

Research on Control Strategy of Intelligent Air Active Suspension System for Passenger Car based on Semi-vehicle Model

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Abstract

The control and comfort of the suspension system is a pair of contradictions, at present, domestic passenger cars all use passive suspension system, passive suspension system in the vehicle driving control, safety and comfort on the compromise value. In domestic high-end imported and joint venture models, semi-active suspension system began to be applied, such as BMW Magic carpet intelligent air suspension system using active dynamic driving system, combined with air spring, electronic servo to improve anti-roll stability; The Magic fuselage of Mercedes uses a hydraulic suspension system, based on binocular stereo cameras, three-axis acceleration sensors and body height sensors, which can be used to predict road conditions. The feasibility and rational design scheme of active dynamic driving system entering middle and low end automobile industry is put forward.

Keywords

Semi-vehicle Model; Intelligent Air Active Suspension System; Passenger Car.

1. Background

If the spring stiffness and shock absorber damping parameters are improperly configured, it will damage the comfort of the vehicle and even endanger the safety of the vehicle. Therefore, it is difficult for passive suspension to reconcile the contradictory requirements of ride comfort and handling stability. The passive suspension system is a compromise in the handling, safety and comfort of the vehicle. In recent years, the domestic high-end imported and joint venture models, the semi-active suspension system began to be applied, such as BMW Magic carpet intelligent air suspension system using active dynamic driving system, combined with air spring, electronic servo to improve anti-roll stability; The Magic fuselage of Mercedes uses a hydraulic suspension system, based on binocular stereo cameras, three-axis acceleration sensors and body height sensors, which can be used to predict road conditions.

2. Project Analysis

2.1. Research Status at Home and Abroad

The suspension that only depends on its own device to adjust the vibration is passive suspension, which is widely used at present. The suspension that needs energy to adjust the damping of suspension shock absorber is semi-active suspension; The suspension which adjusts spring stiffness and damping through the actuator belongs to the category of active suspension.

2.2. Foreign Technology Monopoly, Domestic Passenger Cars do Not Carry Active Suspension System, Active Suspension System Cost is High, Imported Cars are Only Applied to High-End Models

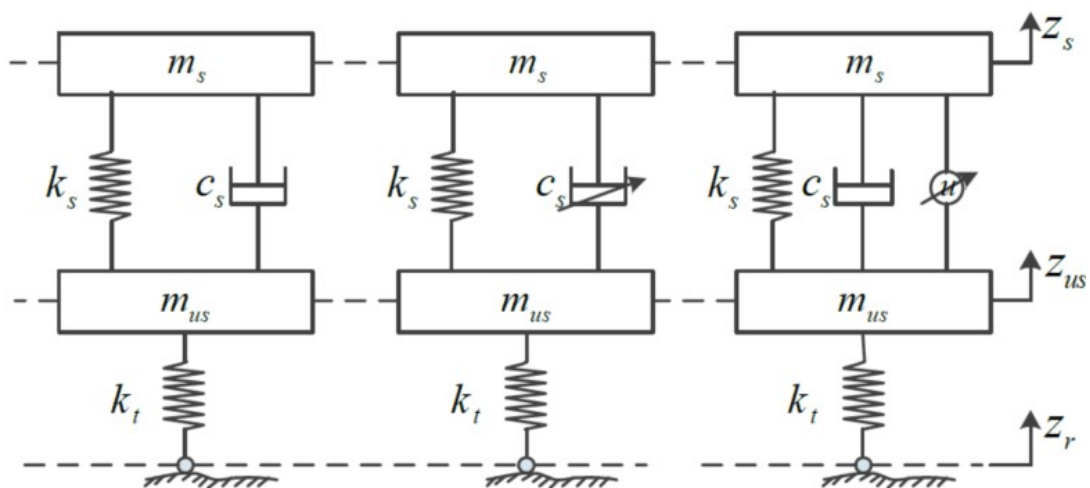
This project comes from the intelligent suspension system developed by domestic Intelligent Suspension Co., Ltd. since 2018. The company has developed and produced related products including: air spring, electronically controlled continuous adjustable shock absorber, electronic control unit (ECU), with independent intellectual property rights and production and detection technology.

The company's ECU adopts fuzzy PID algorithm to identify six specific road conditions and actively adjust the suspension system. But at present in the technical bottleneck. However, it is difficult to set the fuzzy set, determine the parameter stability area and determine the optimal parameter in the process of vehicle tuning, which results in a long tuning cycle. The control algorithm research is relatively simple, and the algorithm performance comparison research has not been carried out. The air spring technology of integrated body height adjustment is independent from the automatic adjustment system of active suspension system, so the research on its integrated control performance is insufficient.

