Analysis of K&C of Torsion Beam Suspension based on a Vehicle Model

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Keywords: The opening angle, Beam position, Bush installation angle, Toe angle, Height of the roll center.

Abstract: In this paper, through the flexible body of torsion beam established by HyperMesh is introduced into ADAMS/CAR software for simulation of suspension K&C characteristics. The influences of three factors, such as the opening angle of the beam, beam position and bush installation angle, on the K&C performance of the suspension are obtained. The analysis shows that the opening angle and position of the beam have a great influence on the K&C characteristics of the suspension, especially the change of toe angle and height of the roll center, and provides a reference for the design of the torsion beam at early stages and a direction for the suspension K&C characteristics optimization in late period.

1 INTRODUCTION

The vehicle suspension is an important component of the vehicle in affecting the ride comfort and handling stability (Shang Guan, etc, 2009), especially when the vehicle passes uneven road, the impact of suspension on the performance of the vehicle is obvious. The torsion beam suspension is semi-independent suspension between rigid axle suspension and independent suspension, because the torsion beam is elastic, both sides of the wheel have a certain independence. Due to the small space and low manufacturing cost, the torsion beam suspension is widely used in various economical cars and SUV. In severe conditions, the beam has a more stable effect on the body roll and steering roll, equivalent to a stabilizer bar (Liao and Su, 2015). Therefore, taking into account the role of load transfer, a reasonable beam opening angle and position are required.

In this paper, based on a model, through the flexible body of torsion beam established by HyperMesh is introduced into ADAMS/CAR software for simulation. The influences of three factors, such as the opening angle of the beam, beam position and bush installation angle, on the K&C performance of the suspension are obtained.

2 DYNAMIC ANALYSIS OF TORSION BEAM SUSPENSION

2.1 Torsion Beam Suspension Model

Torsion beam suspension includes two coil springs and an integral V-section beam which welds a variable cross-section tubular arm to form an overall framework. The front of the trailing arm is articulated with the body by bushings and the rear is connected with the hub and shock absorber (Chen and Ma, 2006). When the car passes through different roads, torsion beam suspension transmits force to the body through bending and torsional deformation. The torsion beam suspension topology is shown in Figure 1.

When the vehicle is driving, the wheels drive the beam to swing up and down relative to the body with the rubber bushes which are an asymmetric rubber wedge structure with low radial stiffness and large axial stiffness at the front of the trailing arm as the fulcrum; The V-shaped section beams produce torsional deformation when the deformation of the suspension on both sides of the beam is not the same, so it should have greater flexibility and act as a stabilizer bar.

Wu, L., Li, G. and Jing, L.
Analysis of KC of Torsion Beam Suspension based on a Vehicle Model.
DOI: 10.5220/0008868900780084
In *Proceedings of 5th International Conference on Vehicle, Mechanical and Electrical Engineering (ICVMEE 2019)*, pages 78-84
ISBN: 978-989-758-412-1

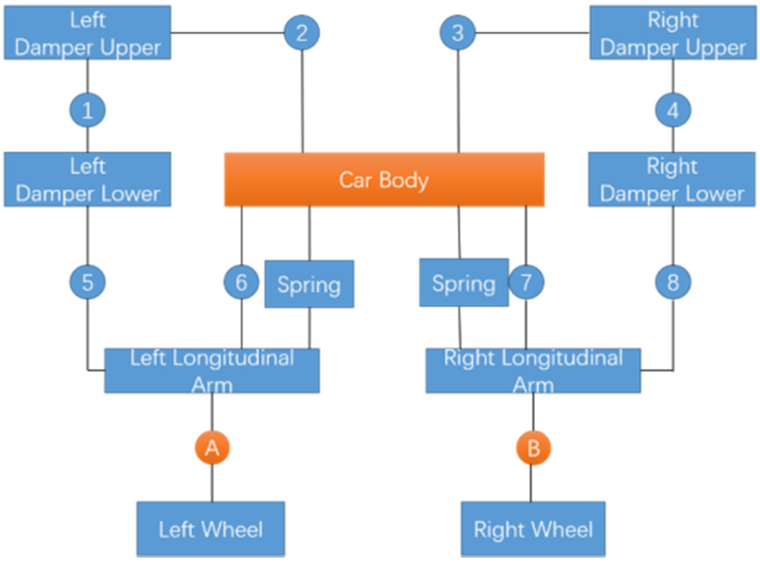

Fig 1. Torsion beam suspension topology.

