ABSTRACT AND REFERENCES

APPLIED PHYSICS. MATERIALS SCIENCE

THE STUDY OF THERMAL FIELD OF AN OBJECT REPRESENTED IN THE BASIS OF GREEN FUNCTIONS (p. 4-11)

Georgiy Kulinchenko, Evgen Mozok

Existing means of thermal field modeling for the construction of the real time spatial distribution of the field were analyzed. The expediency of using the method of integral transformations for solving heat conduction problems was shown.

Based on the comparison of methods of thermal fields construction method of integral transformations in the basis of the Green's functions was chosen. Construction of Green's functions for the use in the experimental facility is performed by the method of Laplace integral transforms.

Software, generated based on the use of Matlab environment, allows to adjust the visualized field pattern by actual measured temperature values. Temperature point values of the experimental facility field were measured by NAT thermocouples, that are connected to a PC through OWEN 150UM controller interface, which makes it possible not only to form an array of measured values of the temperature, but also to adjust the time-varying boundary conditions of the calculated heat equation.

The main purpose of the research is to assess the performance of the developed algorithms to reduce the field frame modeling time, which would allow to use the resulting pattern of the thermal field distribution in the industrial thermal facilities control process.

The advantage of the thermal field constructing algorithm in the basis of the Green's function is the ability of the independent calculation of all points of the investigated area, allowing in the future to speed up the computation by applying high-performance computing.

Keywords: thermal field, heat conduction equation, Green function, method of integral transform, Laplace transform, boundary conditions, visualization system.

References

1. Kulinchenko, G., Mozok, E. (2015). Hardware and software for estimations of the thermal field. Herald of the National Technical University "KhPI, 33 (1142), 98–107.
2. Simchuk, O., Misak, V. (2010). Modelling and automation of the furnace for burning bricks. Eastern-European Journal of Enterprise Technologies, 4 (3 (48)), 29–31. Available at: http://journals.uran.ua/eejet/article/view/3243/3045
3. Pokorny, P., Gerza, M. (2011). The Visualization of the Thermal Flow in a Glass Furnace. 15th WSEAS international conference on Computers, 15, 67–70.
4. Mistry, H., Ganapathi-subbu, Dey, S., Bishnoi, P., Castillo, J. L. (2006). Modeling of transient natural convection heat transfer in electric ovens. Applied Thermal Engineering, 26 (17-18), 2448–2456. doi: 10.1016/j.applthermaleng.2006.02.007
5. Habib, M. A., Ben-Mansour, R., Antar, M. A. (2005). Flow field and thermal characteristics in a model of a tangentially fired furnace under different conditions of burner tripping. Heat and Mass Transfer, 41 (10), 909–920. doi: 10.1007/s00231-004-0593-6
6. ThermNet thermal simulation software. Infolitica corporation aircraft. Available at: http://www.infolytica.com/en/products/thermnet/
7. Protasov, A. (2009). Application of FEMLAB software for simulation of the thermal method for nondestructive testing processes. American Society for Engineering Education, 182, 71–80.
8. Margeirsson, B. (2008). Temperature monitoring and CFD Modelling of a Cold Storage. Cold Chain Management 3rd International Workshop.
9. Temperature and humidity mapping. Available at: http://elin.ru/files/pdf/Application/thermal-mapping(en)-revA.pdf
10. Coexdaq smart system. Composites expertise for aircraft. Available at: http://www.coexpair.com/Equipment/smart-systems/
11. Dymap Software. Temperature Technology. Available at: http://www.t-tec.com.au/dataloggers/T-TEC-data-logger-software/dymap-software/
12. Choi, S.-H., Choi, J., Kim, J.-Y. (2015). Nondestructive testing system with heat transfer characteristics in composite materials. International Journal of Precision Engineering and Manufacturing, 16 (7), 1583–1589. doi: 10.1007/s12541-015-0208-9
13. Tsai, B., Gibson, C. (2004). Heat-Flux Sensor Calibration. National Institute of Standards and Technology Special Publication.
14. Zienkiewicz, O. C., Taylor, R. L., Zhu, J. Z. (2013). The Finite Element Method: Its Basis and Fundamentals, Seventh Edition. Oxford: Butterworth-Heinemann, 756.
15. Guliaev, A. (2008). Recovery and precision of temperature field during firing hearth of the electrolyzer, the problem deals with methods. Scientific publications journal of graduate and doctoral students, 3, 11–15.
16. Qin, Q.-H. (2014). Green's Functions of Magneto-Electro-Elastic Plate Under Thermal Loading. Encyclopedia of Thermal Stresses, 38, 2096–2103. doi: 10.1007/978-94-007-2739-7_96
17. Chernyshov, A. (2009). Control of objects thermal fields with distributed parameters. Bulletin of the Tomsk Polytechnic University, 4, 24–27.
18. Kartashov, E. M. (2013). A new approach in the Green's function method for solving boundary value problems of Dirichlet and Neumann for the Laplace equation. Engineering Journal: Science and Innovation. Available at: http://engjournal.ru/articles/900/900.pdf
19. Cole, K., Beck, J. (2011). Heat Conduction Using Green's Functions. Boca Raton: Taylor and Francis Group.
20. Cole, K. D., Beck, J. V., Woodbury, K. A., de Monte, F. (2014). Intrinsic verification and a heat conduction database. International Journal of Thermal Sciences, 78, 36–47. doi: 10.1016/j.ijthermalsci.2013.11.002

OPTIMIZATION OF THE PROCEDURE OF THERMAL FLAW DETECTION OF THE HONEYCOMB CONSTRUCTIONS BY IMPROVING THE ACCURACY OF INTERFERENCE FUNCTION (p. 12-18)

Volodymyr Storozhenko, Aleksandr Myagkiy, Roman Orel

The thermophysical model of the honeycomb constructions was explored. The given model considers the interferences, which appear on the OC surface, and those caused by

the inhomogeneity of internal structure (by the "adhesion failure" flaw). The process of thermal flaw detection of honeycomb constructions was analyzed on its basis. As a result of the TFD analysis, a number of characteristic interferences, which complicate its industrial application, were revealed. The methods of decreasing interferences, characteristic for the honeycomb constructions, by optimization of the TFD procedure by the value of criterion $\Delta T_{def}/\Delta U$ were proposed.

