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Road vehicles — Test method for the quantification of on-centre handling — Determination of dispersion metrics for straight-line driving

Véhicules routiers — Méthodes d'essai pour la quantification de la stabilité sur l'axe — Détermination de la dispersion métrique pour la conduite en ligne droite

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years with a view to deciding whether it should be confirmed for a further three years, revised to become an International Standard, or withdrawn. In the case of a confirmed ISO/PAS or ISO/TS, it is reviewed again after six years at which time it has to be either transposed into an International Standard or withdrawn.

Attention is drawn to the possibility that some of the elements of this Technical Specification may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 20119 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

Introduction

The dynamic behaviour of a road vehicle is a most important part of active vehicle safety. Any given vehicle, together with its driver and the prevailing environment, forms a unique closed-loop system. The task of evaluating the dynamic behaviour is therefore very difficult because of the significant interaction of these driver–vehicle–road elements, each of which is in itself complex. A complete and accurate description of the behaviour of the road vehicle must necessarily involve information obtained from a number of tests of different types.

Because they quantify only a small part of the whole handling field, the results of these tests can be considered significant only for a correspondingly small part of the overall dynamic behaviour.

Moreover, insufficient knowledge is available concerning the relationship between accident avoidance and the dynamic characteristics evaluated by these tests. A substantial amount of effort 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.

Therefore it is not possible to use these methods and test results for regulation purposes at present. The best that can be expected is that these on-centre handling tests are used as some among many other tests, which together describe an important part of the field of vehicle dynamic behaviour.

Finally, the role of the tyres is important and test results can be strongly influenced by the type and condition of tyres.

Road vehicles — Test method for the quantification of on-centre handling — Determination of dispersion metrics for straight-line driving

1 Scope

This Technical Specification specifies a test schedule that addresses certain aspects of the on-centre handling characteristics of a vehicle, *on-centre handling* being used to describe the steering "feel" and precision of the vehicle during nominally straight-line driving and in negotiating large-radius bends at high speeds but low lateral accelerations. It is applicable to passenger cars in accordance with ISO 3833, and to light trucks.

NOTE The manoeuvres specified are not necessarily representative of real driving conditions but are useful for obtaining measures of vehicle on-centre handling behaviour in response to several specific types of steering input under closely controlled test conditions. Other aspects of on-centre handling are addressed in the companion ISO 13674-1 and ISO 13674-2 (under preparation).

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Technical Specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Technical Specification are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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 15037-1:1998, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*

3 Terms, definitions and symbols

For the purposes of this Technical Specification, the terms, definitions and symbols given in ISO 1176, ISO 2416, ISO 3833 and ISO 8855 apply.

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 Technical Specification defines a test schedule that involves driving the vehicle in a nominally straight line at a constant forward speed. Because this is a closed-loop test procedure, the results are driver-dependent. For this reason it is essential that all vehicles or vehicle configurations be tested using the same driver or drivers. 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 the 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 thus 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 performing this test procedure, the following variables shall be measured:

— steering-wheel angle, δ_H;

— yaw velocity, $\frac{d\psi}{dt}$;

— longitudinal velocity, v_X.

The following variables should also be measured:

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

— lateral acceleration, a_Y.

These variables are defined in 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 given 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°
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 15037-1:1998, 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 manufacturer's 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 transformation 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 15037-1:1998, 4.3.

7 Test conditions

7.1 General

See ISO 15037-1:1998, clause 5.

7.2 Test track

All tests shall be carried out on a smooth, clean, dry and uniform paved road surface. The gradients of this test surface shall not exceed the following values when measured over any distance interval, D, where D may be any value between the vehicle track width and 25 m:

— longitudinal gradient, 5 %

— lateral gradient, 3,5 %

However, the lateral gradient should not exceed 2,0 %.

The test surface used shall not incorporate any turn radii of less than 2 500 m.

For each test, the road surface conditions, gradient variations and paving material shall be recorded in the test report (see ISO 15037-1:1998, annex B).

7.3 Wind velocity

During testing, 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, conditions of significant "gusting" should be avoided, i.e. testing should not be carried out 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 15037-1:1998, 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 15037-1:1998, 5.4.1

7.4.2 Tyres

For general information regarding tyres used for test purposes, see ISO 15037-1:1998, 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, 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 and 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 15037-1:1998, 5.4.3.

7.4.4 Loading conditions of vehicle

For general comments, see ISO 15037-1:1998, 5.4.4. However, for this procedure deviations of the centre of gravity position or moments of inertia, or both, from the vehicle in normal use, are permissible if the procedure is being used to study the effects of loading pattern upon vehicle behaviour.

8 Test procedure

8.1 Warm-up

Warm up all relevant vehicle components prior to the tests in order to achieve a temperature representative of normal driving conditions. Warm-up is achieved by following the initial driving condition.

8.2 Initial driving condition and driver familiarization

The vehicle shall be driven at the test velocity for a distance of at least 10 km on a route representative of that to be used for testing. The initial driving condition fulfils both vehicle warm-up and the driver familiarization requirement.

