# Lab 6 Composite Laminate Design

## Objective

Learn how to design fiber-reinforced composite laminates to a behavior specification.

## Introduction

Composite materials play a key role in modern aircraft structures, and their applications were significantly increased in recent years. In this lab we focus on fiber-reinforced composite laminates which is very frequently used in aircraft structures. In Week 7&8 lectures you were given an overview of composite materials. You also learned the basics of fiber-reinforced composite laminates and were introduced to the classical laminate theory. Given the limited time available in this class, these are a lot to take in, especially the theoretical part. Please be patient and persistent—this knowledge and experience will certainly be your assets if you will pursuit a career in aircraft structures.

## References

[1] Week 7&8 lecture notes
[2] Laminate Calculator user guide (in pdf; available in both supplemental class web site and in Canvas)

## Work to be done

This lab involves no in-lab activity but computerized design that you need to work with your lab partners as a team. Before you are able to proceed with the design, however, there are substantial theory of composite laminates you need to learn first. For this, please study thoroughly the corresponding lecture notes and this lab manual. Note that there is no demo video made for this lab.

### 1. Pelab

Work on separate prelab assignment available in Canvas, after you have completed the study of lecture notes and lab manual.

### 2. Online Design

As described in the lecture, the task for your group in this lab is to design the layup of a fiber-reinforced laminate that has specific behavior under load. The supplemental class web site has an online composite "calculator" for you to accomplish this design process (https://thermal.cnde.iastate.edu/aere322/webdeform/webdeform_laminate.html). The accompanied user manual *Laminate Calculator user guide.pdf* can be found in *Misc* module in Canvas. The objective is to design the layup of an 8-ply fiber-reinforced laminate sheet so that a strip cut off from the laminate sheet will produce maximum twist at the end of the strip when subjected to a bending moment. The actual assembly of a 6"x1" cantilever strip is shown in Fig. 1 in which the horizontal metal bar placed at the end of the laminate strip generates the needed bending moment. Below are the steps of the design process your team should follow:

(1) Review the classical laminate theory described in the lecture notes. Determine what are the key parameters and how to fine tune them to maximize the twist angle. Note that there is no unique answer to this task. Given the fact that you were just exposed to this subject, it will be hard for you to do so anyway. Rather, the learning process of designing the layup itself is the objective of this lab!
(2) The online calculator can be accessed from the main page of the supplemental class web site on the left panel under "Interactive Laminate Calculator". Also from the left panel under "Notes and Assignments" you can find "LaminateCalculator user guide.pdf" in the rightmost "Misc Documents" column.
(3) You will notice that most inputs to the online calculator have been pre-filled for you. Those inputs, e.g. material properties, are good approximations for some common materials which you don't need to change. To begin, you just modify the layer thickness (t_layer under Laminate tab on the left side panel) to 150 $\mu$m, and zero out any applied stress in x direction, sigma_x, on the right side panel.
(4) Apply a nominal bending moment (say M_x = 1 N-m/m) and calculate the curvatures/twists as shown in Fig. 2 in the encircled kappa column. The three components from top to bottom in the kappa column corresponds to the bending curvatures $\kappa_x$ and $\kappa_y$ and twist curvature $\kappa_{xy}$ described on page 20 of the lecture notes. It is the twist curvature $\kappa_{xy}$ controls the twist at the end of the laminate strip in the "virtual test" you will be conducting (Fig. 1).
(5) Play with your layup design and see how it affects these curvatures, particularly $\kappa_{xy}$. Since your objective is to maximize the twist at the end of the strip, should you "randomize" your laminate angles in layup (more of [0, 90, 45, -45, ….]) or "regularize" it (more of [45, 45, 45, 45, …])? Since the laminate is symmetric, you only need to enter half (i.e. four) of the layup entries (in layup under Laminate tab on the left panel). Don't be confused by the deformation plot provided in the online calculator (shown in blue frame on the lower right corner of Fig. 2). Please note that the plot only shows the top view of the strip, and does not show the side view of the twist of the strip.
(6) (20%) Show that the coupling stiffness matrix B (defined on page 22 in lecture notes) vanishes for your symmetric laminate layup. For this, you may need to study materials on pages 6 and 21-24.
(7) (10%) Of the A-B-B-D or a-b-c-d matrices shown on pages 22-24 of lecture notes, which component(s) affect the twist curvature $\kappa_{xy}$ under the loading condition? Show how you identify the component(s).
(8) (70%) In at least 5 design cycles, show how to reach your final largest twist curvature $\kappa_{xy}$ and thus the largest twist angle at the end of the laminate strip. Included in each cycle are:

(a) The design layup you choose,
(b) The reasoning that leads to your choice, and
(c) The value of twist curvature $\kappa_{xy}$ obtained from the online calculator

## Report

Follow “AerE 322 lab summary instruction.pdf” to write a summary for the design process done in this lab. This pdf instruction can be found under *Misc* module in Canvas; it is also available in the supplemental class web site under *Misc* Documents on Notes and Assignments page. In the summary, create a section with heading “Laminate Analyses” and put answers to Parts (6) and (7) there. Create a separate “Design Process” section and put in there all results of the design process defined in Part (8) above. Be sure to include all other standard components such as Introduction, Objectives, etc.

