An ADAMS Model of a Motor Vehicle Front Suspension and its Applications

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Abstract

An ADAMS model of a kind of McPherson strut suspension was built. Based on the model, various analyses were carried out. By transferring the model into ADAMS/Vehicle, the industry-standard suspension characteristics were computed, where the bushing stiffness of some joints may be taken into account. Taking advantage of the DOE algorithm in ADAMS, the feasible area where the differential may be positioned is found. If the differential is positioned out of the area, the condition that enable the inner and outer universal joints of the propeller-shafts to work properly during the process of suspension steering and the wheels moving up and down will be violated. By doing quasi-static equilibrium simulation of the processes of ride and steer, various attitudes of the suspension were determined. The results was used to check the position of the wheels relative to other parts of the vehicle such as the subframe, and can be used to determine the shape of front wheel cowl. Finally, combined with an ADAMS model of a dependent suspension, the McPherson strut was incorporated into a full-vehicle model. The steering behavior of the vehicle model was simulated and the results were compared with that of experiments.

1 Introduction

During the process of motor vehicle product development, even before the first physical prototype is built, engineers always try to predict the characteristics of the product being designed, and needs to know how to make it better. Traditionally empirical formulae were used. And mathematical models were also developed to study the characteristics of vehicle suspensions and full-vehicles, which turned out to be too complex a job. For some kind of suspensions, many simplifications have to be made, and some factors, such as the elasticity of joint bushings, are difficult to be taken into account.

Now using the powerful software of ADAMS, the technology of virtual prototyping has shown its effectiveness. By modeling virtual prototypes, automotive engineers and designers can analyze the characteristics of vehicle suspension and simulate the various behavior of a full-vehicle conveniently, effectively and with high accuracy.

In this paper, an ADAMS model of a motor vehicle front suspension and its applications are introduced. The suspension is a kind of McPherson strut. The model was built in ADAMS/View, which is a powerful modeling and simulating environment, and was transferred into ADAMS/Vehicle to calculate the suspension characteristics.

Using the DOE algorithm of ADAMS, the feasible area where the differential should be positioned is found. The position of differential is one of the factors that should be defined in the early stage of a motor vehicle product development.

By doing quasi-static equilibrium simulation, the wheels were moved up and down. The simulation was repeated with the wheels steered to different angles. The different attitudes of the suspension were exported in the form of IGES files that were used to check the position of the wheels relative to other parts of the vehicle such as the subframe, and can be used to determine the shape of front wheel cowl.

At last, combined with an ADAMS model of a dependent suspension that is composed of leafsprings and shock absorbers, the McPherson strut was incorporated into a full-vehicle model. The steering behavior of the vehicle model was simulated and the results were compared with that of experiments.

2 An ADAMS Model of a McPherson Strut Suspension

The suspension to be modeled is a kind of McPherson strut. It was modeled in ADAMS/View, as shown in Figure 1. This is a parametric model. The position of joints and the size of parts are controlled by key points and variables and can be changed conveniently while the structure of the suspension remains the same. The bushings of some joints play an important role in the suspension. The bushing stiffness was measured through experiments and was taken into account in the suspension model. The ride analysis of the suspension was carried out. The wheel alignment parameters were calculated in the form of ADAMS request. Some of them were compared with experiment results. Figure 2 – Figure 5 are some of the results.

3 Computation of Suspension Characteristics by Means of ADAMS/Vehicle

After the model was built in ADAMS/View, it was transferred into ADAMS/Vehicle to do the characteristics analysis. ADAMS/Vehicle can be used to analyze the motion of suspension through ride, roll and steer motions. Based on these motions, ADAMS/Vehicle computes more than 30 suspension characteristics[1]. The results from ADAMS/Vehicle provide detail information about the suspension. Engineers may use it to evaluate the design.

Here by means of ADAMS/Vehicle, two schemes of the suspension were compared. The difference between the two is that some key points location (such as the wheel center, joints of lower control arm, etc) of one suspension is a little different from another. Figure 6 to Figure 11 show some of the results. These were used to do further analysis.

4 Define the Feasible Area Where the Differential May Be Positioned

The propeller shaft consists of an inner semiaxle, a middle semiaxle and an outer semiaxle which are connected by an inner and an outer constant velocity universal joint. The inner constant velocity universal joint is of extensiontype.

When the wheels steer as well as jounce and rebound, the angles between the outer semiaxle and the middle semiaxle and that between the middle semiaxle and the inner semiaxle change. And the amounts of extension of the extensiontype universal joints also change. In order that the universal joints work under normal condition, the angles between the semiaxles and the extension volumes must be within certain values. For the type of universal joints adopted in this suspension, the angle between the outer semiaxle and the middle semiaxle must be within 45°. For the inner universal joints, the constraint is described in Figure 12, that is, the working condition must within the area enclosed by the dash-dot-dot.

These constraints of the universal joints also constraint the position of the differential. The differential should be located at such a place that enable the universal joints work properly while the wheels jounce, rebound and steer.

Here taking advantage of the DOE algorithm of ADAMS, computer experiments were carried out to find the feasible area where the differential may be positioned. Figure 13 is the result of one scheme of the suspension. Figure 14 - Figure 17 show the working status of some experiment points taken from the boundary of the feasible area.

