MDO APPROACH TO OPTIMAL VARIABLE STIFFNESS STRUCTURE DESIGN

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ABSTRACT

This keynote focuses on the modelling and the optimization of fiber steering, a specialized version of automated fiber placement (AFP), to support the design of variable stiffness structures. Whilst in normal AFP, one tries to minimize non-geodesical placement of fibers in a part, fiber steering actually tries to utilize non-geodesical placement of fibers to control the load paths in the laminate as well as the laminate strength. Load path control is achieved by varying material stiffness with respect to a fixed coordinate system from point-to-point. At the same time, the strength of the laminate is influenced by the steering, since the strength of a laminate is directly related to the fiber directions in its constituting plies. Design for fiber steering therefore aims at the best match between applied loads and strength at each point of the laminate. In addition to tuning stiffness, steering can be used to control other physical properties that depend on fiber orientation.

Keywords: Composite plates, optimization, variable stiffness, automated fiber placement (AFP).

INTRODUCTION

The next level of performance of composite structures is likely to come from three major changes:

First, the development of a variable stiffness design and manufacturing principles. These will allow simultaneous design of load distribution and strength distribution;

Second, the development of fusion bonding based assembly of thermoplastic composites using induction, laser and ultrasonic heating principles. Figure 1 shows a recent and unique welded thermoplastic (constant stiffness) carbon composite control surface for a business jet;

Third, the development of multi-polymer composite structures. Thermoset and thermoplastic polymers offer different advantages when considering the mechanical properties and their manufacturing. It is advantageous to have zones of thermoplastic and zones of thermoset composite in a single structural element.

To successfully combine these three developments, the scientific and engineering challenge is to design and create materials and structures for optimal performance taking into account requirements such as stiffness, strength, conductivity, thermal expansion, and the ability to be fusion bonded at selected zones. This requires a fundamental understanding of the multi-physical properties of variable stiffness, multi-polymer composite laminates and shells.
RESULTS AND DISCUSSION

In this keynote lecture, we will present a design framework for the design of variable stiffness fiber composite panels subject to multiple load cases, each case a combination of tension and shear. The framework consists of a finite element (FE) solver, an optimizer, a module that controls the link between design variables and the stiffness matrix in the FE module and a postprocessor that translates the theoretical optimal result from the optimizer into discrete tow paths for each ply.

The dual mesh formulation of the design variables using a manufacturing mesh separate from the FE mesh limits the number of design variables while preserving smoothness and allows easy specification of manufacturing constraints enforced by the envisioned fiber steering process, for example the minimum course radius to prevent tow buckling. It also allows the incorporation of constraints related to fusion bonding techniques for continuous carbon fiber reinforced thermoplastic composites based on induction heating which require the generation of eddy currents and therefore constrain the fiber orientations and stacking sequence.

The nonconventional character of steered structures requires an alternative approach to the demonstration of structural integrity. Some directions for the solution approach will be discussed as well.

REFERENCES