SYSTEMS AND CONTROL PROCESSES

DIFFRACTION OF SOUND WAVES ON A METAL RING

page 4–8

As the object of research, sensor unit as a multiphase mechanical construction in the operating conditions of hypersonic aircraft flight is exposed to actions of powerful external disturbances such as: ultra-high temperature — more than 2000 °C, vibration, shock N-wave, acoustic penetrating radiation. Less harmful disturbances cause additional measurement errors of characteristics of the flight product. Clarification of the nature and origin in time and space of these errors is one of the most important tasks of navigation.

Precisely delineated investigated phenomenon enables combat the negative influence of external disturbing factors by passive, active or autocompensation methods depending on character of the sensor error — methodological or instrumental.

The obtained result confirms the presence of powerful and fluid motive flow with a spatial structure in a liquid-phase components of component base, which, in combination with generated sound waves form a zone of concentration of sound energy and, in accordance, development of three-dimensional turbulent fluid, and explains the emergence of areas of passive energy, in which is virtually absent turbulence.

The expected effect of an efficient fight against the negative impact of penetrating sound radiation is based on eliminating an effect of aberrations and forming a powerful energy zones (zones of caustic surfaces), technical implementation of which in each case may have its advantages and disadvantages.

Keywords: caustic, aberration, wave size, concentration of sound waves, motive flow, diffraction.

References

1. Gladkiy, V. F. (1969). *The dynamics of the aircraft structure*. Moscow: Nauka, 496.
2. Mel'nick, V., Karachun, V. (2016). The emergence of resonance within acoustic fields of the float gyroscope suspension. *Eastern-European Journal Of Enterprise Technologies, 1(7(79))*, 39–44. doi:10.15587/1729-4061.2016.59892
3. Karachun, V., Mel'nick, V., Korobiichuk, I., Nowicki, M., Szewczyk, R., Kobzar, S. (2016, February 26). The Additional Error of Inertial Sensors Induced by Hypersonic Flight Conditions. *Sensors, 16 (3)*, 299. doi:10.3390/s16030299
4. Mel'nick, V. N. (2007). Stress-strain state of suspension of floating gyroscope under acoustic loading. *Problemi prochnosti, 1*, 39–54.
5. Pavlovskiy, M. A. (1986). *The theory of gyroscopes*. Kyiv: High School, 303.
6. Fesenko, S. V., Shybetskiy, V. Y. (2016). The study of the behavior of cylindrical shell in the ultrasonic field. *Intehrovani intelektualni roboto-tekhnichni kompleksy, 3*, 61.
7. Leporinskaya, L. P. (1967). Endurance aircraft structures with acoustic loads. *Vynoslivost' aviatsionnyh konstruktsii pri akusticheskih nagruzkah, 218*, 317–325.
8. Vyaltsev, V. V., Horguan, V. G. (1961). Powerful low-frequency sound alarm. *Journal of Acoustic Technologies, 3 (7)*, 377–378.
9. Beliy, N. G., Pachando, A. V. (1965). On the acoustic loading of the fuselage of the aircraft IL-18 and its endurance cladding elements. *Prochnost' i dolgovechnost' aviatsionnyh konstruktsii, 11*, 4–57.
10. Dayer, I.; In: Krendel, S. (1967). The vibrations of the spacecraft under the action of the rocket engine noise housing. *Accidental fluctuations*. Moscow: Mir, 192–211.
11. Fox Williams, D. E.; In: Krendel, S. (1967). The noise of high-speed missiles. *Accidental fluctuations*. Moscow: Mir, 45–49.
12. Grinchenko, V. T., Meleshko, V. V. (1981). *Harmonic waves in elastic bodies*. Kyiv: Naukova dumka, 283.
13. Valeev, K. G., Kvitka, V. E. (1970). Determination of the stress state of the flat panels in the acoustic field of the exhaust jet. *Prikladnaya mekhanika, VI (4)*, 39–43.
14. Pavlovskiy, M. A., Petrenko, V. E. (1977). On the self-compensation girotahometrov errors in angular vibration base. *Reports of the Academy of Sciences USSR. Series A, 8*, 81–84.
15. Nwe, T. T. et al. (2008). Application of an Inertial Navigation System to the Quad-rotor UAV using MEMS Sensors. *Engineering and Technology, 42*, 578–582.
16. Woodman, O. J. (2007). *An introduction to inertial navigation*. Cambridge, 37.
17. Le Manh Hung, V. (2009). *Indoor Navigation System for Handheld Devices*. Worcester, 198.
18. Nasiri, S. A. (2004). *Critical Review of MEMS Gyroscopes Technology and Commercialization Status*. California, 8.

CALCULATION AND ANALYSIS OF STATIC ERRORS OF TWO-GYRO SENSOR

page 9–17

New two-gyro sensor is considered. It can be used both in automated aviation gravimetric systems, and as the basic measuring device of weapons stabilizer. The object of research is new two-gyro unit (TGU) on the basis of gyro integrator of linear acceleration (GILA). New TGU consists of free gyroscope located in the inner and outer frames with interframe correction systems containing angle sensor on the axis of inner frame of the gyroscope and torque sensor connected to its output. In addition, free gyroscope that identical to the first is included in the design. Rotor of this gyroscope rotates in the opposite direction from the main gyroscope. Additional gyroscope is also provided by similar correction systems. Two output signals of linear acceleration are formed in TGU as the sum of signals from angle sensors of two gyroscopes. Considered TGU provides higher accuracy than single-gyro sensor due to compensation of the errors because of the impact of cross angular velocity and the angular velocity of the Earth.

Keywords: gyroscope, gravimeter, aviation gravimetric system, stabilizer, sensor.

References

1. Bezvesilna, O. M., Koval, A. V. (2013). *Dvohiroskopnyy hravimetr avtomatyzovanoyi aviatsiynoyi hravimetrychnoyi systemy*. Zhytomyr: ZhSTU, 252.
2. Tadano, S., Takeda, R., Miyagawa, H. (2013). Three Dimensional Gait Analysis Using Wearable Acceleration and Gyro Sensors Based on Quaternion Calculations. *Sensors, 13 (7)*, 9321–9343. doi:10.3390/s130709321
3. Bezvesilnaya, E. N., Tkachuk, A. H. (2014). Corrected gyrocompass synthesis as a system with changeable structure for aviation gravimetric system with piezoelectric gravimeter. *Aviation, 18 (3)*, 134–140. doi:10.3846/16487788.2014.969878
4. Xia, D., Yu, C., Kong, L. (2014). The Development of Micromachined Gyroscope Structure and Circuitry Technology. *Sensors, 14 (1)*, 1394–1473. doi:10.3390/s140101394
5. Singh, A. K. (2007). Piezoelectric Gyro Sensor Technology. *Defence Science Journal, 57 (1)*, 95–103. doi:10.14429/dsj.57.1735
6. Shiratori, N., Hatakeyama, M., Okada, S. (1999). Temperature Characteristic Compensation of a Miniature Bi-Axial Gyro-Sensor Using a Disk-Type Resonator. *Japanese Journal of Applied Physics, Vol. 38, Part 1, № 9B*, 5586–5591. doi:10.1143/jjap.38.5586
7. Koval', A. V. (2015). Simulation of gravimetric measurements by gyroscopic integrator of linear accelerations. *Gyroscopy and Navigation, 6 (4)*, 344–347. doi:10.1134/s2075108715040070
8. Korobiichuk, I., Bezvesilna, O., Tkachuk, A., Nowicki, M., Szewczyk, R., Shadura, V. (2016) Aviation gravimetric system. *International Journal of Scientific & Engineering Research, 6 (7)*, 1122–1126.
9. Tkachev, L. I. (1993). *Sistemy inertsialnoi orientirovki. Part 1. Osnovnye polozheniia teorii*. Moscow: MEI, 213
10. Wilmoth, E. D. (1989). *An investigation of methods for determining gravity anomalies from an aircraft*. Mass. Inst. of Tech., 76.

