TC 22

International Standard 7975

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Road vehicles — Braking in a turn — Open loop test procedure

Véhicules routiers — Freinage en courbe — Méthode d'essai en boucle ouverte

First edition — 1985-06-15

UDC 629.11 : 620.16 : 62-59 **Ref. No. ISO 7975-1985 (E)**

Descriptors : road vehicles, private cars, tests, braking tests, road safety.

Price based on 12 pages

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 7975 was prepared by Technical Committee ISO/TC 22, *Road vehicles*.

Printed in Switzerland

Road vehicles — Braking in a turn — Open loop test procedure

0 Introduction

0.1 General remarks

The road holding ability 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 road holding ability 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 this test can only be considered significant for a correspondingly small part of the overall vehicle handling behaviour.

Moreover, nothing is known about the relationship between the results of this test and accident avoidance. Considerable work is necessary to acquire sufficient and reliable data on the correlation between handling properties in general, and accident avoidance.

It is therefore not possible to use this procedure and test results for regulation purposes at the moment.

The best that can be expected is that the braking in a turn test is used as one among many other mostly transient tests, which together cover the field of vehicle dynamic behaviour.

0.2 Object of the test

The primary object of this test is to determine the effect of braking on the directional behaviour of a vehicle, whose steady state circular motion is disturbed by the braking action only.

This procedure requires the measurement of vehicle behaviour when braking in a turn under conventional conditions and not during real traffic situations. Conventional conditions are considered those of steady state circular motion. Tests are conducted with the steering wheel fixed in the position required by initial steady state turning and then applying a constant braking effort.

It is therefore necessary to measure

	Symbol
— steering wheel angle	δ_H
— pressure in the brake circuit which activates at least one of the front wheel brakes	p_B
or brake pedal force	F_p
or brake pedal travel	s_p
— lateral acceleration (see note to 3.2.5)	a_y
— longitudinal deceleration	a_x
— forward velocity	v_x
— yaw velocity	$\dot{\Psi}$

It is desirable to measure

— stopping distance	s_B
— vehicle roll angle	φ
— vehicle pitch angle	ϑ
— sideslip angle	β
— lateral velocity	v_y
— lateral deviation of the centre of gravity from the reference path[1]	$s_y - s_{y,\mathrm{ref}}$

NOTE — Terminology and symbols given in this International Standard will be revised on publication of a future International Standard covering these subjects; it is currently in preparation.

1 Scope and field of application

This International Standard specifies a test method to determine the effect of braking on the directional behaviour of a vehicle whose steady state movement is altered only by the braking.

It applies to passenger cars as defined in ISO 3833.

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[1] Reference condition is the condition of a vehicle slowing down with the same longitudinal deceleration time history as the test vehicle without any deviation of the vehicle centre of gravity from the initial circular trajectory.

2 References

ISO 1176, *Road vehicles — Masses — Vocabulary.* [1]

ISO 2416, *Passenger cars — Load distribution.*

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

ISO 4138, *Road vehicles — Steady state circular test procedure.*

3 Instrumentation

3.1 Description

Those of the variables listed in 0.2 which are selected for test purposes shall be monitored using appropriate transducers, and the data shall be recorded on a multi-channel recorder having a time base. This does not obligatorily apply to stopping distance, which can be measured directly after the test has been completed. The normal operating ranges and recommended maximum errors of the transducer/recording systems are as shown in table 1.

NOTE — Some of the listed transducers are not widely available and are not in general use. In addition, many such instruments are developed by users. If any system error exceeds the maximum values recommended, this fact and the actual maximum error shall be stated in the general data.

The values in table 1 are tentative and provisional until more experience is available. The minimum overall bandwidth of the entire measurement system including transducers and recorder shall be 8 Hz. Digitization shall be performed at a rate of at least 20 samples per second.

3.2 Installation

Transducer installation and orientation will vary according to the type of instrumentation used. However, if a transducer does not measure the required variable directly, appropriate corrections for linear and angular displacement shall be made to its signals so as to obtain the required level of accuracy.

3.2.1 Steering wheel angle

A transducer shall be installed as specified by the manufacturer so as to obtain steering wheel angle relative to the sprung mass.

3.2.2 Pressure of the braking system

A transducer shall be installed as specified by the manufacturer so as to measure the pressure at master cylinder output.

