SIST

SLOVENSKI STANDARD
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SIST-TP CEN/TR 16303-2:2012
SIST-TP CEN/TR 16303-3:2012
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Oprema cest - Postopek validacije in verifikacije računalniške simulacije preskusnih trčenj v sisteme za zadrževanje vozil

Road restraint systems - Validation and verification process for the use of virtual testing in crash testing against vehicle restraint system

Rückhaltesysteme an Straßen - Validierungs- und Nachweisverfahren für die Nutzung von Computersimulationen bei Anprallprüfungen an Fahrzeug-Rückhaltesysteme

Dispositifs de retenue routiers - Processus de vérification et de validation pour l'utilisation d'essais virtuels dans les essais de choc contre un dispositif de retenue pour véhicules

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English Version

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European foreword

This document (EN 16303:2020) has been prepared by Technical Committee CEN/TC 226 “Road equipment”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2021, and conflicting national standards shall be withdrawn at the latest by February 2021.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes CEN/TR 16303-1:2012, CEN/TR 16303-2:2012, CEN/TR 16303-3:2012 and CEN/TR 16303-4:2012 (which have been merged).

In comparison to the previous Technical Reports, this document contains the following changes:

— some symbols and abbreviations have been modified;

— the roadmap for the validation of the numerical vehicle model has been updated and acceptance conditions have been provided;

— the validation requirements for virtual testing against vehicle restraint systems have been updated;

— the verification evaluation criteria for finite element model have been updated;

— the template of the report has been updated.

Annexes A, B and C are normative and Annexes D to J are informative.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This document provides a common basis for the use of virtual testing to reproduce vehicle impacts against vehicle restraint systems including safety barriers, crash cushions, terminals and passive safety devices in accordance with the EN 1317 (all parts) and the EN 12767:2019.

This document provides requirements to establish the degree to which the numerical models of vehicle restraint system and of vehicle are an accurate representation of the real world from the perspective of the intended uses of the model.

In this document a methodology is defined to validate the results obtained with computational mechanics work and to verify the reliability of the virtual test. It also includes a report template and incorporates specific content for general requirements for the competence of entities performing virtual testing.

General recommendations based on experiences for developing numerical models of vehicle restraint systems and vehicles for virtual tests are also given.

Two main modelling approaches have been considered:

— finite element (FE) method;

— multi-body (MB) approach.

1 Scope[1]

This document defines the accuracy, credibility and confidence in the results of virtual crash test to vehicle restraint systems through the definition of procedures for verification, validation and development of numerical models for roadside safety application. Finally it defines a list of indications to ensure the competences of an expert/organization in the domain of virtual testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1317-1:2010, *Road restraint systems - Part 1: Terminology and general criteria for test methods*

EN 1317-2:2010, *Road restraint systems - Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers including vehicle parapets*

EN 1317-3:2010, *Road restraint systems - Part 3: Performance classes, impact test acceptance criteria and test methods for crash cushions*

ENV 1317-4:2001, *Road restraint systems – Part 4: Performance classes, impact test acceptance criteria and test methods for terminals and transitions of safety barriers*

EN 12767:2019, *Passive safety of support structures for road equipment - Requirements and test methods*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp/ui

3.1
independent expert
third-party qualified expert in virtual testing with experience on vehicle restraint systems and/or passive safety devices, independent from the organisation or the construction product he assesses (see Annex B)

3.2
numerical model
complete mathematical 3-D model of vehicle restraint systems, passive safety devices and vehicles

Note 1 to entry: It refers to a numerical model which might be analytical or discrete and aims to reproduce the basic physical phenomena of a subject.

3.3
passive safety device
support structures for road equipment tested according to EN 12767:2019

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[1] The scope of this document is also applicable to passive safety devices.

3.4
real test
real test performed at a test house according to the relevant standard

3.5
test item
device to be assessed using virtual testing

3.6
validated model
numerical model of the roadside or passive safety device or vehicle that fulfils the requirements of this document after being checked and agreed by an independent expert

3.7
validation
set of activities defined to assess whether a numerical model can be considered representative of a physical system or part in a specified range of conditions

3.8
vehicle restraint system
device tested according to EN 1317-1 and EN 1317-2, EN 1317-3or ENV 1317-4

3.9
verification
set of activities defined to check whether a numerical model is reliable and numerically stable

3.10
virtual test or virtual testing
activities related to the use of a numerical model to reproduce a real test and/or to simulate an impact

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply:

ASI	acceleration severity index
CoG	centre of gravity
D	dynamic deflection
D_{m}	measured maximum dynamic deflection of the real test, in metres (m)
D_{m_mod}	measured maximum dynamic deflection of the real test with a tolerance of ± 0,15 m, in metres (m)
D_{VT}	measured maximum dynamic deflection of the virtual test, in metres (m)
FE	finite elements
FEA	finite elements analysis
HGV	heavy goods vehicle
LD	lateral displacement
LD_{m}	measured lateral displacement of the real test, in metres (m)
LD_{m_mod}	measured lateral displacement of the real test with a tolerance of ± 0,15 m, in metres (m)
LD_{VT}	measured lateral displacement of the virtual test, in metres (m)

