SESG6039 – Composites Engineering Design and Mechanics

Individual Assignment 3

Introduction

Part 3 involves the application and further development/expansion of your CLPT-code (developed in part 1 of assignment) to analyse laminate stress and strain distributions, make predictions of first ply failure using different failure theories, and to predict buckling of composite and sandwich laminates.

Submit a short report of no more than 6 A4 pages to include the answers to the following questions:

Question 1:

Set N_x = 25 kN/m, $N_y = N_{xy} = M_x = M_y = M_{xy} = 0$, and determine the laminate mid-surface strains and curvatures that result from the prescribed loading condition for the [90, 45,-45, 0] laminate discussed in Q5 of Part 1.

Hint: To solve this you should consider the laminate constitutive relations – with the stress/moment resultants prescribed, you can solve for the reference surface strains and curvatures. This is a fully coupled laminate – so complex behaviour is to be expected.

Question 2:

Given the results from Question 1 and assuming that the laminate now represents a cantilever beam, which has a length of 2m and negligible width. What is the deflection of the beam with no forces applied other than that specified in Question 1? (You can assume that k_y and k_{xy} are zero.)

Hint: To solve this you need to use engineer's bending theory and the equation for the deflection of a cantilever beam due to a bending moment given by:

$$\delta = \frac{M_0 L^2}{2EI}$$

Question 3:

Calculate and illustrate graphically the through thickness stress distribution in the [90, 45,-45, 0] laminate configuration in the laminate (x, y) coordinate system. Remember that the laminate stack above is presented top to bottom!

Hint: When assessing your predictions, recall that whilst the strains vary continuously across the laminate thickness, the stresses vary through the thickness of the plies as well, but usually display discontinuous jumps across the ply interfaces.

Question 4:

Calculate and illustrate graphically the through thickness stress distribution in the [90, 45,-45, 0] material in the material (1, 2) coordinate system. Remember that the laminate stack above is presented top to bottom!

Question 5:

Using the material properties in the table below determine the ply or plies that fail first (first ply failure), the predicted mode of failure and the value of N_x for the [90, 45,-45, 0] laminate configuration discussed before. Use the following failure criteria:

a. Maximum stress

b. Maximum strain

c. Tsai-Wu, where the interaction parameter F_{12}* is specified as F_{12} * = -0.5

Compare and discuss the results obtained.

Hint: *You are asked to provide failure load prediction in terms of the stress resultant N_x corresponding to first ply failure – not the total failure load of the laminate.*

Question 6:

Consider a rectangular sandwich plate with composite face sheets that is simply supported along all four plate edges.

The top and bottom face sheets are identical and manufactured using a GFRP material system with the elastic properties quoted in the Table 2 and failure properties given in Table 3.

The sandwich core material is a cross linked PVC material with shear moduli $G_{c,xz}$=$G_{c,yz}$=38 MPa, and Young's modulus E_c=110 MPa (isotropic core).

The sandwich plate dimensions are: Length a (x-direction); Width b (y-direction), Core thickness t_c.

The sandwich plate is subjected to uniform in-plane compressive loading in the x-direction.

Use the results of the sandwich plate theory (based on CLPT modified to account for transverse shear deformations), the design formula for local face sheet instability (wrinkling), and the CLPT analyses presented in the lecture notes to answer the following:

a. Consider the sandwich plate discussed above and assume that that GFRP laminate face sheets composed of 4 plies with a stacking sequence of $[0,90]_S$, a=b=750 mm, and t_c=25 mm:

   Calculate the critical load for global buckling (expressed as the critical value of the compressive normal stress resultant) and determine the corresponding buckling mode (number of half waves in the x and y directions).

b. For the sandwich plate problem defined in question a above:

   Calculate the critical load for local face sheet buckling or wrinkling (expressed as the critical value of the compressive normal stress resultant).

Discuss the result obtained in the context of the answer to question a above, and in the context of what the estimated ultimate load corresponding to 'material' failure (compression failure) would be.

c. Consider the sandwich plate configuration defined in question a, but now change with a=250 mm and a=2250 mm, whilst b=750 mm (i.e. two cases a/b=1/3 and a/b=3):

Calculate the critical loads (expressed as critical value of compressive normal stress resultant) and determine the corresponding buckling modes (number of half waves in the x and y directions).

Discuss the results obtained.

Hint: You can use the CLPT-code you have derived in Part 1 directly to calculate the bending stiffness coefficients in [D]. You need to expand your CLPT-code to calculate the transverse shear stiffness coefficients for the sandwich plate/laminate to accommodate for the effect of finite shear stiffness on the buckling response.

Table 3 Failure stresses (strengths) and strains – data sheet values:

Property	Value
X_t (MPa)	1040
Y_t (MPa)	35
X_c (MPa)	570
Y_c (MPa)	114
S (MPa)	72
ε_{1t}	0.021
ε_{2t}	0.002
ε_{1c}	0.011
ε_{2c}	0.0064
γ_6	0.038

X and Y are the stresses to failure (strengths) in the directions parallel and transverse to the fibres, and S is the shear strength. The subscripts t and c represent tension and compression. Notation according to lecture notes.