INTERNATIONAL STANDARD

ISO 19364

First edition
2016-10-01

Passenger cars — Vehicle dynamic simulation and validation — Steady-state circular driving behaviour

Voitures particulières — Simulation et validation dynamique des véhicules — Tenue de route en régime permanent sur trajectoire circulaire

Reference number
ISO 19364:2016(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics and chassis components*.

Introduction

The main purpose of this document 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 should include 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 — Vehicle dynamic simulation and validation — Steady-state circular driving behaviour

1 Scope

This document specifies a method for comparing computer simulation results from a vehicle mathematical model to measured test data for an existing vehicle according to steady-state circular driving tests as specified in ISO 4138 or the Slowly Increasing Steer Test that is an alternative to ISO 4138. 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.

NOTE The Slowly Increasing Steer method is described in regulations such as USA FMVSS 126 "Federal Register Vol 72, No. 66, April 6, 2007" and UN/ECE Regulation No. 13-H, "Uniform provisions concerning the approval of passenger cars with regard to braking".

2 Normative references

The following documents are referred to in 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.

ISO 4138, *Passenger cars — Steady-state circular driving behaviour — Open-loop test methods*

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

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.

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 http://www.iso.org/obp

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, models, input data, and hardware case of hardware-in-the-loop simulation

3.3
cross plot
plot where the horizontal axis shows values for a variable other than time (e.g. lateral acceleration)

4 Principle

Open-loop test methods defined in ISO 4138 are used to determine the steady-state circular driving behaviour of passenger cars as defined in ISO 3833.

The test characterizes vehicle-handling behaviour in steady-state conditions covering a range of cornering conditions from straight-line up to limit conditions for steering control. Results are typically reported by cross plotting steady-state measures of variables of interest against steady-state levels of lateral acceleration, and possibly calculating characteristic values based on gradients of the plotted data.

Within this document, the purpose of the test is to demonstrate that a vehicle simulation tool can predict the vehicle behaviour within specified tolerances. The vehicle simulation tool is used to simulate a specific existing vehicle running through a steady-state test as specified in ISO 4138, or, alternatively, a Slowly Increasing Steer Test used in stability control evaluation. Simulation results are used to define graphical boundaries for overlaid cross-plots, and the data from physical testing are overlaid to see if the measurements fall within the acceptable ranges.

NOTE This document may be used for several purposes. Depending on the purpose of the validation, only parts of the validation requirements may be met.

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

5 Variables

The following variables shall be compared:

— lateral acceleration;

— steering-wheel angle;

— sideslip angle;

— roll angle.

The steering-wheel torque shall also be compared if this document is used to validate a simulation tool for the purpose of predicting steering torque during steady-state circular driving as defined in ISO 4138.

Measurement requirements shall be taken from ISO 4138 and ISO 15037-1, unless noted otherwise.

For the purpose of this document, lateral acceleration should be measured directly by an inertial measurement unit, rather than using the alternative calculation methods provided in ISO 4138.

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 for the test procedures being simulated. In this document, the mathematical model is used to simulate a steady-state cornering manoeuvres (see 7.2) and provide calculated values of the variables of interest from Clause 5.

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

NOTE Active controllers and active intervention systems that prevent a steady-state condition from being established are not relevant for the tests covered in this document.

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 and the location of the centre of mass are essential properties of the vehicle for the tests covered in this document. On the other hand, moments and products of inertia have no effect under steady-state conditions, when angular accelerations are negligible.

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 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 of 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 inclination can occur under the conditions covered in this document. Longitudinal slip ratios are usually limited to the amounts needed to generate longitudinal forces to maintain a target speed in the test. The tire model shall cover the entire ranges of slip (lateral and longitudinal), inclination angle relative to the ground, and load that occur in the tests being simulated.

The surface friction coefficient between the tire and ground is an important property for the limit friction conditions that can be encountered in steady-state circular driving 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.

The simulated tests involve conditions that are intended to be steady-state; therefore, transient effects in tire response (e.g. relaxation length) are not needed.

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 the model 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 deflection and 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 steady-state steering 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 not significant in steady-state testing.

The model shall include the effects of active intervention systems, if applicable during the steady-state conditions covered in this document.

