SLOVENSKI STANDARD
SIST-TP CEN/TR 16303-2:2012

01-marec-2012

Oprema cest - Smernice za računalniške simulacije preskusnih trčenj v sisteme za zadrževanje vozil - 2. del: Oblikovanje vozil in preverjanje

Road restraint systems - Guidelines for computational mechanics of crash testing against vehicle restraint system - Part 2: Vehicle Modelling and Verification

Rückhaltesysteme an Straßen - Richtlinien für Computersimulationen von Anprallprüfungen an Fahrzeug-Rückhaltesysteme - Teil 2: Fahrzeugmodellierung und Überprüfung

Dispositifs de retenue routiers - Recommandations pour la simulation numérique d'essai de choc sur des dispositifs de retenue des véhicules - Partie 2: Composition et vérification des modèles numériques de véhicules

Ta slovenski standard je istoveten z: CEN/TR 16303-2:2012

ICS:

13.200	Preprečevanje nesreč in katastrof	Accident and disaster control
93.080.30	Cestna oprema in pomožne naprave	Road equipment and installations

SIST-TP CEN/TR 16303-2:2012 en,fr,de

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

CEN/TR 16303-2

January 2012

ICS 13.200; 93.080.30

English Version

Road restraint systems - Guidelines for computational mechanics of crash testing against vehicle restraint system - Part 2: Vehicle Modelling and Verification

Dispositifs de retenue routiers - Recommandations pour la simulation numérique d'essai de choc sur des dispositifs de retenue des véhicules - Partie 2: Composition et vérification des modèles numériques de véhicules

Rückhaltesysteme an Straßen - Richtlinien für Computersimulationen von Anprallprüfungen an Fahrzeug-Rückhaltesysteme - Teil 2: Fahrzeugmodellierung und Überprüfung

This Technical Report was approved by CEN on 8 November 2011. It has been drawn up by the Technical Committee CEN/TC 226.

CEN members are the national standards bodies of 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, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. CEN/TR 16303-2:2012: E

Contents

Page

Foreword

This document (CEN/TR 16303-2:2012) has been prepared by Technical Committee CEN/TC 226 “Road equipment”, the secretariat of which is held by AFNOR.

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

This document consists of this document divided in five Parts under the general title: Guidelines for Computational Mechanics of Crash Testing against Vehicle Restraint System:

— *Part 1: Common reference information and reporting*

— *Part 2: Vehicle Modelling and Verification*

— *Part 3: Test Item Modelling and Verification*

— *Part 4:Validation Procedures*

— Part 5: *Analyst Qualification*[1]

[1] In preparation

Introduction

This part of CEN/TR 16303 is informative. It gives general information for the development of a vehicle model for crash test simulation against vehicle restrain system.

Two different categories of vehicle models can be identified. The first category consists of a detailed model (usually finite element) of a vehicle or of a portion of it, typically used in the automotive industry to assess the structural performance and properties of the vehicle. A second type of vehicle model (finite element or multi-body), instead, is typically used to assess the barrier performance in the simulation of full-scale crash tests. In this case, a less detailed model is required, in order to obtain a computationally cost-effective tool for the analysis of several different crash scenarios. At the same time, it is mandatory to reproduce faithfully the correct inertial properties and outer geometry of the vehicle.

This Part of the guideline is meant to provide the user with all the information necessary to develop a complete and efficient numerical model of a vehicle in order to properly simulate a crash event (second category of vehicle above). It is not convenient to use a very detailed model, because of the unaffordable increase in the computational costs. In this perspective, the vehicle model can be regarded as a tool for the analysis of a crash event.

1 Scope

The aim of this Technical Report is to provide a step-by-step description of the development process of a reliable vehicle model for the simulations of full-scale crash tests giving the reader a first synthetic summary of problems encountered in the different steps of the vehicle modelling process.

2 Normative references

The following referenced documents are indispensable for the application 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.

