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INVESTIGATION OF INFLUENCE OF REINFORCEMENT

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Abstract: *This investigation contains the research of the influence 90°-layers on the buckling stability of the isolated cell of a composite plane wing plating; and the research how the layers arrangement order in the laminate affects to the critical pressure of the cell's buckling stability loss. Influence of the structure on the stability of the composite panel with different way supported edges at pure compression is estimated for obtaining the optimum structure.*

Key words: *buckling stability, laminate, layer, eigenvalue*

1. INTRODUCTION

From large number of studies and numerical simulations, it was determined that laminate structure should include layers with layup 0° and ± 45° relative to loading direction. According to numerous tests results, it is known that structures of plane skins bearing surfaces should have a number of (10-15%) of 90°-layers (James&Starnes, 1979). Fiber orientation angle 90° appears in connection with restrictions on the stability loss. The early efforts in which the existing metal structural components were simply replaced by composite ones with reasonably well understood laminates, such as the commonly used quasi-isotropic layup with 0º, ±45º, and 90º oriented fibers, proved to fall short of the expectations (Gürdal, 2005).

This paper investigates the influence of 90°-layers on stability of isolated cells with hinged edges. In the research are considered variants of behavior of the layered plate with constraints as well as with free deformations in the transverse direction. The results show a complex interaction between plate orthotropy and boundary conditions (Baba, 2007). Laminates with clamped edges are found to be more susceptible to failure due to the transverse shear and delamination, while those with the simply supported edges undergo total collapse at a load slightly higher than the fiber failure load (Singh et al.,1997). It shows the difference between laboratory material tests results and material exploitation properties in real constructions.

Another aspect of this work is the investigation how the layers arrangement order in the laminate affects on the cell's critical buckling stress.

For the initial reliability assessment of numerical simulation as an understudy object is chosen the plate to which one could be easily obtained analytical results. Thus, the skin is presented in the form of rectangular 650 × 130mm laminated cells (with respect to stringer's and rib's steps). Materials: epoxy matrix is reinforced by carbon fiber tape. Thickness of one layer is 0,12 mm, of the entire plate - 2,4 mm. Mechanical properties: E_1=14,3GPa, E_2=840MPa, G_{12}=560MPa, μ_{12}=0,36.

2. RESEARCH AND MAIN RESULTS

The results of stability research of skin cells are obtained numerically by the finite-elements modeling and calculated by computer complex NASTRAN MSC Software. Panels are simulated with different structures.

Each structure is considered for two cases: with constraints and free transverse strains.

The compressive load is distributed per length and calculated according to value of the critical stress.

The calculations of plates for buckling stability are performed and the lowest buckling modes and corresponding eigenvalues for different variants of structures and boundary conditions are determined and shown in table 1.

Structure relatively to NS*		-NS 0_6 45_4 90_0	- NS 0_6 45_3 90_1	- NS 0_6 45_2 90_2	- NS 0_5 45_5 90_0	- NS 0_5 45_4 90_1	- NS 0_5 45_3 90_2
		$0_{60\%}$**			$0_{50\%}$**		
Variant		1	2	3	4	5	6
Free edges	σ_{cr}**** kg/mm^2	7,72	6,86	5,97	8,12	7,18	6,15
	N_x***	4	5	6	5	5	6
	q_x, kg/mm	18,52	16,46	14,33	19,48	17,22	14,76
Hinged supported edges	σ_{cr}**** kg/mm^2	6,00	6,11	5,57	5,73	6,13	5,60
	N_x***	3	5	5	2	4	6
	q_x, kg/mm	14,41	14,67	13,38	13,75	14,72	13,44

Structure relatively to NS*		- NS 0_4 45_6 90_0	- NS 0_4 45_5 90_1	- NS 0_4 45_4 90_2	- NS 0_3 45_7 90_0	- NS 0_3 45_6 90_1	- NS 0_3 45_5 90_2
		$0_{40\%}$**			$0_{30\%}$**		
Variant		7	8	9	10	11	12
Free edges	σ_{cr}**** kg/mm^2	8,33	7,30	6,27	8,46	7,38	6,30
	N_x***	5	6	6	5	6	7
	q_x, kg/mm	19,99	17,53	15,04	20,30	17,70	15,12
Hinged supported edges	σ_{cr}**** kg/mm^2	4,85	5,94	5,50	3,99	5,60	5,30
	N_x***	1	4	6	1	4	5
	q_x, kg/mm	11,64	14,26	13,21	9,57	13,43	12,73

Structure relatively to NS*		- NS 0_2 45_8 90_0	- NS 0_2 45_7 90_1	- NS 0_2 45_6 90_2	- NS 0_1 45_9 90_0	- NS 0_1 45_8 90_1	- NS 0_1 45_7 90_2
		$0_{20\%}$**			$0_{10\%}$**		
Variant		13	14	15	16	17	18
Free edges	σ_{cr}**** kg/mm^2	8,53	7,41	6,30	8,55	7,43	6,31
	N_x***	5	6	7	5	6	7
	q_x, kg/mm	20,46	17,79	15,13	20,52	17,82	15,14
Hinged supported edges	σ_{cr}**** kg/mm^2	3,21	4,91	4,96	2,51	3,79	4,45
	N_x***	1	2	5	1	1	4
	q_x, kg/mm	7,69	11,78	11,91	6,03	9,10	10,68

*Symmetrical layup with respect to the laminate neutral surface (NS).
**In the notation $0_{n\%}$ n- percentage of 0°-layers in the package.
***N_x,-number of half-waves.
****Loading - pure compression along the "X"axis. σ_{cr} is a critical stress for cell.