SYNTHESIS OF GRAPHITIZATION CONTROL SYSTEM OF CARBON PRODUCTS

page 18–24

Current global trends in ferrous and nonferrous metallurgy, machine building, chemical and other industries cause a permanent increase of production of carbon graphite products. Production of graphite products is complex, multistage and very energy-intensive. The analysis of existing graphitization control systems of carbon products has shown that these systems are the systems of program control that do not take into account the current state of the control object, which affects their performance.

A new control system provides graphitization furnace control in two modes of operation - heating and graphitization. The framework of control system in heating mode is based on the use of fuzzy controller, which inputs are calculated using a simplified model of graphitization. The control algorithm in graphitization mode for the purpose of determining in advance the time of power outage of the furnace uses prediction of graphitization degree of carbon products.

Keywords: carbon products, graphitization, control system, fuzzy controller.

References

1. Znamerovskii, V. Yu., Iashkina, V. V. (1985). Issledovanie rezhimov vvoda energii v pechi grafitatsii. *Promyshlennaia energetika, 11*, 40–42.
2. Yarymbash, D. S. (2014). Analiz elektromagnitnyh i termoelektricheskih protsessov v pechah Achesona. *Energozberezhennia. Energetika. Energoaudit, 6*, 11–21.
3. Kuznetsov, D. M., Fokin, V. P. (2001). *Protsess grafitatsii uglerodnyh materialov. Sovremennye metody issledovaniia*. Novocherkassk: YuRGTU, 132.
4. Kuznetsov, D. M. (2003). *Grafitatsiia krupnogabaritnyh elektrodov. Protsess Achesona*. Rostov n/D: RGASHM GOU, 168.
5. Sosedov, V. P., Chalyh, E. F. (1987). *Grafitatsiia uglerodistyh materialov.* Moscow: Metallurgiia, 176.
6. Chichulin, N. I., Davydovich, B. I. (1973). O rezhimah grafitatsii elektrodnyh izdelii. *Sovershenstvovanie tehnologii i uluchshenie kachestva elektrodnoi produktsii, 5*, 114–121.
7. Samohin, I. N., Rozenman, I. M., Sass-Tisovskii, V. B. (1968). Opyt ekspluatatsii pechei s prinuditel'nym ohlazhdeniem sten i podiny pri povyshennoi plotnosti toka v kerne dlia proizvodstva konstruktsionnogo grafita. *Voprosy grafitatsii uglerodistyh materialov, 1*, 70–78.
8. Sosedov, V. P., Sass-Tisovskii, V. B., Karmanov, A. S. (1967). O ratsional'nom grafike podiema moshchnosti i temperatury v protsesse grafitatsii. *Tsvetnye metally,* 2, 62–63.
9. Znamerovskii, V. Yu., Yashkina, V. V. (1985). Issledovanie rezhimov vvoda energii v pechi grafitatsii. *Promyshlennaia energetika, 11*, 40–42.
10. Glushko, I. N. (30.04.1984). Sposob kontrolia teplovogo rezhima protsessa grafitatsii. *Author's certificate1089048 USSR, MKI3 C01B 31/04, G05D 27/00*. Appl. № 3433981/23-26. Filed 01.03.1982. Bull. № 16, 2.
11. Korzhyk, M. V. (2010). *Matematychne modeliuvannia ta avtomatyzovane keruvannia protsesom hrafitatsii v pechakh Achesona*. Kyiv, 230.
12. In: Scheel, H. J., Fukuda, T. (2003). *Crystal Growth Technology.* John Wiley & Sons, Ltd., 668. doi:10.1002/0470871687
13. Shulepov, S. V. (1972). *Fizika uglegrafitovyh materialov.* Moscow: Metallurgiia, 256.
14. Sannikov, A. K., Somov, A. B., Kliuchnikov, V. V. et al. (1985). *Proizvodstvo elektrodnoi produktsii.* Moscow: Metallurgiia, 129.
15. Ahmetshin, N. F., Dorzhiev, M. N., Shaburov, E. N. (1971). Vliianie svoistv mezhduelektrodnoi peresypki na elektricheskie, teplovye pokazateli i kachestvo elektrodov. *Voprosy tehnicheskogo progressa v elektrodnoi promyshlennosti, 3*, 205–213.
16. Passino, K., Yurkovich, S. (2010). Fuzzy Control. *The Control Systems Handbook, Second Edition*. Informa UK Limited, 55-1–55-27. doi:10.1201/b10384-64
17. In: Egupov, N. D. (2002). *Metody robastnogo, neiro-nechiotkogo i adaptivnogo upravleniia. Ed. 2*. Moscow: MGTU im. N. E. Baumana, 744.
18. Korzhyk, M. V., Kutuzov, S. V. (2007). Model temperaturnoho polia pechi hrafitatsii. *Naukovi visti NTUU «KPI», 1*, 17–23.
19. Panov, E. N., Korzhik, M. V., Karvatskii, A. Ya. (2007). Intensifikatsiia protsessa grafitatsii elektrodnyh izdelii v pechah Achesona postoiannogo toka. *XIII mezhdunarodnaia konferentsiia «Aliuminii Sibiri-2007», 11–13 sentiabria 2007*. Krasnoiarsk: Verso, 331–337.
20. Zhuchenko, O., Khibeba, M. (2016). Development of simplified mathematical model of carbon products formation. *Technology Audit And Production Reserves, 5(3(31))*, 16–22. doi:10.15587/2312-8372.2016.81218
21. Gilat, A. (2014). *MATLAB: An Introduction with Applications. Ed. 5*. John Wiley & Sons, Ltd., 416.

ANALYSIS OF NOISE-PROTECTIVE PROPERTIES OF SHEET MATERIAL COMPOSITE STRUCTURES

page 24–28

The object of this research is sound insulation properties of sheet material composite structures. The basis of the working hypothesis is the fact that particular importance has the minimum gap between the layers for the theoretical insulation calculations of the double sheet material structure.

