

Comparison of Fuel Economy and Exhaust Emission Tests of 4WD Vehicles using Single-Axis Chassis Dynamometer and Dual-Axis Chassis Dynamometer

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ABSTRACT

The demands of application of dual-axis chassis dynamometers (4WD-CHDY) have increased recently due to the improvement of performance of 4WD-CHDY and an increase in the number of 4WD vehicles which are difficult to convert to 2WD. However, there are few evaluations of any differences between fuel economy and exhaust emission levels in the case of 2WD-CHDY with conversion from 4WD to 2WD (2WD-mode) and 4WD-CHDY without conversion to 2WD (4WD-mode).

Fuel economy and exhaust emission tests of 4WD vehicle equipped with a typical 4WD mechanism were performed to investigate any differences between the case of the 2WD-mode and the 4WD-mode. In these tests, we measured 'work at wheel' (wheel-work) using wheel torque meters.

A comparison of the 2WD-mode and the 4WD-mode reveals a difference of fuel economy (2WD-mode is 1.5% better than that of 4WD-mode) and wheel-work (2WD-mode is 3.9% less than that of 4WD-mode). However, there are almost no differences of exhaust emission levels.

We found the difference of work of loss at tire (tire-loss-work) between the 2WD-mode and the 4WD-mode affects the difference of fuel economy. Moreover, we found the difference of driving force of each tire affects the difference of the total amount of tire-loss-work between the 2WD-mode and the 4WD-mode.

Such evaluation of these differences is new area of research and there are very few studies using wheel torque meters. Therefore, these results provide very

valuable information to assess the future necessity of application of 4WD-CHDY.

INTRODUCTION

We currently use single-axis chassis dynamometers (2WD-CHDY) with conversion to two-wheel-drive (2WD) for fuel economy and exhaust emission tests of four-wheel-drive (4WD) vehicles. On the other hand, the demands of application of dual-axis chassis dynamometers (4WD-CHDY) have increased recently. Figure 1 illustrates the test case of 2WD-CHDY with conversion from 4WD to 2WD (2WD-mode) and 4WD-CHDY without conversion to 2WD (4WD-mode).

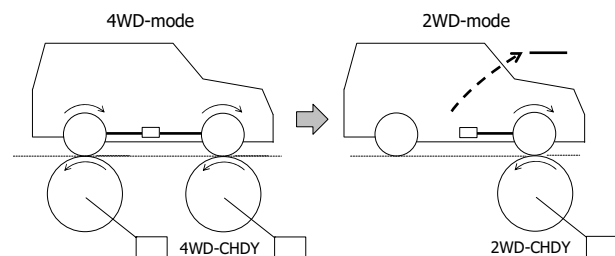


Figure 1 Images of 4WD-mode and 2WD-mode

The following two points are reasons why the demands of the application of 4WD-CHDY have increased.

First, over the past decade, the number of 4WD vehicles that are impossible to convert to 2WD has increased. The reason is the increase of manufacture of 4WD vehicles that include various 4WD mechanisms for the improvement of running stability or drivability on rough roads.

Second, there is a possibility that the characteristics of drive-train-loss such as loss at tire and the drive train

system are different between the 4WD-mode and the 2WD-mode.

Moreover, the reduction of the number of tires in the 2WD-mode has the possibility to influence the loss and the regeneration quantity of electricity in electric 4WD vehicles.

While the demand of application of 4WD-CHDY has increased, 4WD dynamometer technology has also improved. Research in 1992 evaluated 4WD-CHDY as lacking sufficient load reproducibility and speed equality control of front and rear rollers due to the type of mechanical structure and deficient control performance [1]. However, studies in 2007 reported improved 4WD-CHDY performance [2, 3]. Another study in 2009 [4] reported if some requirements of vehicle restraint, cooling system and test procedures are satisfied, 4WD-CHDY system can reproduce vehicle output work constantly.

However, any differences between the 2WD-mode that is current test condition and the 4WD-mode have not been clarified yet. For this reason, future necessity of application of 4WD-CHDY to fuel economy and exhaust emission tests is still unclear.

Therefore, this study seeks to clarify the differences of fuel economy and exhaust emissions between the 4WD-mode and the 2WD-mode by comparisons of tests of 4WD vehicle.

In this study, fuel economy and exhaust emission tests of 4WD vehicles equipped with a typical 4WD mechanism were performed to investigate any differences between the 4WD-mode and the 2WD-mode. In these tests, we measured 'work at wheel' (wheel-work) using wheel torque meters.

We clarified the difference of fuel economy, exhaust emissions and wheel-work between the 4WD-mode and the 2WD-mode. Moreover, the factor of the difference of wheel-work was investigated by dividing into work consumed in part of the tires (tire-loss-work) and work transmitted to the rollers (roller-surface-work). In addition, the factor of the difference of tire-loss-work between the 4WD-mode and the 2WD-mode was examined focusing on the relation between driving force and the tire-loss.

TEST EQUIPMENT

Figure 2 illustrates the fuel economy and exhaust emission test system used for the tests. The details of each equipment are as follows.

VEHICLE

A vehicle equipped with an electronic control 4WD system was used for the tests. Table 1 lists the specifications of the test vehicle.

