Case Study

Crimson Tide Shoots to the Top with Altair Tools

Overview

Formula SAE challenges students by tasking them to design, build and compete with their own race cars annually. The competition features hundreds of universities, multiple races around the world, and features multiple rigorous safety checks, several dynamic events, and a design event where students must defend their designs to industry experts.

Crimson Racing has a history spanning nearly two decades with Formula SAE. However, the past five years have easily been the most successful in team history. Why? A concerted focus on understanding and justifying everything on the car without over complicating it.

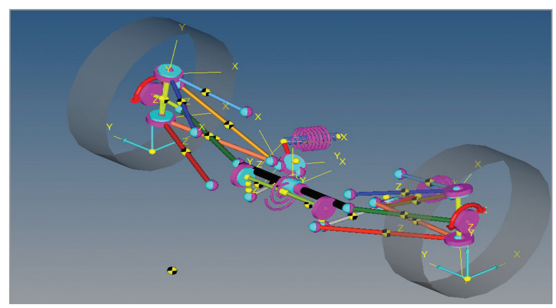
There are many tools and programs that can be used to achieve this goal on various systems, but for structural components in the suspension system, Altair HyperWorks™ has been the most prolific. By using the Altair MotionSolve™ program in HyperWorks, Crimson Racing can evaluate the expected suspension component loads under any given driving scenario and adjust as needed.

The 2019 Crimson Racing Team

Team History

Founded in 2001, the University of Alabama's Formula SAE team has competed in Formula SAE events across the United States, including events in Michigan, Nebraska and Virginia. Throughout the team's history, the cars brought to competition have been in a continuous state of change.

Crimson Racing has made tremendous advancements in recent years, reducing the vehicle weight by nearly 200 pounds and advancing from a perennial 90th place to a Top 20 team in 2017. The team didn't stop there however. They set an ambitious goal to place in the top 10 at FSAE Michigan which would require beating many of the best teams in the world.

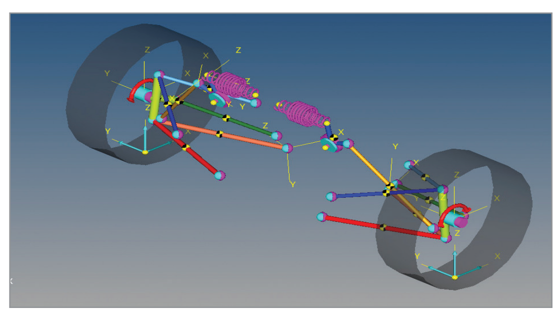


Front Simulation Setup

To achieve their goal, they knew it would require multiple changes, the most significant of which was the addition of a front and rear wing. Crimson Racing recognized this change was not isolated to the aerodynamics team, it affected structures – increased loading, a higher center of gravity (CG), a higher drag force which the powertrain system must overcome – that needed to be dealt with along with the wings.

Challenge

The suspension team already had changes in the works, independent to the addition of an aerodynamic package. These changes revolved around the front suspension and a direct actuation system with anti-roll bars, which proved to be an unsatisfactory solution given the weight and complexity penalties.



Rear Simulation Setup

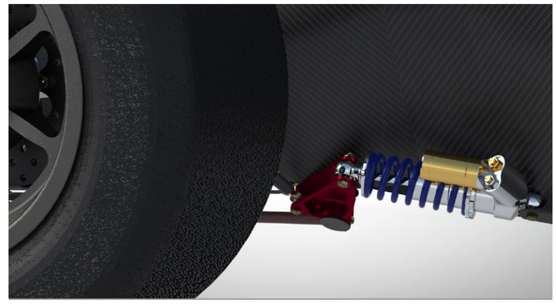
A decision was made to switch to an indirect actuation system for more effective anti-roll bar integration. Additionally, coupled with the knowledge of an increase in CG height due to the addition of wings, a pull-rod suspension quickly became the leading candidate due to its low mass placement.

With the addition of front and rear wings, higher forces were expected due to both the downforce created by the wings as well as increased cornering and braking capability. This necessitated a revalidation of every load bearing suspension component to ensure adequate strength and stiffness requirements would be met, a complex task when analyzing parts moving in three-dimensions.

Solution

Before anything could be analyzed it was necessary to estimate the force inputs to the suspension. This was accomplished with the creation of an in-house tool to estimate vehicle performance when given basic vehicle dimensions, weights and kinematic characteristics. From this tool, maximum tire loads were estimated for cornering, braking and acceleration, and in combined scenarios at various speeds.

With the assistance of Altair's multibody dynamics software, MotionSolve, the team was able to build a model of the front and rear suspension by importing the geometric points, spring stiffnesses, anti-roll bar stiffnesses, and damping coefficients. Using these parameters, rigid bodies were created to represent all relevant suspension parts. Care was taken to ensure that joints connecting these bodies were representative of the different types of bearings used on the car. The expected loads found from the tool were then setup as forces applied at the contact patch. Lastly, virtual sensors were placed on all suspension joints so forces and torques could be recorded and viewed in Altair's post processor HyperView.



CR-19's Front Indirect Actuation System

Results/Benefits

Using HyperView intuitive force vector display, the team was able to visually confirm the model was functioning as intended, as well a quickly identify any highly loaded members. The ease of use has allowed for an earlier start to component design, which allows for modifications to be made to the kinematics if needed. The ability to adjust kinematics to resolve any high loads ultimately saves weight, increases stiffness and reliability.

One issue Motion Solved helped Crimson Racing resolve were the high loads transmitted through the front pull-rod along with the correspondingly high moments acting on the rocker. It was determined to be a significant issue, as it would add considerable mass to the system and may even lead to abandoning the pull-rod concept due to packaging constraints and ground clearance concerns.

With Altair's help, the team was able to employ several design changes to significantly reduce the issue. The first of which was lowering the rocker in the z-axis, which resulted in lower forces through the pull-rod due to a steeper angle of inclination. Based off these numbers, the team also decided to utilize a welded steel pushrod rather than a bonded carbon fiber/aluminum component to increase robustness. Secondly, the moment was reduced by adjusting the actuation plane to be offset from the upper ball-joint at static ride height. The static offset ensured the misalignment decreased as the wheel became more heavily laden. The optimal amount of misalignment was determined using multiple MotionSolve iterations.

Aft View of CR-19 Showing Rear Suspension System

Lastly, the physical size of the bell-crank was also reduced to decrease the moment arm the high forces could create a torque with. Combined, these changes accounted for a 50 percent reduction of the rocker moment.

"Without Altair Hyperworks, we would not have had the structural analysis needed to reach design finals at Michigan, and therefore we would not have been able to achieve our 10th place goal."

John Harber

Geometry Designer, Class of 2020

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