INTERNATIONAL STANDARD

ISO 18580

First edition
2015-11-15

Motorcycles — Verification of total running resistance force during mode running on a chassis dynamometer

Motocycles — Vérification de la force totale de résistance à l'avancement durant les essais sur un banc dynamométrique en mode roulage

Reference number
ISO 18580:2015(E)

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Foreword

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The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 38, *Motorcycles and mopeds*.

Introduction

The ordinary chassis dynamometer has the mechanical inertia system where the running resistance is set on the chassis dynamometer in accordance with ISO 11486 and the verification of force generated by the inertia mass is not necessary because the equivalent inertia mass is mechanically set by a flywheel. A chassis dynamometer using the electric inertia function is not equipped with such a mechanical flywheel equivalent to inertia mass system and the inertia force is electrically set in the same way of the running resistance force control. The inertia force is generated by the acceleration and/or deceleration, therefore, it is necessary to check the performance of electric inertia function during the mode running test and this International Standard specifies the method to verify the chassis dynamometer operated normally. The verification method specified in this International Standard can be applicable not only for the total running resistance check during the exhaust gas and/or fuel consumption mode test but also the system installation and the periodical performance check. The accurate verification can be achieved when this method is applied to the ordinary mechanical inertia system chassis dynamometer.

Motorcycles — Verification of total running resistance force during mode running on a chassis dynamometer

1 Scope

This International Standard specifies the verification method of total running resistance force when the exhaust gas emissions and/or fuel consumption of motorcycles are measured during mode running on a chassis dynamometer. The performance of chassis dynamometer is verified by comparing the measured total running resistance force (measured by a chassis dynamometer absorption force) and the target total running resistance force (calculated from velocity, acceleration and/or deceleration). This International Standard is applicable when the running resistance force of a chassis dynamometer is set in accordance with ISO 11486.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
equivalent inertia mass of motorcycle
m_i
mass obtained by adding the rotating mass of the front wheel to the total mass of the motorcycle, rider and instruments

2.2
mechanical equivalent inertia mass of chassis dynamometer
m_b
equivalent inertia mass of mechanical rotating parts of chassis dynamometer, e.g. roller and shaft and/or fly wheel

2.3
chassis dynamometer absorption force
F_{dy}
tangential force acted on the roller surface which is calculated from a roller shaft or motor cradling torque and roller radius

Note 1 to entry: The chassis dynamometer absorption force is the running resistance force for a chassis dynamometer equipped with a mechanical flywheel equivalent inertia mass system and is sum of running resistance force and inertia force generated by motorcycles for a chassis dynamometer using the electric inertia function.

2.4
total friction loss of a chassis dynamometer
F_f
friction and aerodynamic loss of rotating parts of chassis dynamometer, e.g. bearings and roller(s)

2.5
running resistance force
rolling resistance and aerodynamic loss of motorcycle on flat surface

2.6
inertia force
force generated by inertia mass of motorcycle or chassis dynamometer during acceleration and/or deceleration

2.7
total running resistance force
sum of running resistance force and inertia force of motorcycle

2.8
target total running resistance force
F_{tg}
total running resistance force calculated in accordance with equivalent inertia mass of motorcycle, velocity, acceleration and/or deceleration

2.9
measured total running resistance force
F_m
sum of the chassis dynamometer absorption force, total friction loss of chassis dynamometer and an inertia force generated by the mechanical equivalent inertia mass of chassis dynamometer

2.10
target integral work
W_{tg}
integral work calculated in accordance with measured velocity and F_{tg} during test mode running, in kilo joule

2.11
measured integral work
W_m
integral work calculated in accordance with measured velocity and F_m during test mode running, in kilo joule

3 Symbols

Table 1 — Symbols

Symbols	Definition	Unit
A	slope of the regression line	—
a	rolling resistance of front wheel	N
B	intercept of the regression line	—
b	coefficient proportional to motorcycle speed	N/(km/h)
c	aerodynamic drag coefficient	N/(km/h)^2
e_W	integral work error	%
F_{dy}	tangential force acted on the roller surface	N
F_f	friction and aerodynamic loss of rotating parts of chassis dynamometer	N
F_{tg}	target total running resistance force	N
$F_{tg,i}$	the i-th data of F_{tg} data sets	N
F_m	measured total running resistance force	N
$F_{m,i}$	the i-th data of F_m data sets	N
m_b	equivalent inertia mass of mechanical rotating parts of chassis dynamometer	kg
m_i	mass obtained by adding the rotating mass of the front wheel to the total mass of the motorcycle, rider and instruments	kg
T	time	s
V	roller rotational speed	km/h
W_{tg}	target integral work	J
W_m	measured integral work	J