5 Define the Space Needed for the Travel of Front Wheels

When the geometry of the wheel part reflects the real shape and size of the tire of the vehicle, the suspension model can be used to calculate the space needed for the travel of front wheels.

By doing quasi-static equilibrium simulation, the wheels were steered to a certain angle and were moved up and down. The process was repeated as the wheels were steered to different angles.

With these analyses, different attitudes of the suspension were found and exported to files in the format of IGES. Figure 18 shows one of these files. These results were used to check the position of the wheels relative to other parts of the vehicle such as the subframe (Figure 19) and can also be used to determine the shape of front wheel cowl.

6 A Full-Vehicle Model and the Simulation of its Steering Behavior

Combined with an ADAMS model of a rear suspension, which is a dependent suspension composed of leafsprings and shock absorbers, the front suspension model was incorporated into a full-vehicle model. Figure 20 shows the initial status of the model. By doing static equilibrium simulation, the model was balanced (Figure 21) and stood still on the road. By adding motions to the inner semiaxles and the steering rack, the vehicle was accelerated to certain velocity and was steered. The ramp-to-step steer was simulated and the results were compared to that of experiments. In simulation the steering input adopts that of experiments and the steering wheel angle was converted to the displacement of the steering rack. Figure 22 and Figure 23 show two of the results. The results show that, as far as the steering behavior is concerned, the full-vehicle model behaves nearly the same as the real vehicle. Figure 24 shows the trace of the vehicle during the process of transition from accelerating to steady state cornering. Figure 25 is one of the frames of the simulation.

7 Summary

This paper presents an ADAMS model of a motor vehicle front suspension and some applications of it. Though these are all the basic applications of ADAMS, it has shown the power of the technology of virtual prototyping. The problems that were difficult to be solved before become easy now. Much time has been saved. Still, this is just the beginning. Based on this, further development is already in progress.

Reference

[1] Mechanical Dynamics, Inc., ADAMS/Vehicle™ User's Guide (Version 8.0), November, 1994.

