The effect of electrostatic processing on performance characteristics of axle oil is investigated. Axle oil is used for wetting motor-axial bearings (MAB) of locomotives. There is a pressing and urgent problem of the MAB service life, which is indirectly related to the underdeveloped reserves of anti-wear properties of axle oil. To study them, it was decided to use the method of electrostatic processing, which does not require the introduction of any additives and has proven its effectiveness in the studies of other mineral oils. It is based on the ability of electric fields to destroy micellar aggregates in oil and form a solid boundary layer of molecules on friction surfaces. In the context of solving the current problem of the MAB service life, this method wasn’t considered earlier.

The research was carried out by means of the «roller-pad» friction pair, which was wetted with axle oil at different load conditions and operating times. The dependences of wear of the experimental samples under different load conditions, oil operating times and degrees of electric processing are obtained.

The results show that when using axle oil subjected to ESP, the wear rate of the experimental samples is reduced. Wear rate reduction depends on the oil operating time in the lubrication system. The greatest wear rate reduction of 1.92 times is noted for fresh oil. For the oil state after the locomotive run of 75 thousand km, the reduction is about 1.68 times and for the oil at the end of its service life, wear rate reduction is approximately 1.47 times.

**Keywords**: axle oil, electrostatic processing, motor-axial bearing, wheels and motors unit, wear rate.

**References**

1. Sergienko, N. I. (2010). Reshenie problemy podvizhnogo sostava zheleznyh dorog Ukrainy cherez vzaimodeystvie gosudarstvennogo i chastnogo sektorov. Locomotiv-inform, 6, 40–46.
2. Sergienko, N. I. (2011). Podvizhnoy sostav zheleznyh dorog Ukrainy: sostoyanie i perspektivy. Lokomotiv-inform, 6, 15–24.
3. Kalabukhin, Yu. Ye. (2008). Analiz suchashnego stanu tia-lovoho rukhomo go skladu zaliznyts Ukrainy. Lokomotiv-inform, 11, 4–5.
4. Pro zatverdzhennia prohromy onovlenia lokomotyvnogo parku zaliznyts Ukrainy na 2012–2016 roky (2011). Zbirnyk opravdanych aktiv Ukrainy, 61, 7–8.
5. Rukovodstvo po tekhnicheskomu obsluzhivaniu i tekhnikhemu remontu teplovozov (2004). Moscow, 406.

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DOI: 10.15587/1729-4061.2018.120977

**A STUDY OF THE EFFECT OF ELECTROSTATIC PROCESSING ON PERFORMANCE CHARACTERISTICS OF AXLE OIL** (p. 4–12)
A collector of the milking machine is the nodal element in the system of accumulation and transportation of the received milk to a milk pipeline. It was established that the structural-technological parameters of the milking machine collector influence the efficiency of machine milking. This is related to ensuring the completeness of milking and preserving the quality of the received milk. Existing designs of collectors perform their functions insufficiently and inefficiently. A delay in emptying the milk chamber disrupts operational characteristics of machine milking. It is possible to solve the problem by improving a transportation capability of the collector. For this purpose, we propose a two-section design of the milk chamber, which could eliminate the problem of milk overflow. Additional pressure gradient during the tact of compression can improve the mode of transportation and enable complete emptying of the milk chamber. The level of vacuum pressure under the nipple of a cow depends on the conditions of the transporting link collector-milk pipeline. The desired pressure gradient is established by supplying an additional portion of air from the separating chamber, through a throttle opening. The rate of establishing rational structural-technological parameters of the milking machine collector enables complete emptying of the milk chamber. Losses of vacuum pressure in a flexible network enable complete emptying of the milk chamber. This testifies to the interrelation between structural-technological parameters of the collector’s milk chamber and the modes of efficient milk transportation. A rational correlation between the volume of section of the milk chamber, the diameter of a milk hose and the diameter of a throttle opening enables effective transportation of milk while preserving its quality.
**Keywords:** pressure gradient, throttle opening, speed of milking, air supply, milk quality.

**References**

1. Bluemel, F. E., E. Savary, P., E. Schick, M. (2016). Effects of an extended c-phase on vacuum conditions in the milking cluster. Biosystems Engineering, 148, 68–75. doi: 10.1016/j.biosystemseng.2016.04.004

2. Kudlai, I. M., Lutsenko, M. M. (2010). Perspektyvnii tehnolohiiviy vyrobnytstva moloka. Visnyk Sumskoho nationalnoho ahrarnoho universytetu, 7, 64–68.

3. Besier, J., Bruckmaier, R. M. (2016). Vacuum levels and milk-flow-dependent vacuum drops affect machine milking performance and teat condition in dairy cows. Journal of Dairy Science, 99 (4), 3096–3102. doi: 10.3168/jds.2015-10340

4. Rose-Meierhans, U., Rose-Meierhans, L., Rose-Meierhans, P. (2015). Dynamics of teat-end vacuum during machine milking: types, causes and impacts on teat condition andudder health—a literature review. Journal of Applied Animal Research, 44 (1), 263–272. doi: 10.1080/09712119.2015.1031780

5. Mein, G. A. (2012). The Role of the Milking Machine in Mastitis Control. Veterinary Clinics of North America: Food Animal Practice, 28 (2), 307–320. doi: 10.1016/j.cvfa.2012.03.004

6. Upton, J., Penry, J. F., Rasmussen, M. D., Thompson, P. D., Reinemann, D. J. (2016). Effect of pulsation rest phase duration on teat end congestion. Journal of Dairy Science, 99 (5), 3958–3965. doi: 10.3168/jds.2015-10466

7. Strøgel, U., Rose-Meierhans, R., Brunsch, R. (2014). Design of a vacuum control system with frequent teat-end vacuum adaption for milking machines. Proceedings International Conference of Agricultural Engineering, Zurich, 1–6.