MB	multi-body
MBA	multi-body analysis
THIV	theoretical head impact velocity
TT	type test
VI	vehicle intrusion
VI_{m}	measured vehicle intrusion of the real test, in metres (m)
VI_{m_mod}	measured vehicle intrusion of the real test with a tolerance of ± 0,15 m, in metres (m)
VI_{VT}	measured vehicle intrusion of the virtual test, in metres (m)
VT	virtual test or virtual testing
W	working width
W_{m}	measured working width of the real test, in metres (m)
W_{m_mod}	measured working width of the real test with a tolerance of ± 0,15 m, in metres (m)
W_{VT}	measured working width of the virtual test, in metres (m)
ΔF	change in force
Δs	change in displacement

5 Requirements for numerical vehicle model

5.1 Modelling

A complete 3D numerical model of a real test vehicle according to EN 1317-1:2010 respectively EN 12767:2019, as relevant, shall be created. The geometry of the vehicle and all inertial properties shall be reproduced accurately. The numerical model shall include at least:

— frame;

— body;

— suspensions systems, front and rear;

— wheels;

— steering system;

— windows;

— engine block;

— ballast.

Vehicle specifications under test conditions shall be as specified as in EN 1317-1:2010, Table 1 and the EN 12767:2019, 5.3, as relevant.

The vehicle shall be fitted with, as a minimum, one accelerometer for measurement in the longitudinal (forward) direction, one for the lateral (sideways) direction, one for the vertical direction (downward) and an angular velocity sensor (rate sensor). The accelerometers shall be mounted as prescribed by the EN 1317-1:2010. Vehicular accelerations shown by this accelerometer shall be used for the calculation of the severity indices, according to EN 1317-1:2010.

The model shall be able to reproduce the comparable deformation observed in the type test.

5.2 General vehicle model behaviour assessment

For the validation of the numerical vehicle model, tests shall be performed according to this document, comparable parameters shall be measured and the results shall be fully documented.

The validation tests that shall be carried out to ensure the numerical stability and the capability of the numerical model are divided in categories dealing with vehicle setup, vehicle suspension and steering kinematics, handling and crashworthiness.

5.3 Test methodology

5.3.1 General

The scope of the following analysis is to ensure the stability and robustness of the vehicle model and the level of reliability of the results.

The finite element model and the multi body vehicle model shall be validated with the same requirements and limits.

This procedure consists of a fixed number of compulsory tests and a series of additional tests that can be performed depending on the intended use of the model.

For the vehicle model in order to be considered validated all compulsory tests shall be completed without error terminations for the specified time.

In general the analysis shall be performed when the vehicle development is completed. Modification(s) will require to perform some or the full set of the tests again.

In special situations where requirements of this document cannot be satisfied, deviations from the given rules shall be reported and motivations shall be explained and then checked and agreed by an independent expert (see Annex B). These exceptions shall only be motivated by technical and not by economical reasons. An exception can be e.g. if the measurement in a real test cannot be reproduced consistently.

5.3.2 Test description

5.3.2.1 Compulsory test

The tests are grouped in four different sets:

— Set 1. – Vehicle setup;

— Set 2. – Vehicle suspension and steering kinematics;

— Set 3. – Vehicle handling;

— Set 4. – Vehicle crashworthiness.

The tests included in Table 1 shall be performed to complete the vehicle validation.

The table includes the scope of the test, the results to be provided and the acceptance conditions (limits).

Table 1 — Vehicle validation roadmap compulsory tests

Set 1. – Vehicle setup		
Test 1.1 - Idle test (described in C.2)		
Scope: Verify stability of the vehicle model and general setup when stationary	Results to be provided: — Acceleration time (filtered: filter class CFC60) — Suspensions movement time history	Limits: — Filtered accelerations: a < ± 3,0*9,81[m/s²] — Suspension movement: Δs < |20| [mm] for all vehicles except heavy goods vehicles with mass of 38 tons Δs < |80| [mm] for heavy goods vehicles with mass of 38 tons
Set 2. – Vehicle suspension and steering kinematics		
Test 2.1 – Isolated suspensions system (constrained vehicle) – full compression (described in C.3.1)		
Scope: Verify suspension kinematic and loading and unloading capacity	Results to be provided: — Comparison between input curves and response — Identify the suspension maximum compression	Limits: — Allowed variation between input curves and response: $\Delta F < \|0,05\| * F^0$ Where F^0 is the suspension force when stationary, displacement $s^0 = 0$[mm] (see Figure F.7 and F.8)
Test 2.2 – Isolated suspensions system (constrained vehicle) – full extension (described in C.3.1)		
Scope: Verify suspension kinematic and loading capacity	Results to be provided: — Comparison between input curves and response — Identify the suspension maximum extension	Limits: — Allowed variation between input curves and response: $\Delta F < \|0,05\| * F^0$ Where F^0 is the suspension force when stationary, displacement $s^0 = 0$[mm] (see Figure F.7 and F.8)
Test 2.3 – Isolated steering system (constrained vehicle) – full rotation both sides (described in C.3.2)		
Scope: Verify steering kinematic	Results to be provided: — Comparison between left and right wheel steering angle (time Vs angle curves) — Identify the steering maximum angle with slip-free rolling of the wheels	Limits: — Verify Ackerman principle (described in E.1.5 and Figure E.2)

