23-24 листопада
2023

Матеріали міжнародної
науково-практичної конференції

«Молодь і технічний прогрес в АПВ»

Факультет мехатроніки та інжинірингу
Державний біотехнологічний університет
ХАРКІВ, Україна
2023 р.

https://agromaster.info

UDK 539.3:534.1

MATHEMATICAL MODELING OF NON-STATIONARY VIBRATIONS OF LAMINATED SHELLS WITH A COMPLEX SHAPE AT IMPACT LOADING

Stanislav Tikhonov, Diana Starykova, Students,
Natalia Smetankina, Doctor of Technical Sciences, Professor,
Ievgeniia Misiura, PhD, Associate Professor,
Kateryna Kren, PhD, Associate Professor

Anatolii Pidgornyi Institute of Mechanical Engineering Problems of the National Academy of Sciences of Ukraine, Ukraine
Simon Kuznets Kharkiv National University of Economics, Ukraine
State Biotechnological University, Ukraine
Eötvös Loránd University, Hungary

An analytical method to investigating vibrations of composite shells with a complex shape at impact is offered. The method is based on expanding the sought for functions to trigonometric series. Numerical examples of calculation of shells with different plan form are presented.

Laminated composite structures are advantageous as compared with homogeneous ones. Calculating dynamic response parameters for impact loading is a key effort in analyzing vibrations of composite structures [1–3]. A review of recent studies shows that numerical methods are used widely to analyze laminated structures subjected to impact loads [4]. The analytical solution of these problems is given only for laminated plates and shells with a canonical plan-view shape. This study suggests an analytical method for investigating vibrations of a laminated orthotropic shell with a complex shape under impact loading. Impact loading of the shell is carried out.

The dynamic behaviour of the shells is described by the first-order theory accounting for transverse shear strain, thickness reduction and normal element rotation inertia in each layer. The motion equations are added by the indenter equation of motion and the condition of joint displacement of the indenter and shell. An indenter with a semi-spherical end impacts the outer surface of the shell's first layer. Contact approach is found by solving the Hertzian problem on a ball indentation into an elastic semi-space.

The analytical solution of the problem is derived by the immersion method [5, 6]. According to this method, a complex-shape laminated shell is immersed into an auxiliary enveloping shell with the same composition of layers. An auxiliary shell is one whose contour shape and boundary conditions yield a simple analytical solution. In this case, the auxiliary shell is a simply supported rectangular laminated one, allowing to find the problem solution as trigonometric series. To satisfy actual boundary conditions, the auxiliary shell is subjected over the trace of the initial boundary to additional distributed compensating loads whose intensities must be defined. The compensating loads are found from the system of integral equations which results from the system of actual boundary conditions. The sought-for functions of the problem are expanded into trigonometrical series in domain of the auxiliary shell and along the boundary of the given shell. The system of motion equations of shells is

integrated by expansion into Taylor series. After computing the values of intensities of compensating loads, the required parameters of the shell dynamic response are found.

The method potentialities are demonstrated by calculating stresses in laminated orthotropic shells with different boundary conditions. A good match of results obtained by different methods confirms the feasibility and effectiveness of the method offered. The developed approach can be easily extended to impulse loading and impact applied to different structural elements of complex shape with arbitrary boundary conditions.

References:

1. Malykhina A.I., Merkulov D.O., Postnyi O.V., Smetankina N.V. Stationary problem of heat conductivity for complex-shape multilayer plates. Bulletin of V.N. Karazin Kharkiv National University. Series “Mathematical modeling. Information technology. Automated control system”. 2019. Vol. 41. P. 46–54.
2. Smetankina N.V., Postnyi O.V., Merkulova A.I., Merkulov D.O. Modeling of non-stationary temperature fields in multilayer shells with film heat sources. In: 2020 IEEE KhPI Week on Advanced Technology (KhPIWeek). 2020. P. 242–246.
3. Smetankina N., Semenets O., Merkulova A., Merkulov D., Misura S. Two-stage optimization of laminated composite elements with minimal mass. Smart Technologies in Urban Engineering. STUE-2022. Lecture Notes in Networks and Systems. Springer, Cham, 2023. Vol. 536. P. 456–465.
4. Гонтаровський П. П., Сметанкіна Н. В., Гармаш Н. Г., Глядя А. А., Клименко Д. В., Сиренко В. Н. Дослідження напружено-деформованого стану паливного бака вафельної конструкції ракети-носія. Проблеми обчислювальної механіки і міцності конструкцій. Дніпро, 2019. Вип. 29. С. 91–102.
5. Smetankina N., Malykhina A., Merkulov D. Simulating of bird strike on aircraft laminated glazing. MATEC Web of Conferences. 2019. Vol. 304. P. 01010-01016.
6. Smetankina N., Merkulova A., Merkulov D., Misura S., Misiura Ie. Modelling thermal stresses in laminated aircraft elements of a complex form with account of heat sources. ICoRSE 2022. Lecture Notes in Networks and Systems. 2023. Vol. 534. Springer, Cham. P. 233–246.