Information Processing of Chassis Dynamometer based on Controller Area Network

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Abstract—The development of chassis dynamometer of hybrid vehicle based on CAN bus was studied. Chassis dynamometer of hybrid vehicle measurement methods and loading devices are analyzed, and laid the foundation for the resistance simulation of chassis dynamometer. Road resistance simulation on HEV chassis dynamometer is researched, getting electric quantity simulation type of chassis dynamometer driving resistance. The research and development of hybrid vehicle chassis dynamometer based on CAN Bus is conducive to enhance the level of whole hybrid vehicle and car assembly, establish the test procedures, test methods and test standards, provide a research platform and methods for test evaluation of HEV energy utilization. The chassis dynamometer system needs to be calibrated in order to ensure its accuracy. The drum Test bench surface traction can be measured from the motor casing tangential force using force sensor mounted on the motor casing. The design adopts bidirectional calibration arm, it can decrease the effect of extra torque to ensure the test precision of automobile chassis dynamometer surface traction. The method of hybrid vehicles fuel consumption experiment test is analyzed through experiment test on the HEV chassis dynamometer and actual road. We obtain some regularity of hybrid vehicles fuel consumption experiment test is analyzed through studying lightweight hybrid vehicles fuel economy.

Index Terms—Information Processing, Chassis dynamometer, sensor, Controller Area Network, Fuel consumption

I. INTRODUCTION

The chassis dynamometer detects the vehicle dynamics, emission targets and fuel consumption of multiple loading conditions through vehicle simulating road driving conditions on indoor bench. Chassis dynamometer for Hybrid Electric Vehicle can synthetically test hybrid car vehicle include batteries, motors, energy management system and braking energy recovery system. In the trial, establishing the relationship between the bench and the real vehicle, and simulating the rolling resistance, air resistance and acceleration resistance of Hybrid Electric Vehicle can simulate hybrid vehicle road test indoor to shorten the test cycle. Hybrid vehicle chassis dynamometer test bench can analyze and evaluate the pros and cons of control scheme, is the infrastructure for hybrid electric vehicle development [1-2].

The chassis dynamometer is a very important indoor bench test equipment in the automotive product development process. Not only the power performance detection but also the emission targets and fuel consumption measurement under multiple loading conditions can [3-4] be done through the chassis dynamometer, providing a solid experimental foundation for the research of Vehicle power performance, economy, comfort, and handling stability, playing an important role in accelerating the development of the automobile industry, reducing the product development cycle, saving the cost of product development, improving the detection accuracy of vehicle various performance indicators. The chassis dynamometer system needs to be calibrated in order to ensure its accuracy and reliable before it is put into use. The traction of drum surface is an important parameter in the test, and the force sensor is the tool of measuring the traction of drum surface indirectly [5]. When the traction calibration of the chassis dynamometer is completed, the force sensor's signal will be transmitted to the computer, and the computer will display the force of the drum surface, which laid a foundation for the follow-up calibration of chassis dynamometer [6].

In this paper, the method of tests and assessment for the fuel economy of hybrid vehicles is studied through analysis of HEV energy utilization experiment. The experiment evaluation of HEV fuel consumption is studied, the method of hybrid vehicles fuel consumption experiment test is analyzed through experiment test on the HEV chassis dynamometer and actual road [5-6].

Measurement and control system of hybrid vehicle chassis dynamometer use modular design mainly composed of three subsystems. The measurement system consists of sensors and data acquisition module. Digital signal and signals transformed from analog signal through sensors, other detection equipment, the preamplifier circuit, other peripheral equipment and the A / D converter, were directly taken into computer. The control system consists of the control module and the actuator. The control system is to convert control signal given by the user in the form of digital signals to analog signals to control the behavior of the executing agency, making the parameters of the controlled object can meet user requirements [7-9]. Computer integrated processing system. The three subsystems are connected through the CAN bus.

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DC motor is used as a hybrid electric vehicle chassis dynamometer loading device. It can determine the output power data of original motivation and realize energy recovery in the form of energy recovery, electrical energy recovery rate can reach 70% to 80%, Dynamometer can drive the original motivation, carrying out anti-drag test; Load and load shedding can be used in the dynamometer for the original motivation [10].

DC motor stator deflection transmits the force to torque sensor through measuring arm, voltage signal from torque sensor converted into pulse signal by amplifying and filtering, and V / F converter, then pulse signal was sent to lower computer to acquire pulse number in the setting time, and obtain Instantaneous torque after calculation.