8. Kartashov, L. P. (1982). Mashinno doenci korov. Moscow: Kolos, 301.

9. Besier, J., Lind, O., Bruckmaier, R. M. (2015). Dynamics of teat-end vacuum during machine milking: types, causes and impacts on teat condition andudder health—a literature review. Journal of Applied Animal Research, 44 (1), 263–272. doi: 10.1080/09712119.2015.1031780

10. Strøgel, U., Rose-Meierhans, R., Brunsch, R. (2014). Design of a vacuum control system with frequent teat-end vacuum adaption for milking machines. Proceedings International Conference of Agricultural Engineering, Zurich, 1–6.

11. Paliy, A. P. (2016). Vplyv molokoprovidnykh system doilnykh ustanovok na spozhyvchi pokaznyky moloka. Tavryntstvo Ukrainy, 9, 22–29.

12. Molnar, V. (2014). Riven zakhvoriuvanosti koriv na mastytsiu. Lviv Polytechnic National University, Lviv, Ukraine. doi: 10.15587/1729-4061.2018.123002

13. Fenenko, A. I. (2008). Mekhanizatsiya doilnoho aparatu. Kolektor doilnoho aparatu. Pat. No. 66812 UA. MPK AO1J 7/00. No. 201104208; declared: 07.04.2011; published: 25.01.2012, Bul. No. 2.

14. Idel’chik, I. E.; Shteynberg, M. O. (Ed.) (1992). Spravochnik po gidravlicheskim soprotivleniyam. Moscow: Mashinostroenie, 672.

15. Loysyanskyi, L. G. (2003). Mekhanika zhiddkosti i gaza. Moscow: Drofa, 840.

16. Frolov, E. S., Minaychev, V. E., Aleksandrova, A. T. et. al.; Frolov, E. S., Minaychev, V. E. (Eds.) (1992). Vakuumnaya tehnika. Moscow: Mashinostroenie, 480.

**DOI:** 10.15587/1729-4061.2018.123002

**ESTIMATION OF CARRYING CAPACITY OF METALLIC CORRUGATED STRUCTURES OF THE TYPE MULTIPLATE MP 150 DURING INTERACTION WITH BACKFILL SOIL (p. 18–26)**

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We estimated the stressed state of a railroad structure with a large cross section spanning more than 6 m, which is made from metallic corrugated sheets of the type Multiplate MP 150. The stressed-strained state of the corrugated structure was estimated depending on the residual deformation of vertical diameter of the pipe, the modulus of elasticity of backfill soil, and the degree of compaction. The study conducted has demonstrated that maximum stresses occur on the horizontal sides of a metallic pipe, and maximum deformations—in the pipe vault.

It was established that an increase in the degree of compaction of backfill soil leads to a decrease in the stresses in a metallic pipe by almost half. The stresses grow much faster with an increase in irregularity on the railroad track. Numerical calculations have shown that the equivalent stresses exceed the permissible magnitude of 235 MPa when the degree of compaction of backfill soil is below 90 % and an operational irregularity on the track develops beyond the permissible magnitude.

Operational observations have shown that the pipe is most vulnerable, in terms of resistance against the formation of a plastic hinge, in the initial period of operation when the...
backfill soil has not yet reached the standard compaction. At the initial stage of operation of a metallic corrugated pipe it is necessary to improve the level of technological control in order to timely detect railroad track's irregularities that exceed the standards, and to eliminate them.

Under normal operational conditions, a metallic corrugated structure has a rather large reserve of carrying capacity, which amounts to 80%. However, these structures, despite their high initial strength margin, are very sensitive to an increase in external dynamic loads due to the occurrence of irregularity on the railroad track.

Keywords: residual deformation, carrying capacity, corrugated structure, modulus of elasticity, irregularity on the railroad track.