Since the interferences, caused by inhomogeneous structure of the control object, cannot be removed by optimization of the TFD procedure, the method of processing the obtained results by the algorithm of differential filtration was proposed.

As a result of applying proposed methods, we achieved a decrease in the interference level, connected with the heterogeneity of heating, to 0,7 °C (instead of 1,4 °C), a decrease in the interference, caused by the inhomogeneity of radiation capacity, to 0,6 °C (instead of 2 °C) and a decrease in temperature contrast, caused by the inhomogeneity of the glue layer, to 0,2 °C (instead of 1,2 °C). Owing to this, sensitivity of the thermal flaw detection to the identification of flaws, caused by inhomogeneity, increased: internal – to threshold dimension of a flaw from 6 mm to 3 mm, and reliability of their detection increased by 17–20 %.

Keywords: honeycomb construction, thermal flaw detection, radiating capacity, adhesion failure.

References

1. Storozhenko, V. A., Maslova, V. A. (2004). Termografiya v diagnostike i nerazrushayushchem kontrole. Kharkiv: «Smit», 160.
2. Maldague, P. V. (2001). Theory and Practice of Infrared Technology for Nondestructive Testing. John Wiley & Sons, Inc., 684.
3. Vavilov, V. P. (2009). Infrakrasnaya termografiya i teplovoj kontrol'. Moscow: ID Spektr, 544.
4. Lykov, A. V. (1967). Teoriya teploprovodnosti. Moscow: Vysshaya shkola, 602.
5. Storozhenko, V. A., Malik, S. B., Myagkij, A. V. (2008). Optimizaciya rezhimov teplovoj defektoskopii na osnove teplofizicheskogo modelirovaniya. Visnik Nacional'nogo tekhnichnogo universitetu «Harkivs'kij politekhnichnij institut». Zbirnik naukovih prac'. Tematichnij vipusk: Priladi i metodi nerujnivnogo kontrolyu, 48, 84–91.
6. Storozhenko, V. A., Malik, S. B., Myagkij, A. V., Tihij, V. G. (2013). Optimizaciya procedury teplovoj defektoskopii sotovyh konstrukcij. TD i NK, 3, 31–35.
7. Storozhenko, V. A., Meshkov, S. N., Saprykin, S. A., Myagkij, A. V. (2009). Primenenie termograficheskogo metoda kontrolya dlya opredeleniya soderzhaniya zhidkoj fazy v gazoprovodah. Naukovo-tekhnichnij zhurnal «Metodi ta priladi kontrolyu yakosti», 22, 117.
8. Vavilov, V. P., Sin'yan', Guo, Shiryaev, V. V., Nesteruk, D. A. (2008). Teplovoj kontrol' korrozii v alyuminievyh panelyah samoletov. Defektoskopiya, 4, 48–57.
9. Vavilov, V. P., Ivanov, A. I., Nesteruk, D. A., Shiryaev, V. V. (2010). Metody i ehksperimental'naya realizaciya impul'snogo teplovogo kontrolya plazmennyh pokrytij. Izvestiya TPU/ TPU, 317 (4), 5–9.
10. Obbadi, A., Belattar, S. (2005). Characterization of delamination by a thermal method of non destructive testing. Proc. Vth International Workshop, Advances in Signal Processing for Non Destructive Evaluation of Materials, 203–208.
11. Mallat, S. A. (2008). Wavelet Tour of Signal Processing. The Sparse Way. N. Y.: Academic Press, 805.
12. Yella, S., Dougherty, M. S., Gupta, N. K. (2006). Artificial intelligence techniques for the automatic interpretation of data from non-destructive testing. Insight, 48 (1), 10–20. doi: 10.1784/insi.2006.48.1.10
13. Fominceva, Yu. V., Nesteruk, D. A. (2014). Realizaciya metoda teplovyh voln v teplovom kontrole izdelij iz kompozitov. Vestnik nauk Sibiri, 2 (12), 235.
14. Bazhenov, B. N., Mel'nik, S. I., Chumakov, A. G. (2007). Metod teplovogo kontrolya lopatok turbin s ispol'zovaniem teplovoj volny. Aviacionno-kosmicheskaya tekhnika i tekhnologiya, 9 (45), 97–100.
15. Potapov, A. I., Syas'ko, V. A., Chertov, D. N. (2012). Vyyavlenie rassloenij i glubiny ih zaleganiya v ugleplastikovyh konstrukciyah s ispol'zovaniem vihretokovogo vida nerazrushayushchego kontrolya. Izvestiya vysshih uchebnyh zavedenij, 8, 66–69.
16. Maldague, X. P. V., Jones, T. S., Kaplan, H., Marinetti, S., Prystay, M. (2001). Fundamentals of Infrared and Thermal Testing. in Nondestructive Handbook, Infrared and Thermal Testing. Vol. 3. Columbus, Ohio, ASNT Press, 718.
17. Storozhenko, V. A., Lazorenko, O. V., Myagkij, A. V. (2013). Obrabotka rezul'tatov teplovoj defektoskopii sotovyh konstrukcij s cel'yu ponizhe-niya urovnya pomekh. Visnik NTU «HPI». Seriya: Elektroenergetika ta peretvoryuval'na tekhnika, 34 (1007), 108–112.

