Carbon Sprung Gravel Bike Suspension

Department of MECHANICAL ENGINEERING
THE UNIVERSITY OF UTAH

Team 22: Sam Allen, Bryce Bennett, Skyler Chandler, Taylor Hawkes
Advisor: A.K. Balaji

Introduction

Within the biking world, gravel bike racing is becoming a bigger and bigger sport. A big component of gravel bike racing and where a competitive edge could be extended, is making bikes capable of handling rougher terrain. The bike should be able to absorb the forces generated at high speeds without transmitting them into the riders. Many companies and hobbyists have toyed with different suspension systems. Our goal was to support ENVE composites into entering this territory and develop a working prototype of a gravel bike suspension system to be implemented onto their current bike, The MOG, without using standard air/spring systems. Our design is unique in using a four-bar linkage system with a carbon leaf spring. The prototype should serve as a robust foundation for further testing, refinement, and integration into their product line.

Design Specifications

During the initial stages of the project, we were given full freedom in the design of the product so long as we hit our travel goal of 50 mm or more. Using this as our baseline, we set more goals that kept the functionality of standard front suspension and accommodated to user needs. Through ENVE's expertise and a variety of user feedback, we determined the following metrics for our design:

Metric	Need	Metric	Unit	Target Value	Achieved Value
1	1	System Travel	mm	≥50 mm	61 mm
2	2	Tire clearance when fully compressed	mm	> 12 mm	19.71 mm
3	3	System stiffness	N/m	73,046 N/m	35,260 N/m
4	4	Existence of adjuster knobs or swappable components to accommodate variable rider weight	binary	Yes/No	Yes
5	5	Mass of system	g	< 1700 g	2456 g

Design

Overview: While meeting the design criteria, we created a model that uses a four-bar linkage system. The design includes three main components; the upper fork, lower fork, and the carbon wishbone. The upper and lower fork both encapsulate and provide rigidity to the whole system. Their main function is to hold the system together while providing enough room for the wishbone's travel. The wishbone itself is the actual suspension component of the system. It utilizes the high strength and rebound characteristics that are found in carbon composites to provide the same damping properties as standard air suspension. Other components on the system include the links, wishbone housing, and crown race fitting. Links connect the upper fork, lower fork, and wishbone housings together for interaction with proper movement control. The crown race fitting allows the current MOG's head tube to slip over our custom fork.

Linkage System: Carbon fiber is traditionally a very stiff and strong material. Brittle fracture of the wishbone was a major concern during our design phase. To minimize this risk, we chose to use a linkage system with a 3:1 lever ratio to cut the distance our wishbone must deflect from 50 mm to 17 mm. This decision also required an increase in wishbone stiffness, as all forces absorbed by the system are increased 3-fold due to the positioning of the lever fulcrum.