2.2 Analysis of K&C Characteristics of Torsion Beam Suspension

The kinematics of the suspension system is mainly divided into two aspects: kinematics and elastic kinematics (Kinematics & Compliance), Kinematics related to comfort describes changes in wheel alignment parameters and vertical stiffness characteristics of the suspension during spring deformation or wheel turning; Elastic kinematics related to handing stability describes the changes of wheel alignment parameters and suspension stiffness(Sun, 2012). Operating conditions of suspension K&C feature include Parallel wheel jump, rolling conditions, lateral force conditions, aligning torque conditions, longitudinal force conditions, steering conditions. And related parameters include toe angle change, roll stiffness change, suspension roll center height, etc.

The toe angle is the angle between the longitudinal center plane of the car and the line of intersection between the center plane of the wheel and the ground. If the front of the wheel is inclined toward the longitudinal center plane of the car, it is a toe angle greater than zero, conversely, less than zero, as shown in picture 2. The toe angle is equal to the side slip angle of the tire when viewed in the direction of travel of the car(Chen, 1997), as shown in picture 3, so the car has a good straight-line driving performance and no side-slipping due to the symmetrical arrangement of the wheels diagonally to the longitudinal center plane. In order to reduce the wear and rolling resistance of the tire and ensure the straight running performance of the vehicle, there should not be a large change in the toe angle when wheels jump. For the rear suspension which has a greater effect on the steady state rotation of the vehicle compared with the front suspension. The toe angle increases when the wheel is jumping, and the toe-angle decreases when the wheel is lowered, what ensures the rear axle produces understeer when the car turns.

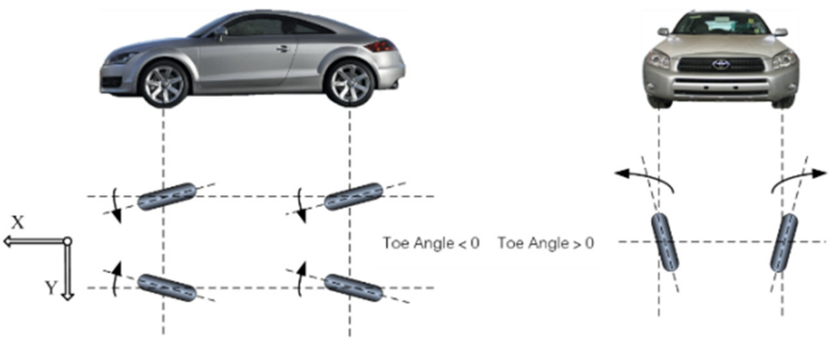

Fig 2. Toe angle.

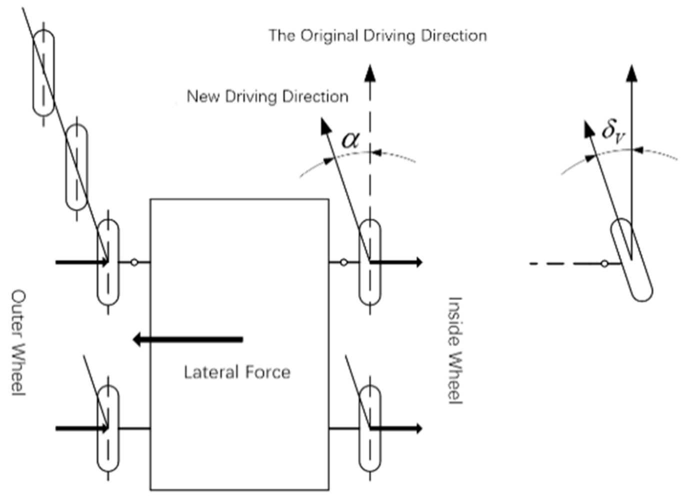

Fig 3. Toe angle in the direction of driving.

