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Automobile tire pressure monitoring technology and development trend

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Abstract: Automobile puncture is one of the major hidden dangers of frequent traffic accidents. Accurate and real-time monitoring of tire pressure of automobile tires is of great significance for improving vehicle safety and improving traffic status. This paper first summarizes and analyzes the published technical methods of automobile tire pressure detection, and analyzes the advantages and disadvantages of related detection methods in combination with previous research results. Finally, this paper proposes a development direction of the tire pressure system. The tire pressure and tire temperature signals obtained by the tire pressure monitoring system are used as the correction amount of the ABS system control signal, and the tire pressure and the tire temperature can always be controlled within a safe range. It can also reduce the chance of tire's bursting due to sudden braking and improve the reliability of the ABS system.

1.Introduction

With the rapid development of the economy, the number of cars has increased rapidly, and the society has stricter requirements for the safety of car driving. The tire pressure monitoring system (TPMS) is an important part of it. It is called the three active safety systems of automobiles. As early as 2007, the US government introduced regulations requiring all passenger cars to install tire pressure monitoring systems; in 2012, the European Commission required cars to install tire pressure monitoring systems; the Korean government required all new passenger cars from 2013 Forced installation of the tire pressure monitoring system, mandatory installation of all models by mid-2014. However, the time for China's development has been relatively late. After more than ten years of continuous exploration and improvement, China's TPMS has a relatively high level, but the products on the market are uneven, and the penetration rate in domestic models is not high, only in the part. It is equipped on the mid-end model. Therefore, compared with foreign countries, in-depth study of automobile tire pressure monitoring system, analysis and summary of its classification and characteristics, to find a suitable TPMS for China has important practical significance.

2.Traditional tire pressure monitoring system

The tire pressure monitoring system is a necessary active safety device on the car. The system monitors tire pressure in real time and alerts you when tire pressure is abnormal. The system is usually divided into an indirect tire pressure monitoring system, a direct tire pressure monitoring system and a hybrid tire pressure monitoring system.

2.1 Indirect method

The indirect tire pressure monitoring system is a tire pressure monitoring system that calculates the

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wheel speed and frequency data measured by the sensors in the ABS system and then calculates the tire pressure by the mechanical model of the tire. At present, the main detection methods are wheel speed detection method, frequency response type, longitudinal stiffness method and magnetic sensitivity method.

2.1.1 Wheel speed monitoring type

The wheel speed detection method mainly uses the tire to reduce the rolling radius when the air leaks, which causes the tire speed of the air leakage to become faster, and compares the wheel speed of the same shaft to determine whether the tire pressure is too low. The specific process is as follows: In the ABS system, the wheel speed sensor transmits the wheel speed signal to the ECU, and the ECU calculates whether the tire pressure difference between the two sides exceeds a preset threshold by an algorithm. If it exceeds, the ECU outputs an alarm signal and issues an alarm. The system does not need to add too much hardware, just add algorithm programs and alarm devices on the ABS system, the cost is very low. However, the disadvantages of this system are also obvious. Since the method is a comparative pressure measurement method, the system will fail when low pressure occurs on both sides of the tire pressure. In addition, the alarm mode is generally that the alarm sounds or shines, and it is impossible to perform numerical monitoring on each tire tire pressure, and it is impossible to identify a specific abnormal tire pressure tire. Due to the method's false positives and low reliability, it is currently used less.

2.1.2 Frequency response type

Because indirect TPMS increases the inherent advantages of a small number of hardware devices and low cost, it is of great value to optimize its algorithm to improve its system limitations. The frequency response method is one of them. The method is to simplify the tire into a spring-damping system and find that the resonant frequency of the system is proportional to the tire pressure and is roughly linear. Therefore, the system can reflect the tire pressure by monitoring the resonance frequency. Zhong Xiang has elaborated that the key technology of the frequency method TPMS. His master's thesis say: Collecting and preprocessing the ESP wheel speed signal, eliminating the coarse signal, and then using the Kalman filtering algorithm to filter the system's own error, the resonant frequency can be estimated by the Kalman algorithm. Compared with the wheel speed monitoring method, this method has improved the sensitivity of the alarm, but there is still room for improvement in accuracy and integration.

