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Road vehicles — Test method for the quantification of on-centre handling —

Part 1: Weave test

Véhicules routiers — Méthode d'essai pour la quantification du centrage —

Partie 1: Essai en petite sinusoïde au volant

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Foreword

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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 document 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).

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics, chassis components and driving automation systems testing*.

This third edition cancels and replaces the second edition (ISO 13674:2010), which has been technically revised.

The main changes are as follows:

— references have been updated to ISO 15037-1:2019 and deleted reference to ISO/TS 20119:2002;

— corrected the key for the abscissa and ordinate dead band in Figure 1;

— removed calculated lateral acceleration to calculate lateral acceleration metrics;

— corrected incomplete steering hysteresis calculation.

A list of all parts in the ISO 13674 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The main purpose of this document 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 interaction of these driver-vehicle-environment elements are each complex in themselves. A complete and accurate description of the behaviour of the road vehicle necessarily 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 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, for any application of this test method for regulation purposes, proven correlation between test results and accident statistics is important.

Road vehicles — Test method for the quantification of on-centre handling —

Part 1:
Weave test

1 Scope

This document specifies a test schedule that addresses a particular aspect of the on-centre handling characteristics of a vehicle: the weave test. It is applicable to passenger cars in accordance with ISO 3833, and to light trucks.

NOTE The manoeuvre specified in this test method is not representative of real driving conditions but is useful for obtaining measures of vehicle on-centre handling behaviour in response to a specific type of steering input under closely controlled test conditions. Other aspects of on-centre handling are addressed in the companion ISO 13674-2.

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 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 15037-1:2019, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*

3 Terms, definitions, and symbols

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 terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
on-centre handling
description of the steering “feel” and precision of a vehicle during nominally straight-line driving and in negotiating large radius bends at high speeds but low lateral accelerations

3.2
ordinate deadband
vertical width of the hysteresis loops at abscissa zero

3.3
abscissa deadband
horizontal width of the hysteresis loops at ordinate zero

3.4
gradient
ratio of change in the ordinate with respect to a unit change in the abscissa, evaluated on each side of the hysteresis loop

4 Principle

On-centre handling represents that part of the straight-line directional stability characteristics of the vehicle existing at lateral acceleration levels, typically no greater than 1 m/s^2. On-centre handling is concerned primarily with features that directly influence the driver's steering input, such as steering system and tyre characteristics. Thus, test schedules for the evaluation of on-centre handling behaviour seek to minimize other factors that influence the wider aspects of straight-line directional stability, such as disturbance inputs due to ambient winds and road irregularities.

This document defines a test schedule that involves driving the vehicle in a nominally straight line at a constant forward speed. During the test, driver inputs and vehicle responses are measured and recorded. From the recorded signals, characteristic values are calculated.

5 Variables

5.1 Reference system

The variables of motion used to describe vehicle behaviour in a test-specific driving situation relate to the intermediate axis system (X, Y, Z) (see ISO 8855).

The location of the origin of the vehicle axis system (X_V, Y_V, Z_V) is the reference point and therefore should be independent of the loading condition. The origin is therefore fixed in the longitudinal plane of symmetry at half-wheelbase and at the same height above the ground as the centre of gravity of the vehicle at complete vehicle kerb mass (see ISO 1176).

5.2 Variables to be measured

When using this test method, the following variables shall be measured:

— steering-wheel angle, δ_H;

— steering-wheel torque, M_H;

— yaw velocity, $\frac{d\psi}{dt}$;

— longitudinal velocity, v_X.

The following variables should be measured:

— lateral acceleration, a_Y;

— steering-wheel angular velocity, $\frac{d\delta_H}{dt}$.

See ISO 8855.

6 Measuring equipment

6.1 Description

All variables shall be measured by means of appropriate transducers and their time histories shall be recorded by a multi-channel recording system. Typical operating ranges and recommended maximum errors of the combined transducer and recording system are shown in Table 1.

Table 1 — Variables, typical operating ranges and recommended maximum errors

Variable	Typical operating range[a]	Recommended maximum error of combined system[b]
Steering-wheel angle	±50°	±0,1°
Steering-wheel torque	±0,1 N · m	±0,1 N · m
Yaw velocity	±10 °/s	±0,1 °/s
Longitudinal velocity	0 m/s to 50 m/s	±0,5 m/s
Lateral acceleration	±5 m/s^2	±0,1 m/s^2
Steering-wheel angular velocity	±100 °/s	±1 °/s
Transducers for measuring some of the listed variables are not widely available and are not in general use. Many such instruments are developed by users. If any system error exceeds the recommended maximum value, this and the actual maximum error shall be stated in the test report (see ISO 15037-1:2019, Annex A).		
[a] These transducer ranges are appropriate for the standard test conditions and might not be suitable for non-standard test conditions.		
[b] The values for maximum errors are provisional until more experience and data are available.		

