Research on Reliability of Mechanical Structure Testing for Hybrid New Energy Vehicle Parts

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Abstract. With the development of new energy in China and the development of the automotive industry, the exhaust emissions of automobiles have caused serious environmental protection issues. The development of new energy requires energy conservation and emission reduction. The development of the automotive industry is contrary to the concept of new energy development and cannot be achieved. The new energy industry and the automotive industry develop together. Therefore, the country needs to complete the reform of automobile maintenance and testing technology in the new energy era to achieve energy conservation and emission reduction, promote the development of China's automobile industry, and better solve the environmental problems in China. This article takes pure electric vehicles and plug-in hybrid vehicles as research objects, divides the diagnosis objects into three parts: mechanical structure, electronic control system and high-voltage equipment, and combines traditional automotive parts detection technology to propose new energy vehicle detection technology methods. Help maintenance personnel better grasp the diagnostic technology of new energy vehicles.

1. Introduction
Based on petroleum pressure and environmental protection requirements, in the development process of each country, it is necessary to achieve reasonable application of resources. For the automotive industry, in order to realize this concept, the most urgent task at present is to find new energy sources. Effective detection of vehicles is not only the basis for managing the vehicle technology, but also the necessary guarantee for staff to understand the vehicle operating conditions in detail. The testing of new energy vehicles is in line with the development of the low-carbon economy and the concept of environmentally friendly vehicles. It is an important process to promote the assessment of the technical status of new energy vehicles and the monitoring of maintenance quality. In order to ensure the smooth implementation of new energy vehicle testing, it is important to improve the level of new energy vehicle testing technology. To this end, the article analyses the application of new energy vehicle detection technology, which has important practical significance [1].
2. Theoretical basis for comprehensive environmental test of new energy vehicle parts

2.1. Spectrum equalization

The so-called equalization is the process of attenuating and amplifying the excitation signal output to the power amplifier to different degrees in different frequency bands, so that the shaking table reaches the set target spectrum. For digital control systems, the equalization process is to estimate the inverse transfer function of the vibration system, which is essentially the process of identifying the vibration system [2].

In the random vibration control test, spectrum equalization is an important issue in the realization of the vibration test process. When a stimulus signal is input to the system, the system generates a response. Its response state depends on the dynamic characteristics of the system, as shown in Figure 1.

![Figure 1. Transmission characteristics of a spectrum equalization system.](image)

In the figure, the frequency domain signal obtained by the Fourier transform of the input signal $x(t)$ is $X(f)$, and its self-power spectral density function is $S_x(f)$, and the corresponding output signal $y(t)$ has $Y(f)$ and $S_y(f)$. The transfer function of the vibration test system is mainly determined by the dynamic characteristics of the shaking table and the test piece. The relationship between its input and output is [3]:

$$Y(f) = H(f)X(f)$$  \hspace{1cm} (1)

In the process of spectrum reproduction wideband random vibration control, the focus is on the amplitude characteristics. The relationship between the self-power spectral function of the input and output signals is:

$$S_y(f) = |H(f)|^2 S_x(f)$$  \hspace{1cm} (2)

In order for the control points on the shaking table to meet a specific reference spectrum $S_r(f)$, that is, requirement $S_y(f)=S_r(f)$, the driving spectrum $S_x(f)$ of the system must meet the requirements of the following formula:

$$S_{x1}(f) = \frac{S_r(f)}{|H_r(f)|^2}$$  \hspace{1cm} (3)
2.2. Power spectral density estimation
The non-parametric model estimation method is based on the periodic spectrum estimation method. It roughly summarizes the classical spectrum estimation algorithm: (1) Whether it is a direct method or an indirect method, its calculation method is based on FFT. The physical meaning is clearly Now commonly used spectral estimation methods. (2) The spectral resolution is proportional to 1 / N. N is the length of the calculated data. When the resolution is too high, the amount of calculation will increase. (3) Affected by the window function, the power of the spectrum in the main lobe of the window is "leaked" to the side lobes, thereby reducing the resolution. This effect is more pronounced when there are fewer calculated data. (4) Because it is not a consistent estimate of the true spectrum, its variance increases, and the curve will fluctuate with the increase of N. (5) The smoothing and averaging of the periodic graph is closely related to the window function. The smoothing and averaging methods are used to improve the variance performance of the periodic graph, but the resolution is reduced and the deviation is increased. The power spectrum estimated using the periodogram method is:

\[ \hat{P}_{\text{PER}}(\omega) = \frac{1}{N} |X_{\omega}(n)|^2 \]  

Where \( X_{\omega}(n) \) represents the windowed Fourier transform of the observation data \( x(n) \) at the point \( N \); \( \hat{P}_{\text{PER}}(\omega) \) represents the estimation of the true power spectrum [4].

