UWO Formula Racing

Technical Accomplishment

Formula SAE Vehicle Dynamics and Suspension

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The following paragraphs summarize the technical approach I employed as the team Technical Director and Head of Suspension Development for the suspension system of the trophy-winning 2010 UWO Formula Racing car.

Introduction

To remove limitations imposed from the past and to maximize learning, I chose to create a completely new system. I began by absorbing dozens of books and technical papers on vehicle dynamics and suspension system design. Once it became clear that suspension design starts with the tires, I applied and was selected as a beta tester for tire analysis software to gain an edge on the competition in analysis of the just-released 2010 tire data. The tires were then selected based on grip potential. The next goal was to realize this potential by ensuring they operate under their most advantageous conditions through detailed suspension system design.

System Design

A relatively soft setup was chosen to minimize normal load variation for maximum grip, with a front Fn of 2.26 Hz and the rear 1.13 times that of the front. Short side-view virtual swing arm lengths (SVSALs) were chosen to prioritize camber control in roll over heave. In order to prevent bottoming under hard braking, to improve braking responsiveness, and to reduce the camber-changing effects in heave of the short SVSALs, advanced anti-dive, anti-lift, and anti-squat geometries were implemented. Due to the small radii of FSAE corners, the minimum legal wheelbase was chosen to minimize yaw-inertia. The track widths were also decreased to reduce the distance the car must travel through a slalom or corner. Tire data suggested that the resulting steady-state loss in lateral force potential due to tire load sensitivity from increased weight transfer was minimal (<0.1%.) Through simulation, it was determined that high kinematic roll centers cause the vehicle to roll not about the kinematic roll axis, but about an axis towards the outside wheels. As a result, the kinematic roll centers were placed close to the ground in both the front and rear to keep the body rolling about the center of the vehicle, providing validity to the camber curves targeted in kinematic analysis. Perfect Ackermann was employed due to the tire data showing relative insensitivity to peak lateral force slip angle at varying tire normal loads although it was also made adjustable to allow this to be validated in testing.

Component Design and Manufacturing

I designed and manufactured CNC-machined aluminum bellcranks which reduced mass by 63%, manufacturing time by 75%, and part count by 80% compared to the previous generation. They were conceived through bio-mimicry of bone structures and validated using FEA analysis to have very good specific stiffness compared to competing concepts. Accuracy in the pickup points was a high priority, so I developed a simple and inexpensive way of precisely locating the pickup points with CNC cut MDF jigs. An additional benefit of this new manufacturing technique was the shortest frame manufacturing time in the team's history. The innovative development of a CAD technique made frame and suspension iterations update each other automatically. This allowed me to efficiently go through over 150 unique suspension iterations with the frame designer to ensure the best integration possible. Compliance was minimized through careful sizing of every component, attention to detail, and PTFE spherical bearings where appropriate.

Results

The 2010 car achieved the best skidpad times in the team's 22 year history and at the 2010 California competition its skidpad times were less than 5/100th of a second off of the competition-winning car. The design judges were thoroughly impressed with the suspension system, my understanding of it, and the overall vehicle package. The 2010 car completed 3 competitions with impeccable reliability and holds a record for the team's best finish to date.

More pictures follow.

