Improvement of uniaxial testing apparatus for micro-scale material systems

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Abstract

Common methods of testing mechanical properties of micro-scale systems need a collection of specialized parts that are costly and difficult to set up. A new uniaxial testing apparatus that has been proposed takes advantage of less costly methods such as 3D printing of tensile fixture and image reference markers for accurate data acquisition. With such less costly methods, resolution, accuracy, and repeatability become more prevalent issues of needed improvement. The purpose of this research is to find methods to improve the resolution, accuracy, and repeatability of this newly designed testing apparatus.

Methodology

- Design a version of a hinged sample for uniaxial testing using criteria from previous literature.
- Use Ansys Static Structural to Simulate scenarios of error due to non-uniaxially applied loads on both a standard dog-bone specimen and the hinged sample design to test the error reduction of the hinged sample design.
- The Material used for both the Dog Bone Specimen and Hinged Sample Design is Single Crystal Silicon with Young's Modulus of (E = 169 GPa) and Poisson's Ratio of (ν = 0.25).
- Design and incorporate an appropriate Uniaxial testing Apparatus (Material of Testing Apparatus is Polylactic Acid (PLA)) to use with the Dog bone specimen and hinged sample design.
- For both the Dog-bone specimen and Hinged Sample Design, Incorporate two different levels of misalignment, one small and another large, into the stage-sample set-up then use Ansys Static Structural to apply a linearly increasing displacements at one end of the stage while keeping the other end fixed.
- Using the data from the previous simulations plot stress-strain curves to determine whether the Hinged Sample design significantly reduced error in calculated Elastic Modulus when compared to a standard dog-bone sample.
- For the dog-bone sample and hinged sample design, compare the three different scenarios of: no testing stage, testing stage with small misalignment, and testing stage with increased misalignment. For all data sets, the elastic modulus and its percent error were calculated. Excel and Origin Pro were used for the data analysis.

