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VIBRATORY-CENTRIFUGAL STRENGTHENING'S INFLUENCE ON FAILURE-FREE PARAMETERS OF DRILLING PUMPS BUSHINGS

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The object of research is finishing-strengthening technological operation and implementing its safety systems to provide indicators of reliability of the bores of drilling pumps. At the finishing and finishing-strengthening operations of technological processes for the manufacture of products, their quality parameters, operational characteristics and reliability indicators are formed, the connections between which are complex, multi-stage and not obvious. The methods of mechanical and thermal processing and coating application can't provide reliability indicators of cylinder bores of drilling pumps. Advantages of the previously developed by the authors' method of vibration-centrifugal strengthening of parts and machines consist in providing a high level of deformation energy, high productivity, simplicity, reliability, compactness and versatility of strengthening devices, the possibility of qualitative processing of internal surfaces of machine parts. In addition, technical requirements are provided, performance indicators are improved and product life is increased. But, not always effective were attempts to adapt Vibrating machines of volumetric processing for vibration-centrifugal strengthening of products. Therefore, in the course of this study, volumetric vibration processing equipment for vibration-centrifugal strengthening of cylinder bores of НБ32 drilling pump was adapted and a technological tool for its implementation was designed. For experimental studies, the material of the bushings made of steel 70 on steel 20 has been changed and their internal execution surfaces have been strengthened using vibrations. In the course of full-scale tests it was established that after the vibration-centrifugal strengthening of the cylinder bushings of the drilling pumps, the dynamics of the change in the reliability factor, conditional probability and the failure rate for vibration-strengthened bushings is better than for base bushings manufactured according to the standard technological process. This is explained by the intensification of the processing and the possibility of adjusting the technological parameters of the process: the amplitude of the oscillations, the processing time, etc. In addition, the average time between failures of the vibration-strengthening bushings made of steel 20 increased 1.65 times compared to the base bushings of steel 70. The paths for further research are marked in the direction of optimization of processing regimes and development of practical recommendations on the use of vibration-centrifugal strengthening with an unbalanced drive.

Keywords: technological equipment for strengthening of bushings, drilling tool, cylindrical bushing, vibration-centrifugal strengthening.

References

1. Kusyj, J. M. (2002). *Tekhnolohichne zabezpechennia fizyko-mekhanichnykh parametriv poverkhnevykh shariv metalevykh dovhomirnykh tsylindrychnykh detalei vibratsiino-vidtsentrovym zmitsnenniam*. Lviv, 260.
2. Kusyj, J., Kuk, A. (2015). Method devised to improve technological reliability of machine parts. *Eastern-European Journal of Enterprise Technologies, 1 (7 (73))*, 41–51. doi:10.15587/1729-4061.2015.36336
3. Kusyj, J., Kuzin, O., Kuzin, N. (2016). The dependence of intergrain damageability of casting on the technological treatment route. *Eastern-European Journal of Enterprise Technologies, 1 (5 (79))*, 39–47. doi:10.15587/1729-4061.2016.59845
4. Kuzin, O., Kusyj, J., Topilnytskyj, V. (2015). Influence of technological heredity on reliability parameters of products. *Technology Audit and Production Reserves, 1 (1 (21))*, 15–21. doi:10.15587/2312-8372.2015.37678
5. Suslov, A. G. (2000). *Kachestvo poverkhnostnogo sloya detaley mashin*. Moscow: Mashinostroenie, 320.
6. Aleksandrovskaya, L. N., Afanasiev, A. P., Lisov, A. A. (2001). *Sovremennye metody obespecheniya bezotkaznosti slozhnykh tekhnicheskikh system*. Moscow: Logos, 208.
7. Bykov, I. Yu., Tskhadaya, N. D. (2004). *Ekspluatatsionnaya nadezhnost' i rabotosposobnost' burovykh mashin*. Ukhta: UGTU, 196.
8. Pronikov, A. S. (1978). *Nadezhnost' mashin*. Moscow: Mashinostroenie, 592.
9. Dalskiy, A. M. (1975). *Tekhnologicheskoe obespechenie nadezhnosti vysokotochnykh detaley mashin*. Moscow: Mashinostroenie, 319.
10. Skoogh, A., Perera, T., Johansson, B. (2012). Input data management in simulation – Industrial practices and future trends. *Simulation Modelling Practice and Theory, 29*, 181–192. doi:10.1016/j.simpat.2012.07.009
11. Wang, L. (2014). *Data representation of machine models. Dynamic thermal analysis of machines in running state*. London: Springer-Verlag, 11–29. doi:10.1007/978-1-4471-5273-6_2
12. McDowell, D. L. (2007). Simulation-assisted materials design for the concurrent design of materials and products. *Journal of the Minerals. Metals and Materials Society, 59 (9),* 21–25. doi:10.1007/s11837-007-0111-7
13. Durham, S. D., Padgett, W. I. (1997). Cumulative damage models for system failure with application to carbon fibers and composites. *Technometrics, 39 (1),* 34–44. doi:10.2307/1270770
14. McEvily, A. J. (2013). *Metal Failures: Mechanisms, Analysis, Prevention. Lecture Notes in Applied and Computational Mechanics*. John Wiley & Sons, 480. doi:10.1002/9781118671023
15. Zohdi, T. I., Wriggers, P. (2005). *An introduction to computational micromechanics. Lecture Notes in Applied and Computational Mechanics*. Springer, 198. doi:10.1007/978-3-540-32360-0
16. Kundu, T. (2008). *Fundamentals of fracture mechanics*. Boca Raton: CRC Press, 304.
17. Yashheritsyn, P. I., Ryzhov, E. V., Averchenko, V. I. (1977). *Tekhnologicheskaya nasledstvennost' v mashinostroenii*. Minsk: Nauka i tekhnika, 256.
18. Aftanaziv, I., Kusyj, J., Kuritnyk, I.-P. (2000). Using vibrations for strengthening of long-sized cylindrical details. *Acta Mechanica Slovaca. Kosice, 3,* 43–46.
19. Stotsko, Z., Kusyj, J., Topilnytskyj, V. (2012). Research of vibratory-centrifugal strain hardening on surface quality of cylindric long-sized machine parts. *Journal of Manufacturing and Industrial Engineering, 11 (1),* 15–17.
20. Aftanaziv, I. S. (1998). *Reliability technological providing of machines details*. Lviv: DULP. 132.
21. Jashcheritcyn, P. I., Minakov, A. P. (1986). *The non-rigid details strengthening's treatment in the engineer*. Minsk: Nauka i tekhnika, 215.
22. Schneider, Y. G. (1982). *Operating properties of details with regular microrelief*. Leningrad: Mashinostroenie. Leningradskoe otdelenie, 248.
23. Vasiliev, A. S., Dalskii, A. M., Klimenko, S. A. et al. (2003). *Tehnologicheskie osnovy upravleniia kachestvom mashin*. Moscow: Mashinostroenie, 256.

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INVESTIGATION OF THE EFFICIENCY AND POTENTIAL POSSIBILITIES OF PAPER PROTECTION BY SILOXAN IN WET ENVIRONMENTS

page 13–19

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The object of research is unbleached pulp-based winding with a thickness of 70±3 μm. One of the main problems is the use of the research object as a packaging material. Particular attention is required to protect paper when it is used in wet conditions. The presence of a layer of adsorbed water on the surface can adversely affect the physical and technical properties. The degree of such influence is determined by the energy state of the surface of the substrate and by the wettability of its water in the liquid-crystal state and the adsorption of water vapor. To ensure the stability of this paper in aggressive media, its modifications are carried out by immersion in 3–5 %, by volume of the solution in water, organic solvents or an aqueous dispersion of organosilicon products. A study of the hydrophobic properties and the mushroom resistance of the surface of the treated paper is also carried out. The results of the investigation of the tensile strength and dielectric parameters of the treated paper are considered. For comparison, IR spectrometry of porous aluminosilicate glass is carried out.

One of the main criteria is the tensile strength of the investigated paper treated with silicone coatings. As a result of the conducted studies, it is found that a less tensile force at the level of 84.6–90.1 % of the initial one is fixed when using coatings based on potassium methyl siliconate and its derivatives in various combinations. Therefore, in comparison with untreated paper, the modified one acquires high performance properties in terms of protection in humid environments.

Keywords: paper strengthening, potassium methyl siliconate, screening degree, wetting contact angle, efficiency coefficient of protective action.