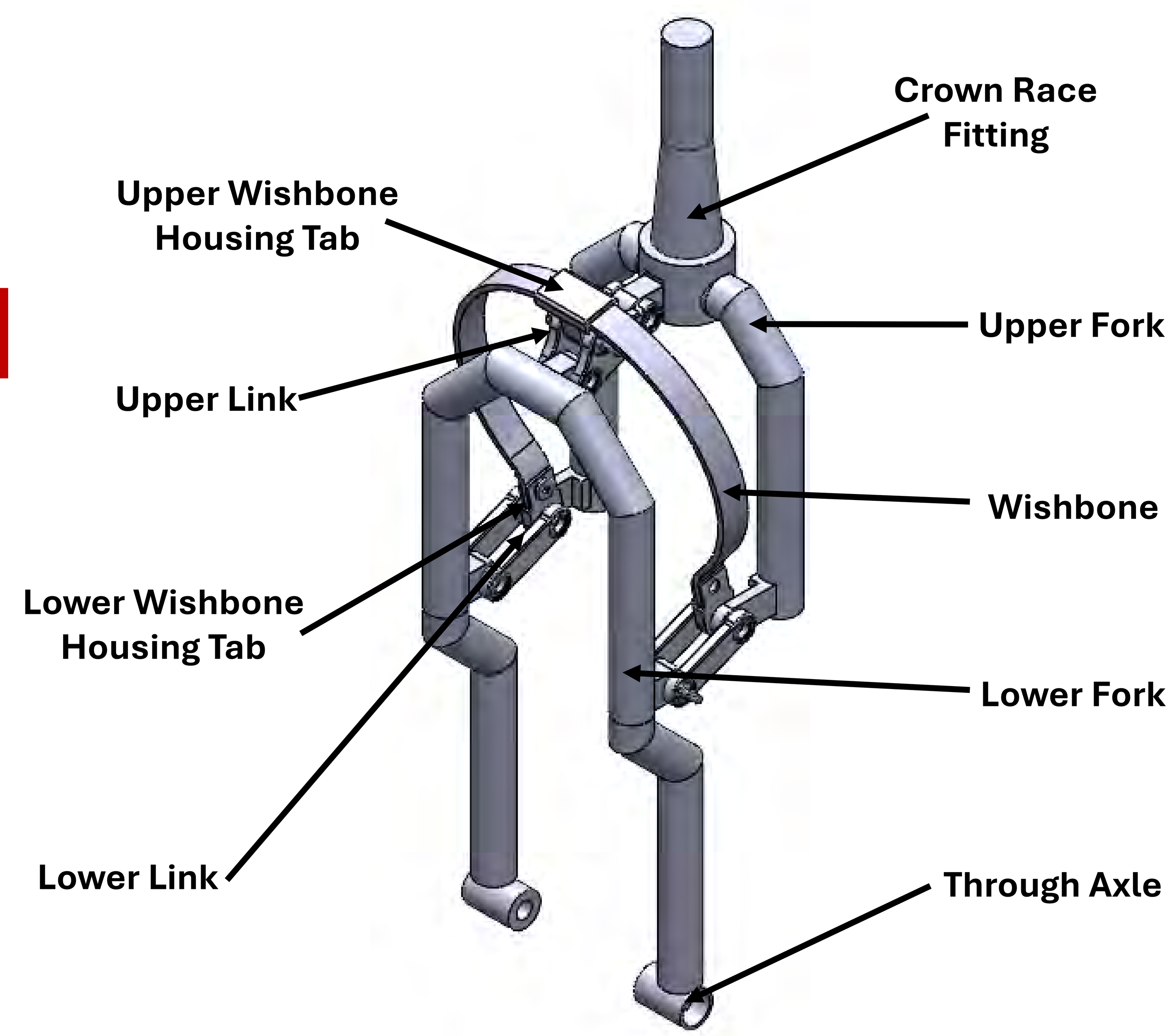


Figure 1: The wishbone with mounting tabs.

Wishbone: The wishbone is a carbon fiber leaf spring designed in a "wishbone" shape, serving as the rebound mechanism within the suspension system. As the system undergoes travel, the suspension links extend, temporarily straightening the wishbone's curved structure. Due to the nature of the carbon fiber, the wishbone naturally returns to its original shape, providing rebound. This undamped system creates highly responsive ride characteristics. The carbon layup is engineered to strike a balance between stiffness and flexibility. It's responsive enough to absorb small dips and washboard terrain common on gravel roads, yet compliant enough to handle bigger impacts. Additionally, the layup is optimized for a progressive response, increasing in stiffness as travel progresses to enhance control and ride quality. The wishbone's carbon laminate features a midplane-symmetric layup with unidirectional carbon fibers oriented at ±60/90/0, repeated throughout the structure. This layup has been optimized over 10 iterations to achieve a stiff yet flexible design.

Testing and Modeling

To create our "wishbones" we used unidirectional pre-impregnated carbon fiber sheets. These sheets can be stacked and orientated in different directions and cured in an oven to bind them. This process is called "Carbon Layup." Depending on how you lay up carbon fiber you can create parts with varying mechanical properties even if they have the same geometry. To expedite our layup optimization, we created a finite element analysis (FEA) to rapidly test different layups in conjunction with our physical testing. A ply stack up, results from one of many FEA models and physical tests can be seen below.

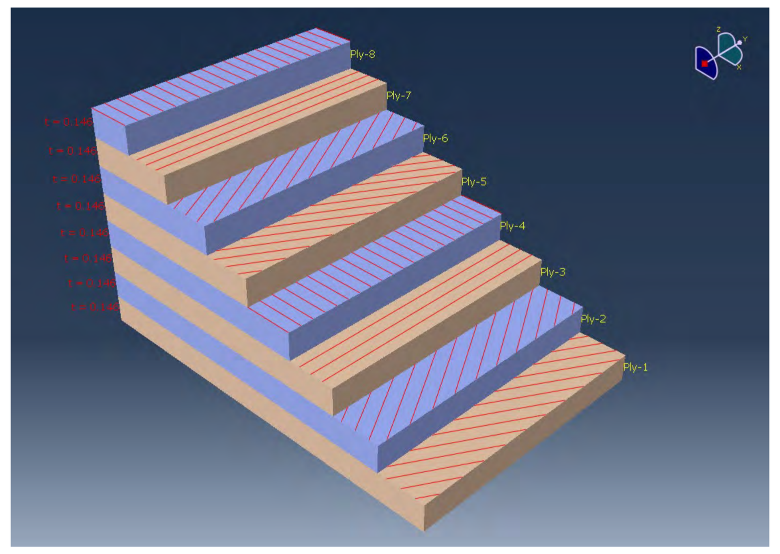
Figure 2: A simplified ply stack up from our FEA shows the ply pattern used in the wishbone and their orientations (shown by the red lines). A 0° ply means the carbon fiber orientation is as strong as possible, while a 90° ply puts the fibers in their weakest orientation.

