Automotive Lateral Stability Development Status and Trends

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Abstract. Lateral stability is an important safety performance of vehicle, and is also a basis of determining the auto's ability resisted horizontal rollover and sideslip. Through consulting literature materials, the paper learned about the development of the electronic stability system at home and abroad, and analyzed bad conditions due to the lateral force generated when the car is steering, such as drift and slip, etc. In addition, it mainly studied automotive electronic control systems how to work under the condition of under steer and over steer when the car is steering and the problems of the degree of car control, and also introduced several modern control systems which are different from traditional electronic control systems.

Introduction

From the invention of vehicle to the development of engine, and with the continuous improvement of road conditions, the max speed is increasing continuously. However, vehicle safety problem is increasingly extruded, and imbalance vehicle accidents are frequently occurred, people begin to work on how to improve the driving safety of automotives [1]. Lateral stability is an important problem of vehicle control, the key is the lateral forces on the automotive by the ground. When the automotive steers or changes lanes at high speed, it will occur horizontal pendulum movement under the action of large centrifugal force, appearing over steer or under steer working conditions, happening the drift and spinout condition. Therefore, it is necessary to research the control system of vehicle lateral stability, then we will discuss the current situation of the electronic control system of lateral stability and its development tendency.

The Current Situation of The Development of Automobile Lateral Stability at Home and Abroad

The Current Situation of The Development of Foreign Auto Lateral Stability

As early as 1985, Nissan company in Tokyo auto show launched a concept car which is initially set by the electronic control system. As time goes on, in 1987, Toyota's FXV - II concept car achieved integrated control that active air suspension AAS, four-wheel steering system 4WS, four-wheel drive system 4WD and ABS anti-lock braking system, but the level is not high, and the method is simple, this was the early lateral stability of the electronic control system[2]. In 2000, German BMW company's Smakman and others did a lot of research on the integrated control of active suspension system and anti-lock braking system, and came to the conclusion about how to make full use of the inherent advantages of both.
Alleyne American University of Illinois, Volkswagen’s Duda, and Japanese scholar Harada, respectively, worked on the different levels of testing and research[3].

In 2004, the German Bosch company developed vehicle dynamics management systems VDM which was integrated AFS, ARC, ESP and other electronic control systems, and validated the control effect on the Audi A6. The results showed that active control system integration allowed the vehicle to achieve a good balance between ride comfort, maneuverability and safety [4]. In 2006, the vehicle dynamics integrated management system VDIM was installed in the Lexus 460 by Toyota company, which controlled the vehicle from the hardware and software levels and managed uniformly driving, braking and steering. The results showed that it could control the car before slipping[5]. In 2010, an American scholar Brad Hopkins and others did a lot of research about the yaw stability control algorithm and emergency control strategy, by changing the strategy of vehicle lateral acceleration to improve the lateral stability of cars, the results suggested that it had obvious effect [6]. In 2014, Vladimir Ivanovic and others proposed what based on filter extended Kalman filter sideslip angle estimation for the estimation of automobile tire force and bending strength, using the vehicle dynamics model and the underlying magic formula tire model, analyzing it and fully using tire force to ensure the vehicle lateral stability [7].

The Current Situation of The Development of Domestic Automobile Lateral Stability

Domestic study of vehicle lateral stability control started late, which mainly concentrated in universities, such as Jilin University, Tsinghua University, Tongji University, etc. They have made a great contribution for stable electronic control technology to our country. In 2005, professor Yu Fan's group of Shanghai Jiao tong University made a research on steering system, anti-lock braking system and active suspension systems, and put forward a lot of new thoughts and methods about the electronic control system, which have great research achievements. They proposed a new vehicle chassis control strategy during the research of 4WS vehicle, slip rate control and overall control of active suspension system., which extremely effectively improved the comprehensive use of cars' performances[8]. In 2006, Tongji University professor Yu Zhuoping and others made AFS control strategy based on synovial variable structure and ESP control system which joint direct yawing moment and the wheel's variable slip rate, analyzed and concluded the principles of coordinated control, and verified its’ validity by the simulation of three typical working conditions [9].

