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Electrically propelled road vehicles — Determination of power for propulsion of hybrid electric vehicle

Véhicules routiers à propulsion électrique — Détermination de la puissance de propulsion des véhicules hybrides

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Foreword

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles.*

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.

Introduction

It is necessary for vehicle manufacturers to show the reasonable value of the power of hybrid-electric vehicle (HEV) system and compare it with the value of the internal combustion engine (ICE) power measured in the existing test methods such as ISO 1585 and UN Regulation No. 85. But at present, there is no international evaluation method for the power of HEV systems available. Vehicle manufacturers indicate the power of HEVs in their catalogues based on their individual calculation method. With the method in this document, it is possible to measure and compare the power of any HEV topology with those of internal combustion engine vehicles (ICEV).

Electrically propelled road vehicles — Determination of power for propulsion of hybrid electric vehicle

1 Scope

This document specifies measurement methods for the maximum system propulsion power of hybrid-electric vehicles (HEV).

The results can be compared with the data of internal combustion engine vehicles (ICEV) power measured with the relevant current method.

NOTE ISO 1585 and UN Regulation No. 85, for example.

This document applies only to the vehicles with the following characteristics:

— HEVs with an internal combustion engine (ICE) and one or more electric motors powered by one or more rechargeable energy storage systems (RESS) for propulsion;

— vehicles classified as passenger cars or light duty trucks.

This document does not apply to fuel cell vehicles.

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 1585, *Road vehicles — Engine test code — Net power*

ISO 23274 (all parts), *Hybrid-electric road vehicles — Exhaust emissions and fuel consumption measurements*

ISO/TR 8713, *Electrically propelled road vehicles — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1585, ISO 23274 (all parts), ISO/TR 8713 and the following apply.

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

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

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

3.1
hybrid-electric vehicle
HEV
vehicle with both a *rechargeable energy storage system* (3.3) and a fuelled power source for propulsion

3.2
externally chargeable HEV
hybrid-electric vehicle (3.1) with a *rechargeable energy storage system* (3.3) that is intended to be charged from an external electric energy source

Note 1 to entry: External charge for the purpose of conditioning of the RESS is not included.

Note 2 to entry: Externally chargeable HEVs are widely known as plug-in HEVs (PHEVs).

3.3
rechargeable energy storage system
RESS
system that stores energy for delivery of electric power and which is rechargeable

EXAMPLE Batteries or capacitors.

4 Symbols and abbreviated terms

AWD	all wheel drive
ICE	internal combustion engine
ICEV	internal combustion engine vehicle
SOC	state of charge
UN	United Nations

5 Test condition

5.1 Test instrumentation

5.1.1 Chassis dynamometer

The chassis dynamometer shall have the absorption capacity for the vehicle propulsion power by fixed speed control.

5.1.2 Test room

Conditions of the test room shall be adjusted as follows:

— reference temperature: 298 K ± 10 K (25 °C ± 10 °C);

— test atmospheric conditions, Pd: 80 kPa < Pd < 110 kPa.

5.1.3 Cooling fan

Fans shall be used to cool the vehicle to maintain the proper operating temperature. However, excessive cooling is prohibited. Air speed in front of the vehicle shall not be higher than the vehicle speed.

5.2 Measurement

5.2.1 Measurement items and accuracy

Table 1 — List of items

Items	Unit	Accuracy	Remark
Engine speed	min^{-1}	±10 min^{-1} or ±0,5 % of measured value whichever is greater	
Intake manifold pressure	Pa	±50 Pa	Intake manifold pressure means inlet depression as used in ISO 1585.
Atmospheric pressure	Pa	±100 Pa	
Fuel flow rate	g/s	±3 %	At least used for compression-ignition engines, and for ICEs if the confirmation of air fuel ratio according to ISO 1585 is necessary.
Voltage	V	±0,5 %	
Current	A	±0,5 %	The current transducer shall have a minimum accuracy of 0,5 % of the measured value or 0,1 % of the maximum value of the scale.
Room temperature	K	±2 K	
Chassis dynamometer roller speed	km/h	±0,5 km/h or ±1 %, whichever is greater	
Time	s	±0,01 s	
Drive shaft or wheel rotational speed	s^{-1}	±0,05 s^{-1} or ±1 %, whichever is greater	
Drive shaft or wheel torque	Nm	±6 Nm or ±0,5 %, whichever is greater	

Measurement devices shall be of certified accuracy, traceable to an approved regional or international standard.

