INTERNATIONAL STANDARD

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

Part 2:
Transition test

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

Partie 2: Essai de la transition

Reference number
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Contents

Page

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 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).

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

This second edition cancels and replaces the first edition (ISO 13674-2:2006), which has been technically revised.

ISO 13674 consists of the following parts, under the general title *Road vehicles — Test method for the quantification of on-centre handling*:

— *Part 1: Weave test*

— *Part 2: Transition test*

Introduction

The main purpose of this part of ISO 13674 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 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.

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

Part 2: Transition test

1 Scope

This part of ISO 13674 specifies a test schedule that addresses a particular aspect of the transition test, the on-centre handling characteristics of a vehicle. It is applicable to passenger cars in accordance with ISO 3833 and to light trucks, N1 category.

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 13674-1.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 15037-1:2006, *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, definitions and symbols given in ISO 1176, ISO 2416, ISO 3833, ISO 8855 and the following apply.

3.1
on-centre handling
description of the steering “feel” and steering 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 threshold
value of a parameter plotted as the ordinate on a graph and defined as the minimum threshold of human perception

3.3
abscissa deadband
horizontal separation between the pair of straight-line fits at ordinate threshold values

3.4
gradient
ratio of change in the ordinate with respect to a unit change in the abscissa, for a straight-line fit to a pair of recorded variables plotted one against the other on Cartesian coordinates

4 Principle

On-centre handling represents that part of the straight-line directional stability characteristics of the vehicle existing at low 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 part of ISO 13674 defines test schedules that involve driving the vehicle in a nominally straight line at a constant forward speed. During the tests, 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 shall be related 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 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, $d\psi / dt$;

— longitudinal velocity, v_x;

— lateral acceleration, a_y (see the NOTE to 6.2).

The following variables should be measured:

— steering-wheel angular velocity, $d\delta_H / dt$;

— roll angle, ψ.

The variables are defined in ISO 8855.

In order to acquire a deeper understanding of the vehicle behaviour, it may be desirable to determine motions of various components within the steering system, especially for vehicles with more than one steering axle.

6 Measuring equipment

6.1 Description

The measuring equipment shall be in accordance with ISO 15037-1.

Typical operating ranges and recommended maximum errors of the combined transducer and recording system are shown in Table 1.

NOTE It is advisable that care be taken to ensure that friction or inertia added to the system by steering robot or steering transducers does not improperly influence the measurement of steering-wheel torque.

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

Variable	Typical operating range[a]	Recommended maximum error of the combined transducer and recorder system[b]
Steering-wheel angle	±50°	±0,1°
Steering-wheel torque	±10 Nm	±0,1 Nm
Yaw velocity	±10 °/s	±0,1 °/s
Longitudinal velocity	0 – 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
Roll angle	±5°	±0,05°

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 (ISO 15037-1:2006, Annex A).

[a] These transducer ranges are appropriate for the standard test conditions and may 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 15037-1:2006, 4.3.

7 Test conditions

7.1 General

General comments relating to test conditions are given in ISO 15037-1:2006, Clause 5.

7.2 Test track

The test track requirements shall be in accordance with those of ISO 15037-1:2006, 5.2. In addition, the lateral gradient of the test surface should not exceed 1 %.

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. In the event that 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 15037-1:2006, Annex B).

Where measurement of wind velocity is not possible, estimation by use of 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 in m/s	0 – 0,2	0,3 – 1,5	1,6 – 3,3	3,4 – 5,4	5,5 – 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

Refer to ISO 15037-1:2006, 5.4.1. Special attention should be paid to the condition of the tyres, axle alignments and the steering system to ensure that the vehicle does not lead or pull when operating on a level surface.

7.4.2 Tyres

For general information regarding tyres used for test purposes, see ISO 15037-1:2006, 5.4.2. 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, it is recommended that only tyres with known characteristics be used if 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, which affect 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 roadwheel rotational frequency) should be avoided.

