



Automobiles — Requirements and evaluation
methods of chassis dynamometers for
four-wheel-drive vehicles — Supplement to fuel
consumption tests

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Automobiles — Requirements and evaluation methods of chassis dynamometers for four-wheel-drive vehicles — Supplement to fuel consumption tests

1. Scope

This standard stipulates requirements⁽³⁾ and evaluation methods⁽⁴⁾ for four-wheel-drive vehicle chassis dynamometers⁽¹⁾ when performing mode testing of fuel consumption rate for four-wheel-drive vehicles⁽²⁾ with a vehicle mass of 3,500 kg or less.

Note: ⁽¹⁾

A chassis dynamometer that can be used for a four-wheel-drive vehicle without vehicle modifications and that has single-axis rollers in both the front and rear.

Note: ⁽²⁾

A vehicle capable of generating drive force or recovering energy with all four of the vehicle wheels, front and rear.

Note: ⁽³⁾

Requirements for the chassis dynamometer body, vehicle cooling devices, vehicle restraining devices, etc.

Note: ⁽⁴⁾

Evaluation methods for chassis dynamometer performance

2. Normative reference

The following standard, when referred to in this standard, constitutes a part of the specifications of this standard. The latest edition of the referenced document (including any amendment) applies.

JIS D 1012 Automobiles -- Rate of fuel consumption test methods

3. Terms and definitions

For the purposes of this standard, the following terms and definitions, other than those given in **JIS D 1012**, apply.

3.1

target road load

road load obtained from driving tests on roads

3.2

chassis dynamometer load

load set to chassis dynamometer that included chassis dynamometer loss

3.3

dynamometer detection force

force detected by the chassis dynamometer load cell

3.4

target driving force

sum of inertia force which is calculated from equivalent inertia mass and target road load

3.5

measured driving force

sum of inertia force which is calculated from fixed inertia mass, dynamometer detection force, chassis dynamometer loss and vehicle loss

3.6

vehicle loss

loss generated due to vehicle drive systems and tire rotation, as measured on the chassis dynamometer

3.7

chassis dynamometer loss

loss that occurs due to the rotation of the chassis dynamometer, converted into a value for force on the roller surface

3.8

mechanical loss

sum of vehicle loss and chassis dynamometer loss

3.9

equivalent inertia mass

inertia mass set in the chassis dynamometer in accordance with the test vehicle mass

3.10

fixed inertia mass

mechanical inertia mass of the chassis dynamometer

3.11

rotating inertia mass

equivalent effective mass of rotating drive train and tires

3.12

electrical inertia mass

electrical inertia mass generated by the chassis dynamometer

3.13

wheel work

work calculated from the wheel-axis torque, which is measured with a wheel torque meter, etc

3.14

roller surface work

sum of work calculated from inertia force of fixed inertia mass, dynamometer detection force and chassis dynamometer loss

3.15

tire loss work

work of loss at the tires. On the chassis dynamometer, tire loss work is calculated from the difference of wheel work and roller surface work

3.16

roller speed

speed of the roller surface on the chassis dynamometer

3.17

primary drive wheels

wheels where the primary driving force is generated

3.18

roller driving distance

driving distance calculated from roller rotation pulses at the chassis dynamometer

3.19

front-rear roller speed difference

value calculated by subtracting the rear roller speed from the front roller speed

3.20

difference in front-rear roller interval distance

difference in driving distance over extremely short intervals, calculated from the front-rear roller speed difference

3.21

front-rear roller total distance difference rate

integrated value for the absolute value of the front-rear roller speed difference in all mode segments, which is calculated by dividing by the roller driving distance of the mode, and is expressed as a percentage

4. Requirements

4.1 General

The requirements for four-wheel-drive vehicle chassis dynamometer equipment and method of use when conducting mode fuel consumption rate testing shall be in accordance with **4.2 and 4.3**.

Note that requirements for mode fuel consumption rate tests that are not included in this standard shall be as indicated in **JIS D 1012**.

4.2 Equipment

4.2.1 Chassis dynamometer specifications

The chassis dynamometer specifications shall be as follows.

- a) There shall be one axis for each roller pair, front and rear.
- b) Roller diameter shall be 1.2 m or greater and the same front and rear.
- c) Roller surface shall be flat and smooth, and the same front and rear.
- d) The connection between the front and rear rollers shall be an electronic linkage.

4.2.2 Running load control performance and front-rear roller speed synchronicity for chassis dynamometer

Running load control performance and front-rear roller speed synchronicity shall be evaluated, and shall meet the allowable ranges in the evaluation items that follow. The allowable ranges are as shown in Table 1.

