DEFORMATION AND STRESS ANALYSIS OF VERTICAL STEEL SHELL OF TANKS BASED ON LASER SCANNING DATA

Andrei A. Sholomitsky
Siberian State University of Geosystems and Technology, 10, Plakhotnogo St., Novosibirsk, 630108, Russia, D. Sc., Professor, Department of Engineering Geodesy and Mine Surveying, phone: (383)343-29-55, e-mail: sholomitskij@mail.ru

Nurgan T. Kemerbaev
Siberian State University of Geosystems and Technology, 10, Plakhotnogo St., Novosibirsk, 630108, Russia, Ph. D. Student, Department of Engineering Geodesy and Mine, phone: (383)343-29-55, e-mail: n.kemerbayev@geo-id.kz

Sergei G. Mogilny
Prydniprovska State Academy of Civil Engineering and Architecture, 24A, Chernyshevskogo St., Dnepropetrovsk, 49600, Ukraine, D. Sc., Professor, Department of Land Management, Road-Building and Geodesy, phone: +38(050)606-43-54, e-mail: mogilnysg@mail.ru

Sergei N. Tsarenko
Kamchatka State Technical University, 35, Klyuchevskaya St., Petropavlovsk-Kamchatsky, 683003, Russia, D. Sc., Associate Professor, Department of Technological Machines and Equipment, e-mail: tzarenko@gmail.com

The article considers a new technology of measurements of vertical steel tanks (ground-based laser scanning), which delivers a huge volume of unstructured information. There has been carried out a review of existing methods for solving tasks of tank walls' defomations determinations on laser reflection point cloud. It is noted that the accuracy of laser scanning and scans' stitching is sufficient for tank walls' defomations determinations. The existing methods are implemented basically through building irregular triangular surfaces of tank shell on which then surface profiles are built manually or semi-automatically and the defomations are determined and compared to tolerance values. The authors suggest a method and algorithm for processing laser reflection point cloud, which by means of several infiltrations by height, radius tolerance and inclinations and interpolation by collocation method is drawn to a rectangular topologically equivalent grid. These allow by several orders to decrease the information volume stored in the database, and regular grid model structure allows to apply numerical calculation method for calculating strains occurring in the tank walls. The strains are determined on semi-momentless theory for cylinder shell calculation. The method and algorithm are implemented in geodetic subsystem of automatic system of technical maintenance and repairs of equipment on the oil processing plant. The suggested method will allow in the future to move from normative assessment of technical tank state to the assessment on actual strains, which gives objective assessment of tank state for making substantiated decision on the prolongation of its exploitation, current maintenance and repair.

Keywords: vertical steel tank, scanning, geodetic monitoring, deformations, accuracy, interpolation, filtration, stresses

REFERENCES

1. Constructions Norms and Regulations. (1963). SNiP II-V.3-62. Steel structures. Design standards. Moscow, 62p. [in Russian].
2. Constructions Norms and Regulations. (1963). SNiP II-V.5-62. Metal constructions. Rules for the manufacture, installation and acceptance. Moscow, 92 p. [in Russian].
3. Temporary instruction for the repair and correction of defects in vertical welded cylindrical tanks for the storage of petroleum products. (1954). Approved Ministry of the Oil Industry of the USSR of May 05, 1954. Moscow, 39 p. [in Russian].

4. RD 153-112-017-97. (1997). Instructions for diagnosing and evaluating the residual life of vertical steel tanks. Ufa: UGNTU Publ., 74 p. [in Russian].

5. Standards Russian Federation. (2010). STO SA 03-004-2009. Tube furnaces, tanks, vessels and apparatuses for oil refining and petrochemical industries. Requirements for technical supervision, revision and rejection. Volgograd: VGIU "Peremena" Publ., 156 p. [in Russian].

6. API Standard 650. (2013). Welded Tanks for Oil Storage (12th ed.). Washington: American Petroleum Institute.

7. API Standard 653. (2014). Tank Inspection, Repair, Alteration, and Reconstruction (5th ed.). Washington: American Petroleum Institute.

8. EN 1993-4-2:2007. (2007). Eurocode 3 - Design of steel structures – Part 4-2: Tanks. European committee for standardization. Brussels.

9. EN 14015:2004. (2004). Specification for the Design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperature and above. European committee for standardization. Brussels.

10. Chang, J., & Lin, C.-C. (2006). A study of storage tank accidents. *Journal of Loss Prevention in the Process Industries*, *19*(1), 51–59. doi: 10.1016/j.jlp.2005.05.015.

11. Pichugin, S. F., & Klochko, L. A. (2019). Accidents Analysis of Steel Vertical Tanks ICBI 2019. *Proceedings of the 2nd International Conference on Building Innovations* (pp. 193–204). doi: 10.1007/978-3-030-42939-3_21.

12. Zdravkov, L., et al. (2020). Typical damage in steel storage tanks in operation. *Procedia Structural Integrity*, *22*, 291–298. doi: 10.1016/j.prostr.2020.01.037.

13. Galkin, P. V., Spiridonov, V. P., Kopylov, A. A., & Bazhenov, S. A. (2020) Ensuring fire safety at fuel and energy facilities through engineering and geodetic control. *Markshejderiya i nedropol'zovanie [Mine Surveying and Subsoil Use]*, 5(109), 17–21 [in Russian].