II. PROPOSED SCHEME

A. Resistance Simulation of Chassis Dynamometer

Chassis dynamometer of Hybrid Electric Vehicle adopts DC motor, to control the torque of the dynamometer through control the DC motor torque, the best way is to control the excitation current of DC motor to realize load or load shedding.

Speed sensor beside the gear transmit 100 pulse signal with DC motor shaft each revolution, the signal was sent to computer after signal amplification and shaping. Speed V (km / h) can be calculated:

\[ V = \frac{2\pi R_c}{100 \times 10^3} \times \frac{10^100 \times 3.6}{t} \approx 0.072 \pi R_c \]  

(1) where \( R_c \) is the roller radius (m); \( H \) is the number of pulses at intervals of \( t \).

Then the distance \( S \) (m) can be calculated:

\[ S = \frac{2\pi R_c}{100} \times k \]  

(2) where Refer to (2): \( k \) is the number of accumulated pulses.

(3) Fuel consumption measuring can be calculated after distance measurement:

\[ Q_s = \frac{100 \times k \times M_i}{S} \]  

(3) where \( Q_s (L/km) \) is the fuel consumption per 100 km at constant speed measurement.

(4) Automotive power measurement

Power measurement requires sample at the same time, output power of driving wheel \( P_c \) can be calculated:

\[ P_c = \frac{2\pi M_c N_v}{60} = \frac{M_c V_v}{3600 R_c} \]  

(4) where Refer to (4): \( M_c \) (Nm) is the torque on the drum; \( N_v \) (r/min) is the roller speed.

Vehicles actual driving resistance can be expressed as follow formula:

\[ F = (A + B \times V + C \times u^2) + \delta \times ETW \times \frac{du}{dt} \]  

(5)

where A is the constant resistance that does not vary with the speed change; B is the constant resistance that vary with the speed change; C is the constant resistance vary with the square of velocity; \( \delta \) is the correction coefficient of mass; ETW is the test quality on the chassis dynamometer:

\[ F_{DYN} = F_{U_{acc}} - F_{LOSS} \]  

(6) where \( F_{DYN} \) is the resistance that dynamometer absorbs; \( F_{LOSS} \) is the parasitic drag of rotating hub.

\[ F_{LOSS} = A' + B' \times u + C' \times u^2 \]  

(7)

\[ F'_{LOSS} = A'' + B'' \times u + C'' \times u^2 + (ETW - M) \times \frac{du}{dt} \]  

(8)

Refer to(7-8): \( A'' = A - A' \), \( B'' = B - B' \), \( C'' = C - C' \), \( M \) is the Inertia test of rotating hub, ETW is the input parameters of test, \( u \) is the Speed, \( du/dt \) is the acceleration.

DC power chassis dynamometer is to use the motor to accurately simulate the resistance, taking into account the load force of the dynamometer (Floss ) and inertia force of rotating parts(\( \Delta m \)), the force of force absorption unit DC motor(FPAU) can be expressed as follows:

\[ F_{PAU} = A + Bu + Cu^2 (m - \Delta m) \frac{du}{dt} - F_{loss} \]  

(9)

\[ F_{PAU} = K(U_1 + U_2) \]  

(10) where \( K \) is the transform coefficients.

Because the force generated by the DC motor is controlled by armature voltage, all of the above formulas are proportional to the analog control voltage \( U_1 \) and \( U_2 \), above formulas can be written as follows:

\[ KU_1 = A + Bu + Cu^2 - F_{loss} \]  

(11)

\[ KU_2 = (m - \Delta m) \frac{du}{dt} \]  

(12) Equation (12) is the electric quantity simulation type of chassis dynamometer driving resistance; vehicle driving resistance can be simulated as long as accurate controlling the analog voltage \( (U_1 + U_2) \).

B. Measuring Principle

Due to the special structure of the automotive chassis dynamometer, loading device could not be installed on the smooth drum surface when measuring the traction of drum surface, the traction of drum surface is measured from the force sensor of the test system[11-12]. The calibration of drum surface traction is achieved through the calibration of the force sensor, the force sensor output voltage after being subject to induction, thus corresponds to each mass, there will be a corresponding voltage value.
The force measurement device of the drum is generally divided into the torque sensor and the force sensor, which can measure the automotive traction torque and the traction force. Electrical dynamometer is the most used currently, its control interface displays the traction force of the drum surface instead of the traction torque, so using force sensor, not torque sensor, to measure the traction force of the drum surface (Figure 2).