7.4.3 Operating components

See ISO 15037-1:2006, 5.4.3.

7.4.4 Loading conditions of the vehicle

See ISO 15037-1:2006, 5.4.4.

8 Test procedure

8.1 Warm-up

See ISO 15037-1:2006, 6.1.

8.2 Initial driving condition

The initial driving condition is that described in ISO 15037-1:2006, 6.2 for the steady-state straight-ahead run condition (with the time intervals as defined in ISO 15037-1:2006, Figure 2). The allowable variations for yaw velocity should be adopted rather than those for lateral acceleration.

An additional requirement is that, for a time interval starting no later than time t_1 and ending at time t_2, the steering wheel shall be subject to zero steer torque input. The recommended method to achieve this is to drive the vehicle under free steering control (i.e. hands free) during this specified time interval.

At time t_0, the steering input specified in 8.3 shall be applied. The transducer signals shall be recorded throughout the initial driving condition and for the duration of the test to ensure that the required data are not affected by the instrumentation system. It is recommended that the steady-state straight-ahead condition be re-established as described in ISO 15037-1:2006, 6.2 and data recorded for a further 1 s after the test run.

See ISO 15037-1:2006, 6.2 for guidance on selection of the appropriate transmission gear for performing the test.

NOTE This test procedure is not suitable for any vehicle that, under free steering control, is not able to remain within the limits of yaw velocity variation given in ISO 15037-1:2006, 6.2.2 for the time interval t_1 to t_2. Any such vehicle and its tyres should be examined for causes of excessive lateral deviation.

8.3 Transition test procedure

The transition test is an open-loop procedure and is conducted from an initial 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; these should be decremented or incremented by 20 km/h from the standard velocity. Details shall be recorded in the test report (see ISO 15037-1:2006, Annex B, under *Test method specific data*).

Whereas the weave test (see ISO 13674-1) examines the outer edge of the response hysteresis loop, this test examines the transition from straight line running to the edge of the hysteresis loop.

Continuing from the initial driving condition specified in 8.2, the steering wheel shall be subjected to a ramp input (that is one that increases in amplitude with a nominally constant angular velocity). To ensure a smooth transition of the vehicle path from the straight-ahead condition onto a curve of diminishing radius, the steering input shall be applied with an angular velocity that increases smoothly from zero up to the nominally constant value. Commencing at time t_0, the steering input shall be applied for a minimum duration of 3 s, and at an angular velocity not exceeding 5 °/s, until the lateral acceleration achieved by the vehicle reaches a minimum of 1,5 m/s^2. The test shall be performed a sufficient number of times in each turn direction (see 9.2), using, nominally, the same steer input profile.

NOTE For improved repeatability, a steering robot may be used if steering velocity is to exceed 1,5 °/s.

Details of the steering input, angular velocity and duration of application shall be recorded in the test report (see ISO 15037-1:2006, Annex B, under *Test method specific data*).

The longitudinal velocity during the test runs to be used for data analysis shall not vary from the nominal value by more than ±3 %.

The steering input shall be done manually or with steering robot. It is expected to reduce the number of test run to meet the criterion in 9.2 by using steering robot.

To quantify the effects of any lateral wind or lateral gradient of the test track, it is recommended that the test be performed in both turn directions for each direction of travel along the test track.

9 Data evaluation and presentation of results

9.1 General

General data shall be presented in the test report as shown in ISO 15037-1:2006, Annex A and Annex B. For every change in vehicle loading or configuration, the general data shall be documented again. Characteristic values determined from runs performed using different steering inputs, longitudinal velocity or lateral acceleration may not be comparable.

9.2 Time histories

Time histories serve to monitor the correct test performance and functioning of the transducers. The time histories are examined to identify valid data for evaluation. For each turn direction, a minimum of five consistent test runs, 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 Presentation of results

For all the test runs selected for data analysis, the recorded variables are taken in pairs (as detailed below) and plotted one against the other on Cartesian coordinates. For each pair of variables, this produces a series of overlaid traces of the form shown in Figure 1.

