ABSTRACT AND REFERENCES

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IMPROVEMENT OF THE DESIGN OF HYDRAULIC TRANSPORT DEVICES FOR THE TRANSPORT OF HYDROABRASIVE MEDIA IN THE ENRICHMENT INDUSTRY (p. 6–16)

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Hydrotransport equipment of mining and processing plants has low operational reliability, insufficient service life due to intense hydroabrasive wear of the working surfaces of pipelines and pumping equipment, design flaws of some ground pump units and their operation. Significant hydroabrasive wear of the main structural element of the ground pump – impeller, causes additional disturbing dynamic forces, which leads to increased vibration of the unit and, therefore, to its premature failure. To date, insufficient attention has been paid to the impact of hydroabrasive wear of the impeller of ground pumps on the service life of their plants.

The analysis of manifestation of cavitation wear of parts of the ground pump flow part is carried out, measures to reduce cavitation due to favorable conditions for the liquid flow into the pump and to reduce the vacuum gauge suction lift are outlined. A number of technological and constructive solutions are also proposed to reduce the harmful effects of cavitation.

Materials for manufacturing parts of a centrifugal ground pump with high performance and service life are selected and analyzed. These alloys showed high corrosion resistance due to high chromium content.

The ways of improving the design of centrifugal ground pump parts are outlined, which allows increasing the service life, creating an automated system for diagnosing the state of the structure as a whole.

Keywords: ground pump, impeller, armored disk, hydroabrasive wear, throttling, measuring stand.

References

1. Adistiya, S., Wijayanta, A. T. (2019). Effect of Clearance Gap on Hydraulic Efficiency of Centrifugal Pump. AIP Conference Proceedings 2097. doi: https://doi.org/10.1063/1.5098228
2. Povetkin, V. V., Kerimzhanova, M. F., Orlova, Y. P., Bukayeva, A. Z. (2018). Improvement of equipment for transport of slurry in mineral processing production. Mining Informational and Analytical Bulletin, 6, 161–169. doi: https://doi.org/10.25018/0236-1493-2018-6-0-161-169
3. Selamat, F. E., Iskandar, W. H., Saffuan, B. (2012). Design and Analysis of Centrifugal Pump Impeller for Performance Enhancement. Journal of Mechanical Engineering, SI 5(2), 36–53.
4. Ragoth Singh, R., Nataraj, M. (2014). Design and analysis of pump impeller using SWFS. World Journal of Modelling and Simulation, 10 (2), 152–160.
5. Remaki, L., Ramezani, A., Blanco, J. M., Garcia, I. (2017). New Simplified Algorithm for the Multiple Rotating Frame Approach in Computational Fluid Dynamics. Journal of Fluids Engineering, 139 (8). doi: https://doi.org/10.1115/1.4036300
6. Aleksandrov, V. I., Sobota, J. (2016). Vibrodiagnostics of the technical state slurry pumps. Journal of mining institute, 218, 242–250.
7. Spence, R., Amaral-Teixeira, J. (2009). A CFD parametric study of geometrical variations on the pressure pulsations and performance characteristics of a centrifugal pump. Computers & Fluids, 38 (6), 1243–1257. doi: https://doi.org/10.1016/j.compfluid.2008.11.013
8. Yao, N., Qiu, H., Xia, J., Sobota, J. (2018). Distribution of Solid Volume Concentration in the Cross-section of a Square Conduit during Hydrotransport of a Coarse Mixture. Ochrona Srodowiska, 40 (3), 47–52.
9. Aleksandrov, V. I., Vasilyeva, M. A. (2018). Hydraulic transportation of thickened tailings of iron ore processing at kachkanarsky gok based on results of laboratory and pilot tests of hydrotransport system. Journal of mining institute, 233, 471–479. doi: http://dx.doi.org/10.31897/pmi.2018.5.471
10. Shen, Z., Chu, W. (2018). Effect of Particle Parameters on Erosion Wear and Performance of Screw Centrifugal Pump. Volume 7: Fluids Engineering. doi: https://doi.org/10.1115/imece2018-88586
11. Li, H., Yu, B., Qing, B., Luo, S. (2017). Cavitation pulse extraction and centrifugal pump analysis. Journal of Mechanical Science and Technology, 31 (3), 1181–1188. doi: https://doi.org/10.1007/s12206-017-0216-z
12. Gülich, J. F. (2010). Centrifugal Pumps. Springer. doi: https://doi.org/10.1007/978-3-642-12824-0
13. Smirnov, N. I., Grigoryan, E. E. (2019). Study of the Impact of Wear of Movable Interfaces on Failures of an Immersible Electrically Operated Vane Pump for Oil Extraction. Journal of Machinery Manufacture and Reliability, 48 (1), 79–83. doi: https://doi.org/10.3103/s105261881901014x
14. Olimstad, G., Osvoll, M., Finstad, P. H. E. (2018). Very Low Specific Speed Centrifugal Pump-Hydraulic Design and Physical Limitations. Journal of Fluids Engineering, 140 (7). doi: https://doi.org/10.1115/1.4039250
15. Guelich, J. F., Bolleter, U. (1992). Pressure Pulsations in Centrifugal Pumps. Journal of Vibration and Acoustics, 114 (2), 272–279. doi: https://doi.org/10.1115/1.2930257
16. Yao, Z., Wang, F., Qu, L., Xiao, R., He, C., Wang, M. (2011). Experimental Investigation of Time-Frequency Characteristics of Pressure Fluctuations in a Double-Suction Centrifugal Pump. Journal of Fluids Engineering, 133 (10). doi: https://doi.org/10.1115/1.4004959
17. Zhang, N., Yang, M., Gao, B., Li, Z., Ni, D. (2015). Experimental Investigation on Unsteady Pressure Pulsation in a Centrifugal Pump With Special Slope Volute. Journal of Fluids Engineering, 137 (6). doi: https://doi.org/10.1115/1.4029574

