Causes of Understeer and New Solutions

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Abstract. This study will discuss the problem of vehicle understeer, in order to explore the situation that the vehicle steering action can not be completed smoothly. With the development of the automobile industry, the vehicles produced by many automobile manufacturers still have the problem of insufficient steering. So we take BMW M3 as the research objects. So far, the known causes of vehicle understeer are camber, automobile suspension, tire wear and so on. The above three problems have been explained in other papers. On their basis, we propose that when turning, the size of the steering angle is related to whether it can turn, and at the same time, the steering angle is related to the turning time. So we make a conjecture whether changing the steering time can improve the problem of understeer. In order to verify this conjecture, we model the vehicle, analyzed various data and charts, and finally came to the conclusion that changing the steering time can improve the problem of understeer. I hope our article can provide a new idea for the future research on understeer.

Keywords: Understeer, Camber angle, steering angle, turning time.

1. Introduction

There are many researches on understeering. The development of understeering and some achievable solutions are described below. In Ref. [1], authors showed that understeer refers to the situation that the car does not reach the expected angle and deviates from the expected track when turning. This phenomenon is particularly obvious in the case of U-turn. After turning, the steering angle is less than 180 degrees, and the perfect turning cannot be completed. In Ref. [2-4], authors showed that insufficient steering is related to the camber of automobile tires, According to Ref. [5], the camber size will affect the life of the tyre, too large or too small will cause bias wear of the tyre. When one front wheel has a larger camber than the other, the wheel will be towed to the side of the larger camber. The reason for this problem may be that the two tyre sizes do not match. Ref. [6] shows that steering instability can be caused by camber under extreme driving conditions. If the front wheel camber is negative, additional stability can be provided for steering and the range of cornering stability can be increased. According to the research in [7], these two important parameters of camber and toe angle are very important to the front wheel of a vehicle. If the matching relationship between them is not reasonable, it will increase the side slip of the front wheel of a vehicle, thus increasing driving resistance, causing eccentric wear and decreasing the service life of the tyre. A reasonable matching relationship can guarantee the driving stability of the vehicle and increase the service life of the tyre. The influence of tyre tread on wet adhesion of tyres has been studied in Ref. [8]. When driving on wet road, the tyre surface will adhere to fluids, which may cause water sliding on the tyre, which is dangerous to driving, while the tyre surface tread can drain water and increase driving stability of the vehicle. Ref. [9] is a tyre pattern pair design which, according to the research results of the patent, can be used for driving on flat roads to ensure the straight-line driving ability of the vehicle while avoiding the phenomenon of insufficient steering force when turning. A study in Ref. [10] found that when a vehicle is steering, lateral road reaction acting on the wheel ground area causes a change in the wheel camber, while an increase in the front wheel camber causes an increase in understeer. Ref. [11] mainly studies the influence of suspension stiffness on vehicle stability. The front coil spring stiffness and the diameter of the transverse stabilizer affect the wheel camber. Therefore, the front coil spring stiffness or the diameter of the transverse stabilizer are effective ways to improve the vehicle's steady-state steering characteristics. According to the research in Ref. [12], the purpose of designing a vehicle with a certain camber is to reduce friction and independent suspension. Tire camber changes when the body rolls, and the change of tire camber changes the cornering angle, thus forming feedback and affecting the steering characteristics of the vehicle. Ref. [13] deals with the additional steering caused by the additional torque generated by the stabilizer boom when the Macpherson suspension rolls, which affects the steering characteristics of the vehicle. If the direction of the additional torque is opposite to the steering direction of the vehicle, the wheel angle will be reduced and the vehicle will tend to understeer. Ref. [14] holds that, although there are many reasons affecting understeering, the vehicle understeers or oversteers mainly depend on the structure selection and hard-point location of the vehicle. Tyres, springs, shock absorbers, stabilizers, etc. all contribute differently to understeering. Later engineers can adjust the adjusting pieces to adjust the understeering characteristics of the entire vehicle to achieve the corresponding performance. In addition to the Ref above, we have also provided our solution to the understeer problem, which may be a new idea. These are objective factors. We use Python to build the vehicle trajectory model and find that understeer may also be related to the steering angle and steering time. We hope to have the opportunity to conduct research and demonstration with physical vehicles in the future.

