Mechanical Properties of G-10 Glass–Epoxy Composite

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MECHANICAL PROPERTIES OF G10 GLASS-EPOXY COMPOSITE

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The mechanical properties of G10 glass-epoxy composites were determined in compression and tension tests. From weight and volume measurements, the volume fraction of glass was estimated to be about 56 percent. The mechanical property results are summarized in Tables I and II. The samples were cut from sheet stock with z-axis along the thickness direction. Appendix A shows the sample dimensions. The modulus values were determined by fitting a straight line to the initial linear portion of the stress-strain curves shown in Figs. 1–5. For the compression test, the strain was calculated from the displacement of the crosshead divided by its gage length; these are plotted in Figs. 1–3. The modulus was calculated after determining that the compliance of the loading system was 1.57×10^{-8} m/N. However, in the tension tests, a clip gage extensometer with a gage length of 1 inch was used. Therefore, the modulus measurements from the tension test are the correct values, while the modulus from the compression tests may be biased with the compliance of the loading system. Photographs of failed compression specimens are shown in Figs. 6 and 7. A similar characteristic failure pattern with a crack at a 45 degree angle is observed. The only difference between the X, Y, and Z was the peak stress at which it cracked.

Table I. Compressive Properties

	Young's Modulus	**Peak Stress**	**Average Modulus**	**Average Peak Stress**	**Standard Deviation of Modulus**	**Standard Deviation of Peak Stress**
	GPa	MPa	GPa	MPa	GPa	MPa
X-1	17.47	368	**18.8**	**365**	1.26	4
X-2	18.89	368				
X-3	19.97	360				
Y-1	19.90	302	**18.9**	**300**	0.89	5
Y-2	18.33	294				
Y-3	18.39	303				
Z-1	7.32	437	**7.83**	**440**	0.87	7
Z-2	7.33	436				
Z-3	8.83	448				

Table II. Tension Properties

	Young's Modulus	Peak Stress	Average Modulus	Average Peak Stress	Standard Deviation of Modulus	Standard Deviation of Peak Stress
	GPa	MPa	GPa	MPa	GPa	MPa
X-t-1	18.63	223	**18.83**	**233**	0.22	10
X-t-2	18.80	244				
X-t-3	19.06	232				
Y-t-1	19.02	319	**19.26**	**310**	1.15	9
Y-t-2	18.25	301				
Y-t-3	20.50	310				

Results from the high strain-rate tests in a split-Hopkinson compression experiment are summarized in Table III. Figs. 11–13 show the results of stress-strain obtained from the Hopkinson bar experiments with aluminum bars. Reliable reflected signals were not always obtained since the specimen began to crumble. Therefore, estimates of both the strain rates and strains are difficult to obtain; it is accurate to indicate that the strain levels were in the order of 10^3 s^{-1}. Dynamic modulus estimates from these tests are also not likely to be accurate and hence these calculations were not performed. The peak stress at breaking is rather well defined since this depends only on the intensity of the strain signal in the output bar of the Hopkinson arrangement. For the X and Y orientations, the compressive strength increases by nearly a factor of two and may be attributed to the strain rate dependence of the polymer matrix. For the Z orientation, the specimen crumbled into a powder suggesting that dilation of the specimen occurred during the nonlinear increasing part of the stress strain curve shown in Fig. 13. Proper interpretation of the data beyond a strain level of about 3 percent is not easily accomplished and the values of peak stress indicated is likely to be a significant overestimate of the actual peak stress.

Table III. Hopkinson-Bar Properties

	Peak Stress
	MPa
X-H-3	-677
X-H-4	-617
Y-H-2	-528
Y-H-3	-528
Z-H-1	-901
Z-H-2	-856

