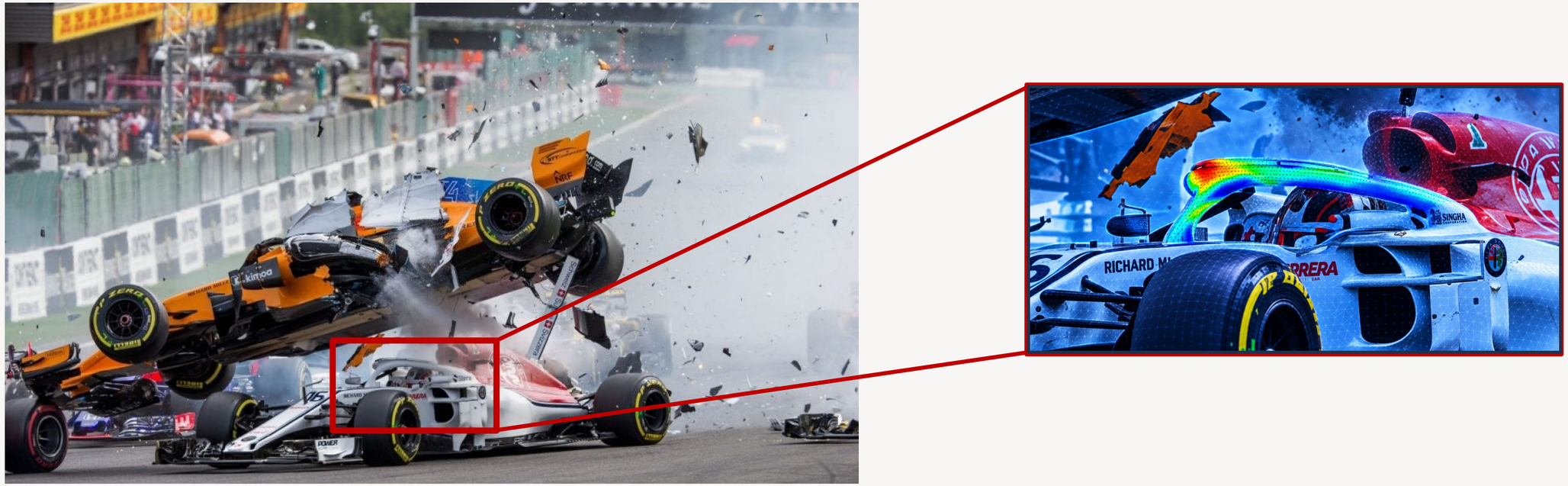
Investigation of Composite Materials as Alternatives to Titanium in the F1 Halo: A Comparative Evaluation Using Static Analysis



Fahriye Sena TOPAL

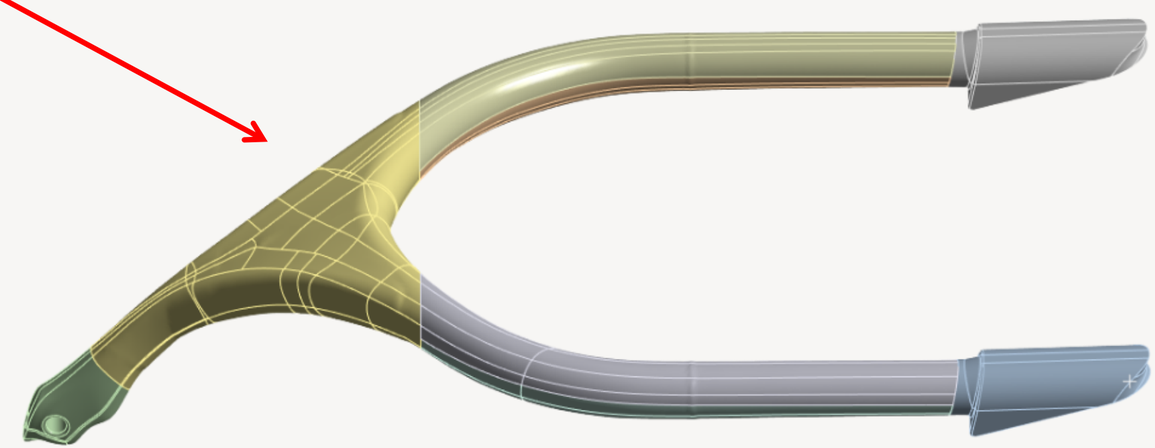
Assist. Prof. Dr. Burak HÜLAGÜ

INTRODUCTION

Why Composite Materials?



