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Effect of porosity on free vibration of FG shallow shells with complex planform

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Abstract: This paper presents application of the R-functions method for investigation of free vibrations of shallow shells with an arbitrary planform. It is assumed that shell is fabricated of functionally graded materials with porosities. Two types of porosity is considered: evenly and unevenly distributed porosities. The volume fractions of metal and ceramic are described by the power law. The first order shear deformation theory is applied to describe mathematical formulation of the problem. Solution of the problem is carried out by the variational Ritz method and the R-functions theory. Very good agreement with available results is shown for FG shell with rectangular planform. Detailed numerical study for shallow shell with complex planform is fulfilled to show effectiveness of the proposed approach. In particular, effects of porosity coefficient, the power law index, boundary conditions on fundamental frequencies are examined.

Keywords: Porous**,** shallow shell, arbitrary planform, FGM, variational method, R-functions.

1. Introduction

As known functionally graded materials (FGM) are widely used in the various field idustry: aerospace, nuclear , biomedical engineering and other ones. Usually FGMs have been fabricated from a mixture of metal and ceramics by sintering. During this process micro-porosities or voids can occur in the materials. Therefore, recently many scientists [1, 2, 3] have paid a great attention to investigation of static and dynamic behavior of porous FG plates and shell. From author review it follows that number of studies devoted to porous FG shallow shells with complex plan form is limited enough.

The present paper focuses on the free vibration analysis of FG shallow shells with complex planform for evenly and unevenly porosity distribution. This problem can be solved by application of the R-functions theory and variational Ritz method [4].

2. Formulation of the problem

Thin shallow shell of an arbitrary planform and constant thickness h made of FGM is considered. It is assumed that porosities appear during the sintering process of metal and ceramics. Suppose that the volume fraction of metal V_m and ceramics phases V_c change by power law distribution

$$V_m = \left(\frac{z}{h} + \frac{1}{2}\right)^p, \quad V_m + V_c = 1. \tag{1}$$

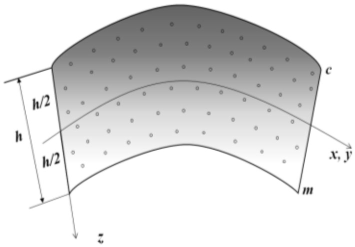

Fig. 1a. Evently distribution of porosity

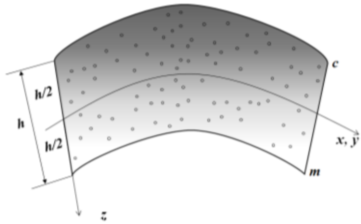

Fig. 1b. Enevently distribution of porosity

In formula (1) index *p* denotes the volume fraction exponent (gradient index).

We study evenly (Fig.1a) and unevenly (Fig.1b) distribubutions of porosities in material. The effective material properties: elastic modulus *E*, Poisson's, and density ρ of FGMs (general disignations as *P*) are defined for evenly distribution of porosities by the following relations [1]:

$$P(z)=(P_m-P_c)V_m+P_c-\frac{1}{2}\alpha(P_m+P_c). \tag{2}$$

For unevenly distribution of porosities the expression (1) takes the form

$$P(z)=(P_m-P_c)V_m+P_c-\frac{1}{2}\alpha\left(1-2\frac{|z|}{h}\right)(P_m+P_c). \tag{3}$$

Indexes *c* and *m* correspond to characteristics of ceramics and metal relatively, and α .characterizes volume fraction of porosities. Values P_m, P_c depend on temperature of the environment [2].

Mathematical statement of the problem is carried out within the first order shear deformation theory of shallow shells (FSDT). The variational Ritz method is applied to solving given problem. The validation of the proposed approach and created software is confirmed by comparison of the obtained results with known. A good agreement allowed to investigate the shells with complex planform.

References

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