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Method of Power Performance Fault Alarm of Hybrid Electric Vehicle Based on Hydraulic Technology

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Abstract

Due to the lack of precision in the modeling of the vehicle power system, the fault diagnosis and alarm accuracy of the current hybrid vehicle dynamic performance fault alarm method is reduced. Therefore, a hybrid vehicle dynamic performance fault alarm method based on hydraulic technology is designed. The power system model of hybrid electric vehicle is built by hydraulic technology, which is the data base of fault diagnosis. The method of self-diagnosis and the knowledge base of fault diagnosis are used to realize the fault diagnosis of vehicle power system. The interface between mobile network and on-board information is selected to realize vehicle fault alarm by setting alarm information content. The fault diagnosis accuracy of this method is always between 88.5% and 94.5%, the fault diagnosis time is less than 0.5 s, and the highest effective failure alarm rate is 99.8%. The experimental results show that the research method has the advantages of high accuracy, short diagnosis time, high effective alarm rate, low cost, superior economic performance and good application effect.

Keywords: hydraulic technology; hybrid vehicle; fault diagnosis; fault early warning; power system modeling; mobile network;

1. Introduction

With the gradual improvement of economic and living standards, the demand for automobiles is increasing rapidly. While automobiles bring convenience, rapidity, and comfort to our life, a series of environmental and energy problems caused by automobiles are gradually prominent. Up to now, automobiles have become one of the important factors affecting the urban environmental construction and the sustainable development of national energy. Therefore, the international traditional automotive research and development, manufacturing and production field is facing great challenges, the transformation of the development of the automotive industry is imperative. With its low energy consumption and clean and pollution-free emissions, new energy vehicles have become the focus of current research in the automobile industry, and related fields, and are favored by scientific research institutions and related production fields of various countries [1, 2].

At present, there are many kinds of problems in the commonly used fuel engine vehicles. According to the relevant data, since the 1990s, due to the increasingly lack of resources and the growing voice of environmental protection in the world, various electric vehicles have emerged. Due to the large mass and volume of the battery pack of electric vehicle, the endurance and power performance of electric vehicle cannot reach the level of current internal combustion engine. In addition, the selection of electric vehicle components such as air conditioning and heating must fully consider the impact of its energy consumption on the endurance of electric vehicles. The high price and limited life of battery pack also limit the market prospect of electric vehicle. The above constraints make the development and application of electric vehicles slow down, and it is impossible to industrialize them in a short period of time. In this case, the "quasi green vehicle"-hybrid vehicle, which integrates the advantages of internal combustion engine vehicles and electric vehicles, has stepped onto the historical stage [3]. In general, hybrid electric vehicle refers to a vehicle in which the motor and engine (engine is generally called auxiliary power unit, APU) are used as the power device at the same time. Through the advanced control system, the two power devices can coordinate organically, realize the optimal distribution of energy, and achieve low energy consumption, low emissions and high automation.

As a quasi-green vehicle, hybrid electric vehicle has many products in developed countries. In order to realize market-oriented and scale-up of domestic hybrid vehicles, problems and challenges need to be solved, including: developing energy storage devices with high specific energy and high specific power, low-cost and efficient electronic communication equipment, as well as engines with high fuel economy and low emissions [4]. At present, major automobile companies are carrying out research on hybrid power unit technology, energy storage technology and vehicle integrated power electronic module. It is estimated that in the next 10 years, more than 40% of the world's newly produced vehicles will be hybrid vehicles.

The research and development of hybrid electric vehicle is of great significance to the smooth development of environmental protection engineering. Although the hybrid

