Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(4):309-313

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Dynamics simulation of automobile steady-state veer characteristics

Zheng Liu* and Ke Chen

School of Automobile and Traffic, Shenyang Ligong University, Shenyang, Liaoning, China

---

ABSTRACT

In this paper, by applying mechanical system simulation ADAMS, the full vehicle multi-body model was created. The vehicle dynamic simulation was carried out. The effects of kingpin inclination and kingpin caster angle on steady-state steering characteristics were studied. The result showed that kingpin inclination and kingpin caster angle have the greater effect on veer stability. Vehicle scanty veer property is improved by adding kingpin inclination and kingpin caster angle.

Keywords: automobile, kingpin, handling stability, dynamics, simulation

---

INTRODUCTION

The car's steering stability refers to the car's ability described below: One the one hand, the car should drive in the direction directed by the driver through the steering system and steering wheel when he is not suffered from stress and fatigue; on the other hand, the car could resist interference and maintain stable driving when it is interfered. Many physical parameters must be used to evaluate it from different directions.

The circular constant-speed driving(steady state response with the condition of steering wheel Angle Step input),is an important time domain response demonstrating the car's handling stability, also commonly called car's stable steering characteristics including understeer, neutral steering and oversteer. With a stable angle and slowly speed-up or different kinds of stable speed, the driving characteristics of the cars with the three different types of steering characteristics are as follows: The steering radius of the understeer car will increase as the car speeds up; the steering radius of the neutral steering car will maintain the same; the steering radius of the oversteer will become smaller. The car with good stable steering should be with moderate understeer. There are many factors influencing the car's stable steering characteristic including alignment parameters such as kingpin inclination angle and kingpin caster angle [1-6]. In this paper, the softwares ADAMS / VIEW are used to the full car modeling ; the simulation analyses of influence of the sizes of the kingpin inclination angle and kingpin caster angle on the characteristics of the car's stable steering are carried out.

2.Analysis and Calculation Method of ADAMS

ADAMS (Automatic Dynamic Analysis of Mechanical System) is an analysis software of mechanical system dynamics produced in American. It not only combines the multi-body dynamics modeling method and the nonlinear analysis function, but also provides integration interfaces of the other CAE sofewares, such as ANSYS-software of finite element analysis. It is the mechanical system dynamics of the highest rate of market occupancy nowadays (the usage rate in car industry is 43%) .

ADAMS' generalized coordinates are the rigid-body mass-center Cartesian co-ordinates and Euler angle which reflects the rigid-body position or the generalized Euler angle. That is:

$$q_i = [x, y, z, \psi, \varphi, \theta]_i^T \quad (1)$$

$$q = [q_1^T, \cdots, q_n^T]^T \quad (2)$$

Its established dynamics equations using the Lagrange multiplier method are as follows:

$$\frac{\partial}{\partial t}\left(\frac{\partial K}{\partial \dot{\boldsymbol{q}}_j}\right) - \frac{\partial K}{\partial \boldsymbol{q}_j} + \sum_{i=1}^{n} \frac{\partial \boldsymbol{\psi}_i}{\partial \boldsymbol{q}_j} \lambda_i = F_j \quad (3)$$

$$\boldsymbol{\psi}_i = 0 \qquad (i = 1,2,\ldots,m) \quad (4)$$

In the above equation, K refers to kinetic energy; q_i refers to generalized coordinates describing the system; $\boldsymbol{\psi}_i$ refers to the system's constraint equation; F_j refers to generalized force in the direction of generalized coordinates; λ_i refers to Lagrange multiplier array of $m \times 1$.

It is inevitable to solve a series of nonlinear algebraic equations when kinesiology and statics are analysed. To solve the equations quickly and precisely, the modified Newton-Raphson iterative algorithm is used in ADAMS.

For the differential equations of kinesiology, according to the characteristic of the mechanical system, different integration algorithm may be used. For the rigid body system, rigid integration program of the BDF (Backwards Differentiation Formulation) with variable coefficient may be used. It is predictor-corrector methods with automatic change of order and step-size. For the high-frequencies system, coordinate-partitioned equation and adams-Bashforth-adams-moulton may be adopted.