2. Main body

Understeer occurs when the vehicle needs more steering wheel angles to maintain the desired path. Next, we will study vehicle steering from camber Angle, tire and suspension, and analyze under which circumstances understeer will occur. Lateral force will be generated when the wheel leans out, leading to lateral slip of the wheel. Sideslipping on the one hand will affect the vehicle steering, on the other hand will aggravate tire wear, affect tire grip, aggravate understeering. Suspension is a force transmission connection device and ground impact buffer device between the frame and the bridge, both stiffness and deformation characteristics of suspension will affect vehicle steering to a certain extent. Here's our analysis of the data.

2.1. Camber angle

The wheel camber produces a lateral force, which is called the camber force. The test shows that the actual camber force F and camber angle α.The relation is in the formula: Fa=ka·α.K is the tilt stiffness, N /(。). The research shows that the magnitude of camber force is directly proportional to camber angle and wheel roll stiffness. The outward tilting force causes the wheel to roll and produce side deviation at the grounding point. The side deviation produces lateral stress. When the lateral stress is greater than the ground adhesion, the tire will produce inward sideslip relative to the ground. As the camber angle increases, the camber and roll slip increase.

2.1.1 Influence of vehicle camber on front wheel sideslip

Wheel camber will produce lateral force. Because the tire is an elastomer, the contact between the bottom of the tire and the ground will be laterally deformed under the action of camber lateral force [2]. In Fig.1 (a), AA is the center line of the tire grounding mark after the lateral deformation of the right front wheel, which is parallel to the center line of the wheel. When the wheel rolls on the road, the center line O and a of the tire grounding imprint will no longer be parallel to Peng, but offset by a certain angle, which is called the camber angle; As shown in Fig.1 (b), the first landing tire imprint point (a') is close to the wheel centerline and has small lateral deformation; Since then, the tire imprint points that landed successively are farther and farther away from the actual driving straight line of the wheel, and the lateral deformation is large. Lateral deformation produces lateral stress, which is directly proportional to lateral deformation; When the lateral stress is greater than or equal to the ground friction, the tire begins to slip, which is called camber slippery.

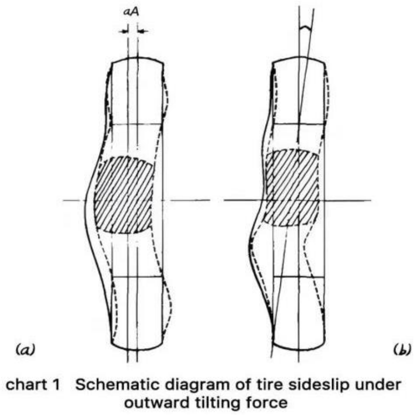

Figure 1. Schematic diagram of tire sideslip under outward tilting force

With the increase of camber angle, the camber force also increases, the tire lateral deformation intensifies, and the tire lateral stress increases, which increases the slip area, and finally leads to the increase of the area of tire surface participating in slip, that is, the amount of camber slip increases, resulting in failure of normal steering and understeer [2].

2.1.2 Front wheel camber will cause tire eccentric wear, resulting in adverse steering

Too little or too much camber of the front wheel will cause eccentric wear of the tire, and too much camber will cause serious wear of the outer shoulder of the tire; Otherwise, the inner shoulder is worn. When the camber angle is positive, the outside diameter of the tire becomes smaller and the other side becomes larger [5]. As a result, the slip in the same (same side) or opposite (inner side) direction as the wheel rolling direction is generated, which intensifies the wear on the outer side of the tire and forms a unilateral drag on the side with smaller diameter, resulting in deviation and insufficient turning when the car turns. There are many reasons for improper camber angle, such as inconsistent tire size, distortion and deformation of front axle, bending and chiseling deformation of wheel auxiliary edge, nonstandard steering knuckle, looseness of kingpin and its bushing, etc. These factors also indirectly affect the wear of tires to a certain extent.

2.1.3 Influence of camber angle on vehicle steering and driving stability under extreme working conditions

In the high-speed driving condition of the vehicle, the camber angle of the wheel will increase sharply due to factors such as roll, camber and load transfer [6]. Moreover, when the vehicle speed is high, the lateral force generated by the front wheel camber angle is more likely to destabilize the vehicle due to the reduction or even negative value of the tire drag distance [7]. By establishing the vehicle steering driving dynamics model, we analyze the relationship between wheel camber and vehicle stable angle, so as to avoid understeer [8].