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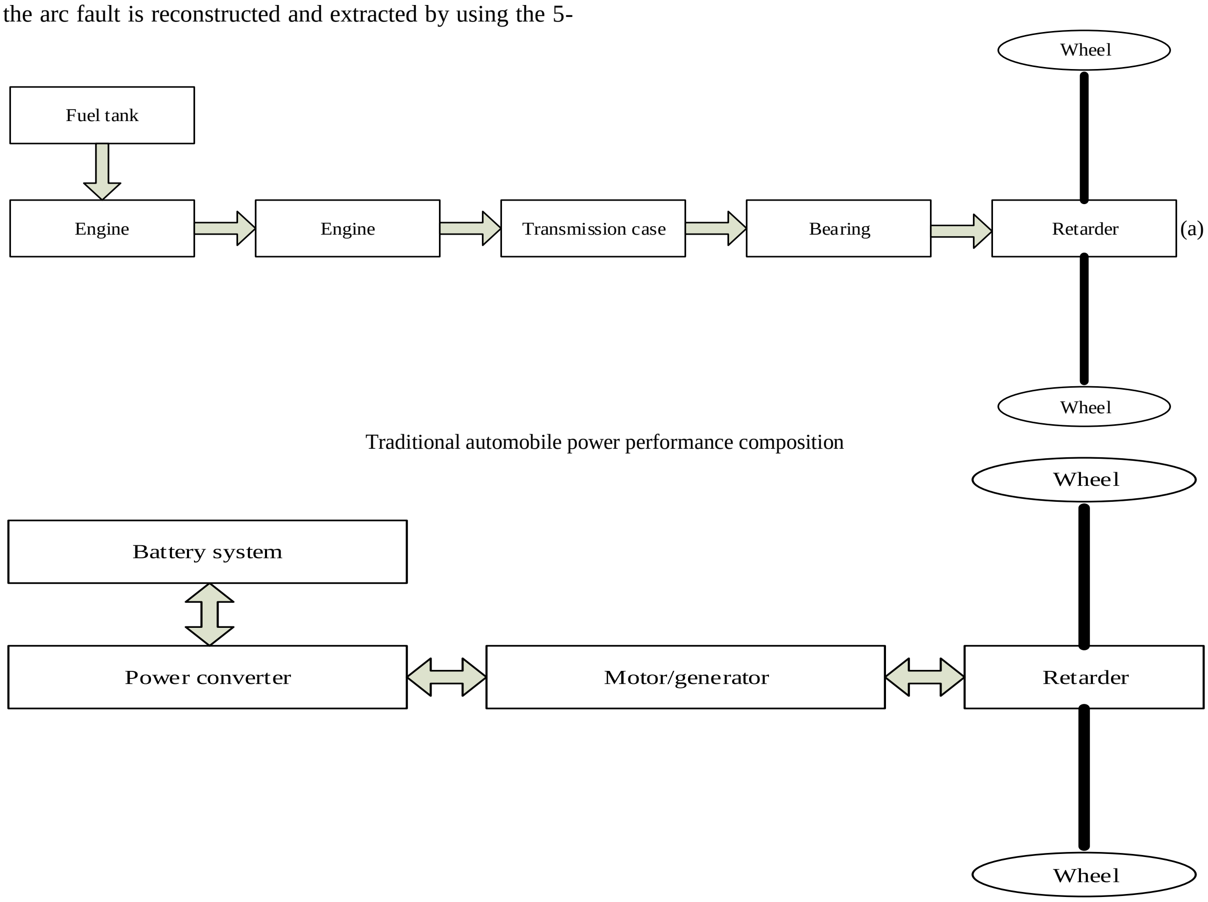
vehicle has been published before the 21st century, the contemporary hybrid vehicle is a brand-new machine, which is totally different from the traditional hybrid vehicle, it is not only a transport vehicle, but also a brand-new electrical equipment [5]. In the application process of hybrid electric vehicle, there are often power performance problems, which need to be diagnosed and dealt with in time to avoid unnecessary economic losses. The research of power performance fault diagnosis is the core of fault alarm. According to different signal types, fault diagnosis technology can be divided into noise diagnosis, temperature diagnosis, oil analysis, spectrum analysis, etc. In recent years, with the development of artificial intelligence technology, the automation and intelligence of fault diagnosis and early warning has gradually become a reality. For example, in literature [6], the local mean decomposition method is used to extract the feature of the fault signal of hybrid electric vehicle, determine the fault noise source, and use the discrete wavelet method to eliminate the noise and restore the fault acoustic signal of vehicle. SDP graphics technology is used to transform the acoustic signal into polar coordinates to judge whether the hybrid electric vehicle has a fault or not. The fault detection results are used to alarm the power performance of the vehicle. However, this method has the problem of long warning time, which is difficult to be widely used in practice. In literature [7], the generation mechanism, characteristics and types of DC fault arc are introduced, and three detection methods of DC fault arc in time domain, frequency domain and time frequency domain are analyzed. A simulation test system is built to obtain the normal arc and fault arc circuit signals under different loads. The time-frequency Cassie arc simulation model is established, and the current signal before and after the arc fault is reconstructed and extracted by using the 5-layer wavelet packet decomposition technology. The energy ratio is used as the characteristic parameter, and this value is taken as the basis of the fault early warning. However, the judgment of the location of the vehicle power fault by this method is not accurate, which results in the early warning results not in line with the reality.

In order to solve the problems of the above methods, this paper uses the characteristics of fault detection and analysis technology, such as long history, mature technology, early structure forming and rich data, which puts forward the fault alarm method of hybrid electric vehicle power performance based on hydraulic technology, and thus studies the structure design of fault early warning framework, fault tree knowledge and fault early warning setting, and at the same time, studies the relational database. Combined with the hydraulic technology, the fault early warning based on the hydraulic technology is realized.

2. Design of power performance fault alarm method of hybrid electric vehicle based on hydraulic technology

Due to the application of electronic technology, computer technology, information technology, automatic control technology, friction and wear technology, new technology and new materials, the hydraulic system and components have been greatly improved. In order to rationalize the design of the fault alarm method for the power performance of the hybrid electric vehicle, the composition of the power part of the hybrid electric vehicle is analyzed by using the advantages of the high power density of the hydraulic components in the hydraulic technology. The specific analysis results are as follows.