3.Modeling

In this paper, ADAMS/View is used to establish full car model of multi-rigid-body system. As shown in Fig. 1, car chassis model, front independent suspension model of double horizontal arms suspension type, steering mechanism model, rear suspension model of oblique arm type, tire model and road surface spectrum are included. At the same time, the parameterized design of the front suspension and steering mechanism is made. In order to modify any parameter freely, eleven variables are created representing respectively kingpin length ,kingpin inclination angle, kingpin caster angle, up horizontal arm length, up horizontal arm plane dip, down horizontal arm length, down horizontal arm plane dip, down horizontal arm plan oblique dip, spring stiffness, shock absorber damping.

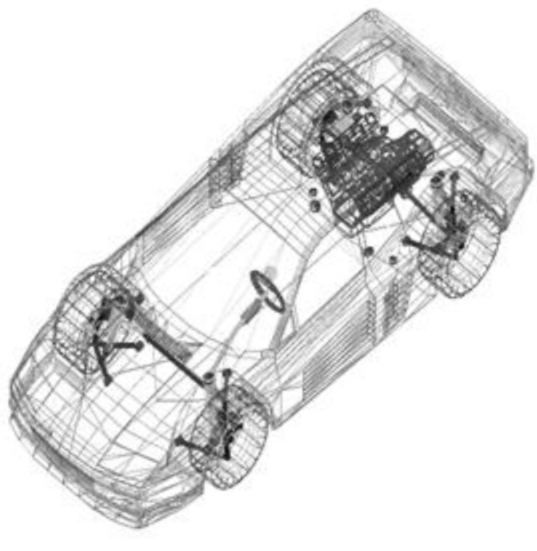

Fig. 1: Full car model of multi-rigid--body system

The whole system includes eleven free degrees including six of the car body, two free rotation degrees of the front suspension left-right horizontal arm, two free rotation degrees of rear left-right horizontal oblique arm and one degree of steering- system stiffness.

RESULTS AND DISCUSSION

Parameters of the full car model: total mass is 2010 kg; axle base is 2600 mm; front wheel base is1650 mm; rear wheel base is 1650 mm; rear wheel kingpin inclination angle is 10^o ; kingpin caster angle is 2^o;distance between mass center and front axle center1335mm is 1335 mm; mass center height is 600 mm. The front suspension is double horizontal arms suspension; the rear suspension is double vertical arms suspension.

Simulation of the driving of the model car: Parameters maintain the same; input the steering wheel Angle Step; output the simulation changing curve of the turning radius based on the change of the speed. As shown in Fig.2.The figure shows that the turning radius become larger and larger as the speed increases. So the car is with the character of understeer.

