ME 450
Winter 2021

Homework 1
Due Date: January 22nd, 2021

1. Identify three composites that haven't been discussed in class, describe their matrix and reinforcement phases, their architecture (e.g. long fiber, short fiber, particulate, etc.), how they are manufactured, and where they are used or found. (**15 points**)

2. For <u>one</u> of the three composites above, what optimized properties does it have that causes it to be used instead of any other material? (**15 points**)

3. Plot the upper (Voigt) and lower (Reuss) stiffness bounds for a unidirectional long fiber composite made of carbon fiber ($E_f = 430\ GPa$) and epoxy ($E_m = 2.3\ GPa$) as a function of volume fraction ($V = 0 \rightarrow 1$). Assume the fibers and matrix are isotropic. What are the upper and lower stiffness values if the fibers are in a <u>square packing</u>? What are the upper and lower stiffness values if the fibers are in a <u>hexagonal packing</u>? Indicate these points on the plot. (**20 points**)

4. Plot the Poisson's ratios ν_{12} and ν_{21} of a unidirectional long fiber composite made of carbon fiber ($\nu_f = 0.21$) and epoxy ($\nu_m = 0.39$) as a function of volume fraction ($V = 0 \rightarrow 1$). Use the values of Young's moduli from the previous problem. Assume the fibers and matrix are isotropic. (**10 points**)

5. A unidirectional fiberglass reinforced epoxy composite is provided with a $V = 65\%$ volume fraction of fibers. It has a stiffness tensor $C = \begin{bmatrix} 121.9 & 3.4 & 0 \\ 3.4 & 11.4 & 0 \\ 0 & 0 & 3.0 \end{bmatrix} GPa$. What stress must be applied to the lamina to generate a strain of $\varepsilon = \begin{bmatrix} 0.01 \\ 0.005 \\ 0.005 \end{bmatrix}$? (**10 points**)

6. The same lamina as in problem 5 has a stress of $\sigma = \begin{bmatrix} 10 \\ 5 \\ 0 \end{bmatrix} MPa$ applied to it at an angle of $\theta = 30°$ relative to the fiber axis. What is the resulting strain in the direction of the applied stress? (*Note: it may be helpful to draw a picture to visualize the applied stress relative to the fibers*). (**20 points**)

Coding

7. Write <u>two functions</u> that generate a 2D stiffness tensor (i.e. a 3x3 matrix) for a long fiber composite, one using a rule-of-mixtures formulation and one using a Halpin-Tsai formulation. Use these functions (and a matrix inverse function) to generate the stiffness and compliance tensors for a silicon carbide (SiC) reinforced aluminum (Al) composite. The SiC fiber properties are $E_f = 196\ GPa$, $G_f = 79\ GPa$ and $\nu_f = 0.14$, the Al properties are $E_m = 68\ GPa$, $G_m = 26\ GPa$ and $\nu_m = 0.33$, and the composite has a fiber volume fraction of $V = 50\%$. (*Note: you should be generating 4 separate matrices*). (**30 points**)

8. Using the Halpin-Tsai stiffness tensor function from the previous problem, plot the E_x, G_{xy} and ν_{xy} of the SiC reinforced Al composite from the previous problem at angles from $\theta = 0° \rightarrow 90°$ in $10°$ increments (see the last widget in the DoITPoMS "Stiffness of laminates" as an example). (*Note: it may be useful to write a separate rotation function*). (**30 points**)

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