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DEVELOPMENT OF A COMBINED TECHNOLOGY FOR PARTS STRENGTHENING

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The aim of this work is to develop a combined technological process for improving the performance characteristics of units and parts with moving contacting surfaces. The process is based on metal surface property modification methods that use physical effects in the interaction of the surface under treatment with concentrated energy fluxes. Consideration is given to a possibility to treat the working surfaces of parts made of a high-strength titanium alloy using ion-beam and ion-plasma technology. All the elements of the technological process must meet progressiveness criteria. It is shown that the effect of factors that adversely affect the functionality and the fatigue life of parts may be significantly diminished or eliminated. Strengthening is achieved by successive or simultaneous use of ion-beam surface treatment, high-intensity low-energy nitrogen atom implantation, and the ion-plasma deposition of a finish functional nanostructured coating. This paper presents part 1 of the work, which is of problem description character. The final goal of the work is achieved with the development of plasma process devices. The results of the development of process devices and the optimization of their use in a process installation will be presented in part 2 of this work.

Keywords: *ion-plasma technology, ion-beam technology, ion implantation, ion polishing, functional coating deposition.*

1. *Nechaev V. V., Smirnov E. A., Kokhteev S. A., Kalin B. A., Polyansky A. A., Statsenko V. I.* Physical Material Science. In 6 volumes. Volume 2. Basics of Material Science (*in Russian*) / *B. A. Kalin* (Ed.) Moscow: MEPhI, 2007. 608 pp.
2. *Stepanova T. Yu.* Technology of Machine Part Surface Strengthening (*in Russian*). Ivanovo: Ivanovo State University of Chemical Technology, 2009. 64 pp.
3. *Alymov M. I., Elmanov N.N., Kalin B. A., Kalashnikov A. N., Nechaev V. V., Polyansky A. A., Chernov I. I., Shtrombakh Ya. I., Shulga A. V.* Physical Material Science. In 6 volumes. Materials with Specified Properties (*in Russian*) / *B. A. Kalin* (Ed.). Moscow: MEPhI, 2008. 672 pp.
4. *Boytsov A. G., Mashkov N. V., Smolentsev V. L., Khvorostukhin L. A.* Part Surface Strengthening by Combined Methods (*in Russian*). Moscow: Mashinostroenie, 1991. 144 pp.
5. *Ryabkov V. I., Kapitanova L.V., Babenko Yu. V., Trofimov V. A., Bychkova N. N.* Features of the use of titanium alloys, stainless steels, metal composites, and antifriction materials in modern aircraft landing gear (*in Russian*). Aviatsiino-Kosmichna Tekhnika I Tekhnologia. 2003. Issue 1 (36). Pp. 6–15.
6. *Bogdanovich V. I., Mikhlin V. I., Dokupina I. L.* Use of titanium in spacecraft friction pair assemblies (*in Russian*). Problemy Mashinostroeniya i Avtomatizatsii. Moscow: 1998. No. 2 – 3. Pp. 100–103.
7. *Ponomarev M. I., Los A. V.* Efficiency of tungsten-based coatings in providing the workability of slide units made from titanium alloys (*in Russian*). Otkrytye Informatsionnye i Komputernye Integrirovannye Tekhnologii. 2014. No. 63. P. 91–95.
8. *Borisov Yu. S.* Thermal Spray Coatings Made from Powder Materials, Handbook (*in Russian*). Kiev: Naukova Dumka, 1987. 342 pp.
9. *Bogorad L. Ya.* Chromium Plating (*in Russian*). Leningrad: Mashinostroenie, 1984. 97 pp.
10. *Vansovskaya K. M.* Chemically Deposited Metal Coatings (*in Russian*). Leningrad: Mashinostrornie,1985. 103 pp.
11. *Baranov O. O.* Problem of ion beam control in plasma-ion treatment plants (*in Russian*). Otkrytye Informatsionnye i Komputernye Integrirovannye Tekhnologii. 2012. No. 55. Pp. 52–66.
12. *Sanochkin Yu. V., Kalashnicov V. K.* The theory of discharge with closed electron drift. ZhTF. 1974. V.44. No. 12. Pp. 2501–2516.
13. *Maishev Yu. P., Vinogradov M. I.* Vacuum Processes and Ion- and Electron-Beam Equipment (*in Russian*). Moscow: Mashinostroenie, 1989. 56 pp.
14. *Zhurin V. V.* Industrial Ion Sources: Broadbeam Gridless Ion Source Technology, First Edition. У 2012 Wiley-VCH Verlag GmbH & Co. KGaA. Published 2012 by Wiley-VCH Verlag GmbH & Co. KGaA. 311 pp.
15. *Kuzmichev A. I.* Magnetron Sputtering Systems. Book 1. Introduction to Magnetron Sputtering Physics and Technology (*in Russian*). Kyiv: Avers, 2008. 244 pp.
16. *Pleshivtsev N. V.* Cathode Sputtering (*in Russian*). Moscow: Atomizdat, 1968. 340 pp.
17. *Berish R.* Ion Bombardment Sputtering of Solids (*in Russian*). Moscow: Mir, 1984. 336 pp.
18. *Brown I.* The Physics and Technology of Ion Sources (*in Russian*).Moscow: Mir, 1998. 496 pp.
19. *Ivanovsky G. F., Petrov V. I.* Ion-Plasma Treatment of Metals (*in Russian*). Moscow: Radio i Sviaz, 1986. 232 pp.
20. *Gabovich M. D.* Physics and Technology of Plasma Ion Sources. Moscow: Atomizdat, 1972. 304 pp.