This study aims to investigate lighter composite materials with sufficient mechanical performance as potential alternatives to the titanium Halo structure used in Formula 1 cars. Six selected composite materials were evaluated through linear static analyses based on the loading conditions of FIA Standard 8869-2018. The materials were compared in terms of stress, deformation, and mass to identify promising alternatives.



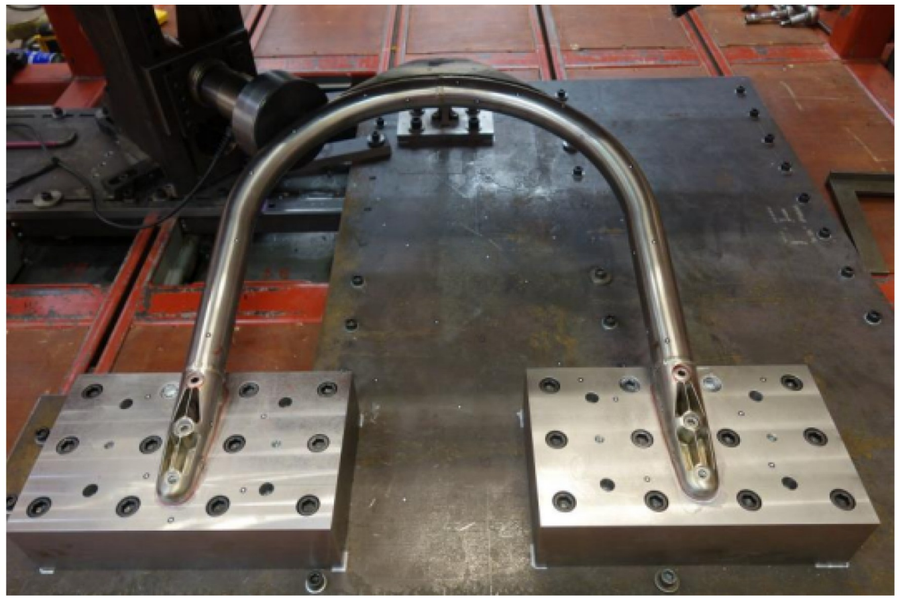
Halo Tests According to FIA Standards

Test 1



17mm

Test 2



17mm

Literature Review

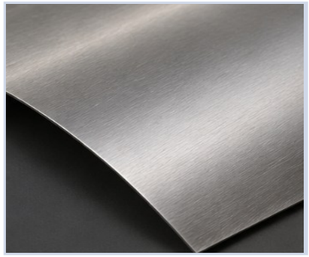
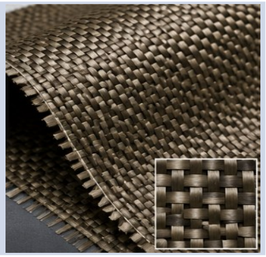
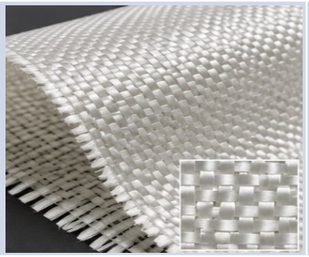
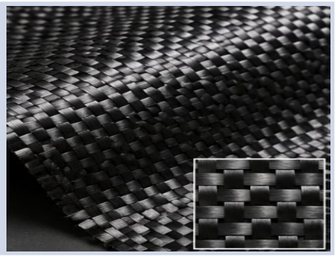
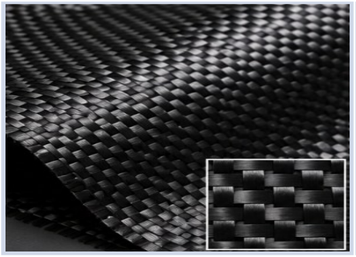
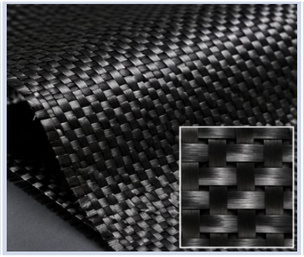
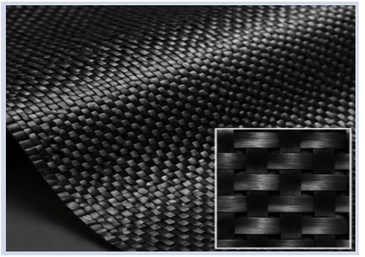
Previous Numerical Studies on Halo Structures

