ABSTRACT AND REFERENCES

APPLIED MECHANICS

DOI: 10.15587/1729-4061.2018.125490

STABILITY OF STRUCTURAL ELEMENTS OF SPECIAL LIFTING MECHANISMS IN THE FORM OF CIRCULAR ARCHES (p. 4–10)

Viktor Orobey
Odessa National Polytechnic University, Odessa, Ukraine
ORCID: http://orcid.org/0000-0002-2001-2274

Oleksandr Daschenko
Odessa National Polytechnic University, Odessa, Ukraine
ORCID: http://orcid.org/0000-0002-7700-2333

Leonid Kolomiets
Odessa State Academy of Technical Regulation and Quality, Odessa, Ukraine
ORCID: http://orcid.org/0000-0003-2341-3345

Oleksandr Lymarenko
Odessa National Polytechnic University, Odessa, Ukraine
ORCID: http://orcid.org/0000-0002-3607-5253

The system of differential equations of stability of circular arches with symmetric sections and the sixth-order resolving ordinary differential equation are derived. It is noted that these equations have variable coefficients and their analytical solution under existing external loads leads to serious mathematical difficulties. The problem of finding exact solutions can be substantially simplified if we use the numerical-analytical version of the boundary element method (BEM). Here it is necessary to have a solution of the resolving equation of the problem, but with constant coefficients. This problem is much simpler than the initial one and can be realized according to the known procedure for constructing the fundamental functions of an ordinary differential equation. In this regard, the constants for integrating the general solutions of the differential equation are determined for the two most common cases and rationing of the fundamental functions in the matrix resolving form is performed. Recommendations are given on the solution of various boundary-value problems of stability of the simple bending of arch elements of special lifting mechanisms using them.

Keywords: stability problems, system of differential equations with variable coefficients, fundamental functions, BEM.

References

1. De Backer, H., Outtier, A., Van Bogaert, P. (2014). Buckling design of steel tied-arch bridges. Journal of Constructional Steel Research, 103, 159–167. doi: 10.1016/j.jcsr.2014.09.004
2. Louise, C. N., Md Othuman, A. M., Ramli, M. (2012). Performance of lightweight thin-walled steel sections: theoretical and mathematical considerations. Advances in Applied Science Research, 3 (5), 2847–2859.
3. Pi, Y.-L., Bradford, M. A. (2013). In-plane stability of preloaded shallow arches against dynamic snap-through accounting for rotational end restraints. Engineering Structures, 56, 1496–1510. doi: 10.1016/j.engstruct.2013.07.020
4. Becque, J., Lecce, M., Rasmussen, K. J. R. (2008). The direct strength method for stainless steel compression members. Journal of Constructional Steel Research, 64 (11), 1231–1238. doi: 10.1016/j.jcsr.2008.07.007
5. Andreew, V. I., Chepurnenko, A. S., Yazyev, B. M. (2014). Energy Method in the Calculation Stability of Compressed Polymer Rods Considering Creep. Advanced Materials Research, 1004-1005, 257–260. doi: 10.4028/www.scientific.net/amr.1004-1005.257
6. Artyukhin, Yu. P. (2012). Approximate analytical method for studying deformations of spatial curvilinear bars. Uchenye zapiski Kazanskogo Universiteta. Physics and mathematics, 154, 97–111.
7. Qiu, W.-L., Kao, C.-S., Kou, C.-H., Tsai, J.-L., Yang, G. (2010). Stability Analysis of Special-Shape Arch Bridge. Tamkang Journal of Science and Engineering, 13 (4), 365–373.
8. Pettit, J. R., Walker, A. E., Lowe, M. J. S. (2015). Improved detection of rough defects for ultrasonic nondestructive evaluation inspections based on finite element modeling of elastic wave scattering. IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, 62 (10), 1797–1808. doi: 10.1109/tuffc.2015.007140
9. Langer U., Schanz M., Steinbach O., Wendland W. L. (Eds.) (2012). Fast Boundary Element Methods in Engineering and Industrial Applications. Lecture Notes in Applied and Computational Mechanics. Springer. doi: 10.1007/978-3-642-25670-7
10. Orobey, V., Kolomiets, L., Lymarenko, A. (2015). Boundary element method in problem of plate elements bending of engineering structures. Metallurgical and Mining Industry, 4, 295–302.
11. Kolomiets, L., Orobey, V., Lymarenko, A. (2016). Method of boundary elements in problems of stability of plane bending of rectangular section beams. Metallurgical and Mining Industry, 3, 58–65.
12. Orobey, V., Daschenko, O., Kolomiets, L., Lymarenko, O., Ovcharov, Y. (2017). Mathematical modeling of the stressed-deformed state of circular arches of specialized cranes. Eastern-European Journal of Enterprise Technologies, 5 (7 (89)), 4–10. doi: 10.15587/1729-4061.2017.109649

DOI: 10.15587/1729-4061.2018.125937

THE INFLUENCE OF THE BLADE FEATHER CONSTRUCTIONAL INHOMOGENEITY ON THE TURBINE COOLING BLADES STRESS-STRAIN STATE (p. 11–17)

Serhii Morhun
Admiral Makarov National University of Shipbuilding, Mykolaiv, Ukraine
ORCID: http://orcid.org/0000-0003-2881-7541

The problem of gas turbine engines inhomogeneous rotor blades stress-strain state has been studied. For this purpose, the new, more correct mathematical model, based on the special three-dimensional curvilinear finite elements has been used. Such elements have three modifications, applied for the blade feather and its transition zones correct modeling. The complex influence of vibration and heat loads on the blade feather has also been taken into consideration.

The values of maximum dynamic stresses and their localization zones have also been found. The main concentrators of stresses are located in the transfer zones between the cooling channels and blade feather surfaces. The blade output edge is another zone of maximum dynamic stresses localization.

