

Proposal for amendment to the Resolution on the Construction of Vehicles (R.E.3)

Insert a new Annex 8 on the Resolution on the Construction of Vehicles (R.E.3)

Annex 8 Virtual testing Guideline with regards to Tests for Approval

0. Introduction

This annex describes the method that can be used to consider virtual testing as an alternative to physical testing, based on the manufacturer request.

This method is mainly based on two separate activities:

- (a) Activity 1: The development, management, verification and validation of the toolchain; and,
- (b) Activity 2: The use of virtual testing results to conduct testing required for approval process. This activity shall be integrated into or amended in the related Regulation (target regulation) referring to this annex

In order to make use of Virtual Testing, relevant UN Regulations shall refer to this annex to introduce relevant definitions and provisions as follows:

1. Definitions

- 1.1 “*Virtual testing*” is the process of testing a system using one or more simulation models.
- 1.2. “*Model*” is a description or representation of a system, entity, phenomenon, or process.
- 1.3. “*Toolchain*” is the combination of simulation model implementations as tools that emulate a vehicle function.
- 1.4. “*Validity domain*” is the domain of applicability of the toolchain.
- 2. Activity 1: The development, management, verification and validation of the toolchain
 - 2.1. General specifications
 - 2.1.1. Credibility of the toolchain that is used for the virtual testing shall be demonstrated by the vehicle manufacturer to the satisfaction of the Type Approval Authority or its Technical Service.

For this, the following five criteria shall be considered:

- (a) Capability – what the toolchain can do, and what the associated risks are;
- (b) Accuracy – how well the toolchain reproduces the target data recorded in physical tests;

(c) Correctness – how sound and robust are the data and the algorithms in the tools;

(d) Fit for Purpose – how suitable the toolchain is for the assessment (e.g. vehicle dynamic model, structural behavior model, system control model, environment model, use cases model, targets model, ...) within its validity domain;

(e) Usability – The training and experience, which is needed and the quality of the processes that manage the toolchain's use.

2.2. Development of the virtual testing method

2.2.1. Developing and using the toolchain is the responsibility of the vehicle manufacturer. The toolchain shall reflect the vehicle, system and components that are to be tested.

2.3. Toolchain management

The following information shall be provided by the manufacturer to the Technical Service:

2.3.1 A description of the models and tools which constitute the toolchain and the method used to trace input data, parameters and output data back to the corresponding toolchain version.

2.3.2. The processes which ensure that the personnel developing, testing and validating the toolchain and its components have appropriate experience, expertise, and training and evidence that these processes are implemented and effective. If there are any activities not directly controlled by the manufacturer, there must be an explanation of measures taken to ensure confidence in the quality and integrity of these activities.

2.3.3. A description of the input parameters, along with any uncertainties in the model parameters, which have been used to validate the models included in the tools and toolchain. The manufacturer shall also provide documentation demonstrating that the data used to validate the models covers the intended scope and functionality of the toolchain.

2.3.4. A description of the overall approach to data management.

2.3.5. A description of the management activities which describe the modifications between toolchain releases, version control and the review processes to ensure those modifications result in a toolchain that is still suitable.

2.3.6. Description and analysis of toolchain and components

2.3.6.1. All parts of the toolchain, tools and models shall be described by the manufacturer.

2.3.6.2. The vehicle manufacturer shall define the validity domain on which the toolchain will be applicable and how the validity domain has been derived including any performance according to the expected requirements, influencing factors, parameter ranges, assumptions, limitations and tolerances.

2.3.6.3. The documentation shall include a description of the key performance indicators which will be assessed during validation, (e.g. time to collision, time to fire ...).

- 2.3.6.4. The documentation shall include a description of the accuracy requirements for the toolchain and its components, including comparison with physical tests.
- 2.3.6.5. The documentation of the toolchain shall include assumptions, limitations, uncertainties and the necessary levels of fidelity.
- 2.3.6.6. The manufacturer shall provide a description of the toolchain assessment methodology, including the impact of any errors and uncertainties on the results and the subsequent consequences for the compliance of the system with the requirements.
- 2.3.7. The manufacturer shall review the information produced in addressing the requirements of paragraph 2.3.6.2. and document any implications for the use of the toolchain.
- 2.4. Verification
 - 2.4.1. The toolchain and its components shall be capable of accurately representing the relevant aspects of the physical vehicle, system, component or numerical test tool that is being modelled.
 - 2.4.2. The manufacturer shall provide documentation on the verification activity of the modelling that implements vehicle, system, component or numerical test tool in the toolchain and its components. This shall include a description of the models, their implementation, how they represent the vehicle, system, or component and a description of the activities that have been performed to confirm that the models have been correctly implemented.
 - 2.4.3. The manufacturer shall provide an estimation of the numerical errors affecting the toolchain and its components and analysis that the errors remain sufficiently bounded.
 - 2.4.4. The manufacturer shall demonstrate the effect of variations of the model parameters on the output values and identification of the most critical parameters which will influence the results. This shall also include a robust calibration procedure for these parameters.
- 2.5. Validation
 - 2.5.1. The vehicle manufacturer shall describe their overall approach to validation including performance measures and a validation strategy. The validation strategy shall be agreed by the Type Approval Authority or its Technical Service, including physical tests performed to demonstrate that the toolchain is an accurate representation of the physical vehicle, system, component or numerical test tool. The tests performed shall ensure a statistical comparison between physical and simulation results is possible.
 - 2.5.2. The validation strategy shall be defined by the manufacturer and presented to the Type Approval Authority or its Technical Service for review and agreement.
 - 2.5.3. The manufacturer shall demonstrate how the toolchain achieves the key performance indicators defined in paragraph 2.3.6.3. and accuracy requirements defined in paragraph 2.3.6.4. This shall

include justification for the choice of key performance indicators and accuracy requirements, and what the criteria is for satisfying these indicators and requirements.