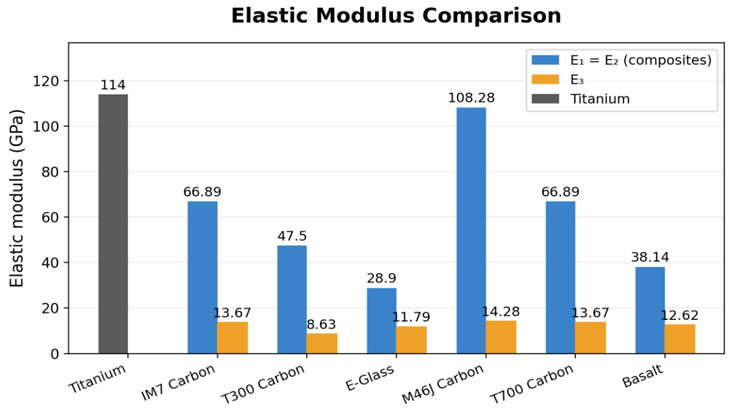
Article / Study	Halo Material	Halo Mass	Other Materials in the Analysis
Cherukara & Yeddu (2024), IJERT	Ti-6Al-4V (Grade 5 Titanium)	7 kg	ARMCO steel crash barrier
Shendge, Shinde & Patel (2021), IRJET	Ti-6Al-4V (Grade 5 Titanium)	Approx. 7 kg	Concrete crash wall
IRJET-V8I8442 (2021)	Ti-6Al-4V (Grade 5 Titanium)	Approx. 7 kg	Concrete crash wall

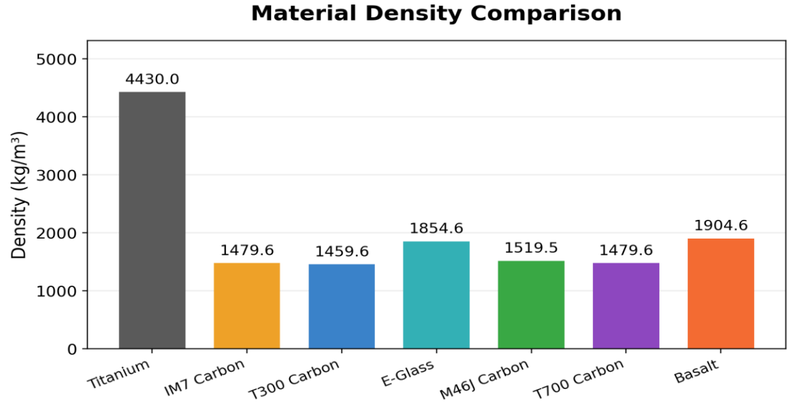
No studies involving composite Halo structures were identified in the open literature reviewed.