References
1. Posiybny do VBN V 2.3-218:198:2007 (2007). Sporudy transportu. Proektuvannya ta buduvnyctvo sporud iz metal-leykovykh hofrovanikh konstruktsiyi na avtomobilnych do-rohakh zahalnoho korystuvannia: Rekomendovano nauko-tekhnichnou radoiu DerzhdorNDI vid 17 lystopada 2006 r. No. 14. Kyiv, 122.
2. Koval, P. M., Babiak, I. P., Sitydьkova, T. M. (2010). Normuvannya pry proektuvannya i buduvnyctv sporud zn metal-leykovykh hofrovanikh konstruktsiyi. Visnyk Dnipropetrovskoho natsionalnoho universytetu zaliznychnoho transportu, 39, 114–117.
3. Luchko, Y. Y., Kovalechuk, V. V., Nabochenko, O. S. (2015). Study of carrying capacity of a corrugated metal construction by criterion of yield hinge development. Science & Transport Progress. Bulletin of Dnipropetrovsk National University of Railway Transport, 5 (59), 180–194. doi: 10.15802/stp2015/55340
4. Ssysyn, M., Kovalchuskh, W., Nabotschenko, O., Gerber, U. (2016). Die Tragfähigkeit von Eisenbahndurchlässen in Abhängigkeit von der Bauausführung und der Instandhal- tung. ETR – Eisenbahn-technische Rundschau, 39–44.
5. Luchko, Y. Y. (2013). Gruntoznavstvo, mekhanika gruntiv, osnovy ta fundamenty. L'viv: Kameniar, 320.
6. Kovalchuk, V., Luchko, J., Bondarenko, I., Markul, R., Parne- tа, B. (2016). Research and analysis of the stressed-strained state of metal corrugated structures of railroad tracks. Eastern-European Journal of Enterprise Technologies, 6 (7 (84)), 4–9. doi: 10.15587/1729-4061.2016.84236
7. Wysockowski, A., Janusz, L. (2007). Mostowe konstrukcje gruntowo – powlokowe. Laboratoryjne badania niszczace. Awarie w czasie budowy i eksploataacji. XXIII konferencja naukowo-techniczna. Szczeciń, 541–550.
8. Esmaeii, M., Zakeri, J. A., Ablurazagh, P. H. (2013). Minimum depth of soil cover above long-span steel-steel railway bridges. International Journal of Advanced Structural Engineering, 5 (1), 7. doi: 10.1186/2006-6605-5-7
9. Akad, F. R., Enakoutsa, K., Solanki, K. N., Tijpovidjojo, Y., Bammann, D. J. (2013). Modeling the Dynamic Failure of Railroad Tank Cars Using a Physically Motivated Internal State Variable Plasticity/Damage Nonlocal Model. Modeling and Simulation in Engineering, 2013, 1–11. doi: 10.1155/2013/815158
10. Novodzinskyi, A. L., Klevko, V. I. (2014). Uchet vliyaniya tolschchiny gofrorovanogo elementa na prochnost’ i us-tochivost’ metallicheskih vodoropusknyh trub. Vestnik PNIPU. Stroitel’stvo i arhitektura, 1, 81–94.
11. Saat, M. R., Barkan, C. P. L. (2011). Generalized railway tank car safety design optimization for hazardous materials transport: Addressing the trade-off between transportation efficiency and safety. Journal of Hazardous Materials, 189 (1-2), 62–68. doi: 10.1016/j.jhazmat.2011.01.136
12. AASHTO: Standart Specifications for Highway Bridges (2011). American Association of State Highway and Transport-ation Officials, 444 N. Capitol St., N. W., Ste. 249, Washington, D. C.
13. Handbook of steel drainage and highway construction products (2002). American Iron and Steel Institute. Canada.
14. Waster, M. (2008). RORBOAR. Verifiering av nyutvecklet dimensioneringsprogram samt vidareutveckling for jernvag-strafik. Orebro University, Sweden, 143.
15. Machelski, C. (2008). Modelowanie mostowych konstrukcji gruntowo-powlokowych. Dolno-slaaskie Wydawnictwo Eduka-acyjne, 208.
16. ODM 218.2.001-2009. Rekomendacii po proektirovaniyu vodoropunuyx metallicheskih gofrorovanoyx trub: Raspso-ryzhenie Federal’nogo dorozhnogo agentstva ot 21 iyulya 2009 г. No. 252-r.
17. Pettersson, L., Sundquist, H. (2007). Design of soil steel composite bridges. Structural Desing and Bridges, Stockholm, 84.
18. Posiybny do VBN V 2.3-218:198:2007 (2007). Sporudy transportu. Proektuvannya ta buduvnyctv sporud iz metal-leykovykh hofrovanikh konstruktsiyi na avtomobilnych do-rohakh zahalnoho korystuvannia. Kyiv, 122.
19. Chmelski, C. (2010). Kinematic method for determining influence function of internal forces in the steel shell of soil-steel bridge. Studia Geotechnica et Mechanica, XXXII (3), 28–40.
20. El-Sawy, K. M. (2003). Three-dimensional modeling of soil-steel culverts under the effect of truckloads. Thin-Walled Structures, 41 (6), 747–768. doi: 10.1016/S0263-8241(03)00022-3
21. Machelski, C. (2010). Kinematic method for determining influence function of internal forces in the steel shell of soil-steel bridge. Studia Geotechnica et Mechanica, XXXII (3), 28–40.
22. Elshimi, T. M. (2011). Three-dimensional nonlinear analysis of deep-corrugated steel culverts. Queen’s University Publ., 738.
23. Barbato, M., Bowman, M., Herbin, A. (2010). Performance evaluation of buried pipe installation. Louisiana State Univer-sity Press., 123.
24. Kovalchuk, V. V. (2015). The effect of corrugated elements thickness on the deflected mode of corrugated metal structures. Science and Transport Progress. Bulletin of Dnipropetrovsk National University of Railway Transport, 3 (57), 199–207. doi: 10.15802/stp2015/46079
25. Pettersson, L., Leander, J., Hansing, L. (2002). Fatigue de-sign of soil steel composite bridges. Archives of institute of civil engineering, 12, 237–242.

DOI: 10.15587/1729-4061.2018.123025
ON THE LIMITED ACCURACY OF BALANCING
THE AXIAL FAN IMPELLER BY AUTOMATIC BALL
BALANCERS (p. 27–35)

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The study explores the process of dynamic balancing of the impeller of an axial fan VO 08-300 (Ukraine) by two automatic ball balancers.

The computer simulation of the dynamics of the fan in the absence and presence of automatic balancers has confirmed the qualitative results of a previously conducted field full-scale experiment. Thus, the presence of automatic balancers reduces the following:

- the mean square value of the vibration velocity in the segment from the rotor start to the beginning of automatic balancing,
- the vibration velocity values at two resonant peaks when the rotor is running down, and
- the peaks of the vibration velocities in the section of the start of automatic balancing (74 times in the 3D modelling; 5.4 times in the field experiment).

The computer simulation of the dynamics of the axial fan with the on and off gravity forces has allowed determining the following:

- the effect of gravity on the accuracy of balancing the impeller decreases rapidly with increasing the cruising speed of the impeller,
- when increasing the forces of viscous resistance to the motion of the balls, the effect of gravity on the accuracy of the rotor balancing increases;
- at low speeds of rotation (15 r/s), the impeller can be balanced not better than by accuracy class G 2.5, but at the rated speed of 25 r/s, it is balanced according to accuracy class G 1.

Hereafter, the residual vibration velocities that are caused only by gravity decrease with increasing the rotor speed.