Dependence observation of the air gap size between the two layers of interior walls suggests that for maximum sound insulation ability the air gap size should be no less than five times greater than the maximum thickness of one of them.

Comparison of the estimated sound insulation characteristics R_N with the measured frequency response of air sound insulation R shows that the actual sound insulation of two sheet structure is significantly lower than estimated. This difference is between 3 to 5 dB over the entire frequency range. It also confirms the low acoustic efficiency of modern plastic windows.

The results of this work will allow as a promising direction for further research to identify the program to adjust the sound insulation properties of any translucent walling (including window fillings), also consisting of sheet materials.

Keywords: sound insulation, sheet materials, workspaces, accommodations, reverberation chamber, sound level meter.

References

1. Sankov, P. M. (2011). Shum yak faktor ekolohichnoi nebezpeky arkhitekturnoho seredovyshcha. *Novyny nauky Prydniprovia. Seriia «Arkhitektura ta mistobudivnytstvo», 3*, 53–59.
2. Sankov, P. N., Tkach, N. A. (2013). Usovershenstvovanie algoritma lokalizatsii shumovogo zagriazneniia zhilyh territorii s tsel'iu obespecheniia akusticheskoi bezopasnosti v spal'nyh raionah gorodov. *Materialy VIII mezhdunarodnoi zaochnoi nauchno-prakticheskoi konferentsii «Nauchnaia diskussiia: voprosy tehnicheskih nauk»*. Moscow: Mezhdunarodnyi tsentr nauki i obrazovaniia, 145–150.
3. In: Eliseev, D. V. (2014). *Vliianie tehnogennyh faktorov na ekologiiu.* Novosibirsk: SibAK, 164.
4. Seidman, M. D., Standring, R. T. (2010). Noise and Quality of Life. *International Journal of Environmental Research and Public Health, 7 (10)*, 3730–3738. doi:10.3390/ijerph7103730
5. Samoiliuk, E. P. (1999). *Osnovy gradostroitel'noi akustiki.* D.: PGASA, 438.
6. OUR PRODUCT RANGE. (2016). *Knauf Gips KG.* Available: https://www.knauf.com/en/products-and-references/worldwide-references/
7. Stroitel'nye paneli: fanera, DVP, DSP, MDF, HDF, OSB-3. (2015). *OOO «Laverna»*. Available: http://www.lawerna.ru/panel-fanera-osb-dvp-mdf-hdf.html
8. Sankov, P. N., Tkach, N. A., Gorb, A. V., Miheenko, Yu. Yu., Chechuro, A. V. (2015). Razrabotka razdela proekta OVOS dlia obiekta rekonstruktsii v gorode Dnepropetrovske. *Mizhnarodnyi naukovyi zhurnal, 6*, 78–83.
9. Harris, A. S., Fleming, G. G., Lang, W. W., Schomer, P. D., Wood, E. W. (2003). Reducing the impact of environmental noise on quality of life requires an effective national noise policy. *Noise Control Engineering Journal, 51 (3)*, 151–154. doi:10.3397/1.2839708
10. Scales, J. A., Snieder, R. (1998). What is noise? *GEOPHYSICS, 63 (4)*, 1122–1124. doi:10.1190/1.1444411
11. Vakuumnye steklopakety zapushcheny v massovoe proizvodstvo. (18.10.2016). *Portal o plastikovyh oknah «Okna media»*. Available: http://www.oknamedia.ru/spage-publish/detail-45139/section-article.html
12. V Avstrii razrabotany bezramnye perila dlia frantsuzskih okon. (02.08.2016). *Arhitekturno-stroitel'nyi portal «Stroitel'nyi Ekspert»*. Available: http://ardexpert.ru/article/7019
13. Evoliutsiia energosberezheniia s sistemami KVE. (14.09.2016). *Arhitekturno-stroitel'nyi portal «Stroitel'nyi Ekspert»*. Available: http://ardexpert.ru/article/7318
14. V blizhaishee vremia na rynke mogut poiavit'sia prozrachnye pokrytiia na steklo, generiruiushchie elektroenergiiu. (07.11.2016).

Arhitekturno-stroitel'nyi portal «Stroitel'nyi Ekspert». Available: http://ardexpert.ru/article/7839
15. Kak sdelat' pravil'nyi vybor okon PVH? (09.11.2016). *Arhitekturno-stroitel'nyi portal «Stroitel'nyi Ekspert»*. Available: http://ardexpert.ru/article/7892
16. Boganik, A. (2003). Problemy zvukoizoliatsii v elitnyh domah i puti ih resheniia. *Tehnologii Stroitel'stva, 4 (20)*. Available: http://www.acoustic.ru/ref_book/articles/39/

ANALYSIS OF AMBIENT TEMPERATURE CHANGE ON DEPLETION INTENSITY OF POWDER CHARGES DURING LONG-TERM STORAGE OF AMMUNITION

page 28–35

Changes in physical properties of the powder charges during their long-term storage are a negative effect on the ballistic characteristics of ammunition: the longer the ammunition storage period — the more the negative impact of this phenomenon. One of the main parameters that determine the storage of powder charges, and the most influential factor in determining the rate of molecular diffusion is the ambient temperature.

We propose a method of forecasting changes in ambient temperature. The temperature difference and the accuracy of the forecast annual average temperature were 0,58 °C and 5,6 % respectively. It is proved that these predicted results 2,9 and 3,7 times, respectively, closer to real than the most recent official table data.

Molecular diffusion coefficient is predicted on the basis of this methodology. The error in this case is 3 times less than using the last temperature table values and there is 0,4 % vs. 1,2 %, respectively.

During the calculation and analysis of the impact of the daily, monthly and seasonal temperature changes in the intensity of mass transfer, as the main factor of the powder charge depletion, average error is calculated and there is 8,6 %.

Thus, the total error in the calculations of the total nitrogen removal from the powder components is 15,2 %, which for the warranty period of ammunition storage in 30 years makes the difference at the time of 4,6 years, and in fact is 25,4 years. And, taking into account the «global warming» effect, this term will only decrease later.

Keywords: ambient temperature, depletion of powder charges, long-term storage of ammunition.