The roll center of the suspension belongs to a point in the cross section of the car at the axle. At this point, when the lateral force is applied to the vehicle body, the angular displacement of the sprung mass does not occur. Because the roll center is the instantaneous center of rotation of the cross section of the car at the axle. It is also called "the instant heart"(Ma, etc, 1999). When the vehicle turns, the load of the vehicle shifts laterally. Under the effect of centrifugal force, the carriage roll around the roll center, so that the body roll moment changes. The roll moment is the sprung mass centrifugal force multiplied by the roll center to the force vertical distance. For the torsion beam suspension, the torsion beam suspension is twisted when the vehicle is running on a curve, increasing the lateral stiffness of the suspension, reducing the body roll angle. Plays a role in improving the stability and stability of vehicles. The torsion force of the torsion beam is shown in Figure 4, and the roll center is shown in Figure 5.

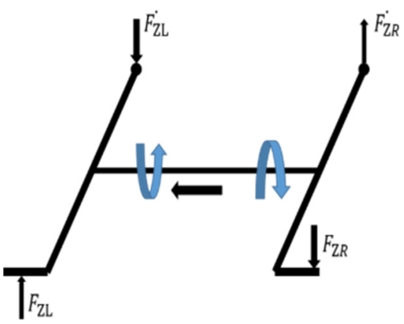

Fig 4. Torsion beam force when rolling.

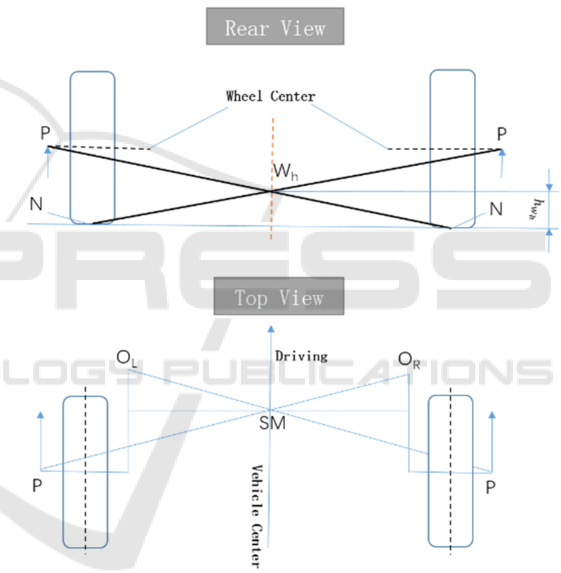

Fig 5. Roll center height of torsion beam Suspension.

The beam torsional moment T of torsion beam is generated by two pairs of couples:

$$\begin{cases} 2(F_{ZL}b + \dot{F_{ZL}}a) = T \\ F_{ZL}d + \dot{F_{ZL}}c = 0 \\ T = k\theta \end{cases} \tag{1}$$

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In the formula:

a —The longitudinal distance from the torsion beam to the body mounting point;

b —The longitudinal distance from the torsion beam to the rear wheel center;

c —The rear wheel track;

d —The lateral distance from the torsion beam to the body mounting point;

θ —The relative twist angle of the two ends of the beam

The greater the height of the roll center, the shorter the distance from the center of roll to the center of mass, the smaller the roll arm and roll moment, so that the vehicles achieve a smaller body roll angle and lateral transfer load, what contributes to the vehicle's transient steering performance. However, if the roll center is too high, the wheelbase changes too much when the body roll occurs, which intensifies tire wear, and straight-line driving performance of the car reduced. If the roll center is reduced, the wheelbase changes greatly, and a camber angle less than zero is formed, what increase the ability to withstand lateral forces, but will reduce the jump limit of the suspension. In short, the height of the roll center of the suspension needs to have a reasonable range. Generally, the height range of the front independent suspension center is 0~120mm, and the rear independent suspension range is 80~150mm. Rear torsion beam suspension has a higher roll center height of 100-150mm.

Roll center height H:

$$H = \frac{\Delta b}{\Delta s} * \frac{b_v}{2} \qquad (2)$$

In the formula:

Δb—the change of wheel track, Δs—round trip, b_v—track distance.

3 THE K&C SIMULATION ANALYSIS OF TORSION BEAM SUSPENSION

Based on a small car with a rear torsion beam suspension, the comparison of the K&C characteristics of the suspension is performed by selecting different opening beam angles, beam positions, and the bush installation angle. The main design parameters of the rear suspension of this sample car are shown in Table 1.

