[Test Systems]

New Type of Drive Robot System

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Abstract

As the rate of automobile development has increased and technology has become more complex in recent years, the necessity and importance of vehicle evaluation in a test laboratory has increased. In testing labs, a number of chassis dynamometers are increasingly being used to test complete vehicles, and challenges such as an increase in driving time for drivers and high requirements for driving accuracy are growing. Demand is rising for a drive robot, a device used on a chassis dynamometer to perform automated driving in vehicle development, such as exhaust gas tests for internal combustion engine vehicles and electricity efficiency tests for Electric Vehicles (EVs). The vehicle's accelerator, clutch, transmission, brake, and ignition key can be operated using electric actuators in the same way as a human operator, allowing the vehicle to be driven in any test driving pattern. To meet the market's expectations for drive robots in recent years, we have updated the actuator, control panel, and operation control.

1 Preface

There is a current increase in demand for drive robots that perform accelerator, brake, and shift operations in place of the driver for the reproduction of vehicle driving on chassis dynamometers and in environmental tests simulating cold and high altitudes. Requirements for the usability of drive robots include the ability to add them to existing chassis dynamometer equipment and the ability to share them across multiple test rooms.

In response to changing customer demands and increased precision, we have developed new robot actuators, operation panels, and controls. This paper introduces the new drive robot TYPE-i.

2 Standard Specifications

Fig. 1 shows the configuration of the drive robot system. The operation panel is connected to the robot actuators, and consists of a Personal Computer (PC) that performs operation and measurement, a controller (MDC II) that controls the robot system, a Programmable Logic Controller (PLC) that controls the actuators, and a servo driver.

Table 1 shows a list of standard specifications,

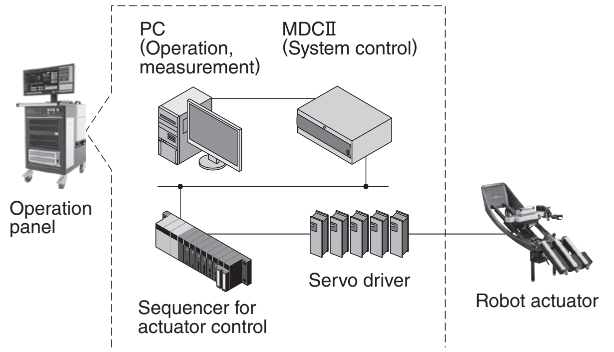

Fig. 1 Configuration of Drive Robot System

An overall configuration of the drive robot system is shown.

and Fig. 2 shows an outline drawing.

3 New Type Robot Actuator

Conventional robot actuators have a total mass of approximately 70 kg, and each part must be mounted on the seat of a vehicle by a testing section personnel in a half- seated position. Such a robot setting work was challenging. Reducing the burden on workers and responding to the requirement that such installation work can be done by

Table 1 List of Standard Specifications

Major specifications of the drive robot system are shown.

Operation control functions	Auto/manual operation
	Vehicle speed control (Time, distance)
	Accelerator aperture control
	Brake ON/OFF
	Clutch ON/OFF
	Shift position selection
	Actuator stroke range adjustment
Learning function	Drive force characteristic logging
Mass	Actuator: 23.5 kg (Including frame, shift, accelerator, brake, and clutch actuator)
	Operation panel: 105 kg
Edit function	Operational schedule editing
	200,000 steps per mode
	Foul judgment function
	Step transfer condition (Time, distance, measurement)
Display function	Analog display, digital meter, bar graphs
	Chronological display
Measuring functions	Sampling period: 1 ms minimum
	Scheduler interlock function
	Result output (CSV, MAT, ATFX)
	Versatile analog input/output
	OBD data measurement
Operating environment	Actuator Ambient temperature: 0-40℃, Ambient humidity: RH30-80%
	Control wagon Ambient temperature: 0-40℃, Ambient humidity: RH30-80%
Options	Seat cover, optional fixing arm, shift chucking
Actuator operating force	Rated operating force and stroke
Accelerator	160 N/150 mm 0.2 s
Brake	400 N/200 mm 0.4 s
Clutch	250 N/200 mm 0.3 s
Shift	140 N/250 mm 0.2 s
Selection	120 N/200 mm 0.2 s