References

1. Buller, M. F., Mezhevich, G. V. (2005). *Metody ispytaniia utiliziruemyh porohov.* Kyiv: OOO «DIA», 188.
2. Espinoza, E. O., Thornton, J. I. (1994). Characterization of smokeless gunpowder by means of diphenylamine stabilizer and its nitrated derivatives. *Analytica Chimica Acta, 288 (1-2)*, 57–69. doi:10.1016/0003-2670(94)85116-6
3. Frys, O., Bajerova, P., Eisner, A., Ventura, K., Skladal, J. (2010). Analyses of New Nontoxic Stabilizers and Other Components in Smokeless Powders. *Central European Journal of Energetic Materials, 7 (3)*, 253–267.
4. Petrzilek, J. (2000). *Relations Between Chemical Composition and Stability of Smokeless Powders.* University of Pardubice, 37–38.
5. Gorst, A. G. (1972). *Poroha i vzryvchatye veshchestva.* Moscow: Mashinostroenie, 208.
6. Anipko, O. B., Busiak, Yu. M. (2010). *Vnutrenniaia ballistika stvol'nyh sistem pri primenenii boepripasov dlitel'nyh srokov hraneniia.* Kharkiv: Academy of the Interior Troops of Ukraine, Ministry of Internal Affairs of Ukraine, 128.
7. Anipko, O. B., Biryukov, I. Yu., Baulin, D. S. (2006). Model' massoperenosa pri hranenii porohovyh zariadov s uchiotom izmeneniia temperatury okruzhaiushchei sredy. *Zbirnyk naukovykh prats Kharkivskoho universytetu Povitrianykh Syl, 2 (8)*, 50–54.
8. SNiP 2.01.01-82. Stroitel'naia klimatologiia i geofizika. *Inzhenerno-tehnicheskii tsentr «Spetstehnologii»*. Available: http://specteh.dn.ua/images/stories/normativnye_dokumenty/snip_2.01.01-82_stroitelnye_normy_i_pravila.pdf.
9. SNiP 23-01-99. Building Climatology. *EIFS (Exterior Insulation and Finishing Systems)*. Available: http://www.eifs.ru/download/snip_23-01-99_klimat.pdf
10. Global warming. *Wikipedia*. Available: https://en.wikipedia.org/wiki/Global_warming
11. Biryukov, A., Biryukov, I. (2014). Formulation of the problem and experimental study of wear barrel 9 мм Makarov when firing ammunition storage periods. *Sistemi ozbroennya i viyskova tehnika, 3 (39)*, 12–17.
12. Anipko, O. B., Baulin, D. S., Biryukov, I. Yu. (2007). Vliianie dlitel'nosti hraneniia boepripasov na ballisticheskie harakteristiki strelkovogo oruzhiia. *Intehrovani tekhnolohii ta enerhozberezhennia, 2*, 97–100.
13. Anipko, O. B., Mulenko, A. O., Demchenko, A. A. (2013). Eksperimental'noe issledovanie iznosa stvola 5,45 mm avtomata Kalashnikova AK-74 pri strel'be boepripasami dlitel'nyh srokov hraneniia. *Intehrovani tekhnolohii ta enerhozberezhennia, 2*, 121–126.
14. Biryukov, A. I. (2013). Osobennosti ekspluatatsii pistoletov so svobodnoi otdachei zatvora pri ispol'zovanii boepripasov poslegarantiinyh srokov hraneniia. *Intehrovani tekhnolohii ta enerhozberezhennia, 2*, 80–85.
15. Biryukov, A. (2016). Experimental investigations influence of lengths barrel pistol on ballistic characteristics by use of long-term storage ammunition. *Technology Audit and Production Reserves, 4(1(30))*, 9–21. doi:10.15587/2312-8372.2016.74846
16. DSTU-NBV.1.1-27:2010. Zakhyst vid nebezpechnykh heolohichnykh protsesiv, shkidlyvykh ekspluatatsiinykh vplyviv, vid pozhezhi. Budivelna klimatolohiia. (2011). *Order of the Ministry of Regional Development from 16.12.2010 № 511.* Kyiv: Ministry of Regional Development, 123.
17. Prognoz pogody v Ukraine. *Meteopost*. Available: http://meteopost.com
18. *WeatherArchive.ru — Prognoz i arhiv pogody.* Available: http://weatherarchive.ru

MODEL PREDICTIVE CONTROL OF DISTILLATION COLUMN IN THE CARBON DIOXIDE RECYCLING IN METHANOL TECHNOLOGICAL PROCESS

page 36–40

The distillation column (DC) was taken as the research object. A homogeneous catalyst is necessary for continuous operation of the column. Considered object is promising for carbon dioxide recycling in the methanol production enterprises, power plants, boiler stations. Modern high-quality model predictive control system is developed for the column. It is a basic unit of the latest technological process of carbon dioxide recycling in the methanol production. Its feature is the ability to take into account the non-linearity and the use of optimization procedure. The controller settings are calculated for *DC*: *P* controllers to stabilize levels (for channel *D-MD* $K_p = -2$; for channel *B-MB* $K_p = 0{,}2$) and the PI controllers for stabilization of concentrations (for channel *L-y D* $K_p = 2$ and $T_i = 0{,}01$, for channel *V-xB* $K_p = -30$, $T_i = 0{,}1$). For a system with *MPC* were calculated: discrete step (c) = 0,5; prediction horizon = 500; control horizon = 2; balance of stability and speed = 0,8; observer sensitivity = 0,5. Methanol production process was simulated with 2 systems. The comparison results show that the quality of transients in a system with model-predictive control higher when all perturbations, except perturbation over the phase state of the input stream. However, the latter in the above technological process practically does not occur. Use of MPC algorithm can significantly improve the effectiveness of the control system. The developed control system is very good meeting the major perturbation to change the product concentration, which enters the column from the synthesis reactor. System with MPC controller has more quality than a system with PI controller. When implementing the distillation column, an amount of emitted CO_2 and use of methanol as a finished product, and as a raw material will by reduced. In the future there is the possibility of applying a model predictive system for other objects and processes to improve the quality of transients.

Keywords: model predictive control, distillation column, technological process, recycling, carbon dioxide, methanol.

References

1. Stopakevich, A., Skakun, N. (2015). O vozmozhnosti primenenija sovremennyh SAPR himiko-tehnologicheskih system dlia sinteza SAU neftianymi rektifikatsionnymi kolonnami, *4 International Scientific Conference «Economics and control in the conditions of*

informational society growth», Odessa, 27–29.04.2015. Odessa: ONAT, 82–84.
2. Stopakevich, A., Stopakevich, A. (2015). Synthesis and Research of Supervisory Digital Control System for Oil Distillation Column. *Automation of Technological and Business Processes, 4 (7)*, 24–34.
3. Veremey, E., Sotnikova, M. (2014). *Upravlenie s prognoziruiushchimi modeliami.* Saint-Petersburg: SPBGU, 212.
4. Huyck, B., De Brabanter, J., De Moor, B., Van Impe, J. F., Logist, F. (2014). Online model predictive control of industrial processes using low level control hardware: A pilot-scale distillation column case study. *Control Engineering Practice, 28,* 34–48. doi:10.1016/j.conengprac.2014.02.016
5. Van der Ham, L. G. J., Van den Berg, H., Benneker, A., Simmelink, G., Timmer, J., Van Weerden, S. (2012). Hydrogenation of carbon dioxide for methanol production. *Chemical Engineering Transactions, 29*, 181–186. doi:10.3303/CET1229031
6. Wang, L. (2009). *Model Predictive Control System Design and Implementation Using MATLAB.* London: Springer, 378. doi:10.1007/978-1-84882-331-0
7. Skogestad, S. (1997). Dynamics and Control of Distillation Columns — A Critical Survey. *Modeling, Identification and Control: A Norwegian Research Bulletin, 18 (3),* 177–217. doi:10.4173/mic.1997.3.1
8. Skogestad, S. (2007). The Dos and Don'ts of Distillation Column Control. *Chemical Engineering Research and Design, 85 (1),* 13–23. doi:10.1205/cherd06133
9. Kothandaraman, J., Goeppert, A., Czaun, M., Olah, G. A., Prakash, G. K. S. (2016). Conversion of CO2from Air into Methanol Using a Polyamine and a Homogeneous Ruthenium Catalyst. *Journal of the American Chemical Society, 138 (3),* 778–781. doi:10.1021/jacs.5b12354
10. Drgona, J., Klauco, M., Valo, R., Bendzala, J., Fikar, M. (2015). Model identification and predictive control of a laboratory binary distillation column. *2015 20th International Conference on Process Control (PC), June 9-12, 2015, Strbske Pleso, Slovakia.* Available: https://www.researchgate.net/publication/278392589_Model_Identification_and_Predictive_Control_of_a_Laboratory_Binary_Distillation_Column. doi:10.1109/pc.2015.7169989
11. Stopakevich, A. (2013). *Sistemnyi analiz i teoriia slozhnyh sistem upravleniia.* Odessa: Astroprint, 380.

