Setting Up Race Cars in a Virtual Environment

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For more than 15 years, Newman/Haas Racing (Lincolnshire, Illinois) has been using MSC.ADAMS and ADAMS/Insight to better understand the trade-offs in setting up cars for specific racetracks. Marcel Staniak, an engineer with Newman/Haas Racing, says, "ADAMS/Insight for vehicle and system modeling has proven to be an effective tool for efficiently producing a complex yet quantifiable understanding of model behavior. These methods have produced significant gains in runtime and understanding, and we have discovered opportunities to further improve efficiency and output. By using macros to eliminate factor combinations that are not physically possible or not meaningful, experiment design efficiency and output can be improved."

Increasing Experiment Design Efficiency

With a winged, ground-effect racecar producing a large amount of downforce, a constraint for a given spring rate and static ride height must be set high enough to avoid excessive contact with the ground at high speed. Conversely, for a given spring rate, the static ride height must be set as low as possible to produce maximum downforce. Therefore, the design space results in a band matrix factor that defines the area of normal operation and combinations not physically possible and not meaningful.

"To improve the efficiency, we have written macros defining this nominal relationship and defining an offset to the nominal relationship to get some width in that design space," says Staniak. "We can do that for two or more factors, eliminating simulation runs we're not interested in before post-processing." A similar band matrix results if these factors are replaced with front and rear roll stiffness. Regions of the design space will have factor combinations that are physically possible but not meaningful, such as high front-roll stiffness and low-rear roll stiffness or vice-versa.

Customer:
Newman/Haas Racing
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Software:
MSC.ADAMS®, ADAMS/Insight

Summary:

Newman/Haas Racing uses the ADAMS/Motorsport toolkit and ADAMS/Insight for vehicle system modeling and design of experiments (DOE) to optimize the setup trade-offs required to deliver a more competitive car. The methods provided by MSC.Software have produced a more intuitive understanding of the model and significant gains in runtime, and helped Newman/Haas Racing discover opportunities to further improve efficiency and output. Using test chassis set-up options in a virtual environment, Newman/Haas Racing can take best advantage of limited on-track practice and testing time.

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"This gives us a more intuitive understanding of the model," says Staniak. "When we change springs at the race track, the ride height is always changed, because we want the car operating in the optimum ride-height region. We can do a contour plot of the response metrics using spring rate and ride height factors. But we are only interested in one line through it, where springs and ride height are changed as they would be on the track. We use a macro to automatically adjust the ride height as a function of spring, and look at a response surface as a function of spring. It makes the ride height changes inside the model so we can look at a true performance effect."

Depending on complexity and/or nonlinearity, the relationship of the spring rate and ride height factors expressed in an equation is defined manually or using response equations from a preliminary Design of Experiments (DOE). The factors are modified by converting one of them to a delta from the nominal value. The delta factor defines the width of the band matrix. The nominal relationship equation is programmed in a macro for use in the DOE. In each trial simulation, the factor value for spring rate is utilized in the macro equation to calculate a nominal ride height value. The factor value for the ride height delta is added to the nominal value. The macro can easily be expanded to include multiple factors.

This technique can also be used for coordinate transformation. For example, if a hard point location is defined by a plane not aligned with the vehicle coordinate system, a macro can be used to transform local Cartesian or polar coordinates into global vehicle coordinates. This reduces the design space by one degree of freedom to include only meaningful factor combinations.

Output Improvements

The performance of a racecar on a given track always involves compromise in setting up the vehicle. Simulation helps to understand and optimize the setup trade-offs required to deliver a more competitive car. The main issue is the racecar's behavior at multiple track locations, which can be obtained using full or partial lap simulations, such as multiple discrete or quasi-static simulations representing various track locations. In this example, multiple types of results may be included and multiple DOE response results merged to improve output.

Mid-corner data can be sampled for representative slow and fast corners. Then as many points as possible can be added, such as entry and exit points for the corners. The results may include quasi-static or dynamic handling simulations as previously mentioned, ride simulation results and test results, such as ride testing, or even sub-system simulations. This can be taken a step further by using macros to incorporate factor-dependent results prior to simulation, such as factor ride effects derived from simulations or tests into handling simulations. Merging multiple DOE response results is useful for optimization, implementing weighting functions, and over-plotting responses. In general, merging results yields a cohesive tool for analyzing and optimizing tradeoffs.

Output is improved by combining results to better optimize vehicle setup tradeoffs. Results may come from a single DOE, such as a lap simulation DOE, or multiple DOEs of similar simulation type. In any case, properly combining response results is critical in weighing and understanding the vehicle setup tradeoffs.

Correlation

Correlation between physical test data and analysis results ensures models represent the real world. But correlation is difficult because of the variation exhibited by a racetrack. Even tires aren't consistent from run to run. Staniak says, "We get tire model data, aerodynamic data from wind tunnels, mass and stiffness and inertia testing of the components. We do lap simulations and overlay simulation data with log data from the car. We log loads and driver inputs and engine performance and all sorts of ride heights of the car, so we can overlay them and see if there is a problem or if things aren't matching. Then we can adjust the database according to where we see the problem."

"We have achieved higher efficiency by using these macros and improving output and optimization capabilities of the car by merging the results," says Staniak. "Rarely is there a change where the driver says everything is better. Most of the time changes are made through trial and error or with an educated guess and experience. But we can use simulation tools to approach setup changes from an engineering discipline."

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