

Robot driver for vehicle durability emission test on chassis dynamometer

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Abstract: A method for a vehicle durability emission test using a robot driver instead of human drivers on the chassis dynamometer is presented. The system architecture of vehicle durability emission test cell, the road load simulation strategy and the tele-monitoring system based on Browser/Client structure are described. Furthermore, the construction of the robot driver, vehicle performance self-learning algorithm, multi-mode vehicle control model and vehicle speed tracking strategy based on fuzzy logic are also discussed. Besides, the capability of control parameters self-compensation on-line makes it possible to compensate the wear of vehicle components and the variety of clutch true bite point during the long term test. Experimental results show that the robot driver can be applicable to a wide variety of vehicles and the obtained results stay within a tolerance band of ± 2 km/h. Moreover the robot driver is able to control tested vehicles with good repeatability and consistency; therefore, this method presents a solution to eliminate the uncertainty of emission test results by human drivers and to ensure the accuracy and reliability of emission test results.

Key words: robot driver; durability emission test; chassis dynamometer; driving test cycle

Due to the increasingly strict laws of environmental protection, emission regulations for vehicles are more rigid. Furthermore, with the rapid increase of vehicles in use, the percentage of pollution to atmosphere generated by vehicle exhaust emission gas is increasing. The automobile industry has exerted tremendous effort to decrease the quantity of exhaust gas and improve fuel economy. Moreover, the type approval test of ageing test for verifying the durability of anti-pollution devices prescribed in GB 18352.2—2001 regulates that a vehicle must be tested following a specified type-V driving cycle (a speed versus time trace) for 8×10^4 km on a straight even proving ground or on the chassis dynamometer test stand^[1].

A conventional way to measure the vehicle emission level is usually performed by a trained human driver following a prescribed driving test cycle on the chassis dynamometer. However, the variable nature of human drivers' behavior greatly influences emission test results, especially for low and ultra-low emission vehicles. To eliminate the uncertainty of test results and to free test drivers from uncomfortable and tedious working conditions, some automobile manufactures have developed robot drivers to replace human drivers in emission tests. The robot driver can produce

emission test results with good repeatability and accuracy, and therefore the test results are more reliable and valid^[2–4].

1 System Configuration and Road Load Simulation

1.1 System configuration

A vehicle durability emission test system is composed of a chassis dynamometer system, a robot driver system, an exhaust gas emission analyzer, an experimental vehicle and other auxiliary equipments, as shown in Fig. 1. The chassis dynamometer system provides a test environment for tested vehicles just like the straight and even road, and it provides protection equipment to fasten tested vehicles in emergency situations. It mainly consists of an electronic dynamometer, a roller and a set of flywheels. The robot driver system performs the driving task of tested vehicles following a given driving test cycle in replace of human drivers to obtain consistent driving patterns, and the exhaust gas emission analyzer acquires the elements in the exhaust gas of gasoline vehicles, such as hydrocarbons HC, CO_x and NO_x, every 10^4 km. And the driver aid displayer shows the real time vehicle speed for convenience. In addition, there are two fans to cool down rolling tyres.

1.2 Road load simulation

Under the condition of straight and even proving ground without tyre sliding, the forces acting on tested vehicles follow the equation as $F = F_f + F_j + F_w$,

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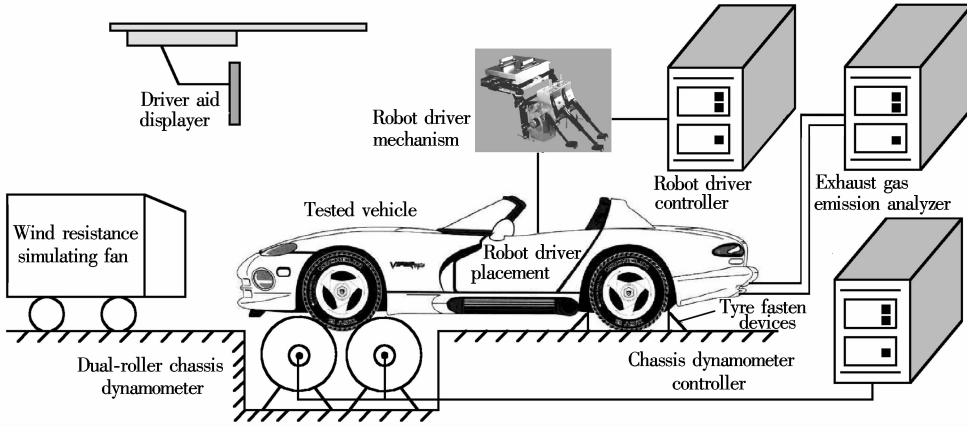


