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

*Voitures particulières - Simulation et validation dynamique des
véhicules - Essais de contrôle de la stabilité en sinus avec palier*

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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*.

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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 involves 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.

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Passenger cars — Validation of vehicle dynamic simulation — Sine with dwell stability control testing

1 Scope

This document specifies a method for comparing computer simulation results from a vehicle mathematical model to test data measured for an existing vehicle undergoing sine with dwell tests that are typically used to evaluate the performance of an electronic stability control (ESC) system. 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 sine with dwell test method described in this document is based on the test method specified in regulations USA FMVSS 126 and UN/ECE Regulation No. 13-H.

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.

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

ISO 19365:2016

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3 Terms and definitions [3274706d02a2/iso-19365-2016](https://standards.iteh.ai/catalog/standards/sist/4f8edefd-fc09-4922-a8de-3274706d02a2/iso-19365-2016)

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 (3.1) environment including software, model, input data, and hardware in the case of hardware-in-the-loop simulation

3.3 electronic stability control system

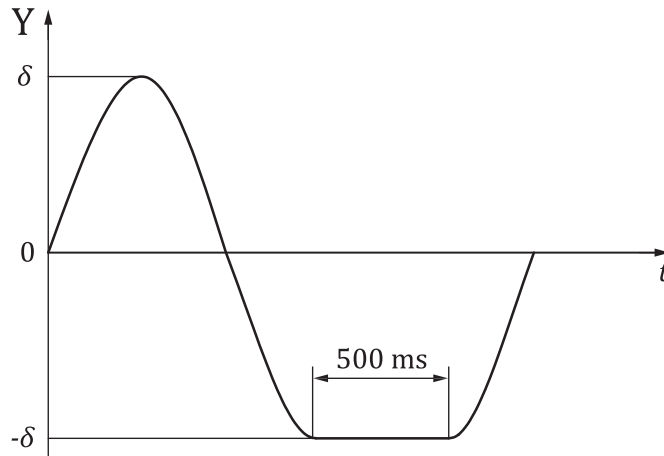
ESC system

control system that intervenes to maintain directional stability of vehicle and responsiveness on steering input

3.4
sine with dwell test

test in which the vehicle is steered by a robot using a steering pattern of a sine wave at a frequency of 0,7 Hz with a delay of 500 ms beginning at the second peak amplitude

Note 1 to entry: See [Figure 1](#).



Key

Y steering-wheel angle

t time

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Figure 1 — Steering-wheel input for a sine with dwell test

3.5
sine with dwell test series <https://standards.iteh.ai/catalog/standards/sist/4f8edef1-fc09-4922-a8de-21740640236f-iso-19365-2016>

series of *sine with dwell tests* ([3.4](#)) in which the amplitude of the steering pattern is increased with each test

3.6
beginning of steer
BOS

time at which the steering begins for a *sine with dwell test* ([3.4](#))

3.7
completion of steer
COS

time at which the steering is completed for a *sine with dwell test* ([3.4](#))

3.8
ESC system performance standard

published standard, typically issued by a regulatory organization, that defines *ESC system* ([3.3](#)) performance requirements using a *sine with dwell test* ([3.4](#)) series

Note 1 to entry: For example, UN/ECE Regulation No. 13-H or USA FMVSS 126.

4 Principle

A sine with dwell test sequence is used to evaluate the behaviour of a vehicle with ESC. In this sequence, the vehicle is subjected to two series of tests that are run using a steering pattern of sine with dwell as shown in [Figure 1](#). One series uses counterclockwise steering for the first half cycle, and the other series uses clockwise steering for the first half cycle.

Within this document, the purpose of the test is to demonstrate that a simulation tool can predict vehicle behaviour in the sine with dwell test sequence as described in a specific ESC system performance standard.

A comparison is made between measured and simulated behaviour using samples taken at a few specified points during each run, using tolerances specified in this document.

A simulation tool being evaluated for use with the sine with dwell test should first be validated for steady-state circular driving behaviour as specified in ISO 19364. A simulation tool that cannot reproduce steady-turning behaviour should not be considered for use in simulating the sine with dwell response.

5 Variables

The following variables shall be measured from the physical testing and obtained from the simulation tool:

- steering-wheel angle;
- yaw rate;
- lateral acceleration.

6 Simulation tool requirements

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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 [Clause 5](#)) for the test procedures being simulated. In this document, the mathematical model is used to simulate a sine with dwell test series as specified in the ESC system performance standard of interest.

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.

6.2 Mass and inertia

The mathematical model should include all masses, such as the chassis, engine, payloads, unsprung masses, outriggers, 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 document.

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 document. Large longitudinal slip ratios might be generated as a result of intervention of the ESC. 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 are typically encountered in a sine with dwell test series.

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 and C) tests.

The model shall cover the full nonlinear range encountered in the sine with dwell 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 should cover the range of suspension jounce and rebound rate encountered in the sine with dwell tests.

6.5 Steering system

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

The sine with dwell test requires that a robot provide 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 sine with dwell tests.

NOTE Because a robot controller provides the steering, the model does not need to predict the associated steering-wheel torque for this document. However, it should be recognized that inadequate steering robot torque capacity can result in steering displacement inputs that do not match the intended displacements. 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 80 km/h.

6.7 Brake system

The vehicle brake model shall include the actuators and dynamic response properties that affect the interventions generated by the ESC. Accurate prediction of the dynamic interaction of the brake torque and the controls from the ESC, including the sequence of brake torque application, are critical for successful simulation of sine with dwell testing.

6.8 Powertrain

In the sine with dwell manoeuvre covered in this document, the vehicle is coasting in the highest gear from an initial speed of 80 km/h. 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 ESC intervention 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 the coast-down condition of this manoeuvre; 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 sine with dwell manoeuvre covered in this document shall be included in the simulated version. In particular, the representation of the ESC system is critical to the validity of the simulation.

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 Clause 5. For example, sensor location, orientation, data processing including filtering, etc. in the simulation should match the physical test setup.

6.11 Driver controls

The simulation tool shall be capable of providing steering control for the sine with dwell test.

7 Physical testing

7.1 General

An existing vehicle of interest shall be tested using the sine with dwell test sequence as defined in the applicable ESC system performance standard. The applicable ESC system performance standard shall be identified in the report.

NOTE This document does not define all of the details of the testing procedure; these details are obtained from the applicable ESC system performance standard. This subclause does describe the parts of the test procedure that are typically simulated.

7.2 Conditioning the vehicle

The vehicle is prepared as described in the applicable ESC system performance standard. This involves loading as needed with fuel and ballast, setting tire pressures, possibly installing outriggers to prevent rollover, and other steps covered in published test descriptions. Once equipped, the vehicle is typically exercised to condition the tires and brakes.

7.3 Slowly increasing steer tests

7.3.1 Slowly increasing steer procedure

The vehicle is subjected to two series of runs of the slowly increasing steer test using a constant vehicle speed of (80 ± 2) km/h and a steering pattern that increases by $13,5^\circ/\text{s}$ until a lateral acceleration of