ASEN 5212 - Composite Structures and Materials
Final Project

Handed out: April 3rd, 2025
Due date: May 1st, 2025 (at 11:59pm)

1 Introduction

The goal of the project is to design the lightest laminate able to satisfy a given set of requirements. Your design variables are the number of laminas, the orientation of each one, and the specific value of the volume fraction within an allowed range. The material properties, and other relevant information about the laminas, are:

- Carbon fibers with $E_{1f} = 270$ GPa, $E_{2f} = 14$ GPa, $G_{12f} = 10$ GPa, $\nu_{12f} = 0.22$, $\rho_f = 1750$ kg/m^3
- Epoxy with $E_m = 3.5$ GPa, $\nu_m = 0.37$, $\rho_f = 1200$ kg/m^3
- The volume fraction can change between 40% and 65%. It needs to be the same for all laminas within the laminate. Assume $\xi_1 = \xi_2 = 1$ in all cases.
- Each lamina has a thickness of 0.1 mm when the volume fraction is $V_f = 50\%$; you will need to calculate for other cases.

The failure properties of each material are:

- Fibers in tension, $\varepsilon_f^u = 1\%$
- Matrix in tension, $F_{mt} = 120$ MPa
- Matrix in compression, $F_{mc} = 150$ MPa
- Matrix in shear, $F_{ms} = 80$ MPa

You will be able to work in groups of up to three students. The final report should not only include the final laminate, but also explain the design process followed, with as many results as needed to show how you end up with your design. Despite of how well commented your code is, you need to provide enough explanation of what you are doing in the main document. Make sure your plots are readable (sufficient font size, smart use of line colors and styles, etc.). The report should be at least 5 pages and at most 15 pages, font size 12 of your choice (but please a readable one), single space, one inch margins. Use appendixes, if needed, for code, additional results, or material that does not fit well within the main narrative.

It is expected that finding the absolute lightest laminate possible, with absolute certainty, will be hard, bordering on impossible. There is no ”right final answer” you are supposed to get to. The goal is to perform a well reasoned and thorough exploration of the design space, and then present sufficient details and evidence to convince the reader.

1.1 Design for stiffness

First, design the lightest laminate able to satisfy the following requirements for its ABD matrix:

- $A_{xx} \geq 100,000$ N/mm, in the main $x - y$ reference frame.
- $A_{\overline{xx}} \geq 30,000$ N/mm, for all possible rotations of the main reference frame into a different $\overline{x} - \overline{y}$ reference frame.
- $D_{xx} \geq 25,000$ N mm, in the main $x - y$ reference frame.
- $D_{yy} \geq 15,000$ N mm, in the main $x - y$ reference frame.

Explain your design rationale, and how you are verifying that all requirements are satisfied. Make sure you explain the way you are making sure that the laminate is as light as possible.

1.2 Design for strength

Now find the lightest laminate able to survive the following loads:

- $N_{xx} = 600$ N/mm
- $N_{\theta\theta} = 200$ N/mm, applied at any possible direction θ
- $M_{xx} = \pm 100$ N

The loads will be applied either individually, or combined, in any possible combination. For example, the maximum normal load in the x direction will be $N_{xx} = 800$ N/mm, as a combination of the given N_{xx} and $N_{\theta\theta}$ when $\theta = 0$. Please, note that the applied moment can be either positive or negative.

Use the Tsai-Wu theory. Do not worry about safety factors, assume they are already included in the requirements. Explain and justify any decisions you have made to model the strength of the laminas beyond the values provided.

1.3 Design for stiffness and strength

Finally, design the lightest laminate able to satisfy both sets of requirements, stiffness and strength.

As before, make sure to explain your design rationale, and how you are verifying that both sets conditions are satisfied. Comment on how the stiffness and strength requirements relate to each other (*e.g.*, is there a more stringent set? do they push the design in different directions?).