INTERNATIONAL STANDARD

ISO 23280

First edition
2022-05

Electrically propelled mopeds and motorcycles — Test method for evaluation of energy performance using motor dynamometer

Motocycles et cyclomoteurs à propulsion électrique — Méthode d'essai pour l'évaluation de la performance énergétique à l'aide d'un dynamomètre

Reference number
ISO 23280:2022(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 38, *Mopeds and Motorcycles*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Electrically propelled mopeds and motorcycles — Test method for evaluation of energy performance using motor dynamometer

1 Scope

This document specifies a test method to evaluate energy performance of electric motorcycles and mopeds by measuring performance of a test motor system (3.4) to be installed to an electric moped or motorcycle under consideration.

The test is carried out on a motor dynamometer test bench where the traction motor system is connected to a load motor system (3.3) that simulates resistance torque arising from running resistance of vehicle and drive train friction loss and inertia effect.

This method provides estimates of specific energy consumption and range of an electric moped or motorcycle to which the traction motor system is intended to be applied.

This document is only applicable to two-wheeled motorcycles and mopeds.

NOTE This test method is applicable to motorcycle or moped regardless of types of power transmission devices, such as chains, belts, gears, ratio controllable CVTs, shaft drives, direct drives, etc., once gear ratios (ratio of input to output speed) and transmission efficiencies (ratio of input to output torque) are provided.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11486, *Motorcycles — Methods for setting running resistance on a chassis dynamometer*

ISO 13064-1, *Battery-electric mopeds and motorcycles — Performance — Part 1: Reference energy consumption and range*

ISO 13064-2, *Battery-electric mopeds and motorcycles — Performance — Part 2: Road operating characteristics*

ISO 28981, *Mopeds - Methods for setting the running resistance on a chassis dynamometer*

IEC 60034-1, *Rotating electrical machines — Part 1: Rating and performance*

IEC 60034-2-1, *Rotating electrical machines — Part 2-1: Standard methods for determining losses and efficiency from test (excluding machines for traction vehicles)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13064-2, IEC 60034-1, IEC 60034-2-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
driving mode
test mode used for performance evaluation of mopeds and motorcycles such as UDC (urban driving cycle), EUDC (extra-urban driving cycle), WMTC (world motorcycle test cycle)

Note 1 to entry: For reference to UDC, see ISO 13064-1:2012, Annex A for mopeds and Annex B for motorcycles, and EUDC, see ISO 13064-1:2012, Annex B for mopeds, and WMTC, see UN-ECE GTR No.02.

3.2
load motor
electric motor that provides torque control function defined from running resistance, friction loss and inertia effect of the drive train when testing a traction motor system of electrically propelled mopeds and motorcycles

3.3
load motor system
combination of a *load motor* (3.2) and its pairing inverter

3.4
test motor system
combination of a traction motor and its pairing inverter under test that is used as a main traction motor for electric mopeds or motorcycles

3.5
speed-torque control mode
test mode performed in a *motor dynamometer* (3.6) where a *test motor system* (3.4) is speed controlled and *load motor system* (3.3) is torque controlled

3.6
motor dynamometer
test equipment for measuring *test motor system* (3.4) energy performance comprising test motor system, *load motor system* (3.3), DC power supply, transducers, data acquisition and analysing system

4 Principle

This test method specifies a test procedure to evaluate energy performance, such as consumed energy (7.1), travelled distance (7.2), motor system efficiency (7.3) and reference energy consumption (7.4) of electric motorcycles and mopeds with a traction motor system to be fitted to a vehicle under consideration. Instead of chassis dynamometer test that requires a full vehicle, this method is carried out with a traction motor system on a motor dynamometer and provides estimate of energy performance of vehicle with nominal information of the vehicle.

NOTE Reference energy consumption (7.4) defined in this document is different from those in other standards, such as ISO/TR 8713, ISO 8714 and ISO 13064-1, where reference energy consumption is defined as electric energy required to fully recharge the traction battery from the main electric supply network system after completion of a selected driving cycle. While in this document reference energy consumption is the ratio of consumed energy (7.1) to travelled distance (7.2).

In order to determine resistance torque to the traction motor system, running resistance acting on the driving wheel of a vehicle, in accordance with ISO 11486 for motorcycles and ISO 28981 for mopeds, shall be converted to the resistance torque to the traction motor system, and additionally the inertia effects and friction losses of the drive train of vehicle shall be accounted for.

5 Determination of resistance torque to traction motor system

5.1 Running resistance of vehicle

Running resistance of motorcycle and moped, respectively according to ISO 11486 and ISO 28981, is given as Formula (1):

$$F_w = m_i A + a + b\,v^2 \tag{1}$$

where

F_w is the running resistance acting on the driving wheel;

m_i is the equivalent mass;

A is the acceleration of vehicle;

a is the rolling resistance of the front and rear wheel;

b is the aero dynamic drag coefficient;

v is the velocity of the vehicle.

While values for m_i and b can be adopted from ISO 11486 and ISO 28981, rolling resistance a shall account for both front and rear wheels for motor dynamometer test. In this document, a is determined by assuming 50:50 weight distribution between front and rear wheels and the same rolling resistance coefficients. Care should be taken for the application of this method to mopeds and motorcycles having extraordinary weight distribution characteristics. Values m_i, a, and b for motorcycles and mopeds are given in Annex A and Annex B, respectively.

