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INFLUENCE OF VARIOUS FACTORS ON THE VALUE OF CRITICAL FORCE AND THE FREQUENCY OF FREE OSCILLATIONS OF POLYHEDRAL SHELLS

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Abstract. In this paper, we present the results of analytical researches on the influence of various factors on the value of critical force and the frequency of free oscillations of thin shallow polyhedral shells made of flat plates. Here we show the dependency graphs of the free oscillation frequency on the shell aspect ratio and the number of fractures and give practical recommendations to the design engineers.

1. Introduction

In this paper, we investigate a thin shallow homogeneous polyhedral shell with positive Gaussian curvature at the right-angular design with hinge support along the outline. The shell has the shape of polyhedra, inserted into the spherical unstiffened shell. It consists of flat elements, rigidly connected to each other by the lines of fracture on the middle surface. The fractures are located along the coordinate axes.

For investigation, we used approved mathematical solutions and theorems of structural mechanics. Here we present the analysis of the calculation results of critical forces and free oscillation frequencies of the shell with various structural peculiarities.

2. Calculation Methods.

Energy method for problem solution of engineering structures dynamics is represented in reference [1]. In references [2] there is a numerical method of investigation of reinforced shells. Development of analytical methods is reflected in references [3-11]. In reference [7] the analytical calculations are made with the use of the Maple software.

3. Peculiarities of the Analytical Calculation Method of the Shell with Fractures

General Kirchhoff-Lyav hypotheses are accepted for the theory of shallow shells. Shell with fractures is governed with single differential equations. Inconsistencies of the surface in the form of fractures are governed with Dirac δ-function [3, 4] through the conventional curvature for polyhedral shell. The method based on the single approach excludes the solution of conjugating problems. It allows using the same calculation methods as those applied for calculation of unstiffened shells with consistent surface.

Application of the formulas, obtained analytically in references [10], allows changing the number of fractures and calculating the shells at the same and different fracture angles θ_i and θ_j and at positive and negative values of the angles.

Polyhedral shell has advantages of flat and spatial structure.

4. Testing the Critical Force

The methods for analytical calculation of polyhedral shells for stability properties have been developed in reference [8].

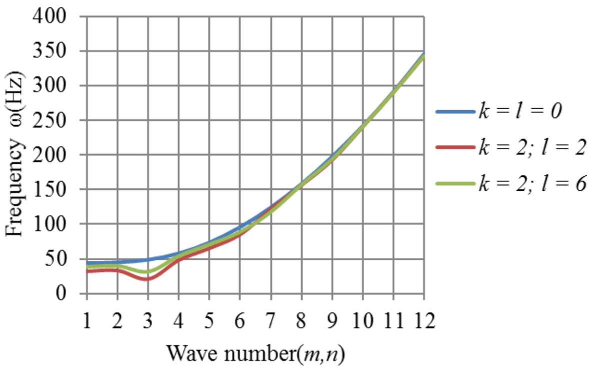
Analysis of stability of thin shallow shells under the action of transverse distributed load, influence of various factors on the value of critical load and Stability of shallow polyhedral shells in geometrically nonlinear setting is investigated in reference [9].

5. Influence of Various Factors on the Frequency of Free Oscillations of Polyhedral Shells

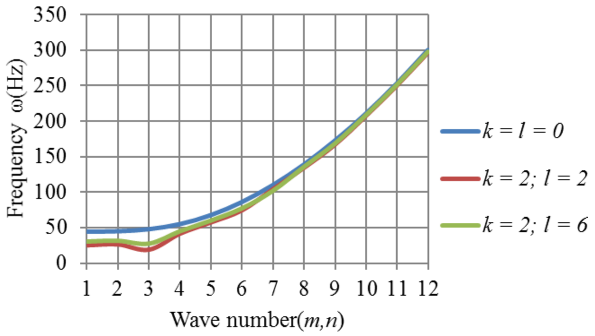
Thin homogenous shallow folded shell consists of flat elements rigidly connected to each other by the lines of fracture. It has the following size: a – along x-coordinate, b – along y-coordinate, h – thickness of the shell panel, θ_i – fracture angle along x-coordinate, θ_j – fracture angle along y-coordinate. We use the formulas determined in references [10].

As an example let's consider the shells with the same parameters: thickness of shell for unstiffened shell and thickness of plate for polyhedral shell h=0,1 m; camber of arch f = 1,6 m; specific gravity of material γ = 2400 kg/m^3; modulus of elasticity E = 2.104 MPa; Poisson ratio μ = 0,2. We define the frequencies of the shells free oscillations with various number of fractures in the middle surface in two orthogonally related directions, where k – number of fractions in x-direction, l – number of fractions in y-direction. We investigated the symmetrical molding of plates with the same projections in the plan. For comparison we also considered unstiffened shells at k=l=0.

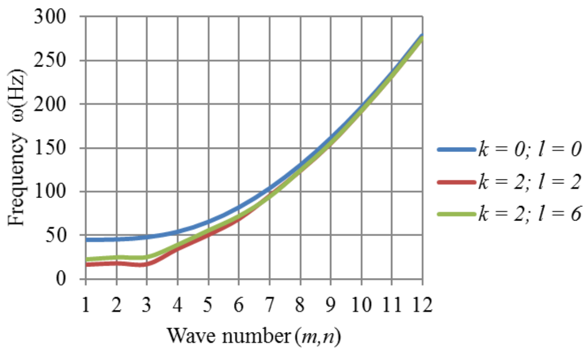
In Figure 1 there are dependencies of frequencies of free oscillations on number of fractions k, l; on the aspect ratio of the shell plan. Investigation of dependency of the change of shell thickness h is represented in reference [11].



a)



b)



c)

Fig. 1. Dependency graphs of free oscillations on various parameters
a – shell 8x12 m; b – shell 8x16 m; c – shell 8x20 m.

6. Practical Recommendations

Rigidness of shell decreases with the increase in the planned sizes.

By decreasing the conventional curvature the frequency of free oscillation decreases and within the limit goes to known values of frequencies for plates.

Minimum frequency of free oscillations emerges at m = 1 and n = 1, if the number of fractures is more than three, because polyhedral shell within the limit goes to unstiffened shell (k = l = 0).

Minimum frequency of free oscillations emerges at m = k +1, n = l +1, if the number of fractures k < 3 и l < 3.

Minimum frequency for shell with a/b correlation < 2: at m = n = 2, if k = 1 and l ≥ 1; at m = 3, n = 2, if k = 2 and l = 1; at m = 3, n = 3, if k = 2 and l ≥ 2; at m = 2, n = 2, if k = 3 and l = 1; at m = 2, n = 1, if k ≥ 3 and l ≥ 2; at m = 1 and n = 1, if k >3 and и l >3.

For shell with a/b correlation ≥ 2 minimum frequency of free oscillation emerges at m = n = 1, if k >2 and l >2.

7. Conclusion

Comparison of polyhedral shells with unstiffened showed, that polyhedral shells have better dynamic peculiarities, i.e. they less react to the change of thickness of the shell and have more solid frequency spectrum of free oscillations.

The results obtained analytically are well agreed with the results obtained by numerical methods. The formulas obtained analytically allow forecasting the result without enumeration of possibilities of the numerical method.

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