NOTE Since separate sets of data are used for the two turn directions, the data plots are not continuous through the origin as apparently depicted in Figure 1.

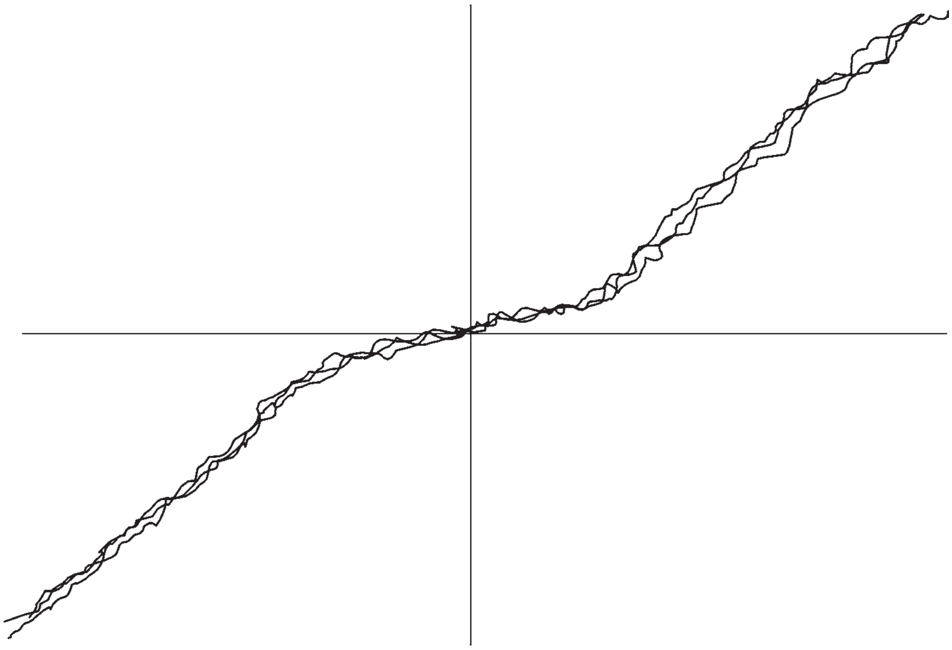


Figure 1 — Cartesian plots of data obtained from several test runs

Data from tests using left turns and right turns are combined for purposes of determining characteristic values.

Either of two approaches may be used.

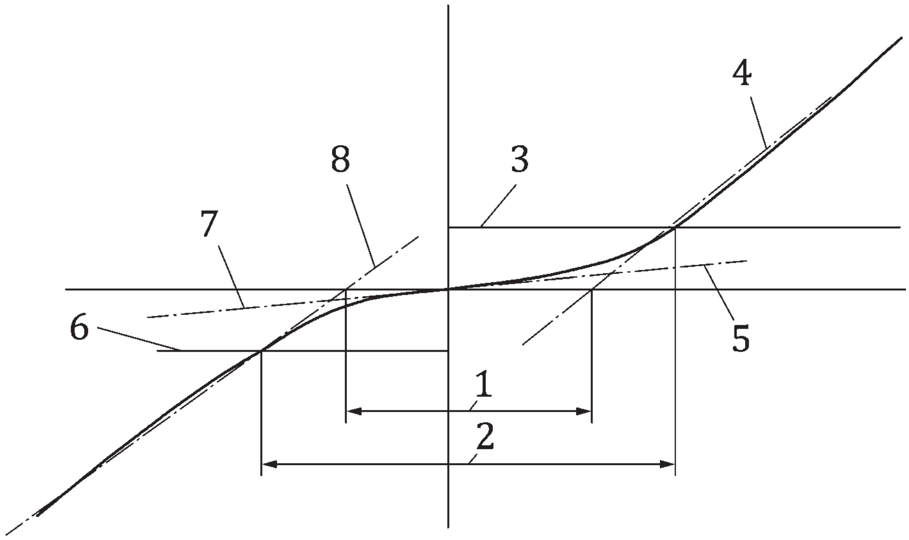
a) Characteristic values calculated from each individual turn data may be averaged separately for left and right turn directions with subsequent averaging of the left and right characteristic value averages to produce overall mean characteristic values. This method is preferred as it facilitates the calculation of statistics for each left and right turn characteristic value in addition to overall characteristic value statistics.

