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Lab 08 - ADAMS

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Abstract

This report presents the optimization of a vehicle suspension system using Adams. Through a Full Factorial Design of Experiments (DoE), the study analyzed the influence of suspension hardpoint coordinates on kinematic and dynamic behavior. Two phases were conducted: a suspension-only elasto-kinematic analysis to minimize camber and toe variations, and a full vehicle analysis during a step steer maneuver to reduce roll angle and yaw rate. The results demonstrate that modifying specific hard points can significantly improves vehicle stability and handling.

Contents

1. Introduction

In this laboratory a multibody model of a road vehicle implemented in MSC Adams is considered. The aim is to investigate the effect of changing the coordinates of some characteristic points of the suspension on the vehicle behavior.

There are four parameters that need to be optimized:

- X, Y, Z coordinates of the connection point between the lower arm and the hub carrier (*hpl_lca_outer*)
- Z coordinate of the spherical joint connecting the tie rod to the hub carrier (*hpl_tierod_outer*)

Possible approaches:

1. **OFT: One Factor at a Time**. It has been demonstrated that changing one parameter at a time while keeping the other ones fixed doesn't allow to fully characterize the interaction between the different parameters; therefore, this approach cannot be used.
2. **Full factorial design:** all the possible combinations of values the design variables can assume in the feasible domain are tested. If the computational time and power allow to perform this type of analysis, this provides for sure the most detailed results; in case this is not possible, fractional factorial designs are used to extract the maximum amount of information possible from a limited number of simulations.

1.1 Description of the problem

- The parameters described previously need to be optimized in two different scenarios
- **Part 1:** suspension kinematics analysis
    - Only the suspension assembly is used
    - A parallel wheel travel test is considered
    - The **objective functions** to be minimized are the **camber and toe angle variations**

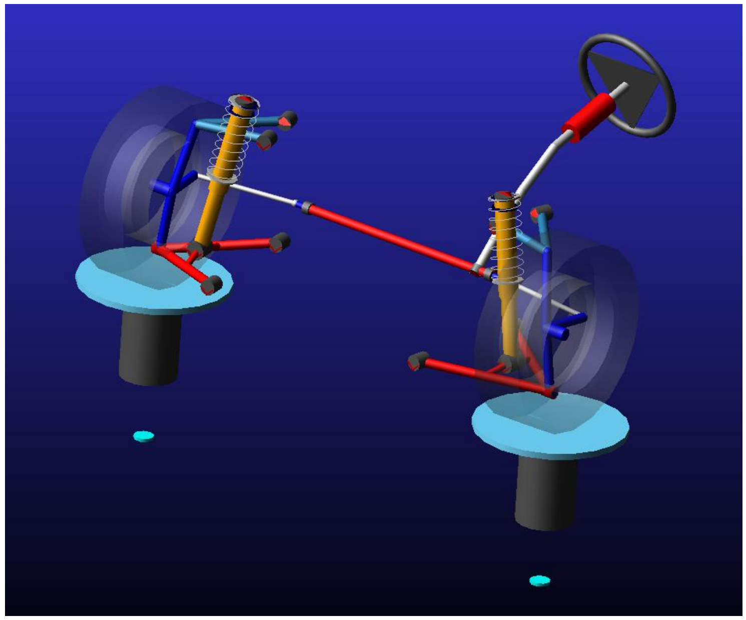

Figure 1

- **Part 2**: full vehicle analysis
    - The whole vehicle assembly is used
    - Step steer $0° \div 45°$ maneuver is considered
    - The **objective functions** to be minimized are the **steering angle, the yaw rate and the roll moment**