Figure 2. Force sensor

C. Calibration of Drum Surface Traction

Drum surface traction test system calibration is achieved by force sensor calibration. In the actual use of the sensor, its zero point, the full range [16], linearity and repeatability may change, while in the automotive testing process, it requires that test results and real does not change much, this requires special calibration of force sensor’s zero point, the full range, linearity and repeatability. Bidirectional calibration arm is better to one-way calibration arm during calibration, which can reduce the impact of the additional torque [17].

Calibration arm is mounted on the top of the motor shell, it is used to simulate the torque acting on the motor shell by loading weight in the calibration arm end. Conventional calibration arm is one-way arm, which is made of metal and irregular geometry[18], the torque generated by the motor shell can’t be calculated precisely because the centroid of the one-way arm is difficult to determine. In this paper, the design of two-way arm can compensate for the deviation caused by one-way arm. The center of mass of bidirectional arm is located in the geometric symmetry line, perpendicular to the upper surface of the motor shell, and it passes through motor spindle rotation centers. So the bidirectional arm dead weight does not generated torque to the motor shell and also does not effect to the force sensor(Fig.3). Weights are placed symmetrically on one side of the bidirectional arm, the right and left ends(Fig.4), it can avoid generating additional torque caused by Asymmetric loading position affecting traction test results.

Figure 3. Bidirectional calibration arm

The force of the force sensor mounted on the drum motor shell can be calculated:

\[ F = \frac{W * L}{2R} \]  

(13)

W is the counterbalance mass loaded on the calibration arm, L is the length of calibration arm, R is the radius of drum, F is the sensor measurement value.

It will take 20 minutes to heat engine before calibration, heat engine can reduce the friction in the bearings of the drum motor spindle, improve the system sensitivity, so the force sensor can collect the current load data in real time. start drum brake after the completion of heat engine, thus the drum can fix to the drum frame, and the outside interference will not cause the drum to produce movement and load.

After the completion of the boot and brake of the chassis dynamometer, when the drum motor is not loaded, and there is no suspension weights in the calibration arm, then the current traction value will be read on the control surface of Chassis dynamometer. If the force is non-zero, set the current reading for 0:00 .Then load weights in one side of the calibration arm, and record the measurement results displayed on control interface after each load until full-scale. The current reading should be equal to designed range of the chassis dynamometer, If there are differences, set the current value for the full scale, and then uninstall weights individually and record the measurement results. Load weights at the other end of the calibration arm and record the results in the same way above, the traction force zero and full scale calibration are done [19-21].

In the process of traction zero and full-scale calibration, test data is collected when loading and uninstalling weights, Linear equations obtained through curve fitting of the average data value by one time fitting method, Linearity and repeatability of the force sensor will be test through the fitting curves of linear equation.

D. System Calibration

The system calibration is critical to ensure system accuracy. The calibration method is to measure the known parameter, bias between the display and actual value will meet the accuracy requirements through various regulation means.

1) Select the speed channels, while Speed indication error is at 40km/h, 60km /h, speed indication error at ± 0.5%.

2) Calibration tool: one digital optical speed meter with accuracy class 0.5.
(3) Calibration method: select the calibration points, setting a speed limit of 40km/h or 60km/h, standard speed of calibration points V_k (r/min) can be calculated:

\[ V_k = 60 \times n_k \times \pi \times D \times 10^{-6} \]  

(14)

Refer to (13): \( n_k \) is the roller speed of calibration points (r/min); \( D \) is the roller diameter (mm)

Do a clear mark on the roller, start the car, drive roller rotation, and let speed stabilize at the calibration points, Use an optical speed meter, repeat the measurement three times, calculate the speed indication error as follows:

\[ \delta_v = \left| \frac{V - V_k}{V_k} \right| \times 100\% \]  

(15)

Refer to (14): \( \delta_v \) is the indication error of speed; \( V \) is the value of display window (km/h). \( V_k \) is the Standard speed value of calibration points

Select the driving force channel and the driving force indication error with ± 2.0%. The driving force indication error can be calculated as follows:

\[ \delta_F = \left| \frac{F - F_k}{F_k} \right| \times 100\% \]  

(16)

Hang the weights of different weights in the calibration arm incision of DC dynamometer, do loading and unloading test three times and collect the number of pulses per second. Establish the torque and pulse equivalency factors in the torque measurement system after regression analysis, and to determine the measurement error of the measurement system.

