Comparative stress analysis in nonsymmetrical multilayer composite plates in the asymptotic theory and three-dimensional finite element calculation

© Yu.I. Dimitrienko, Yu.V. Yurin

Bauman Moscow State Technical University, Moscow, 105005, Russia

The article analyzes the accuracy of previously developed multilayer thin plates' asymptotic theory. We compare the solution results of the bending problem for a multilayer asymmetric plate under pressure obtained in the asymptotic theory and in the exact three-dimensional elasticity theory. The problem solution in the asymptotic theory for the asymmetric plate case was obtained for the first time. The paper shows that the plate layers' arrangement asymmetry leads to the longitudinal plate displacements at transverse pressure. We used a software finite-element ANSYS package with a specially constructed finite element mesh to solve the elasticity theory three-dimensional problem. This grid allows for a finite element nodes thickening along the plate thickness while maintaining a relatively small grid lateral elements total number. The paper compares all stresses distributed along the plate thickness, obtained by means of the asymptotic theory and finite elements method. We show that the developed asymptotic theory provides high solution accuracy for all stress components, including transverse and shear stresses.

Keywords: *asymptotic theory of plates, multilayer thin plates, asymmetric plates, finite element method, lateral stresses, numerical simulation*

REFERENCES

[1] Grigolyuk E.I., Kulikov G.M. *Mekhanika kompozitsionnykh materialov — Mechanics of Composite Materials*, 1988, vol. 24, no. 4, pp. 698–704.

[2] Ghugal Y.M., Shmipi R.P. *Journal of Reinforced Plastics and Composites*, 2001, vol. 20, no. 3, pp. 255–272.

[3] Tornabene F. *Computer Methods in Applied Mechanics and Engineering*, 2011, no. 200, pp. 931–952.

[4] Alfutov N.A., Zinoviev P.A., Popov B.G. *Raschet mnogosloynykh plastin i obolochek iz kompozitsionnykh materialov* [Calculation of multilayer plates and shells made of composite materials]. Moscow, Mashinostroenie Publ., 1980, 324 p.

[5] Sheshenin S.V. *Izvestiya RAN. Mekhanika tverdogo tela — Mechanics of Solids. A Journal of the Russian Academy of Sciences*, 2006, no. 6, pp. 71–79.

[6] Zveryaev E.M., Makarov G.I. *Prikladnaya matematika i mekhanika — Journal of Applied Mathematics and Mechanics*, *RAS*, 2008, vol. 72, no. 2, pp. 308–321.

[7] Nazarov S.A., Svirs G.H., Slutsky A.S. *Matematicheskii Sbornik — Sbornik: Mathematics*, 2011, vol. 202, no. 8, pp. 41–80.

[8] Kohn R.V., Vogelius M. *International Journal of Solids and Structures*, 1984, vol. 20, no. 4, pp. 333–350.

[9] Panasenko G.P., Reztsov M.V. *Dokl. AN SSSR — Reports of Acad. Sci. USSR*, 1987, vol. 294, no. 5, pp. 1061–1065.

[10] Levinski T., Telega J.J. *Plates, laminates and shells*. *Asymptotic analysis and homogenization*. Singapore, London, World Sci. Publ., 2000, 739 p.

[11] Kolpakov A.G. *Homogenized models for thin-walled nonhomogeneousstructures with initial stresses*. Berlin, Heidelberg, SpringerVerlag, 2004, 228 p.

[12] Dimitrienko Yu.I., Yakovlev D.O. *Inzhenernyy zhurnal: nauka i innovatsii — Engineering Journal: Science and Innovation*, 2013, iss. 7 (19). Available at: http://engjournal.ru/catalog/mathmodel/technic/899.html (accessed August 21, 2017).
[13] Dimitrienko Yu.I. *Vestnik MGTU im. N.E. Baumana. Ser. Estestvennye nauki — Herald of the Bauman Moscow State Technical University. Series: Natural Sciences*, 2012, no. 3, pp. 86–100.
[14] Dimitrienko Yu.I., Gubareva E.A., Sborschikov S.V. *Matematicheskoe modelirovanie i chislennye metody — Mathematical Modeling and Computational Methods*, 2014, no. 1, pp. 36–57.
[15] Dimitrienko Yu.I., Fedonyuk N.N., Gubareva E.A., Sborschikov S.V., Prozorovsky A.A., Erasov V.S., Yakovlev N.O. *Vestnik MGTU im. N.E. Baumana. Ser. Estestvennye nauki — Herald of the Bauman Moscow State Technical University. Series: Natural Sciences*, 2014, no. 5, pp. 66–82.
[16] Dimitrienko Yu.I., Dimitrienko I.D., Sborschikov S.V. *Inzhenernyy zhurnal: nauka i innovatsii — Engineering Journal: Science and Innovation*, 2016, iss. 11, (59). DOI 10.18698/2308-6033-2016-11-1555
[17] DimitrienkoYu.I., Dimitrienko I.D. *Applied Mathematical Sciences*, 2016, vol. 10, no. 60, pp. 2993–3002. Available at: www.m-hikari.com https://doi.org/10.12988/ams.2016.68231
[18] Dimitrienko Yu.I. *Mekhanika sploshnoy sredy. V 4 tomakh. Tom 4. Osnovy mekhaniki tverdogo* tela [Continuum mechanics. In 4 vols. Vol. 4. Fundamentals of solid-state mechanics]. Moscow, BMSTU Publ., 2013, 580 p.
[19] Dimitrienko Yu.I. *Mekhanika sploshnoy sredy. V 4 tomakh. Tom 1. Tenzorny analiz* [Continuum mechanics. In 4 vols. Vol. 1. Tensor analysis]. Moscow, BMSTU Publ., 2011, 463 p.

Dimitrienko Yu.I. (b. 1962) graduated from Lomonosov Moscow State University in 1984. Dr. Sc. (Phys.-Math.), head of the Department of Computational Mathematics and Mathematical Physics, Bauman Moscow State Technical University, head of the Scientific and Educational Center Supercomputer Engineering Modeling and Development of Software Complexes at BMSTU, member of the Academy of Engineering Sciences. Author of over 350 scientific publications in the field of continuum mechanics, computational mechanics, gas dynamics, mechanics and thermomechanics of composites, mathematical modeling in the science of materials. e-mail: dimit.bmstu@gmail.com

Yurin Yu.V. (b. 1989) graduated from Bauman Moscow State Technical University in 2012. Post-graduate student of the Department of Computational Mathematics and Mathematical Physics, BMSTU. Author of 20 scientific publications in the field of composite mechanics. e-mail: yvyurin@yandex.ru