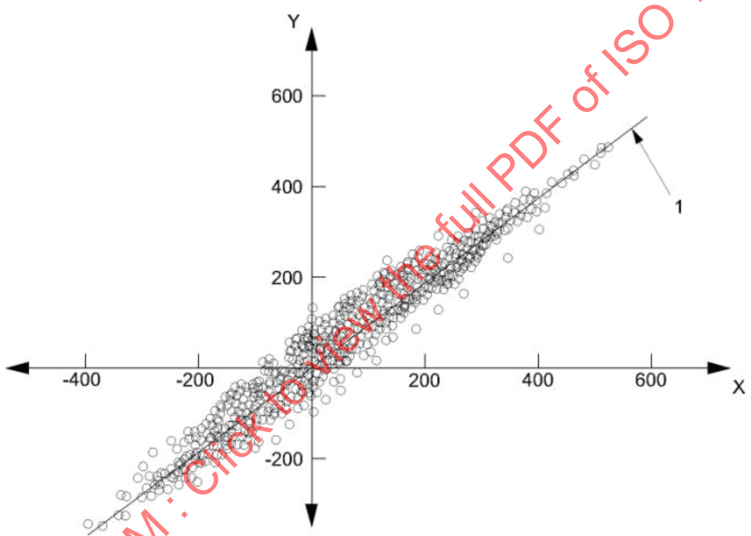
Table 1 *(continued)*

Symbols	Definition	Unit
γ	correlation coefficient	—
σ	standard deviation	—
σ_{cov}	relative standard deviation (cov: coefficient of variation)	%

4 Verification

4.1 Principle

The equivalence between the target and measured total running resistance force is verified by the linear regression statistical analysis. Data combination of target and measured total running force shall be plotted as shown in Figure 1 and the performance of chassis dynamometer shall be evaluated from the slope and intercept of the regression line, correlation coefficient and relative standard deviation.



Key

1 regression line $A \times F_{tg} + B$

X target running resistance force [N]

Y measured running resistance force [N]

Figure 1 — Image of relationship between target and measured total running resistance force

4.2 Calculation

4.2.1 Data sets of speed, chassis dynamometer absorption force and total friction loss of a chassis dynamometer shall be simultaneously measured during the mode running in a time series. If the total friction loss of a chassis dynamometer cannot be simultaneously measured, the total friction loss shall be determined from the relationship between speed and total friction loss which is obtained prior to the test.

4.2.2 Both target and measured total running resistance force shall be calculated from adequate data sets of speed, chassis dynamometer absorption force and total friction loss of a chassis dynamometer by Formulae (1) and (2), respectively.

$$F_{tg} = a + bV + cV^2 + m_i \frac{dV}{dt} \quad (1)$$

$$F_m = F_{dy} + F_f + m_b \frac{dV}{dt} \quad (2)$$

4.2.3 The relationship between target and measured total running resistance force obtained in 4.2.2 shall be plotted as shown in Figure 1. The slope and intercept of the regression line, correlation coefficient and relative standard deviation shall be calculated in accordance with following formulae using all data sets measured during the mode running.

A shall be calculated in accordance with Formula (3).

$$A = \frac{\sum_{i=1}^{n} F_{tg,i}{}^2 \times \sum_{i=1}^{n} F_{m,i}{}^2 - \sum_{i=1}^{n}\left(F_{tg,i} \cdot F_{m,i}\right) \times \sum_{i=1}^{n} F_{tg,i}}{n \times \sum_{i=1}^{n} F_{tg,i}{}^2 - \left(\sum_{i=1}^{n} F_{tg,i}\right)^2} \quad (3)$$

B shall be calculated in accordance with Formula (4).