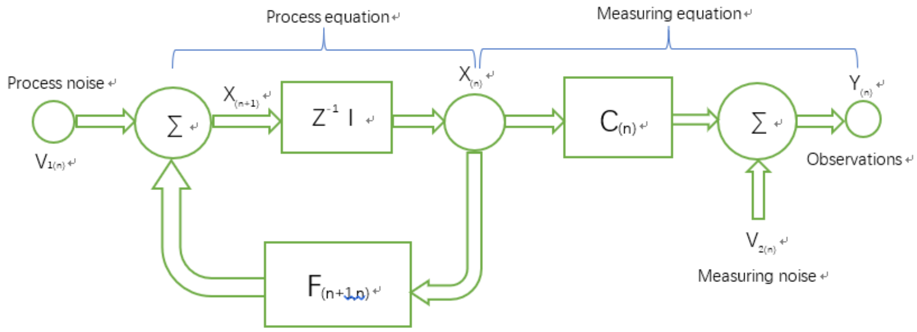

Figure 1 Flow response method flow chart

System equation: X(n+1)=F(n+1,n)X(n)+V1(n) ......(1)

Measuring equation: Y(n)=C(n)X(n)+V2(n) ......(2)

2.1.3 Longitudinal stiffness method

The longitudinal stiffness of the tire is such that the tire subjected to a certain vertical load only moves longitudinally on a horizontal rigid road surface without rolling, and the ratio of the longitudinal force of the tire to the longitudinal movement of the ground center of the tire at this time. Yan Yulong's master thesis "Research on Automotive ABS and TPMS Integrated Controller" introduces the method

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of estimating tire tire pressure by longitudinal stiffness. Based on the initial "magic formula" tire model, the formula for calculating the longitudinal force of the car is listed. The curve of the slip ratio and the longitudinal force is fitted by the magic formula module. According to the principle of automobile dynamics, the final car drive is obtained. The mathematical model for estimating the longitudinal stiffness of the driving wheel tire is as follows:

$$\frac{C_D A V^2}{21.15} + ma = 2C_x \frac{V - R\omega}{V}$$

Where CD, A, m are constants, which are constant values, ω is a measurable variable, and Cx is the longitudinal stiffness coefficient of the tire. With the specific measurement of ω, V and a can be obtained, and then the optimization method can be utilized. The system identification theory estimates Cx and R. Since the longitudinal stiffness and the tire pressure are approximately linear, the model can be used to estimate the tire pressure more effectively.

For the tire pressure detection, the determined tire state judgment principle is as follows. When the tire is under voltage or overpressure, the system will automatically alarm.

Table 1 Tire state judgment method

Longitudinal stiffness comparison result	C<A	A<C<B	C>B
Tire pressure status	Undervoltage	normal	Overpressure

2.2 Direct method

The principle of the direct tire pressure monitoring system is to install a pressure sensor in four automobile tires, and send the tire pressure signal to the central receiver module through the wireless transmitter.

The direct tire pressure monitoring system has high precision, and accurately displays the real-time tire pressure and temperature of each tire through the vehicle display screen with small error.

2.2.1 Active TPMS

The principle of active TPMS is: the tire pressure sensor is powered by a lithium battery, which transmits the signal to the central receiver module through the wireless transmitter, displays the converted tire pressure signal on the monitor of the cab, and alarms when abnormal.

Active TPMS systems are universal, but lithium battery’s life, cost and environmental constraint limit safety and cost performance.