18. Wu, Y., Chen, X., Dou, H.-S., Zheng, L., Zhu, Z., Cui, B., Khoo, B. C. (2017). Numerical simulation and analysis of flow characteristics in the front chamber of a centrifugal pump. Journal of Mechanical Science and Technology, 31 (11), 5131–5140. doi: https://doi.org/10.1007/s12206-017-1007-2
19. Povetkin, V. V., Lem, V. P. (2010). Pat. No. 23554 RK. Gruntoviy nasos. published: 15.12.2010, Bul. No. 12.
20. Povetkin, V. V., Lem, V. P. (2011). Pat. No. 24120 RK. Gruntoviy nasos. published: 15.06.2011, Bul. No. 6.
21. Grigoriev, S., Mayorov, S., Polyakov, R. (2017). Centrifugal pump's impeller optimization using methods of calculation hydrodynamics. IOP Conference Series: Materials Science and Engineering, 233, 012009. doi: https://doi.org/10.1088/1757-899x/233/1/012009
22. Caridad, J. A., Kenyery, F. (2005). Slip Factor for Centrifugal Impellers Under Single and Two-Phase Flow Conditions. Journal of Fluids Engineering, 127 (2), 317–321. doi: https://doi.org/10.1115/1.1891153
23. Pagalthivarthi, K. V., Furlan, J. M., Visintainer, R. J. (2017). Effective Particle Size Representation for Erosion Wear in Centrifugal Pump Casings. Proceedings of the ASME fluids engineering division summer meeting. doi: https://doi.org/10.1115/fedsm2017-69240
24. Zhou, F.-M., Wang, X.-F. (2016). Effects of staggered blades on the hydraulic characteristics of a 1400-MW canned nuclear coolant pump. Advances in Mechanical Engineering, 8 (8), 168781401665794. doi: https://doi.org/10.1177/1687814016657944
25. Kocaaslan, O., Ozgoren, M., Aksoy, M. H., Babayigit, O. (2016). Experimental and Numerical Investigation of Coating Effect on Pump Impeller and Volute. Journal of Applied Fluid Mechanics, 9 (7), 2475–2484. doi: https://doi.org/10.18869/acadpub.jafm.68.236.25094

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EVALUATION OF GAS SEPARATOR EFFECT ON OPERABILITY OF GAS-MOTOR PISTON COMPRESSOR VALVES (p. 17–21)

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To increase the efficiency of gas-lift oil and gas production, it is necessary to improve the operation of compressor stations, namely, to increase the reliability of the gas-motor piston compressor units installed in them. It is found that one of the vulnerable units affecting the reliability and efficiency of the gas-motor piston compressor are direct-flow self-acting valves.

In the process of preparing gas for transportation, as well as to ensure the reliability and efficiency of the entire production process, it is necessary to eliminate all gas leaks, prevent liquid hydrocarbon components and solids from entering the valve plates.

To solve this problem, associated petroleum gas must be cleaned from solids, heavy hydrocarbon components and moisture. To this end, it is recommended to install an additional new design horizontal gas separator on the suction line of gas-motor piston compressors.

The usefulness and importance of the new gas separator lie in a more efficient cleaning of associated petroleum gas supplied to the suction of the 1st stage compressor cylinders, which improves compressor performance, minimizing the leakage of valve plates.

The new design separator is used to clean gas from coarse and fine-grained dropping liquid, partially liquid in the vapor-phase state and solids. The new separator can also be used in various sectors of the oil and gas industry.

The purpose of installing a new gas separator is to increase the efficiency of gas cleaning from liquid and solid impurities.

Keywords: separator, valve plates, tightness, oil, gas, gas lift, gas-motor piston compressor.

References

1. Aliev, V. I. (2007). Nauchnye osnovy povysheniya effektivnosti raboty gazomotokompressorov v sistemah gazlifta i transporta gaza morskih mestorozhdeniy Azerbaydzhana. Baku, 317.
2. Aliev, V. I. (2002). Sposob zashchity oborudovaniya sistemy ohlazhdeniya gazomotornyh kompressorov, rabotayushchih v sisteme gazlifta ot nakipi i korrozii. Azerbaydzhanskoe neftyanoe hozyaystvo, 2, 140–144.
3. Lieberman, N. (2019). Reciprocating Compressors. Understanding Process Equipment for Operators and Engineers, 269–281. doi: https://doi.org/10.1016/b978-0-12-816161-6.00034-5
4. Fotin, B. S., Pirumov, I. B., Prilutskiy, I. K., Plastine, P. I.; Fotin, B. S. (Ed.) (1987). Porshnevye kompressory. Leningrad: Mashinostroenie, 372.
5. Adzhiev, A. Ju., Bojko, S. I., Litvinenko, A. V., Shul'ga, T. N. (2004). Pat. No. 2253502 RF. Separator for a gas purification from impurities. No. 2004118733/15; declareted: 21.06.2004; published: 10.06.2005, Bul. No. 16. Available at: http://www.freepatent.ru/images/patents/215/2253502/patent-2253502.pdf
6. Suleymanov, A. B., Mamedov, K. K., Gasanov, Z. T., Aliev, V. I. (1989). Pat. No. 1792726 RF. Ustroystva dlya ochistki gaza. declareted: 31.05.1989; published: 07.02.1993, Bul. No. 5. Available at: https://findpatent.ru/img_show/7650560.html
7. Wang, Y., Xue, C., Jia, X., Peng, X. (2015). Fault diagnosis of reciprocating compressor valve with the method integrating acoustic emission signal and simulated valve motion. Mechanical Systems and Signal Processing, 56-57, 197–212. doi: https://doi.org/10.1016/j.ymssp.2014.11.002
8. Farzaneh-Gord, M., Niazmand, A., Deymi-Dashtebayaz, M., Rahbari, H. R. (2015). Effects of natural gas compositions on CNG (compressed natural gas) reciprocating compressors performance. Energy, 90, 1152–1162. doi: https://doi.org/10.1016/j.energy.2015.06.056
9. Simons, S., Hinchliff, M., White, B., Talabisco, G., Kurz, R., Ji, M. (2019). Compressor System Design and Analysis. Compression Machinery for Oil and Gas, 427–447. doi: https://doi.org/10.1016/b978-0-12-814683-5.00011-0
10. Bahadori, A. (2014). Gas Compressors. Natural Gas Processing, 223–273. doi: https://doi.org/10.1016/b978-0-08-099971-5.00005-2
11. Loukopoulos, P., Zolkiewski, G., Bennett, I., Sampath, S., Pilidis, P., Duan, F. et. al. (2019). Reciprocating compressor prognostics of an instantaneous failure mode utilising temperature only measurements. Applied Acoustics, 147, 77–86. doi: https://doi.org/10.1016/j.apacoust.2017.12.003
12. Zhongyi, W., Changlong, Y., Jia, H., Yunliang, Y. (2011). The Analysis of Internal Flow Field in Oil-Gas Separator. Procedia Engineering, 15, 4337–4341. doi: https://doi.org/10.1016/j.proeng.2011.08.814
13. Il'ina, M. N. (2007). Trebovaniya k podgotovke poputnogo neftyanogo gaza dlya maloy energetiki. Izvestiya Tomskogo politehnicheskogo universiteta, 310 (2), 167–171.
14. Mazgarov, A. M., Kornetova, O. M. (2015). Tehnologii ochistki poputnogo neftyanogo gaza ot serovodoroda. Kazan': Kazan. un-t, 70.
15. Aliev, V. I., Gabibov, I. A., Seidahmedov, N. S. (2015). Pat. No. U20150022. Razlichnye tehnologicheskie protsessy. declareted: 04.09.2015.