References

1. *Pulp and Paper Online*. Available at: https://www.pulpandpaperonline.com/. Last accessed: 11.12.2017.
2. Yan, L.-Y., Li, S.-Y., Song, X.-L. (2016). Preparation of Paper Strengthening Agent by Esterification of Cellulosic Fines. *BioResources, 12 (1),* 469–477. doi:10.15376/biores.12.1.469-477
3. Ashori, A., Nourbakhsh, A. (2008). A comparative study on mechanical properties and water absorption behavior of fiber-reinforced polypropylene composites prepared by OCC fiber and aspen fiber. *Polymer Composites, 29 (5),* 574–578. doi:10.1002/pc.20582
4. Landel, R. F., Nielsen, L. E. (1993). *Mechanical Properties of Polymers and Composites.* CRC Press, 580.
5. Chen, Y., Wan, J., Ma, Y., Lv, H. (2010). Modification of properties of old newspaper pulp with biological method. *Bioresource Technology, 101 (18),* 7041–7045. doi:10.1016/j.biortech.2010.04.015
6. Dienes, D., Egyhazi, A., Reczey, K. (2004). Treatment of recycled fiber with Trichoderma cellulases. *Industrial Crops and Products, 20 (1),* 11–21. doi:10.1016/j.indcrop.2003.12.009
7. Marton, J., Roberts, J. (1996). *Dry-strength additives. Paper Chemistry.* New York: Springer, 83–97. doi:10.1007/978-94-011-0605-4_6
8. Wang, J., Zhang, J. (2014). *Application status and research developments of paper dry strength. Thermosetting Resin.* North Carolina, 53–58.
9. Yang, D., Li, H., Li, X. (2004). *Study on the cationic emulsifuing dry strength agents of paper. Vol. 1.* Shandong: Shandong Chemical Industry, 3–5.
10. Astratov, M. S., Homelia, M. D., Movchaniuk, O. M. (2007). *Tekhnolohiia pererobky paperu i kartonu. Part 1.* Kyiv: NTUU «KPI», 231.
11. Koptiukh, L. A. (1998). *Novi tekhnolohii i protsesy stvorennia pakuvalnoho paperu ta filtruvalnoho kartonu dlia kharchovoi promyslovosti.* Kyiv, 33.
12. Karyakina, M. I. (1988). *Ispytanie lakokrasochnykh materialov i pokrytiy*. Moscow: Khimiya, 272.
13. Prymakov, S. P., Barbash, V. N. (2002). *Tekhnolohiia paperu i kartonu.* Kyiv: EKMO, 396.
14. Lamburn, R. (Ed.). (1991). *Lakokrasochnye materialy i pokrytiya. Teoriya i praktika*. Saint Petersburg: Khimiya, 512.
15. Davis, J. R. (2001). *Surface Engineereing for Corrosion and Wear Resistance*. ASM International, 257.
16. Parfitt, G. D., Sing, K. S. W. (1976). *Characterization of Powder Surfaces*. London: Academic Press, 348.
17. Smith, A. L., Elving, P. J., Winefordner, J. D., Kolthoff, I. M. (Eds.). (1979). *Applied Infrared Spectroscopy: Fundamentals Techniques and Analytical Problem-Solving*. John Wiley & Sons, Inc., 336.
18. Brok, T., Groteklaus, M., Mishke, P.; Tsorll, U. (Ed.). (2004). *Evropeyskoe rukovodstvo po lakokrasochnym materialam i pokrytiyam*. Moscow: Peynt-Media, 548.
19. Mostyka, K. V. (2012). *Formuvannia vlastyvostei vodonepronyknykh paperovykh pakuvalnykh materialiv dlia kondyterskykh vyrobiv.* Kyiv, 21.
20. Sviderskyi, V. A., Salnyk, V. H., Cherniak, L. P. (2012). *Fizyko-khimichni vlastyvosti poverkhni kaoliniv i kaoliniievmisnykh hlyn ta yikh vydnykh dyspersii*. Kyiv: Znannia, 166.
21. Karyakina, M. I. (1988). *Ispytanie lakokrasochnykh materialov i pokrytiy*. Moscow: Khimiya, 272.
22. Pashhenko, A. A., Sviderskiy, V. A. (1988). *Kremniyorganicheskie pokrytiya dlya zashhity ot biokorozii*. Kyiv: Tekhnika, 136.
23. Sviderskyi, V. A., Cherniak, L. P., Salnyk, V. H. (2017). *Instrumentalni metody khimichnoho analizu sylikatnykh system*. Kyiv: National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», 171.

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USE OF HIGH-PERFORMANCE PLASTICIZERS TO PROVIDE DESIGN AND OPERATIONAL REQUIREMENTS FOR THE CONCRETE COMPOSITION FOR THE CONSTRUCTION OF FLOATING COMPOSITE DOCKS

page 19–27

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The object of research is plasticizers, which are the most popular additives for improving the quality properties of concrete, is used to build high-strength reinforced concrete products for hydrotechnical purposes. One of the most problematic places is the strength of concrete. This is due to extreme operating conditions and loads that survive the construction of the floating dock.

Methods of analysis and generalization of scientific literature on design and operational requirements for concrete of hydraulic structures were used during the research.

Data have been obtained that make it possible to compact the concrete mixture, reduce the consumption of cement, increase the frost resistance and waterproofness of concrete. This is due to the fact that the superplasticizers are introduced into the concrete mixture in an amount of 0.15...1.2 % of the cement mass, dilute the concrete mixture to a greater extent than conventional plasticizers. Superplasticizers have a number of features, in particular, the plasticizing effect persists for 1.0...1.5 hours after the addition, and after 2...3 hours it almost disappears.

Thanks to the use of plasticizers it is possible to increase the mobility of the concrete mix without reducing the strength of the concrete.

The combination of plasticizers with other types of additives (hardening accelerator, microsilica, air entraining admixtures) for concretes and mortars allows plants to produce high strength mixtures with unique properties.

Keywords: floating composite dock, shipbuilding concrete, plasticizing additives, superplasticizers, strength of concrete.

