

Fault analysis and elimination of motor sensors in pure electric vehicles

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Abstract. Sensor as the main component of the motor drive system is to ensure its stable and reliable operation of the core components, so to drive the system's normal operation must learn how to analyse and diagnose the motor sensor fault accurately. This paper first introduces different fault classification and basic diagnosis methods, uses the CNN algorithm to collect sensor information, and uses matrix, dot product and other mathematical operations to make deep diagnosis. The sensor's real-time working status and accurate fault feedback can be obtained. CNN algorithm is fully suitable for the research and application of motor sensor fault diagnosis and can provide the basis for fault diagnosis according to the change of its own operating data parameters, and achieve efficient analysis and elimination of existing faults, to a certain extent, it can provide reference for the replacement of motor sensors and provide analysis for personnel engaged in related diagnosis industries.

Keywords: Motor sensor; CNN algorithm; Signal simulation method; thermistor.

1. Introduction

The core components and key technologies of pure electric vehicles are mainly composed of pure electric vehicle power systems, brake energy recovery systems, vehicle controllers and drive motor systems. The motor controller is a device responsible for controlling the energy transmission between the motor and the power supply in the drive motor system. Its main function is to provide three-phase alternating current to the drive motor to drive the vehicle, and it also plays the function of signal detection [1]. The electric vehicle is a kind of comprehensive product with a high level of electrification integration, and its core technology is mainly based on the vehicle power battery system, the motor system used to drive the vehicle and the electronic control system corresponding to each part of the vehicle. The motor controller is directly related to the operating performance and energy utilization rate of pure electric vehicles. As the core part of pure electric vehicles, it is closely related to its healthy development. Therefore, it is necessary to monitor the operating state of the motor controller of pure electric vehicles and analyse and eliminate sensor faults, and it is also extremely important for the normal operation of the drive system [2]. At the same time, with the improvement of science and technology in recent years, pure electric vehicles have developed rapidly with the advantages of zero emissions and low noise, and have been favoured by consumers, and their popularity has gradually increased, accompanied by a series of various problems and challenges. In this way, there is also the problem of sensor position in the motor controller. This has also attracted the attention of many experts and scholars. At present, domestic researchers mainly use motor simulators, upper control machines and other signal detection and control instruments to analyze and judge motor sensor faults. The motor controller is an extremely important part, but the continuous improvement of the complexity of the control system increases the possibility of its failure. It can timely adjust the operation of the system through the information monitoring and feedback of three parts: temperature sensor, position sensor and current sensor [3]. Most sensors work in harsh environments such as high temperature, strong pressure and large vibration amplitude, and are prone to failure [4]. If the sensor fails, the performance of the measurement signal distortion system will decline, and other components will be damaged or even cause serious economic losses due to the closed-loop control strategy of the drive system, threatening people's safety [5]. Therefore, it is of

great practical significance and helps to learn the fault analysis and diagnosis method of motor control system sensors. This paper mainly introduces the working principle of the motor controller and each working sensor and the various types of faults that may be encountered, as well as the analysis and diagnosis methods when encountering these faults, including voltage detection method, signal simulation method, and the process involved in the diagnosis and some related algorithms.

2. Fault analysis of motor sensors in pure electric vehicles

2.1. Fault Analysis

The motor controller will continuously obtain the current motor operating status and adjustment requirements through current, position and temperature sensors, and will extract, convert, amplify and filter all the information obtained to determine that the obtained information is useful. After processing the information, the motor controller will issue signal instructions to adjust the engine temperature, air conditioning temperature, engine fuel consumption, and emissions, and control the speed by changing the motor winding current. The implementation of these decisions depends on the quality of the sensor and the accuracy of the measurement, but various faults will inevitably occur during the use of the sensor [6].

As shown in Figure 1, the temperature sensor is an important component of the motor controller, which is mainly responsible for sensing and monitoring the temperature of the automobile engine, air conditioning and other parts. The temperature sensor relies on the temperature-sensitive characteristics of metal materials to complete the work. When the external temperature changes, the volume of the metal material will also change accordingly, and then this change will be converted into a change in the resistance value to output electrical signals [7]. Traditional motor temperature sensors mostly use PT1000 or PT100 platinum resistors, which are installed by welding leads of motor manufacturers, resulting in poor reliability and processing tolerance, and high defective product and failure rates [8]. Ageing or damage to thermistors is a common cause of performance degradation over time and continuous exposure to extreme environments. As well as the improper composition of the coolant inside the cooling system will erode the sensor housing and the internal circuit, affecting normal operation.

The position sensor is an extremely important component that is responsible for detecting the position of the measured object and converting the measured position and rotational speed into digital information through photoelectric encoders, magnetic encoders and ultrasonic sensors [9]. When the position sensor runs for a long time under harsh conditions, when the components lose all functions, it will fail to accurately control the motor, resulting in motor instability, loss of control and even system crash and personnel safety.



