INTERNATIONAL STANDARD

ISO 11012

First edition
2009-09-15

Heavy commercial vehicles and buses — Open-loop test methods for the quantification of on-centre handling — Weave test and transition test

Véhicules utilitaires lourds et autobus — Méthode d'essai en boucle ouverte pour mesurer la tenue de route en ligne — Essai de changement de trajectoire et essai transitoire

Reference number
ISO 11012:2009(E)

Contents

Page

Foreword ... iv
Introduction ... v
1 Scope ... 1
2 Normative references ... 1
3 Terms, definitions and symbols ... 1
3.1 Terms and definitions ... 1
3.2 Symbols ... 2
4 Principle ... 2
5 Variables ... 2
5.1 Reference system ... 2
5.2 Variables ... 3
6 Measuring equipment ... 3
7 Test conditions ... 4
8 Test procedure ... 4
8.1 General ... 4
8.2 Warm-up ... 4
8.3 Initial driving condition ... 4
8.4 Weave test procedure ... 4
8.5 Transition test procedure ... 5
9 Data evaluation and presentation of results ... 5
9.1 General ... 5
9.2 Time histories ... 5
9.3 Characteristic values for the weave test ... 6
9.4 Characteristic values for the transition test ... 8
Annex A (normative) Test report — General data and test conditions ... 11
Annex B (informative) Calculating the time delay from sinusoidal data ... 12
Bibliography ... 14

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 11012 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

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 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 the test method described in this International Standard 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 the test method described in this International Standard for regulation purposes will require proven correlation between test results and accident statistics.

Heavy commercial vehicles and buses — Open-loop test methods for the quantification of on-centre handling — Weave test and transition test

1 Scope

This International Standard describes two open-loop test methods for determining on-centre handling characteristics of a vehicle in response to specific types of steering input under closely controlled test conditions:

— the weave test, and

— the transition test.

This International Standard applies to heavy vehicles, i.e. commercial vehicles, commercial vehicle combinations, buses and articulated buses as defined in ISO 3833 (trucks and trailers with maximum weight above 3,5 tonnes and buses and articulated buses with maximum weight above 5 tonnes, in accordance with ECE and EC vehicle classification, categories M3, N2, N3, O3 and O4).

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 1176, *Road vehicles — Masses — Vocabulary and codes*

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

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

ISO 15037-2:2002, *Road vehicles — Vehicle dynamics test methods — Part 2: General conditions for heavy vehicles and buses*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1176, ISO 3833, ISO 8855, ISO 15037-2 and the following apply.

3.1.1
on-centre handling
objective 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

3.1.2
ordinate deadband
vertical width of the hysteresis loops at an abscissa value of zero

3.1.3
abscissa deadband
horizontal width of the hysteresis loops at an ordinate value of zero

3.1.4
gradient
ratio of the change in the ordinate to a unit change in the abscissa

3.2 Symbols

For the purposes of this document, the symbols given in ISO 8855 and ISO 15037-2 apply.

4 Principle

On-centre handling represents that part of the straight-line directional stability characteristics of the vehicle existing at low levels of lateral acceleration, typically not larger 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 characteristics 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 International Standard defines two test schedules that involve driving the vehicle in a nominally straight line at a constant forward speed:

— the weave test examines the response at the outer edge of the hysteretic region (see 8.4);

— the transition test examines the transition from straight-line driving to the edge of the hysteretic region (see 8.5).

During these 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) of the first vehicle unit (see ISO 8855).

For the purposes of this International Standard, the location of the reference point shall be in the plane of symmetry and at the longitudinal and vertical position of the wheel centre of the first axle of the first vehicle unit at static load and straight-ahead steering.

NOTE This provision overrides the provision of 15037-2.

5.2 Variables

When using these test methods, the following variables shall be determined for the first vehicle unit:

a) steering-wheel angle, δ_H;

b) steering-wheel torque, M_H;

c) yaw velocity, $d\psi/dt$;

d) longitudinal velocity, v_X;

e) lateral acceleration at the reference point, a_Y .

