ABSTRACT AND REFERENCES

APPLIED MECHANICS

DOI: 10.15587/1729-4061.2019.184551

IMPROVING THE MASS EFFICIENCY OF A COMPOSITE LAUNCH VEHICLE HEAD FAIRING WITH A SANDWICH STRUCTURE (p. 6–18)

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Analysis of practical experience in the construction and operation of the main fairings of launch vehicles has revealed the currently widely used sandwich structures with composite load-bearing sheathing combined with a cellular filler. The considered structures are characterized by a rather large number of parameters whose variation significantly changes the mass of an article.

An approach to optimizing such structures as the main fairing of a launch vehicle in terms of mass has been further developed. The approach includes the essentially improved components of fragments of known analogs, previously developed by a team of authors, as well as the new fragments, which were not taken into consideration before. In contrast to known works, the approach has made it possible to solve the complex multi-parametric task on the optimal design of the considered class of equipment, almost without loss of accuracy. To this end, the optimization process was divided into several stages based on the reasonable levels of parameters' significance that are included in the objective function – a minimal mass. An analysis of effectiveness of the reinforcement structure for bearing sheaths has been performed, as well as the preliminary optimization of a cellular filler's properties, which significantly simplified the selection of their optimal parameters. It has been shown that at a minimum gain in mass due to the optimal reinforcement scheme, which is approximately 5 % compared to a quasi-homogeneous sheath, there is an actual risk of a two-fold increase in the mass of a sheath when choosing a substantially non-optimal structure of the sheath.

The result of this study is the established rational parameters for a scheme of reinforcement of bearing sheaths and a cellular filler, as well as their geometric parameters, which ensured a reduction in the mass of the main fairing in comparison with the basic variant, by 51 % or 118.2 kg. The results obtained allow further development and improvement, with almost no changes in its concept and structure in the direction of integration of auxiliary structural elements of the head fairing into optimization.

Keywords: optimization for mass, head fairing, sandwich structures, bearing sheaths, cellular filler.

References

1. Webb, G., Da Silva Curiel, A. (2008). Is Access to Space Really a Hurdle? Proceedings of the International Astronautical Congress, IAC 59. Glasgow, United Kingdom, 4064–4077.
2. Milinevsky, G., Yatskiv, Y., Degtyaryov, O., Syniavskyi, I., Mishchenko, M., Rosenbush, V. et. al. (2016). New satellite project Aerosol-UA: Remote sensing of aerosols in the terrestrial atmosphere. Acta Astronautica, 123, 292–300. doi: https://doi.org/10.1016/j.actaastro.2016.02.027
3. Slyvyns'kyy, V., Gajdachuk, V., Gajdachuk, A., Slyvyns'ka, N. (2005). Weight optimization of honeycomb structures for space applications. 56th International Astronautical Congress of the International Astronautical Federation, the International Academy of Astronautics, and the International Institute of Space Law. doi: https://doi.org/10.2514/6.iac-05-c2.3.07
4. Slyvynskyi, V. I., Sanin, A. F., Kharchenko, M. E., Kondratyev, A. V. (2014). Thermally and dimensionally stable structures of carbon-carbon laminated composites for space applications. Conference: 65th International Astronautical Congress. At Toronto, Canada.
5. Griffin, M. D., French, J. R. (2004). Space vehicle design. Reston. doi: https://doi.org/10.2514/4.862403
6. Ochinero, T., Deiters, T., Higgins, J., Arritt, B., Blades, E., Newman, J. (2009). Design and Testing of a Large Composite Asymmetric Payload Fairing. 50th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference. doi: https://doi.org/10.2514/6.2009-2696
7. Henson, G. (2018). Materials for Launch Vehicle Structures. Aerospace Materials and Applications, 435–504. doi: https://doi.org/10.2514/5.9781624104893.0435.0504
8. Nunes, J. P., Silva, J. F. (2016). Sandwiched composites in aerospace engineering. Advanced Composite Materials for Aerospace Engineering, 129–174. doi: https://doi.org/10.1016/b978-0-08-100037-3.00005-5
9. Herrmann, A. S.; Virson, J. R. (Ed.) (1999). Design and Manufacture of Monolithic Sandwich Structures with Cellular Cares. Stockholm, 274.
10. Slyvynskyi, V. I., Alyamovskyi, A. I., Kondratjev, A. V., Kharchenko, M. E. (2012). Carbon honeycomb plastic as light-weight and durable structural material. 63th International Astronautical Congress, 8, 6519–6529.
11. Vasiliev, V. V., Gurdal, Z. (1999). Optimal Design: Theory and Applications to Materials and Structures. CRC Press, 320.
12. Slyvyns'kyy, V., Slyvyns'kyy, M. et. al. (2006). New Concept for Weight Optimization of Launcher Nose Firings Made of Honeycomb Structures. 57th International Astronautical Congress. doi: https://doi.org/10.2514/6.iac-06-c2.p.1.11
13. Ganguli, R. (2013). Optimal Design of Composite Structures: A Historical Review. Journal of the Indian Institute of Science, 93 (4), 557–570.
14. Linnik, A. K., Krasnikova, R. D., Lipovskiy, V. I., Baranov, E. Yu. (2018). Kompozity v konstruktsiyah korpusov raket-nositeley. Sistemniy analiz problem i perspektiv razrabotki i primeneniya. Dnipro: LIRA, 260.
15. Gaidachuk, V. E., Kondratiev, A. V., Chesnokov, A. V. (2017). Changes in the Thermal and Dimensional Stability of the Structure of a Polymer Composite After Carbonization. Mechanics of Composite Materials, 52 (6), 799–806. doi: https://doi.org/10.1007/s11029-017-9631-6
16. Smerdov, A. A. (2000). A computational study in optimum formulations of optimization problems on laminated cylindrical shells for buckling I. Shells under axial compression. Composites Science and Technology, 60 (11), 2057–2066. doi: https://doi.org/10.1016/s0266-3538(00)00102-0
17. Smerdov, A. A. (2000). A computational study in optimum formulations of optimization problems on laminated cylindrical shells for buckling II. Shells under external pressure. Composites Science and Technology, 60 (11), 2067–2076. doi: https://doi.org/10.1016/s0266-3538(00)00103-2