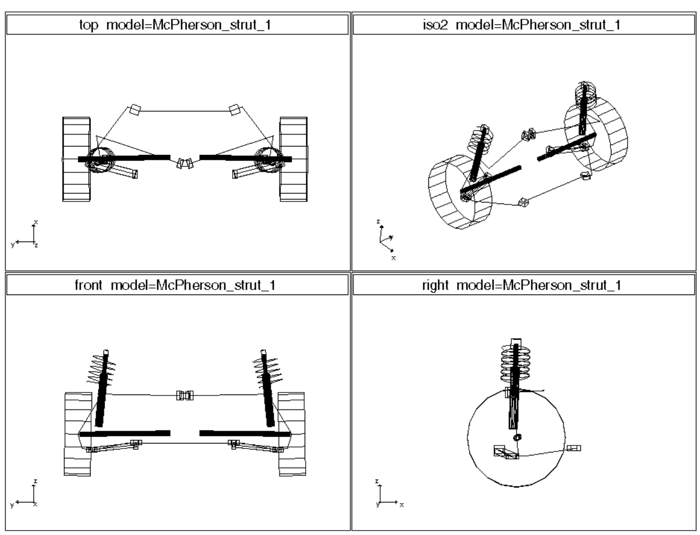


Figure 1. An ADAMS model of a McPherson strut

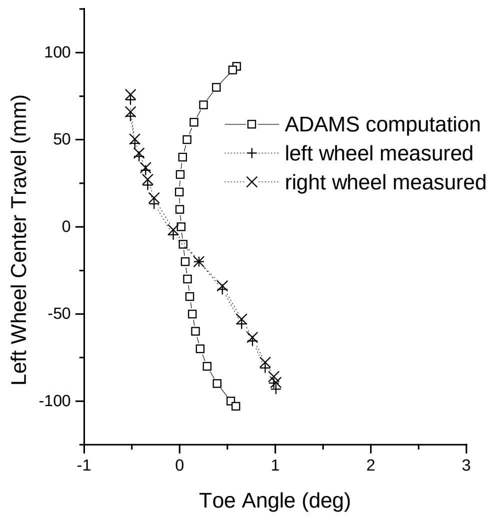


Figure 2. Toe-in alteration as the wheels jounce and rebound

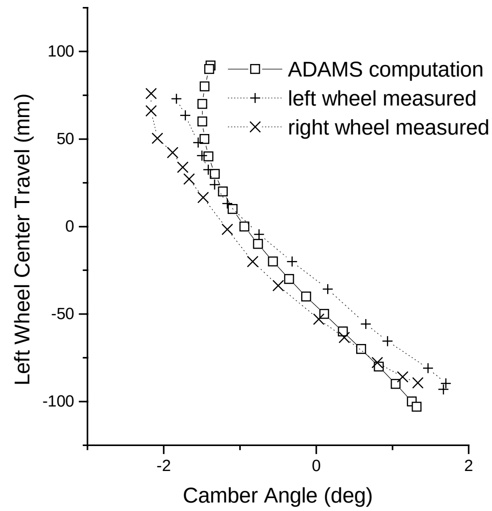


Figure 3. Camber alteration as the wheels jounce and rebound

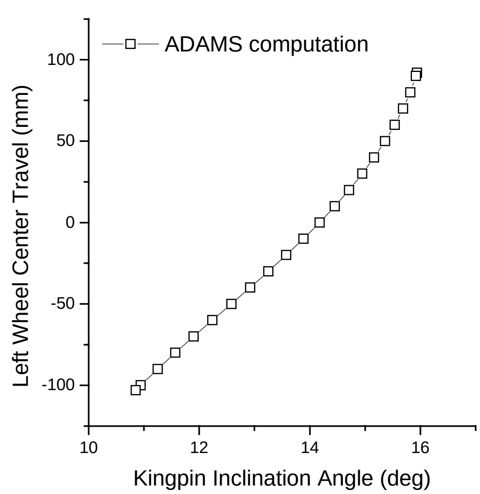


Figure 4. Kingpin inclination alteration as the wheels jounce and rebound

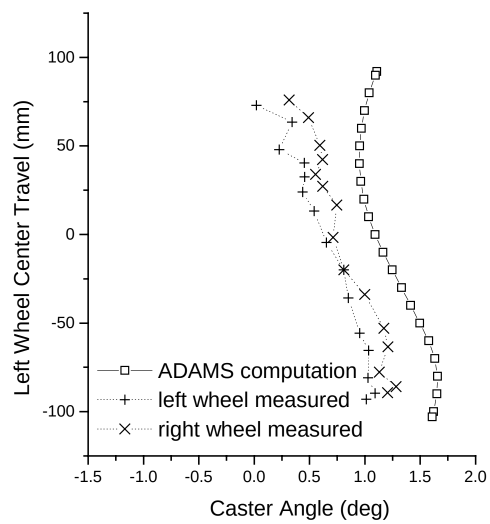


Figure 5. Caster alteration as the wheels jounce and rebound

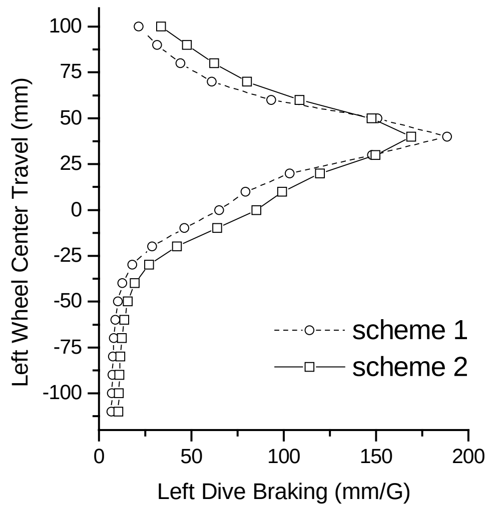


Figure 6. Dive braking alteration as the wheels jounce and rebound

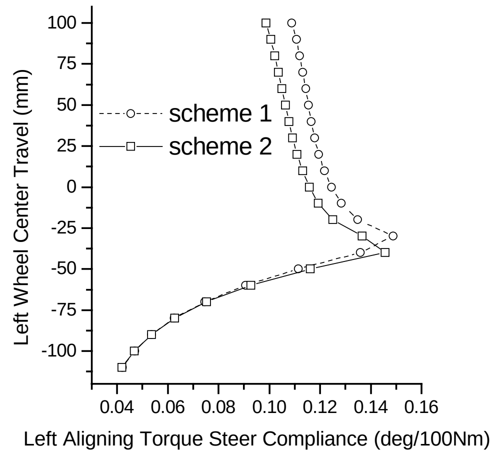


Figure 7. Aligning torque steer compliance alteration as the wheels jounce and rebound

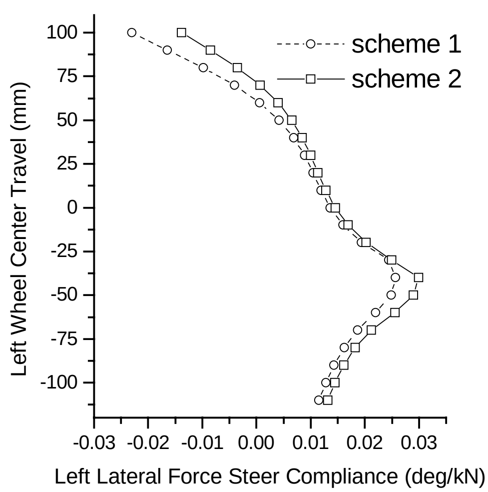


Figure 8. Lateral force steer compliance alteration as the wheels jounce and rebound

