INTERNATIONAL STANDARD

ISO 4138

Fourth edition
2012-06-01

Passenger cars — Steady-state circular driving behaviour — Open-loop test methods

Voitures particulières — Tenue de route en régime permanent sur trajectoire circulaire — Méthodes d'essai en boucle ouverte

Reference number
ISO 4138:2012(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

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.

ISO 4138 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

This fourth edition cancels and replaces the third edition (ISO 4138:2004), which has been technically revised.

Introduction

The main purpose of this International Standard is to provide repeatable and discriminatory test results.

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 results of these tests can only be considered significant for a correspondingly small part of the overall dynamic behaviour.

Moreover, insufficient knowledge is available concerning the relationship between overall vehicle dynamic properties and accident avoidance. A substantial amount of work is necessary to acquire sufficient and reliable data on the correlation between accident avoidance and vehicle dynamic properties in general and the results of these tests in particular. Consequently, any application of this test method for regulation purposes will require proven correlation between test results and accident statistics.

Passenger cars — Steady-state circular driving behaviour — Open-loop test methods

1 Scope

This International Standard specifies open-loop test methods for determining the steady-state circular driving behaviour of passenger cars as defined in ISO 3833 and of light trucks, such behaviour being one of the factors comprising vehicle dynamics and road-holding properties. The open-loop manoeuvres included in these methods are not representative of real driving conditions, but are nevertheless useful for obtaining measures of vehicle steady-state behaviour resulting from several specific types of control inputs under closely controlled test conditions.

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.

ISO 3833:1977, *Road vehicles — Types — Terms and definitions*

ISO 8855:2011, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ISO 15037-1:2006, *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 8855 and the following apply.

3.1
low-speed path radius
radius of the circular path transcribed by the origin of the vehicle axis system when the vehicle is operated at constant speed with a given fixed steering-wheel angle and with approximately zero lateral acceleration

4 Principle

4.1 Test methods

Three test methods are specified:

— Method 1, the constant-radius test method;

— Method 2, the constant steering-wheel angle test method;

— Method 3, the constant-speed test method.

Each method is presented with two variations and differs in requirements for testing space, driver skill and instrumentation. Methods 1 and 3 depend upon the path-keeping ability of the driver to minimize instrumentation requirements. Method 2 uses fixed steering-wheel angle and calculates path radius from measures of inertial instruments.

4.2 Equivalence of test methods

The nature of any stable steady-state is independent of the method by which it is achieved. Therefore, to obtain a desired set of steady-state equilibrium conditions of speed, steering-wheel angle and turning radius, it is possible to hold any one of them constant, vary the second and measure the third. Thus, either a *constant-radius* test method (in which speed is varied and steering-wheel angle is measured), a *constant steering-wheel angle* test method (in which speed is varied and radius is calculated from variables of vehicle motion) or a *constant-speed* test method (in which radius is varied and steering-wheel angle is either measured or varied and the radius calculated from variables of vehicle motion) may be used. The conditions that are to be held constant, varied and measured or calculated are summarized in Table 1.

Table 1 — Test conditions

Test method	Constant	Varied	Measured or calculated
Constant radius	Radius	Speed	Steering-wheel angle
Constant steering-wheel angle	Steering-wheel angle	Speed	Radius
Constant speed with discrete turn radii	Speed	Radius	Steering-wheel angle
Constant speed with discrete steering-wheel angles	Speed	Steering-wheel angle	Radius

All three test methods will produce equivalent steady-state results, provided they span the same combination of speed–steer–radius steady-state conditions. Moreover, in principle, an equivalent to any of the methods can be obtained by cross plotting a series of results from one to produce the results from another.

EXAMPLE Taking points at constant speed from a series of constant-radius tests run on different turn radii.

In practice, however, results obtained from tests conducted with different combinations of speed, steer and radius may differ due to differences in road-load throttle, aerodynamics, tyre slip and inclination angles at different steering angles, etc. Also, the steering system is nonlinear in many vehicles and does not have a fixed overall steering ratio. Gradients obtained using one method at a given steady-state equilibrium condition can differ from those obtained using another and, whereas in one method lateral acceleration is controlled by changing speed, in another it is controlled by changing the steering-wheel angle. Practical considerations such as tyre heating during long test runs and failure to maintain true steady-state also tend to affect test results.