Analysis and Results

Figure 1: **Hinged Sample Design**

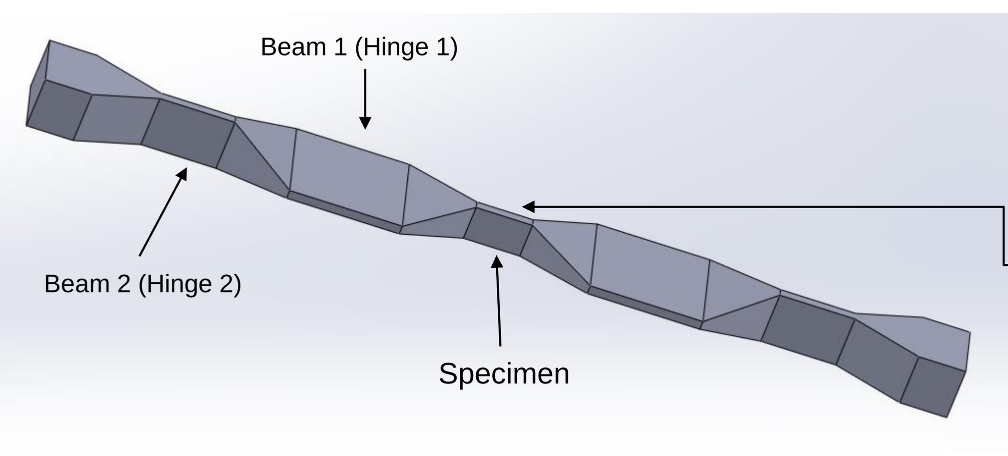


Figure 2: **Uniaxial Testing Apparatus**

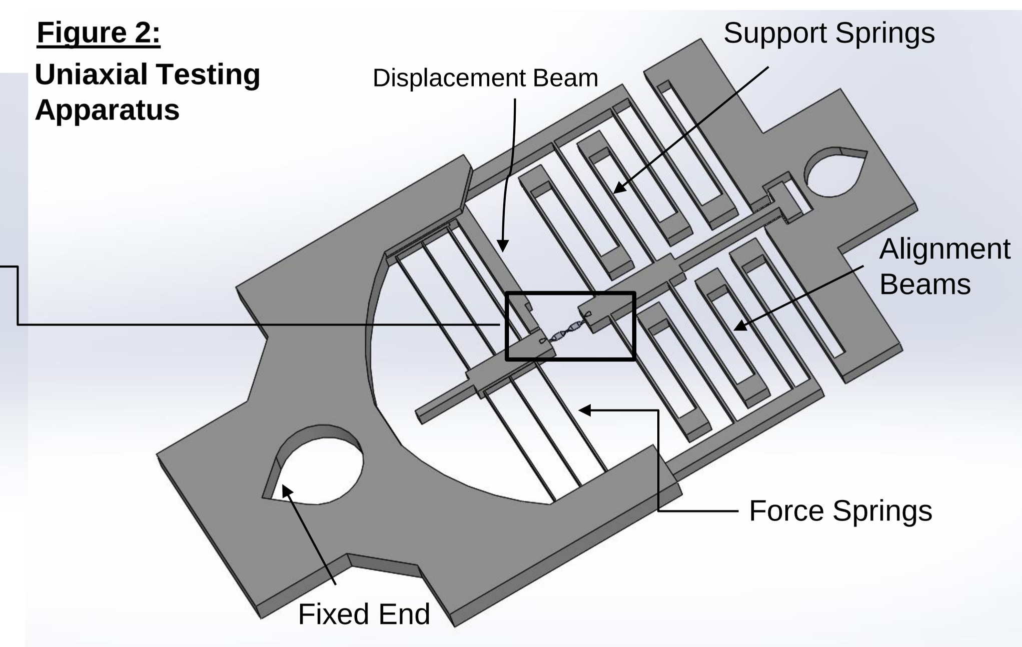
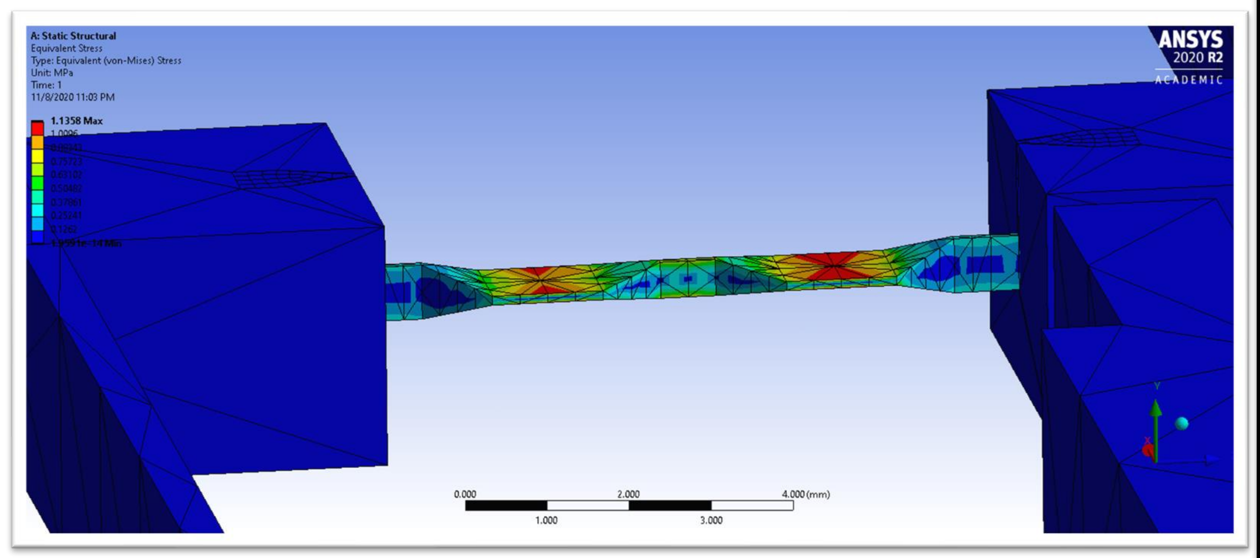
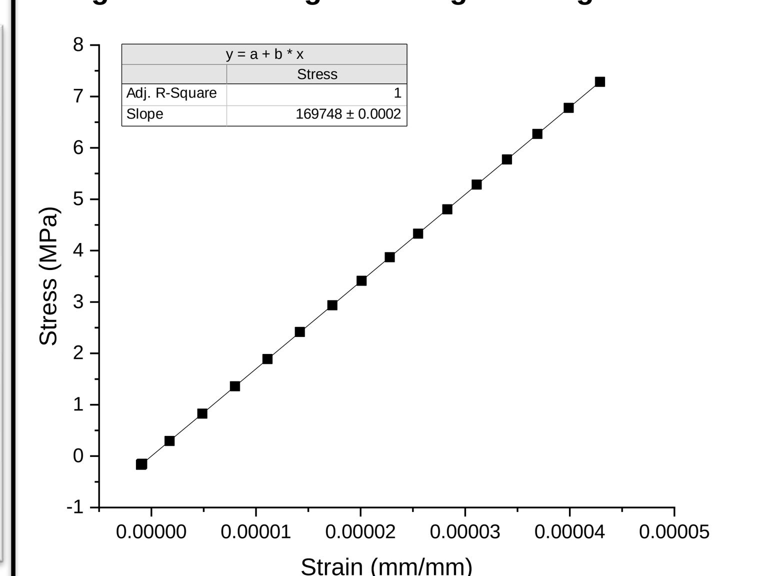