RESEARCH RESULTS PROVING THE DEPENDENCE OF THE COPPER CONCENTRATE AMOUNT RECOVERED FROM BASALT RAW MATERIAL ON THE ELECTRIC SEPARATOR FIELD INTENSITY (p. 19-24)

Vladimir Naduty, Zinovii Malanchuk, Yevhenii Malanchuk, Valerii Korniyenko

The study proves the efficiency of using electric separation for extracting the copper concentrate from a crushed mass of basalt, lava-breccia, and tuff after their preliminary magnetic separation. We have determined the preferred particle-size classes (–1.0 +0.63 mm) in the processes of preparing the ore and classifying the components of the basaltic rock mass (from –0.25 +0.05 mm to –1.0 +0.63 mm) before electric separation; the copper concentrate outputs have been specified for basalt, tuff, and lava-breccia with regard to the electric field voltage for different particle-size fractions in the initial product.

The undertaken tests have revealed a linear dependence of the native copper output on the electric field voltage of the separator, which must be taken into account while developing the technological scheme of extracting native copper from basaltic raw materials.

We have proved that all the three components of the basaltic raw material (basalt, lava-breccia, and tuff) contain some percentage of copper that is of commercial interest. To extract substantial amounts of copper, it is essential to have a specific particle-size composition of the basaltic raw material before feeding it into the electric separator (basalt – 10.370 %, lava-breccia – 5.741 %, and tuff – 4.074 %; thereby, the particle size class of the feedstock is –1.0 +0.63 mm, and the electric field voltage is 30 kW).

The obtained findings help develop the basic requirements for industrial tests. It is expedient to carry out more field tests and to create an industrial site for a complex

processing of basalt raw materials. The completed study is a necessary element of developing a non-waste technology of processing the basalts of the Rafalovsky basalt quarry in Ukraine. In addition to native copper, these deposits contain such useful components as iron, titanium, manganese, and a silicate part. While extracting strategically valuable raw materials, the ecological situation in the region is improved due to the processing of industrial wastes such as tuff and lava-breccia.

Keywords: native copper, titanomagnetite, electrical separation, lava-breccia, basalt, tuff, copper concentrate.

References

1. Guo, Z., Zhu, D., Pan, J., Wu, T., Zhang, F. (2016). Improving Beneficiation of Copper and Iron from Copper Slag by Modifying the Molten Copper Slag. Metals, 6 (4), 86. doi: 10.3390/met6040086
2. Collini, L. (Ed.). (2012). Copper Alloys - Early Applications and Current Performance – Enhancing Processes. InTech, 186. doi: 10.5772/1912
3. Fiore, V., Scalici, T., Di Bella, G., Valenza, A. (2015). A review on basalt fibre and its composites. Composites Part B: Engineering, 74, 74–94. doi: 10.1016/j.compositesb.2014.12.034
4. Zhang, D., Zhou, T., Yuan, F., Fiorentini, M. L., Said, N., Lu, Y., Pirajno, F. (2013). Geochemical and isotopic constraints on the genesis of the Jueluotage native copper mineralized basalt, Eastern Tianshan, Northwest China. Journal of Asian Earth Sciences, 73, 317–333. doi: 10.1016/j.jseaes.2013.04.043
5. Cervi, E. C., da Costa, A. C. S., de Souza Junior, I. G. (2014). Magnetic susceptibility and the spatial variability of heavy metals in soils developed on basalt. Journal of Applied Geophysics, 111, 377–383. doi: 10.1016/j.jappgeo.2014.10.024
6. Tabosa, E., Rubio, J. (2010). Flotation of copper sulphides assisted by high intensity conditioning (HIC) and concentrate recirculation. Minerals Engineering, 23 (15), 1198–1206. doi: 10.1016/j.mineng.2010.08.004
7. Bölükbaşı, Ö. S., Tufan, B. (2014). Steelmaking slag beneficiation by magnetic separator and impacts on sinter quality. Science of Sintering, 46 (3), 331–344. doi: 10.2298/sos1403331b
8. Naduty, V., Malanchuk, Z., Malanchuk, E., Korniyenko, V. (2015). Modeling of vibro screening at fine classification of metallic basalt. Theoretical and Practical Solutions of Mineral Resources Mining, 441–443. doi: 10.1201/b19901-77
9. Malanchuk, E., Malanchuk, Z., Hristuk, A., Zagorovsky, V. (2015). Simulation of the comminution process to complex processing of metal-bearing basalt raw material. Cambridge Journal of Education and Science, 542–549.
10. Malanchuk, Ye., Rudenko, T., Naduty, V., Kovalenko, S., Malanchuk, Z. (2012). Patent number 75586 Ukraine. Method of production tuff. и 2012 05357, Bul. 23.

INVESTIGATION OF THE OXIDE PHASE CONVECTIVE HOMOGENIZATION WHILE VACUUM-ARC WITH HOLLOW CATHODE REMELTING OF STEEL (p. 25-32)

Oksana Andreeva, Boris Borts, Andrii Kostikov, Victor Tkachenko

Discussion of the requirements for the placement of ZrO_2 powder in the cathode, which must be taken into account in the production of ODS steel by vacuum-arc remelting in order to provide the high level of homogenization of the oxide particle is presented. The description of the experimental setup and the cathode structure for vacuum-arc remelting of steel, alloyed with oxide nano-powder is given. The role of convective processes in the homogenization of nano-particles in the production of ODS steel is highlighted. The convective flow of liquid metal captures ZrO_2 powder particles and carries them throughout its volume.

The use of the elementary cylindrical convective cell with mixed boundary conditions is proposed for the description of homogenization of the oxide particles. The structure and spatial distribution of the convective mass transfer in the cylindrical convective cell with the cosinusoidal bottom profile are provided.