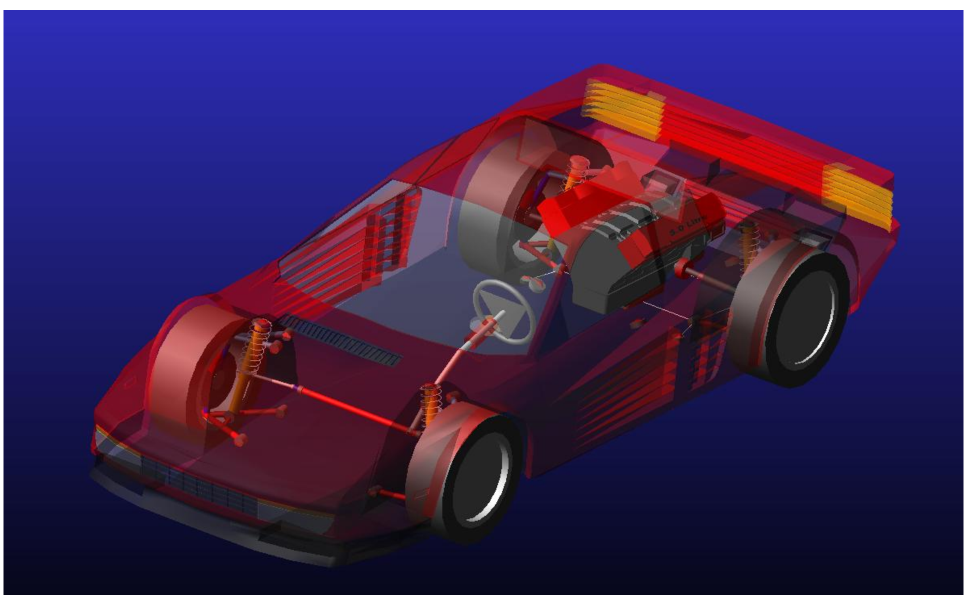

Figure 2

2. Suspension elasto-kinematic analysis

2.1 Settings of the optimization

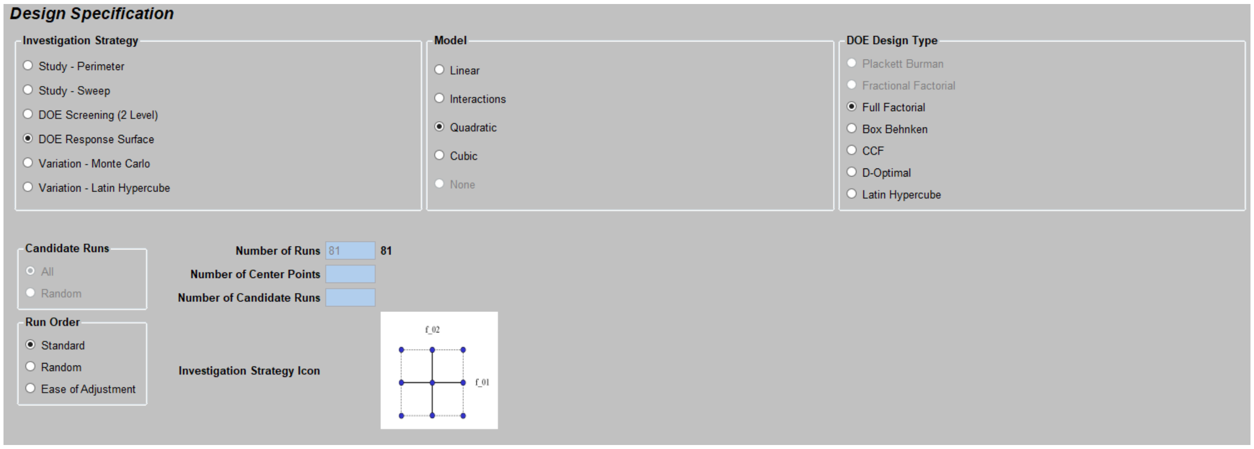

Figure 3

Explanation of each term meaning:

- Investigation strategy: **DOE Response surface**
    - Through this strategy it is possible to build a predictive model of the system. Unlike simple screening, this allows us to visualize how inputs interact with each other and pinpoint the exact optimal settings, rather than just identifying significant trends
- Model: **Quadratic**
    - Three levels for each factor are considered
    - Considering four factors, the number of simulations is: $3^{n_{factor}} = 81$
    - The model is fit with a quadratic equation
- DOE design type: **Full Factorial**
    - All the three levels for each factor are considered, not a fraction of the total