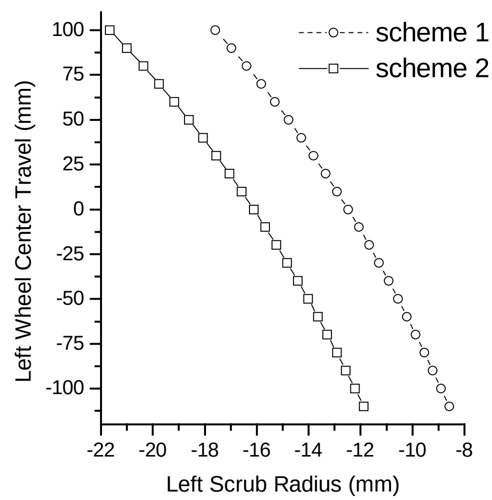


Figure 9. Scrub radius alteration as the wheels jounce and rebound

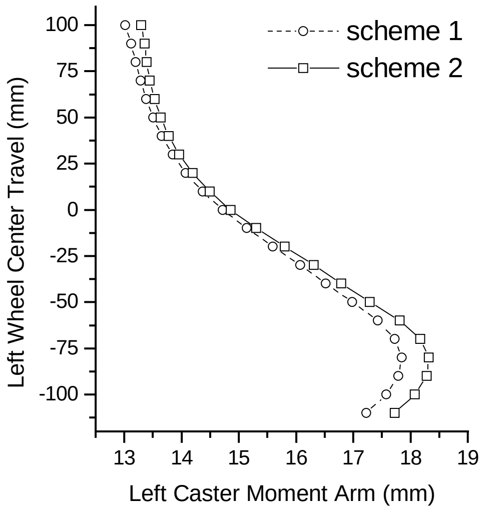


Figure 10. Caster moment arm alteration as the wheels jounce and rebound

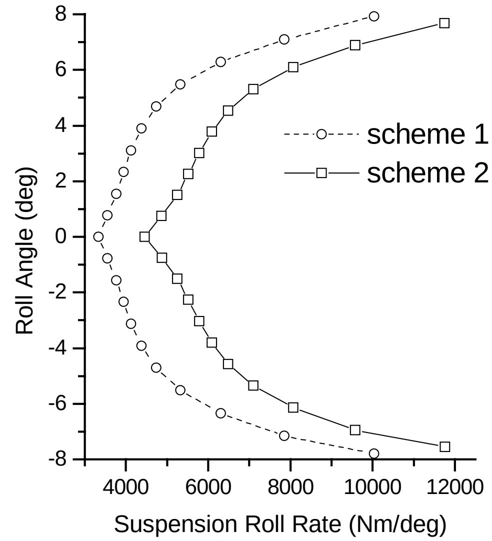


Figure 11. Suspension roll rate alteration as the vehicle body roll

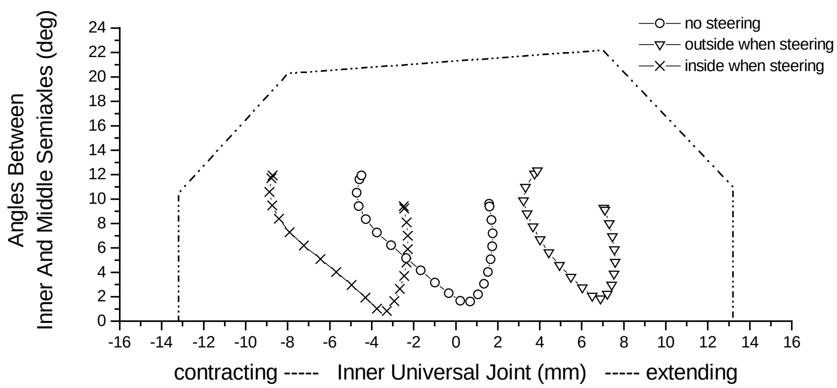
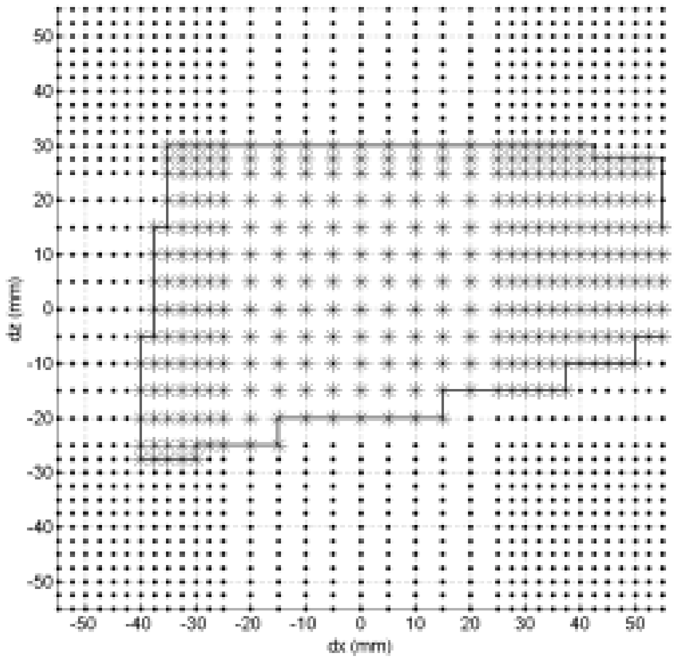


Figure 12. The normal working condition of the extensiontype constant velocity universal joint



* feasible point • unfeasible point (dx, dz: offset from the original place)
Figure 13. The feasible area where the differential may be positioned

