Chapter 7

Concluding Remarks

7.1 Conclusions

A new scheme for the design of composite panels, which accounts for the effect of the parameters associated with the manufacturing process on the uncertainty in the geometry of the panels, was developed. The new scheme is composed of three major modules that could be replaced at will with equivalent tools for the design of other structures. It was demonstrated that the new scheme yields more reliable designs than currently used schemes that assume some nominal imperfections for a panel..

The three modules required to implement the newly suggested design scheme are:

1 – Design and analysis module

In this study, a nonlinear finite element code for postbuckling analysis of stiffened panels with geometric imperfections was developed. A four node, six-degree-of-freedom per node, rectangular, conformal element was used. Transverse shear effects were neglected since the width to thickness ratio of the panels under consideration is over 500. A maximum stress failure criterion was added to the finite element code to predict the panel postbuckling failure load. The element was validated using several standard example problems where results were compared to both analytical and experimental results available. Next, the nonlinear analysis code was linked to a genetic algorithm optimizer. Optimization studies were performed to tune the optimizer for the problem in hand. However, due to the expensive nature of the analysis, a deep investigation of the characteristics of the genetic algorithm when applied to this problem was beyond reach.

2- Manufacturing simulation module

An accurate manufacturing model is essential to the successful incorporation of the manufacturing feedback link in the design process. In this study, a one dimensional curing model for epoxy matrix composites has been extended to the calculation of the local process induced curvatures. An extension of the previous model to the prediction of a two dimensional surface cured shape was presented. The model and its numerous extensions have been validated using experimental scanning results of a variable stiffness laminate. Next, randomness in the primitive variables (resin and fiber material properties) were included in the manufacturing model. This was the only source of imperfections considered in this study. Knowing the probability density function of the material properties, spatially varying random numbers can be used to generate a sample of panels with different imperfect profiles. Finally, studies were performed to show the effects of the stacking sequence parameters on the final cured panel profile.

3 – Convex model of uncertainties in geometry

Due to the uncertain nature of the geometric imperfections, the incorporation of a model for uncertainties in the design scheme is essential. In this study, a convex model for uncertainties was developed and used to predict the weakest panel profile among a family of panels defined over an ellipsoidal convex area. The predictions of the convex model were compared to those obtained using the traditional Monte Carlo simulation. It was shown that the convex model requires a minimal amount of information about the imperfection in order to give an accurate prediction for the weakest panel profile in a set of panels.

7.2 Future work

The objective of this study was to demonstrate a new way for including manufacturing and uncertainty information in the design process, the application of this new scheme should by no mean be limited to composite stiffened panels. From this discussion, one can suggest the application of the new design scheme in the design of other imperfection-sensitive structures by simply replacing the manufacturing simulation and the analysis modules with the appropriate tools.

The author would finally like to recommend the experimental validation of the suggested scheme. This would be done by manufacturing and testing a panel designed by the new scheme, to verify that the predicted failure load is greater than the minimum acceptable load.