

Status Report of New Issues TF –CFD* sub wg

*CFD: Computational Fluid Dynamics method, method to simulate aero drag

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Background of CFD wg under New Issues TF

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- During Dec. 2017 New Issues TF meeting, Exa (software vender) proposed revisions to text related to CFD in Annex 7 of GTR 15.


WLTP Simulation Requirements
ECE/TRANS/WP.29/2017/140 (page 247)

- Current text:
 - a) The alternative determination method shall fulfill an accuracy for $\Delta(CD \times Af)$ of $\pm 0.015 \text{ m}^2$ and additionally, in the case that simulation is used, the Computational Fluid Dynamics method should be validated in detail, so that the actual air flow patterns around the body, including magnitudes of flow velocities, forces, or pressures, are shown to match the validation test results;
- Comments:
 - The requirements for the validation of the alternative method state that the "method should be validated in detail". It is also stated that "the actual air flow patterns around the body, including magnitudes of flow velocities, forces, or pressures, are shown to match the validation test results." These statements are vague. The validation requirements need to be quantified in order to enable clear validation procedure.
 - The validation with respect to test results needs to take into account the measurement accuracy. The drag coefficient can be measured $\pm 1\%$ accurate, while the velocity and pressure not less than $\pm 10\%$
 - The validation for any alternative determination method should have the same requirements when it comes to the prediction of the flow pattern. For example, based on the current regulation text a wind tunnel with static ground could be used for evaluation of the rotating wheel drag despite the fact the the flow pattern will be wrong.
- Proposal:
 - a) The alternative determination method shall fulfill accuracy level for $\Delta(CD \times Af)$ of $\pm 0.015 \text{ m}^2$ and should be validated so that the actual air flow patterns around the body match the validation test results. The predicted flow velocities and pressures need to be within 10% of the validation test results accuracy band;

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WLTP Simulation Requirements
ECE/TRANS/WP.29/2017/140 (page 247)

- Current text:
 - b) The alternative method shall be used only for those aerodynamic-influencing parts (e.g. wheels, body shapes, cooling system) for which equivalency was demonstrated;
- Comments:
 - Since an alternative method can be used for the evaluation of variances, it should be explicitly stated that the equivalency needs to be demonstrated for variances in aerodynamic-influencing parts.
 - It is not clear how the equivalence should be demonstrated and to whom. It would be helpful to have an explicit statement about it.
- Proposal:
 - b) The alternative method shall be used only for those aerodynamic-influencing parts (e.g. wheels, body shapes, cooling system) for which variance equivalency was demonstrated. The equivalency needs to be demonstrated for each of the variances:
 - Between different wheels if alternative method is to be used for wheels
 - Between different body shapes if alternative method is to be used for body shapes
 - Between different cooling systems if alternative method is to be used for cooling systemsThe variance equivalency can be verified by a responsible authority.

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- During Mar. 2018 New Issues TF meeting in Paris, Japan proposed to compose a CFD expert working group as a reply to Exa proposal. TF members agreed Japan to compose the member list and lead a kick-off meeting of CFD expert working group.

Comments by Japan

- We should consider these text revisions after we discuss to create a concrete regulatory text like Paragraph 3.2. of Annex 4 Wind tunnel criteria. Or, after we discuss whether we should create a regulatory text like Paragraph 3.2. or not, at first.
- To do this, we propose to set a separate working group in New Issues TF for discussion of CFD and invite specialists from software vendors and vehicle manufacturers. And in that TF, we discuss Terms of Reference (ToR) at first, then solve those problems.
- If there are any requests on urgent discussions on this from software vendors and vehicle manufacturers, they should make clear on the proposal of regulatory text development plan.

[Example of discussion timeline in UN]

- To finalize GTR in 2019 summer: Need to finish discussion within 2018. (Preferably by Sep. 2018.)
- To finalize GTR in 2020 summer: Need to finish discussion by Sep. 2020.