Table 1

Variable	Range	Recommended maximum error of the combined transducer/recorder system
Steering wheel angle	± 180°	± 2°
Pressure of the braking system	150 bar[1]	± 1,5 bar[1]
Brake pedal force	700 N	± 7 N
Brake pedal travel	0,15 m	± 0,002 m
Lateral and longitudinal acceleration	± 15 m/s^2	± 0,15 m/s^2
Forward velocity	0 to 35 m/s	± 0,5 m/s
Yaw velocity	± 50°/s	± 0,5°/s
Stopping distance	150 m	± 0,5 m
Roll angle	± 15°	± 0,15°
Pitch angle	± 15°	± 0,15°
Sideslip angle	± 20°	± 0,5°
Lateral velocity	± 5 m/s	± 0,1 m/s
Lateral deviation of the centre of gravity from the reference path[2]	—	± 0,1 m

1) For hydraulic braking systems.

2) Reference condition is the condition of a vehicle slowing down with the same longitudinal deceleration time history as the test vehicle without any deviation of the vehicle centre of gravity from the initial circular trajectory.

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[1] At present at the stage of draft. (Revision of ISO 1176-1974.)

3.2.3 Brake pedal force

A transducer shall be installed as specified by the manufacturer.

3.2.4 Brake pedal travel

A transducer shall be installed as specified by the manufacturer.

3.2.5 Lateral acceleration

An accelerometer shall be installed as specified by the manufacturer and mounted on the sprung mass at any position within 50 cm of the whole vehicle centre of gravity, and parallel to the vehicle y-axis. In this case, it will measure "side acceleration" and its output shall be corrected (see note) for the component of gravity on the accelerometer axis due both to the vehicle roll angle and any track surface inclination.

NOTE — If lateral acceleration is measured by an accelerometer parallel to the vehicle y-axis[1], its output may be affected both by vehicle roll angle and vehicle sideslip angle.

In the steady state, that is before braking begins, the effect of roll angle will be significant and a correction must be made, but the effects of sideslip angle will be negligible. After braking has started, the effect of roll angle will remain the same, but the effect of sideslip angle will become greater because the lateral accelerometer will measure a component of longitudinal deceleration. In the case of a car which tends to spin out, the effect will be very great.

If corrections are made to allow for these effects, data analysis will become very complicated and it is by no means certain that the corrected values will have any more significance than the uncorrected ones.

The following action is recommended at the moment to provide maximum usefulness of results without very complex processing :

a) In the period before braking begins, the initial steady state conditions (see table 2) should be set up by driving at the forward velocity required for the chosen radius. In this way the problems associated with lateral acceleration correction are avoided. If this is not possible then lateral acceleration must be used, measured by an accelerometer parallel to the y-axis, mounted either on a stable platform, or on the body. In the latter case, it will measure side acceleration and a correction must be made for roll angle. In both cases, it is unnecessary to correct for sideslip angle. Roll angle becomes a necessary, but not desirable, parameter.

b) In the period after braking has started, although it is acknowledged that significant interaction will occur between natural gravity and longitudinal and centripetal accelerations because of sideslip and roll angles, the outputs of the longitudinal and lateral accelerations shall not be corrected whether mounted on a stable platform or not.

3.2.6 Longitudinal decelerations

An accelerometer shall be installed as specified by the manufacturer parallel to the vehicle x-axis and its output may need to be corrected for the vehicle pitch angle in order to stay within the range of the recommended maximum error (see table 1).

3.2.7 Forward velocity

A velocity transducer shall be installed as specified by the manufacturer. If it is not aligned so as to operate in the x-z plane, and parallel to the test track surface, its output shall be corrected for any linear or angular displacement therefrom.

3.2.8 Yaw velocity

A transducer shall be installed as specified by the manufacturer with its axis aligned with or parallel to the vehicle z-axis.

3.2.9 Stopping distance

A transducer shall be installed as specified by the manufacturer and on the vehicle centreline for best accuracy (see 3.1).

3.2.10 Vehicle roll angle

A transducer shall be installed as specified by the manufacturer so as to measure the angle between the vehicle y-axis and the track surface.

3.2.11 Vehicle pitch angle

A transducer shall be installed as specified by the manufacturer so as to measure the angle between the vehicle x-axis and the track surface.

