

Executive Summary

The S.T.R.I.K.E. senior design team is redesigning a 7005-aluminum recumbent trike frame using carbon fiber. The objective is to develop and evaluate a carbon fiber frame concept while maintaining the strength and stiffness required for safe, reliable performance. To support this redesign, the existing frame was reverse engineered using 3D scanning and SolidWorks, then evaluated in Ansys under multiple loading conditions. Early forged carbon fiber prototypes were also developed to explore manufacturing methods and support concept selection. Together, these efforts established a structural benchmark for the current frame and guided the next phase of carbon fiber design development.

Background

Recumbent trikes are three-wheeled cycles designed to improve rider stability, comfort, and aerodynamic efficiency compared to traditional bicycles. The frame must support rider loads while resisting bending and torsional forces generated during riding and uneven terrain. These structural demands require careful material selection and frame design. While metal frames are commonly used due to their strength and ease of manufacturing, composite materials such as carbon fiber offer alternative construction methods. Carbon fiber tube-and-joint systems allow frame structures to be assembled using modular components rather than traditional welded joints. Investigating these composite construction approaches provides insight into how advanced materials could be applied to recumbent trike frame design.



Figure 1. Catbike 700

Experimental Setup



Figure 2. Dog-bone Manufacturing



Figure 3. SolidWorks Model

Reverse engineering of the recumbent trike frame produced an accurate CAD model that served as the structural baseline for analysis and concept development. The reconstructed geometry captured key frame dimensions and structural features for simulation. Forged carbon fiber dog-bone specimens were manufactured using custom molds and chopped carbon fiber reinforced epoxy to evaluate the manufacturability and consistency of the forged composite process. Fabrication observations highlighted factors such as fiber distribution, mold filling, and curing behavior that will guide future composite joint development



Figure 4. 3D Scan

Experimental Test Plan

Four forged carbon fiber dog-bone specimens were tested in tension to evaluate tensile strength and stiffness. During each test, load and strain were recorded until failure. Engineering stress was calculated by dividing the applied load by the measured cross-sectional area, and the resulting stress-strain curves were used to determine ultimate tensile strength and Young's modulus of the carbon fiber composite material. The results were compared across specimens to assess material consistency and characterize the mechanical response of the forged carbon fiber process.



Figure 5. Dog-bone Specimens



Figure 6. Dog-bone in Test Machine

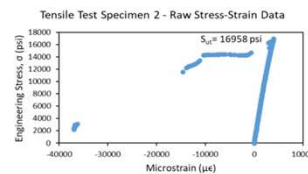


Figure 7. Dog-bone Testing

Experimental Results

Tensile testing of four forged carbon fiber dog-bone specimens produced stress-strain curves that were used to determine the material's mechanical properties. The tested specimens exhibited an average ultimate tensile strength of approximately 17,125 psi and an average elastic modulus of approximately 5,063 ksi. When compared to 7005-aluminum, the forged carbon fiber material demonstrated approximately 41% of the aluminum yield strength and about 49% of its elastic modulus. These experimentally derived properties were then used to support further structural modeling and component design. Preliminary finite element simulations of the forged carbon fiber crucifix joint showed a maximum deflection of roughly 0.05 in under the applied loading conditions, helping evaluate the structural feasibility of the carbon fiber frame concept.

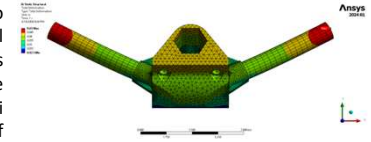


Figure 8. Deflection of Crucifix Joint

Specimen	Area (in ²)	Load max (lbf)	S_u (psi)	Young's Modulus E (ksi)
1	0.08399	916	10902	3760
2	0.06727	1141	16958	4810
3	0.10230	1404	13723	4410
4	0.07913	2130	26918	7370
Average	0.08317	1398	17125	5063
Std. Dev.	0.01450	527	6982	1582
Reference Material Properties				
			S_y (psi)	E (ksi)
7005 Aluminum			42300	10400
Normalized Material Comparison				
			$S_{u,CF}/S_{u,A}$	E_{CF}/E_{Al}
Forged CF Material Relative to 7005 Aluminum			0.41	0.49

Figure 9. Dog-bone Specimen Results

Conclusions

This project established the analytical and experimental foundation for redesigning an aluminum recumbent trike frame using carbon fiber. Reverse engineering, CAD modeling, and finite element analysis provided a structural benchmark for the existing aluminum frame. Experimental tensile testing of forged carbon fiber specimens produced material property data that can now be used for more accurate structural simulations. Initial analysis and component sizing studies suggest that carbon fiber tube structures could provide a lightweight alternative while maintaining sufficient stiffness and strength for the trike frame. Future work will focus on continued structural analysis, four-point bending tests, refinement of assembled design, and development of a final prototype components.



Figure 10. Redesigned Solid works model

References

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