In this paper, the three-dimensional models of different torsion beams established by CATIA software are imported into the HyperMesh finite element processing software, are divide grid with attributes, and are import into ADAMS/CAR software. Finally, a rigid-flexible coupled multi-body dynamics model of the rear torsion beam suspension was established and simulated of K&C. The simulation results are compared with the test results to verify the accuracy of the model.

Table 1. Design Parameters.

system	parameter	value
Vehicle	Total mass (Kg)	1058
	Wheelbase (mm)	2320
	Track distance (mm)	1450
Rear torsion beam suspension	Toe angle (°)	-0.476
	Camber (°)	-1
	Spring stiffness (N/mm)	30.7
	Beam thickness (mm)	29

In the original model, the opening direction of rear torsion beam is downward, Then performing a suspension K&C comparison analysis by rotating 90 degrees, 180 degrees clockwise, turning 90 degrees counterclockwise from the beam original state; performing a suspension K&C comparison analysis by 50mm in longitudinal direction and 50mm in backward direction from the beam original position; performing a suspension K&C comparison analysis by rotating 45 degrees, 90 degrees, 135 degrees of longitudinal arm bush from original installation angle.

3.1 The Opening Direction of Beam

In this section, the torsion beam suspensions with different opening directions are simulated about K&C characteristic analysis. And analyzing the large difference curve in K&C simulation results, Torsion beam suspension structure is shown in Figure 6. The resulting curves are shown in Figure 7-12.

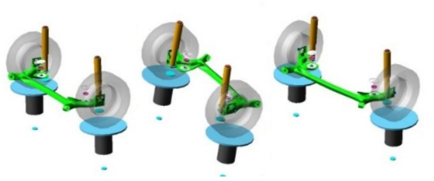

Fig 6. Torsion beam suspension with different opening direction beams.

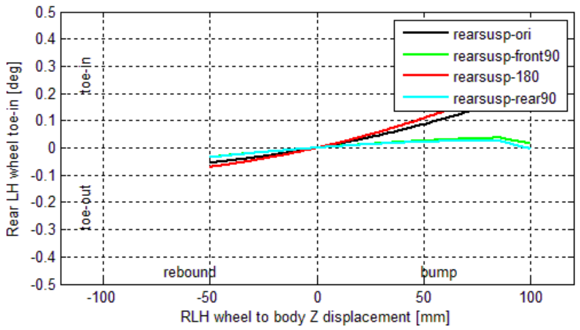

Fig 7. Variation of toe angle in parallel wheel jumping conditions.

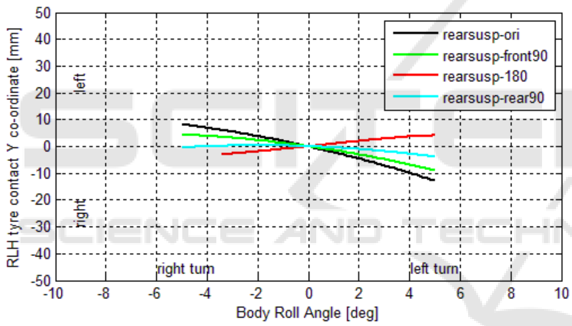

Fig 8. Lateral displacement of the tire's grounding point in rolling conditions.

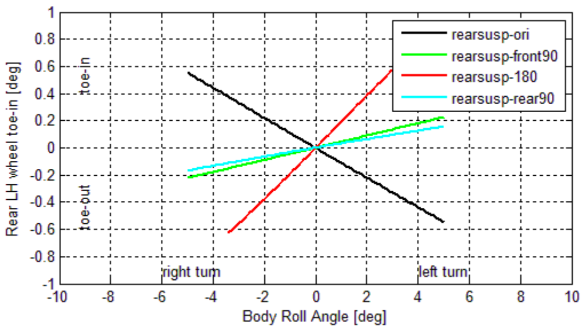

Fig 9. Variation of toe angle in rolling conditions.