It is also recommended that the following variable be determined:

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

The listed 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

The measuring equipment shall be in accordance with ISO 15037-2.

Table 1 shows typical operating ranges and recommended maximum errors of the combined transducer and recording system, which are not given in ISO 15037-2.

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

Table 1 — Typical operating ranges and maximum errors of variables not listed in ISO 15037-2

Variable	Typical operating range	Recommended maximum error of combined system
Steering-wheel angle	± 80°	± 0,5°
Steering-wheel torque in case of power steering	± 10 Nm	± 0,1 Nm
Yaw velocity	± 10°/s	± 0,1°/s
Lateral acceleration	± 5 m/s^2	± 0,05 m/s^2
Steering wheel angular velocity	± 100°/s	± 1°/s

7 Test conditions

Specifications for test conditions shall be in accordance with ISO 15037-2 together with the additional specifications listed below.

a) The lateral gradient of the test surface should not exceed 1 % over any distance greater than or equal to the vehicle track.

b) 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.

c) 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 where there is significant wind 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.

8 Test procedure

8.1 General

The weave test requires a test track of approximately 1 000 m length and 20 m width for standard test conditions. The transition test requires less length but approximately 40 m width.

The vehicle is driven at a nominally constant longitudinal velocity. The standard test velocity is 80 km/h. Other velocities may be used. The test velocity should preferably be decremented or incremented by steps of 10 km/h. For each test run, the average longitudinal velocity shall be maintained within a tolerance of ± 2 km/h of the selected speed. A deviation of vehicle longitudinal velocity of ± 3 km/h from the selected longitudinal velocity is permissible. 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.

It is preferable that the steering inputs for these tests be made with a steering machine.

Details shall be recorded in the test report (see Annex A).

8.2 Warm-up

See ISO 15037-2.

8.3 Initial driving condition

The initial driving condition shall be as described in ISO 15037-2 for the steady-state straight-ahead run. The allowable variations for yaw velocity should be used rather than those for lateral acceleration.

In the time interval, starting no later than time t_1 and ending at time t_2 (see ISO 15037-2:2002, 7.2), the steering wheel shall be held fixed within ± 3°. If possible, the steering wheel should be subject to zero input torque. At time t_0, the steering input specified in 8.4 and 8.5 shall be applied.

8.4 Weave test procedure

The weave test procedure requires an oscillatory steering input following the initial driving condition. The standard waveform of the steering input is sinusoidal, but other waveforms (e.g. triangular) may be used. The standard frequency of the steering input is 0,2 Hz, but other frequencies may be used. The amplitude of the steering input shall be sufficient to ensure that adequate test data are available for analysis at the lateral acceleration level of 1 m/s^2 and that the vehicle and its subsystems are working outside of the hysteretic region.

NOTE 1 To accomplish this goal, some vehicles might require peak lateral accelerations of 2 m/s^2 or more.

Details of the steering input frequency and waveform, and the lateral acceleration amplitude shall be reported.

Throughout the test, the waveform of the steering input shall be as constant as possible. Both the peak amplitude of the steering angle and the angular velocity of the steering wheel through the centre position shall be as constant as possible. A minimum of four consistent cycles of steering input and of vehicle response is required for subsequent data analysis. Variations from the nominal steering frequency may be $\pm$ 10 %.

NOTE 2 In most cases, vehicle responses to the initial steering cycle will include start-up transients. Consequently, these data might not be appropriate for data analyses.

NOTE 3 To aid in establishing the proper zero-reference steering condition, it might be useful to end the procedure by re-establishing the steady-state straight-ahead condition at the end of the test run.