The accuracy and resolution of associated parameters, such as time, distance, temperature, speed, mass and energy, is in accordance with ISO 13064-1, which is given in Table 1.

Table 1 — Accuracy and resolution of parameters

Parameter	Unit	Accuracy	Resolution
Time	s	±0,1 s	0,1 s
Distance	m	±0,1 %	1,0 m
Temperature	°C	±1,0 K	1,0 K
Speed	km/h	±1,0 %	0,2 km/h
Mass	kg	±0,5 %	1,0 kg
Energy	Wh	class 0,2 S[a]	class 0,2 S[a]

[a] According to IEC 62053-22.

5.2 Resistance torque for central drive system

A typical configuration for a central drive system is shown in Figure 1, where a chassis mounted traction motor is connected to driving sprocket via gears, and power is transmitted to driven sprocket with a chain or belt. Besides chain, belt and sprocket, other types of transmission devices, such as CVT, gear, shaft drive, direct drive, etc. Resistance torque T_m [N-m] that shall be applied to the traction motor system on a motor dynamometer test setup can be given as (see Annex C for derivation) Formula (2):

$$T_m = \left(\frac{r}{\eta N}\right) F_w \tag{2}$$

where r is the rear wheel radius, η is overall torque transmission efficiency between traction motor and wheel, and N is overall gear ratio between traction motor and wheel.

NOTE 1 In case of drive configuration given in Figure 1, η is given as $\eta = \eta_g \times \eta_c$, where η_g is the transmission efficiency of gear between traction motor and driving sprocket, and η_c is the transmission efficiency of the chain drive system connected with driving sprocket and driven sprocket (see Annex C).

If a traction motor system is combined with internal transmission gears to form a single assembly, then the whole assembly is regarded as a traction motor unit. If this is the case, transmission efficiency η_g shall not be taken into consideration, thus, the overall torque transmission efficiency is $\eta = \eta_c$, and the overall gear ratio becomes $N = N_w$.

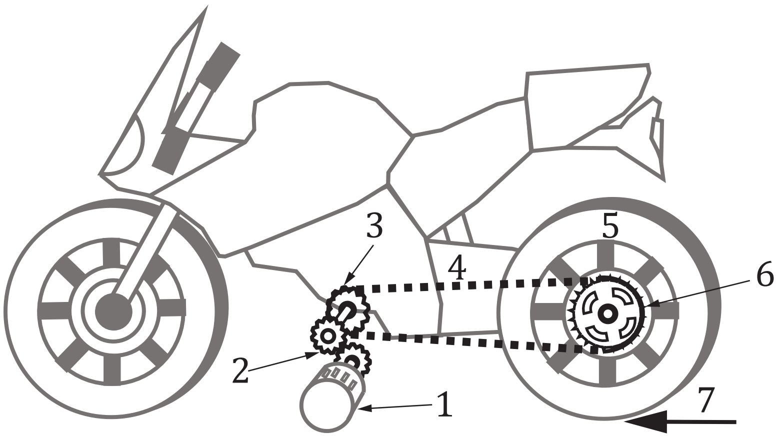
If the traction motor system and gear between traction motor and driving sprocket is combined to form a single assembly, and tested as a one unit, which is the case when a traction motor system assembly has integrated internal gears whose gear ratio may be varying (see NOTE 2), then, both transmission efficiency η_g and gear ratio N_g between traction motor and driving sprocket need not be considered and set to 1. In this case all energy performance results are valid for the assembly, and not for a traction motor. When traction motor system assembly has varying gear ratios, then gear shifting shall be implemented in the test according to the test motor gear shifting map (see NOTE 3).

NOTE 2 Gear ratios can change stepwise or continuously like CVT.

NOTE 3 Gear ratios are determined depending on acceleration throttle angle (desired speed), traction motor speed and torque, traction motor efficiency etc., and gear shifting strategy is expressed as so called “gear shifting map” in conjunction with acceleration throttle angle and traction motor current relations (map), and traction motor speed–torque–current relations (map).

Typical values for η_g and η_c are $\eta_c = \eta_g = 0{,}9$. However, other efficiency values or non-constant values that depend on load, speed, etc., can be used by agreement between parties involved. The adopted values for each power transmission devices shall be reported.

In case of Figure 1, N is given as $N = N_g \times N_w$, where N_g is the gear ratio between traction motor and driving sprocket, and N_w is the gear ratio between driving sprocket and driven sprocket (see Annex C). The adopted values for N_g and N_w shall be reported.



Key

1 traction motor
2 gear between traction motor and driving sprocket
3 driving sprocket
4 chain
5 wheel
6 driven sprocket
7 running resistance applied to wheel

Figure 1 — Configuration of a central drive system

5.3 Resistance torque for in-wheel drive system

A typical configuration for in-wheel drive system is shown in Figure 2, where a traction motor is connected to a wheel with gears.