The residual vibration velocities that are caused only by the eccentricities of the racesways increase directly proportionally to the rotor speed. Therefore, fast-turning rotors need a more precise installation of automatic balancers. It is recommended to reduce the eccentricity of the racesway of the automatic balancer at least 2.5 times in relation to the maximum permissible value.

Residual vibration velocities in the automatic balancing mode (up to 3 mm/s) on the test fan are mostly caused by gravity. The probable causes of residual vibration velocities are eccentricities of the racesways of the automatic balancers, standstill of the balls (lack of reaction to small unbalances), etc. Therefore, residual vibration velocities can be reduced at the stages of manufacturing and installing automatic balancers into a fan.

Keywords: axial fan, automatic ball balancer, automatic balancing, static balancing, dynamic balancing, transients.

References
1. Polyakov, V., Skvortsov, L. (1990). Pumps and Fans. Moscow: Stroyizdat, 336.
2. Ziborov, K., Vanga, G., Marenko, V. (2013). Imbalance As A Major Factor Influencing The Work Rotors Mine Main Fan. Modern engineering. Science and education, 3, 734–740. Available at: http://mmese-2017.spbstu.ru/mese/2013/734_740.pdf
3. Korneev, N., Polyakova, E. (2014). Aerodynamic disbalance of the turbocompressor as the reason of lowering of power indexes of internal combustion engines. Machine Builder, 1, 51–57.
4. Yatsun, V., Filimonikhin, G. (2008). Experimental study of the efficiency of equilibration of impellers of axial fans by passive auto-balancers. Konstruyuvannya, vyrobnytstvo ta eksplyyatatsiya silskohospodarskykh mashyn, 38, 100–105.
5. Filimonikhin G., Yatsun, V. (2008). Chyslove modeluvannia protsesu zrivnovazhennia kulovymy avtobalansyramy krylchatky osovooho ventylatora [Numerical modeling of the balancing process by ball-type auto-balancers of an axial fan impeller]. Naukovyi visnyk natsionalnoho hirnychoho universytetu, 10, 72–77.
6. Olijnichenko, L., Filimonikhin, G. (2014). Optimization of parameters of autobalancers for dynamic balancing of impeller fans by 3D modeling. Eastern-European Journal of Enterprise Technologies, 6 (7 (72)), 12–17. doi: 10.15587/1729-4061.2014.30498
7. Olijnichenko, L., Goncharov, V., Sidei, V., Horpyynchok, O. (2017). Experimental study of the process of the static and dynamic balancing of the axial fan impeller by ball auto-balancers. Eastern-European Journal of Enterprise Technologies, 2 (1 (86)), 42–50. doi: 10.15587/1729-4061.2017.96374
8. Goncharov, V., Filimonikhin, G., Nevadka, A., Pirogov, V. (2017). An increase of the balancing capacity of ball or roller-type auto-balancers with reduction of time of achieving auto-balancing. Eastern-European Journal of Enterprise Technologies, 1 (7 (85)), 15–24. doi: 10.15587/1729-4061.2017.92834
9. Chung, J. (2005). Effect of gravity and angular velocity on an automatic ball balancer. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 219 (1), 43–51. doi: 10.1243/095440605X3833
10. Chan, T. C., Sung, C. K., Chao, P. C. P. (2012). Friction effect on ball positioning of an automatic balancer in optical disk drives. Microsystem Technologies, 18 (9-10), 1343–1351. doi: 10.1007/s00542-012-1540-y
11. Bykov, V. G., Kovachev, A. S. (2014). Dynamics of a rotor with an eccentric ball auto-balancing device. Vestnik St. Petersburg University: Mathematics, 47 (4), 173–180. doi: 10.3103/s1063454114040037
12. Sung, C. K., Chan, T. C., Chao, C. P., Lu, C. H. (2013). Influence of external excitations on ball positioning of an automatic balancer. Mechanism and Machine Theory, 69, 115–126. doi: 10.1016/j.meccmech.2013.05.009
13. Chang, K.-H. (2008). Motion Simulation and Mechanism Design with COSMOSMotion 2007. Norman, Oklahoma, Paperback: Schreff Development Corporation, 142.

DOI: 10.15587/1729-4061.2018.121507

PREREQUISITES FOR THE DEVELOPMENT OF HYDRO-JET TECHNOLOGY IN DESIGNING WOMEN’S HEADGEAR AT HOSPITALITY ESTABLISHMENTS (p. 36–46)

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this case, mean value of coefficient of losses is

Measurements are carried out at the distance of 1–30 mm between the mouthpiece, which makes it possible to calculate the desired parameters of pressure in the range from 0.01 to 10 MPa.

The influence of geometric parameters of conoidal jet-forming mouthpieces with round and elliptical outlet openings on dynamic pressures of submerged hydro-jets, formed by them, was explored. The experimental values of dynamic pressures of hydro-jet were found to be within specific formation effort ranging from 0.02 to 0.12 MPa. In this case, mean value of coefficient of losses is $K_p = 0.66–0.99$ when using conoidal mouthpieces with round outlet opening, and $K_p = 0.42–0.99$ when using conoidal mouthpieces with an elliptical outlet opening.

Selection of the submerged hydro-jet as a tool for shaping volumetric headgear details was substantiated. The experimental device for determining dynamic pressures of the submerged hydro-jet, which consists of the dynamometer, the power source, the contact group, the platform for operation of the submerged hydro-jet, as well as the top platform, was developed. The device operates so that the measurement of pressure of the submerged hydro-jet could be carried out by measuring reaction force, the module of which is equal to pressure module, and the vector is reverse. This happens due to the transfer of action forces from the fluid to the air medium with the help of the two-arm lever. Measurements are carried out at the distance of 1–30 mm between the jet-forming mouthpiece and the surface of material, treated at maximal pressure of working medium of 150 MPa.

