Research on Development of Vehicle Chassis Dynamometer

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Abstract. Vehicle chassis dynamometer, as an important part of vehicle test equipment, plays an important role in the research and development of the vehicle's entire life cycle. The development history of vehicle chassis dynamometer from hydraulic dynamometer to AC dynamometer was reviewed, and it was proposed that AC chassis dynamometer has become the mainstream trend. The vehicle chassis dynamometer was further discussed from the aspects of measurement and control system and road simulation system. On the basis of the current research status of dynamometers, based on the virtual test technology, network, intelligence and function expansion, the development direction and research focus of vehicle chassis dynamometers are given to provide reference for the further development of vehicle chassis dynamometers.

Keywords. Chassis dynamometer; Measurement and control system; Virtual test; Networked; Function extension.

1. Introduction
In engineering technology, any successful product is the product of close combination of design and test. The development of the vehicle industry and its products is inseparable from vehicle test research today [1-2]. With the rapid development of the vehicle industry, the requirements for vehicle performance and quality are getting higher and higher, so the pace of vehicle diagnostics and testing technology has to be accelerated, especially the accuracy and reliability of vehicle dynamometers for vehicle-related performance testing. Higher requirements have also been raised [3]. This article analyzes the development history and research status of vehicle chassis dynamometer from the technical perspective, and provides reference for the further development of vehicle chassis dynamometer.

2. Development History of Vehicle Chassis Dynamometer
Prior to the 1980s, vehicle detection equipment was mainly based on mechanical structures, and vehicle chassis dynamometers were represented by hydraulic dynamometers, which were mainly based on mechanical simulation, using mechanical flywheel sets to simulate the inertia of the vehicle during driving. The inertia included the inertia of the vehicle's translation and the internal moment of inertia of the vehicle. This type of chassis dynamometer could only detect the parameters of the vehicle at a low speed, and the accuracy was very low.

After entering the 1980s, with the development of electromechanical integration, on the basis of traditional chassis dynamometer, mechanical transmission links were minimized, and high-precision sensors with fast response speed, computer and mechanical system were combined to design chassis
measurement the power machine provides the possibility to detect the authenticity of the vehicle in high-speed driving. The chassis dynamometer at this stage mainly adopted mechanical-electrical simulation method. The flywheel group was used to simulate the vehicle inertia resistance. The eddy current simulated the other part of the driving resistance, which greatly improved the detection accuracy.

With the deepening of the research, the flywheel group that can simulate the inertia resistance of the vehicle step by step can no longer meet the requirements of the accuracy of the chassis dynamometer [4].

Because the DC motor has the advantages of simple control, good speed regulation performance and superior performance, most current vehicle chassis dynamometers use DC motors. However, due to the influence of the commutator, the DC motor cannot be suitable for high-speed operation. Therefore, when performing a high-speed test of a vehicle, a DC chassis dynamometer often uses a mechanical speed regulating device, which complicates the system and increases noise.

Vehicle AC chassis dynamometer adopts synchronous or asynchronous motor because of no commutator problem. It has simple structure and high reliability. Because of its wide torque speed adjustment range and excellent dynamic response, it is suitable for various types of vehicles the performance test is a new type of mechatronic dynamometer. With the deepening of research, the AC drive system has been significantly improved in dynamic and static performance. It has obvious advantages over other dynamometers in terms of control response speed, control stability, reliability, and economy, making the AC chassis dynamometer Machine becomes the mainstream trend.

3. Research Status of Vehicle Chassis Dynamometer

3.1. Measurement and Control System

The vehicle chassis dynamometer measurement and control system refers to the measurement of the speed and torque of the driving wheels of the vehicle, calculates the real-time load that needs to be loaded, and controls the loading device to load the drum to simulate its driving on the road.

Foreign researches on the measurement and control system of chassis dynamometer mainly focus on the testing of the load capacity of electric mechanical transmission system and the theoretical research on advanced control algorithms of measurement and control system. Rodicm [5] and others proposed a control strategy for a dynamometer system that can accurately simulate the dynamic characteristics of mechanical loads, and perform experimental simulation and error analysis on linear and non-linear loads. Aiming at the characteristics of slow response speed, time-varying parameters and non-linearity of dynamometers, some scholars have applied classical control technologies such as fuzzy control, neural network control, adaptive predictive control to the research of chassis dynamometer control algorithms to improve control accuracy.