Resistance torque to traction motor system can be given as (see Annex D for derivation) Formula (3):

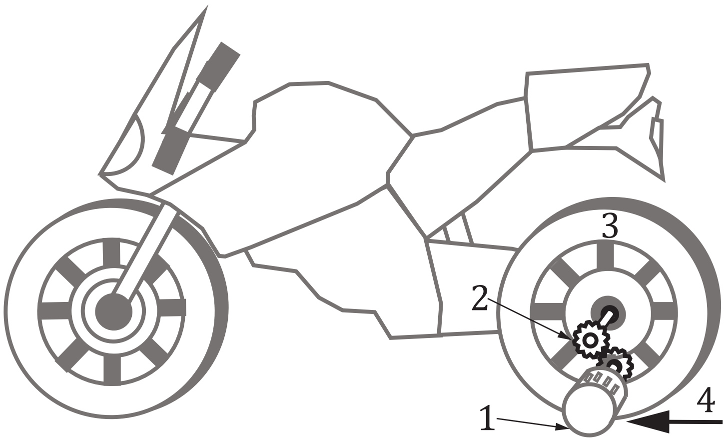
$$T_{\mathrm{m}} = \left(\frac{r}{\eta N}\right) F_{\mathrm{w}} \tag{3}$$

where η is torque transmission efficiency between traction motor and wheel, and N is the gear ratio between traction motor and wheel.

If a traction motor system is combined with internal transmission gears to form a single assembly, then the whole assembly is regarded as a traction motor unit. If this is the case, the overall torque transmission efficiency is $\eta = 1$, and the gear ratio is $N = 1$.

Typical values for $\eta = 0{,}9$, or other value can be adopted by agreement between parties involved. If this is the case, then the adopted values shall be reported.

The adopted values for N shall be reported.



Key

1 traction motor
2 gear between traction motor and wheel
3 wheel
4 running resistance applied to wheel

Figure 2 — Configuration of in-wheel drive system

6 Test conditions

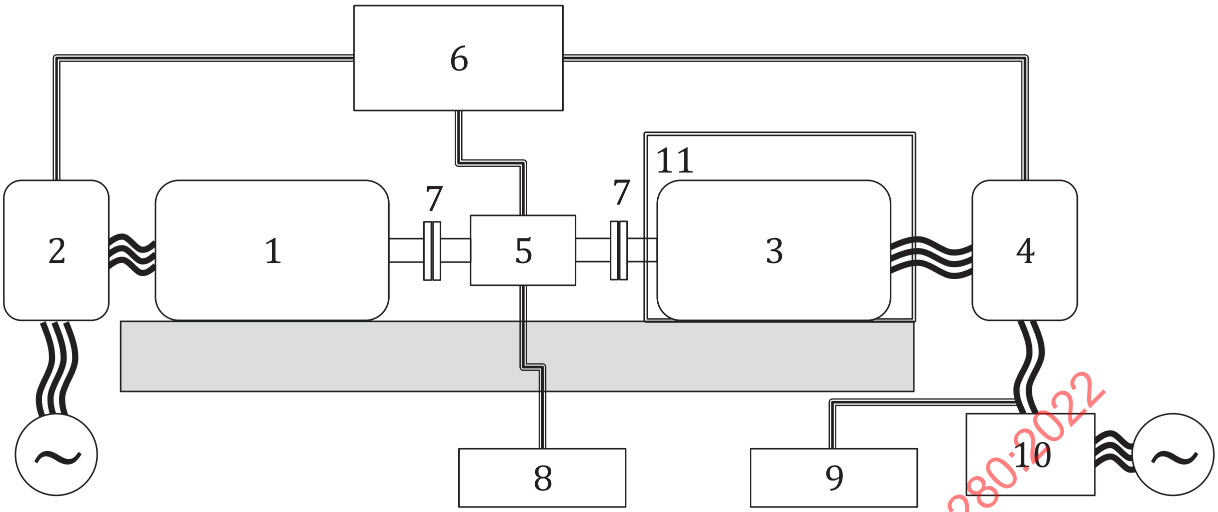
6.1 Motor dynamometer

Figure 3 shows a motor dynamometer test bench consisting of a load motor system and a test motor system that are mechanically connected by a coaxial mechanical coupling, power supply, torque and speed sensors, power meter, and data acquisition and processing equipment.

When the test motor is driven in a selected driving mode, the load motor shall be able to generate running resistance torque given in Formulae (2) or (3) as a function of rotational speed and acceleration. When the traction motor is operating as a generator in regenerative braking mode, the load motor shall be able to generate braking torque defined in a selected driving mode.

A temperature chamber should be used to control the temperature of the test motor. Temperature shall be maintained between 20 °C and 30 °C in accordance with ISO 13064-1.

Sampling rate for load, velocity, voltage and current shall be at least 10,0 Hz.



Key

1 load motor
2 load inverter
3 test motor
4 test inverter
5 torque sensor
6 main controller
7 coupling
8 torque/speed meter
9 power meter
10 DC power supply
11 temperature chamber

Figure 3 — Schematic diagram of the test system

6.2 Driving mode

The test motor system shall be able to perform any driving mode such as UDC, EUDC and WMTC.

The load motor system shall be controlled to emulate any driving mode, where WMTC driving mode is given in Figure C.1 as an example.

Tolerances on speed and time in the test sequence shall subject to ISO 8714:2002, Clause 5/Figure 1 and ISO 13064-1.

6.3 Operation for the motor dynamometer

The speed-torque control mode (3.5) shall be used, since test motor shall be driven in accordance with a selected driving mode, and load motor shall be able to generate corresponding running resistance torque.

Traction motor system shall be driven with the rotational speed(ω_m) given as Formula (4):

$$\omega_m = \frac{Nv}{r} \tag{4}$$

where v is the vehicle velocity specified in a selected driving cycle.