2.2 Results of the optimization

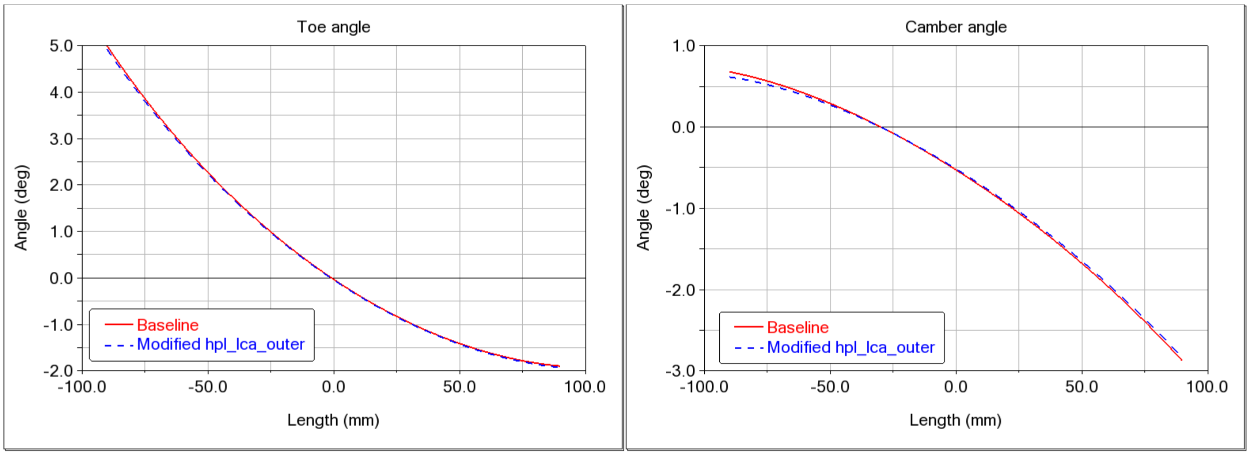

Figure 4

At first, before running the optimization, two simulations were run: a baseline case and a slightly modified one to see how the angles would vary as function of the modifiable parameters.

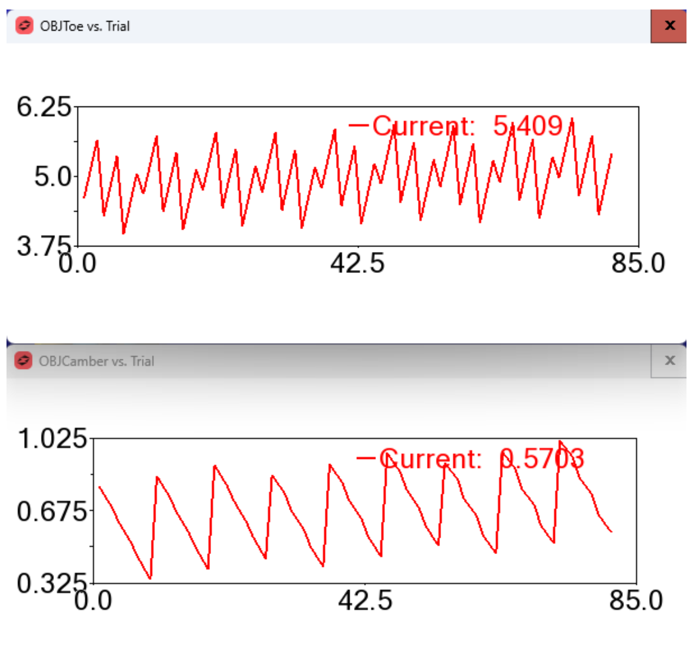

Figure 5

Afterwards, the DOE was run and in Figure 5 the trend of the objective functions plotted against the number of simulations tested is showed. It can be noticed that the solution is (as the combinations are tested) is a compromise between the 2.

Rules-of-thumb summary for model "Model_01"

	Toe	Camber
Fit		
Term		
Residuals	?	

Figure 6

Goodness-of-fit for model "Model_01"

	Toe	Camber
R2	1	1
R2adj	1	1
P	3.38e-213	1.52e-205
R/V	1.74e+04	1.38e+04

Figure 7

In Figure 6 and Figure 7, the quality of the regression is shown. As it can be noticed, it is considered by the algorithm as an appropriate regression.

