Thermal design of the wing skin of a tourist class reusable spacecraft

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The design of the wing of a tourist class suborbital reusable spacecraft is a challenging scientific and technical problem that requires, among other things, solving the thermal design problem. For this purpose, it is necessary to have information about the thermal loads acting on the vehicle during the flight, and data on the thermophysical characteristics of the materials of the wing. The external thermal loads acting on the wing and the body of the spacecraft during its reentry are determined by mathematical simulation of the aerodynamic flow using the ANSYS CFX software package. The thermophysical characteristics of materials are obtained by simulation of the heat transfer in a representative element of the material volume using the software products Digimat and ANSYS Workbench. Moreover, the problem of warming up the wing structure is solved and the most heat-loaded sections of the wing are identified. The analysis of the temperature fields revealed the need for a special layer of thermal protection. As a heat-protective coating, plastomagnet was chosen. As a result of solving the thermal design problem, we determined optimal from the point of view of weigh thicknesses distribution of the plastomagnet coating on the wing surface.

Keywords: *thermal design, aerodynamic flow modeling, thermal protection, reusable spacecraft, space tourism*

REFERENCES

[1] Seedhouse E. *Tourists in Space: A Practical Guide*. Chichester, Springer, 2008, 281 p.

[2] Collins G. *Europe in Space*. New York, Palgrave Macmillan, 2014, 235 p.

[3] Chavagnac C., Laporte-Weywada H. The Suborbital Space Tourism Project of EADS Astrium. *American Institute of Aeronautics and Astronautics*, 2009, 9 p. Available at: http://enu.kz/repository/2009/AIAA-2009-5516.pdf (accessed August 31, 2017).

[4] Von der Dunk, Frans G. Space Tourism, Private Spaceflight and the Law: Key Aspects. *Space, Cyber, and Telecommunications Law Program Faculty Publications*, 2011, pp. 146–152. Available at: http://digitalcommons.unl.edu. DOI: 10.1016/j.spacepol.2011.04.015 (accessed August 24, 2017).

[5] Zurita P. The New Orient Express: Current Trends and Regulations in Space Tourism and the Need for Commercial Hypersonic Point to Point Travel. *The Global Business Law Review*, 2014, 39 p. Available at: http://engagedscholarship.csuohio.edu/gblr/vol4/iss2/3 (accessed August 30, 2017).

[6] Webber D. Space Tourism — Essential Step in Human Settlement of Space. *63rd International Astronautical Congress*, 2012, 7 p. Available at: http://www.spaceportassociates.com/pdf/human_settlement.pdf (accessed September 5, 2017).

[7] Ageeva T.G. *Razrabotka metodiki proektirovaniya teplonagruzhennykh elementov konstruktsii krylev suborbitalnykh mnogorazovykh kosmicheskikh apparatov*. Diss. kand. tekhn. nauk [Development of a technique for designing heat-loaded structural elements of the wings of suborbital reusable spacecrafts. Cand. eng. sci. diss.]. Moscow, 2017, 183 p.

[8] Reznik S.V., Prosuntsov P.V., Ageeva T.G. *Vestnik NPO im. S.A. Lavochkina (Bulletin of Lavochkin Research and Production Association)*, 2013, no. 17, pp. 38–42.

[9] Gofin M.Ya. *Zharostoikie i teplozashchitnye konstruktsii mnogorazovykh aerokosmicheskikh apparatov* [Heat-resistant and heat-protective constructions of reusable aerospace vehicles]. Moscow, TF MIR Publ., 2003, 671 p.

[10] Turner M.J. *Rocket and Spacecraft Propulsion. Principles, Practice and New Developments (Third Edition)*. Chichester, Springer, 2009, 404 p.

[11] Ageeva T.G., Dudar E.N., Reznik S.V. *Aviakosmicheskyia tekhnika i tekhnologiya — Aerospace Technology*, 2010, no. 2, pp. 3–8.

[12] Ageeva T.G., Ashikhmina E.R., Prosuntsov P.V. *Vestnik MGTU im. N.E. Baumana. Ser. Mashinostroenie — Herald of the Bauman Moscow State Technical University. Series Mechanical Engineering*, in print.

[13] Mikhaylin Yu.A. *Voloknistye polimernye kompozitsionnye materialy v tekhnike* [Fibrous polymer composite materials in engineering]. St. Petersburg, Nauchnye osnovy i tekhnologii Publ., 2013, 720 p.

[14] *Digimat*. The Nonlinear Multi-Scale Material and Structure Modeling Platform. Available at: http://www.mscsoftware.com/product/digimat (accessed December 5, 2016).

[15] *Stekloplastiki, svyazuyushchie materialy, penoplasty, poliamidy, fotopolimery* [Fiberglass, binding materials, foams, polyamides, photopolymers]. Available at: http://www.xn----7sbnoidkjddgcex2t.xn-p1ai/penoplasty_poliamidy_sopolimery/ (accessed May 5, 2017).

[16] Cardarelly F. *Materials Handbook. A Concise Desktop Reference*. 2nd Edition. Tucson, Springer, 2008, 1340 p.

[17] Trofimov A.N., Zarubina A.Iu., Simonov-Emelyanov I.D. *Plasticheskie massy — International Polymer Science and Technology*, 2014, no. 11, 12, pp. 3–8.

[18] Sokolov I.I. *Sferoplastiki na osnove termoreaktivnykh svyazuyuschikh dlya izdelii aviatsionnoy tekhniki.* Avtoref. dis. kand. tekhn. nauk [Spheroplastics based on thermoreactive binders for aeronautical products. Cand. eng. sc. auth. abstr.] Moscow, 2013, 21 p.

[19] Yakovenko T.V., Yarullina G.K., Garustovich I.V. *Uspekhi v khimii i khimicheskoy tekhnologii — Advances in Chemistry and Chemical Technology*, 2016, vol. 30, no. 8, pp. 71–73.

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