The project team cooperated with the domestic Intelligent Suspension Co., LTD to conduct research and development, mainly focusing on its control algorithm, parameter setting, control strategy for comprehensive research.

3. Passive Suspension System

At present, passive suspension is mostly applied to low and medium grade cars. Olley proposed the concept of passive suspension in 1934, and its structure diagram is shown in Figure 1(a). Passive suspension is composed of spring and damper (shock absorber), spring stiffness and damping are fixed values can not be adjusted, because of the traditional mechanical structure, has the advantages of simple structure, reliable performance, low cost.



(a) Passive suspension (b) semi-active suspension (c) active suspension

Fig 1. Classification of vehicle suspension system

The passive suspension can not adjust the system parameters according to the excitation and can not adapt to various excitation changes. The limitation of passive suspension is due to the fixed characteristic parameters.

Reducing the stiffness of the elastic element (suspension spring) is conducive to improving the ride comfort and ride comfort of the car, but the soft spring needs a large space arrangement, which is difficult to achieve on the vehicle. At the same time, when the offset frequency of the suspension is less than 0.7Hz, it is also easy to cause passenger motion sickness.

4. Semi-active Suspension System

The performance limitation of passive suspension makes people hope to adjust the performance and application range of suspension by changing the parameters of suspension. The concept of semi-active suspension control was first proposed by Crosby and Kamopp in the early 70's. Different from passive suspension, a damper whose damping coefficient can be adjusted in a wide range is used in semi-active suspension. The damper with variable damping coefficient greatly improves the adaptability of the suspension to different roads, and greatly improves the ride comfort and handling stability of the car.

By developing a high-performance controller and adjusting suspension damping in real time according to the required controlling force, good performance superior to passive suspension and approaching active suspension can be provided, as shown in Figure 1(b).

At present, the research and development of semi-active suspension mainly focuses on the continuous adjustment of damping. By changing the size of the throttle hole or changing the viscosity of the damping fluid, the research and development focuses on the development of high-performance actuators and efficient control strategy.

5. Control Decision

ECU sends control instructions to the actuator to generate the required control force, and closed-loop adjustment is carried out on the damping and stiffness of the suspension system. The structure is shown in 1(c). According to the different controlled media, active suspension can be divided into hydraulic active suspension, air active suspension, oil gas active suspension and electromagnetic active suspension and other forms.

5.1. Hydraulic Active Suspension

In this system, sensors are used to detect signals such as the vertical acceleration of the body, the lateral acceleration of the body, the load of each axle, the angular velocity of deflection, the speed of the vehicle, and the operation of the driver. ECU analyzes and processes the signals and feeds them back to the four wheels. And the feedback control of load, unsprung mass acceleration and suspension travel can reduce the change of body attitude. In addition, this system can minimize the movement of sprung mass and obtain good ride comfort.

5.2. Oil-gas Active Suspension

The hydro-pneumatic active suspension combines the incompressible oil with the air spring, so the high pressure of the system can be achieved, which is conducive to improving the sensitivity of the response. The larger the gas volume, the more throttle holes in the pressure oil path, the softer the elasticity and the smaller the damping effect. The center of the system is a computer control device, which constantly receives the data information about the driving condition and selects the corresponding suspension state. However, there are still some unsolved problems in this system, such as cost, function, power consumption, weight, occupied space and vibration and noise.

5.3. Air Active Suspension

The high frequency shock absorption ability of air suspension is strong, but due to the use of highly compressed air as the power source, the response sensitivity is not too high, the structure is complex, and the price is high.

5.4. Electromagnetic Active Suspension

The electromagnetic active suspension is a new type of active suspension which is being researched and developed in recent years. It uses the electromagnetic mechanism as the actuator. The electromagnetic mechanism generates the electromagnetic force by changing the current in the electromagnetic mechanism according to the detected body acceleration changes and other parameters, so as to adjust the suspension stiffness and damper damping, so as to improve the riding comfort.

Active suspension system was proposed as early as 1954 when General Motors suspension system was designed. Although it was proposed earlier, it has not made a big breakthrough in a long time due to complex control, high energy consumption, high cost and system reliability, and many other problems involved in many disciplines.

A variety of active suspensions with good performance have been successfully manufactured and applied in automobile production. At present, Mercedes-Benz, Audi, BMW, GM, Ford, Volkswagen and other foreign imported models and joint venture models carry different technology active suspension system, develop intelligent control algorithm to meet the requirements of different working conditions, and constantly improve the control quality and performance level of automobile active suspension.

Compared with foreign countries, domestic research on main semi-active and active suspension technology started late, and there is still a certain gap compared with foreign advanced technology. At present, domestic passenger cars almost all use passive suspension technology.