N/A

3 General considerations on the modelling techniques of a vehicle

3.1 General

Particular attention shall be paid on the modelling of vehicular kinematics and of the components that realize it: front and rear suspensions, wheels, steering system, etc. The geometry of the vehicle shall be reproduced correctly to simulate the interaction with the barrier. The model shall include only significant parts and few details (internal parts should be modelled only regarding their inertial properties, etc.) in order to reduce the computational cost of the model.

3.2 Finite Element and Multi-body approaches

Two main modelling approaches can be considered, using two different analysis tools: the Finite Element Method (FEM) and the Multi-Body (MB) approach. Both methods are widely known and broadly used in many fields of engineering, including the Automotive Industry.

The first method allows the user to build a very detailed vehicle model and to assess global results such as the barrier or vehicle performance in a crash test as well as the stress data in a local area of the vehicle. As a counterpart, a FEM analysis requires significant computational costs, thus proving less valid for parametric studies where a large number of simulations may be required.

Crash tests finite element (FE) simulations are usually run with a dynamic, non-linear and explicit finite element code. Computer runtime is usually significant, with the order of 30-40 hours on a 2,4 GHz personal computer for the simulation of a full-scale crash test with an effective simulated time of 0,25 second. In fact, the model must include not only the vehicle model, but also several meters of roadside barriers (depending on the barrier type, up to 80 meters of barrier) to faithfully reproduce the interaction between the vehicle and the barrier and the boundary conditions. The integration time step is controlled by the minimum dimension of the smallest element of the FE mesh, therefore, the mesh size shall be a trade-off between the need for geometrical and numerical accuracy and computational cost: large elements guarantee a high time step but poor accuracy of the model and possible instabilities, while small elements give a better accuracy but a smaller time step. General criteria for the mesh can be identified. The most significant parts of the vehicle shall be modelled explicitly with a detailed mesh (vehicle body, wheels, etc.). Other parts can be modelled implicitly, reproducing their inertial properties (engine) or their function and kinematics (suspension and steering systems).

On the other hand, the MB approach consists roughly in modelling the vehicle as a number of rigid bodies connected by means of joints with specified stiffness characteristics. The method is particularly suitable to assess the kinematics of the vehicle, while less applicable to determine data about levels of stress and strains. When reliable and validated data are available, the MB approach is very useful to perform parametric studies, since the computational cost of the analysis can be dramatically less than that of the corresponding FEM analysis.

3.3 General scheme of a vehicle

Three main categories of vehicles can be identified:

a) passengers cars;

b) heavy goods vehicles (HGVs);

c) buses.

Despite their differences, basically in terms of mass and geometry, they share many common elements:

— frame;

— body;

— suspensions (front and rear);

— wheels;

— steering system;

— glasses;

— engine block;

— vehicle's interiors.

Regarding the vehicle structure, it must be pointed out that two main different structural options can be identified: the body-on-frame vehicle, typical for trucks and HGVs and the unit-body vehicle, typical for passenger cars. In the first case, three structural modules that are bolted together to form the vehicle structure can be identified: frame, cabin and box or bed (for a pick-up truck for example). In the second case, the vehicle combines the body and frame into a single unit constructed from stamped sheet metal and assembled by spot welding or other fastening methods. This structure is claimed to enhance whole vehicle rigidity and provide for weight reduction.

Suspensions can also be subdivided into two main groups: dependent and independent. Generally, independent suspensions are used for passenger cars and dependent suspensions are employed in commercial vehicles and buses.

Wheels can be single or coupled. The latter configuration is customary for rear wheels of HGVs and buses.

3.4 Vehicle validation considerations

Once the vehicle model has been built, it shall be validated with simple tests, both components tests and full-model tests, observing the global response of the model and the behaviour of the single parts (suspensions, wheels). Numerical stability of the model shall be assessed. Subsequently, the model can be used to simulate full-scale crash tests.

The same validation approach shall be applied both to FEM and MB modelling. This document can be applied to different modelling techniques, codes or vehicles. Despite different models, the same level of validation shall be required if these models will be applied during the certification process.