18. Zheng, Q., Jiang, D., Huang, C., Shang, X., Ju, S. (2015). Analysis of failure loads and optimal design of composite lattice cylinder under axial compression. Composite Structures, 131, 885–894. doi: https://doi.org/10.1016/j.compstruct.2015.06.047
19. Totaro, G., Gürdal, Z. (2009). Optimal design of composite lattice shell structures for aerospace applications. Aerospace Science and Technology, 13 (4-5), 157–164. doi: https://doi.org/10.1016/j.ast.2008.09.001
20. Totaro, G. (2013). Local buckling modelling of isogrid and anisogrid lattice cylindrical shells with hexagonal cells. Composite Structures, 95, 403–410. doi: https://doi.org/10.1016/j.compstruct.2012.07.011
21. Slyvyns'kyy, V., Slyvyns'kyy, M., Polyakov, N. et. al. (2008). Scientific fundamentals of efficient adhesive joint in honeycomb structures for aerospace applications. 59th International Astronautical Congress 2008.
22. Vijayakumar, S. (2004). Parametric based design of CFRP honeycomb sandwich cylinder for a spacecraft. Composite Structures, 65 (1), 7–12. doi: https://doi.org/10.1016/s0263-8223(03)00176-4
23. Karpov, Y. S., Gagauz, P. M. (2010). Structural optimization of composite panels under strength and stability restrictions. Strength of Materials, 42 (6), 631–636. doi: https://doi.org/10.1007/s11223-010-9251-z
24. Gaydachuk, V., Koloskova, G. (2016). Mathematical modeling of strength of honeycomb panel for packing and packaging with regard to deviations in the filler parameters. Eastern-European Journal of Enterprise Technologies, 6 (1 (84)), 37–43. doi: https://doi.org/10.15587/1729-4061.2016.85853
25. Kondratiev, A., Gaidachuk, V. (2019). Weight-based optimization of sandwich shelled composite structures with a honeycomb filler. Eastern-European Journal of Enterprise Technologies, 1 (1 (97)), 24–33. doi: https://doi.org/10.15587/1729-4061.2019.154928
26. Mackerle, J. (2002). Finite element analyses of sandwich structures: a bibliography (1980–2001). Engineering Computations, 19 (2), 206–245. doi: https://doi.org/10.1108/02644400210419067
27. Frulloni, E., Kenny, J. M., Conti, P., Torre, L. (2007). Experimental study and finite element analysis of the elastic instability of composite lattice structures for aeronautic applications. Composite Structures, 78 (4), 519–528. doi: https://doi.org/10.1016/j.compstruct.2005.11.013
28. Pirk, R., Desmet, W., Pluymers, B., Sas, P., Goes, L. C. S. (2002). Vibro-acoustic Analysis of the Brazilian Vehicle Satellite Launcher (VLS) fairing. PROCEEDINGS OF ISMA 2002.
29. Slyvyns'kyy, V., Gajdachuk, V., Kirichenko, V., Kondratiev, A. (2012). Basic parameters' optimization concept for composite nose fairings of launchers. 62nd International Astronautical Congress, 9, 5701–5710.
30. Gaydachuk, V. E., Kirichenko, V. V., Kondrat'ev, A. V., Tanchik, E. V., Slivinskiy, V. I., Kushnarev, A. P., Kovalenko, V. A. (2011). Raschet golovnogo bloka rakety-nositelya «Tsiklon-4» pri razlichnyh sluchayah nagruzheniya. Effektivnost' sotovyh konstruktsiy v izdeliyah aviatsionno-kosmicheskoy tehniki: sb. materialov IV mezhdunar. nauch.-praktich. konf. Dnepropetrovsk, 91–97.
31. Kondratiev, A. V., Kovalenko, V. O. (2019). Optimization of design parameters of the main composite fairing of the launch vehicle under simultaneous force and thermal loading. Space science and technology, 25 (4), 3–21.
32. Banichuk, N. V., Kobelev, V. V., Rikards, R. B. (1988). Optimizatsiya elementov konstruktsiy iz kompozitsionnyh materialov. Moscow: Mashinostroenie, 224.
33. Gaydachuk, V. E., Kondrat'ev, A. V., Kirichenko, V. V., Slivinskiy, V. I. (2011). Optimal'noe proektirovanie kompozitnyh sotovyh konstruktsiy aviakosmicheskoy tehniki. Kharkiv: Nats. aerokosm. un-t «Har'k. aviats. in-t», 172.
34. Kondratiev, A., Prontsevych, O. (2018). Stabilization of physical-mechanical characteristics of honeycomb filler based on the adjustment of technological techniques for its fabrication. Eastern-European Journal of Enterprise Technologies, 5 (1 (95)), 71–77. doi: https://doi.org/10.15587/1729-4061.2018.143674
35. Kondratiev, A., Gaidachuk, V., Nabokina, T., Kovalenko, V. (2019). Determination of the influence of deflections in the thickness of a composite material on its physical and mechanical properties with a local damage to its wholeness. Eastern-European Journal of Enterprise Technologies, 4 (1 (100)), 6–13. doi: https://doi.org/10.15587/1729-4061.2019.174025
36. Vasiliev, V. V., Morozov, E. V. (2007). Advanced Mechanics of Composite Materials. Elsevier, 504. doi: https://doi.org/10.1016/b978-0-08-045372-9.x5000-3
37. Kondratiev, A., Nabokina, T. (2019). Effect of technological camber in the facets of a cellular filler on its physical and mechanical characteristics. Eastern-European Journal of Enterprise Technologies, 5 (7 (101)), 6–18. doi: https://doi.org/10.15587/1729-4061.2019.179258

DOI: 10.15587/1729-4061.2019.184946

DETERMINING THE INFLUENCE OF PHYSICAL NONLINEARITY OF SOIL STRENGTH PROPERTIES ON THE ESTIMATED BASE RESISTANCE (p. 19–27)

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The paper has examined the potential of using nonlinear models of strength in determining the initial critical load on soil, as well as the standardized and estimated base resistance, which makes it possible to reduce labor intensity in the process of determining the strength properties of soils.

Based on the analysis and generalization of results from theoretical studies into geomechanical processes using analytical mathematical methods, the formula modifications have been derived that are intended for determining the initial critical load on soil, as well as the standardized and estimated base resistances.

We have established interrelation between strength, in particular specific cohesion, and the angle of internal friction, which are included in the strength conditions by Mohr-Coulomb and A. Shashenko, thereby making it possible to improve the procedure for calculating external loads on soil.

The dependences of critical loads on base on the mean pressure under the sole of the foundation haven been analyzed in the range of pressure $P=100...500$ kPa using the strength conditions by Mohr-Coulomb and A. Shashenko.

It has been established that when using generally accepted estimation formulae to determine the critical loads on base, it is required that the pressure range should be taken into consideration at which the properties of soil strength were determined. In this case, using the Shashenko failure criterion to determine critical loads on base makes it possible to properly consider the impact exerted by the mean pressure on them under the sole of the foundation.

In contrast to dependences used currently in the Ukrainian, Belarusian, Russian regulatory documents, as well as in other countries' standards, the resulting formulae make it possible to take into consideration the dependences of soil strength properties on the mean pressure on soil under the sole of the foundation. The results obtained make it possible to improve the reliability of determining the initial critical load on soil, as well as the standardized and estimated base resistances. This is achieved by taking into consideration the nonlinearity of the Mohr limiting circles' envelope using the strength condition by A. Shashenko.

Keywords: failure criteria by Mohr-Coulomb and A. Shashenko; load on soil, cohesion, angle of internal friction.

References

1. Shashenko, O., Kovrov, O., Rakishev, B. (2016). Failure criteria for structurally heterogeneous materials. Mining of Mineral Deposits, 10 (3), 84–89. doi: https://doi.org/10.15407/mining10.03.084
2. TaghaviGhalesari, A., Tabari, M. K., Choobbasti, A. J., EsmaeilpourShirvani, N. (2019). Behavior of eccentrically loaded shallow foundations resting on composite soils. Journal of Building Engineering, 23, 220–230. doi: https://doi.org/10.1016/j.jobe.2019.01.036
3. Zhang, C., Fan, W., Zhao, J., Zeng, K. (2016). Unified solution of critical load for foundation in unsaturated soils under linear suction. Journal of Central South University (Science and Technology), 47 (12), 4190–4197. Available at: http://www.zndxzk.com.cn/down/2016/12_zkb/30-p4190-950610.pdf
4. Volkov, V. (2016). Control over distribution of construction loads on foundations of tower buildings. Architecture and Engineering, 1 (4), 42–45. doi: https://doi.org/10.23968/2500-0055-2016-1-4-42-45
5. Hataf, N., Sayadi, M. (2018). Experimental and numerical study on the bearing capacity of soils reinforced using geobags. Journal of Building Engineering, 15, 290–297. doi: https://doi.org/10.1016/j.jobe.2017.11.015
6. Salam, S. A., El-kady, M. S. (2017). Foundations for low cost buildings. Journal of Computational Design and Engineering, 4 (2), 143–149. doi: https://doi.org/10.1016/j.jcde.2016.09.002
7. Zhang, C., Gao, B., Yan, Q., Zhao, J., Wu, L. (2019). Development of allowable bearing capacity for strip foundations in unsaturated soils. Computers and Geotechnics, 114, 103138. doi: https://doi.org/10.1016/j.compgeo.2019.103138
8. Oh, W. T., Vanapalli, S. K. (2018). Modeling the stress versus settlement behavior of shallow foundations in unsaturated cohesive soils extending the modified total stress approach. Soils and Foundations, 58 (2), 382–397. doi: https://doi.org/10.1016/j.sandf.2018.02.008
9. Wang, J., Li, S., Feng, T. (2019). A method analyzing deformation of anchor foundations in soft clay under static and cyclic loads. Applied Ocean Research, 84, 133–144. doi: https://doi.org/10.1016/j.apor.2019.01.010
10. TaghaviGhalesari, A., Tabari, M. K., Choobbasti, A. J., EsmaeilpourShirvani, N. (2019). Behavior of eccentrically loaded shallow foundations resting on composite soils. Journal of Building Engineering, 23, 220–230. doi: https://doi.org/10.1016/j.jobe.2019.01.036
11. Morici, M., Minnucci, L., Carbonari, S., Dezi, F., Leoni, G. (2019). Simple formulas for estimating a lumped parameter model to reproduce impedances of end-bearing pile foundations. Soil Dynamics and Earthquake Engineering, 121, 341–355. doi: https://doi.org/10.1016/j.soildyn.2019.02.021
12. DBN V.2.1-10-2009. Osnovy ta fundamenty sporud (2009). Kyiv: Minrehionbud Ukrainy, 80.
13. DBN V.2.1-10:2018. Osnovy i fundamenty budivel ta sporud (2018). Kyiv: Minrehionbud Ukrainy, 36.
14. Shashenko, O. M., Hapieiev, S. M., Shapoval, V. G., Khalymendyk, O. V. (2019). Analysis of calculation models while solving geomechanical problems in elastic approach. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 1, 28–36. doi: https://doi.org/10.29202/nvngu/2019-1/21
15. Shashenko, O. M., Kovrov, O. S. (2016). Comparative analysis of two failure criteria for rocks and massifs. Scientific Bulletin of National Mining University, 6 (156), 54–59.
16. Sotnikov, S. N., Simagin, V. G., Vershinin, V. P.; Sotnikov, S. N. (Ed.) (1986). Proektirovanie i vozvedenie fundamentov vblizi sushchestvuyushchih sooruzheniy. Moscow: Stroyizdat, 96.
17. Shapoval, A. V., Shokarev, E. A., Shapoval, V. G., Shokarev, A. V. (2012). K voprosu opredeleniya privedennyh harakteristik gruntovyh osnovaniy, armirovannyh zhestkimi vertikal'nymi elementami. Svit heotekhniky, 2, 28–30.

