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THE KINEMATICS AND COMPLIANCE TEST ON A SUSPENSION SYSTEM USING ADAMS CAR

P.RAVICHANDRA[1], M.R.KHODKE[2], DR.U.S.CHAVAN[3]

[1]PG Scholar, Department of Mechanical (Design) Engineering, Vishwakarma Institute of Technology, Pune, India
[2]Professor, Department of Mechanical Engineering, Vishwakarma Institute of Technology, Pune, India
[3]Professor, Department of Mechanical Engineering, Vishwakarma Institute of Technology, Pune, India

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Abstract - *The experimental approach is usually used as the way to develop or modify a suspension system to obtain maximum ride comfort and handling characteristics. This approach is a time-consuming process, costly, and may not guarantee the optimum solution. Thus, to avoid this, a virtual vehicle suspension system is necessary. In this paper, a half-car body of an actual suspension system based on a four wheel vehicle was modeled and simulated. In total, 10 components consisting of different joint types and a number of degrees of freedom. The model was developed by defining the location of the hard point or coordinate before specifying the component characteristics and joint type. The completed suspension model was simulated using the vertical parallel movement test. Integral-link suspension modeling and simulation was carried out using ADAMS/Car. Toe, camber and caster variation with respect to vertical displacement of the wheel are obtained and the curve trends are compared with the existing model for validating the concept model.*

Key Words: Suspension modeling; McPherson suspension, multilink suspension, vertical parallel and oppose wheel movement test

1. INTRODUCTION

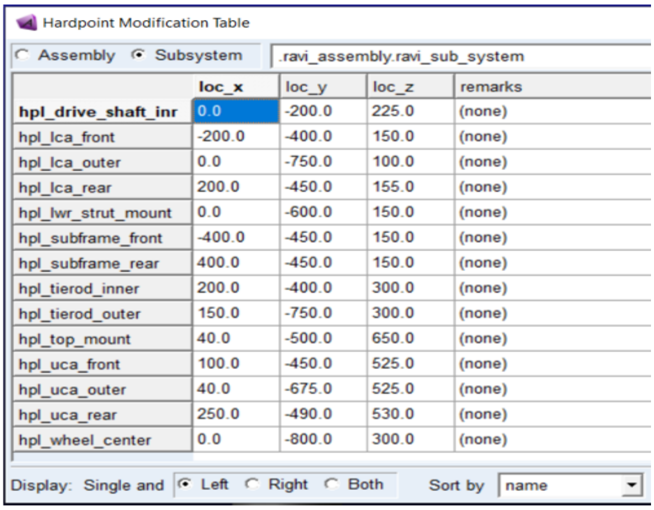
Nowadays, the automotive industry is one of the fastest growing industries around the world [1]. In order to improve the handling and riding comfort of a vehicle, the suspension system design is the main factor as it is used to support the load, and protect the passengers by absorbing the shock and vibration [2]. Overall, the suspension system consists of dampers, springs, arms, knuckles and anti-roll bars as the main components and bushings, bearings and fasteners as the support components [3-7]. It is crucial for the suspension setup and design that modifications are made correctly at the start by considering the entire performance and vehicle capability [8]. The purpose of this study is to generate and simulate a fully working virtual suspension model of a four wheel vehicle double wishbone type for the front suspension systems. Generating the virtual suspension system model is basically to reduce the number of result errors [8]. Traditionally, in order to develop or modify the components of a suspension system, the testing method using a suspension test rig is employed to ascertain the characteristics. Basically, this approach is time consuming, costly, requires workmanship and might include errors due to the human factor, thus may not guarantee the optimum solution. However, the suspension system has to be proven to be correctly modeled. One of the solutions is to use the verification method. Verification can be achieved by comparing the simulated result with the help of graphs generated [3]. In this paper, only the simulated result will be compared with the various changes in hardpoints of upper control arm. Both the results only consider the value of the toe change, camber change and caster change when subjected to the vertical parallel movement test movement test, replicating the same experimental setup used by Four wheel vehicle. In the following subsection, the methodology adopted for this study is discussed briefly including modeling of the suspension system and the simulation process. Finally, detailed discussions on the result and the conclusion are presented.

1.1 METHODOLOGY

The process for this study involved several important steps, starting with the modeling of a front half suspension system using the MSC/ADAMS car, employing the movement simulation analysis test, and generating the kinematics and compliance (K&C) data for selected outputs for verification purposes.

