Simulation and Optimization of MPV Suspension System Based on ADAMS

Dongchen Qin[1], Junjie Yang[1], Qiang Zhu[1], Peng Du[1]

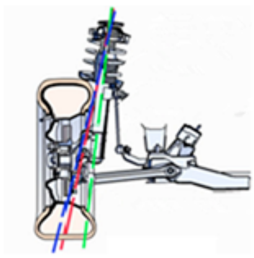
[1] Zhengzhou University, Zhengzhou, China, dcqin@zzu.edu.cn

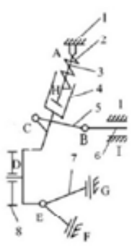
1. Abstract
The suspension system is one of the key parts in vehicles, which can directly influence such performances as the steering stability and the ride comfort. The multi-body dynamics model of multi-purpose vehicles (MPV) front suspension is built with ADAMS/VIEW, and the location parameters of the front wheel are simulated. In order to improve the kinematics performance and steering stability, the sensitivity analysis and optimization design for the front suspension are carried out. The results can provide some guide and reference for the R&D of the MPV.
2. Keywords: Macpherson Suspension, Multi-body Dynamics, ADAMS/VIEW, Optimization Design

3. Introduction
The most important assembly designs of the automobile are suspension, engine and transmission. The design of suspension system influences a variety of performances. Vehicle suspension is the important structure linked to the frame and tires. In the paper, the front McPherson independent suspension of a MPV was analysed for improving its performance. And the virtual prototype model for this suspension, the dynamic simulation models, parametric processing and the optimization of front independent suspension are established. The suspension set up and perfect virtual prototyping model, will upgrade this MPV's independent suspension design level, and also provide foundations for a new suspension design of similar models.

4. Multi-body dynamics model of MPV suspension
Utility of vehicle suspension system is to pass all forces and moments between the wheel and the frame (or body), and to ease the impact load coming from rough road, which can reduce the vibration of bearing system caused by the impact load. And also the suspension system can reduce the interior nose of vehicle and increase occupant comfortable, which can ensure the vehicle's ride comfort. As an important force transmission member connected the frame (or body) and the axle (or wheel), the vehicle suspension system is a key component to ensure the vehicle safety.

4.1 Composition and characteristic of McPherson independent suspension
The front suspension of this MPV uses McPherson independent suspension. Figure1 shows a typical configuration.





1-body;2-coil spring;3-shock absorber upper body;4-knuckle assembly;5-tie rod;6-steering rack;7-under the arm8-wheel assembly

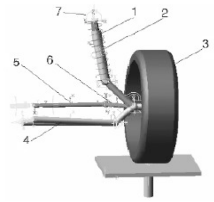
Figure1: McPherson suspension structure diagram

4.2 Coordinates of the key points of the model
The spatial coordinates and parameters of the key points are important for establishing suspension model, which is the most important task before executing the kinematic simulation in ADAMS. This article uses the coordinate mapping instrument to get the space parameters of the left suspension under no-load conditions. The table1 shows the front suspension positional parameters.

Table1: The positional parameters of front McPherson independent suspension

Parameter name	The kingpin inclination angle	The caster angle	The toe angle	The camber of front wheel	The volume of wheel spin(mm)
Value of design	9°—11.5°	2.5°—3.5°	0°—4°	0°—0.95°	9

4.3 The simulation model
A drive was added on the test platform after building the model of the guiding mechanism. The figure2 shows the model and the test platform.