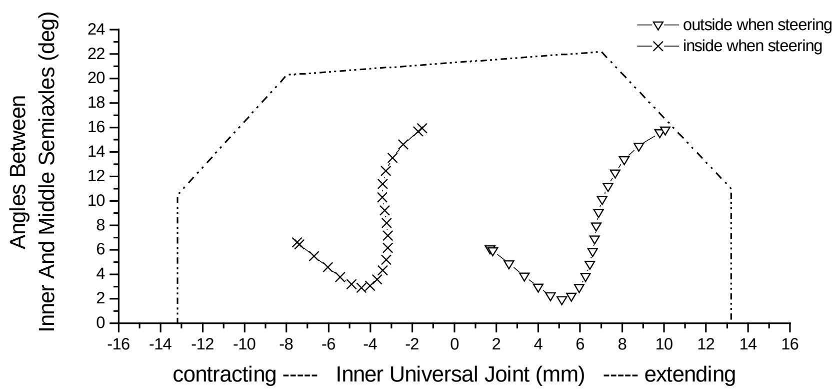


Figure 14. The working status of the inner universal joints: dx=-35.0, dz=30.0

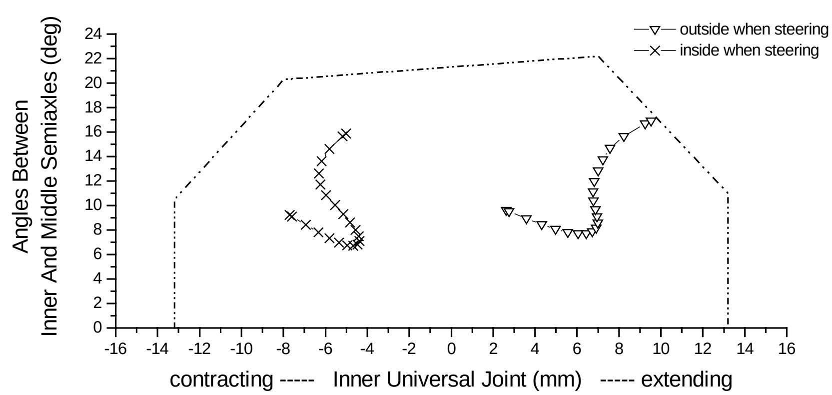


Figure 15. The working status of the inner universal joints: dx=52.5, dz=27.5

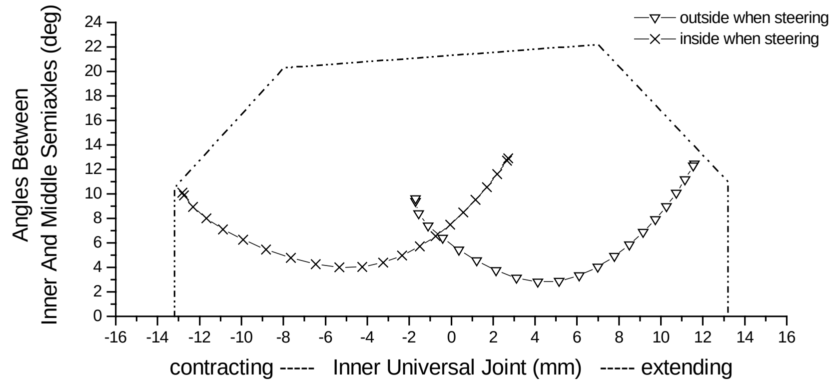


Figure 16. The working status of the inner universal joints: dx=-40.0, dz=-27.5