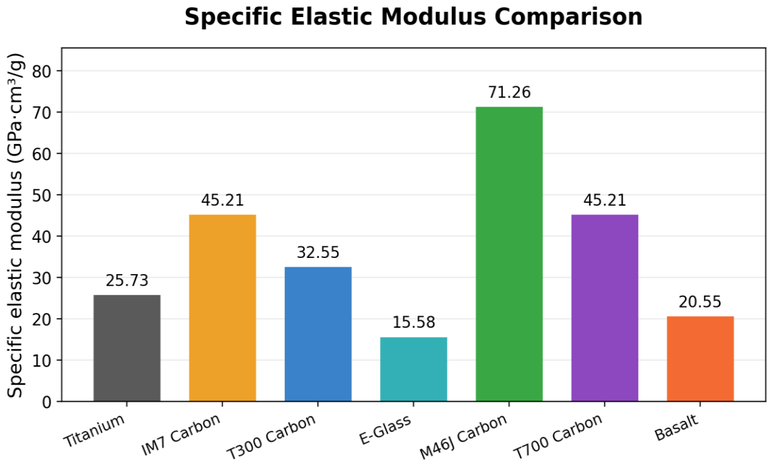
METHOD AND MATERIALS

Mechanical Comparison of Reference and Alternative Materials

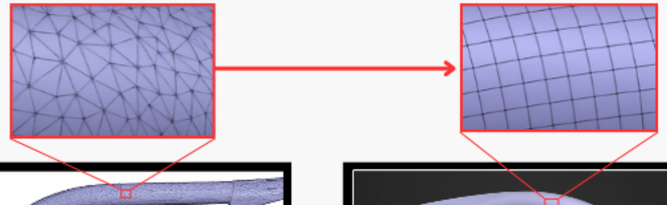
Titanium	Basalt	E-Glass	T300 Carbon	T700 Carbon	IM7 Carbon	M46J Carbon
						
https://hwn-titan.com/en/materials/titanium/titanium-grade-5/	https://www.basaltft.com/pdf/RDR_Technical_Data_Sheet.pdf	https://basalt-fibertec.ch/images/pdf_data_sheets_en/basalt_properties_comparison_en.pdf	https://toray-cfe.com/wp-content/uploads/2025/02/Torayca-T300-Technical-Data-Sheet.pdf	https://toray-cfe.com/wp-content/uploads/2025/02/Torayca-T300-Technical-Data-Sheet.pdf	https://3937524.app.netsuite.com/core/media/media.nl?id=172313&c=3937524&h=dab869f57f81854c6a97&_xt=.pdf	https://toray-cfe.com/wp-content/uploads/2025/02/Torayca-M46J-Technical-Data-Sheet.pdf