5.2.2 Measurement frequency

All the items in Table 1, except atmospheric pressure and room temperature, shall be measured and recorded at a frequency of not less than 10 Hz.

The items atmospheric pressure and room temperature shall be at least recorded as single measurement activity at start of vehicle operation (see 6.8.4) and after end of vehicle running (see 6.8.6).

6 Test procedure

6.1 General

The purpose of the following test procedures is to determine the maximum system propulsion power of an HEV (maximum HEV system power) on a chassis dynamometer at fixed speeds. Two optional test procedures are applicable, namely:

— a test procedure via measured RESS power and determined ICE power, consecutively named test procedure option 1 (TP1); and

— a test procedure via torque and speed measurement at the drive shaft(s) or wheel(s), consecutively named test procedure option 2 (TP2).

The test result for the maximum HEV system power shall be stated always in connection with the performed test procedure.

NOTE Depending on the power transfer rate in series and power-split types, the results for the maximum HEV system power differ in TP1 and TP2.

6.2 Preparation of chassis dynamometer

6.2.1 Roller

The chassis dynamometer roller(s) shall be clean, dry and free from foreign material which can cause tire slippage.

6.2.2 Tire slippage

Additional weight may be placed on or in the vehicle to eliminate tire slippage. The use of any additional weight shall be recorded.

6.2.3 Chassis dynamometer warm-up

The chassis dynamometer shall be warmed up in accordance with the dynamometer manufacturer's recommendations, or as appropriate.

6.2.4 Chassis dynamometer control

The chassis dynamometer shall be controlled in fixed speed mode for the power test. Only for the requirements towards vehicle conditioning (6.8.2), the chassis dynamometer shall be controlled in road load mode.

6.3 Preparation of vehicle

The tire pressure shall be adjusted in accordance with the vehicle manufacturer's recommendations or the owner's manual. The vehicle lubricants and levels specified by the manufacturer shall be used.

Fuel shall be selected in accordance with the vehicle manufacturer's recommendations. If there are no recommendations, the fuel specified in ISO 1585 shall be used.

6.4 Preparation of measurement devices

The measurement devices shall be installed at suitable position(s) and warmed up as appropriate.

Specifically for TP2, the gearbox output shaft(s) or the driven wheel(s) shall be prepared with appropriate, calibrated torque and rotational speed measurement device(s).

For a driven axle powered via differential and two wheels, it is sufficient to install only one torque and rotational speed measurement device on a drive shaft or wheel. In this case, the measured torque at a drive shaft or wheel shall be multiplied by 2 in order to get the sum of torque per driven axle.

NOTE The torque and rotational speed measurement devices can be substituted by traction force and speed measured by the chassis dynamometer, if the accuracy of this measurement devices fulfil the same requirements as for the drive shaft or wheel measurement devices. If so, it is necessary that the measured values for traction force and speed be transformed, by calculation, to the required values for torque and rotational speed at drive shaft or wheel taken into account the specific data of the tires and the proportional vehicle weight at the wheels used during the test (e.g. rolling friction losses, dynamic rolling radius).

6.5 Initial charge of RESS

The RESS of the vehicle shall be charged to the SOC specified by the vehicle manufacturer.

After the SOC has been set, the current and voltage measurements shall be started.

The SOC shall be adjusted by regenerative braking or by charging from the external electric power supply or by discharging via electric driving.

The SOC adjustment may be carried out during vehicle soak (6.6) in case of externally chargeable HEVs.

6.6 Vehicle soak

The vehicle shall be soaked in accordance with the vehicle manufacturer's recommendations. Unless otherwise specified, the room temperature shall be 298 K ± 10 K (25 °C ± 10 °C).

6.7 Vehicle installation

The vehicle shall be installed on the chassis dynamometer roller in accordance with the dynamometer manufacturer's recommendation. During the test, auxiliary systems (for example, air-conditioning and heating) which are not contributing to vehicle propulsion shall be turned off. Auxiliary systems not contributing to vehicle propulsion shall be turned off. If auxiliaries except DC/DC converter cannot be turned off, then the $P_{auxiliary}$ shall be measured or calculated and finally subtracted from the measured RESS power.

6.8 Test sequence

6.8.1 General

The test shall be carried out in accordance with 6.8.2 to 6.8.6, and 6.9 to 6.10 (see Figure 2). The test shall be stopped immediately if warning indicator(s) with regard to the power train turns on.