We developed a method for determining dynamic pressures of the submerged hydro-jet depending on geometrical parameters of mouthpieces, such as: length of cylindrical and conoidal parts of the mouthpiece, inlet and outlet diameters of the mouthpiece, radius of the mouthpiece, initial section of the submerged hydro-jet with round outlet openings, radius of the jet in the transition section, semi-axes of the elliptic outlet opening of the mouthpiece, initial section of the submerged hydro-jet with elliptical outlet openings, semi-axes of jets in the transition cross-section. The method provides for determining of hydro impact power of the submerged jet depending on cross-section area at a fixed distance from the end of the mouthpiece, which makes it possible to calculate the desired parameters of pressure in the range from 0.01 to 10 MPa.

Keywords: hydro-jet technology, women's headgear, design, shaping of headgear details, submerged hydro-jet.

References
1. Yakymchuk D., Yakymchuk O., Chepeliuk O., Myrohorod ska N., Koshkevko J., Orlenko O., Nosova I. (2017). Study of cutting presses in designing a women’s costume for hospitality industry. Eastern-European Journal of Enterprise Technologies, 5 (1 (89)), 26–36. doi: 10.15587/ 1729-4061.2017.110962

2. Yakymchuk, O. V., Yakymchuk, D. M., Myrohorod ska, N. V. (2017). Innovative feminine Indian suit as an inspiration of clothes design of hospitality establishments, Science and Education a New Dimension. Humanities and Social Sciences, 23 (139), 7–9.

3. Borkovski, J., Shimizu, S., Peng, G., Oguma, Y. (2015). Simulation of a high-pressure water jet structure as an innovative tool for pulverizing copper ore in KGHM Polska Miedz S. A. Mining Science, 22, 147–159. doi: 10.5277/msc152212

4. Zakharkevich, O. V., Kuleshova, S. G. (2017). Development of the method of scaling patterns and virtual garments forms. Vlakna a Textil, 4, 34–40.

5. Cui, L., An, L., Gong, W. (2006). Optimizing process parameters of high pressure water jet null. The 8th Pacific Rim International Conference on Water Jet Technology, 138–145.

6. Peng, G., Shimizu, S., Fujikawa, S. (2009). Numerical simulation of Turbulent Cavitating Water Jets Issued from a Submerged Orifice Nozzle. 9th Pacific Rim International Conference on Water Jetting Technology, 139–144.

7. Shimizu, S., Chimoda, Y., Peng, G. (2008). Flow characteristics of water jet issuing from a fan jet nozzle. 19th International Conference on Water Jetting, BHR Group Ltd., UK, 55–65.

8. Shimizu, S. (2006). Structure and erosive characteristics of water jet issuing from fan jet nozzle. 18th International Conference on Water Jetting, 337–345.

9. Ito, H., Aoyama, T., Peng, G., Shimizu, S. (2009). Observations of cavitating jets issuing from a sheathed nozzle. 9th Pacific Rim International Conference on Water Jetting Technology, 97–100.

10. Seminska, N. (2007). Hidrostrumyjni metody ruinvannia materialiv. Masynoznavstvo, 5, 22–25.

11. Atanov, G. A. (1987). Gidroimpu’snl'ne ustanovki dlya razrusheniya gornyh porod. Kyiv: Vyysche shkola, 155.

12. Stepanov, V. G., Shavrov, I. A. (1975). Vysokoenergeticheskie impul’snye metody obrabotki materialov. Leningrad: Mashinostroenie, 280.

13. Lamekin, N. S. (2000). Kavitatsiya: teoriya i primenenie. Moscow: RUSAKI, 248.

14. Fedorkin, I. M., Gulya, I. S. (1998). Kavitatsiya. Kavita-tionnye energeticheskie apparaty i ustanovki. Kyiv: Ark- tur-A, 131.

15. Plyuta, V. E., Sivakov, A. L., Gorchakov, G. M., Kordochkin, B. A. (1986). Sposob roki vyosokonapornoy struey zhidkosti i ustrystvno dlya ego ososhchestvlenia: A. s. No. 1377172a SSSR. MKI4 B 23 D 31/00. No. 4079367/25-27; declared: 20.06.1986; published: 29.02.1988, Bul. No. 8.

16. Burlyka, A. F., Shul’man, G. M., Fridman, R. A., Guenko, V. S., Zenkin, A. S., Larionov, M. T. (1983). Sposob gidrostrumyneyo roki listovych materialov: A. s. No. 159162a SSSR. MKI5 B 23 D 31/00. No. 3607698/25-27; declared: 13.06.1983; published: 30.06.1985, Bul. No. 24.

17. Sokolov, N. Yu., Zadonin, A. S. (1990). Ustanovka dlya roki listovogo materiala struy zhidkosti sverhvysoko-
Abstract and References. Engineering technological systems

22. Tihonirov, R. A., Kovalev, Yu. V., Petuhov, E. N., Stari-kov, I. D. (1987). Sopol’ k ustroystvu dlya rezki zhidkosti vysokogo davleniya: A. s. No. 1734964 SSSR. MK15 V 23 D 31/00. No. 4800884/27; declared: 30.01.1990; declared: 23.05.1992, Bul. No. 19.

18. Novikov, V. A., Arhipov, A. N., Shoshlin, V. G., Sarateev, A. N. (1987). Ustroystvo dlya rezki struey vody: A. s. No. 1549679a SSSR. MK14 B 23 D 31/00. No. 4259091/31-27; declared: 17.04.1987; published: 23.03.1989, Bul. No. 11.

19. Belyaev, S. V., Kedrovskiy, B. G., Klaptsov, Yu. V., Petko, I. V., Yanikin, I. N., Kudryavtsev, K. K. (1986). Nasadka sopla: A. s. No. 14094240a SSSR. MK14 B 23 D 31/00. No. 26 F 3/00. No. 4203511/27; declared: 21.10.1987; published: 30.03.1991, Bul. No. 11.