DOI: 10.15587/1729-4061.2019.183403

ESTIMATION OF THE AERODYNAMIC CHARACTERISTICS OF A STEPPED NACELLE FOR THE AIRCRAFT POWERPLANT (p. 27–31)

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The purpose of this work is to estimate the aerodynamic characteristics of the stepped nacelle of a gas turbine engine with a turbofan unit. The research was based on the method of model physical experiment. The wind tunnel applied for the study was provided with the necessary equipment, which includes various nozzles of static and dynamic pressure with coordinate devices, etc. For the experimental study, we built the models of nacelles for an aviation power plant with front location of the fan module and with the rear arrangement of a turbofan unit. We have experimentally investigated the aerodynamic characteristics of the stepped nacelle for a gas turbine engine with a turbofan unit.

The results of this study demonstrated a possibility to decrease the aerodynamic drag of the stepped nacelle for an engine with a turbofan unit compared to the nacelle of a turbojet double-pass engine with the front arrangement of the fan. In the range of angles of attack α=0...20° the value of aerodynamic drag of the stepped nacelle for a gas turbine engine with a turbofan unit decreases by 49...55 %.

The obtained results showed that the coefficient of lifting power of the stepped nacelle for a gas turbine engine with a turbofan unit increases by 24...64 %. The coefficient of aerodynamic drag is lower by 18...28 % compared with the aerodynamic drag coefficient of a cylindrical nacelle for a double-pass turbojet engine in the range of angles of attack α=2...20°. Our findings indicate the prospects of using engines with a turbofan unit. The structural feature of the stepped nacelle would reduce the loss of efficient engine thrust by decreasing aerodynamic drag almost by two times and could increase fuel efficiency of the engine.

Keywords: stepped nacelle, aerodynamic drag, lift force, gas turbine engine, turbofan unit.

References

1. Chekalova, N. I. (2015). Methods of calculation of engine gondolas and landing gears resistance. Civil Aviation High Technologies, 211, 136–137.
2. Malouin, B., Gariépy, M., Trépanier, J.-Y., Laurendeau, É. (2015). Internal Drag Evaluation for a Through-Flow Nacelle Using a Far-Field Approach. Journal of Aircraft, 52 (6), 1847–1857. doi: https://doi.org/10.2514/1.c033093
3. Zhang, Y., Chen, H., Fu, S., Zhang, M., Zhang, M. (2015). Drag prediction method of powered-on civil aircraft based on thrust drag bookkeeping. Chinese Journal of Aeronautics, 28 (4), 1023–1033. doi: https://doi.org/10.1016/j.cja.2015.06.015
4. Robinson, M., MacManus, D. G., Sheaf, C. (2018). Aspects of aero-engine nacelle drag. Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering, 233 (5), 1667–1682. doi: https://doi.org/10.1177/0954410018765574
5. Trapp, L. G., Argentieri, H. G. (2010). Evaluation of nacelle drag using computational fluid dynamics. Journal of Aerospace Technology and Management, 2 (2), 145–153. doi: https://doi.org/10.5028/jatm.2010.02026410
6. Li, J., Gao, Z., Huang, J., Zhao, K. (2013). Aerodynamic design optimization of nacelle/pylon position on an aircraft. Chinese Journal of Aeronautics, 26 (4), 850–857. doi: https://doi.org/10.1016/j.cja.2013.04.052
7. Sasaki, D., Nakahashi, K. (2011). Aerodynamic Optimization of an Over-the-Wing-Nacelle-Mount Configuration. Modelling and Simulation in Engineering, 2011, 1–13. doi: https://doi.org/10.1155/2011/293078
8. Peters, A., Spakovszky, Z. S., Lord, W. K., Rose, B. (2014). Ultra-Short Nacelles for Low Fan Pressure Ratio Propulsors. Volume 1A: Aircraft Engine; Fans and Blowers. doi: https://doi.org/10.1115/gt2014-26369
9. Robinson, M. H., MacManus, D. G., Richards, K., Sheaf, C. (2017). Short and slim nacelle design for ultra-high BPR engines. 55th AIAA Aerospace Sciences Meeting. doi: https://doi.org/10.2514/6.2017-0707
10. Savelyev, A., Zlenko, N., Matyash, E., Mikhaylov, S., Shenkin, A. (2016). Optimal design and installation of ultra high bypass ratio turbofan nacelle. AIP Conference Proceedings, 1770. doi: https://doi.org/10.1063/1.4964065
11. Tereshchenko, Y. Y., Tereshchenko, Y. M., Doroshenko, K. V., Usenko, V. Y. (2018). Profile resistance of a gas-turbine engine nacelle with a turbofan attachment. Problems of friction and wear, 4, 64–73.
12. Yugov, O. K., Selivanov, O. D. (1980). Soglasovanie harakteristik samoleta i dvigatelya. Moscow: Mashinostroenie, 200.

DOI: 10.15587/1729-4061.2019.182995
STUDYING THE EXCITATION OF RESONANCE OSCILLATIONS IN A ROTOR ON ISOTROPIC SUPPORTS BY A PENDULUM, A BALL, A ROLLER (p. 32–43)

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We have analytically examined the steady motion modes of the system, composed of a balanced rotor on the isotropic elastic-viscous supports, and a load (a ball, a roller, a pendulum), mounted inside the rotor, thus enabling its relative motion. In this case, the pendulum is freely mounted onto the rotor shaft, while the ball or roller rolling without slipping along a ring track centered on the longitudinal axis of the rotor.

The physical-mathematical model of the system has been described. We have recorded differential equations of the system's motion with respect to a coordinate system rotating at a constant speed of rotation in the dimensionless form.

All steady motion modes of the system have been defined under which a load rotates at a constant angular velocity. In the coordinate system that rotates synchronously to a load, these motions are stationary.

Our theoretical study has shown that under motion steady modes:

– in the absence of resistance forces in the system, a load rotates synchronously with the rotor;

– in the presence of resistance forces in the system, a load is lagging behind the rotor.

The load jamming regimes are the one-parameter families of steady motions. Each jamming mode is characterized by the corresponding jam frequency.

Depending on the system parameters, one, two, or three possible load jam velocities may exist. If, at any rotor speed, there is only a single angular velocity of a load jam, then the corresponding motion mode (a one-parameter family) is globally asymptomatically steady. If the number of jam velocities varies depending on the angular rotor speed, the asymptomatically steady are:

– the only existent mode of jamming (globally asymptomatically steady when there are no others);

– jamming modes with the smallest and greatest velocities.