Any driving cycle can be adopted, however tolerances on speed and time for a selected driving cycle shall be satisfied in accordance with the specification given in the original document for the driving cycle.

6.3.1 Resistance torque to traction motor

To reproduce running resistance torque due to inertia, rolling resistance and aero dynamic drag to the test motor system, the test motor system shall be driven with resistance torque specified in Formula (2) for chain drive and Formula (3) for in-wheel drive at a given rotational speed for a specific driving mode.

6.3.2 Load motor system

Both rotating speed and torque of the load motor system shall be controllable. The maximum speed and torque shall be at least 1,2 times greater than those of the test motor system.

6.3.3 Torque and speed sensors

Torque and speed sensors are installed between the test motor system and the load motor system. The measurement range of the motor torque and speed sensors shall be at least 1,2 times greater than those of the test motor system.

The accuracy of the torque and speed sensors shall be within ±0,2 % and ±0,1 % of the maximum value, respectively, as defined in IEC 60034-2-1.

Care should be taken not to break torque sensors by severe jerk (acceleration divided by time).

6.4 DC Power supply

As power source, DC power supply is used for reproducibility of test, even though there may be some discrepancy with measurement using a battery as power source. This test is intended to measure energy performance of test motor system excluding effects of voltage and current changes of battery during driving and braking.

In order to emulate charging and discharging of the vehicle traction battery, the power supply shall be able to allow bidirectional flow of electric energy, for example, power application during driving and power absorption during regenerative braking. With regard to this requirement, an example of possible configuration of DC power supply system would be a combination of DC power supply device and electric load device, which may have, for example, simple voltage or current setting functions or have programmable function for emulation of a battery. The configuration of power supply system including adopted device type such as DC power supply and electric load, makers and technical specifications of devices, description to device settings and/or used program in case of programmable device, etc., shall be reported in the test report given in Table E.1 of Annex E.

DC power with rated voltage of intended moped or motorcycle battery supply shall have the minimum capacity of 1,5 times larger than the input power of the test motor system given in the specification.

Cables should be the same ones intended to be used in the actual vehicle, and the length should be the same as much as possible. The maker and specification of used cables, such as length and resistance, shall be reported.

Measurement position between DC power supply and test motor inverter should be the terminal of test motor inverter, and between test motor and test motor inverter, measurement position should be the mid-point between them.

6.5 Power meter

The power meter calculates the efficiency by measuring the electrical power of the test motor system under test. In regeneration mode, the mechanical input power and the electric output power are measured. In motor mode, the electric input power and the mechanical output power are measured.

The power meter shall have an accuracy within ±0,2 % of the maximum value.

6.6 Measurement of voltage and current

When measuring input voltage and current to the inverter from DC power supply, voltage and current sensor shall have the minimum bandwidth of 3 kHz and the accuracy of ±0,3 % (IEC 60034-2-1) of the maximum value.

6.7 Measurement of temperature

Temperatures of test motor system is measured to protect them from over temperature beyond manufacturers' specification. Temperatures of test motor system shall not exceed the limit specified by the manufacture. The measuring equipment for a test motor winding and its pairing inverter shall have accuracy within ±1 °C.

7 Performance calculation

7.1 Consumed energy

Consumed energy E [Wh] during a selected driving mode is the integration of voltage $V(t)$ [V] multiplied by current I(t) [A] from starting time t_0 [sec] to ending time t_f [sec] as defined in Formula (5):

$$E = \frac{\int_{t_0}^{t_f} V(t) I(t) \mathrm{d}t}{3\ 600} \tag{5}$$

7.2 Travelled distance

Travelled distance D [km] during a selected driving mode is defined as Formula (6):

$$D = \frac{\int_{t_0}^{t_f} r N \omega_m(t) \mathrm{d}t}{1\ 000} \tag{6}$$

where r is radius of tire [m], N is motor to wheel overall gear ratio, ω_m (t) is traction motor angular velocity [rad/sec].

7.3 Motor system efficiency

Mechanical energy output of the test motor system is integration of traction motor angular velocity multiplied by traction motor torque from starting time t_0 to ending time t_f during a selected driving mode. Efficiency of motor system η is ratio of electric input energy to mechanical output energy, which is given as Formulae (7) and (8);

$$\eta = \frac{\int_{t_0}^{t_f} \omega_m(t) T_m(t) \mathrm{d}t}{\int_{t_0}^{t_f} V(t) I(t) \mathrm{d}t} \tag{7}$$

$$\eta = \frac{2\pi \int_{t=0}^{t_f} n(t) T(t) \mathrm{d}t}{60 \int_{t=0}^{t_f} V(t) I(t) \mathrm{d}t} \tag{8}$$

where $T_m(t)$ is traction motor torque [N-m].

7.4 Reference energy consumption

Reference energy consumption Q [Wh/km] is the ratio of consumed energy to travelled distance as defined as Formula (9):

$$Q = \frac{E}{D} \tag{9}$$

8 Presentation of results

The results of energy performance calculations along with test conditions used shall be reported as specified in Annex E.

Annex A
(informative)

Classification of equivalent inertia mass and the running resistance for motorcycles

Equivalent inertia mass and the running resistance for motorcycles are given in Table A.1.