Spatial distribution of convective flow in the cell is described by the Stokes lines, which are concentrically arranged smooth closed lines, which indicates the formation of convective flow in the form of a single vortex in the cell with mixed boundary conditions. Near the bottom, the Stokes lines reflect the curved cosine bottom profile. Criteria of vacuum-arc melting and convective mixing of ZrO_2 nano-particles are formulated.

Drops of the liquid material of the cathode with ZrO_2 nano-particles penetrate to the central vertical flow of the convective cell. Then, near the wall of the crystallizer, the particles are subjected to vertical forces: Archimedes force (always directed in vertical direction, i.e. upwards); gravity force (always directed downwards); friction force (Stokes force) (directed along the liquid velocity vector) on these particles.

The Archimedes force depends on the volume, i.e. size, of the particle. Thus, the less the nano-particle size, the lower the buoyancy force. The criterion of overcoming the Archimedes force allows determining the sizes of the particle at which their uniform distribution in the cell volume is possible.

Criteria of convective homogenization ZrO_2 nanoparticles are the following:

– droplets of cathode material penetrate into the cylindrical convective cell on a circular line which corresponds to the inner circumference of the hollow cathode;

– drops of the cathode material penetrate to a depth of convective cells, consistent with its half-height;

– ZrO_2 particles with sizes less than 90 nm will be stored for a long time in the melt, and homogenized in volume of the melt as a result of convective mass transport.

Keywords: reactor's steel, oxide powder, hollow cathode, vacuum-arc remelting, convective cell, mixed boundary conditions, mass transfer, homogenization.

References

1. Rogozhkin, S. V., Aleev, A. A., Zaluzhnyi, A. G., Nikitin, A. A., Iskandarov, N. A., Vladimirov, P. et. al. (2011). Atom probe characterization of nano-scaled features in irradiated ODS Eurofer steel. Journal of Nuclear Materials, 409 (2), 94–99. doi: 10.1016/j.jnucmat.2010.09.021
2. Rogozhkin, S. V., Nikitin, A. A., Aleev, A. A., Germanov, A. B., Zaluzhnyi, A. G. (2013). Atom probe study of radiation induced precipitates in Eurofer97 Ferritic-Martensitic steel irradiated in BOR-60 reactor. Inorganic Materials: Applied Research, 4 (2), 112–118. doi: 10.1134/s2075113313020160
3. Azarenkov, N. A., Vojevodin, V. N., Kirichenko, V. G., Kovtun, G. P., Kurinny, V. V., Lytovchenko, S. V. (2013). Nanostructural Materials in the Nuclear Engineering. The Journal of KNU. №1059. Physical series «Nuclei, Particles, Fields», 2 (58), 19–29.

4. Antsyferov, N., Bobrov, H. V., Druzhynyn, L. K. et. al. (1987). Poroshkovaia metallurhyia y napilenyia pokrityia. Moscow: Metallurhyia, 792.
5. Aheev, V. S., Nykytyna, A. A., Saharad, V. V., Safronov, B. V., Chukanov, A. P., Tsvelev, V. V. (2007). Yspolzovanye metodov metallurhyy raspilennikh y bistrozakalennikh poroshkov dlia yzghotovlenyia obolochek tvelov yz dyspersno-uprochnennikh oksydamy (DUO) zharoprochnikh ferrytno-martensytnikh stalei. VANT. Seryia: Fyzyka radyatsyonnikh povrezhdenyi y radyatsyonnoe materyalovedenye, I (2), 134–141.
6. Aheev, V. S., Hyrshov, V. L. (2015). Horiachee yzostatycheskoe pressovane metallycheskykh poroshkov. Komplekt: YTO, 08, 28–30.
7. Hilger, I., Boulnat, X., Hoffmann, J., Testani, C., Bergner, F., De Carlan, Y. et. al. (2016). Fabrication and characterization of oxide dispersion strengthened (ODS) 14Cr steels consolidated by means of hot isostatic pressing, hot extrusion and spark plasma sintering. Journal of Nuclear Materials, 472, 206–214. doi: 10.1016/j.jnucmat.2015.09.036
8. Pozdniakov, V. A. (2007). Plastychnost nanokrystallycheskykh materyalov s bymodalnoi zerennoi strukturoi. Pysma v ZhTF, 33 (23), 36–42.
9. Lu, C., Lu, Z., Xie, R., Liu, C., Wang, L. (2016). Microstructure of HIPed and SPSed 9Cr-ODS steel and its effect on helium bubble formation. Journal of Nuclear Materials, 474, 65–75. doi: 10.1016/j.jnucmat.2016.03.010
10. Ijiri, Y., Oono, N., Ukai, S., Ohtsuka, S., Kaito, T., Matsukawa, Y. (2016). Oxide particle–dislocation interaction in 9Cr-ODS steel. Nuclear Materials and Energy. doi: 10.1016/j.nme.2016.06.014
11. Auger, M. A., de Castro, V., Leguey, T., Lozano-Perez, S., Bagot, P. A. J., Moody, M. P., Roberts, S. G. (2016). Effect of the milling atmosphere on the microstructure and mechanical properties of a ODS Fe-14Cr model alloy. Materials Science and Engineering: A, 671, 264–274. doi: 10.1016/j.msea.2016.06.054
12. Chen, C.-L., Zeng, Y. (2016). Effect of consolidation and oxide dispersoid addition on phase formation and mechanical properties of WTi ODS alloy. International Journal of Refractory Metals and Hard Materials, 60, 11–16. doi: 10.1016/j.ijrmhm.2016.06.012
13. Loyer-Prost, M., Merot, J.-S., Ribis, J., Le Bouar, Y., Chaffron, L., Legendre, F. (2016). High resolution Transmission Electron Microscopy characterization of a milled oxide dispersion strengthened steel powder. Journal of Nuclear Materials, 479, 76–84. doi: 10.1016/j.jnucmat.2016.06.050
14. Borts, B. V., Vanzha, A. F., Korotkova, Y. M., Sityn, V. Y., Tkachenko, V. Y. (2014). Yssledovanye vozmozhnosty poluchenyia dyspersno-uprochnennikh oksydamy (DUO) stalei metodom vakuumno-duhovoho pereplava. VANT. Seryia: Fyzyka radyatsyonnikh povrezhdenyi y radyatsyonnoe materyalovedenye, 4 (92), 117–124.
15. Bozbiei, L., Borts, B., Neklyudov, I., Tkachenko, V. (2016). Investigation of the oxide phase homogenization in the convective cell while producing vacuum-arc remelting. Eastern-European Journal of Enterprise Technologies, 2 (5 (80)), 14–21. doi: 10.15587/1729-4061.2016.65424
16. Patochkina, O. L., Borts, B. V., Tkachenko, V. I. (2015). Elementary Convection Cell in the Horizontal Layer of Viscous Incompressible Liquid with Rigid and Mixed Boundary Conditions. East-European J. of Phys., 2 (1), 23–31.
17. Yachykov, Y. M., Morozov, A. P., Portnova, Y. V. (2007). Patent RU 2293268, MPK F27V3/08. Sposob elektroplavky v duhovoi pechy postoiannoho toka. 2005115622/02, declareted: 23.05.2005, published: 10.02.2007, Bul. 4, 10.
18. Gershuni, G. Z., Zhuxovickij, E. M. (1972). Convective stability of incompressible fluid. Moscow: Nauka, 393.