NOTE Warnings are coolant temperature and engine check lamp, for example.

6.8.2 Vehicle conditioning

In order to stabilize the vehicle, it shall run at the speed of 60 km/h at the vehicle road load for at least 20 minutes, or with the vehicle manufacturer's recommendations.

When the vehicle conditioning has to be performed due to a measurement loop at various fixed dynamometer speeds (see 6.10), the time to run the vehicle for stabilization in the second or further loop may be shorter than 20 minutes according the vehicle manufacturer's recommendation or if the temperature of components is measured and not higher than before the first test.

6.8.3 RESS adjustment

During vehicle conditioning according to 6.8.2, the SOC shall be monitored and adjusted at the end of vehicle conditioning, according to the requirements specified in 6.5.

6.8.4 Vehicle operation

The measurement devices shall start collecting data. The driving mode switch shall be selected appropriately in order to obtain the maximum HEV power.

Run the vehicle at a fixed speed in accordance with the vehicle manufacturer's recommendations.

To be able to measure the maximum power value, a sufficient number of tests shall be carried out at appropriately varied speeds of chassis dynamometer (see 6.10).

6.8.5 Pedal operation

The maximum accelerator pedal command shall be given by either the pedal position or by vehicle communication network for duration of at least 10 s.

NOTE Prior to the maximum accelerator pedal command, it is possible to modulate the accelerator pedal position.

6.8.6 End of vehicle running

After measurements according to 6.8.5, the vehicle and measurement devices, except those for the current and voltage, shall be stopped.

6.9 Calculation of HEV system power

6.9.1 General

The time series data obtained from 6.8 shall be analysed to determine power. Regardless of TP1 or TP2, two power calculations shall be performed:

1) a 2-second "peak" power that applies a 2-second moving average filter for the 10 s measurement time;

2) a "sustained" power that defines the average power within the measurement time window from 8 s to 10 s.

NOTE In case of ICE power corrections according to ISO 1585, one can ask the vehicle manufacturer if necessary. It is possible that HEV power trains possess their own power compensation.

6.9.2 Calculation for TP1

a) ICE power (in kW): The test results of measurements according to ISO 1585 are necessary. ICE power is based on the measured engine speed, intake manifold pressure in inlet system and fuel flow rate if the confirmation of air fuel ratio according to ISO 1585 is necessary. It shall be determined by a relevant engine dynamometer test. The engine dynamometer test fuel shall be the same as in 6.3.

   The engine dynamometer test to obtain the ICE power can be conducted under the conditions specified in ISO 1585 using the above-measured engine speed, intake manifold pressure in inlet system and fuel flow rate if the confirmation of air fuel ratio according to ISO 1585 is necessary. If the intake manifold pressure or fuel flow rate deviates significantly from ISO 1585, conduct ISO 1585 under the conditions using the above-measured engine speed and intake manifold pressure in inlet system or fuel flow rate, ask the vehicle manufacturer or conduct TP2.

b) converted RESS power, $P_{RESS(con)}$, (in kW): Use Formula (1):

$$P_{RESS(con)} = (U_{RESS} \times I_{RESS} / 1\,000 - P_{DCDC} - P_{aux}) \times K \quad (1)$$

where

U_{RESS} is the measured RESS voltage (in V);

I_{RESS} is the measured RESS current (in A);

P_{DCDC} is the power to DC/DC converter for 12 V auxiliaries (1,0 kW or measured value) (in kW);

P_{aux} is the power to auxiliaries except DC/DC converter for 12 V auxiliaries (measured value) (in kW);

K is the conversion factor from electrical power to mechanical power (0,85 or measured value).

If the power is measured, P_{DCDC} and P_{aux} are calculated with Formulae (2) and (3):

$$P_{DCDC} = U_{DCDC} \times I_{DCDC} / 1\,000 \quad (2)$$

$$P_{aux} = U_{aux} \times I_{aux} / 1\,000 \quad (3)$$

where

I_{aux} is the current to auxiliaries except DC/DC converter for 12 V auxiliaries (in A);

I_{DCDC} is the current to DC/DC converter for 12 V auxiliaries (in A);

P_{DCDC} is the power to DC/DC converter for 12 V auxiliaries (1,0 kW or measured value) (in kW);

P_{aux} is the power to auxiliaries except DC/DC converter for 12 V auxiliaries (measured value) (in kW);

U_{aux} is the voltage to auxiliaries except DC/DC converter for 12 V auxiliaries (in V);

U_{DCDC} is the voltage to DC/DC converter for 12 V auxiliaries (in V).

