ANALYSIS OF BUCKLING AND POST-BUCKLING STATE OF PLATE BUILT OF FUNCTIONALLY GRADED MATERIAL

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1. INTRODUCTION

The functionally graded material (FGM) belongs to modern materials that through its varying properties throughout thickness can work in ultrahigh conditions, hard environments and/or under high temperature. The gradual changes in volume fraction of the constituents and non-homogenous structure provide continuous graded macroscopic properties (hardness, wear resistance, thermal conductivity, specific heat, mass density, among others). The techniques of manufacturing of FGM nowadays are different but with regard to contrast properties no one of them can be found as excellent [1]. Among methods of FGM fabrication one can distinguish: gas based method (chemical vapour deposition, thermal spray, surface reaction process), liquid phase processes (chemical solution deposition, laser deposition., electrochemical gradation) or solid phases processes (spark plasma sintering, powder metallurgy).

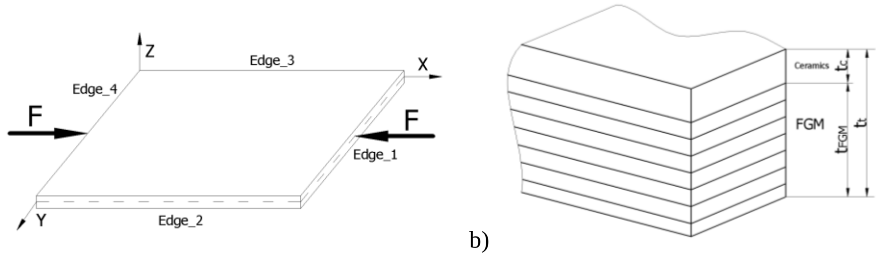
At present, in literature there are many works concerning analysis of structures made of FGMs [2-5]. Authors of those papers investigated the behavior of FGMs structures under thermal and/or mechanical loads assuming the perfect distribution material across the wall thickness often based on mathematical equation.

2. PROBLEM DESRIPTION

The object of investigation was the square FGM plate subjected to compression load (Fig. 1a). The length and total thickness of plate amounted to 200 mm and 2 mm (t_t), respectively. The whole thickness comprise FGM (Al-$Al_2 0_3$) and pure ceramics (Fig. 1b). To solve the problem, two methods were employed: analytical-numerical on asymptotic Koiter's approach and numerical on the basis of finite element method. It was investigated pre- and post-buckling state of plate with different boundary conditions (SSSS, SCCS, where S and C denote simply supported edge and clamped edge, respectively) and different relative thickness of ceramics. To verify the influence of material distribution it was considered from 5 to 15 layers of FGM.

Table 1. Material properties of constituents applied to analysis

Components	Young modulus [GPa]	Poisson's ratio [-]
Al	70	0.33
$Al_2 0_3$	393	0.25



a) b)

Fig. 1. Object of investigation (a) and schematic material distribution across the wall (b)

3. RESULTS

In the first stage, it was determined critical forces for both methods. Some of critical forces (for plate SSSS) are given in Table 2. The discrepancies didn't exceed 5%. The calculated forces correspond to plate with 11 layers of FGM where thickness of ceramics from 0.2 mm to 1 mm, and thickness of FGM from 1.8 mm to 1 mm. The discrepancies didn't exceed 1%. The further study concerned the assessment of the behaviour of plate in post-buckling state with respect to different parameters. The results of calculations were presented and discussed.

Table 2.Critical forces obtained by two methods

No	t_t [mm]	t_c [mm]	t_{FGM} [mm]	FEM [N]	A-N method [kN]
1	2	0.2	1.8	29663	29392
2	2	0.4	1.6	30777	30524
3	2	0.6	1.4	31910	31716
4	2	0.8	1.2	33244	33140
5	2	1	1	34954	34956

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