(b) Power performance composition of hybrid electric vehicle
Figure 1. Composition of vehicle power performance

Hybrid vehicle refers to a vehicle with two or more power sources, and at least one energy provides electric energy for the vehicle. According to the different types of energy, there are also many types of hybrid vehicles, such as gasoline and battery, diesel and battery, battery and fuel cell, battery and super capacitor as the power source of vehicles. Hybrid electric vehicles are considered to have both internal combustion engines and electric motors, both of which are used as driving systems.

The power system of hybrid electric vehicle is mainly composed of control system, drive system, auxiliary power system and battery pack. At the beginning of vehicle driving, the battery is in full state, its energy output can meet the requirements of vehicle, auxiliary power system does not need to work. When the battery power is less than 60%, the auxiliary power system starts: when the vehicle energy demand is large, the auxiliary power system and the battery pack provide energy for the drive system at the same time; when the vehicle energy demand is small, the auxiliary power system provides energy for the drive system and charges the battery pack at the same time.

In this paper, the vehicle driven by the mixture of internal combustion engine and electric motor is studied. As shown in Figure 1(a) is a traditional hybrid vehicle powered by diesel and fuel. Figure 1(b) is the electric drive part of the hybrid vehicle, which is the power performance part composed of generator and motor. The fault early warning method takes the above Figure 1(b) as the design basis.

2.1. Model construction of hybrid vehicle power system

According to the literature research, the hybrid vehicle uses hydraulic accumulator, hydraulic pump/motor as the power component. Taking advantage of the high-power density of the hydraulic accumulator, the hydraulic hybrid vehicle can fully recover the braking energy of the vehicle and release the energy of the amplified power in a short time [8]. The hydraulic pump/motor can work in four quadrants by changing the swashplate swing angle in the torque angle domain. It can be used to drive the vehicle under the motor condition and brake the vehicle under the pump condition. Moreover, the hydraulic pump/motor has the advantages of strong operability, high reliability and easy to change the working condition. Therefore, in this design, the hydraulic technology will be used to build the hybrid vehicle power performance model, and this model will be used as the data source of vehicle power performance fault alarm.

The displacement of hydraulic pump/motor and swashplate angle of hybrid vehicle are calculated by hydraulic technology. Because the power of the hydraulic pump/motor selected by the vehicle should be able to meet the requirement that the hydraulic power system, it can provide enough torque when the vehicle is started independently and can provide enough braking torque when the vehicle is braked. With the increase of displacement of hydraulic pump/motor, its ability to recover braking energy is greater. The driving equation of the vehicle is:

$$f(a) = f(b) + f(c) + f(d) + m_a \tag{1}$$

where: $f(a)$ is driving force of vehicle driving (N); $f(b)$ is resistance of vehicle driving slope (N); $f(c)$ is resistance of vehicle driving air (N); m_a is acceleration of vehicle driving (m/s^{-2}). The time from the start-up acceleration of the hydraulic hybrid vehicle to the uniform driving speed v is:

$$T = \frac{1}{3.6}\int_0^v \frac{m_a}{f(a) - f(c) - f(b)} dv \tag{2}$$

When the vehicle is in driving condition and the hydraulic power system is used to drive the vehicle independently, the minimum output power of the hydraulic pump/motor under the set average pressure shall be able to meet the power requirements of vehicle driving, which is expressed as:

$$Y\min = \frac{1}{3600*\beta}\left[P*f + \frac{J_d*a_m*v^2}{21.15}\right]*v_{avg} \tag{3}$$

where: $Y\min$ is the power of the hydraulic pump/motor (kW); P is the total power of the vehicle during driving; f is the kinetic energy consumption coefficient; J_d is the total mileage of the vehicle; v_{avg} is the average driving speed (km/h). When the hydraulic pump/motor operates at the maximum pressure set by the accumulator, it shall meet the power requirements of the vehicle at the maximum speed and certain climbing capacity, namely:

$$Y\max = \max(Y_1, Y_2) \tag{4}$$

$$Y1 = \frac{1}{3600*\beta}\left[P*f + \frac{J_d*a_m*v^2}{21.15}\right]*v_{\max} \tag{5}$$

$$Y2 = \frac{1}{3600*\beta}\left[P*\sin\chi + P*\cos\chi*f + \frac{J_d*a_m*v^2}{21.15}\right]*v_{slop} \tag{6}$$

where: β is the transmission efficiency from the hydraulic pump/motor to the wheel; $v_{\max}$ is the maximum speed (km/h); v_{slop} is the climbing speed (km/h); χ is the angle of climbing.