8.5 Transition test procedure

The transition test procedure requires a ramp-steering input following the initial, straight-line driving condition. The test shall be conducted with steering inputs producing both left turns and right turns with a minimum of five repeats in each direction. As indicated in 9.4.1, results from left turns and right turns are combined during data reduction. This process requires that the initial conditions of all tests be as nearly identical as possible. Thus, whenever possible, each test should be initiated at the same point on the test surface with the vehicle travelling in the same direction and under similar wind conditions. Because of the desirability of similar initial conditions, it is also advisable to conduct tests by alternating turns in one direction and then the other, rather than conducting all tests in one direction and then all tests in the other direction.

To avoid inappropriate initial transient response, the ramp-steering input should be started gradually, not abruptly. Commencing at time t_0, the steering ramp shall be applied until the lateral acceleration of the first vehicle unit reaches a minimum of 1,5 m/s^2 and is high enough that the vehicle and its subsystems are working outside of the hysteretic region. The steering ramp shall be such that the rate of increase of lateral acceleration does not exceed 0,5 m/s^2/s.

Details of the steering input, angular velocity and duration of application, shall be reported.

9 Data evaluation and presentation of results

9.1 General

General data shall be presented in the test report in accordance with ISO 15037-2 (see Annex A).

At the present level of knowledge, it is not yet known which characteristic values best represent the subjective feeling of the driver. Therefore, the following specified characteristic values represent only examples for the evaluation of results.

NOTE Characteristic values determined from runs performed using different steering inputs, longitudinal velocity or lateral acceleration might not be comparable.

9.2 Time histories

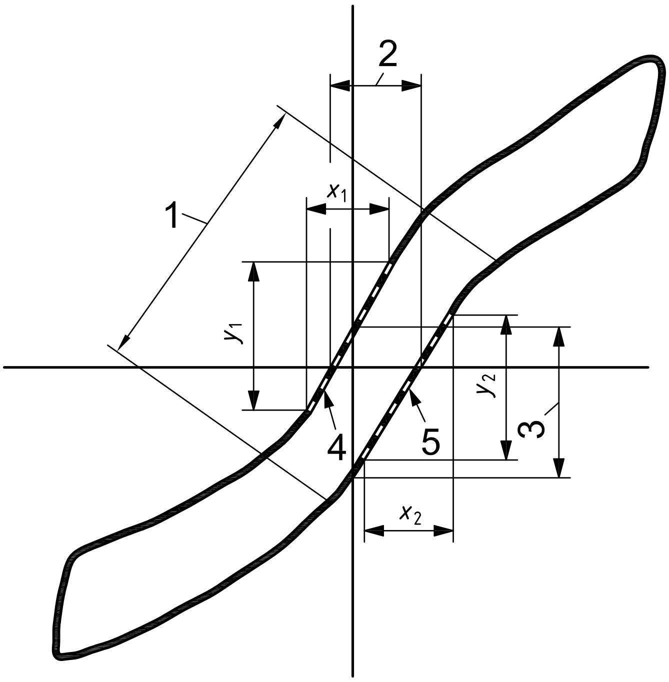
Time histories serve to monitor correct test performance and functioning of the transducers. Time histories of the variables listed in Clause 5 shall be reported for the data selected for analysis.

9.3 Characteristic values for the weave test

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 co-ordinates. For each pair of variables, this produces a series of hysteresis loops laid one over another; the number of loops corresponds to the number of data cycles analysed.

The upper and lower boundaries of the hysteresis loops should be averaged by a suitable method. The recommended method is to make curve fits for each of the upper and lower sides of the combined hysteresis loops over an appropriate range of the data (see Figure 1). The curve-fit method that is used shall be recorded. The range chosen for curve fitting should be sufficiently large to adequately cover the data of interest (spanning at least $\pm$ 1 m/s^2), but sufficiently restrictive to avoid effects from the limits of the loops.



Key

1 range of curve fits
2 abscissa deadband
3 ordinate deadband
4 gradient 1 (y_1/x_1)
5 gradient 2 (y_2/x_2)

Figure 1 — Definition of parameters for the weave test

NOTE As illustrated in Figure 1, the data plots can often be asymmetric with respect to the distribution of hysteresis about the origin (i.e. at the nominal condition of zero steering). Such asymmetries arise from steering torque offsets due to a variety of factors, including asymmetric alignment, weight distribution, tyre properties (e.g. pull forces, rolling resistance), road slope, cross winds and other factors.