References

1. Rashkovskyi, O. S., Shchedrolosiev, O. V., Yermakov, D. V., Uzlov, O. M. (2015). *Proektuvannia, tekhnolohiia i orhanizatsiia pobudovy kompozytnykh plavuchykh dokiv*. Mykolaiv, 254.
2. Drapalyuk, M. V. (2009). The technology of semi-dry concrete forming for elements of hydraulic structures. Science and transport progress. *Bulletin of the Dnepropetrovsk National University of Railway Transport, 27,* 178–180.
3. Dvorkin, L. Y., Dvorkin, O. L. (2015). *Proektuvannia skladiv betoniv*. Rivne: NUVHP, 353.
4. Pshinko, A. N. (2000). *Podvodnoe betonirovanie i remont iskusstvennykh sooruzheniy*. Dnipropetrovsk: Porogi, 412.
5. Batrakov, V. G. (1998). *Modifitsirovannye betony. Teoriya i praktika*. Moscow: Stroyizdat, 768.
6. Punahin, V. M., Pshinko, O. M., Rudenko, N. M. (1998). *Pryznachennia skladiv hidrotekhnichnoho betonu*. Dnipropetrovsk: Art-Pres, 213.
7. Usov, B. A., Okolnikova, G. E. (2015). Chemical additives in prefabricated reinforced concrete technology. *Ecology and construction, 4,* 7–14.
8. Saliya, M. G., Kostyuk, T. A., Spirin, Yu. A., Plugin, A. A. (2012). Physico-chemical studies of cement stone with chemical and mineral additives, increasing crack resistance and waterproofness. *Collected scientific works of Ukrainian State University of Railway Transport, 130,* 49–56.
9. Nikiforova, N. A., Momot, V. O., Verhun, O. O. (2012). Vplyv kompleksnykh modyfikovanykh dobavok na morozostiikist vazhkykh betoniv. *Zbirnyk naukovykh prats DNUZT, 2,* 41–44.
10. Kovalenko, V. V., Kovalenko, S. V., Vovk, A. I., Zayats, Yu. L. (2012). Issledovanie struktury i svoystv mineral'nykh dobavok dlya betonov i stroitel'nykh rastvorov. *Zbirnyk naukovykh prats DNUZT, 1,* 28–32.
11. Chub, A. A. (2012). Issledovanie morozostoykosti, prochnostnykh i deformativnykh svoystv betona ot tekhnologicheskikh kharakteristik betonnykh smesey. *Zbirnyk naukovykh prats DNUZT, 1,* 120–125.
12. Romanenko, O. V. (2012). Physico-chemical studies of cement stone with additives superplasticizer and hardening accelerator. *Collected scientific works of Ukrainian State University of Railway Transport, 130,* 40–49.
13. Alexashin, S. V., Bulgakov, B. I., Popova, M. N. (2014). Fine concrete for hydraulic engineering modified by complex additive. *Izvestiya SFedU. Engineering Sciences, 1 (150),* 195–201.
14. Ramachandran, V. S. (1988). *Dobavki v beton*. Moscow: Stroyizdat, 291.
15. Perez Fernandez, R., Lamas Pardo, M. (2013). Offshore concrete structures. *Ocean Engineering, 58,* 304–316. doi:10.1016/j.oceaneng.2012.11.007
16. Sousa Coutinho, J. (2003). The combined benefits of CPF and RHA in improving the durability of concrete structures. *Cement and Concrete Composites, 25 (1),* 51–59. doi:10.1016/s0958-9465(01)00055-5
17. Bai, J., Sabir, B. B., Wild, S., Kinuthia, J. M. (2000). Strength development in concrete incorporating PFA and metakaolin. *Magazine of Concrete Research, 52 (3),* 153–162. doi:10.1680/macr.2000.52.3.153
18. Bai, J., Wild, S., Sabir, B. B. (2003). Chloride ingress and strength loss in concrete with different PC–PFA–MK binder compositions exposed to synthetic seawater. *Cement and Concrete Research, 33 (3),* 353–362. doi:10.1016/s0008-8846(02)00961-4
19. Bonavetti, V., Donza, H., Rahhal, V., Irassar, E. (2000). Influence of initial curing on the properties of concrete containing limestone blended cement. *Cement and Concrete Research, 30 (5),* 703–708. doi:10.1016/s0008-8846(00)00217-9
20. Ghrici, M., Kenai, S., Said-Mansour, M. (2007). Mechanical properties and durability of mortar and concrete containing natural pozzolana and limestone blended cements. *Cement and Concrete Composites, 29 (7),* 542–549. doi:10.1016/j.cemconcomp.2007.04.009
21. Gartner, E. (2004). Industrially interesting approaches to «low-CO_2» cements. *Cement and Concrete Research, 34 (9),* 1489–1498. doi:10.1016/j.cemconres.2004.01.021
22. Kaushik, S. K., Islam, S. (1995). Suitability of sea water for mixing structural concrete exposed to a marine environment. *Cement and Concrete Composites, 17 (3),* 177–185. doi:10.1016/0958-9465(95)00015-5
23. Khan, M. I., Lynsdale, C. J. (2002). Strength, permeability, and carbonation of high-performance concrete. *Cement and Concrete Research, 32 (1),* 123–131. doi:10.1016/s0008-8846(01)00641-x
24. Khatib, J. M., Hibbert, J. J. (2005). Selected engineering properties of concrete incorporating slag and metakaolin. *Construction and Building Materials, 19 (6),* 460–472. doi:10.1016/j.conbuildmat.2004.07.017
25. Limeira, J., Etxeberria, M., Agullo, L., Molina, D. (2011). Mechanical and durability properties of concrete made with dredged marine sand. *Construction and Building Materials, 25 (11),* 4165–4174. doi:10.1016/j.conbuildmat.2011.04.053
26. Dmitrenko, A. E., Khachaturyan, A. P., Makhinin, B. V. (2012). Otsenka effektivnosti organicheskikh i mineral'nykh dobavok v melkozernistom betone. *Nauchno-tekhnicheskoe i ekonomicheskoe sotrudnichestvo stran ATR v XX veke, 1,* 289–295.
27. Shkorko, M. Yu., Zhurovich, E. A., Kozlova, K. S., Bessonova, Yu. V. (2017). Plasticizers in concrete. *Innovative science, 4–3,* 145–147.
28. Zakharov, S. A. (2008). Optimizatsiya sostavov betonov vysokoeffektivnymi polikarboksilatnymi plastifikatorami. *Stroitel'nye materialy, 3,* 42–43.
29. Aminova, G. K., Maskova, A. R., Buylova, E. A., Gorelov, V. S., Mazitova, A. K. (2012). Plastifikatory dlya polivinilkhloridnykh kompozitsiy stroitel'nogo naznacheniya. *Promyshlennoe proizvodstvo i ispol'zovanie elastomerov, 4,* 29–32.
30. Dudynov, S. V. (2003). Ekonomicheski bezvrednyy plastifikator stroitel'nogo naznacheniya. *Vestnik mordovskogo universiteta, 1–2,* 138–145.
31. Topchiy, Yu. S., Khabirov, D. M. (2013). Modifitsirovannyy belkovyy plastifikator dlya tsementnykh sistem. *Tekhnologii betonov, 11 (88),* 46–47.
32. Ruzhitskaya, A. V., Potapova, E. N. (2009). Vliyanie dobavok-plastifikatorov na svoystva belogo portlandtsementa. *Innovatsionnaya nauka. Tekhnika i tekhnologiya silikatov, 16 (1),* 14–23.
33. Suraev, V. (2002). Gidrofobizatsiya. Teoriya i praktika. *Tekhnologii stroitel'stva, 1,* 120–121.
34. Pashhenko, A. A. (1973). *Gidrofobizatsiya*. Kyiv: Naukova dumka, 174.
35. Pashhenko, A. A. (1968). *Kremniyorganicheskie gidrofobizatory v stroitel'stve*. Alma-Ata: Kazakhstan, 78.
36. Lukinskiy, O. A. (2008). Gidrofobizatsiya zdaniy. *Zhilishhnoe stroitel'stvo, 11,* 21–23.
37. Orentlikher, L. P., Novikova, I. P., Lifanov, I. I., Yurchenko, E. N. (1991). Sposoby otsenki vliyaniya poverkhnostnoy gidrofobizatsii betona i modifitsiruyushhikh ego strukturu dobavok. *Beton i zhelezobeton, 2 (431),* 28–30.
38. Gurinovich, L. S., Usov, B. A. (2015). The mechanochemical treatment of the building materials. *Ecology and construction, 3,* 22–25.
39. Demyanova, V. S. (2000). Aktivnost' portlandtsementov v prisutstvii plastifikatora. *Zhilishhnoe stroitel'stvo, 11,* 30.
40. Kamalova, Z. A., Rakhimov, R. Z., Ermilova, E. Yu., Stoyanov, O. V. (2013). Superplastifikatory v tekhnologii izgotovleniya kompozitsionnogo betona. *Vestnik Kazanskogo tekhnologicheskogo universiteta, 8,* 148–152.
41. Kalashnikov, V. I. (2011). Terminologiya nauki o betonakh novogo pokoleniya. *Stroitel'nye materialy, 3,* 103–106.

42. Bazhenov, Yu. M., Demyanova, V. S., Kalashnikov, V. I. (2006). *Modifitsirovannye vysokoprochnye betony*. Moscow: Assotsiatsiya stroitel'nykh vuzov, 368.
43. Strokova, V. V., Molovieva, L. N. (2009). Otsenka vliyaniya kristallicheskikh zatravok na strukturoobrazovanie tsementnogo kamnya. *Stroitel'nye materialy, 3,* 97–98.
44. Rashkovskiy, A. S., Slutskiy, N. G. (2008). Optimizatsiya sostava betona dlya pontonov kompozitnykh plavuchikh dokov. *Zbirnik naukovikh prats' NUK, 5 (422),* 17–24.

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RESEARCH OF THE PECULIARITIES OF PLASMA-ELECTROLYTIC TREATMENT OF AK12M2MGN PISTON ALLOY WITH FORMATION OF CERAMIC-LIKE COATINGS

page 27–35

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The object of research is the processes of the piston alloy AK12M2MgH treatment by the method of plasma electrolytic oxidation (PEO) with the formation of ceramic-like coatings. One of the most problematic places is the influence of the chemical composition of the Al-Si alloy on the process of treatment and formation of ceramic coatings. It is established that electrochemical technologies are widely used to modify the surface of silumins by forming coating of various composition and purpose.

In the course of the study it was shown that PEO of piston silumin should be carried out in alkaline complex electrolytes with the addition of manganese and/or cobalt salts. This makes it possible to homogenize the surface layer of the alloy by composition, to reduce the content of its alloying components and to create conditions for the formation of a uniform oxide coating with incorporation of the admissible components.

It has been established that oxidation in pyrophosphate cobaltous solution allows obtaining mosaic structures of blue-violet color with cobalt content up to 24 at %. PEO silumin in the manganous alkaline electrolyte provides the formation of a brown-black ceramic-like layer with manganese content up to 35 at %. Consecutive PEO treatment in these solutions leads to the formation of a mixed fine-dispersed porous oxide coating with a total content of dopant 25–30 at %. Based on the research results, it has been proposed to oxidize the piston silumin in a regime of incident power to form uniform coatings with a high content of dopant.

Obtained oxide systems have a developed surface and a significant content of catalytically active components. In comparison with the known methods of PEO treatment of piston silumin, the silicon content in the surface oxide layers does not exceed 3 at %, which is one of the requirements for catalytically active materials.

The ceramics-like coatings show high catalytic activity in model oxidation reactions of CO and benzene and reduce the emission of toxic gas emissions from internal combustion engines. The proposed systems are promising for use in intracylindrical catalysis technologies and improving the fuel economy of engines.

Keywords: AK12M2MgN piston alloy, plasma-electrolytic oxidation, piston silumin, ceramic-like coating.