A load jam mode with the lowest angular velocity (close to resonance) can be used in order to excite resonance oscillations in vibration machines. The highest frequency of a load jam is close to the rotor speed. This mode can be used to excite the non-resonance oscillations in vibration machines.

Keywords: passive auto-balancer, Sommerfeld effect, inertial vibration exciter, resonance vibration machine, bifurcation of motions.

References

1. Filimonikhin, G., Yatsun, V. (2015). Method of excitation of dual frequency vibrations by passive autobalancers. Eastern-European Journal of Enterprise Technologies, 4 (7 (76)), 9–14. doi: https://doi.org/10.15587/1729-4061.2015.47116
2. Filimonikhin, G., Filimonikhina, I., Ienina, I., Rahulin, S. (2019). A procedure of studying stationary motions of a rotor with attached bodies (auto-balancer) using a flat model as an example. Eastern-European Journal of Enterprise Technologies, 3 (7 (99)), 43–52. doi: https://doi.org/10.15587/1729-4061.2019.169181
3. Filimonikhin, G., Yatsun, V., Filimonikhina, I., Ienina, I., Munshtukov, I. (2019). Studying the load jam modes within the framework of a flat model of the rotor with an autobalancer. Eastern-European Journal of Enterprise Technologies, 5 (7 (101)), 51–61. doi: https://doi.org/10.15587/1729-4061.2019.177418
4. Green, K., Champneys, A. R., Lieven, N. J. (2006). Bifurcation analysis of an automatic dynamic balancing mechanism for eccentric rotors. Journal of Sound and Vibration, 291 (3-5), 861–881. doi: https://doi.org/10.1016/j.jsv.2005.06.042
5. Artyunin, A. I. (1993). Issledovanie dvizheniya rotora s avtobalansirom. Izvestiya vysshih uchebnyh zavedeniy. Mashinostroenie, 1, 15–19.
6. Artyunin, A. I., Eliseev, S. V., Sumenkov, O. Y. (2018). Experimental Studies on Influence of Natural Frequencies of Oscillations of Mechanical System on Angular Velocity of Pendulum on Rotating Shaft. Lecture Notes in Mechanical Engineering, 159–166. doi: https://doi.org/10.1007/978-3-319-95630-5_17
7. Artyunin, A. I., Eliseyev, S. V. (2013). Effect of «Crawling» and Peculiarities of Motion of a Rotor with Pendular Self-Balancers. Applied Mechanics and Materials, 373-375, 38–42. doi: https://doi.org/10.4028/www.scientific.net/amm.373-375.38
8. Jung, D., DeSmidt, H. (2017). Nonsynchronous Vibration of Planar Autobalancer/Rotor System With Asymmetric Bearing Support. Journal of Vibration and Acoustics, 139 (3). doi: https://doi.org/10.1115/1.4035814
9. Jung, D. (2018). Supercritical Coexistence Behavior of Coupled Oscillating Planar Eccentric Rotor/Autobalancer System. Shock and Vibration, 2018, 1–19. doi: https://doi.org/10.1155/2018/4083897
10. Ryzhik, B., Sperling, L., Duckstein, H. (2004). Non-synchronous Motions Near Critical Speeds in a Single-plane Auto-Balancing Device. Technische Mechanik, 24, 25–36.
11. Lu, C.-J., Tien, M.-H. (2012). Pure-rotary periodic motions of a planar two-ball auto-balancer system. Mechanical Systems and Signal Processing, 32, 251–268. doi: https://doi.org/10.1016/j.ymssp.2012.06.001
12. Jung, D., DeSmidt, H. A. (2016). Limit-Cycle Analysis of Planar Rotor/Autobalancer System Influenced by Alford's Force. Journal of Vibration and Acoustics, 138 (2). doi: https://doi.org/10.1115/1.4032511
13. Antipov, V. I., Dentsov, N. N., Koshelev, A. V. (2014). Dynamics of the parametrically excited vibrating machine with isotropic elastic system. Fundamental research, 8, 1037–1042. Available at: http://www.fundamental-research.ru/ru/article/view?id=34713
14. Strauch, D. (2009). Classical Mechanics: An Introduction. Springer. doi: https://doi.org/10.1007/978-3-540-73616-5
15. Nayfeh, A. H. (1993). Introduction to Perturbation Techniques. Wiley, 536.
16. Ruelle, D. (1989). Elements of Differentiable Dynamics and Bifurcation Theory. Academic Press, 196. doi: https://doi.org/10.1016/c2013-0-11426-2

DOI: 10.15587/1729-4061.2019.183291

ESTABLISHING THE EFFECT OF A DECREASE IN POWER INTENSITY OF SELF-OSCILLATING GRINDING IN A TUMBLING MILL WITH A REDUCTION IN AN INTRACHAMBER FILL (p. 43–52)

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Effect of the degree of chamber filling with the charge on efficiency of the self-oscillating grinding process in a tumbling mill has been assessed.

By using the approximate analytical and experimental method, dynamic effect of increasing the self-oscillating impact action of grinding fill on the crushed material was compared with the conventional steady-state motion mode. A significant increase in average sums of vertical components of the self-oscillating collision momenta and the average sums of power of such components with a decrease in the chamber filling degree was found. Manifestation of this effect is due to the increase in the self-oscillations swing with

decreasing filling. An increase in the maximum momentum values was found to be approximately 2.4 times at the degree of filling $\kappa=0.45$, 3.1 times at $\kappa=0.35$ and 5.8 times at $\kappa=0.25$. An increase by 5.7 times in maximum values of momentum power was found at $\kappa=0.45$, by 9.6 times at $\kappa=0.35$ and by 45.5 times at $\kappa=0.25$.

Technological effect of significant decrease in the specific power intensity and productivity growth of the innovative self-oscillating grinding process as compared to the characteristics of the conventional steady-state process with a reduction in the chamber filling degree have been experimentally established.

The process of grinding cement clinker with a complete filling of gaps between spherical grinding bodies with a relative size of 0.026 with particles of the crushed material was considered. It was found that during excitation of self-oscillations, power intensity of grinding decreased and productivity increased. A decrease in relative specific power intensity was observed: 27 % at $\kappa=0.45$, 42% at $\kappa=0.35$ and 55 % at $\kappa=0.25$. A 7 % increase in relative productivity was found at $\kappa=0.45$, 30 % at $\kappa=0.35$, and 46 % at $\kappa=0.25$.

The effects established in operation have allowed us to predict rational parameters of the self-oscillating grinding process carried out in a tumbling mill with variation in the chamber filling degree.

Keywords: tumbling mill, chamber filling degree, fill self-oscillation, specific power intensity in grinding.