It has also been found that the influence of the geometric parameters of cooling channels in the blade feather cavity on the value of maximum dynamic stresses is sharper than the influence of cooling holes on the blade output edge.

By comparing the obtained calculated results with the experimental data, we can state the high adequacy and reliability of the developed mathematical model. All calculations and experimental procedures were held by equal boundary conditions. The results of the research can be used as a base for further studying of the whole rotor stress-strain state and processes of blades fatigue destruction.

Keywords: turbine engine blades, geometric parameters, three-dimensional finite elements, dynamic stresses.

References

1. Samaras, C. (2009). Emissions and lifetime estimation modeling of industrial gas turbines. M. Sc. Progress Review, Cranfield University, UK, 30–35.
2. Sukhvinder, K. B., Shyamala Kumari, M. L., Neelapu, M. L., Kedarinath, C. (2006). Transient state stress analysis on an axial flow gas turbine blades and disk using finite element procedure. Proceedings of the 4th WSEAS Int. Conf. on Heat Transfer, Thermal Engineering and Enviroment. Elounda, Greece, 323–330.
3. Krishnakanth, P. V., Narasa Raju, G. et. al. (2013). Structural and Thermal Analysis of Gas Turbine Blade by using FEM. International Journal of Scientific Research Engineering and Technology, 2 (2), 060–065.
4. Mrinaline, M. (2016). Steady state structural analysis of single crystal turbine blade. International Journal of Engineering Research and Technology, V5 (10), 382–384. doi: 10.17577/ijertv5is100314
5. Ugargol, R., Narayanaswamy, K. S., Sesha Kumar, C. V. (2017). Life estimation of turbine blisk for a gas turbine engine. International Journal of Mechanical Engineering and Technology, 8 (8), 393–399.
6. Rzadkowski, R., Gnesin, V., Kolodyazhnaya, L., Kubitz, L. (2014). Unsteady forces acting on the rotor blades in the turbine stage in 3D viscous flow in nominal and off-design regimes. Journal of Vibration Engineering, and Technologies, 2 (2), 89–95.
7. Baqersad, J., Niezrecki, C., Avitabile, P. (2014). Predicting full-field dynamic strain on a three-bladed wind turbine using three dimensional point tracking and expansion techniques. Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems 2014. doi: 10.1117/12.2046106
8. Postnov, V. V., Starovoitov, S. V., Fomin, S. Y., Basharov, R. R. (2014). Theoretical and experimental stress-strain analysis of machining gas turbine engine parts made of the high energy structural efficiency alloy. Journal of Engineering Science and Technology Review, 7 (5), 47–50.
9. Bitkina, O., Kang, K.-W., Lee, J.-H. (2015). Experimental and theoretical analysis of the stress-strain state of anisotropic multilayer composite panels for wind turbine blade. Renewable Energy, 79, 219–226. doi: 10.1016/j.renene.2014.11.004
10. Kostyuk, A. G. (1982). Dinamika i prochnost' turbomashin. Moscow: Mashinostroenie, 264.
11. Sosunov, V. A., Chepkin, V. M. (2003). Teoriya, raschet i proektirovanie aviacionnyh dvigateley i energeticheskih ustanovok. Moscow: Mosk. energ. in-t., 677.
12. Vorob'ev, Yu. S. (1988). Kolebaniya lopatochnogo apparata turbomashin. Kyiv: Naukova dumka, 224.
13. Pyhalov, A. A., Milov, A. E. (2007). Staticheskiy i dinamicheskiy analiz sbornyh rotorov turbomashin. Irkutsk: Izd-vo Irkut. tekhn. un-ta, 194.
14. Morgun, S. (2016). The blades constructions finite elements models development. Bulletin of the National Technical University «KhPI». Series: New Solutions in Modern Technologies, 42 (1214), 86–91. doi: 10.20998/2413-4295.2016.42.14
15. Abramovich, G. N. (1991). Prikladnaya gazovaya dinamika. Moscow: Nauka, 600.
16. Samarskiy, A. A., Vabicevich, P. N. (2009). Vychislitel'naya teploperedacha. Moscow: Editorial, 784.
17. Kairov, A. S., Morgun, S. A. (2013). Eksperimental'noe issledovanie peremennyh vibronapryazheniy v rabochih lopatkah turbomashin. Prohresyvni tekhnolohiyi i systemy mashynobuduvannia, 1 (45)-2 (46), 131–138.

DOI: 10.15587/1729-4061.2018.126512

INVESTIGATION OF THE WORK OF THE ROAD CONSTRUCTION AT THE SITES BY PIPE DRENES FROM MATERIALS OF DIFFERENT ORIGIN (p. 18–26)

Olena Slavinska
National Transport University, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-9709-0078

Vyacheslav Savenko
National Transport University, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0001-8174-7728

Andrey Bubela
National Transport University, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0002-5619-003X

Andrey Yaremov
National Transport University, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0001-7239-8060

The paper reports research into operation of road structures with tubular drains made from materials with different physical-mechanical properties, which makes it possible to identify basic factors that affect operational conditions under the influence of own mass and the rated load from rolling stock in accordance with the building norms of Ukraine. Non-standard road structures were simulated in the SCAD environment. The results of numerical simulation allowed us to derive diagrams of normal stresses and deformations of structural layers in road surfacing, as well as in the body of tubular drains. The calculations were performed both for the standard and the actual compaction of material used as a trench backfill, for a PVC pipe and a concrete pipe.

Consideration of tubular openings in solid layered road structures made it possible to estimate the actual stressed-deformed state at the sections of roads that require control over a water-heat mode. The proposed method of study enables the selection of individual design-structural parameters for drainages of shallow laying for general-purpose public roads of different technical categories as opposed to the standard approaches implied by the building regulations of Ukraine.

Keywords: road structure, drainage structure of shallow laying, tubular drain, polyvinylchloride pipe, concrete pipe.