2.2. Tire factors

Uneven adhesion caused by inconsistent tire pressure, pattern, weight and wear degree (old and new degree) will lead to vehicle deviation and understeer [3]. The front and rear axle loads of the vehicle are different, and the tire pressure of the front and rear tires may also be different, resulting in deviation to the side with low tire pressure. In addition, it is absolutely wrong to adjust the running deviation by using the uneven air pressure of the tire, which will cause understeer. When the vehicle deviates irregularly from left to right, it may be that the tire wear is seriously uneven.

2.2.1 Tyre tread designed to solve understeering

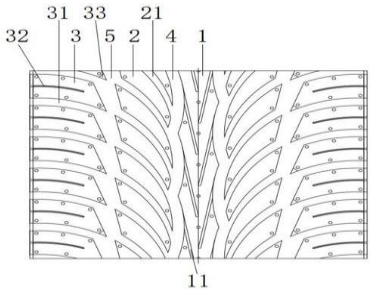

Figure 2. Tyre tread for flat roads [8]

Fig.2 is a tyre pattern design that can be used to keep the vehicle straight on a flat road while reducing the impact of understeering.

2.2.2 Effect of Tire Friction on Understeering

Affected by the friction ellipse of the tyre, the lateral deflection of the tyre is rigid when there is slip in the longitudinal direction [9]. Degree will change significantly, resulting in a significant change in understeer.

2.3. Suspension

2.3.1 Influence of McPherson front independent suspension on steering characteristics

The suspension is a force transmission connecting device between the frame and the axle, which can alleviate the impact load transmitted to the frame from the uneven road surface and ensure the smooth driving of the vehicle [10]. We use the flexible multi-body model to analyze the force and deformation characteristics of the suspension, and explore the correlation coefficient that determines the relevant parameters of the vehicle understeer. In this section, we will mainly analyze the deformation characteristics of lateral force. When the vehicle turns and runs, the lateral reaction force of the road surface acts on the wheel contact area, which causes the lateral deformation of the components of the tire and suspension guide rod system, and will cause the change of wheel camber and wheel angle at the same time. The understeer of a car is the difference between the total side deflection angles of the front and rear axles. The understeer of a car is the difference between the total side deflection angles of the front and rear axles: U=D1-D2. Where D1 and D2 represent the side deflection angle of front and rear axles respectively.

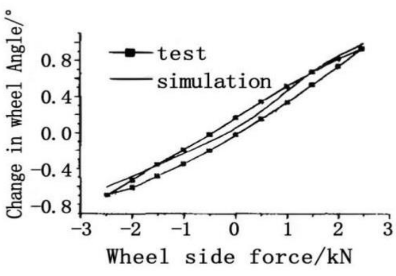

Figure 3. Relationship between front wheel camber and lateral force

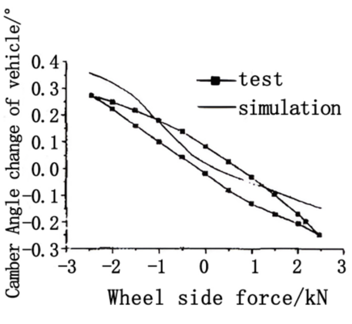

Figure 4. Relationship between front wheel angle and lateral force

Fig.3 shows the relationship curve of the camber angle of the front suspension of the car with the applied lateral force. Lateral acceleration 0.4g. Within the range, the measured value of the average change rate of the front wheel camber of the car is 0.35°/kN and the calculated value is 0.348°/kN. The increase of the front wheel camber is conducive to increasing the understeer trend of the car.

Fig. 4 is the curve of the variation of the wheel angle of the front suspension of the car with the applied lateral force. The front wheel angle of the car decreases with the increase of lateral force. The measured value of the average change rate of the front wheel angle is 0.112°/kN and the calculated value is 0.114°/kN. For the front wheel, this lateral force deformation steering characteristic has the same effect as the increase of the front wheel side deflection angle. It can be seen from equation (1) that the front wheel side deflection angle increases and the insufficient steering degree of the car increases. Therefore, this lateral force deformation steering can increase the insufficient steering. However, for the rear wheel, the side deflection angle increases. It can be seen from equation (1) that the understeer of the vehicle decreases, which will increase oversteer and cause understeer.