References

1. Belov, N. A. (2010). *Fazovyi sostav promyshlennykh i perspektivnykh alyuminievykh splavov*. Moscow: Izdatelskiy dom MISiS, 511.
2. Glazoff, M. V., Zolotorevsky, V. S., Belov, N. A. (2007). *Casting Aluminum Alloys*. Oxford: Elsiever, 544. doi:10.1016/b978-0-08-045370-5.x5001-9
3. Sakhnenko, M. D., Ved, M. V., Karakurkchi, H. V., Yermolenko, I. Yu., Zyubanova, S. I. (2013). Resursozaoshchadzhuval'na tekhnolohiya vidnovlennya znoshenykh detaley. *Intehrovani tekhnolohiyi ta resursozberezhennya, 2,* 9–13.
4. Kolmykov, D. V., Honcharov, A. N. (2012). Kombynyrovannye metody uprochnenyia. *Visnyk Sumskoho natsionalnoho ahrarnoho universytetu, 6 (24),* 46–50.
5. Mazurenko, Ye. A., Herasymchuk, A. I., Ovsiannykov, V. P. (2001). Khimichne osadzhennia z hazovoi fazy, syntez funktsionalnykh materialiv (ohliad). *Fizyka i khimiia tverdoho tila, 2 (3),* 339–349.
6. Bobzin, K., Ernst, F., Richardt, K., Schlaefer, T., Verpoort, C., Flores, G. (2008). Thermal spraying of cylinder bores with the Plasma Transferred Wire Arc process. *Surface and Coatings Technology, 202 (18),* 4438–4443. doi:10.1016/j.surfcoat.2008.04.023
7. Nosov, A. S., Meleshin, V. V., Tovmasyan, A. B., Babich, A. G. (2017). Obzor tehnologicheskih meropriyatiy, napravlennyih na povyishenie nadezhnosti tsilindro-porshnevoy gruppyi dvigatelya vnutrennego sgoraniya. *Sovremennyie materialyi, tehnika i tehnologii, 3 (11),* 80–85.
8. Okada, A. (2010). *Innovative materials for automotive industry*. New York: Nova Science Publishers, 147.
9. Sakhnenko, N., Ved, M., Karakurkchi, A., Galak, A. (2016). A study of synthesis and properties of manganese-containing oxide coatings on alloy VT1-0. *Eastern-European Journal of Enterprise Technologies, 3 (5 (81)),* 37–43. doi:10.15587/1729-4061.2016.69390
10. Yar-Mukhamedova, G. Sh., Ved, M. V., Karakurkchi, A. V., Sakhnenko, N. D. (2017). Mixed alumina and cobalt containing plasma electrolytic oxide coatings. *IOP Conference Series: Materials Science and Engineering, 213.* doi:10.1088/1757-899x/213/1/012020
11. Nemenenok, B. M., Kalinichenko, V. A., Sadoha, M. A., Gutko, V. I. (2005). Povyishenie resursa rabotyi porshney dvigateley vnutrennego sgoraniya. *Lite i metallurgiya, 2 (34),* 175–178.
12. Rudnev, V. S., Lukiyanchuk, I. V., Vasilyeva, M. S., Medkov, M. A., Adigamova, M. V., Sergienko, V. I. (2016). Aluminum- and titanium-supported plasma electrolytic multicomponent coatings with magnetic, catalytic, biocide or biocompatible properties. *Surface and Coatings Technology, 307,* 1219–1235. doi:10.1016/j.surfcoat.2016.07.060
13. Ved, M. V., Sahnenko, N. D., Karakurkchi, A. V., Ermolenko, I. Yu. (2014). Electroplating and functional properties of Fe-Mo and Fe-Mo-W coatings. *Voprosyi himii i himicheskoy tehnologii, 5–6 (98),* 53–60.
14. Gupta, P., Tenhundfeld, G., Daigle, E. O., Ryabkov, D. (2007). Electrolytic plasma technology: Science and engineering–An overview. *Surface and Coatings Technology, 201 (21),* 8746–8760. doi:10.1016/j.surfcoat.2006.11.023
15. Rogov, A. B., Slonova, A. I., Shayapov, V. R. (2012). Peculiarities of iron-containing microplasma coating deposition on aluminum in homogeneous electrolyte. *Applied Surface Science, 261,* 647–652. doi:10.1016/j.apsusc.2012.08.075
16. Borisov, A. M., Krit, B. L., Lyudin, V. B., Morozova, N. V., Suminov, I. V., Apelfeld, A. V. (2016). Microarc oxidation in slurry electrolytes: A review. *Surface Engineering and Applied Electrochemistry, 52 (1),* 50–78. doi:10.3103/s106837551601004x
17. Malyshev, V. N., Zorin, K. M. (2007). Features of microarc oxidation coatings formation technology in slurry electrolytes. *Applied Surface Science, 254 (5), 1*511–1516. doi:10.1016/j.apsusc.2007.07.079
18. Sakhnenko, M., Karakurkchi, A., Galak, A., Menshov, S., Matykin, O. (2017). Examining the formation and properties of TiO2 oxide coatings with metals of iron triad. *Eastern-European Journal of Enterprise Technologies, 2 (11 (86)),* 4–10. doi:10.15587/1729-4061.2017.97550
19. Parsadanov, I. V., Sakhnenko, M. D., Khyzhnyak, V. O., Karakurkchi, H. V. (2016). Improving the environmental performance of engines by intra-cylinder neutralization of toxic exhaust gases. *Internal Combustion Engines, 2,* 63–67. doi:10.20998/0419-8719.2016.2.12
20. Ved, M. V., Sakhnenko, N. D., Karakurkchi, A. V., Myrna, T. Yu. (2017). Functional mixed cobalt and aluminum oxide coatings for environmental safety. *Functional Materials, 24 (2),* 303–310. doi:10.15407/fm24.02.303

21. Sakhnenko, N. D., Ved, M. V., Androshchuk, D. S., Korniy, S. A. (2016). Formation of coatings of mixed aluminum and manganese oxides on the AL25 alloy. *Surface Engineering and Applied Electrochemistry, 52 (2),* 145–151. doi:10.3103/s1068375516020113
22. Kotok, V., Kovalenko, V., Malyshev, V. (2017). Comparison of oxygen evolution parameters on different types of nickel hydroxide. *Eastern-European Journal of Enterprise Technologies, 5 (12 (89)),* 12–19. doi:10.15587/1729-4061.2017.109770
23. Xu, F., Xia, Y., Li, G. (2009). The mechanism of PEO process on Al–Si alloys with the bulk primary silicon. *Applied Surface Science, 255 (23),* 9531–9538. doi:10.1016/j.apsusc.2009.07.090
24. Wang, P., Li, J. P., Guo, Y. C., Yang, Z., Wang, J. L. (2016). Ceramic coating formation on high Si containing Al alloy by PEO process. *Surface Engineering, 32 (6),* 428–434. doi:10.1179/1743294415y.0000000003
25. Dudareva, N. Y., Abramova, M. M. (2016). The Structure of Plasma-Electrolytic Coating Formed on Al–Si alloys by the Micro-Arc Oxidation Method. *Protection of Metals and Physical Chemistry of Surfaces, 52 (1),* 128–132. doi:10.1134/s2070205116010093
26. Xue, W., Shi, X., Hua, M., Li, Y. (2007). Preparation of anti-corrosion films by microarc oxidation on an Al–Si alloy. *Applied Surface Science, 253 (14),* 6118–6124. doi:10.1016/j.apsusc.2007.01.018
27. Dai, L., Li, W., Zhang, G., Fu, N., Duan, Q. (2017). Anti-corrosion and wear properties of plasma electrolytic oxidation coating formed on high Si content Al alloy by sectionalized oxidation mode. *IOP Conference Series: Materials Science and Engineering, 167,* 012063. doi:10.1088/1757-899x/167/1/012063
28. Rogov, A. B. (2015). Plasma electrolytic oxidation of A1050 aluminium alloy in homogeneous silicate-alkaline electrolytes with edta 4–complexes of Fe, Co, Ni, Cu, La and Ba under alternating polarization conditions. *Materials Chemistry and Physics, 167,* 136–144. doi:10.1016/j.matchemphys.2015.10.020
29. Boguta, D. L., Rudnev, V. S., Yarovaya, T. P., Kaidalova, T. A., Gordienko, P. S. (2002). On Composition of Anodic-Spark Coatings Formed on Aluminum Alloys in Electrolytes with Polyphosphate Complexes of Metals. *Russian Journal of Applied Chemistry, 75 (10),* 1605–1608. doi:10.1023/a:1022263331315
30. Rudnev, V. S. (2008). Multiphase anodic layers and prospects of their application. *Protection of Metals, 44 (3),* 263–272. doi:10.1134/s0033173208030089
31. Krishtal, M. M., Yasnikov, I. S., Ivashin, P. V., Polunin, A. V. (2012). O primenenii tehnologii mikrodugovogo oksidirovaniya dlya remonta i vosstanovleniya izdeliy iz siluminov. *Aviatsionnaya i raketno-kosmicheskaya tehnika, 3 (34),* 225–228.
32. Krishtal, M. M., Ivashin, P. V., Kolomiets, P. V. (2012). Ispolzovanie tehnologii mikrodugovogo oksidirovaniya pri razrabotke DVS s blokom tsilindrov iz alyuminievogo splava. *Izvestiya Samarskogo nauchnogo tsentra Rossiyskoy akademii nauk, 12 (4),* 242–246.
33. Dudareva, N., Kal'shchikov, R., Dombrovskii, O., Butusov, I. (2015). Experimentally Studied Thermal Piston-head State of the Internal-Combustion Engine with a Thermal Layer Formed by Micro-Arc Oxidation Method. *Science and Education of the Bauman MSTU, 15 (5),* 115–125. doi:10.7463/0515.0774148
34. Butusov, I., Dudareva, N. (2013). Influence of micro-arc oxidation on durability of IC-engine's piston. *Science and Education of the Bauman MSTU, 13 (9),* 127–144. doi:10.7463/0913.0606017
35. Stepanov, V. A. (2014). Uluchshenie ekspluatatsionnyih pokazateley avtomobiley mikrodugovyim oksidirovaniem dnisch porshney dvigateley. *Science and world, 1 (5),* 115–117.
36. Nurutdinov, A. Sh., Stepanov, V. A., Hohlov, A. L., Uhanov, D. A., Kanyaeva, O. M. (2013). Povyishenie tehniko-ekspluatatsionnyih pokazateley DVS modernizatsiey tsilindroporshnevoy gruppyi. *Vestnik SGAU im. N. I. Vavilova, 11,* 56–59.
37. Marchenko, A. P., Shpakovskiy, V. V. (2011). Vliyanie korundovogo sloya na rabochih poverhnostyah porshney na protsess sgoraniya v DVS. *Dvigateli vnutrennego sgoraniya, 2,* 24–28.
38. Marchenko, A. P., Shpakovskyi, V. V., Pylov, V. V. (2013). Pidvyshchennya ekonomichnosti benzynovoho dvyhuna na riznykh rezhymakh roboty pry zastosuvanni chastkovo-dynamichnoyi teploizolyatsiyi porshniv. *Visnyk NTU «KhPI», 32 (1005),* 106–110.
39. Sakhnenko, N. D., Ved, M. V., Karakurkchi, A. V.; Fesenko, O., Yatsenko, L. (Eds.). (2017). Chapter 38. Nanoscale Oxide PEO Coatings Forming from Diphosphate Electrolytes: Proceedings // *Nanophysics, Nanomaterials, Interface Studies, and Applications*. Springer International Publishing AG, 507–531. doi:10.1007/978-3-319-56422-7_38
40. Ved, M. V., Karakurkchi, A. V., Sakhnenko, N. D., Gorohivskiy, A. S. (2017). Synthesis of Catalytic Cobalt-Containing Coatings on Alloy Al25 Surface by Plasma Electrolytic Oxidation. *Chemistry, Physics and Technology of Surface, 82 (1),* 73–79. doi:10.15407/hftp08.01.073
41. Parsadanov, I. V., Sakhnenko, N. D., Ved, M. V., Rykova, I. V., Khyzhniak, V. O., Karakurkchi, A. V., Gorohivskiy, A. S. (2017). Increasing the efficiency of intra-cylinder catalysis in diesel engines. *Voprosyi himii i himicheskoy tehnologii, 52 (6),* 145–151.