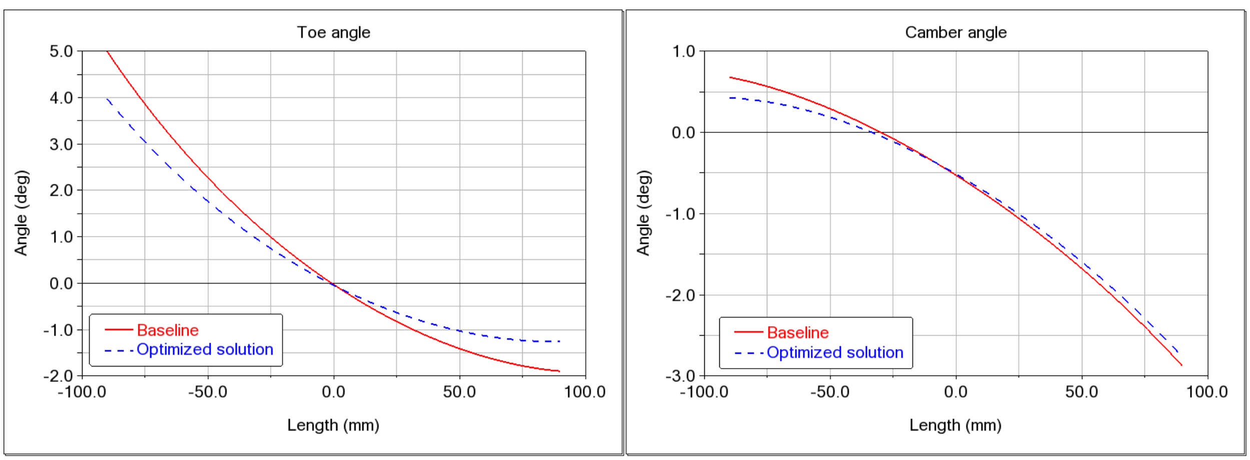

Figure 8

Finally, the optimization was performed on the quadratic model. In Figure 8, the simulation was run with the optimized parameters and the result show that the toe angle variation is minimized to avoid unwanted changes in direction when the suspensions goes up and down. Instead, keeping the camber angle as negative as possible helps to have a larger contact patch and so increase the lateral grip.

3. Full vehicle analysis

3.1 Settings of the optimization

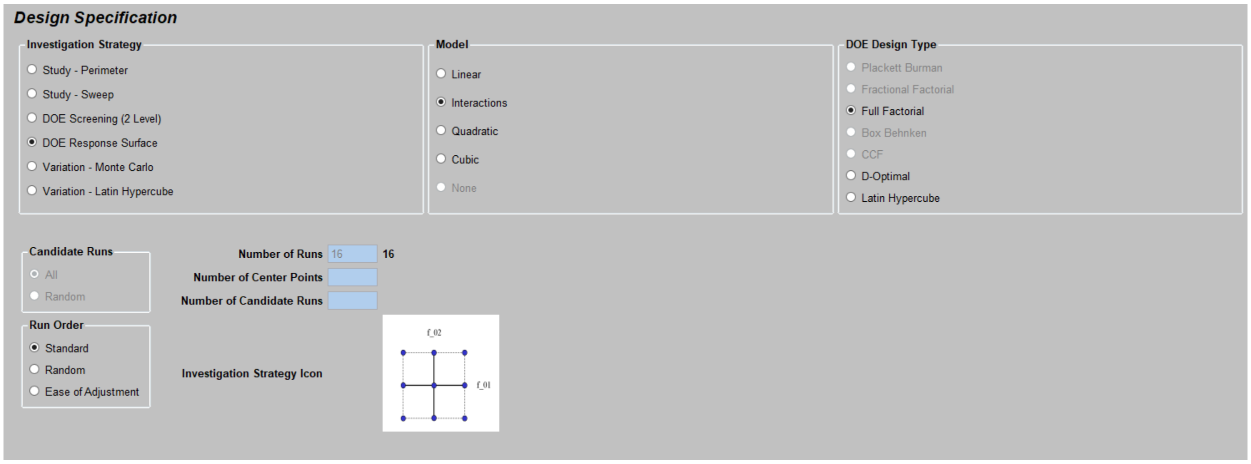

Figure 9

Explanation of each term meaning:

- Investigation strategy: **DOE Response surface**
  - Through this strategy it is possible to build a predictive model of the system. Unlike simple screening, this allows us to visualize how inputs interact with each other and pinpoint the exact optimal settings, rather than just identifying significant trends
- Model: **Interactions**
  - The model is fit with an equation that includes linear and interaction terms but not quadratic ones
- DOE design type: **Full Factorial**
  - All the three levels for each factor are considered, not a fraction of the total

3.2 Results of the optimization

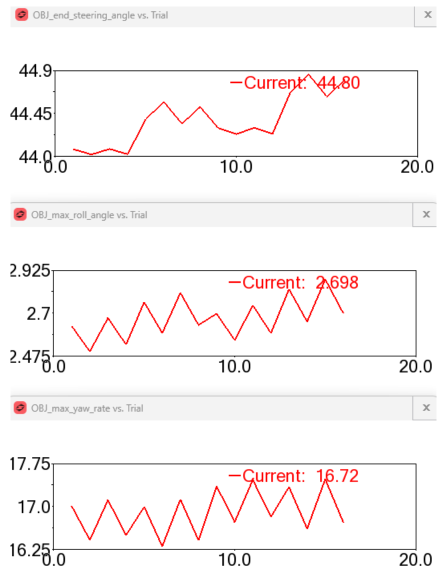

Figure 10

Running the DOE, the variation of the parameters as function of the different combinations tested was run. Once again the variations of the parameters imply a compromise between the objectives that need to be met.