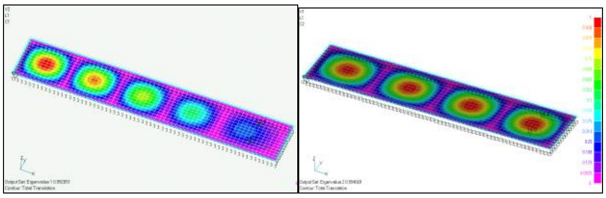
Tab. 1 Influence of Material Structure on the Isolated Cell Buckling Stability

From the structures is chosen the most stable one (with the highest critical stress) in the case of limited transverse strains as the most typical. The influence of the various layers location (with respect to the neutral axis) on the cell's general stability is determined by varying layers order. The critical buckling stress values for hinged supported bearing structures with 10% of 90°-layers for structures with different order of the layup are obtained and shown in table 2.

Structure relatively to NS		-NS 0_5 45_4 90_1	-NS 0_5 90_1 45_4	-NS 45_4 0_5 90_1	-NS 45_4 90_1 0_5	-NS 90_1 0_5 45_4	-NS 90_1 45_4 0_5
		$0_{50\%}$					
Variant		5.0	5.1	5.2	5.3	5.4	5.5
Hinged supported edges	σ_{cr} kg/mm^2	6,13	6,32	3,98	2,45	5,7	2,06
	N_x,	4	3	4	2	2	1
	q_x, kg/mm	14,72	15,17	9,54	5,89	13,68	4,95

Tab. 2 Influence of material structure on the buckling stability of the isolated cells at 10% content of the 90◦-layers

Fig.1 shows the critical buckling stresses of the cell with 10% of 90º-layers with different support conditions (variant 5 in Table 1). Fig. 2 shows the critical buckling stresses of the most stable panel with 10% of 90º-layers and hinged supported edges (variant 5.1 in Tab.2).



a) b)

Fig. 1. Critical buckling stress of cell with 10% of 90º-layers with a)free edges; b) hinged supported edges (Tab.1, variant 5).

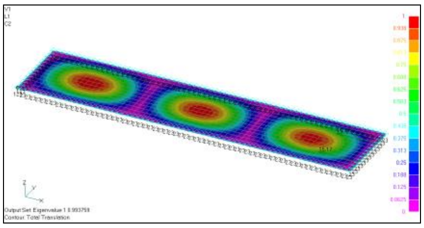


Fig.2. Critical buckling stress of the most stable cell with 10% of 90º -layers and hinged supported edges (Tab.2, variant 5.1).

Fig. 3-5 show the critical buckling stresses of the cell with different percentages of 90º-layers under different support conditions.

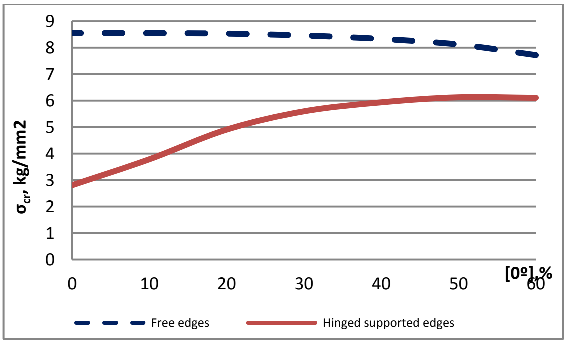


Fig. 3. Diagram of cell's critical buckling stresses at 0% content of 90º- layers

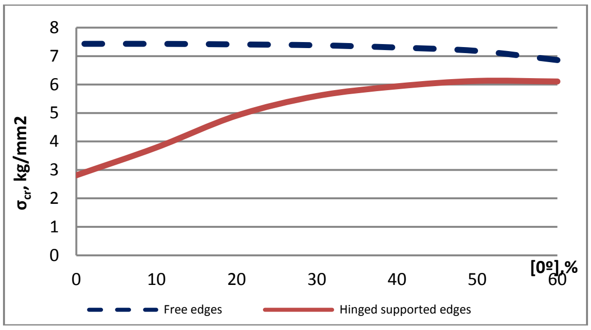


Fig. 4. Diagram of cell's critical buckling stresses at 10% content of 90º -layers

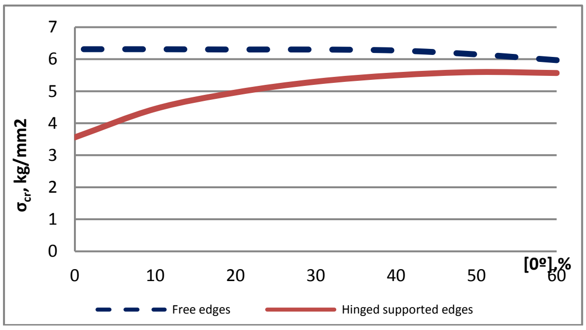


Fig. 5. Diagram of cell's critical buckling stresses at 20% content of 90º -layers

3. CONCLUSION

For laminate composite skin panels with characteristic for the bearing surface dimensions 10% of 90°-layers in the structures with layup of 0° and ± 45° significantly improves the results of buckling stability of the cell (variant 5 in Tab.1). As the results of study of the alternating layers effect, the most closest to optimal are structures in which layers of ± 45 ° are located at the edges (outside) the laminate (variant 5.1, in Tab.2).

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