b) Alternatively, the cross-plot data from all left turns may be averaged by appropriate means independently from the cross-plot data from all right turns and characteristic values determined independently for the left and right averaged data. These averaged data for the left and right turns may then be averaged in turn to produce overall mean characteristic values.

A minimum of five pairs of left and right turns should be analysed.

On each Cartesian plot, a separate best straight-line fit is made to the data for each turn direction (see Figure 2). Each straight-line fit should exclude either data that is severely nonlinear, such as that in the on-centre region (typically that obtained in the lateral acceleration range ±0,5 m/s^2), or data obtained at lateral accelerations in excess of ±1,2 m/s^2. The data range that is used to make each straight-line fit shall be recorded in the test report (see ISO 15037-1:2006, Annex B).

The upper bound of ±1,2 m/s^2 is advisory; if linear characteristics are not apparent at lateral accelerations below this value, then an alternative data range may be chosen following prudent examination of the characteristic shape. The data below the ordinate threshold are changing for some set of data. It is hard to obtain stable values. It is advised to plot results as a function of steering velocity to check the tendency to steering velocity and the variation.



Key

1 abscissa deadband, left and right together
2 abscissa deadband at the ordinate threshold
3 ordinate threshold (+)
4 straight-line fit to left-turn data
5 gradient at zero, left-turn data
6 ordinate threshold (–)
7 gradient at zero, right-turn data
8 straight-line fit to right-turn data

Figure 2 — Definition of parameters

From each Cartesian plot and the pair of straight-line fits to the data, the following parameters are evaluated:

— abscissa deadband;

— gradient as slope of straight-line fit 4 and 5.

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 specified variables listed below represent only examples for the evaluation of results. Annex A provides a recommendation for a more detailed analysis based on more recent experiments.

Curves may be fitted to the plotted points either freehand or by one of the many mathematical routines available. The method of curve fitting should be stated. This is particularly true where the process involves fitting smooth curves to experimental data for the purpose of evaluating the gradients. The type of curve and the method of fitting will influence the results obtained. Within the context of an International Standard, it is not possible to recommend any one way as being better than any other.

The following lists the pairs of variables that are plotted (ordinate given first) and the characteristics that may be evaluated. Principle examples are shown in Figure A.1 and A.2.

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

Steering-wheel torque gradients (left and right) at zero.

Steering-wheel torque gradients (left and right) of the straight-line fits.

Steering-wheel torque deadband (left and right together) of the straight-line fits.

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

Yaw-velocity gradients (left and right) at zero.

Yaw-velocity gradients (left and right) of the straight-line fits.

Steering-wheel angle deadband (left and right together) of the straight-line fits.

Steering-wheel angle deadband (left and right together) at ordinate thresholds of ±1,1 °/s.

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

Yaw-velocity gradients (left and right) at zero.

Yaw-velocity gradients (left and right) of the straight-line fits.

Steering-wheel torque deadband (left and right together) of the straight-line fits.

Steering-wheel torque deadband (left and right together) at ordinate thresholds of ±1,1 °/s.

9.3.5 Lateral acceleration versus steering-wheel angle (a_y vs. δ_H)

Lateral-acceleration gradients (left and right) at zero.

Lateral-acceleration gradients (left and right) of the straight-line fits.