SYNCHRONIZATION OF THE DYNAMICS OF SIMILAR BOILERS WORKING FOR A COMMON LINE

page 40–44

The object of research is the system of the three boilers ПТВМ-50. With a system of three or more boilers it can ensure the normal operation of thermal power facilities, i. e. the uninterrupted supply of hot water and constant heating the coolant to the desired temperature. When receive a perturbation signal, load on the system is changed, but while having three boilers, it can provide the new load parameters and the system will not operate at maximum capacity.

The operation algorithm of similar objects on the common system with maintaining a given load was used in order to ensure synchronous operation.

The result is the reaction of the whole system with a deviation of the average temperature that issued by the boilers in the network in an amount equal to 0,14 °C. This result was achieved through the use of the chosen control system to synchronization and stabilization of operation of the boilers.

Keywords: synchronization, similar boilers, control system, stabilization, line, perturbation.

References

1. Boisvert, P. G., Runstedtler, A. (2014). Fuel sparing: Control of industrial furnaces using process gas as supplemental fuel. *Applied Thermal Engineering, 65 (1-2),* 293–298. doi:10.1016/j.applthermaleng.2013.12.047
2. Davoudi, M., Rahimpour, M. R., Jokar, S. M., Nikbakht, F., Abbasfard, H. (2013). The major sources of gas flaring and air contamination in the natural gas processing plants: A case study. *Journal of Natural Gas Science and Engineering, 13,* 7–19. doi:10.1016/j.jngse.2013.03.002
3. Berghout, N., van den Broek, M., Faaij, A. (2013). Techno-economic performance and challenges of applying CO_2 capture in the industry: A case study of five industrial plants. *International Journal of Greenhouse Gas Control, 17,* 259–279. doi:10.1016/j.ijggc.2013.04.022
4. Liu, H., Li, P., Wang, K. (2013). Optimization of PEM fuel cell flow channel dimensions — Mathematic modeling analysis and experimental verification. *International Journal of Hydrogen Energy, 38 (23),* 9835–9846. doi:10.1016/j.ijhydene.2013.05.159
5. Tucakovic, D., Stupar, G., Zivanovic, T., Petrovic, M., Belosevic, S. (2013). Possibilities for reconstruction of existing steam boilers for the purpose of using exhaust gases from 14 MW or 17 MW gas turbine. *Applied Thermal Engineering, 56 (1-2),* 83–90. doi:10.1016/j.applthermaleng.2013.03.028
6. Rusinowski, H., Stanek, W. (2010). Hybrid model of steam boiler. *Energy, 35 (2),* 1107–1113. doi:10.1016/j.energy.2009.06.004
7. Bujak, J. (2009). Optimal control of energy losses in multi-boiler steam systems. *Energy, 34 (9),* 1260–1270. doi:10.1016/j.energy.2009.05.005
8. Stopakevich, A. (2013). *Sistemnyi analiz i teoriia slozhnyh sistem upravleniia.* Odessa: Astroprint, 380.
9. Demchenko, V. (2001). *Avtomatizatsiia i modelirovanie tehnologicheskih protsessov TES i AES.* Odesa: Astroprint, 305.
10. Prohorenkov, A., Kachala, N. (2011). Parametricheskii sintez reguliatorov teploenergeticheskih obiektov s ispol'zovaniem informatsionnogo podhoda. *Vestnik Murmanskogo gosudarstvennogo tehnicheskogo universiteta, 14 (4),* 704–711.

OPTIMIZATION OF ARC IGNITION PROCESS FOR MACHINES OF ARC DIMENSIONAL MACHINING

page 44–51

The article examines the arc ignition at the arc dimensional machining (ADM). The audit found that:

— This process not paying attention in scientific literature.

— Feed rate of the electrode-tool with no arc combustion is set non-optimal.

The main aim of research is to optimize the process of electrode-tool feed rate at the arc ignition and, thus, reduce shock loads to the electrode-tool.

The nature of the change of the working fluid pressure in the electric erosion chamber at arc ignition is given. The pressure value is experimentally determined at which the automatic change of the maximum rate to working is ensured by the system of automatic feed of the electrode-tool to the workpiece. A functional of optimal arc ignition process of arc dimensional machining is proposed. It is possible to determine the maximum permissible rate of electrode-tool feed and reduce the likelihood of tool failure during the arc ignition. Thus, during machining due to rapid electrode-tool feed in the machining area, the technological operation time is decreased.

Research results can be used by designers that create an automatic system of electrode-tool feed at dimensional (ADM), arc (EAM), blasting (BEAM) and other related electric erosion methods of metal machining.

Keywords: automatic system, arc dimensional machining, working fluid pressure, feed rate, electrode-tool, arc ignition.

References

1. Nosulenko, V. I. (1999). *Rozmirna obrobka metaliv elektrychnoiu duhoiu.* Kyiv, 36.
2. Meshcheriakov, G., Nosulenko, V., Meshcheriakov, N., Bokov, V. (1988). Physical and Technological Control of Arc Dimensional Machining. *CIRP Annals — Manufacturing Technology, 37 (1),* 209–212. doi:10.1016/s0007-8506(07)61619-9
3. Nosulenko, V. I. (2006). O fizicheskoi prirode, ob obshchem i otlichiiah, tehnologicheskih vozmozhnostiah elektricheskih razriadov i klassifikatsii sposobov elektrorazriadnoi obrabotki metallov. *Elektronnaia obrabotka materialov, 1*, 4–14.
4. Nosulenko, V. I. (2005). Razmernaia obrabotka metallov elektricheskoi dugoi. *Elektronnaia obrabotka materialov, 1*, 8–17.
5. Nosulenko, V. I. (2005). Elektricheskaia duga v poperechnom potoke sredy-dielektrika kak istochnik tepla dlia novyh tehnologii. *Elektronnaia obrabotka materialov, 2*, 26–33.
6. Bokov, V. M. (2015). Elektroduhove frezeruvannia. *Konstruiuvannia, vyrobnytstvo ta ekspluatatsiia silskohospodarskykh mashyn, Vol. 45, Part 2*, 180–188.

