ABSTRACT AND REFERENCES

APPLIED MECHANICS

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PREDICTION OF OPERABILITY OF THE PLATE ROLLING ROLLS BASED ON THE MIXED FRACTURE MECHANISM (p. 4-11)

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Influence of fracture of the mixed nature on the life of rolls of plate-rolling mills was considered. This is important because the time of trouble-free operation of plate-rolling rolls significantly affects the cost of the final product. However, there are objective difficulties connected with definition of the optimal model of prediction calculation of the final roll life because there is an insufficient definiteness of influence of the mixed fracture mechanism on the roll life.

Conventionally, when predicting roll durability, a posteriori models of the roll service life obtained by the methods of mathematical statistics are used. However, the use of such models causes some complexity since preliminary processing of large volumes of statistical information is required. In the framework of the study described in the article, solution to this problem was proposed by determining influence of the mechanism of a mixed fracture on the roll life. This influence indicates the possibility of using the method of survivability curves for estimating the roll durability.

Thus, an applied aspect of using the obtained scientific result is the possibility of improving the conventional method for calculating the roll service life. This, in turn, makes it possible to optimize previously obtained technological solutions for constructing a diagnostic algorithm of estimating the technical state of the plate-rolling rolls and predicting their residual life.

Keywords: service life of the roll, residual life of the roll, method of survivability curves.

References

1. Yashchura, A. I. (2006). Sistema tekhnicheskogo obsluzhivaniya i remonta obshchepromyshlennogo oborudovaniya. Moscow: Izd-vo NTS ENAS, 360.
2. Belodedenko, S. V., Yatsuba, A. V., Klimenko, Y. M. (2015). Technical condition assessment and prediction of the survivability of the mill rolls. Metallurgical and Mining Industry, 1, 85–94.
3. Appolonov, I. V. (Ed.) (1989). Nadezhnost' i effektivnost' v tekhnike. Vol. 7. Kachestvo i nadezhnost' v proizvodstve. Moscow: Mashinostroenie, 280.
4. Zhil'tsov, A. P., Ahtyrtsev, S. A. (2013). Metod differentsirovannogo ucheta udel'nogo raskhoda valkov tonkolistovyh stanov v zavisimosti ot urovnya nagruzheniya i dlitel'nosti ekspluatatsii. Uspekhi sovremennogo estestvoznaniya, 9, 163–165.
5. Steblov, A. B. (2010). Issledovanie iznosa sortovyh prokatnyh valkov. Proizvodstvo prokata, 10, 21–23.
6. Troshchenko, V. T., Tsybanev, G. V., Gryaznov, B. A., Nalimov, Yu. S. (2009). Ustalost' metallov. Sostoyanie poverhnosti i kontaktnye vzaimodeystviya. Kyiv: In-t probl. prochnosti im G. S. Pisarenko NAN Ukrainy, 664.
7. Holan, L., Pippan, R., Pokluda, J., Hornikova, J., Hohenwarter, A., Slamechka, K. (2009). Near–threshold propagation of Mode II and Mode III cracks. Crack paths (CP 2009). Vicenza, 585–592.
8. Ohkomori, Y., Kitagawa, I., Shinozuka, K., Miyamoto, R., Yazaki, S., Inoue, M. (1988). Cause and Prevention of Spalling of Backup Rolls for Hot Strip Mill. Transactions of the Iron and Steel Institute of Japan, 28 (1), 68–74. doi: 10.2355/isijinternational1966.28.68
9. Sekimoto, Y. (1970). Analysis of hot strip work roll damage due to cobble. Transactions ISIJ, 10, 341–349.
10. Murakami, Y., Sakae, C., Hamada, S. (1999). Mechanism of rolling contact fatigue and measurement of ΔKIIth for steels. Engineering against fatigue. Rotterdam&Brookfield: A.A. Balkema Publ., 473–485.
11. Romaniv, O. N., Yarema, S. Ya., Nikiforchin, G. I. et. al. (1990). Mekhanika razrusheniya i prochnost' materialov. Vol. 4. Ustalost' i tsiklicheskaya treshchinostoykost' konstruktsionnyh materialov. Kyiv: Naukova Dumka, 680.
12. Kapadia, B. M., Marsden, K. W. (1996). Safe minimum operating diameter of duplex cast roll with shell/core interface separation. 37th MWSP conf. proc. ISS, 33, 221–242.
13. Yamamoto, H., Uchida, S., Araya, S., Nakajima, K., Hashimoto, M., Kimura, K. (1994). Characteristics of high–speed tool steel as material of work roll in hot rolling. Vol. 2. 6th Int. rolling conf. proc. Dusseldorf, 59–64.
14. Sonoda, A., Kashiwagi, S., Hamada, S., Noguchi, H. (2008). Quantitative Evaluation of Heat Crack Initiation Condition Under Thermal Shock. Journal of Solid Mechanics and Materials Engineering, 2 (1), 128–136. doi: 10.1299/jmmp.2.128
15. Sonoda, A., Kashiwagi, S., Noguchi, H. (2009). Analysis of Small Spalling Mechanism on Hot Rolling Mill Roll Surface. Memoirs of the Faculty of Engineering, Kyushu University, 69 (1).
16. Dong, Q., Cao, J., Li, H., Zhou, Y., Yan, T., Wang, W. (2014). Analysis of Spalling in Roughing Mill Backup Rolls of Wide and Thin Strip Hot Rolling Process. Steel Research International, 86 (2), 129–136. doi: 10.1002/srin.201300476
17. Matvienko, V. N. (2006). Povyshenie rabotosposobnosti sheek i galteley valkov prokatnyh stanov naplavkoy sloya metalla. Zakhyst metalurhiyinykh mashyn vid polomok, 9, 153–157.
18. Gasiak, G., Rabak, G. (2006). Fatigue life of constructional materials under bending with torsion for crack propagation. Mechanical fatigue of metals: Proceeding of the 13-th Int. Colloquim. Ternopil, TSTU, 270–276.
19. Son, I. S., Cho, J.-R., Yoon, H. (2008). Effects of moving mass on the dynamic behavior of cantilever beams with double cracks. Int. J. of Precision engineering and manufacturing, 9 (3), 33–39.
20. Murakami, Y. (2002). Metal fatigue: effects of small defects and nonmetallic inclusions. Oxford: Elsevier, 384.
21. Desimone, H., Gonzalez, J. K., Beretta, S. (2004). A model for influence of inclusions in high cycle contact fatigue. Tenaris.
22. Broek, D. (1974). Elementary engineering fracture mechanics. Leyden: Noordhoff Int. Publ., 408.
23. Jodejko-Pietruczuk, A., Nowakowski, T., Werbińska-Wojciechowska, S. (2013). Block inspection policy model with imperfect inspections for multi-unit systems. RT&A, 8 (3 (30)), 75–86.
24. Belodedenko, S. V., Goryanoy, V. M., Buh, I., Yatsuba, A. V. (2014). Prognozirovanie rabotosposobnosti listoprokatnyh valkov. Problemy prochnosti, 5, 89–95.
25. Datsyshyn, O. P., Panasyuk, V. V. (2017). Methods for the Evaluation of the Contact Durability of Elements of the Tribojoints (A Survey). Materials Science, 52 (4), 447–459. doi: 10.1007/s11003-017-9977-x

