

Interactive comment on “Real-world measurement and mechanical-analysis-based-verification of NO_x and CO₂ emissions from in-use heavy-duty vehicle” by Hiroo Hata et al.

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1 General comments

1.1 Introduction

The authors should pay more attention to the introduction and make clear what is the purpose of the paper. There are several statements about the representativeness of the laboratory testing compared to the on-road measurements, but it is not clear why this is discussed, while both approaches have pros and cons. Without proper listing

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of them cannot enable a comparison between the two approaches. In this section, it is needed to clarify better the goals of the paper and why the authors conducted this research.

1.2 Methodology

Please describe the methodological approach (testing, analyses, etc) by offering an overview before moving into describing the testing process. With this structure, the reader is confused as the text moves directly into explaining the testing, but there has been no frame to put it into. Also, a clear description of the post-processing and the analyses that are performed to reach the goal of the paper is missing. Please provide an overview of the approach, describe each step of the approach and indicate all the analyses that you've performed. Additionally, please avoid presenting equations that a reader would already be familiar to, e.g. formula of acceleration.

1.3 Results and discussion

The authors need to improve the presentation of the results in terms of text structure and language. Several times it has been unclear what they wanted to say, while some other times the text was repetitive. Please present all the analyses that help you answer those questions that you have set. At this point, it seems only a simple presentation of the measurement results. This is useful to enhance the literature in the topic, but it does not add up significantly, while there is potential for this. Please consider adding a more detailed sensitivity analysis, an energy analysis (energy share on wheel, auxiliaries, etc) and an improved comparison between the WHVC and on-road conditions. These are just recommendations to improve the paper, based on what is already included. Consider expanding the analyses as you see fit.

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1.4 Conclusions

The conclusion sector is unclear to what outcome the analysis reached. This section should avoid repeating what has already been presented in the discussion and actually reach to some conclusions and evaluate whether the paper's goals have been achieved or not, what new questions have arisen and what could be done next. The sole outcome is that the road gradient is the most important factor affecting NO_x and CO₂ emissions, which is hardly new. The authors conducted an experimental campaign that should gain visibility, but it needs more analyses, reach some solid conclusions that could actually contribute in the field.

2 Specific comments

Line 20 Please provide references and/or examples of major countries/regions that are concerned with pollutants.

Line 23 Please provide reference to the NASA report or database.

Line 25 The Saito 2010 reference is already 10 years old. Please add also a projection from newer studies if possible.

Line 25 – 26 “. . . photochemical oxidant is a well known short-term air pollutant. . .” It is not clear which photochemical oxidant the authors refer to and also there's lack of any reference to back this statement. Please elaborate on the whole sentence.

Line 30 – 31 “To address the problems of global warming and photochemical pollutants, it is necessary to mitigate air pollution.” This statement is not quite accurate. Pollutants cause health problems mainly and also sometimes have a global warming potential. The major factor for global warming from the automotive sector are CO₂ emissions. CO₂ is not a pollutant and it doesn't cause health problems by inhaling it. Please

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elaborate.

Line 40-41 “In general, the laboratory temperature is set at approximately 25 °C, and it cannot be easily changed via the normal laboratory system.” This is not quite true, the temperature in the laboratory and more specifically in the vehicle test cell can be adjusted to a range of different temperatures. In some cases, however, it could require additional investment in infrastructure such as to achieve a temperature of -7 °C that are required in some countries. The 25°C temperature is mandated by the testing protocol and the regulation that has adopted this protocol and not necessarily from the technical capabilities of the laboratory. Please elaborate the sentence.

Line 43 “. . . a specific activation temperature that cannot be attained in cold seasons. . .”, this is quite a bold statement and not entirely true. The activation temperature will be reached at some point, but under cold conditions, it could take longer. In the case of small trips and low temperatures, then it is possible that the activation temperature is not reached. Please elaborate.

Line 44 – 46 “Moreover, the road gradient also influences the amount of exhaust emissions because it directly affects the driving force, which is presumed to be proportional to CO₂ and other exhaust emissions.” This statement is not correct. The gradient increases the required engine load and it indeed increases CO₂ emissions, but this is not done necessarily linearly. The road gradient force formula is defined as $m \cdot g \cdot \sin(a)$ (m = vehicle mass, g = acceleration of gravity, a = road grade). The engine needs to operate at a higher load to compensate for this force, but the operation point depends also on the transmission ratio. In any case, the road grade increases fuel consumption and therefore CO₂ emissions – not necessarily linearly. In the case of pollutants, they could increase but this depends on the engine operation point that affects what kind of pollutants are produced in the engine. Whether these pollutants make it to the exhaust relies heavily on the operation of the aftertreatment systems.