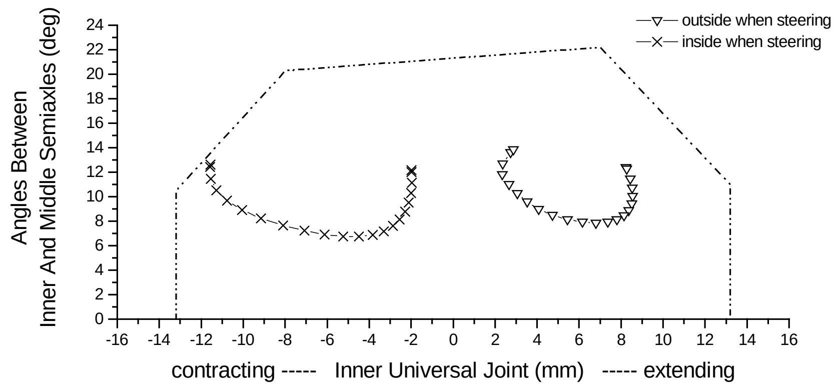


Figure 17. The working status of the inner universal joints: dx=55.0, dz=-5.0

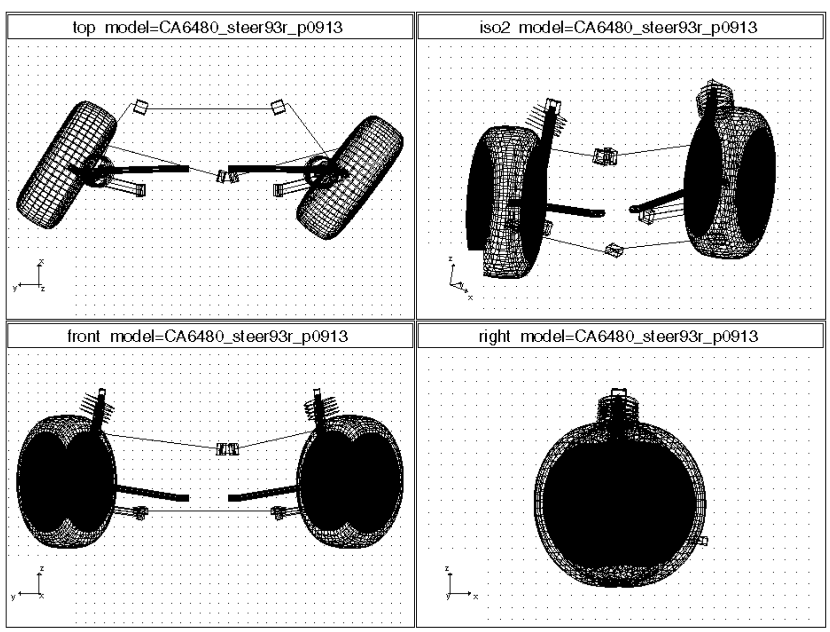


Figure 18. An IGES file of a suspension attitude, shown in ADAMS/View

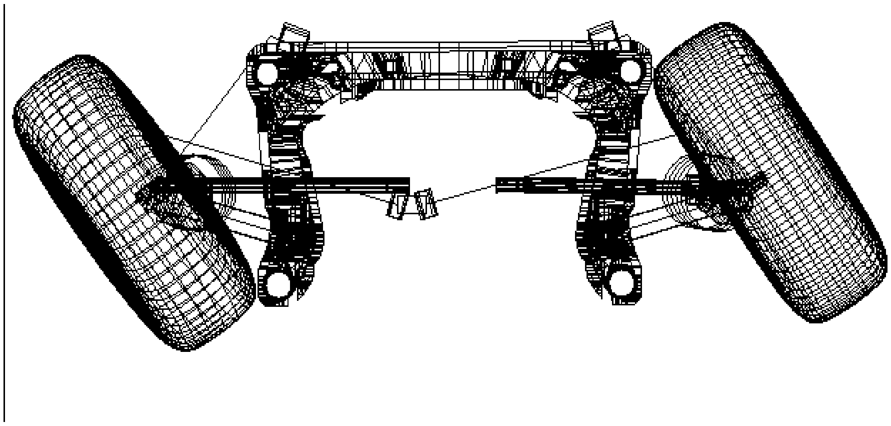