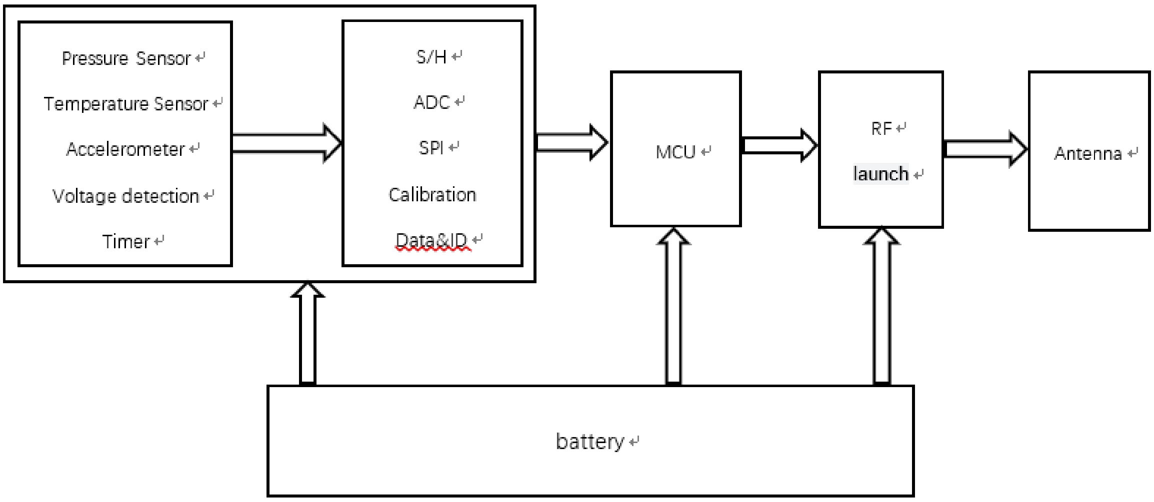

Figure 2 Active TPMS transmitter composition

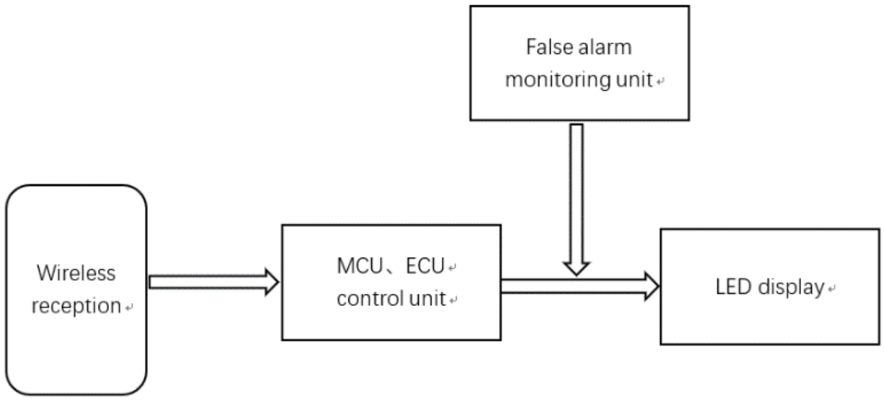

Figure 3 Active TPMS receiver composition

2.2.2 Passive TPMS

At present, many scholars are developing passive (passive) TPMS. Common passive TPMS are:

(1)Piezoelectric Ceramic Power Generation TPMS

Piezoelectric ceramics have piezoelectricity. After being subjected to external mechanical stress, the internal positive and negative charges are displaced to generate polarization, and finally the opposite ends of the material are generated, and the charges can be made to be slightly displaced in the atom or molecule range. The material is small in size, light in weight and high in sensitivity, and the generated electric energy is proportional to the stress, but the piezoelectric ceramic has a short life and a limited number of deformations. For example, the model 165/70R14 tires travel 100km per day, the rim circumference is 1.13m, and the tires rotate 88,500 times per day. Therefore, the piezoelectric power supply can only be used for about 10 days. The replacement frequency is too high and the practicality is not high.