1-shock absorber; 2-coil spring; 3-wheel; 4-lower control arm; 5-tie rod; 6-knuckle assembly; 7-body

Figure2: The simulation model of the front McPherson suspension

5 The performance simulation and analysis of MPV suspension
The common analysis method of the kinematic characteristics of the suspension is that wheels beat with a wheel on one side or both sides up and down along the vertical directional, variation of wheel position parameters is calculated and analyzed. Based on full load, the range of the run out is at popular -50~+50mm for a vehicle of this study, while the characteristics of the toe angle of wheel, camber angle and wheel hop gauge changing are calculated.
The range of the front toe angle is -0.77°~0.80° in figure3, and which meets the requirements, that is, the change in angle of less than ±1°. The jump has a positive camber angle, varied from -0.38°~+2.74° in figure4. The range of variation is too large, and the straight running stability will deteriorate automobiles. The range of the caster angle is 2.77°~3.37° in figure5. The amount of change is small, which meets the design requirements, and is favor of the vehicle load handing and stability. The range of kingpin inclination angle is 7.47°~11.16° in the figure6. The amount of change is too large and is not conducive to vehicle handing and stability. The figure7 shows that the change range of the wheel tread is between -22.844 mm/50mm and 12.723mm/50mm, which it's an important performance for a worn tirer.

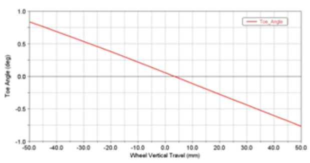


Figure3: the curve of toe angle

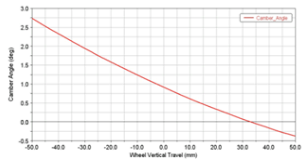


Figure4: the curve of the wheel camber angle

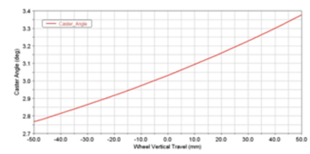


Figure5: the curve of the caster angle

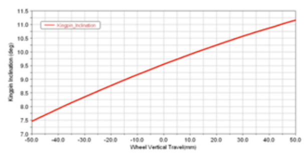


Figure6: the curve of the kingpin inclination angle

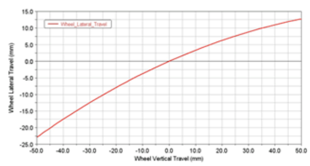


Figure7: the curve of the front wheel tread

The simulation model was builded in ADAMS/VIEW, and combined the date of the front McPherson suspension, and elected the method of left wheel jumping, and executed the kinematic simulation of the McPherson suspension. The curve of front toe angle, the camber angle, the kingpin inclination angle, the caster angle and wheel tread could be got. And the front toe angle of front wheel is too large, and the change range of the wheel tread is beyond the common. So these will increased tire wear.

6. Suspension performance sensitivity analysis

The performance of the vehicle front suspension for sensitivity analysis can get the properties of all the suspension components and installation location of vehicle suspension and provide a reference to the design of suspension. The model of suspension is built and the design parameters of suspension and the sensitivity of the performance of the vehicle are calculated with using the Insight module and CAR module in ADAMS. And the sensitivity of suspension performance is analyzed in VIEW. In this article, the ADAMS/VIEW is selected for analyzing the sensitivity of suspension performance. The main impact factors of operational stability can be found from this model.

6.1 Design variables

According to the front suspension structure and the position parameters of the front wheel, the length and position angle in space of links EG, EF, CB are elected as design variables sensitivity analysis. The table2 shows the symbol and the significance of 9 variables.

Table2: Definition of the design variable

Number	Design	Means	Code in ADAMS
1	x1	The length of EG	DV_1
2	x2	The angle between the EG and xy plane	DV_2
3	x3	The angle between EG projection in the xy plane and x-axis	DV_3
4	x4	The length of EF	DV_4
5	x5	The angle between EF and xy plane	DV_5
6	x6	The angle between EF projection in the xy plane and x-axis	DV_6
7	x7	The length of CB	DV_7
8	x8	The complement of the angle between CB and xy plane	DV_8
9	x9	The complement of the angle between CB projection in the xy plane and the y-axis	DV_9

6.2 Sensitivity analysis

This paper focuses on the front wheel alignment toe angle, the camber angle, and the volume of tire lateral slip, which was recorded with the initial values of the sensitivity.The conclusion can be got from the figures 8 to 16.