Questions to WLTP IWG


Proposal #3

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- ▶ Define demonstration of equivalence to be 'sufficiently large'
 - ▷ Require a well defined set of cases such that it is very unlikely CFD results could be correct for incorrect reasons (e.g. cancellation of errors)
 - ▷ Multiple vehicles must be demonstrated
 - ▶ Multiple variants must be shown for each vehicle
- ▶ Reasoning
 - ▷ Provides well defined process for OEM to follow to certify CFD method
 - ▷ Eliminates uncertainty of flow visualization
 - ▷ Relies on data OEM already has from physical WLTP process
 - ▷ Volume of variants demonstrated gives confidence that CFD method is accurate
- ▶ Drawbacks
 - ▷ Does not compare to measured flow field results
 - ▷ OEMs with limited vehicles may not have enough variants to meet requirements
 - ▶ Depending on how demonstration of equivalence requirements are defined

Proposal #3
Example of individual vehicle variants

	Test configurations per vehicle				
	Wheel A	Wheel B	Wheel C	Wheel D	Wheel E
Baseline	OPEN GRILLE	50% OPEN	CLOSED	OPEN GRILLE	OPEN GRILLE
Optional Equipment A	OPEN GRILLE	-	-	-	-
Optional Equipment B	OPEN GRILLE	-	-	-	-



Proposal #3
Require at least 3 different vehicles for all deltas

Optional Equipment	Test configurations per vehicle				
	Wheel A	Wheel B	Wheel C	Wheel D	Wheel E
Baseline	OPEN GRILLE	50% OPEN	CLOSED	OPEN GRILLE	OPEN GRILLE
Optional Equipment A	OPEN GRILLE	-	-	-	-
Optional Equipment B	OPEN GRILLE	-	-	-	-



- ▶ Total vehicles: 3
- ▶ Variants per vehicle: 7
- ▶ Total vehicle deltas: 18
- ▷ Very unlikely 18 deltas could be predicted correctly by random chance (0.00038% chance)

Is it acceptable to define the common procedure to certify CFD software?
Does any CPs/TAA/TSs require workshop on CFD?

Status of CFD discussion

Proposal from WLTP CFD sub-wg on discussion

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for software validation for simulation of aero drag

(See WLT-26-11e_app1 for more details)

■ Motivation

- Current requirement for flow-field validation in Annex 7, § 3.2.3.2.2.3.2. (a) to GTR 15 doesn't specify the measurement method and criteria
- CFD sub-wg members propose to add $\Delta c_D \cdot A$ correlation approach (in analogy to wind tunnel method validation in Annex 4, § 6.2)
- We also propose to replace the requirement for flow-field validation with the proposed $\Delta c_D \cdot A$ correlation approach

■ Premise

- CFD simulation in WLTP is intended for calculation of optional equipment (not absolute values, only $\Delta c_D \cdot A$).

■ General idea of the $\Delta c_D \cdot A$ correlation approach

- Compare the results ($\Delta c_D \cdot A$) from the Wind Tunnel and the simulation software for one or more vehicle types/body-styles (depending on model portfolio and intended simulation usage) and a specific number of optional equipment parts (e.g. several types of wheels).
- Large enough set of compared variants can assure the validity of the CFD method and indirectly prove the validity of the flow-field.

CFD sub-wg members want to clarify the method

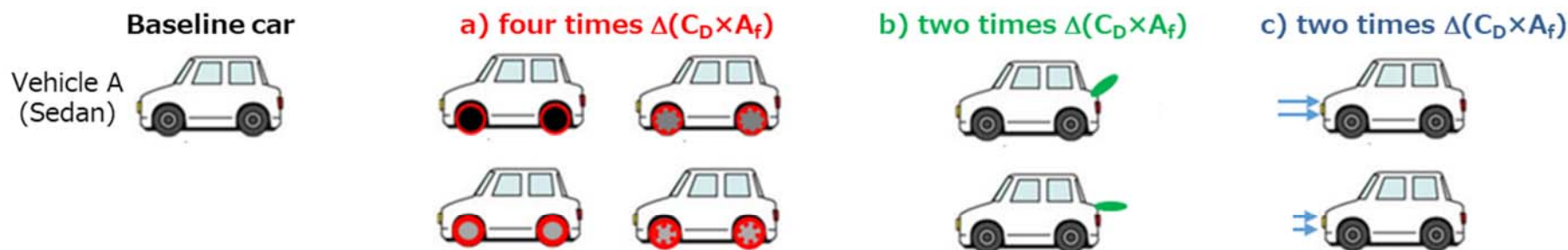
**WLTP IWG approved that
CFD sub-wg members to work on clarification of the method.**

- 3 meetings were held after 26th WLTP IWG. (No status report on 27th WLTP IWG)
- Japan announced that **Japan cannot accept CFD method in Japanese legislation.** Therefore, the following text will be added in GTR 15 for alternative method to determine $\Delta(C_D \times A_f)$.

