Introduction to Yield Envelope/Surface Determination

Laboratory Assignment

Due date: October 9, 2002

The following assignment is to be conducted by each group team and is not an individual assignment. Present your answers in a form of a report (at least one and a half page long).

Please specify in your report with subsections for each specific question you have responded to. Follow the attached format on how to write a report. Report should be typed with 12pt font with single spacing, it should be elegant. Any writing style is acceptable. Equations should be typed in a scientific manner (e.g. equation mode in Word should be used).

1. Describe the Enhanced Arcan Apparatus (EAA) test set-up for determining yield envelope/surface of ultralight materials; e.g. what are its main components, how is it used to determine the yield surface, what forces are measured, what is used to measure those forces, describe potential sources of error and quantify those errors if possible, describe any necessary calibratrion, etc. Why is it important to have uniform stress and strains acting in the gage section of the tested specimen in the EAA?

2. Describe the loading configuration of the EAA: is it statically determinate or indeterminate, is it plane stress or plane strain configuration? Let the direction perpendicular to the gage section of the butterfly specimen be y and the direction parallel to its gage section be x. List the stresses and strains acting on the specimen.

3. Draw a free body diagram of the reaction forces acting on the ultralight specimen and at the EAA joints after the EAA undergoes a resultant displacement of δ applied by the MTS testing machine.

4. If F_V represents the reaction force along the resultant displacement δ and F_H represents the perpendicular reaction, prove from your free body diagrams that the longitudinal and shear stresses in the gage section of the butterfly specimen are given by

$$\sigma_{yy} = \frac{F_V}{A}\boldsymbol{sin}\,\alpha - \frac{F_H}{A}\boldsymbol{cos}\,\alpha$$

$$\sigma_{xy} = \frac{F_V}{A}\boldsymbol{cos}\,\alpha + \frac{F_H}{A}\boldsymbol{sin}\,\alpha$$

where α is the angle between F_V and the gage section. In the lab demonstration F_V was measured by the load cell of the MTS testing machine, while F_H was not measured. Instead, a longitudinal force F_L was measured, so that the longitudinal stress can be obtained directly as follows

$$\sigma_{yy} = \frac{F_L}{A}$$

$$\sigma_{xy} = \boldsymbol{?}$$

draw a free body diagram with F_V and F_L acting on the specimen and determine σ_{xy} as a function of A, F_V, α .

5. Given a uniform displacement filed u^o, v^o at the boundary of the butterfly specimen in x and y directions respectively, assume the following kinematically admissible displacement field within the specimen

$$u = \frac{u^o}{2} + \frac{u^o}{h} y$$
$$v = \frac{v^o}{2} + \frac{v^o}{h} y$$

where h is the gage length of the specimen. Determine the longitudinal and shear strains acting in the specimen. Using the constitutive relations for an isotropic material in plane stress, find β in the following equation

$$\frac{\sigma_{yy}}{\sigma_{xy}} = \beta \frac{\varepsilon_{yy}}{\gamma_{xy}}$$

6. Suppose that the loading joint in the EAA was a roller support with F_V the only non-vanishing force acting in the specimen. From the free body diagram, determine the longitudinal and shear stresses

$$\sigma_{yy} = ?$$
$$\sigma_{xy} = ?$$

Calculate the error you would have on the stress determinations using the above equations instead of the original equations determined in Question 4.

7. Your group was given experimental data of F_L, F_V for a honeycomb tested during the lab demonstration for a given angle. Calculate the σ_{xy}, σ_{yy}. Define the turning point of the $\sigma_{xy} - \sigma_{yy}$ curve as the yield point for the honeycomb and obtain its value. Does this correspond with the following yield surface for this honeycomb (*determined by Doyoyo and Mohr, 2002*)

$$\left(\frac{\sigma_{xy}}{\tau^o}\right)^2 - \frac{\sigma_{yy}}{\sigma^-} - 1 = 0$$

where $\boldsymbol{t}^o = 1.0 \pm 0.05$ MPa and $\boldsymbol{s}^- = 3.0 \pm 0.1$ MPa.

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8. Two different yield surfaces, namely; the Mises and Tresca criterions apply for metals, while Mohr-Coulomb yield envelope is used for soils, rocks or concrete. What types of tests are used to determine these yield surfaces for metals and soils? How do they differ from the current test (i.e. the EAA) for ultralight materials? Discuss briefly. Is uniformity of stress and strains at the gage section also a requirement?