III. EXPERIMENTAL RESULTS

A. Calibration Results Analysis

This paper choose calibration pressure as the calibration method, it can obtain higher calibration accuracy than One-Point Calibration. The selection of the calibration points is according to size of the drum surface traction force range, and the calibration pressure falls on the best accuracy pressure range of the force sensor. We can get the linear equation after the data processing.

\[ y = 849.03x + 29.624 \]  

(17)

The curve of the linear equation is shown in Figure 5:

![Figure 5. Force sensor calibration data analysis](image)

The calibration curve obtained above shows good linearity and repeatability of the force sensor, the loading error of the two directions is relatively small, it is in line with the chassis dynamometer test requirements.

B. Fuel Consumption Test

The test is divided into two parts, a portion of the chassis dynamometer test according to NEDC cycle and a portion of the actual road test. The test system consists of chassis dynamometer, CVS and gas analyzer, etc [7]. And increasing wattmeter and related current sensors are for measuring the charge and discharge amount of vehicle battery [8]. Wattmeter is equipped with two current sensors respectively measuring a current value of the two power battery main wire. The HEV main battery SOC, the current charge and discharge value data can be read using CAN bus signal read records software Can Monitor provided by the vehicle manufacturer [9-10].

The chassis dynamometer detects the vehicle dynamics, emission targets and fuel consumption of multiple loading conditions through vehicle simulating road driving conditions on indoor bench. Chassis dynamometer for Hybrid Electric Vehicle can synthetically test hybrid car vehicle include batteries, motors, energy management system and braking energy recovery system. In the trial, establishing the relationship between the bench and the real vehicle, and simulating the rolling resistance, air resistance and acceleration resistance of Hybrid Electric Vehicle can simulate hybrid vehicle road test indoor to shorten the test cycle. Hybrid vehicle chassis dynamometer test bench can analyze and evaluate the pros and cons of control scheme, is the infrastructure for hybrid electric vehicle development.

The HEV dynamometer test bench experiment is according to new European driving cycle NEDC.

![Figure 6. NEDC driving cycle](image)

The experimental vehicle parked 6 hours at room temperature 20 to 30 degrees, then warm machine 40 s, and experiment is carried out according to the urban driving cycle ECE15 for 4 consecutive times cycles and suburban driving cycle EUDC for one cycle. The whole experimental circulation time sustained 23 minutes, corresponding driving distance is 11 km, the average speed is 32.5km/h, and the maximum speed is 120km/h. The car was placed on a chassis dynamometer, The driver drive the car according to a prescribed driving cycle with the help of display screen displaying the actual and theoretical driving cycle speed [11].

The hybrid vehicle evaluation needs a long time experimental running, because the additional energy provided by the engine management is not sufficient for...
RESS system affecting the SOC state. The many times long test cycle can increase the possibility of low net energy change (NEC) at the cycle start and end. The Experimental driving cycle lasted for 4000s in road experiment and 10 times repeating NEDC cycle on the chassis dynamometer [12-13].

Harmonized test method is adopted for different energy storage device [14-15]. The current and voltage value of the electric power meter real-time detection energy storage system transform to the current energy change by integral, the discharge is positive, and the charging is negative. The net energy change NEC is obtained according to the electric power meter parameters through integral. The energy change of the RESS system must be monitored during the test, the NEC of the power battery be calculated by the equation (1).

\[
NEC = \int_{t_{\text{initial}}}^{t_{\text{final}}} I U dt \quad (18)
\]

NEC is the net energy change, it sun it is the Joule (J) in the formula; I is the input or output current of power battery bus, its unit is ampere (A); U is the voltage of power battery, its unit is volt (V); t is the time, its unit is the second (s).

The method is through the power meter 20HZ or more frequencies to detect the current and voltage, and finally through the integral to calculate the final power change. The method with high precision is suitable for different energy storage systems, because the NEC value calculated by integral is real-time monitored [16-17].

The energy consumption of the vehicle is the sum of electric energy and fuel consumption after each test cycle, it requires unified unit and then calculated. The formula of power consumption transforming into fuel consumption is calculated as follows:

\[
V_{\text{fuel}} = \frac{E_i \cdot 3600}{D_{\text{fuel}} \cdot Q_{\text{fuel-low}} \cdot \eta_{\text{eng}} \cdot \eta_{\text{gen}}} \quad (19)
\]

The test is divided into two parts, a portion of the chassis dynamometer test according to NEDC cycle and a portion of the actual road test. The Experimental driving cycle lasted for 4000s in road experiment and 10 times repeating NEDC cycle on the chassis dynamometer [18-19].

