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TAILORING OF A PRESSURIZED FUSELAGE PANEL WITH A CUTOUT USING TOW-PLACED STEERED FIBERS

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ABSTRACT

Manufacturing of repeatable high quality fiber-reinforced composite structures with spatially varying fiber orientation is possible using advanced tow-placement machines. Changing the fiber orientation angle within the lamina produces paths with variable stiffness properties. Contrary to traditional composites with straight fibers that provide uniform directional properties, this method allows the designer to fully benefit from the distributed directional material properties of the composite to improve laminate performance.

An intensive study of rectangular panels with steered fiber paths, termed variable stiffness panels, was carried out by Gürdal et al. [1]. The fiber paths in those studies were generated from a base curve that changes its orientation angle linearly from one end of the panel to the other. By using linear variation of fiber orientation angles, earlier studies showed that significant improvements in the laminate response can be obtained for panels with and without holes under compression and shear loads [2-3].

A challenging problem in the design of pressure loaded thin-walled stiffened panel structures, such as the aircraft fuselage panels, is the so-called pressure pillowing problem. An unstiffened fuselage would carry this internal pressure load as a shell in membrane response, like pressure vessels. However, internal longitudinal and transverse stiffeners are necessary to carry maneuver loads. The presence of these stiffeners prevents the fuselage skin from expanding as a membrane, and the skin bulges, or “pillows”, within each panel bay under the action of the internal pressure. When the skin is restrained against out-of-plane expansion at the stiffener locations, a bending boundary layer is formed causing bending stress concentrations. Such stresses can cause peeling of the skin-stiffener interface, and hence designs have to be usually modified to account for them. In a recent study [4], the variable stiffness concept based on steered fibers has been used to alleviate the problem. It was demonstrated that the failure loads of panels can be substantially improved by using tailored fiber paths.

In the proposed paper, tailoring for pressure pillowing problem of a fuselage panel with

a cutout bounded by two frames and two stringers is addressed using tow-placed steered fibers. The panel is modelled as a two-dimensional plate with a typical fuselage window opening and loaded by out-of- plane pressure and in-plane loads. A Python-ABAQUS script is developed to perform the nonlinear finite element analysis of variable stiffness panels for various combinations of fibre path parameters. An in-depth parametric study using steered fibers with linear variation of fiber orientations is carried out to determine the failure loads of panels. Designs for both straight fibers and steered fibers are obtained for different loading cases and boundary conditions.

Preliminary results indicate that by using steered fibers, the pressure pillowing problem can be alleviated for panels with cutouts, and the load carrying capacity of the structure can be significantly improved compared to traditional designs with straight fibers. For example, for a pressure loaded panel with clamped edges an improvement in the load carrying capacity of about 40% was obtained using steered fibers over the optimal straight fiber design. The corresponding fiber distribution is illustrated in Fig. 1. The proposed paper will include complete set of results for various boundary conditions, including the conditions around the cutout, and combined loads.

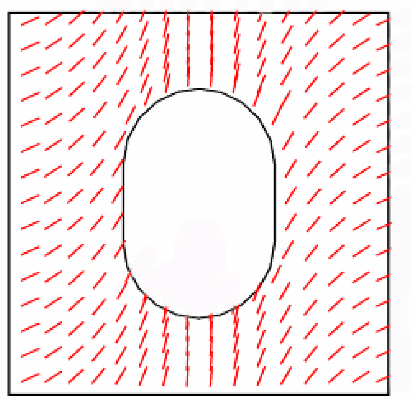

Fig 1. The distribution of fiber orientations for maximum pressure failure load.

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