Flexible Filament 3D Printing for Tensile Testing Equipment Validation

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Introduction

Tensile testing is a fundamental procedure for material testing, and a material's tensile strength is widely used as a simple yet effective predictor for its behavior. This testing procedure is well defined at many scales, but some are lacking. In this instance, my lab mentors have designed clamping grips to perform tensile testing on atypical microscale specimens like soft tissue or contact lenses. To validate the precision and accuracy of tests using the grips, a microscale test specimen is needed so that experimental results can be compared to a known tensile strength value.

Methodology

An Original Prusa i3 MK3S 3D printer was used to print dog bone tensile test samples from Recreus Filaflex 70A filament. This filament is a highly elastic polyurethane to simulate flexible test specimens. The printing profile was refined for size (14 mm x 3 mm x 0.27 mm, 7 mm x 2mm gauge length) and fill consistency. A solution of water-soluble PVA glue was applied to the printing surface and allowed to dry; after printing, water was used to free the samples without applying any stress. Enough samples were printed to determine appropriate tensile testing parameters. Tensile testing results were then compared to the stress values at 20%, 100%, and 300% elongation provided by the filament manufacturer.

Results

Figure 1: Microscope view for material fill validation

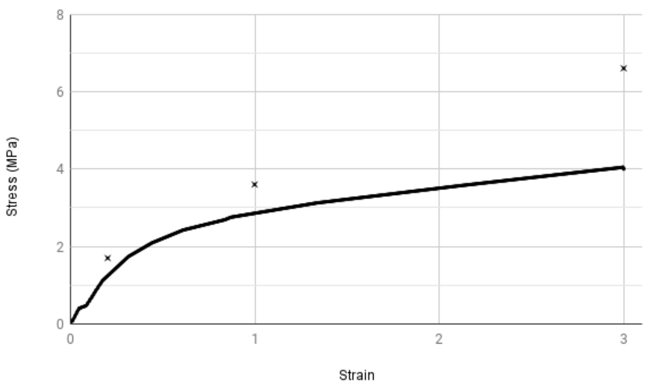

Figure 2: Experimental stress versus strain data from tensile test, shown with manufacturer's data points at 20%, 100%, and 300% elongation

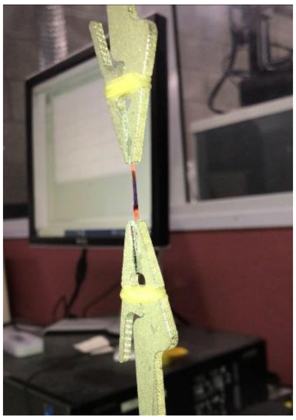

Figure 3: Clamping grip mechanism; inclusion of unmarked material not in original gauge length

Discussion

Measured stress values consistently underperformed compared to manufacturer values at every given strain. This effect is more severe as strain increases. For example, the manufacturer provides a stress value of 3.6 MPa at 100% elongation, while the average specimen tested around 2.8 MPa at that strain. Possible sources of this underperformance include slipping from the grips, compounding strain effects from the grip deformation, and abnormal tensile behavior due to the micro scale. Since the specimens were not observed to move in the clamps during testing, complete slipping was ruled out. The loads were small enough (<2 N) to rule out clamp deformation. Some specimens were marked only along their gauge length. It was observed that unmarked material made its way into the testing length of the specimen, shown above in Figure 3. This effect would cause the understatement of stress values. Unfortunately, it seems to be an intrinsic property of the filament. However, when the marked section was measured across multiple tests, it remained constant around 9.9 mm. This is a positive sign for the consistency of the clamps, but more work is needed to see how this would affect the desired test samples, e.g., contact lenses.

Conclusion

- Clamping grip design gives consistent testing conditions so that measurement variability is likely from the samples
- Current design may be more adequate for comparisons between specimens, but not yet for absolute measurements

References

DIN ISO 53504:1994-05, *Determination of tensile stress/strain properties of rubber*

Recreus "Filaflex 70A Ultra-Soft," Datasheet, Revised 02.12.20

Acknowledgements

Many thanks to Ryan Paetzold and Dr. Christopher Musgrave, both of the UCD School of Mechanical and Materials Engineering. Their generosity in time and expertise (and their clamp design) made this research possible.