See ISO 15037-1:1998, 6.2 for guidance on selection of the appropriate transmission gear for performing the test.

8.3 Straight-line procedure

The straight-line test is a closed-loop procedure, and is conducted on a test surface that follows a straight-line path or incorporates turn radii $\geqslant$ 2 500 m. 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 15037-1:1998, annex B, under *test method specific data*).

Where the test is conducted exclusively on a uniform surface having consistent gradients and following a true straight line of sufficient length to enable the vehicle to run at test velocity for at least 1,0 km, run the test at least three times in each of the two opposing directions of travel.

Where the test is conducted on a route that incorporates turns and gradient variations, run the test for a total time duration of 10 min. This may be accomplished as a single continuous test run or as several shorter test sequences that together exceed 10 min.

Record the transducer signals throughout the duration of the test or each test sequence.

Throughout the test or test sequence the longitudinal velocity shall not vary from the nominal value by more than $\pm$ 3 %.

The test procedure is essentially a path-following task, where the trajectory is nominally a straight line. The test driver shall be instructed to drive the test or test sequence, while striving to simultaneously minimize both the steering wheel activity and the lateral deviation of the vehicle from the intended trajectory. The recommended strategy for the driver is to adopt a long look-ahead distance, typically 250 m.

Because this test procedure is closed-loop, the results are driver-dependent. For this reason it is essential that all vehicles or vehicle configurations be tested using the same driver or drivers (the test should be undertaken with several drivers).

NOTE Turn radii and road gradients preload chassis systems and hence influence test results. It might not then be possible to compare results obtained from different test routes.

9 Data evaluation and presentation of results

9.1 General

General data shall be presented in the test report in accordance with ISO 15037-1:1998, 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. characteristic values) best describe the dynamic reactions of vehicles. Therefore, the following specified variables represent only examples for the evaluation of results.

9.2 Data preparation

Data shall be processed initially according to the provisions of ISO 15037-1:1998, 4.3. Where data have been obtained from testing on a route that incorporates turns and gradient variations, they shall be processed additionally to remove the effects of the gradients and turn radii. This shall be done by filtering with a high-pass filter having a cut-off frequency of nominally 0,1 Hz. A phaseless (zero phase shift) digital filter shall be used, incorporating the following characteristics:

— passband shall be high-pass, commencing at 0,15 Hz maximum;

— stopband shall be 0 Hz to 0,05 Hz minimum;

— filter gain in the passband shall be 1 ± 0,005 (100 % ± 0,5 %);

— filter gain in the stopband shall be $\leqslant$ 0,01 ($\leqslant$ 1 %).

9.3 Referred steer angle

Referred steer angle, δ_R, is computed from steering-wheel angle data. Referred steer angle is defined as

$$\delta_R = \frac{\delta_H}{i_C}$$

where i_C is the steering ratio about the on-centre region (± 10° of steering-wheel angle).

9.4 Power spectral density (PSD)

Compute the PSD for each of the following:

— steering-wheel angle, δ_H;

— referred steer angle, δ_R;

— yaw velocity, $\frac{d\psi}{dt}$.

The computational factors for each PSD shall be detailed in the test report (see ISO 15037-1:1998, annex B, under *test procedure specific data*). The details required are as follows (with example values in parenthesis):

— Number of segments (e.g. six);

— Number of sampling points per segment (e.g. 1 024);

— Sampling rate (e.g. 50 Hz);

— Window function (e.g. Welch);

— Overlapping (e.g. 50 %).

The resultant PSDs are indicated as $\Phi\delta_H$ (f), $\Phi\delta$ (f) and $\Phi \frac{d\psi}{dt}$ (f).

9.5 Characteristic values

9.5.1 Average standard deviation

From all relevant runs, the average standard deviation is calculated and reported for

— steering-wheel angle, δ_H, and

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

9.5.2 Partial root mean square (PRMS)

The following PRMS values shall be calculated and reported:

— PRMS δ_H =

$$\sqrt{\int_a^b \Phi\delta_H (f) df}$$

— PRMS δ_R =

$$\sqrt{\int_a^b \Phi\delta_R (f) df}$$

— PRMS of $\frac{d\psi}{dt}$ =

$$\sqrt{\int_a^b \Phi \frac{d\psi}{dt} (f) df}$$

where a = 0,2 Hz and b = 3,0 Hz.

Bibliography

[1] ISO 13674-1, *Road vehicles — Test method for the quantification of on-centre handling — Part 1: Weave test*

[2] SAE 840069, *Objective Evaluation of On-Center Handling Performance*

[3] SAE 930827, *An Objective Measurement Technique for the Quantification of On-Centre Handling Quality*

[4] SOMMERVILLE J., FARRER D.G., and WHITEHEAD J.P., Improvements in the Quantification of On-Centre Handling Quality. *IMechE* C466/049/93J

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