INTERNATIONAL STANDARD

ISO 11026

First edition
2010-07-01

Heavy commercial vehicles and buses — Test method for roll stability — Closing-curve test

Véhicules utilitaires lourds et autobus — Méthode d'essai de stabilité au renversement — Essai en courbe se fermant

Reference number
ISO 11026:2010(E)

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

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 11026 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 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.

Heavy commercial vehicles and buses — Test method for roll stability — Closing-curve test

1 Scope

This International Standard specifies an open-loop test method for determining the roll stability of a vehicle negotiating a curve on dry surface.

It applies to heavy vehicles, that is commercial vehicles, commercial vehicle combinations, buses and articulated buses as defined in ISO 3833 (trucks and trailers with maximum weight above 3,5 t and buses and articulated buses with maximum weight above 5 t, according to ECE and EC vehicle classification, categories M3, N2, N3, O3 and O4).

The method is intended for vehicles equipped with electronic roll stability control systems.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3833, *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

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

3.1
jerk
rate of change of lateral acceleration

3.2
steady-state rollover threshold
maximum magnitude of lateral acceleration that a vehicle can sustain during steady-state cornering on a flat and level surface without rolling over

4 Principle

The objective of this test method is to determine the effect of roll stability control on the roll stability of a vehicle travelling at constant longitudinal velocity on a path with a constantly increasing curvature, a closing curve. Also, effects on the yaw stability will be considered. The initial state for the test is driving in a straight line at constant longitudinal velocity.

The path is defined by the curvature rate, k_c, which gives the curvature, κ, along the path:

$$\kappa = k_c \cdot s$$

where s is the distance along the path.

At constant longitudinal velocity, V_X, the jerk, k_a, is constant.

$$k_a = k_c \cdot V_X{}^3$$

The path can be expressed in Cartesian coordinates in the earth-fixed system as follows:

$$X_E(s) = \int \cos(\nu)\, ds$$

$$Y_E(s) = \int \sin(\nu)\, ds$$

where ν is the course angle, calculated as follows:

$$\nu = \int \kappa \cdot ds = \frac{k_a}{2 \cdot V_X{}^3} \cdot s^2$$

The severity of the test depends both on the jerk and on the longitudinal velocity. Higher velocity on a path with a certain jerk is more demanding than a lower velocity on another path with the same jerk. Thus, varying the jerk by changing the velocity on a given path is not identical to changing the path while maintaining the velocity.

5 Measuring equipment

The measuring equipment, transducer installation and data processing shall be in accordance with ISO 15037-2.

6 Variables

The variables of motion used to describe the behaviour of the vehicle shall be related to the intermediate axis system (X, Y, Z) of the first vehicle unit (see ISO 8855). For the purpose of this International Standard, the location of the reference point is at ground level in the plane of symmetry and at the longitudinal position of the first axle of the first vehicle unit.

The following variables shall be determined for compliance with this International Standard:

— longitudinal velocity, V_X;

— lateral acceleration, a_Y;

— indication of intervention of the electronic stability control system;

— indication of roll instability, which may be indicated by the outriggers touching the ground if they are mounted at a height that corresponds to roll instability;

— indication of yaw instability of vehicle combinations, which may be indicated by the engagement of the anti-jackknife device if it is mounted in such a way that it allows an articulation angle of at least 45°.

NOTE Determination of lateral acceleration is most important prior to intervention of the stability control system. During this period, vehicle behaviour is likely to be sufficiently quasi-static to allow determination of lateral acceleration from the product of yaw velocity and longitudinal velocity.

The following variables should also be determined:

— steering-wheel angle, δ_H;

— yaw velocity, $\dot{\psi}$;

— articulation angles between vehicle units, $\Delta\psi_i$;

— brake pressures of interest, p_B;

— rotational velocity of wheels, ω_i;

— retarder operation;

— engine-torque demand;

— engine-torque actual;

— sideslip angle at the first rear axle of the first vehicle unit;

— longitudinal acceleration, a_X.