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ESTIMATION OF DURABILITY OF CARRIER SHAFTS IN ECCENTRIC MECHANISMS (p. 22–28)

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This paper has suggested a procedure to analyze durability of supporting shafts in eccentric mechanisms based on finite-element modeling. When conducting the analysis, the steady movement of the mechanism is investigated. The analysis of durability is based on the model of additive accumulation of damage. The shaft stress assessment is carried out based on the finite-element modeling of the mechanism that operates under a steady mode at working frequencies that are closest to the critical ones. Following the detection of stress concentrators and the most stressed shaft regions, an analysis of the characteristic cycle of loading is performed. After reducing a loading cycle to a series of symmetric cycles, the shaft damage assessment at each cycle is performed and its resource is estimated.

Based on the proposed method, we have analyzed durability of a carrier shaft in the centrifugal-gyratory ore mill of link type. A simplified estimated model has been built based on the mechanical model in order to improve efficiency and performance of the finite-element calculation. The model of ore movement in grinding chambers under a steady motion mode has been proposed. We have built the Campbell's diagrams for oscillations of the system and have established that the mill's mechanism is not part of the resonance at the working frequency of excitation. The region of mechanical stresses concentration and the region of maximal mechanical stresses in the mill shaft have been identified. The shaft operating conditions have been analyzed and a value for the shaft material's endurance limit in the zone of greatest stresses has been calculated. We have built a characteristic cycle of the mill shaft loading under a steady mode of operation, which consists of 16 sections. Each section has been reduced to a symmetric cycle, which has made it possible to calculate shaft damage at each section of the cycle and over the entire load cycle in general. Application of the additive damage accumulation procedure has made it possible to estimate the resource of a mill shaft. The proposed methodology for estimating durability of the carrier shaft could be used to analyze the resource of various mining and processing mechanisms, light industry equipment, and vibration generators.

Keywords: eccentric mechanism, multicycle fatigue, finite-element analysis, dynamic loads, Campbell diagram.

References

1. Fatemi, A. (2004). Fatigue behavior and life predictions of notched specimens made of QT and forged microalloyed steels. International Journal of Fatigue, 26(6), 663–672. doi: https://doi.org/10.1016/j.ijfatigue.2003.10.005
2. Daemi, N., Majzoob, G. H. (2011). Experimental and Theoretical investigation on notched specimen's life under bending loading. International Journal of Mechanical and Mechatronics Engineering, 5 (8), 1639–1643.
3. Bader, Q., Kadum, E. (2014). Effect of V notch shape on fatigue life in steel beam made of AISI 1037. International Journal of Engineering Research and Applications, 4 (6 (6)), 39–46.
4. Zhao, L.-H., Xing, Q.-K., Wang, J.-Y., Li, S.-L., Zheng, S.-L. (2019). Failure and root cause analysis of vehicle drive shaft. Engineering Failure Analysis, 99, 225–234. doi: https://doi.org/10.1016/j.engfailanal.2019.02.025
5. Shinde, V., Jha, J., Tewari, A., Miashra, S. (2017). Modified Rainflow Counting Algorithm for Fatigue Life Calculation. Proceedings of Fatigue, Durability and Fracture Mechanics, 381–387. doi: https://doi.org/10.1007/978-981-10-6002-1_30
6. Wang, Y. (2010). Spectral fatigue analysis of a ship structural detail – A practical case study. International Journal of Fatigue, 32 (2), 310–317. doi: https://doi.org/10.1016/j.ijfatigue.2009.06.020
7. GopiReddy, L. R., Tolbert, L. M., Ozpineci, B., Pinto, J. O. P. (2015). Rainflow Algorithm-Based Lifetime Estimation of Power Semiconductors in Utility Applications. IEEE Transactions on Industry Applications, 51 (4), 3368–3375. doi: https://doi.org/10.1109/tia.2015.2407055
8. Fatemi, A., Yang, L. (1998). Cumulative fatigue damage and life prediction theories: a survey of the state of the art for homogeneous materials. International Journal of Fatigue, 20 (1), 9–34. doi: https://doi.org/10.1016/s0142-1123(97)00081-9
9. Quigley, J. P., Lee, Y.-L., Wang, L. (2016). Review and Assessment of Frequency-Based Fatigue Damage Models. SAE International Journal of Materials and Manufacturing, 9 (3), 565–577. doi: https://doi.org/10.4271/2016-01-0369
10. Ariduru, S. (2004). Fatigue life calculation by rainflow cycle counting method. Ankara.
11. Yoon, M., Kim, K., Oh, J. E., Lee, S. B., Boo, K., Kim, H. (2015). The prediction of dynamic fatigue life of multi-axial loaded system. Journal of Mechanical Science and Technology, 29 (1), 79–83. doi: https://doi.org/10.1007/s12206-014-1212-1
12. Rao, J. S. (2010). Optimized Life Using Frequency and Time Domain Approaches. IUTAM Bookseries, 13–26. doi: https://doi.org/10.1007/978-94-007-0020-8_2
13. Ragan, P., Manuel, L. (2007). Comparing Estimates of Wind Turbine Fatigue Loads Using Time-Domain and Spectral Methods. Wind Engineering, 31 (2), 83–99. doi: https://doi.org/10.1260/030952407781494494
14. Singh, A., Soni, V., Singh, A. (2014). Structural Analysis of Ladder Chassis for Higher Strength. International Journal of Emerging Technology and Advanced Engineering, 4 (2), 253–259.
15. Thriveni, K., Chandraiah, B. J. (2013). Modeling And Analysis Of The Crankshaft Using Ansys Software. International Journal of Computational Engineering Research, 3 (5), 84–89.
16. Espadafor, F. J., Villanueva, J. B., García, M. T. (2009). Analysis of a diesel generator crankshaft failure. Engineering Failure Analysis, 16 (7), 2333–2341. doi: https://doi.org/10.1016/j.engfailanal.2009.03.019
17. Fonte, M., Reis, L., Romeiro, F., Li, B., Freitas, M. (2006). The effect of steady torsion on fatigue crack growth in shafts. International Journal of Fatigue, 28 (5-6), 609–617. doi: https://doi.org/10.1016/j.ijfatigue.2005.06.051
18. SongSong, S., MaoSong, W., Hui, W., Ying, Z., Mei, X. X. (2019). Study of component high cycle bending fatigue based on a new critical distance approach. Engineering Failure Analysis, 102, 395–406. doi: https://doi.org/10.1016/j.engfailanal.2019.04.050
19. Zhu, C., He, J., Peng, J., Ren, Y., Lin, X., Zhu, M. (2019). Failure mechanism analysis on railway wheel shaft of power loco-

