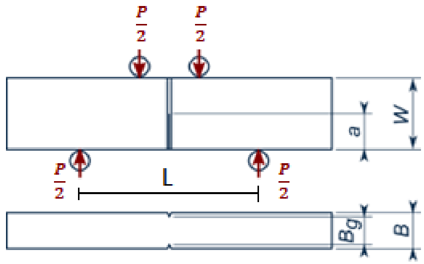
Fracture testing for polymers: python script for creep compliance calibration method

1. Introduction:

Creep compliance calibration forms the foundation for creep fracture testing of polymers, especially in the context of samples exhibiting a crack. The method establishes a relationship between material behavior under a sustained load and the progression of a crack in the sample.

2. Theoretical Background:

In the creep testing machines, a four-point bending setup on a SENB sample (picture below) is utilized.



The stress intensity factor, represented by *K*, is a measure of the stress distribution near a crack tip and plays a pivotal role in the analysis. It's computed as:

$$K = Y\left(\frac{a}{W}\right)\frac{PL\sqrt{\pi a}}{B^{*}W}$$

Where the shape factor *Y*, dependent on the sample geometry, is given by:

$$Y = 1.12 - 1.39\left(\frac{a}{W}\right) + 7.32\left(\frac{a}{W}\right)^{2} - 13.1\left(\frac{a}{W}\right)^{3} + 14\left(\frac{a}{W}\right)^{4}$$

This shape factor is valid up to a/W = 0.6, ensuring its application within the limits of this experimental setup.

An inherent challenge in the process is the difficulty in visually observing the specimens due to the design of the testing machines. Hence, a compliance calibration method is preferred. The premise of this technique is that the increase in sample compliance $C = \frac{displacement}{Load}$ can be expressed in terms of distinct contributions from viscoelastic creep and crack growth. The four-point bending configuration allows *C* to be defined as:

$$C\left(\frac{a}{W},t\right) = D(t) * \Phi\left(\frac{a}{W}\right)$$

For a given specimen, only two parameters, D(t), the creep compliance of the material and (a/W), vary during the test. The term Φ(a/W) acts as a geometry calibration factor. In fracture mechanics, samples can be categorized based on their notch type. A sharp sample (SENB with a sharp notch) will have a pronounced crack or defect that could propagate under stress. On the other hand, a blunt sample (SENB with a blunt notch) possesses a less pronounced crack or defect. Differentiation is vital, as sharp samples are primarily used in this testing procedure for determining crack onset and progression. Blunt samples, analyzed separately, are critical for understanding the material's intrinsic creep behavior.

To decipher the onset of the crack, the ratio $\frac{D_{sharp}}{D_{blunt}}$ is monitored. The moment this ratio surpasses 1.01, crack initiation is presumed.

3. Script Overview & Sample Naming Convention:

The script provides a structured process for creep test data analysis, focusing on time vs displacement analysis from LVDT data.

Sample Name Convention:

Samples are code-labeled like this *X NN greek b:*

- **Material Type (X):** Represents the polyethylene grade (A, B, C, D).

- **Plate Number (NN):** A two-digit identifier for the plate of origin (like 05 for 5).

- **Test Type (greek):** Denotes the test type: alfa for SENB sharp notch, delta for SENB blunt notch.

- **Sample Number (b):** Pinpoints the sample's specific number from a particular plate.

Sample Name Examples:

- A04alfa1

- B10alfa11

- C02delta3

4. Script Execution Steps:

4.1 User Input & Sample Identification:

- The user specifies the sample to analyze.

- The script checks "creep_database.txt" for the sample name.

- Using `get_variable_value(sample_name, variable_name)`, relevant data is extracted from the database.

4.2 Data Retrieval & Preliminary Analysis:

- It locates the corresponding data file (based on the test end date).

- Adjusts displacement data based on the initial position (L_0) of the LVDT.

- Reduces data points for computational efficiency using "reduce_arrays(x, y, threshold=1E-4)".

4.3 Visualization & Data Elaboration:

- Displays the displacement vs. time graph.

- Offers options to refine data:

  1. Remove pre-test points.

  2. Adjust plot limits for better pinpointing of the test's start.

  3. Exit the script.

- The user typically selects the first option to fine-tune the data's start point.

4.4 Compliance Calculation & Comparison:

- Computes the fictitious creep compliance of the sample using database data.

- The user is shown plots comparing the computed compliance against blunt samples from the database.

- An interactive graph is displayed. The user may need to adjust the sharp sample's compliance vertically to superimpose it over the blunt sample's curve. This adjustment addresses measurement discrepancies in initial values and geometrical parameters.

4.5 Crack Onset & Calibration Method:

- Utilizing the criterion $\frac{D_{sharp}}{D_{blunt}} \geq 1.01$, the crack onset point is determined.

- The calibration method is then employed to generate the defect values (a) against time.

4.6 Data Fit & Output:

- The scattered values of 'a' are fitted using an hyperbolic function.

- This fit yields two crucial outputs:

  1. The stress intensity factor (K) as a function of time.

  2. The derivative of 'a' concerning time, leading to a da/dt vs. K plot.

- Finally, the script produces two output files. One holds all the analytical data (in the output_folder), and the other (a series of files) segments the data based on the material and test environment (in sorted_folder).