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A METHOD DEVELOPED TO CALCULATE LATERAL EARTH PRESSURE ON A SHEET PILE WALL WITH COUNTERFORTS (p. 11-18)

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A method has been developed for calculating the lateral earth pressure on a sheet pile wall with counterforts of various shapes – rectangular, trapezoidal with downward expansion, and trapezoidal with upward expansion. Moreover, in the design scheme, two characteristic areas are distinguished along the height of the wall – with and without a counterfort. As a result of considering the equilibrium conditions for elementary volume, equations for determining the lateral earth pressure along the height of the wall have been obtained in the considered sections. The study has produced a mathematical modeling of the system "a sheet pile wall with counterforts plus the soil environment". Diagrams of the lateral earth pressure are considered for a sheet pile with counterforts. A quantitative evaluation of the relief action of counterforts of various shapes has been obtained.

The conducted tests show that the use of counterforts in a sheet pile wall with the considered parameters reduces the pressure of the filling soil to 26 % due to the friction forces along the lateral surface of the counterforts.

The introduction of the developed calculation method into engineering practice will allow designing hydraulic engineering structures such as a sheet pile wall with various shapes of counterforts. This will enable the construction of new deepwater hydraulic structures with an increased bearing capacity.

Keywords: calculation method, sheet pile wall, counterfort, lateral earth pressure, relief effect.

References

1. Doubrovsky, M., Poizner, M., Petrosyan, V., Kalugnya, V. (2007). European choice – deep water terminals from combined dowel. Ports of Ukraine, 06 (68), 42–44.
2. The deep water berth is being built (2010). Ports of Ukraine, 4 (96), 3.
3. Fumiaki, T., Noriyuki, S. (1991). Self-erecting type landslide protection wall construction: Pat. No. 05009930 A Japan. Int. Cl E02D 5/02, E02D 17/04. declareted: 04.07.1991; published: 19.01.1993.
4. Doubrovsky, M. P., Meshcheryakov, G. N. (2012). Sheet pile testing & design improvement. Proceedings of IS-Kanazawa 2012 "Testing and Design for Deep Foundation". Kanazawa University, Japan, 589–596.
5. Slobodyanik, A. V., Bagrationy, R. R., Slobodyanik, A. V. (2015). Research of the Work of Thin Retaining Wall with Stiffeners. Eastern European Scientific Journal (Gesellschaftswissenschaften), 3, 146–151.
6. Dubrovsky, M. P., Slobodyanik, G. V. (2006). Retaining wall: Pat. No. 84888 UA. *M*PK (2006) E02D 29/2, E02B 3/06. No. a200605883; declareted: 29.05.2006; published: 10.12.2008, Bul. No. 23, 4.
7. Slobodyanik, G. V. (2016). A method of erection of hydraulic structures such as a hinged wall: Pat. No. 115379 UA. *M*PK (2017.01) E02B 3/06, *E*02D 5/00, *E*02D 29/02. No. 201611675; declareted: 18.11.2016; published: 10.04.2017, Bul. No. 7, 4.
8. Shiau, J., Smith, C. (2012). Developing Numerical Models for the Design of Cantilever Sheet Pile Wall. Research, Development and Practice in Structural Engineering and Construction. doi: 10.3850/978-981-08-7920-4_gfe-12-0308
9. Bekdaş, G., Temür, R. (2017). Metaheuristic approaches for optimum design of cantilever reinforced concrete retaining walls. Challeng Journal of Structural Mechanics, 3 (1), 23–30. doi: 10.20528/cjsmec.2016.11.031
10. Shehata, H. F. (2016). Retaining walls with relief shelves. Innovative Infrastructure Solutions, 1 (1). doi: 10.1007/s41062-016-0007-x
11. Farouk, H. (2014). Finite element analysis for the retaining wall with relief shelves. XV Danube – European Conference on geotechnical engineering (DECGE 2014). Vienna, No. 52.
12. Hu, Y., Liu, G., Zhao, Y. (2013). Calculation Method of Deformation and Inner Force of a Sheet Pile Wall with Relieving Platform. ICTE 2013. doi: 10.1061/9780784413159.025
13. Evstigneev, V. N. (1967). Experimental study of soil pressure on the wall with counterfoils. Port Hydrotechnical Construction, 15 (21), 23–28.
14. Shihiev, F. M., Fel'dman, Ya. N. (1967). Some cases of ground pressure on fences with a nonplanar problem. Port Hydraulic Engineering, 15 (21), 88–91.
15. Zelensky, V. S. (1969). Determination of pressure of friable environment on retaining walls with the ribbed verge. Ground, foundations and mechanics of soil, 6, 6–8.
16. Zelensky, V. S. (1978). Calculation of the spreading pressure of the soil on the walls of the quay embankments, taking into account the unloading effect of buttresses. Marine hydraulic engineering, 6, 13–20.
17. Kovacshazy, F. (1968). Model studies on retaining walls. Acta Technica Academial Scientiarum Hungarical, 62 (1-2), 28–35.
18. Sokolov, A. D. (2005). Ground pressure on retaining structures with buttresses from the ground backfilling depending on the movements. Questions of construction mechanics, safety of structures and hydraulics, 3, 124–146.
19. Sokolov, A. D. (2006). Lightweight retaining walls with ribbed pressure face. Transport construction, 8, 20–24.
20. Measurement of the spreading of the backfill and pressure on the bottom of the embankment in the port of Hakata (Japan) (1964). Pros. Harbour Engng, 40, 4756–4775.
21. RD 31.31.27-81. Guidelines for the design of marine berthing facilities (1984). Moscow: Mortekhinformreklama, 399.
22. Slobodyanik, A. V. (2009). The calculated substantiation of methods of technical operation of water transport facilities of sheet walls of increased rigidity. News of Odessa National Marine University, 26, 118–131.
23. Slobodyanik, A. V., Honeliya, N. N. (2016). Results of studies of the lateral pressure of the backfill soil on a thin retaining wall. Budivelni konstruktsiyi, 83, 397–402.