Set 3. – Vehicle handling		
Test 3.1 - Linear track test (described in C.4.1)		
Scope: Verify the general behaviour of the vehicle (steering and suspension system) and its capability to run. The model shall be able to follow the linear trajectory for about 1,0 s.	Results to be provided: — Trajectory plot — Energies balance in time	Limits: — Following the linear trajectory for minimum of 1,0 [s] with the maximum speed — Acceptable deviation Δs_0 from the linear trajectory with the length L_t: $\Delta s_0 < 0,1^* L_t$
Test 3.2 - Test on curvilinear track (described in C.4.2)		
Scope: Verify the general behaviour of the vehicle (steering and suspension system) and its capability of steering under an applied load or by rotating the steering wheel and returning in neutral (without steering) when the force is removed, or the steering wheel is in neutral position. The model shall be able to follow the curvilinear trajectory for about 1,0 s.	Results to be provided: — Trajectory plot — Energies balance in time	Limits (with a speed of 30 % of test speed): — The steer shall be applied until the vehicle rotates at least 20[°] from the original direction — After reaching the 20[°], the model shall follow the curvilinear trajectory of about 1,0 [s] with an acceptable angle deviation of: $\Delta\beta < \pm 5$[°] — Then, when the steering is removed, the trajectory shall reach a straight line
Test 3.3 - Step test (described in C.4.3)		
Scope: Verify dynamic behaviour of the suspension system and general robustness of the model to demonstrate the damping of the suspension.	Results to be provided: — Spring suspension change in length Vs time curve. — Kinetic and total energy time histories	Limits: — Falling from a step height of ΔH = 80[mm] with a vehicle speed of 25[km/h], the length vs time curve oscillation shall be damped to 50 % of the first peak, in 2 cycles
Set 4. – Vehicle crashworthiness		
Test 4.1 - Against rigidwall (EN 1317-2:2010) (described in C.5)		
Scope: Verify the capability of suffering strong deformations. Control of the contact definition.	Results to be provided: — Post-impact analyses (severity indices for cars) — Kinetic and total energy time histories	Limits: — Severity indices tolerance according to 8.3.8 — Total energy lost < 10 %

Test 4.2 – Front collision test (EN 12767:2019, EN 1317) (described in C.5)		
Scope: Ensure that the front characteristics of the test vehicle are within a specified range.	Results to be provided: — Velocity time histories	Limits: — Limits according to EN 12767:2019, Clause 6 and Clause 7

A more detailed test description is provided by the guidelines within Annex C.

If one of the above virtual tests is not relevant for the analysis to be performed, the entity performing VT activity shall explain his motivations inside the final validation report and those motivations shall be checked and agreed by the independent expert.

Tests defined in Set 2 are mandatory only for new vehicles models, not for further revisions of existing validated models. Some minor modifications (e.g. Mass) may be accepted if explained without further testing (see Annex A, Virtual Testing – Template for Report).

5.3.2.2 Additional test

Additional tests could be done to evaluate features of the vehicle that are not evaluated by the test in Table 1 such as the suspension failure (using a test similar to the "Isolated suspensions tests") or a front vehicle deformation.

5.4 Verification

For the verification of the numerical vehicle model, requirements of 5.3.2 shall be fulfilled.

5.5 Reporting

All tests shall be reported in vehicle model verification and validation report (see Annex A).

If vehicle models are modified the validated vehicle model shall be mentioned as basis (report reference to vehicle model validation report) and all changes shall be described in detail.

6 Requirements for numerical model of vehicle restraint system

6.1 Modelling

A complete 3D numerical model of the vehicle restraint system shall be created. The geometry of the vehicle restraint system and all inertial properties shall be reproduced accurately, according to the reference drawings of the test item. The numerical model shall include:

— device components;

— components connections;

— fixation to the roadbed / anchoring;

— ground (any soil, asphalt, concrete);

— boundary conditions (e.g. attached terminals or safety barriers).