Feedback to EVE 31st regarding validation testing results

Input from VDA representatives

Feedback to EVE 31st on HEV System Power validation test results

General

Background:

- TP1 and TP2 results from validation program show big deviations.

Question:

- What is the reason of this deviations?

Assumption in last EVE meeting in Stockholm:

- K1 and K2 could be a possible sources of this deviation.

Feedback from experts from VDA:

- Effect coming from K1 and K2 is not the reason for these big deviations
- Nevertheless, a procedure for the determination of the factors can be provided
- Most important: in order to compare TP1 and TP2 power values in a correct manner, the measurement procedures need to follow exactly the given requirements and accuracies, e.g. see ISO 20762. This needs to be ensured.

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Examples for incorrect results at TP1

Only engine rpm (and in addition intake manifold pressure) are measured:

- This doesn't deliver exact results for the delivered engine power under test
- In addition, at least atmospheric conditions, fuel quality and fuel flow rate are necessary data in order to get a chance to determine the actual engine power by comparison with previous ECE-R85 data

According to ECE-R85 Annex 7, the net power of internal combustion engine to verify conformity of production shall not differ by more than ±5% from the approval figure:

- This means: the max. power of any other engine of the same approval type can differ in a range of ±5% from the measured ECE-R85 max. power
- Due to the fact that TP1 shall determine the actual engine power by comparison with previous ECE-R85 data, this will work only, if ECE-R85 and actual engine measurement data match quite well
- If there are deviations, then there are a set of correction methods missing and no correct actual engine power can be determine

Electric motor power shall be measured via HV-battery power, not via inverter power

→ leads to incorrect higher values

HV-battery power shall be corrected by auxiliary HV-battery power not contributing to vehicle traction

→ e.g. DC/DC-power, power for air or battery conditioning, power for auxiliary HV-components

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TP1: Requested data in order to be able to determine engine power

Data	Accuracy	Remark
Engine data of previously performed ECE-R85 power measurement available	ECE-R85 requirements	To take into account: – All data are measured under atmospheric conditions of local test facility. – Official max. power value has to be corrected according to standard atmospheric conditions (T=298 K and P_s = 100 kPa)
Fuel quality	ECE-R85 requirements	No official correction factor available
Barometric pressure	ECE-R85 requirements	Power correction factor according to ECE-R85
Intake air temperature	ECE-R85 requirements	Power correction factor according to ECE-R85
Intake manifold pressure	ECE-R85 requirements	No official correction factor available
Engine speed	ECE-R85 requirements	
Fuel flow rate	ECE-R85 requirements	No official correction factor available

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TP1: Requested data in order to be able to determine electric motor power

Data	Accuracy	Remark
HV-battery voltage	ISO 20762 requirements	Measurement of inverter voltage leads at series and mixed hybrid configuration to an overestimated value
HV-battery current	ISO 20762 requirements	Measurement of inverter current leads at series and mixed hybrid configuration to an overestimated value
HV-battery power for auxiliaries not contributing to vehicle traction	ISO 20762 requirements	HV power for auxiliaries shall be subtracted from the HV-battery power
K1	ISO 20762 requirements	ISO proposal or input by vehicle manufacturer

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Examples for incorrect results at TP2

- Speed and torque shall be measured with specific implemented measurement devices at axle(s) or wheel(s) at the vehicle under test
- Power values derived from torque and speed measurement devices of the roller dynamometer include tyre power losses (slippage, flexing) and leads to lower power values

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TP2: Requested data in order to be able to determine system power

Data	Accuracy	Remark
Fuel quality	ECE-R85 requirements	No official correction factor available
Speed at axle(s) or wheel(s)	ISO 20762 requirements	Special prepared measurement device necessary
Torque at axle(s) or wheel(s)	ISO 20762 requirements	Special prepared measurement device necessary
K2	ISO 20762 requirements	ISO proposal under consideration of the different hybrid configurations or input by vehicle manufacturer
Additional data, if correction of determined system power according to standard atmospheric conditions are necessary:		
Barometric pressure	ECE-R85 requirements	Power correction factor according to ECE-R85
Intake air temperature	ECE-R85 requirements	Power correction factor according to ECE-R85
HV-battery voltage	ISO 20762 requirements	Measurement of inverter voltage leads at series and mixed hybrid configuration to an overestimated value
HV-battery current	ISO 20762 requirements	Measurement of inverter current leads at series and mixed hybrid configuration to an overestimated value
HV-battery power for auxiliaries not contributing to vehicle traction	ISO 20762 requirements	HV power for auxiliaries shall be subtracted from the HV-battery power
K1	ISO 20762 requirements	ISO proposal or input by vehicle manufacturer

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Question: Identical test results for TP1 and TP2 possible?