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THINWALLED STRUCTURES: ANALYSIS OF THE STRESSEDSTRAINED STATE AND PARAMETER VALIDATION (p. 18-29)

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The approach is developed to substantiate technical solutions for thin-walled machine building structures. It implies that the problem is considered in the space of generalized parameters. These parameters combine design and technological factors, as well as operating conditions. In addition, we introduce criterial and constraint dependences to a given space. In the generated uniform parametric space an approximated response surface is constructed, which stretches over a discrete set of solutions to analysis problems. For example, based on the results of examining the stresses-strained state, maximum stresses or displacements, mass or other controlled magnitudes are determined. They are unambiguously computed (a point in a common parametric space) for a specific set of variable generalized parameters. Having a cloud of such points, it is possible to construct an approximated response surface. Approximation constraints are also built on it. Next, by using the methods of nonlinear programming, we search on the set of permissible values for the minimum (or maximum) of quality function of the examined structure.

Specifically, for the thin-walled structures, important parameters are the shape and dimensions in a plan, as well as thickness of individual elements. Using a number of structures as examples, authors of present work performed analysis of influence of these parameters on the strength of designed structures.

Keywords: thin-walled machine building structure, stressed-strained state, response surface, innovative product.

References

1. Neittaanmäki, P., Repin, S., Tuovinen, T. (Eds.) (2016). Mathematical Modeling and Optimization of Complex Structures. Switzerland: Springer, 328. doi: 10.1007/978-3-319-23564-6
2. Zarchi, M., Attaran, B. (2017). Performance improvement of an active vibration absorber subsystem for an aircraft model using a bees algorithm based on multi-objective intelligent optimization. Engineering Optimization, 49 (11), 1905–1921. doi: 10.1080/0305215x.2017.1278757
3. Serpik, I. N., Mironenko, I. V., Averchenkov, V. I. (2016). Algorithm for Evolutionary Optimization of Reinforced Concrete Frames Subject to Nonlinear Material Deformation. Procedia Engineering, 150, 1311–1316. doi: 10.1016/j.proeng.2016.07.304
4. Kuczek, T. (2015). Application of manufacturing constraints to structural optimization of thin-walled structures. Engineering Optimization, 48 (2), 351–360. doi: 10.1080/0305215x.2015.1017350
5. Chepurnoy, A. D., Sheychenko, R. I., Graborov, R. V., Tkachuk, N. A., Bondarenko, M. A. (2017). Innovatsionnyy vagon-tsisterna dlya perevozki legkovesnyh himicheskih produktov modeli 15-6899. Podvizhnoy sostav XXI veka: idei, trebovaniya, proekty: materialy XII Mezhdnarodnoy nauchno-tekhnicheskoy konferentsii. Sankt-Peterburg: FGBOU VO PGUPS, 32–33.
6. Marchenko, A., Chepurnoy, A., Senko, V., Makeev, S., Litvinenko, O., Sheychenko, R. et. al. (2017). Analysis and synthesis of complex spatial thin-walled structures. Proceedings of the Institute of Vehicles. Institute of Vehicles of Warsaw University of Technology, 1, 17–29.
7. Nocedal J., Wright S. (2006). Numerical Optimization. New York: Springer-Verlag, 664.
8. Chinneck, J. W. Practical optimization: a gentle introduction. Available at: http://www.sce.carleton.ca/faculty/chinneck/po.html
9. Zienkiewicz, O. C., Taylor, R. L., Zhu, J. Z. (2013). The Finite Element Method: Its Basis and Fundamentals. Oxford: Butterworth-Heinemann, 756.
10. Sachsenberg, B., Schittkowski, K. (2015). A combined SQP–IPM algorithm for solving large-scale nonlinear optimization problems. Optimization Letters, 9 (7), 1271–1282. doi: 10.1007/s11590-015-0863-x
11. Byrd, R. H., Chin, G. M., Nocedal, J., Wu, Y. (2012). Sample size selection in optimization methods for machine learning. Mathematical Programming, 134 (1), 127–155. doi: 10.1007/s10107-012-0572-5
12. Tanchenko, A. Yu., Tkachuk, N. A., Artemov, I. V., Litvinenko, A. V. (2013). Dinamicheskie i prochnostnye harakteristiki tonkostennyh elementov mashinostroitel'nyh konstruktsiy pri umen'shenii tolshchiny v protsesse ekspluatatsii. Aktual'nye voprosy mashinovedeniya, 2, 210–213.
13. Karmanov, V. G. (2008). Matematicheskoe programmirovanie. Moscow: Fizmatlit, 263.
14. Vasidzu, K. (1987). Variatsionnye metody v teorii uprugosti i plastichnosti. Moscow: Mir, 542.