motive. Engineering Failure Analysis, 104, 25–38. doi: https://doi.org/10.1016/j.engfailanal.2019.05.013
20. Rusiński, E., Harnatkiewicz, P., Przybyłek, G., Moczko, P. (2010). Analysis of the Fatigue Fractures in the Eccentric Press Shaft. Solid State Phenomena, 165, 321–329. doi: https://doi.org/10.4028/www.scientific.net/ssp.165.321
21. Thamaraiselvan, A., Thanesh, A., Suresh, K., Palani, S. (2016). Design and Development of Reliable Integral Shaft Bearing for Water Pump in Automotive Engine to Reduce Assemble Time and Increase Production. Indian Journal of Science and Technology, 9 (1). doi: https://doi.org/10.17485/ijst/2016/v9i1/85756
22. Kurle, A., Raut, L. (2013). A Review on Design and Development of Eccentric Shaft for Cotton Ginning Machine. International Journal of Engineering Research & Technology, 2 (1).
23. Arinova, D. B., Askarov, E. S., Popov, G. (2018). Investigation and design testing of the centrifugal gyratory mill of a coulisse type. News of the National Academy of Sciences of the Republic of Kazakhstan, 2 (428), 61–71.
24. Vol'dek, A. I., Popov, V. V. (2010). Elektricheskie mashiny peremennogo toka. Sankt-Peterburg: Piter, 350.
25. Nisbett, J. K., Budynas, R. G. (2006). Shigley's Mechanical Engineering Design. New York: McGraw-Hill Education, 1109.
26. Marin, J. (1962). Mechanical Behavior of Engineering Materials. New Jersey: Prentice-Hall, 502.
27. Dragunov, Yu. G., Zubchenko, A. S., Kashirskiy, Yu. V. et. al. (2014). Marochnik staley i splavov. Moscow, 1216.

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DEVELOPMENT OF A METHOD FOR GEOMETRICAL MODELING OF THE AIRFOIL PROFILE OF AN AXIAL TURBOMACHINE BLADE (p. 29–38)

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A method for geometric modeling of the contours of the suction and the pressure side profiles of axial turbomachine blades described by compound curves and formed by two sections has been proposed. Each section of the profile contour was modeled by a curve described in a natural parameterization. The cubic law of curvature distribution was applied to the leading sections of the profile and square law was used for the trailing section. Juncture of the leading and trailing sections of the profiles of the suction and the pressure side was provided with smoothness of the third order which assumes equality of values of functions, function derivatives, curvature and curvature derivatives in the junction point. When modeling the blade profile, thirteen kinematic and geometric parameters were used. Unknown coefficients of the square and cubic laws of distribution as well as lengths of the profile arcs of the suction and the pressure side sections were determined in the process of modeling the profile cascade for specified parameters. The problem was solved by minimizing deviations of the plotted curves from the reference points of the modeled profile located in the throat of the blade channel and on the circle, which determines maximum thickness of the profile.

Based on the proposed method, a program code was developed which in addition to the digital information on the modeled turbomachine blade profile displays the results in a graphical form on a computer screen. The calculation studies confirmed feasibility of the proposed advanced method of modeling the suction and the pressure side profiles of axial turbine blades. The developed method can be useful in organizations engaged in the design and manufacture of blades of axial gas turbines of gas turbine engines.

Keywords: axial turbine, blade profile, geometric modeling, natural parameterization, curvature distribution laws.

References

1. Boyko, A. V., Govorushchenko, Yu. N., Burlaka, M. V. (2010). Metody parametricheskoy optimizatsii navala napravlyayushchih turbinnyh lopatok. Vestnik Nats. tehn. un-ta «KhPI»: sb. nauch. tr. Temat. vyp.: Energeticheskie i teplotehnicheskie protsessy i oborudovanie, 2, 13–21.
2. Homylev, S. A., Rudenko, V. T., Lyusina, A. V. (2011). Chislennoe issledovanie vliyaniya formy peredney kromki na effektivnost' turbinnoy reshetki. Vestnik Nats. tehn. un-ta «KhPI»: sb. nauch. tr. Temat. vyp.: Energeticheskie i teplotehnicheskie protsessy i oborudovanie, 5, 45–50.
3. Mamaev, B. I., Mityushkin, Yu. I. (2006). Calculating axisymmetric gas flow trough vane row of turbine stage of non-traditional design. Problemy energetiki, 7-8, 3–11.
4. Levina, M. E., Grebnev, V. K. (1996). Vliyanie geometricheskih harakteristik turbinnoy stupeni na radial'niy gradient reaktivnosti. Teploenergetika, 1, 43–48.
5. Mengistu, T., Ghaly, W. (2008). Aerodynamic optimization of turbomachinery blades using evolutionary methods and ANN-based surrogate models. Optimization and Engineering, 9 (3), 239–255. doi: https://doi.org/10.1007/s11081-007-9031-1
6. Deych, M. E., Filippov, G. A., Lazarev, L. Ya. (1965). Atlas profiley reshetok osevyh turbin. Moscow: Mashinostroenie, 96.
7. Elqussas, N., Elzahaby, A., Khalil, M., Elshabka, A. (2018). Automated axial flow turbine design with performance prediction. Journal of Engineering Science and Military Technologies, 2 (2), 72–81. doi: https://doi.org/10.21608/ejmtc.2017.1694.1058
8. Adnan, F. P., Hartono, F. (2018). Design of Single Stage Axial Turbine with Constant Nozzle Angle Blading for Small Turbojet. Journal of Physics: Conference Series, 1005, 012026. doi: https://doi.org/10.1088/1742-6596/1005/1/012026
9. Levenberg, V. D., Borisenko, V. D., Gil'mutdinov, L. A. (1980). Analiticheskoe profilirovanie turbinnyh reshetok dlya sistemy avtomatizirovannogo proektirovaniya. Nikolaev: NKI, 51.
10. Deych, M. E., Filippov, G. A., Nauman, V. I. (1964). Lemniskatniy metod postroeniya profiley dozvukovyh reshetok. Teploenergetika, 7, 74–78.
11. Zhuravlev, V. A. (1970). Analiticheskiy metod postroeniya profiley turbinnyh lopatok GTD. Trudy RIIGA, 187, 90–108.
12. Souverein, L., Veggi, L., Sudhof, S. et. al. (2017). On the effect of axial turbine rotor blade design on efficiency: a parametric study of the Baljé-diagram. 7th European conference for aeronautics and space sciences (EUCASS). doi: http://doi.org/10.13009/EUCASS2017-241
13. Aronov, B. M. (1971). Metod analiticheskogo proektirovaniya profiley lopatok osevyh gazovyh turbin. Aviatsionnaya tehnika, 1, 129–136.