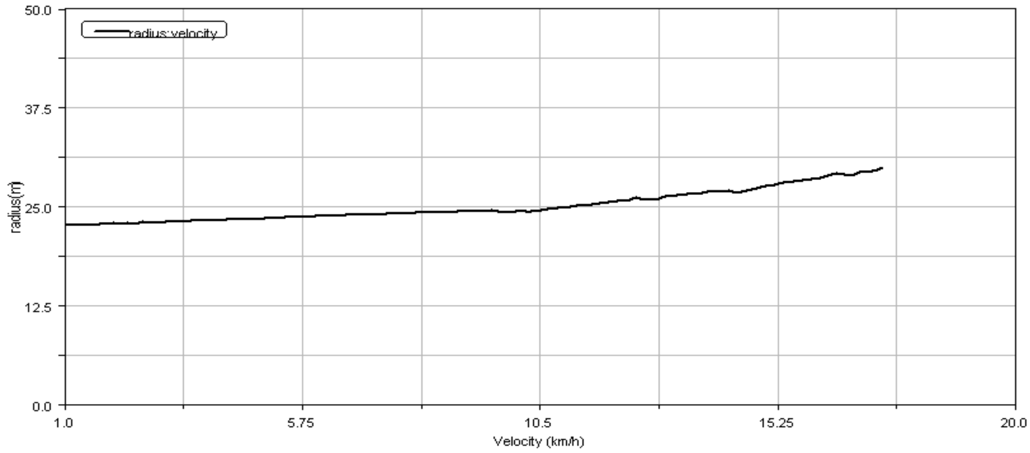

Fig. 2: Turning radius with the change of speed

On the condition that other conditions maintain the same, according to the full model car, the kingpin inclination angles will be modified into 5^o, 8^o,11^o,14^o in turn and simulates them respectively to get the curve of the steering radius according to the change of the car's speed(figure 3).

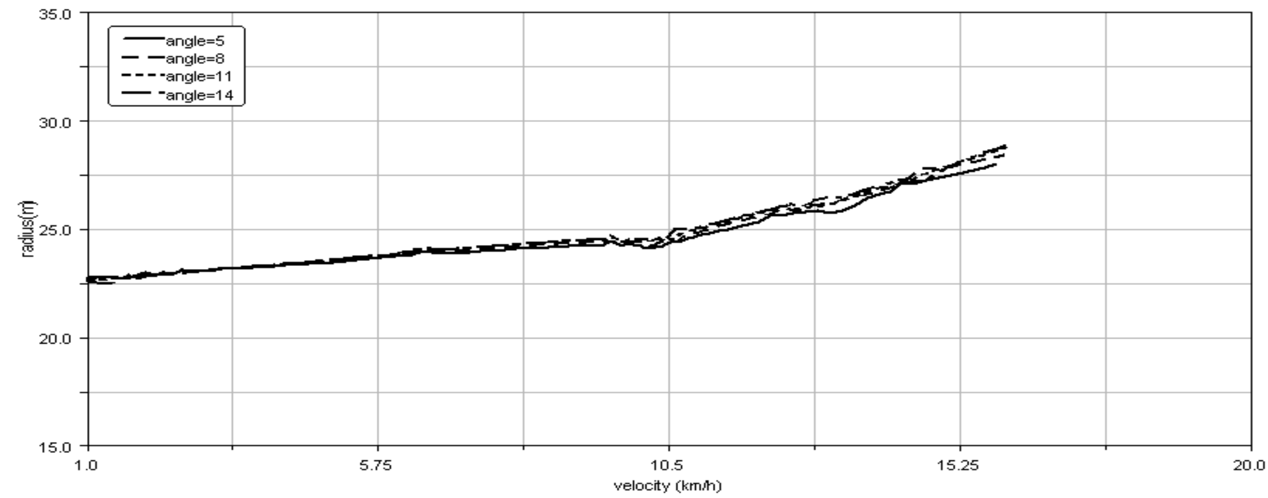

Fig. 3: Turning radius with the change of speed

As shown in Fig. 3, the speed basically changes as the kingpin inclination angles increases, and the turning radius become larger, the characteristics of the understeer increase. The influence of the kingpin inclination angles on the steering stability mainly concentrates on the self-turning moment which makes an effect on the elevation of the body of the car. At the same time, the front wheel self-turning moment is created as the potential energy of the car system increases. As the kingpin inclination angles become larger, the range of the body elevated grows and the self-turning moment increases, the characteristics of the understeer increases.

On the condition that other conditions maintain the same, modify the kingpin caster angle into 0^o, 4^o, 7^o, 10^o in turn and simulate them respectively to get the curve of the steering radius according to the change of the car's speed (figure 4).

