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Electrically propelled mopeds and motorcycles — Test method for evaluating performance of regenerative braking systems

À propulsion électrique cyclomoteurs et des motocycles — Méthode d'essai pour évaluer l'efficacité du système de freinage régénératif

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Foreword

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

Electrically propelled mopeds and motorcycles — Test method for evaluating performance of regenerative braking systems

1 Scope

This document specifies test procedures for measuring performance of regenerative braking systems used for electric motorcycles and mopeds that are propelled by traction motors with electric batteries. Performance of regenerative braking systems is dealt with two perspectives: first, how much a regenerative braking system can extend range of a motorcycle or moped or reduce energy consumption, and second, the efficiency of the driving motor system when working as generator in regenerative braking mode.

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 13064-1:2012, *Battery-electric mopeds and motorcycles — Performance — Part 1: Reference energy consumption and range*

ISO 13064-2:2012, *Battery-electric mopeds and motorcycles — Performance — Part 2: Road operating characteristics*

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 terminological databases for use in standardization at the following addresses:

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

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

3.1
load motor
electric motor that can simulate road load, as well as braking torque, when testing a *test motor system* (3.11) of electric mopeds and motorcycles

Note 1 to entry: During test, both rotational speed and torque of load motor shall be controllable within a specified range.

3.2
load motor system
combination of a *load motor* (3.1) and its inverter

3.3
reference energy consumption
quantity of electric energy from the mains needed to charge the traction battery, divided by the distance covered after an electric motorcycle or moped has been driven through the specified test sequence

Note 1 to entry: The reference energy consumption is usually expressed in watt-hours per kilometres (Wh/km).

[SOURCE: ISO/TR 8713:2012, 2.62, modified — "the vehicle" has been replaced by "an electric motorcycle or moped".]

3.4
reference energy consumption gain
ratio of *reference energy consumption* (3.3) to change in reference energy consumption due to regenerative braking system

Note 1 to entry: Gain is positive when reference energy consumption is decreased by regenerative braking system.

3.5
reference range
distance covered by an electrically propelled motorcycle or moped over a designated test sequence on a fully charged traction battery to the end of the test sequence as defined by the end of test sequence criteria

Note 1 to entry: The reference range is usually expressed in kilometeres (km).

[SOURCE: ISO/TR 8713:2012, 2.63, modified — "vehicle" has been replaced by "motorcycle or moped".]

3.6
reference range gain
ratio of *reference range* (3.5) to change in reference range due to *regenerative braking system* (3.7)

Note 1 to entry: Gain is positive when reference range is increased by regenerative braking system.

3.7
regenerative braking system
brake system which, during deceleration, provides for the conversion of kinetic energy into electrical energy

3.8
regenerative braking efficiency of traction motor system
efficiency of a traction motor system when working as a generator in regenerative braking mode, which is the ratio of mechanical power input to electrical power output

3.9
state of charge
SOC
actual capacity of a battery pack or system, indicated as percentage of the rated capacity

3.10
test motor
motor under test that is used as a main traction motor for electric mopeds and motorcycles, which generates traction torque as well as regenerative electric energy during braking

3.11
test motor system
combination of *test motor* (3.10) and its inverter

4 Principles

Performance of a regenerative system is affected by various elements, i.e. motor and inverter, battery SOC, temperature, brake control strategy, road load, traffic situation, driving behaviour of drivers, etc.

In order to measure performance of regenerative braking system accounting for these wide range of factors, performance is defined for both vehicle and traction motor system perspectives. Performance of regenerative braking system in view of vehicle is defined in reference range gain (see 5.2) or reference energy consumption gain (see 5.3), while performance in view of traction motor system is defined in terms of efficiency of traction motor system when used as a generator (see Clause 6).

NOTE Reference energy consumption gain or reference range gain represents measure of performance improvement of the vehicle system by regenerative braking in terms of reference energy consumption and reference range, respectively.

5 Test procedure for reference range gain and reference energy consumption gain

5.1 General

Measurements of reference range gain and reference energy consumption gain are based on the reference range and reference energy consumption specified in ISO 13064-1, where test sequence for mopeds is defined in ISO 13064-1:2012, Annex A and the test sequence for motorcycles is defined in ISO 13064-1:2012, Annex B.

5.2 Reference range gain

To measure reference range gain, reference range of a motor cycle or moped shall be determined according to ISO 13064-1 with regenerative braking system ON and OFF. The test procedure to determine reference range gain consists of the following steps:

a) initial charging of the traction battery (see ISO 13064-1:2012, 7.4.2);

b) application of the appropriate test sequence with regenerative braking system ON until the tolerance on velocity defined in ISO 13064-1:2012, Clause 5 is met and measurement of the reference range d_{on} (see ISO 13064-1:2012, 7.4.3);

c) application of the appropriate test sequence with regenerative braking system OFF until the tolerance on velocity defined in ISO 13064-1:2012, Clause 5 is met and measurement of the reference range d_{off} (see ISO 13064-1:2012, 7.4.3);

d) calculation of reference range gain, G_{range}, according to Formula (1):

$$G_{range} = \frac{d_{on} - d_{off}}{d_{on}} \times 100 \quad (1)$$

5.3 Reference energy consumption gain

To measure reference energy consumption gain, reference energy consumption of a motorcycle or moped shall be determined according to ISO 13064-1 with regenerative braking system ON and OFF. The test procedure to determine reference energy consumption gain consists of the following steps:

a) initial charging of the traction battery (ISO 13064-1:2012, 7.4.2);

b) application of appropriate test sequences with regenerative braking system OFF until the tolerance on velocity defined in ISO 13064-1:2012, Clause 5 is met and recording of the number of completed test sequences for step d);