Figure 19. Check the position of the wheels relative to the subframe

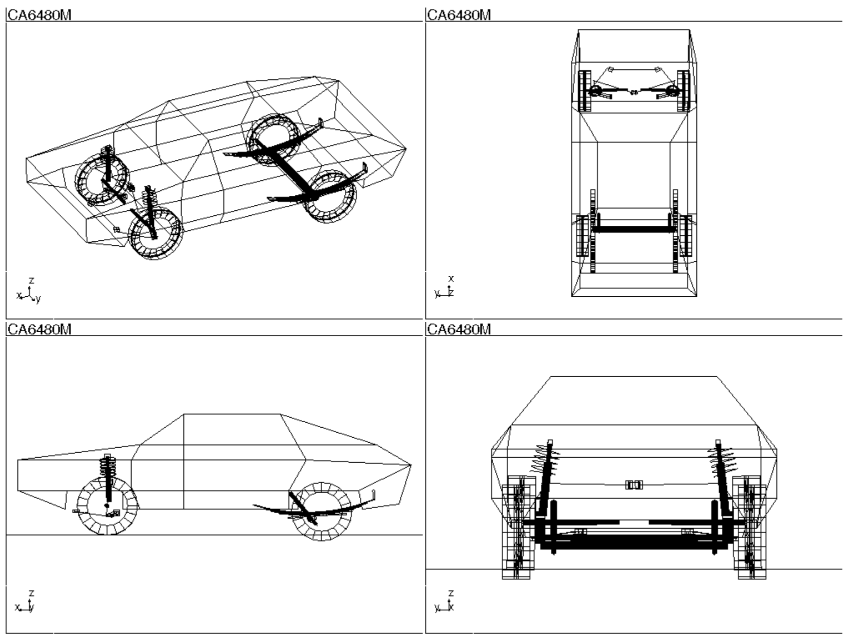


Figure 20. The initial status of the full-vehicle model

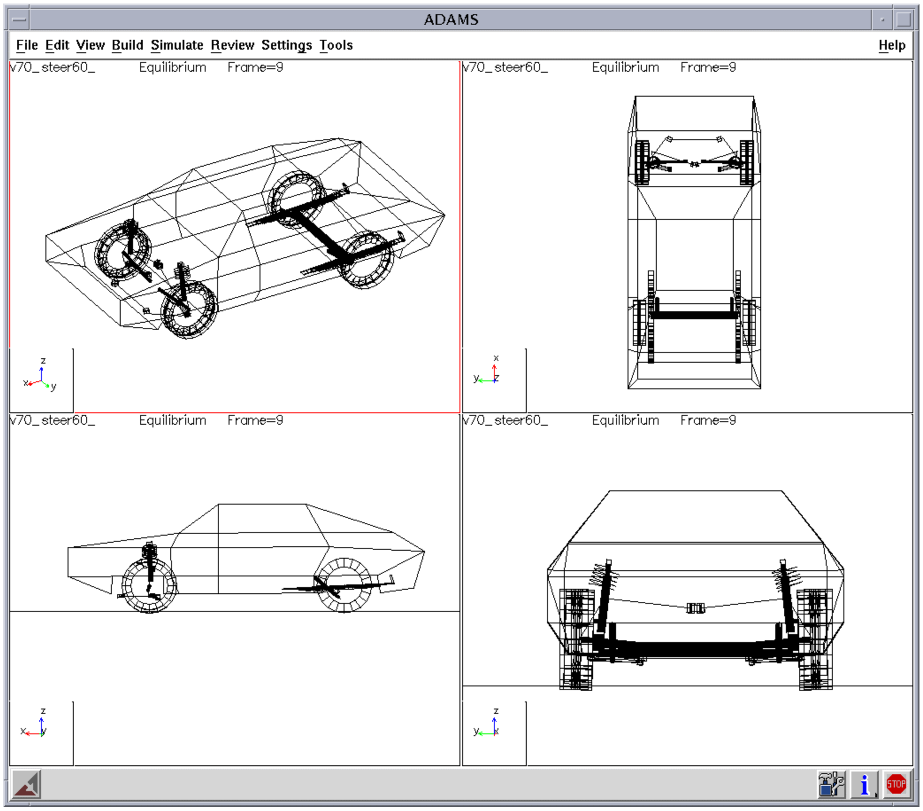


Figure 21. The equilibrium status of the full-vehicle model

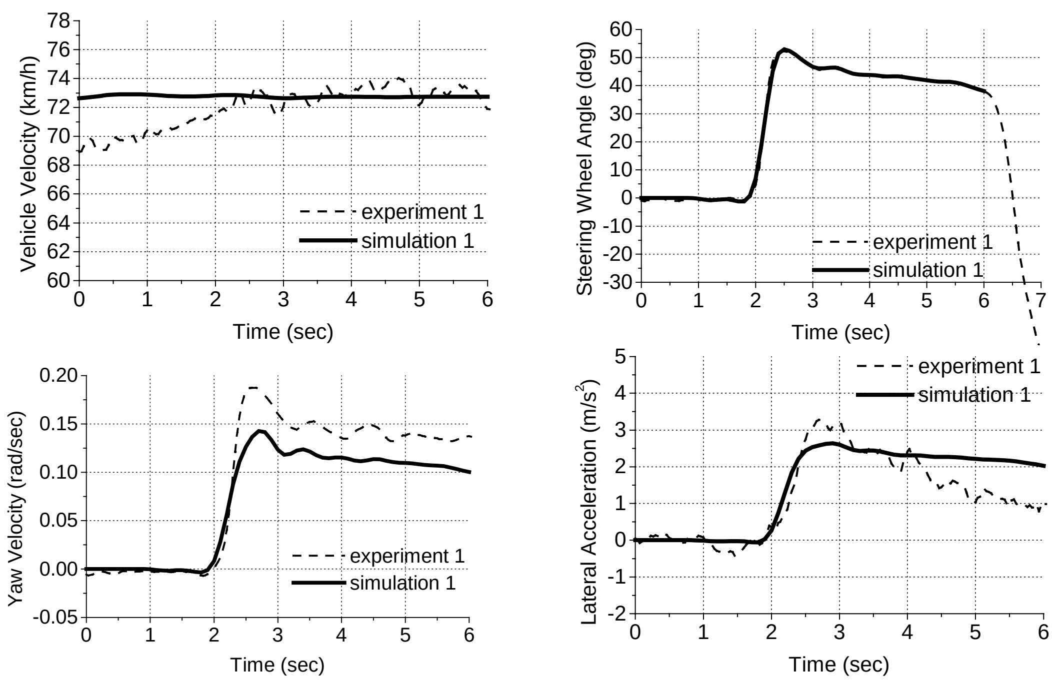


