UDC 539.3

B. USPENSKYI[1], K. AVRAMOV[1], O. SALENKO[2], O. NIKONOV[3]

DYNAMIC INSTABILITY IN THE INTERACTION OF A COMPOSITE SHELL MADE BY ADDITIVE TECHNOLOGIES WITH A GAS FLOW

[1] *A. Pidhornyi Institute of Power Machines and Systems of the National Academy of Sciences of Ukraine*
2/10 Komunalnykiv St., Kharkiv 61046, Ukraine; e-mail: kvavr@kharkov.ua
[2] *National Technical University of Ukraine*
«Igor Sikorsky Kyiv Polytechnic Institute»
37 Beresteiskyi Ave., Kyiv 03056, Ukraine
[3] *Kharkiv National Automobile and Highway University*
25 Yaroslava Mudrogo St., Kharkiv 61002, Ukraine

The dynamic instability of a composite cylindrical-conical thin-walled structure interacting with a supersonic gas flow is analyzed. This structure consists of three layers. The middle layer is manufactured by FDM additive technologies from ULTEM material. The top and bottom layers are manufactured from carbon-filled plastic. Free linear vibrations of the thin-walled structure are studied by Rayleigh–Ritz semi-analytical method to obtain a model of dynamic instability. The free linear vibrations are analyzed numerically. The obtained eigenfrequencies and eigenmodes are in close agreement with the data obtained by the ANSYS commercial software. The calculated eigenmodes were used to construct a model of composite cylindrical-conical shell instability. This model of instability is a system of ordinary linear differential equations in the generalized coordinates of the thin-walled structure. The supersonic gas flow is described by a piston theory, which accounts for the angle of attack. The study of the dynamic instability of the composite cylindrical-conical shell reduces to analyzing the trivial equilibrium instability of the system of ordinary differential equations. Characteristic exponents are calculated to analyze the stability of the trivial solution. These characteristic exponents are calculated from an eigenvalue problem. If the angle of attack is 12° and the Mach number is small, the minimal value of the critical pressure is observed for three circular waves. If the Mach number is increased, the minimal critical pressure is observed for four and five circular waves. If the angle of attack is 6° and the Mach number is small, the minimal critical pressure is observed for two circular waves. If the Mach number is increased, the minimal critical pressure is observed for three and four circular waves. The dynamic stability is lost for eigenmodes with a small number of circular waves (2÷5).

Keywords: *dynamic instability, supersonic gas flow, composite thin-walled structure.*

1. Zarei M., Rahimi G. H. Buckling resistance of joined composite sandwich conical-cylindrical shells with lattice core under lateral pressure. Thin-Walled Struct. 2022. V. 174. 109027. https://doi.org/10.1016/j.tws.2022.109027

2. Avramov K., Myrzaliyev D., Uspensky B., Sakhno N., Seitkazenova K. K. Buckling of functionally graded carbon nanotubes reinforced composite joined spherical-cylindrical-spherical thin-walled structure. Proc. Inst. Mech. Eng. Part C. J. Mech. Eng. Sci. 2021.V. 235(22). Pp. 6287-6310. https://doi.org/10.1177/09544062211005795

3. Uspensky B., Avramov K., Nikonov O., Sahno N. Dynamic instability of functionally graded carbon nanotubes-reinforced composite joined conical-cylindrical shell in supersonic flow. Int. J. Struct. Stability and Dyn. 2022. V. 22. No. 7. 2250039. https://doi.org/10.1142/S0219455422500390

4. Sobhani E., Masoodi A. R., Ahmadi-Pari A. R. Vibration of FG-CNT and FG-GNP sandwich composite coupled Conical-Cylindrical-Conical shell. Comp. Struct. 2021. V. 273. 114281. https://doi.org/10.1016/j.compstruct.2021.114281

5. Fu T., Wu X., Xiao Z., Chen Z., Li B. Analysis of vibration characteristics of FGM sandwich joined conical-conical shells surrounded by elastic foundations. Thin-Walled Struct. 2021. V. 165. 107979. https://doi.org/10.1016/j.tws.2021.107979

6. Zuo P., Shi X., Ge R., Luo J. Unified series solution for thermal vibration analysis of composite laminated joined conical-cylindrical shell with general boundary conditions. Thin-Walled Struct. 2022. V. 178. 109525. https://doi.org/10.1016/j.tws.2022.109525

7. Li J., Li H., Yang Y., Fang Y., Wang H., Wang X., Zhang H., Wang H., Cao H., Hou J., Sun G., Du D., Liu X., Xu Z., Sun W., Luo Z., Han Q. Vibration behaviours of composite conical-cylindrical shells with damping coating: Theory and experiment. Thin-Walled Struct. 2024. V. 203. 112218. https://doi.org/10.1016/j.tws.2024.112218

8. Catapano A., Montemurro M. A multi-scale approach for the optimum design of sandwich plates with honeycomb core. Part I: homogenisation of core properties. Comp. Struct. 2014. V. 118. Pp. 664-676. https://doi.org/10.1016/j.compstruct.2014.07.057

9. Reddy J. N. A refined nonlinear theory of plates with transverse shear deformation. Int. J. Sol. and Struct. 1984. V. 20. Pp. 881-896. https://doi.org/10.1016/0020-7683(84)90056-8

10. Amabili M. Nonlinear Mechanics of Shells and Plates in Composite, Soft and Biological Materials. Cambridge: Cambridge University Press, 2018. https://doi.org/10.1017/9781316422892

11. Meirovitch L. Fundamentals of Vibrations. New York: Mc Graw Hill, 1970. 20 pp.

12. Avramov K., Uspensky B. Nonlinear supersonic flutter of sandwich truncated conical shell with flexible honeycomb core manufactured by fused deposition modeling. Int. J. Non-Lin. Mech. 2022. V. 143. 104039. https://doi.org/10.1016/j.ijnonlinmec.2022.104039

Received on August 26, 2024,
in final form on September 27, 2024