Typical operating ranges of the variables to be determined for this International Standard are shown in Table 1 and in ISO 15037-2.

Table 1 — Variables, typical operating ranges and recommended maximum errors of variables not listed in ISO 15037-2

Variable	Typical operating range	Recommended maximum error of the combined transducer–recorder system
Brake pressure in air systems	0 to 1 500 kPa	±15 kPa
Brake pressure in hydraulic systems	0 to 30 MPa	±0,3 MPa
Rotational velocity of wheels	0 to 4 000 °/s	±5 °/s

7 Test conditions

7.1 General

The test conditions specified in ISO 15037-2 apply. In addition, 7.2 applies.

7.2 Test vehicle

7.2.1 Safety equipment

Anti-rollover outriggers should be used when executing the test, especially if the test is used to investigate the performance limits of the stability control system. In the case of vehicle combinations, anti-jackknifing devices should be used.

7.2.2 Loading conditions

The standard loading condition is maximum loading with the centre of gravity of the load at least high enough to cause rollover during a test if the stability control system were disabled. The height of the centre of gravity of the load of the vehicle shall be reported. The steady-state rollover threshold should also be reported. Additional loading conditions are recommended.

8 Test method

8.1 Initial driving condition

The initial driving condition for the test shall be driving straight ahead as specified in ISO 15037-2.

8.2 Performance of the steering procedure

The vehicle shall be steered in such a way that its reference point follows a path that starts with a straight line and ends with a circular curve. The transition between the straight ahead part and the circular part shall give a constant jerk, k_a (m/s^3), at constant longitudinal velocity, V_X (m/s). The curvature of the circular part, $1/R_i$, shall give a lateral acceleration, at the test velocity, that exceeds the steady-state rollover threshold of the vehicle by at least 50 %. The accelerator pedal shall be kept constant throughout the test. Cruise control shall not be engaged. For manual transmissions, a gear position that gives an engine speed as close as possible to the maximum number of revolutions per minute shall be chosen. In order to avoid inappropriate self-calibration of the electronic vehicle stability control system, and to ensure that system parameters have achieved a steady state, test runs should be interspersed with sufficient periods of "normal" driving. Normal driving includes straight ahead driving, moderate turning in both directions and moderate accelerations and decelerations. For each combination of jerk and longitudinal velocity, the test shall be conducted at least three times, both in left- and right-hand turns. A test run is finished when the vehicle has reached steady state on the circular curve or when roll or yaw instability has occurred.

The closing-curve part of the path, as a function of the length coordinate s (m) along the path, is defined in Cartesian coordinates with the following equations. Δs is an incremental step along the path. It should not exceed 0,01 m in order to get sufficient accuracy.

$$X_m = \sum_{i=0}^{i=m} \cos\left(\frac{k_a}{2 \cdot V_X^3} \cdot s_i^2\right) \cdot \Delta s$$

$$Y_m = \sum_{i=0}^{i=m} \sin\left(\frac{k_a}{2 \cdot V_X^3} \cdot s_i^2\right) \cdot \Delta s$$

Annex B shows an example of calculating a path.

In order to find the value of jerk at which the vehicle eventually rolls over at a given test velocity, the jerk shall be increased in steps by changing the path.

To get a complete understanding of the ability of the roll stability system to prevent rollovers, as a function of jerk and velocity, tests should be carried out with different velocities. Annex C shows various examples of sequencing the tests.

Depending on the purpose, the test may be carried out with any number of combinations of velocity and jerk. In the simplest case, only one combination of velocity and value of jerk may be used.

9 Data evaluation

9.1 General

General data and test conditions shall be presented in the test report in accordance with ISO 15037-2:2002, Annex A. For every change in vehicle loading or configuration, the general data shall be documented again.

For every test run, time histories of the variables listed in Clause 6 shall be presented. Apart from their evaluation purposes, the time histories serve to monitor correct test performance and functioning of the transducers.