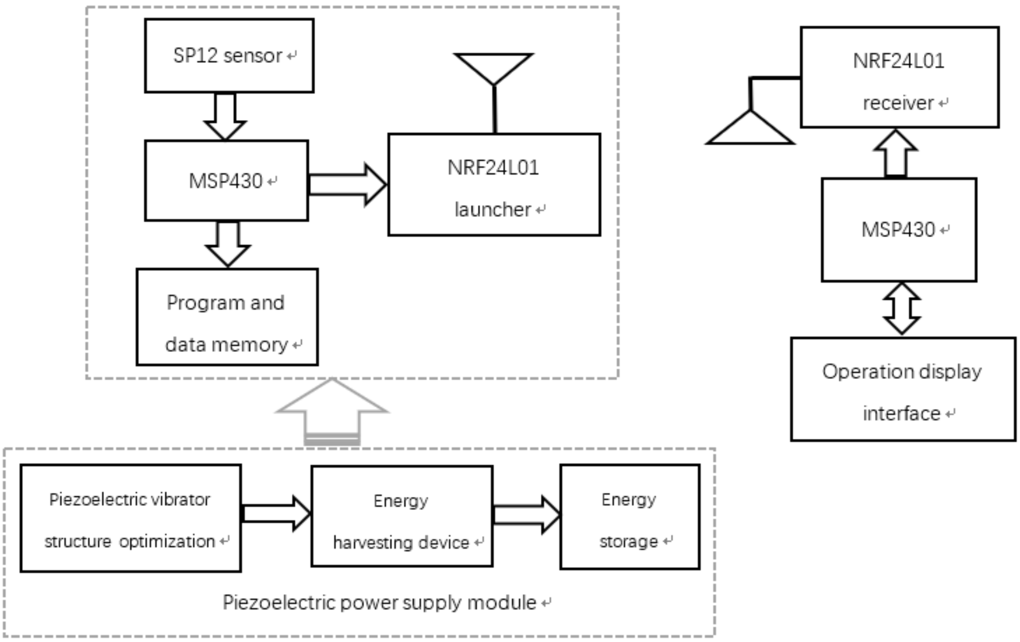

Figure 4 Piezoelectric ceramic power supply TPMS system structure

(2)Micro-vibration power generation TPMS

This method is derived from the patent “a kind of micro-vibration generator” applied by He Chongzhong in China. The device is mounted on the tire rim. As the car vibrates, the coil inside the device cuts the magnetic induction line, and the generated electric energy is more than electromagnetic induction. The power generation method has a large power generation capacity, but due to the limitation of the internal space of the tire, the vibration amplitude is small, the magnetic flux change rate is small, and large energy cannot be generated.

(3)RF passive TPMS

The method replaces the central receiver in a conventional direct TPMS with a central transceiver that receives the sensor's data signal, modulates the signal, and passes it to the sensor portion, where the oscillator vibrates, from the transceiver After the input signal is disconnected, the sensor sends the residual signal back to the central transceiver. The advantage of the system is that it solves the problem of large weight and volume brought by the active battery, and has high sensitivity and wide working range, but the circuit composition is complex and the design is difficult.

In addition to the above-mentioned mainstream passive TPMS types, there are also power generation methods such as surface acoustic wave type TPMS and temperature difference power supply type TPMS. However, due to the high cost of passive power generation chips, the problem of low power generation efficiency has not yet been popularized. The mainstream direct tire pressure detection system still uses active TPMS.

2.3 Mixed method

The hybrid TPMS is based on an indirect TPMS with a pressure sensor mounted in two diagonally diagonal tires, and an RF receiver mounted. The pressure sensor solves the problem that the indirect sensor cannot monitor two coaxial or ipsilateral tires while the tire pressure is too low. Although the detection capability and reliability are improved compared to the indirect method, when the diagonal tires are at a low pressure at the same time, only one of the tires can be monitored at a low pressure, and the reliability is poor, so that the application is less.

Through the above analysis, it is easy to see that compared with the direct tire pressure monitoring system, the indirect tire pressure monitoring system does not need to introduce new sensors and other hardware, and only uses the wheel speed sensor in the ABS system to provide input signals, and the cost is low. But the shortcomings are also obvious. First, the sensitivity is not high. The tire pressure needs to be reduced to less than 70% to report the alarm. When the tire pressure is generally reduced to less than 50%, it is very dangerous. In addition, this system will not monitor the tire pressure in the static situation. After the car starts, it will take more than one kilometer to react, and the reliability is not high. In addition, this system will not monitor the tire pressure in the static situation. After the car starts, it will take more than one kilometer to react, and the reliability is not high. The hybrid method solves the problem of being unable to monitor the tire pressure of the coaxial or the same side tire, but the sensitivity is low, the installation is inconvenient, and the application is less. The direct tire pressure monitoring system has high precision and can monitor the pressure and temperature of each tire in real time, but the cost is high. At present, the application rate of the direct tire pressure monitoring system is still much higher than the other two direct tire pressure detection methods.

3.Development status and trend of modern tire pressure sensor

At present, the technical problems faced by the tire pressure monitoring system mainly include: 1. How to ensure the reliability and stability of wireless signal transmission under high speed conditions. 2. Sensor life and pressure resistance. 3. How to improve the accuracy of the alarm.

