ME 450
Winter 2021

Homework 3
Due Date: February 19th, 2020

1. Find and describe a real-world example of a method for enhancing the bond strength between different phases of a composite. Include the materials system, the details of the technique being used and the resulting bonding mechanisms (e.g. chemical bonding, keying, residual stress, etc.)? (**20 points**)

2. For a CFRP composite in axial tension, why do some of the fibers break before the final failure of the sample (this can be heard as pinging during the tensile test)? Do those broken fibers still support any load, and if so, what equation could you use to describe how much load they can support? (**10 points**)

3. For a carbon fiber reinforced epoxy composite with $G_f = 110\,GPa$ and $G_m = 1.4\,GPa$, plot the compressive failure strength as a function of volume fraction from $V_f = 0.2 - 0.9$ for three different imperfection angles of $\phi_o = 1°, 2°$ and $3°$. Take the shear yield strength to be $\tau_{12*} = 80\,MPa$. Assume that plastic microbuckling will be the dominant failure mechanism. (**15 points**)

4. The failure strength of a given set of glass fibers can be well described by a Weibull distribution with $m = 14.2$ and $\sigma_o = 963\,MPa$ for a given reference length $L_o = 100\,mm$. If a glass fiber composite is made that has fibers that are $L = 300mm$ long, at what applied stress would the fibers have a 1% chance of failure. At what stress would they have a 50% chance of failure? (**20 points**)

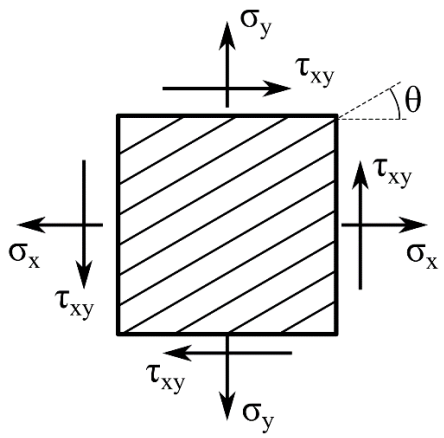
5. In the tension testing lab, a CFRP composite was used with strengths and stiffnesses of the fiber and matrix phase of $\sigma_f = 4.9\,GPa$ and $E_f = 240\,GPa$ and $\sigma_m = 168\,MPa$ and $E_m = 3.8\,GPa$ respectively. If the measured 0° modulus was $E_1 = 125\,GPa$, what was the fiber volume fraction V_f? What are the expected axial and transverse tensile strengths? If the actual strengths were $\sigma_{1*} = 2.1\,GPa$ and $\sigma_{2*} = 60\,MPa$, what is the knockdown on these properties? (**15 points**)

6. Take a fiber composite with $\sigma_{1*} = 500\,MPa$, $\sigma_{2*} = 20\,MPa$ and $\tau_{12*} = 50\,MPa$. A stress is applied of $\underline{\sigma} = \begin{bmatrix} 100 \\ 15 \\ 0 \end{bmatrix} MPa$ at an angle $\theta = 15°$ relative to the fiber axis. Predict whether the composite will fail using the max normal criterion and the Tsai-Hill criterion. Is there a difference in the prediction, and if so, why? *Hint: you can use your stress rotation functions from previous assignments*. (**20 points**)

Coding

7. Write two functions that determine whether a lamina will fail under a given applied stress, one using the Tsai-Hill condition and one using the max stress condition. The inputs to the functions should be the composite strengths (σ_{1*}, σ_{2*}, and τ_{12*}) and the applied stress ($\underline{\sigma}$). It can be assumed that the stress is aligned with the fiber direction. The functions should return true or false if the composite does or does not fail. Validate them by checking that a composite with $\sigma_{1*} = 2100\ MPa$, $\sigma_{2*} = 100\ MPa$ and $\tau_{12*} = 180\ MPa$ under a stresses of $\underline{\sigma} = \begin{bmatrix} 2000 \\ 110 \\ 100 \end{bmatrix}$, $\underline{\sigma} = \begin{bmatrix} 2200 \\ 90 \\ 80 \end{bmatrix}$ and $\underline{\sigma} = \begin{bmatrix} 1800 \\ 60 \\ 200 \end{bmatrix}$ all fail. (**20 points**)

8. Write a function that incorporates the two functions from the previous problem to determine whether a lamina will fail under an applied stress at an arbitrary angle relative to the fiber direction. The inputs should be the applied stress ($\bar{\underline{\sigma}}$), the stress orientation relative to the fiber axis (θ), the composite strengths (σ_{1*}, σ_{2*}, and τ_{12*}) and the failure criterion ('Tsai-Hill' or 'Max Stress'). Use this function to predict the loading angle θ that will cause failure for an applied stress of $\bar{\underline{\sigma}} = \begin{bmatrix} 300 \\ 80 \\ 100 \end{bmatrix}$ under both the Tsai-Hill and max stress conditions. Take the composite strengths to be $\sigma_{1*} = 900\ MPa$, $\sigma_{2*} = 150\ MPa$ and $\tau_{12*} = 200\ MPa$, and determine the failure angle to within 0.5°. *Hint: you can rotate the stress to different angles using the rotation function from the previous homework and then use this new function to check when failure occurs.* (**30 points**)



Total value of this homework = 12.5% of the course grade (150 points)