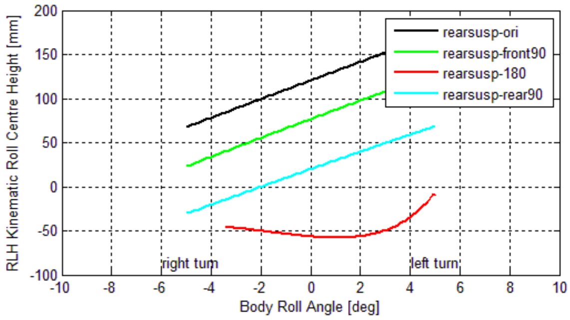

Fig 10. Rolling center height in roll condition.

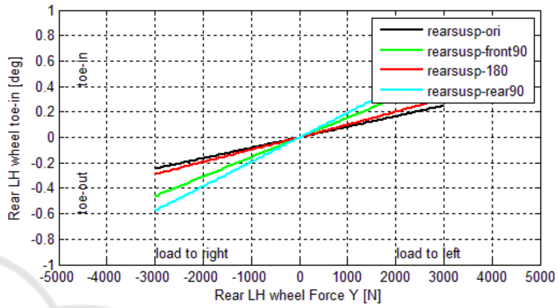

Fig 11. Variation of toe angle in reverse lateral force conditions.

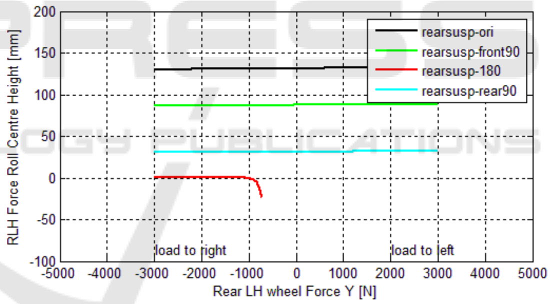

Fig 12. The height of the roll center in the same lateral force conditions.

In the case of parallel wheel jumping and rolling conditions, the variation of toe angle is significantly different. In the parallel wheel-jumping condition, the rate of change of the toe angle between the forward and backward directions of the opening of the beam is significantly reduced. Which is not conducive to the understeer; in the rolling conditions, the direction of the toe angle changes in the opposite direction to the original change, which leads to oversteering of the vehicle and is not conducive to the vehicle's lane changing performance; the lateral displacement of the tire's grounding point is significantly different, When the opening direction of the beam is upward, the lateral displacement of the tire ground point is a positive rate of change, which aggravates the tire wear. In the rolling conditions and the reverse lateral force conditions, the height of the suspension roll center is reduced, especially, when the opening direction of the beam is upward, the height of the roll center is zero, even less than zero, which is not conducive to the steady-state steering performance of the car.

3.2 Beam Position

The torsion beam suspension is a semi-independent suspension, namely a composite suspension. The more forward the beam is, the closer the suspension performance is to the independent suspension. Conversely, the closer the beam is to the wheel center, the closer the suspension performance is to the rigid axle suspension. Because of the structural constraints, this section will move the beam position 50mm forward and 50mm backward, and compare them with the initial position. The resulting figure is as follows:

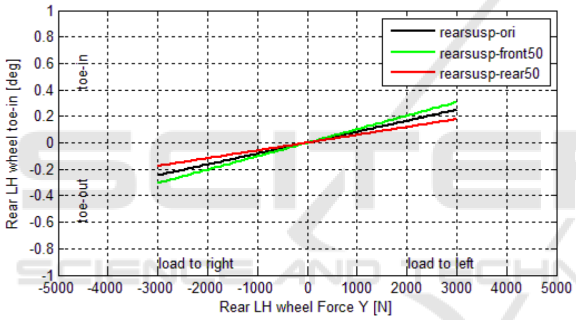

Fig 13. Reverse lateral force toe angle change.

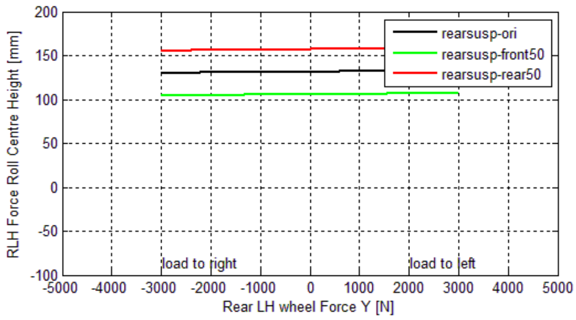

Fig 14. Same lateral force roll center height.