Line 46 “Consequently. . .” This statement does not exactly explain why the govern-

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ments are making PEMS tests and it seems like a leap of thought. Also no references are provided to back this statement. The following statement in line 48 “Gallus et al. (2017). . .” refers to an experimental campaign and not to the adoption of PEMS as an official protocol to define emissions. The following references also refer to research campaigns and not protocols. Please re-phrase and elaborate.

Line 55 “Nevertheless, the conduction of road measurement experiments using PEMS is a relatively new domain, and only a few studies have been performed to assess the analytical data. . .” This is not quite true, please check the literature on this issue and elaborate. PEMS is common in testing, especially on light-duty vehicles, where in the European Union at least is part of the vehicle type approval procedure for pollutants requires Real Driving Emission (RDE) testing (Regulation (EU) 2017/1151). The cold start is important for light-duty vehicles as they are often doing short trips and the aftertreatment systems do not reach always optimal operation temperature. However, for heavy-duty vehicles the cold start effect is limited as the vehicles operate for long time (e.g. 8 hours or longer for a typical city bus operation) and they are compensated by the long operation time.

Line 60 The term “classical mechanics” is a bit redundant in this context. Please consider to elaborate.

Line 62 Please take into consideration the instrument accuracy. PEMS can be utilized everywhere on-road, but could face accuracy issues, while these problems are minimized in the laboratory where the methodology and the instruments (e.g. bag result analysis) could be more accurate.

Line 98 The Eq. 1 seems redundant, but it could be retained. However, what the authors are describing here is a rolling average with a step of 5 observations. Please clarify.

Line 101 The Eq. 2 seems redundant as it presents the calculation of acceleration based on speed, which must be a well-known topic for the reader. Retain it if you

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consider it useful for your narration, otherwise please remove and elaborate.

Line 103 The authors in this section (2.3.2) describe the synchronization of the data. For every data that are retrieved from the vehicle there's a time lag between the phenomenon that occurs and the measurement time. Combustion process and exhaust emissions are directly correlated as the latter are products of the former process but the data are retrieved with a time lag as gases need to travel from the combustion chamber to the exhaust where they are measured. Data timestamps from the combustion chamber and the exhaust would correspond to different events and they need to be synchronized. This applies to all the sensors but not all the events can be correlated in this way. This section seems that it is not needed as this process is standard for the post-processing. However, if you retain it please elaborate this section and consider merging it with another one where you describe the data post-processing.

Line 120 The μr and $\mu\alpha$ are not defined. Please define that are the rolling resistance and air drag coefficients.

Line 122 You mentioned the vehicle weight was set at 5880. Have you measured the vehicle on a balance or did you derive this value from your calculations?

Line 142 The “engine room” could mean the whole compartment where the engine is placed. Please consider replacing it with the more appropriate term “combustion chamber”.

Line 186 “which is not taken into account by the WHVC approach.”. The WHVC development was based on real-world data in order to produce a representative situation of real-world conditions. The claim that the testing conditions are not represented in the WHVC is useful as observation, but it needs to back it with enough data. First, it should be quantified how many times are encountered the testing conditions that were outside the WHVC approach. The following questions must be answered. Has it been on every test, has it been affected by the driving style or has it been due to the requirements of your experiment? Second, it is needed to compare to real-world route conditions to the

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overall WHCV approach and quantify the effect and its significance.

Line 199-207 This is methodology, please move to the respective part.

Line 217 - 218 It should be clarified that the use of air conditioning poses an additional load to the engine that could make the engine operate in less optimum operation ranges under some conditions. In this way it could lead to an increase in pollutants.

Line 245 – 250 It is stated several times that “a parameter depends on the same parameter” such as “the road gradient depends on the cosine of the road gradient”, which is quite obvious. Please elaborate the whole text and remove such statements.

Line 253 – 254 “the WHVC driving mode is currently applied worldwide.” I am not sure whether this is true and it is quite vague. Please mention major countries/regions that use this protocol and for what reasons. In Europe for instance, the heavy-duty vehicle type approval procedure is performed through a simulatory approach that utilizes other driving cycles.

3 Technical corrections

Line 28 “(O’Neill et al., 2004; Chappelka and Samuelson, 1998; Wang et al., 2017)” please re-arrange in chronological order.

Line 44 Please provide an accurate reference for the EPA.

Line 54 “(Kousoulidou et al, 2013; Kwon et al, 2017; Liu et al, 2009; Luján et al, 2018; O’Driscoll et al, 2016)” please re-arrange in chronological order.

Line 70 “current Japanese regulation set in 2016.” Please cite the exact law. Line 76 “. . .in our previous work. . .” Please avoid using possessive pronouns and especially in the first person. Consider removing them entirely and retain the reference to your work. If you want to retain the connection with your work for any reason, please consider

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using the third person e.g. “in the authors’ previous work”.

Line 259 “in the Japanese market were conducted”, I think you mean a vehicle that is available in the Japanese market, but it unclear. Please correct.

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