14. Pritchard, L. J. (1985). An Eleven Parameter Axial Turbine Airfoil Geometry Model. Volume 1: Aircraft Engine; Marine; Turbomachinery; Microturbines and Small Turbomachinery. doi: https://doi.org/10.1115/85-gt-219
15. Slitenko, A. F., Kuz'menko, A. A. (1988). Postroenie reshetok turbinnyh profiley s pomoshch'yu polinomov Beziera-Bernshteyna. IVUZ «Mashinostroenie», 9, 77–81.
16. Polikarpov, A. L. (1991). Primenenie sostavnyh krivyh Bez'e dlya postroeniya reshetok turbinnyh profiley. IVUZ «Energetika», 3, 89–93.
17. Vinogradov, L. V., Alekseev, A. P., Kostjukov, A. V. (2013). Turbine blade profile of curves Bezier. Vestnik Rossiyskogo universiteta druzhby narodov. Seriya: Inzhenernye issledovaniya, 3, 10–15.
18. Ramana Murthy, S. V., Kishore Kumar, S. (2014). Development and validation of a Bezier curve based profile generation method for axial flow turbines. International journal of scientific and technology research, 3 (12), 187–192.
19. Gribin, V. G., Tishchenko, A. A., Gavrilov, I. Y. et. al. (2017). Turbine blade profile design using Bezier curves. Proceedings of 12th European Conference on Turbomachinery Fluid dynamics & Thermodynamics ETC12. Stockholm.
20. Karelin, A. M. (1989). Postroenie reshetki turbinnyh profiley na osnove ratsional'nyh parametricheskih krivyh. Lopatochnye mashiny i struynye apparaty, 9, 79–89.
21. Ghaly, W. S., Mengistu, T. T. (2003). Optimal geometric representation of turbomachinery cascades using NURBS. Inverse Problems in Engineering, 11 (5), 359–373. doi: http://doi.org/10.1080/1068276031000086778
22. Sindhu, N., Chikkanna, N. (2017). Design and analysis of gas turbine blade. International Journal for Research in Applied Science & Engineering Technology, 5 (VI), 1097–1104.
23. Borisenko, V., Ustenko, S., Ustenko, I. (2019). Development of the method for geometric modeling of S-shaped camber line of the profile of an axial compressor blade. Eastern-European Journal of Enterprise Technologies, 1 (1 (97)), 16–23. doi: https://doi.org/10.15587/1729-4061.2019.154270
24. Hooke, R., Jeeves, T. A. (1961). «Direct Search» Solution of Numerical and Statistical Problems. Journal of the ACM, 8 (2), 212–229. doi: https://doi.org/10.1145/321062.321069

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STUDY OF THE PROBLEM ON CONSTRUCTING QUADRICS AT THE ASSIGNED TANGENT CONES (p. 39–48)

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The research focuses on solving the problems, related to modeling the second-order surfaces (quadrics), the determinant of which includes tangent cones. All research was performed by the paradigm of using constructive methods of creation of algorithms. This is caused by the fact that there is a possibility to rely on a significant number of basic geometric tasks implemented in the DSS.

The problem of modeling of quadrics by tangent cones is relevant because there are at least its two important applications. The first is the construction of the surfaces by its contour line on perspective images. In this case, the point of view and the perspective contour line assign the enveloping cone, which in the case of quadrics coincides with the tangent cone. Such problems are solved in the context of problems of technical aesthetics and architectural design.

The second application is found in the problems of constructing the quadrics that are conjugated by the assigned curves or in the problems of conjugation of two quadrics by the third one. The problem of conjugation of surfaces is of wide practical significance, which is proved by the interest of users and developers of computer modeling systems.

Within the framework of this research, the existing theoretical geometric properties for modeling the quadrics, the determinant of which includes tangent cones, were accumulated, and a series of new geometric properties were found.

We developed the method, by which through assigning the contact line on one cone, there is a possibility to find a contact line on the second cone, as well as to find the center of the quadric inscribed in these two cones. An alternative method for modeling the described surfaces was also proposed. In this way, the cross-sections of all quadrics, tangent to two cones, are inscribed in quadrangulars, the vertices of which belong to the lines of the intersection of the assigned cones. Based of structural geometric research, the algorithms for computer realization of problems of modeling objects by their contour lines on their perspective images were developed.

The research results in the form of the theoretical calculations and examples of their application show the effectiveness of the proposed algorithms. The described approach to the solution of the stated tasks makes it possible to extend the possibilities of existing computer systems in their being applied in the work of designers and greatly simplify the process of the creation of actual objects.

Keywords: quadric, tangent cones, surface determinant, contact line, perspective image, conjugation of surfaces.

References

1. Gfrerrer, A., Zsombor-Murray, P. (2009). Quadrics of Revolution on Given Points. Journal for Geometry and Graphics, 13 (2), 131–144.
2. Zsombor-Murray, P., Fashny, S. (2006). A Cylinder of Revolution on Five Points. Journal for Geometry and Graphics, 10 (2), 207–213.
3. Breuils, S., Nozick, V., Sugimoto, A., Hitzer, E. (2018). Quadric Conformal Geometric Algebra of $R^{9,6}$. Advances in Applied Clifford Algebras, 28 (2). doi: https://doi.org/10.1007/s00006-018-0851-1
4. Emery, J. Conics, Quadrics and Projective Space. Available at: http://www.stem2.org/je/quadric.pdf
5. Trocado, A., Gonzalez-Vega, L. (2019). Computing the intersection of two quadrics through projection and lifting. Available at: https://arxiv.org/pdf/1903.06983.pdf
6. Bobenko, A. I., Suris, Yu. B. Discrete differential geometry. Consistency as integrability. Available at: https://arxiv.org/pdf/math/0504358.pdf
7. Doliwa, A. (1999). Quadratic reductions of quadrilateral lattices. Journal of Geometry and Physics, 30 (2), 169–186. doi: https://doi.org/10.1016/s0393-0440(98)00053-9
8. Polezhaev, Yu. O., Fatkullina, A. A., Borisova, A. Yu. (2012). Geometric models of junctions of quadrics in fragments of architectural pieces. Vestnik MGSU, 9, 18–23.

9. Mihaylenko, V. E., Obuhova, V. S., Podgorniy, A. S. (1972). Formoobrazovanie obolochek v arhitekture. Kyiv: Budivel'nik, 207.
10. SolidWorks. Available at: https://en.wikipedia.org/wiki/SolidWorks
11. Korotkiy, V. A., Usmanova, E. A., Khmarova, L. I. (2017). Geometric Modeling of Construction Communications with Specified Dynamic Properties. IOP Conference Series: Materials Science and Engineering, 262, 012110. doi: https://doi.org/10.1088/1757-899x/262/1/012110
12. Korotkiy, V. A., Usmanova, E. A., Khmarova, L. I. (2016). Dinamic connection of second-order curves. 2016 2nd International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM). doi: https://doi.org/10.1109/icieam.2016.7911687
13. Korotkiy, V. A. (2018). Construction of a Nine-Point Quadric Surface. Journal for Geometry and Graphics, 22 (2), 183–193.
14. Heyfets, A. L. (2002). Issledovanie linii peresecheniya poverhnostey vtorogo poryadka v kurse teoreticheskih osnov komp'yuternogo geometricheskogo modelirovaniya. International Conference Graphicon 2002. Available at: http://graphicon2002.unn.ru/demo/2002/Kheyfets_2_Re.pdf
15. Ivanov, G. S. (2014). Konstruktivniy sposob issledovaniya svoystv parametricheski zadannyh krivyh. Geometriya i grafika, 2 (3), 3–6.
16. Ivanov, G. S., Zhirnyh, B. G. (2015). Geometricheskoe obespechenie postroeniya gladkih sopryazheniy iz otsekov konicheskih poverhnostey vtorogo poryadka. Inzhenerniy vestnik, 06, 1026–1033. Available at: http://engsi.ru/doc/777408.html
17. Monzh, G. (2013). Nachertatel'naya geometriya. Klassiki nauki. Moscow: Kniga po trebovaniyu, 292.
18. Rahmann, S. (2003). Reconstruction of Quadrics from Two Polarization Views. Pattern Recognition and Image Analysis, 810–820. doi: https://doi.org/10.1007/978-3-540-44871-6_94
19. Sazonov, K. A., Yankovskaya, L. S. (2009). Komp'yuternoe modelirovanie sfericheskih poverhnostey obektov dizayna na perspektivnyh izobrazheniyah. Tekhnichna estetyka i dyzain, 6, 19–26.
20. Sulimenko, S. Yu., Anpilohova, V. O, Levina, Zh. H. (2016). Formoutvorennia poverkhon obertannia druhoho poriadku za yikh liniyamy obrysiv. Suchasni problemy arkhitektury ta mistobuduvannia, 44, 320–325.
21. Sulimenko, S. Yu. (2016). Konstruktyvno-parametrychnyi analiz formoutvorennia elipsoidiv za yikh liniyamy obrysiv. Suchasni problemy arkhitektury ta mistobuduvannia, 42, 109–115.
22. Modenov, P. S. (1969). Analiticheskaya geometriya. Moscow: MGU, 688.
23. Adamar, Zh. S. (1951). Elementarnaya geometriya. Chast' vtoraya. Stereometriya. Moscow: ONTI, 760.

