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Passenger cars — Validation of vehicle dynamics simulation — Lateral transient response test methods

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO N132 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

Introduction

The main purpose of this International Standard is to provide a repeatable and discriminatory method for comparing simulation results to measured test data from a physical vehicle for a specific type of test.

The dynamic behaviour of a road vehicle is a very important aspect of active vehicle safety. Any given vehicle, together with its driver and the prevailing environment, constitutes a closed-loop system that is unique. The task of evaluating the dynamic behaviour is therefore very difficult since the significant interactions of these driver–vehicle–environment elements are each complex in themselves. A complete and accurate description of the behaviour of the road vehicle must necessarily involve information obtained from a number of different tests.

Since this test method quantifies only one small part of the complete vehicle handling characteristics, the validation method associated with this test can only be considered significant for a correspondingly small part of the overall dynamic behaviour.

Passenger cars — Validation of vehicle dynamics simulation — Lateral transient response test methods

1 Scope

This International Standard specifies methods for comparing computer simulation results from a vehicle mathematical model to measured test data for an existing vehicle according to ISO 7401. The comparison is made for the purpose of validating the simulation tool for this type of test when applied to variants of the tested vehicle.

It is applicable to passenger cars as defined in ISO 3833.

2 Normative references

The following referenced documents are indispensable for the application of this document. For these undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1176, *Road vehicles — Masses — Vocabulary and codes*

ISO 2416, *Passenger cars — Mass distribution*

ISO 3833, *Road vehicles — Types — Terms and definitions*

ISO 8855, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ISO 15037-1, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*

ISO 19364, *Passenger cars — Vehicle dynamic simulation and validation — Steady-state circular driving behaviour*

ISO 19365, *Passenger cars — Validation of vehicle dynamic simulation — Sine with dwell stability control testing*

ISO 7401, *Road vehicles — Lateral transient response test methods — Open-loop test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1176, ISO 2416, ISO 3833, ISO 8855 and the following apply

3.1
simulation
calculation of motion variables of a vehicle from equations in a mathematical model of the vehicle system

3.2
simulation tool
simulation environment including software, model, input data, and hardware in the case of hardware in the loop simulation

4 Principle

Open-loop test methods specified in ISO 7401 are used to determine the lateral transient response of passenger cars in time and frequency domain as defined in ISO 3833.

In time domain:

— step input,

— sinusoidal input (one period). In frequency domain:

— random input,

— pulse input,

— continuous sinusoidal input.

The test characterizes transient response behaviour of a vehicle. Characteristic values and functions in time and frequency domains are considered necessary for characterizing vehicle transient response.

Important characteristics in time domain are:

— time lags between steering-wheel angle, lateral acceleration and yaw velocity;

— response times of lateral acceleration and yaw velocity;

— lateral acceleration gain (lateral acceleration divided by steering-wheel angle);

— yaw velocity gain (yaw velocity divided by steering-wheel angle); and

— over-shoot values.

Important characteristics in frequency domain are the frequency responses, i.e. amplitudes and phases of:

— lateral acceleration related to steering-wheel angle;

— yaw velocity related to steering-wheel angle.

Within this International Standard, the purpose of the test is to demonstrate that a vehicle simulation tool can predict the vehicle behaviour within specified tolerances. A vehicle simulation tool is used to simulate a specific existing vehicle running through the open-loop tests specified in ISO 7401.

The existing vehicle is physically tested at least three times to allow the test data to be compared with the simulation results.

For time domain, response comparison is made between measured and simulated characteristic values using tolerances of percent errors specified in this International Standard.

For frequency domain, response comparison is made between measured and simulated characteristic functions of amplitudes and phases using tolerances specified in this International Standard. Simulation results are used to define boundaries for frequency response curves, and the data from physical testing are overlaid to see if the measurements fall within the acceptable ranges.

NOTE 1 This International Standard may be used for different purposes. Depending on the purpose of the validation, only parts of the validation requirements may be met.

NOTE 2 Tolerance requirements may differ for applications, thus different tolerance values can be agreed between parties involved depending on the applications.

5 Variables

The following variables shall be measured from physical testing, and applying the measured steering-wheel angle and longitudinal velocity as simulation input, yaw velocity and lateral acceleration are computed.

— Steering-wheel angle, δ_H;

— Yaw velocity $\dot{\Psi}$

— Lateral acceleration, a_Y;

— Longitudinal velocity, v_X.

The following optional variables may be measured from physical testing, and obtained from a simulation tool:

— Roll angle, φ;

— Sideslip angle, β;

— Lateral velocity, v_Y;

— Steering-wheel torque, M_H.

6 Simulation tool requirements

6.1 General

The simulation tool used to predict behaviour of a vehicle of interest shall include a mathematical model capable of calculating variables of interest (see Section 5) for the test procedures being simulated. In this International Standard, the mathematical model is used to simulate an open-loop test series as specified in ISO 7401 and provide calculated values of the characteristic variables and functions of interest.

The simulation tool shall be able to cover the lateral acceleration level of time domain tests where lateral acceleration value starts from the nominal value of 4,0 m/s^2.

NOTE The procedure for obtaining input data from experiments may differ for simulation tools, however, the input data shall not be manipulated for better correlation. Nontheless, adaptation of input data to actual testing conditions such as road friction should be allowed.

6.2 Mass and inertia

The mathematical model should include all masses, such as the chassis, engine, payloads, unsprung masses, etc. The value of the mass, the location of the centre of mass, and moments and products of inertia are essential properties of the vehicle for the tests covered in this International Standard.

Vehicles with significant torsional frame compliance require a more detailed representation that includes frame-twist effects that occur in extreme manoeuvres.