14. Modern method of checking for VST deformations. (n. d.). Retrieved from https://zen.yandex.ru/media/id/5d53b415ec575b00ada3bb66/sovremennyi-metod-proverki-na-deformacii-rvs-5d763c28f73d9d00ae3d3d6b [in Russian].

15. A modern method for checking the deformation of oil tanks using 3D laser scanning. (n. d.). Retrieved from https://lazer.rf/2019/11/29/15085/LAZERNOESKANIROVANIE29.11.2019158.

16. Technologies for monitoring and calibration of storage tanks for oil and oil products. (n. d.). Retrieved from https://www.youtube.com/watch?v=rBDFl33VdUs [in Russian].

17. Verification and calibration of tanks by laser scanning. (n. d.). Retrieved from http://www.souzgiprozem.ru/izyskaniya-graduirovka-reservuarov-nalivnyh.html [in Russian].

18. Laser scanning and 3D modeling in industry. (n. d.). Retrieved from https://www.promgeo.com/ services/engineering/industrial/ [in Russian].

19. Application of laser scanning in the monitoring of oil reservoirs. (n. d.). Retrieved from https://laserscanningeng.ru/blog/primenenie-lazernogo-skanirovaniya-pri-monitoringe-neftyanyh-rezervuarov/ [in Russian].

20. 3D laser scanning and calibration of RVSPK-100000 tanks on the coast of Chikhachev Bay, Sea of Japan. (n. d.). Retrieved from https://www.ngce.ru/pg_projects255.html [in Russian].

21. Monitoring and inspection of Leica MS60 and Leica RTC360 tanks. (n. d.). Retrieved from https://kzsection.info/green/monitoring-i-inspektirovanie-rezervuarov-rvs-bullity-leica-ms60-i-leica-rtc360/035_caWsqq5pq3k.html [in Russian].

22. Kotel'nikov, S. I. (2016). Application of laser scanning technology for monitoring oil tanks. *Marksheyderskiy vestnik [Mine Surveying Bulletin]*, 2, 1–5 [in Russian].

23. Ivanov, V. A., & Feshchenko, A. A. (2018). Features of approaches to maintenance and repair of equipment in continuous production. *Vestnik Permskogo nacional'nogo issledovatel'skogo politekhnicheskogo universiteta. Mashinostroenie, materialovedenie [Bulletin of the Perm National Research Polytechnic University. Mechanical Engineering, Materials Science]*, *20*(3), 82–89. doi: 10.15593/2224-9877/2018.3.10. [in Russian].

24. A new approach to the operation and repair of equipment at machine-building enterprises of the defense industry. (n. d.). Retrieved from https//ufastanki.ru /sarticles/0/41 [in Russian].

25. Maintenance system from different points of view. (2013). *Elektroenergiya. Peredacha i raspredelenie [Electricity. Transmission and Distribution]*, 3, 10–14 [in Russian].

26. Kemerbaev, N. T. (2020). Geodetic information in the system of automated maintenance and repairs. *Vestnik SGUGiT [Vestnik SSUGT]*, 25(4), 27–36. doi: 10.33764/2411-1759-2020-25-4-27-36 [in Russian].

27. Maximo Asset Management Documentation V 7.6.0.7. (n. d.). Retrieved from https://www.ibm.com/support/knowledgecenter/ru/SSLKT6_7.6.0.7/com.ibm. mam.doc/welcome.html.

28. Gorbatov, V. A. (2000). *Fundamental'nye osnovy diskretnoy matematiki. Informatsionnaya matematika [Fundamentals of discrete mathematics. Information Mathematics]*. Moscow: Nauka. Fizmatlit Publ., 544 p. [in Russian].

29. Strel'cov, V. I., & Mogil'nyj, S. G. (1989). *Marksheyderskoe obespechenie prirodopol'zovaniya nedr [Mine Surveying Support of Natural Resources Management]*. Moscow: Nedra Publ., 205 p. [in Russian].

30. Boyarshinov, S. V. (1973). *Osnovy stroitel'noy mekhaniki mashin [Fundamentals of structural mechanics of machines]*. Moscow: Mashinostroenie Publ., 456 p. [in Russian].

31. Vlasov, V. Z. (1962*). Izbrannye trudy. Obshchaya teoriya obolochek: T. 1 [Selected works. General shell theory: Vol. 1]*. Moscow: USSR Academy of Sciences Publ., 528 p. [in Russian].

32. Vlasov, V. Z. (1964). *Izbrannye trudy. Tonkostennye prostranstvennye sistemy: T. 3 [Selected works. Thin-walled spatial systems: Vol. 3]*. Moscow: USSR Academy of Sciences Publ., 472 p. [in Russian].

33. Shevchenko, F. L. (2007). *Mekhanika uprugikh deformiruemykh sistem: Ch. 2, Slozhnoe napryazhenno-deformirovannoe sostoyanie [Mechanics of elastic deformable systems: Part 2, Complex stress-strain state]*. Doneck: DonNTU Publ., 306 p. [in Russian].

Received 27.02.2022