Steering-wheel angle deadband (left and right together) of the straight-line fits.

Steering-wheel angle deadband (left and right together) at ordinate thresholds of ±0,6 m/s^2.

9.3.6 Lateral acceleration versus steering-wheel torque (a_y vs. M_H)

Lateral-acceleration gradients (left and right) at zero.

Lateral-acceleration gradients (left and right) of the straight-line fits.

Steering-wheel torque deadband (left and right together) of the straight-line fits.

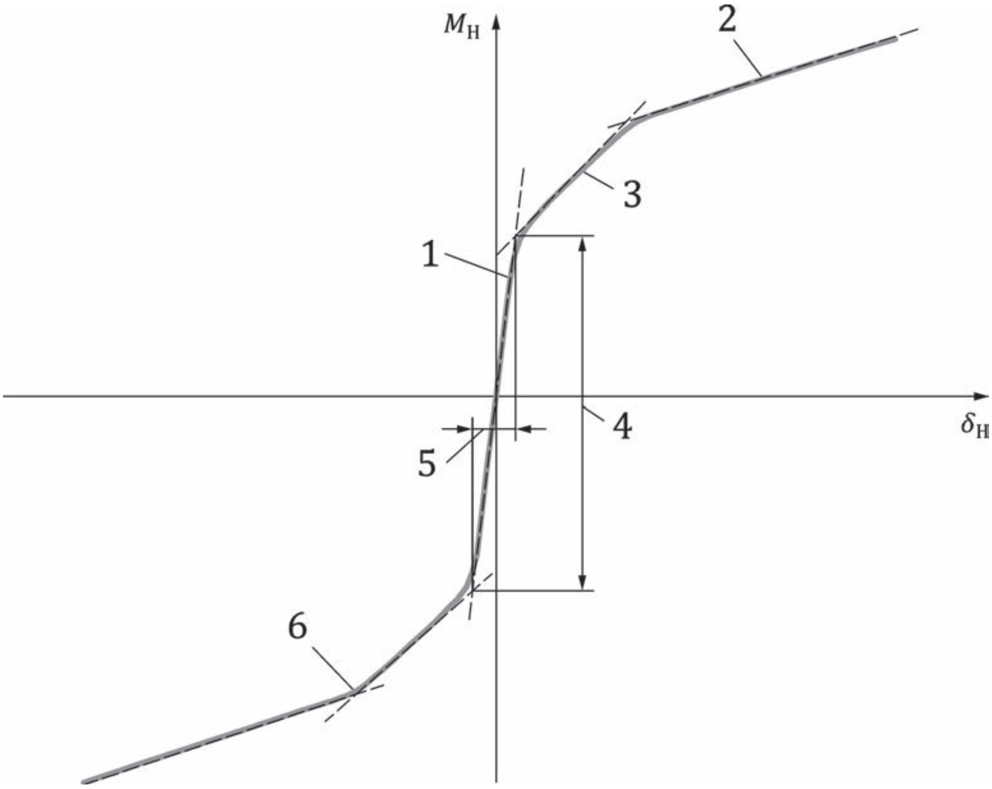
Steering-wheel torque deadband (left and right together) at ordinate thresholds of ±0,6 m/s^2.

Annex A
(informative)

Characteristic values

A.1 Presentation of results

This section presents a more detailed recommendation for analysis of the results based on more recent tests. Each section lists the pairs of variables that are plotted (ordinate given first) and the characteristics that may be evaluated. Principle examples are shown in Figures A.1 and A.2.



