Working Paper No. **HDH-07-07**
(7th HDH meeting, 12 to 14 October 2011)

Feasibility study for Chassis dynamometer based Emission testing procedure as an alternative to HILS for Heavy Duty Hybrid Electric Vehicles (HD-HEV)

INDIA

BACKGROUND

- Based on the discussions which happened subsequent to the original working paper HDH-04-04e, this paper is a re-submission of HDH-04-04e with additional explanation in magenta colour. Technical amendments are shown also in magenta colour in revised table in slide 4 attached herewith.

- Terms of references (ToR) for Informal Group prepared during 1st and 2nd IG meeting

- ToR (GRPE-60-11) adopted by GRPE in 60th GRPE meeting during June, 2010.

- Point No. 6 of ToR calls for the assessment of feasibility for Chassis dynamometer based Emission testing procedure as an alternative to HILS for HD-HEV's.

- In Jan, 2011, India presented its paper at 4th HDH meeting (working paper HDH-04-04e) which concluded that chassis dyno testing provisions do not require additional work and consequently the chassis dyno procedure is considered a feasible alternative. Ref MOM of 4th HDH meeting HDH-04-06.

- During 61st session of GRPE (Jan, 2011), it was submitted by HDH Secretariat that assessment of chassis dyno method will be done in parallel (GRPE-61-16)

PROPOSAL

- Major parameters required for chassis dynamometer based procedure are :
  - Driving cycle
  - Reference Mass
  - Gear shifting pattern
  - Specification of chassis dynamometer
  - Test cell condition
  - Emission measurement procedure
  - Emission calculations

- Sr. No. 2 of ToR calls for verification procedure on Chassis dynamometer for Engine cycle output of the HILS model. This will anyway call to define chassis dynamometer specification.

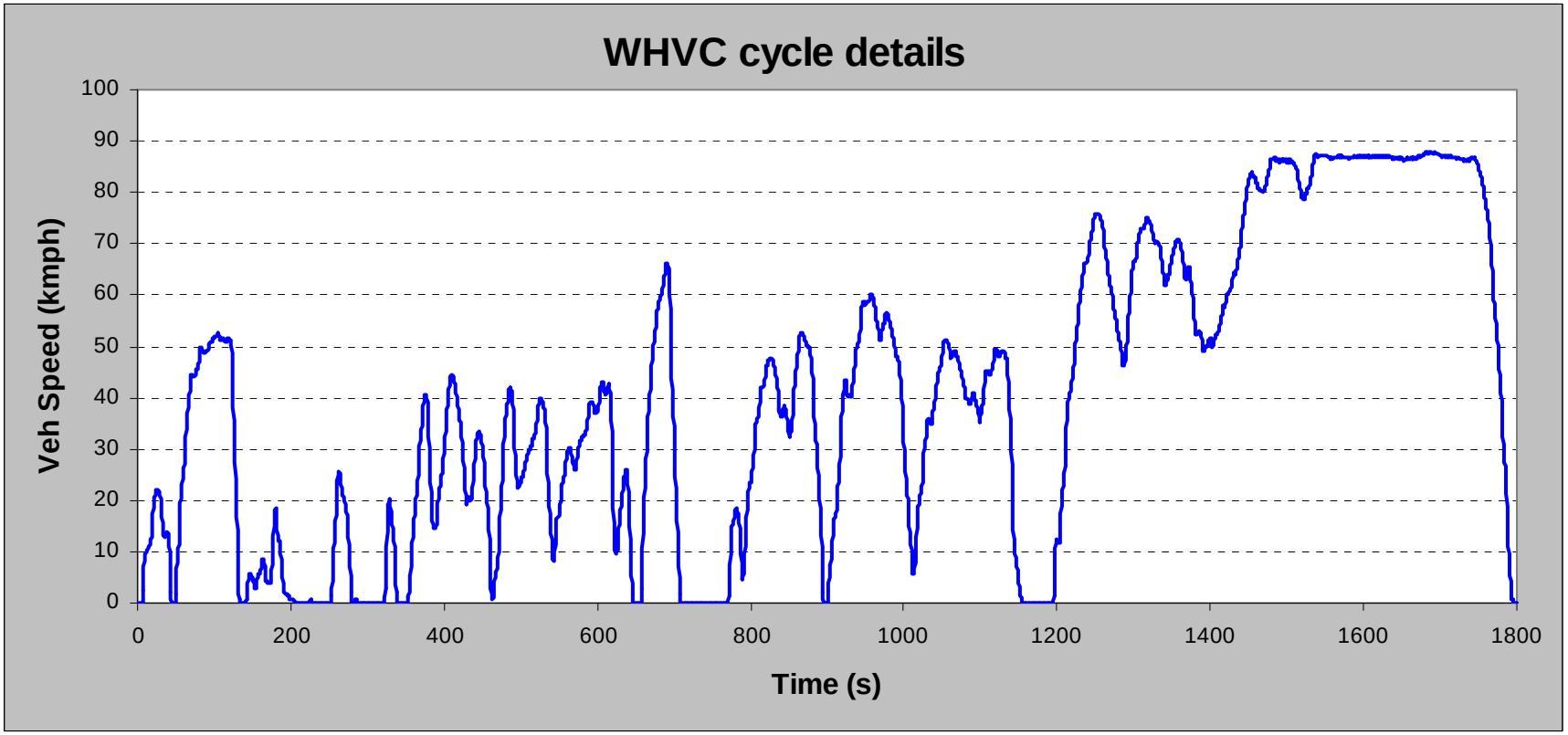
- All above parameters once developed / decided for HILS can be directly used for Chassis dynamometer procedure. (See next Slide)