It is recommended that the gradients be determined from the curve fit in the region of interest.

Other methods may be employed for analysing and averaging the data. For example, a straight-line fit in a local region of interest, rather than higher order 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. Whether the data are analysed together or per hysteresis loop, those parameters quantifying hysteresis and gradients as described below, can be evaluated uniquely for clockwise and counter-clockwise turn directions.

The actual procedures and details used will depend upon the analytical methods employed and the nature of the data, and they shall be stated in the test report (see Annex A).

The following parameters are evaluated from the curves fitted to the combined hysteresis loops:

- ordinate magnitudes at specified abscissa values;
- ordinate deadband;
- abscissa deadband;
- gradients in both directions.

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)

The following characteristics can be evaluated:

- steering-wheel torque gradients: gradients evaluated at a specified steering angle or lateral acceleration;
- steering-wheel torque gradients at zero steer: gradients evaluated at zero steering angle;
- steering-wheel torque hysteresis at zero steer: ordinate deadband;
- steering-wheel angle hysteresis at zero torque: abscissa deadband.

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

The following characteristics can be evaluated:

- yaw velocity response gain: gradient evaluated at a specified steering angle or lateral acceleration;
- yaw velocity response gain at zero steer: gradient evaluated at zero steer angle;
- yaw velocity time delay: time delay of yaw velocity with respect to steering angle.

NOTE There are different methods for calculating effective time delay. With the assumption of pure sinusoidal inputs and outputs, the time delay can be calculated as described in Annex B [see Equation (B.1)]. Alternatively, the delay between inputs and outputs can be determined by subtracting the value of time where output is zero from the time at which the input is zero, or else the steering-angle and yaw-velocity time histories can be cross correlated to determine the delay that produces the highest correlation.

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

The following characteristic can be evaluated:

- steering wheel torque hysteresis at zero yaw velocity: abscissa deadband.

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

The following characteristics can be evaluated:

- lateral acceleration gradient: gradient evaluated at a specified steering angle or lateral acceleration;
- minimum lateral acceleration gradient: minimum gradient evaluated within the lateral-acceleration range of ± 1 m/s^2;
- lateral acceleration gradient at ± 1 m/s^2: gradient evaluated at lateral accelerations of ± 1 m/s^2 while steering away from centre;
- lateral acceleration hysteresis: ordinate deadband;
- steering-wheel angle hysteresis: abscissa deadband;
- mean steering-wheel angle hysteresis: area bounded by the hysteresis loop and ordinate values ± 1 m/s^2, divided by 2 m/s^2.

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

The following characteristics can be evaluated:

- steering-wheel torque at lateral acceleration ± 1 m/s^2: ± torque levels at lateral accelerations of ± 1 m/s^2 while steering away from centre;
- steering-wheel torque gradient at zero lateral acceleration: gradient evaluated at 0 m/s^2;
- steering-wheel torque gradients at lateral acceleration ± 1 m/s^2: gradients evaluated at lateral accelerations of ± 1 m/s^2 while steering away from centre;
- steering-wheel torque hysteresis at zero lateral acceleration: ordinate deadband;
- lateral acceleration hysteresis at zero torque: abscissa deadband.

9.4 Characteristic values for the transition test

9.4.1 General

For all the test runs selected for data analysis, the individual recorded variables are taken in pairs (as indicated in 9.4.2 to 9.4.6) and plotted one against the other on Cartesian co-ordinates. For each pair of variables, this produces a series of overlaid traces of the form shown in Figure 2.

Data from tests using left turns and right turns are combined for purposes of determining characteristic values. Either of two approaches may be used: the data from all left turns may be averaged by appropriate means, as may the data from all right turns. These averaged data may then be combined and used jointly to produce characteristic values. Alternatively, data from the one left-turn test may be combined with that of one right-turn test and the combination used to produce characteristic values. Repeating this process with a minimum of five pairs of left and right tests, all results may then be analysed to produce average characteristic values as well as measures of variance.