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STUDY OF THE INFLUENCE OF A FASTCHANGING TEMPERATURE ON METROLOGICAL CHARACTERISTICS OF THE TENSORESISTIVE PRESSURE SENSOR (p. 30-37)

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Based on dependences that describe the nonstationary temperature fields in the membrane and casing of the tensoresistive pressure sensor, we derived equations for thermomechanical processes in these elements, specifically equations of thermal deformation and thermal stresses. These equations make it possible to explore the effect of a thermal deflection in the membrane, as well as thermal stresses and thermal deformations in it, on the static and dynamic characteristics of the sensor.

It is shown that the combination of thermal elastic processes in the membrane under a fast-changing effect of temperature on it significantly distorts the static and dynamic characteristics. It was established that during thermal deflection relative deformations on the surface of the membrane can be commensurate with the working deformations during pressure measurement, while a transitional characteristic of the sensor may differ from normal by up to 60 %.

Our research shows that it is possible, when enabling radial thermal deformation, synchronized with the membrane of the sensor's casing, in the region of coupling with the membrane, to minimize thermal stresses in it. In addition, by minimizing the heat transfer along the perimeter of the sensor's membrane it is possible to eliminate the gradient of a temperature field along the radius. This is the way to minimize a thermal deflection of the membrane and decrease a temperature error of the sensor. Employing such measures may substantially reduce the influence of a fast-changing temperature on metrological characteristics of the sensor.

Keywords: pressure sensor, membrane, fast-changing temperature, metrological characteristics.

References

1. Kraft, M., White, N. M. (Eds.) (2013). MEMS for Automotive and Aerospace Applications. Woodhead Publishing Limited, 355. doi: 10.1533/9780857096487
2. Custom Pressure Sensors for the Aerospace Industry (2015). Merit Sensor. Available at: https://meritsensor.com/custom-pressure-sensors-for-the-aerospace-industry/
3. Sensors for Aerospace & Defense. PCB Piezotronics. Available at: https://www.pcb.com/aerospace
4. Markelov, I. G. (2009). Complex of pressure sensors for operation at nuclear power facilities. Sensors and systems, 11, 24–25.
5. Mokrov, J. A., Vasilev, V. A., Belozubov, J. M. (2005). Application of thermal protection films to minimize the influence of non-stationary temperatures on thin-film strain-gauge pressure sensors. Sensors and systems, 9, 21–23.
6. Zhao, L. B., Zhao, Y. L., Jiang, Z. D. (2006). Design and Fabrication of a Piezoresistive Pressure Sensor for Ultra High Temperature Environment. Journal of Physics: Conference Series, 48, 178–183. doi: 10.1088/1742-6596/48/1/033
7. Hsieh, C.-C., Hung, C.-C., Li, Y.-H. (2013). Investigation of a Pressure Sensor with Temperature Compensation Using Two Concentric Wheatstone-Bridge Circuits. Modern Mechanical Engineering, 03 (02), 104–113. doi: 10.4236/mme.2013.32015
8. Chiou, J. A., Chen, S. (2005). Thermal Stress Analysis for Differential Pressure Sensors. ASME 2005 International Mechanical Engineering Congress and Exposition. Orlando, Florida, USA, 273–278. doi: 10.1115/imece2005-82946
9. Mokrov, J. A., Belozubov, J. M., Tihomirov, D. V. (2004). Minimization of the error of thin-film strain-resistive pressure sensors under the influence of non-stationary temperature. Sensors and systems, 1, 26–29.
10. Guo, Z., Lu, C., Wang, Y., Liu, D., Huang, M., Li, X. (2017). Design and Experimental Research of a Temperature Compensation System for Silicon-on-Sapphire Pressure Sensors. IEEE Sensors Journal, 17 (3), 709–715. doi: 10.1109/jsen.2016.2633324
11. Aryafar, M., Hamedi, M., Ganjeh, M. M. (2015). A novel temperature compensated piezoresistive pressure sensor. Measurement, 63, 25–29. doi: 10.1016/j.measurement.2014.11.032
12. Tykhan, M., Mokrytskyy, V., Teslyuk, V. (2017). Efect of the membrane thermodeflection on the accuracy of a tensoresistive pressure sensor. Eastern-European Journal of Enterprise Technologies, 4 (7 (88)), 32–37. doi: 10.15587/1729-4061.2017.107239
13. Timoshenko, S. P., Woinowsky-Krieger, S. (1979). Theory of Plates and Shells. New York: McGraw-Hill, 580.
14. Beeby, S., Ensell, G., Kraft, M., Whait, N. (2004). MEMS Mechanical Sensors. Artech House Publishers, 271.
15. Barlian, A. A., Park, W.-T., Mallon, J. R., Rastegar, A. J., Pruitt, B. L. (2009). Review: Semiconductor Piezoresistance for Microsystems. Proceedings of the IEEE, 97 (3), 513–552. doi: 10.1109/jproc.2009.2013612

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GEOMETRICAL MODELING OF THE PROCESS OF WEAVING A WIRE CLOTH IN WEIGHTLESSNESS USING THE INERTIAL UNFOLDING OF A DUAL PENDULUM (p. 37-46)