Note:

Running load control performance and front-rear roller speed synchronicity are evaluated by running the vehicle on the four-wheel-drive vehicle chassis dynamometer and recording and calculating data with the

evaluation device connected to the chassis dynamometer (refer to **Clause 5** for details). Running load control performance is calculated by measuring the dynamometer detection forces at the front and rear wheels during mode driving and adding them to obtain the measured driving force, and this is statistically evaluated against target running force using a linear regression formula. Moreover, front-rear roller speed synchronicity shall be evaluated to check that the mode driving distance ratios for front-rear roller speed difference during driving, the roller distance difference for a constant interval, and the front-rear roller driving distance difference for all model intervals, are all within the allowable value ranges.

Table 1 Evaluation indicators and allowable ranges for running load control performance and front-rear roller speed synchronicity

	Evaluation indicator	Symbol	Acceptable range
Running load control performance	Correlation coefficient	γ	0.98 or higher
	Tilt of regression line	a	1.00 ± 0.02
	Intercept of regression line	b	± 20 N
	Driving force deviation rate	s	5% or lower
Front-rear roller speed synchronicity	Front-rear roller speed difference	$\Delta \bar{V}_{\text{chdy, max}}$	0.16 km/h or lower
	Difference in front-rear roller interval distance	$\Delta X_{\text{chdymax}}$	0.10 m or lower
	Front-rear roller total distance difference rate	$\Delta X^{\circ}_{\text{chdy}}$	Within 0.20% of roller driving distance ^(a)
Note: ^(a) Use the speed signal selected in the running load control performance evaluation.			

4.2.3 Vehicle cooling device

The vehicle cooling device shall be capable of blowing wind on the front of the vehicle at a speed equivalent to the vehicle speed, and the area of the nozzle opening shall be 0.4 m² or more.

4.3 Method of use

4.3.1 Vehicle restraining method

The test vehicle shall be set on the chassis dynamometer in a totally straight position, the set road load shall be reproducible, and the vehicle shall be restrained to ensure safe testing. The front-to-rear center positions for tire contact surfaces shall be within ± 25 mm of the top of the roller or within $\pm 2\%$ of the roller diameter, whichever is smaller.

NOTE 1:

3.2.4.2 (Setting the vehicle) and **4.1.3.3** (Setting the vehicle) in **JIS D 1012** are related to this stipulation.

NOTE 2:

As an example of a vehicle restraining method to ensure reproducibility of the set road load, the uniform leveling method is shown in **Annex A**.

4.3.2 Warming up before setting road load

Warm up running before setting road load is as follows.

NOTE:

3.2.4.3 (Warming up the vehicle) in JIS D 1012 is related to this stipulation.

a) Load setting

For chassis dynamometers with coefficient settings, set the chassis dynamometer load using the coefficients A_d , B_d , and C_d in the formula that follows.

$$F_d = A_d + B_d V_{chdy} + C_d V_{chdy}^2$$

where,

- F_d : Chassis dynamometer load (N) during warm up running before setting road load.
- A_d : Chassis dynamometer load constant term (N) during warm up running before setting road load.
- B_d : Chassis dynamometer load primary term coefficient [N/(km/h)] during warm up running before setting road load.
- C_d : Chassis dynamometer load secondary term coefficient [N/(km/h)²] during warm up running before setting road load.
- V_{chdy} : Roller speed (km/h)

The recommended load setting method is shown below.

$$1) A_d = 0.1 \times A_t, \quad B_d = 0.2 \times B_t, \quad C_d = C_t$$

In this formula, A_t , B_t , and C_t are coefficients for target road load.

2) This is either the empirical load setting coefficient (coefficient setting formula) for the chassis dynamometer, which is used for load setting of similar vehicles, or the load setting value (multi-point setting formula).

b) Warm up method

Appropriate warm up running shall be performed at or below the highest standard vehicle speed. At a typical speed, it is normally preferable to run the vehicle for 30 minutes or more.

NOTE:

Transmission fluid and tire temperatures change data when driving at 60 km/h are shown in **Annex B**.

4.3.3 Electrical inertia ratio

For the electrical inertia-type chassis dynamometer, the use of an electrical inertia ratio in the range of -60% to +200% is preferable. The electrical inertia ratio is calculated using the following formula.

$$E_r = \frac{M_{r, chdy} - M_b}{M_b} \times 100$$

where,

- E_r : Electrical inertia ratio (%)
- $M_{r, chdy}$: Equivalent inertia mass (kg)
- M_b : Fixed inertia mass (kg)

4.3.3 Roller speed signal used for the driving instruction device

The roller speed signal used for the driving instruction device (hereafter referred to as the driver's aid) shall

be the same signal as that used in the running load control performance evaluation (refer to 5.4).