Domestic research on the control algorithm of dynamometer system has also developed [6-7]. Southeast University proposed and developed control strategies for dynamic matrix control, fuzzy self-correction of gain coefficients and feedback prediction compensation decoupling. Northwestern Polytechnical University verified the feasibility of fuzzy control method in constant speed control through simulation experiments. Southeast University proposed a self-learning algorithm for vehicle performance, a multi-layered vehicle control model, and a vehicle speed tracking control method based on fuzzy logic, and applied it to a chassis dynamometer emission durability test. Chongqing University introduced human-like intelligent control into the chassis dynamometer system to control the loading of road simulation resistance of the eddy current dynamometer. Henan University of Science and Technology designed adaptive fuzzy PID control of speed and current double closed loop control, adopted rapid prototype development mode, and built an open chassis dynamometer measurement and control system around RapidECU.

In summary, the research on the eddy current chassis dynamometer measurement and control system is relatively mature, but there are still problems such as large accidental parameter calibration, low test efficiency, large system deviation, time-varying and uncertain mathematical models. The research direction of power machine measurement and control system uses fuzzy control, neural network control, genetic control and other algorithms for measurement and control system to achieve the goal
of accurate measurement control and rapid response. AC chassis dynamometers have problems such as energy feedback causing grid fluctuations. Research on AC motors is in its infancy and development is not mature. Research on AC motor load control is still in the development stage. With the continuous research of direct torque control technology In-depth, the development of power electronics technology is bound to have a greater impact on the performance and algorithms of direct torque control.

3.2. Road Simulation System

The vehicle chassis dynamometer road simulation system calculates the size of the load that the loading device needs to load in real time based on the data collected by the vehicle on the road and the dynamometer, so as to load the test vehicle through the roller. Related scholars have studied the road simulation system [8-10]. With regard to the calculation method of road driving resistance loading force, Chang'an University obtained experimental road driving resistance coefficients and air resistance coefficients through experimental research, and determined the method for calculating the road resistance loading force of the chassis dynamometer.

As a non-linear, time-varying system, there are a large number of factors that affect the test accuracy of the chassis dynamometer system. Hebei University of Technology had studied the factors that affect the test accuracy of the chassis dynamometer, designed a corresponding calibration method, and completed Calibration work. Jilin University used the back drag test method to test and study the resistance of the bench system, and obtained the rule of the internal resistance of the bench changing with the load.

The main problems in current road simulation systems include mismatch of test parameters and test conditions, inadequate theoretical models, inaccurate data processing methods, and insufficient test simulation methods. In order to get closer to the real simulated vehicle ground driving conditions, the following research should establish a rolling resistance correction model, introduce a fitting experiment method during the test, modify the correction coefficient in the software, and use the load dynamometer method to measure the equivalent rolling Resistance coefficient to improve vehicle dynamics detection accuracy.

4. Research Focus of Vehicle Chassis Dynamometer

4.1. Virtual Test Technology

Virtual test technology is the use of computer modeling and simulation technology combined with test technology, communication technology and computer technology. A new test technology developed for product performance test, technical index assessment, and comprehensive effectiveness evaluation [11]. Vehicle chassis dynamometer is an important vehicle test equipment. Through research on its construction technology, modeling technology, database management technology, test process modeling technology and platform technology, a virtual test system for vehicle chassis dynamometer is constructed, as shown in Figure 1. As shown, it provides performance evaluation and test verification technology for the development of new products throughout the entire product development process (from design to evaluation).

Through the research of virtual test system construction technology and modeling technology, a common technical support platform for each system of vehicle chassis dynamometer is built and dynamometer model, test vehicle model and virtual driving model are established to solve various vehicle tests heterogeneity, real-time, interchangeability and other issues in the process, improving the interoperability, reusability and versatility of the test system. A bridge of data exchange between physical test resources and virtual test verification tools are established to survive "test design-test run-test analysis" full life cycle for the test system.
Aiming at the multiple sources of test data for vehicle chassis dynamometer systems, the multi-source data volume is large, the structure is complex, the modal is changeable, the real-time performance is high, and the correlation is high. A distributed real-time test database is established, and the test data object management technology is adopted. Uniformly standardize various complex data structures and data formats, and support the maintenance, storage, transfer, conversion, matching, display and analysis of data during the vehicle test.