- Hence, it clearly shows that chassis dynamometer procedure does not require additional work.

- Propose this group that it is feasible to develop Chassis dynamometer based procedure along with HILS.

Comparison of major parameters required for HILS and Chassis Dynamometer procedure			
Parameter	**HILS**	**Chassis Dynamometer**	**Remark**
Driving Cycle	WHVC	Same as HILS	
Reference mass	work item	Same as HILS	
Rolling and Air resistance coeff.	work item	Same as HILS	
Mathematical model providing Engine cycle output	work item	Not required	
Gear shifiting pattern	work item	Same as HILS	
Model / Vehicle family detais	work item	Same as HILS	
HILS model development			
Component level testing, equipments and detailed procedure	work item	Not required	
Specification of test equipment for components	work item	Not required	
Development of code for model	work item	Not required	
integrating all system level models	work item	Not required	
HILS model verification on Chassis Dyno and testing of vehicle on chassis dyno			
Specifications of chassis dyno	work item	Same as HILS	
Measurement of Engine cycle (Torque & Speed)	work item	Same as HILS	
Model acceptance criteria	work item	Not required	
Testing			
Test cell conditions	Inline with GTR No. 4 (clause No. 6)	Same as HILS. Inline with GTR No. 4 (clause No. 6)	Engine Air intake requirements as per clause 6.1 of GTR can be maintained for Chassis Dynamometer
Emission measurement procedure	Inline with GTR No. 4 (clause No. 7) Raw and CVS	Same as HILS Inline with GTR No. 4 (clause No. 7) Only CVS	GTR mentiones that both the procedures are equivalent, but being CVS followed for chassis dynamometer in smaller vehicles, we can start with CVS.
Emissions Calculations			
Results in g/test	Inline with GTR No. 4 (clause No. 8)	Same as HILS	
Evaluation of total workdone (kWh) at system output shaft for calulating specific emissions in g/kWh	work item	Same as HILS	1) Results obtained in g/test will be divided by system level kWh and results can be declared in g/kWh. System level positive energy can be calculated by the actual measurement / CAN signal of system level speed and torque with sampling period of 0.2 sec or less. Refer Clause 4-3 of chapter 4 of Kokujikan 281. 2) Alternatively, establish a co-relation between gm/km and gm/kwh by testing representative hybrid vehicles on chassis dyno for emissions in gm/km, followed by their engine tests on engine cycle derived from HILS method.