Conversion factor K is defined as output power of motor divided by input power of inverter. 0,85 is applicable to permanent magnet synchronous (PMS) motor. In case of other types of motor, the conversion factor K of the system at the maximum power shall be provided.

The HEV system power is calculated by adding the total of a) and b).

6.9.3 Calculation for TP2

6.9.3.1 Calculation

The HEV system power at the wheels is calculated by multiplying individually the measured data of each drive shaft or wheel torque with the corresponding drive shaft or wheel speed to get the individual drive shaft or wheel power values and finally by the sum of each individually drive shaft or wheel power values according to Formulae (4) and (5):

$$P_w = (2\pi \times S_w \times M_w) / 1\,000 \quad (4)$$

$$P_{HEVw} = \sum P_w \quad (5)$$

where

M_w is the drive shaft or wheel torque (in Nm);

P_w is the drive shaft or wheel power (in kW);

P_{HEVw} is the HEV system power at all axles or all wheels (in kW);

S_w is the drive shaft or wheel speed (in s^{-1}).

In order to calculate the HEV system power value comparable to the engine or motor power value at the engine or motor output shaft, the measured HEV system power value at wheels shall be corrected by the gearbox system efficiency factor according to Formula (6):

$$P_{HEV} = \frac{P_{HEVw}}{\eta_{gb}} \quad (6)$$

where

P_{HEV} is the HEV system power (in kW);

P_{HEVw} is the HEV system power at all axles or all wheels (in kW);

η_{gb} is the gearbox system efficiency factor.

The gearbox system efficiency factor depends on individual gearbox system configurations. Therefore, a value for this factor shall be used according to the vehicle manufacturer's recommendation or if not available, according to similar HEV examples and their gearbox system efficiency factors described in Annex A.

6.9.3.2 ICE power correction factors

The ICE power portion of the HEV system power shall be corrected according to the provision given in ISO 1585:1992, Clause 6, if

— the reference atmospheric and temperature conditions, given in ISO 1585:1992, 6.2.1, or

— the automatic control conditions according to ISO 1585:1992, 6.3

cannot be fulfilled.

If the ICE power portion needs to be corrected, follow 6.9.3.3. Otherwise, continue with 6.10.

6.9.3.3 Corrected HEV system power for test procedure option 2 (TP2)

TP2 does not deliver a measured value for the ICE power portion. If a correction of the ICE power portion according to 6.9.3.2 is required, the following additional actions for TP2 are required:

— Determine in addition to the already measured torque and speed values (see 6.8.5) the RESS power via DC voltage and current measurement at the RESS.

— Formula (7) calculates the ICE power, P_{ICE}:

$$P_{ICE} = P_{HEV} - P_{RESS(con)} \quad (7)$$

where

$P_{RESS(con)}$ is the converted RESS power (in kW) calculated with Formula (1) [see 6.9.2 b)];

P_{HEV} is the HEV system power (in kW).

— Formula (8) calculates the corrected ICE power, $P_{ICE(corr)}$, according to ISO 1585:

$$P_{ICE(corr)} = P_{ICE} \times f \quad (8)$$

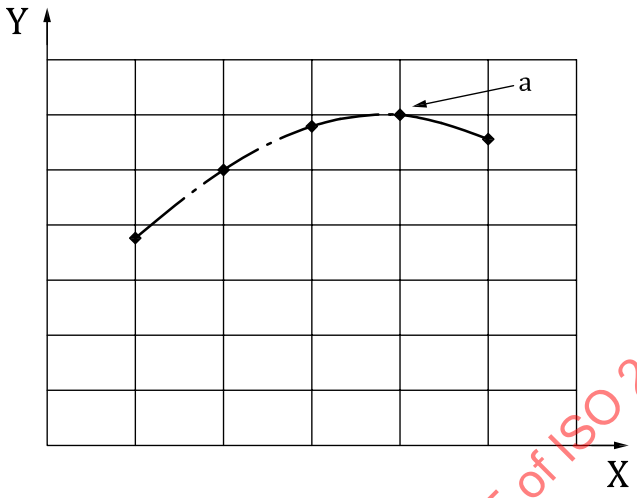
where f is the power correction factor (according to ISO 1585:1992, Clause 6).