21. *Anders A.* Plasma and ion sources in large area coatings. Surface and Coatings Technology. 2005. Vol. 200. Pp. 1893–1906.
22. *Gabovich M. D., Pleshivtsev N. V., Semashko N. N.* Atom and Ion Beams for Controlled Fusion and Technological Purposes (*in Russian*). Moscow: Energoatomizdat, 1986. 248 pp.
23. *Pleshivtsev N. V., Bazhin A. I.* Physics of Ion Beam Action (*in Russian*).Moscow: Vuzovskaya Kniga, 1998. 341 pp.
24. *Odinokova E. V., Panfilov Yu. V., Yurchenko P. I.* Prospects for obtaining a nanometer surface roughness by the ion-beam method (*in Russian*). Nauka i Innovatsii. 2013. Issue 6. URL: http://engjournal.ru/catalog/nano/hidden/801.
25. *Cherezova L. A.* Ion-Beam Methods in Optical Technology (*in Russian*). Saint Petersburg: SPt SU ITMO, 2007. 151 pp.
26. *Sulima V. A, Shulov V. A., Yagodkin Yu. D.* Surface Layer and Operational Properties of Machine Parts (*in Russian*). Moscow: Mashinostroenie, 1988. 240 pp.
27. *Prikhod'ko V. Zh., Petrova L. G., Chudina M. N.* Metallophysical Basics of Strengthening Technologies (*in Russian*). Moscow: Mashinostroenie, 2003. 384 pp.
28. *Polzer G., Meissner F.* Basics of Friction and Wear (*in Russian*). Moscow: Mashinostroenie, 1984. 264 pp.
29. *Pozdniakov V. A.* Physical Material Science of Nanostructured Materials (*in Russian*). Moscow: MSIU, 2007. 424 pp.
30. *Gleiter H.* Nanostructured materials: basic concepts and microstructure. Acta Material. 2000. 324 pp.
31. *Azarenkov N. A., Pogrebniak A. D., Beresnev V. M. et al*. Nanomaterials, Nanocoatings, Nanotechnologies (*in Russian*). Kharkov: Karazin Kharkov National University, 2009. 209 pp.
32. *Zabelin S. F.* Resolution of the metal strength problem by surface nanocrystallization methods (*in Russian*). Uchenye Zapiski ZabGU. 5(62). 2015. Pp. 48–58.
33. *Belous V. A., Lapshin V. I., Marchenko I. G., Neklyudov I. M.* Radiation technologies of surface modification (*in Russian*). FIP. 2003. V. 1. No. 1. Pp. 41–48.
34. *Lakhtin Yu. M., Kogan Ya. D. et al*. Nitride Hardening Theory and Technology (*in Russian*). Moscow: Metallurgia, 1991. 320 pp.
35. *Arzamasov B. N.* et al. Ion Chemical and Thermal Treatment of Alloys (*in Russian*). Moscow: Bauman Moscow State Technical University, 1999. 400 pp.
36. *Ryabchikov A. I.* High-Frequency Plasma Pulse Nitrogen Implantation into Steel (*in Russian*). Izvestiya Vuzov. Fizika. 2013. V. 56. No, 12/2. Pp. 69–71.
7. *Aksenov I. I., Andreev A. A., Belous V. L., Strelnitsky V. E., Khoroshikh V. M.* Vacuum Arc (*in Russian*). Kiev: Naukova Dumka, 2012. 727 pp.
38. *Andreev A. A., Sablev L. P., Shulaev V. M., Grigoriev S. N.* Vacuum Arc Devices and Coatings (*in Russian*). Kharkov: NSC KhPhTI, 2005, 236 pp.
39. *Borisov D. P.* Generation of a Homogeneous Gas-Discharge Plasma in a Low-Pressure Non-Self-Maintained Discharge for Material and Product Surface Modification (*in Russian*). PhD Thesis (Engineering). National Research Tomsk State University. Tomsk, 2015. 161 pp.
40. *Belyi A. V.* High-intensity low-energy nitrogen ion implantation *(in Russian*). Fizicheskaya Mezomekhanika. 2002. No. 1. 95 pp.
41. *Belyi A. V.* Physical and Technological Basics of Ion-Beam Material Treatment (*in Russian*).Novopotsk: PSU, 2010. 84 pp.
42. *Berlin E. V., Seidman L. A.* Ion-Plasma Processes in Thin-Film Technology (*in Russian*). Moscow: Tekhnosfera, 2010. 528 pp.
43. *Berlin E. V., Koval N. N., Seidman L. A.* Chemical and Thermal Plasma Treatment of the Surface of Steel Parts (*in Russian*). Moscow: Tekhnosfera, 2012. 464 pp.
44. Nanostructured Coatings (*in Russian*). *A. Cavaleiro, D. de Hosson* (Eds.). Moskow, 2011. 752 pp.
45. *Musil J., Ŝuna J.* The role of energy in formation of sputtered nanocomposite films. Mater. Scien. Forum. 2005. V. 502. Pp. 29 –296.
46. *Levchuk D.* Plasma assisted techniques for deposition of superhard nanocomposite coatings. Surface and Coatsng Technologies. 2007. Pp. 6071–6077.
47. *Svadkovsky I. V.* Lines of development of magnetron sputtering systems (in Russian). Doklady BGUIR. 2007. No. 2(18). Pp. 112–121.
48. *Window B., Savvides N*. Unbalanced DC magnetrons as sources of high ion fluxes. J. Vac. Sci. Technol. A. 1986. V. 4. Pp. 453–456.
49. *Savvides N., Window B.* Unbalanced magnetron ion-assisted deposition and property modification of thin-films. J. Vac. Sci. Technol. A. 1986. V. 4, No. 3. Pp. 504–506.