20. Belyaev, S. V., Kedrovskiy, B. G., Klaptsov, Yu. V., Petko, I. V., Slobodyanyuk, V. A. (1987). Sposob rezaniya voskoksokorost- noy struey zhidkosti: A. s. No. 1433606a SSSR. MK14 B 23 D 31/00. No. 4206762/28-27; declared: 09.03.1987; declared: 30.10.1988, Bul. No. 40.

21. Preobrazhenskiy, V. P. (1978). Teplotekhnicheskie izmereniya i pribory. Moscow: Energiya, 704.

22. Petko, I. V., Slobodyanyuk, V. A. (1992). Obespechenie stabilnosti istecheniya strui zhidkosti za schet vybora ratsional’nykh parametrov gidroreznoy ustanovki. Izvestiya vysshih uchebnyh zavedeniy. Tekhnologiya legkoy promyshlennosti, 4, 127–131.

23. Petko, I. V., Kedrovskiy, B. G., Klaptsov, Yu. V., Slobodyanyuk, V. A. (1992). Perspektivy razvitiya gidroreznoy ustanovki vo vremya pereklyucheniya gidroraspredelitelya. Izvestiya vysshih uchebnyh zavedeniy. Tekhnologiya legkoy promyshlennosti, 5, 125–127.

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DOI: 10.15587/1729-4061.2018.121712

MOДЕLLING THE LOADING OF THE NOSE-FREE CUTTING EDGES OF FACE MILL WITH A SPIRAI-SPETED ARRANGEMENT OF INSERTS (p. 46–54)
A mathematical model of loading of the nose-free cutting edges of each insert of the face mill with a spiral-stepped cutting scheme was created. It was established that the size of the cut elements depends on the feed magnitude, the design parameters of the mill and the position of inserts on the contact arc. Variable factors of simulation included the feed magnitude, the clearance angle of the inserts and slope angles of the cutter assemblies. This made it possible to determine the chip thickness and width of cut, the depth of cut, the maximum value of the main cutting edge angle and the cut area at an arbitrary position of the face mill on the contact arc. Simulation in the SolidWorks Motion environment has confirmed reliability of mathematical modeling of loading of the cutting edges of the mill. The relative error in determination of the cut area was in the range from 1.8% to 5.7%.

Calculation of the cut elements in the arbitrary position of the cutter insert on the contact arc was made in the Maple environment. Analysis of influence of the design parameters of the cutter and the magnitude of feed on the values of the cut elements was made. It has been established that an increase in feed caused a linear increase in the chip thickness and width of cut and the depth of cut for the inserts of all steps. Optimal values of the clearance angle of the mill inserts (16°) and slope of the cutting assemblies (6°) were determined for the milling depth of 3 mm. Recommendations on the choice of rational values of design parameters of the face mill for its effective operation at various depths of cut were given.

Thus, there are grounds to assert the possibility of improving productivity of machining flat surfaces at a required quality due to the use of nose-free face mills with a spiral-stepped cutting scheme.

**Keywords:** face milling, cut elements, stepped cutting schemes.

**References**

1. Akıntaş, Y., Budak, E. (1995). Analytical Prediction of Stability Lobes in Milling. CIRP Annals, 44 (1), 357–362. doi: 10.1016/s0007-8506(07)62342-7
2. Euan, I. G., Ozturk, E., Sims, N. D. (2013). Modeling Static and Dynamic Cutting Forces and Vibrations for Inserted Ceramic Milling Tools. Procedia CIRP, 8, 564–569. doi: 10.1016/j.procir.2013.06.151
3. Stepchyn, Ya. A. (2015). Porivinialna kharakterystyka dynamiky protsesuv toptsevoho frezeruvannia frezamy standartnykh ta spetsialnykh konstruktsiyi. The Journal of Zhytomyr State Technological University, 1 (72), 51–56.
4. Klimenko, S. A. (2017). Improvement of performance of finishing of details with a cutting tool. The Journal of Zhytomyr State Technological University, 2 (2 (80)), 56–66. doi: 10.26642/tu-2017-2(80)-56-66
5. Hlombotska, L. Ye., Melnychuk, P. P. (2010). Vdoksovalonnia protsesuv toptsevoho frezeruvannia zahartovanych stali: problemy, propozytysi, obruggruntuvannia. Visnyk ZhDU, 2 (53), 3–15.
6. Muiñe-Escalona, P., Maropoulos, P. G. (2015). A geometrical model for surface roughness prediction when face milling Al 7075-T7351 with square insert tools. Journal of Manufacturing Systems, 36, 216–223. doi: 10.1016/j.jmsy.2014.06.011
7. Sat, K., Bouzid, W. (2005). Roughness modeling in up-face milling. The International Journal of Advanced Manufacturing Technology, 26 (4), 324–329. doi: 10.1007/s00170-004-2305-2
8. Moskvin, P., Balyskina, N., Melnychuk, P., Rudnetskiy, V., Krylyovych, V. (2017). Special features in the application of fractal analysis for examining the surface microrelief formed at face milling. Eastern-European Journal of Enterprise Technologies, 2 (1 (86)), 9–15. doi: 10.15587/1729-4061.2017.96403
9. Popke, H., Emmer, T., Alex, R. (2001). Dynamisch stabile Fäden mit Schnittaufteilung. Werkstatt und Betrieb: WB (München), 12 (134), 23–29.
10. Karpuschewski, B., Batt, S. (2007). Improvement of Dynamic Properties in Milling by Integrated Stepped Cutting. CIRP Annals, 56 (1), 85–88. doi: 10.1016/j.cirp.2007.05.001
11. Vyhovskiy, H. M., Hromovyi, O. A., Melnychuk, P. P. (2000). Vykorystannia kinematychnykh skhem rizannia pri chysto-vomu tortsevomu frezeruvanni. Visnyk ZhitTI, 13, 18–25.
12. Vyhovskiy, H. M., Hromovyi, O. A., Melnychuk, P. P. (1999). Rozrakhunok syl rizannia pri obrobtsi detalei stupin chastymy tortsevymy frezamy. Visnyk ZhitTI, 11, 58–66.
13. Vyhovskiy, H. M. (1998). Kolivannia syl rizannia pri obrobtsi detalei tortsevymy stuppin chastymy frezamy. Visnyk ZhitTI, 9, 28–32.
14. Ghorbani, H., Moetakef-Imani, B. (2016). Specific cutting force and cutting condition interaction modeling for round insert face milling operation. The International Journal of Advanced Manufacturing Technology, 84 (5-8), 1705–1715. doi: 10.1007/s00170-015-7985-2
15. Manohin, A. S., Klimenko, S. A., Mel‘niychuk, Yu. A. (2010). Parametry secheniya sreza pri tochenii instrumentom s tsilindricheskoy peredney poverhnostyu. Rezanie i instrument v tsehnologicheskikh sistemah, 78, 105–112.
16. Mel‘niychuk, Yu. A., Klimenko, S. A., Manohin, A. S. (2011). Vliyanie rezhimov ohraborki na sily rezaniya pri tochenii detalei iz zakalennoy stali instrumentom s tsilindricheskoy peredney poverhnostyu. Nadzivnist instrumentu ta optymizatsiya tsekhonolohichnych system, 28, 39–43.