1.2 Suspension Modeling

The multi-body model of a suspension system is based on the actual Four wheel vehicle passenger car suspension system. As mentioned before, double wishbone will be used for the front suspension system. In order to replicate the actual suspension system, the model must be built using the same parameters as the actual suspension, such as the hard-point geometry, damper profiles spring stiffness, anti-roll bar stiffness, material selection for the components, joining type and orientation as well as bushing properties [9]. In total, 10 component hard point in the x, y, z directions for both suspension models with specific joining types and orientations were found. The modeling stage starts by generating the suspension model template. Once the template is made, it must be saved as a subsystem. At this point, not as many parameters can be changed as can be changed at the template stage. Finally, the subsystems are assembled as one working suspension system assembly ready for simulation. Note that only complete assembly systems can be analyzed and simulated to generate the data results [10]. The individual suspension component positions and topology modeling for each suspension and the connectivity of each component with other components via joint type as well as the number of degrees of freedom.



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hpl_lca_front	-200.0	-400.0	150.0	(none)
hpl_lca_outer	0.0	-750.0	100.0	(none)
hpl_lca_rear	200.0	-450.0	155.0	(none)
hpl_lwr_strut_mount	0.0	-600.0	150.0	(none)
hpl_subframe_front	-400.0	-450.0	150.0	(none)
hpl_subframe_rear	400.0	-450.0	150.0	(none)
hpl_tierod_inner	200.0	-400.0	300.0	(none)
hpl_tierod_outer	150.0	-750.0	300.0	(none)
hpl_top_mount	40.0	-500.0	650.0	(none)
hpl_uca_front	100.0	-450.0	525.0	(none)
hpl_uca_outer	40.0	-675.0	525.0	(none)
hpl_uca_rear	250.0	-490.0	530.0	(none)
hpl_wheel_center	0.0	-800.0	300.0	(none)

Display: Single and ● Left ○ Right ○ Both

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Figure 1. Hardpoint co-ordinates

2. Suspension Simulation

The suspension model simulation test is conducted using a suspension test . The method and procedure is the same as the experimental setup. The vertical parallel wheel movement test, where both the left and right wheels are subjected to simultaneously parallel movement in the same vertical direction with 300 steps of 100 mm bound and rebound travel value (total of 200 mm of wheel travel).

The complete suspension assembly simulation setup and Modified suspension assembly simulation setup on ADAMS/car test rig are created using rigid bodies with hardpoints references as shown in figure 2 and figure 3. These are known as general parts which are movable parts which cannot deform and have mass, inertia properties.

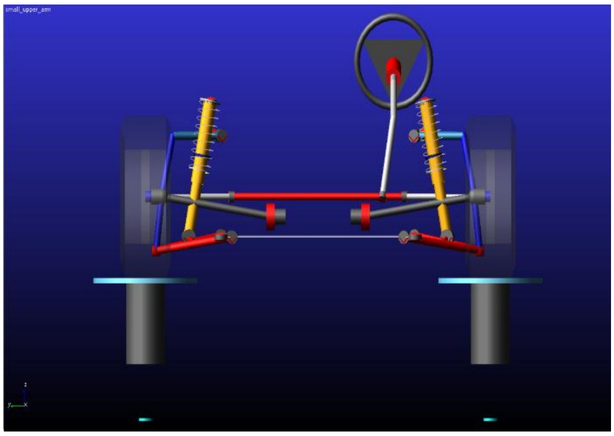


Figure 2. Complete suspension assembly simulation setup on MSC/ADAMS car test rig

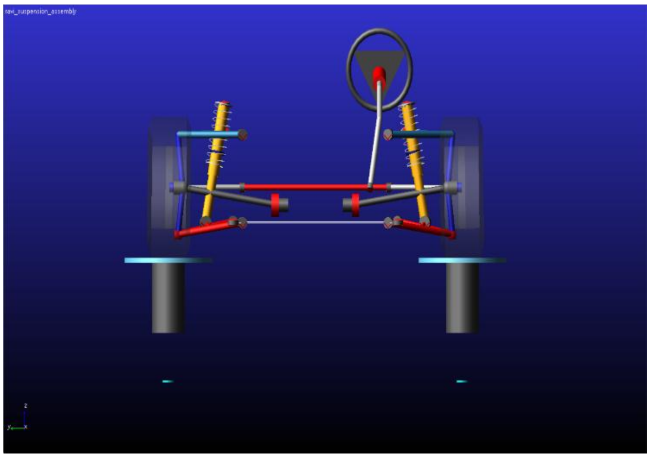


Figure 3. Modified suspension assembly simulation setup on MSC/ADAMS car test rig

3. RESULTS AND DISCUSSION

The simulation test generates a K&C data set. As mentioned before, only toe change, camber change and caster change values to the wheel movement are considered in comparison with the help of graphs, since they give the significant effect of the overall K&C to the ride comfort and handling characteristics of the vehicle [11]. Thus, a total of 3 graphs were generated. At the start of generating the virtual suspension system model, the left and right sides of the suspension were set to be symmetrical having the same component properties to be simulated and tested. Thus, either the left or right data set can be used in the comparison after the simulation.

