Exploration of the Torsional Properties of EPON 826/LS-81K Epoxy

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1) Motivation

Tubular braided composites (TBCs) are tubular structures made by interlacing fibers over a mandrel at adjustable angles as shown in Figure 1. To create TBCs, interlaced fibers in a tubular shape are cured with an epoxy resin to create a matrix that binds together the reinforcing fibers, thereby distributing the loads and provide cohesion to the composite overall structure.

The goal of this Dean Research Award (DRA) is to understand and accurately predict the failure mode of TBCs under compression. To do so, epoxy compression and torsion samples will be created and experiments will then be conducted to determine the shear strength and by extension, the shear modulus of epoxy resin. Experimental data will also show the failure mode of the epoxy, which will be compared with the model predictions.

Figure 1: Solid model of TBC

Some of the major factors that determine failure mode of TBCs in compression:

1. Modified Load Factor, $\frac{PE^2}{t^2k^3}$
   a) Load, P
   b) Length, l
   c) Elastic Modulus, E
   d) Shear strength, k
2. Modified Shape Factor, $\frac{k\Phi}{E}$
   a) Shape efficiency, $\Phi = \frac{r}{t}$
   b) Radius, $r = \frac{outer\ diameter}{2}$
   c) Thickness, $t = \frac{outer\ diameter - inner\ diameter}{2}$

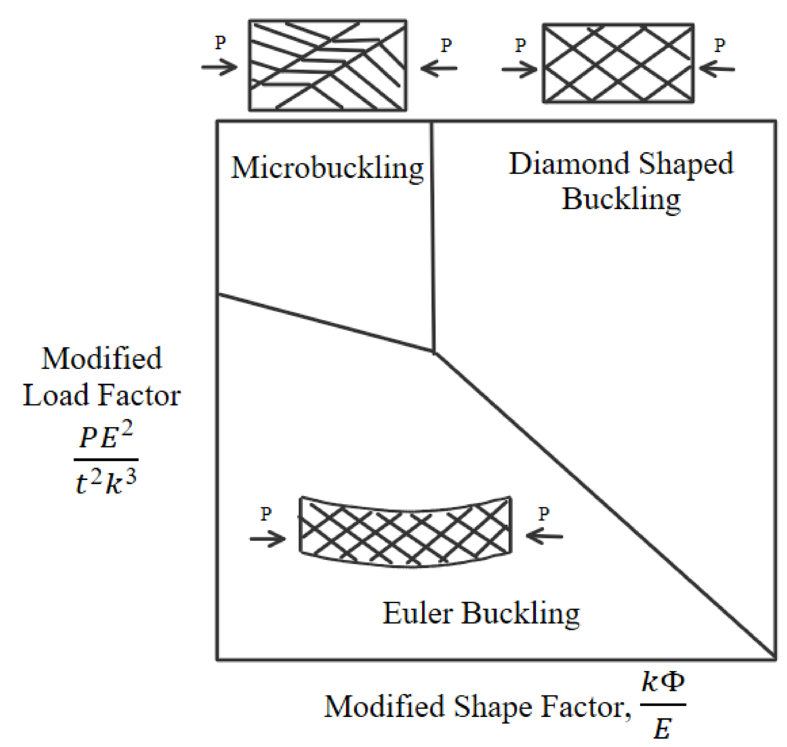


Figure 2: Shape efficiency map for TBCs recreated from Harte and Fleck [2]

2) Background

Epoxy resin is considered a homogenous, isotropic material with a brittle tensile failure. Shear properties of epoxies are currently derived from tensile results. However, results from other research papers suggest that the epoxy resin may fail in ductile manners under torsion loads [1] [2]. Hence, it is necessary to measure shear properties directly through testing.