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SIMULATION OF PARTIAL DISCHARGES UNDER INFLUENCE OF IMPULSE VOLTAGE

page 36–41

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The object of research is an equivalent circuit for a dielectric with a weakened insulation (for example, with a gas cavity) with a partial discharge. The test with partial discharge measurement by application of alternating voltage is one of the main methods of diagnostics and non-destructive tests. According to GOST 1516.2, the application of impulse test voltage does not necessarily end with a breakdown of the electrical equipment insulation or the absence of breakdown. There may be a partial breakdown of insulation, in which not all insulation of electrical equipment will be damaged, but only some of its part. It is quite difficult to detect such damage in accordance with GOST 1516.2, but registration of partial discharges will allow this to be detected by increasing their intensity.

The use of existing technical means for measuring the characteristics of partial discharges at alternating voltage is not acceptable for the task in question. Therefore, it is preliminary necessary to carry out computer simulation of partial discharges when the impulse voltage is applied.

A circuit simulation model of a dielectric with a gas cavity with partial discharge has been created. It is shown how, by means of a combination of various elements, to simulate the breakdown of a gas cavity. The operability of the model under the influence of alternating voltage is checked. It is confirmed that voltage harmonic distortions lead to an increase in the number of partial discharges. A study of the model is carried out when it is subjected to a full lightning voltage impulse. As a result, it has been established that partial discharges occur in the gas cavity both at the impulse front and at its tail.

Diagnosis of the insulation condition using the measurement of the partial discharge characteristics under the influence of impulse voltage will be more informative. In particular, it will allow to detect partial breakdowns of insulation that occur during impulse tests and are absent in standard tests with application of alternating voltage. To carry out such measurements it is necessary to develop new techniques, equipment and diagnostic procedures.

Keywords: circuit simulation, partial discharge, impulse voltage, higher voltage harmonics.

References

1. Brzhezitsky, V. O., Scherba, A. A., Podoltsev, A. D., Trotsenko, Ye. A., Shevchenko, S. Yu., Haran, Ya. A., Atarod, S. (2011). A Study of the Causes of Electric Overlapping of the Middle Phase Insulator String of the Overhead Power Line. *Research Bulletin of National Technical University of Ukraine «Kyiv Polytechnic Institute», 6,* 36–41.
2. Eigner, A., Rethmeier, K. (2016). An overview on the current status of partial discharge measurements on AC high voltage cable accessories. *IEEE Electrical Insulation Magazine, 32 (2),* 48–55. doi:10.1109/mei.2016.7414231
3. Gemant, A., Philippoff, W. (1932). Die Funkenstrecke mit Vorkondensator. *Zeitschrift für Technische Physik, 13 (9),* 425–430.
4. Lemke, E. (2012). A critical review of partial-discharge models. *IEEE Electrical Insulation Magazine, 28 (6),* 11–16. doi:10.1109/mei.2012.6340519
5. Florkowski, M., Florkowska, B. (2006). Distortion of partial-discharge images caused by high-voltage harmonics. *IEE Proceedings – Generation, Transmission and Distribution, 153 (2),* 171–180. doi:10.1049/ip-gtd:20050008
6. Florkowski, M., Florkowska, B., Furgal, J., Zydron, P. (2013). Impact of high voltage harmonics on interpretation of partial discharge patterns. *IEEE Transactions on Dielectrics and Electrical Insulation, 20 (6),* 2009–2016. doi:10.1109/tdei.2013.6678848
7. Li, Y., Mu, H.-B., Deng, J.-B., Zhang, G.-J., Wang, S.-H. (2013). Partial discharge characteristics of oil/polypropylene film with a needle-plate electrode excited by impulse voltages. *2013 Annual Report Conference on Electrical Insulation and Dielectric Phenomena,* 1225–1228. doi:10.1109/ceidp.2013.6748256
8. Deng, J., Wang, M., Zhou, Y., Zhou, Z., Zhang, Y., Zhang, L., Liu, X. (2016). Partial discharge characteristics of uniform gap in oil-impregnated paper insulation under switching impulse voltage. *IEEE Transactions on Dielectrics and Electrical Insulation, 23 (6),* 3584–3592. doi:10.1109/tdei.2016.005508
9. Do, T., Lesaint, O., Auge, J.-L. (2008). Streamers and partial discharge mechanisms in silicone gel under impulse and AC voltages. *IEEE Transactions on Dielectrics and Electrical Insulation, 15 (6),* 1526–1534. doi:10.1109/tdei.2008.4712654
10. Vdoviko, V. P. (2007). *Chastichnye razriady v diagnostirovanii vysokovol'tnogo oborudovaniia*. Novosibirsk: Nauka, 155.
11. Gunawardana, S. D. M. S., Kanchana, A. A. T., Wijesingha, P. M., Perera, H. A. P. B., Samarasinghe, R., Lucas, J. R. (2015). A Matlab Simulink Model for a Partial Discharge Measuring System. *2015 Electrical Engineering Conference (EECon),* 29–34.
12. Pahomov, A. I. (2005). *Metody i sredstva diagnostiki izoliatsii asinhronnyh dvigatelei sel'skohoziaistvennogo proizvodstva na osnove chastichnyh razriadov.* Krasnodar, 32.
13. Beyer, M., Boeck, W., Möller, K., Zaengl, W. (1986). *Hochspannungstechnik: Theoretische und praktische Grundlagen*. Springer-Verlag Berlin Heidelberg, 362. doi:10.1007/978-3-642-61633-4
14. *Micro-Cap 11. Electronic Circuit Analysis Program. Reference Manual.* (2014). Sunnyvale, CA: Spectrum Software, 1040. Available at: http://www.spectrum-soft.com/down/rm11.pdf
15. Trotsenko, Y., Brzhezitsky, V., Masluchenko, I. (2017). Circuit simulation of electrical breakdown in air using Kind's equal-area criterion. *Technology audit and production reserves, 3 (1 (35)),* 44–49. doi:10.15587/2312-8372.2017.102240
16. Babicheva, A. A., Protsenko, O. R., Trotsenko, Ye. O. (2016). Modeliuvannia proboiu izoliatsiinoho promizhku iz zadanoiu volt-sekundnoiu kharakterystykoiu. *Mizhnarodnyi naukovo-tekhnichnyi zhurnal molodykh uchenykh, aspirantiv i studentiv «Suchasni problemy elektroenerhotekhniky ta avtomatyky»,* 357–359.
17. Brzhezitsky, V., Trotsenko, Y., Haran, Y. (2017). Analysis and comparison of metal-oxide surge arrester models. *Technology audit and production reserves, 6 (1 (38)),* 40–46. doi:10.15587/2312-8372.2017.117836

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SYNTHESIS OF RADIOMETRIC RECEIVERS ON THE CRITERION OF STATISTICAL INVARIANCE TO FLUCTUATIONS OF STRENGTHENING AND NARROW-BAND INTERFERENCE

page 42–47

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The tasks of practical veterinary medicine related to the development of new methods and tools for the operative diagnosis of inflammatory diseases and traumas of agricultural and domestic animals require the development of fundamentally new methods and equipment for noninvasive diagnosis of the condition of animals.