Fig. 1 Configuration of the vehicle durability emission test system

where F_f , F_j and F_w are the rolling resistance, acceleration resistance and wind resistance, respectively. F_j is simulated by combination of six flywheels as the vehicle rolling inertia, and these flywheels are jointed to the rollers via an electromagnetic clutch. F_f and F_w are the quadratic functions of vehicle speed v , respectively. The load force $F = A + Bv + Cv^2$, where A , B and C are the coefficients which are normally obtained experimentally from a coast-down test on a level road. By regulating the load voltage of the electronic backset dynamometer and the rolling speed of fan, a simulated environment of real road test can be realized on the chassis dynamometer test stand.

1.3 Tele-monitoring system

A set of tele-monitoring systems based on Browser/Client structure is integrated in the test system. The advantages are as follows: ① First, the supervising department of the vehicle test can easily monitor the real-time test situation, such as experimentation scene, test data and test carves via the Internet network; ② Secondly, researchers and developers can configure control parameters of tested vehicles, perform fault diagnosis and eliminate malfunctions; therefore, it is possible to gather vehicle performance data and establish an expert database of all kinds of vehicle types; ③ Finally, the vehicle manufacturers can obtain the durability emission test results of tested vehicles in time for further improvement of techniques and production flow.

2 Robot Driver Control System

2.1 Schematic diagram

The robot driver is very complicated and it primarily consists of the following components: a mechanical unit that includes actuators for the accelerator, brake, clutch pedals and the gear stick; sensors for position detection, force, vehicle speed and engine rolling speed measurement; pneumatic control units to drive pneumatic cylinders. Fig. 2 shows the schematic diagram of the robot driver system.

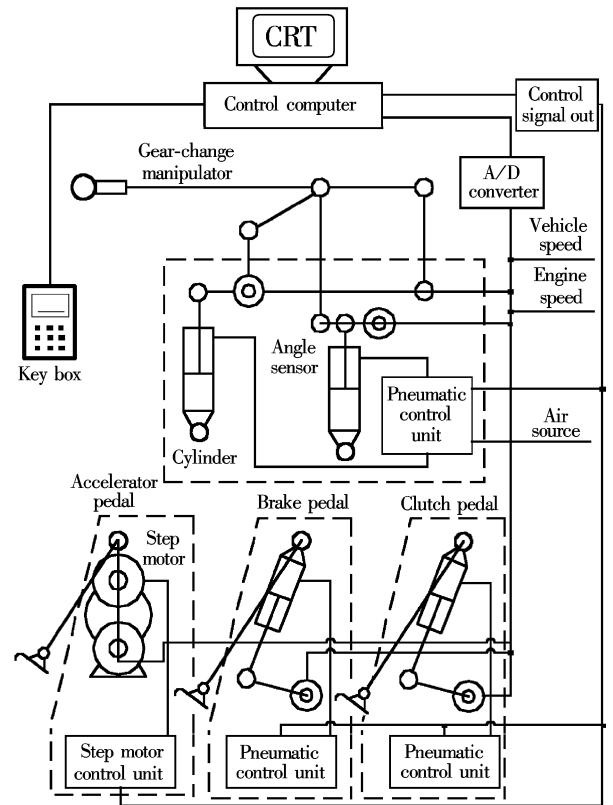


Fig. 2 Schematic diagram of the robot driver system

This paper is mainly concerned with two problems: ① Vehicle performance self-learning and self-compensation algorithm to improve the applicable ability of robot drivers; ② The vehicle speed tracking strategy to obtain good accuracy.