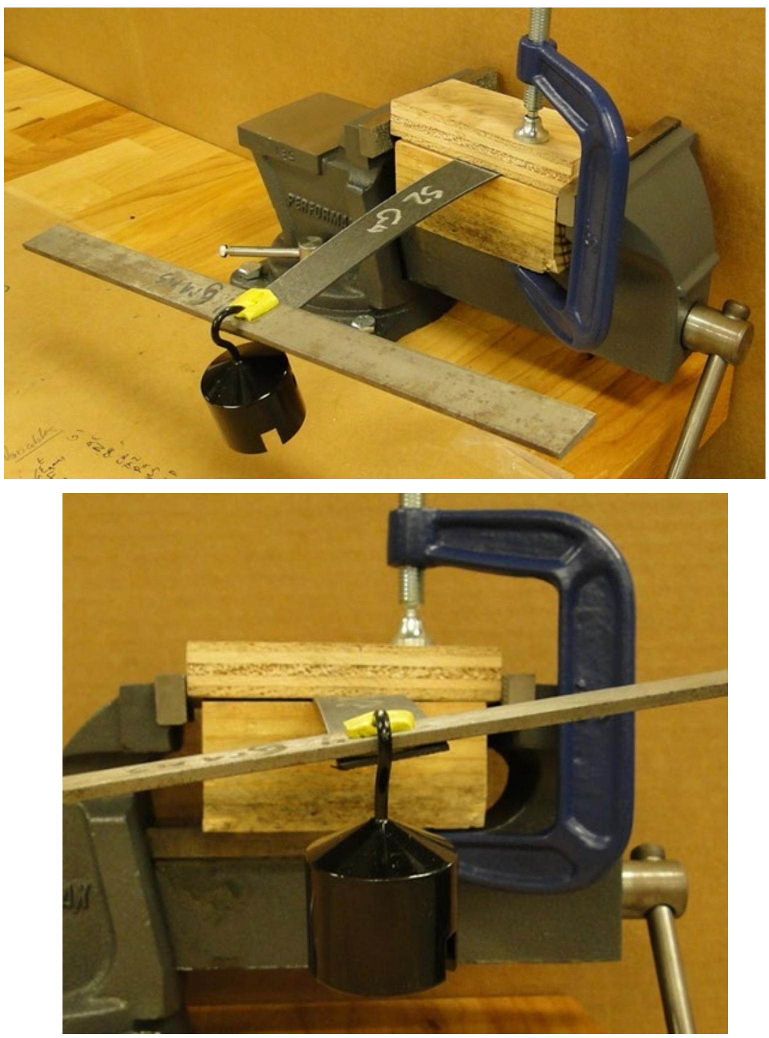

Figure 1. Laminate test assembly (top) demonstrating twist at the end of sample strip (bottom)

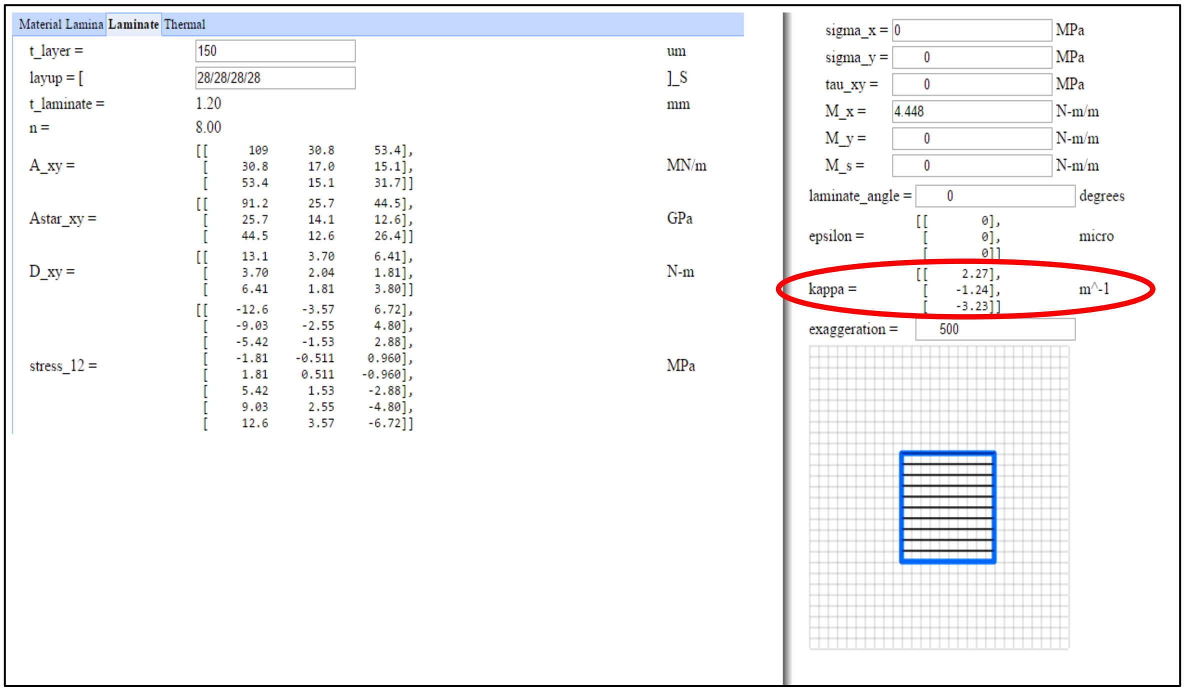


Figure 2. The graphical user interface of the online laminate calculator