References

1. Drainage manual (2018). Tallahassee, Florida, 123. Available at: http://www.fdot.gov/roadway/drainage/files/drainagemanual.pdf
2. Abou Rjeily, Y., Abbas, O., Sadek, M., Shahrour, I., Hage Chehade, F. (2017). Flood forecasting within urban drainage systems using NARX neural network. Water Science and Technology, 76 (9), 2401–2412. doi: 10.2166/wst.2017.409
3. Tiğrek, Ş., Sipahi, S. O. (2011). Rehabilitation of storm water collection systems of urban environment using the small roads as conveyance channels. International Journal of Environmental Science and Technology, 9 (1), 95–103. doi: 10.1007/s13762-011-0002-x
4. Mukherjee, D. (2014). Highway Surface Drainage System & Problems of Water Logging In Road Section. The International Journal Of Engineering And Science (IJES), 3 (11), 44–51. Available at: http://www.theijes.com/papers/v3-i11/Version-1/G031101044051.pdf
5. Slavinska, O. S., Styozhka, V. V. (2016). Optimization of engineering solutions: the case of comparison of comparison of shallow drainage constructions. Avtomobilni dorohy i dorozhnie budivnytstvo, 98, 228–237. Available at: http://publications.ntu.edu.ua/avtodorogi_i_stroitelstvo/98/228-237.pdf

6. Stormwater drainage manual. Available at: https://www.dsd.gov.hk/EN/Files/Technical_Manual/technical_manuals/Stormwater_Drainage_Manual_Eurocodes.pdf
7. Allen, D., Arthur, S., Haynes, H., Olive, V. (2016). Multiple rainfall event pollution transport by sustainable drainage systems: the fate of fine sediment pollution. International Journal of Environmental Science and Technology, 14 (3), 639–652. doi: 10.1007/s13762-016-1177-y
8. Latvala, J., Nurmikolu, A., Luomala, H. (2016). Problems with Railway Track Drainage in Finland. Procedia Engineering, 143, 1051–1058. doi: 10.1016/j.proeng.2016.06.098
9. Sandberg, U., Kragh, J., Goubert, L. et. al. (2011). Optimization of Thin Asphalt Layers – State-of-the-Art Review. Swedish National Road and Transport Research Institute (VTI), Danish Road Institute (DRI) & Belgian Road Research Centre (BRRC).
10. Sangghaleh, A., Pan, E., Green, R., Wang, R., Liu, X., Cai, Y. (2013). Backcalculation of pavement layer elastic modulus and thickness with measurement errors. International Journal of Pavement Engineering, 15 (6), 521–531. doi: 10.1080/10298436.2013.786078
11. Gopalakrishnan, K., Papadopoulos, H. (2011). Reliable pavement backcalculation with confidence estimation. Scientia Iranica, 18 (6), 1214–1221. doi: 10.1016/j.scient.2011.11.018
12. Cao, Z., Han, J., Xu, C., Khatri, D. K., Corey, R., Cai, Y. (2016). Road surface permanent deformations with a shallowly buried steel-reinforced high-density polyethylene pipe under cyclic loading. Geotextiles and Geomembranes, 44 (1), 28–38. doi: 10.1016/j.geotexmem.2015.06.009
13. Bishop, R. R. Retention of Pipe Stiffness for Polyvinyl Chloride (PVC) Pipe Samples Exposed to Various Environments and Constant Strain. Buried Plastic Pipe Technology. doi: 10.1520/stp42110s
14. Polyvinyl Chloride (PVC) Pipe (2013). Pipelines for Water Conveyance and Drainage, 35–46. doi: 10.1061/9780784412749.ch05
15. Talakh, S. M., Dubyk, O. M., Lysnytska, K. M. (2017). Numerical calculation of the stress-strain state of non-rigid pavements, renovated by cold recycling technology. ScienceRise, 1 (2 (30)), 31–38. doi: 10.15587/2313-8416.2017.91111
16. Pavlenko, N. V. (2014). Osoblyvosti rozrakhunku nezhorstkykh dorozhnikh odiahiv za kryteriyamy mitsnosti. Naukovi notatky, 45, 412–416.
17. Shmyh, R. A., Dobrianskyi, I. M.; Shmyh, R. A. (Ed.) (2015). Rozrakhunok budivelnykh konstruktsiyi v obchysliuvalnomu kompleksi SCAD. Lviv: Liha Pres, 80. Available at: http://shron1.chtyvo.org.ua/Shmyh_Roman/Rozrakhunok_budivelnykh_konstruktsii_v_obchysliuvalnomu_kompleksi_SCAD.pdf
18. Shvec, V. B., Shapoval, V. G., Petrenko, V. D. et. al. (2008). Fundamenty promyshlennyh, grazhdanskih i transportnyh sooruzheniy na sloistyh gruntovyh osnovaniyah. Dnepropetrovsk: Novaya ideologiya, 274.
19. Gorodeckiy, A. S., Zavorickiy, V. I., Lantuh-Lyashchenko, A. I., Rasskazov, A. O. (1981). Metod konechnyh elementov v proektirovanii transportnyh sooruzheniy. Moscow: Transport, 144.
20. Bugrov, A. K., Zarhi, A. A. (1978). Nekotorye rezul'taty resheniya smeshannyh zadach teoriy uprugosti i plastichnosti gruntov osnovaniy. Osnovaniya, fundamenty i mekhanika gruntov, 3, 35–39.
21. Pavliuk, D. O., Pavliuk, V. V., Lebediev, O. S., Bulakh, Ye. O., Peristyi, O. O. Nachipne obladnannia dlia otsinky mitsnosti i deformatyvnosti dorozhnikh konstruktsii ta gruntovykh osnov. Available at: http://road-laboratory.com/files/%E2%84%962.pdf
22. Piskunov, V. H., Sipetov, V. S., Shevchenko, V. D., Fedorenko, Yu. M.; Piskunov, V. H. (Ed.) (1995). Opir materialiv z osnovamy teoriyi pruzhnosti y plastychnosti. Ch. 2, Kn. 3. Opir dvo- i tryvymirnykh til. Kyiv: Vyshcha shkola, 273.

