Assignment 1: Stress analysis of thermo-mechanically loaded laminate

January 18, 2019

1 Introduction

The assignment is a part of the course TME240 Composite Mechanics during the academic year 2018/2019 and should be solved by use of MATLAB. The aim of the present assignment is to give some knowledge and experience of how to compute stresses and strains in a continuous-reinforced composite laminate.

1.1 Requirements

The computer assignment is to be carried out in groups of two students. Make sure to register your group (which will remain the same for the two subsequent assignments) on the course homepage. The assignment tasks are in total worth at most 3 points (out of 18 for the full course examination), see course memo for details. Deadline for submitting in the report via Ping-Pong is Monday, February 11th 2019, **17:00**. All reports will be automatically checked for plagiarism using the urkund-system (covers also the code in pdf-format, which is therefore essential to include).
In order to obtain any points for the assignment work, you need to (before the deadline):

- submit a full report in pdf-format including the MATLAB source code, motivations for assumptions made and choice of methods used, the main results and discussion thereof and
- upload the MATLAB source-code as an archive (zip/rar) via the course homepage

1.2 Point distribution

The rough point distribution is as follows:

- Calculate and plot the residual stress distribution across the thickness (separately for σ_x, σ_y and τ_{xy}) caused by the thermal loads only (cooling) (2p)
- Calculate the maximum longitudinal, transverse and shear stress in the laminate due to the combined loading by temperature decrease and external loads/strains and use this info to estimate the risk of failure initiation in any of the plies (1p)

Full points also require a well written report. The report must contain the following parts:

- Problem description. A brief description of the problem. What is known and what is sought for?
- Method. Presentation of the solution. Including assumptions and references to any equations/formulas used.
- Results. Presentation of the results sought for: specific output data, figures etc.
- Discussion. Brief discussion on the results and assumptions made. Are the results expected or not? How do they relate to the assumptions?
- Source code. A pdf-copy of all the MATLAB source code used to solve the problem.

2 Assignment description

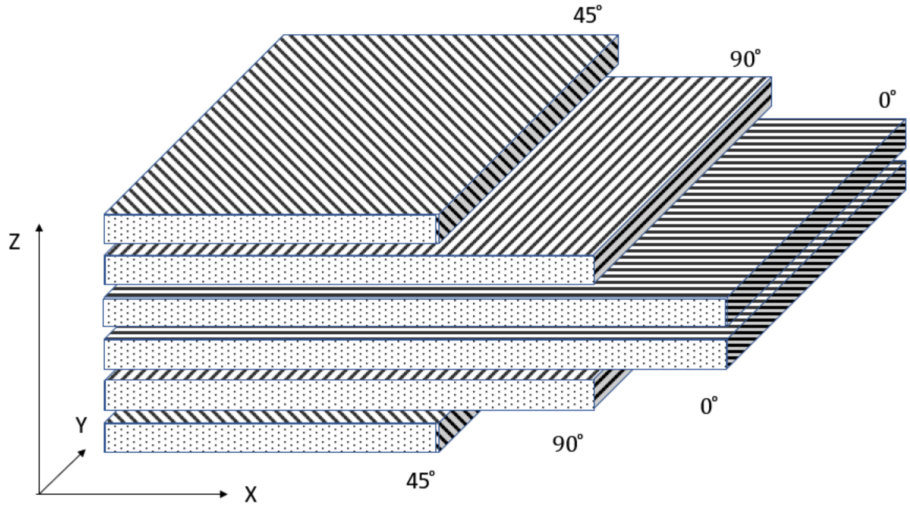

Figure 1: Principal sketch of stacking of the plies of the lamina considered in Computer Assignment 1

A 1.2 mm thick carbon-fibre/epoxy laminate $[45/90/0]_S$ (cf. Figure 1 and Appendix 3 in the course book for details) consisting of carbon fibres and epoxy resin is to be considered. The composite is manufactured such that the fibre volume fraction is 60% and such that each ply/lamina is assumed to have the same thickness. Furthermore, during the manufacturing, the composite laminate was cured at 125 °C and then cooled down to room temperature of 25 °C without being subjected to any mechanical loads or constraints. After cooling, a load is applied in the x-direction such that the strain in the same direction is ε_x^0 = 0.05 %. In a second step, also a stress resultant moment load is applied as:

$$\mathrm{M} = \begin{Bmatrix} \mathrm{M_x^M} \\ \mathrm{M_y^M} \\ \mathrm{M_{xy}^M} \end{Bmatrix} = \begin{Bmatrix} \overline{\mathrm{M}}_\mathrm{x} \\ \overline{\mathrm{M}}_\mathrm{y} \\ \overline{\mathrm{M}}_\mathrm{xy} \end{Bmatrix} = \begin{Bmatrix} 75 \\ 50 \\ 0.0 \end{Bmatrix} \frac{\mathrm{Nm}}{\mathrm{m}}$$

Constituent properties

Carbon fibres

(For the sake of simplicity, assume that the carbon fibres are isotropic which they in reality are not)
E = 350 GPa, ν = 0.2, ρ = 2.0 g/cm^3, α = -1.0 x 10^{-6} 1/ °C

Epoxy resin

E = 3.5 GPa, ν = 0.35, ρ = 1.2 g/cm^3, α = 50 x 10^{-6} 1/ °C

Main task

Calculate the stresses in each lamina due to the combined loads from the temperature change and the applied loads. For this purpose, a MATLAB script should be created which involves computation of lamina properties, the laminate stiffness matrix (including the [A], [B] and [D] matrices), resulting stresses and strains and routines for visualising the results. The code should be written in a general way in terms of thickness, number of plies and orientation of the fibres in the different plies in order to enable the usage of the same routines in Computer Assignment 2.

Subtasks

1. Calculate and plot the residual stress distribution across the thickness (separately for σ_x, σ_y and τ_{xy}) caused by the thermal cooling. (2p)

Points of discussion:

- Are the results realistic? Hint: how can the resultant forces and resultant moments be used to check this?
- How does the plate deform and why?
- How would the deformation change if the laminate was unsymmetric? Qualitatively describe/sketch the deformation of a $[90_2/0_2]$ (starting from $z = z_{min}$) rectangular laminate subjected to the same temperature change with no restrictions on the deformation.

2. Calculate the maximum longitudinal, transverse and shear stress in the laminate due to the combined loading by temperature decrease and external loads/strains and use this info to estimate (to the best of your knowledge) the risk of failure initiation in any of the plies (1p)

Hints

If you write your MATLAB code in a general way you can use

- Example 3-1 and Example 3-3 to verify/evaluate the computation of E_L and E_T .
- Example 5-3 and Example 5-5 to verify the step from lamina properties E_L;E_T ; ν_{LT} and G_{LT} to the $[\overline{Q}]$ matrix.
- Example 6-2 to verify the step from $[\overline{Q}]$ matrices to the matrices [A], [B] and [D]
- Example 6-10 to verify the calculation of residual thermal stresses based on given $[\overline{Q}]$ matrices. Be careful when considering the orientation of the z-axis in this case.