318 (1-2), 1–11. doi: 10.1016/j.wear.2014.06.005
7. Hideo, A., Hidetoshi, T., Seong-Woo, K., Natsuko, A., Koji, K., Tsutomu, Y., Toshiro, D. (2014). Evaluation of subsurface damage in GaN substrate induced by mechanical polishing with diamond abrasives. Applied Surface Science, 292, 531–536. doi: 10.1016/j.apsusc.2013.12.005
8. Xie, J., Tamaki J. (2007). Parameterization of Micro-Hardness Distribution in Granite Related to Abrasive Machining Performance. Journal of Materials Processing Technology, 186 (1-3), 253–258. doi: 10.1016/j.jmatprotec.2006.12.041
9. Yavuz, H., Ozkahraman, T., Demirdag, S. (2011). Polishing experiments on surface quality of building stone tiles. Construction and Building Materials, 25 (4), 1707–1711. doi: 10.1016/j.conbuildmat.2010.10.016
10. Ozguven, A., Ozcelik, Y. (2013). Investigation of some property changes of natural building stones exposed to fire and high heat. Construction and Building Materials, 38, 813–821. doi: 10.1016/j.conbuildmat.2012.09.072
11. Vázquez, M. A., Galán, E., Guerrero, M. A., Ortiz, P. (2011). Digital image processing of weathered stone caused by efflorescences: A tool for mapping and evaluation of stone decay. Construction and Building Materials, 25 (4), 1603–1611. doi: 10.1016/j.conbuildmat.2010.10.003
12. Benavente, D., Martínez-Verdú, F., Bernabeu, A., Viqueira, V., Fort, R., García del Cura, M. A., Ordóñez, S. (2003). Influence of surface roughness on color changes in building stones. Color Research & Application, 28 (5), 343–351. doi: 10.1002/col.10178
13. Thornbush, M., Viles, H. (2004). Integrated digital photography and image processing for the quantification of colouration on soiled limestone surfaces in Oxford, England. Journal of Cultural Heritage, 5 (3), 285–290. doi: 10.1016/j.culher.2003.10.004
14. Thornbush, M., Viles, H. (2004). Surface soiling pattern detected by integrated digital photography and image processing on exposed limestone in Oxford, England. Air Pollution and Cultural Heritage, 221–224. doi: 10.1201/b17004-34
15. Thornbush, M. J., Viles, H. A.; Přikryl, R., Smith, B. J. (Eds.) (2007). Photo-Based Decay Mapping of Replaced Stone Blocks on the

Boundary Wall of Worcester College, Oxford. Building Stone Decay: From Diagnosis to Conservation, Geological Society, London, 69–75.
16. Thornbush, M. J., Viles, H. A. (2008). Photographic Monitoring of Soiling and Decay of Roadside Walls in Oxford, England. Environmental Geology, 56 (3-4), 777–787. doi: 10.1007/s00254-008-1311-3
17. Thornbush, M. J. (2007). Grayscale calibration of outdoor photographic surveys of historical Stone Walls in Oxford, England. Color Research & Application, 33 (1), 61–67. doi: 10.1002/col.20374
18. Shamrai, V. I. (2015). Quality management of finished products made with granodiorite using different methods of polishing natural stone. News of ZSTU. Technical sciences, 4 (75), 137–144.
19. Korobiichuk, I., Korobiichuk, V., Iskov, S., Nowicki, M., Szewczyk, R. (2015). Peculiarities of natural stone extraction technology with the help of diamond wire machines. 16 th International Multidisciplinary Scientific GeoConference Science and Technologies in Geology, Exploration and Mining, Book 1, 2, 649–657.

STUDY OF THE FORMATION OF GAS-VAPOR IN THE LIQUID MIXTURE (p. 58-65)

Anatoliy Pavlenko, Hanna Koshlak, Andrii Cheilytko, Maksym Nosov

Equilibrium conditions of the pore former agent in the material during the formation of the porous structure, pressure and temperature of the pore former agent gas inside the closed spherical pore, heat transfer between the growing pore and the surrounding mixture were researched. The calculation of the gas vapor area was made with obtained equations. This calculation needs for prediction of pore growth dynamics. Obtained dependences show that, in general, the peak values of the growth speed of vapor volume, movement of the pore boundary, mass flow, heat flow have smaller values under lower periods of oscillations. The character of changing of the calculation quantities under 130 °C and 180 °C are the same. This temperature range was chosen, because real swelling happens under the same range. Obtained equation of the overheat temperature of the pore former agent gas inside the pore clarifies the temperature (180 °C), under which the inertial period of formation of the gas microphase in the first heating stage is missing. The equilibrium conditions give a chance to assess energy parameters of the swelling process under stabilization of the predictable pore sizes.

