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Improving the Accuracy of Geometric Interpolation for Determining Fundamental Frequency of Parallelogram Plates Vibration

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Abstract

The paper considers a method of geometric interpolation of basic solutions for two-dimensional problems in the theory of elasticity and structural mechanics, particularly as applied to mechanical engineering. The scope of the study is the vibrations of thin elastic parallelogram plates of constant thickness. To determine the fundamental frequency of vibration it is suggested to use an interpolation method with a newly introduced geometric characteristic of plates which is a ratio of inner conformal radius to outer conformal radius. Taken from the theory of conformal mapping, the conformal radii of domains are obtained by mapping the plates onto the interior and exterior of a unit circle. The studies have shown that the use of the suggested ratio gives up to twice more accurate results of the geometric interpolation. The paper presents the basic terms and formulas of the method with comparative analysis of the curve diagrams using a shape factor and a conformal radii ratio.

Keywords: parallelogram plates; dynamic vibration; basic frequency; conformal radius; form factor interpolation technique.

1. The essence of the interpolation with respect to the shape factor

A. Korobko has introduced the theoretical basis of an engineering approach for solving two-dimensional problems of structural mechanics of plates, namely, the method of interpolation with respect to the shape factor [1, 2]. The shape factor Kf is the basic integral characteristic of geometric shape of plates characterizing the integral physical parameters such as the fundamental frequency ω. The functional relationship between the fundamental frequency of vibration and the shape factor for plates is presented as follows:

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$$\omega = k_\omega \sqrt{\frac{D}{m}\frac{K_\mathrm{f}}{A}} \tag{1}$$

where k_w is the proportionality coefficient dependent on the boundary conditions of a plate and on the geometric transformation which combines a certain (specified) subset of plate shapes; m is the self-weight of a plate; D is the flexural rigidity of a plate; A is the plate area.

Using the known solutions to the problem documented in scientific literature, the dependence diagrams for plates hinged (Fig. 1a) and fixed (Fig. 1b) along all edges have been plotted.

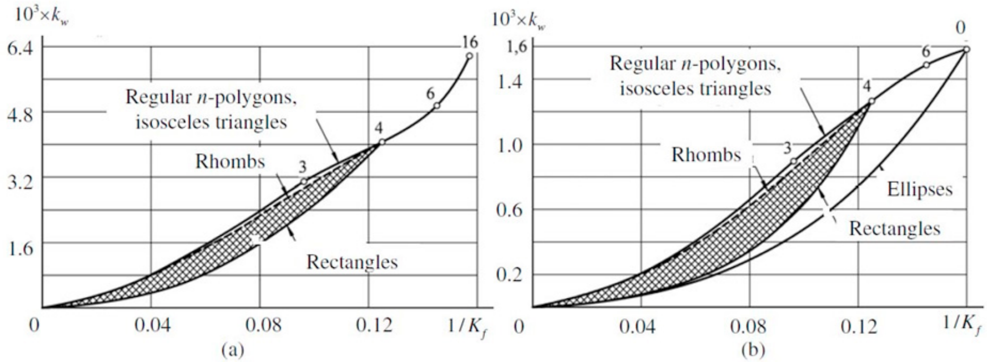

Fig. 1. Proportionality coefficient of fundamental frequency vs. reciprocal of shape factor
a) simply supported plates, b) plates with fixed edges

In Fig. 1a, points 3, 4, 6 and 16 correspond to the value of k_w for the plates of regular shapes, curve 0 – 3 is for isosceles triangular plates; In Fig. 1b, point 0 corresponds to the value of k_w for round plates.

In [1], it was proved that the entire set of possible values of k_w for quadrilateral plates is bounded below by values of k_w for rectangular plates, and above by values of k_w for the plates of regular shapes and isosceles triangles; the upper limit for the parallelogram plates represents values of $\mathrm{k_w}$ for rhombic plates.

The essence of the interpolation with respect to the shape factor is to select a subset of plate shapes united by a certain geometric transformation (including the giving plate and the other two basic plates, solutions for which are known (basic solutions)). The values of vibration frequency for all the intermediate plates can be found by interpolating the basic solutions with respect to the shape factor using the following approximations:

$$\omega = K\sqrt{\frac{D}{m}\frac{K_\mathrm{f}^n}{A}} \;\; or \;\; \omega = \left(B + \frac{C}{K_\mathrm{f}^n}\right)\sqrt{\frac{D}{m}\frac{1}{A}} \tag{2}$$

The unknown parameters K, n, B, C can be found from above-mentioned basic solutions.

In order to find a solution for the entire set of parallelogram plates using interpolation with respect to the shape factor it is necessary to know the solution for rectangular and rhombic plates. An example of geometric transformation of a parallelogram plate into rectangular and rhombic plate is shown in Fig. 2, this transformation is called shear mapping.