Table A.1 — Equivalent inertia mass and resistance for motorcycles

Reference mass, m_{ref} [kg]	Equivalent inertia mass, m_i [kg]	Rolling resistance of front and rear wheel, a [N]	Aero drag coefficient, b [N/(km/h)^2]
$95 < m_{ref} \leqslant 105$	100	17,6	0,021 5
$105 < m_{ref} \leqslant 115$	110	19,4	0,021 7
$115 < m_{ref} \leqslant 125$	120	21,1	0,021 8
$125 < m_{ref} \leqslant 135$	130	22,9	0,022 0
$135 < m_{ref} \leqslant 145$	140	24,6	0,022 1
$145 < m_{ref} \leqslant 155$	150	26,4	0,022 3
$155 < m_{ref} \leqslant 165$	160	28,2	0,022 4
$165 < m_{ref} \leqslant 175$	170	29,9	0,022 6
$175 < m_{ref} \leqslant 185$	180	31,7	0,022 7
$185 < m_{ref} \leqslant 195$	190	33,4	0,022 9
$195 < m_{ref} \leqslant 205$	200	35,2	0,023 0
$205 < m_{ref} \leqslant 215$	210	37,0	0,023 2
$215 < m_{ref} \leqslant 225$	220	38,7	0,023 3
$225 < m_{ref} \leqslant 235$	230	40,5	0,023 5
$235 < m_{ref} \leqslant 245$	240	42,2	0,023 6
$245 < m_{ref} \leqslant 255$	250	44,0	0,023 8
$255 < m_{ref} \leqslant 265$	260	45,8	0,023 9
$265 < m_{ref} \leqslant 275$	270	47,5	0,024 1
$275 < m_{ref} \leqslant 285$	280	49,3	0,024 2
$285 < m_{ref} \leqslant 295$	290	51,0	0,024 4
$295 < m_{ref} \leqslant 305$	300	52,8	0,024 5
$305 < m_{ref} \leqslant 315$	310	54,6	0,024 7
$315 < m_{ref} \leqslant 325$	320	56,3	0,024 8
$325 < m_{ref} \leqslant 335$	330	58,1	0,025 0
$335 < m_{ref} \leqslant 345$	340	59,8	0,025 1
$345 < m_{ref} \leqslant 355$	350	61,6	0,025 3
$355 < m_{ref} \leqslant 365$	360	63,4	0,025 4
$365 < m_{ref} \leqslant 375$	370	65,1	0,025 6

[a] Rolling resistance is obtained in consistence with the formula of $a = 0{,}088\ m_i$ for the front wheel given in ISO 11486:2006, Table 4. In this case the total rolling resistance becomes twice that of the front wheel, assuming 50:50 weight distribution between front and rear wheels. The value shall be rounded to one decimal place.

[b] The value shall be rounded to four decimal places.

Table A.1 *(continued)*

Reference mass, m_{ref} [kg]	**Equivalent inertia mass,** m_i [kg]	**Rolling resistance of front and rear wheel,** a [N]	**Aero drag coefficient,** b [N/(km/h)^2]
$375 < m_{ref} \leqslant 385$	380	66,9	0,025 7
$385 < m_{ref} \leqslant 395$	390	68,6	0,025 9
$395 < m_{ref} \leqslant 405$	400	70,4	0,026 0
$405 < m_{ref} \leqslant 415$	410	72,2	0,026 2
$415 < m_{ref} \leqslant 425$	420	73,9	0,026 3
$425 < m_{ref} \leqslant 435$	430	75,7	0,026 5
$435 < m_{ref} \leqslant 445$	440	77,4	0,026 6
$445 < m_{ref} \leqslant 455$	450	79,2	0,026 8
$455 < m_{ref} \leqslant 465$	460	81,0	0,026 9
$465 < m_{ref} \leqslant 475$	470	82,7	0,027 1
$475 < m_{ref} \leqslant 485$	480	84,5	0,027 2
$485 < m_{ref} \leqslant 495$	490	86,2	0,027 4
$495 < m_{ref} \leqslant 505$	500	88,0	0,027 5
At every 10 kg	At every 10 kg	$a = 0{,}176\ m_i$ [a]	$b = 0{,}000\ 015\ m_i + 0{,}020\ 0$ [b]

[a] Rolling resistance is obtained in consistence with the formula of $a = 0{,}088\ m_i$ for the front wheel given in ISO 11486:2006, Table 4. In this case the total rolling resistance becomes twice that of the front wheel, assuming 50:50 weight distribution between front and rear wheels. The value shall be rounded to one decimal place.

[b] The value shall be rounded to four decimal places.

Annex B
(informative)

Classification of equivalent inertia mass and the running resistance for mopeds

Equivalent inertia mass and the running resistance for motor mopeds are given in Table B.1.