6.3 Tires

The vertical, lateral, and longitudinal forces and aligning and overturning moments where each tire contacts the ground provide the main actions on the vehicle. The fidelity of the prediction of vehicle movement depends on the fidelity of the calculated tire forces and moments. Differences between the tire force and moment measurements used for the model and those used in vehicle testing can be expected due to different wear and aging histories. Although difficult to account for these differences, it is important to acknowledge and understand them.

Large lateral slip angles and camber angles can occur under the conditions covered in this International Standard,. The tire model shall cover the entire range of slip (lateral and longitudinal), inclination angle relative to the ground, and load that occur in the tests being simulated. Note in particular that the tire lateral force reduction at high slip angles is a critical characteristic that shall be comprehended by the tire testing and modelling. The effect of combined tire lateral and longitudinal slip on forces and moments shall also be modelled.

The surface friction coefficient between the tire and ground is an important property for the limit friction conditions that may be encountered in tests.

The simulated tests take place on a flat homogenous surface; detailed tire models that handle uneven surfaces are not needed. If the test surface has inclination for water drainage, this should be included in the simulation

6.4 Suspensions

The properties of the suspensions that determine how the tire is geometrically located, oriented, and loaded against the ground shall be represented properly in order for the tire model to generate the correct tire forces and moments. The suspension properties also determine how active and reactive forces and moments from the tires are transferred to the sprung mass.

The suspension properties should include change of location and orientation of the wheel due to suspension vertical deflection, steering, and compliance due to applied load as would be measured in a physical system in kinematics and compliance (K&C) tests.

The model shall cover the full nonlinear range encountered in the tests for springs, jounce and rebound bumpers, and auxiliary roll moments due to anti-roll bars and other sources of roll stiffness.

Rate-dependent forces such as shock absorbers are significant and shall cover the range of suspension jounce and rebound rate encountered in the tests.

6.5 Steering system

The steering system interacts with the suspensions to determine how the tire is oriented on the ground.

The test requires that either a robot or driver provides steering wheel control. The model should include kinematical and compliance relationships needed to calculate the road wheel angles from the steering-wheel angle.

The model should include the effects of active control systems, if applicable in the test.

NOTE If a robot controller provides the steering, the model does not need to predict the associated steering-wheel torque for this International Standard. However, it should be recognized that inadequate steering robot torque capacity can result in steering inputs that do not match the intended angle. This can be a source of discrepancy between simulation and test results.

6.6 Aerodynamics

The model should include aerodynamic effects that influence tire load and overall vehicle drag for speeds up to 120 km/h.

6.7 Brake system

If the brakes are not engaged during the testing, then the brake system is not needed. However, if an active controller engages that uses the brakes to control the vehicle during the test covered in this International Standard (see 6.9), then the vehicle brake model shall include the actuators and response properties that affect the controlled vehicle response.

6.8 Powertrain

In the open-loop steering manoeuvre covered in this International Standard, the standard speed is 100 km/h, and other test speeds of interest may be used (preferably in 20 km/h steps). The model should include the drag on the driven wheels, as needed to replicate this behaviour. Inertial effects that influence the wheel spin dynamics during any intervention by active control system shall be included.

Other aspects of powertrain behaviour that are important for other kinds of tests (engine power, dynamic responses to throttle, shifting and clutch behaviour) are probably not needed for constant speed of the tests; however, if a chassis control system engages, then any aspects of the powertrain that influence the controller behaviour shall be included in the powertrain model.

6.9 Active control system (ESC system, active roll control, etc.)

Any electronic control system that engages in the physical vehicle for the open-loop test manoeuvre covered in this International Standard shall be included in the simulated version.

Physical controllers and/or mechanical components may be linked to the simulated vehicle by hardware in the loop.

The control system model shall include actuators that are not already part of the vehicle brake model (see 6.7), transfer delays, and control logic.

The transmission behaviour of the signal quality and the time delay should be included in the model.

6.10 Data acquisition

Procedures for extracting signals from the simulation should mimic the procedures used to obtain signals from the physical vehicle for the variables listed in Section 5. E.g., sensor location, orientation, data processing including filtering, etc. in the simulation should match the physical test setup.

6.11 Driver controls

The test methods described in Section 7 require control of steering and speed. The simulation tool shall be capable of applying the driver controls (steering, throttle, gear selection) measured from the selected test method.

7 Physical testing

7.1 General

An existing vehicle of interest shall be tested using test procedures specified in ISO 7401, where five test methods are defined; step input and one period sinusoidal input test for time domain, and random input, pulse input, and continuous sinusoidal input test for frequency domain. These test methods are optional, but at least one of each domain type shall be performed.

NOTE This International Standard does not define all of the details of the testing procedure. This section does describe the parts of the test procedure that are typically simulated.

7.2 Measuring equipment

Specification for measuring equipments, installation and data processing shall be in accordance with ISO 7401 Section 8.

7.3 Test conditions

General test conditions shall be in accordance with ISO 7401 Section 9.

Tests shall be carried out with the design loading condition where the total vehicle mass shall consist of the complete vehicle kerb mass (Code: ISO-M06) in accordance with ISO 1176:1990, 4.6, plus the masses of the driver and the instrumentation. The mass of the driver and the instrumentation shall not exceed 150 kg. The load distribution shall be equivalent to that of two occupants in the front seats, in accordance with ISO 2416. (See Section 9.2.2 in ISO 7401).

NOTE ISO 7401 requires testing with both the design and maximum loading conditions. However, since minimum loading condition represents more realistic driving situation, validation is performed with the design loading condition.