6.2 Transducer installations

The transducers shall be installed according to the manufacturers' instructions, where such instructions exist, so that the variables corresponding to the terms and definitions of ISO 8855 can be determined.

If a transducer does not measure a variable directly, appropriate transformations into the specified reference system shall be carried out.

NOTE Lateral acceleration, as defined, is measured in the intermediate *XY*-plane. However, for the purpose of this test procedure, measurement of “sideways” acceleration in the vehicle $X_V Y_V$-plane (i.e. corrupted by vehicle roll) is typically adequate, provided that the roll angle versus lateral acceleration characteristic for the vehicle is known and an appropriate correction in respect of roll angle can be made to the “sideways” acceleration.

6.3 Data processing

See ISO 15037-1:2019, 5.3.

7 Test conditions

7.1 General

See ISO 15037-1:2019, Clause 6.

7.2 Test track

The test track requirements shall be in accordance with those of ISO 15037-1:2019, 6.2. In addition, the gradient of the test surface should not exceed 1 %, and the test track shall follow a straight-line path.

7.3 Wind velocity

During a test, the ambient wind velocity shall not exceed 5 m/s when measured at a height above ground of not less than 1 m. Ideally, the maximum ambient wind velocity should not exceed 1,5 m/s. If this cannot be achieved, then conditions of significant "gusting" should be avoided, i.e. testing should be avoided in conditions where changes in wind velocity exceed a range of 1,5 m/s. If the ambient velocity exceeds 1,5 m/s or the range of "gusting" exceeds 1,5 m/s, or both, the vehicle should be tested in a direction such that the ambient wind is a tail wind. For each test, the climatic conditions shall be recorded in the test report (see ISO 15037-1:2019, Annex B).

Where measurement of wind velocity is not possible, estimation using the Beaufort scale is suggested (see Table 2).

Table 2 — Estimation scale for wind intensity for observer without measuring instrument (Beaufort scale)

Wind intensity (Beaufort scale)	**0**	**1**	**2**	**3**	**4**
Name	Calm	Light air	Light breeze	Gentle breeze	Moderate breeze
Velocity m/s	0 to 0,2	0,3 to 1,5	1,6 to 3,3	3,4 to 5,4	5,5 to 7,9
Identification sign	Smoke rises vertically in a straight line	Wind direction indicated only by smoke	Leaves rustle, wind felt in face	Leaves and thin twigs move	Moves twigs and thin branches, dust rises

7.4 Test vehicle

7.4.1 General data

See ISO 15037-1:2019, 6.4.1.

7.4.2 Tyres

For general information regarding tyres used for test purposes, see ISO 15037-1:2019, 6.4.2. In addition, the following recommendations are offered for guidance.

Since tyre characteristics can have a profound effect upon the vehicle behaviour being measured in this procedure, tyres with known characteristics should be used wherever possible. Failing this, original equipment rather than replacement market tyres should be used.

For similar reasons, caution should be exercised if worn tyres are to be used. For example, it is known that some tyre characteristics affecting vehicle on-centre handling change significantly during the early wear life (up to several thousand kilometres) of the tyre but continue to change throughout the life of the tyre. In any event, tyres without a known history should be avoided.

All wheel/tyre assemblies should be balanced before use. Assemblies exhibiting large run-out or imbalance (detectable as vibration at road wheel rotational frequency) should be avoided.

7.4.3 Operating components

See ISO 15037-1:2019, 6.4.3.

7.4.4 Loading conditions of vehicle

See ISO 15037-1:2019, 6.4.4.

8 Procedure

8.1 Warm-up

See ISO 15037-1:2019, 7.1.

8.2 Initial driving condition

This test schedule does not mandate any specific initial driving condition. However, the user may find a steady-state, straight-ahead run useful for establishing the vehicle at the required longitudinal test velocity and obtaining transducer reference values. In this event, the procedure in accordance with ISO 15037-1:2019, 7.2.2 and Figure 2, should be used. The user could find it useful to end the steer input by re-establishing the steady-state, straight-ahead condition at the end of the test run.

See ISO 15037-1:2019, 7.2, for guidance on selection of the appropriate transmission gear for performing the test.

8.3 Weave test procedure

The weave test is an open-loop procedure conducted on a test track that follows a straight-line path. The vehicle is driven at a nominally constant longitudinal velocity.

The standard test velocity is 100 km/h.

Other longitudinal velocities may be used: they should be decremented or incremented by 20 km/h from the standard velocity. Details shall be recorded in the test report (see ISO 15037-1:2019, Annex B, under "Test method specific data").

The transducer signals shall be recorded throughout the initial driving condition, if applicable, and for the duration of the test. In order to ensure that the required data are not affected by the instrumentation system, recording should be continued for a further 1 s after the test runs.