In the same lateral force conditions, the toe angle and the roll center height change significantly. The results can provide reference for model optimization.

3.3 Bushing Installation Direction

When the vehicle is turning, if lateral load transfer is not considered, that is, the lateral forces acting on the left and right tires are the same, the force acting on the tire's grounding point can be decomposed into the lateral force acting on the connecting body's bushing which helps to increase the understeer and the moment acting on the torsion beam's beam. Due to the large bushing used for the bushing at the body joint, the rigidity in the X and Y directions is different. This section investigates the effect of the bushing on the K&C characteristics by turning the bushings at different angles.

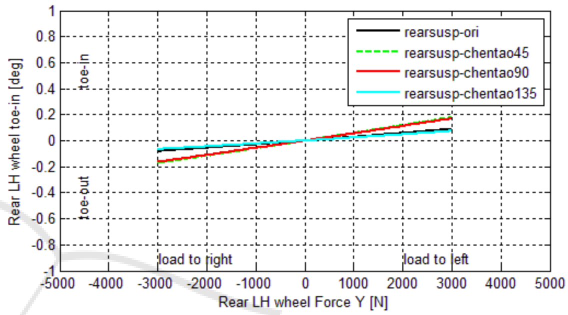

Fig 15. Variation of toe angle in the same lateral force conditions.

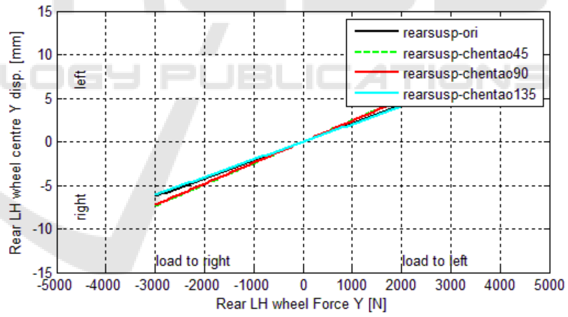

Fig 16. Variation of lateral stiffness in the same lateral force conditions.

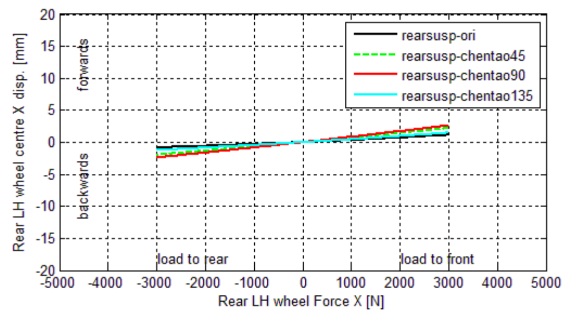

Fig 17. Variation of longitudinal stiffness in the same longitudinal force conditions.

The angle of rotation of the bushing at the connection between the longitudinal beam and the body has little effect on the characteristics of the suspension K and has an effect on the characteristics of the suspension C. From the above figure, we can see that the installation direction of the bushing has a greater influence on the toe angle change and stiffness change in rolling conditions. The change of the toe angle of the lateral force condition should be consistent with the direction of the lateral force, and the change gradient is positive, which is conducive to the under steering of the vehicle. The stiffness changes in longitudinal conditions affect the pitch attitude of the vehicle and affect the smooth performance of the vehicle.

4 CONCLUSIONS

1. The opening direction of the beam of torsion beam suspension has significant influence on the K&C characteristics of the suspension. By adjusting the opening direction, optimizing variation of toe angle and height change of roll center, the vehicle performance can be improved.

2. The beam position of the torsion beam suspension has a great influence on the roll center height, which can provides a reference for the design of the early suspension.

3. In this paper, by changing the beam position and opening direction, we study their effects on the K&C characteristics of the suspension. But the strength and life of the torsion beam are not analyzed. In the later period, the finite element analysis of the torsion beam can be added, and the influence of the beam on the performance of the vehicle can be studied.

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