DOI: 10.15587/1729-4061.2018.119727

NUMERICAL SIMULATION OF TWO-DIMENSIONAL PROBLEMS OF CREEP CRACK GROWTH WITH MATERIAL DAMAGE CONSIDERATION (p. 27–33)

Dmytro Breslavsky
National Technical University
«Kharkiv Polytechnic Institute», Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-3792-5504

Alyona Kozlyuk
National Technical University
«Kharkiv Polytechnic Institute», Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-2011-2977

Oksana Tatarinova
National Technical University
«Kharkiv Polytechnic Institute», Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-3090-8469

Approach for numerical simulation of the process of the creep crack growth taking into account the hidden material damage is proposed. The approach is based on the application of finite element creep modeling, accompanied by damage. For calculations, the FEM Creep software package is used. Using the proposed algorithm for rebuilding the grid with the removal of the destroyed elements, the current picture of deformation and fracture is analyzed. This takes into account the growing level of damage during the crack motion in each element. Numerical fracture simulation data are used to determine the constants in the differential creep fracture propagation equation. As an example, the creep fracture of planar specimens with sharp notches in their plane is considered. The material of the specimens is a high-temperature nickel-based alloy EI 867 at a temperature of 950 °C. Calculations are carried out for different values of the load. For different times, finite element grids with remote elements are shown. Graphs of the dependence of crack length on time are built. Comparison of numerical and calculated data obtained with the motion equation of a crack shows their acceptable coincidence. The possibility of using the proposed approach for obtaining constants in the equation of crack motion as an alternative to the existing experimental one is discussed.

Keywords: creep, damage, creep crack growth, finite element calculation model.

References

1. Erdogan, F. (2000). Fracture mechanics. International Journal of Solids and Structures, 37 (1-2), 171–183. doi: 10.1016/s0020-7683(99)00086-4
2. Rice, J. R. (1968). A Path Independent Integral and the Approximate Analysis of Strain Concentration by Notches and Cracks. Journal of Applied Mechanics, 35 (2), 379. doi: 10.1115/1.3601206
3. Webster, G. A., Nikbin, K. M. (1981). History of Loading Effects on Creep Crack Growth in 1/2% Cr, 1/2% Mo, 1/4% V Steel. Creep in Structures, 576–591. doi: 10.1007/978-3-642-81598-0_38
4. Riedel, H. (1981). The Extension of a Macroscopic Crack at Elevated Temperature by the Growth and Coalescence of Microvoids. Creep in Structures, 504–519. doi: 10.1007/978-3-642-81598-0_33
5. Hayhurst, D. R., Morrison, C. J., Brown, P. R. (1981). Creep Crack Growth. Creep in Structures, 564–575. doi: 10.1007/978-3-642-81598-0_37
6. Moës, N., Dolbow, J., Belytschko, T. (1999). A finite element method for crack growth without remeshing. International Journal for Numerical Methods in Engineering, 46 (1), 131–150. doi: 10.1002/(sici)1097-0207(19990910)46:1<131::aid-nme726>3.3.co;2-a
7. Hayhurst, D. R., Brown, P. R., Morrison, C. J. (1984). The Role of Continuum Damage in Creep Crack Growth. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 311 (1516), 131–158. doi: 10.1098/rsta.1984.0022

8. Ohtani, R. (1981). Finite Element Analysis and Experimental Investigation on Creep Crack Propagation. Creep in Structures, 542–563. doi: 10.1007/978-3-642-81598-0_36
9. Chaboche, J. L. (2003). Damage Mechanics. Comprehensive Structural Integrity, 213–284. doi: 10.1016/b0-08-043749-4/02085-1
10. Riedel, H. (1989). Creep Crack Growth. Fracture Mechanics: Perspectives and Directions (Twentieth Symposium), 101–101-26. doi: 10.1520/stp18822s
11. Perrin, I. J., Hayhurst, D. R. (1999). Continuum damage mechanics analyses of type IV creep failure in ferritic steel crossweld specimens. International Journal of Pressure Vessels and Piping, 76 (9), 599–617. doi: 10.1016/s0308-0161(99)00051-4
12. Yatomi, M., Nikbin, K. M., O'Dowd, N. P. (2003). Creep crack growth prediction using a damage based approach. International Journal of Pressure Vessels and Piping, 80 (7-8), 573–583. doi: 10.1016/s0308-0161(03)00110-8
13. Cuvillez, S., Feyel, F., Lorentz, E., Michel-Ponnele, S. (2012). Transition from a gradient damage model to a cohesive zone model within the framework of quasi-brittle failure. Proc. of First Int. Conf. on Damage Mechanics ICDM1. Belgrade, 97–100.
14. Astaf'ev, V. I., Radaev, Yu. N., Stepanova, L. V. (2004). Nonlinear fracture mechanics. Samara: Samarskiy universitet, 562.
15. Xu, M., Chen, J., Lu, H., Xu, J., Yu, C., Wei, X. (2016). Effects of residual stress and grain boundary character on creep cracking in 2.25Cr-1.6W steel. Materials Science and Engineering: A, 659, 188–197. doi: 10.1016/j.msea.2016.02.025
16. Breslavskii, D. V., Morachkovskii, O. K. (1998). Nonlinear creep and the collapse of flat bodies. International Applied Mechanics, 34 (3), 287–292.
17. Breslavsky, D. V., Korytko, Yu. M., Tatarinova O.A. (2017). Design and development of Finite Element Method software. Kharkiv: KhPi, 232.
18. Breslavs'kyi, D. V., Korytko, Y. M., Morachkovs'kyi, O. K. (2011). Cyclic thermal creep model for the bodies of revolution. Strength of Materials, 43 (2), 134–143. doi: 10.1007/s11223-011-9279-8
19. Lemaitre, J., Chaboche, J. L. (1994). Mechanics of solid materials. Cambridge University Press, 556.
20. Golub, V. P. (1983). Cyclic Creep of Refractory Nickel Alloys. Kyiv: Naukova dumka, 224.
21. Taira, S., Otani, R. (1986). Theory of High-Temperature Strength of Materials. Moscow: Metallurgiya, 280.