— Formula (9) calculates the corrected HEV system power, $P_{HEV(corr)}$:

$$P_{HEV(corr)} = P_{ICE(corr)} + P_{RESS(con)} \quad (9)$$

6.10 Determination of maximum HEV system power

The maximum HEV system power shall be determined as the maximum value in the relation between power and speed (see Figure 1). This requires measurements at various fixed dynamometer speeds or at one fixed speed only, if defined in accordance with the vehicle manufacturer's recommendations.



Key

X speed (in km/h)

Y power (in kW)

[a] maximum HEV system power.

Figure 1 — Relation between power and speed

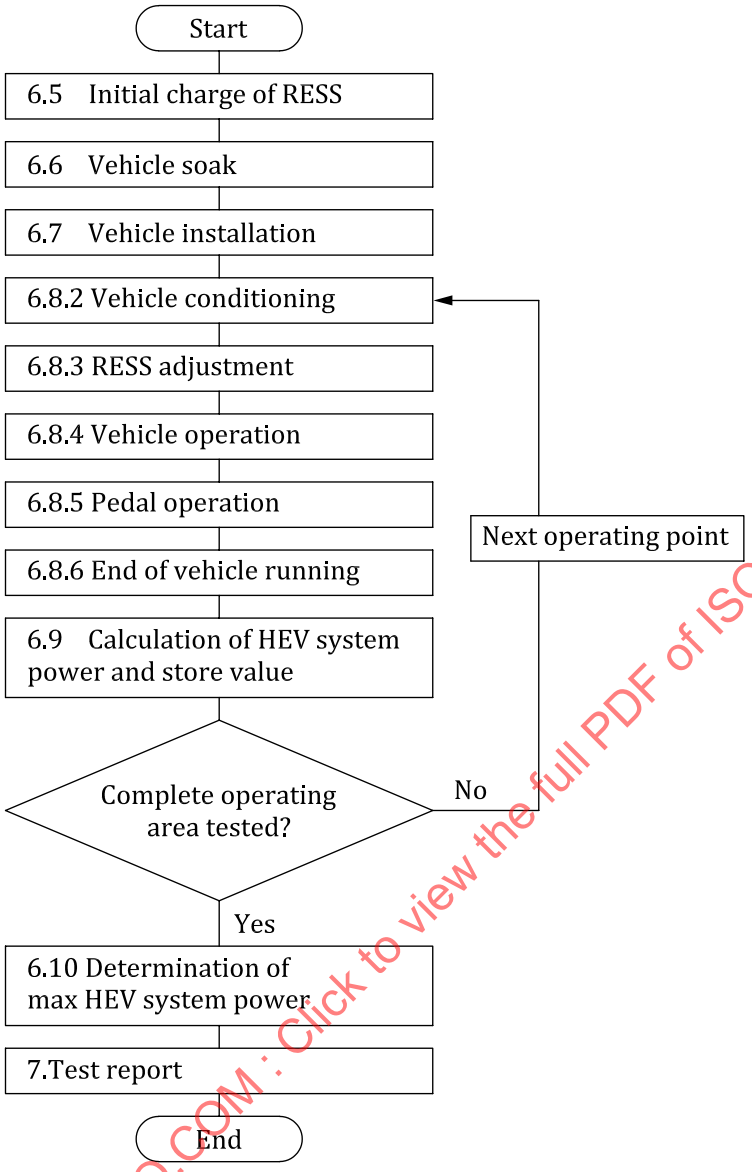


Figure 2 — Test sequence for determination of maximum HEV system power

The test sequence from 6.8.2 to 6.10 in Figure 2 shall be continued until the maximum HEV system power is determined.

Then, shut-down the voltage and current measurement devices and continue with Clause 7.

7 Test report

7.1 General

The test report and the statement of result shall indicate which test procedure (TP1 or TP2 in 6.1) was performed and which power calculation [1) peak power or 2) sustained power in 6.9.1] was used. The test report also includes at least the following items.

All measured and calculated data for Figure 1 should be included.