9.2 Average jerk

The average jerk is obtained from the portion of the time history of the lateral acceleration after the first occurrence of 1 m/s^2 and prior to intervention by the electronic roll stability system. This portion of the time history shall be subjected to linear curve fitting, and the slope of the resulting line shall be taken as the average jerk. The curve fitting shall be shown in the test report.

9.3 Validity criteria

Each closing-curve test shall meet the following criteria in order to be considered valid.

— The average jerk shall not deviate more than ±10 % from the intended value of jerk.

— The deviation of the reference point of the vehicle from the intended path shall not exceed ±0,5 m.

— The longitudinal velocity shall not vary from the intended value by more than ±5 % prior to the intervention of the electronic stability control system.

9.4 Characteristic values

The following characteristic values shall be determined for each individual closing-curve test:

— roll stability or instability for the given jerk and velocity;

— yaw stability or instability for the given jerk and velocity;

— lateral acceleration and longitudinal velocity when the electronic roll stability system intervenes.

If a series of tests with different jerks is conducted at the same velocity, the minimum average jerk at which roll instability occurs shall be determined.

9.5 Other values of interest

Other values, such as the following, should be considered:

— peak lateral acceleration for given jerk and velocity;

— peak longitudinal acceleration for given jerk and velocity.

In the case of a series of tests, the results should be displayed on a graph of initial velocity versus jerk, as shown in Figure C.1.

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.

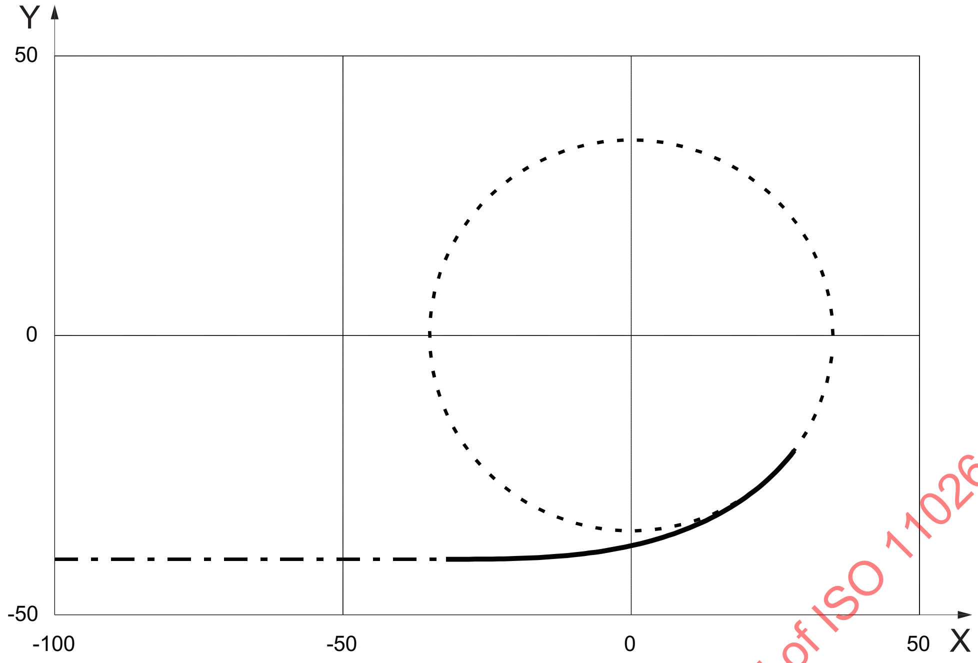
Annex B
(informative)

Example of calculating a test path

As an example, the coordinates for points at three-metre intervals along the closing-curve part of the path for the jerk 2 m/s^3 at the velocity 60 km/h are shown in Table B.1, together with the corresponding values of lateral acceleration. The coordinate system is transformed to the origin of the centre of the circular part of the path. A graph of the path, consisting of a straight line and the closing-curve part connected to the circular part with the radius 35 m, is shown in Figure B.1.