RESEARCH OF THE MECHANISM OF FORMATION AND PROPERTIES OF TRIPOLYPHOSPHATE COATING ON THE STEEL BASIS (p. 33-39)

Olena Vlasova, Vadym Kovalenko, Valerii Kotok, Sergey Vlasov

The mechanism, protective properties, microstructure, phase composition of coats on steel have been investigated. According to the developed method, the coats were deposited potentiodynamically and potentiostatically in an aqueous solution of sodium tripolyphosphate. Based on the results of electrochemical studies, it has been established, that on potentiodynamic curves, characterizing the corrosion behavior of low-carbon steel in an aqueous sodium TPP solution, up to three passivation plateaus can be observed. The multi-stage formation mechanism of tripolyphosphate coat has been proposed. The mechanism includes three stages: at the start the adsorptive film is formed, that afterwards is modified two times, accompanied by a change of properties and composition. By using the methods of optical and scanning electron microscopy, X-ray diffraction, it has been established that the coat formed in an aqueous Na TPP solution by the potentiodynamic method under conditions of complete passivation, is composed of two layers: first – thin, compact layer, that contains a crystalline phase of phosphate nature, and second – thick hydrophilic layer, capable of drying. Such coat possesses the best protective properties in 0.1 N Na_2SO_4 solution, that models conditions of atmospheric corrosion.

The nature of the electrochemical formation mechanism of tripolyphosphate coats and features of their structural and phase composition have been established.

The further studies will be directed at the development of effective deposition methods of tripolyphosphate coats with estimated set of properties for the protection of metal goods from atmospheric and high-temperature gas corrosion.

Keywords: sodium tripolyphosphate, anodic curve, passivation coat, protective properties, formation mechanism.

References

1. Akolzin, A. P. (1989). Protivokorrozionnay zashita stali plenkoobrazova-telymi. Moscow: Metallurgiy, 192.
2. Lipkin, Y. N., Shtanko, V. M. (1982). Chimicheskay I elektrochimicheskay obrabotka stalnch trub. Moscow: Metallurgiy, 216.
3. Kuznecov, Y. I. (2013). Organicheskie ingibitory atmosfernoy korrozii metallov. Vestnik Tambovskogo universiteta, 18 (5), 103–109.
4. Abrashov, A. A., Rozanova, D. I., Grigoryan, N. S., Vagrtamyan, T. A., Akimova, E. F., Kolesnikov, V. A., Asnis, N. A. (2011). O vozmozhocti zameny processov chromatirovaniy na processya fosfatirovaniy ocinkovannoy poverchosti. Korroziy, materialy, zashita, 16, 44–48.
5. Gomelya, N. D., Kuznecov, Y. I., Radovenchik, V. M., Shutko, G. L. (1996). Issledovanie processov stali v vode. Ekotechnologii i resursosberezheniya, 1, 36–40.
6. Kuznecov, Y. I. (2001). Ingibitory korrozzii v konversionnych pokrytiyach II. Zashita metallov ot korrozii, 37 (2), 119–125.

