

DISCUSSION PAPER

Determination of Powertrain Performance of Hybrid Electric Vehicles

Provided by the EVE “system power” lead Germany Korea
Intended for Discussion during EVE-16-Meeting

October 2015

Content

- DISCUSSION PAPER 1
- 1. Project Charter 2
- 1.1. BACKGROUND 2
- 1.2. PROBLEM..... 2
- 1.3. MOTIVATION 2
- 1.4. GOAL 2
- 2. Scope of Work 3
- 2.1. APPRAISAL OF STAKEHOLDER INTERESTS 3
- 2.2. PROJECT FRAME 4
- 2.3. MULTI GENERATION PLAN 5
- 2.4. PROJECTS WITH SIMILAR FOCUS - DEPENDENCY ASSESSMENT AND SYNERGIES 5
- 3. Project Structure..... 7
- 3.1. Reference Method 7
- 3.2. Candidate Method 7

1. Project Charter

1.1. BACKGROUND

For purposes of the determination of the power the UNECE provides currently a regulation under the 58' Agreement that can be used for approval of internal combustion engines (ICE) and electric drive trains in M and N category vehicles¹. It focusses on the determination of engine power values, however, the technical description part of the regulation merely provides for the individual determination of the power of either an ICE or an electric motor.

1.2. PROBLEM

The role of the propulsion battery is not considered by the regulation. A determination or recommendation for a calculation of the 'motive power' of the vehicle expressed as combined power or system power is missing. Furthermore in many cases (if not even in the majority) it is the propulsion battery system, also referred to as rechargeable electric energy storage system (REESS) and not the electric motor that's being the limiting element and therefore determines the power of an electric power train. Consequently in many cases of state-of-the-art power train concepts of electrified vehicles, the concept of an individual determination of the engine's or electric motor's power is insufficient or even leads to misinterpretation of results. This holds for cases, where distinct information about the combined power of the system is eligible or needed. The outlined situation may become even worse, since in future more and more sophisticated hybrid vehicle concepts for instance with distributed power sources are likely to gain market maturity (e.g. electrified vehicles with rim motor concepts).

1.3. MOTIVATION

Currently a strong demand for an improved power determination prescription comes from the Informal Working Group on the development of the "Worldwide harmonized Light Duty Test Procedure" (WLTP). The so-called subgroup "Electrified Vehicles" is asking for a system power specification for the following purposes:

- classifications of electrified vehicles into distinct Power-to-Mass ratio classes,
- application of the so-called "downscaling method" that enables adaption of the test reference cycle for low powered vehicles, and
- application of a gear-shift-calculation model, already developed under the WLTP.

Furthermore system power specifications may be used in different fields. Among others, it may serve as customer technical information (e.g. maximum declared power), may be used by the legislator (as basis for taxation schemes) or by insurance providers (as a classifier for tariff determination).

1.4. GOAL

Being aware of the above described situation and according to its mandate under the ceiling of the UNECE, the EVE-IWG meanwhile identified action demand and established a subgroup "Determining power of EVs". The goal is to clarify, how an improved technical prescription for the determination of the system power of such sophisticated powertrains like with pure and hybrid electric vehicles, could be realized in an efficient and easy way.

¹Regulation No. 85 of the Economic Commission for Europe of the United Nations (UNECE) – Uniform provisions concerning the approval of internal combustion engines or electric drive trains intended for the propulsion of motor vehicles of categories M and N with regard to the measurement of net power and the maximum 30 minutes power of electric drive trains"

Scope of the work covers light duty vehicles (M1 and N1) and shall result in a recommendation or regulation for determination of the performance criteria “power” and “torque”. In this regard the group may take advantage from the fact that activities with similar focuses are currently also being pursued by international standardization organizations.

2. Scope of Work

The following chapter gives a proposal for the scope of the work prepared by the EVE “system power” lead. It shall be completed after discussion of both, the evaluation of responses from a stakeholder survey (questionnaire) and feed-back on the present proposal on the upcoming 16th EVE-Meeting.

2.1. APPRAISAL OF STAKEHOLDER INTERESTS

EVE “system power” leading team has carried out an inquiry among relevant stakeholders of the contracting parties (’58-Agreement and ’98-Agreement) regarding their attitude, possible applications and needs with respect to the topic. The following gives a brief appraisal of the feedback received.

CAN and the U.S.

As the U.S. and CAN are being party of the ’98-Agreement the UN-R85 has not been adopted or applied.

Both contracting parties abstained from voting on phase 1 of WLTP since analysis of the GTR 15 (WLTP) is still ongoing and because stringent light duty vehicle reg. are already in place domestically.

