TUT / Plastics and Elastomer Technology

MOL-5526 Advanced Course on Composites

2nd Mid-term examination 2.5.2011 / Jyrki Vuorinen, Olli Orell

Max 30 points in total! Saa vastata myös suomeksi.

Answer to three (3) questions only!

1. Compare adhesive bonding and bolting/riveting as joining methods for composites – design, usability and maintenance aspects? (10p)

2. Drivers for light weight materials – why composite use seems to be increasing? (10p)

3. Impact damage of composites – what, why and where? (10p)

4. Challenges in modelling of composite structures? (10p)

Some properties of typical unidirectional polymer composites

	Carbon/epoxy composite	**Glass/epoxy composite**
E_1	155 GPa	50 GPa
E_2	12.1 GPa	15.2 GPa
E_3	12.1 GPa	15.2 GPa
ν_{12}	0.248	0.254
ν_{13}	0.248	0.254
ν_{23}	0.458	0.428
G_{12}	4.4 GPa	4.7 GPa
G_{13}	4.4 GPa	4.7 GPa
G_{23}	3.2 GPa	3.28 GPa
X_T	1500 MPa	1140 MPa
X_C	900 MPa	570 MPa
Y_T	27 MPa	35 MPa
Y_C	200 MPa	114 MPa
S	80 MPa	72 MPa
ε_{1T}	1.087 %	2.132 %
ε_{1C}	0.652 %	1.065 %
ε_{2T}	0.245 %	0.197 %
ε_{2C}	1.818 %	0.644 %
γ_{12U}	4 %	3.8 %

$$\{\varepsilon\} = [S]\{\sigma\} \qquad \{\sigma\} = [C]\{\varepsilon\}$$

$$\begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{Bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & 0 & 0 & 0 \\ S_{21} & S_{22} & S_{23} & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66} \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{31} \\ \tau_{12} \end{Bmatrix}$$

$$S_{21} = -\frac{\nu_{12}}{E_1} = -\frac{\nu_{21}}{E_2} = S_{12} \qquad S_{31} = -\frac{\nu_{13}}{E_1} = -\frac{\nu_{31}}{E_3} = S_{13} \qquad S_{32} = -\frac{\nu_{23}}{E_2} = -\frac{\nu_{32}}{E_3} = S_{23}$$

$$S_{11} = \frac{1}{E_1} \qquad S_{22} = \frac{1}{E_2} \qquad S_{33} = \frac{1}{E_3} \qquad S_{44} = \frac{1}{G_{23}} \qquad S_{55} = \frac{1}{G_{13}} \qquad S_{66} = \frac{1}{G_{12}}$$

$$C_{11} = \frac{S_{22}S_{33} - S_{23}S_{23}}{S} \qquad C_{22} = \frac{S_{33}S_{11} - S_{13}S_{13}}{S} \qquad C_{33} = \frac{S_{11}S_{22} - S_{12}S_{12}}{S}$$

$$C_{12} = \frac{S_{13}S_{23} - S_{12}S_{33}}{S} \qquad C_{13} = \frac{S_{12}S_{23} - S_{13}S_{22}}{S} \qquad C_{23} = \frac{S_{12}S_{13} - S_{23}S_{11}}{S}$$

$$C_{44} = \frac{1}{S_{44}} \qquad C_{55} = \frac{1}{S_{55}} \qquad C_{66} = \frac{1}{S_{66}}$$

$$S = S_{11}S_{22}S_{33} - S_{11}S_{23}S_{23} - S_{22}S_{13}S_{13} - S_{33}S_{12}S_{12} + 2S_{12}S_{23}S_{13}$$

$$\bar{S}_{11} = S_{11}\cos^4\theta + (2S_{12} + S_{66})\sin^2\theta\cos^2\theta + S_{22}\sin^4\theta$$
$$\bar{S}_{12} = S_{12}(\sin^4\theta + \cos^4\theta) + (S_{11} + S_{22} - S_{66})\sin^2\theta\cos^2\theta$$
$$\bar{S}_{22} = S_{11}\sin^4\theta + (2S_{12} + S_{66})\sin^2\theta\cos^2\theta + S_{22}\cos^4\theta$$
$$\bar{S}_{16} = (2S_{11} - 2S_{12} - S_{66})\sin\theta\cos^3\theta - (2S_{22} - 2S_{12} - S_{66})\sin^3\theta\cos\theta$$
$$\bar{S}_{26} = (2S_{11} - 2S_{12} - S_{66})\sin^3\theta\cos\theta - (2S_{22} - 2S_{12} - S_{66})\sin\theta\cos^3\theta$$
$$\bar{S}_{66} = 2(2S_{11} + 2S_{22} - 4S_{12} - S_{66})\sin^2\theta\cos^2\theta + S_{66}(\sin^4\theta + \cos^4\theta)$$

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \begin{bmatrix} \bar{S}_{11} & \bar{S}_{12} & \bar{S}_{16} \\ \bar{S}_{12} & \bar{S}_{22} & \bar{S}_{26} \\ \bar{S}_{16} & \bar{S}_{26} & \bar{S}_{66} \end{bmatrix} \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} \qquad \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} = \begin{bmatrix} c^2 & s^2 & 2cs \\ s^2 & c^2 & -2cs \\ -cs & cs & c^2 - s^2 \end{bmatrix} \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix}$$