$$B = \frac{n \times \sum_{i=1}^{n}\left(F_{tg,i} \cdot F_{m,i}\right) - \sum_{i=1}^{n} F_{tg,i} \times \sum_{i=1}^{n} F_{m,i}}{n \times \sum_{i=1}^{n} F_{tg,i}{}^2 - \left(\sum_{i=1}^{n} F_{tg,i}\right)^2} \quad (4)$$

γ shall be calculated in accordance with Formula (5).

$$\gamma = \cos\theta = \frac{\mathrm{cov}\left(F_{tg}, F_m\right)}{\sigma_1 \times \sigma_2} \quad (5)$$

where

$$\sigma_1{}^2 = \frac{\sum_{i=1}^{n}\left(F_{tg,i} - \overline{F_{tg}}\right)^2}{n};$$

$$\sigma_2{}^2 = \frac{\sum_{i=1}^{n}\left(F_{m,i} - \overline{F_m}\right)^2}{n};$$

$$\mathrm{cov}\left(F_{tg}, F_m\right) = \frac{\sum_{i=1}^{n}\left(F_{tg,i} - \overline{F_{tg}}\right)\left(F_{m,i} - \overline{F_m}\right)}{n}$$

where

$$\overline{F}_{tg} = \frac{1}{n}\sum_{i=1}^{n} F_{tg,i}$$

$$\bar{F}_m = \frac{1}{n}\sum_{i=1}^{n} F_{m,i}$$

σ_{cov} shall be calculated in accordance with Formula (6).

$$\sigma_{cov} = \frac{\sigma}{\bar{F}_m} \times 100 \tag{6}$$

where

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left[E_{m,i} - \bar{E}_m\right]^2}{n}}$$

$$E_{m,i} = F_{m,i} - \left(A \times F_{tg,i} + B\right)$$

$$\bar{E}_m = \frac{1}{n}\sum_{i=1}^{n} E_{m,i}$$

4.2.4 The equivalence between the measured and target total running resistance force shall be evaluated by comparison with tolerances of slope and intercept of the regression line, correlation coefficient and relative standard deviation.

4.2.5 Both target and measured integral work shall be calculated from adequate data sets of speed, chassis dynamometer absorption force and total friction loss of a chassis dynamometer by Formulae (7) and (8), respectively. The integral work error, e_w, shall be calculated in accordance with Formula (9).

$$W_{tg} = \frac{1}{3\,600 \times n_{sample}}\sum_{i=1}^{n}(F_{tg,i} \times V_i) \tag{7}$$

$$W_m = \frac{1}{3\,600 \times n_{sample}}\sum_{i=1}^{n}(F_{m,i} \times V_i) \tag{8}$$

$$e_w = \frac{W_m - W_{tg}}{W_{tg}} \times 100 \tag{9}$$

where

n_{sample} is the number of data measured in one second.

5 Procedure

5.1 Tools

5.1.1 Data logger

The data logger shall be capable of sampling and logging the signals of the chassis dynamometer roller speed, chassis dynamometer absorption force and chassis dynamometer friction loss at the frequency of at least 50 ms. If the signal of chassis dynamometer friction loss cannot be logged simultaneously, the functions of speed obtained prior to the test shall be used for the verification. The memory capacity for data logging shall be large enough to store all the data during the test cycle. Data conversion system shall be the A/D conversion. It is desirable to use a stand-alone system, while a built-in system is permissible.

5.1.2 Verification software

The verification software shall be capable of the processing of data in accordance with the principle given in 4.1 to 4.2. An example of data processing is shown in Annex A.

5.2 Preparation

5.2.1 Check of chassis dynamometer

Check that roller speed, absorption force and equivalent inertia mass are calibrated in accordance with the manufacturer's recommendation.

5.2.2 Calibration of data logger

Transmit the signals of the roller speed and the absorption force to the data logger, and calibrate the data logger so that the values indicated at the chassis dynamometer coincide with the measured values taken into the logger.

5.3 Data collection

5.3.1 Selection of test cycle

Select one test cycle for exhaust emission and fuel consumption measurement.

5.3.2 Data logging

Collect and log data during the test cycle continuously with a constant interval.

5.4 Data processing

Process the logged data with the verification software as specified in 5.1.2 to obtain a result. (See Annex A.)

