COMPOSITE LAMINATE MULTICRITERIA MEMBRANE
STIFFNESS MATRIX COMPONENTS OPTIMIZATION USING
LAMINATION PARAMETERS

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Key words: Multicriteria optimization, Membrane stiffness, Lamination parameters.

Summary. This work presents the composite laminate multicriteria optimization of the $A_{xx}$, $A_{yy}$ and $A_{ss}$ membrane stiffness matrix components. Each membrane stiffness matrix component has a minimal desired value so that the lamination parameters space is limited by a feasible region. The multicriteria optimization is done using the minimax strategy and an algorithm based on lamination parameters.

1 INTRODUCTION

Two types of approach are typically used for structural optimization problems involving lamination angles as design variables. The optimization may be performed either on the angular orientation space or in the lamination parameters space. Miki and Sugiyama [1] performed their optimization on the lamination parameters space taking into account a corresponding feasible region. Some authors, such as Foldager et al [2], perform their optimization on the angular orientation space considering some lamination parameters information to prevent local optimum. In this case, the problem is very ill conditioned.

In this work the optimization is performed by random search in the lamination parameters space. A mapping between the angular orientations and the lamination parameters is used so that all lamination parameters used in the optimization process have a corresponding feasible physical angular orientation. A linear approximation of the objective functions is used. This dramatically reduces the computational cost of the algorithm because there is no the need for frequently updating the gradient. This approach is both efficient and robust since the laminate stiffness is a linear function of the lamination parameters and consequently has constant gradient in the laminate parameter space. Moreover, it avoids need to compute gradient on the angular orientation space that is often ill conditioned and leads to numerical problems. It can be demonstrated that both the linearized buckling and vibration frequency problems are also approximately linear in the laminate parameter space. This fact significantly extends the practical applicability of the current approach.
2 DEVELOPMENT

The membrane extensional stiffness matrix components $A_{ij}$ are given in terms of the lamination parameters in Eq. (1). Considering that there are some minimal required values for $A_{xx}$, $A_{yy}$ and $A_{ss}$ it is possible to define the optimization problem as a multicriteria optimization where the goal is to simultaneously maximize $A_{xx}$, $A_{yy}$ and $A_{ss}$ with minimum constraints: $A_{xx} > a_x$, $A_{yy} > a_y$ and $A_{ss} > a_s$. In this way the multicriteria optimization problem deals with three objective functions and is solved by the minimax strategy as described by Eq. (1).

$$A_{ij} = t \begin{bmatrix} U \end{bmatrix} \left\{ 1 \begin{bmatrix} \xi_1^A & \xi_2^A & \xi_3^A & \xi_4^A \end{bmatrix}^T \right\} \max \min \left\{ A_{ij}^* \right\}, \quad A_{ij}^* > 1 \quad \text{and} \quad A_i^* = \frac{A_i}{a_i}, \quad i = x, y, s \quad (1)$$

Using the objective functions and their constraints it is possible to define three straight lines on the lamination parameters space that limit the feasible design region, as depicted in Figure 1. The optimization process always finds the centroid of the triangle as optimum which is the expected solution. The presented example has a known optimal point and is used to validate the optimization procedure adopted. The methodology will be applied to the optimization of a composite laminate under two compressive and one shear load with a prescribed minimum buckling load for each of these loadings.

![Figure 1 - Feasible region.](image)

REFERENCES