DOI: 10.15587/1729-4061.2018.126548

DESIGN OF THE LABORATORY BENCH FOR A HYDROVOLUMETRIC-MECHANICAL TRANSMISSION OF THE TRACKED TRACTOR (p. 34–43)

Nikolay Mittsel
National Technical University «Kharkiv Polytechnic Institute»,
Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-0722-7799

Double-flow hydrovolumetric mechanical transmissions is an advanced technical solution that aims to increase productivity, improve efficiency and convenience of control over wheeled and tracked tractors. Their arrangement renders considerable potential for their modernization and makes it possible to introduce recuperation systems that would enhance their performance efficiency coefficient to the level of mechanical transmissions. Innovativeness of these transmissions and the lack of a sufficient number of prototypes largely hinder their implementation in production.

A large number of possible HT circuits necessitates the creation of an original bench-prototype for each of them. In order to solve this task, we proposed in this paper a kinematic circuit of the universal testing laboratory bench for HT of the tracked tractor. Its design makes it possible to study HT circuits of the type with a differential «at the output», the type with a differential «at the input» for both wheeled and tracked vehicles, and to simulate the process of work of a hydrovolumetric turning mechanism. Introduction of electric generators to the design makes it possible to estimate in practice the effectiveness of recuperation of kinetic energy at braking, as well as parasite power that circulates in the closed circuit of HT during acceleration and braking.

We give quasi-static characteristics of basic HT circuits that are simulated at the laboratory bench. The results were obtained based on an improved mathematical model that makes it possible to determine the volumetric, mechanical, and full performance efficiency coefficient of separate hydraulic machines in the direct and reverse flows of power and special working regions of hydraulic gear. For the transmissions with a differential «at the output», maximal performance efficiency coefficient reaches 83 %, indicating the proper selection of gear ratios and standard size of hydraulic machines.

The results obtained are of interest for industrial and design organizations, specializing in the development of transmissions for transportation vehicles. Employing the developed bench would significantly reduce the time between designing and industrial implementation. There is a possibility to confirm experimentally the efficiency and high technical-economic indicators of the proposed transmission. Such a bench will make it possible for scientific institutions to discover new phenomena and processes in HT, systematize the influence of gear ratios of reducers, planetary mechanisms, and their number, on the working processes in HT.

Keywords: tractor, transmission, laboratory bench, planetary mechanism, circulation of power, hydrovolumetric turning mechanism.

References

1. Samorodov, V., Kozhushko, A., Pelipenko, E. (2016). Formation of a rational change in controlling continuously variable transmission at the stages of a tractor's acceleration and braking. Eastern-European Journal of Enterprise Technologies, 4 (7 (82)), 37. doi: 10.15587/1729-4061.2016.75402
2. Samorodov, V. B., Taran, I. A. (2012). Analiz raspredeleniya potokov moshchnosti s uchetom KPD gidroob'emnoy peredachi v dvuhpotochnyh besstupenchatyh gidroob'emno-mekhanicheskih transmissiyah s differencialom na vyhode. Visnyk Natsionalnoho tekhnichnoho universytetu «KhPI», 60 (966), 7–16.
3. Bondarenko, A. I. (2015). Kolichestvennaya ocenka stepeni utomleniya operatorov-voditeley kolesnyh traktorov s razlichnymi tipami transmissiy. Privolzhskiy nauchniy vestnik, 2 (42), 11–14.
4. Chmil', V. P., Chmil', Yu. V. (2012). Sistema rekuperacii kineticheskoy energii avtomobilya KamAZ. Avtomobil'naya promyshlennost', 8, 13–15.
5. Gusakov, S. V., Markov, V. A., Afanas'eva, I. V. (2012). Uluchshenie ekspluatacionnyh pokazateley transportnyh sredstv pri ispol'zovanii gibridnyh silovyh ustanovok. Izvestiya vysshih uchebnyh zavedeniy. Mashinostroenie, 2, 32–41.
6. Bottiglione, F., De Pinto, S., Mantriota, G. (2014). Infinitely Variable Transmissions in neutral gear: Torque ratio and power re-circulation. Mechanism and Machine Theory, 74, 285–298. doi: 10.1016/j.mechmachtheory.2013.12.017
7. Mantriota, G. (2002). Performances of a parallel infinitely variable transmissions with a type II power flow. Mechanism and Machine Theory, 37 (6), 555–578. doi: 10.1016/s0094-114x(02)00018-6
8. Samorodov, V. B., Rogov, A. V., Ostroverh, A. O. (2009). Universal'naya matrichnaya metodika rascheta trekhzvennyh planetarnyh mekhanizmov v avtomobile i traktorostroenii. Visti Avtomobilnodorozhnoho instytutu, 2 (9), 141–148.