The test is carried out when 3000km mileage, a current sensor clipped to the battery cathode leading line measures current in the test. The charge-discharge net value is obtained through time integral of the electric meter current. The HEV main battery SOC, the current charge and discharge value data can be read using CAN bus signal read records software Can Moniter. The HEV electric drive, the power generation system, and the engine system is inter coupling, the vehicle power system running mode includes engine drive, electric drive, deceleration charge etc. Certain mode is to charge the battery, and certain mode is to discharge the battery. According to characteristics of the car’s main battery (Nickel metal hydride battery), a certain section of the range of SOC is the most suitable for the HEV. HEV control scheme generally have a battery SOC target equilibrium value for the SOC keeping in the most appropriate range during traveling of the vehicle. Control scheme appropriately regulating the working conditions of the power system, the main battery SOC is controlled in the vicinity of the equilibrium value; it reserves space for the next charging / discharging process. When Running a cycle, if the initial moment SOC of vehicle is too much higher than the target equilibrium value, the power system will run longer in the discharged state, so the SOC will close to the target equilibrium value at the end of test, and it will generally be smaller than the initial SOC, \( \triangle \) SOC is negative. If the initial moment SOC is far lower than the target equilibrium value, the charging process will be better than the discharge process, \( \triangle \) SOC is positive.

![Figure 7. SOC curve in NEDC experiment cycle](image)

![Figure 8. Current curve in NEDC experiment cycle](image)

![Figure 9. Rotate speed curve in fact city cycle](image)

![Figure 10. Vehicle speed curve in fact city cycle](image)
In the ECE15 cycle, the results as follows:

Fuel consumption test according to NEDC cycle adopts a current sensor measuring the dominant line current of the battery positive, the charge-discharge net value $Q$ is obtained through time integral of the electric meter current.

The HEV fuel consumption experimental is typically according to GB/T19753-2005, $Q$=0.2 ~ 0.3Ah. The manufacturers need to provide the slope of the fitted line shown in Figure 8 to the certified laboratory when the authentication test is carried out. A experiment is carried out in the certification test laboratories, the value of the measured fuel consumption is corrected using the slope and the measured $Q$ value. The pretreatment process of HEV fuel consumption experiment is composed of two NEDC cycles, providing a longer charge and discharge adjustment process, the initial SOC is in the vicinity of the net value of charge-discharge close to zero, so the SOC is generally not too high or too low at the end of preprocessing, this SOC is the initial SOC of the formal testing procedure, so the $Q$ value is often in the vicinity of zero.

IV. CONCLUSIONS

\[
Q = \int_{\text{initial}}^{\text{final}} I \, dt
\]
This chapter explores the development of chassis dynamometer of hybrid vehicle based on CAN bus. Chassis dynamometer of hybrid vehicle measurement methods and loading devices are analyzed, and laid the foundation for the resistance simulation of chassis dynamometer. Road resistance simulation on HEV chassis dynamometer is researched, getting electric quantity simulation type of chassis dynamometer driving resistance, vehicle driving resistance can be simulated as long as accurate controlling the analog voltage (U1+U2).

The calibration arm in the conventional method of calibration is unidirectional arm, so it’s hard to calculate the additional torque of the unidirectional arm acting on the motor shell, and the resulting error can’t compensate. This paper adopts Bi-directional arm calibration method based on the domestic chassis dynamometer design. Loading weights symmetrically on one side of Bi-directional arm makes up for the additional error of one-way arm calibration to some extent. It will take 20 minutes for heat engine to reduce the frictional force of system before calibration, and the force sensor can collect the current load in real time during calibration. The slight trembling of the bi-directional arm when loading weights has a great impact on test data, so we read test data when the Bi-directional arm completely still. The accurate bi-directional arm calibration of the drum surface traction force is achieved through calibrating the force sensor zero, full-scale, linearity and repeatability, it can reduce more measurement error than one-way arm calibration, and improve the measurement accuracy of the Chassis dynamometer to ensure the precision and accuracy of various performance test of the automobile. The Bi-directional arm calibration method in this paper provides some reference of calibration method for depth study of domestic Chassis dynamometer.

The research and development of hybrid vehicle chassis dynamometer based on CAN Bus is conducive to enhance the level of whole hybrid vehicle and car assembly, establish the test procedures, test methods and test standards, provide a research platform and methods for test evaluation of HEV energy utilization.

The experiment evaluation of HEV fuel consumption is studied, the method of hybrid vehicles fuel consumption experiment test is analyzed through experiment test on the HEV chassis dynamometer and actual road. We obtain some regularity of hybrid vehicles energy consumption and hybrid vehicles fuel consumption test method through studying lightweight hybrid vehicles fuel economy.

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