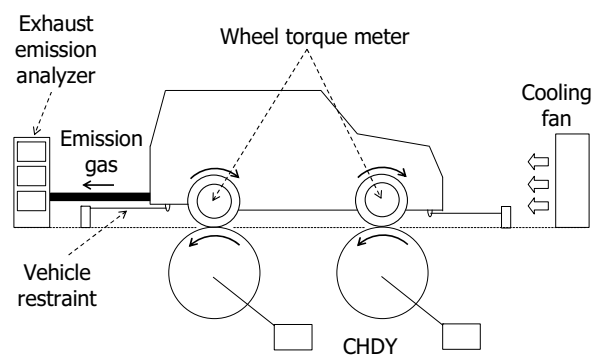


Figure 2 Fuel economy and exhaust emission test system (4WD-mode)

Table.1 Specifications of test vehicle

Type of 4WD system	Active torque control
Curb mass	1400 kg
Tested vehicle mass (including measurement equipment and testers)	1783 kg

Electronic control 4WD

Electronic control 4WD is a system to control the ratio of front and rear driving force using information of the difference of rotational speed of the front and rear wheels and electronic control coupling.

Ratio of driving force of main driving wheel

In the vehicle used for the tests, the ratio of driving force of the main driving wheels is about 80% on average in the Japanese driving pattern, 10·15 mode.

Method of converting to 2WD

We converted the vehicle to 2WD by detaching the propeller shaft in the 2WD-mode.

CHASSIS DYNAMOMETER (CHDY)

The tests were performed using the latest 4WD-CHDY. We can switch to both single-axis and dual-axis types. Table 2 lists the specifications of the CHDY system. This CHDY satisfies load control evaluation criteria [5].

Table.2 Specifications of CHDY system

Roller	Surface	Smooth
	Type	Single×2
	Diameter × Width	1591.5×800 mm
Dynamometer type		Over hang
Fixed mechanical inertia mass		Front: 950 kg Rear: 950 kg
Electric inertia range		-1100 ~ +1600 kg
Vehicle restraint		Chain pulling
Cooling fan	Type	Turbo fan
	Velocity	Equivalent vehicle speed
	Outlet size	800×1800 mm
	Distance to the radiator grille	1000 mm

Measurement of fuel economy

Fuel economy was calculated by the carbon balance method with exhaust emission analyzers. We referred the 'Test procedure of the fuel economy of gasoline vehicles in 10·15 mode' (TRIAS 5-3-1999).

Measurement of exhaust emissions

We measured CO, NMHC, and NO_x with the exhaust emission analyzers and referred to the 'Test procedure of the idling and 10·15 mode exhaust emission of gasoline vehicles' (TRIAS 23-4-1999).

Measurement of wheel-work

The wheel-work was calculated from the wheel torque and the rotational speed that were measured by wheel torque meters (Figure 3). Table 3 lists the specifications of the wheel torque meters. The rated capacity of the torque measurement of these meters is smaller than other general wheel torque meters to measure the torque during running the fuel economy and exhaust emission test cycle.

Table.3 Specifications of wheel torque meters

Rated capacity of torque measurement	$\pm 0.5 \text{ kN}\cdot\text{m}$
Type of signal transmission	Telemetry



Figure 3 Wheel torque meter

Zero point drift is created by the difference of temperature of the wheel torque meter. This temperature difference is created by heat in the brakes and the difference of vehicle warming up conditions. However, the effect of temperature drift on these meters is 0.6% or less of the wheel-work in the 10·15 mode.

TEST METHOD

TEST PROCEDURE

We referred to the 'Test procedure of the fuel economy of gasoline vehicles in 10·15 mode' (TRIAS 5-3-1999).

TEST CYCLE

The 10·15 mode, Japanese emission test cycle was used. Figure 4 illustrates the driving cycle of the 10·15 mode.

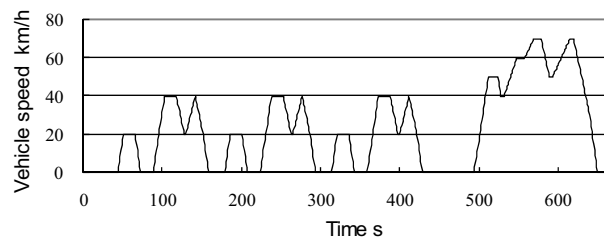


Figure 4 Driving cycle of 10·15 mode

ROAD LOAD

The following values were used for the calculation of the road load.

Inertia mass of the vehicle

The inertia mass of the vehicle was the measured values that included measurement equipments and drivers.

Inertia mass of the rotational parts

The inertia mass of the rotational parts was 1.8% of curb mass in the 2WD-mode and 3.5% of curb mass in the 4WD-mode. These values are described in the 'Test procedure of the fuel economy of gasoline vehicles in 10·15 mode' (TRIAS 5-3-1999).

CONDITION OF TARGET ROAD LOAD

We generally calculate the target road load for the CHDY test by coast down time measured on the test course. We used the road load measured in 4WD as a target road load for both the 4WD-mode tests and the 2WD-mode tests.

VEHICLE RESTRAINT

In the 4WD-mode, the vehicle restraint method is pulling by chain that is generally used in Japan. Figure 5 illustrates the vehicle restraint in the 4WD-mode.

In the 2WD-mode, the vehicle restraint method is fixing the rear wheel with belts that are generally used in Japan. Figure 6 illustrates the vehicle restraint in the 2WD-mode.

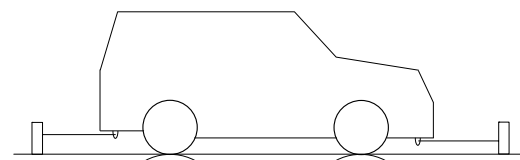


Figure 5 Vehicle restraint in 4WD-mode

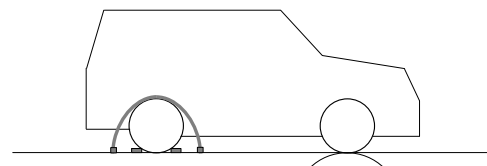


Figure 6 Vehicle restraint in 2WD-mode