7. Nosulenko, V. I., Yuriev, V. V. (2015). Rozmirna obrobka elektrychnoiu duhoiu otvoriv skladnoho konturu. *Zbirnyk naukovykh prats Kirovohradskoho natsionalnoho tekhnichnoho universytetu. Tekhnika v silskohospodarskomu vyrobnytstvi, haluzeve mashynobuduvannia, avtomatyzatsiia, 28*, 70–73.
8. Sisa, O. F. (2014). Rozmirna obrobka elektrychnoiu duhoiu bichnoi poverkhni tverdosplavnoho prokatnoho valka. *Konstruiuvannia, vyrobnytstvo ta ekspluatatsiia silskohospodarskykh mashyn, 44*, 153–159.
9. Savelenko, G., Ermolaev, Y., Sobinov, O., Gutsul, V. (2015). Development of software and hardware device of automated system of the process stabilization of arc dimensional processing. *Technology Audit And Production Reserves, 1(3(21))*, 22–28. doi:10.15587/2312-8372.2015.36244
10. Savelenko, G. (2015). The method of automatic determination of arc sizing machining process stability. *Eastern-European Journal Of Enterprise Technologies, 1(5(73))*, 9–13. doi:10.15587/1729-4061.2015.36226
11. Pawade, M. M., Banwait, S. S. (2013). A Brief Review of Die Sinking Electrical Discharging Machining Process towards Automation. *American Journal of Mechanical Engineering, 1 (2)*, 43–49. doi:10.12691/ajme-1-2-4
12. Zhang, M., Zhang, Q., Dou, L., Zhu, G., Dong, C. (2016). An independent discharge status detection method and its application in EAM milling. *The International Journal of Advanced Manufacturing Technology, 87 (1-4)*, 909–918. doi:10.1007/s00170-016-8537-0
13. Zhou, J. P., Liang, C. H., Teng, W. J., Xu, Y., Zhou, B. S. (2008). Study on Rules in Material Removal Rate and Surface Quality of Short Electric Arc Machining Process. *Advanced Materials Research, 33-37,* 1313–1318. doi:10.4028/www.scientific.net/amr.33-37.1313
14. Zhou, J. P., Liang, C. H., Xu, Y., Zhou, B. S. (2013). The NC Power Supply Design of Large Current and Wide Frequency Pulse in Short Electric Arc Machining. *Applied Mechanics and Materials, 278-280,* 1051–1055. doi:10.4028/www.scientific.net/amm.278-280.1051
15. Zhao, W., Gu, L., Xu, H., Li, L., Xiang, X. (2013). A Novel High Efficiency Electrical Erosion Process – Blasting Erosion Arc Machining. *Proceedings of the Seventeenth CIRP Conference on Electro Physical and Chemical Machining, 6,* 621–625. doi:10.1016/j.procir.2013.03.057
16. Zhao, W. S., Gu, L., Xu, H., Li, L., Xiang, X. (2012). High-speed Electrical Arc Machining Based on Hydrodynamic Arc Breaking Mechanism. *Electromachining & Mould, 300 (5),* 50–54. Available: http://en.cnki.com.cn/Article_en/CJFDTOTAL-DJGU201205012.htm
17. Savelenko, G. V., Ermolaev, Y. A. (2014). Study workflow dimensional processing of arc on a machine with electromechanical drive. *Computer-integrated technologies: education, science and industry, 14*, 164–169.
18. Savelenko, H. V., Yermolaiev, Y. O.; assignee: Kirovograd State Technical University. (10.11.2015). Method for determining moment of arc ignition and change of movement mode at idling of electrode-tool of machine for size processing by stationary arc. *Patent 110050 Ukraine, MPK (2006.01) B23H 7/26. B23H 7/32. B23H 1/02. B23H 7/18. G05B 13/02. H05B 7/152*. Appl. № a201311270. Filed 23.09.2013. Bull. № 21, 3.

IMPROVEMENT OF THE MANAGEMENT OF MATERIAL AND TECHNICAL RESOURCES OF WATER CLEANING PROJECTS FROM EXPLOSIVE OBJECTS

page 51–56

The object of research in the article is the management of material and technical resources of water cleaning projects from explosive objects in Ukraine. At this time, these projects are performed by State Emergency Service of Ukraine (SES) using diving technologies that endanger human life and health and has low productivity.

Implementation of robotic technology for water cleaning from explosive objects in Ukraine is proposed using integrated involvement of marine robotics tools in SES expeditionary units consisting towed, self-propelled autonomous and remote-controlled underwater vehicles-robots, unmanned surface vessels and aircrafts.

Project management process model of robotics of water cleaning from explosive objects is obtained as the component of management submodel of basic robotic underwater tasks and management submodel of the basic tasks on the effective use of special means of marine robotics. The obtained process model forms the theoretical basis for improving the management of material and technical of water cleaning projects through the use of safe and highly efficient robotic technologies for water cleaning.

As a result of equipment of SES expeditionary units by specially developed or procured means of marine robotics will increase productivity and quality of marine operations as the tasks of national importance, and significantly decrease risks to life and health of people involved in such operations.

Keywords: marine water area, explosive object, underwater robot, management of material and technical resources of the projects.