According to the vehicle chassis dynamometer test project, research the process modeling, control, and monitoring related content of the test system, and realize the process management of user login, system configuration, calibration, test, and output results based on the test project. According to the actual test process, develop a test process template to perform different tasks.

Based on the functional requirements of the vehicle chassis dynamometer system, the platform technology is studied. By integrating design tools such as solidwork, adams, matlab/simulink, solvers, and self-developed programs, the software can be automatically called and the data can be automatically uploaded. The appropriate tool software according to the test content and process is selected to develop corresponding analytical work.

4.2. Networked and Intelligent

The emergence of modern Internet technology has made the test system break through the traditional distance and geographical restrictions. The test data can be accessed at any time and anywhere. Therefore, the networked test system is one of the development trends and research focuses of the chassis dynamometer system. In terms of intelligence, the Institute of Internal Combustion Engines of Tianjin University developed a chassis dynamometer system based on EtherCat by integrating real-time Ethernet technology with multi-sensor acquisition and variable frequency control technology, and designed an autopilot to improve. The intelligence level of the chassis dynamometer system is also shown. Tianjin University [12] applied intelligent subject technology to the intelligent construction of vehicle chassis dynamometer system, constructed object dynamometer platform and road physical...
model using object-oriented technology, and realized MCG-100 vehicle chassis dynamometer VR 3D synchronous simulation platform.

Figure 2 is the hardware structure diagram of the newly developed chassis dynamometer. In terms of networking, the system adopts a layered design. The upper layer of the network layer adopts a CAN bus-based network architecture. The interface is reserved for later project expansion. The entire system communicates with the Internet through the Internet. Remotely log in to the computer to connect to achieve various test operations and monitoring. If abnormal conditions are found, the power can be cut off directly to terminate the test. In the bottom equipment layer, various sensors are used to collect signals such as speed and torque. The driving robot is integrated into the chassis dynamometer control system. The test cycle specified in the test standard is preset. Other tests can be easily customized on the self-programming platform. In the cycle, the controller is connected to the drive motor through the power module to realize the real-time loading of the dynamometer's resistance torque. It communicates with the test vehicle control module based on the CAN bus and can monitor the performance of each part of the vehicle engine through the CAN bus of the vehicle. The entire test process, including the selection of feature information points, data storage, gear shifting and acceleration of the entire vehicle, can be completed by software to achieve an unmanned test workshop and improve the level of intelligence.

![Figure 2: Vehicle chassis dynamometer hardware structure diagram.](image)

### 4.3. Function Expansion

The early chassis dynamometer had a single function and could only detect the parameters of the vehicle at low speed. With the deepening of the research, the functions of the vehicle chassis dynamometer were gradually improved. At present, its basic functions are: speed and odometer verification; chassis Power test; maximum speed test/lowest stable speed; acceleration test/taxi test; fuel economy test; start acceleration test/exceed acceleration test; long climb test/steep climb test.

In recent years, the functions of chassis dynamometers have continued to expand. For a dual-drum chassis dynamometer, the speed of the main and auxiliary drums is measured to test the vehicle slip rate and the driving force/drive at different slip rates efficiency test. With further research, the chassis dynamometer can also perform functions such as vehicle wind resistance simulation, road load spectrum simulation, and vehicle shifting rule research.

By modifying the hardware of the chassis dynamometer and adding corresponding equipment, the functions of the chassis dynamometer can be further expanded. The addition of electrical power testers and other equipment can carry out related tests of new energy vehicles, such as vehicle driving mileage test and vehicle energy consumption rate test. And battery electrical performance test. It is also possible to test tractor traction performance by adding a traction device to simulate the tractor's rotary tiller, such as the maximum traction test and traction power test. In terms of software, the chassis
dynamometer can realize an open road cycle editing function through a V-type development model based on rapid prototypes.

5. Conclusion
This article summarizes that the vehicle chassis dynamometer has gone through three stages: mechanical simulation, mechanical-electric simulation, and electrical simulation. Due to the excellent dynamic and static response of AC motors, AC chassis dynamometers have become the mainstream trend. The key points for future research are proposed: the use of virtual test technology to build a vehicle chassis dynamometer system to support the vehicle's full life cycle verification; the use of modern measurement and control devices for the chassis dynamometer measurement and control system to improve the level of networked intelligence; through transformation of hardware and development of software to expand the test objects and functions of the chassis dynamometer.

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