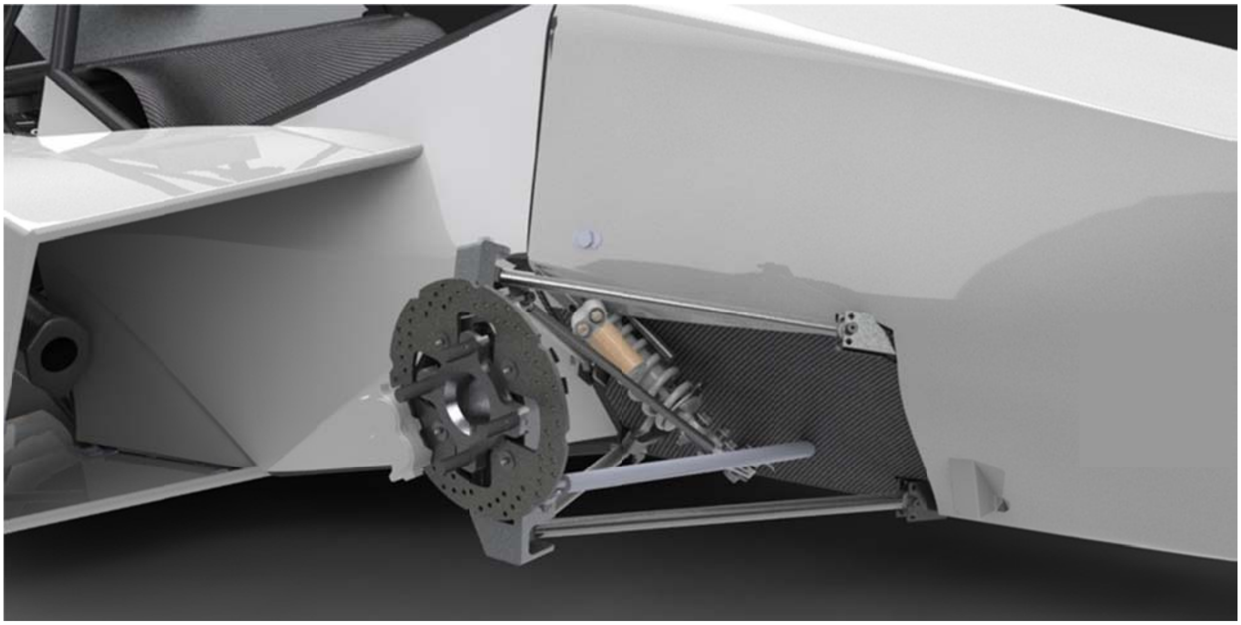

FIGURE 1: FRONT SUSPENSION IN CAD (NOTE: 2011 RENDER SHOWN)

FIGURE 2: REAR SUSPENSION IN CAD (NOTE: 2011 RENDER SHOWN)