In 2011 Jilin University professor Zong Changfu group achieved the collection control of braking and steering by using model predictive control algorithm, through the global collection control of braking, steering and suspension they put forward a problem based on the quadratic programming tire force distribution in the case of guaranteeing the angle of integrated chassis control constraints[10]. In 2013, professor li keqiang, Tsinghua University team found a distributed electric vehicle vertical horizontal and vertical force coordinated control method, and used the vehicle information, obtained the vehicle's expectations of the resultant force and moment, built constraint condition and objective function, realized complete tire force optimization. In addition, some of the colleges and universities scholars and professors also made a great contribution [11].

Vehicle Lateral Stability Control System

ABS Anti-lock Braking System

Traditional ABS anti-lock system, by monitoring the tendency of wheel lock, increasing, decreasing or maintaining braking pressure automatically, ensures vehicles near the optimal
slip ratio to prevent the wheels’ skid due to lock. This is a way to control the rate of vehicle lateral sway, indirectly improving vehicle handling stability. But most of the time, vehicle will lose balance because of insufficient side force in the best lateral rate[12]. But if ABS can change slip rate threshold value adapting to the actual yawing velocity, namely when the actual yawing angular velocity is bigger than the reference value, the system will be judged as excessive steering. However vehicle with normal ABS is in excessive steering conditions, owing to axial load transfer, braking force in the outer wheel is greater than in the inner wheel, producing a stable torque to correct excessive steering. But the stable torque is too small to correct excessive steering, even if driver tries it utmost to brake. Consequently, it is easy to appear dangers such as slides as well as spin. But the improved ABS system can appropriately increase upper and lower threshold value of the outer wheel slip ratio, reduce the inner upper and lower threshold value, increase the lateral wheel braking force, produce a compensatory yawing torque correcting excessive steering, and enhance the lateral stability of vehicle. Similarly, when it is in insufficient steering, by appropriately reducing the lateral height and increasing the upper and lower threshold value of the inner wheel slip ratio, the vehicle lateral stability is improved then[13].

**ESP Automotive Electronic Stability Control System**

ESP, automotive electronic stability control system, which is the function inheritance and expansion of ABS and TCS. The ways it controls a vehicle are to control the yaw moment, improve the drawbacks in lateral stability of ABS and TCS as well as detect with various sensors and identify the driver’s intention by ECU, To ensure the safety of vehicles. ESP is able to make an accurate and timely response to the sudden obstacles in several special conditions by controlling the engine. Take the car, which avoid the other one coming out of the byroad in a sudden, as an example. The car turns out to be under steering, in the meantime, ESP brakes the rear left wheel, producing an anticlockwise torque and braking the wheels, which decreases the vehicle’s speed and results in the fact that the rear wheel differential makes the rotational speed of rear right wheel increase with the increasing one of left wheel, and then, turning is done. When it demonstrates that it over steers, and immediately, ESP cut down the rear wheels’ torque to reduce the longitudinal force but increase the lateral one. Now ,the speed is low, which provides a proper environment to maintain stability. Moreover, the brake is forced on the front left wheel so as to increase the anticlockwise yaw moment to the maximum and guarantee the safety driving of vehicle[14].

**Four-wheel Drive-slip Control System**

Four-wheel drive vehicle make the motor directly mounted wheels or nearby, can achieve a variety of sophisticated driving mode. Compared to conventional cars which simplifies the mechanical transmission mechanism, improve the transmission efficiency and reduce the body mass, simplifies automotive structural arrangement and improves the dynamic response of vehicle wheels [15]. It has a good performance, but there are also insufficient in four-wheel vehicle, for example, short-time four wheel drive vehicle have tedious operation, constant time four wheel drive vehicle drive axle and differential connection between the left and right wheels. As long as one wheel at a low adhesion coefficient road, almost the whole car will lose the driving force. But if we make the drive slip system in the four wheel drive vehicle, the problem of slippage can be solved. TCS system can automatically identify the road conditions and vehicle condition, according to the previous control strategy, respond to control wheel slip [16]. For example, if the drive wheel slips when the car turns around, the
front wheel will appear under steer condition, while the rear wheel is over steer, in severe cases Slip. At this point, TCS system will automatically control the drive wheels; make the slippage of tire within a reasonable range, so as to make the car smoothly turn around.