3. Classification of test objects for new energy vehicles
Both pure electric vehicles and hybrid vehicles include three parts: mechanical structure, electronic control system and high voltage equipment:

3.1. Mechanical structure
Pure electric vehicles are divided into two types of traditional centralized driving structure and distributed driving structure according to different driving methods. Pure electric vehicles with traditional centralized drive structure mainly include five aspects of suspension, steering, reducer, transmission, and drive shaft. Pure electric vehicles with distributed drive structure mainly include suspension, Three aspects of steering and reducer. The mechanical structure of the plug-in hybrid vehicle includes the engine, suspension, steering, reducer, transmission and drive shaft. When the drive system is parallel or hybrid, it also includes a mechanical coupling device [5].

3.2. Electronic control system
Electronic control technology has evolved from the widespread application of engine and brake systems to various vehicle systems and functions, including body electrical systems, air conditioning systems, powertrain systems, and safety and comfort systems. In new energy vehicles, electronic control technology is still the "neural network" of the entire vehicle, and its functions and applications have been further expanded. Taking pure electric vehicles as examples, battery management control systems, motor control systems, and vehicle control have been added. System, etc.

3.3. High-voltage equipment
New energy vehicles are equipped with high-voltage equipment, which is the biggest difference from traditional fuel vehicles, mainly including power batteries, high-voltage wires, electric compressors, PTC heaters, junction boxes, charging systems, DC / DC converters and drive motors (including Inverter) and other seven parts, the relationship is shown in Figure 2 [6].
Figure 2. Composition of high-voltage equipment for new energy vehicles.

4. Structural reliability vibration simulation
The main functions realized by the vibration simulation system are the reliability verification of the comprehensive environmental test system for new energy automobile parts, the reproduction of the power spectrum of uneven excitation vibration of the new energy automobile road surface, and the research on the shaking table control method. In order to complete the above tasks, the control software of the vibration simulation system mainly needs to realize the synchronization of input and output modules, the setting of specific power spectral density and the import of road spectral power spectrum, the measurement of vibration acceleration and power spectral density estimation, the shaking table and power. Amplifier system impedance estimation, system equalization control, random signal generation, and control of spectral output after equalization. The functional diagram of the control software of the vibration simulation system is shown in Figure 3 [7].

Figure 3. Software function diagram of the vibration simulation system.

4.1. Reliability analog inputs and outputs
The most important thing for shaking table control is the acquisition of analog signals, the output of control signals, and the analysis of the random signals acquired. It is very important to ensure the real-time synchronization of the output control signal and the acquisition of the analog signal when performing the equalization calculation. To this end, the broadcaster must solve the synchronization problem of the analog input and analog output. First, set up analog voltage input and analog voltage
output channels respectively. In the DAQmx timing VI, set t continuous sampling mode and write DAQmx to the rebirth mode in the property node. Set the sampling clock to t for analog. For the clock of the output module, set t in the DAQmx trigger VI to the falling edge of the start digital edge trigger, and the trigger clock is the trigger clock of the analog voltage input [8].

4.2. Power Spectrum Setting and Import
In order to generate a random signal with a specific power spectral density or a specified road excitation power spectral density, a power spectrum setting or specific road spectral power spectral density data needs to be imported before testing. General road spectrum power spectrum density data is obtained by analysing the acceleration signal of the pedal position of a specific type of light new energy vehicle.

4.3. Vibration acceleration measurement and power spectral density estimation
When digitizing the acquired signal, the signal must be sampled. In the sampling process, the sampling frequency has a crucial impact on the approximation of the original signal. The choice of the sampling frequency directly determines the quality of the signal restoration and the time-consuming data processing. In order to make the discretized signal better represent the original signal, it is hoped that the higher the sampling frequency, the better, but too high a sampling frequency results in too much data and increases the workload of data processing. For this reason, under the premise of satisfying the sampling theorem, the highest frequency of the signal is generally selected to be 3-5 times. In this way, frequency mixing can be avoided, and high-frequency information in the original signal is lost when the signal is restored.

