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Reliability Analysis of Variable Stiffness Composite Laminate Structures

Authors : A. Sohouli, A. Suleman

Abstract : This study focuses on reliability analysis of variable stiffness composite laminate structures to investigate the potential structural improvement compared to conventional (straight fibers) composite laminate structures. A computational framework was developed which it consists of a deterministic design step and reliability analysis. The optimization part is Discrete Material Optimization (DMO) and the reliability of the structure is computed by Monte Carlo Simulation (MCS) after using Stochastic Response Surface Method (SRSM). The design driver in deterministic optimization is the maximum stiffness, while optimization method concerns certain manufacturing constraints to attain industrial relevance. These manufacturing constraints are the change of orientation between adjacent patches cannot be too large and the maximum number of successive plies of a particular fiber orientation should not be too high. Variable stiffness composites may be manufactured by Automated Fiber Machines (AFP) which provides consistent quality with good production rates. However, laps and gaps are the most important challenges to steer fibers that effect on the performance of the structures. In this study, the optimal curved fiber paths at each layer of composites are designed in the first step by DMO, and then the reliability analysis is applied to investigate the sensitivity of the structure with different standard deviations compared to the straight fiber angle composites. The random variables are material properties and loads on the structures. The results show that the variable stiffness composite laminate structures are much more reliable, even for high standard deviation of material properties, than the conventional composite laminate structures. The reason is that the variable stiffness composite laminates allow tailoring stiffness and provide the possibility of adjusting stress and strain distribution favorably in the structures.

Keywords : material optimization, Monte Carlo simulation, reliability analysis, response surface method, variable stiffness composite structures
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