WHVC CYCLE


WHVC cycle details
Veh Speed (kmph)
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
Time (s)

CLAUSE 6 of GTR

6. TEST CONDITIONS

6.1. Laboratory test conditions

The absolute temperature (*T*a) of the engine intake air expressed in Kelvin, and the dry atmospheric pressure (*p*s), expressed in kPa shall be measured and the parameter *f*a shall be determined according to the following provisions. In multi-cylinder engines having distinct groups of intake manifolds, such as in a "Vee" engine configuration, the average temperature of the distinct groups shall be taken. The parameter *f*a shall be reported with the test results. For better repeatability and reproducibility of the test results, it is recommended that the parameter *f*a be such that: $0.93 \leq f\text{a} \leq 1.07$. Contracting Parties can make the parameter *f*a compulsory…….

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CLAUSE 7 of GTR

7. TEST PROCEDURES

7.1 Principles of emissions measurement : To measure the specific emissions, …….. The measurement of specific emissions requires the determination of the mass of components in the exhaust and the corresponding engine cycle work. The components are determined by the sampling methods described in paragraphs 7.1.1. and 7.1.2.

7.1.1 Continuous sampling : In continuous sampling, the component's concentration is measured continuously from raw or dilute exhaust. This concentration is multiplied by the continuous (raw or dilute) exhaust flow rate at the emission sampling location to determine the component's mass flow rate. The component's emission is continuously summed over the test cycle. This sum is the total mass of the emitted component.

7.1.2. Batch sampling : In batch sampling, a sample of raw or dilute exhaust is continuously extracted and stored for later measurement. The extracted sample shall be proportional to the raw or dilute exhaust flow rate. Examples of batch sampling are collecting diluted gaseous components in a bag and collecting particulate matter (PM) on a filter. The batch sampled concentrations are multiplied by the total exhaust mass or mass flow (raw or dilute) from which it was extracted during the test cycle. This product is the total mass or mass flow of the emitted component. To calculate the PM concentration, the PM deposited onto a filter from proportionally extracted exhaust shall be divided by the amount of filtered exhaust.

8. Measurement procedures : This gtr applies **two measurement procedures that are functionally equivalent**. Both procedures may be used for both the WHTC and the WHSC test cycle:

a) The gaseous components are sampled continuously in the **raw exhaust gas,** and the particulates are determined using a partial flow dilution system;

b) The gaseous components and the particulates are determined using a **full flow dilution system (CVS system).**

Any combination of the two principles (e.g. raw gaseous measurement and full flow particulate measurement) is permitted…….

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CLAUSE 8 of GTR

8. EMISSION CALCULATION

8.1. Dry/wet correction

If the emissions a ……

8.6.3. Calculation of the specific emissions

The specific emissions *e*gas or *e*PM (g/kWh) shall be calculated for each individual component in the following ways depending on the type of test cycle.

For the WHSC, hot WHTC, or cold WHTC, the following formula shall be applied:

$$e = \frac{m}{W_{act}}$$

where:

m is the mass emission of the component, g/test

*W*act is the actual cycle work as determined according to paragraph 7.8.6., kWh

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- The broad level comparison shows that parameters once decided / developed for HILS procedure, they can be directly used for chassis dynamometer.

- HILS will need following additional parameters to be developed / decided.
  - Component level testing,
  - Equipments and detailed procedure
  - Acceptance criteria for model after Evaluation on chassis dynamometer

- ~~It is to be reiterated that chassis dyno method is being suggested as an alternative to HILS as an option for those CPs who have chassis dyno facility~~
- The chassis dyno method can be followed as an alternative to HILS as an option by those CPs who have chassis dyno facility

THANK YOU