Figure 3: **Zoom in view of Hinged Sample Design on Testing Apparatus while going through loading (Neutral Axis Visible)**



The Stress Analysis shown in figure 3 serves as a visual representation of how the Hinge-like beams in the Hinged Sample design will take away and reduce non-uniaxial stress undergone by the specimen.

Figure 4: **Stress-Strain Curve for Hinged Sample Design while on stage with large misalignment**



The Linear Fit to the Stress-Strain curve in Figure 4, displayed a slope or Elastic Modulus of 169.748 GPa which is very close to the theoretical Value of 169 GPa with only an error of 0.44%.

Table 1: **Results of Elastic Modulus and Percent Errors Calculations for all Simulations**

Without Testing Apparatus and with Misalignment	Calculated Elastic Modulus (GPa)	Error in Elastic Modulus (%)
Dog-Bone Sample	156.867	7.18
Hinged Sample Design	171.001	1.18
Testing Apparatus with Increased Misalignment	**Calculated Elastic Modulus (GPa)**	**Error in Elastic Modulus (%)**
Dog-Bone Sample	166.188	1.66
Hinged Sample Design	169.748	0.44
Testing Apparatus with Small Misalignment	**Calculated Elastic Modulus (GPa)**	**Error in Elastic Modulus (%)**
Dog-Bone Sample	167.701	0.77
Hinged Sample Design	169.396	0.23

Conclusion

One of the proposed methods to reduce error was to introduce a sample which uses hinge-like mechanisms to reduce non-uniaxial loading on the central specimen, this sample was called the Hinged Sample Design and was initially proposed by Dr. Wonmo Kang. The results display that, not only does the uniaxial testing apparatus reduce errors, but the introduction of the Hinged Sample design further reduces them. Figure 4 highlights the significance of using the combination of a Hinged Sample Design and the Uniaxial Testing Apparatus. Even with large misalignment of the hinged sample design on the loading frame, error was heavily reduced; the percent error was only 0.44%. As can be seen from the results in Table 1, even without the uniaxial testing stage, the hinged sample design still largely outperformed the standard dog bone sample. The results in Table 1 also show that using a testing stage with a standard sample will still show relatively small percent error values such as1.66% with large misalignment.

Impact

- Small errors in the presented micro-scale material characterization testing systems will help make these tests more affordable and accessible which will facilitate further research in the growing field of nano-technology.
- The next step is to bring these simulations to life and develop a reliable, convenient, and reproducible method for these uniaxial testing systems.

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Works Cited

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