Table B.1 — Equivalent inertia mass and resistance for mopeds

Reference mass, m_{ref} [kg]	Equivalent inertia mass, m_i [kg]	Rolling resistance of front and rear wheel, a [N]	Aero drag coefficient, b [N/(km/h)^2]
$95 < m_{ref} \leqslant 105$	100	17,6	0,021 5
$105 < m_{ref} \leqslant 115$	110	19,4	0,021 7
$115 < m_{ref} \leqslant 125$	120	21,1	0,021 8
$125 < m_{ref} \leqslant 135$	130	22,9	0,022 0
$135 < m_{ref} \leqslant 145$	140	24,6	0,022 1
$145 < m_{ref} \leqslant 155$	150	26,4	0,022 3
$155 < m_{ref} \leqslant 165$	160	28,2	0,022 4
$165 < m_{ref} \leqslant 175$	170	29,9	0,022 6
$175 < m_{ref} \leqslant 185$	180	31,7	0,022 7
$185 < m_{ref} \leqslant 195$	190	33,4	0,022 9
$195 < m_{ref} \leqslant 205$	200	35,2	0,023 0
$205 < m_{ref} \leqslant 215$	210	37,0	0,023 2
$215 < m_{ref} \leqslant 225$	220	38,7	0,023 3
$225 < m_{ref} \leqslant 235$	230	40,5	0,023 5
$235 < m_{ref} \leqslant 245$	240	42,2	0,023 6
$245 < m_{ref} \leqslant 255$	250	44,0	0,023 8
$255 < m_{ref} \leqslant 265$	260	45,8	0,023 9
$265 < m_{ref} \leqslant 275$	270	47,5	0,024 1
$275 < m_{ref} \leqslant 285$	280	49,3	0,024 2
$285 < m_{ref} \leqslant 295$	290	51,0	0,024 4
$295 < m_{ref} \leqslant 305$	300	52,8	0,024 5
$305 < m_{ref} \leqslant 315$	310	54,6	0,024 7
$315 < m_{ref} \leqslant 325$	320	56,3	0,024 8
$325 < m_{ref} \leqslant 335$	330	58,1	0,025 0
$335 < m_{ref} \leqslant 345$	340	59,8	0,025 1
$345 < m_{ref} \leqslant 355$	350	61,6	0,025 3
$355 < m_{ref} \leqslant 365$	360	63,4	0,025 4
$365 < m_{ref} \leqslant 375$	370	65,1	0,025 6

[a] Rolling resistance is obtained in consistent with the formula of $a = 0{,}088m_i$ for the front wheel given in ISO 28981:2009, Table 4. In this case the total rolling resistance becomes twice that of the front wheel, assuming 50:50 weight distribution between front and rear wheels. The value shall be rounded to one decimal place.

[b] The value shall be rounded to four decimal places.

Table B.1 *(continued)*

Reference mass, m_{ref} [kg]	**Equivalent inertia mass,** m_i [kg]	**Rolling resistance of front and rear wheel,** a [N]	**Aero drag coefficient,** b [N/(km/h)^2]
$375 < m_{ref} \leqslant 385$	380	66,9	0,025 7
$385 < m_{ref} \leqslant 395$	390	68,6	0,025 9
$395 < m_{ref} \leqslant 405$	400	70,4	0,026 0
$405 < m_{ref} \leqslant 415$	410	72,2	0,026 2
$415 < m_{ref} \leqslant 425$	420	73,9	0,026 3
$425 < m_{ref} \leqslant 435$	430	75,7	0,026 5
$435 < m_{ref} \leqslant 445$	440	77,4	0,026 6
$445 < m_{ref} \leqslant 455$	450	79,2	0,026 8
$455 < m_{ref} \leqslant 465$	460	81,0	0,026 9
$465 < m_{ref} \leqslant 475$	470	82,7	0,027 1
$475 < m_{ref} \leqslant 485$	480	84,5	0,027 2
$485 < m_{ref} \leqslant 495$	490	86,2	0,027 4
$495 < m_{ref} \leqslant 505$	500	88,0	0,027 5
At every 10 kg	At every 10 kg	$a = 0{,}176\ m_i$ [a]	$b = 0{,}000\ 015\ m_i + 0{,}020\ 0$ [b]

[a] Rolling resistance is obtained in consistent with the formula of $a = 0{,}088m_i$ for the front wheel given in ISO 28981:2009, Table 4. In this case the total rolling resistance becomes twice that of the front wheel, assuming 50:50 weight distribution between front and rear wheels. The value shall be rounded to one decimal place.

[b] The value shall be rounded to four decimal places.

Annex C
(informative)

Derivation of traction motor torque for central drive system

From Figure (1), relation between running resistance at the driving wheel F_w and driving torque of the traction motor system T_m can be given as:

$$F_w = \frac{1}{r}\left[\eta_g \eta_c N_g N_w T_m - \eta_c N_w (J_s + J_c)\alpha_s - J_w \alpha_w\right] \quad \text{(C.1)}$$

Definition of variables for Formula (C.1), along with their nominal values for a typical medium-sized motorcycle, are given in Table C.1. From Formula (C.1) driving torque of traction motor can be solved as Formula (C.2):

$$T_m = \frac{1}{\eta_c \eta_g N_g N_w}\left[F_w r + \eta_c N_w (J_s + J_c)\alpha_s + J_w \alpha_w\right] \quad \text{(C.2)}$$

Kinematic relation between acceleration of vehicle A, and wheel angular acceleration α_w is as defined in Formula (C.3):

$$A = r\,\alpha_w \quad \text{(C.3)}$$

where r is the radius of the wheel.