The power system model of hybrid electric vehicle consists of hydraulic pump/motor model and hydraulic accumulator model. Through the above vehicle energy calculation results, combined with hydraulic technology, the hybrid energy vehicle power system model is constructed, as follows.

After simplification, combination and linearization, the dynamic mathematical model of the electro-hydraulic servo valve can be expressed as follows [9]:

$$Q(u) = \frac{w(u)}{l(u)} = \frac{r_v}{\frac{u^2}{\delta_u^2} + \frac{2\delta u}{\delta_u^2} + 1} \tag{7}$$

where: r_v is the flow gain of servo valve; $\frac{w(u)}{l(u)}$ is the output flow of servo valve; δ_u is the natural frequency of electro-hydraulic servo valve; δ is the damping ratio of servo valve. If the frequency width of the hydraulic control system is low, the electro-hydraulic servo valve can be represented by the first order inertia link, namely:

$$\frac{w(u)}{l(u)} = r_v \tag{8}$$

The mathematical model of the motor is as follows:

$$g_i = s_i\frac{dk_i}{dt} + E_i q_i + \frac{V_i}{4\wp}\frac{dp}{dt} \tag{9}$$

where,

$$E_i = E_u + E_r \tag{10}$$

where: g_i is the flow into the high-pressure chamber of the variable cylinder; s_i is the effective working area of the variable cylinder piston; k_i is the displacement of the variable cylinder piston; E_i is the total leakage coefficient of the variable cylinder; E_u is the internal leakage coefficient of the variable cylinder; E_r is the external leakage coefficient of the variable cylinder; q_i is the pressure difference between the high-pressure chamber and the low-pressure chamber of the variable cylinder (Pa); V_i is the total volume of the two chambers of the variable cylinder; $\wp$ is the bulk elastic modulus of the oil. Through the analysis of this formula, the mathematical model of vehicle accumulator can be obtained as follows:

$$W_a = h_a - h_b = \frac{x}{S_a^2}(l_a \frac{dfa}{dt} + L_a z_a) \tag{11}$$

where: S_a is the cross-sectional area of the hydraulic accumulator oil; l_a is the mass of the liquid in the hydraulic accumulator; L_a is the viscous damping coefficient of the liquid in the hydraulic accumulator; z_a is the flow into the hydraulic accumulator; h_a is the energy generated by the power system; h_b is the energy consumed when the vehicle is braked. The flow continuity equation of accumulator is as follows:

$$q_a = -\frac{dv_j}{dt} \tag{12}$$

According to Boyle's law of thermodynamics, the power system model of hybrid electric vehicle is as follows:

$$Z = h_{a0}V_{j0}^n - h_a V_j + W(u) + g_i + W_a + q_a \tag{13}$$

where: h_{a0} and V_{j0}^n respectively represent the stable working points of the hydraulic accumulator under different constant pressure variable pump set pressure.

Through the above steps, the hybrid vehicle powertrain model is built. In the hybrid vehicle, the accumulator plays a decisive role in the power performance and braking performance of the whole vehicle. When the minimum working pressure of the accumulator is fixed, then the larger the volume is, the smaller the change range of the system pressure in the process of energy recovery is. Also, the stronger the energy recovery capacity of the system is; when the accumulator volume is fixed, the larger the inflation pressure is, the smaller the change range of the whole working pressure is when the power system provides power and recovers braking energy. In case when the volume of the accumulator is fixed, the higher the maximum working pressure of the hydraulic accumulator is, the stronger the ability of driving the vehicle independently. Also, when the maximum working pressure of the accumulator is fixed, the larger the volume is, the smaller the change range of the system pressure is, the stronger the ability of driving the vehicle independently is. Therefore, it is necessary to build the mathematical model of the accumulator accurately, so as to realize the high-precision diagnosis of the power performance fault of the hybrid electric vehicle.

2.2. Power performance fault diagnosis of hybrid electric vehicle

Using the above-mentioned mathematical model, the power composition and performance of hybrid vehicles are studied, and the self-diagnosis method is used to compare the fault diagnosis results with the rated results to complete the fault diagnosis of vehicle power performance. The self-diagnosis method uses the characteristic that the computer itself can quickly monitor the working condition of the control system and store the data. According to a certain preset program, it can automatically monitor the faults within the scope of the automobile-controlled system and store them in the form of codes in the automobile computer, so as to obtain the automobile fault information and carry out the fault diagnosis. The power performance fault diagnosis process of hybrid vehicle is shown in Figure 2.