CAN and the U.S. follow the same procedures for compliance testing of BEVs. Recommended Practice (RP) after SAE J1634 rules the procedure for determination of energy consumption and range. However, there is no compliance procedure for vehicle power.

EU

EU regards the subject important and relevant for many other Regulations. System power would form the basis for proper vehicle classification. Therefore the group should consider to expanding the scope beyond PC and LDCV and should strive for a harmonized procedure also for L-Category vehicles and NRMM.

For all engines, motors and combinations of propulsion units up to a to be determined limit there should be a single harmonized way to determine its continuous maximum rated net and peak propulsion unit performance.

Purpose: WLTP and others

Way forward: Upgrade of UN R85 and development of a GTR in parallel.

Japan

JP understands that the demand is only for the WLTP and is limited to the determination of the system power of hybrid electric vehicles (HEV). There is only need to define the combined power of HEVs and no need to re-define the power of battery electric vehicles

(BEV) and fuel cell vehicles (FCV), since the electric drive train has already been defined in UN-R85.

Purpose: WLTP, for Power-to-Mass (P-t-M) classification of HEV.

Way forward: Target should be achieved by a world-wide agreed (ISO) Standard rather than a Global Technical Regulation (GTR), UN-Regulation (UN-R) or Recommendation / Mutual Resolution

KOR

Net power ratings from current UN-R85 are being regarded as sufficient but the power limit ascribed to the traction battery should be properly considered and determined.

Determination of power and torque should be done with a completed vehicle applying a kind of chassis dyno or power train dyno measurement.

Purpose: WLTP

Way forward: Upgrade of UN R85 and development of a GTR in parallel

OICA

OICA supports the development of a harmonized procedure for every category of electrified vehicles to determine comparable system power / system torque (if required) based on needs, priorities and requests from relevant groups (e.g. WLTP-IWG).

The preferred methodology would be the measurement of the individual components (e.g. power of ICE, battery output) followed by a calculation method that finally results in the system power rating. The value shall be derived by a standardized procedure and by harmonized load collectives for the sake of good reproducibility and competitive comparison.

Purpose: WLTP, since it is the only current regulation where system power (SP) and system torque (ST) is needed. SP is needed for cycle classification and downscaling. ST for gear shift calculation in case of a MT.

Way forward: Integration either into GTR 15 or as another GTR

2.2. PROJECT FRAME

Note: regarding topics that should be in scope or out of scope of the present project, shall be discussed, settled and decided during the EVE 16 Meeting.

The following paragraph aims for an evaluation of the given feedback in order to come to a well-defined project that seeks for a solution for the most urgent topics in a reasonable time frame. Finally, should the project proposal be successfully adopted by WP.29/AC.3 in order to receive permission to develop a new regulation it is pertinent to remember that the project needs fully support by all stakeholders.

As being quoted in all answers from the stakeholders the “system power” leading team proposes the following topics to be regarded as within the scope of the project (“Within the frame”). Additionally “in the frame” should cover the most urgent demand from WLTP:

- ✓ HEV (light duty: M, N-category vehicles)
- ✓ Rated System Power (according “WLTP-demands”)
- ✓ Component testing, chassis dyno testing
- ✓ Integration into GTR15

✓ “In the frame”

The leading team estimated following topics as being “On the frame”. This means that these topics remain for clarification, whether they should be treated in a later phase or rather still shall be shifted into the frame for immediate action:

- ❖ ---BEV----- “On the frame”
- ❖ ---System Peak Power and other system power ratings----- “On the frame”
- ❖ ---Amendment of UN-R85 in order to properly treat the power limitation of the traction battery ----- “On the frame”
- ❖ ---Torque (according “WLTP-demands”)-----
- ❖ ---Separate GTR-----

The following topics were regarded as “Out of the frame” during a project phase that should tackle the most urgent tasks. However, owing to its generic relevance it should be discussed, whether these topics should be handled during a follow-up project.

“Out of frame”----- “Out of frame”

- NRMM, L-category (non-road mobile machinery, two-wheelers, etc.)
- All engines, motors and combinations of propulsion units

Note: regarding topics that should be in scope or out of scope of the present project, shall be discussed, settled and decided during the EVE 16 Meeting.

2.3. MULTI GENERATION PLAN

It is suggested to assign agreed topics (“within the frame”) to the first generation of project (“Phase I”), whereas excluded items (“on the frame”, “out of frame”) shall be covered by a second and third generation of the project (“Phase II”, “Phase III”).

Phase I aims at a solution for Rated System Power and Torque ratings for GTR 15 (WLTP) purposes

Phase II extends the results from Gen. I to BEV vehicle types and system peak power as well as other relevant system power ratings

Phase III strives for a harmonized regulation for NRMM and L-cat. vehicles, covering all kinds of propulsion units.