7.2 Calculated values based on measured data

— HEV system peak power (TP1) (in kW)

— HEV system sustained power (TP1) (in kW)

— HEV system peak power (TP2) (in kW)

— HEV system sustained power (TP2) (in kW)

— HEV system power at wheels, peak (specific to TP2) (in kW)

— HEV system power at wheels, sustained (specific to TP2) (in kW)

— ICE power, peak (specific to TP1) (in kW)

— ICE power , sustained (specific to TP1) (in kW)

— Converted RESS power, peak (specific to TP1) (in kW)

— Converted RESS power , sustained (specific to TP1) (in kW)

— Maximum HEV system peak power (TP1) (in kW)

— Maximum HEV system sustained power (TP1) (in kW)

— Maximum HEV system peak power (TP2) (in kW)

— Maximum HEV system sustained power (TP2) (in kW)

7.3 Measured data

— Chassis dynamometer roller speed (in km/h)

— ICE speed, peak (TP1) (in min^{-1})

— ICE speed, sustained (TP1) (in min^{-1})

— Intake manifold pressure, peak (TP1) (in Pa)

— Intake manifold pressure, sustained (TP1) (in Pa)

— Fuel flow rate, peak (for compression-ignition engines and for ICEs if the confirmation of air fuel ratio according to ISO 1585 is necessary, (TP1) (in g/s)

— Fuel flow rate, sustained (for compression-ignition engines and for ICEs if the confirmation of air fuel ratio according to ISO 1585 is necessary, (TP1) (in g/s)

— U_{RESS} , peak (in V)

— U_{RESS} , sustained (in V)

— I_{RESS} , peak (in A)

— I_{RESS} , sustained (in A)

— U_{DCDC} (in V) and I_{DCDC} (in A), peak (if measured)

— U_{DCDC} (in V) and I_{DCDC} (in A), sustained (if measured)

— U_{aux} (in V) and I_{aux} (in A), peak (if measured)

— U_{aux} (in V) and I_{aux} (in A), sustained (if measured)

— Drive shaft or wheel rotational speed, peak (TP2) (in s^{-1})

— Drive shaft or wheel rotational speed, sustained (TP2) (in s^{-1})

— Drive shaft or wheel torque, peak (TP2) (in Nm)

— Drive shaft or wheel torque, sustained (P2) (in Nm)

— Conversion factor from electrical to mechanical power, K, if measured

— Gearbox system efficiency factor, $\eta_{gearbox}$, if measured (TP2)

7.4 Environmental data

— Atmospheric pressure (in Pa)

— Room temperature (in °C)

7.5 Assumed values

— P_{DCDC} (in kW)

— Conversion factor from electrical power to mechanical power, K

— Gearbox system efficiency factor (TP 2) ,η_{gb}

7.6 General vehicle data based on the manufacturer's information (informative)

— Vehicle name and type

— Gearbox system

— RESS system

— Nominal voltage RESS system (in V)

— RESS energy (in kWh)

— ICE system

— ICE displacement (in cm^3)

— Maximum ICE power at engine speed (in kW /min^{-1})

— Type of motor

— Maximum motor power at motor speed (in kW /min^{-1})

Annex A
(informative)

Examples for gearbox system efficiency factor (includes gearbox and differential) at maximum HEV system power

A.1 General

Clause 6 describes TP 2, a measurement method to determine the maximum HEV system power via a torque and speed measurement at axle/wheels of HEVs. In order to be able to compare HEV power values with those by ICE or motor-driven vehicles only, these HEVs measured power values at axle/wheel need to be transformed to a power level based on engine and/or motor shaft output level. In order to be able to perform this power transformation by calculation, it is necessary to take the gearbox system efficiency factor at maximum HEV system propulsion power into account. The gearbox system efficiency factor, η_{gb}, indicates the efficiency value for the mechanical power transfer for propulsion from input, P_{in}, to output, P_{out}, of the gearbox system representing Formula (A.1):

$$\eta_{gb} = P_{out} / P_{in} \quad \text{(A.1)}$$

where

P_{out} is the HEV system propulsion power at axle or wheel (in kW);

P_{in} is the sum of mechanical ICE and motor power at gearbox input (in kW).

The gearbox system efficiency value, η_{gb}, depends on the individual HEV system configuration and will be in a range typically between 0,95 and 0,98. The individual value for the tested HEV configuration shall be requested from the vehicle manufacturer. If this is not possible, the following typical gearbox system efficiency factors for the listed typical HEV configurations shall be used for the calculation of HEV system propulsion power according to 6.2.

Typically, the values for gearbox system efficiency depend on HEV configurations.