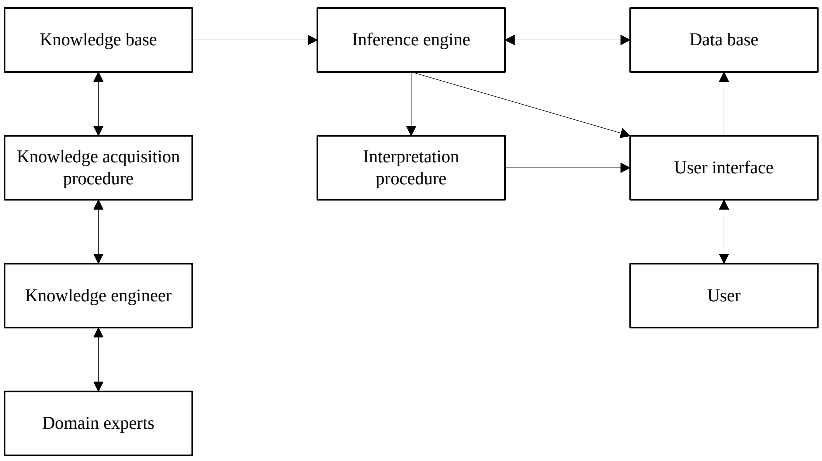


Figure 2. Diagnosis process of power performance fault of hybrid electric vehicle

Knowledge base is the core of power performance fault diagnosis of hybrid electric vehicle. Its perfection will directly affect the effect of fault diagnosis and the efficiency of fault alarm. According to prior knowledge, fault knowledge can be divided into three types: descriptive knowledge, process knowledge and control knowledge [10, 11]. Descriptive knowledge is used to describe concepts; process knowledge is used to describe the characteristics of descriptive knowledge and their relationship with each other; and control knowledge is a strategy to control and use the two types of knowledge. In the design of the fault diagnosis knowledge base, the dynamic performance faults are classified according to the causes, location, time, development of faults and possible consequences. According to the location and cause of the fault, the fault can be divided into three types: motor body fault, actuator fault and sensor fault.

Motor failure often occurs in the stator part, rotor part and bearing part of the motor body [12]. In order to monitor the fault signal, sensors are usually installed on the power components of the hybrid electric vehicle, which can collect the parameters of the power equipment during the operation of the HEV electric drive system and judge the data. In order to systematize the knowledge display of vehicle dynamic performance fault, it is set as the form of data table and stored in the diagnosis knowledge base. Among them, the classification and causes of hybrid vehicle power performance faults are shown in Table 1.

Table 1. Power performance fault table of hybrid vehicle

Fault No	Failure mode	Cause of failure
1	Damaged failure mode	Bearing wear End ring cracking Stator winding short circuit/open circuit
2	Degraded failure mode	Demagnetization of permanent magnet Aging of stator winding insulation
3	Loose fault mode	Loose stator core Loose sensor connector
4	Maladjustment failure mode	Rotor eccentricity
5	Leakage proof failure mode	Blocked/blocked cooling water Cooling water leakage
6	Other failure modes	Noise/vibration

In the research of motor fault, three kinds of faults, stator, rotor and bearing, are selected to detect and judge. Among them, stator failure includes stator core and stator winding [13, 14]. The failure of stator core may be caused by loose core or overheated temperature. The stator winding fault may be caused by turn to turn short circuit and insulation crack. There are two kinds of rotor problems: support problem and unbalance problem. Bearing fault includes vibration, high temperature and electrified. To improve the accuracy of fault diagnosis, set the fault information list of motor body as shown in Table 2.

The fault of power controller mainly occurs in the cooling process, power conversion unit and control module. The main causes of cooling failure are water pump problem and water circuit problem. The fault of the inverter includes the fault of the filter energy storage unit, the fault of the high voltage power on unit and the fault of the inverter circuit. The abnormality of control unit mainly includes additional power supply failure and sensor unit failure. The specific fault information is classified as shown in Table 3.

Table 2. List of hybrid vehicle motor fault information

Fault location	Specific failure causes	
Stator failure	Stator core	Loose core Local overheating
	stator winding	Turn to turn short circuit Insulation crack
Rotor failure	Bracket cracking out-off-balance	
Bearing failure	Vibration Over temperature Charged	

Table 3. Fault information list of hybrid vehicle power controller

Fault No	Fault type	Fault performance
1	Cooling failure	Water pump failure Waterway failure
2	Inverter unit failure	Filter energy storage unit failure High voltage power on unit failure Inverter circuit fault
3	Control unit fault	Auxiliary power failure Sensor unit failure

Through the above information list, the dynamic performance fault knowledge base is established and used to diagnose the vehicle dynamic performance fault. In addition to the above diagnosis information, the fault diagnosis problem is converted to the deviation of vehicle power state or variable characteristics within the normal range. Therefore, the failure of dynamic performance may lead to the degradation of system performance and failure. According to the time characteristics, faults can be divided into sudden faults, gradual faults and intermittent faults. The sudden fault mainly occurs suddenly and permanently (similar to step signal), which can be understood as the deviation of system signal; when the gradual fault occurs, its value starts from zero and occurs slowly at a certain speed; the intermittent fault mainly occurs when it occurs and disappears when it occurs, and its fault amplitude also changes constantly, increasing the above setting to In order to improve the reliability of vehicle power performance diagnosis, fault diagnosis knowledge base is used.

