COMPARISON OF FAILURE CRITERIA APPLICATION FOR FML BUCKLING STRENGTH ANALYSIS

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1. FIBRE METAL LAMINATE (FML)

The subject of this study is a thin-walled profile made of Fibre Metal Laminate - material which is a hybrid composite consisting of alternating thin layers of aluminium and fibre-reinforced epoxy. That combination provides many benefits such as higher bearing strength and huge impact resistance comparing pure metallic material. Connection with fibre reinforced material also guarantees better fatigue characteristics as well as high strength and stiffness of the structure. FMLs are also characterized by relatively high corrosion and fire resistance which increase significantly its durability [1]. Furthermore, Fibre Metal Laminate composites can be designed to be strong in a specific direction which gives engineers a lot of possibilities for specific industrial application. Another great advantage of FMLs over conventional material is a low density of the material which results in lower mass of entire structure.

For the purpose of this study, the 3-2 FML profiles of Z-section were designed by appropriate composite layers arrangement. To obtain accurate profile geometry and properties samples were manufactured in the pressure chamber of the autoclave system. Performing curing cycle of that system at a specific heating rate and pressures allowed to obtain high-quality composite structures [5].

2. NUMERICAL MODEL AND STRUCTURAL STABILITY ANALYSIS

Numerical analysis was performed with ANSYS software application, where structural element SHELL181 was applied to create a discrete model of experimentally tested Z-shape profiles. In FEM model 3-2 FML stacking was defined by the Lay-up technique which allowed to specify each layer separately. Simply support boundary conditions were defined by blocking kinematic degrees of freedom of loaded edges [4]. Specific nodes were coupled to guarantee the equal displacement and uniform compression in axial direction.

Numerical analyses of the structure stability were performed in two stages. First, linear eigenvalue buckling technique was used to predict buckling load and corresponding buckling mode shape. Next, a post-buckling behaviour was studied by means of nonlinear buckling analysis which included large deflection response and initial imperfections of chosen magnitude. Furthermore, the structure stability was examined under various laminate configuration and reinforcement directions. For determined buckling load and load carrying capacity cases, the comparative analysis of failure criteria applications was performed. As an example, the table below shows that each considered criterion gives different results for the single FML layer under the same load.

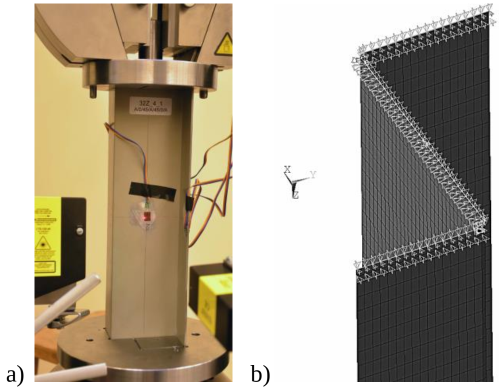

Fig. 1. Experimental test rig (a) and B-C of discrete model (b)

In Table 1 the headings stand for: TWSI - Tsai-Wu strength index; TWSR - inverse of Tsai-Wu strength ratio index; HFIB - Hashin fiber failure criterion; HMAT - Hashin matrix failure criterion; PFIB - Puck fiber failure criterion; PMAT - Puck inter-fiber (matrix) failure criterion - respectively [3].

Table 1. Comparison of failure criteria results for selected FML layer

Type of load	Failure criteria					
	TWSI	TWSR	HFIB	HMAT	PFIB	PMAT
Buckling load	0.400	0.665	0.009	1.242	0.093	0.663
Load carrying capacity	1.005	1.002	0.020	2.193	0.141	0.999

Further detailed analysis allows to assess the stress tensor components participation in the FML failure. Implementing real parameters and strengths of the material obtained in laboratory tests allowed to estimate the potential failure of the structure in a buckling and post-buckling range. Determined FC results also were mapped onto the profile geometry to indicate regions greatly exposed to failure.

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REFERENCES

[2] Chang P., Yeh P., Yang J., Fatigue crack initiation in hybrid boron/glass/aluminum fiber metal laminates, Materials Science and Engineering, 2008, pp. 273-280.

[3] Hintona M.J., Kaddourb A.S., Soden P.D., A comparison of the predictive capabilities of current failure theories for composite laminates, judged against experimental evidence, Com. Science and Technology, 62, 2002, pp. 1725-1797.

[4] Mania RJ. Comparative static buckling study of FML thin-walled profiles. ECCM16 - 16th European Conference on composite materials. Seville, Spain, 2014.

[5] Vlot A., Gunnink J.W., Fibre Metal Laminates - An Introduction, Kluwer academic publishers, Delft, 2001.