For remote measurement of their own thermal electromagnetic radiation of animals, the radiometric receiver was synthesized behind the criterion of statistical invariance to the AC fluctuations and to the effect of narrow-band interference.

The scheme of a synthesized radio receiver is substantiated, which is invariant with respect to the AC fluctuations and completely invariant with respect to a narrow-band harmonic type. The peculiarity of this scheme is that in this radio receiver the input signal coming from the antenna in the input circuit is divided by power into two components, one of which is delayed by the time τ, and then these components are added together in the adder. Then there is amplification followed by division into two components, one of which is delayed for the same time τ, and then these components are multiplied, and their product is averaged.

In accordance with the obtained expressions, for the impulse response of the input circuit and the quadratic detection scheme, the structure of the synthesized radio measuring receiver is constructed. For practical purposes, a radio measuring receiver with parameters is made: sensitivity – 10–17 W; frequency range – 30–40 GHz; measuring speed – 0.5 s; measurement accuracy – 0.1–0.2 °C.

Practical testing of the radiometric receiver shows the possibility of displaying the temperature of internal tissues, obtaining a visual

picture of the heat field, which allows the veterinarian to establish the correct diagnosis.

Keywords: radiometric receiver, electromagnetic radiation of animals, fluctuations of the amplifying coefficient, narrow-band interference.

References

1. Malkmus-Opperman. (1990). *Osnovy klinicheskoy diagnostiki vnutrennikh bolezney domashnikh zhivotnykh*. Moscow-Leningrad: GIZ, 436.
2. Cherenkov, A. D., Avrunin, O. G. (2014). Primenenie nizkoenergeticheskikh EMP dlya upravlyayushhego vozdeystviya na biofizicheskie protsessy v biologicheskikh obiektakh. *Energosberezhenie. Energetika. Energoaudit, 8 (126)*, 62–66.
3. Konstantinov, I. S., Mamatov, A. V., Sapryka, V. A., Cherenkov, A. D., Sapryka, A. V., Kosulina, N. G. (2015). Theoretical Analysis of Electromagnetic Field Electric Tension Distribution in the Seeds of Cereals. *Research Journal of Pharmaceutical, Biological and Chemical Scinces, 6 (6)*, 1686–1694.
4. Polishhuk, E. S. (Ed.). (1984). *Elektricheskie izmereniya elektricheskikh i neelektricheskikh velichin*. Kyiv: Vishha shkola, 359.
5. Esepkina, N. A., Korolkov, D. V. (2009). *Radioteleskopy i radiometry*. Moscow: Nauka, 116.
6. Ioshenko, A. N. (2009). Noise interference of broadband communication systems with various methods of suppressing the spectrum-concentrated interference. *Works of Educational Communication Institutes, 55*, 19–30.
7. DuBois, P. R., Williams, D. J. (1980). Increased incidence of retained placenta associated with heat stress in dairy cows. *Theriogenology, 13 (2)*, 115–121. doi:10.1016/0093-691x(80)90120-x
8. Lomba, F. (2009). Aspects du syndrome part dans cing drandes expoitations baines. Freguence ct reperceesions. *Ann. Med Veter, 24 (18)*, 577–584.
9. Ash, C. J., Cook, J. R., Auner, C. R. (2009). The use of rectal temperature to monitor heat stroke. *Missouri Medicine, 89 (5)*, 283–291.
10. Ogren, J. M. (1990). The Inaccuracy of Axillary Temperatures Measured With an Electronic Thermometer. *Archives of Pediatrics & Adolescent Medicine, 144 (1)*, 109–111. doi:10.1001/archpedi.1990.02150250121048
11. Van Lamsweerde-Gallez, D., Meessen, A. (1975). The role of proteins in a dipole model for steady-state ionic transport through biological membranes. *The Journal of Membrane Biology, 23 (1)*, 103–137. doi:10.1007/bf01870247
12. Maldague, X. (2001). *Theory and Practice of Infrared Technology for Nondestructive Testing*. New York: Wiley, 684.
13. Jones, B. F. (1998). A reappraisal of the use of infrared thermal image analysis in medicine. *IEEE Transactions on Medical Imaging, 17 (6)*, 1019–1027. doi:10.1109/42.746635
14. Zheng, L., Tidrow, M. (2009). Analyses of infrared focal plane array figure of merit and its impact on sensor system trades. *Infrared Physics & Technology, 52 (6)*, 408–411. doi:10.1016/j.infrared.2009.08.001
15. Ring, E. F. J., Ammer, K. (2000). The Technique of Infra red Imaging in Medicine. *Thermology International, 10 (1)*, 7–14.
16. Poradish, F. J., Habbe, J. M. (1982). Millimeter Wave Radiometric Imaging. *Proc. SPIE 0337, Millimeter Wave Technology I*. doi:10.1117/12.965939
17. Skou, N. (1989). *Microwave Radiometer Systems: Design and Analysis*. Boston-London: Artech House, 162.

TECHNOLOGY AND SYSTEM OF POWER SUPPLY

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CHOICE AND GROUND FOR DIRECTION OF ENERGY EFFICIENCY INCREASING FOR UKRAINIAN BUILDINGS AND FACILITIES

page 48–55

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The object of research is a complex thermal modernization of a building or structure, namely its tandem as part of a heating system and facade thermal insulation. One of the most problematic places is not enough to study the features of the thermal regime in the operation of buildings and structures, as well as the lack of optimization approaches to carrying out thermal modernization.

In the course of the study, a comprehensive approach to the solution of the set tasks is used, including economic and statistical analysis, analysis of world experience and synthesis of results and retrospectives, a historical, evolutionary and logical approach. System theory and system analysis are also used to identify strategic prospects for a significant reduction in the energy consumption of existing Ukrainian buildings and structures and, in the future, dissemination of the results obtained to foreign buildings and facilities that have similar energy efficiency challenges.

Based on the analysis of patent information sources, innovative organizational and technical solutions for the thermal modernization of Ukrainian buildings and structures are proposed. In particular, it is proposed to introduce new elements in the system of complex thermal modernization in the form of new transit pipelines of a two-pipe system of central water heating. No less important task is the optimal placement of new transit pipelines of a two-pipe system of central water heating with reference to the locations of existing heating appliances.

The expected positive effect is achieved due to the provision of the possibility to take into account and regulate the consumption of heat by consumers taking into account the operational factors of maintaining the specified temperature regime inside the heated premises of buildings and structures.

Due to this, it is possible to increase the efficiency of using heat energy in the proposed system of central water heating of premises and to reduce the consumption of thermal energy for maintaining the optimal conditions for living in a residential area. And it is possible in almost all climatic zones, where there is a need for thermal modernization, especially for housing, mainly the period of construction until the 90s of the last century.

Keywords: thermal modernization of buildings and structures, facade heat insulation, modernization of pipelines of the central water heating system.

References

1. Pyrkov, V. V. (2010). *Gidravlicheskoe regulirovanie sistem otopleniia i ohlazhdeniia: teoriia i praktika*. Kyiv: Taki spravy, 5.
2. *DSTU B V.3.2-3:2014. Nastanova z vykonannia termomodernizatsii zhytlovykh budynkiv.* (2014). Introduced: 01.10.2015. Kyiv: Minrehion Ukrainy, 70.
3. V termomodernizatsii nuzhdaetsia 80 % zhilogo fonda Ukrainy. (08.10.2015). *Informatsionnoe agentstvo LIGABiznesInform*. Available at: http://biz.liga.net/all/nedvizhimost/novosti/3127248-v-termomodernizatsii-nuzhdaetsya-80-zhilogo-fonda-ukrainy.htm. Last accessed: 12.01.2018.
4. Isachenko, V. P., Osipova, V. A., Sukomel, A. S. (1975). *Teploperedacha*. Moscow: Energiia, 423.
5. Tytar, S. S. (2002). *Systemy enerhopostachannia promyslovykh pidpryiemstv*. Odesa: AT BAKhVA, 356.
6. Saviovskii, V. V., Bolotskih, O. N. (1999). *Remont i rekonstruktsiia grazhdanskih zdanii*. Kharkov: Vaterpas, 287.
7. Weglarz, A., Gilewski, P. G. (2016). A Method of Evaluation of Polioptimal Thermo-modernization Schemes of Buildings. *Procedia Engineering, 153*, 862–865. doi:10.1016/j.proeng.2016.08.194
8. Kuzniar, K., Zajac, M. (2017). Numerical evaluation of natural vibration frequencies of thermo-modernized apartment buildings