References

1. Naumenko, Yu. V. (1999). The antitorque moment in a partially filled horizontal cylinder. Theoretical Foundations of Chemical Engineering, 33 (1), 91–95.
2. Naumenko, Yu. V. (2000). Determination of rational rotation speeds of horizontal drum machines. Metallurgical and Mining Industry, 5, 89–92.
3. Naumenko, Y. (2017). Modeling of fracture surface of the quasi solid-body zone of motion of the granular fill in a rotating chamber. Eastern-European Journal of Enterprise Technologies, 2 (1 (86)), 50–57. doi: https://doi.org/10.15587/1729-4061.2017.96447
4. Naumenko, Y., Sivko, V. (2017). The rotating chamber granular fill shear layer flow simulation. Eastern-European Journal of Enterprise Technologies, 4 (7 (88)), 57–64. doi: https://doi.org/10.15587/1729-4061.2017.107242
5. Naumenko, Y. (2017). Modeling a flow pattern of the granular fill in the cross section of a rotating chamber. Eastern-European Journal of Enterprise Technologies, 5 (1 (89)), 59–69. doi: https://doi.org/10.15587/1729-4061.2017.110444
6. Tavares, L. M., Cavalcanti, P. P., de Carvalho, R. M., da Silveira, M. W., Bianchi, M., Otaviano, M. (2018). Fracture probability and fragment size distribution of fired Iron ore pellets by impact. Powder Technology, 336, 546–554. doi: https://doi.org/10.1016/j.powtec.2018.06.036
7. Cavalcanti, P. P., de Carvalho, R. M., das Chagas, A. S., da Silveira, M. W., Tavares, L. M. (2019). Surface breakage of fired iron ore pellets by impact. Powder Technology, 342, 735–743. doi: https://doi.org/10.1016/j.powtec.2018.10.044
8. Deineka, K. Y., Naumenko, Y. V. (2018). The tumbling mill rotation stability. Scientific Bulletin of National Mining University, 1, 60–68. doi: https://doi.org/10.29202/nvngu/2018-1/10
9. Deineka, K., Naumenko, Y. (2019). Revealing the effect of decreased energy intensity of grinding in a tumbling mill during self-excitation of auto-oscillations of the intrachamber fill. Eastern-European Journal of Enterprise Technologies, 1 (1 (97)), 6–15. doi: https://doi.org/10.15587/1729-4061.2019.155461
10. Wang, M. H., Yang, R. Y., Yu, A. B. (2012). DEM investigation of energy distribution and particle breakage in tumbling ball mills. Powder Technology, 223, 83–91. doi: https://doi.org/10.1016/j.powtec.2011.07.024
11. Owen, P., Cleary, P. W. (2015). The relationship between charge shape characteristics and fill level and lifter height for a SAG mill. Minerals Engineering, 83, 19–32. doi: https://doi.org/10.1016/j.mineng.2015.08.009
12. Cleary, P. W., Owen, P. (2018). Development of models relating charge shape and power draw to SAG mill operating parameters and their use in devising mill operating strategies to account for liner wear. Minerals Engineering, 117, 42–62. doi: https://doi.org/10.1016/j.mineng.2017.12.007
13. Cleary, P. W., Owen, P. (2019). Effect of particle shape on structure of the charge and nature of energy utilisation in a SAG mill. Minerals Engineering, 132, 48–68. doi: https://doi.org/10.1016/j.mineng.2018.12.006
14. Deniz, V. (2011). Influence of interstitial filling on breakage kinetics of gypsum in ball mill. Advanced Powder Technology, 22 (4), 512–517. doi: https://doi.org/10.1016/j.apt.2010.07.004
15. Gupta, V. K., Sharma, S. (2014). Analysis of ball mill grinding operation using mill power specific kinetic parameters. Advanced Powder Technology, 25 (2), 625–634. doi: https://doi.org/10.1016/j.apt.2013.10.003
16. Gupta, V. K. (2016). Determination of the specific breakage rate parameters using the top-size-fraction method: Preparation of the feed charge and design of experiments. Advanced Powder Technology, 27 (4), 1710–1718. doi: https://doi.org/10.1016/j.apt.2016.06.002
17. Öksüzoğlu, B., Uçurum, M. (2016). An experimental study on the ultra-fine grinding of gypsum ore in a dry ball mill. Powder Technology, 291, 186–192. doi: https://doi.org/10.1016/j.powtec.2015.12.027
18. Petrakis, E., Stamboliadis, E., Komnitsas, K. (2017). Identification of Optimal Mill Operating Parameters during Grinding of Quartz with the Use of Population Balance Modeling. KONA Powder and Particle Journal, 34, 213–223. doi: https://doi.org/10.14356/kona.2017007
19. Panjipour, R., Barani, K. (2018). The effect of ball size distribution on power draw, charge motion and breakage mechanism of tumbling ball mill by discrete element method (DEM) simulation. Physicochemical Problems of Mineral Processing, 54 (2), 258–269. doi: http://doi.org/10.5277/ppmp1811
20. Schnatz, R. (2004). Optimization of continuous ball mills used for finish-grinding of cement by varying the L/D ratio, ball charge filling ratio, ball size and residence time. International Journal of Mineral Processing, 74, S55–S63. doi: https://doi.org/10.1016/j.minpro.2004.07.024
21. Deniz, V. (2012). The effects of ball filling and ball diameter on kinetic breakage parameters of barite powder. Advanced Powder Technology, 23 (5), 640–646. doi: https://doi.org/10.1016/j.apt.2011.07.006
22. Deniz, V. (2016). An investigation on the effects of the ball filling on the breakage parameters of natural amorphous silica. Advanced Powder Technology, 27 (4), 1272–1279. doi: https://doi.org/10.1016/j.apt.2016.04.017
23. Cayirli, S. (2018). Influences of operating parameters on dry ball mill performance. Physicochemical Problems of Mineral Processing, 54 (3), 751–762. doi: http://doi.org/10.5277/ppmp1876

24. Yin, Z., Peng, Y., Zhu, Z., Yu, Z., Li, T., Zhao, L., Xu, J. (2017). Experimental study of charge dynamics in a laboratory-scale ball mill. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 232 (19), 3491–3499. doi: https://doi.org/10.1177/0954406217738031
25. Orozco, L. F., Nguyen, D.-H., Delenne, J.-Y., Sornay, P., Radjai, F. Discrete-element simulation of particle breakage inside ball mills: A 2D model. Available at: https://arxiv.org/ftp/arxiv/papers/1901/1901.07402.pdf
26. Cleary, P. W., Owen, P. (2019). Effect of operating condition changes on the collisional environment in a SAG mill. Minerals Engineering, 132, 297–315. doi: https://doi.org/10.1016/j.mineng.2018.06.027
27. Rezaeizadeh, M., Fooladi, M., Powell, M. S., Mansouri, S. H. (2010). Experimental observations of lifter parameters and mill operation on power draw and liner impact loading. Minerals Engineering, 23 (15), 1182–1191. doi: https://doi.org/10.1016/j.mineng.2010.07.017
28. Soleymani, M. M., Fooladi, M., Rezaeizadeh, M. (2016). Experimental investigation of the power draw of tumbling mills in wet grinding. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 230 (15), 2709–2719. doi: https://doi.org/10.1177/0954406215598801
29. Mulenga, F. K., Mkonde, A. A., Bwalya, M. M. (2016). Effects of load filling, slurry concentration and feed flowrate on the attainable region path of an open milling circuit. Minerals Engineering, 89, 30–41. doi: https://doi.org/10.1016/j.mineng.2016.01.002
30. Soleymani, M., Fooladi Mahani, M., Rezaeizadeh, M. (2016). Experimental study the impact forces of tumbling mills. Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 231 (2), 283–293. doi: https://doi.org/10.1177/0954408915594526
31. Yin, Z., Peng, Y., Zhu, Z., Yu, Z., Li, T. (2017). Impact Load Behavior between Different Charge and Lifter in a Laboratory-Scale Mill. Materials, 10 (8), 882. doi: https://doi.org/10.3390/ma10080882

DOI: 10.15587/1729-4061.2019.184592

CONSTRUCTION OF MATHEMATICAL MODELS OF THE STATICS OF GRAIN MEDIA CONSIDERING THE REYNOLDS EFFECT (p. 53–62)

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This study addresses the construction of a mathematical model, the statement of boundary-value problems on the statics of a grainy material related to the technological processes of agricultural production. A working apparatus employed to construct the model of a grainy material is the methods of equilibrium thermodynamics. We have stated the main thermodynamic equality, which makes it possible to derive a rheological ratio that establishes the connection between stresses and deformations of the granular material. The chosen grainy material is a granular medium that manifests a Reynolds effect. This effect occurs in the case of small deformations and indicates the presence of a dependence of dilation on the stress tensor deviator. In contrast to the classical methods that consider a model of continuous medium with the non-deformed and smooth grain's particles, the present work takes into consideration both a Reynolds effect and the presence of elastic deformations. The resulting rheological ratio produces the dependence for a stress tensor on the deformation tensor corresponding to ratios from the linear theory of elasticity.

For the case of an isothermal process of deformation, a boundary-value problem on the grain material's statics in the field of gravity has been stated. This paper shows the statement and solution to two particular tasks on the balance of a granular layer along the horizontal plane: in the absence of surface forces and under the action of tangent surface forces on a free surface.

The boundary problems on the equilibrium of a granular material are nonlinear in character, and the resulting solution represents a complex mathematical apparatus involving numerical methods.