2.3.2 Influence of McPherson suspension stiffness on vehicle steady-state steering characteristics

In the actual deformation process of McPherson independent suspension, the wheel camber and other positioning angles will change significantly, which will affect the yaw stiffness of the front axle [11]. The stiffness of front coil spring and the diameter of transverse stabilizer bar are important parameters affecting the camber of left and right wheels of curved vehicles. Using the multi-body system dynamics method and taking a micro vehicle as an engineering example, we establish a dynamic analysis model of the whole vehicle multi-body system that meets the analysis of steady-state steering characteristics, and study the effects of the coil spring stiffness of the front suspension and the diameter of the transverse stabilizer bar on the steady-state steering characteristics of the vehicle.

2.3.3 Influence of rear suspension elastic parameters on vehicle passive steering characteristics

Some studies have shown that the passive steering technology applied to the rear axle of the vehicle plays an obvious role in improving the handling performance of the vehicle [12-13]. The application of this technology to the vehicle with independent rear suspension can make the vehicle use the slight steering generated by the elastic movement of the rear suspension to help the vehicle turn smoothly [14], so as to maintain the driving track without losing control of the vehicle, so as to avoid understeer.

2.4. Steering time and steering angle

Next is our research on steering time and steering angle. In order to discuss the relationship between steering time and steering angle, we take BMW M3 and Chevy Cavalier as research objects to model, study the relationship between steering time and steering angle of BMW M3 in U-turn and Lane change and in sharp turn, and compare the experimental results. Here is the data from our experiments using Python for modeling.

2.4.1 Steering angle

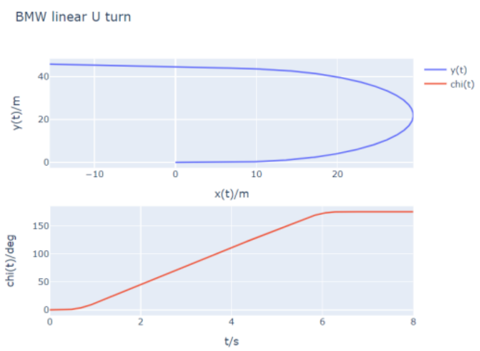

Figure 5. BMW linear U-turn

Because Fig.5 linear U turn requires 180 degrees of rotation to complete steering. However, according to the experimental results, the steering angle is about 175.3 degrees, less than 180 degrees. So BMW M3 cannot make full steering.

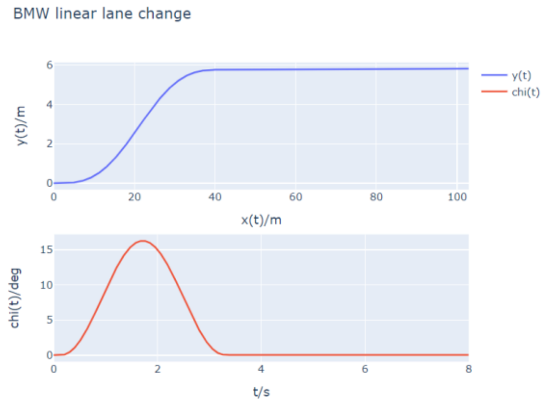

Figure 6. BMW linear lane change

However, Lane change needs to change the steering angle to 0 after Lane change.Fig.6 shows that the result of the experiment is about 0.04 degrees, so BMW M3 can not complete Lane change.