2.2 Vehicle performance self-learning algorithm

Because vehicle geometric size and dynamic parameters are markedly different, it is necessary to perform a special learning sequence to learn some basic information on tested vehicles and to reduce the preparation time before mileage accumulation test. The vehicle performance self-learning algorithm is structured in three steps. First, the basic mechanical components of

the robot driver are installed in the vehicle, and the actuators are attached to foot pedals and gearlever. Secondly, the robot driver automatically learns the position and travel distance of the accelerator, brake, and clutch pedals; this can be summarized as a geometric learning. Furthermore, human drivers teach the position of each gear to the robot driver by key box. In the last step, the robot driver performs a vehicle performance learning procedure. The robot driver learns the reactions of the vehicle speed to stepped changes of the throttle pedal in every gear and the relationship between brake force and deceleration respectively to create a performance map of the vehicle.

2.3 Multi-level vehicle control model

As mentioned above, a modern vehicle is an extremely complex system with non-linear characteristics. It is a difficult task for the robot driver to control the vehicle tested, being to follow the given driving cycle, and to manipulate the vehicle throttle while operating the gear shift and brake pedal. The best control strategy for a robot driver must be “human like”, that is to say, it should be able to think, judge and act like human drivers. A multi-level vehicle control model based on the Saridis’s hierarchical control architecture is provided in Fig. 3.

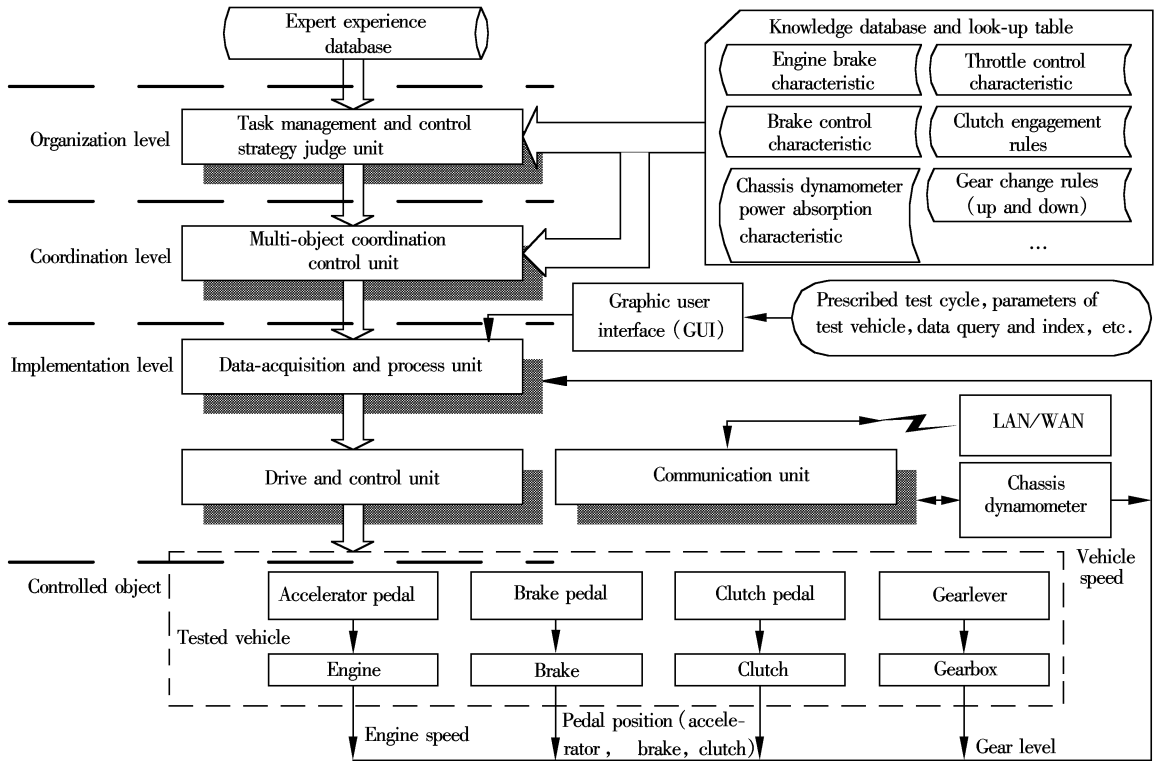


Fig. 3 Block diagram of the multi-level vehicle control model

The organization level syncretizes expert drivers’ experience, basic knowledge database and learned performance characteristics of tested vehicles, such as clutch engagement rules and brake control characteristics to make decisions on the action of the robot driver. In the coordination level, the robot driver collaborates with the actuators. There are many control modules in this level: brake force control module, throttle/brake switch module, clutch engage speed control module, gear shift position module, gear change module, speed cruise control module, and distance compensation module, etc. Take the gear change procedure, for example. The robot driver firstly disengages the clutch to full to cut off power transfer and at the same time re-