Some general comments can be emphasized to accurately predict ASI and THIV, as calculated from a vehicle body mounted accelerometer:

a) correct representation of stiffness, strength and inertial properties of the vehicle body

⇒ part strength, crush mode and timing of front wing, engine firewall, bonnet, A Pillar, floor and other parts affect the accelerations recorded;

b) correct representation of tyre interaction with the vehicle body, and hence tyre stiffness

⇒ for stiffer barriers especially, how the tyre loads the sill and wheel arch affects the accelerations;

c) accurate capturing of steering, suspension motion, suspension spring and damper properties

⇒ for weak post systems in particular, longitudinal acceleration is greatly influenced by whether a wheel strikes a post, which can be determined by how the front wheels react/steer from previous strikes;

⇒ lateral accelerations are affected by the vehicles ability/inability to steer

d) sufficient detail for modelling is required for representative vehicle behaviour

⇒ reducing the model detail and integrity cannot be substituted for lack of computational resource;

⇒ accelerometer sampling rate can affect results and needs to set at an appropriate level to give results convergence;

e) a combination of element size and time step can produce mass scaling of the vehicle. Mass scaling should be kept to a minimum (aim at less than 2 %) as mass added to the vehicle on initialisation could affect the impact results. The added mass should not be concentrated in critical areas.

In building a model we make assumptions on what effects are important and to level of accuracy to capture those effects. It is only by conducting a physical test that we discover what physical effects actually occur, and the relative importance of those effects.

It is also possible that poorly constructed models can produce, what appear to be accurate high level results that match test e.g. peak ASI, THIV and PHD, however, the underlying accelerations can be far from reality. Therefore detailed analysis of the elements making up the high level results need to be fully understood.

4 Step by step development of a vehicle for crash test analysis

Annex A refer to the development of a Finite Element model of a vehicle. In particular:

— A.1 focuses on the vehicle components to be modelled, describing extensively the function of the component and its role in the model as well as some of the *ad hoc* techniques to achieve an efficient model of the part. On the basis of these considerations the user can basically develop any vehicle model, be it a passenger car or a pick-up truck.

— A.2 deals with organisation aspects of the model. Models, in fact, often need to be used by different organisations and pass from user to user. It is, therefore, important that the models have a standard structure and an organisation predictable and easy to understand. A modular model structure is recommended and extensively presented in this annex.

— A.3 a brief presentation of material models suitable for dynamic analyses is provided. Materials and their properties are fundamental aspects of a reliable model, since the vehicle models that are objective of this manual are going to be used for the simulation of a dynamic event.

— A.4 includes specific recommendations on the mesh features.

Annex B refer to the development of a Multi-Body model of a vehicle. In particular:

5 Validation procedures of a vehicle for crash test analysis

5.1 General

This clause deals with the validation phase of the model. Significant numerical tests are recommended to check the stability and reliability of the model.

5.2 Test methodology

5.2.1 General

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

The vehicle will be considered validated, for a certain class of impacts, if the comparison between simulation and testing will fit inside the limits described by this Validation Roadmap (tests description is in Annex C).

The Validation Roadmap includes several simple tests made to ensure the numerical stability and the capability of the numerical model. There are two classes of tests: component test and full scale vehicle test.

5.2.2 Components tests

Simulated tests shall be performed on vehicle components to demonstrate the capabilities of the sub structures.

The tests of components involve mainly the suspension system; they require simulations and correlations with experimental tests. The results from tests on front and rear suspension should be compared with simple pendulum tests.

Description of tests is in C.1

5.2.3 Full scale vehicle test

During these phase all the vehicle shall be modelled.

Different typologies of tests are scheduled:

— Idle tests: this analysis is needed to guarantee the stability of the vehicle (Description of test is in C.2);

— Linear/circular track tests: this second typology is made to control the performances of the vehicle while is moving or turning with a fixed or variable radius (Description of tests are in C.3);

— Curb test: The vehicle model is forced to override curbs to test the response of the suspension system and wheels to small impacts (Description of tests are in C.4);

— Full-scale vehicle test: these tests are made in order to assess the global response of the vehicle while impacting against a rigid wall and a deformable barrier impacts (Description of tests are in C.5).