9. Mittsel, M. O., Kozhushko, A. P., Mittsel, M. O. (2015). Dorozhni vyprobuvannia kolisnoho traktoru z dvopotokovoiu hidroobiemno-mekhanichnoiu transmisieiu. Perviy nezavisimiy nauchniy vestnik, 1, 54–61.
10. Kalinin, S. V., Samorodov, V. B., Derkach, O.I., Zabielyshynskyi, Z. E., Shuba, S. O., Avrunin, H. A. (2011). Pat. No. 66541 UA. Hidroobiemno-mekhanichna transmisiya transportnoho zasobu. MPK7 F16H 47/00. No. u201107120; declareted: 06.06.2011; published: 10.01.2012, Bul. No. 1.
11. Derkach, O. I., Samorodov, V. B., Sysoiev, O. V., Butylin, O. A., Zhuravlov, S. V., Shyhin, Ya. V., Zaozerskyi, O. V. (2010). Pat. No. 52807 UA. Hidroobiemna transmisiya transportnoho zasobu. MPK 7 B60K 17/00. No. u201002675; declareted: 10.03.2010; published: 10.09.2010, Bul. No. 17.
12. Shuba, S. O. (2006). Pat. No. 17851 UA. Hidroobiemno-mekhanichna transmisiya transportnoho zasobu. MPK7 F16H 3/44. No. u200604301; declareted: 17.04.2006; published: 16.10.2006, Bul. No. 10.
13. Kalinin, S. V., Samorodov, V. B., Derkach, O. I., Zabielyshynskyi, Z. E., Shuba, S. O., Shapovalov, Yu. K. (2011). Pat. No. 66540 UA. Hidroobiemno-mekhanichna transmisiya transportnoho zasobu. MPK7 F16H 47/00. No. u201107114; declareted: 06.06.2011; published: 10.01.2012, Bul. No. 1.
14. Samorodov, V. B., Mitcel', N. A. (2014). Investigation of step electric drive as a control system for double-split hydrostatic mechanical transmissions. Eastern-European Journal of Enterprise Technologies, 5 (7 (71)), 52–58. doi: 10.15587/1729-4061.2014.28219
15. Samorodov, V. B. (1998). Osnovy teorii avtomatizirovannoy generacii matematicheskih modeley transmissiy. Mekhanika i mashinostroenie, 1, 109–115.
16. Mittsel, M. O. (2015). Doslidzhennia yavyshcha neodnochasnoi zminy roboty obiemnykh hidromashyn. Silskohospodarski mashyny, 32, 119–125.

DOI: 10.15587/1729-4061.2018.126693

GEOMETRICAL MODELING OF THE SHAPE OF A MULTILINK ROD STRUCTURE IN WEIGHTLESSNESS UNDER THE INFLUENCE OF PULSES ON THE END POINTS OF ITS LINKS (p. 44–58)

Leonid Kutsenko
National University of Civil Defence of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-1554-8848

Oleg Semkiv
National University of Civil Defence of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-9347-0997

Leonid Zapolskiy
Ukrainian Research Institute of Civil Defense, Kyiv, Ukraine
ORCID: http://orcid.org/0000-0003-4357-2933

Olga Shoman
National Technical University
«Kharkiv Polytechnic Institute», Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-3660-0441

Nelli Ismailova
Military Academy, Odessa, Ukraine
ORCID: http://orcid.org/0000-0003-0181-4420

Serhii Vasyliev
National University of Civil Defence of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0002-6602-8765

Irina Adashevska
National Technical University
«Kharkiv Polytechnic Institute», Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-5447-5114

Volodymyr Danylenko
Kharkiv National Automobile
and Highway University, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0003-4952-7498

Andrey Pobidash
National University of Civil Defence of Ukraine, Kharkiv, Ukraine
ORCID: http://orcid.org/0000-0001-8736-0524

We have examined a geometrical model of the new technique for unfolding a multilink rod structure under conditions of weightlessness. Displacement of elements of the links occurs due to the action of pulses from pyrotechnic jet engines to the end points of links in a structure. A description of the dynamics of the obtained inertial unfolding of a rod structure is performed using the Lagrange equation of second kind, built using the kinetic energy of an oscillatory system only.

The relevance of the chosen subject is indicated by the need to choose and explore a possible engine of the process of unfolding a rod structure of the pendulum type. It is proposed to use pulse pyrotechnic jet engines installed at the end points of links in a rod structure. They are lighter and cheaper as compared, for example, with electric motors or spring devices. This is economically feasible when the process of unfolding a structure in orbit is scheduled to run only once.

We have analyzed manifestations of possible errors in the magnitudes of pulses on the geometrical shape of the arrangement of links in a rod structure, acquired as a result of its unfolding. It is shown at the graphical level that the error may vary within one percent of the estimated value of the magnitude of a pulse. To determine the moment of fixing the elements of a multilink structure in the preset unfolded state, it is proposed to use a «stop-code». It is a series of numbers, which, by using functions of the generalized coordinates of the Lagrange equation of second kind, define the current values of angles between the elements of a rod structure.

Results are intended for geometrical modeling of the unfolding of large-size structures under conditions of weightlessness, for example, power frames for solar mirrors, or cosmic antennae, as well as other large-scale orbital facilities.

Keywords: rod structure, process of unfolding in space, multilink rod structure, Lagrange equation of second kind.

References

1. Alpatov, A. P., Gorbulin, V. P. (2013). Space platforms for orbital industrial complexes: problems and prospects. News of the National Academy of Sciences of Ukraine, 12, 26–38.
2. Alpatov, A. P., Belonozhko, P. A., Belonozhko, P. P., Vitushkin, A. A., Fokov, A. A. (2007). Large reflecting surfaces in space. Antennas by the communication satellite. System technologies, 3 (50), 73–87.
3. Alpatov, A. P., Belonozhko, P. A., Belonozhko, P. P., Vitushkin, A. A. Fokov, A. A. (2007). Large reflecting surfaces in space. Radotelescopes, solar concentrators, flat reflectors. System Technology, 3 (50), 88–101.
4. Robert, H. (2015). SpiderFab. Architecture for On.Orbit Manufacture of Large Aperture Space Systems. FISO Briefing, 33.
5. Alpatov, A. P. (2013). Dynamics of perspective space vehicles. Visnik NAN Ukraine, 7, 6–13.
6. Udwadia, F. E., Koganti, P. B. (2015). Dynamics and control of a multi-body planar pendulum. Nonlinear Dynamics, 81 (1-2), 845–866. doi: 10.1007/s11071-015-2034-0
7. Lopes, A. M., Tenreiro Machado, J. A. (2016). Dynamics of the N-link pendulum: a fractional perspective. International Journal of Control, 90 (6), 1192–1200. doi: 10.1080/00207179.2015.1126677
8. Fritzkowski, P., Kaminski, H. (2008). Dynamics of a rope as a rigid multibody system. Journal of Mechanics of Materials and Structures, 3 (6), 1059–1075. doi: 10.2140/jomms.2008.3.1059