- TP1 and TP2 deliver theoretically identical output shaft power values only at parallel hybrid vehicles.
- For series and mixed hybrid vehicles, TP1 will always deliver a higher value.
- The difference depends on the power transferred through the series power conversion path.
- The higher this power is, the greater the determined power difference between TP1 and TP2
- Remark: Could be solved with an adjustment which bring TP1 on the level of TP2 (but no adjustment factor defined yet)

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Question discussed within EVE on incorrect K1 and K2 correction factor values

Currently EVE focuses the discussion on incorrect K1 and K2 factors (derived from examples given in ISO 20762) as reason for the deviations derived from testing activities at TP1 and TP2 conditions

From VDA representatives point of view, this is not the first and most urgent problem to solve.

What need to be done is the following:

- The accuracy and determination of data at TP1 and TP2 shall be performed according to the given requirements, e.g. ISO 20762
- It shall be taken into account
  - that ECE-R85 approval data can deviate in a range of ±5% from the current vehicle engine and motor under test
  - that theoretically TP1 and TP2 deliver only at parallel hybrid configurations the same system power results
  - The power deviations at hybrid configurations with a series or mixed configuration can be theoretically determined in order to judge the difference.
- Finally, K1 or K2 factors for the vehicle under test for determination of the max. system power will not deviate significantly from the values shown in ISO 20762 for the different drive train configuration. During a homologation procedure for a specific type of vehicle, the vehicle manufacturer will be a able to deliver specific requested detailed data for K1 and K2 to the technical service, if necessary. This can be stated in the homologation procedure for max. system power)
- There, VDA sees currently no requirement to develop specific test procedures for the determination of K1 and K2 factors
  - If necessary, K1 can be determined according to requirements given at ISO 21782-2
  - If necessary, K2 can be determined according to efficiency measurements at mechanical converters, that means measurement of input and output torque and speed at specific torque and speed points under specific conditions (e.g. atmospheric conditions, temperature of lubricant). K2 is to be determined by division of output power by input power.

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Recommendation for the further proceeding

If both TP1 and TP2 stay in the legislation

- → Minimum requirements on accuracy and data to be measured and recorded needs to be ensured
- → But also in that case:
  - → Only applicable for parallel hybrids as only for these kind of hybrids, identical values can be expected
  - → Serial and power split hybrids will always have a different system power value (TP1 vs. TP2)

Possible solution:

- → For parallel hybrids: both TP1 and TP2 can be applied if the minimum requirements are fulfilled
- → For serial and power split hybrids, one of the following options:
  - → either TP1
  - → or TP2
  - → or adjustment of TP1 to the level of TP2 (to take the losses of the mechanical path into account)

For performed validation testing:

It needs to be checked if all requirements, stated in this document, are fulfilled

For future validation testing:

It needs to be checked before the start of testing if all requirements, stated in this document, are fulfilled.

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Empirical method as an alternative way forward?

- For the determination of max. hybrid power which may be used as a type approval value in the future, a vehicle based testing procedure is not an easy, accurate and economic solution
- Therefore, EVE should think about discussing a theoretical method to determine the max. system power value as an alternative method
- A theoretical method to determine the max. system power should be easy to define based on the already available max. torque/speed curves of engine and motor(s) according to ECE-R85 and the hybrid system configuration and control function delivered by the vehicle manufacturer
- During a homologation procedure, the technical service is always in a close connection with the vehicle manufacturer and it should be in the interest of the vehicle manufacturer to deliver all necessary technical data to judge the drive system and to calculate based on existing data the max. system power performance

BACK UP

Feedback to EVE 31st on HEV System Power validation test results

Extended comment part: TP1 and TP2

General

- The direct measurement of mechanical power via torque and speed at the vehicles engine and motor output shafts is not a practical solution
  Therefore it is discussed to measure other points upstream (TP1) or downstream of the output shafts (TP2) and to convert this measured values into power values based on a virtual output shaft.
- TP1 and TP2 derived from the ISO 20762 standard
  Both measurements are based on a vehicle operated on a roller dynamometer at given operating and measurement conditions.
- TP1 and TP2 deliver theoretically identical output shaft power values only at parallel hybrid vehicles. ***At hybrid vehicles with a series power conversion part (mechanical energy from engine to electrical energy via a generator and electrical energy from the generator to mechanical energy via a motor, e.g. at series or power split hybrid-electric vehicles), the determined hybrid power is at TP1 always greater than at TP2***
  - ***Reason: TP1 doesn't take the power losses due to the energy conversions in the series power conversion part into account). The difference depends on the power transferred through the series power conversion path.***
  - ***The higher this power, the greater the determined power difference between TP1 and TP2***

