Construction and experimental research of multifunctional hybrid powertrain test bench

Yi Yan¹,²,*, Bin Chen¹,², Zhi Yang Liu¹,², Bo Huang¹,²

¹China Merchants Testing Certification Vehicle Technology Research Institute Co., Ltd., Chongqing, China
²Chongqing Key Laboratory of Industrial and Information Technology of Electric Vehicle Safety Evaluation, Chongqing, China

*Corresponding author e-mail: cjyanyi@cmhk.com

Abstract. With the development of hybrid electric vehicles, the demand for test benches is becoming more and more vigorous. Based on the traditional engine test bench, this paper builds a multifunctional hybrid powertrain test bench by matching appropriate equipment such as battery simulators, power analyzers, fuel consumption meters, and air flow meters. The test bench has the characteristics of modularization, flexibility, and multi-function. It can be used for testing single engine, single generator and hybrid power system. Finally, the range extender produced by a domestic manufacturer was used as the test object, and the endurance test was carried out on the modified test bench. The test further verified the reliability and feasibility of the multifunctional hybrid powertrain test bench.

Keywords: Hybrid electric vehicles, Test Bench.

1. Introduction

Major automakers and parts companies at home and abroad have deployed hybrid systems one after another. Products are constantly being introduced and the technological level is improving day by day. High integration is the trend and direction of the future development of hybrid powertrain systems, so a large number of hybrid powertrain benches are required for related tests. For passenger cars, although most manufacturers have their own hybrid powertrain test benches, due to the numerous test tasks and long test cycles, bench resources are very tight. For commercial vehicles, the current high-precision hybrid powertrain benches are expensive. Commercial vehicle companies have almost no such powertrain benches. On the other hand, with the continuous development of new energy vehicles, the utilization rate of traditional engine benches is gradually decreasing. Based on this, a battery simulator, power analyzer and other equipment can be added to the engine benches to transform the engine benches into a multifunctional benches that can be used for engine testing, motor testing and hybrid system testing. Compared with purchasing a special hybrid powertrain bench, this method is low-cost and has the ability to be compatible with a variety of test objects. The first part of the article introduces the development trend of hybrid electric vehicles and the situation of hybrid test benches. Part II explains the process of building a multifunctional powertrain test bench, Part III takes the range extender produced by a domestic company as the test object to verify the practicality of the
multifunctional hybrid powertrain test bench. Part IV is grateful to the units and projects that have supported and funded this research.

2. Hybrid powertrain system development trend and test bench introduction

2.1. Development Trend of Hybrid Powertrain System
As the country's requirements for vehicle emissions and fuel consumption become more and more stringent, major OEMs and parts manufacturers will regard hybrid vehicles as their new growth point and breakthrough point in their future strategic planning. The future development of hybrid technology will show the following trends. From the perspective of engines, due to changes in usage scenarios, the future hybrid dedicated engines will continue to evolve toward high efficiency, constant working conditions, simplicity, and low cost. In terms of transmission, the degree of electromechanical coupling of the hybrid transmission will gradually deepen, so that the engine will change from surface operating conditions to line operating conditions or even point operating conditions to improve fuel system economy. From the perspective of motor electronic control, the motor will develop in the direction of high speed, high pressure and high efficiency. The electronic control system will gradually be iterated from a distributed architecture to a centralized. From the perspective of the battery system, the system integration and cell power density will be further improved, and the vehicle performance will be improved through efficient thermal management and integrated lightweight design.

2.2. Introduction to Hybrid Powertrain System Test Bench
Major institutions and universities at home and abroad have set up hybrid powertrain system test benches. The University of Stuttgart has built a test bench that can be used for hybrid powertrain system testing of various configurations [1]. Xing Jinjin and others of Shanghai Jieneng Automotive Technology Co., Ltd. used LabVIEW software to build a test bench for transient simulation of commercial vehicle hybrid powertrain systems [2]. Luo Yongping from Chongqing University has built a hybrid powertrain test bench with multi-source testing capabilities [3, 4]. The above test benches are all modified by adding modules such as battery simulators, power analyzers, and cooling systems on the basis of traditional engine test benches. It can be seen that this method is highly feasible.

3. Build the Test bench

3.1. Requirements and composition of multifunctional hybrid powertrain System test bench
The configuration of the hybrid powertrain system is complex, which leads to the lack of a fixed form of the hybrid powertrain test bench. Therefore, the test bench should have the characteristics of modularization, flexibility, and multifunction to meet the test requirements of the multi-source powertrain. This requires the test bench to meet:

(a). Able to carry out individual tests, debugging and calibration of important hybrid powertrain components such as engines, motors, generators, and provide corresponding operating environment

(b). Able to perform testing, debugging and calibration of hybrid powertrains of various configurations, and effectively provide a comprehensive evaluation of the powertrain performance, economy and other performance and provide a verification platform for the control strategy and algorithm of the hybrid powertrain system.

(c). While completing the vehicle dynamics test, it provides the simulation of the road driving conditions of the hybrid electric vehicle, and can carry out the test of the working conditions specified in the relevant national laws and regulations.