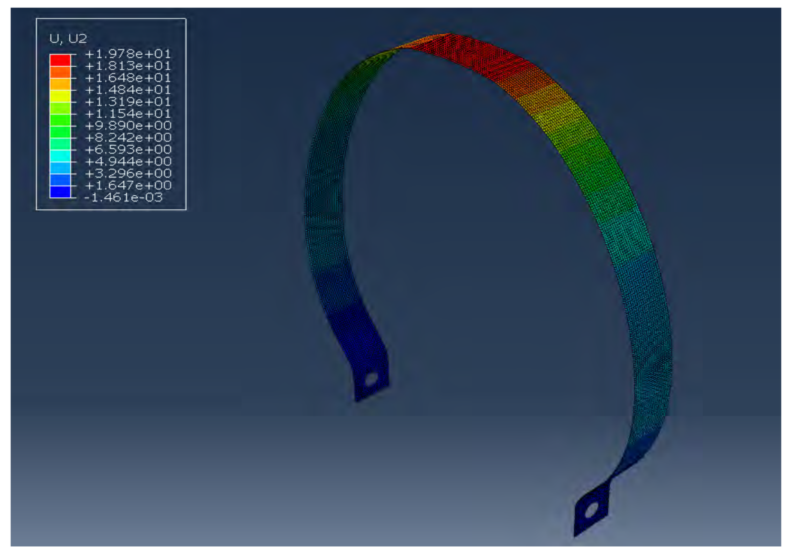
Figure 3: Shows the deformed shape and the calculated vertical displacement of Wishbone 6 with a the assumed loads of a 180 lb. stationary rider. The results are reported in mm.

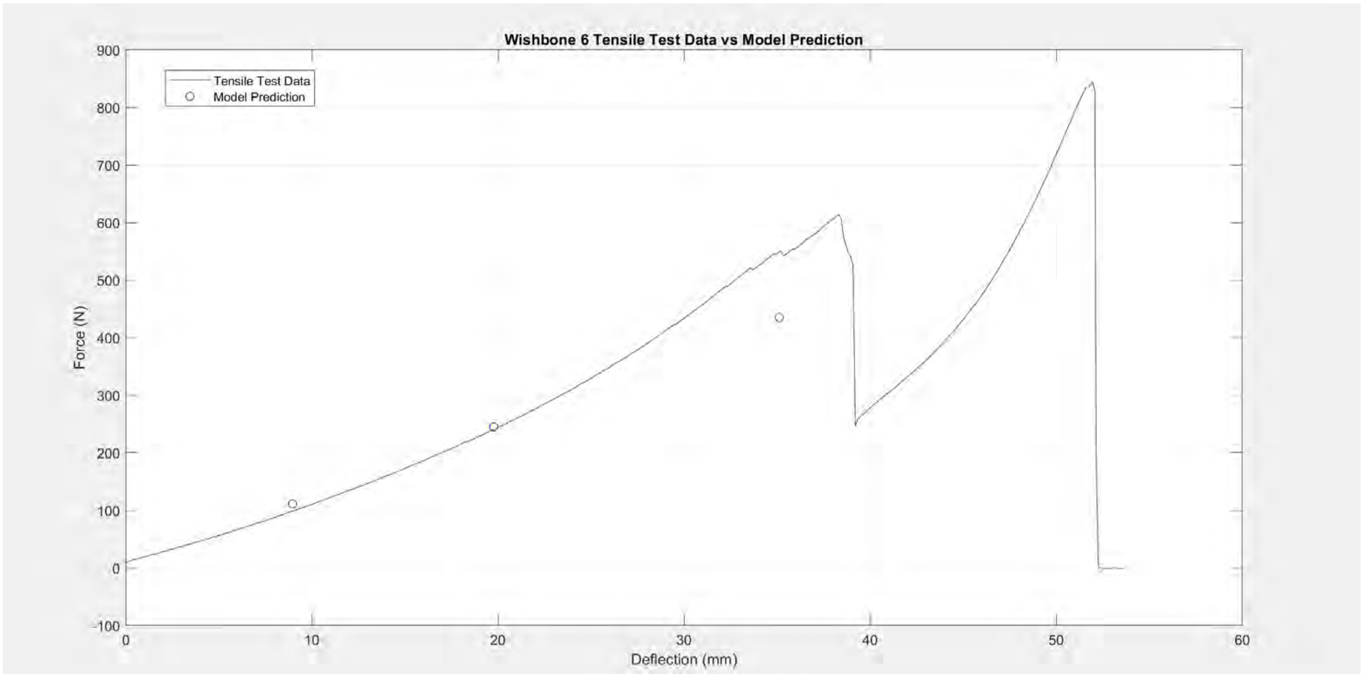

Figure 4: Using an Instron machine we were able to test our wishbones under loading conditions mimicking real loading conditions. This data was critical for validating our FEA models and driving changes to our wishbone layup.

Conclusion

After 10 wishbone iterations, we were able to achieve over 30mm of deflection, allowing for 60mm of travel, at 500 Newtons of force. The linkage design successfully houses the wishbone, utilizing a 3:1 leverage ratio to reduce risk of cracking and promote a progressive travel path. By laying carbon plies in a +-60/90/0 orientation, we were able to take advantage of the stiffness and strength properties of carbon fiber as well its ability to flex when placed at different angles. The future of our design requires increased stiffness, weight reduction, and greater compactness. The design, in its current condition, has an acceptable response to ride forces, but could certainly be fine-tuned to handle different rider weights.