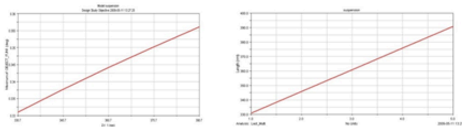


Figure8: the sensitivity of the DV_1 to toe angle

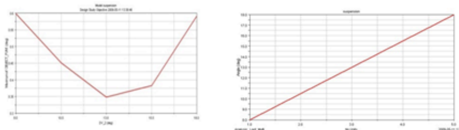


Figure9: the sensitivity of the DV_2 to toe angle

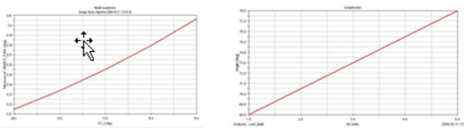


Figure10: the sensitivity of the DV_3 to toe angle

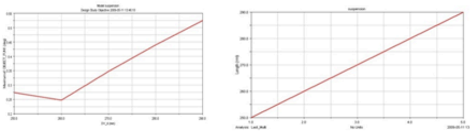


Figure11 the sensitivity of the DV_4 to toe angle

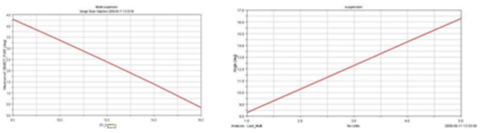


Figure12 the sensitivity of the DV_5 to toe angle

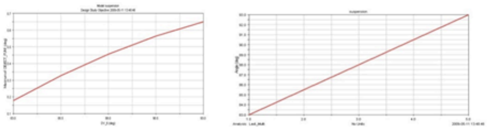


Figure13 the sensitivity of the DV_6 to toe angle

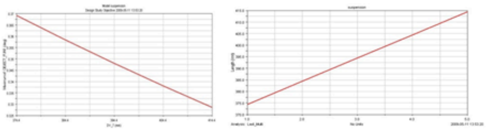


Figure14 the sensitivity of the DV_7 to toe angle

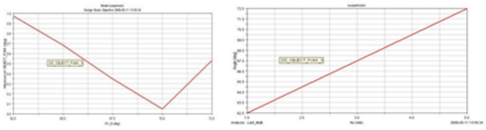


Figure15 the sensitivity of the DV_8 to toe angle

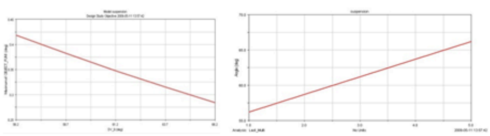


Figure16 the sensitivity of the DV_9 to toe angle

(1) On a larger camber factors followed as: angle between the link EF and xy plane(x5), and complementary angle of xy plane with connecting rod CB(x8), angle between the connecting rod EG and xy plane(x2), other factors less affected.

(2) The front wheel lateral amount greater factor in turn: the angle between the link rod CB and xy plane(x8), the link EF and xy plane angle(x5), EG and xy plane angle(x2), other factors less affected.

7. The optimization of the MPV suspension

The smallest amount of sideslip change is made in order to optimize the range direction. The simulation mode is executed in the ADAMS/View, with adjustments to the hard point coordinates of air spring independent suspension, and then the best hard point coordinate as the last optimization design point. Such parameters as angle between EF and xy plane, angle between EF projection in the xy plane and the x-axis, angle between complementary angle of CB and the xy plane, and angle between complementary angle of CB projection and y-axis are optimized, and the curve of experimental and results of optimization are obtained.

7.1 The bjective function

In order to reduce tire wear, we select the front wheel lateral slip amount as the optimization of the objective function. Through optimizing such parameters as angle between EF and xy plane, angle between CB and xy plane, angle between complementary angle of CB projection and xy plane, angle between complementary angle of CB projection in the xy plane and y-axis, the value of the minimum lateral slip of the wheels is obtained.