9. 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
10. Gutovsky, I. E., Zolin, A. V., Kurkov, S. V., Panteleev, V. A., Khlebnikov, V. A. (2012). Modeling of the dynamics of the opening of the truss frame of the transformed reflector of the space-based antenna by the finite element method. Modern machine building. Science and education, 2, 276–285.
11. Bakulin, D. V., Borzykh, S. V., Ososov, N. S., Shchiblev, Yu. N. (2004). Simulation of the process of solar battery opening. Matem. Modeling, 16 (6), 88–92.
12. Anokhin, N. V. (2013). The reduction of a pendulum pendulum to a position of equilibrium by means of a single control moment. Izv. RAN. Theory and control systems, 5, 44–53.
13. Deployable Perimeter Truss with Blade Reel Deployment Mechanism. Available at: https://www.techbriefs.com/component/content/article/tb/techbriefs/mechanics-and-machinery/24098
14. Bushuev, A. Yu., Farafonov, B. A. (2014). Mathematical modeling of the process of disclosure of a large-scale solar battery. Mathematical Modeling and Numerical Methods, 2, 101–114.
15. Schessnyak, S., Romanov, A. (2009). Designing and calculating large-scale unfolding structures using software packages MSC.Software. CADmaster, 2-3, 28–36.
16. Boykov, V. G. (2009). Program complex of automated dynamic analysis of EULER multicomponent mechanical systems. CAD and graphics, 9, 17–20.
17. Zimin, V. N., Krylov, A. V., Meshkovsky, V. E., Sdobnikov, A. N., Faizullin, F. R., Churilin, S. A. (2014). Peculiarities of calculating the opening of large-sized transformable structures of various configurations. Science and Education. MGTU im. N.E. Bauman, 10, 179–191.
18. Martınez-Alfaro, H. Obtaining the dynamic equations, their simulation, and animation for N pendulums using Maple. Available at: http://www2.esm.vt.edu/~anayfeh/conf10/Abstracts/martinez-alfaro.pdf
19. Yan, X., Fu-ling, G., Yao, Z., Mengliang, Z. (2012). Kinematic analysis of the deployable truss structures for space applications. Journal of Aerospace Technology and Management, 4 (4), 453–462. doi: 10.5028/jatm.2012.04044112
20. Hoyt, R., Cushing, J., Slostad, J. (2013). SpiderFab: Process for On-Orbit Construction of KilometerScale Apertures. NASA Goddard Space Flight Center 8800 Greenbelt Road Greenbelt, MD 20771, 53.
21. 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
22. Kutsenko, L. M. (2017). Illustrations for geometric modeling of inertial disclosure of a multi-faceted pendulum in weightlessness. Available at: http://repositsc.nuczu.edu.ua/handle/123456789/4868
23. Kutsenko, L., Semkiv, O., Zapolskiy, L., Shoman, O., Kalynovskyi, A., Piksasov, M. et. al. (2018). Geometrical modeling of the process of weaving a wire cloth in weightlessness using the inertial unfolding of a dual pendulum. Eastern-European Journal of Enterprise Technologies, 1 (7 (91)), 37–46. doi: 10.15587/1729-4061.2018.121022
24. Kutsenko, L. M. Heometrychne modeliuvannia pletinnia sitkopolotna v nevahomosti za dopomohoiu inertsiynoho rozkryttia podviinoho maiatnyka. Available at: http://repositsc.nuczu.edu.ua/handle/123456789/5143
25. Kutsenko, L. M. Iliustratsiyi do statti heometrychne modeliuvannia protsesu rozkryttia sterzhnevykh konstruktsiyi u nevahomosti. Available at: http://repositsc.nuczu.edu.ua/handle/123456789/6335
26. An umbrella-shaped deployable mechanism constructed by six Myard linkages a Two 5R Myard linkages, b 2-Myard mechanism by sharing one common sub-chain. Available at: https://www.researchgate.net/figure/An-umbrella-shaped-deployable-mechanism-constructed-by-six-Myard-linkages-a-Two-5R-Myard_271570634
27. Self deployable truss. Available at: https://www.youtube.com/watch?v=sH7NHZwPzMM
28. Wang Yaping shows pendulum motion in space. Available at: https://www.youtube.com/watch?v=dqcVONfly8U
29. Gladkov, S. V. Computer simulation of oscillations of the «Chaotic pendulum». Available at: http://old.exponenta.ru/educat/referat/student8/index.asp
30. Ter Haar, D. (1974). Fundamentals of Hamiltonian mechanics. Moscow: Nauka, 224.
31. Pyrotechnics Test Facility. Available at: https://www.nasa.gov/centers/johnson/engineering/human_space_vehicle_systems/energy_systems_test_area/pyrotechnics/index.html
32. Prospects for the application of spatial structures from plastics in space technology. Available at: http://stroi-archive.ru/polimery-v-stroitelstve/706-perspektivy-primeneniya-prostranstvennyh-konstrukciy-iz-plastmass-v-kosmicheskoy-tehnike.html

