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Multilevel Postbuckling Design of Aerospace Structures

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ABSTRACT

Mass minimisation is a key objective in aircraft design, resulting in reduced material costs, fuel consumption and environmental impact. Metals are increasingly being replaced by lightweight composite materials which can be tailored to specific loading requirements. Aircraft wings and fuselages comprise slender stiffened panels which are susceptible to buckling, but advantage can often be taken of a substantial postbuckling reserve of strength.

The software VICONOPT [1, 2] performs initial buckling, postbuckling and free vibration analysis of metal or composite stiffened panels, using an exact stiffness formulation and the Wittrick-Williams algorithm [3]. Minimum mass design is achieved by optimising plate widths and layer thicknesses subject to buckling, strength, stiffness and geometric constraints. VICONOPT is a computationally efficient alternative to finite element analysis in the preliminary design of aircraft structures, where many alternative configurations need to be explored. In this context, it is important to note that design changes to individual panels influence the stress distribution over the whole structure, and must also be compatible with the geometry of adjacent panels.

VICONOPT MLO [4] is a Visual C++ program providing a multilevel interface between VICONOPT [4] and the finite element software MSC/NASTRAN [5], as illustrated in Fig. 1. At system level, finite element models are constructed using a pre-/post-processor such as MSC/PATRAN and analysed using MSC/NASTRAN. Then the model data (i.e. geometry, material properties, stress distributions, etc.) is translated to panel level by VICONOPT MLO, which also requires users to specify the design variables and their bounds. VICONOPT analyses and optimises each of the panels, and the updated geometry is returned to MSC/NASTRAN via VICONOPT MLO. Further finite element analysis of the whole structure determines the new stress distributions in each panel. The process is repeated until a convergence criterion on the overall mass of the structure is met.

The present paper extends the procedure by allowing each panel to buckle before the design load is reached [6]. The remaining load is carried under a regime in which the stiffness of the panel is reduced by differing amounts due to the re-distribution of stress among and within the component plates [7]. Fig. 2 plots stress s against strain e in the postbuckling regime for a square plate of width b loaded in longitudinal compression.

The stresses and strains are shown at locations (a) *b*/12 and (b) 5*b*/12 from the longitudinal edge, and have been normalised by dividing them by their values s_{cr} and e_{cr} at critical buckling. Average values for the plate are also plotted, showing that the postbuckling stiffness of the plate is about one third of the prebuckling stiffness. VICONOPT MLO passes this reduced stiffness information to MSC/NASTRAN, for use in the subsequent system level analysis which updates the stress distribution across the structure.

Further illustrative results will be presented for the optimum design of representative wing structures comprising skin and spar panels under various loading conditions, including in-plane shear. Indications will be given of the mass savings that can be achieved by allowing for the postbuckling reserve of strength during the optimisation.

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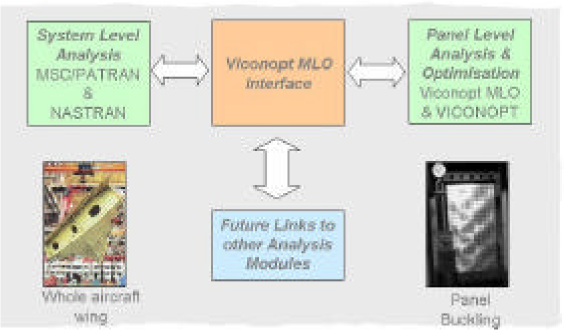

Fig.1 Multilevel optimisation procedure for an aircraft wing [4].

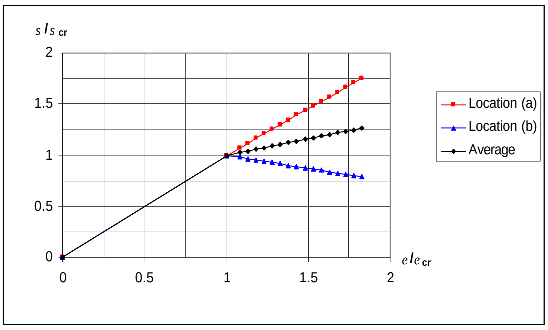

Fig.2 Postbuckling stresses in a square plate loaded in longitudinal compression.