2.3. Realization of hybrid vehicle power performance fault alarm

Using the above design content, the fault diagnosis of hybrid vehicle's power performance is completed. On this basis, the fault warning of hybrid vehicle's power performance is realized.

The fault information of the vehicle is integrated into computer language, and the fault information is sent to the mobile information receiving terminal of the vehicle owner through the vehicle communication interface, and the alarm sound effect is sent out by the sound inside the vehicle. After analyzing some functions of fault alarm, the products of gntop company, the intelligent hardware supplier of vehicle network, are finally selected [15, 16]. The main control chip of the product is ELM327, which supports all communication protocols. In addition, there is a Bluetooth module, which supports Bluetooth 3.0 and has stable performance. The fault alarm implementation flow is shown in Figure 3.

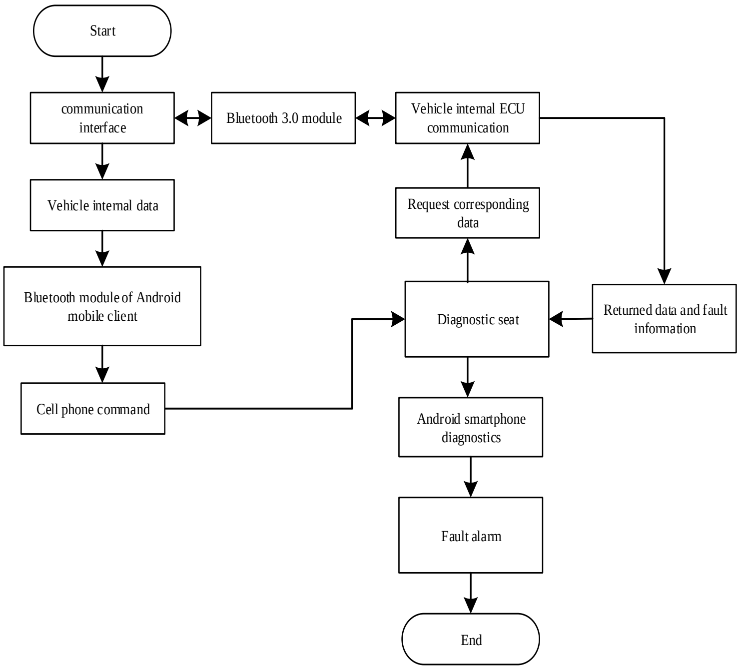


Figure 3. Realization process of fault alarm

Analysis of the above figure shows that the communication interface communicates with the vehicle internal ECU (Electronic control unit) through the Bluetooth 3.0 module and sends the acquired vehicle internal data to the Bluetooth module of the Android mobile phone client. The diagnosis seat is inserted under the dashboard on the driver's side of the cab, which is the connector for communication between the automobile ECU and the Android smartphone terminal diagnosis program. The diagnosis base receives the command from the mobile phone through the embedded Bluetooth module, sends the command to the vehicle ECU to request the corresponding data after self-analysis, then receives the data and fault information returned by the vehicle, and then sends the software to the mobile phone client through Bluetooth to realize the fault alarm.

In addition to the above design, Android client design is the most important part of the system. According to the system demand analysis, the main function modules of the client include user management, fault diagnosis, map service, intelligent early warning, value-added service, system setting, automatic upgrade, etc. In order to realize these functional modules, the client architecture is analyzed. The client can collect vehicle driving information, including vehicle speed, rotating speed, battery voltage, engine coolant temperature, power performance fault code, vehicle position, etc., and can also play the role of driving record. The diagnostic program automatically adapts and selects the communication protocol, which is saved as the default configuration after correct initialization. The program will automatically identify the power performance diagnostic base and establish the Bluetooth serial port connection. The user can choose the sensor data to be monitored by himself. After the original data is returned, it will be displayed to the user through the analysis of the diagnostic program and saved to the local storage. The program will package GPS position information, power performance fault diagnosis information, owner information, etc. and send them to the server through the network. Client architecture design is mainly to complete the purpose of layered design software modules. Firstly, the module level is designed, and then the modules are designed in detail. From the bottom up, the client app can be divided into four layers: system hardware layer, middleware layer, software function layer and software UI (user interface) layer. Set the contents of vehicle fault alarm information table as shown in Table 4.