Graphs plotted for the suspension systems when subjected to the vertical parallel wheel movement test. The suspension system shows a reduction in both toe and camber from positive to negative values when subjected to both of the vertical wheel movement tests. This setup allows better vehicle handling and stability during cornering [11-12]. The different setup comes into the suspension system by providing an increase in toe change while reducing the camber change when subjected to the same test as the hardpoint co-ordinates of suspension system changed. The change in toe setting from the negative to the positive value for the suspension system is basically to compensate for the front-wheel-drive's understeer since it induces a little oversteering during cornering. On the other hand, the negative camber of the suspension system provides the same benefits as the modified suspension system.

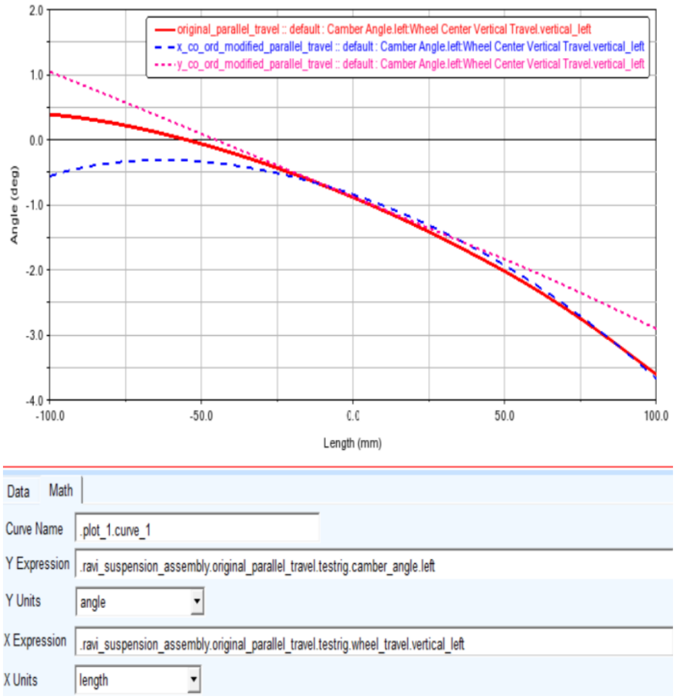
4. Analysis of kinematics and compliance of a passive suspension system using ADAMS car:

4.1. Sensitivity Study:

The sensitivity of a system to changes in its parameter values is one of the basic process in the analysis of a system and knowledge of sensitivity is very valuable in optimizing the design. In the case of suspension kinematic studies, it would be appropriate to consider the suspension hard points location in the space as system parameters.

4.2. Camber Analysis vs Wheel Travel:

By changing the x co-ordinate of UCA ball joint the gradient and angle variation for the camber curve was increased and decreased when it was lowered to the extreme position during jounce and rebound. Decreasing the length i.e. by changing the y co-ordinate showed negligible variation but made the curve a bit linear, where the y-axis is camber angle and x-axis is wheel travel. The red curve is the initial characteristic of the suspension and blue curve shows the variation in hardpoints as discussed above. The pink dotted curve is obtained when the y co-ordinates of UCA ball joint is changed.



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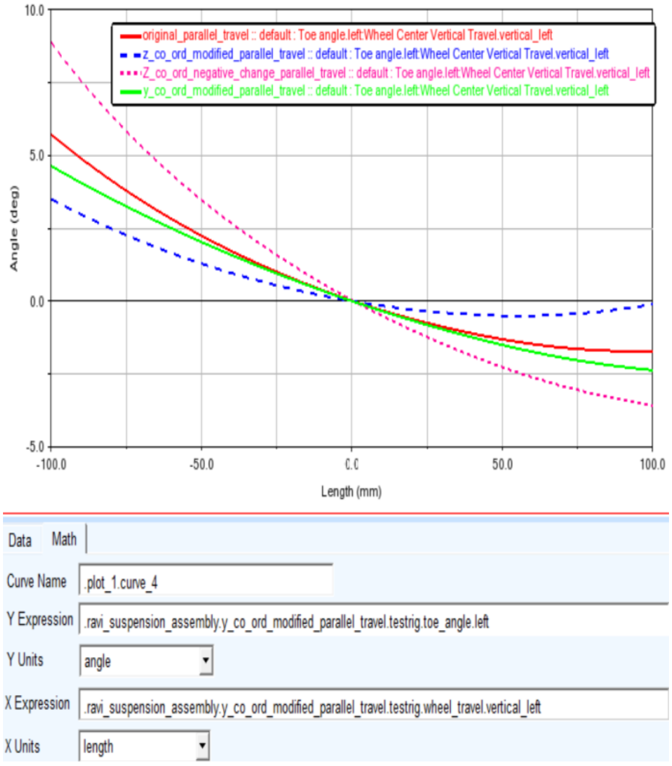
Y Units angle
X Expression .ravi_suspension_assembly.original_parallel_travel.testrig.wheel_travel.vertical_left
X Units length