7. Burokas, V., Martušienė, A., Bikulčius, G. (1998). The influence of hexametaphosphate on formation of zinc phosphate coatings for deep drawing of steel tubes. Surface and Coatings Technology, 102 (3), 233–236. doi: 10.1016/s0257-8972(98)00359-4
8. Lee, S.-J., Toan, D. L. H., Chen Y.-H., Peng H.-C. (2016). Performance Improvement of Phosphate Coating on Carbon Steel by Cathodic Electrochemical Method. Int. J. Electrochem. Sci., 11, 2306–2316.
9. Tumbaleva, Y., Ivanova D., Fachikov L. (2011). Effect of the P_2O_5:NO_3 – retio on the zink phosphate coating formation. Journal of the University of Chemical Technology and Metallurgy, 46 (4), 357–362
10. Deyá, M., Di Sarli, A. R., del Amo, B., Romagnoli, R. (2008). Performance of Anticorrosive Coatings Containing Tripolyphosphates in Aggressive Environments. Industrial & Engineering Chemistry Research, 47 (18), 7038–7047. doi: 10.1021/ie071544d
11. Deyá, M., Vetere, V. F., Romagnoli, R., del Amo, B. (2001). Aluminium tripolyphosphate pigments for anticorrosive paints. Pigment & Resin Technology, 30 (1), 13–24. doi: 10.1108/03699420110364129
12. Vetere, V. F., Deyá, M. C., Romagnoli, R., Amo, B. (2001). Calcium tripolyphosphate: An anticorrosive pigment for paint. Journal of Coatings Technology, 73 (6), 57–63. doi: 10.1007/bf02698398
13. Fahim, I., Kheireddine, A., Belaaouad, S. (2013). Sodium tripolyphosphate (STPP) as a novel corrosion inhibitor for mild steel in 1M HCL. Journal of optoelectronicsand advanced materials, 15 (5-6), 451–456.
14. Kapralov, V. I., Gaisin, N. F., Sokol, P. G. (1991). Vlieanie structury fosfat iona na korrozionnuu stoykost stali v neytralnych vodnych sredach. Izv. AN Kaz. SSR, ser. khim., 2, 20–23.
15. Sankara Naraynan, T. S. N. (2005). Surface Pretreatmant by phosphate conversion coatings – a revive. Rev. Adv. Mater. Sci., 9, 134–177.
16. Ghali, E. I., Potvin, R. J. A. (1972). The mechanism of phosphating of steel. Corrosion Science, 12 (7), 583–594. doi: 10.1016/s0010-938x(72)90118-7
17. Zhou, Y., Xiong, Q. Y., Xiong, J. P. (2015). The Study of a Phosphate Conversion Coating on Magnesium Alloy AZ91D: I. Formation, Morphology and Composition. Int. J. Electrochem. Sci., 10, 2812–2824.
18. Abdalla, K., Rahmat, A., Azizan, A. (2012). The Effect of pH on Zinc Phosphate Coating Morphology and its Corrosion Resistance on Mild Steel. Advanced Materials Research, 626, 569–574. doi: 10.4028/www.scientific.net/amr.626.569
19. Burlov, V. V., Alcybeeva, A. I., Kuzikova, T. M. (2011). Lokalnaya korro-ziya oborudovaniya sovremennogo neftepererabatyvaushego zavoda. Izvestiya Sankt – Peterburgskogo gosudarstvennogo universiteta (techichtskogo universeteta), 11 (37), 92–96.
20. Vlasova, E. V., Kovalenko, V. L., Kotok, V. A. (2015). The effect of the time of coating on the properties and structure of tripolyphosphate coatings resulting under the conditions of intensive washing. Collectrion of research papers of National mining university, 49, 176–182.
21. Vlasova, E. V., Levko, E. N, Kovalenko,V. L., Kotok, V. A. (2015). Influence of Additive Compounds on the Properties of mining Inter-op Tripolyphosphate Coverages. Collectrion of research papers of National mining university, 48, 200–208.
22. Vlasova, E. V., Karasik, T. L., Levko, E. N., Kovalenko, V. L., Lizogub, A. A. (2011). Rolled metal products functional coatings based on alkali metals phosphates. Eastern-European Journal of Enterprise Technologies, 5 (6 (53)), 30–33. Available at: http://journals.uran.ua/eejet/article/view/1244/1146

INFLUENCE OF THE RATIO OF OXIDES AND TEMPERATURE ON THE STRUCTURE FORMATION OF ALKALINE HYDRO-ALUMINOSILICATES (p. 40-48)

Pavlo Kryvenko, Volodymyr Kyrychok, Sergii Guzii

In the course of optimization of compositions of alkaline hydro-aluminosilicates of general structural formula – $(0,7\div1Na_2O+0\div0,3K_2O)\cdot Al_2O_3\cdot(2\div7)SiO_2\cdot nH_2O$, it is established that the phase composition of artificial stone depends more on the ratio of basic oxides; the temperature of hardening in the range of 20÷80 °C increases the speed of structure formation of zeolite-like phases.

A determining factor of influence on the type of hydrated new formations is the ratio of SiO_2/Al_2O_3; its increase leads to the creation of zeolite-like phases with high content of silica in its composition. At hardening of alkaline hydro-aluminosilicate of the given structural forms under standard conditions of hardening, providing for a high degree of crystallinity of structure, optimal is the ratio $SiO_2/Al_2O_3=4\div5$.

Introduction of potassium ions into the composition of hydro-aluminosilicate contributes to obtaining potassium and sodium-potassium zeolite-like new formations and to increasing the degree of crystallinity of the indicated phases. To accelerate the structure formation of alkaline hydro-aluminosilicate under standard conditions of hardening, it is necessary to introduce potassium oxide at $K_2O/R_2O=0,15\div0,3$.

With an increase in the temperature of hardening of alkaline hydro-aluminosilicate from 20 to 80°, the phase composition of artificial stone remains practically unchanged; however, this leads to an increase in the velocity of structure formation and the degree of crystallinity of artificial stone.

As a result of optimization, we determined optimum structural formula of hydro-aluminosilicate $(0,8Na_2O+0,2K_2O)\cdot Al_2O_3\cdot4,5SiO_2\cdot nH_2O$, which makes it possible under standard conditions of hardening to obtain water-resistant artificial stone by the synthesis in the composition of hydrated new formations of zeolite-like minerals of the type of zeolite Na–A; sodium and potassium heulandite, as well as sodium potassium phillipsite.

Keywords: alkaline hydro-aluminosilicate, ratio of basic oxides, temperature of hardening, phase composition, structure formation.

References

1. Shi, C., Mo, Y. (2008). High-performance construction materials: science and applications. London: World Scientific, 448.
2. Glukhovsky, V. D. (1959). Gruntosilikaty. Kyiv: Gosstroiizdat Publish, 127.
3. Glukhovsky, V. D. (Ed.) (1979) Alkaline and alkali-alkaline earth hydraulic binders and concrete. Kyiv: Vyshcha Shkola, 232.
4. Pacheco-Torgal, F. (2014). Handbook of Alkali-activated Cements, Mortars and Concretes. UK: Woodhead Publishing in Elsevier, 852.

