Study on Simulation Analysis of Vehicle Handling Stability Based on MATLAB

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Abstract. Vehicle handling stability is an important performance index of vehicle, which directly affects the safety performance of vehicle. Driving speed, tire lateral stiffness, center of mass position, front wheel Angle are important factors affecting vehicle handling stability. This paper analyzes the influence of these four factors on the vehicle handling stability, draws the corresponding curve with Matlab software, and simulates the vehicle handling stability. This study provides a research method for analyzing the influence of driving speed, tire lateral stiffness, center of mass position and front wheel Angle on vehicle maneuvering stability.

1. Introduction
With the development of social economy, the technology of automobile industry is more and more advanced, which puts forward higher requirements for the stability of automobile operation. Based on Matlab simulation, this paper analyzes the influence of driving speed, tire lateral stiffness, center of mass position and front wheel Angle on vehicle maneuvering stability, providing a research method for improving vehicle maneuvering stability.

2. Overview of vehicle handling stability
Vehicle handling stability means that under the condition that the driver does not feel excessively nervous and tired, the vehicle can drive in the direction given by the driver through the steering system and steering wheels. And when subjected to external interference, the car can resist interference and maintain stable driving performance. The vehicle handling stability has been paid more and more attention, and has become one of the important performance of modern cars. Therefore, the analysis of the factors affecting the vehicle handling stability has become more and more important[1].

Vehicle handling stability involves a wide range of problems, it needs to use more physical parameters to evaluate from many aspects. In the study of vehicle maneuvering stability, the vehicle is often used as a control system to obtain the time-domain response and frequency-domain response of vehicle curve driving, and to characterize the vehicle maneuvering stability with them[2].

In order to grasp the basic characteristics of maneuvering stability, we study a vehicle model simplified as linear two degrees of freedom[3]. The car is simplified into a two-wheeled motorcycle model, as shown in Fig 1.
3. Influence factors of handling stability

3.1. The Influence of Vehicle Speed on Handling Stability

The selection of automobile model parameters is as follows:

| name | The parameter value |
|------|---------------------|
| Vehicle mass m/kg | 1818.1 |
| The distance from the front wheel to the center of mass a/m | 1.462 |
| The distance from the back wheel to the center of mass b/m | 1.585 |
| The moment of inertia of a pendulum IZ/(kg*m^2) | 3884 |
| Front wheel total lateral stiffness k1/(N/rad) | -62617 |
| Front wheel total lateral stiffness k2/(N/rad) | -110186 |

According to above analysis, combined with vehicle part parameters, we can determine the relevant variables, input car related parameters in the MATLAB command window, use the plot command to available car steady-state yawing angular velocity gain curve as shown in Fig2. By choosing a series of different speed, we can give the front wheel Angle, and remain the same, then draw yawing angular velocity response curve of the vehicle as shown in Fig 3, the center of mass side-slip Angle response curve as shown in Fig 4.
3.2. Influence of Tire Lateral Stiffness on Steering Stability

Two groups of tires with different lateral stiffness were selected: one group was $k_1 = -62618 \text{N/\text{rad}}$, $k_2 = -110185 \text{N/\text{rad}}$, and the other group was $k_1 = -44880 \text{N/\text{rad}}$, $k_2 = -51154 \text{N/\text{rad}}$. The vehicle was running at a constant speed, and the yaw velocity curve of the vehicle under the front wheel angle step input was shown in Fig 5. At the same time, the steering radius under the steady-state response of the two lateral stiffness are simulated respectively, and the simulation curve is shown in Fig 6.

According to comparing two curve in figure 5, it can be seen that under the condition of the same car speed and angle, increasing respectively the front and back of car tire cornering stiffness, car had lower overshoot amount, reaction time is reduced, the steady-state yawing angular velocity is reduced, yawing angular velocity fluctuation is roughly same, auto damping ratio change is not big. It can be concluded that with the increase of tire cornering stiffness of vehicle handling stability is good. According to figure 6, when the lateral stiffness of the tire is changed, the turning radius of the vehicle under steady-state condition changes[4]. Therefore the lateral stiffness of the tire should be reasonably increased to avoid the reduction of the mobility of the vehicle.
3.3. Influence of vehicle center of mass moving back and forth on vehicle handling stability

According to the formula of automobile stability factors, it can be seen that the distance of automobile center of mass from front and rear axles affects the positive and negative of stability factors. When the vehicle speed is constant, under the input of the front wheel Angle step, the simulation is carried out when the vehicle's center of mass moves forward and backward by 200mm respectively. The steady-state turning radius of the vehicle is shown in Fig 7, the response curve of yaw angular velocity is shown in Fig 8, and the response curve of vehicle centroid side deflection is shown in Fig 9.

![Figure 7](image1)

Figure 7. The relationship between the steady state steering radius and the velocity squared of the vehicle mass center

![Figure 8](image2)

Figure 8. Response curves of yaw rate of vehicle centroid change

![Figure 9](image3)

Figure 9. The vehicle side slip angle change curve of velocity response

According to Fig 7, it can be seen that with a gradual backward center of mass the stability factor of the vehicle decreases, and when the vehicle reaches a steady state, its steering radius decreases and its mobility is good. According to Fig 8, when the vehicle's center of mass moves backward, the vehicle's yaw velocity value gradually increases, the reflection time increases, the steering response is slow, the damping ratio increases, and the overshot decreases. Therefore, the backward center of mass can improve the handling stability of the vehicle at high speed. As can be seen from Fig 9, when the center of mass of the vehicle moves backward, the peak value of the eccentric velocity on the side of the center of mass increases sharply, and the handling stability of the vehicle decreases.

3.4. Influence of steering Angle of front wheel on steering stability of automobile

The vehicle is running at a constant speed, and the front wheels are input with different angular step signals, and the rotation Angle is kept unchanged[5]. At this time, the yaw angular velocity response curve of the vehicle is shown in Fig 10, and the yaw response curve of the side of the center of mass is shown in Fig 11.
As can be seen from Fig 10, with the increase of the front wheel's rotation Angle, the yaw velocity increases, the overshoot also gradually increases, and the vehicle's reaction time increases. As can be seen from Fig 11, with the increase of the front wheel Angle, the peak value of the vehicle's centroid side Angle increases, and the vehicle's handling stability becomes worse. Therefore, it is necessary to avoid large front wheel Angle when driving at high speed.

4. Conclusions

For the two-degree-of-freedom vehicle model, MATLAB simulation software was used to analyze the influence of vehicle speed, tire lateral stiffness, center of mass position, front wheel Angle and other parameters on vehicle yaw angular velocity, side Angle of center of mass, and steady-state steering radius. Through the analysis of each simulation curve, it is concluded that when the vehicle speed increases, the vehicle yaw angular velocity changes violently, the centroid side Angle fluctuates greatly, and the handling stability becomes worse. Therefore, the vehicle speed should be controlled reasonably according to the environment in which the vehicle is located. At the same time, when the speed increases, the damping ratio of the car decreases. Therefore, in the design of the car, the damping ratio at high speed should not be too small to avoid the violent swing at high speed. Reasonable increasing the front and rear wheel side stiffness can improve the vehicle operational stability. Changing the front wheel or rear wheel side stiffness alone can change the performance of operational stability[6]. When the center of mass moves backward, the insufficient steering quantity of the vehicle decreases, which can improve the maneuverability of the vehicle, but at the same time, the side Angle peak value also increases. When the steering Angle of the front wheel increases, the steering stability of the car becomes worse.

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