System Compliance Correction

Problem

In a tensile testing machine, the measured crosshead displacement includes both the actual specimen deformation and the elastic deformation of the machine frame, load cell mount, and clamping system. In this machine, the structural components are 3D-printed from CF-PLA, which has limited stiffness compared to metal, and dimensional tolerances of printed parts introduce additional play in the load path. As a result, the system compliance is significant relative to the specimen deformation and must be corrected to obtain accurate strain and modulus values.

Characterization

The system compliance was measured by loading a rigid steel specimen (negligible deformation) and recording force vs. displacement. This isolates the pure machine deformation as a function of applied force.

Key findings:

• The system behaves nonlinearly at low forces due to progressive seating of contact surfaces in the load path.

• Above approximately 100 N, the system stiffness is linear at approximately 800 N/mm and highly reproducible.

• Repeated measurements showed a displacement scatter of less than ±0.005 mm and a stiffness variation of less than 0.5% across the full force range.

Correction Method

Rather than using a simple linear stiffness correction (which would introduce errors in the low-force region), a lookup table approach was chosen:

1. Multiple steel reference measurements were averaged to produce a mean force–displacement curve for the system.

2. This curve is stored as a lookup table with force in 5 N increments.

3. During post-processing, the system displacement is interpolated from the lookup table for each measured force value and subtracted from the raw displacement:

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d_corrected(F) = d_measured(F) - d_system(F)
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This approach captures the full nonlinear compliance behavior without requiring a parametric model, and is straightforward to update if the machine setup changes — simply repeat the steel reference measurement.

Effect on Results

Without correction, the measured displacement is dominated by the system compliance, leading to a significant underestimation of the E-modulus. After applying the lookup table correction, the calculated material properties are consistent with expected literature values for 3D-printed PLA and PETG.