5. Evaluation method

5.1 General

Running load control performance and front-rear roller speed synchronicity are evaluated by running the vehicle on the four-wheel-drive vehicle chassis dynamometer and recording and calculating data with the evaluation device connected to the chassis dynamometer. The evaluation method and its content are described below.

5.2 Evaluation driving mode

Evaluation driving mode is a period of time for emissions collection, in order to measure fuel consumption in the Japanese 10-15 mode for fuel consumption rate testing or the JC08 mode.

NOTE:

Refer to **TRIAS 5-3-2008** or **TRIAS 5-4-2008** for information about the 10-15 mode. Additionally, refer to **TRIAS 5-9-2009** for information about the JC08 mode.

5.3 Evaluation device

5.3.1 General

The evaluation device shall fulfill the requirements in **5.3.2** and **5.3.3**.

5.3.2 Device requirements

The device used for evaluation shall fulfill the following requirements.

- a) The device shall be capable of measuring front and rear roller speed and integrated running distance.
- b) The device shall be capable of measuring front and rear dynamometer detection force and mechanical loss.
- c) The synchronicity of the data shall be ensured.
- d) The device shall be capable of measuring at a sampling time of 50 ms for 1,400 seconds or more.
- e) The device shall be capable of converting the measured data to physical numbers.

5.3.3 Measurement requirements

5.3.3.1 Roller speed measurement

Measurement of roller speed shall use pulse signals. Measurement specifications shall fulfill the following requirements.

- Speed measurement range: 0.1 km/h to 90 km/h
- Resolution: 0.01 km/h or fine
- Response speed: 5 ms or fine

NOTE:

The minimum required number of pulses in order to detect a speed of 0.1 km/h in 50 ms is, for example, 2,715 pulses per rotation for roller diameter of 1,200 mm or 2758 pulses for roller diameter of 1,219.2 mm (48 inch).

5.3.3.2 Measurement of dynamometer detection force and mechanical loss

The measurement specifications for dynamometer detection force and mechanical loss shall fulfill the following requirements.

- Measurement accuracy: $\pm 0.1\%$ FS or fine

- Analog/digital conversion response speed: 5 ms or fine
- Before measurement, signal zero/span adjustment shall be performed for the dynamometer detection force.
- For measurements other than analog measurements, accuracy shall be equivalent to that shown above.

NOTE:

The coefficient calculated from target road load, chassis dynamometer load, and chassis dynamometer loss can be used for the mechanical loss value, instead of the value output in real time. When the coefficient for vehicle loss can be used, the coefficient calculated from vehicle loss and chassis dynamometer loss can be used.

5.4 Evaluation of running load control performance

5.4.1 General

Evaluation of driving force linear regression⁽⁶⁾ shall be used for evaluation of running load control performance. Front and rear roller dynamometer detection force during mode driving is measured to calculate the sum of measured driving forces, and this is statistically evaluated against target running force, using a linear regression formula.

Note: ⁽⁶⁾

This has been adopted in **JASO TP-06001**.

5.4.2 Evaluation procedure

Input the roller speed and dynamometer detection force from the chassis dynamometer into the evaluation device, and record them during mode driving. After that, evaluate running load control performance of the chassis dynamometer using statistical evaluation values. Refer to **Annex C** for details.

5.4.3 Data sampling

Shall be performed at a cycle of 50 ms (20 Hz).

5.4.4 Roller speed signal

The roller speed signal used in evaluation of running load control performance shall be the roller speed for the primary drive wheels, or the average of the front and rear roller speeds.

Note that it is preferable for the roller speed signal used for setting road load to be the same as the signal used for evaluating running load control performance.

5.4.5 Data processing method

5.4.5.1 Evaluation range of application

The range shall be the evaluation driving mode, with vehicle speeds below 3.0 km/h excluded. Furthermore, for vehicles with a manual transmission, the 2 seconds after starting and the 1 second before and 2 seconds after gear shift standard points shall be excluded.