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We proposed a geometrical model for weaving a wire cloth using the oscillations of a system of two-link pendulums within an abstract plane and under conditions of weightlessness. It is expected to initiate oscillations through the application of pulses to each of the nodal elements of each of the pendulums, induced by two pulse jet engines. The pendulums are arranged in line on the platform, aligned with an abstract plane. The plane moves in the direction of its normal using the jet engines. Attachment points of the dual pendulums are selected so that when unfolded their last loads come into contact. Upon simultaneous initiation of oscillations of all pendulums and setting the platform in motion, we consider traces from the spatial displacements of the last loads of pendulums. It is assumed that wire that accepts the shape of the specified traces comes from the last loads and forms the zigzag-like elements of the mesh. In order to fix elements of the mesh, it is suggested that they should be point welded at the moments of contact between the last loads of the pendulums. A description of the inertial unfolding of dual pendulums is compiled using a Lagrange equation of the second kind, in which potential energy was not taken into consideration because of weightlessness. Reliability of the considered geometrical model for weaving a wire cloth was verified in a series of created animated videos that illustrated the process of formation of the elements of a wire cloth. Results might prove useful for designing large-sized structures in weightlessness, for example, antennas for ultralong waves.

Keywords: geometrical modeling, woven wire cloth, dual pendulum, unfolding of antenna, Lagrangian equation of the second kind.

Reference

1. Semler, D., Tulintseff, A., Sorrell, R., Marshburn, J. (2010). Design, Integration, and Deployment of the TerreStar 18-meter Reflector. 28th AIAA International Communications Satellite Systems Conference (ICSSC-2010). doi: 10.2514/6.2010-8855
2. Ermolenko, I. V. (2013). Novyi aspekt vykorystannia osnovoviazanykh sitkopoten. Visnyk Khmelnytskoho natsionalnoho universytetu. Ser.: Tekhnichni nauky, 3, 73–78.
3. Zavaruev, V. A., Belyaev, O. F., Khalimanovich, V. I. (2017). Use of textile technologies for creation of a reflecting surface of transformable space antennas. Modern problems of engineering sciences: the collection of scientific works of the VIth International Scientific and Technical Symposium «Modern Energy and Resource Saving Technologies SETT-2017». Vol. 4. Moscow: GBOU V «RSU them. A. N. Kosygin», 915–919.
4. Zavaruev, V. A., Kotovich, O. S. (2007). Investigation of the influence of the types of loops of warp knitwear from metal threads on its physicomechanical and electrophysical properties. Izvestiya Vuzov. Technology of the textile industry, 3S (302), 91–93.
5. Belyaev, O. F., Zavaruev, V. A., Kudryavin, L. A., Podshivalov, S. F., Khalimanovich, V. I. (2007). Knitted metal netoplotna for the reflecting surface of transformable terrestrial and space antennas. Technical textiles, 16.
6. Ponomarev, S. V. (2011). Transformable reflectors of spacecraft antennae. Bulletin of Tomsk State University. Mathematics and mechanics, 4 (16), 110–119.
7. Zimin, V., Krylov, A., Meshkovskii, V., Sdobnikov, A., Fayzullin, F., Churilin, S. (2014). Features of the Calculation Deployment Large Transformable Structures of Different Configurations. Science and Education of the Bauman MSTU, 10, 179–191. doi: 10.7463/1014.0728802
8. Zimin, V. N. (2005). Specific features of calculating the unfolding truss space structure. Problems of Machine Building and Machine Reliability, 1, 20–25.
9. Melnikov, V. M., Matyushenko, I. N., Chernova, N. A., Kharlov, B. N. (2017). Problems in the Creation of Large-Dimensional Structures in Space. Electronic Journal Proceedings of the MAI, 78. Available at: http://trudymai.ru/upload/iblock/b87/b87ab54fb2066fe8ae55665c93427b09.pdf
10. Meshkovsky, V. Ye. (2009). Geometric model of a large-dimensional space truss structure opening. Vestnik of the MSTU. N. E. Bauman. Ser.: Natural Sciences, 4, 56–71.
11. Kudryavin, L. A., Zavaruev, V. A., Belyaev, O. F. (2013). The use of knitted metal netoploten for the reflecting surface of the transformed terrestrial and space antennas. The use of new textile and composite materials in technical textiles. Kazan: KNITU Publishing House, 92–97.
12. Goryachkin, O. V., Maslov, I. V. (2016). Analysis of an antenna system design for a synthetic L- and P-band aperture radar. VESTNIK of Samara University. Aerospace and Mechanical Engineering, 15 (3), 153–162. doi: 10.18287/2541-7533-2016-15-3-153-162
13. Hoyt, R. P., Cushing, J. I., Slostad, J. T., Jimmerson, G., Moser, T., Kirkos, G. et. al. (2013). SpiderFab: An Architecture for Self-Fabricating Space Systems. American Institute of Aeronautics and Astronautics, 17. Available at: http://www.tethers.com/papers/SPACE2013_SpiderFab.pdf
14. Hoyt R., Cushing J., Jimmerson G., Slostad J., Dyer R., Alvarado S. SpiderFab™: Process for On-Orbit Construction of Kilometer Scale Apertures. Available at: https://www.nasa.gov/sites/default/files/atoms/files/niac_hoyt_spiderfab_ph_2_finalreport_tagged.pdf
15. SpiderFab™ Orbital Manufacturing and Construction Technologies. Available at: http://www.tethers.com/SpiderFab.html
16. Archinaut. Available at: https://singularityhub.com/2016/03/02/archinaut-a-3d-printing-robot-to-make-big-structures-in-space
17. Kutsenko, L., Shoman, O., Semkiv, O., Zapolsky, L., Adashevskay, I., Danylenko, V. et. al. (2017). Geometrical modeling of the inertial unfolding of a multi-link pendulum in weightlessness. Eastern-European Journal of Enterprise Technologies, 6 (7 (90)), 42–50. doi: 10.15587/1729-4061.2017.114269
18. Kutsenko, L. N. Illustrations to the geometric modeling of the inertial opening of the multi-link pendulum in g-zero. Available at: http://repositsc.nuczu.edu.ua/handle/123456789/4868
19. Szuminski, W. (2014). Dynamics of multiple pendula without gravity. Chaotic Modeling and Simulation, 1, 57–67. Available at: http://www.cmsim.eu/papers_pdf/january_2014_papers/7_CMSIM_Journal_2014_Szuminski_1_57-67.pdf
20. Kutsenko, L. M. Iliustratsiy do heometrychnoho modeliuvannia pletinnia sitkopolotna v nevahomosti za dopomohoiu inertsiynoho rozkryttia podviynoho maiatnyka. Available at: http://repositsc.nuczu.edu.ua/handle/123456789/5143
21. Kutsenko, L. N., Adashevskaya, I. Yu. (2008). Geometric modeling of oscillations of multi-link pendulums. Kharkiv: «NTMT», 176.