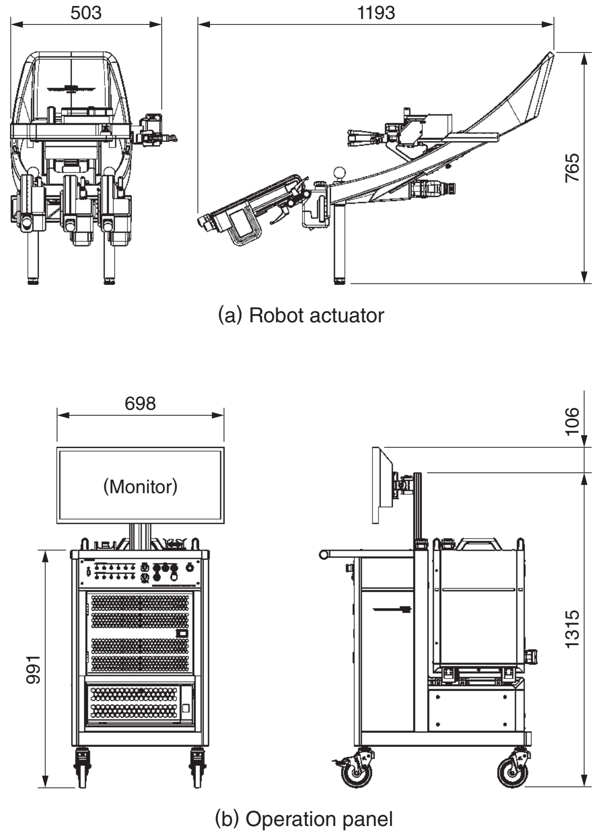

Fig. 2 Outline Drawing

External dimensions are shown for (a) robot actuator and (b) operation panel.

(a) How to attach and detach shift actuator

(b) How to attach and detach pedal actuator

Fig. 3 How to Attach and Detach Divided Parts

(a) shows how to attach and detach shift actuator and (b) shows how to attach and detach pedal actuator.

people of all ages and genders, we worked to significantly reduce the mass.

As for the overall structure, the newly developed product was developed under the supervision of our design department, and while incorporating a design that is friendly to people and vehicles, it has a Carbon Fiber Reinforced Plastic (CFRP) frame. By optimizing the structure using plastic molded parts and incorporating a split structure, we also achieved a reduction in the number of parts and mass reduction to a total mass of 23.5 kg. Each part has a mass less than 8 kg. Anyone can, therefore, easily install it. In addition, we devised an actuator holding structure with an integrated connector that completes the electrical wiring connection at the same time as fixing the actuator, eliminating the need for complicated cable connection work. Fig. 3 shows how to attach and detach the divided parts.

To install the actuator on the seat, it is difficult to firmly hold it there because car seat is made to be

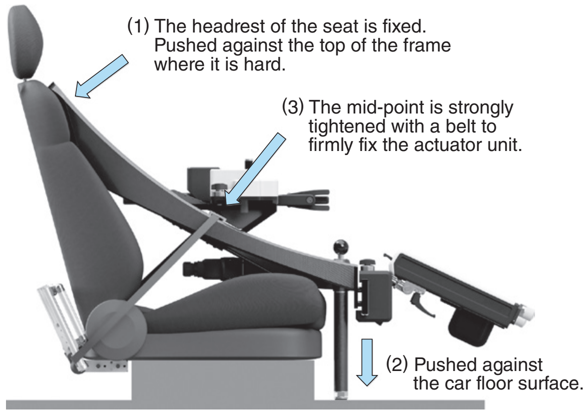

Fig. 4 **How to Affix Firmly on Vehicle Seat**

The actuator unit is not just placed on the seat, it is firmly fastened on the seat and to the floor of the car, and tightened with a belt so that both fixing strength and usability can be secured.

Fig. 5 **Robot Actuator**

An external appearance of the robot actuator is shown.

soft and gentle on people, and there can be large differences in reproducibility depending on the setting accuracy of the person doing the installation work. This affects the vehicle control accuracy and misalignment. In Fig. 4, we reconsidered the fixing method as shown here. Two points ((1) the seat frame and (2) the floor legs) are fixed in the 3-point fixation method by combining (3) where the sling belt is tightened. The strong fixation that does not depend on skill level was achieved. By simply putting the robot on the seat and securing it with a belt, it can be installed easily and quickly.