The development trend of the current tire pressure monitoring system is mainly in the following four aspects:

(1) Integration, that is, the pressure and temperature sensors of the tire pressure monitoring module and the RF transmitter are combined to reduce the overall quality of the tire pressure monitoring module, and it is convenient to realize the lightweight of the vehicle.

(2) Passive, the sensor battery in the direct tire pressure monitoring system limits the use environment and service life of the tire pressure monitoring system, and has shortcomings such as leakage and increased vehicle weight. No power sensor will be a major trend in the future.

(3) Accuracy, that is, to achieve the reliability and sensitivity of the alarm, which will greatly

improve the fuel consumption and safety of the automobile. Indirect TPMS mainly uses optimization algorithms to make alarms accurate, while direct TPMS mainly improves the stability and reliability of wireless transmission signals to improve accuracy.

(4) Integration, integration with vehicle ECU, global positioning system, geographic information system and other technologies will greatly expand the application of tire pressure monitoring system.

4.Direct TPMS optimization and development direction

4.1 Low-energy optimization of direct TPMS

At present, the mainstream direct TPMS system on the market mainly uses button batteries as the built-in power supply for the tire pressure sensor. The traditional direct TPMS system has no low-energy design, and the tire pressure sensor is detected during the whole process of vehicle driving and parking. The energy consumption is very serious, which greatly reduces the battery life. At present, the low energy consumption optimization for direct TPMS is mainly to introduce MEMS acceleration sensor in the tire pressure detection module, and use the mass block to sensitivity to the centrifugal force caused by the wheel speed change, and control the sleep and wake of the tire pressure detection module. When the wheel rotates, the MEMS acceleration sensor senses the centrifugal force, sends the control signal to the tire pressure sensor, and wakes up the tire pressure detection function; when the vehicle stops, the MEMS acceleration sensor has no induction, so that the tire pressure sensor is in a sleep state, achieving energy saving. purpose.

4.2 Direct TPMS and ABS system fusion

There are many reasons for tire puncture. There are three main reasons: excessive tire temperature, abnormal tire pressure and structural damage caused by tire wear. Tire aging and wear problems can be solved by regular inspection and replacement of tires. At present, the main factors that need to be controlled are tire pressure and tire temperature. The tire pressure monitoring system can accurately measure the tire pressure value of each tire. When braking, it is the most severe change in tire temperature. Because the ABS system keeps the wheels at the wheel. A state of rolling and slipping that is about to be locked but not completely locked. The wheel and the road surface are rubbed sharply, and a large amount of heat is generated, which is difficult to dissipate in a short time, causing the temperature of the tire to rise sharply. If the tire pressure detection signal can be fused to In the ABS system, as the correction amount of the ABS braking force signal, the ECU calculates and adjusts the ABS control signal to control the braking force, so that the tire pressure and the tire temperature are always controlled within a safe range, which can reduce the sudden braking. The probability of a puncture increases the safety of the vehicle. However, improving the safety performance of the vehicle by appropriately reducing the braking force will sacrifice the minimum braking distance of some of the vehicle's emergency brakes. How to balance the advantages and disadvantages of the two and improve the overall safety performance of the vehicle needs further study.

5.Conclusion

By analyzing and summarizing the existing research results, this paper can draw the following conclusions:

At present, the tire pressure monitoring system mainly has three methods: direct method, indirect method and hybrid method. The advantage of the indirect method is mainly in the convenience of installation and cost. It is not as good as the direct method in the safety of driving safety, and does not conform to the development trend. The hybrid method is also the same, so the direct tire pressure monitoring system is more in line with the future development trend.

In order to solve the problem of sensor life of direct tire pressure monitoring system, the current mainstream MEMS accelerometer is used. By means that the centrifugal force of the accelerometer is different at different speeds of the wheel, a valve device for opening and closing the tire pressure detection system can realized low energy design of the direct tire pressure system.

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This paper proposes a method to prevent emergency brakes from bursting with TPMS and ABS system, which leads to a safety accident, that is, it combines with the ABS system to stabilize the tire pressure and tire temperature within a safe range, reduce the probability of tire blasting.

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