5.5 Evaluation of chassis dynamometer

Evaluate the following 5 items of the chassis dynamometer:

— correlation coefficient, γ;

— slope of the regression line, A;

— intercept of the regression line, B;

— relative standard deviation, $\sigma_{\rm COV}$;

— integral work error, $e_{\rm W}$.

If criteria, which shall be agreed among the parties involved, on each item are satisfied, then the chassis dynamometer shall be deemed eligible for exhaust emission and fuel consumption measurement.

5.6 Report

A full description of the motorcycle shall be provided in accordance with Annex B.

A full description of the chassis dynamometer and instruments shall be provided in accordance with Annex C.

A full description of the test result shall be provided in accordance with Annex D.

Annex A
(informative)

Example of verification calculation

A.1 Test conditions

Verification range: ECE 40, 1 cycle (195 s)

Sampling frequency: 50 ms

Table A.1 — Chassis dynamometer basic information and chassis dynamometer output requirement

Mass simulation range	100 kg to 530 kg
Base(fixed) inertia	140 kg
Electric inertia simulation range	−40 kg to +390 kg
Roller diameter	530,5 mm
Roller width	300 mm
Maximum operating speed	180 km/h
Tolerance of inertia simulation	≤2 %
Repeat tolerance of inertia simulation	≤1 %
Dynamo capacity	45 kW
Output signal	
— Roller rev. (pulse or analog)	1 024 p/r, V(volt)(full scale)
— Force or torque	±10 V/ ± 1 100 N(Nm)
Others (please specify)	
— Roller rev. digital	p/rev. km/h 0-Hz
— Force digital	1 100 N
— Friction loss data none/exist	110 N

A.2 Verification calculating method using spread sheet

Figure A.1 shows the input data of the roller speed, chassis dynamometer absorption force and total friction loss of the chassis dynamometer.

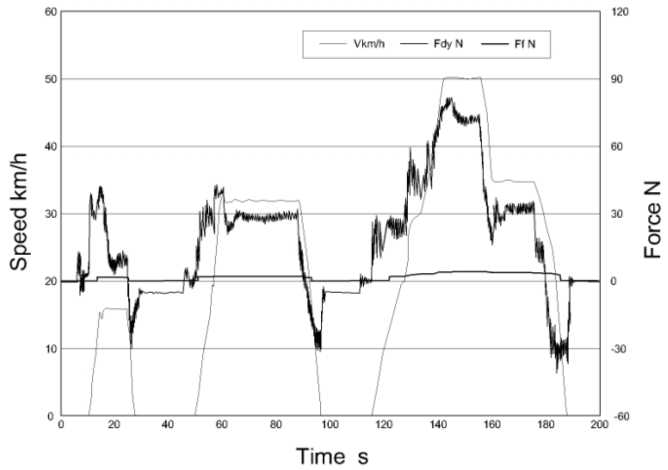


Figure A.1 — Logging data of roller speed, absorption force and total friction loss

When the logged data are input into the spread sheet, in which the calculation process is embedded, the verification result is automatically calculated. The details of the spread sheet are as follows.

— Input the logged data into the cells in the area of A10 through D3910 (the number of cell depends on the data volume).

— Cells A1, B1, C1, D1, E1 and F1 are for the test conditions. Input data of the test conditions in cells A3, B3, C3, D3, E3 and F3.

With the above data input and the test conditions setting, the verification results are indicated in cells A6, B6, C6, D6, E6, F6 and G6. The elements necessary for the verification calculations are shown in the cells in the area of E10 through J3910.