The obtained models for the statics of a continuous environment precede the consideration of dynamic problems, in particular, the study of equilibrium stability.

Keywords: granular materials, equilibrium thermodynamics, Reynolds effect, horizontal grain layer, boundary-value problem, boundary conditions.

References

1. Aranson, I. S., Tsimring, L. S. (2006). Patterns and collective behavior in granular media: Theoretical concepts. Reviews of Modern Physics, 78 (2), 641–692. doi: https://doi.org/10.1103/revmodphys.78.641
2. Börzsönyi, T., Halsey, T. C., Ecke, R. E. (2008). Avalanche dynamics on a rough inclined plane. Physical Review E, 78 (1). doi: https://doi.org/10.1103/physreve.78.011306
3. Gujjula, R., Mangadoddy, N. (2015). Hydrodynamic Study of Gas–Solid Internally Circulating Fluidized Bed Using Multiphase CFD Model. Particulate Science and Technology, 33 (6), 593–609. doi: https://doi.org/10.1080/02726351.2015.1013590
4. Das, P., Puri, S., Schwartz, M. (2018). Granular fluids with solid friction and heating. Granular Matter, 20 (1). doi: https://doi.org/10.1007/s10035-018-0789-y
5. Schwedes, J. (2003). Review on testers for measuring flow properties of bulk solids. Granular Matter, 5 (1), 1–43. doi: https://doi.org/10.1007/s10035-002-0124-4
6. Nanka, A., Ievlev, I. (2017). About separation of the impurity in the carrying stream of the grain environment. Visnyk

Kharkivskoho natsionalnoho tekhnichnoho universytetu silskoho hospodarstva imeni Petra Vasylenka, 181, 215–222.
7. Tishchenko, L., Kharchenko, S., Kharchenko, F., Bredykhin, V., Tsurkan, O. (2016). Identification of a mixture of grain particle velocity through the holes of the vibrating sieves grain separators. Eastern-European Journal of Enterprise Technologies, 2 (7 (80)), 63–69. doi: https://doi.org/10.15587/1729-4061.2016.65920
8. Nesterenko, O. V., Leshchenko, S. M., Vasylkovskyi, O. M., Petrenko, D. I. (2017). Analytical assessment of the pneumatic separation quality in the process of grain multilayer feeding. INMATEH. Agricultural Engineering, 53 (3), 65–70.
9. Minh, N. H., Cheng, Y. P. (2016). On the contact force distributions of granular mixtures under 1D-compression. Granular Matter, 18 (2). doi: https://doi.org/10.1007/s10035-016-0625-1
10. Swisher, N. C., Utter, B. C. (2014). Flow profile of granular avalanches with imposed vertical vibration. Granular Matter, 16 (2), 175–183. doi: https://doi.org/10.1007/s10035-014-0488-2
11. Kaviani Rad, H., Nejat Pishkenari, H. (2018). Frictional viscoelastic based model for spherical particles collision. Granular Matter, 20 (4). doi: https://doi.org/10.1007/s10035-018-0835-9
12. Gnoli, A., Lasanta, A., Sarracino, A., Puglisi, A. (2016). Unified rheology of vibro-fluidized dry granular media: From slow dense flows to fast gas-like regimes. Scientific Reports, 6 (1). doi: https://doi.org/10.1038/srep38604
13. Dijksman, J. A., Wortel, G. H., van Dellen, L. T. H., Dauchot, O., van Hecke, M. (2011). Jamming, Yielding, and Rheology of Weakly Vibrated Granular Media. Physical Review Letters, 107 (10). doi: https://doi.org/10.1103/physrevlett.107.108303
14. Gnoli, A., Puglisi, A., Sarracino, A., Vulpiani, A. (2014). Nonequilibrium Brownian Motion beyond the Effective Temperature. PLoS ONE, 9 (4), e93720. doi: https://doi.org/10.1371/journal.pone.0093720
15. Liu, H., Yoon, S., Li, M. (2016). Three-dimensional computational fluid dynamics (CFD) study of the gas–particle circulation pattern within a fluidized bed granulator: By full factorial design of fluidization velocity and particle size. Drying Technology, 35 (9), 1043–1058. doi: https://doi.org/10.1080/07373937.2016.1230628
16. Ford, K. J., Gilchrist, J. F., Caram, H. S. (2009). Transitions to vibro-fluidization in a deep granular bed. Powder Technology, 192 (1), 33–39. doi: https://doi.org/10.1016/j.powtec.2008.11.017
17. Jaeger, H. M., Nagel, S. R., Behringer, R. P. (1996). The Physics of Granular Materials. Physics Today, 49 (4), 32–38. doi: https://doi.org/10.1063/1.881494
18. Schreck, C. F., O'Hern, C. S., Shattuck, M. D. (2013). Vibrations of jammed disk packings with Hertzian interactions. Granular Matter, 16 (2), 209–216. doi: https://doi.org/10.1007/s10035-013-0458-0
19. Chou, C. (2004). The kinematic model for granular flow in a two-dimensional symmetrical louvered moving granular filter bed. Journal of the Chinese Institute of Engineers, 27 (2), 299–304. doi: https://doi.org/10.1080/02533839.2004.9670876
20. Dahl, S. R., Hrenya, C. M., Garzó, V., Dufty, J. W. (2002). Kinetic temperatures for a granular mixture. Physical Review E, 66 (4). doi: https://doi.org/10.1103/physreve.66.041301
21. Pouliquen, O., Forterre, Y. (2009). A non-local rheology for dense granular flows. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 367 (1909), 5091–5107. doi: https://doi.org/10.1098/rsta.2009.0171
22. Das, M. K., Mukherjee, P. P., Muralidhar, K. (2018). Modeling Transport Phenomena in Porous Media with Applications. Springer. doi: https://doi.org/10.1007/978-3-319-69866-3
23. Bezmaternykh, A. V., Ofrikhter, V. G. (2017). The phenomenon of dilatancy and its impact on the nature of deformation of soil under load. MASTER'S JOURNAL, 2, 85–90.
24. Bileush, A. I., Krivonog, A. I., Krivonog, V. V., Filimonov, V. Yu. (2011). Strength of granular soil having dilatancy. Prykladna hidromekhanika, 13 (3), 23–32.
25. Liu, H., Zhang, S.-H., Cheng, M., Song, H.-W., Trentadue, F. (2015). A minimum principle for contact forces in random packings of elastic frictionless particles. Granular Matter, 17 (4), 475–482. doi: https://doi.org/10.1007/s10035-015-0567-z
26. Nicolis, G. (1970). Thermodynamic theory of stability, structure and fluctuations. Pure and Applied Chemistry, 22 (3-4), 379–392. doi: https://doi.org/10.1351/pac197022030379
27. Marin, V. I., Didenko, B. A. (2002). Modelirovanie akusticheskogo trakta ustroystva izmereniya protsentnogo soderzhaniya svyazuyushchego. Matematicheskie metody v tehnike i tehnologiyah: sb. tr. XV Mezhdunar. nauch. konf. Tambov, 59–62.
28. Langston, P. A., Nikitidis, M. S., Tüzün, V., Heyes, D. M. (1998). Tomographic measurements and distinct element simulations of binary granular flow voidage. World Congress on particle Technology 3. Brighton, UK, 333.
29. Millen, M. J., Sowerby, B. D., Abemethy, D. A., Kingsiey, R., Grima, C. (1997). On-line measurement of pulverised coal mass flow using an ultrasonic technique. Powder technology, 92, 105–113.
30. Schlaberg, H. I., Podd, F. J. W., Hoyle, B. S. (2000). Ultrasound process tomography system for hydrocyclones. Ultrasonics, 38 (1-8), 813–816. doi: https://doi.org/10.1016/s0041-624x(99)00189-4
31. Dolgunin, V. N., Ivanov, O. O., Borshchev, V. Ya. (2016). Sdvigovye techeniya zernistyh sred: zakonomernosti i tehnologicheskie aspekty. Tambov: Izd-vo FGBOU VO «TGTU», 168.
32. Jaeger, H. M., Nagel, S. R., Behringer, R. P. (1996). Granular solids, liquids, and gases. Reviews of Modern Physics, 68 (4), 1259–1273. doi: https://doi.org/10.1103/revmodphys.68.1259

DOI: 10.15587/1729-4061.2019.184645
DETERMINING MECHANICAL PROPERTIES OF A PRESSURE FIRE HOSE THE TYPE OF «T» (p. 63–70)

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Experimental research into determining the mechanical properties (elastic and dissipative) of the pressure fire hose of type «T» with an inner diameter of 66 mm under conditions of static load were presented. The experiment was conducted on the experimental setup, which makes it possible to measure force and deformation. In the course of research, a series of field experiments in stretching with the sample under conditions of static loading-unloading cycles was carried out. The tests consisted of 5 cycles (modes) of loading-unloading, which were performed with a two-minute interval. Taking into consideration the experimental data, the elasticity module at stretching the material of the hose in the longitudinal (along the base) direction was determined. It was established that numerical results of mechanical properties depend on the hose loading «history», that is, in the first two load modes, elasticity modules increased and were stabilized only in the subsequent modes. The above, along with a significant reduction in residual deformations, increases the elastic properties of the fire hose material.

