Stacking Sequence Optimization of FRP Composites for Maximization of Failure Strength Based on Tsai – Wu Criterion Using Genetic Algorithm.

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Composite materials in mechanical, aerospace, and other branches of engineering are increasingly used due to their excellent weight saving and the ease of tailoring. In spite of tremendous progress in analytical capability to analyze the behavior of composite materials and structures, there is a lack of design models which may allow efficient tailoring of their properties to specific requirements for structural components. To improve this long-pending problem, the optimum design of composite materials has been a subject of research for many years. Strength was considered as constraints in many problems. The present paper treats the optimal stacking sequence design of carbon/Epoxy composite lamina under in-plane loading for maximum strength. Tsai –Wu failure criterion is taken as objective function. Genetic Algorithms are generally used for stacking sequence optimization problems. Genetic algorithm is a direct search algorithm based on probability based optimization. Classical laminate theory is used to establish relations between applied loads, stresses and strains in any layer of a laminate.

INTRODUCTION

The usual object of optimum design is to design layer thickness or layer orientation which will give the minimum weight or the maximum strength under in-plane or transverse loadings. In practical use the fiber angles in laminate are limited to small sets comprises of 0º, ± 15º ± 30º, ± 45º, ± 60º, ± 75º, ± 90º. Hence ply angles are restricted to take any of the above.
Strength was considered as constraints in many problems. There are, however, a few studies which consider the strength criterion as an objective function of optimum design. Quadratic failure criteria such as Tsai-Wu theory has been used widely for predicting failure of composite materials subjected to combined stress.

Steps In Analysis Of Laminated Composites

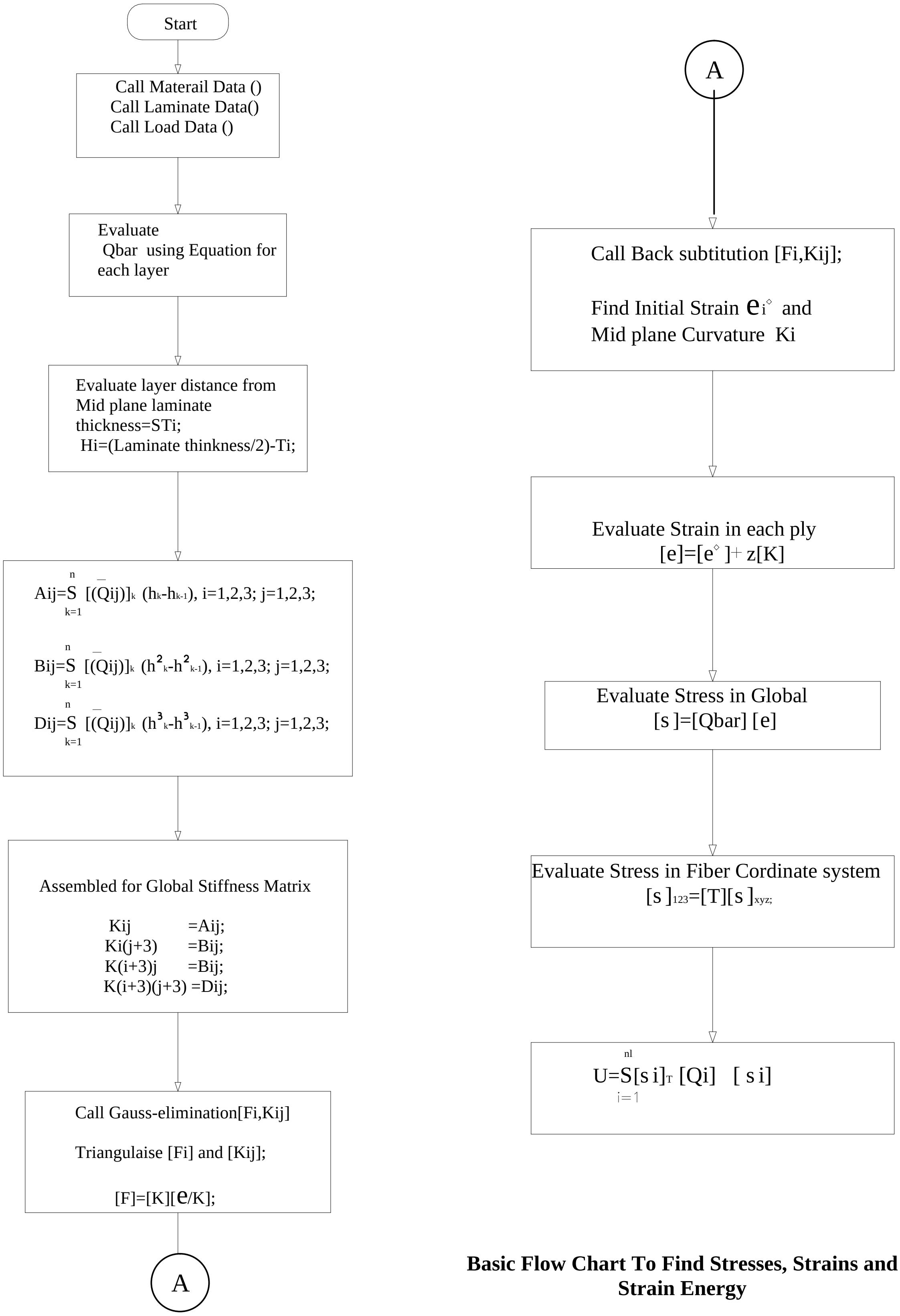
The following are the steps for analyzing a laminated composites subjected to the applied forces and moments.

1. Find the values of the reduced stiffness matrix [Q] for each ply using its elastic moduli E1, E2, v12, G12 using equation 4.3.2 or 4.3.3.
2. Fine the values of the transformed reduced stiffness matrix for each layer using [Q] matrix in step 1 and the angle of the ply using equation 4.6.1 or equation 4.6.2.
3. Knowing the thickness of each layer, find the coordinates of the each layer from mid-plane.
4. Use the $[\bar{Q}]$ matrices from step 2 and the location of each layer from step 3 to find the three stiffness matrices [A], [B] and [D] from equations 4.15 and 4.15.1.
5. Substitute the stiffness matrices found in step 4 and the applied forces and moments in equation 4.15.2.
6. Solve six simultaneous equations in equation 4.15.2 to find the mid plane strains and curvatures.
7. Knowing the location of each layer find the global strains in each layer using equation 4.15.4.
8. Find global stresses using equation 4.6.1.
9. Find Local stresses using transformation matrices in equation 4.4.1.
10. Find local strains using transformation matrices in equation 4.5.2.

Basic flow chart to find stresses, strains and strain energy in each layer of a laminate is given in the figure 4.6.

Conclusion

Optimum Stacking sequence problem in case of a given load depends on finding required number of layers to sustain the load, then optimize the laminate to maximize the Failure strength. For this case minimum layers required to sustain the load is 14 and above. Optimized laminate will have 15 layers and the maximum Tsai-Wu strength factor for this case is 0.83 and optimum sequence for this case is 0/-45 /75 /60 /45 /45 /45 /45 /45 /45 /45 /45 /45 /45 /45 /45.



Basic Flow Chart To Find Stresses, Strains and Strain Energy