Table B.1 — Global coordinates (m) of the closing-curve part of the path for 60 km/h and 2 m/s^3 and corresponding lateral acceleration, a_y (m/s^2)

X	Y	a_y	X	Y	a_y	X	Y	a_y
–32,1	–40,0	0,0	–8,1	–39	2,9	14,7	–32,2	5,8
–29,1	–40,0	0,4	–5,2	–38,6	3,2	17,3	–30,7	6,1
–26,1	–40,0	0,7	–2,2	–38,1	3,6	19,8	–29,0	6,5
–23,1	–40,0	1,1	0,7	–37,5	4,0	22,1	–27,2	6,8
–20,1	–39,9	1,4	3,6	–36,7	4,3	24,4	–25,1	7,2
–17,1	–39,8	1,8	6,5	–35,8	4,7	26,4	–23,0	7,6
–14,1	–39,6	2,2	9,3	–34,8	5,0	28,3	–20,6	7,9
–11,1	–39,4	2,5	12,0	–33,6	5,4			



Key

Closing curve part.

Circular part.

Straight part.

Figure B.1 — The closing-curve path for 2 m/s³ at 60 km/h

Annex C
(informative)

Examples of sequencing closing-curve tests

Both jerk and vehicle velocity will influence the results of a closing-curve test. If conducted at constant velocity, the test with the highest jerk will impose the highest demands on an electronic roll stability control system. Similarly, when driven with constant jerk, the test with the highest velocity will be the most demanding. Both test parameters are important and the test procedure should be able to investigate them both, each parameter on its own and in combination.

In Tables C.1 to C.4, the rows represent examples of different test paths and the columns represent examples of desired levels of jerk. The tables give the vehicle velocity needed for achieving the desired jerk on the particular path.

Table C.1 — Velocity (km/h) as a function of closing-curve path and jerk

Closing-curve path	Jerk m/s^3				
	1,0	1,5	2,0	2,5	3,0
3,0 m/s^3 at 60 km/h					60
2,5 m/s^3 at 60 km/h				60	64
2,0 m/s^3 at 60 km/h			60	65	69
1,5 m/s^3 at 60 km/h		60	66	71	76
1,0 m/s^3 at 60 km/h	60	69	76	81	87
1,0 m/s^3 at 70 km/h	70	80	88	95	
1,0 m/s^3 at 80 km/h	80	92			
1,0 m/s^3 at 90 km/h	90				

Three different sequences of testing are now considered.

In the first case (Table C.2), the initial velocity is kept constant and the jerk is increased by using a sharper closing curve. This requires a different test path for each run.

Table C.2 — Velocity (km/h) as a function of closing-curve path and jerk (increasing jerk at constant velocity)

Closing-curve path	Jerk m/s³				
	1,0	1,5	2,0	2,5	3,0
3,0 m/s³ at 60 km/h					60
2,5 m/s³ at 60 km/h				60	64
2,0 m/s³ at 60 km/h			60	65	69
1,5 m/s³ at 60 km/h		60	66	71	76
1,0 m/s³ at 60 km/h	60	69	76	81	87
1,0 m/s³ at 70 km/h	70	80	88	95	
1,0 m/s³ at 80 km/h	80	92			
1,0 m/s³ at 90 km/h	90				

In the second case (Table C.3), the jerk is kept constant and the initial velocity is increased. This requires different test paths for each run, which become less sharp with increasing velocity.

Table C.3 — Velocity (km/h) as a function of closing-curve path and jerk (increasing velocity at constant jerk)

Closing-curve path	Jerk m/s³				
	1,0	1,5	2,0	2,5	3,0
3,0 m/s³ at 60 km/h					60
2,5 m/s³ at 60 km/h				60	64
2,0 m/s³ at 60 km/h			60	65	69
1,5 m/s³ at 60 km/h		60	66	71	76
1,0 m/s³ at 60 km/h	60	69	76	81	87
1,0 m/s³ at 70 km/h	70	80	88	95	
1,0 m/s³ at 80 km/h	80	92			
1,0 m/s³ at 90 km/h	90				