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Research on Hydraulic Suspension Technology of Tractor

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Abstract. The main control algorithms of hydraulic suspension of tractor are analyzed. The advanced electro-hydraulic suspension control system in foreign countries is introduced in detail, and the development trend of hydraulic suspension control technology is expounded. The article points out that the integration of mechanical, electronic, hydraulic will be the development direction of hydraulic suspension. Integrated control mode, intelligent control algorithm and CAN bus transmission technology are the research subjects at this stage, which can put forward some suggestions for hydraulic suspension control technology of tractor.

Introduction

With the development of agricultural mechanization, the field work has put forward higher requirements for tractors, especially hydraulic suspension control technology of tractor. At the same time, the land is gradually moderately intensive, and the demand for large and medium-sized tractors is increasing. The hydraulic suspension technology will determine the efficiency and quality of the tractor. At present, the large tractor has been equipped with an electric control hydraulic suspension control technology in foreign advanced production enterprises, while in domestic enterprises, electronic hydraulic hitch control technology will be optional only in a few high-end tractor. So it has important significance to find out the hydraulic suspension control technology, control algorithm and advanced technology of tractor.

Overview of control methods

Suspension is an important part of tractors, and it is a necessary device for farming. In the early days, the rope or chain was used for traction. In 1830s, the hydraulic three point rotating device was adopted. Now the tractor has been basically equipped with hydraulic suspension system. The earliest tractor suspension device adopted the method of height adjustment, and the resistance regulation, position adjustment and force position adjustment are gradually appeared. In recent years, some foreign enterprises have adopted torque adjustment, pressure regulation, slip rate adjustment and so on[1].

Height adjustment

The height adjustment of hydraulic suspension means that the tractor restricts the working depth of the working tools by means of the depth limiting device. During operation, the hydraulic system is in a floating state, and under the influence of the limited wheel, the suspension and the machine fluctuate up and down with the terrain. This adjustment applies to soft soil. If soil is hard or soil moisture is large, the limited wheel can not play a better role, the quality of farming is poor.

Position adjustment

Position adjustment means when the tractor is working on the land, the tractor working depth is kept within a certain range by adjusting the suspension position. Traditional position adjustment adopts mechanical hydraulic mechanism to carry on servo control. The feedback and automatic adjustment of the suspension position can be realized by the spring mechanism and the cam mechanism, and its position can be kept in where the position controls handle setting. Electronic hydraulic suspension uses position sensors to obtain position signals, and the controller controls the commutation and opening of the proportional valve according to the position signal, and then controls suspension position in present

position. The method of adjustment is not suitable for operations with complicated soil conditions and undulating land, because load stability of the engine and tillage uniformity will be affected.

Force adjustment

Force adjustment means when the tractor is working on the land, the tractor's working resistance is maintained within a certain range by adjusting the suspension position. Force adjustment also uses mechanical hydraulic mechanism for servo control. Electronic hydraulic suspension uses pressure sensors to obtain resistance signals, and the controller controls the commutation and opening of the proportional valve according to the resistance signal, and then controls suspension resistance in present position. The method of adjustment is not suitable for the operation with complicated soil conditions, because the evenness of the tillage depth will be affected.

Slip rate adjustment

Slip rate adjustment refers to when the tractor is working on the land, the tractor's slip rate is maintained within a certain range by adjusting the suspension position. Slip rate adjustment is commonly used in electronic hydraulic suspension systems. When working, the tractor speed and wheel speed are achieved, and then the slip rate of tractor can be calculated. The controller adjusts the commutation and opening of the proportional valve according to the pre-set slip rate, and then controls slip rate in the set range by adjusting the lifting of the suspension.

Integrated adjustment

Single parameter control has its own characteristic. Like the force control, it can keep working resistance within a certain range, but when the soil resistance changes greatly, the depth of tillage is lager, which affects the uniformity of operation. Force-position integrated system uses the force and position as control parameter. It can combine the advantages of two single parameter control, and maximize the uniformity of operation, and improve adaptability and stability[2].