References

1. Blintsov, O. V., Hrytsaienko, M. H. (2014). Telekerovani pidvodni aparaty na sluzhbi morehospodarskoi diialnosti Mykolaivshchyny. *Sudnobuduvannia i morska infrastruktura, 1,* 28–33.
2. Hammer, M., Champy, J. (2009). *Reengineering the Corporation: A Manifesto for Business Revolution*. Harper Collins, 368.
3. Niv, G. R. (2005). *Space Dr. Deming: The principles of sustainable business*. Harvard Business Review, 370.
4. Burkov, V. N., Blintsov, V. S., Voznyi, A. M., Koshkin, K. V., Mihailov, K. M., Haritonov, Yu. N., Chernov, S. K., Shamrai, A. N. (2010). *Mehanizmy upravleniia proektami i programmami regional'nogo i otraslevogo razvitiia*. Nikolaev: Vidavnitstvo Torubari O. S., 176.
5. Pysarenko, Yu. V. (2007). *Virtualne proektuvannia intelektualizovanykh robotiv dlia rozvidky i neitralizatsii nebezpechnykh ekolohichnykh podii: Thesis PhD*. Kyiv, 20.
6. Templeton, J. (2006). *Offshore Technology in Civil Engineering: Hall of Fame Papers from the Early Years*. American Society of Civil Engineers, 160.
7. *Oceanography and Mine Warfare*. (2000). Washington, D.C.: National Academy Press, 112. doi:10.17226/9773
8. In: Siciliano, B., Khatib, O. (2016). *Springer Handbook of Robotics*. Berlin: Springer-Verlag, 2197. doi:10.1007/978-3-319-32552-1
9. Robin, R. (2014). *Disaster Robotics (Intelligent Robotics and Autonomous Agents series)*. Cambridge: The MIT Press, 240.
10. In: Kin, L. (2006). *Industrial Robotics: Programming, Simulation and Applications*. Pro Literatur Verlag, 700. doi:10.5772/40
11. Hallond, C. (2003). *Combat Robot Weapons*. TAB Books Inc., 207.
12. Antonelli, G. (2006). Underwater Robots – 2nd Edition. *Springer Tracts in Advanced Robotics*. Springer Berlin Heidelberg, 265. doi:10.1007/11540199
13. Roberts, G. N., Sutton, R. (2012). *Advances in Unmanned Marine Vehicle*. The Institution of Engineering and Technology, 441. doi:10.1049/pbce077e
14. Christ, R. D., Wernli, R. L. (2007). *The ROV Manual: A User Guide for Remotely Operated Vehicles*. Butterworth-Heinemann, 308.
15. Button, R. W., Kamp, J., Curtin, T. B., Dryden, J. (2009). *A Survey of Missions for Unmanned Undersea Vehicles*. National Defense Research Institute, 189.
16. Kachroo, P. (2010). *Autonomous Underwater Vehicles: Modeling, Control Design and Simulation*. CRC Press, 165. doi:10.1201/b10463
17. In: Seto, M. L. (2013). *Marine Robot Autonomy*. New York: Springer, 2013. – 382 p. doi:10.1007/978-1-4614-5659-9
18. *A Guide to the Project Management Body of Knowledge (*PMBOK® Guide*): Russian translation. Ed. 5*. (2014). Project Management Institute, 589.
19. Bushuev, S. D., Bushueva, N. S. (2006). *Upravlenie proektami: Osnovy professional'nyh znanii i sistema otsenki kompetentnosti proektnyh menedzherov*. IRIDIUM, 208.
20. Blintsov, S. V. (2014). *Teoretychni osnovy avtomatychnoho keruvannia avtonomnymy pidvodnymy aparatamy*. Mykolaiv: NUK, 242.
21. Pro zatverdzhennia Statutu dii u nadzvychainykh sytuatsiiakh orhaniv upravlinnia ta pidrozdiliv Operatyvno-riatuvalnoi sluzhby tsyvilnoho zakhystu. *Decree of the Cabinet of Ministers of Ukraine from May 25, 2012 № 101*. Available: http://zakon0.rada.gov.ua/laws/show/z0835-12
22. Pro zatverdzhennia typovykh polozhen pro funktsionalnu i terytorialnu pidsystemy yedynoi derzhavnoi systemy tsyvilnoho zakhystu. *Decree of the Cabinet of Ministers of Ukraine from March 11, 2015 № 835/21147*. Available: http://zakon3.rada.gov.ua/laws/show/101-2015-п

STATE AND PROSPECTS OF DEVELOPMENT OF TIRE RECYCLING TECHNOLOGIES AND THEIR ENVIRONMENTAL IMPACT

page 57–63

Because of rapid increase in the number of cars, there is an actual problem of warehousing, storage, transportation and recycling of dozen million tires annually. On the one hand, scrap tire is a waste, on the other — a valuable recyclable material.

In this article the most common recycling technologies for tires are investigated. There are recovery, incineration, mechanical crushing and pyrolysis.

Shredding of rubber wastes is recognized as the simplest and most rational way of recycling because it allows to preserve physical, mechanical and chemical properties of the material. However, the final stage of use of the resulting crumbs is a stumbling block of cost-effective solution to the problem of full recycling of rubber wastes.

Incineration of tires leads to significant pollution with heavy metals (cadmium, nickel), sulfur oxides and carbon compounds.

Pyrolysis of tire recycling provides the lowest level of emissions and complete recycling of tires.

The study shows that typical pyrolysis plant with four waste-heat boilers does not result in the emission of heavy metals and sulfur. As a result of pyrolysis with an average load — 850–1000 tons/year of rubber wastes there are produced: the liquid fraction — 500 liters/day (500 m^3/year), high-carbon residue — 1 ton/day (1,000 tons/year), metal — 0,2 tons/day (200 tons/year), gas — 200 m^3/day (200,000 m^3/year). Surface concentrations of pollutants is calculated using «EOL+». A map of the MPC levels of certain contaminants in nine areas is developed depending on the distance to the source of the emission.

The research confirms the environmental safety tire pyrolysis recycling.

Keywords: technology, tire recycling, environment, waste, emissions, pyrolysis.

References

1. Holik, Yu. S., Voitenko, Yu. S., Voitenko, A. V., Illiash, O. E. (2009). *Zakonodavstvo Yevropeiskoho soiuzu u sferi okhorony navkolyshnoho seredovyshcha*. Poltava, 170.
2. Analiz tehnologii pererabotki avtoshin. (05.09.2009). *Otraslevoi portal «Othody.Ru»*. Available: http://www.waste.ru/modules/section/item.php?itemid=140
3. Setko, N. P., Gomonova, O. B., Delov, V. S. (1994). Vliianie ekzogennyh serosoderzhashchih himicheskih veshchestv na zhenskii organizm (obzor). *Gigiena i sanitariia, 6,* 14–17.
4. Petruk, V. H., Prokopenko, V. O., Turchyk, P. M. (2009). Otsinka vplyvu na navkolyshnie seredovyshche shynnoi promyslovosti. *Zbirnyk materialiv II-ho Vseukrainskoho zizdu ekolohiv za mizhnarodnoi uchastiu,* 73–76.
5. European Commission. (01.09.2011). Sixth Environment Action Programme (EAP). *Environment 2010: Our Future, Our Choice. L-2985*. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:l28027
6. European Commission. (04.05.2001). Communication «The Clean Air for Europe (CAFE) Programme: Towards a Thematic Strategy for Air Quality». *6th Environment Action Programme. COM(2001)245*. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52001DC0245
7. *European Commission*. Available: http://ec.europa.eu
8. *European Environment Agency*. Available: http://www.eea.europa.eu/
9. European Union emission inventory report 1990-2008 under the UNECE Convention on Long-range. Transboundary Air Pollution (LRTAP). (09.06.2010). *European Environment Agency.* Available: http://www.eea.europa.eu/publications/lrtap-emission-inventory-report
10. Dyrektyva 2000/60/YeS Yevropeiskoho Parlamentu i Rady vid 23 zhovtnia 2000 roku «Pro vstanovlennia ramok diialnosti Spivtovarystva v haluzi vodnoi polityky». (11.03.2008). *Verkhovna Rada Ukrainy.* Available: http://zakon2.rada.gov.ua/laws/show/994_962
11. Voitenko, A. V., Holyk, Yu. S. (2010). Yevropeiskyi pidkhid do vyrishennia problem zabrudnennia i zabezpechennia yakosti atmosfernoho povitria. *Ekolohichna bezpeka, 2,* 23–24.
12. *ADEME – Changement climatique – transition ecologique, energetique*. Available: \www/URL: http://www.ademe.fr/
13. Décret n° 2002-1563 du 24 décembre 2002 relatif à l'élimination des pneumatiques usagés. *Légifrance, le service public de l'accès au droit.* Available: https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000418004&dateTexte=&categorieLien=id
14. «Derzhavnyi avtotransportnyi naukovo-doslidnyi i proektnyi instytut»: vid vytokiv do sohodennia. *DP «DERZhAVTOTRANSDIPROEKT»*. Available: http://www.insat.org.ua/phpfiles/menu/about/
15. Beev, V. (28.02.2012). Utilizatsiia avtomobil'nyh shin: ukraintsy ezdiat na vechnyh shinah? *Autocentre.ua*. Available: https://www.autocentre.ua/opyt/tehnologii/utilizatsiya-avtomobilnyh-shin-ukraintsy-ezdyat-na-vechnyh-shinah-90173.html
16. Markov, V. A., Bashirov, R. M., Gabitov, I. I. (2002). *Toksichnost' otrabotavshih gazov dizelei. Ed. 2.* Moscow: MSTU n.a. Baumana, 375.
17. Klius, V. P. (2014). Energoeffektivnaia pererabotka amortizirovannyh shin v al'ternativnoe toplivo. *Energetica, 4,* 125–128.
18. *Zbirnyk pokaznykiv emisii (pytomykh vykydiv) zabrudniuiuchykh rechovyn v atmosferne povitria riznymy vyrobnytstvamy. Vol. 1.* (2004). Donetsk, 184.