Fig. 5 shows the external appearance of the robot actuator. The development concept that reduces the burden on workers, such as the significant mass reduction and ease of installation, was highly praised and won two design awards.

Fig. 6 **Operation Panel of Drive Robot**

The operation panel of drive robot is shown.

(1) 2021: Good Design Award[(1)]
(2) 2022: Red Dot Design Award[(2)]

4 New Type of Operation Panel

Fig. 6 shows the appearance of the operation panel of the drive robot. The operation panel that operates and controls the drive robot is our unique mobile operation panel. Like the drive robot, the mass of the conventional model was 165 kg, but now it mass 105 kg. The smaller size and lighter mass improve portability. The servo driver unit of the operation panel can be installed separately from the operation panel, allowing for flexible equipment layouts that suit the test environment, such as remote control between the test room and the control room. The operation screen has been improved to be easier to see and use, and the software has also been significantly improved in operability compared to previous models, including improved design coordination with the drive robot and improved control performance.

5 New Control Method

Fig. 7 shows an example of a driver model for drive robot control. In addition to measuring driving force characteristics, which previously only measured on the accelerator side, we have enhanced the

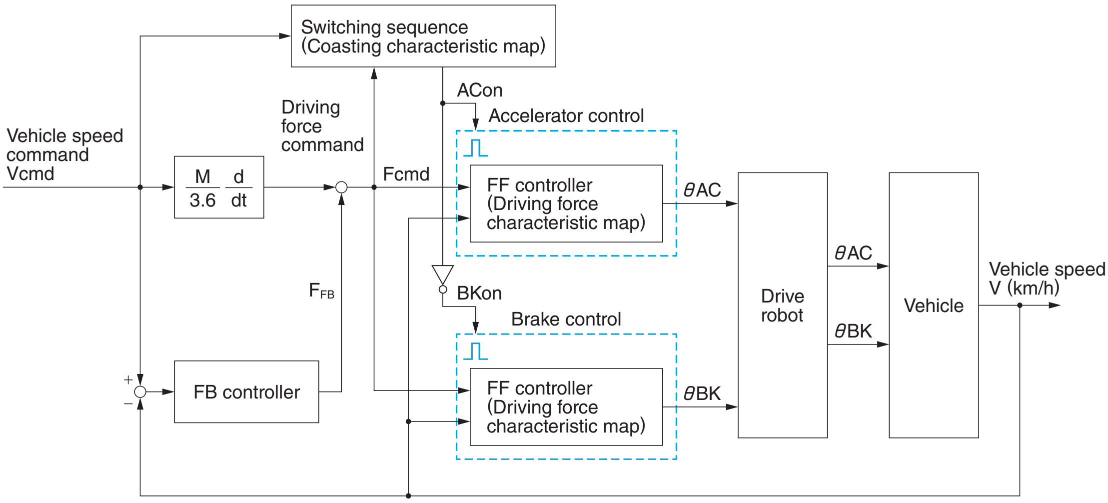

Fig. 7 **Example of Driver Model**

This shows the system overview diagram of drive robot control.