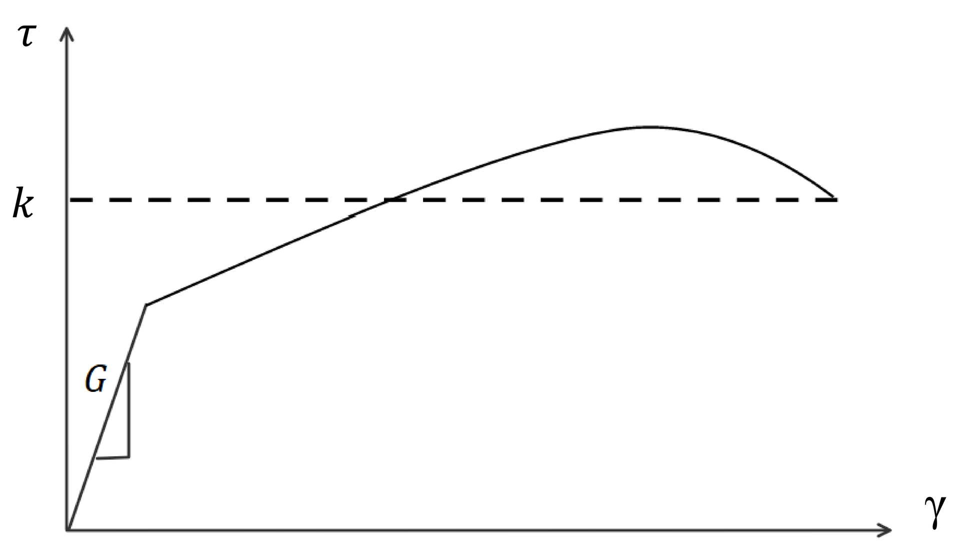
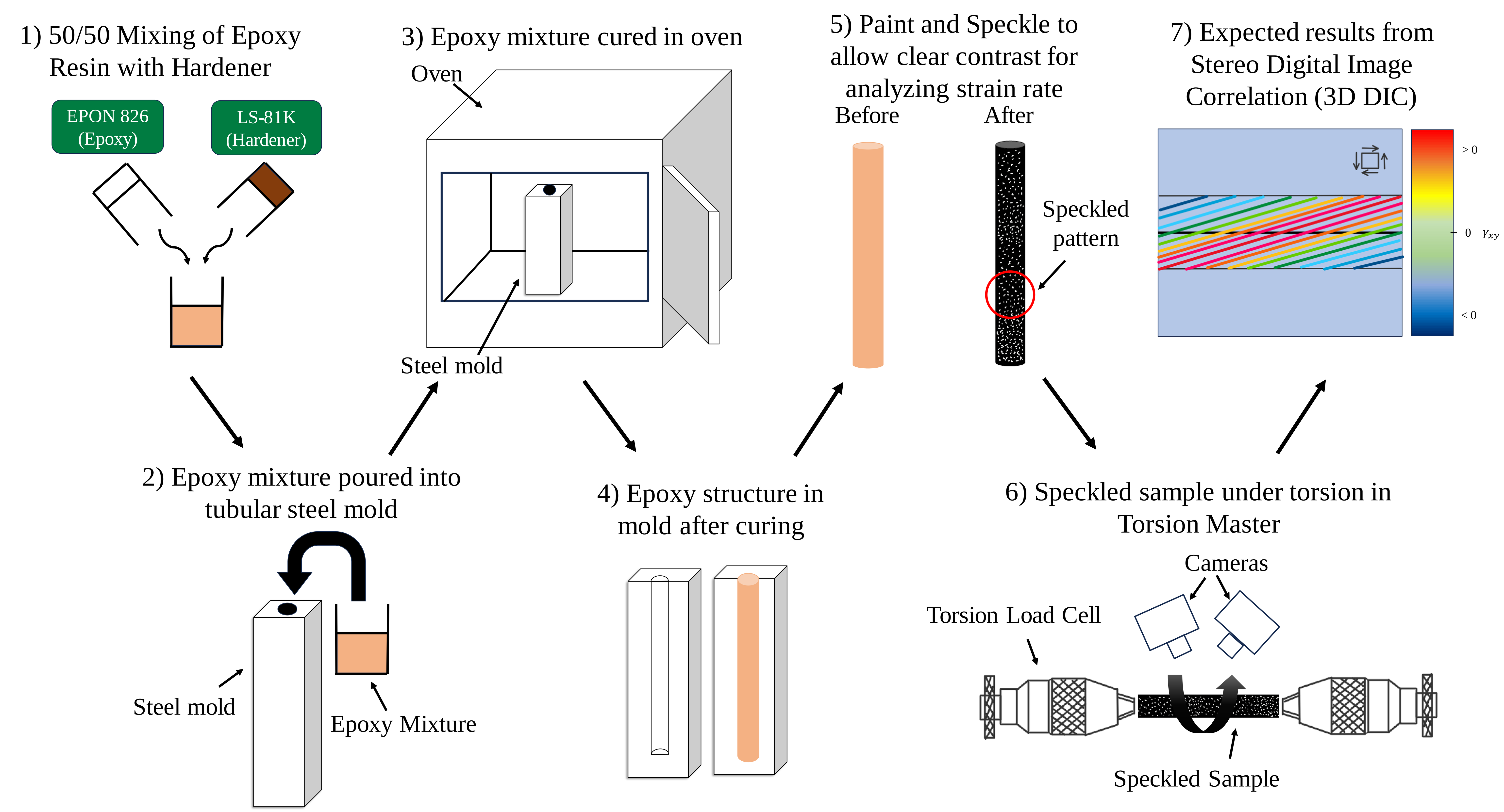


Figure 3: Generalized shear stress versus shear strain graph

From a typical ductile shear stress vs shear strain diagram, the shear modulus, G, can be found as the slope of the linear elastic region and the shear strength, k, can be found as the maximum shear stress.

3) Manufacturing and Testing



4) Analysis

After the testing is complete, load data is extracted from the Torsion Master and combined with deformation data from the 3D DIC to create shear stress vs shear strain diagrams. Consequently, this will be used for:

1. Shear stress, τ, will be calculated using the torque output, T, from the Torsion Master

$$\tau = \frac{Tr}{J}; J = \frac{\pi r^4}{2}\ for\ a\ circular\ tube$$

2. Shear strain, γ, will be calculated from the images by using the image processing software, DaVis 8.2.

This will allow us to find the shear strength, the shear modulus as the slope of the linear elastic region and therefore failure mode of the epoxy.

5) Conclusion

For the purposes of the DRA, the torsion test or the DIC data have yet to be processed and analyzed. However, all the necessary theory and experimental procedures are laid out to find the shear strength and shear modulus of EPON 826/LS-81K. This data will later be used to compare with the mechanical properties obtained from the tensile tests to show whether epoxy can be assumed to be a homogenous and isotropic material.

6) References

[1] Y. Hu, Z. Xia, and F. Ellyin, "The Failure Behavior of an Epoxy Resin Subject to Multiaxial Loadings," 2006.

[2] Harte, A. M., & Fleck, N. A. (2000). DEFORMATION AND FAILURE MECHANISMS OF BRAIDED COMPOSITE TUBES IN COMPRESSION AND TORSION. www.elsevier.com/locate/actamat