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INVESTIGATING THE PROCESS OF SHRINKAGE DEPRESSION FORMATION AT THE COMBINED RADIAL-BACKWARD EXTRUSION OF PARTS WITH A FLANGE (p. 49–57)

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The possibilities of using an energy method to forecast defect formation in the form of shrinkage depression in the combined extrusion processes have been investigated. We have proposed a mathematical model of the combined radial-backward extrusion process of hollow details with a flange, taking into consideration the degeneration of the trapezoidal module into a rectangular one. Separate stages in the deformation process have been defined, depending on the magnitude of the active tool stroke compared with the thickness of the bottom of the cup. We have devised a generalized estimation scheme for the process of combined radial-backward extrusion of parts with a flange taking into consideration the final stage of deformation ($H_{bottom}<h_1$). The magnitude of the reduced pressure of deformation has been derived as a function of the geometric, technological, and kinematic parameters of the extrusion process. A role of the kinematic parameter of the process belongs to a relative speed of metal flow in the vertical direction (filling the cup's wall at the inverse flow of metal). The magnitude for the reduced pressure of deformation has been optimized based on this parameter. We have analyzed the character of change in the optimum magnitude of a relative speed of metal flow in the vertical direction in the course of the process. The differences have been established in the derived dependences of a given kinematic parameter for the process with the formation of shrinkage depression in the bottom part of a component and without defect formation.

It has been substantiated that the use of combined extrusion in the manufacture of hollow parts with a flange, when compared with the application of simple schemes of deformation, improves the technological capabilities of the process. We have proven that the technologies for introducing combined extrusion had not been sufficiently studied and there is a lack of recommendations on predicting the formation of a defect in the form of shrinkage depression. The estimation scheme has been proposed for the radial-backward extrusion process, taking into consideration the emergence of shrinkage depression at the final stage of deformation. We have modeled the process of combined extrusion of hollow parts with a flange and established the influence of friction conditions on the time of the emergence of shrinkage depression in the bottom part of a component.

It has been confirmed that the proposed generalized estimation scheme makes it possible to predicting the occurrence of a defect in the form of shrinkage depression at all stages and under different technological conditions for a deformation process. Obtaining a preliminary assessment, based on it, of possible defect formation would facilitate the development of appropriate technological recommendations to avoid defects of this type.

Keywords: combined extrusion, energy method, parts with a flange, defect formation, shrinkage depression, deformation process.

References

1. Markov, O., Zlygoriev, V., Gerasimenko, O., Hrudkina, N., Shevtsov, S. (2018). Improving the quality of forgings based on upsetting the workpieces with concave facets. Eastern-European Journal of Enterprise Technologies, 5 (1 (95)), 16–24. doi: https://doi.org/10.15587/1729-4061.2018.142674
2. Zhang, S. H., Wang, Z. R., Wang, Z. T., Xu, Y., Chen, K. B. (2004). Some new features in the development of metal forming technology. Journal of Materials Processing Technology, 151 (1-3), 39–47. doi: https://doi.org/10.1016/j.jmatprotec.2004.04.098
3. Plancak, M., Barisic, B., Grizelj, B. (2008). Different Possibilities of Process Analysis in Cold Extrusion. Key Engineering Materials,