- 2.5.4. The manufacturer shall provide the list of validation use cases. The manufacturer shall provide the parameter descriptions and accuracy requirements that were needed to perform the validation tests.
- 2.5.5. The manufacturer shall provide documentation describing the validation that was performed to establish the credibility of the toolchain. This shall include information related to the processes that were followed, physical tests that were performed and models and tools that were used.
- 2.5.6. The manufacturer shall provide documentation that demonstrates how they have characterized the uncertainty in the input data and evaluated the model parameters. The overall uncertainty of the results shall be quantified based on the toolchain structure and from the data and its flow through the toolchain. This uncertainty quantification shall allow estimates of the likely errors and the required safety margins that shall be applied to the results when the toolchain is used for virtual testing.
- 2.5.7. At the request of the Type Approval Authority or its Technical Service, in addition to the documentation provided by the vehicle manufacturer, additional confirmatory validation, which shall include physical tests, shall be performed or witnessed. These tests may be relevant to the entire toolchain, specific parts of the toolchain or any of its components.
- 2.5.8. The number of physical tests shall be defined in agreement between the manufacturer and the Type Approval Authority or its Technical Service. They shall be sufficient to cover the validity domain specified by the vehicle manufacturer.
- 2.5.9. The methodology used to generate physical validation data, such as data recording equipment, data processing, calculation of scalar values shall be documented as part of the validation documentation.

3. Necessary provision for the relevant UN Regulations

Note: The following paragraphs shall be integrated into or amended in the related Regulation (target regulation) referring to this annex.

In the "Definitions" paragraph of the target regulation, insert a new paragraph, to read:

"x.x. For the definitions with regard to the use of Virtual Testing , refer to the Consolidated Resolution on the Construction of Vehicles (R.E.3) Annex 8 Paragraph 1,

In the relevant "Test procedure" paragraph or Annex of the target regulation, insert a new paragraphs, to read :

"x.x Virtual testing

x.x.x. Virtual testing may be used by request of the vehicle manufacturer as an alternative for some of the tests described in the relevant paragraphs. The virtual testing shall be verified and validated according to Annex 8 of RE.3 for Activity 1 and relevant Annex of this regulation for activity 2.

x.x.y. Virtual testing may be used in the evaluation of tests for approval in accordance with paragraph 1.8. of Schedule 3 and Schedule 8 of Revision 3 of the 1958 Agreement.

x.x.z. In case the approval requires different use cases and in order to demonstrate that the complete physical system can reliably deliver the required performance, a minimum amount ~~*~~of required tests shall be performed physically including at least one test of each use cases. The tests to be performed shall be agreed between the manufacturer and Type Approval Authority or its Technical Service. Those tests already performed as part of the model validation, and corresponding to the vehicle type approval, can be considered as part of the minimum amount of required tests.

Footnote:* The value of the minimum amount of required test shall be discussed for each regulation, and is considered as a first step. It is expected that this value will be reduced in the future. Therefore, this value should be reviewed regularly in each relevant Working Party to take practical experience into account.

x.x.z.1 Notwithstanding paragraph x.x.z , in the case of modification of the vehicle, system or component type and extension of the approval according to the relevant paragraph, the proportion of physical tests required to demonstrate that the complete physical system continues to reliably deliver the required performance may be less than the minimum amount value referred in paragraph x.x.z of the required tests. This shall be agreed between the manufacturer and Type Approval Authority or its Technical Service.

x.x.z.2 Where virtual testing is used by the manufacturer, a separate report including at least the additional information specified in the relevant Annex of each regulation for activity 2 shall be annexed to the test report.

Insert a new annex related to Activity 2:

Activity 2: The use of virtual testing results to conduct testing required for approval process

1. Compliance of the vehicle, system or component with the performance requirements as defined in the regulation may be demonstrated by the vehicle manufacturer to the Type Approval Authority or its Technical Service by making use of virtual testing.
 2. All virtual testing results provided by the manufacturer in applying for an Approval in accordance with Approval paragraph of the regulation shall refer to the toolchain evaluated and validated according to Annex 8 of RE.3.
 3. For each approval application the manufacturer shall provide a confirmation that the virtual testing:
 - a. Was conducted using a validated toolchain;
 - b. Was performed by staff with appropriate competences and skills;
 - c. Has been performing using a toolchain that has a unique identifier and sufficient information including scope, regulatory applicability and validation history to ensure that there is traceability and assurance that the toolchain is suitable and fit for purpose; and
 - d. Has been performed using a toolchain within its scope and in accordance with any restrictions.”
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