NOTE If the tolerance on velocity defined in ISO 13064-1:2012, Clause 5 is not met at sequence number N+1, then the completed number of test sequences is N.

c) charging of the traction battery and measurement of the energy consumption, E_{off}, at the mains (see ISO 13064-1:2012, 7.4.4);

d) application of the N appropriate test sequences recorded in step b) with regenerative braking system ON;

e) charging of the traction battery and measurement of the energy consumption, E_{on}, at the mains (see ISO 13064-1:2012, 7.4.4);

f) calculation of the reference energy consumption gain, G_{energy}, according to Formula (2):

$$G_{energy} = \frac{E_{on} - E_{off}}{E_{on}} \times 100 \quad (2)$$

6 Test procedure for regenerative braking efficiency of traction motor system

6.1 Test setup

6.1.1 General

Figure 1 shows a typical test setup consisting of a load motor system and a test motor system that are mechanically connected through coaxial coupling, power supply, torque and speed measuring sensors, power analyser and data processing equipment.

When the test motor is operating as traction motor in driving mode, the load motor shall be able to simulate any predefined road load in terms of angular velocity and torque. When the traction motor is operating as a generator in regenerative braking mode, the load motor shall be able to generate braking torque at a specified speed defined in test procedure.

A temperature chamber shall be used to control the temperature of the test motor.

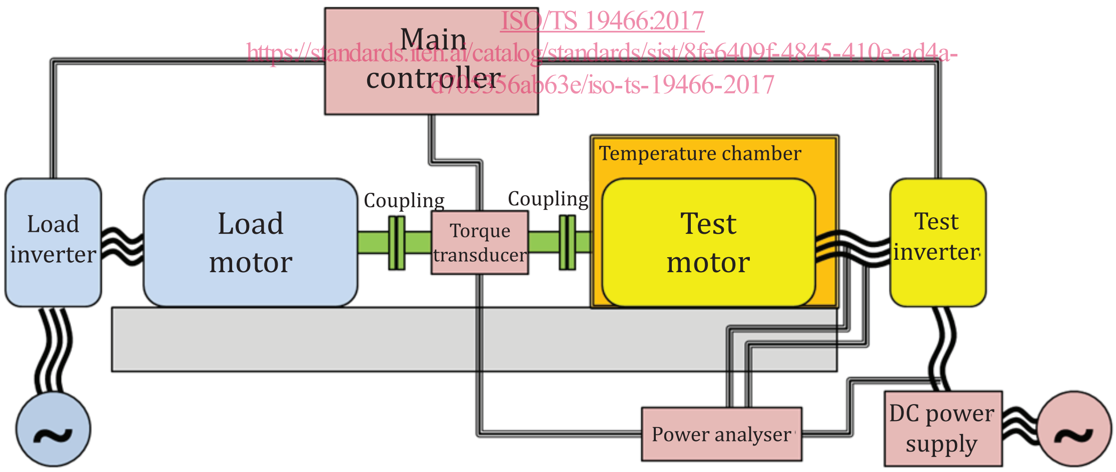

Figure 1 — Schematic diagram of the test system

6.1.2 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 whose speeds and torques are given in Table 1 and Table 2.

6.1.3 Torque and speed sensors

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

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.

6.1.4 DC power supply

In order to simulate charging and discharging of the vehicle traction battery, the power supply shall allow bidirectional flow of electric energy, power application for driving and power absorption for regenerative braking.

The measurement accuracy shall be within ±5 % of the maximum voltage and current at the time of power application and absorption.

DC power supply shall have the minimum capacity of 1,5 times the input power to the test motor given in Table 1 and Table 2.

When using vehicle traction battery, the SOC should be in the range of 75 % ~ 90 % of the full capacity.

6.1.5 Power analyser

A power analyser calculates the efficiency of a test motor system under test using mechanical input to the motor under test and electrical output of a test motor system.

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

6.1.6 Voltage and current measurement

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

6.1.7 Temperature measurement

The measuring equipment for a test motor winding temperature shall have accuracy within ±1 °C.

6.2 Test procedure

6.2.1 General

Regenerative braking efficiency of a test motor system is measured at steady state (see 6.2.2) and transient state (see 6.2.3). For steady state, efficiency is measured at a given constant speed and torque, and for transient state, efficiency is measured at varying speed and torque as function of time.

6.2.2 Steady-state regenerative braking efficiency

The regenerative braking efficiency of a test motor system is measured at the predetermined steady-state speeds and torques that cover the range of design specifications of the test motor.

The load motor system provides mechanical input to test motor system at a specified test points based on the rated torque (see Table 1 and Figure 2) or the rated power(see Table 2 and Figure 3).

The specified speed and torque values of test motor system, shown in Table 1 and Figure 2, are based on the percentage of rated torque, while in Table 2 and Figure 3, speed and torque values are defined based on the percentage of rated power.

The steady-state regenerative braking efficiency of a test motor system, η_S, at each speed and torque point is calculated by Formula (3):

