

**NUMERICAL ANALYSIS OF THE EFFECT OF TAPE INCLUSIONS ON THE STRESS CONCENTRATION IN THIN CYLINDRICAL AND CONICAL SHELLS WITH RECTANGULAR OPENINGS***Oles Honchar Dnipro National University**72 Gagarin Ave., Dnipro 49010, Ukraine; e-mail: hart@ua.fm, semencha.aleksey@gmail.com*

Thin-walled plate-shell structures are widely used in various branches of technology and the national economy, in particular in the aerospace industry, the oil and gas industry, power engineering, construction, etc. The continuity of such structures is often disrupted by various inhomogeneities in the form of openings, inclusions, recesses, cracks, etc., which are local stress concentrators. Reducing the concentration of the stresses that develop in the vicinity of such structural inhomogeneities is an important problem in deformable solid mechanics. In particular, a pressing problem in the design of new equipment in modern mechanical engineering is a significant reduction in material consumption and an increase in the service life of cast parts taking into account the use of new materials and technologies. Such parts are responsible for the competitiveness of new equipment for various industries.

This paper presents the results of a numerical simulation and analysis of the stress and strain field of thin-walled cylindrical and truncated conical shells with rectangular openings and tape inclusions around them. The material of the inclusions has properties that differ from those of the base material of the shells. The effect of the geometrical and mechanical characteristics of the inclusions on the parameters of the stress and strain field in the vicinity of the openings was studied by varying the elastic modulus of the inclusion material and the inclusion width. For definiteness, the inclusions were assumed to be homogeneous and located in the shell plane. The stress and strain intensity distributions in the zones of local stress concentration were obtained. The numerical results for shells of both shapes were compared with the corresponding results for shells with a circular opening. The study showed that the presence of a "soft" homogeneous tape inclusion helps in reducing the stress concentration around rectangular openings by ~ (21 – 54) % depending on the width of the inclusion and its elastic modulus, both in cylindrical and in conical shells. Unlike shells with a circular opening, in this case the presence of inclusions does not cause the mechanical effect of shifting the stress concentration zone from the contour of the opening to the interface between the materials.

**Keywords:** *thin-walled cylindrical shell, thin-walled truncated conical shell, rectangular opening, tape inclusion, stress and strain field, stress concentration factor, finite-element method.*

1. Avdonin A. S. Applied Methods of Calculation of Shells and Thin-Walled Structures. Moscow, 1969. 402 pp. (in Russian).

2. Hart E. L., Semencha O. O. Numerical investigation of the stress and strain field of an elastic trapezoidal plate with a rectangular opening and a tape inclusion. Problems in Computational Mechanics and Structural Strength. Dnipro, 2021. Iss. 33. Pp. 43-54. (in Ukrainian).

3. Hart E. L., Semencha O. O. Computer modeling of the effect of annular inclusions on the stress concentration in thin-walled cylindrical and conical shells with circular openings. Teh. Meh. 2023. No. 4. Pp. 60-75. (in Ukrainian).  
<https://doi.org/10.15407/itm2023.04.060>

4. Grigorenko Y. M., Molchenko L. V. Theory of Plates and Shells. Kyiv, 1993. 232 pp. (in Ukrainian).

5. Grigorenko Y. M., Vlaikov G. G., Grigorenko A. Ya. Numerical-Analytical Solution of Problems in Shell Mechanics Based on Various Models. Kyiv, 2006. 472 pp. (in Russian).

6. Hudramovich V. S., Skalskyi V. R., Selivanov Yu. M. Holographic and Acoustic-Emission Diagnostics of Heterogeneous Structures and Materials. Lviv: Prostir-M, 2017. 492 pp. (in Ukrainian).

7. Guz A. N., Chernyshenko I. S. et al. Theory of Opening-Weakened Thin Shells. Kyiv, 1980. 636 pp. (in Russian).
8. Savin G. N. Stress Distribution around Openings. Kyiv, 1968. 888 pp. (in Russian).
9. Storozhuk E. A. Maksymyuk V. A., Chernyshenko I. S. Stress concentration in the region of a rectangular opening on the side surface of a nonlinear elastic orthotropic conical shell. *Dopov. Nats. Akad. nauk Ukr.* 2019. Iss. 11. Pp. 41-48. (in Ukrainian).  
<https://doi.org/10.15407/dopovidi2019.11.041>
10. Chernobryvko M. V., Avramov K. V., Batutina T. V. Dynamic instability of reinforced conical fairings of launch vehicles in a supersonic gas flow. *Teh. Meh.* 2015. No. 1. Pp. 15-29. (in Russian).
11. Darvizeh M., Haftchenari H., Darvize A., Ansari R., Sharma C. B. The effect of boundary conditions on the dynamic stability of orthotropic cylinders using a modified exact analysis. *Composite Structures.* 2006. V. 74. Pp. 495-502.  
<https://doi.org/10.1016/j.compstruct.2005.05.004>
12. Han X., Xu D., Liu G. R. Transient responses in a functionally graded cylindrical shell to a point load. *Journal of Sound and Vibration.* 2002. V. 251. Iss. 5. Pp. 783-805.  
<https://doi.org/10.1006/jsvi.2001.3997>
13. Hua L., Lam K. Y. Orthotropic influence on frequency characteristics of a rotating composite laminated conical shell by the generalized differential quadrature method. *Int. J. of Solids and Structures.* 2001. V. 38. Pp. 3995-4015.  
[https://doi.org/10.1016/S0020-7683\(00\)00272-9](https://doi.org/10.1016/S0020-7683(00)00272-9)
14. Hudramovich V. S., Hart E. L., Marchenko O. A. Reinforcing inclusion effect on the stress concentration within the spherical shell having an elliptical opening under uniform internal pressure. *Strength of Materials.* 2020. V. 52. No. 6. p. 832-842.  
<https://doi.org/10.1007/s11223-021-00237-7>
15. Zienkiewicz O. C., Taylor R. L. *The Finite Element Method for Solid and Structural Mechanics.* New York: Elsevier, 2005. 632 pp.

Received on February 12, 2024,  
in final form on March 13, 2024