5.3 Acceptance criteria and results to be provided

The simulations described in Clause 6 of this guideline are required to demonstrate the stability of the model regarding numerical integration and suspension system. The model shall respond without any instability during all the simulation.

In Table 1 are described all the result that shall be provided for each test:

Table 1 — Vehicle test list purposes and results

N°	Type of simulation	Scope of simulation	Results to be provided
1.1	Isolated suspension	Verify the correct behaviour of both the shock absorber and the failure of the system	Animation showing the movement of the suspension. Load deflection history of the load transferred to the wheel. Wheel orientation versus time
1.2.1	Suspension load. Each wheel shall be loaded separately.	Verify suspension kinematics and loading unloading capabilities. Uncoupling of shaking / steering movement (for front wheels).	Animation showing the movement of the suspension. Load deflection history of the load transferred to the wheel. Wheel orientation versus time
1.2.2	Suspension load. Frontal suspension and rear suspension wheel shall be loaded separately. Symmetrical load	Verify suspension kinematics and loading unloading capabilities. Suspensions coupling due to stabilizer bar.	Animation showing the movement of the suspension. Load deflection history of the load transferred to the wheel. Wheel orientation versus time
1.2.3	Suspension load. Frontal suspension and rear suspension wheel shall be loaded separately. Non-symmetrical load	Verify suspension kinematics and loading unloading capabilities	Animation showing the movement of the suspension. Load deflection history of the load transferred to the wheel. Wheel orientation versus time
2.1	Vehicle in idle	To verify stability of the vehicle model itself	Acceleration time histories. Kinetic and total energy time histories.
3.1	Linear track.	To verify stability of the vehicle, steering and suspension system.	Acceleration time histories. Kinetic and total energy time histories.
3.2	Circular track.	To verify stability of vehicle, steering and suspension system	Acceleration time histories. Kinetic and total energy time histories.
4.1	Curb testing: Both front wheels	To verify stability of the suspension and steering system	Acceleration time histories. Kinetic and total energy time histories.
4.2	Curb testing: Both rear wheels	To verify stability of the suspension and steering system	Acceleration time histories. Kinetic and total energy time histories.
4.3	Curb testing: Right front wheel	To verify stability of the suspension and steering system	Acceleration time histories. Kinetic and total energy time histories.

Table 1 *(continued)*

N°	Type of simulation	Scope of simulation	Results to be provided
4.4	Curb testing: Left front wheel	To verify stability of the suspension and steering system	Acceleration time histories. Kinetic and total energy time histories.
4.5	Curb testing: Right rear wheel	To verify stability of the suspension and steering system	Acceleration time histories. Kinetic and total energy time histories.
4.6	Curb testing: Left rear wheel	To verify stability of the suspension and steering system	Acceleration time histories. Kinetic and total energy time histories.
5.1	Full scale crash against a rigid wall	To verify the capability of suffering strong deformations	Acceleration time histories. Kinetic and total energy time histories.
5.2	Full scale crash against a deformable barrier.	To verify the capability of representing the interaction with a real barrier.	Comparison with experimental results according to the Validation Roadmap

5.4 Verification of model validation

Model validation should be verified by the Acceptance Body according to the validation Guideline. To preserve the property of models, these simulations could be run using restart files created at time zero. With this technique simulations can be run without having the original models.

The Acceptance Body, using his results, must verify the time histories reported in the validation report.

5.5 Standard Reports and Output Parameters

The validation activity shall be described inside a report. The validation report shall comply with the format given the Reporting Guideline and has to be included in the documentation enclosed with the vehicle model.

For the model validation the comparison between experimental tests and simulation shall be reported according to this Validation Roadmap.

This documentation shall contain also the history of the model and the use in already performed activities. The history shall contain also the modifications applied to the vehicle and the justification for that.