leases the throttle pedal; then shifts to the goal gear; engages clutch pedal to bite point quickly; presses throttle pedal slowly and synchronously engages clutch pedal slowly; after the engagement procedure, it fully engages the clutch pedal quickly^[5]. The detailed curve of the process is described in Fig. 4. Besides, the implementation level is the interface between control unit and users, chassis dynamometers, and actuators.

2.4 Vehicle speed tracking strategy based on fuzzy logic^[6-11]

Due to the fact that the fuzzy logic is similar to the thinking process of human drivers, a speed tracking algorithm based on the fuzzy control method is adopted. For the consideration of keeping good per-

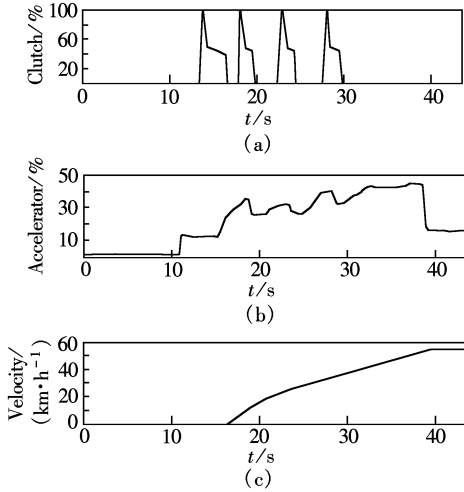


Fig. 4 Traces of startup and gear change process. (a) Clutch actuator position; (b) Accelerator actuator position; (c) Velocity

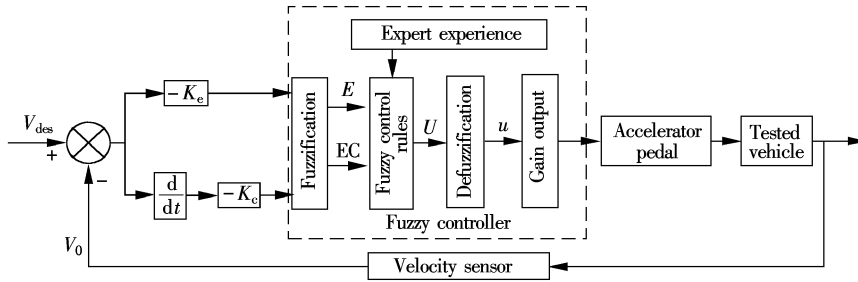


Fig. 5 Schematic diagram of the fuzzy logic velocity controller

formance of the engine, the goal of the speed tracking controller is to achieve a smooth driving style to reduce the fluctuating operation of throttle pedal which deteriorates emission results. That is to say, the control movement should try best to keep the accelerator pedal unchanged. The fuzzy control method can integrate the driving knowledge and experience of human drivers and it is robust to disturbance. Fig. 5 shows the diagram of the fuzzy logic velocity controller.

The diagram of the fuzzy controller is a two-input one-output controller. In an independent thread, the robot control program acquires the test vehicle’s speed to compute speed error and error variety, and then carries them through fuzzy reasoning to compute the movement value of the accelerator pedal (the anti-

fuzzy proportional factor is dependent on different cycle speeds). The output of the fuzzy controller propels step motor to control the accelerator pedal, and then controls vehicle speed.

In addition, to minimize unnecessary changes in the throttle position, the speed controller of the robot driver looks forward, that is to say, it uses the prescribed reference speed to a point about 1.5 to 2.0 s in the future.

2.5 Control parameters self-compensation on-line

Because of the wear and tear of vehicle components, it is necessary for the robot driver to self-tune the control constants to match the variable of vehicle characteristics during the long term durability emission test. In the speed tracking module, the robot driver controls the vehicle’s throttle based on the velocity error and the relationship stored in knowledge databases. By comparison of the output of controller with data stored in tables, the robot driver adjusts the table data on-line to compensate the control error. Moreover, since the true bite point of the clutch changes over the whole test period, the robot driver learns the correct start point from every startup procedure and applies it to the gear change procedure during the course of ac-

celeration. By this means, the wear and tear of the clutch can be compensated for during the complete durability test process.