4.3. Toe Analysis vs Wheel Travel:

When z co-ordinate of Tie rod outer was changed to 20mm from initial position, the gradient for the toe curve was increased and decreased when it was lowered to -20mm. Even the variation in position of UCA outer affected toe angle. The change in length of toe link by varying y co-ordinate of Tie rod outer made the toe cure behave linear by reducing the end variation during jounce and rebound where the y-axis is toe angle and x-axis is wheel travel.

The red curve is the initial characteristic of the suspension and blue and pink curve shows the variation respectively as discussed above. The green curve was obtained when the y co-ordinates of UCA ball joint is changed.



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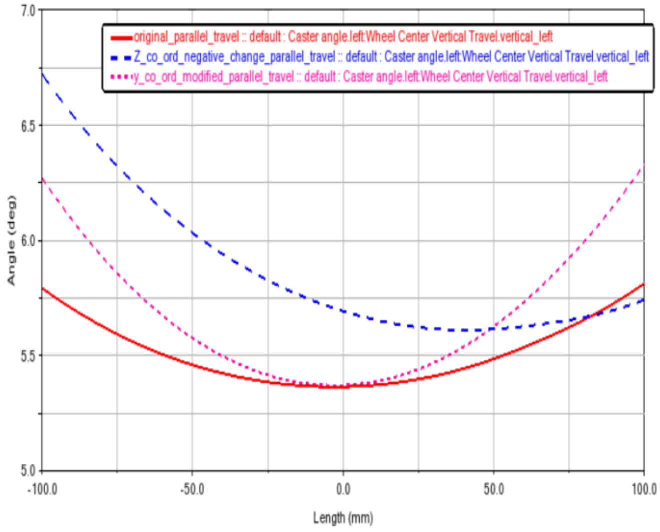
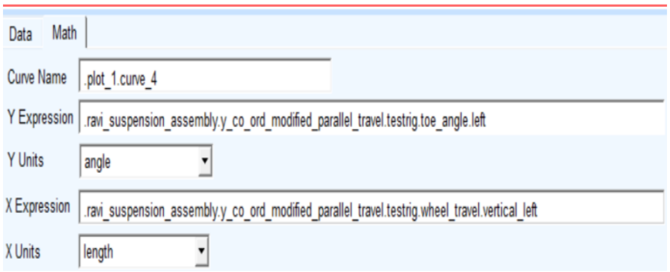
Y Units angle
X Expression .ravi_suspension_assembly.y_co_ord_modified_parallel_travel.testrig.wheel_travel.vertical_left
X Units length

Caster Analysis vs Wheel Travel:

The change in z co-ordinate of UCA outer when shifted toward the side of wheel center by 25mm changed the caster curve drastically, but when y o-ordinates are modified the change is small, where the y-axis is caster angle and x-axis is wheel travel. The red curve is the initial characteristic of the suspension and blue curve shows the variation when the geometry was altered. The pink dotted curve was obtained when y co-ordinates of UCA ball joint is changed.





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X Units: length

The study helped in choosing the specific input hardpoint variables which will affect the suspension geometry during optimization of the model. It was also observed that the what the literature [7] [12] explains is seen but the actual behaviors is different as the complete variation in the kinematics are combination of hardpoints of other linkages as well.

CONCLUSION

The virtual model of the front suspension system of the Four wheel vehicle was produced and simulated based on the same tests as for the actual suspension system. Both original and modified suspension models will be compared and validated with the help of graphs. Overall, even when the suspension is validated, the percentage error between the original and modified may still need to be improved and be minimized. Further study has to be undertaken to solve this problem. Future work aims to conduct virtual full vehicle testing on the dynamic characteristics of the suspension system.

FUTURE SCOPE

The other purpose of virtual suspension modeling and analysis is to verify the simulated result with the experimental result. However, some of the simulation data do not show 100% the same value when subjected to the same wheel travel as the experimental data. It is difficult to determine whether the simulated or experimental results are correct [3], but we could consider that human factor might have influenced the outcome of the experimental results (e.g. human error during the experiment or during component setup on the actual test rig). One of the other solutions and recommendations is to verify the simulation result with the mathematical model.

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