Overview of control algorithm

Commonly control algorithm that tractor hydraulic suspension control technology used are PID control、fuzzy control、fuzzy PID and so on. Each of control algorithms is studied by scholars. Among them, PID control has been widely used because of its stability and adaptability. Here are a brief introduction of them.

PID control algorithm

In the PID control algorithm, the proportion, integral, differential three control methods have their own unique role. Proportion control is primary control mode, it works when there is deviation. Integral control eliminates static tolerances that can not be eliminated by pure proportional control. Differential control can be suppressed in the moment of rapid system changes, increasing the stability of the system. Combining the three methods together is the proportional integral derivative (PID) control.

PID control algorithm is simple, easy to use and well-adapted. Zhu Si Hong and Zhang Chao, who are from Nanjing agricultural university, adopted the PID control algorithm in electric-hydraulic suspension system. They established mathematical models and carried out the simulation. The analysis shows that PID algorithm has the advantages of good stability, high control precision and quick response. PID also has shortcomings, its robustness is weak, it is sensitive to the parameters of the controlled object changes. Furthermore, PID's control effects for non-linear and time-delay system are not very satisfactory[3].

Fuzzy control algorithm

The notion of fuzzy gather and fuzzy control was first proposed by LA.Zadeh, a famous professor at the university of California. The basic idea of fuzzy control is to describe the control experience of the operator with a vague language variable. The control rules and the corresponding fuzzy reasoning are formed with a set of conditional statements. And finally the precise control is got by fuzzy decision. It is possible to make the complex system realistic and conform to the human way of thinking. Gao Xiang, Sun Chang Wang and Shi Jin Zhong, who are from Jiangsu University, have put forward the design method of electric control hydraulic suspension system fuzzy controller. They established fuzzy

inference system. The result shows that fuzzy control is more suitable for tractor hydraulic suspension systems than PID control.

Fuzzy PID control

For large hysteresis, time-varying, non-linear complex systems, the key parameters are unknown or slowly changing, and obtaining accurate mathematical models is not available. For these systems, using traditional control algorithm cannot reach control effect. Tractor hydraulic suspension system is typical time-varying、nonlinear system. Some scholars combine the fuzzy control and PID control to design the fuzzy PID controller. It combines the advantages of flexible and strong adaptability of fuzzy control, and the characteristics of high precision of PID control. The algorithm has been extensively researched and developed in automotive filed[4].

Introduction of advanced control systems

Now, some of the internationally famous tractor enterprises are equipped with advanced electronic control hydraulic suspension system. Among them, BOSCH Rexroth electronic hydraulic suspension control (EHR) system is the most well-known, which is introduced in detail. Bosch Rexroth, a German firm, developed a tractor's electronic control hydraulic suspension system in 1980s, which is shown in figure 1. The system basically realized the hydraulic suspension resistance, position, cylinder pressure and slip rate control, and it also used the CAN bus transmission technology. This technique has been widely used in foreign advanced enterprises, and it is very mature. Some domestic enterprises installed it on some high-end tractors.