Similarly, kinematic relation between velocity of vehicle v and wheel angular velocity ω_w is as defined in Formula (C.4):

$$v = r\,\omega_w \quad \text{(C.4)}$$

Relation between angular acceleration of motor α_m and angular acceleration of driving sprocket α_s and angular acceleration of wheel α_w is respectively given as Formulae (C.5) and (C.6):

$$\alpha_m = \frac{\alpha_s}{N_g} \quad \text{(C.5)}$$

$$\alpha_s = \frac{\alpha_w}{N_w} \quad \text{(C.6)}$$

Similarly, relations between angular velocity of traction motor ω_m, angular velocity of driving sprocket ω_s, and angular velocity of wheel ω_w can be given as Formulae (C.7) and (C.8):

$$\omega_m = \frac{\omega_s}{N_g} \quad \text{(C.7)}$$

$$\omega_s = \frac{\omega_w}{N_w} \tag{C.8}$$

Converting angular acceleration α_s and α_w in Formula (C.2) in terms of vehicle acceleration A using Formulae (C.3), (C.5), (C.6) and substituting into Formula (C.2) gives driving torque to traction motor system in terms of running resistance and vehicle acceleration as:

$$T_m = \left(\frac{r}{\eta_c \eta_g N_w N_g} \right) F_w + \left[\frac{(J_c + J_s)}{\eta_g N_g N_w r} + \frac{J_w}{\eta_c \eta_g N_g N_w r} \right] A \tag{C.9}$$

The first term at the right-hand side of Formula (C.9) is steady-state relation between T_m and F_w, which depends on gear ratios (N_w, N_g) and transmission efficiencies (η_c, η_g), while the second term is transient torque arising from acceleration of vehicle (A) and inertias of chain (J_c), driving sprocket (J_s), and wheel (J_w).

The second term at the right-hand side of Formula (C.9) is much less than the second term, thus Formula (C.9) can be reduced to:

$$T_m = \left(\frac{r}{\eta_c \eta_g N_w N_g} \right) F_w \tag{C.10}$$

To demonstrate validity of Formula (C.10), Figure (C.1) compares driving torques computed by Formula (C.9) and Formula (C.10) with four different cases subject to WMTC driving mode, where typical values of transmission efficiency of chain (η_c) and transmission efficiency between motor and driving sprocket (η_g) are assumed as $\eta_g = \eta_c = 0{,}91$). The different cases are the following:

1) no friction loss ($\eta_c = \eta_g = 1$) with inertia effect (J_c, J_g and J_w: nominal values in Table C.1),

2) no friction loss ($\eta_c = \eta_g = 1$) without inertia effect ($J_c = J_g = J_w = 0$, second term at the right-hand side of Formula (C.9) becomes zero),

3) with friction loss ($\eta_c = \eta_g = 0{,}9$) and with inertia effect (J_c, J_g and J_w: nominal values in Table C.1),

4) with friction loss ($\eta_c = \eta_g = 0{,}9$) and without inertia effect ($J_c = J_g = J_w = 0$, second term at the right-hand side of Formula (C.9) becomes zero).

Cases 1) and 2) compare driving torque by, respectively, Formulae (C.9) and (C.10) both with $\eta_c = \eta_g = 1$, while cases 3) and 4) compare driving torque by, respectively, Formulae (C.9) and (C.10) both with $\eta_c = \eta_g = 0{,}9$. Cases 1) and 2) show almost the same values of torques, and similarly cases 3) and 4) show almost the same values of torques. Thus, validity of Formula (C.10) can be demonstrated.

Table C.1 — Drive train components and parameters for central drive system

Parts	Parameters	Symbol [unit]	Value
Vehicle	Equivalent mass	m_i [kg]	[a]
	Rolling resistance	a [N]	[a]
	Aero dynamic drag coefficient	b [N/(Km/h)^2]	[a]
	Velocity	v [Km/h]	[b]
	Acceleration	A [m/sec^2]	[b]
	Running resistance	F_W[N]	$m_i A + a + b v^2$
Wheel	Radius of wheel	r [m]	0,3
	Wheel moment of inertia	J_W [kg- m^2]	0,3 [c]
	Wheel angular acceleration	α_W [rad/ sec^2]	A/r
Sprocket	Driving sprocket to wheel gear ratio	N_W	
	Angular acceleration	α_S [rad/sec^2]	α_W / N_W
	Moment of inertia	J_S [kg- m^2]	0,000 48 [d]
Chain	Transmission efficiency	η_c	0,9 [e]
	Moment of inertia	J_C [kg- m^2]	0,000 43 [f]
Motor	Transmission efficiency	η_g	0,9 [g]
	Torque	T_m [Nm]	
	Motor to driving sprocket gear ratio	N_g	

[a] Values are given in Annexes A and B.

[b] Velocity values are determined from a selected driving cycle such as WMTC.