**DOI:** 10.15587/1729-4061.2018.123223

**ALOE VERA AS CUTTING FLUID OPTIMIZATION USING RESPONSE SURFACE METHOD (p. 53–63)**

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The fluid of vegetable Aloe Vera has characteristics as a cutting fluid, Aloe Vera cutting fluid (AVCF) has an excess of environmental reduction effects from oil-based cutting fluid (OBCF). Surface Response Methodology (RSM) based Central Composite Design (CCD) was applied as an experimental design, to predict the optimum parameters in the turning process. Because RSM is the final description of a good experimental design to improve the linear response surface model, and in determining the optimum operating...
conditions. Twenty sets of experimental tests were prepared by three reversed parameter factors, feed rate ($f$), depth of cut ($a$), and AVCF three type. Roughness ($Ra$) and flank wear ($Vf$) were defined as response variables and then analyzed by multiple quadratic regression to determine the most appropriate mathematical model. The combined effects of the parameters were investigated using contour plots and surface plots. HSS as a cutting tool and Steel St.42 workpiece were used to achieve 20 tests. The adequacy of the developed model was examined using Analysis of Variance. Based on the results, the optimum process is shown by the following parameters: $f=0.140$ mm/rev; $a=2.0556$ mm, and AVCF=71.8970 cSt provide optimal cutting conditions with lower $Ra$ and $f=0.20$ mm/rev, $a=2.50$ mm, and AVCF=8.8050 cSt gieoptimatimal conditions with lower VB. Therefore, the improvement of AVCF as a substitute for OBCF continued experiments.

**Keywords:** Optimization, Aloe Vera, Flank Wear, Surface Roughness.

**References**

1. Lawal, S. A., Choudhury, I. A., Nukman, Y. (2012). Application of vegetable oil-based metalworking fluids in machining ferrous metals – A review. International Journal of Machine Tools and Manufacture, 52 (1), 1–12. doi: 10.1016/j.ijmachtools.2011.09.003
2. Ramana, M. V., Rao, K. M., Rao, D. H. (2013). Effect of Process Parameters on Surface Roughness in Turning of Titanium Alloy under Different Conditions of Lubrication – Recent. Recent Advances in Robotics, Aeronautical and Mechanical Engineering, 85–91.
3. Sharafaddeen, K. K., Jamin, K. O. (2013). Performance Evaluation of Vegetable Oil-Based Cutting Fluids in Mild Steel Machining. Chemistry and Materials Research, 3 (9), 35–45.
4. Rahim, E. A., Sasahara, H. (2011). A study of the effect of palm oil as MQL lubricant on high speed drilling of titanium alloys. Tribology International, 44 (3), 309–317. doi: 10.1016/j.triboint.2010.10.032
5. Priarone, P. C., Robiglio, M., Settineri, L., Tebaldo, V. (2015). Effectiveness of Minimizing Cutting Fluid Use when Turning Difficult-to-cut Alloys. Procedia CIRP, 29, 341–346. doi: 10.1016/j.procir.2015.02.006
6. Prakash, D., Ramana, M. V. (2013). Performance Evaluation of Different Tool in Turning of Ti-6Al-4V Alloy Under Different Coolant Condition. International Journal of Science and Research.
7. Deb Nath, S., Reddy, M. M., Yi, Q. S. (2014). Environmental friendly cutting fluids and cooling techniques in machining a review. Journal of Cleaner Production, 83, 33–47. doi: 10.1016/j.jclepro.2014.07.071
8. Deb Nath, S., Reddy, M. M., Yi, Q. S. (2016). Influence of cutting fluid conditions and cutting parameters on surface roughness and tool wear in turning process using Taguchi method. Measurement, 78, 111–119. doi: 10.1016/j.measurement.2015.09.011
9. Machai, C., Ishbal, A., Biermann, D., Upmeier, T., Schumann, S. (2013). On the effects of cutting speed and cooling methodologies in grooving operation of various tempers of β-titanium alloy. Journal of Materials Processing Technology, 213 (7), 1027–1037. doi: 10.1016/j.jmatprotec.2013.01.021
10. Liu, Z., An, Q., Xu, J., Shen, M., Han, S. (2013). Wear performance of (nc-AlTiN)/(α-Si3N4) coating and (nc-AlCrN)/(α-Si3N4) coating in high-speed machining of titanium alloys under dry and minimum quantity lubrication (MQL) conditions. Wear, 305 (1-2), 249–259. doi: 10.1016/j.wear.2013.02.001
11. Shyha, I., Gariani, S., Bhatti, M. (2015). Investigation of Cutting Tools and Working Conditions Effects when Cutting Ti-6Al-4V using Vegetable Oil-Based Cutting Fluids. Procedia Engineering, 132, 577–584. doi: 10.1016/j.proeng.2015.12.535
12. Hartono, P., Pratikto, Suprapto, A., Irawan, Y. S. (2017). Characterisation of Aloe Vera as a Cutting Fluid. Modern Machinery Science Journal.
13. Komposisi Kimia Gel Lidah Buaya (Aloe vera L.) (1992). Ministry of Health of Republic of Indonesia.