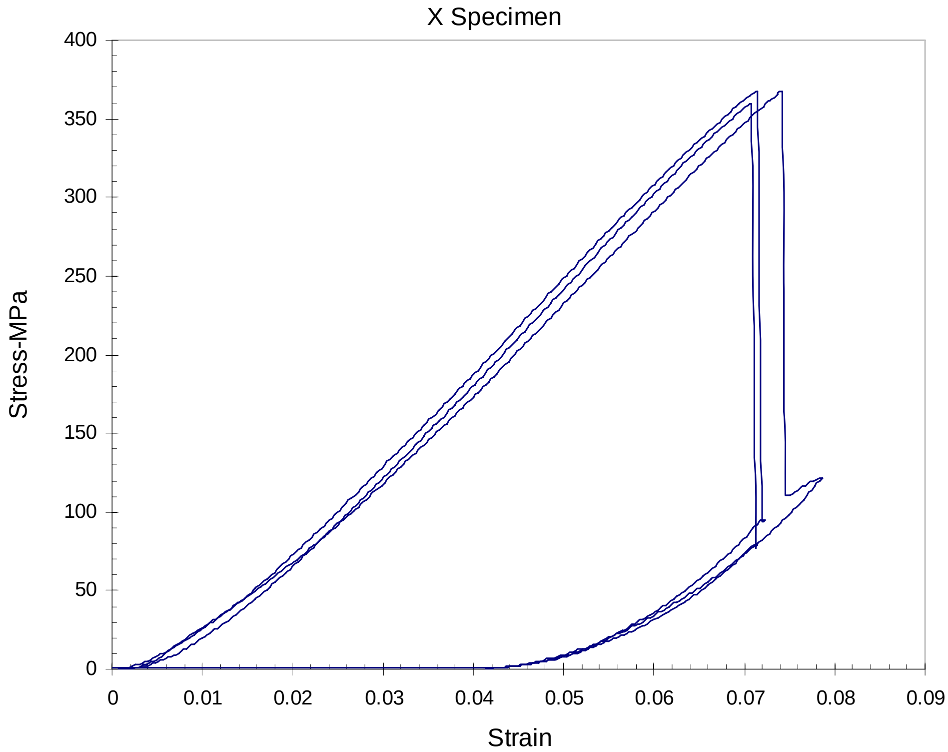

Figure 1. Stress-strain curve for G10-Orientation X; compression.

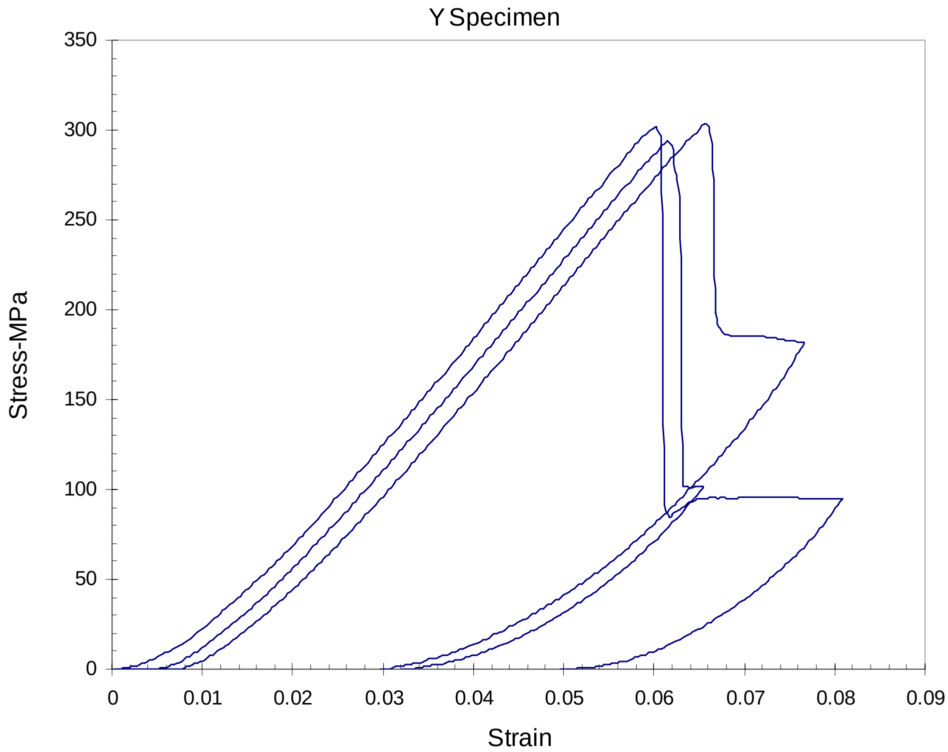

Figure 2. Stress-Strain curve for G10-Orientation Y; compression.