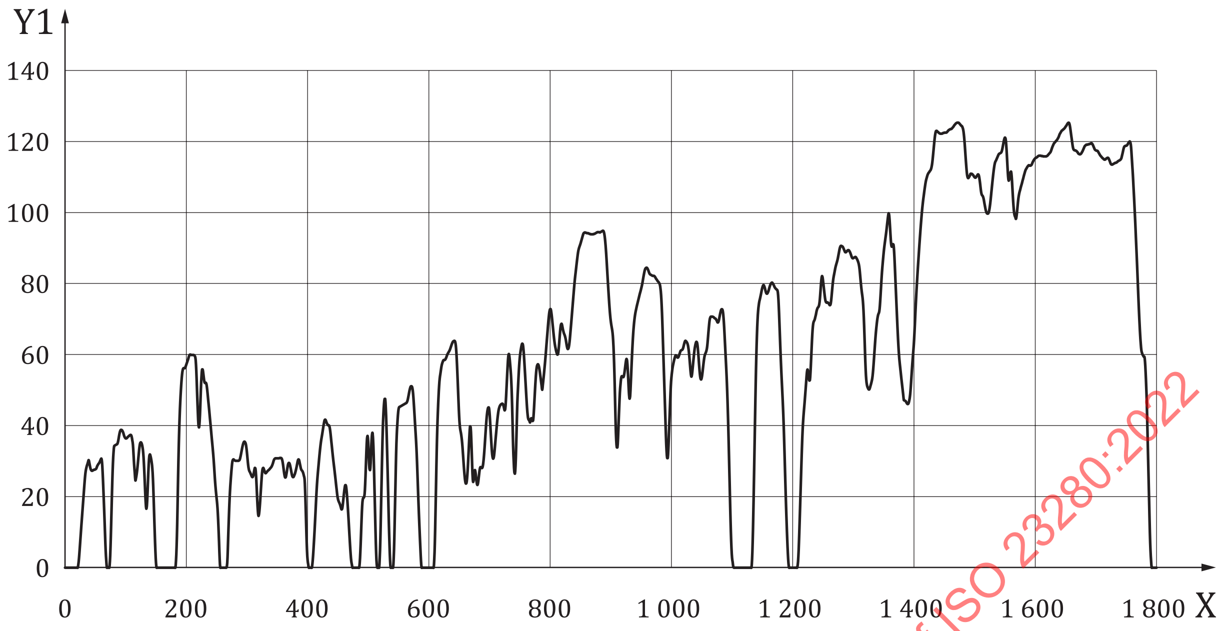
[c] This represents nominal value for a medium size motorcycle, including wheel and wheel gear assembly.

[d] This represents nominal value for a medium size motorcycle, including driven sprocket and all components on the same axis.

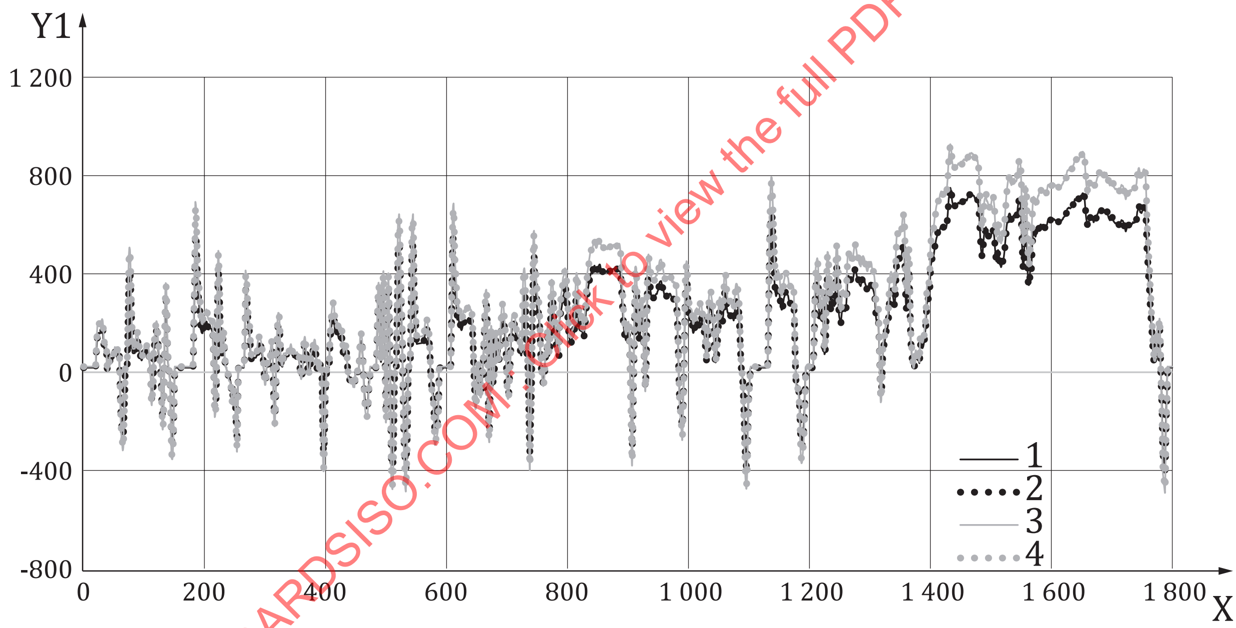
[e] This represents nominal values for transmission efficiency of chain drive system including driving and driven sprocket and chain.

[f] This represents nominal value for medium size motorcycle measured with respect to driving sprocket.

[g] This represents nominal value for transmission efficiency between motor and driving sprocket.



a) Driving mode as function of time



b) Traction motor torque as function of time

Key

X time [sec]

Y_1 velocity [km/h]

Y_2 torque [N-m]

1 no friction loss ($\eta_c = \eta_g = 1$) with inertia effect (J_c, J_g and J_w),

2 no friction loss ($\eta_c = \eta_g = 1$) without inertia effect ($J_c = J_g = J_w = 0$)

3 with friction loss ($\eta_c = \eta_g = 0.9$) and with inertia effect (J_c, J_g and J_w),

4 with friction loss ($\eta_c = \eta_g = 0.9$) and without inertia effect ($J_c = J_g = J_w = 0$)

Figure C.1 — Traction motor torque for different values of transmission efficiency and moment of inertia