5. Provis, J. L., Van Deventer, J. S. J. (2009). Geopolymers: Structures, Processing, Properties and Industrial Applications. Elsevier: Amsterdam, 464.
6. Krivenko, P., Kovalchuk, G. (2007). Hydration Dehydration Structure Formation Processes in Geocements. Geopolymer Binders – Aachen, 97–118.
7. Marín-López, C., Reyes Araiza, J. L., Manzano-Ramírez, A., Rubio Avalos, J. C., Perez-Bueno, J. J., Muñiz-Villareal, M. S. et. al. (2009). Synthesis and characterization of a concrete based on metakaolin geopolymer. Inorganic Materials, 45 (12), 1429–1432. doi: 10.1134/s0020168509120231
8. Silva, P. D., Sagoe-Crenstil, K., Sirivivatnanon, V. (2007). Kinetics of geopolymerization: Role of Al_2O_3 and SiO_2. Cement and Concrete Research, 37 (4), 512–518. doi: 10.1016/j.cemconres.2007.01.003
9. Granizo, N., Palomo, A., Fernandez-Jiménez, A. (2014). Effect of temperature and alkaline concentration on metakaolin leaching kinetics. Ceramics International, 40 (7), 8975–8985. doi: 10.1016/j.ceramint.2014.02.071
10. Kovalchuk, G., Fernández-Jiménez, A., Palomo, A. (2007). Alkali-activated fly ash: Effect of thermal curing conditions on mechanical and microstructural development – Part II. Fuel, 86 (3), 315–322. doi: 10.1016/j.fuel.2006.07.010
11. Palomo, A., Fernández-Jiménez, A., Criado, M. (2006). Alkali activated fly ash binders. A comparative study between sodium and potassium activators. Materiales de Construcción, 56 (281). doi: 10.3989/mc.2006.v56.i281.92
12. Mo, B., Zhu, H., Cui, X., He, Y., Gong, S. (2014). Effect of curing temperature on geopolymerization of metakaolin-based geopolymers. Applied Clay Science, 99, 144–148. doi: 10.1016/j.clay.2014.06.024
13. Rovnaník, P. (2010). Effect of curing temperature on the development of hard structure of metakaolin-based geopolymer. Construction and Building Materials, 24 (7), 1176–1183. doi: 10.1016/j.conbuildmat.2009.12.023
14. Guzii, S., Hela, R., Kirichok, V. (2013). Rehabilitation of Concrete Surfaces of Hydropower Engineering Structures Deteriorated by Soft Corrosion and Cavitation. Advanced Materials Research, 688, 107–112. doi: 10.4028/www.scientific.net/amr.688.107
15. Krivenko, P. V., Guziy, S. G., Kyrychok, V. I. (2014). Geocement-Based Coatings for Repair and Protection of Concrete Subjected to Exposure to Ammonium Sulfate. Advanced Materials Research, 923, 121–124. doi: 10.4028/www.scientific.net/amr.923.121
16. Kyrychok, V., Drochytka, R., Kryvenko, P. (2015). Influence of Temperature on Structure Formation Processes Geocements for Rehabilitation of Concrete. Advanced Materials Research, 1122, 111–114. doi: 10.4028/www.scientific.net/amr.1122.111
17. Kryvenko, P., Guzii, S., Kovalchuk, O., Kyrychok, V. (2016). Sulfate Resistance of Alkali Activated Cements. MSF, 865, 95–106. doi: 10.4028/www.scientific.net/msf.865.95
18. Barrer, R. (1982). Hydrothermal chemistry of zeolites. London: Academic Press, 360.
19. Zhdanov, S. P. (1990). Synthetic Zeolites. Vol. 1-2. UK: Published by Routledge.

EFFECT OF MULTIPHASE STRUCTURE OF PLASMA COATINGS ON THEIR ELASTIC AND STRENGTH PROPERTIES (p. 49-57)

Viacheslav Kopylov

We examined physical and mechanical characteristics of multiphase plasma coatings of lamellar structure, which include nanocomponents based on silicon dioxide. Elastic and strength properties of composite materials are explored, connected with peculiarities of the formation of structure and composition of coatings at plasma spraying, based on the proposed calculation-experimental technique, as well as with using results of measurements of internal friction and testing of compositions for the three-point bend. The work presents results of evaluation of the parameters of crack resistance and character of destruction of composite materials, based on examination of energy balance of the system "base – plasma coating" at the moment of crack initiation at exfoliation and cracking of coatings. We obtained values of intensity of stresses K_{1c} of different systems and for the appropriate regions – in the grain body, on the border between the particles, in the area of interphase zone. The parameters of crack resistance (G_{1c}, K_{1c}) are calculated of the coating itself at its exfoliation and/or destruction.

We applied the corresponding techniques for determining cohesive strength for some cases of the crack propagation in the coating of dispersed structure depending on the composition of coating and ratio of modules of elasticity of the components of the given composition. The parameters of crack resistance are compared to physical and mechanical characteristics of plasma coatings – their adhesive and cohesive strength. The values of intensity of the released energy and coefficients of intensity of stresses at exfoliation or cracking are compared to such properties as adhesive and cohesive strength of the considered coatings.

Keywords: plasma coating, modulus of elasticity, internal friction, crack resistance, strength, multiphase structure.