In 2014, Yutong bus semi-active suspension technology filled the gap in bus suspension technology industry. However, in the passenger car market, only a small number of test vehicles have been designed and installed. In the mass production of ordinary passenger models, semi-active and active suspension technology has not been seen.

At the present stage, in the field of automobile electronically controlled intelligent suspension, the core technology from actuator to control unit has long been monopolized by foreign enterprises such as ZF Friedrichshafen, Tennero, Manto, etc., and there is a lack of complete systematic research and development and production enterprises in China. The active or semi-active suspension of medium and high-end vehicles relies heavily on imports to achieve matching. Due to its high price, it can only be used in a few high-end cars. Therefore, on the basis of previous studies on continuous damping adjustable shock absorber and air suspension system, this project plans to optimize the structure and process of key components by using modeling and simulation and other advanced means to further improve the product performance level. Advanced control technology is adopted to further improve the control algorithm of the suspension system combined with the standard model, and the control quality of the suspension system under different working conditions is comprehensively improved. Finally, the research results of this project will be transformed into enterprises to optimize the control strategy and control algorithm, reduce the vehicle tuning cycle of enterprises, and comprehensively master the core technology of the system.

6. Development Trend

At present stage in our country, passive suspension system occupies a mainstream position. It is simple structure, reliable performance, low cost and does not consume automotive energy. But it can only be guaranteed to achieve better results under specific road conditions. Due to the requirements of car ride comfort and handling stability, the safe, comfortable and intelligent active suspension will be the general trend of car suspension development in the future, which is mainly reflected in the following aspects:

(1) Automobile electronically controlled suspension will further develop to the direction of high performance.

Domestic and foreign scholars have studied the control strategy and algorithm of automobile active suspension in many aspects, canopy principle, floor principle, PID control, adaptive control, neuron control and other algorithms have been studied and compared. But each algorithm has its own defects, the future control algorithm will develop to the direction of compound control. The "predictive" control technology based on image recognition and other technologies can judge the road condition in advance, which has become the focus of technology research in recent years.

(2) Market-oriented, active suspension matching technology in the field of passenger cars develops in a systematic direction.

At present, intelligent air spring technology is developed and applied in some models of commercial vehicle and heavy duty car in our country. It also has applications in some special vehicles. But the application of ordinary car is still blank. Domestic universities and scientific research institutions have done a lot of work on the active suspension system and accumulated certain research results. With the development and evaluation of technology as the focus, the key issues of design and process are broken through to promote the industrialization of technology. In the future, the popularization of active suspension system and the localization of active suspension system technology should be the general trend. Active suspension matching technology is also reflected in the chassis design, component installation and other links.

(3) The active suspension system is developing in the direction of intelligence

In addition to its intelligent adaptive adjustment mechanism, the active suspension system can cope with various complex road conditions and vehicle driving states, provide multi-mode operation options, and integrate into the car bus system to obtain vehicle running parameter data and participate in vehicle data acquisition and intelligent decision control.

7. Summary

It is one of the important measures to improve the performance of modern automobile to study and analyze the vehicle vibration, adjust the relevant parameters of suspension according to the vibration and reduce the vibration to the minimum. Therefore, the implementation of active control of automobile suspension and the development of intelligent suspension system can attenuate the vibration in the running, reduce the damage to automobile parts, improve the operating stability and safety of the vehicle in the running, and improve the overall performance of the vehicle.

The latest National Development and Reform Commission "Guidance Catalogue for Industrial Structure Adjustment (2019)" began to be implemented from January 1, 2020, among which key automotive parts encouraged include: air suspension, automotive electronic control system including: electronically controlled intelligent suspension.

The General Office of Zhejiang Provincial People's Government has issued the Action Plan for High-quality Development of Zhejiang Automobile Industry (2019-2022). The plan proposes that the core technologies of development include modularization of core parts and serialization of vehicle development.

With the upgrading and development of domestic automobile manufacturing industry, as well as the requirements of comfort and safety brought by the development of automobile technology. Automobile core components will develop from a single component to a systematic and integrated direction. Locomotive suspension technology needs to get rid of the situation of relying on imports and foreign technology monopoly, and develop an intelligent active suspension system with independent intellectual property rights, combining intelligent air

suspension and adaptive damping regulation system, especially in-depth research on its control algorithm and control strategy. Make it with higher technical advancement, with lower price, and then popularize to domestic independent brand cars, so that most of the domestic consumers can experience the comfort and safety of intelligent suspension vehicles, fill the domestic gap, to improve the competitiveness of domestic cars in the global market, promote the rapid development of domestic automobile industry is of great significance.

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