5 Variables

5.1 Reference system

The provisions given in ISO 15037-1 apply.

5.2 Measurement

Measure the following variables:

a) longitudinal velocity, v_X.

b) lateral acceleration, a_Y;

c) steering-wheel angle, δ_H.

Alternatively, lateral acceleration may be determined from other motion variables (see 9.2).

NOTE The method chosen to determine lateral acceleration could require the measurement of additional variables (yaw velocity, vehicle roll angle or sideslip angle) for use in the computation.

The following variables should also be measured:

— yaw velocity, $\mathrm{d}\psi/\mathrm{d}t$;

— sideslip angle, β, and/or lateral velocity, v_{Y};

— longitudinal acceleration, a_{X};

— vehicle roll angle, φ_{V};

— steering-wheel torque, M_{H}.

The front steer angle, δ_{F}, and rear steer angle, δ_{R}, may also be measured.

6 Measuring equipment

6.1 Description

The variables selected for test purposes shall be measured using appropriate transducers and the data recorded on a multi-channel recording system having a time base. Typical operating ranges and recommended maximum errors of the transducer and recording system are given in ISO 15037-1 and Table 2.

6.2 Transducer installation

The transducer installation shall be in accordance with ISO 15037-1:2006, 4.2.

6.3 Data processing

The provisions given in ISO 15037-1:2006, 4.3, apply.

Table 2 — Variables, their typical operating ranges and recommended maximum errors

Variable	Typical operating range	Recommended maximum error of the combined transducer/recorder system
Front-steer angle	±20°	±0,2°
Rear-steer angle	±10°	±0,1°
NOTE Increased measurement accuracy could be desirable for computation of some of the characteristic values given in 10.3.		

7 Test conditions

Test conditions shall be in accordance with ISO 15037-1:2006, Clause 5. General data on the test vehicle shall be recorded as specified in ISO 15037-1:2006, 5.4.1. In addition, the tyre type, tyre brand, any special equipment on the test vehicle, any deviation in type or operating condition of components from the manufacturer's specification, the odometer reading at the beginning and end of the test, and any other condition that could affect test results shall be recorded on the test report for general data (see ISO 15037-1:2006, Annex A).

8 Test procedure

8.1 Warm-up

The warm-up shall be carried out in accordance with ISO 15037-1:2006, 6.1.

8.2 Initial driving condition

The conditions shall be in accordance with 15037-1:2006, 6.2.1 and 6.2.3, and with 8.3 to 8.6 as follows, according to which method and variation is used.

8.3 General test description

All necessary variables shall be recorded throughout the manoeuvre. Data shall be taken for both left and right turns.

For tests utilizing discrete increments of speed, radius or steering-wheel angle, all of the test data may be taken in one turning direction followed by all the data in the other turning direction, as experience has shown that this minimizes data scatter. However, to obtain more even tyre wear and reduced tyre heating, data may be taken in alternating turning directions at each test speed/radius/steering-wheel angle.

The method chosen shall be noted on the test report, in the section on test-method-specific data for test conditions (see ISO 15037-1:2006, Annex B). At a minimum, data shall be taken at increments of lateral acceleration no larger than 0,5 m/s^2.

NOTE Where data vary rapidly with changes in lateral acceleration, it can be useful to decrease the speed/radius/steering-wheel angle increments.

The test should be repeated several times so that the results can be examined for repeatability and averaged.

Caution should be exercised during testing so that tyre heating is minimized as much as possible. Tyre heating is a particular concern for test methods using continuous speed increase, with attendant long periods of data acquisition, and for all test methods at high levels of lateral acceleration. The tyres should be cooled to normal operating temperatures between test runs.

8.4 Method 1 — Constant radius

8.4.1 Description

This test method requires driving the test vehicle at several speeds over a circular path of known radius. The standard radius of the path shall be 100 m, but larger and smaller radii may be used, with 40 m as the recommended lower value and 30 m as the minimum.