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SEARCH FOR THE DUALFREQUENCY MOTION MODES OF A DUALMASS VIBRATORY MACHINE WITH A VIBRATION EXCITER IN THE FORM OF PASSIVE AUTO-BALANCER (p. 47-54)

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We analytically investigated dynamics of the vibratory machine with rectilinear translational motion of platforms and a vibration exciter in the form of a ball, a roller, or a pendulum auto-balancer.

The existence of steady-state motion modes of the vibratory machine was established, which are close to the dual-frequency regimes. Under these motions, loads in the auto-balancer create constant imbalance, cannot catch up with the rotor, and get stuck at a certain frequency. In this way, loads serve as the first vibration exciter, inducing vibrations with the frequency at which loads get stuck. The second vibration exciter is formed by the unbalanced mass on the casing of the auto-balancer. The mass rotates at rotor speed and excites faster vibrations of this frequency. The auto-balancer excites almost perfect dual-frequency vibrations. Deviations from the dual-

frequency law are proportional to the ratio of loads' mass to the mass of the entire machine, and do not exceed 2 %.

A dual-frequency vibratory machine has two oscillation eigenfrequencies. Loads can get stuck only at speeds close to the eigenfrequencies of vibratory machine's oscillations, or to the rotor rotation frequency.

The vibratory machine has always one, and only one, frequency at which loads get stuck, which is slightly lower than the rotor speed.

At low rotor speeds, there is only one frequency at which loads get stuck.

In the case of small viscous resistance forces in the supports, at an increase in the rotor speed, the quantity of frequencies at which loads get stuck in a vibratory machine increases, first, to 3, then to 5. In this case, new frequencies at which loads get stuck:

– occur in pairs in the vicinity of each eigenfrequency of the vibratory machine's oscillations;

– one of the frequencies is slightly lower, while the other is slightly higher, than the eigenfrequency of vibratory machine's oscillations.

Arbitrary viscous resistance forces in the supports may interfere with the emergence of new frequencies at which loads get stuck. That is why, in the most general case, the quantity of such frequencies can be 1, 3, or 5, depending on the rotor speed and the magnitudes of viscous resistance forces in supports.

Keywords: inertial vibration exciter, dual-frequency vibrations, resonance vibratory machine, auto-balancer, dual-mass vibratory machine, Sommerfeld effect.

References

1. Bukin, S. L., Maslov, S. G., Lyutiy, A. P., Reznichenko, G. L. (2009). Intensification of technological processes through the implementation of vibrators biharmonic modes. Enrichment of minerals, 36 (77)-37 (78).
2. Kryukov, B. I. (1967). Dinamika vibratsionnyih mashin rezonansnogo tipa [Dynamics of vibratory machines of resonance type]. Kyiv: Naukova dumka, 210.
3. Lanets, O. S. (2008). Vysokoefektyvni mizhrezonansni vibratsiyni mashyny z elektromagnitnym pryvodom (teoretychni osnovy ta praktyka stvorennia) [High-Efficiency Inter-Resonances Vibratory Machines with an Electromagnetic Vibration Exciter (Theoretical Bases and Practice of Creation)]. Lviv: Publishing house of Lviv Polytechnic National University, 324.
4. Filimonikhin, G. B., Yatsun, V. V. (2015). Method of excitation of dual frequency vibrations by passive autobalancers. Eastern-European Journal of Enterprise Technologies, 4 (7 (76)), 9–14. doi: 10.15587/1729-4061.2015.47116
5. Artyunin, A. I. (1993). Research of motion of the rotor with autobalance. Proceedings of the higher educational institutions. Mechanical Engineering, 1, 15–19.
6. Sommerfeld, A. (1904). Beitrage zum dinamischen Ausbay der Festigkeislehre. Zeitschriff des Vereins Deutsher Jngeniere, 48 (18), 631–636.
7. Yatsun, V., Filimonikhin, G., Dumenko, K., Nevdakha, A. (2017). Equations of motion of vibration machines with a translational motion of platforms and a vibration exciter in the form of a passive auto-balancer. Eastern-European Journal of Enterprise Technologies, 5 (1 (89)), 19–25. doi: 10.15587/1729-4061.2017.111216
8. Yatsun, V., Filimonikhin, G., Dumenko, K., Nevdakha, A. (2017). Search for two-frequency motion modes of single-mass vibratory machine with vibration exciter in the form of passive auto-balancer. Eastern-European Journal of Enterprise Technologies, 6 (7 (90)), 58–66. doi: 10.15587/1729-4061.2017.117683
9. Fedorenko, I. Ya., Gnezdilov, A. A. (2016). Dinamicheskiye svoystva dvukhmassnoy vibratsionnoy tekhnologicheskoy mashiny [The dynamic properties of a two-mass vibration technological machine]. Vestnik Altayskogo gosudarstvennogo agrarnogo universiteta, 3 (137), 179–183.
10. Lanets, O. S., Hurskyi, V. M., Lanets, O. V., Shpak, Ya. V. (2014). Obgruntuvannya konstruktsiyi ta modelyuvannya roboty rezonansnoho dvomasovoho vibrostola z inertsiynym pryvodom [Justification of the design and simulation of the operation of a resonant two-mass vibration table with an inertia drive]. Visnyk Natsionalnoho universytetu "Lvivska politekhnika". Dynamika, mitsnist ta proektuvannia mashyn i pryladiv, 788, 28–36.
11. Makarenkov, O. Yu. (2013). Asymptotic stability of fluctuations of two mass of a resonant roar. Applied mathematics and mechanics, 77 (3), 398–409.
12. Antipov, V. I., Palashova, I. V. (2010). Dynamics of a two-mass parametrically excited vibration machine. Journal of Machinery Manufacture and Reliability, 39 (3), 238–243. doi: 10.3103/s1052618810030052
13. Zhao, J., Liu, L., Song, M., Zhang, X. (2015). Influencing Factors of Anti-Resonant Inertial Resonant Machine Vibration Isolation System. 2015 3rd International Conference on Computer and Computing Science (COMCOMS). doi: 10.1109/comcoms.2015.22
14. Xiaohao, L., Tao, S. (2016). Dynamic performance analysis of nonlinear anti-resonance vibrating machine with the fluctuation of material mass. Journal of Vibroengineering, 18 (2), 978–988.
15. Nayfeh, A. H. (1993). Introduction to Perturbation Techniques. New York, United States: John Wiley and Sons Ltd., 533.