subjected to mining tremors. *Procedia Engineering, 199,* 296–301. doi:10.1016/j.proeng.2017.09.039
9. Hurnik, M., Specjal, A., Popiolek, Z., Kierat, W. (2018). Assessment of single-family house thermal renovation based on comprehensive on-site diagnostics. *Energy and Buildings, 158,* 162–171. doi:10.1016/j.enbuild.2017.09.069
10. Zender-Swiercz, E., Piotrowski, J. Z. (2013). Thermomodernization a building and its impact on the indoor microclimate. *Structure and Environment: Architecture, Civil Engineering, Environmental Engineering and Energy, 5 (3),* 37–40.
11. Jaworska-Michalowska, M. (2009). Ochrona historycznej elewacji w procesie termomodernizacji – wybrane zagadnienia. *Czasopismo Techniczne. Budownictwo, 106 (2-B),* 151–161.
12. Sadowska, B., Sarosiek, W. (2014). Efficiency of raising low-energy buildings and thermomodernization of existing ones. *Biuletyn Wojskowej Akademii Technicznej, 63 (1),* 179–191.
13. Rutkowska, G., Wojnowski, D. (2014). Analysis of variants thermomodernization of a dwelling house from a point of view of optimal energetic demands. *Inzynieria Ekologiczna, 37,* 162–173.
14. Lundström, L., Wallin, F. (2016). Heat demand profiles of energy conservation measures in buildings and their impact on a district heating system. *Applied Energy, 161,* 290–299. doi:10.1016/j.apenergy.2015.10.024
15. Balić, D., Maljković, D., Lončar, D. (2017). Multi-criteria analysis of district heating system operation strategy. *Energy Conversion and Management, 144,* 414–428. doi:10.1016/j.enconman.2017.04.072
16. Kolosov, A. E., Virchenko, G. A., Kolosova, E. P., Virchenko, G. I. (2015). Structural and Technological Design of Ways for Preparing Reactoplastic Composite Fiber Materials Based on Structural Parametric Modeling. *Chemical and Petroleum Engineering, 51 (7–8),* 493–500. doi:10.1007/s10556-015-0075-3
17. Churylo, O. V. (15.12.2005). Sposib rekonstruktsii systemy opalennia budynku. *Patent UA 11514 U, MPK F24D3/00, F16L9/00, E04G23/00.* Appl. No. u200507560. Filed 29.07.2005. Bull. No. 12.
18. Moulding Prefabricated Wall or Roof Panels. (20.08.1980). *UK Patent applicaton GB 2039819 A, Int. Cl. B29D3/02.*
19. Tuerk, M., assignee: Diedrichsen Jens Dipl. Ing. (11.03.1999). Building wall insulation section refurbishing and heating older buildings. *Patent DE 19740074 A1, Int. Cl. E04B1/78.*
20. Jansen, H. (04.07.1991). Two-panel wall cladding section – has heat insulating layer and heating pipe between panels. *Patent DE 4031483 A1, Int. Cl. E04B2/72.*
21. Hamkokov, R. M., Panibratov, Yu. P., Krutikov, P. G. (16.12.1999). Sistema teplosnabzheniia mnogoetazhnogo zdaniia. *Patent RU 12155 U1, MPK E03S1/04.*
22. Kasianov, N. M. (20.06.2011). Sistema teplosnabzheniia mnogokvartirnogo zdaniia s kak minimum odnoi podiezdnoi sektsiei. *Patent RU 105720 U1, MPK E24D3/00.* Bull. No. 17.
23. Kasianov, N. M. (27.03.2015). Sistema teplosnabzheniia mnogokvartirnogo doma. *Patent RU 151295 U1, MPK E24D3/02.* Bull. No. 9.
24. Orlov, D. P. (27.06.2007). Sposob otopleniia zdanii. *Patent RU 2301944 S1, MPK F24D15/00.* Bull. No. 18.
25. Robakiewicz, M., Panek, A. (2014). *Termomodernizatsiia zhilogo doma*. Kyiv, Available at: http://teplydim.com.ua/static/storage/filesfiles/Danfoss_manual_Thermal_Moderniz_2014_Rus.pdf. Last accessed: 12.01.2018.
26. Zender-Swiercz, E., Telejko, M. (2016). Impact of Insulation Building on the Work of Ventilation. *Procedia Engineering, 161,* 1731–1737. doi:10.1016/j.proeng.2016.08.766
27. Lulic, H., Civic, A., Pasic, M., Omerspahic, A., Dzaferovic, E. (2014). Optimization of Thermal Insulation and Regression Analysis of Fuel Consumption. *Procedia Engineering, 69,* 902–910. doi:10.1016/j.proeng.2014.03.069
28. González-Aguilera, D., Lagüela, S., Rodríguez-Gonzálvez, P., Hernández-López, D. (2013). Image-based thermographic modeling for assessing energy efficiency of buildings façades. *Energy and Buildings, 65,* 29–36. doi:10.1016/j.enbuild.2013.05.040
29. Sierra-Pérez, J., Boschmonart-Rives, J., Gabarrell, X. (2016). Environmental assessment of façade-building systems and thermal insulation materials for different climatic conditions. *Journal of Cleaner Production, 113,* 102–113. doi:10.1016/j.jclepro.2015.11.090
30. Sulakatko, V., Lill, I., Witt, E. (2016). Methodological Framework to Assess the Significance of External Thermal Insulation Composite System (ETICS) on-site Activities. *Energy Procedia, 96,* 446–454. doi:10.1016/j.egypro.2016.09.176
31. Elarga, H., De Carli, M., Zarrella, A. (2015). A simplified mathematical model for transient simulation of thermal performance and energy assessment for active facades. *Energy and Buildings, 104,* 97–107. doi:10.1016/j.enbuild.2015.07.007
32. Vox, G., Blanco, I., Schettini, E. (2018). Green façades to control wall surface temperature in buildings. *Building and Environment, 129,* 154–166. doi:10.1016/j.buildenv.2017.12.002
33. Cvetković, D., Bojić, M. (2014). Optimization of thermal insulation of a house heated by using radiant panels. *Energy and Buildings, 85,* 329–336. doi:10.1016/j.enbuild.2014.09.043
34. Pflug, T., Nestle, N., Kuhn, T. E., Siroux, M., Maurer, C. (2018). Modeling of facade elements with switchable U-value. *Energy and Buildings, 164,* 1–13. doi:10.1016/j.enbuild.2017.12.044
35. Kremensas, A., Stapulionienė, R., Vaitkus, S., Kairytė, A. (2017). Investigations on Physical-mechanical Properties of Effective Thermal Insulation Materials from Fibrous Hemp. *Procedia Engineering, 172,* 586–594. doi:10.1016/j.proeng.2017.02.069
36. Aparicio-Fernández, C., Vivancos, J.-L., Ferrer-Gisbert, P., Royo-Pastor, R. (2014). Energy performance of a ventilated façade by simulation with experimental validation. *Applied Thermal Engineering, 66 (1–2),* 563–570. doi:10.1016/j.applthermaleng.2014.02.041
37. Kolosov, A. E., Sivetskii, V. I., Kolosova, E. P., Lugovskaya, E. A. (2013). Procedure for analysis of ultrasonic cavitator with radiative plate. *Chemical and Petroleum Engineering, 48 (11–12),* 662–672. doi:10.1007/s10556-013-9677-9
38. Klychnikov, R. Yu., Ezerskii, V. A., Monastyrev, P. V. (2011). *Tehniko-ekonomicheskaia otsenka termomodernizatsii zhilyh zdanii.* Moscow: ASV, 176.
39. Zaitsev, D. V., Klymchuk, O. A., Balasanian, H. A. (2015). Analiz osnovnykh sposobiv termomodernizatsii budivel ta metodyka yikh vprovadzhennia. *Visnyk Natsionalnoho tekhnichnoho universytetu «KhPI». Enerhetychni ta teplotekhnichni protsesy y ustatkuvannia, 17,* 156–160.
40. Borys, G. (2015). Selected directions of increasing efficiency in supporting thermomodernization in buildings from public funding. *Prace Naukowe Uniwersytetu Ekonomicznego We Wrocławiu, 397,* 68–77. doi:10.15611/pn.2015.397.05
41. Ickiewicz, I. (2013). Building thermomodernization and reducing air pollution. *Ecological Chemistry and Engineering S, 20 (4).* 805–816. doi:10.2478/eces-2013-0056
42. Wciślik, S. (2017). Energy efficiency and economic analysis of the thermomodernization of forest lodges in the Świętokrzyski National Park. *EPJ Web of Conferences, 143,* 02144. doi:10.1051/epjconf/201714302144
43. Kryk, B. (2016). Rachunek korzyści ekologicznych z inwestycji termomodernizacyjnych na przykładzie spółdzielni mieszkaniowych województwa zachodniopomorskiego / Account of environmental benefits from thermomodernization investment on the example of cooperative housing of West Pomeranian Voivodeship. *Prace Naukowe Uniwersytetu Ekonomicznego We Wrocławiu, 454,* 92–101. doi:10.15611/pn.2016.454.08
44. Basinska, M., Koczyk, H., Kosmowski, A. (2015). Assessment of Thermo Modernization Using the Global Cost Method. *Energy Procedia, 78,* 2040–2045. doi:10.1016/j.egypro.2015.11.204
45. Fanti, M. P., Mangini, A. M., Roccotelli, M. (2018). A simulation and control model for building energy management. *Control Engineering Practice, 72,* 192–205. doi:10.1016/j.conengprac.2017.11.010
46. Adamczyk, J., Dylewski, R. (2017). Analysis of the sensitivity of the ecological effects for the investment based on the thermal insulation of the building: A Polish case study. *Journal of Cleaner Production, 162,* 856–864. doi:10.1016/j.jclepro.2017.06.123
47. Yeromin, A. V. (27.11.2017). Systema kompleksnoi termomodernizatsii budivel i sporud za Yerominym. *Patent UA 121347 U, MPK F24D3/00, F16L59/00.* Bull. No. 22.
48. Yeromin, A. V. (27.11.2017). Sposib kompleksnoi termomodernizatsii budivel i sporud za Yerominym. *Patent UA 121348 U, MPKF24D 3/00, F16L59/00.* Bull. No. 22.

