FAILURE ANALYSIS OF THIN-WALLED GLARE COLUMNS DURING BUCKLING AND POSTBUCKLING RESPONSE

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1. SUBJECT OF THE RESEARCH

The subject of this study is a thin-walled glass reinforced aluminium laminate (GLARE) columns. Considered GLARE structure is a hybrid composite that consists of alternating thin layers of aluminium alloy sheets and unidirectional glass fibre-reinforced prepregs. Such laminates guarantee high material strength, huge impact resistance and improved damage tolerance [1]. GLARE provides also improved strength and stiffness, especially when compared to other conventional materials on a unit weight basis. More importantly, depending on fibre alignment the composite can be designed to be stiffer in a specific direction [2], which makes these structures the material of choice for multiple industrial applications.

Comprehensive study was performed for different thin-walled, open cross–section profiles that included channel, Z-shape and top hat sections. Different 3/2 symmetrical lay-ups were investigated for which 7 stacking sequences were distinguished based on fibres alignment in the composite layer (Table 1). Main focus of this study was to assess the performance of top hat sections which provided the highest strength when subjected to corresponding axial compression. GLARE composites columns were manufactured by autoclaving technique which provided the high-quality of multi-layered laminates.

Table 1. GLARE configurations of laminate stacking

No	Lay-up
1	Al/0/90/Al/90/0/Al
2	Al/90/0/Al/0/90/Al
3	Al/45/0/Al/0/45/Al
4	Al/0/45/Al/45/0/Al
5	Al/0/0/Al/0/0/Al
6	Al/25/0/Al/0/25/Al
7	Al/0/25/Al/25/0/Al

2. EXPERIMENTAL AND NUMERICAL FAILURE ANALYSIS

The compression failure test was performed in laboratory by a universal electromechanical strength testing machine of Instron upgraded with Zwick/Roel control software. Considered double column static testing unit had a maximum capacity of 200kN for which applied screw type testing machine provided a displacement control loading of

1 mm/min (Fig. 1a). In a numerical model 3/2 GLARE stacking was defined by the Lay-up technique which allowed to specify each layer separately. Boundary conditions were in the form of simply supported connection, defined by blocking kinematic degrees of freedom of loaded edges (Fig. 1b). Specific nodes were coupled to guarantee the same displacement in axial direction. Compression of the profile was realized by a uniform load in the form of axial force applied at the one, upper edge of Z-section.

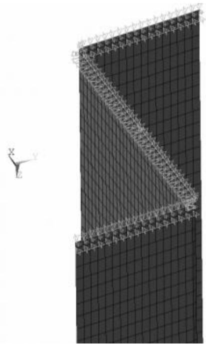
a)  b) 

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

Numerical computations were performed to predict the damage of the multi-layered GLARE structure in a buckling and post-buckling state. Analysis was introduced at each layer separately. Layers modelled as isotropic aluminium were judged by equivalent stress (EQVS) calculated by Huber-Mises-Hencky criterion. For the strength analysis of composite layers Hashin criterion was introduced to calculate different failure factors for matrix (HMAT) and fibre damage (HFIB). It is claimed that Hashin criterion provides sufficient predictive capabilities and there is an increasing adoption of this criterion especially in FRP's failure prediction [3]. By means of this criterion failure factors were determined and mapped onto the profile geometry. Failure criteria were introduced simultaneously with the nonlinear analysis performed with the incremental load. This allowed one to investigate failure factors at the specific load-step corresponding to the column's load carrying capacity. Determined maps of failure factors distinguished regions that are greatly susceptible to material failure, which was further judged by experimental evidences.

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