5.4.5.2 Calculating measured driving force and target driving force

The evaluation shall use target driving force $F_{v,tg}$ and measured driving force $F_{v,m}$. The measured driving force shall be the sum of the front and rear values.

$$F_{v,m} = F_{v,m,f} + F_{v,m,r}$$

where,

- $F_{v,m}$: Measured driving force (N)
- $F_{v,m,f}$: Front wheel measured driving force (N)
- $F_{v,m,r}$: Rear wheel measured driving force (N)

The target driving force $F_{v,tg}$ and measured driving force $F_{v,m}$ are expressed by the following formula.

$$F_{v,tg} = A_{tg} + B_{tg} \times V_{chdy} + C_{tg} \times V_{chdy}^2 + M_{v,chdy} \times \frac{dV_{chdy}}{dt}$$

where,

- $F_{v,tg}$: Target driving force (N)
- A_{tg} : Constant term for target road load (N)
- B_{tg} : Primary term coefficient for target road load [N/(km/h)]
- C_{tg} : Secondary term coefficient for target road load [N/(km/h)²]
- V_{chdy} : Roller speed (km/h)
- $M_{v,chdy}$: Equivalent inertia mass (kg)

$$F_{v,m} = F_{dy} + L_{ml} + M_b \times \frac{dV_{chdy}}{dt}$$

where,

- $F_{v,m}$: Measured driving force (N)
- F_{dy} : Dynamometer detection force (N)
- L_{ml} : Mechanical loss (N)
- M_b : Fixed inertia mass (kg)
- V_{chdy} : Roller speed (km/h)

The roller degree of acceleration $\frac{dV_{chdy}}{dt}$ used in the calculation of target driving force $F_{v,tg}$ and measured driving force $F_{v,m}$ is calculated from the primary differentiation by the least squares method of quadratic approximation for 7 data points for roller speed.

$$\frac{dV_{chdy(i)}}{dt} = \frac{-3V_{chdy(i-3)} - 2V_{chdy(i-2)} - V_{chdy(i-1)} + V_{chdy(i+1)} + 2V_{chdy(i+2)} + 3V_{chdy(i+3)}}{28\Delta t}$$

where,

- $V_{chdy(i)}$: Roller speed V_{chdy} data item number i.
- Δt : Data sampling time

When using the mechanical loss value, which is not a value measured in real time, the following formula shall be used.

$$L_{ml} = A_{ml} + B_{ml} \times V_{chdy} + C_{ml} \times V_{chdy}^2 + D_{ml} \times V_{chdy}^3$$

where,

- L_{ml} : Mechanical loss (N)
- A_{ml} : Constant term of mechanical loss (N)
- B_{ml} : Primary term coefficient of mechanical loss [N/(km/h)]
- C_{ml} : Secondary term coefficient of mechanical loss [N/(km/h)²]

D_{ml} : Third order term coefficient of mechanical loss [N/(km/h)³]
 V_{chdy} : Roller speed (km/h)

NOTE:

For chassis dynamometers that only hold the mechanical loss coefficient to the second order, the third order term can be ignored.

When the mechanical loss value is calculated from target road load, chassis dynamometer load, and chassis dynamometer loss, then the following formula shall be used.

$$L_{ml} = F_{tg} - F_{chdy} + L_{chdy}$$

where,

F_{tg} : Target road load (N)

$$F_{tg} = A_{tg} + B_{tg} \times V_{chdy} + C_{tg} \times V_{chdy}^2$$

A_{tg} : Constant term for target road load (N)

B_{tg} : Primary term coefficient for target road load [N/(km/h)]

C_{tg} : Secondary term coefficient for target road load [N/(km/h)²]

F_{chdy} : Chassis dynamometer load (N)

$$F_{chdy} = A_s + B_s \times V_{chdy} + C_s \times V_{chdy}^2$$

A_s : Constant term for chassis dynamometer load (N)

B_s : Primary term coefficient for chassis dynamometer load [N/(km/h)]

C_s : Secondary term coefficient for chassis dynamometer load [N/(km/h)²]

L_{chdy} : Chassis dynamometer loss (N)

$$L_{chdy} = A_l + B_l \times V_{chdy} + C_l \times V_{chdy}^2 + D_l \times V_{chdy}^3$$

A_l : Constant term for chassis dynamometer loss (N)

B_l : Primary term coefficient for chassis dynamometer loss [N/(km/h)]

C_l : Secondary term coefficient for chassis dynamometer loss [N/(km/h)²]

D_l : Third order term coefficient for chassis dynamometer loss [N/(km/h)³]

When the mechanical loss value is calculated from vehicle loss and chassis dynamometer loss, the following formula shall be used.

$$L_{ml} = L_v + L_{chdy}$$

where,

L_v : Vehicle loss (N)

$$L_v = A_v + B_v \times V_{chdy} + C_v \times V_{chdy}^2 + D_v \times V_{chdy}^3$$

A_v : Constant term of vehicle loss (N)

B_v : Primary term coefficient of vehicle loss [N/(km/h)]

C_v : Secondary term coefficient of vehicle loss [N/(km/h)²]

D_v : Third order term coefficient of vehicle loss [N/(km/h)³]