The directional-control response characteristics are determined from data obtained while driving the vehicle at successively higher speeds on the constant-radius path. This procedure can be conducted in a relatively small area. The procedure can be adapted to existing test track facilities by selecting a circle or path of appropriate radius. A constant-radius (in plane) road will often suffice for a test facility.

The constant-radius test exists in two variations. In the first, the vehicle is driven on the circular path at discrete constant speeds. Data are taken when steady-state is attained. The test can be run on any level constant-radius path of sufficient length to attain and hold on-radius steady-state for at least a 3 s measurement period. In the second, the vehicle remains on the circle with a continuous, slow speed increase, during which data are taken.

8.4.2 Procedure

8.4.2.1 General

First drive the vehicle on the desired circular path at the lowest possible speed. Record data with the steering-wheel and throttle positions fixed, so that the approximate Ackermann steer angle can be recorded.

Then drive the vehicle at the next speed at which data are to be taken.

Increase the level of the lateral acceleration and take data until it is no longer possible to maintain steady-state conditions.

8.4.2.2 With discrete test speeds

Drive the vehicle onto the circle at each test speed. After attaining steady-state, in which the desired path radius is held within ± 0,5 m, the steering wheel and throttle positions shall be held constant for at least 3 s.

8.4.2.3 With continuous speed increase

Steadily increase the speed and record data continuously for as long as the vehicle remains on the desired circular path within ± 0,5 m. The maximum rate of increase of lateral acceleration should be 0,1 m/s^2/s. The maximum permissible rate of increase of lateral acceleration shall be 0,2 m/s^2/s.

8.5 Method 2 — Constant steering-wheel angle

8.5.1 Description

This test method requires driving the test vehicle at several speeds with a single selected steering-wheel angle that is held fixed. The path radius is determined by computation: from horizontal velocity and yaw velocity, or from horizontal velocity and lateral acceleration. The test exists in two variations: a series of discrete test runs, or a single continuous test run. In the first, the steering-wheel angle is applied with the vehicle travelling at discrete speeds, and is maintained until steady-state conditions are reached. In the second, the steering-wheel angle is held fixed while speed is increased continuously at a slow rate, up to the limit of control.

The standard steering-wheel angle shall provide a low-speed path radius of 30 m. Other radii may be used, with 20 m as the minimum. For testing to the limit of control with the standard initial condition, the path radius can increase to 100 m or more.

8.5.2 Procedure

8.5.2.1 General

First drive the vehicle at the lowest possible speed to establish the steering-wheel angle for the selected low-speed path radius.

Then drive the vehicle at successively higher speeds, with the steering-wheel angle held constant or mechanically fixed within ± 1° of the selected steering-wheel angle. Run the test through the desired range of lateral acceleration, or until the limits of test space, vehicle speed or vehicle stability are reached.

8.5.2.2 With discrete test speeds

At each selected speed, the steering wheel shall be turned to the pre-selected steering-wheel angle and maintained until steady-state conditions, including speed and throttle, are attained. The steering-wheel angle and throttle position shall be held constant for at least 3 s.

NOTE Except that in this this procedure the steering-wheel angle is maintained and the speed varied, it and the procedure given in 8.5.2.3 are the same.

8.5.2.3 With continuous speed increase

The steering-wheel angle shall be held constant or mechanically fixed at the pre-selected steering-wheel angle while the vehicle speed is steadily increased. The maximum rate of increase of lateral acceleration is 0,1 m/s^2/s. The maximum permissible rate of increase of lateral acceleration shall be 0,2 m/s^2/s.

8.6 Method 3 — Constant speed

8.6.1 Description

This test method requires driving the test vehicle at one speed on circular paths of different radii, utilizing a range of steering-wheel angles. The directional-control response characteristics are determined from data plotted against lateral acceleration. This test method could require large test areas, depending on the combination of speed and lateral acceleration. The discrete turn radii method requires a number of marked circles or circular segments with different radii, sufficient in number to provide 0,5 m/s^2 lateral acceleration increments at the selected speed. An adjustable steering stop should be used, for maintaining constant steering-wheel angles when using the discrete steering-wheel angle method.