Key

1 steering stiffness

2 steering-wheel torque gradient – off-centre

3 steering-wheel torque gradient – on-centre

4 steering-wheel torque deadband

5 steering-wheel angle deadband

6 steering-wheel torque gradient breakpoint

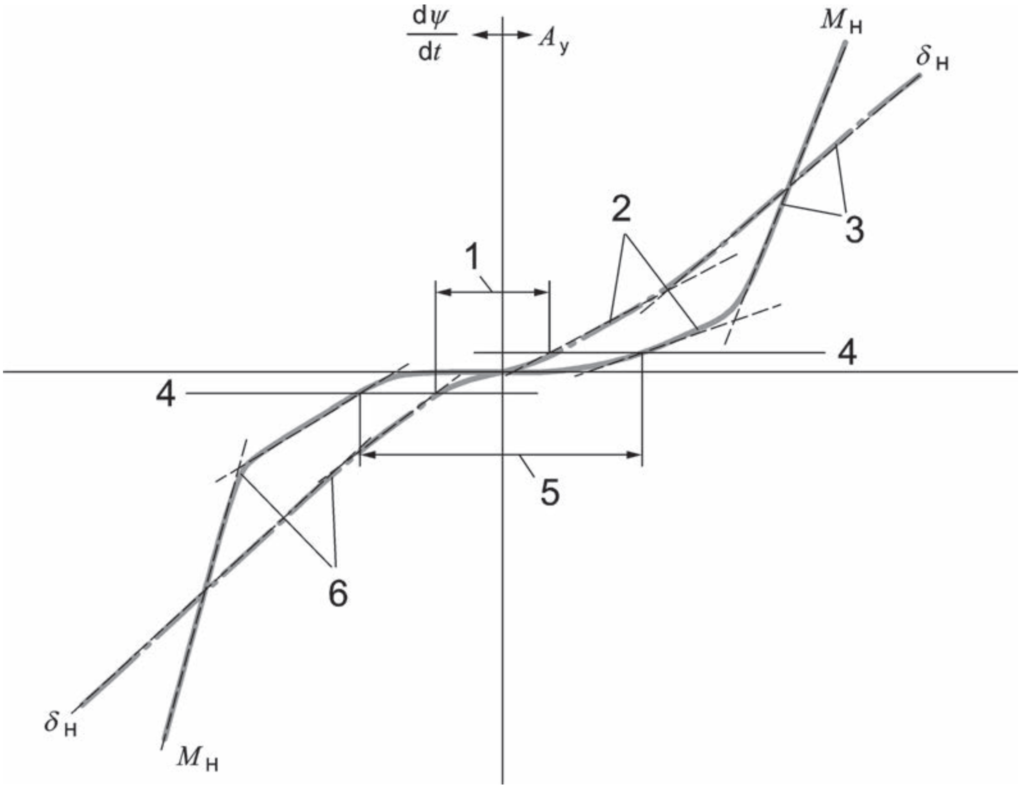
Figure A.1 — Definition of parameters, steering-wheel torque response

NOTE Steering stiffness, shown in Figure A.1, quantifies steering system compliance observed prior to vehicle response.

A.2 Steering-wheel torque versus steering-wheel angle (M_H vs. δ_H)

The following lists the pairs of variables that are plotted (ordinate given first) and the characteristics that may be evaluated. Principle examples are shown in Figure A.1.

Steering stiffness	–	gradient of straight-line fit to data for each turn direction from zero steering-wheel angle;
Steering-wheel torque gradient – on-centre reference steering-wheel angle	–	gradient of straight-line fit to data for each turn direction at a specified steering-wheel angle, yaw rate and/or lateral acceleration;
Steering-wheel torque gradient – off-centre reference steering-wheel angle	–	gradient of straight-line fit to data for each turn direction at a specified steering-wheel angle, yaw rate and/or lateral acceleration;
Steering-torque deadband reference steering-wheel angle	–	ordinate value for each turn direction and the sum of both directions where the straight-line fit of the steering stiffness and on-centre gradients intersect;
Steering-torque angle deadband reference steering-wheel angle	–	abscissa value for each turn direction and the sum of both directions where the straight-line fit of the on-centre and off-centre gradients intersect.
Steering-wheel angle at gradient breakpoint – off-centre reference steering-wheel torque	–	abscissa value for each turn direction and the sum of both directions where the straight-line fits of the on-centre and off-centre gradients intersect.