During the calculation of the pressure inside the closed spherical pore it was found that the bigger the difference between the chemical potentials of material-pore systems, the lower the gas pressure inside the pore. Since the convective heat transfer in a gas is directly proportional to the pressure, next statement can be made: to achieve minimum heat transfer of pore, it's necessary to increase the difference between the chemical potentials of material-pore systems. Obtained methodology allows finding conditions of controlled swelling and conditions of controlled structure formation of the material with predicted thermophysical properties. It can be real only, because this methodology takes into account physical properties of the raw mixture, the chemical potential of the mixture components, levels of energy influence on the raw mixture and the impact of all above factors on the size of the gas-vapor area (pore). The differences of new methodology allow predicting the porosity of thermal insulating material and its thermophysical properties.

These results are proposed to use in designing technological processes of production of porous materials for various purposes.

Keywords: vaporization, movement of pore's boundary, pore's heat transfer, conditions of controlled swelling.

References

1. Bodnar'ova, L., Hela, R., Hubertova, M., Novakovu, I. (2014). Povedenija legkogo keramzita betona, podverzhennyh vozdejstviju vysokih temperatur. Mezhdunarodnyj zhurnal grazhdanskoj, jekologicheskoj, strukturnoj, stroitel'stva i arhitekturnogo proektirovanija, 8 (12), 1205–1208.
2. Nimmo, J. R. (2004). Porosity and Pore Size Distribution. Encyclopedia of Soils in the Environment. London: Elsevie, 295–303.
3. Shpac, A., Cheremskoj, P., Kunickij, Ju., Sobol, O. (2005). Clasters nanostrukturnye materials. Poristost 'as a special state samoorganizovannoi structure in the solid state and materials. Kyiv: Akademperiodika, 516.
4. Freire-Gormaly, M. (2013). The Pore Structure of Indiana Limestone and Pink Dolomite for the Modeling of Carbon Dioxide in Geologic Carbonate Rock Formations. Department of Mechanical and Industrial Engineering University of Toronto, 85. Available at: https://tspace.library.utoronto.ca/bitstream/1807/42840/1/Freire-Gormaly_Marina_201311_MASc_thesis.pdf
5. Eom, J.-H., Kim, Y.-W., Raju, S. (2013). Processing and properties of macroporous silicon carbide ceramics: A review. Journal of Asian Ceramic Societies, 1 (3), 220–242. doi: 10.1016/j.jascer.2013.07.00
6. Komissarchuk, O., Xu, Z., Hao, H. (2014). Pore structure and mechanical properties of directionally solidified porous aluminum alloys. China Foundry, 11 (1), 1–7. Available at: https://doaj.org/article/002c72e2e01345db8bf4fef190113057
7. Bajare, D., Kazjonovs, J., Korjakins, A. (2013). Lightweight Concrete with Aggregates Made by Using Industrial Waste. Journal of Sustainable Architecture and Civil Engineering, 4 (5). doi: 10.5755/j01.sace.4.5.4188
8. Lopez-Pamies, O., Castañeda, P. P., Idiart, M. I. (2012). Effects of internal pore pressure on closed-cell elastomeric foams. International Journal of Solids and Structures, 49 (19-20), 2793–2798. doi: 10.1016/j.ijsolstr.2012.02.024
9. Vesenjak, M., Öchsner, A., Ren, Z. (2005). Influence of pore gas in closed-cell cellular structures under dynamic loading. German LS-DYNA Forum. Bamberg. Available at: https://www.dynamore.de/de/download/papers/forum04/new–methods/influence–of–pore–gas–in–closed–cell–cellular
10. Aboudi, J., Arnold, S. M., Bednarcyk, B. A. (2013). Micromechanics of Composite Materials: A Generalized Multiscale Analysis Approach. Elsevier, 973.
11. Bratuta, E., Pavlenko, A., Koshlak, H. (2010). Porous insulating materials. Kharkiv: "Eden", 105.
12. Pavlenko, A. M., Koshlak, H. V., Usenko, B. O. (2014). Peculiarities control the forming of the porous structure. Metallurgical and Mining Industry, 6, 50–55.
13. Pavlenko, A. M., Klimov, R. A., Basok, B. I. (2006). Kinetics of evaporation in the homogenization. Prom. heat engineering, 28 (6), 14–20.
14. Vukalovich, M. P., Novikov, I. I. (1972). Termodinamika. Moscow: "Mashinostroenie", 672.