Table 4. Alarm information

Describe	Field	Data type	Remarks
Vehicle number	carId	Bigint	Primary key
license plate number	carCode	varChar(3 0)	Not null
Vehicle color	carColor	varChar(3 0)	Not null
Vehicle type	carCype	varChar(3 0)	Not null
4S shop name	shame	varChar(3 0)	Not null
4S shop phone	sPhone	varChar(3 0)	Not null
Fault code	troubleId	Bigmt	Primary key
Fault number	troubelCode	Int	Not null
Fault type	trouble	varChar(30)	Not null
Alarm number	alarmId	Bigint	Primary key
Alarm time	alarmTime	DataTime	Not null

In the hybrid electric vehicle power performance fault alarm, Android system is introduced to complete the reading of vehicle operation parameters, vehicle location information, vehicle information, fault information, etc., and then Android Bluetooth technology is used to build a short-range wireless communication mode inside the vehicle, which is transmitted to the software platform of Android terminal, and at the same time, GPS global positioning technology is used to obtain the real-time position of the vehicle. Finally, through the communication technology, the owner information, vehicle information and vehicle fault information are sent to the remote service center, so as to realize the real-time alarm of vehicle power performance fault. So far, the design of fault alarm method of hybrid electric vehicle power performance based on hydraulic technology has been completed.

3. Method application test

In order to prove the feasibility and accuracy of the fault alarm method based on hydraulic technology, the experiment is carried out. In this test, the methods of literature [6] and literature [7] will be used to compare and test with the design methods in the paper, so as to verify the feasibility of the design methods in the paper.

3.1. Test environment

In order to ensure the authenticity and effectiveness of this test, the test object is Toyota hybrid vehicle. The specific components are as shown in Figure 4.

(a) Hybrid vehicle

(b) Test motor

(c) Test accumulator

Figure 4. Physical diagram of test hybrid vehicle powertrain

In the test process, in order to control the uniformity of its variables, the above test sample model and manufacturer are set, and the specific design results are as shown in Table 5.

Table 5. Components and parameters of test object

Component manufacturer model	Component manufacturer model	Component manufacturer model
Variable hydraulic pump/motor	Guizhou Liyuan Co., Ltd	GY-A4V40
Bladder type hydraulic accumulator	Fenghua Chaori Hydraulic Co., Ltd	NXQL16/200-A
Constant pressure variable axial piston pump	Beijing Metallurgical Hydraulic Machinery Factory	TZB63H-F-R
Oil source drive motor	Dalian electric machinery factory	JO2-82-4

Through the above parameters, the test samples in this test are composed, and the design method, literature [6] method and literature [7] method are used to compare, so as to test the application effect of the design method in the paper.

3.2. Analysis of test results

1. Accuracy rate of fault diagnosis

The accuracy rate of fault diagnosis is the basis of the power performance fault alarm of hybrid electric vehicle. Therefore, the accuracy rate of fault diagnosis of different research methods is compared, and the results are shown in Figure 5.

It can be seen from the comprehensive comparison of the three methods that the accuracy of fault diagnosis of the research method is always between 88.5% and 94.5, which is far higher than the experimental comparison method, which shows that the method can realize the accurate diagnosis of the hybrid vehicle power performance fault.

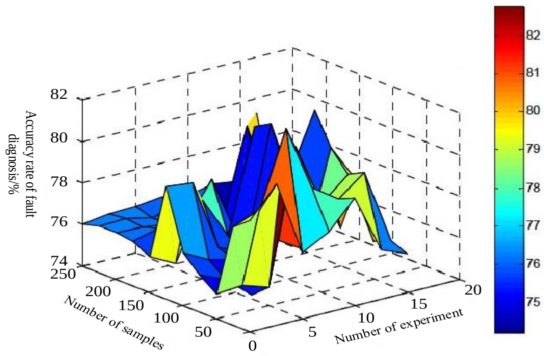
2. Troubleshooting time

The fault diagnosis time is the main factor affecting the fault alarm efficiency of the hybrid electric vehicle power performance. Therefore, the fault diagnosis time of different methods is compared, and the results are shown in Figure 6.

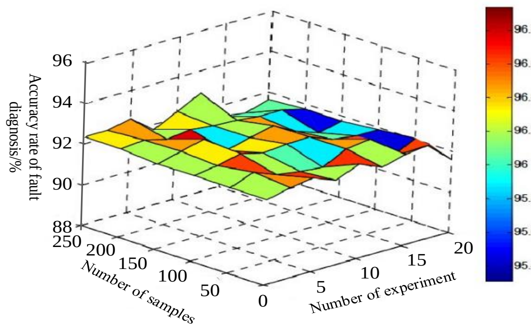
It can be seen from the analysis of Figure 6 that the fault diagnosis time of literature [6] method is between 0.7 s-7.0 s, and the fault diagnosis time of literature [7] method is also between 0.7 s-7.0 s. The change of the fault diagnosis time curve of the two methods is large, which shows that the performance of the two methods is not stable. Compared with the two methods, the fault diagnosis time of the proposed method is less than 0.5 s, which shows that the method can be realized for the rapid diagnosis of hybrid vehicle power performance fault.