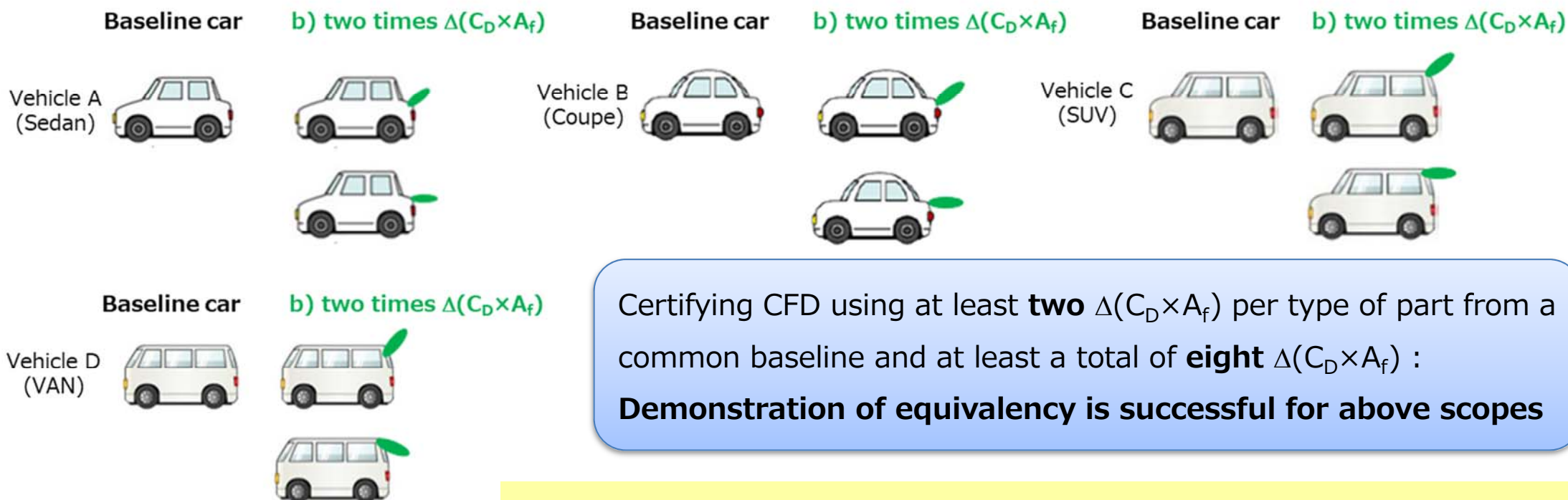
“At the option of the Contracting Party, part of or whole of the alternative method may be excluded”
- Japan proposed to clarify in the text on **the right of Responsible Authority to request for actual test to any vehicle before/after type approval.** (Same concept as Annex 4 Para 3) However, sub-wg members decided to focus on Validation method and re-validation criteria of CFD method.
- Validation method
 - To use “smoke” to visualise the air flow for Annex 4 approved wind tunnel and compare it with CFD result during validation is difficult because “smoke” disappear over 50kph.
 - CFD experts discussed at least 3 cases per types of parts/groups including the baseline need to be tested for CFD method validation. Also, from their experience, at least 9 to 15 cases for total need to be done. One of the way to explain their experience of the “number of cases” is to use probability. The probability whether the result of CFD method matches/does not matches with Annex 4 approved wind tunnel.
 - From the discussion, CFD sub-wg members decided to validate **at least two $\Delta(C_D \times A_f)$ per type of part from a common baseline** and **at least a total of eight $\Delta(C_D \times A_f)$.**
- Re-validation criteria
 - Clarified that the revalidation criteria for CFD method.
 - Any change made to a simulation model.
 - Any change made to the software likely to invalidate the validation report. (Text copied from EU legislation)

Conclusion by CFD sub-wg

- 1) **Certification scope single baseline:** using multiple parts (a, b, c) with mixed number of modifications per part vs. one baseline 5/5



- 2) **Certification scope multiple baselines:** using single type of part (b) applied on different baseline vehicles



Certifying CFD using at least **two** $\Delta(C_D \times A_f)$ per type of part from a common baseline and at least a total of **eight** $\Delta(C_D \times A_f)$:

Demonstration of equivalency is successful for above scopes

CFD sub-wg would like to ask for approval of the text.

**Thank you very much
for your attention!**