**Four-wheel Steering System and Active Front-wheel Steering System**

Conventional cars generally use the front wheels to turn, and the driver can only operate on the steering wheel to change the forward direction of the car, in the same time, the rear wheels can only make a passive shift. In fact, in the early 1900s, engineers discovered that the reverse rotation of the front and rear wheels can effectively reduce the turning radius of vehicles in the low speed operating conditions, which is the precursor of four-wheel steering. When the vehicle is driving, it can control the inputting angles of rear wheels by the information to improve vehicle handling and stability. Compared to conventional cars, four-wheel steering system can reduce the course of the yaw rate and lateral acceleration, plus, it has faster response and higher sensitivity. For driving, at low-speed steering, the opposite turning direction of front and rear-wheel steering can reduce the turning radius and enhance flexibility, achieving "inverted shift"; at high-speed steering, when the wheels are in the same direction, the small sideslip angles decrease the body swept envelope area and make the moving route more smooth, achieving "symmetry shift"[17]. Advantages of four-wheel steering system come from the independent control of rear-tire lateral force, but the rear-wheel steering angle generally can not exceed 5% of the peak of front-wheel steering angle. There are also active front-wheel steering system (AFS), which can produce the steering angle of the drive wheels to achieve control of the car through active mechanism in accordance with drivers’ intention. However, the difference is that the front wheels of AFS can reduce the complexity and cost of production to improve operational stability at a high speed. AFS also relies on the lateral force of tires to control the car's direction, if in the conditions of large lateral acceleration, the control performance will be greatly reduced by the force saturation characteristics of tires. As far as the actual application is concerned, ESP and AFS will be the most effective and promising integrated program [18].

**TVC Torque Vector Control System**

TVC torque vector control system can inhibit the under steer or excessive of car and enhance the car's lateral stability of the system by the distribution of the left and right or front and rear wheels’ drive. The large centrifugal force High speed of automobile steering makes the center of gravity outwardly inclined and the pressure and friction of outer wheels greater, in the same time, pressure inside wheel is reduced, causing the idling of the inside of the wheels. And the most current way to resolve slipping is braking the slipping wheels and reducing output torque. TVC can distribute the power to the left and right wheels according to road conditions, without affecting the speed and power loss in the case of differential torque transfer through. It can control the driving torque of each driving wheel and make a driving force difference between the wheels. Such as when the car is under steering, inter axle torque distribution system will transfer the driving wheel to the rear axle, and wheel torque distribution system distribute the drive force of rear axle to the outer wheels, so that the left and right wheel can generate an additional lateral torque to correct under steer. When the car appears over steering, TVC system will transfer driving force forward shaft by the intermediate shaft torque distribution system, and the wheel torque distribution system between the method of allocation to the inside wheel torque to suppress over steer. So TVC
system can greatly improve lateral stability and safety of the vehicle without the loss of power, and I believe that in the near future it will be fully use of the four-wheel drive car [19].

**Summary**

Vehicle’s lateral stability ability has a limit value. Especially in high speed, vehicle under the effect of transverse force is likely to lose lateral stability, sideslip or rollover. So in order to ensure safety, many developed countries have begun to develop technical regulations of imposing chassis control measures to improve the vehicle lateral stability, ensure in extreme conditions to actively intervene vehicle maneuverability, make cars remain in a stable condition, reduce automobile traffic accident happened because of the out of control. In the next few years, vehicle active safety control system represented by "electronic stability control program" will be one of the most important automobile active safety facilities. Compared to developed countries or regions such as Europe and America, Japan, the auto industry in China started late, but car ownership in China is promoted continuously, so also should pay attention to improve the level of automobile technology, especially in automotive safety technology. It requires our government departments, production enterprises and the examination organizations value in many aspects. From various aspects to improve auto safety stability, and actively promote the use of advanced active safety control system of the chassis, formulate relevant laws and regulations and in line with international standards, to promote the improvement of China's automobile safety equipment [20].

**References**