On each plot, the gradient at the zero ordinate value shall be evaluated for each turn direction. Also, a separate straight-line fit shall be made for the data of a specified range for each turn direction. Each straight-line fit shall exclude data that are substantially nonlinear, such as the data in the on-centre region and at higher levels of lateral acceleration.

For each data plot, the following parameters shall be evaluated (see Figure 2):

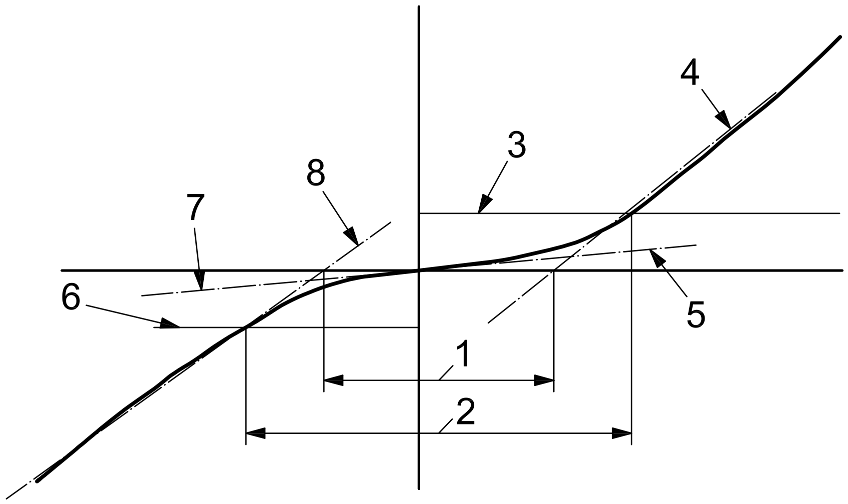
a) the gradients at zero ordinate value;

b) the gradients of the left-turn and the right-turn straight-line fits;

c) the abscissa deadband of the straight-line fits.

Additionally, for all plots except that of steering-wheel angle versus steering-wheel torque (see 9.4.2), the following characteristic values shall be evaluated:

— the abscissa deadbands at ordinate thresholds of ± 1,1°/s or 0,6 m/s^2.



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 for the transition test

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

The following characteristics can be evaluated:

— steering-wheel torque gradients (left and right) at zero,

— steering-wheel torque gradients (left and right) of the straight-line fits;

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

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

The following characteristics can be evaluated:

— 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.

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

The following characteristics can be evaluated:

— 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.

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

The following characteristics can be evaluated:

— 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.

9.4.6 Lateral acceleration versus steering-wheel torque (a_Y versus M_H)

The following characteristics can be evaluated:

— 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
(normative)

Test report — General data and test conditions

A.1 General data

The test report for general data shall be as given in ISO 15037-2:2002, Annex A.

A.2 Test conditions

The test report for test conditions shall be as given in ISO 15037-2:2002, Annex B.

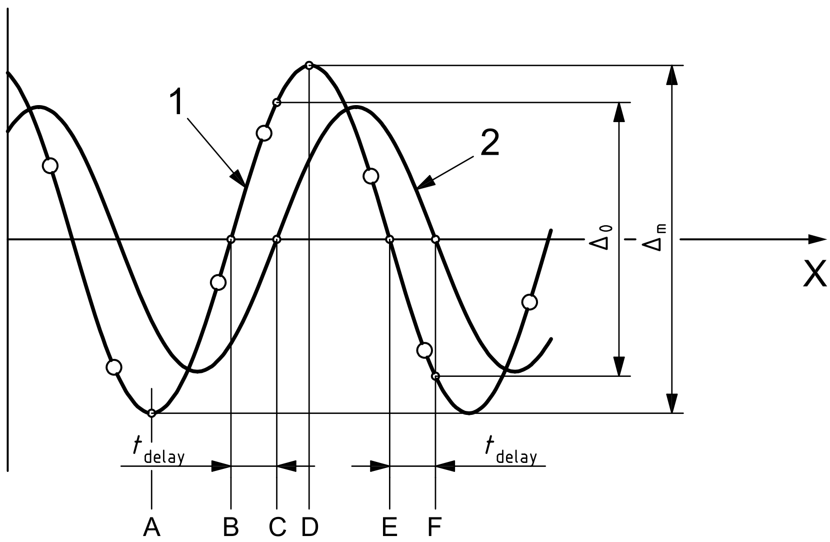
Annex B
(informative)