3 Experimental Results and Analysis

To validate the control performance of the robot driver, experiments are performed in the durability emission test laboratory of Yuejin Automobile Group Company. Primary test equipments are listed in Tab. 1.

Tab. 1 Primary test equipments for vehicle durability emission test

Chassis dynamometer	MD900
Vehicle model	Siena ELX
Transmission type	Manual, 5
Manufacturer	Mustang
Engine volume/L	1.461
Fly wheels weight/kg	907.2

After configuring the test parameters such as vehicle information, speed table, drive sequence table, shift sequence table, and bringing the chassis dynamometer control computer into action, the robot driver automatically performs the driving of given test cycle. Fig. 6 shows the three kinds of test cycle required in

GB 18352.2—2001. One part of 56 km/h test cycle result is shown in Fig. 7.

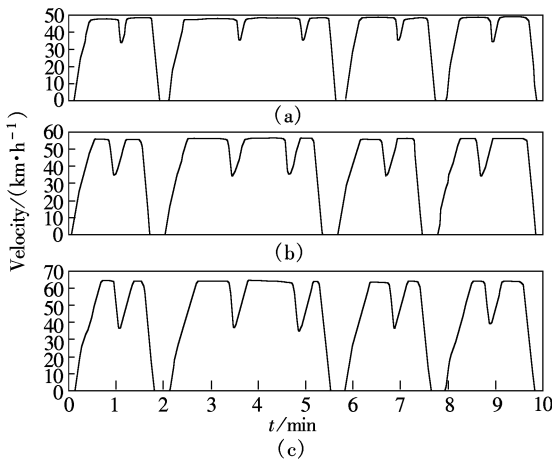


Fig. 6 Experimental results of three driving cycles. (a) 48 km/h test cycle; (b) 56 km/h test cycle; (c) 64 km/h test cycle

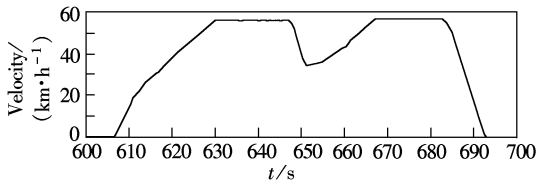


Fig. 7 Vehicle speed tracking result of 56 km/h test cycle

It can clearly be seen from the experimental results shown in Fig. 6 and Fig. 7 that the obtained results stay within a tolerance band of ± 2 km/h. No vibration occurs during the vehicle speed cruise control process and the trend line of vehicle speed is smooth with high accuracy.

4 Conclusion

Compared with the durability emission test on road driving by human drivers, the robot driver has advantages in test time, cost and test accuracy. The method is applicable to a wide variety of vehicles. Moreover, the test process and results can be monitored. The application of robot drivers includes exhaust emission test, climatic test, durability emission test, and fuel economy test. It can markedly quicken the development and test procedure of new model vehicles and provide more reliable and repeatable results than human drivers.

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底盘测功机上用于汽车排放耐久性试验的驾驶机器人

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摘要: 提出利用驾驶机器人在底盘测功机上代替人类驾驶员进行排放耐久性试验的方法. 给出了汽车排放耐久性试验系统的组成, 底盘测功机道路阻力模拟策略和基于 B/S 架构的远程监控系统; 着重讨论了驾驶机器人的构成, 汽车性能自学习算法, 多层汽车控制模型和基于模糊逻辑的车速跟踪控制方法. 此外, 驾驶机器人还具有控制参数在线补偿能力, 补偿了长时间试验过程中汽车部件的磨损以及离合器接合点的漂移. 试验结果表明, 驾驶机器人车速控制精度在 ± 2 km/h 范围内, 精度高, 重复性好, 可以消除汽车试验中人为因素的影响, 保证了排放试验数据的准确度和有效性.

关键词: 驾驶机器人; 排放耐久性试验; 底盘测功机; 驾驶循环工况

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