**DOI:** 10.15587/1729-4061.2018.122970

**INFLUENCE OF THE PROPERTIES OF BLAST FURNACE SLAG ON CAST IRON HEATING AT PULVERIZED COAL INJECTION (p. 63–70)**

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In the course of the studies at two industrial blast furnaces, we established a change in the characteristics of slag mode and cast iron heating, resulting from the transition to the pulverized coal fuel injection with a decrease in basicity of CaO/SiO2 slag from 1.16 to 1.10 and from 1.20 to 1.12 units. It was shown that depending on a particular influence of alumina and magnesia in the slag composition, as well as on their ratio, a decrease in slag basicity can be accompanied by both an increase and a decrease in viscosity. During the research, the dependence between slag viscosity at the temperature of 1,400 °C and chemical heating of cast iron heating at the outlet was established. According to obtained data, an increase in slag viscosity by 0.1 Pas was accompanied by an increase in silica concentration in cast iron by 0.08–0.1 %.

The relation of physical heating of metal with slag basicity and stoichiometry was established. It was shown that a decrease in basicity of (CaO+MgO)/SiO2 by 0.1 units led to a decrease in cast iron temperature by 30 °C. Such a substantial effect of basicity of metal heating indicates the need to take this influence into account not only to control the blast furnace process, but also to state the thermal balance of steel smelting.

It was shown that in the studied range of slag compositions, the influence of magnesia on heating of cast iron is limited. A slight influence of MgO on physical heating of metal was pronounced at a magnitude of the ratio Al2O3/MgO that is close to unity.

Results of present research could be used to improve control over blast furnace smelting in terms of taking into consideration slag influence on heating of cast iron.
Keywords: blast furnace, slag practice, viscosity, basicity, slag composition, heating of cast iron.

References
1. Kuznetsov, M. S., Kryachko, G. Yu., Lebed, Yu. K., Valuyeva, N. N. (2016). Slag changing properties and cast iron heating while natural gas and pulverized coal blowing in the hearth of the blast-furnace. Metallurgicheskaya i gornorudnaya promyshlennost', 4, 3–7.
2. Zamuraev, V. M., Popov, V. E., Ivlev, V. P., Khrapko, A. V., Didevich, A. V., Tyutyunnik, Yu. M. (2010). Development of blast furnace melting technology without using natural gas with pulverized coal injection. Metallurgical and mining industry, 5, 14–16.
3. Muller, J., Erwee, M. (2011). Blast Furnace Control using Slag Viscosities and Liquidus Temperatures with Phase Equilibria Calculations. Southern African Pyrometallurgy, Johannesburg, 309–326.
4. Shiau, J.-S., Liu, S.-H., Ho, C.-K. (2012). Effect of Magnesium and Aluminum Oxides on Fluidity of Final Blast Furnace Slag and Its Application. MATERIALS TRANSACTIONS, 53 (8), 1449–1455. doi: 10.2320/matertrans.m2012170
5. Chen, M., Zhang, D., Kou, M., Zhao, B. (2014). Viscosities of Iron Blast Furnace Slags. ISIJ International, 54 (9), 2025–2030. doi: 10.2355/isijinternational.54.2025
6. Ghosh, D., Krishnamurthy, V. A., Sankaranarayanan, S. R. (2010). Application of optical basicity to viscosity of high alumina blast furnace slags. Journal of Mining and Metallurgy, Section B: Metallurgy, 46 (1), 41–49. doi: 10.2298/jmmb1001041g
7. Sugura, M., Otani, Y., Nakashima, M., Omoto, N. (2014). Continuous Temperature Measurement of Liquid Iron and Slag Tapped from a Blast Furnace. SICE Journal of Control, Measurement, and System Integration, 7 (3), 147–151. doi: 10.9746/jcmsi.7.147
8. Suthar, M. S., Patel, I. J., Zinzala, P. (2015). Analysis of Slag Flow in Blast Furnace during the Extraction of Iron. International Journal of Engineering Development and Research, 3 (3).
9. Liu, Z., Chu, M., Wang, H., Zhao, W., Xue, X. (2016). Effect of MgO content in sinter on the softening–melting behavior of mixed burden made from chromium-bearing vanadium-titanium magnetite. International Journal of Minerals, Metallurgy, and Materials, 23 (1), 25–32. doi: 10.1007/s12613-016-1207-2
10. Voskoboinikov, V. G., Dunaev, N. Ye., Mikhalevich, A. G., Kukhtin, T. I., Shtengel-Miner, S. V. M. (1975). Properties of liquid blast-furnace slags. Moscow: Metallurgy, 184.
11. Togobitskaya, D. N., Stovpchenko, A. P., Lisova, L. A., Polishko, A. A., Stepanenko, D. A. (2016). Prediction of physicochemical properties of slag ESR based on the model of interatomic interaction. Modern electrometallurgy, 4, 16–21.