Figure 22. The ramp-to-step steer simulation 1

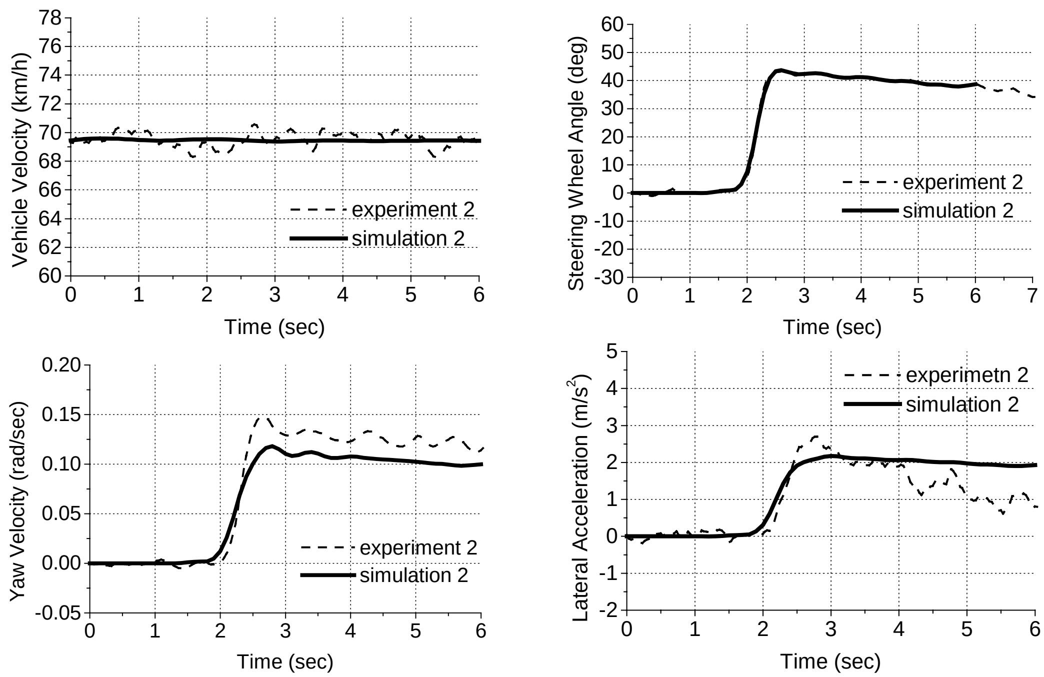


Figure 23. The ramp-to-step steer simulation 2

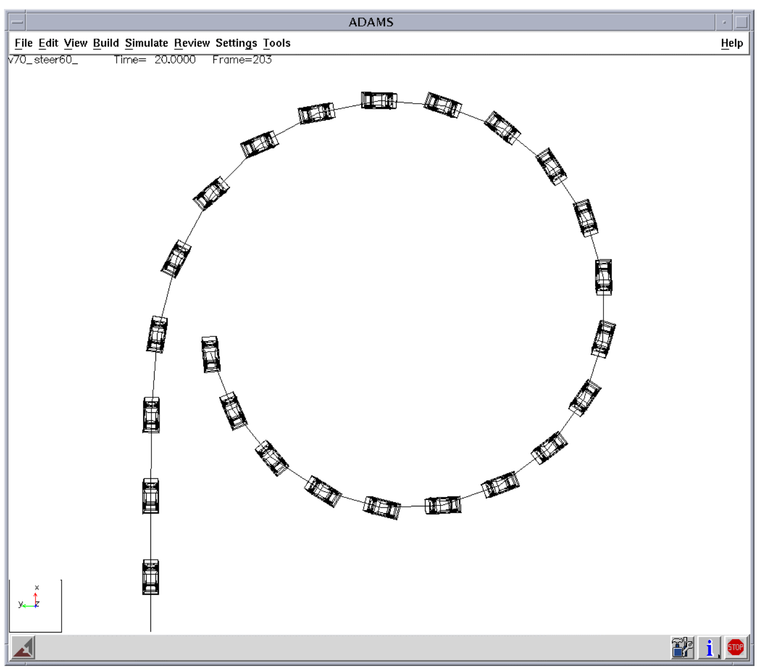


Figure 24. Vehicle trace from accelerating to steady state cornering

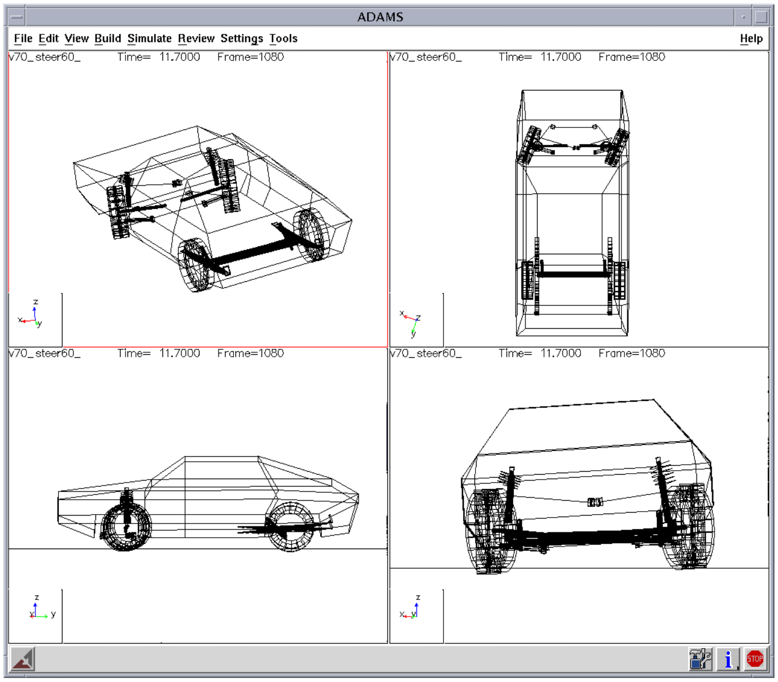


Figure 25. The steering status of the full-vehicle model