6.5 Steering system

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

The model shall include kinematical and compliance relationships between the steering-wheel angle and road wheel angle.

The model shall include the effects of active intervention systems, if applicable during the steady-state conditions covered in this document.

6.6 Aerodynamics

The model should include aerodynamic effects that influence tire load and overall vehicle drag for the speeds covered in the testing.

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 steady-state conditions covered in this document (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 steady-state steering manoeuvre covered in this document, the powertrain is applied as needed to achieve the vehicle target lateral acceleration. The transfer of drive torque to the wheels should be included in the model, with the proper drivetrain configuration (front-wheel drive, rear-wheel drive, all-wheel drive, electric motors, differentials, etc.).

Aspects of powertrain behaviour that are important for other kinds of tests (engine power, dynamic responses to throttle, shifting and clutch behaviour) might not be needed for the steady-state steering manoeuvres; 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 controllers

If any electronic controller is engaged in the physical vehicle for the steady-state steering manoeuvres covered in this document, its model 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 controller model should include actuators that are not already part of the vehicle brake model (see 6.7) and control logic.

6.10 Data acquisition

Signals extracted from the simulation should mimic the signals extracted from the physical vehicle. For example, sensor location, orientation, data processing (filtering, etc.; see 7.4) in the simulation should match the physical test setup.

6.11 Driver controls

The test methods described in 7.2 require control of steering and speed. The simulation tool shall be capable of providing the driver controls (steering, throttle, gear selection) required for the selected test method.

7 Physical testing

7.1 General

An existing vehicle of interest shall be tested using a constant-radius test or constant-speed test as defined in ISO 4138, or alternatively, the Slowly Increasing Steer Test variant of the constant-speed test used in stability control evaluation (e.g. UN/ECE Regulation No. 13-H, "Uniform provisions concerning the approval of passenger cars with regard to braking.”). Unless noted otherwise in this document, the tests should be conducted and results should be reported as specified in ISO 4138 and ISO 15037-1.

7.2 Test methods

7.2.1 Constant-radius

The constant-radius method requires driving the vehicle at several speeds over a circular path of known radius. The standard radius of the path specified in ISO 4138 is 100 m, but larger and smaller radii may be used, with 40 m the smallest recommended radius and 30 m the minimum permitted radius.

Results depend on the turn radius; therefore, the radius used shall be reported along with the plots.

ISO 4138 defines two variations of this method, one with a set of tests each done with a constant speed and the other with a single test in which speed is slowly increased. The variation used in physical testing shall also be used in the simulation and shall be reported along with the method.

7.2.2 Constant speed

7.2.2.1 General

The constant-speed method requires driving the vehicle at a constant speed over a range of lateral acceleration generated with changes in steering. The plotted curves can vary with speed; therefore, the speed shall be reported along with the plots.

7.2.2.2 Multiple tests with discrete steer or radius

ISO 4138 defines two variations of this method: one involving discrete changes in steering-wheel angle, and the second involving discrete changes in path radius (marked with painted circles on the surface of the test space). The variation used in physical testing shall also be used in the simulation, and shall be reported along with the method.

7.2.2.3 Slowly Increasing Steer Test

In a third variation, an open-loop test is performed at a constant speed with steering control provided by a robot. In this test, the steering pattern increases the steering-wheel angle at a constant rate to run through the desired range of lateral acceleration, or until limits of test space, or vehicle stability are reached.

The rate of steering-wheel increase shall be 13,5°/s or less.

The same rate of steering-wheel increase shall be used for all physical tests and simulations, and shall be reported along with the plots.

7.3 Documentation of limit condition

The steady-state circular turning procedures described in ISO 4138 involve testing until steady-state conditions can no longer be achieved. Depending on the method and variation used, limits might be reached due to the capability of the driver, lack of space, intervention of active systems that cause dynamic motions that prevent steady conditions from occurring, or other reasons.

In each test series, the factor causing the limit condition shall be reported.

7.4 Low-pass filtering of measured data

The vehicle behaviour of interest in this document involves steady conditions or slowly changing conditions. The low-pass filtering of the variables measured in these test may use a cut-off frequency