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INCREASING THE ACCURACY OF THE NON-CONTACT TEMPERATURE MEASUREMENT IN THE CASE OF ENERGY AUDITS OF DIFFERENT OBJECTS

page 55–61

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The object of research is the process of thermal inspection of enclosing structures with the help of a thermal imager. One of the most problematic places of thermal imaging energy is the presence of a significant methodological error. The reason for this is a large number of factors affecting the process of measuring the temperature of the surfaces of objects in thermal imaging diagnostics. In the course of the study, methods were used to analyze and isolate the factors that have the greatest effect on the thermogram of the investigated object.

Results are obtained on the evaluation of the influence degree of each influencing factor on the measurement result and the total methodical error from simultaneous influence of all influencing factors is estimated. The total methodical error of thermal imaging energy surveys (up to 4 %) is estimated. This is due to the fact that the proposed methods for improving the accuracy of energy audit have a number of features, in particular, the result of energy audit largely depends on the experience and qualification of the operator. But the use of the proposed recommendations allows the operator to make measurements at a high professional level. Thanks to this, it is possible to improve the accuracy of the energy audit. In comparison with similar known energy audit methods, the proposed method makes it possible: to reduce the methodical error of thermal imaging energy surveys, to increase the energy efficiency of buildings and to reduce the cost of their heating.

Keywords: energy audit using thermal imagers, matrix radiation detector, radiation coefficient, measurement accuracy.

References

1. Baza danykh «Zakonodavstvo Ukrainy». Pro enerhozberezhennia. Law of Ukraine No. 74/94-VR from July 1, 1994. *Verkhovna Rada Ukrainy.* Available at: http://zakon3.rada.gov.ua/laws/show/74/94-%D0%B2%D1%80?lang=uk
2. *DBN V.2.631:2006. Konstruktsiibudynkiv i sporud. Teplova izoliatsiia budivel.* (2006). Kyiv. Available at: http://online.budstandart.com/ua/catalog/doc-page?id_doc=6919
3. *DSTUNBA.2.25:2007. Nastanova z rozroblennia ta skladannia enerhetychnoho pasporta budynkiv pry novomu budivnytstvi ta rekonstruktsii.* (2008). Kyiv: Minrehionbud Ukrainy, 44.
4. *DSTU B EN 13187:2011. Teplovi kharakterystyky budivel. Yakisne vyiavlennia teplovykh vidmov v ohorodzhuvalnykh konstruktsiiakh. Infrachervonyi metod.* (2011). Kyiv: Minrehionbud Ukrainy, 33.
5. *DSTU B V.2.6-101:2010. Metod vyznachennia oporu teploperedachi ohorodzhuvalnykh konstruktsii.* (2010). Kyiv: Minrehionbud Ukrainy, 84.
6. *DSTU 2820-94. Teploviziini systemy. Terminy ta vyznachennia.* (1994). Introduced: 1996-01-01. Kyiv: DerzhstandartUkrainy, 27.
7. Vavilov, V. P. (2009). *Infrakrasnaya termografiya i teplovoy kontrol.* Moscow: Spektr, 544.
8. Skripal, A. V., Sagaydachnyi, A. A., Usanov, D. A. (2009). *Teplovizionnaya biomeditsinskaya diagnostika*. Saratov, 118.
9. Afonin, A. V., Nyuport, R. K., Polyakov, V. S. et al.; Nyuport, R. K., Tadzhibaev, A. I. (Eds.). (2004). *Osnovy infrakrasnoy termografii.* Saint Petersburg: Izdatel'stvo PEIPK, 240.
10. Gossorg, J. (1988). *Infrakrasnaya termografiya. Osnovy, tekhnika, primenenie.* Moscow: Mir, 416.
11. Levshina, B. C., Novitskiy, P. V. (1983). *Elektricheskie izmereniya fizicheskikh velichin. Izmeritel'nye preobrazovateli.* Leningrad: Energoatomizdat, 320.
12. Sizov, F. F. (2015). IR-photoelectronics: photon or thermal detectors? Outlooks. *Sensor Electronics and Microsystem Technologies, 12 (1),* 26–52. doi:10.18524/1815-7459.2015.1.104447
13. Tohyama, S., Sasaki, T., Endoh, T., Sano, M., Kato, K., Kurashina, S. et al. (2013). Uncooled infrared detectors toward smaller pixel pitch with newly proposed pixel structure. *Optical Engineering, 52 (12),* 123105. doi:10.1117/1.oe.52.12.123105
14. Korotaev, V. V., Melnikov, G. S., Mikheev, S. V. et al. (2012). *Osnovy teplovideniya.* Saint Petersburg: NIU ITMO, 122.
15. Evtikhiev, N. N., Kupershmidt, Ya. A., Papulovskiy, V. F., Skugorov, V. N. (1990). *Izmerenie elektricheskikh i neelektricheskikh velichin.* Moscow: Energoatomizdat, 352.
16. Voytsekhovskiy, A. V., Izhnin, I. I., Savchin, V. P., Vakiv, N. M. (2013). *Fizicheskie osnovy poluprovodnikovoy fotoelektroniki.* Tomsk: Izdatel'skiy Dom Tomskogo gosudarstvennogo universiteta, 560.
17. Tompkins, U., Uebster, J. (Eds.). (1992). *Sopryazhenie datchikov i ustroystv vvoda dannykh s komp'yuterami IBM PC.* Moscow: Mir, 592.
18. Ilyushin, V. A. (2003). *Mnogoelementnye fotopriemnye ustroystva i teplovizory.* Novosibirsk: Izdatel'stvo NGTU, 57.
19. Proshkin, S. S. (2014). K voprosu o tochnosti izmereniya temperatury s pomoshh'yu teplovizora. *Vestnik mezhdunarodnoy akademii kholoda, 1,* 51–54.
20. Vavilov, V. P., Larioshina, I. A. (2012). Metodicheskie pogreshnosti teplovizionnogoenergoaudita stroitel'nykh sooruzheniy. *Vestnik nauki Sibiri, 5 (6),* 49–53.
21. Vavilov, V. P. (2010). Pessimisticheskiy aspekt teplovizionnogoenergoaudita stroitel'nykh sooruzheniy. *Defektoskopiya, 12,* 49–54.
22. Frunze, A. V. (2012). Metodicheskie pogreshnosti energeticheskikh pirometrov i sposoby ikh minimizatsii. *Metrologiya, 7,* 19–38.
23. Enyushin, V. N., Kraynov, D. V. (2013). O vliyanii izluchatel'noy sposobnosti poverkhnosti issleduemogo obekta na tochnost' izmereniya temperatur pri teplovizionnom obsledovanii. *Izvestiya KTASU, 1 (23),* 99–103.
24. Golofeeva, M. A., Levinskiy, A. S., Tonkonogiy, V. M. (2016). Povyshenie tochnosti izmereniya temperatury s pomoshh'yu priborov infrakrasnoy tekhniki. *High technologies in machine engineering, 1 (26),* 14–18.
25. Levinskiy, A. S., Golofeeva, M. A., Ryabushenko, Yu. A. (2016). The improving the accuracy of temperature measurement through devices of the infrared technology. *Technologes of informations are in education, science and production, 2 (13),* 153–158.
26. Ivanova, G. M., Kuznetsov, N. D., Chistyakov, V. S. (2005). *Teplotekhnicheskie izmereniya i pribory.* Moscow: Izdatel'stvo MEI, 460.
27. Kulakov, M. V. (1983). *Tekhnologicheskie izmereniya i pribory dlya khimicheskikh proizvodstv.* Moscow: Mashinostroenie, 424.
28. Oleynik, B. M., Lazdina, S. I., Zhagullo, O. M. (1987). *Pribory i metody temperaturnykh izmereniy.* Moscow: Izdatel'stvo standartov, 296.
29. Preobrazhenskiy, V. P. (1978). *Teplotekhnicheskie izmereniya i pribory.* Moscow: Energiya, 704.
30. Polyakov, V. S. (1990). Primenenie teplovizionnykh priemnikov dlya vyyavleniya defektov vysokovol'tnogo oborudovaniya. *Metodicheskie ukazaniya po kontrolyu oborudovaniya teplovizorami.* Leningrad: PEIPK, 57.
31. Galanov, E. K., Filatov, M. K. (2009). Metrologicheskie voprosy izmereniya temperatury poverkhnostey beskontaktnym metodom IK pirometrii. *Opticheskiy zhurnal, 76 (3),* 44–47.
32. Gobrey, R. M., Chernov, V. F., Udod, E. I. (2007). *Diagnostirovanie elektroustanovok 0.4–750 kV sredstvami infrakrasnoy tekhniki.* Kyiv: KVITS, 374.