3. Effective failure alarm rate

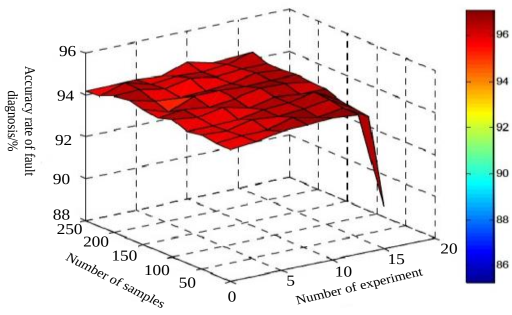
Effective fault alarm rate refers to the probability of early warning for these fault information after obtaining the fault location information. The comparison results are shown in Figure 7.



(a) Literature [6] method



(b) Literature [7] method



(c) Proposed method

Figure 5. Test of fault diagnosis accuracy of different methods

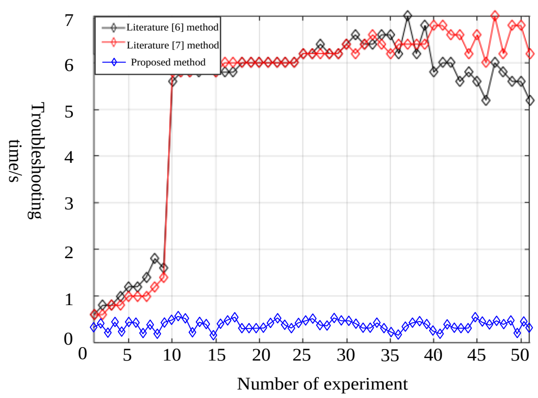


Figure 6 Fault diagnosis time test of different methods

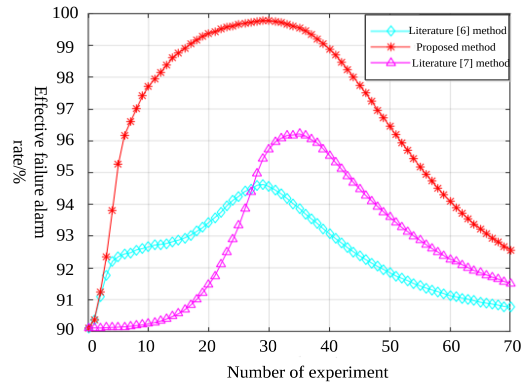


Figure 7. Effective failure alarm rate

From Figure 7, it can be seen from the test results of the above formula that there are certain differences between the proposed method and the other two methods in terms of effective fault alarm rate. The highest effective failure alarm rate of literature [6] method is 94.7%, the highest effective failure alarm rate of literature [7] method is 96.2%, the highest effective failure alarm rate of research method is 99.8%, and the effective failure alarm rate is always higher than that of literature comparison method, which shows that the performance of this method is optimal.

4. Cost comparison

Cost is a comprehensive indicator to verify the application performance of the method in this paper. Therefore, compare the cost changes of hybrid vehicles before and after the method in this paper, and the results are shown in Figure 8.

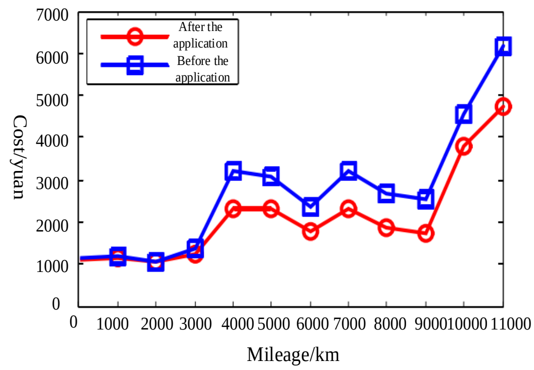


Figure 8. Cost change test

It can be seen from the analysis figure that the driving cost of hybrid electric vehicle decreases after adopting the method in this paper, which shows that the economic performance of this method is superior.

4. Conclusions

The research of fault alarm is an important part of the development process of hybrid electric vehicle. How to use more effective methods to improve the accuracy, reliability and adaptability of the fault diagnosis of hybrid electric vehicle is an important topic in the research. In this paper, the theory and method of hydraulic technology are used to deeply mine the fault diagnosis and alarm methods of vehicle. The research data at home and abroad show that there are many researches on the fault diagnosis of the drive system of the hybrid electric vehicle, but the key is to find out the fault diagnosis method suitable for the system according to the characteristics of the hybrid electric vehicle, and it is difficult to consider the practicability and feasibility of the design method. In this paper, the characteristics of the electric system of electric vehicles are studied and the advantages and disadvantages of various fault diagnosis methods are compared. A fault alarm method based on hydraulic technology for the power performance of hybrid electric vehicles is proposed. The experimental results show that compared with the traditional method, this method has the advantages of high accuracy, short diagnosis time, high effective alarm rate, low cost, superior economic performance and good application effect. Due to the limited time and level, there are still some shortcomings in this method, which should be improved in future research.

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