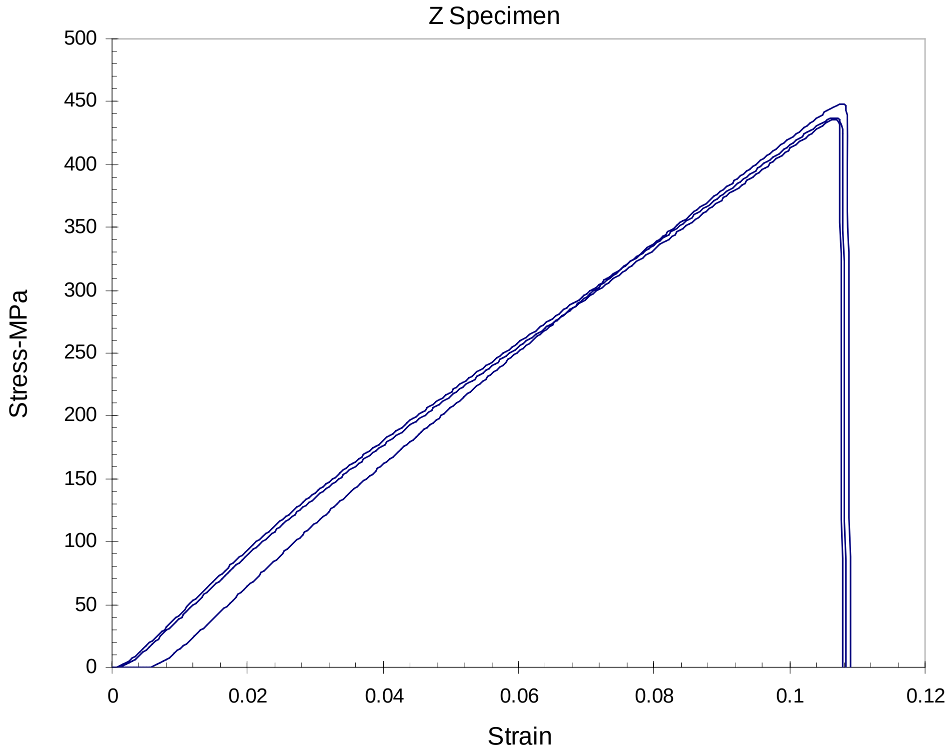

Figure 3. Stress-Strain curve for G10-Orientation Z; compression.

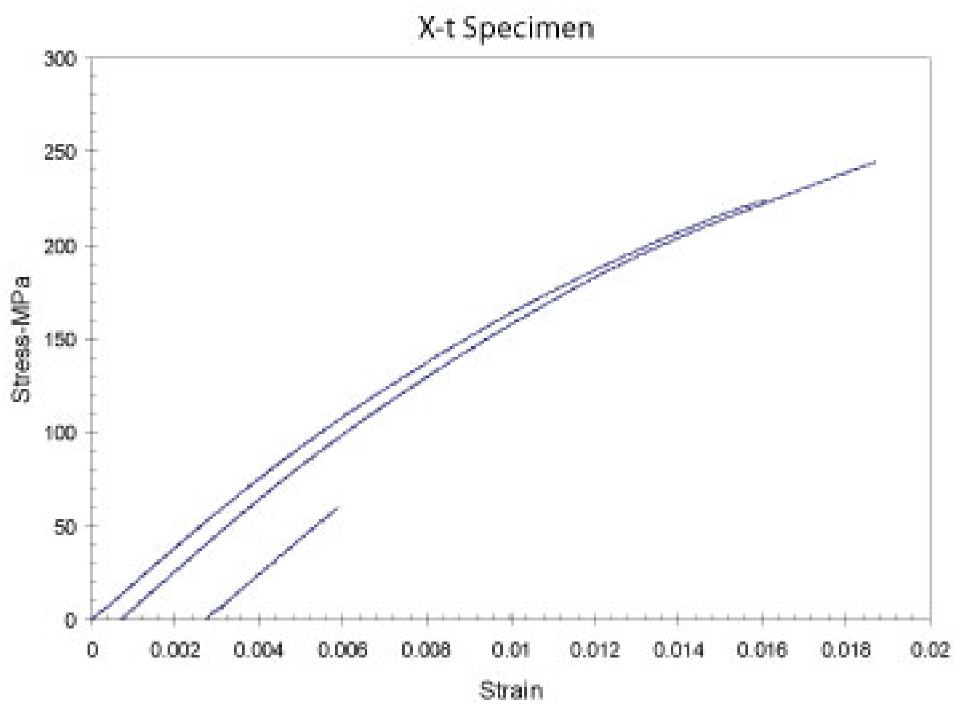

Figure 4. Stress-Strain curve for G10-Orientation X; tension.