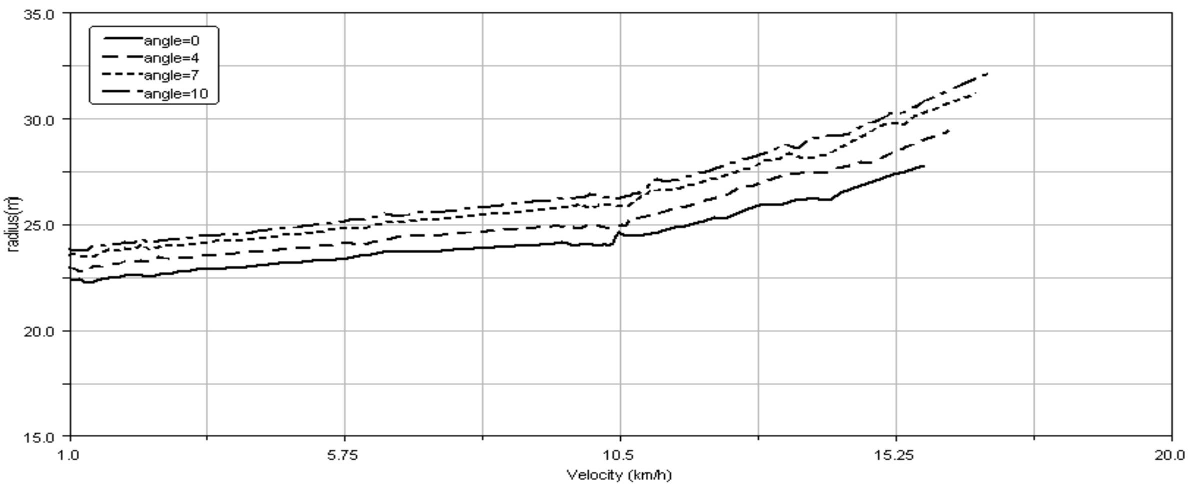

Fig. 4: Turning radius with the change of speed

As shown in the Fig. 4, with the increase of the kingpin caster angle and the increase of the speed, the turning radiuses all become larger gradually and the understeer inclination become larger. The influence of the kingpin caster angle on the steering stability mainly concentrates on the wheel's self-turning moment coming from the sideways force. The moment creates an additional corner in proportion to the sideways force. The corner has a effect on the increasing inclination of the understeer and is beneficial to the characteristics of steering stability. Self-turning moment become larger when the kingpin caster angle is increased and the increase of the additional have an effect on the increase of the understeer. The reason why the change of the starting steering radius is so large is that on the one hand, self-turning moment increases when the kingpin caster angle become larger, on the other hand, on the condition of the corner of the unchanged steer, when the kingpin caster angle become larger and the steering pull-arm become longer, the wheel corner decrease 1^{o} o and the radius curve moves up. Besides, the figure also shows that the increase inclination of the steering radius corresponding to the caster angles from small to large and in order not to increase too much weight of the steering wheel, the caster angles should not be too large.

Taking the characteristic of the understeer into consideration, objective function is the car's steering radius and optimal variables are kingpin inclination angle and kingpin caster angle. The range of variables is 5^{o} -14^{o} of the kingpin inclination angle，0^{o} -10^{o} of the kingpin caster angle. By the way of optimal simulation analysis, the turning radius is largest when the kingpin inclination angle is 14^{o} and the kingpin caster angle is 10^{o}； the turning radius is the smallest when kingpin inclination angle is 5^{o}，the kingpin caster angle is 0^{o}（shown above the dotted line in Fig. 5.