7.2 The optimization model

The objective function in the optimization and design variables are set in the window of ADAMS. The design variables are DV_5, DV_6, DV_8 and DV_9. And the optimization goal is that the objective function takes the minimum value. For optimization of the front independent suspension performance, the sequential quadratic programming method of ADAMS/VIEW is used. Table3 shows the optimization result.

7.3 The optimization results

Table3 shows the different values of DV_5, DV_6, DV_8, DV_9 for the twice optimization iteration.

Table3: The result of suspension optimization

Iterations	Objective function(mm)	x5(deg)	x6(deg)	x8(mm)	x9(deg)
0	2.9869	61.20	73.085	270	73.085
1	0.33697	62.33	72.601	266.46	72.601
2	0.33712	64.60	72.601	266.46	72.601

7.4 Suspension characteristic curves comparing

The simulation curves of the optimized models are shown as following. The blue curve represents the simulation after optimization, and the red curve represents the simulation before optimization. Figures17~21 show the comparison results of the alignment parameters.

The range of variation optimized camber is 0.579°~1.769° from the figure17. The changes of the toe angle of the front wheel are not large as that can be seen from figure18. The optimization result of the toe angle is acceptable when the wheels balanced and within the design limits. Figure19 shows that the kingpin inclination optimized range is 2.733°~3.412°, with expanding the scope of change little compared with optimization before. The change

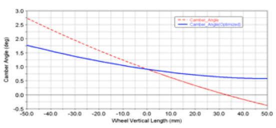


Figure17: the comparison of camber angle

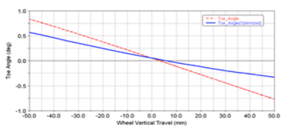


Figure18: the comparison of the toe angle

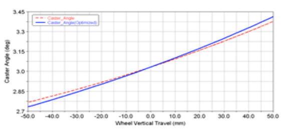


Figure19: the comparison of the caster angle

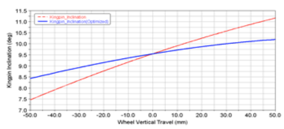


Figure20: comparison of the kingpin inclination angle

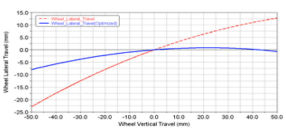


Figure21: the comparison of volume lateral slip of wheels

range of the kingpin inclination angle is 8.432°~10.193° from the figure20. The volume of wheel lateral slip range is -7.945~0.79 from the figure21.The curve of optimization is better than that of before.
The parameters of the internal connect position of the steering tie rod, the external position of the lower support arm change very large for this suspension model. By adjusting the parameters a greater response to the result of each change can be obtained. The camber angle of front wheel, the caster angle, and the volume of lateral slip will become better through the comparison of simulation curves, while the change of the toe angle is not obvious. We can get a new suspension layout scheme by optimizing design. The simulation results of the suspension performance are more reasonable. And the maneuverability and stability of the vehicle can be greatly improved.

8. Conclusions

In this paper, taking the front McPherson independent suspension of a MPV as the object, the structure of the suspension is analyzed briefly, and the dynamics model of the suspension combined with multi-body system dynamics theory is established in ADAMS/VIEW. And the curves of the vehicle performance are obtained, which include the toe angle, the camber angle, the kingpin inclination angle, the caster angle and the volume of lateral slip of the front wheel. On the basis of the suspension performance simulation, by using ADAMS/VIEW to set the variables of the suspension, the influence of the camber angle, the kingpin angle and the volume of lateral slip can be analyzed. Those results can provide data for improving the design of MPV suspension. The coordinates of two inner points and the tie rod inner point are changed through using optimized design parameters. The layout scheme is optimized and executed. Comparing with the previous design, the optimized simulation results are more reasonable.

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