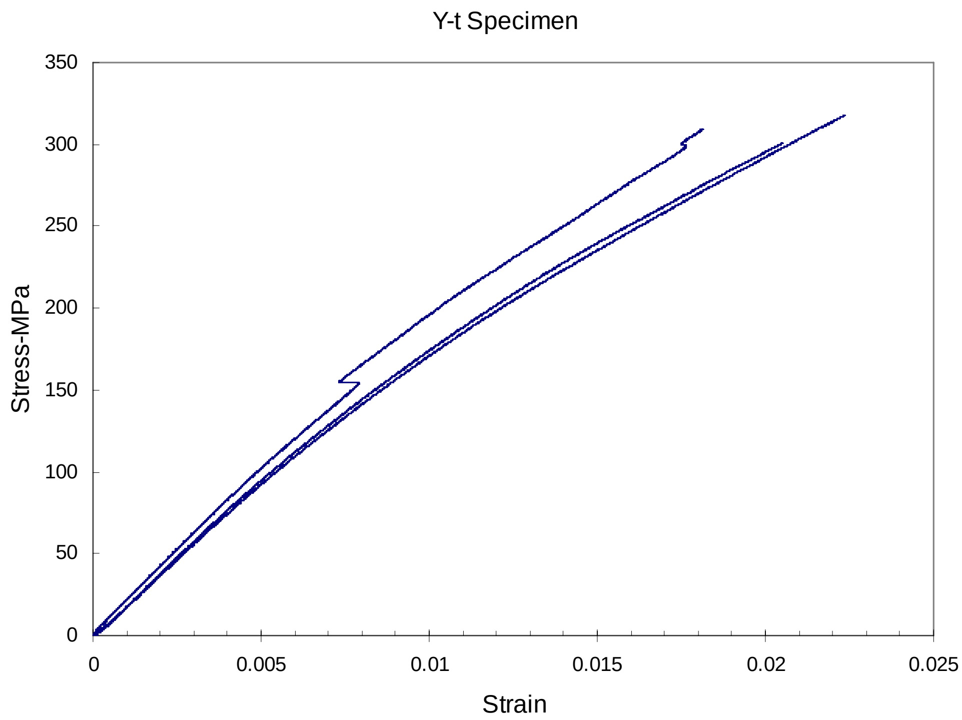

Figure 5. Stress-Strain curve for G10-Orientation Y; tension.

Figure 6. Photograph showing failure mode; Specimen X-3.

Figure 7. Photograph showing failure mode; Specimen Z-2.

The failure patterns in the tension tests are shown in Figs. 8, 9, and 10. While many of them splintered (Figs. 9 and 10), others had a cleaner break. However, all specimens broke on the gage section between the clip gage extensometer, indicating a valid peak stress measurement.

Figure 8. Photograph showing failure mode; Specimen X-t-1.

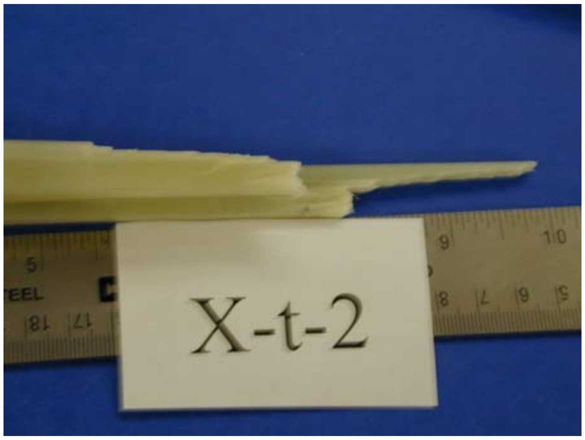

Figure 9. Photograph showing failure mode; Specimen X-t-2.

Figure 10. Photograph showing failure mode; Specimen Y-t-2.