Goodness-of-fit for model "Model_01"

	yaw_rate	roll_angle	SA
R2	● 0.994	● 0.994	? 0.942
R2adj	● 0.992	● 0.991	● 0.921
P	● 3.15e-12	● 5.02e-12	● 9.83e-07
R/V	● 59.8	● 67.7	● 18.1

Figure 11

Rules-of-thumb summary for model "Model_01"

	yaw_rate	roll_angle	SA
Fit	●	●	?
Term	?	?	?
Residuals	●	●	●

Figure 12

In Figure 11 and Figure 12 the quality of the regression is shown. Being a little worse than the previous case, it is still considered acceptable by the guidelines.

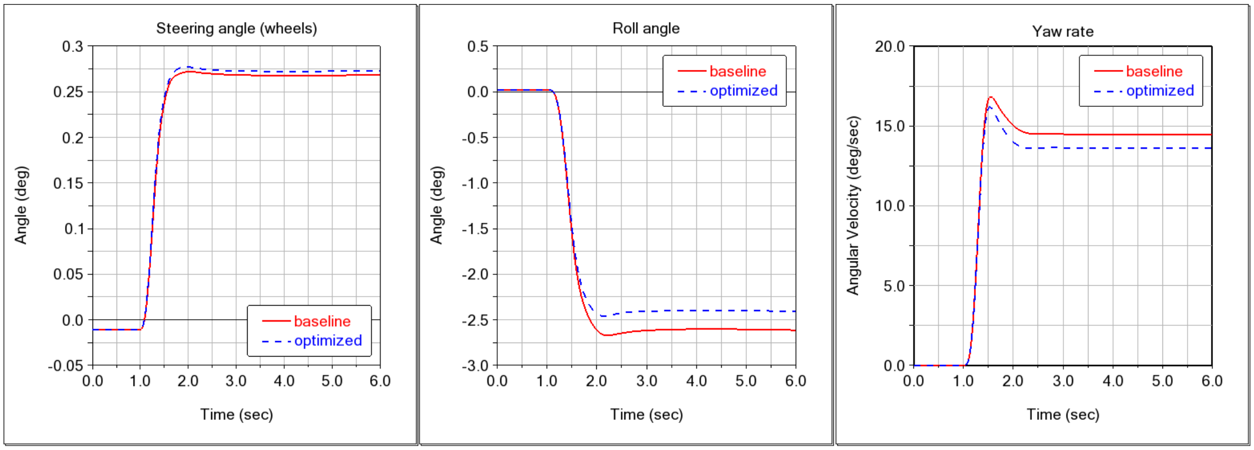

Figure 13

The optimization is being performed to enhance the stability, responsiveness, and overall handling of the vehicle during cornering. This is achieved by reducing the body roll: less body roll means the vehicle feels more stable, safer, and the tires maintain better contact with the road. Moreover, also the yaw rate has to be reduced: a lower, more controlled yaw rate generally indicates a smoother, more predictable, and less aggressive turning response, which improves directional stability and control.

4. Conclusion

In this assignment, the topic of design of experiments was explored in Adams Insight. Specifically, at first only the front suspension group was considered, simulating a parallel wheel travel test with the objective of optimizing camber and toe angle variations. A full factorial quadratic model was adopted, since the simulations were faster with respect to the whole vehicle model, 81 simulations were run.

Instead, as far as the whole vehicle model is concerned, a step steer maneuver was considered and the objective functions to be minimized were the steering angle, the yaw rate and the roll moment. In this case simulations were performed still through a full factorial plan, but it was avoided to apply the quadratic model since the simulations would require too much time; instead, an interaction model was considered.

This assignment explored exactly how, considering different models and simulations, the experimental plan varies according to them, to collect the highest possible quantity of information without having computational time that is too high.