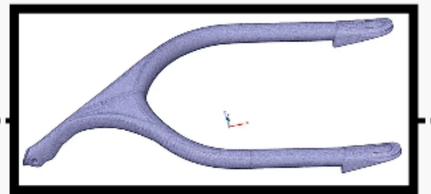




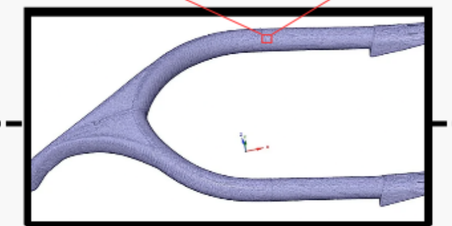


Finite Element Analysis Workflow

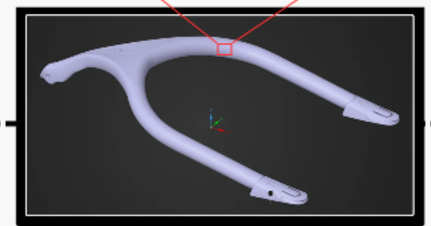




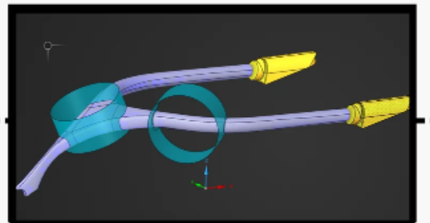
Obtain reference model online



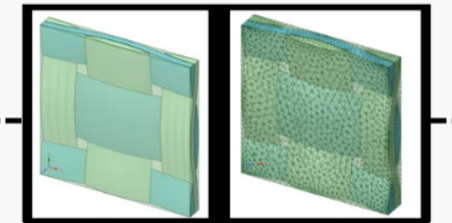
Inspect the topology



Refine the topology

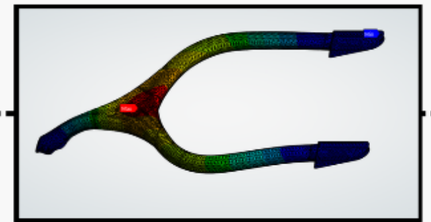


Prepare the Halo test setup according to FIA standards

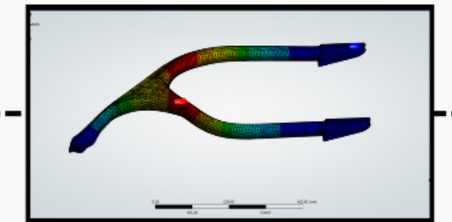


Create materials in Material Designer

