Development of a spacecraft load bearing structures using topology optimization for two versions of manufacturing technologies

© A.A. Borovikov[1], O.N. Tushev[2]

[1]JSC "MIC "NPO Mashinostroyenia", Reutov, 143966, Russia
[2]Bauman Moscow State Technical University, Moscow, 105005, Russia

The article compares the approaches to the development of load bearing structures using topology optimization (TO) for two manufacturing options. As an example of the design, the spacecraft adapter is used. In the first variant, a construction for manufacturing by additive technologies is intended, in the second — for manufacturing by traditional methods (machining, welding, etc.). As a problem solver, the MSC Nastran software package is used. Also, the article considers the problems of using the TO in the development of the design and looks at ways to solve them. The TO method, design variables, constraints and objective function are indicated. Recommendations for the preparation of the initial model and the choice of the parameters of the TO algorithm for the variants considered and a detailed description of each stage of the design development are given. A comparison of the obtained structures with a description of the advantages and disadvantages of the approaches is shown. According to the results of the analysis, the conclusions on the use of the TO for the design development of the spacecraft adapter are made. In addition, recommendations on the use of the TO in the manufacture of construction by traditional methods in conditions of insufficient information about the product being developed are given.

Keywords: *topological optimization, technological limits, mass perfection, additive technology*

REFERENCES

[1] Floudas C.A., Pardalos P.M., eds. *Encyclopedia of Optimization*. 2nd ed. New York, Springer, 2009, 4626 p.

[2] Bendsøe M.P., Sigmund O. *Topology Optimization. Theory, Methods and Application*. 2nd ed, Berlin, Springer, 2004, 370 p.

[3] Zhihao Zuo. *Topology Optimization of Periodic Structures*. School of Civil, Environmental and Chemical Engineering. College of Science Engineering and Health. RMIT University, 2009, 239 p.

[4] *Primenenie programmnykh produktov Altair HyperWorks v aviakosmicheskoy otrasli* [The use of Altair HyperWorks software products in the aerospace industry]. Available at: http://assets.fea.ru/uploads/hyperworks/materials/aerospace/CaseStudy_Aerospace_RU.pdf (accessed April 17, 2018).

[5] Poddubko S.N., Shmelev A.V., Ivchenko V.I., Zabolotskiy M.M., Trukhanov L.I., Khatskevich A.S. *Aktualnye voprosy mashinovedeniya — Mechanics of Machines, Mechanisms and Materials*, 2016, no. 5, pp. 86–90.

[6] Chang K.-H., Tang P.-S. *Advances in Engineering Software*, 2001, no. 32, pp. 555–567.

[7] Vasil'ev B.E., Magerramova L.A. *Vestnik Samarskogo universiteta. Aerokosmicheskaya tekhnika, tekhnologii i mashinostroenie — Vestnik of Samara University. Aerospace and Mechanical Engineering*, 2015, no. 3, pp. 139–147. DOI: 10.18287/2412-7329-2015-14-3-139-147

[8] Brackett D., Ashcroft I., Hague R. Topology Optimization for Additive Manufacturing. In: *22nd annual international solid freeform fabrication symposium*. Austin, Texas, 2011, 348 p.

[9] Zuo K.T., Chen L.P., Zhang Y.Q., Yang J. Manufacturing- and machining-based topology optimization. *Int. J. Advd. Mfg. Technol.*, 2006, no. 27, pp. 531–536.

[10] Lu J., Chen Y. Manufacturable mechanical part design with constrained topology optimization. *Proc. Inst. Mech. Eng. Part B. J. Eng. Manuf.*, 2002, no. 226, pp. 1727–1735.

[11] *MSC Nastran 2013. Design Sensitivity and Optimization User's Guide*. Available at: https://simcompanion.mscsoftware.com/infocenter/index?page=content&id=DOC10355&cat=MSC_NASTRAN_DOCUMENTATION_2013&actp=LIST (accessed November 7, 2014).

[12] Borovikov A.A., Tenenbaum S.M. *Aerokosmicheskiy nauchnyy zhurnal — Aerospace scientific journal*, 2016, no. 5, pp. 16–30. DOI: 10.7463/aersp.0516.0847780 (accessed April 17, 2018).

[13] Maksimov P.V., Fetisov K.V. *Mezhdunarodnyy nauchno-issledovatelskiy zhurnal — International Research Journal*, 2016, no. 9, pp. 58–60, DOI: 10.18454/IRJ.2016.51.102 (accessed April 17, 2018).

Borovikov A.A., post-graduate student, JSC "MIC "NPO Mashinostroyenia"**.**
e-mail: borovic68@mail.ru

Tushev O.N., Dr. Sc. (Eng.), Professor, Department of Aerospace Systems, Bauman Moscow State Technical University. e-mail: kafsm2@bmstu.ru