Evaluation of critical loads of three-layered annular plates with damaged composite facings

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1. Introduction

Composite layered structures are subjected to different forms of failure. It could be the local or global forms and evaluated as microscopic damage, like: fibre or matrix crack or macroscopic one, like global buckling [3]. Their connections could be especially dangerous for strength of construction element. The problem of the evaluation of the critical parameters for the three-layered, annular plate with damaged facings made of fibrous composite is presented. The wide range of application of sandwich annular plates in for example mechanical and nuclear engineering or aerospace industry and the quick development of composite structures create practically important issue.

2. Problem formulation

The cross-section structure of plate is symmetric composed of thin composite facings and thicker foam core (see, Figure 1). Accepted exemplary configuration of facing laminate composite is expressed by the code [0°/-45°/45°/90°]. This configuration is characteristic for composite called quasi-isotropic one. Composite facing consists of n=4 laminas each of thickness equal to h_i=0.000125 m. Plate geometry is expressed by inner radius r_i=0.2 m and outer one r_o=0.5 m.

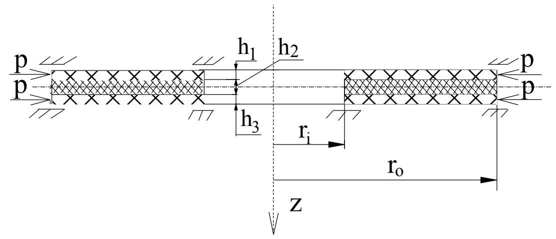

Figure 1. Scheme of three-layered annular plates with composite facings.

The core thickness is equal to: h_2=0.005 m. The material parameters are following: glass/epoxy composite as facing material E_1=53.781 GPa, E_2=17.927 GPa, G_{12}=8.964 GPa, ν_{12}=0.25 [2], polyurethane foam as core material treated as isotropic G_2=5 MPa, ν_2=3. The calculated, according to expressions presented in work [1], engineering constants of quasi-isotropic glass/epoxy composite are following: E=31.1 GPa, G=12.5 GPa, ν=0.24. Accepted model of the composite degradation is based on the correction parameter method [3]. The matrix crack causes the rigidity elimination in transverse direction to the fibres. It is expressed by the correction parameter η, whose value is in the range of [0.1,0.4]. The mechanical properties of lamina change. Mathematically, it is described by the modification of the stiffness matrix [3].

3. Plate models

The problem was solved analytically and numerically using the finite difference method (FDM) and numerically using the finite element method (FEM). Solving the buckling problem of the sandwich plates with quasi-isotropic composite facings the eigen-value task was formulated. The description of the solution to the problem is presented in work [4], in detail. The calculations using the FEM method were carried out at the Academic Computer Center CYFRONET-CRACOW using the ABAQUS system (KBN/SGI_ORIGIN_2000/PŁódzka/030/1999). Two kinds of plate models were built: in circular, symmetrical, annular form called as basic model and simplistic one built of axisymmetrical elements.

4. Example results

The Table 1 shows the critical static loads p_{cr} of plates loaded on inner or outer edges. The case of matrix crack is examined for different laminas combination. Laminas are expressed as lamina 1, 2, 3 and 4 according to composite code [0°/-45°/45°/90°] (for example: lamina 1 is for fibres arranged with angle 0°). The correction parameter η is equal to η=0.1. Presented results are for basic and simplistic FEM plate models and in order to compare the values for FEM and FDM plate models with non-damaged quasi-isotropic composite facings (the results are shown in brackets). The notation (≈1) means that the bucking mode isn't axisymmetrical. There is tendency to loss of plate stability in the form of single circumferential wave. The results show the decrease in value of critical load p_{cr} for plate models with damaged laminas. The observations present that this decrease isn't significant even when the matrix of two laminas is damaged. Configuration of non-damaged laminas arranged as [0°/90°] seems to keep higher structure resistance to the stability loss of plate loaded on inner or outer edge. The values of critical loads calculated for plate models with quasi-isotropic composite facings and composite non-damaged facings are comparable. Difference in buckling mode corresponding to minimal value of critical load obtained for FEM and FDM plate models with quasi-isotropic facings loaded on outer edge is observed.

		critical static load p_{cr} [MPa] / buckling mode m							
plate model		simplistic	basic	simplistic	basic	simplistic	basic	simplistic	basic
damaged lamina									
		1		2		3		4	
edge loading	inner	32.93/0	34.28/0	36.26/0	35.90/0	35.75/0	35.90/0	33.61/0	34.28/0
edge loading	outer	22.00/0	-	23.42/0	-	23.36/0	-	22.91/0	-
edge loading	outer	-	12.90/≈1	-	13.03/≈1	-	13.03/≈1	-	12.90/≈1

		damaged laminas combination							
		1+2		1+4		2+3		2+4	
edge loading	inner	31.85/0	32.61/0	30.37/0	32.15/0	35.28/0	34.98/0	33.12/0	33.35/0
edge loading	outer	20.50/0	-	19.99/0	-	22.48/0	-	21.98/0	-
edge loading	outer	-	11.42/≈1	-	12.70/5	-	12.88/5	-	11.45/≈1

		non-damaged laminas				
plate model		simplistic		basic		FDM
edge loading	inner	36.64/0	(39.96/0)	36.84/0	(40.76/0)	(38.89/0)
edge loading	outer	24.07/0	(26.21/0)	24.02/0	(26.22/0)	(29.15/0)
edge loading	outer	-		14.63/6	(15.45/9)	(17.39/6)

Table 1. Values of critical loads with corresponding buckling modes of plate models.

5. References

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