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A MULTIFACTOR ANALYSIS OF THE RAIL TRANSPORT CAR THAT PASSES OVER A JOINT UNEVENNESS WITH RESPECT TO THE PHASES OT ITS MOTION (p. 55-61)

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We have studied the influence of loading a four-axle railroad car, geometrical and mechanical characteristics of the rail, joint bars, sleepers, and a ballast layer on the parameters of static interaction between a railroad car and a rail track. The results obtained are universal and apply to railroad cars of any purpose: tram cars or passenger or freight cars for railroad transportation. The discrete-continuum model of the transport complex "railroad car – rail track" corresponds to the phase of car motion. The estimation schemes of static interaction relate to all four phases of the railroad car motion, as well as geometrical and structural parameters of the track dispatching and receiving rails and a four-axle railroad car. The structure of the research method and numerical algorithm implies determining the deflections of the track dispatching and receiving rails at the end, as well as the height of the joint that emerges in this case, depending on the car load.

Research into the influence of operating and structural parameters of a railroad car and the upper structure of a track on the static interaction between a railroad car and a rail track in the zone of a butt joint was carried out based on a comprehensive approach and general correlations in mechanics. We have calculated, in the transport systemic discrete-continuum mechanical complex "railroad car – rail track", using the methods of modeling and numerical analysis, the height of a joint unevenness depending on the phase of motion and load of the car. We established a parabolic character of the impact of a car load on the static interaction when passing over a joint unevenness, which corresponds to a monotonous growth in the height of a joint when increasing the load of a railroad car at all phases of its motion.

The obtained theoretical results allow practical implementation of the improvement of structural and operating parameters in the operation of a railroad car and the upper structure of a track through rational selection and optimization.

Keywords: rolling stock, four-axle railroad car, rail track, ballast layer, joint unevenness, dispatching and receiving track rails.

References

1. Shpachuk, V. P., Daleka, V. Kh., Kovalenko, A. V. (2005). Stykova dynamika tramvaia. Kharkiv: KhNAMH, 150.
2. Verigo, M. F., Kogan, A. Ya. (1986). Vzaimodeystvie puti i podvizhnogo sostava. Moscow: Transport, 559.
3. Lazaryan, V. A. (1964). Dinamika vagonov. Ustoychivost' dvizheniya i kolebaniya. Moscow: Transport, 255.
4. Shpachuk, V. P., Chuprynin, O. O., Suprun, T. O. (2014). Doslidzhennia vplyvu ekspluatatsiynykh faktoriv na statychni i dynamichni prohyny reikovoi koliyi v zoni stykovoi nerivnosti. Vibratsiyi v tekhnitsi ta tekhnolohiyakh, 4 (76), 100–108.
5. Vinogradov, B. V. (2015). Ekvivalentnoe chislo tsiklov napryazheniy pri raschete na vynoslivost' otkrytyh zubchatyh peredach barabannyh mel'nits. Naukovyi visnyk NHU, 1, 72–76.
6. Gursky, V., Kuzio, I. (2016). Strength and durability analysis of a flat spring at vibro-impact loadings. Eastern-European Journal of Enterprise Technologies, 5 (7 (83)), 4–10. doi: 10.15587/1729-4061.2016.79910
7. Pukach, P. Ya., Kuzio, I. V. (2015). Resonance phenomena in quasi-zero stiffness vibration isolation systems. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 3, 62–67.
8. Vinogradov, B. V., Fedin, D. O. (2016). The stress state of heavy loaded open gearing with incomplete tooth contact. Scientific Bulletin of National Mining University, 3, 35–40.
9. Kostovasilis, D., Ntotsios, E., Hussein, M. F. M., Thompson, D. J., Squicciarini, G. (2014). A holistic approach for the design and assessment of railway tracks. Proceedings of the 9th International Conference on Structural Dynamics, EURODYN 2014. Porto, 855–861.
10. Srihari, P., Azad, D., Sreeramulu, D. (2014). Optimization of rail inserts using finite element analysis. International Journal of Engineering, Science and Technology, 6 (2), 65. doi: 10.4314/ijest.v6i2.5
11. Noorzaei, J., Thanoon, W. A. M., Yeat, W. F., Pour, P. M., Jaafar, M. S. (2009). Numerical modeling of railway track supporting system using finite-infinite and thin layer elements. IJE Transactions A: Basics, 22 (2), 131–144.
12. Rose, J. G., Teixeira, P. F., Ridgway, N. E. (2010). Utilisation of Asphalt/Bituminous Layers and Coatings in Railway trackbeds. A Compendium of International Applications. Proceedings of the 2010 Joint Rail Conference. Urbana, Illinois.
13. Andreatta, A., Theiner, Y., Hofstetter, G., Feix, J. (2013). A Drivable Slab Track Cover System For Railway Tunnels. Advances in Civil and Environmental Engineering, 01 (02), 84–98.
14. Allan, J. (2012). Soil Mechanics of High Speed Rail Tracks. In Proc. 1st Civil and Environmental Engineering Student. Imperial College London, 206–212.
15. Shpachuk, V. P., Chuprynin, O. O., Harbuz, A. O., Suprun, T. O. (2016). Rivni statychnoi vzaiemodiyi tramvaia z reikovoiu koliyeiu na chetvertiy fazi prokhodzhennia vahonom stykovoi nerivnosti. Zbirnyk naukovykh prats UkrDUZT, 162, 11–20.