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Extended comment part: TP1 specific features (1/3)

Determination of engine power:

- Comparison of measured engine speed and additional engine, vehicle and test room data with available comparative data from previous R85 engine power measurements.
  If a comparison of all major data fits, then it can be assumed that the max. engine power during test is in the same range but not necessarily at the same value as the max. R85 engine power.
- According to R85 Annex 7, the net power of internal combustion engine to verify conformity of production shall not differ by more than ±5% from the approval figure.
  This means, that the max. power of any other engine of the same type of approval type can differ in a range of ±5% from the measured R85 max. power.
- The R85 max. power shall be measured under given atmospheric conditions
  - room temperature $\rightarrow 288\ K \leq T \leq 308\ K$
  - barometric pressure $\rightarrow 80\ kPa \leq Ps \leq 110\ kPa$

  After the measurement of max. power (by speed and torque measurement), ***this power value shall be corrected by use of the power correction factors to the type approval max. power value, which corresponds to standard atmospheric conditions at T=298 K and Ps = 100 kPa.***
- Due to the fact that at the TP1 measurement procedure the vehicle speed and therefore the engine speed is fixed by the roller dynamometer***, the intake manifold pressure is not a representative indicator for the engine power value in case of aspirated engines***. The intake manifold pressure at a fixed speed is in a wide power range nearly constant, the power depends at a fixed speed point on the fuel flow rate.

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Extended comment part: TP1 specific features (2/3)

Determination of engine power:

- ***The comparison of only measured engine speed and intake manifold pressure with the R85 data doesn't deliver an exact measured power value.*** It can only be estimated, that the engine's max. power output will be under standard conditions the same as at the R85 power measurement, ***the exact delivered engine power value will be unknown.***
- At least the following data of a TP1 activity to determine the engine power shall be measured and checked for conformity with available R85 data:
  - fuel according to R85 requirements
  - barometric pressure
  - intake air temperature
  - intake manifold pressure
  - engine speed
  - fuel flow rate
  - engine test results according to ECE-R85 available

➔ Only if all this data match with the available previous performed R85 power measurement data at the given speed point, then the engine max. power of the vehicle under test is the same as at the R85 max. engine power measurement.

➔ If there are deviations in the two sets of data (vehicle under test and previous R85 data) others then atmospheric conditions, then an exact max. power value for the vehicle under test **can't** be determined because of the fact that there are currently no further power correction methods depending on intake manifold pressure or fuel flow rate available

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Extended comment part: TP1 specific features (3/3)

Determination of electric motor power:

- Due to the fact that the measurement of motor torque in a given vehicle is not a practical solution, TP1 solution is to measure upstream electrical power delivered by the traction battery and to calculate with given energy conversion factors (for power electronics and motor) the corresponding mechanical power output of the motor
- Only the electric power delivered from the HV-battery for the motor shall be measured. Other electrical power delivered from the HV-battery, but not contributing to vehicle traction (e.g. for DC/DC-converter (HV/12V), power steering, air conditioner, other HV auxiliary systems) shall be subtracted from the total HV-battery power
- Additional electrical power for the motor, delivered e.g. from a generator set to the engine, shall not take into account. This power will be already took into account due to the engine power determination
- The following data shall be measured:
  - HV-battery voltage
  - HV-battery current
  - HV-battery power for auxiliaries not contributing to vehicle traction
- The determined electrical motor power shall be converted by multiplication with the given factor K1 (or by an inverter-motor efficiency factor requested from the vehicle manufacturer) to the mechanical motor power

Determination of hybrid system power:

- The hybrid system power is the sum of determined engine power (valid for standard atmospheric conditions) and mechanical motor power

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Extended comment part: TP2 specific features

Determination of hybrid system power:

- The system power is measured downstream of engine and motor shaft via torque and speed measurement at the axle shaft(s) or at the wheel(s)
- For the system power measurement, axle shaft(s) or wheel(s) have to be prepared with suitable sensors for torque and speed measurement that meet the required accuracies. Tyre losses are not relevant, due to the fact that torque and speed are measured upstream of the tyre(s)
- If torque and speed are measured by devices installed in the roller dynamometer, then the measurement accuracy including the correction of tyre losses (by slippage and flexing), depending on type of tyre, tyre air-pressure and weight load on tyre shall be taken into account in a traceable manner in order to get the same results as at the axle shaft(s) or wheel(s) measurement
- The measured system power shall be converted by division with the for the test vehicle given representative factor K2 (or by a transmission efficiency factor requested from the vehicle manufacturer) to the determined hybrid system power
- The hybrid system power shall be valid for standard atmospheric conditions. If not measured under standard atmospheric conditions, the engine power part shall be corrected with the room temperature and barometric correction factors given in R85