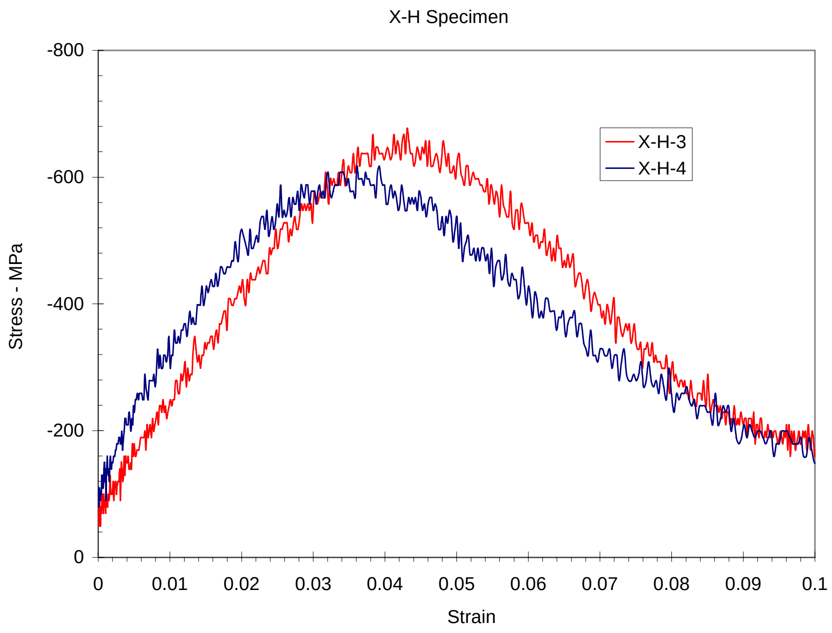

Figure 11. Stress-strain curve for G10-Orientation X; Hopkinson.

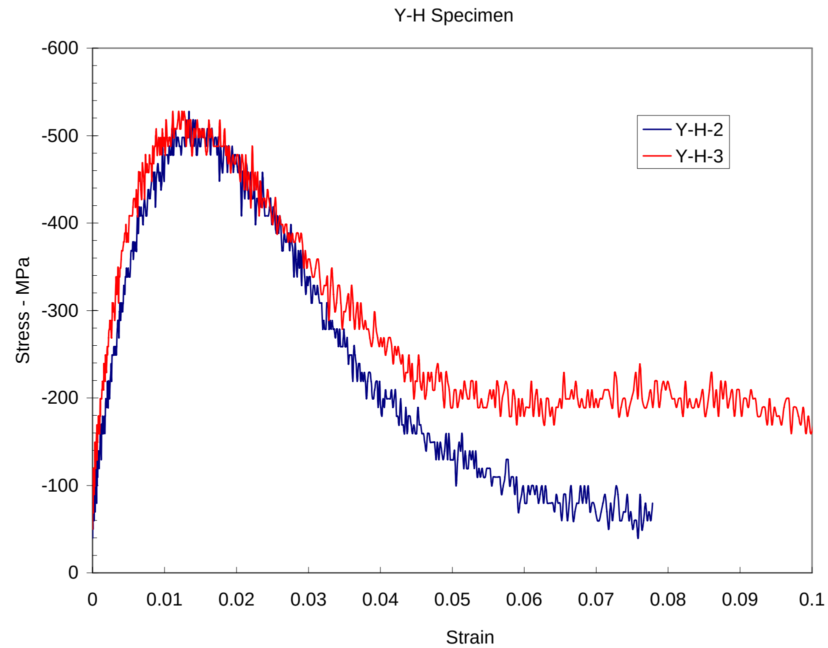

Figure 12. Stress-strain curve for G10-Orientation Y; Hopkinson.