The results of the conducted studies showed that in the first two cycles, the material demonstrates short-term creep, which gets stabilized in modes 4–5. To generalize the experimental research, the results were approximated by corresponding trend lines. The curves of the sample deformation, which under conditions of cyclic loading-unloading formed the hysteresis loops, were determined. The hysteresis loops obtained during the study showed that in the first two modes, the loop are subjected to quantitative and qualitative changes, specifically, the slope of the hysteresis loop and its area decreases.

It was determined that a change of the properties of the material of the fire hose at consecutive loading-unloading deformation cycles are reversed, the gaps between the deformation cycles result in partial restoration of the mechanical characteristics, approximating them to the initial values. Relaxation time is from several hours to several days and even weeks, which depends heavily on the magnitude of the previous relative deformation.

Keywords: pressure fire hose, elasticity module, hysteresis, dissipative properties.

References

1. Dubinin, D., Korytchenko, K., Lisnyak, A., Hrytsyna, I., Trigub, V. (2018). Improving the installation for fire extinguishing with finelydispersed water. Eastern-European Journal of Enterprise Technologies, 2 (10 (92)), 38–43. doi: https://doi.org/10.15587/1729-4061.2018.127865
2. Korytchenko, K., Sakun, O., Dubinin, D., Khilko, Y., Slepuzhnikov, E., Nikorchuk, A., Tsebriuk, I. (2018). Experimental investigation of the fireextinguishing system with a gas-detonation charge for fluid acceleration. Eastern-European Journal of Enterprise Technologies, 3 (5 (93)), 47–54. doi: https://doi.org/10.15587/1729-4061.2018.134193
3. Vasiliev, M. I., Movchan, I. O., Koval, O. M. (2014). Diminishing of ecological risk via optimization of fire-extinguishing system projects in timber-yards. Scientific Bulletin of National Mining University, 5, 106–113.
4. Dubinin, D., Korytchenko, K., Lisnyak, A., Hrytsyna, I., Trigub, V. (2017). Numerical simulation of the creation of a fire fighting barrier using an explosion of a combustible charge. Eastern-European Journal of Enterprise Technologies, 6 (10 (90)), 11–16. doi: https://doi.org/10.15587/1729-4061.2017.114504
5. Semko, A., Rusanova, O., Kazak, O., Beskrovnaya, M., Vinogradov, S., Gricina, I. (2015). The use of pulsed high-speed liquid jet for putting out gas blow-out. The International Journal of Multiphysics, 9 (1), 9–20. doi: https://doi.org/10.1260/1750-9548.9.1.9
6. Kovalenko, R., Kalynovskyi, A., Nazarenko, S., Kryvoshei, B., Grinchenko, E., Demydov, Z. et. al. (2019). Development of a method of completing emergency rescue units with emergency vehicles. Eastern-European Journal of Enterprise Technologies, 4 (3 (100)), 54–62. doi: https://doi.org/10.15587/1729-4061.2019.175110
7. Tiutiunyk, V. V., Ivanets, H. V., Tolkunov, I. A., Stetsyuk, E. I. (2018). System approach for readiness assessment units of civil defense to actions at emergency situations. Scientific Bulletin of National Mining University, 1, 99–105. doi: https://doi.org/10.29202/nvngu/2018-1/7
8. Abrosimov, Yu. G., Koval', E. V. (2006). Gidravlicheskie soprotivleniya v sistemah podachi vody na pozharotushenie. Vesnik Akademii GPS MCHS Rossii, 5, 25–28.
9. Hoang, Z. B. (2009). Experimental installation for research of hydraulic resistance of pressure head fire hoses. Internet-zhurnal «Tehnologii tehnosfernoy bezopasnosti», 5. Available at: http://agps-2006.narod.ru/ttb/2009-5/08-05-09.ttb.pdf
10. Motorin, L. B., Stepanov, O. S., Bratolyubova, E. V. (2010). Matematicheskaya model' dlya prochnostnogo rascheta napornyh pozharnyh rukavov pri gidravlicheskom vozdeystvii. Izv. vuzov. Tehnologiya tekst. prom-sti, 8, 103–109.
11. Motorin, L. B., Stepanov, O. S., Bratolyubova, E. V. (2011). Uproshchennaya matematicheskaya model' dlya prochnostnogo rascheta napornyh pozharnyh rukavov pri gidravlicheskom vozdeystvii. Izv. vuzov. Tehnologiya tekst. prom-sti, 1, 126–133.
12. Druginyn, P. V., Babushkin, M. Yu. (2013). Diagnosing and prediction of the residual capacity of the high pressure hoses. Tehniko-tehnologicheskie problemy servisa, 3 (25), 6–12.
13. Fedorko, G., Molnar, V., Dovica, M., Toth, T., Fabianova, J. (2015). Failure analysis of irreversible changes in the construction of the damaged rubber hoses. Engineering Failure