The weave test procedure requires the steering-wheel to be subjected to an oscillatory input. The preferred steering input waveform is nominally sinusoidal, but other steering input waveforms (e.g. triangular) may be used. The frequency of the steering input shall be 0,2 Hz ± 10 %.

The amplitude of the steering input shall be sufficient to produce the required peak value of vehicle lateral acceleration ±10 %. To ensure that good and adequate test data are available for analysis at lateral acceleration levels of 1 m/s^2 and that the vehicle and its subsystems are working outside of hysteresis effects, the standard peak value is 2 m/s^2, but lower values and values up to 4 m/s^2 may also be used.

Details of the steering input waveform and the lateral acceleration amplitude shall be recorded in the test report (see ISO 15037-1:2019, Annex B, under “Test method specific data”).

Throughout the test, both the peak amplitude of the steering angle and the angular velocity of the steering-wheel through the centre position shall be as near constant as possible. In addition, variation in the position of the accelerator pedal shall be kept to a minimum, consistent with maintaining vehicle longitudinal velocity within required limits. The longitudinal velocity during the test sequence or sequences to be used for data analysis shall not vary from the nominal value by more than ± 3 %.

Choice of data used for analysis is based upon consistency of steering input and of vehicle longitudinal velocity relevant to that data. A minimum of four consistent cycles of steering input and of vehicle response are required for subsequent data analysis.

The steering input for this test may be made manually or with a steering robot machine. Where manual input is used, in order to obtain the minimum number of cycles required for analysis, the test should be performed for a minimum continuous duration of 40 s, sufficient to capture at least eight cycles of data. Where proving-ground space limitations prohibit a run of this duration, and consequently the reliable capture of a sufficiently long sequence of consistent data, it is permissible to perform a series of shorter runs and to combine the data for analysis. In this event, a nominal 20 cycles of data should be captured, and statistical methods should be used during analysis. The use of a steering robot offers the possibility of enhanced consistency of steering input and hence of test data, allowing fewer test cycles.

9 Data evaluation and presentation of results

9.1 General

General data shall be presented in the test report in accordance with ISO 15037-1:2019, Annexes A and B. For every change in vehicle loading or configuration, the general data shall be documented again.

At the present level of knowledge, it is not yet known which variables best represent the subjective feeling of the driver and which variables — i.e. which characteristic values — best describe the dynamic reactions of vehicles. Therefore, the following specified variables represent only examples for the evaluation of results.

NOTE Variables evaluated from runs performed at different nominal peak amplitudes of lateral acceleration, or from runs performed using different waveforms of steering input, might not be comparable.

9.2 Time histories

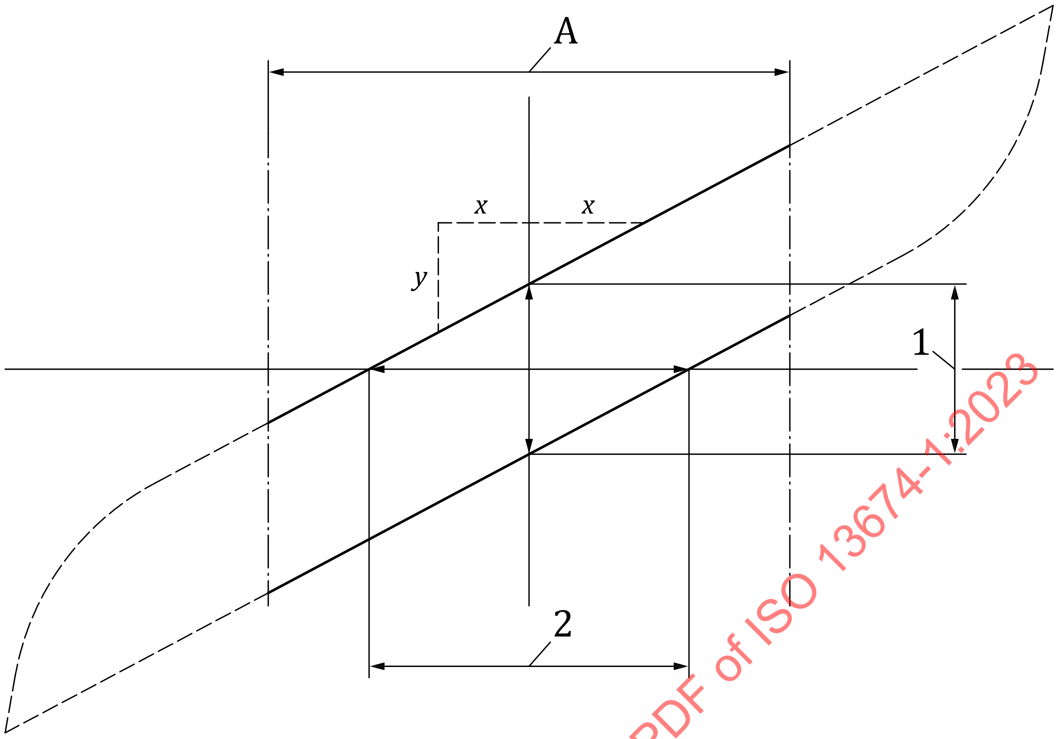
Time histories serve to monitor correct test performance and functioning of the transducers. In particular, the time histories of steering angle amplitude, steering-wheel angular velocity, vehicle longitudinal velocity and vehicle lateral acceleration are examined to identify valid data for evaluation. A minimum of four consistent cycles, for which the control criteria are best met, shall be selected for data analysis. Time histories of the variables listed in Clause 5 shall be presented for the data selected for analysis.