Table A.2 — Outline of the spread sheet

cell	A	B	C	D	E	F	G	H	I	J
1	m_i	m_b	dt	a	b	c				
2	kg	kg	s							
3	170	140	0,05	0,000	0,000	0,0285				
4	γ	A	B	σ_{COV}	W_{tg}	W_m	e_w			
5					kJ	kJ	%			
6	0,997	0,986	2,85	2,10	46,033	47,724	3,67			
7	T	V	F_{dy}	F_f	dv/dt	F_{tg}	F_m	$F_m\_F_{tg}$	$W_{tg,i}$	$W_{m,i}$
8	s	km/h	N	N	m/s^2	N	N	N	kJ	kJ
10	0,00	0,00	0,1	0,0						
11	0,05	0,00	0,2	0,0						
12	0,10	0,00	−0,3	0,0						
13	0,15	0,00	−0,5	0,0	0,00	0,0	0,0	0,000	0,00	0,00
3 903	194,60	0,00	−1,7	0,0	0,00	0,0	0,0	0,000	0,00	0,00
3 904	194,65	0,00	−1,9	0,0	0,00	0,0	0,0	0,000	0,00	0,00
3 905	194,70	0,00	−2,0	0,0	0,00	0,0	0,0	0,000	0,00	0,00
3 906	194,75	0,00	−2,0	0,0	0,00	0,0	0,0	0,000	0,00	0,00
3 907	194,80	0,00	−1,7	0,0	0,00	0,0	0,0	0,000	0,00	0,00

Table A.2 *(continued)*

cell	A	B	C	D	E	F	G	H	I	J
3 908	194,85	0,00	−1,7	0,0						
3 909	194,90	0,00	−1,7	0,0						
3 910	194,95	0,00	−1,6	0,0						

The calculation processes of each element are as follows:

— *dv*/*dt* are calculated with the least squares method of quadratic approximation for 7 data points for roller speed.

$$\frac{dv}{dt} = \frac{-3V_{i-3} - 2V_{i-2} - V_{i-1} + V_{i+1} + 2V_{i+2} + 3V_{i+3}}{28\Delta t} \tag{A.1}$$

Table A.3 shows *dv*/*dt* calculation spread sheet. E271 in Table A.3 is calculated from B268 to B274 data.

Table A.3 — *dv*/*dt* calculation spread sheet

Cell	A	B	C	D	E
7	T	V	F_{dy}	F_f	dv/dt
8	s	km/h	N	N	m/s^2
268	12,85	5,48	5,48	0,0	1,19
269	12,90	5,71	5,71	0,0	1,18
270	12,95	5,91	5,91	0,0	1,19
271	13,00	6,13	6,13	0,0	1,18
272	13,05	6,35	6,35	0,0	1,17
273	13,10	6,56	6,56	0,0	1,17
274	13,15	6,76	6,76	0,0	1,18
275	13,20	6,96	6,96	0,0	1,19

Table A.4 — F_{tg} and F_m calculation spread sheet

Cell	A	B	C	D	E	F	G
1	m_i	m_b	dt	A	b	c	
2	Kg	kg	s				
3	170	140	0,05	0,000	0,000	0,028	
4	Γ	A	B	σ_{COV}	W_{tg}	W_m	e_w
5					kJ	kJ	%
6	0,997	0,986	2,85	2,10	46,033	47,724	3,67
7	T	V	F_{dy}	F_f	dv/dt	F_{tg}	F_m
8	S	km/h	N	N	m/s^2	N	N
268	12,85	5,48	5,48	0,0	1,19	202,4	171,4
269	12,90	5,71	5,71	0,0	1,18	202,2	171,4
270	12,95	5,91	5,91	0,0	1,19	202,6	171,9
271	13,00	6,13	6,13	0,0	1,18	201,8	171,5
272	13,05	6,35	6,35	0,0	1,17	199,7	169,9
273	13,10	6,56	6,56	0,0	1,17	200,8	170,9
274	13,15	6,76	6,76	0,0	1,18	201,6	171,7

Table A.4 *(continued)*

Cell	A	B	C	D	E	F	G
275	13,20	6,96	6,96	0,0	1,19	203,4	173,3
276	13,25	7,19	7,19	0,0	1,21	207,0	176,5
277	13,30	7,41	7,41	0,0	1,22	208,9	178,2
278	13,35	7,63	7,63	0,0	1,23	210,1	179,3
279	13,40	7,86	7,86	0,0	1,22	208,6	178,2