367, 209–214. doi: https://doi.org/10.4028/www.scientific.net/kem.367.209
4. Aliev, I. S. (1988). Radial extrusion processes. Soviet Forging and Sheet Metal Stamping Technology, 6, 1–4.
5. Cho, H. Y., Min, G. S., Jo, C. Y., Kim, M. H. (2003). Process design of the cold forging of a billet by forward and backward extrusion. Journal of Materials Processing Technology, 135 (2-3), 375–381. doi: https://doi.org/10.1016/s0924-0136(02)00870-1
6. Pepelnjak, T., Milutinović, M., Plančak, M., Vilotić, D., Randjelović, S., Movrin, D. (2016). The Influence of Extrusion Ratio on Contact Stresses and Die Elastic Deformations in the Case of Cold Backward Extrusion. Strojniški Vestnik - Journal of Mechanical Engineering, 62 (1), 41–50. doi: https://doi.org/10.5545/sv-jme.2015.3051
7. Aliev, I. S., Lobanov, A. I., Borisov, R. S., Savchinskij, I. G. (2004). Investigation of die blocks with split matrixes for the processes of cross extrusion. Kuznechno-Shtampovochnoe Proizvodstvo (Obrabotka Metallov Davleniem), 8, 21–26.
8. Farhoumand, A., Ebrahimi, R. (2009). Analysis of forward-backward-radial extrusion process. Materials & Design, 30 (6), 2152–2157. doi: https://doi.org/10.1016/j.matdes.2008.08.025
9. Seo, J. M., Jang, D. H., Min, K. H., Koo, H. S., Kim, S. H., Hwang, B. B. (2007). Forming Load Characteristics of Forward and Backward Tube Extrusion Process in Combined Operation. Key Engineering Materials, 340-341, 649–654. doi: https://doi.org/10.4028/www.scientific.net/kem.340-341.649
10. Kalyuzhnyi, V. L., Alieva, L. I., Kartamyshev, D. A., Savchinskii, I. G. (2017). Simulation of Cold Extrusion of Hollow Parts. Metallurgist, 61 (5-6), 359–365. doi: https://doi.org/10.1007/s11015-017-0501-1
11. Noh, J., Hwang, B. B., Lee, H. Y. (2015). Influence of punch face angle and reduction on flow mode in backward and combined radial backward extrusion process. Metals and Materials International, 21 (6), 1091–1100. doi: https://doi.org/10.1007/s12540-015-5276-y
12. Aliieva, L., Zhbankov, Y. (2015). Radial-direct extrusion with a movable mandrel. Metallurgical and Mining Industry, 11, 175–183.
13. Filippov, Yu. K., Ignatenko, V. N., Golovina, Z. S., Anyuhin, A. S., Ragulin, A. V., Gnevashev, D. A. (2011). Teoreticheskoe issledovanie kombinirovannogo protsessa radial'nogo i obratnogo vydavlivaniya v konicheskoy matritse. Kuznechno-shtampovochnoe proizvodstvo. Obrabotka materialov davleniem, 7, 3–7.
14. Laptev, A. M., Perig, A. V., Vyal, O. Y. (2013). Analysis of equal channel angular extrusion by upper bound method and rigid blocks model. Materials Research, 17 (2), 359–366. doi: https://doi.org/10.1590/s1516-14392013005000187
15. Ogorodnikov, V. A., Dereven'ko, I. A., Sivak, R. I. (2018). On the Influence of Curvature of the Trajectories of Deformation of a Volume of the Material by Pressing on Its Plasticity Under the Conditions of Complex Loading. Materials Science, 54 (3), 326–332. doi: https://doi.org/10.1007/s11003-018-0188-x
16. Dereven'ko, I. A. (2012). Deformiruemost' i kachestvo zagotovok v usloviyah kombinirovannogo formoizmeneniya. Obrabotka metallov davleniem, 3 (32), 87–96.
17. Aliiev, I., Aliieva, L., Grudkina, N., Zhbankov, I. (2011). Prediction of the Variation of the Form in the Processes of Extrusion. Metallurgical and Mining Industry, 3 (7), 17–22.
18. Shestakov, N. A. (1998). Energeticheskie metody rascheta protsessov obrabotki metallov davleniem. Moscow: MGIU, 125.
19. Hrudkina, N., Aliieva, L., Abhari, P., Kuznetsov, M., Shevtsov, S. (2019). Derivation of engineering formulas in order to calculate energy-power parameters and a shape change in a semi-finished product in the process of combined extrusion. Eastern-European Journal of Enterprise Technologies, 2 (7 (98)), 49–57. doi: https://doi.org/10.15587/1729-4061.2019.160585
20. Aliieva, L., Grudkina, N., Zhbankov, I. (2012). Analysis of billet deformation during the combined radialbackward extrusion. New technologies and achievements in metallurgy and materials engineering. Czestochowa: Quick-druk, 389–396.

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PREDICTION OF CHATTER STABILITY IN TURNING (p. 58–64)

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A new technology for predicting chatter in turning, based on simulation of the cutting process in time and frequency domains using the Nyquist diagram has been developed. The cutting process is presented as carried out in an elastic closed-loop technological machining system (TMS), taking into account the machining «by trace». The dynamic model is represented as two-degrees-of-freedom system in the direction of the longitudinal and transverse axes of coordinates. The mathematical model is built in accordance with the system approach, in the form of a block diagram of the connection of elements with transfer functions according to Laplace, is non-linear and has a fourth order. Therefore, the simulation is performed numerically using the fourth-order Runge-Kutta procedure. It is shown that when studying chatter, three groups of factors should be taken into account: tool geometry, dynamic parameters and cutting mode, which should be represented as an analogue of the material removal rate. The dynamic parameters of the system are obtained by processing the experimental weight characteristics obtained by striking the system with a special hammer. An application program that allows simulation of the process of regenerative oscillations occurrence in time domain and building the amplitude-phase characteristic of TMS in cutting has been created. The application program performs modeling based on the source data of the cutting conditions and dynamic characteristics of the system. Dynamic characteristics of the system are presented in the form of stiffness and frequency of the main harmonic along the corresponding coordinate axes. The simulation showed that the results completely coincide with the frequency analysis results of the profilogram of the actually machined part that allow recommending this technology for predicting and evaluating chatter and stability in turning.

Keywords: chatter in machining turning, two-degrees-of-freedom dynamic model, delay function.

References

1. Nicolescu, M., Frangoudis, C., Semere, D., Archenti, A., Rashid, A. (2015). New paradigm in control of machining system's dynamics. Journal of Machine Engineering, 15 (3), 117–137.
2. Moon, F. C., Kalmár-Nagy, T. (2001). Nonlinear models for complex dynamics in cutting materials. Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences, 359 (1781), 695–711. doi: https://doi.org/10.1098/rsta.2000.0751

3. Korendyasev, G. K. (2013). On the physical models of auto-oscillations at the processing of metal. Vestnik nauchno-tehnicheskogo razvitiya, 7 (71), 15–25.
4. Altintas, Y. (2012). Manufacturing automation: metal cutting mechanics, machine tool vibrations, and CNC design. Cambridge University Press, 366. doi: https://doi.org/10.1017/cbo9780511843723
5. Cypkin, J. S. (1946). Stability of systems with retarding ferdback. Avtomat. i Telemekh., 7 (2-3), 107–129. Available at: http://www.mathnet.ru/links/5ee3c3be11a608350b9a033b7920668b/at13125.pdf
6. Eynian, M. (2014). Frequency Domain Study of Vibrations above and under Stability Lobes in Machining Systems. Procedia CIRP, 14, 164–169. doi: https://doi.org/10.1016/j.procir.2014.03.068
7. Mann, B. P., Patel, B. R. (2010). Stability of Delay Equations Written as State Space Models. Journal of Vibration and Control, 16 (7-8), 1067–1085. doi: https://doi.org/10.1177/1077546309341111
8. Stephenson, D. A., Agapiou, J. S. (2016). Metal Cutting Theory and Practice. CRC Press, 969. doi: https://doi.org/10.1201/9781315373119
9. Virtual CNC. Available at: https://www.malinc.com/products/virtual-cnc/
10. Palpandian, P., Prabhu Raja, V., Satish Babu, S. (2013). Stability Lobe Diagram for High Speed Machining Processes: Comparison of Experimental and Analytical Methods – A Review. International Journal of Innovative Research in Science, Engineering and Technology, 2 (3), 747–752.
11. Petrakov, Yu. V., Drachev, O. I. (2014). Avtomaticheskoe upravlenie protsessami rezaniya. Stariy Oskol: TNT, 408.
12. Tang, A., Liu, Z. (2008). Three-dimensional stability lobe and maximum material removal rate in end milling of thin-walled plate. The International Journal of Advanced Manufacturing Technology, 43 (1-2), 33–39. doi: https://doi.org/10.1007/s00170-008-1695-y
13. Mazur, N. P., Vnukov, Yu. N., Grabchenko, A. I., Dobroskok, V. L., Zaloga, V. A., Novoselov, Yu. K., Yakubov, F. Ya.; Mazur, N. P., Grabchenko, A. I. (Eds.) (2013). Osnovy teorii rezaniya materialov. Kharkiv: NTU «KhPI», 534.
14. Trybrat, K. O., Petrakov, Yu. V. (2019). Modeliuvannia avtokolyvan pry tokarnomu obroblenni. Naukovi konferentsiyi Ukrainy, innovatsiyi molodi v mashynobuduvanni 2019. Available at: http://imm-mmi.kpi.ua/imm2019/paper/view/17039