TECHNOLOGY TRANSFER IN THE TRANSPORT INDUSTRY

FORMATION OF SERVICE AND RESOURCE STABILITY CONDITIONS OF URBAN PUBLIC PASSENGER TRANSPORT

page 64–69

Service and resource parameters of urban public passenger transport operation are dominant for formation of its sustainability from the standpoint of internal and external processes. The sustainability of urban public passenger transport reflects its properties to keep under the influence of internal and external influences for a long time, which is correlated with time and changing the system, processes of its homeostatic equilibrium state, structure, nature of operation and to ensure the effective functioning of the urban environment. Its sustainability is achieved by forming reaction responses to influence, which aims to compensate their negative impact. The source of the formation of such compensatory actions is reserves of its internal (transport resources) and external resources (transport network resources). Formation of compensatory actions to influence must provide the appropriate level of its operation results of urban public passenger transport. Synthesis of the requirement to provide compensation of resource needs and performance characteristics helps to define the conditions for achieving sustainability of functional processes of urban public passenger transport.

The form of the boundaries of acceptable sustainability parameters of urban public passenger transport is revealed from the standpoint of service and resource characteristics of its operation. The sustainability scheme of functional processes of urban public passenger transport is reflected conditions and principles of sustainable development of urban environments and allows to assess sustainability degree using an available form of their accounting.

Keywords: sustainability, urban public passenger transport, sustainability area, service and resource conditions.

References

1. Vdovychenko, V., Nagornyy, Y. (2016). Formation of methodological levels of assessing city public passenger transport efficiency. *Eastern-European Journal Of Enterprise Technologies, 3(3(81)),* 44–51. doi:10.15587/1729-4061.2016.71687

2. Kubey, R., Csikszentmihalyi, M. (1990). *Television and the Quality of Life: How Viewing Shapes Everyday Experience*. Routledge, 296. doi:10.4324/9780203812266
3. Dolnicar, S., Yanamandram, V., Cliff, K. (2012). The contribution of vacations to quality of life. *Annals of Tourism Research, 39 (1),* 59–83. doi:10.1016/j.annals.2011.04.015
4. Bobylev, S. N., Kudriavtseva, O. V., Solovieva, S. V. (2014). Indikatory ustoichivogo razvitiia dlia gorodov. *Ekonomika regiona, 3,* 101–109.
5. Steg, L., Gifford, R. (2005). Sustainable transportation and quality of life. *Journal of Transport Geography, 13 (1),* 59–69. doi:10.1016/j.jtrangeo.2004.11.003
6. Metz, D. H. (2000). Mobility of older people and their quality of life. *Transport Policy, 7 (2),* 149–152. doi:10.1016/s0967-070x(00)00004-4
7. Redman, L., Friman, M., Garling, T., Hartig, T. (2013). Quality attributes of public transport that attract car users: A research review. *Transport Policy, 25,* 119–127. doi:10.1016/j.tranpol.2012.11.005
8. Abramovych, B. M. et al. (2002). Transportne obsluhovuvannia naselennia yak faktor staloho rozvytku mista. *Avtomobilist Ukrainy, 3,* 11–13.
9. Samchuk, G. (2016). Using sustainable development principles to assess the efficiency of transport interchanges functioning. *Automobile Transport, 38,* 13–20.
10. Harchenko, O. I. (2016). Otsenka parametrov, harakterizuiushchih ustoichivoe razvitie zheleznyh dorog. *Transportnye sistemy i tehnologii perevozok, 11,* 67–71.
11. Eboli, L., Mazzulla, G. (2012). Performance indicators for an objective measure of public transport service quality. *European Transport, 51 (3),* 1–21.
12. Mihyeon Jeon, C., Amekudzi, A. (2005). Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics. *Journal of Infrastructure Systems, 11 (1),* 31–50. doi:10.1061/(asce)1076-0342(2005)11:1(31)
13. Yelahin, Yu. V. (2012). Problemy zabezpechennia staloho rozvytku suspilnoho transportu ta suspilni transportni vytraty. *Visnyk ekonomichnoho transportu ta promyslovosti, 35,* 254–256.
14. Manaugh, K., Badami, M. G., El-Geneidy, A. M. (2015). Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America. *Transport Policy, 37,* 167–176. doi:10.1016/j.tranpol.2014.09.013
15. Dobranskyte-Niskota, A., Perujo, A., Pregl, M. (2007). *Indicators to assess sustainability of transport activities. Part 1: Review of the Existing Transport Sustainability Indicators Initiatives and Development of an Indicator Set to Assess Transport Sustainability Performance*. Italy: European Communities, 59. doi:10.2788/54736
16. Jeon, C. M., Amekudzi, A. A., Guensler, R. L. (2010). Evaluating Plan Alternatives for Transportation System Sustainability: Atlanta Metropolitan Region. *International Journal of Sustainable Transportation, 4 (4),* 227–247. doi:10.1080/15568310902940209
17. Vdovychenko, V. (2014). Otsinka resursnykh mozhlyvostei miskoho pasazhyrskoho transportu. *Zbirnyk naukovykh prats Dnipropetrovskoho natsionalnoho universytetu zaliznychnoho transportu imeni akademika V. Lazariana. Transportni systemy ta tekhnolohii perevezen, 8,* 35–39.