Table A.5 — W_{tg} and W_m calculation spread sheet

cell	A	B	C	D	E	F	G	H	I	J
1	m_i	m_b	dt	a	b	c				
2	kg	kg	s							
3	170	140	0,05	0,000	0,000	0,028				
4	γ	A	B	σ_{COV}	W_{tg}	W_m	e_W			
5					kJ	kJ	%			
6	0,997	0,986	2,85	2,10	46,03	47,72	3,67			
7	T	V	F_{dy}	F_f	dv/dt	F_{tg}	F_m	F_m-F_{tg}	$W_{tg,i}$	$W_{m,i}$
8	S	km/h	N	N	m/s2	N	N	N	kJ	kJ
270	12,95	5,91	36,5	0,0	1,19	202,6	202,5	0,056	0,016	0,016
271	13,00	6,13	42,2	0,0	1,18	201,8	207,6	5,709	0,017	0,017
272	13,05	6,35	41,0	0,0	1,17	199,7	204,5	4,717	0,017	0,018
273	13,10	6,56	37,0	0,0	1,17	200,8	201,3	0,462	0,018	0,018
274	13,15	6,76	41,5	0,0	1,18	201,6	206,4	4,777	0,0	0,019
275	13,20	6,96	43,1	0,0	1,19	203,4	209,5	6,036	0,019	0,020
276	13,25	7,19	37,3	0,0	1,21	207,0	206,6	0,399	0,020	0,020

Annex B
(normative)

Motorcycle description

B.1 Motorcycle

Category: two wheeler/three wheeler(delete as applicable)

Trade-name (-mark): ....

Model: ....

Engine model: ....

Cycle: two stroke/four stroke (delete as applicable)

Number and layout of cylinders: ....

Engine displacement: .... cm^3

Gear-box: manual/automatic(delete as applicable)

Number of gear ratios (speeds): ....

Drive ratios:—primary: ....

—final: ....

Maximum speeds: ....km/h

Reference speed:..........km/h (and ....km/h)

Mileage accumulated at test: .... km

B.2 Test motorcycle mass

Motorcycle mass: —kerb:.......... kg

—reference: .... kg

Rider mass: ....kg

Instruments mass:.......... kg

Front wheel loaded mass:.......... kg

Rear wheel loaded mass:.......... kg

Test motorcycle mass: .... kg

B.3 Equivalent inertia mass of rotating parts

Drive wheel:

— drive train: .... kg

— rear wheel and tyre with brake drum or disc: .... kg

Steering wheel:

— front wheel and tyre .... kg

— percentage of test motorcycle mass: .... %

On-road rotating mass: .... kg

— percentage of test motorcycle mass: .... %

On-bench rotating mass: .... kg

— percentage of motorcycle mass: .... %

B.4 Tyres

Sizes: front: .... rear: ....

Make: ....

Pressures:

	Specified	Actual	Dynamic tyre radius
— front:	.... kPa	.... kPa	.... mm
— rear:	.... kPa	.... kPa	.... mm

Chassis dynamometer test drive wheel tyre:

— pressure:	.... kPa	.... kPa	.... mm

B.5 Frontal area determination

Rider height: .... m

Frontal area: .... m^2

Annex C
(normative)

Chassis dynamometer and instruments description

C.1 Chassis dynamometer

Trade-name (-mark) and model: ....

Diameter of roller: .... mm

Chassis dynamometer type: DC/ED/AC (delete as applicable)

Capacity of power absorbing unit (pau): .... kW

Speed range: .... km/h

Power absorption system: polygonal function/coefficient control (delete as applicable)

Resolution: .... N

Type of inertia simulation system: mechanical /electrical (delete as applicable)

Equivalent inertia mass: .... kg,

in steps of: .... kg

Coastdown timer: digital/analogue/stop-watch (delete as applicable)

Table C.1 — Chassis dynamometer basic information

Mass simulation range	100 kg to 530 kg
Base(fixed) inertia	140 kg
Electric inertia simulation range	−40 kg to +390 kg
Roller diameter	530,5 mm
Roller width	300 mm
Maximum operating speed	180 km/h
Tolerance of inertia simulation	≤2 %
Repeat tolerance of inertia simulation	≤1 %
Dynamo capacity	45 kW
Output signal	
— Roller rev. (pulse or analog)	1 024 p/r, V(volt)(full scale)
— Force or torque	±10 V/ ± 1 100 N(Nm)
Others (please specify)	
— Roller rev. digital	p/rev. km/h 0-Hz
— Force digital	1 100 N
— Friction loss data none/exist	110 N