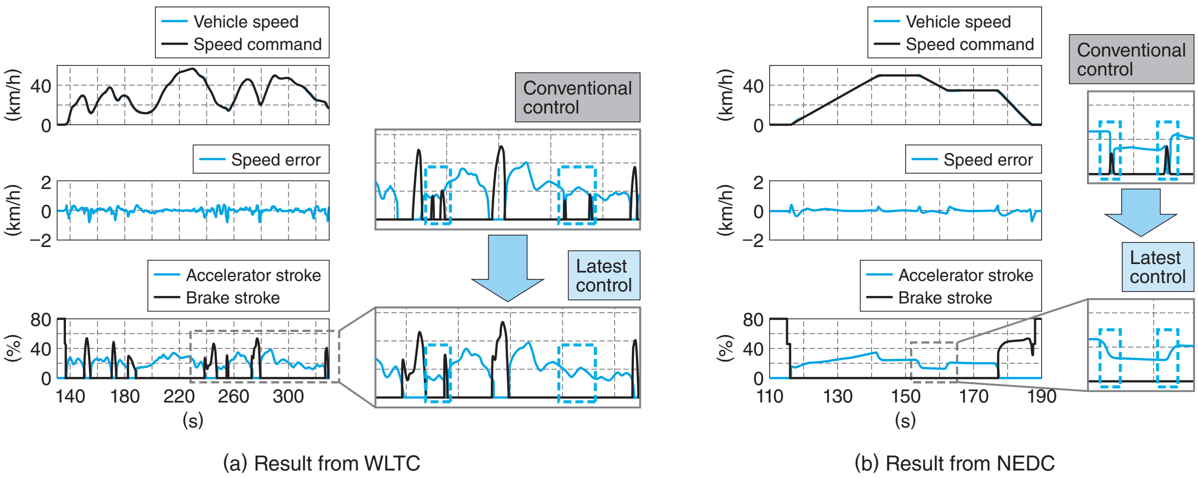

Fig. 8 **Comparison of Accelerator and Brake Operations**

The result of driving in WLTC drive mode is shown. The situation of brake improvement is also shown.

ability to acquire vehicle characteristics such as braking force characteristics and coasting characteristics on the brake side. In addition to reviewing the control structure, vehicle characteristics have been reflected in accelerator/brake control and pedal shift sequences. Vehicle characteristics are determined through automatic recording and analysis of driving data from driving learning mode. This vehicle characteristic measurement test can be performed with a single button from the operation panel as part of driving adjustment.

By accurately understanding the characteristics of each vehicle in detail, we have achieved accelerator and brake work that produces high follow-up performance, as well as optimal decision-making when stepping on the pedal.

6 Example of Actual Vehicle Test

Using a new type of drive robot, the operation tests were conducted to total 19 types of passenger cars including the StepAT, a Continuously Variable Transmission (CVT) unit, a Hybrid Electric Vehicle (HEV), and a Battery Electric Vehicle (BEV).

Fig. 8 shows a comparison of the accelerator and brake operations between the old drive robot and the new drive robot in the running results at the Worldwide-harmonized Light vehicles Test Cycle (WLTC) and the New European Driving Cycle (NEDC).

Compared with the conventional control, the new control reduces the number of pedal changes, making it possible to make optimal pedal change

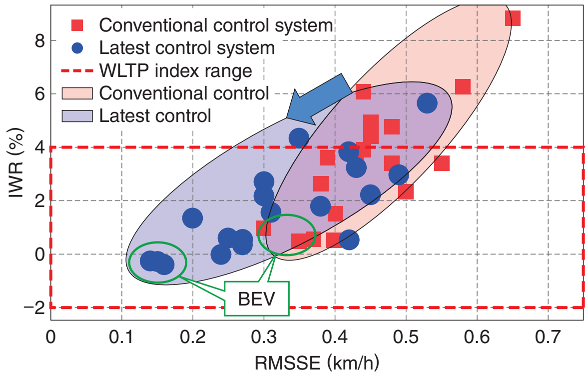

Fig. 9 Correlation between Driving Indicators

The result of the driving index evaluation (RMSSE vs. IWR) in 19-model driving is shown.

decisions closely like how people actually drive.

Fig. 9 shows the correlation between driving indicators. Regarding WLTC driving results, the Worldwide harmonized Light-duty Test Procedure (WLTP) driving index measures the discrepancy between the reference vehicle speed of the driving results and the actual vehicle speed. In this connection, **Fig. 9** shows the result of mapping with Inertia Work Rating (IWR) and Root Mean Square of Speed Error (RMSSE) indicated on the axes of coordinates and abscissas. Each point is the result for each vehicle, ■ is the result with conventional control, and ● is the result with the latest control. As WLTP indicators, RMSSE is less than 1.3 km and IWR is within −2.0 to 4.0%. With conventional control, some vehicles are outside the WLTP index, but with the latest control, more vehicles are included within the WLTP index. As an overall trend, driving indicators have improved, and especially in BEV vehicles, robot control has fully brought out the controllability of the vehicle itself, achieving high scores comparable to that of professional drivers.

7 Postscript

We introduced the new drive robot TYPE-i. Drive robots are in high demand for performing tests as a replacement for test drivers. Such tests place a heavy burden on test drivers, such as for long periods of time, high repetitions, or under harsh environments for tests that require repeatability under the same conditions.

In the future, we will continue to strive to improve the performance and quality of drive robots, such as their ability to follow a vehicle speed, achieving both compact size and lightweight, durability, operational convenience, and provide products that meet the needs of our customers.

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