Calculating the time delay from sinusoidal data

For data sets wherein the input and output can both be assumed to be sinusoidal, the time delay of the output following the input, t_{delay}, may be calculated as follows:

$$t_{delay} = \sin^{-1}(\Delta_0/\Delta_m)/2\pi f \qquad (B.1)$$

where f is the frequency of the sinusoid (in Hz) and the parameters Δ_0 and Δ_m are as shown in Figures B.1 and B.2.



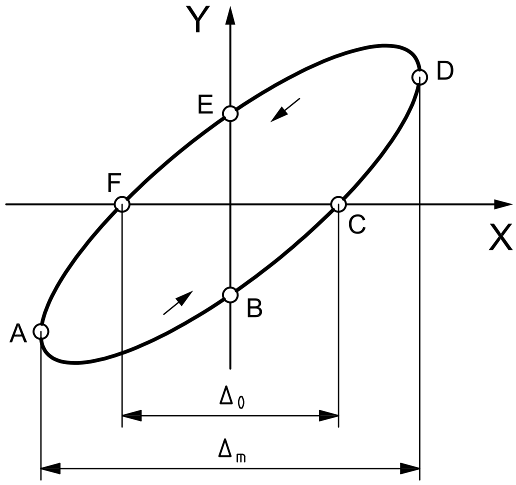
Key

X time axis

1 input

2 output

Figure B.1 —Time histories of sinusoidal input and output variables



Key

X input

Y output

Figure B.2 — Data plot of the output variable versus the input variable

In these two figures, the input variable reaches its minimum and maximum at A and D, respectively. The input has a value of zero at B and E, and the output has a value of zero at C and F. Δ_m is the full range of the input variable, and Δ_0 is the range of input when the output is zero. From Figure B.1, it can be seen that:

$$\Delta_0/2 = \Delta_m/2 \sin(2\pi f\, t_{delay}) \tag{B.2}$$

Equation (B.2) may readily be solved for t_{delay} to yield Equation (B.1).

Note that the same result may be obtained by defining Δ_m as the full span of the output and Δ_0 as the span of the output when the input is zero. In this case, the points A and D would mark the maximum and minimum of the output rather than the input. Δ_m would then be the full range of the output from point A to D and Δ_0 would be the range of the output from point B to E.

Bibliography

[1] ISO/TS 20119, *Road vehicles — Test method for the quantification of on-centre handling — Determination of dispersion metrics for straight-line driving*

[2] FARRER D.G., *An Objective Measurement Technique for the Quantification of On-Centre Handling Quality*, Paper 930827, Society of Automobile Engineers, 1993

[3] MCRUER D.T. and KRENDEL E.S., *Mathematical Models of Human Pilot Behavior*; NATO Advisory Group for Aerospace Research and Development, AGARD-AG-188, 1974

[4] NEWCOMB T.P., *Driver Behaviour During Braking*, Paper 810832, Society of Automobile Engineers, 1981

[5] NORMAN K.D., *Objective Evaluation of On-Center Handling Performance*, Paper 840069, Society of Automobile Engineers, 1984

[6] SOMMERVILLE J., FARRER D.G. and WHITEHEAD J.P., *Improvements in the quantification of on-centre handling quality*, Paper C466/049/93, Institution of Mechanical Engineers, London, 1993

ICS 43.080.01

Price based on 14 pages