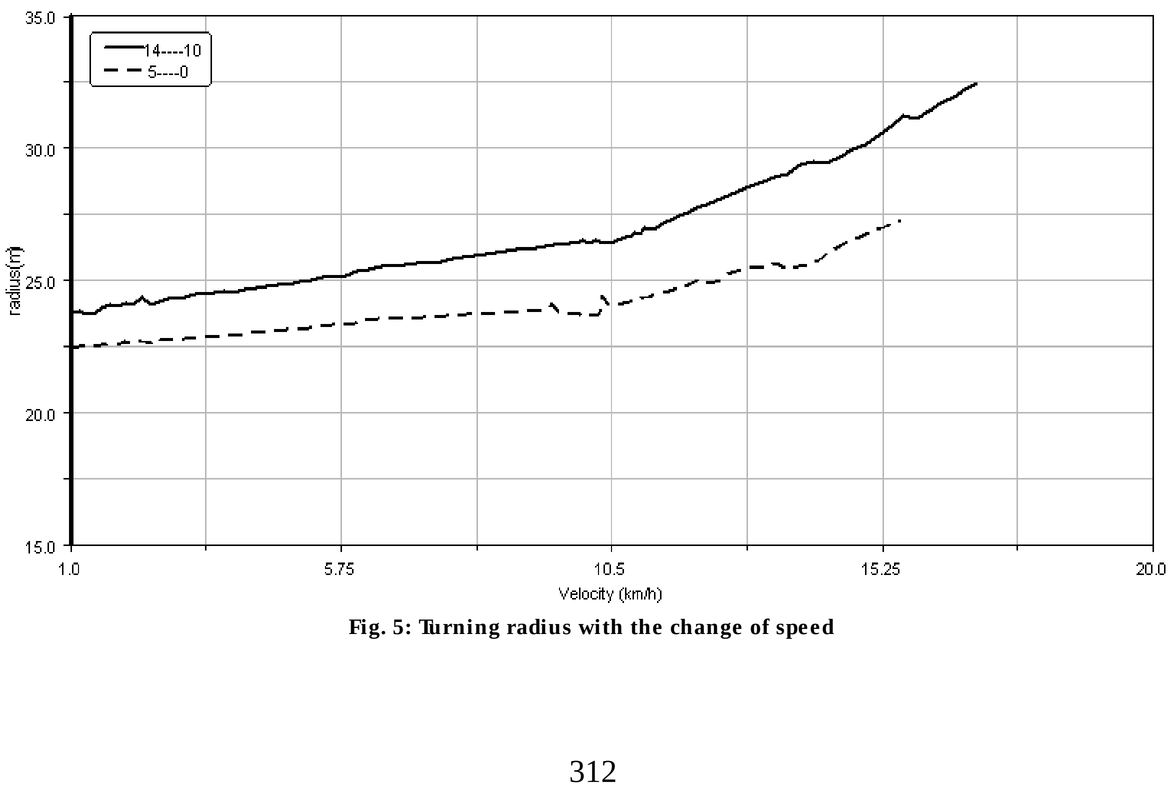

Fig. 5: Turning radius with the change of speed

As the contrast between the results of simulation with the kingpin angle enlarged and the results of simulation with the original parameters shows, the slope of the curve about the steering radius with the change of speed is apparently become larger. It means that the characteristics of the understeer of the car are improved. But because the modification of the kingpin parameters will have an influence on the steering force of the steering wheel, so all aspects of factors should be taken into consideration before modifying the kingpin parameters.

CONCLUSION

Use the software of ADAMS / VIEW to build full car model and make the parameterized design of the front suspension and steering mechanism. The simulation results show that the steering radius should be enlarged and the characteristics of the understeer should be increased by increasing the kingpin inclination angle and the kingpin caster angle.

REFERENCES

[1]Daniel A, M ántarasa, Pablo Luquea, Carlos Verab. *Mechanism and Machine Theory*. **2004**, 39 (6): 603-619.
[2]Diomidis Katzourakisa, Joost C.F. de Wintera, Stefan de Groota, Riender Happeea. *Simulation Modelling Practice and Theory*. **2012**, 26: 96-112.
[3]P.S. Els, N.J. Theron , P.E. Uys , M.J. Thoresson. *Journal of Terramechanics*. **2007**, 44 (4): 303-317.
[4]Nuksit Noomwongs, Hidehisa Yoshida, Masao Nagai, Katsuhiro Kobayashi, Takashi Yokoi. *JSAE Review*. **2003**, 24 (4): 457-464.
[5]Keiji Watanabe, Masanori Kitano, Akihiro Fugishima. *Journal of Terramechanics*. **1995**, 32 (6): 285-302.
[6]P.H. Cronjé, P.S. Els. *Journal of Terramechanic*. **2010**, 47 (3): 179-189.