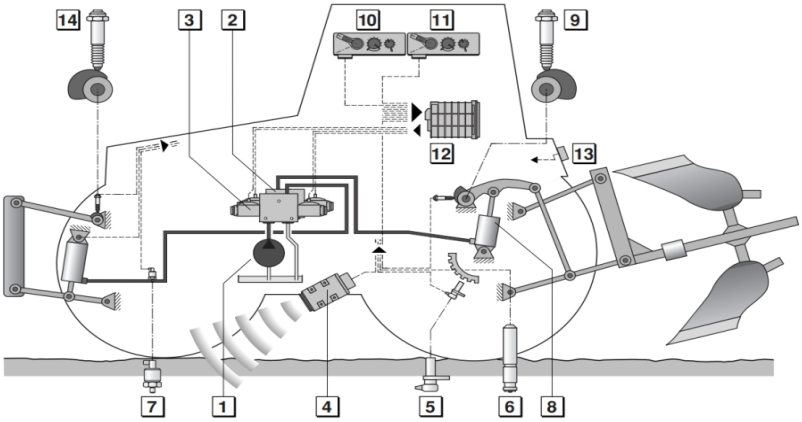

Fig.1 BOSCH electronic control hydraulic suspension mechanism diagram
1.hydraulic pump 2.rear hydraulic valve 3.front hydraulic valve 4.redar speed sensor 5.speed sensor 6.tenison pressure sensor 7.pressure sensor 8.lifting cylinder 9.position sensor 10.front control panel 11.rear control panel 12.control unit 13.rear drive point 14.position sensor

Research of development direction

Electronic direction control

With the improvement of the field operation tillage's quality requirements, the control method based on single parameter will be phased out gradually, and the multi parameter integrated control method based on resistance, position and slip rate will be the development direction. With the development of sensor technology, the resistance and position signals can be achieved by the corresponding tension sensors and angle sensors, and the slip rate signals can be obtained by speed sensors and wheel speed sensors. At this stage, the majority of electric hydraulic suspension use 51 signal-chip. But with the development of tractor information display and virtual panel technology, more advanced controller will gradually replace the traditional single chip, such as AVR, ARM single chip.

CAN bus signal transmission

Controller Area Network, referred to as CAN, was researched by the German Bosch, and it has become ISO international standardization of serial communication protocol. Compared with the

general communication bus, its data communication has outstanding reliability, real-time and flexibility. With the development of tractor technology, the mechanical-electrical-hydraulic tractor will need more signal transmission, stage and display, and CAN bus technology can fully meet these requirements, it will be the development of tractor signal transmission technology.

Intelligent control algorithm

With the development of control theory, scholars have proposed some intelligent control methods, such as fuzzy, fuzzy PID, neural network, etc. which are based on the traditional PID control and its deformation control. Artificial neural network (ANN) refers to the technology of simulating the structure and function of human brain by means of engineering technology. It uses electronic computers to simulate human brain neurons to process, store and search information. But there is no mature product yet[5,6].

References to GPS Technology

At present, tractor speed measurement is mainly used non-drive wheel speed, but this method is prone to error due to the presence of factors such as road roughness, slippery road tires, and so on, which can not meet the precise control of hydraulic suspension based on slip rate. Now the market already has a high precision GPS for agriculture, and some foreign advanced tractor companies have also been equipped with GPS technology, which can accurately obtain the running speed of tractor based on navigation, and provide accurate speed signal for the tractor electronic hydraulic hitch.

Conclusions

The hydraulic suspension of tractor is mainly controlled by force control, position control, slip rate control and integrated control. PID, fuzzy and fuzzy PID control algorithms are mainly adopted. Electronic integrated control, CAN bus transmission, intelligent control algorithm and GPS technology will be the research direction of tractor. The foreign advanced tractor enterprises have been widely used electronic control technology in the large tractor, and other new technologies also have mature products. Domestic enterprises need to learn foreign technology, find out the situation, grasp the main direction of development and improve research efforts.

References

[1] Tan Yu. Tractor hydraulic suspension and loading system performance research [D]. Beijing: China Agricultural University, 2004.

[2] Zhou Yiming. Car tractor machine chassis construction [M]. Beijing: China Agricultural University Press, 2000: 193-196.

[3] Tao Yonghua. New PID control and its application [M]. Beijing: Mechanical Industry Press, 2000: 143-149.

[4] ZHU Si-hong, ZHANG Chao.Study on PID Control Simulation of Tractor Electro-hydraulic Suspension System [J]. China Manufacturing Information, 2008,37 (21): 49-53.

[5] Wei Wei, He Yan. Intelligent control basis [M]. Beijing: Tsinghua University Press, 2008: 101-166.

[6] PANG Chang-le, ZONG Bo-hua, E Zhuo-mao. Fuzzy comprehensive control model and simulation experiment of tractor operating unit [J] .Journal of Agricultural Engineering, 2003,19 (4): 111-113.