The hybrid powertrain test bench includes the following modules:
(a). Modules under test Including engines, electric motors, transmissions, controllers, power coupling devices, etc.
(b). Load modules, including electric dynamometers, brakes, etc.
(c). Measurement and control modules, including power analyzers, torque sensors, temperature and
pressure sensors, vehicle control systems, engine control systems, motor control systems, power battery control systems, transmission control systems, dynamometer control systems, etc.

(d) Operation guarantee module, including temperature control system, compressed air, smoke exhaust system, fuel supply system, intake air conditioning, etc.

3.2. **Multifunctional hybrid powertrain test bench construction**

The multifunctional hybrid powertrain test bench described in this article is shown in Figure 1. A battery simulator, power analyzer, fuel consumption meter and air flow meter are added on the basis of the engine bench. Complete platform control and communication with the hybrid powertrain system HCU through the desktop host computer. Multifunctional hybrid powertrain test bench can complete the test of single engine, single motor, and hybrid powertrain System. Through the control of the host computer, the simulation of constant working conditions, variable working conditions and road driving conditions can also be realized.

![Schematic diagram of test bench](image)

**Figure 1.** Schematic diagram of test bench

4. **Test verification**

This article takes the range extender produced by a domestic manufacturer as the test object to test the durability performance of the range extender under variable load conditions, frequent start and stop conditions, and overspeed conditions. The test site is shown in Figure 2.

![Test site](image)

**Figure 2.** Test site
The results after the test are shown in Table 1 below.

**Table 1. Summary of test results**

| Test type | Test projects | unit | Deviation/deterioration rate limit | Deviation/deterioration rate (%) |
|-----------|---------------|------|-----------------------------------|---------------------------------|
| Deterioration rate of performance indicators after reliability | General startability | Time(s) | ≤2 | / |
| | Idle speed | r/min | ≤±10 | / |
| | Highest efficiency generating speed/power | r/min/kW | ≤3% | 0.07 |
| | Rated generating speed/power | r/min/kW | ≤3% | 0.1 |
| | Peak generating speed/power | r/min/kW | ≤3% | -1.42 |
| | Maximum speed rated generating speed/power | r/min/kW | ≤3% | -1.03 |
| | Maximum speed peak generating speed/power | r/min/kW | ≤3% | -0.69 |
| | The highest efficiency power generation lowest point specific fuel consumption | g/(kW·h) | ≤2% | -4.01 |
| | Rated minimum fuel consumption for power generation | g/(kW·h) | ≤2% | -3.55 |
| | Minimum fuel consumption for peak power generation | g/(kW·h) | ≤2% | -2.24 |
| | Maximum speed rated power generation minimum fuel specific fuel consumption | g/(kW·h) | ≤2% | -3.34 |
| | Lowest specific fuel consumption for peak power generation at maximum speed | g/(kW·h) | ≤2% | -3.06 |

| Number and frequency of reliability test failures | Fatal failure | Time(s) | / | / |
| | Serious failure | Time(s) | / | / |
| | General failure | Time(s) | / | 2 |
| | Minor failure | Time(s) | / | 1 |
| | Mean time to failure | hours | ≥50 | / |
| | Mean time between failures | hours | ≥30 | / |

| Evaluation of mechanical disassembly inspection after reliability | Fatal injury | Numbers | / | / |
| | Serious injury | Numbers | / | / |
| | General injury | Numbers | / | / |
| | Minor injury | Numbers | / | 2 |
It can be seen from the table that after the test the range extender exceeded the limit in the highest efficiency power generation lowest point specific fuel consumption, Rated minimum fuel consumption for power generation, Minimum fuel consumption for peak power generation, Maximum speed rated power generation minimum fuel specific fuel consumption, Lowest specific fuel consumption for peak power generation at maximum speed. The durability of the prototype needs to be further optimized. The modified multifunctional hybrid power train bench can fully meet the needs of hybrid powertrain testing. Through this experiment, the manufacturer has also found the shortcomings of the prototype design, and provided a reference and basis for the manufacturer's next optimization.

Acknowledgments
Thanks to China Merchants Testing Certification Vehicle Technology Research Institute Co., Ltd. Chongqing Key Laboratory of Industrial and Information Technology of Electric Vehicle Safety Evaluation. Thanks for the support of the project: Research on Testing Technology of Commercial Vehicle Hybrid Powertrain (19AKC4)

References
[1] Ing. D, Michael, Böhm, et al. The New PowerTrain and Hybrid Test Bench at the University of Stuttgart[J]. Mtz Worldwide Emagazine, 2011.
[2] Jinjin X, Hua S, Yunxiao L. Commercial vehicle hybrid powertrain test bench construction[J]. Electronic technology application, 2018,44(07):86-88.
[3] Yongping L. Research on Multi-energy Powertrain Test System and Test Technology [D], 2015.
[4] Zhifu Z. Hybrid Electric Vehicle Transmission System Design and Bench Test [D], 2012.