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DESIGN AND OPTIMIZATION OF A VARIABLE STIFFNESS COMPOSITE WING

Abstract

The use of fiber-reinforced composites is rapidly increased in the aerospace industry due to the demand of lightweight structures. In order to increase structural performance or reduce weight, the fiber can be steered in plane to make the best of directionality of these materials by treating the fiber angle as a function of space, resulting in the so-called variable stiffness composites(VSC). However, due to the complexity of modeling and analysis of the VSC structure, current research on VSC is limited to regular geometry, including panel, cylindrical and conical surface. Practical engineering systems are mostly composed of irregular geometry, thus it is necessary to explore the performance of VSC on irregular structure. Generally, it is almost impossible to optimize the VSC with geometry and fiber angles both as design variables. Therefore, a two-step design optimization strategy of a VSC wing under aerodynamic load is carried out to achieve the maximum load-carrying capability in this paper. Firstly, the geometry configuration of a traditional composite material wing with straight fiber of a minitype unmanned aerial vehicle is optimized to minimize the weight. This optimal configuration will serve as the baseline wing against which the VSC wings are compared. Subsequently, a VSC wing with the same geometry configuration, material parameters, weight and aerodynamic load as the previous optimal design is optimized to obtain the maximum buckling load, with the fiber orientation angles at each end of the root chord of the wing as the design variables. The design methodology for the variations of stiffness in the chord direction by fiber placement is described in detail. The structural analysis is implemented in the commercially available finite element package ABAQUS. The material directional property of the VSC skin of the wing is derived from the fiber placement algorithm. The optimal scheme for the curvilinear fiber path yielding the largest critical buckling load is obtained. It is found that the generated critical buckling load of the designed VSC wing is increased up to 50% compared to that of the baseline wing by optimizing the fiber orientation angles, which demonstrates the effectiveness of the proposed two-step optimization method. The structural performance of VSC configuration can be greatly improved through reasonable design of the fiber orientation path.