References

1. Barvinok, V. A., Bogdanovich, V. A. (2012). Physical and mathematical modeling of processes of formation mesostructure-ordered plasma coatings. Journal technical physics, 82 (2), 105–112.
2. Morks, M. F., Tsunekawa, Y., Okumiya, M., Shoeib, M. A. (2003). Splat Microstructure of Plasma Sprayed Cast Iron With Different Chamber Pressures. Journal of Thermal Spray Technology, 12 (2), 282–289. doi: 10.1361/105996303770348393
3. Li, C.-J., Wang, W.-Z., He, Y. (2004). Dependency of fracture toughness of plasma sprayed Al2O3 coatings on lamellar structure. Journal of Thermal Spray Technology, 13 (3), 425–431. doi: 10.1361/10599630419364
4. Tillmann, W., Nebel, J. (2010). Analysis of the Mechanical Properties of an Arc Sprayed WC-FeCSiMn Coating: Compression, Bending, and Tension Behavior. Journal of Thermal Spray Technology, 20 (1-2), 317–327. doi: 10.1007/s11666-010-9567-z
5. Kopylov, V. I., Antonenko, D. A. (2014). Physical-mechanical properties and internal friction of multiphase materials with plasma coatings. Engineering problems, 2, 72–89.
6. Li, H., Khor, K. A., Cheang, P. (2002). Young's modulus and fracture toughness determination of high velocity oxy-fuel-sprayed bioceramic coatings. Surface and Coatings Technology, 155, 21–32. doi: 10.1016/s0257-8972(02)00026-9
7. Brantner, H. P., Pippan, R., Prantl, W. (2003). Local and Global Fracture Toughness of a Flame Sprayed Molybdenum Coating. Journal of Thermal Spray Technology, 12 (4), 560–571. doi: 10.1361/105996303772082314
8. Golovin, J. I. (2008). Nanoindentation and mechanical properties of solid bodies in submicrometer, thin surface layers and films (Review). Solid state Physics, 50 (12), 2113–2142.

9. Bashta, A. V. (2012). Mechanical strength of the surface layers of the structural ceramics. Visnyk of NTU "HTU", 48 (954), 15–24.
10. Dolgov, A. N. (2004). The method of determining the elastic modulus of thermal spray coatings. Powder metallurgy, 7/8, 110–115.
11. Wu, D. J., Mao, W. G., Zhou, Y. C., Lu, C. (2011). Digital image correlation approach to cracking and decohesion in a brittle coating/ductile substrate system. Applied Surface Science, 257 (14), 6040–6043. doi: 10.1016/j.apsusc.2011.01.119
12. Yamazaki, Y., Schmidt, A., Scholz, A. (2006). The determination of the delamination resistance in thermal barrier coating system by four-point bending tests. Surface and Coatings Technology, 201 (3-4), 744–754. doi: 10.1016/j.surfcoat.2005.12.023
13. Bao, Y. W., Zhou, Y. C., Bu, X. X., Qiu, Y. (2007). Evaluating elastic modulus and strength of hard coatings by relative method. Materials Science and Engineering: A, 458 (1-2), 268–274. doi: 10.1016/j.msea.2006.12.131
14. Dolgov, N. A., Chihira, I. V., Stuchliak, P. D., Buketov I. B. (2010). Using the criterion of adhesion-cohesin runano during flexion to create coatings with the best combination of strength characteristics. Oil and gas industry, 6, 41–45.
15. Ivanchenko A. V., Dolgov, N. A., Besov, A. V., Chernyi, A. V. (2015). Peculiarities of adhesive-cohesive fracture plazminoguena coatings. Bulletin of the KhNTU, 3 (54), 126–132.
16. Yu, L., Ma, Y., Zhou, C., Xu, H. (2005). Damping efficiency of the coating structure. International Journal of Solids and Structures, 42 (11-12), 3045–3058. doi: 10.1016/j.ijsolstr.2004.10.033
17. Kopylov, V. I., Smirnov, I. V., Rybakov, S. V. (2005). Influence of composition and microstructure of oxide ceramic coatings on physico-mechanical properties of composite materials. Engineering problems, 2, 3–19.
18. Kopylov, V. I., Varvus, I. A., Strongin, B. G. (1991). Main features of the formation of multi-component thermal spray coatings determining the physical and mechanical properties of the compositions during deposition. Phys.-Khim. mechanics of materials, 1, 65–70.
19. Kopylov, V. I., Revo, S. L., Smirnov, I. V., Ivanenko, E. A., Lozovy, F. V., Antonenko, D. A. (2010). Influence of plasma coatings of powders with nano-size components on the internal friction of iron. Nanosistemy, nanomaterials, nanotechnology, 8 (1), 209–215.
20. Kopylov, V. I., Smirnov, I. V., Dolgov N. A. (2004). The Use of failure criteria to assess the strength properties of thermal spray coatings. Engineering problems, 4, 3–11.
21. Fastow, J. K. (1963).The determination of internal friction damping coatings. Izv. An SSSR, OTN, Mechanics and mechanical engineering, 3, 127–128.
22. Hu, M. S., Evans, A. G. (1989). The cracking and decohesion of thin films on ductile substrates. Acta Metallurgica, 37 (3), 917–925. doi: 10.1016/0001-6160(89)90018-7
23. Kopylov, V. I. (1999). Optimization of obtaining solid compositions based on the combination of technological and operational parameters of plasma spraying. Problems of strength, 1, 68–75.
24. Rebinder, P. A., Shchukin, E. D., Margolis L. Y. (1964). On the mechanical strength of porous disperse bodies. Reports of as USSR, 154 (3), 695–698.
25. Maksimovich, G. G., Shatinsky, V. F., Kopylov, V. I. (1983). Physico-chemical processes in plasma spraying and the destruction of materials with coatings. Kyiv: Naukova Dumka, 264.
26. Chernoivanov, V. I., Karakozov, E. S. (1984). Physical-chemical processes of formation of the compounds during the deposition of powder materials. Statement of the problem. Welding production, 1, 2–5.