Analysis, 58, 31–43. doi: https://doi.org/10.1016/j.engfailanal.2015.08.042
14. Cho, J. R., Yoon, Y. H., Seo, C. W., Kim, Y. G. (2015). Fatigue life assessment of fabric braided composite rubber hose in complicated large deformation cyclic motion. Finite Elements in Analysis and Design, 100, 65–76. doi: https://doi.org/10.1016/j.finel.2015.03.002
15. Kwak, S.-B., Choi, N.-S. (2009). Micro-damage formation of a rubber hose assembly for automotive hydraulic brakes under a durability test. Engineering Failure Analysis, 16 (4), 1262–1269. doi: https://doi.org/10.1016/j.engfailanal.2008.08.009
16. Stenmark, N. (2007). Small Leak in Hydraulic Hose Reveals Big Problem. Journal of Failure Analysis and Prevention, 7 (3), 183–186. doi: https://doi.org/10.1007/s11668-007-9033-5
17. Larin, A. A., Vyazovichenko, Y. A., Barkanov, E., Itskov, M. (2018). Experimental Investigation of Viscoelastic Characteristics of Rubber-Cord Composites Considering the Process of Their Self-Heating. Strength of Materials, 50 (6), 841–851. doi: https://doi.org/10.1007/s11223-019-00030-7
18. Cardone, D., Gesualdi, G. (2012). Experimental evaluation of the mechanical behavior of elastomeric materials for seismic applications at different air temperatures. International Journal of Mechanical Sciences, 64 (1), 127–143. doi: https://doi.org/10.1016/j.ijmecsci.2012.07.008
19. Haseeb, A. S. M. A., Jun, T. S., Fazal, M. A., Masjuki, H. H. (2011). Degradation of physical properties of different elastomers upon exposure to palm biodiesel. Energy, 36 (3), 1814–1819. doi: https://doi.org/10.1016/j.energy.2010.12.023
20. Budinski, M. K. (2013). Failure analysis of a rubber hose in anhydrous ammonia service. Case Studies in Engineering Failure Analysis, 1 (2), 156–164. doi: https://doi.org/10.1016/j.csefa.2013.04.009
21. Mefedova, Yu. A. (2011). Calculation of hoses of high pressure for load distribution between braiding layers. Vestnik Saratovskogo gosudarstvennogo tehnicheskogo universiteta, 3, 97–102.
22. Larin, O. O. (2015). Probabilistic Model of Fatigue Damage Accumulation in Rubberlike Materials. Strength of Materials, 47 (6), 849–858. doi: https://doi.org/10.1007/s11223-015-9722-3
23. Gu, F., Huang, C., Zhou, J., Li, L. (2009). Mechanical response of steel wire wound reinforced rubber flexible pipe under internal pressure. Journal of Shanghai Jiaotong University (Science), 14 (6), 747–756. doi: https://doi.org/10.1007/s12204-009-0747-2
24. Cho, J. R., Jee, Y. B., Kim, W. J., Han, S. R., Lee, S. B. (2013). Homogenization of braided fabric composite for reliable large deformation analysis of reinforced rubber hose. Composites Part B: Engineering, 53, 112–120. doi: https://doi.org/10.1016/j.compositesb.2013.04.045
25. Cho, J.-R., Yoon, Y.-H. (2016). Large deformation analysis of anisotropic rubber hose along cyclic path by homogenization and path interpolation methods. Journal of Mechanical Science and Technology, 30 (2), 789–795. doi: https://doi.org/10.1007/s12206-016-0134-5
26. Lee, G.-C., Kim, H.-E., Park, J.-W., Jin, H.-L., Lee, Y.-S., Kim, J.-H. (2011). An experimental study and finite element analysis for finding leakage path in high pressure hose assembly. International Journal of Precision Engineering and Manufacturing, 12 (3), 537–542. doi: https://doi.org/10.1007/s12541-011-0067-y
27. Pavloušková, Z., Klakurková, L., Man, O., Čelko, L., Švejcar, J. (2015). Assessment of the cause of cracking of hydraulic hose clamps. Engineering Failure Analysis, 56, 14–19. doi: https://doi.org/10.1016/j.engfailanal.2015.05.014
28. Noda, N.-A., Yoshimura, S., Kawahara, H., Tuyunaru, S. (2008). FEM Analysis for Sealing Performance of Hydraulic Brake Hose Crimped Portion and Its Life Estimation. Transactions of the Japan Society of Mechanical Engineers Series A, 74 (748), 1538–1543. doi: https://doi.org/10.1299/kikaia.74.1538
29. Cho, J. R., Song, J. I., Noh, K. T., Jeon, D. H. (2005). Nonlinear finite element analysis of swaging process for automobile power steering hose. Journal of Materials Processing Technology, 170 (1-2), 50–57. doi: https://doi.org/10.1016/j.jmatprotec.2005.04.077
30. Cho, J. R., Song, J. I. (2007). Swaging process of power steering hose: Its finite element analysis considering the stress relaxation. Journal of Materials Processing Technology, 187-188, 497–501. doi: https://doi.org/10.1016/j.jmatprotec.2006.11.113

DOI: 10.15587/1729-4061.2019.183864

CONSTRUCTION OF A THEORETICAL METHOD FOR EVALUATING THE KINEMATIC AND GEOMETRIC PARAMETERS OF LOOSENING ROLLERS IN THE CLEANERS OF RAW COTTON FROM LARGE IMPURITIES (p. 71–79)

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The scheme of a feeder has been constructed, in which, along with conventional lobed rollers, the pinned or pinned-planked loosening rollers are used. The feeder of such a design achieves both a smooth and uniform feed of cotton to the machine and a change in the technological characteristics of raw cotton. Additional rollers lead to a change in the technological characteristics of raw cotton, thereby forming a process of intensive removal of weed impurities. The mechanics of interaction between the working elements of feeding devices and the layer of a transported material has been investigated; in addition, the feed systems with a directed change in the technological properties of raw cotton have been selected.

It has been proven that a high cleaning effect could be achieved not only by intensifying the cleaning process, but also by a directed change in the technological properties of raw cotton while maintaining or improving the quality of the resulting product. It is obvious that the deformation that a particle undergoes in the examined scheme would be maximally possible, limiting, because the structure excludes the slippage of a product in the zones between the lobed and loosening rollers, which is not excluded in an actual design.

The technological properties of raw cotton as a cleaning material have been studied, the structural characteristics of cotton have been investigated, as well as the relation between their kinetics and cleaning processes. Relations between a structure coefficient and the magnitude of open surfaces of the raw cotton structural units have been established. The spatial characteristics of raw cotton clogging and the conditions of interaction between fiber and weeds in the

volume of clogged cotton mass have been studied. Variants of combinations of feed rollers with various structures of pinned rollers have been given, which make it possible to formulate the main ways to intensify the existing, and create new, technological processes of raw cotton cleaning.

Based on the established functional links, it becomes possible to construct new, or improve existing, structures of pinned sections in the cleaning machines ChKh-3M1. Experience shows that the application of the developed scheme of the feeder in the cleaners from large impurities produces a significant increase in the cleaning effect of the machine.

Keywords: fibrous material, large impurities, pinned rollers, cotton element, loosening rollers.

References

1. Baker, R. V., Stedronsky, V. L. (1998). Seed cotton and cottonseed handling wish air yet conveyrs. U. S. Department of agriculture, 18.
2. Baydyuk, P. V. (1994). Primenenie kalkovyh ustroystv pri pressovanii voloknistyh materialov. TSINTI, 4, 2–8.
3. Chapman, W. E., Spindle, D. (1983). Twists in cotton Ginning. Textile Research Journal, 53 (10), 638.
4. Sapon, A. L., Samandarov, S. A., Libster, S. L. (2007). Potochnaya liniya pervichnoy pererabotki hlopka-syrtsa PLPH. Hlopkovaya promyshlennost', 3, 1–3.
5. William, Y. M., Stedronsky, L. V. (1999). Effect of variations in design of gin-saw teeth on lint guality u ginning efficiency. Washington, D. C., 25.
6. Nesterov, G. P., Borodin, P. N., Belyalov, R. F. (2008). Novaya potochnaya liniya sushki i ochistki hlopka-syrtsa. Hlopkovaya promyshlennost', 1, 2–4.
7. Korabel'nikov, R. V., Ibrogimov, H. I. (2008). Kompleksnyy pokazatel' vozdeystviya ochistitelya hlopka na hlopok-syrets v protsesse ochistki. Tehnologiya tekstil'noy promyshlennosti, 3, 35–38.
8. Boldinskiy, G. I., Samandarov, S. A., Benenson, A. L. (1974). Vybor formy kolka v ochistitelyah melkogo sora. Hlopkovaya promyshlennost', 1, 16–17.
9. Hafizov, I. K., Rasulov, A. (2009). Issledovanie razryhlitel'nogo effekta razdelitelya dolek tonkovoloknistogo hlopka-syrtsa na letuchki. Hlopkovaya promyshlennost', 3, 9–21.
10. Mirochnichenko, G. I., Korabelnikov, R. V., Jakubov, D., Tjutin, P. N. Pat. No. 1.475.448. Great Britain and Northern Ireland.
11. Ibrogimov, H. I., Zul'fanov, S. Z., Ruziev, R. B. (2007). Pat. TJ No. 82. MGSHCH2006) F24V6/10. Teploobrazovatel'. published: 30.03.2007.
12. Shaw, G. S, Franks, S. N. (1994). Hand book for cotton Gunners. Washington, 28–32.
13. Veliev, F. (2019). Construction of a theoretical method for estimating the calculation of power used by feed rollers in the cleaners of raw cotton from fine debris. Eastern-European Journal of Enterprise Technologies, 4 (7 (100)), 46–54. doi: https://doi.org/10.15587/1729-4061.2019.174213
14. Ibrogimov, H. I., Korabel'nikov, R. V. (2008). Modelirovanie protsessa razrezheniya sloya hlopka-syrtsa v pitatele ochistitelya melkogo sora. Tehnologiya tekstil'noy promyshlennosti, 4, 34–38.
15. Veliev, F. (2019). Influence of elastic characteristics of raw cotton on the mechanics of feed rollers in the cleaners from small impurities. Eastern-European Journal of Enterprise Technologies, 1 (1 (97)), 33–40. doi: https://doi.org/10.15587/1729-4061.2019.154342