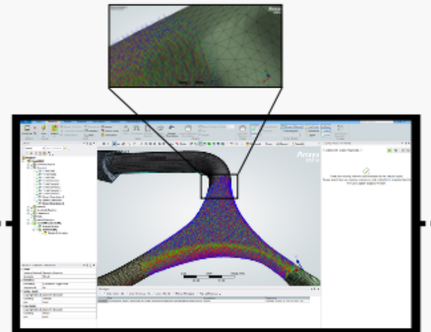
Reverse Engineering



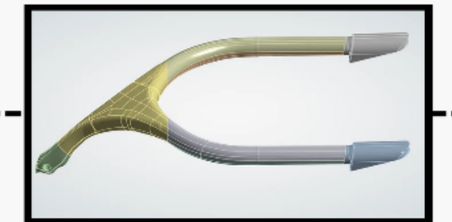
Perform analysis for Test 1



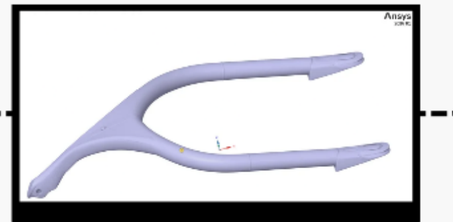
Perform analysis for Test 2



Define element orientation



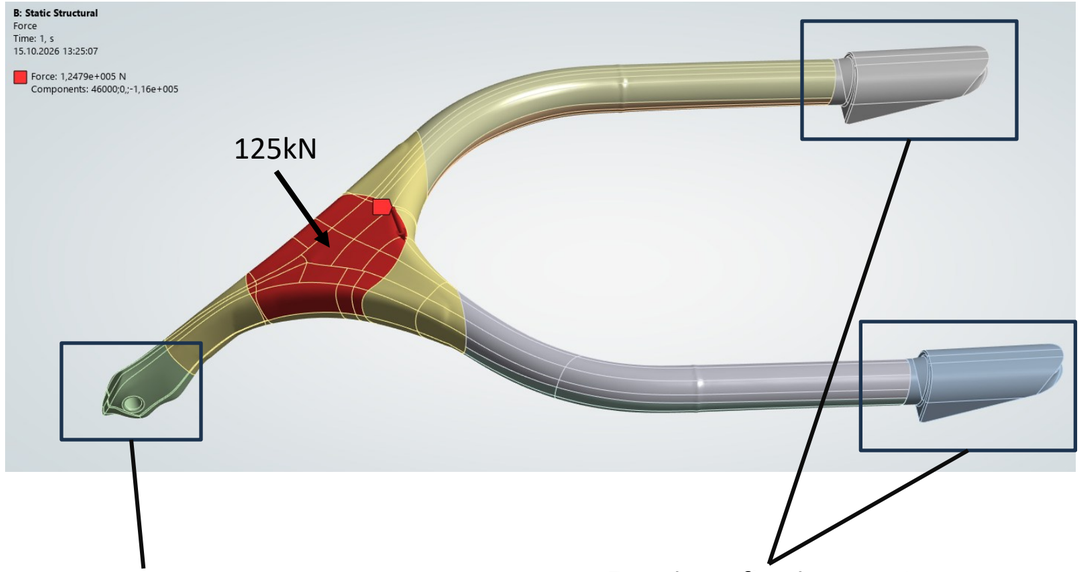
Apply surface geometry



Import the prepared model into ANSYS

Definition of Boundary Conditions and Supports

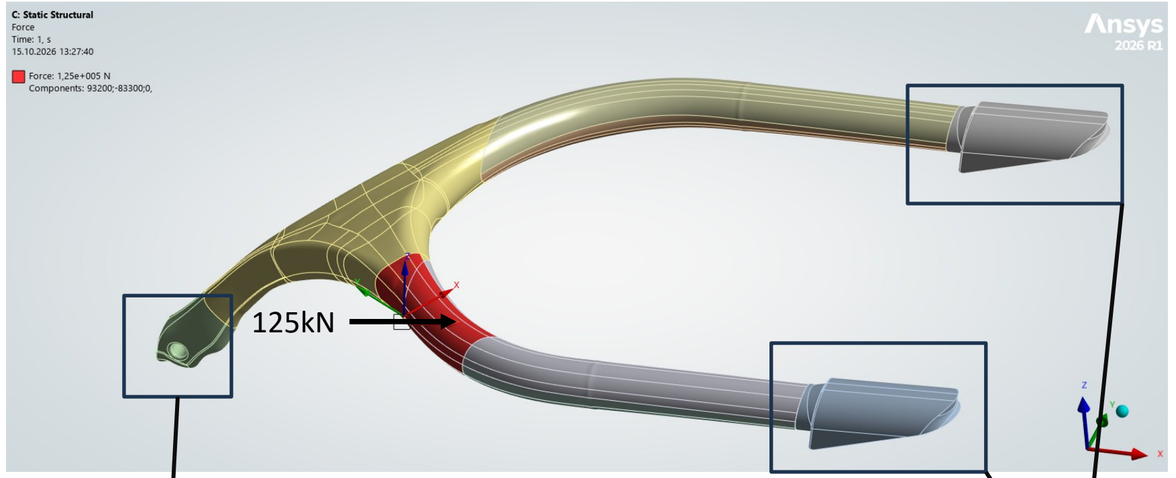
Boundary conditions for Test 1



Front connection: pinned support

Rear legs: fixed supports