FIGURE 3: REAR SUSPENSION CLOSE-UP

FIGURE 4: FRONT SUSPENSION WHILE CORNERING

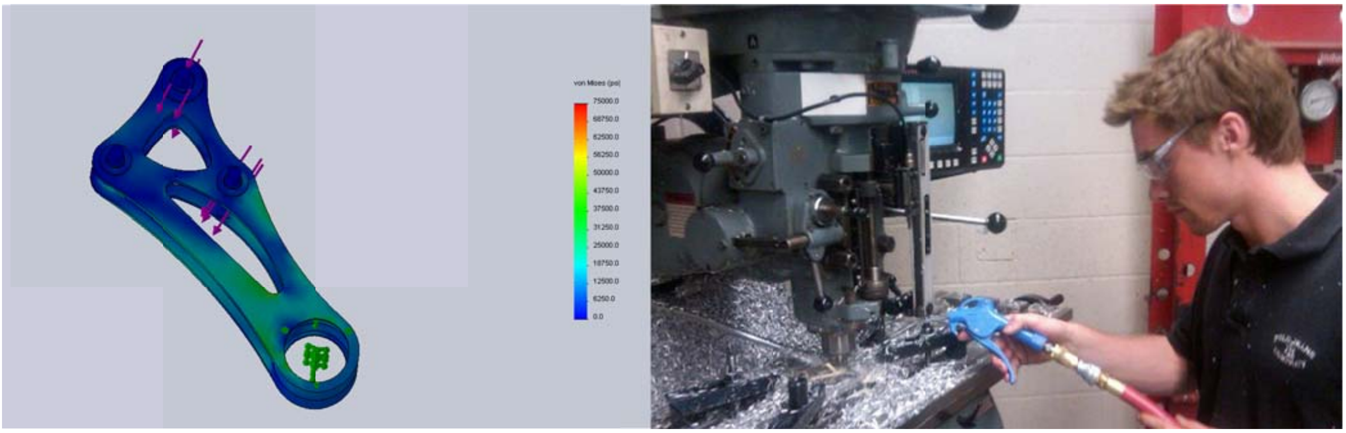

FIGURE 5: BELLCRANK FEA ANALYSIS AND CNC MACHINING

FIGURE 6: FINISHED BELLCRANK

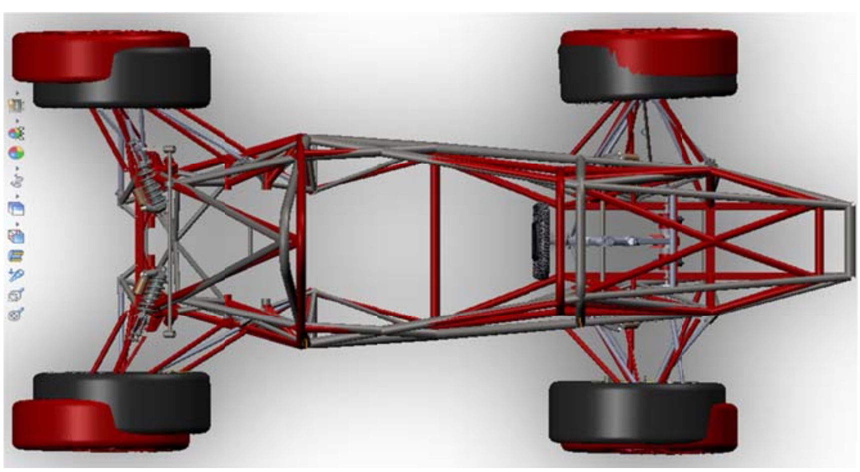

FIGURE 7: 2009 VS 2010 CHASSIS COMPARISON

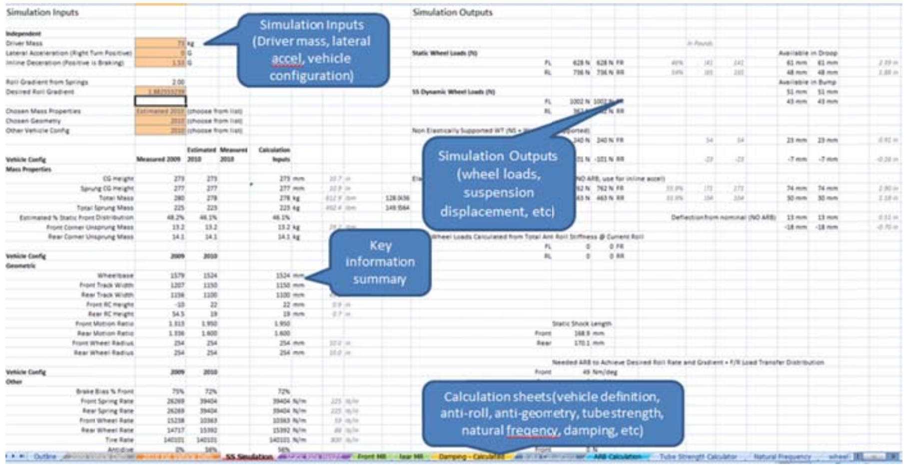

FIGURE 8: SUSPENSION DESIGN CALCULATOR OVERVIEW

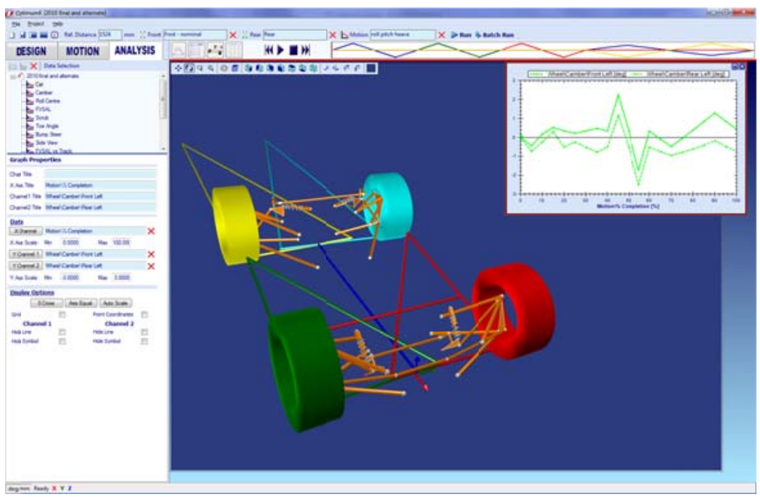

FIGURE 9: KINEMATIC ANALYSIS (CAMBER CHANGETHROUGH A MOTION OF ROLL PITCH AND HEAVE)

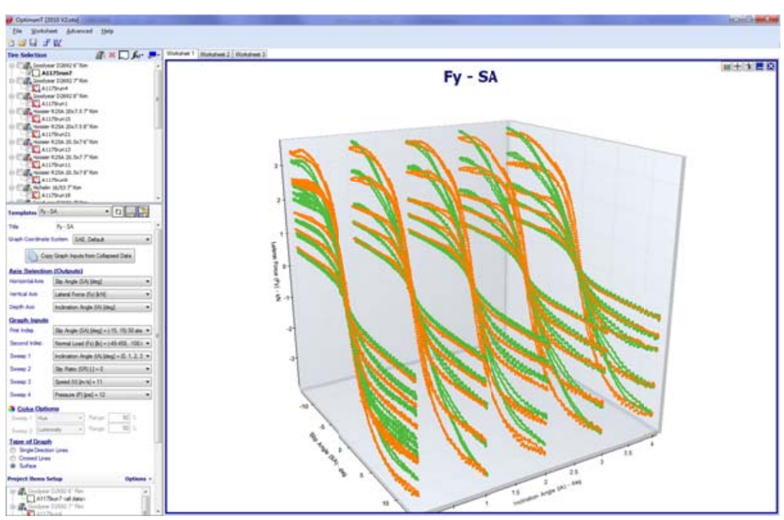

FIGURE 10: TIRE DATA ANALYSIS (LATERAL FORCE VERSUS SLIP ANGLE AT VARIOUS INCLINATION ANGLES AND NORMAL LOADS FOR 2 TIRES)

FIGURE 11: COMPETITION PHOTOS