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AN IMPACT OF THE LADLE LINING ON THE REFINING OF REINFORCED STEEL WHEN BLOWING WITH POWDERS (p. 65–71)

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When refining steel by blowing powders, the ladle lining material plays a serious role. The dependency graphs of the degree of desulfurization on the consumption of silicocalcium powder during blowing in ladles lined with various materials have been presented. It has been noted that the amount of FeO in the slag seriously affects the average degree of desulfurization. With a large amount of FeO in the slag, the degree of resulfurization is greatly increased. The placement plan of the unit for refining the liquid steel in the ladle has been illustrated. Simultaneously, for powder blowing, a device diagram of the ladle furnace fitted with equipment for blowing liquid steel with powders has been presented. In this equipment, powder lining can be used and steel blowing with silicocalcium based powders can be carried out. The degree of desulfurization is also seriously affected by the initial amount of sulfur in the metal charge for steelmaking The presence of a roof in the pouring ladles improves the conditions for metal blowing, oxidation and metal loss are reduced.

It has been observed that the process of refining liquid steel in a ladle is complex and depends on many factors. The amount of sulfur in the primary metal charge, the lining of the ladle, the composition of the powder of the blown material and the technological parameters of the blowing are important. The complete desulfurization of steel by blowing with powders primarily depends on the initial amount of sulfur in the metal. It has been found that there is a linear dependence of the final sulfur content on its initial content in steel when metal is blown in a ladle with a mixture of 70 % MgO, 20 % CaO, and 10 % CaF_2. The desulfurization of steel by blowing with powders, especially by blowing magnesium and calcium alloys, can be significantly affected by ladle lining.

Keywords: ladle lining, powder blowing, desulfurization, resulfurization, dolomite lining, ladle furnace.

References

1. Smolyakov, A. S., Shakhov, S. I., Kerimov, R. (2017). Modernization of Baku Steel Company Metallurgical Plant Section CBCM for Producing Round Pipe Billets. Metallurgist, 61 (7-8), 543–548. doi: https://doi.org/10.1007/s11015-017-0530-9
2. Kudrin, V. A. (2003). Teoriya i tehnologiya proizvodstva stali. Moscow: «Miri, OOO» izdatel'stvo AST», 528.
3. Kozlov, L. Ya., Kolokol'tsev, V. M., Vdovin, K. N. et. al. (2003). Proizvodstvo stal'nyh otlivok. Moscow: MISIS, 352.
4. Svenchanskiy, A. D., Smelyanskiy, M. Ya. (1970). Elektricheskie promyshlennye pechi. Ch. 2. Dugovye pechi. Moscow: Energiya, 264.
5. Kerimov, R. I. (2019). Experience of implementation of physical methods in the treatment of electrostals. Tehnologiya mashinostroeniya i materialovedenie, 3, 73–82. doi: https://doi.org/10.26160/2542-2146-2019-3-73-82
6. Kerimov, R. I., Bayramov, A. T. (2019). Improving the quality of high-quality billets through the use of electromagnetic stirring of metal. Sovremennye problemy teorii mashin, 7, 78–82. doi: https://doi.org/10.26160/2307-342X-2019-7-78-82
7. Schürmann, E., Fünders, P., Litterscheidt, H. (1975). Dampfdruck des Calciums über Calcium-Silicium- und Calcium-Aluminium-Schmelzen sowie über Calcium-Aluminium-Silicium-Legierungen. Archiv Für Das Eisenhüttenwesen, 46 (8), 473–476. doi: https://doi.org/10.1002/srin.197503664
8. Rahmanov, S. R., Topolov, V. L., Gasik, M. I., Mamedov, A. T., Azimov, A. A. (2017). Protsessy i mashiny elektrometallurgicheskogo proizvodstva. Baku, 568.
9. Knyuppel', G. (2004). Raskislenie i vakuumnaya otrabotka stali. Moscow: Metallurgiya, 416.
10. Smirnov, N. A. (2015). Sovremennye metody analiza i kontrolya produktov proizvodstva. Moscow: Metallurgiya, 256.
11. Smolyakov, A. S., Shakhov, S. I., Kerimov, R. I. (2017). Modernization of billet CCMOF metallurgical plant Baku Steel Company for producing tube rounds. Metallurg, 7, 37–41.
12. Aslanov, T. I. (2002). Fundamentals of metal technology and welding in construction. Baki: Təhsil, 528.
13. Sokolov, G. A. (1977). Vnepechnoe rafinirovanie stali. Moscow: Metallurgiya, 208.

14. Knop, K., Rommerswinkel, H.-W. (1974). Kinetik der Desoxidation und Entschwefelung von Stahlschmelzen durch Calcium. Archiv Für Das Eisenhüttenwesen, 45 (8), 493–497. doi: https://doi.org/10.1002/srin.197403912
15. Smolyakov, A. S., Shakhov, S. I., Kerimov, R. I., Rafiev, O. Y. (2017). The Reconstruction of the Existing Billet Continuous Caster at the Baku Steel Company in order to Cast the Large Billets for the Pipe and Tube Industry Needs. Ferrous Metallurgy. Bulletin of Scientific , Technical and Economic Information, 1, 43–46. Available at: https://chermetinfo.elpub.ru/jour/article/view/535/502#
16. Smolyakov, A. S., Shakhov, S. I., Kerimov, R. (2017). Modernization of Baku Steel Company Metallurgical Plant Section CBCM for Producing Round Pipe Billets. Metallurgist, 61 (7-8), 543–548. doi: https://doi.org/10.1007/s11015-017-0530-9
17. Fischer, W. A., Wahlster, M. (1957). Untersuchungen über die Abscheidungsgeschwindigkeit primärer Desoxydationsprodukte aus Eisenschmelzen. Archiv Für Das Eisenhüttenwesen, 28 (10), 601–609. doi: https://doi.org/10.1002/srin.195702183
18. Spelitsin, R. I. (1975). Issledovanie zaglubleniya elektricheskoy dugi v zhidkuyu vannu v usloviyah vysokomoshchnyh DSP. Elektrotermiya, 12, 10–11.
19. Shakhov, S. I., Kerimov, R. I. (2018). Modernization of the existing high-grade continuous caster of the plant «Baku Steel Company» for the purpose of round tube billets production. Tyazheloe mashinostroenie, 5, 9–13.
20. Kerimov, R. I. (2019). Improving steel melting intensity in the process of electrosmelting from waste and pellets (HBI). Eastern-European Journal of Enterprise Technologies, 3 (1 (99)), 35–42. doi: https://doi.org/10.15587/1729-4061.2019.168352