3.2.12 Sideslip angle

A transducer shall be installed as specified by the manufacturer so as to measure sideslip angle. If it does not measure the angle in the plane of the track surface, an appropriate correction shall be made.

Sideslip angle can be calculated from coincident measurements of other variables, for example lateral and forward velocity at any point in the vehicle.

The point of the vehicle to which the output of the transducer is referred shall be indicated in annex A.[2]

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[1] As referred to **vehicle axis system (x, y, z)** : A right-hand orthogonal axis system fixed in the vehicle such that its origin is in the centre of gravity of the vehicle. The x-axis is in the longitudinal direction, the y-axis is lateral and the z-axis is vertical.

[2] It is recommended that the centre of gravity or the point of intersection between a line connecting the rear wheel centres and the vehicle's longitudinal median plane be used as a reference point.

3.2.13 Lateral velocity

A velocity transducer shall be installed as specified by the manufacturer. If it is not aligned so as to operate in the y-z plane, and parallel to the test track surface, its output shall be corrected for any linear or angular displacement therefrom.

The point of the vehicle to which the output of the transducer is referred shall be indicated in annex A.[1]

4 Test conditions

4.1 Test track

All tests shall be carried out on a uniform hard surface which is free of contaminants and has no more than 2 % gradient measured over a distance between 5 and 25 m in any direction. For standard test conditions, a smooth dry pavement of asphalt or cement concrete or a high friction test surface is recommended. The ambient wind speed shall not exceed 7 m/s.

4.2 Tyres

The test may be performed with tyres in any state of wear so long as, at the end of the test, a minimum of 1,5 mm of tread depth remains over the whole circumference of the tyre (see note). However, for a standard tyre condition, new tyres shall be taken and run-in for 150 to 200 km in the appropriate position on the test car without excessive harsh use, for example braking, accelerating, cornering, hitting the kerb, etc.

Tyres shall be inflated to the pressure specified by the vehicle manufacturer for the vehicle. The tolerance for setting the cold pressure is ± 0,05 bar for pressures $\leqslant$ 2,5 bar and ± 2 % for pressures $>$ 2,5 bar.

NOTE — As in certain cases the tread depth has a significant influence on test results, it is recommended that it should be taken into account when making comparisons between vehicles or between tyres.

The circumference is that part of the tyre which contacts the road surface when the vehicle is stationary and the steered wheels are in the straight-ahead position.

4.3 Operating components

All operating components likely to influence the results of this test (for example shock absorbers, springs and suspension parts) shall be inspected to ensure that they meet the manufacturer's specifications and are properly adjusted and secure.

The brakes shall be bedded fully and correctly according to procedures specified by the vehicle manufacturer or to other available specifications. The procedure used shall be indicated in the general data.

4.4 Vehicle loading conditions

4.4.1 General conditions

In no case shall the manufacturer's maximum total mass and the manufacturer's axle load, both according to ISO 1176, be exceeded.

The complete vehicle kerb mass according to ISO 1176 shall be regarded as the minimum mass.

4.4.2 Minimum loading condition

The total vehicle mass for the minimum loading condition shall consist of the complete vehicle kerb mass (see 4.4.1), plus the mass of the driver and instrumentation.

4.4.3 Maximum loading condition

For the maximum loading condition the total mass of a fully laden vehicle shall consist of the complete vehicle kerb mass (see 4.4.1), plus 68 kg for each seat in the passenger compartment, and the maximum luggage mass equally distributed over the luggage compartment according to ISO 2416. Loading of the passenger compartment shall be such that the actual wheel loads are equal to those obtained by loading each seat with 68 kg according to ISO 2416. The mass of instrumentation shall be included in the vehicle mass. Care shall be taken to give minimum error in the moments of inertia as compared to the loading conditions of the vehicle in normal use.

5 Test procedure

5.1 Tyre warm-up

The tyres shall be warmed up by a procedure equivalent to driving 500 m at a lateral acceleration of 3 m/s² on the radius to be used for the tests; the pressures may be recorded.

5.2 Initial conditions

The vehicle shall be brought to steady state initial conditions by driving around the desired circular path (see table 2) in the highest gear compatible with the conditions of the test at any level of lateral acceleration defined in table 2. The position of the steering wheel and accelerator pedal shall be kept as constant as possible. The initial conditions before brake application are defined in table 2.