Boundary conditions for Test 2

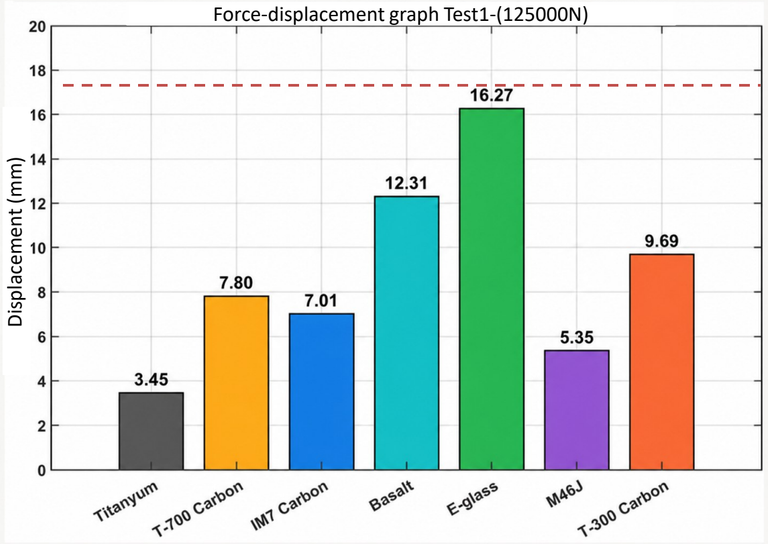


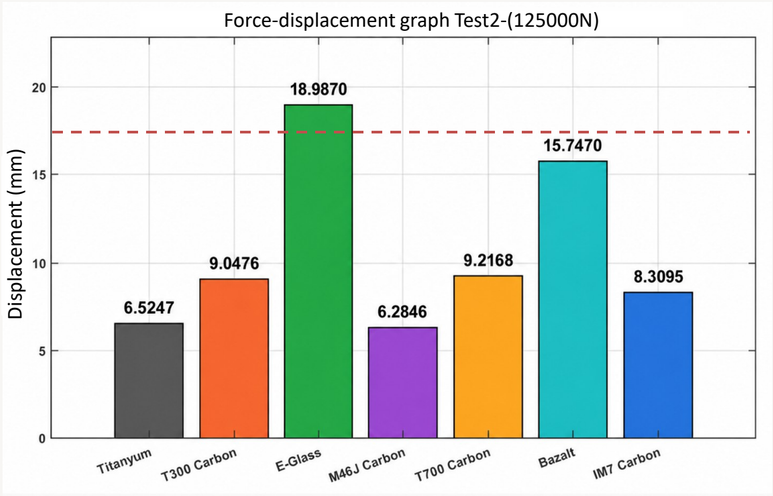
Front connection: pinned support

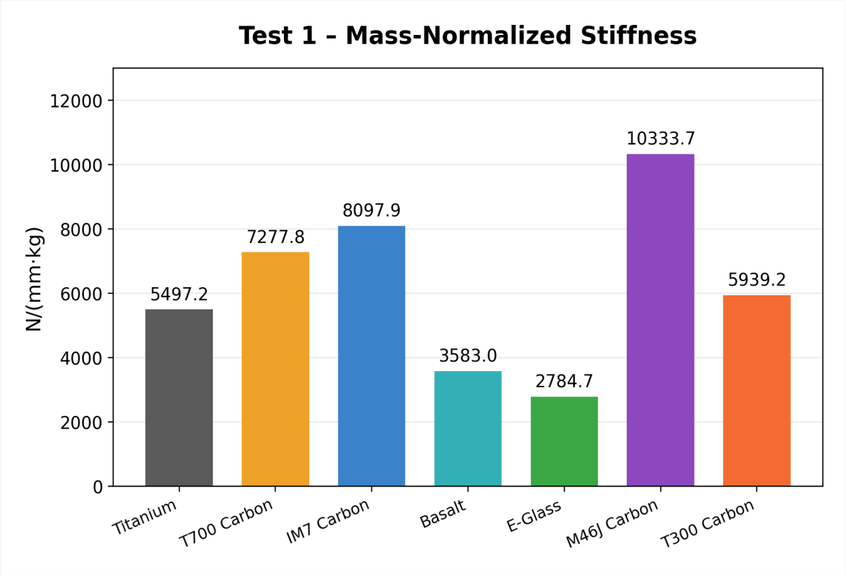
Rear legs: fixed supports

RESULTS

Displacement Comparison Under FIA Loading Scenarios







Mass-Normalized Structural Stiffness

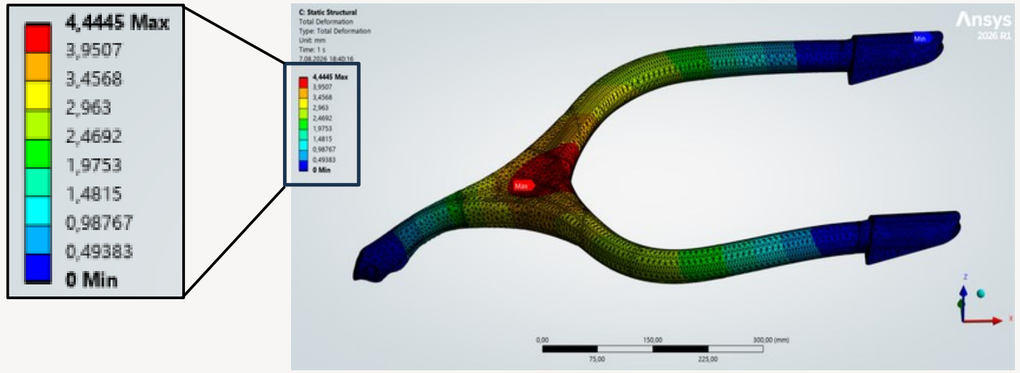
$$k/m = F / (\delta \cdot m)$$

F: applied force (N) δ: displacement (mm) m: mass (kg)

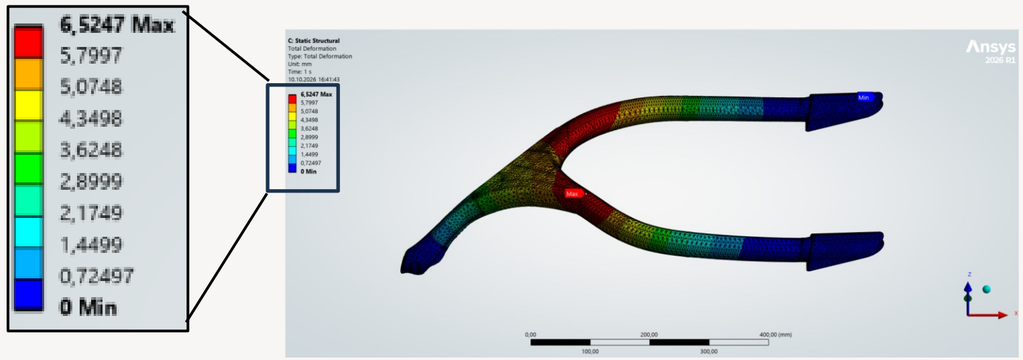
Unit: N/(mm·kg)