4.4. System impedance estimation
The system impedance is essentially the inverse of the frequency response function of the system, which is \( Z(f) = \frac{1}{H(f)} \). In this paper, a non-parametric model identification method, namely \( Z(f) = \frac{S_y(f)}{S_x(f)} \), is used, and the method of parameter model identification is simulated. The parameters estimation of the recursive least squares method (FFRLS) with the forgetting factor and the recursive least squares method (RLS) are simulated and compared. In order to excite each frequency of the system, a wideband random white noise is used for system identification. The relationship between the recursive least square’s method with forgetting factor and the recursive least squares method is that when the forgetting factor = 1, the recursive least squares method with forgetting factor is degraded to the recursive least square’s method. FIG. 4 is a recursive least squares parameter estimation with a forgetting factor and a recursive least squares parameter estimation.

![Figure 4. FFRLS parameter estimation.](image-url)
5. Analysis of component structure inspection methods with electronic control system

The electronic control system consists of three parts: sensor, actuator and control unit. Although new energy vehicles have technical changes in powertrain technology, the structure and principles of vehicle sensors and low-voltage actuators are the same. The sensor signal collection and control of low-voltage actuators are the same, which is suitable for the basic detection of new energy vehicle parts. Methods include:

5.1. Resistance measurement method

Use the multimeter resistance file function to measure and determine the state of the wire, such as whether there is an open or short circuit fault; measure and determine the standard resistance value of the component itself, such as temperature sensor, heating wire, relay, fuse, solenoid valve coil, clutch coil, light bulb, switch, Resistors, such as rheostats, must be well protected during measurement and disconnected from the vehicle's power source [9].

5.2. Voltage measurement method

Use the multimeter’s voltage range function to measure the line voltage value to determine the condition of the vehicle's circuit under test; to determine whether the power supply voltage is normal. Since the measurement of voltage requires vehicle power supply, from a safety perspective, this method should be prevented from being used with high-voltage wires or connector accessories to avoid the risk of electric shock. Even if it can be used, safety protection and operating regulations must be strictly observed.

5.3. Test lamp measurement method

The test lamp is used to measure the low-voltage power circuit, and the circuit state is judged by the on and off states of the test lamp.

5.4. Data flow method

The function of reading the data flow of sensors or actuators using the diagnostic instrument, observing the changes in the data flow parameter values of the tested components, and judging whether there is a fault in the control circuit or component. It is often used for sensor signal wires, actuator control wires, and switch signal wires. Detection and judgment, this method is simple and convenient, but requires a technical basis for maintenance technicians.

5.5. Action test method

Without any disassembly of the vehicle, the diagnostic instrument is used to drive the actuator to determine whether the actuator and its control circuit are faulty.

5.6. Replacement

The replacement method includes component replacement and signal replacement. Sensor component replacement is usually replaced by normal parts to determine whether the replaced part is normal. Replacement of actuator components can be replaced by normal parts or test lights. Test light replacement can determine whether the relevant control circuit is normal. The signal replacement is to replace the generator that can simulate the signal of the sensor into the control circuit, and determine whether the replaced sensor has a fault through the running state or the change of the data flow. Based on the requirements of safety regulations, when performing diagnostic measurements on new energy vehicle electronic control systems, it is necessary to use testing equipment and tools that meet the insulation requirements and do their own protection.

6. Conclusion

As the public's awareness of environmental protection continues to increase, the public is eager to find environmentally friendly and developable ways to promote the development of science and technology.
The emergence of electric vehicles is a major step in promoting sustainable development. Industry attention. In the future, the automotive industry needs to start with energy and is committed to researching energy conservation plans that use less energy and have more environmental protection. In the future, China’s traditional cars will be eliminated due to the impact of oil consumption on the environment, the probability of electric vehicles entering the market will gradually increase, the development of the automotive industry will become more difficult, and the requirements for automotive maintenance technology will become higher and higher. The ability to improve the professional quality of maintenance personnel, so that the detection technology in the era of new energy vehicles can promote the sustainable development of our country, the future development of the automotive industry is inestimable.

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