9.3 Characteristic values

9.3.1 General

The recorded variables are taken in pairs (see 9.3.2 to 9.3.6) and plotted one against the other on Cartesian coordinates. For each pair of variables, this produces a series of hysteresis loops laid one over another, the number of loops corresponding to the number of data cycles analysed.

The hysteresis loops should be “averaged” by some suitable method. The recommended method is to make a polynomial curve fit to the combined data over the range “A” for each of the upper and lower sides of the combined hysteresis loops, where “A” is an appropriate percentage of the peak-to-peak abscissa range of the data (see Figure 1). The recommended order for the polynomial curve fit is 3, and the recommended value for “A” is between 50 % and 70 %. The value chosen for “A” should be sufficiently large to adequately cover the range of data of interest, but sufficiently restrictive to avoid end effects from the limits of the loops.



Gradient = $\frac{y}{2x}$

Key

1 ordinate deadband

2 abscissa deadband

A range of polynomial curve fit

Figure 1 — Definition of parameters

The recommended method for evaluating a gradient is to make a best straight line fit to the polynomial in the region of interest. For an average gradient, this would be over a specified range (as detailed below), and for an "instantaneous" gradient, this would be over a small interval around the point of interest; typically, the size of the interval would correspond to that defined by a lateral acceleration of ±0,1 m/s^2.

Other methods may be employed for analysing and averaging the data. For example, straight line rather than polynomial curve fitting may be used. Each hysteresis loop may be analysed individually and the characteristic parameters, yielded from all the loops, averaged to obtain overall results.

The actual procedures and details used will depend upon the analysis software package employed and the nature of the data and shall be stated in the test report (see ISO 15037-1:2019, Annex B, under "Test method specific data").

From the polynomial curve fits to the combined hysteresis loops, the following parameters are evaluated:

— ordinate deadband;

— abscissa deadband;

— gradient.

The pairs of variables to be plotted (ordinate given first) and the characteristics that can be evaluated are given in 9.3.2 to 9.3.6.

9.3.2 Steering-wheel torque versus steering-wheel angle (M_H versus δ_H)

Steering stiffness:	average gradient over range ± x°, where x = 10 % of the peak steering angle
Steering stiffness at zero steer:	gradient evaluated at zero steering angle
Steering friction:	ordinate deadband
Angle hysteresis:	abscissa deadband

9.3.3 Yaw velocity versus steering-wheel angle ($d\psi/dt$ versus δ_H)

Yaw velocity response gain:	average gradient over range ± x°, where x = 20 % of the peak steering angle
Yaw velocity time delay:	time delay of yaw velocity with respect to steering angle input

9.3.4 Yaw velocity versus steering-wheel torque ($d\psi/dt$ versus M_H)

Response deadband:	abscissa deadband

9.3.5 Lateral acceleration versus steering-wheel angle (a_Y versus δ_H)

Steering sensitivity:	average gradient over range ± x°, where x = 20 % of the peak steering angle
Minimum steering sensitivity:	minimum instantaneous gradient evaluated within range ± 1 m/s^2
Steering sensitivity at 1 m/s^2:	gradient evaluated at 1 m/s^2 while steering away from centre
Lateral acceleration deadband:	ordinate deadband
Angle deadband:	abscissa deadband
Steering hysteresis:	area bounded by hysteresis loop and ordinate values ± 1 m/s^2, divided by 2 m/s^2 (equivalent to average angle deadband)
Lateral acceleration time delay:	time delay of lateral acceleration with respect to steering angle input

9.3.6 Steering-wheel torque versus lateral acceleration (M_H versus a_Y)

Torque at 0 m/s^2:	±torque levels at zero m/s^2
Torque at 1 m/s^2:	±torque levels at ± 1 m/s^2 while steering away from centre
Lateral acceleration at 0 N · m:	±lateral acceleration levels at 0 N · m
Torque gradient at 0 m/s^2:	gradient evaluated at 0 m/s^2
Torque gradient at 1 m/s^2:	gradient evaluated at 1 m/s^2 while steering away from centre
Torque hysteresis:	ordinate deadband