Comparative Analysis Results for Titanium and M46J Composite

Static loading results for titanium (Tests 1 and 2)

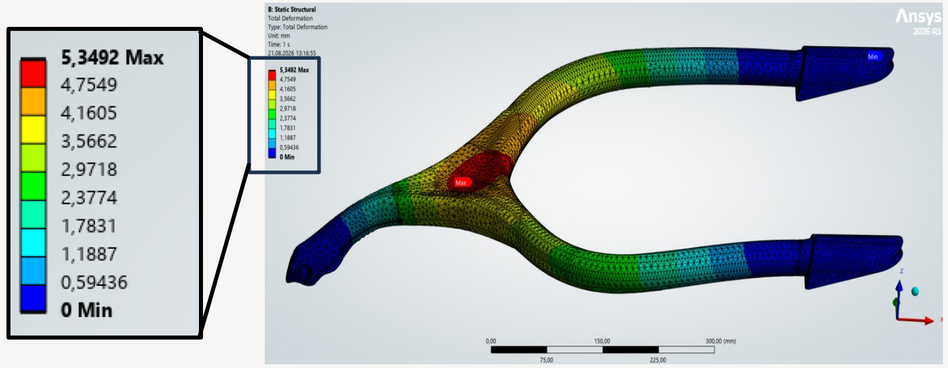


Test 1

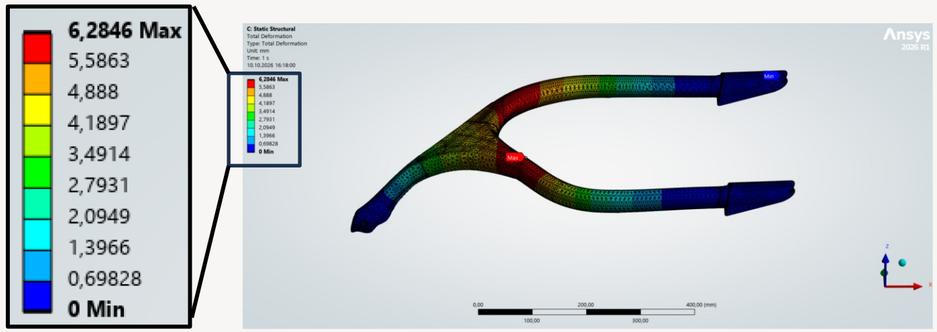


Test 2

Static loading results for M46J (Tests 1 and 2)



Test 1



Test 2

CONCLUSION

M46J satisfies the FIA static deflection limit and offers a potential Halo mass reduction of up to approximately 66% based on the density ratio. However, strength and failure behavior still require verification.

Limitations and Future Work

Dynamic Impact Analysis: Extend the study beyond static loading through high-speed crashworthiness simulations using explicit solvers such as LS-DYNA.

Failure Criteria and Delamination: Apply Tsai–Wu and Puck failure criteria and investigate brittle fracture and delamination behavior.

Fiber Orientation Optimization: Optimize ply angles and thicknesses for specific load paths using genetic algorithms.

Physical Prototyping: Manufacture a composite prototype and test it on a physical rig to validate the numerical results.

Thank You for Listening

Source

1. Fédération Internationale de l'Automobile (FIA). (2018). *Standard 8869-2018: Advanced Frontal Protection (Halo)*. Geneva, Switzerland.
2. Jones, R. M. (1999). *Mechanics of Composite Materials*. CRC Press.
3. Shendge, S., Shinde, Y., & Patel, H. (2021). Study and analysis of a designed F1 Halo safety system according to FIA. *International Research Journal of Engineering and Technology (IRJET)*, 8(8), 3875-3882.
4. Ansys® Academic Research Mechanical, Release 2023 R1. Help System, Composite PrepPost User's Guide.