Fig 1. Temperature sensor.

2.2. Diagnosis Process

It is very important to know how to diagnose the faults of automobile sensors. Fault identification is to further determine the type, severity and location of the fault, to provide convenient and practical help to drivers or maintenance personnel and to ensure the safety and reliability of the system [10].

The fault detection methods of automotive sensors include the resistance detection method, electrical signal detection method, signal simulation method, knowledge method, etc. CNN algorithm can also be applied to the diagnosis process. The resistance detection method is a more common method, that is, by detecting the resistance value of the sensor to determine whether it can operate normally. For example, when diagnosing the sensor coil, use the resistance of the multimeter and insert two pens into both ends of the sensor. If the resistance value is displayed close to 0, it means that the sensor coil is short-circuited. If the resistance value is ∞ , the sensor coil has a break [11]. The electrical signal detection method observes the target signal according to the system model and the internal health variables through the mathematical model of the system, subtracting the observed value of the signal and the output value of the sensor to get the current residual, to obtain the diagnosis result. Taking the temperature sensor as an example, the temperature sensing element in the temperature sensor is connected in series with a known resistor at this time, which is a voltage-dividing voltage circuit. According to the principle of voltage dividing voltage, when the resistance value of the temperature sensing element changes, the voltage in the circuit will also change, and the voltage at this time can be measured to obtain an electrical signal related to temperature. Then the measurement results can be compared with the normal operation of the sensor data to obtain a diagnostic result.

The most important function of a sensor is that the output signal can accurately reflect our input [12]. The signal simulation method refers to the fault location obtained by simulating the normal operating state of the sensor or the input and output signals when detecting the fault of the sensor. First, it is necessary to know the type and working principle of the sensor to be diagnosed and the data during normal operation, select the instrument required for detection such as a multimeter, signal generator, oscilloscope, etc., and manually simulate the necessary parameters such as the waveform and frequency and the amplitude of change of the sensor during normal operation. Then disconnect the connection between the sensor and the original working system, use our artificial simulated signal instead of the sensor to connect to the working system, start the signal generator to input it into the working system, then observe and record the output signal and the state of the system at this time and compare it with the operation of the detected sensor to diagnose the fault of the sensor. For example, in the AFE engine fault diagnosis, the operation status of the electronic control system is detected by simulating the Hall sensor signal, opening the ignition switch and connecting the spark plug with the Hall sensor. Because the speed signal is artificially simulated at this time, the ECU will control the ignition primary circuit to disconnect, and the spark plug will jump. Because the ECU has received the artificially simulated speed signal, the electric gasoline pump will operate normally, and the pulse phenomenon of the inlet and return tubing can be found. When a fault occurs, the fault operating state can be compared with the above normal operating state to obtain the result [13].

The function and role of the CNN algorithm is to extract a large amount of data to obtain the needed ImageNet data set and grid image and use them for detection and optimization, which can also improve the recognition rate [14]. This algorithm has strong computing power but inevitably consumes high resources [15]. The results of information extraction and fault diagnosis using the CNN model have high accuracy. CNN has a convolution layer, pooling layer and fully connected layer. Convolution is the core operation of the CNN algorithm. In a convolution layer of CNN, the convolution kernel first performs convolution operations with local input data, and the result is input to the excitation function [16]. Matrices of different sizes are used to perform mathematical operations, and the formula is:

$$s(t)=(x \times w)(t) \quad (1)$$

Expand the convolution kernel w to get a one-dimensional vector, arrange it so that it can dot the product, and make sure that the convolution kernel is close to the picture and multiply all the corresponding elements one by one [17]. When applying the CNN algorithm to the sensor fault diagnosis direction, the diagnosis steps are as follows:

(1) First collect the parameters and working status information of the detected sensor, then extract the information, and then simulate to further divide the extracted information.

(2) Make sure that the basic parameters of the model include the size of the convolution kernel, the pool kernel and the convolution step, and set the required relevant activation function and the number of iterations. Initialize the parameters of the network model.

(3) The grid is trained through the training set of data, and then the network performance is detected, and the function value is lost by using the test set of data.

For example, the three-phase PMSM vector control system model is first established for fault diagnosis of the current sensor, and then four fault models such as drift, gain, failure and noise are simulated and set. Then the information and data under these four faults and normal operation are extracted. The noise fault is taken as an example to add a function to the simulation model to simulate the impact of noise. It can be observed from Figure 2 that small amplitude pulse vibration occurs compared with the normal operating state of torque and current [18].

