Homework No. 2

Due Date: April 07 (Mon) 6:30 PM

1.

By writing out the stress-strain equations as matrices, show the relationship between the 21 independent compliances in contracted notation S_{mn} ($m,n = 1$ to 6) and the compliances in tensor notation S_{ijkl} ($i,j,k,l = 1$ to 3).

2.

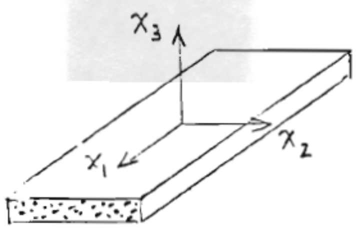
Show that the 3-D compliances S_{ij} ($i,j = 1$ to 6) can be used without modification (with $i,j = 1, 2, 6$) for 2-D plane stress calculations. Show (but do not do the algebra) that this is not the case for the stiffnesses C_{ij}.

3.

Given a transversly isotropic material about the x_1 axis.

a) Write out the 3-D compliances S_{ij} for this material. How many constants are required to characterize it?

b) If the material is in plane stress along the x_1, x_2 axes ($\sigma_3 = \sigma_4 = \sigma_5 = 0$), what are the corresponding 2-D compliances S_{ij}^* ? How many constants are required to characterize it?



4.

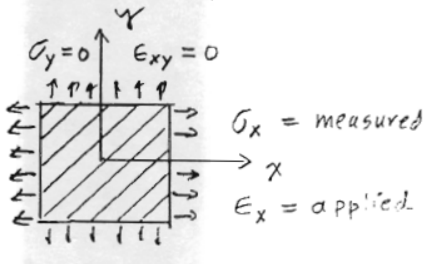
Attached are test resuults for two tests of laminates made from AS4/3501-6 material. The applied stress (in GPa or MPa) is plotted against the longitudinal strain measured with a strain gage (in μstrain, i.e., strain times 10^{-6}). The computer in some cases has printed "E0X" at the end of an axis -- this means multiplying the values shown on that axis by 10 .

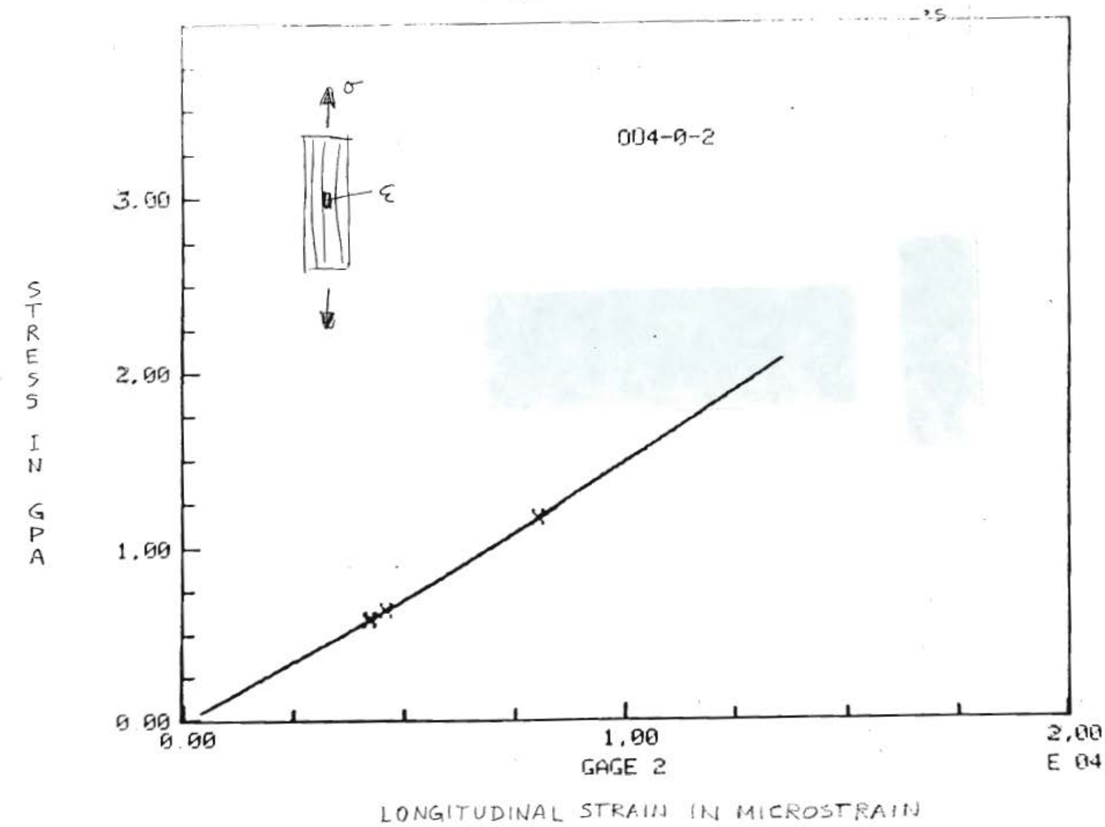
a) The first graph is the results from a longitudinal tensile test. Use this information to find E_L for this material. Show how you derived your value from the test results. Your value may not agree exactly with published values due to test scatter.