Key

1 steering-wheel angle deadband
2 response gain – on-centre
3 response gain – off-centre
4 ordinate threshold
5 steering-wheel torque deadband
6 response gain breakpoint

Figure A.2 — Definition of parameters, vehicle response gain

A.3 Yaw velocity versus steering-wheel angle ($d\psi / dt$ vs. δ_H)

The following lists the pairs of variables that are plotted (ordinate given first) and the characteristics that may be evaluated. Principle examples are shown in Figure A.2.

Yaw-velocity response gain – on-centre reference steering-wheel angle	–	gradient of straight-line fit to data for each turn direction from zero yaw velocity;
Yaw-velocity response gain – off-centre reference steering-wheel angle	–	gradient of straight-line fit to data for each turn direction at a specified yaw velocity;
Steering-wheel torque deadband reference yaw velocity	–	abscissa deadband at ordinate threshold of 1,1 °/s for each turn direction and the sum of both directions;
Steering-wheel angle at response gain breakpoint reference yaw velocity	–	abscissa value for each turn direction and the sum of both directions where the straight-line fits of the on and off-centre gradients intersect.

A.4 Yaw velocity versus steering-wheel torque ($d\psi / dt$ vs. M_H)

The following lists the pairs of variables that are plotted (ordinate given first) and the characteristics that may be evaluated. Principle examples are shown in Figure A.2.

Yaw-velocity response gain – on-centre reference steering-wheel torque	–	gradient of straight-line fit to data for each turn direction from zero yaw velocity;
Yaw-velocity response gain – off-centre reference steering-wheel torque	–	gradient of straight-line fit to data for each turn direction at a specified yaw velocity;
Steering-wheel torque deadband reference yaw velocity	–	abscissa deadband at ordinate threshold of 1,1 °/s for each turn direction and the sum of both directions;
Steering-wheel torque at response gain breakpoint reference yaw velocity	–	abscissa value for each turn direction and the sum of both directions where the straight-line fits of the on and off-centre gains intersect.

A.5 Lateral acceleration versus steering-wheel angle (a_y vs. δ_H)

The following lists the pairs of variables that are plotted (ordinate given first) and the characteristics that may be evaluated. Principle examples are shown in Figure A.2.

Lateral-acceleration response gain – on centre reference steering-wheel angle	–	gradient of straight-line fit to data for each turn direction from zero lateral acceleration;
Lateral-acceleration response gain – off centre reference steering-wheel angle	–	gradient of straight-line fit to data for each turn direction at a specified lateral acceleration;
Steering-wheel angle deadband reference lateral acceleration	–	abscissa deadband at ordinate threshold of 0,6 m/s^2 for each turn direction and the sum of both directions;
Steering-wheel angle at response gain breakpoint reference lateral acceleration	–	abscissa value for each turn direction and the sum of both directions where the straight-line fits of the on and off-centre gains intersect.

A.6 Lateral acceleration versus steering-wheel torque (a_y vs. M_H)

The following lists the pairs of variables that are plotted (ordinate given first) and the characteristics that may be evaluated. Principle examples are shown in Figure A.2.

Lateral-acceleration response gain – on-centre reference steering-wheel torque	–	gradient of straight-line fit to data for each turn direction from zero lateral acceleration;
Lateral-acceleration response gain – off-centre reference steering-wheel torque	–	gradient of straight-line fit to data for each turn direction at a specified lateral acceleration;
Steering-wheel torque deadband reference lateral acceleration	–	abscissa deadband at ordinate threshold of 0,6 m/s^2 for each turn direction and the sum of both directions;
Steering-wheel torque at response gain breakpoint reference lateral acceleration	–	abscissa value for each turn direction and the sum of both directions where the straight-line fits of the on and off-centre gains intersect.

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