---

DOI: 10.15587/1729-4061.2018.128265

ON STABILITY OF THE DUAL-FREQUENCY MOTION MODES OF A SINGLE-MASS VIBRATORY MACHINE WITH A VIBRATION EXCITER IN THE FORM OF A PASSIVE AUTO-BALANCER (p. 59–67)

Volodymyr Yatsun
Central Ukrainian National Technical University,
Kropivnitskiy, Ukraine
ORCID: http://orcid.org/0000-0003-4973-3080

Gennadiy Filimonikhin
Central Ukrainian National Technical University,
Kropivnitskiy, Ukraine
ORCID: http://orcid.org/0000-0002-2819-0569

Antonina Haleeva
Mykolayiv National Agrarian University, Mykolayiv, Ukraine
ORCID: http://orcid.org/0000-0002-8017-3133

Andrey Nevdakha
Central Ukrainian National Technical University,
Kropivnitskiy, Ukraine
ORCID: http://orcid.org/0000-0002-0849-9331

By employing computational experiments, we investigated stability of the dual-frequency modes of motion of a single-mass vibratory machine with translational rectilinear motion of the platform and a vibration exciter in the form of a passive auto-balancer.

For the vibratory machines that are actually applied, the forces of external and internal resistance are small, with the mass of loads much less than the mass of the platform. Under these conditions, there are three characteristic rotor speeds. In this case, at the rotor speeds:

– lower than the first characteristic speed, there is only one possible frequency at which loads get stuck; it is a pre-resonance frequency;

– positioned between the first and second characteristic speeds, there are three possible frequencies at which loads get stuck, among which only one is a pre-resonant frequency;

– positioned between the second and third characteristic speeds, there are three possible frequencies at which loads get stuck; all of them are the over-resonant frequencies;

– exceeding the third characteristic speed, there is only one possible frequency at which loads get stuck; it is the over-resonant frequency and it is close to the rotor speed.

Under a stable dual-frequency motion mode, the loads: create the greatest imbalance; rotate synchronously as a whole, at a pre-resonant frequency. The auto-balancer excites almost perfect dual-frequency vibrations. Deviations of the precise solution (derived by integration) from the approximated solution (established previously using the method of the small parameter) are equivalent to the ratio of the mass of loads to the mass of the entire machine. That is why, for actual machines, deviations do not exceed 2 %.

There is the critical speed above which a dual-frequency motion mode loses stability. This speed is less than the second characteristic speed and greatly depends on all dimensionless parameters of the system.

At a decrease in the ratio of the mass of balls to the mass of the entire system, critical speed tends to the second characteristic speed. However, this characteristic speed cannot be used for the approximate computation of critical speed due to an error, rapidly increasing at an increase in the ratio of the mass of balls to the mass of the system. Based on the results of a computational experiment, we have derived a function of dimensionless parameters, which makes it possible to approximately calculate the critical speed.

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

References

1. Bukin, S. L., Maslov, S. G., Ljutyj, A. P., Reznichenko, G. L. (2009). Intensification of technological processes through the implementation of vibrators biharmonic modes. Enrichment of minerals, 36 (77)-37 (78), 81–89.
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 elektromahnitnym 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, 1, 15–19.
6. Filimonikhin, G. (2004). Zrivnovazhennia i vibrozakhyst rotoriv avtobalansyramy z tverdymy koryhuvalnymy vantazhamy [Balancing and protection from vibrations of rotors by autobalancers with rigid corrective weights]. Kirovohrad: KNTU, 352.
7. Sommerfeld, A. (1904). Beitrage zum dinamischen Ausbay der Festigkeislehre. Zeitschriff des Vereins Deutsher Jngeniere, 48 (18), 631–636.
8. 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
9. 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
10. Filimonikhin, G. B., Filimonikhina, I. I., Pirogov, V. V. (2014). Stability of Steady-State Motion of an Isolated System Consisting of a Rotating Body and Two Pendulums. International Applied Mechanics, 50 (4), 459–469. doi: 10.1007/s10778-014-0651-9
11. Ruelle, D. (1989). Elements of Differentiable Dynamics and Bifurcation Theory. Academic Press Inc., 187.
12. Nayfeh, A. H. (1993). Introduction to Perturbation Techniques. New York, United States: John Wiley and Sons Ltd., 533.
13. Blekhman, I. I. (1988). Synchronization in Science and Technology. New York: ASME Press, NY, USA, 255.
14. Lanets, O. V., Shpak, Ya. V., Lozynskyi, V. I., Leonovych, P. Yu. (2013). Realizatsiya efektu Zommerfelda u vibratsiynomu maidanchyku z inertsiynym pryvodom [Realization of the Sommerfeld effect in a vibration platform with an inertia drive]. Avtomatyzatsiya vyrobnychykh protsesiv u mashynobuduvanni ta pryladobuduvanni, 47, 12–28. Available at: http://nbuv.gov.ua/UJRN/Avtomatyzac_2013_47_4
15. Hou, Y., Fang, P. (2016). Investigation for Synchronization of a Rotor-Pendulum System considering the Multi-DOF Vibration. Shock and Vibration, 2016, 1–22. doi: 10.1155/2016/8641754
16. Ryzhik, B., Sperling, L., Duckstein, H. (2004). Non-synchronous Motions Near Critical Speeds in a Single-plane Autobalancing Device. Technische Mechanik, 24 (1), 25–36.
17. 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: 10.1016/j.ymssp.2012.06.001
18. Artyunin, A. I., Alhunsaev, G. G., Serebrennikov, K. V. (2005). Primenenie metoda razdeleniya dvizheniy dlya issledovaniya dinamiki rotornoy sistemyi s gibkim rotorom i mayatnikovyim avtobalansirom [The application of the method of separation of movements to study the dynamics of a rotor system with a flexible rotor and a pendulum autobalance]. Izvestiya vysshih uchebnyh zavedeniy. Mashinostroenie, 9, 8–14.
19. 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: 10.4028/www.scientific.net/amm.373-375.38