b) From other tests, we find $E_T = 9.8$ GPa and $\nu_{LT} = .30$. The second graph shows resuls of testing a $[+45/-45]_S$ laminate. Use this information, and the material properties you already know, to find G_{LT} for this material. Again show your work. To do this, consider a +45 ply as shown below. Assume that the boundary conditions on this ply are σ_x = applied stress from the graph, $\sigma_y = 0$, and $\varepsilon_{xy} = 0$ (not $\sigma_{xy} = 0$). Given that you know ε_x (from the strain gage), use the rotated Hooke's law $\bar{\sigma} = \bar{Q}\bar{\varepsilon}$ to find the unknowns ε_y, σ_{xy}, and G_{LT}. Use the early, linear region of the plot.

c) Can you justify the assumptions used for the boundary conditions in b)?

d) Compute the $\underset{\sim}{Q}$ and $\underset{\sim}{S}$ matrices for this material. Compare Q_{11} to E_L .





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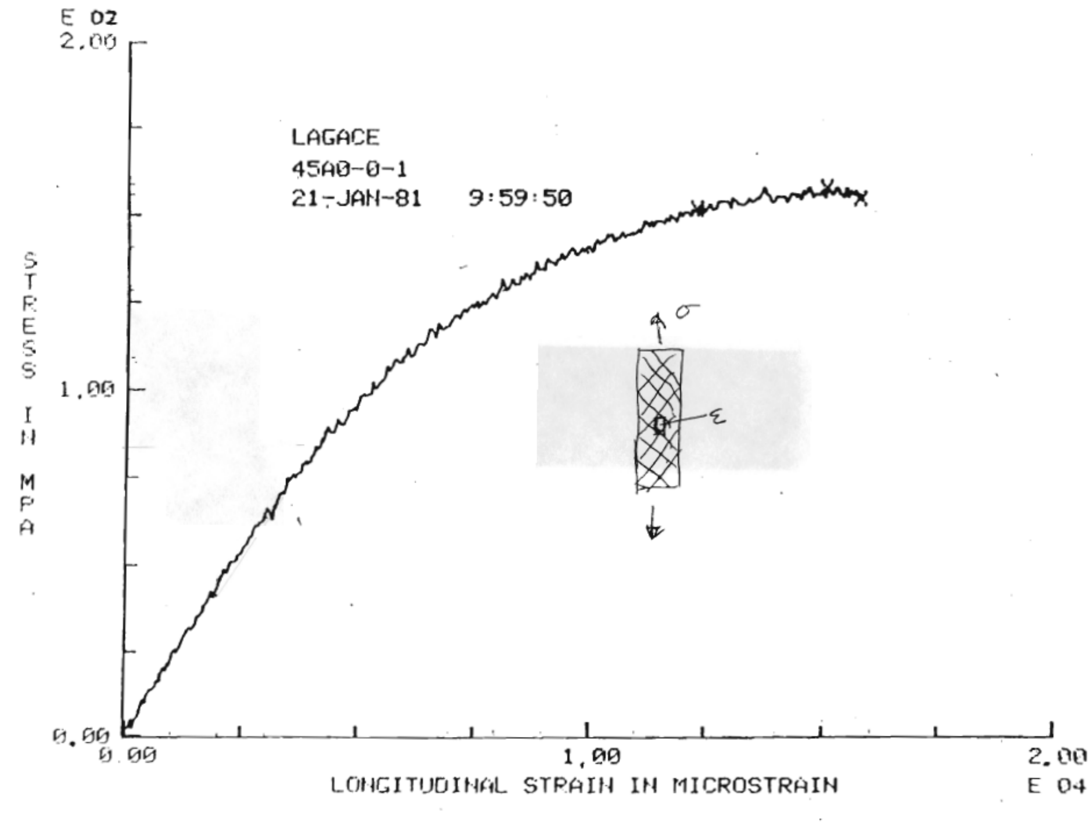
GAGE 2
LONGITUDINAL STRAIN IN MICROSTRAIN



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LONGITUDINAL STRAIN IN MICROSTRAIN

5.

For a ply rotated by an angle θ, compute the rotated Q matrix, $\underset{\sim}{Q}$, for AS4/3501-6. Plot Q_{11}, Q_{12}, Q_{16} and Q_{66} for θ from 0 to 90 degrees

6.

Consider a stack of 3 plies of AS4/3501-6, 0.125 mm thick each, not glued together, in a $[0/90/0]_T$ arrangement. We apply to each ply individually, the boundary conditions of

$$\varepsilon_x = .001 \qquad \sigma_y = 0 \qquad \sigma_{xy} = 0$$

a) What are the stresses and strains σ_x, ε_y, ε_{xy} in each of the plies?

b) Why is what we just did, not a solution of the laminate problem (in which the plies are glued to each other)?

Note: For doing these calculations, and for later use, produce convenient computer subroutines, MATLAB routines, etc., for your personal use. Suggested routines are,

a) Compute the $\underset{\sim}{Q}$ matrix from given E_L, E_T, ν_{LT}, G_{LT}.

b) Rotate $\underset{\sim}{Q}$ by θ

c) Invert $\underset{\sim}{\bar{Q}}$ (get $\underset{\sim}{S}$) and extract effective engineering constants.