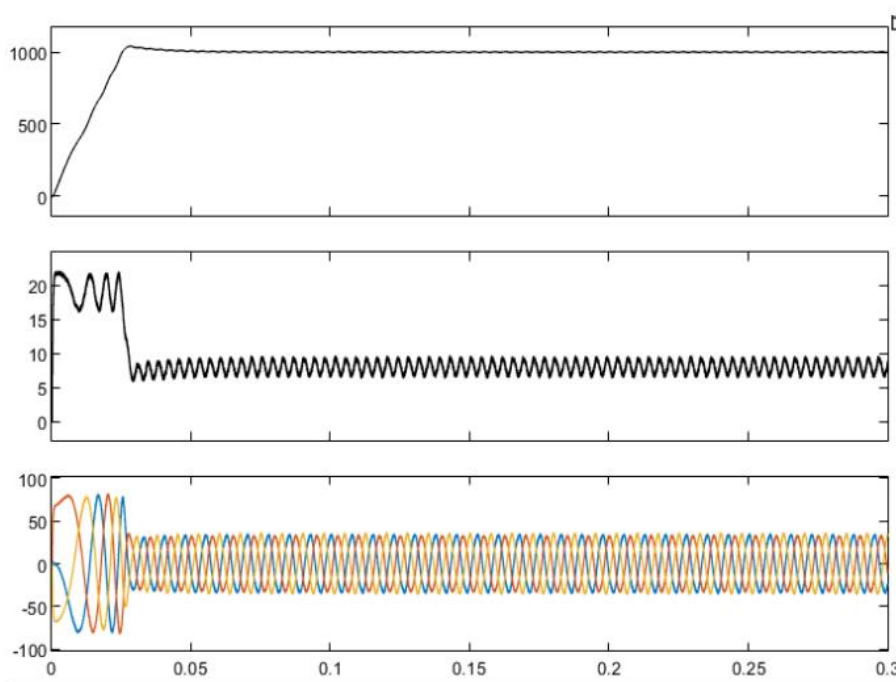


Fig 2. Waveform of speed - torque - current under noise fault.

The knowledge-based fault detection method mainly collects a large amount of fault data through the microprocessor and carries out pre-processing and feature extraction. Then, the extracted feature information is systematically processed, a large amount of fault information is trained, and then the information is compared with the normal working state of the system to obtain the real-time status of the sensor and the cause of the fault, and then the feedback is given. Paper studies an intelligent detection method based on a neural network [19]. This method needs to collect and train the current data sets of two-phase current sensors under normal and fault conditions. The research results show that this method can successfully diagnose the bias fault of current sensors.

At the same time, in the process of fault diagnosis, replacement methods and comparison methods are also more convenient and effective diagnosis methods, which can quickly determine the fault location and save the energy of sensor data transmission [20]. The replacement method is to replace the parts that may have problems to diagnose, and gradually narrow the possible fault location in the equipment during the replacement process, to take more effective and accurate maintenance measures. The comparison rule is to analyse and compare the faulty vehicle with the normal vehicle to replace the parts that may be suspected of fault, but it should be noted that before replacement, some harmful faults should be analyzed and eliminated, such as abnormal power supply, load short circuit and other failures that cause component damage, if not eliminated first, the plug-in on the replacement will continue to burn out.

3. Conclusion

This paper introduces the cause of the fault of motor sensor position in pure electric vehicles and how to diagnose it. The temperature sensor, current sensor and position sensor in the motor controller are the parts with a high incidence of failure, which usually cause abnormal work due to external temperature, body vibration and other factors. When the sensor fails, the signal simulation method, knowledge method and CNN algorithm can be used to carry out diagnosis to help us obtain the real-time operating status and fault location of the sensor. The types and causes of faults and traditional diagnosis methods are described in detail. Meanwhile, the CNN algorithm is added to carry out accurate diagnosis of motor sensor parts, which can analyse and eliminate faults with high efficiency and high precision. It can provide a reference for the replacement of motor sensors and help personnel engaged in related diagnostic industries. But at the same time, with the complexity of network structure, the CNN algorithm inevitably needs a lot of training data and consumes a lot of computing resources and time, which has higher requirements for hardware resources. When CNN processes images in complex environments, it is prone to be affected by conditions such as illumination, Angle and occlusion, resulting in a decline in the accuracy of recognition. These are all aspects that need to be faced and solved in the future and further optimized. In response to these challenges, more efficient data is used to improve the generalization ability of the model, more efficient CNN network structures such as lightweight networks are designed to reduce the amount of computation, and adversarial data and training are introduced to improve the robustness of the model in complex environments, and multi-mimicry data such as audio and text are combined to improve the accuracy of computer vision algorithms. These are the research directions and emphases of applying the CNN algorithm to the fault diagnosis function of motor sensors in the future.

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