2.4. PROJECTS WITH SIMILAR FOCUS - DEPENDENCY ASSESSMENT AND SYNERGIES

During the preparative phase of information gathering, other projects with similar focus have been checked in order to get an overview of activities undertaken worldwide. It turned out that the standardization organizations SAE, ISO and the Korea Automobile Testing &

Research Institute (KATRI) are currently working in the field of system power determination of electrified vehicles. Responsible project leaders have been invited to share their current state of work with the EVE-IWG in order to ensure an effective exchange of information and to seek for synergies that might be used for an efficient work. The principle was coincident with that of three research groups, which are that hybrid system power is the power of ICE plus the power of electric source by system power test. The following chapter gives an appraisal of the current situation.

SAE

SAE J2908 TF led by Argonne National Laboratory (ANL) started the project in November 2014. The project was scheduled to be finalized within the fourth quarter 2015. Current activity is under a draft documentation of the test procedure. Two hybrid system power approaches were considered, namely a nominal system power rating and a system power test. Both methods use chassis dyno with added instrumentation or hub dyno.

Nominal rating method is based upon component-level power and similar to current engine power rating.

[Hybrid system power = Engine power + Electric power]

Hybrid system power is a rated powertrain power comparable to current engine ratings. Engine power is rated power by SAE J1349. Electric power is a measured electric assist on dyno.

System power test is based upon dyno test and provides accurate measurement of axle or wheel power. It is verifiable test for engineers to communicate power levels.

The SAE J2908 TF also gives information on system power as well as the power of electric assist and regeneration.

ISO

JARI proposed the necessity of determination of power for propulsion of hybrid electric vehicle in April 2015. ISO New Work Item Proposal (NWIP) was approved by vote in June. It was started as a formal project of ISO/WD20762. JARI will submit a working document to SC37/WG2 in December. Working Document has not changed with content which Japan explained by EVE-IWG in June (EVE-15-05e).

Principal concept is followings.

[Hybrid system power = Engine power + Battery power]

It is necessary to measure the battery output under the HEV system control. Engine power is rated power by ISO 1585. The battery output should be measured when the hybrid system as a whole outputs the maximum power on Chassis dyno.

KATRI

KATRI started the research project in July 2013. The project was finalized in June 2015. Current activity makes supplements by testing SAE test procedure. Nominal rating and system power test were studied. Test methods use powertrain dyno or chassis dyno with added instrumentation.

[Hybrid system power = Engine power + Electric power]

Engine power is rated power by UN Regulation No. 85. Electric power is a measured power of electric source on dyno.

System power test provides not only accurate measurement of wheel or axle power but also useful information of system torque.

3. Project Structure

From the current general picture of opinions we understood it worthwhile to develop a reference method for HEV system power and allow also candidate methods that must be validated against the reference. The following block diagram maps the project structure currently proposed by the “system power” leading team and reflects the development of a new power (and eventually torque) regulation for HEV (and eventually BEV) vehicles intended to incorporate into GTR 15.

3.1. Reference Method

//1//It assumes a close cooperation between the expert groups from the respective standardization organizations SAE, ISO and the KATRI and being the leading experts concerning the determination of the system power by means of chassis or hub dyno methods. These are to deliver necessary test capabilities. Outstanding attendance must be given to a meaningful determination of the collectives of burden applied during test. Since this item is closely related to demands coming from the WLTP (GTR 15), it is indispensable that experts from this group (most probably WLTP SG-EV) are to support the work.

The system power and torque will be determined based on SAE, ISO standards //2// Besides a thoroughly evaluation //3//of the applicability of results for WLTP purposes (i.e. P-t-M classification and gear shift model calculation), it would be eligible to improve //4//the method, being then able to compare values from system power measurement with testbed results by means of a re-normalization or correlation tool. This would overcome potential gaps of information or divergent ratings of vehicles motive power.

3.2. Candidate Method

With respect to economics and for sake of process flexibility during type approval it stands to reason that car manufacturers are keen to have a certified procedure available that is based on a combination of component testing //5// (partly after UN-R85, partly pursuant battery specification practice//6//) and computer aided simulation//7// calculation. That is why such a pathway should be investigated as well. The latter methodology, however, must be carefully validated //8//against the SAE / ISO /KATRI standard before it could be endorsed as an alternative method.

//9// A drafting task force shall be established, responsible for setting up the wording of the new regulation.

Suppliers:
 OICA,
 KATRI
 ISO/JARI
 SAE /ANL

Input:
 Expertise
 Data
 Lab capacity
 Software code
 Programming

Process:
 WLTP
 calculations
 (gearshift,
 downscaling,..)
 Evaluation
 Improvements
 Normalization/
 Correlation
 Drafting

Output
 New Regulation