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SYNTHESIS OF ENERGYEFFICIENT ACCELERATION CONTROL LAW OF AUTOMOBILE (p. 62-70)

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We have established the laws of change in the vehicle acceleration time at the existing step transmission of ICE, when implementing the total traction force, boundary for the drive wheels adhesion to the road, and during implementation of the proposed rational law for acceleration control. To model ICE speed characteristics, we applied the empirical dependence by S.R. Leyderman. The analytical expressions obtained allow us to implement such a change in vehicle acceleration depending on its speed that makes it possible to ensure maximum dynamism at minimal engine power consumption, taking into consideration a nonlinear change in external resistance. The maximum acceleration, which is possible to implement using the rational dynamic characteristic, can reach 7 m/s^2. Based on the

dependences obtained, it is possible to determine effective work of ICE required to accelerate a vehicle at different gears. An analysis of calculation results revealed that the transition from lower to higher gears is accompanied by a sharp decrease in engine energy expenditure required to accelerate the vehicle.

It was established that for the case of hybrid vehicles, acceleration using the electric drive, rather than accelerating at lower gears of the mechanical drive, makes it possible to reduce energy losses by 20 % (for a four-cylinder internal combustion engine). Energy preservation is accomplished by reducing the fluctuation of traction force, as well as the possibility of a step-free change in motion speed.

Keywords: acceleration dynamics, rational control, reducing energy consumption, rational speed.

References

1. Turenko, A., Podrygalo, M., Klets, D., Hatsko, V., Barun, M. (2016). A method of evaluating vehicle controllability according to the dynamic factor. Eastern-European Journal of Enterprise Technologies, 3 (7 (81)), 29–33. doi: 10.15587/1729-4061.2016.72117
2. Nkomo, L. I., Dove, A., Ngwako, M. T., Nyandoro, O. T. (2017). Heaviside based optimal control for ride comfort and actuation energy optimisation in half-car suspension systems. IFAC-PapersOnLine, 50 (2), 259–264. doi: 10.1016/j.ifacol.2017.12.055
3. Podrigalo, M., Klets, D., Podrigalo, N., Abramov, D., Tarasov, Y., Kaidalov, R. et. al. (2017). Creation of the energy approach for estimating automobile dynamics and fuel efficiency. Eastern-European Journal of Enterprise Technologies, 5 (7 (89)), 58–64. doi: 10.15587/1729-4061.2017.110248
4. Travesset-Baro, O., Gallachóir, B. P. Ó., Jover, E., Rosas-Casals, M. (2016). Transport energy demand in Andorra. Assessing private car futures through sensitivity and scenario analysis. Energy Policy, 96, 78–92. doi: 10.1016/j.enpol.2016.05.041
5. Daly, H. E., Ó Gallachóir, B. P. (2011). Modelling future private car energy demand in Ireland. Energy Policy, 39 (12), 7815–7824. doi: 10.1016/j.enpol.2011.09.027
6. Yu, F., Liu, Z. (2016). Direct Energy Rebound Effect of Family Cars: An Analysis Based on a Survey in Chang-Zhu-Tan City Group. Energy Procedia, 104, 197–202. doi: 10.1016/j.egypro.2016.12.034
7. Daly, H., Ó Gallachóir, B. P. (2011). Modelling private car energy demand using a technological car stock model. Transportation Research Part D: Transport and Environment, 16 (2), 93–101. doi: 10.1016/j.trd.2010.08.009
8. Matas A., Raymond J.-L., Dominguez A. (2017). Changes in fuel economy: An analysis of the Spanish car market. Transportation Research Part D: Transport and Environment, 55, 175–201. doi: 10.1016/j.trd.2017.06.025
9. Ohara, H., Murakami, T. (2008). A Stability Control by Active Angle Control of Front-Wheel in a Vehicle System. IEEE Transactions on Industrial Electronics, 55 (3), 1277–1285. doi: 10.1109/tie.2007.909051
10. Hsu, J.-Y., Chen, B.-R., Hu, T.-H. (2013). Vehicle stability control method and system: Pat. 20130103263 TW. USPC Class: 701 42. Class name: Vehicle subsystem or accessory control steering control feedback, transfer function or proportional and derivative (p&d) control. AB62D600FI; published: 25.04.2013, 4.
11. Chung, T., Yi, K. (2006). Design and evaluation of side slip angle-based vehicle stability control scheme on a virtual test track. IEEE Transactions on Control Systems Technology, 14 (2), 224–234. doi: 10.1109/tcst.2005.863649