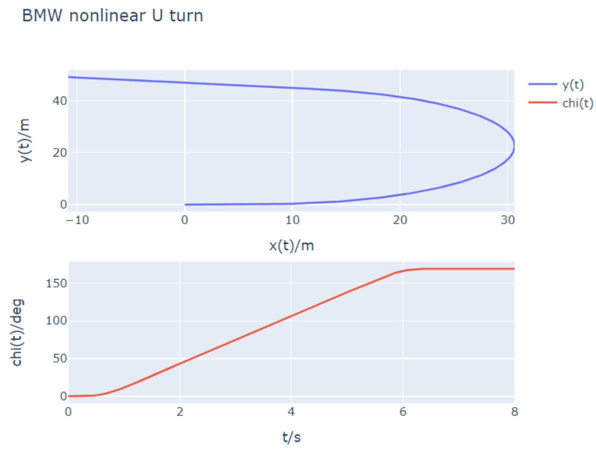

Figure 7. BMW nonlinear U turn

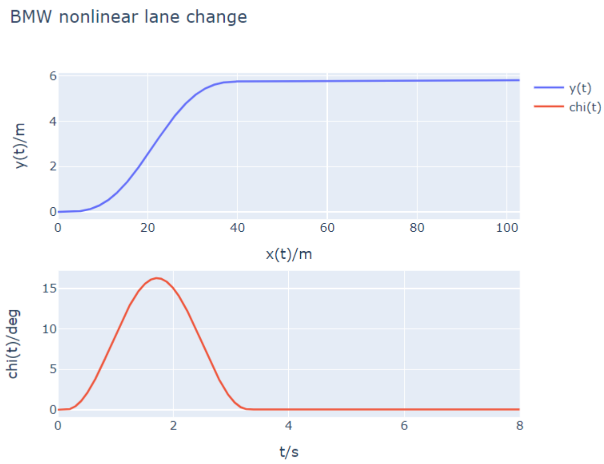

Figure 8. BMW nonlinear lane change

Fig.7 and Fig.8 are non-linear models. The comparison between non-linear U-turn, lane change and linear U-turn, lane change is made. First, the comparison between linear and non-linear U-turn is made. The non-linear result is that the steering angle is about 168.7 degrees, while the steering angle under linear condition is 175.3 degrees. The comparison between non-linear lane change and linear lane change is known from experimental data. There is no need to change much between linearity and nonlinearity. The steering angle values are all around 0.04 degrees. From this we can conclude that vehicles cannot complete U turn and lane change in both linear and non-linear situations.

2.4.2 Steering time

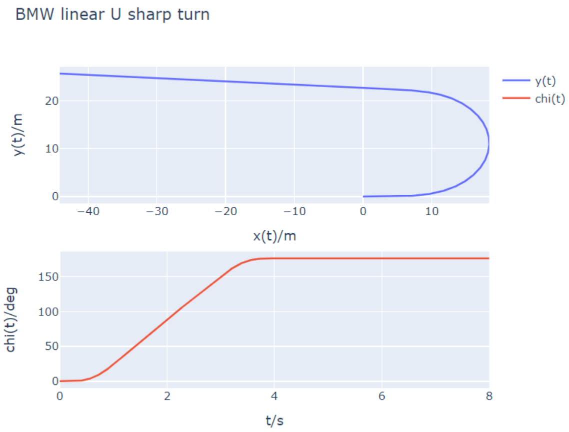

Figure 9. BMW linear U sharp turn

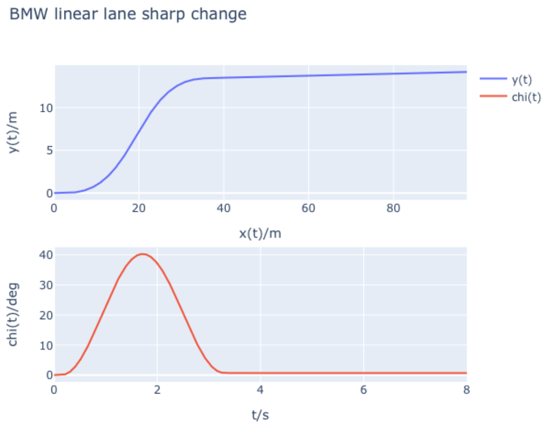

Figure 10. BMW linear lane sharp change

Based on previous data, in the case of a non-linear U-turn, the steering angle maximum is less than the linear maximum and less than the previous test conditions. In the previous model and the steering model, we assumed that a perfect U turn would occur when the steering time exceeded 5.45 seconds. So from Fig.9 and Fig.10, we could conclude that when the steering time was extended. The steering angle could be changed to improve understeering.

3. Conclusion

Based on the known papers, we could get that the camber angle is closely related to understeer. Understeer could also be caused by load, center of gravity and tire wear. At the same time, on the basis of previous studies, we have also opened up a new idea for the study of vehicle understeer. Whether changing the steering time can change the steering angle and improve the problem of understeer is what we want to study. We hope that in the future, the problem of vehicle understeer can be better solved.

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