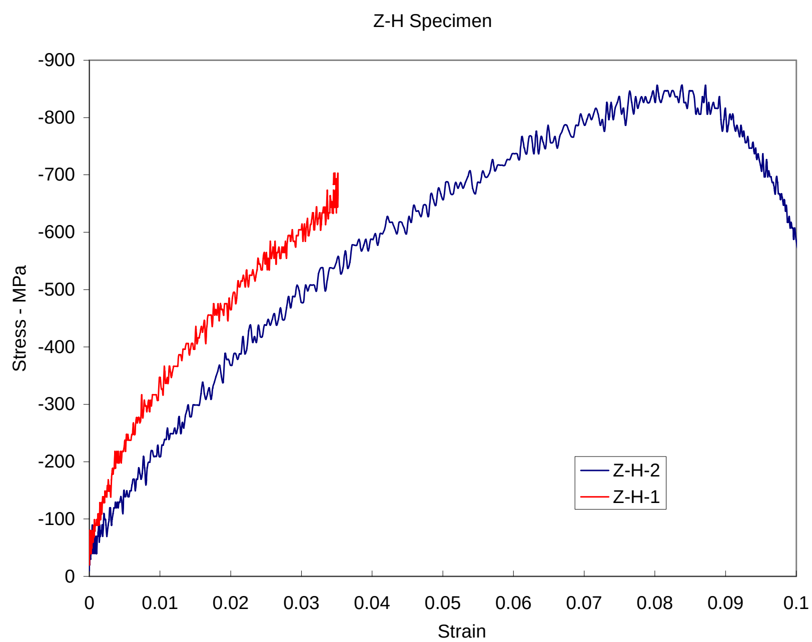

Figure 13. Stress-strain curve for G10-Orientation Z; Hopkinson.

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APPENDIX A

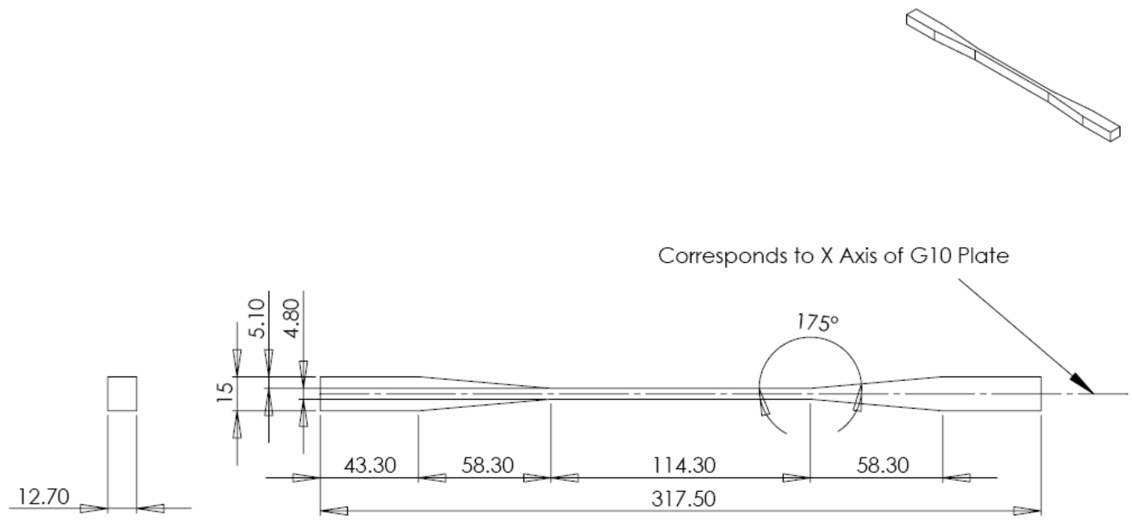

Figure A-1.Sample dimensions for tensile tests.

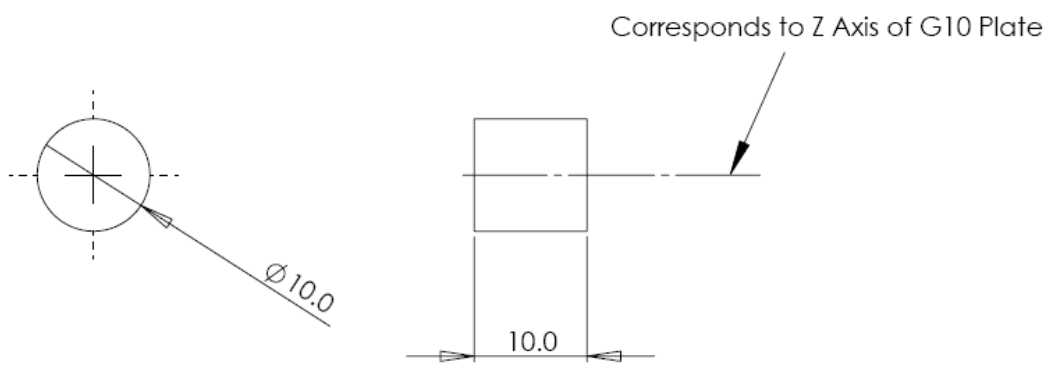

Figure A-2. Sample dimension for Split-Hopkinson bar experiment.