Table 2

Radius	Lateral acceleration		Corresponding forward velocity	
m	m/s²	tol., %	km/h	tol., %
30 to 50	5	± 10	44 to 57	± 5
100	4	± 10	72	± 5

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[1] It is recommended that the centre of gravity or the point of intersection between a line connecting the rear wheel centres and the vehicle's longitudinal median plane be used as a reference point.

In order to verify that in the time interval immediately preceding the braking procedure the values of lateral acceleration and forward velocity have been as constant as possible, one of the following methods may be used :

a) Determination of the standard deviation from the digitized values (see 3.1); in this case the standard deviation of the lateral acceleration shall not exceed 5 % of its mean value for at least 1 s before brake application and the standard deviation of the forward velocity shall not exceed 3 % of its mean value for the time interval of 0,3 to 1,3 s before brake application.

b) Determination of the difference between the mean values during 1,3 to 0,8 s and 0,8 to 0,3 s before brake application for the lateral acceleration and forward velocity. This difference shall not exceed the latter mean value by more than 5 % for the lateral acceleration and not more than 3 % for the forward velocity.

NOTE — It is known that increased test speed gives greater discrimination between different vehicles, but the extent of this effect and that of the test radius is not yet known. The above conditions are suggested until more information is available.

5.3 Braking procedure

The accelerator pedal shall be released and braking applied as quickly as possible. The clutch may be disengaged immediately or at the end of the test run; the option chosen shall be indicated in the general data in annex A.

After the rise time (less than 0,4 s, see figure 1) the pressure in the braking system (see 6.1.1) or the brake pedal force or brake pedal travel (see 6.1.2) shall be kept as constant as possible (a hydraulic pressure limiter or an adjustable stop under the pedal may serve) and the steering wheel shall be fixed until the test run is finished.

The test runs for each combination of radii and lateral accelerations defined in table 2 shall be made at increasing levels of pressure, pedal force, pedal travel until lock up of one wheel occurs (if possible). The test may be continued beyond this point resulting in further wheels locking until lock up of all wheels has occurred, but testing under these conditions may result in rapid and large changes of tyre characteristics, which may cause wide variation in test results.

The minimum braking action (see 6.1) shall correspond to a mean longitudinal deceleration (see 6.2.1) of 2 m/s^2 and then increase by increments of not more than 1 m/s^2; if the results vary rapidly with longitudinal deceleration, it may be better to select smaller increments.

Tests shall be carried out in both turn directions.

6 Data analysis

6.1 Braking action

6.1.1 Definition of initial time and rise time

Figure 1 shows the pattern of pressure in the braking system and of longitudinal deceleration versus time.

The interval between the time t_d when the longitudinal deceleration first exceeds 0,5 m/s1) and the time t_i shall not exceed 0,4 s (see figure 1).

The rise time shall also not exceed 0,4 s. This is defined as the interval between the time t_i when the pressure reaches 5 % and the time t_o when the pressure reaches 90 % of the mean value.

The mean pressure is evaluated during the time interval between the pressure first reaching 95 % of the pressure 1,8 s after the time t_d, and 1,8 s after the time t_d.

The difference between the mean pressure defined above and the mean pressure in the time interval from 1,8 and 2,8 s after t_d shall not exceed 10 % of the first mean value.

6.1.2 Alternatives

If brake pedal force or brake pedal travel is measured instead of pressure in the braking system, the rise time is defined in the same way as shown under 6.1.1. In this case braking pressure is replaced by brake pedal force or travel.

6.2 Longitudinal deceleration

6.2.1 Mean longitudinal deceleration

Mean longitudinal deceleration is the average value of longitudinal deceleration during each brake application.

This average value may be obtained by either

a) measuring the distance needed by the car to stop from instant t_i; mean longitudinal deceleration will be

$$\bar{a}_x = \frac{v_{\text{eff}}^2}{2 s_{\text{eff}}}$$

where

s_{eff} is the actual stopping distance,

v_{eff} is the actual initial test speed; or

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1) In the steady state condition the indicated value of the longitudinal acceleration can deviate from zero caused by the measurement of the acceleration in the direction of the vehicle's longitudinal axis. In this case t_d can be defined as the time when the acceleration reaches the value 0,5 m/s^2 less than the value in the initial condition.

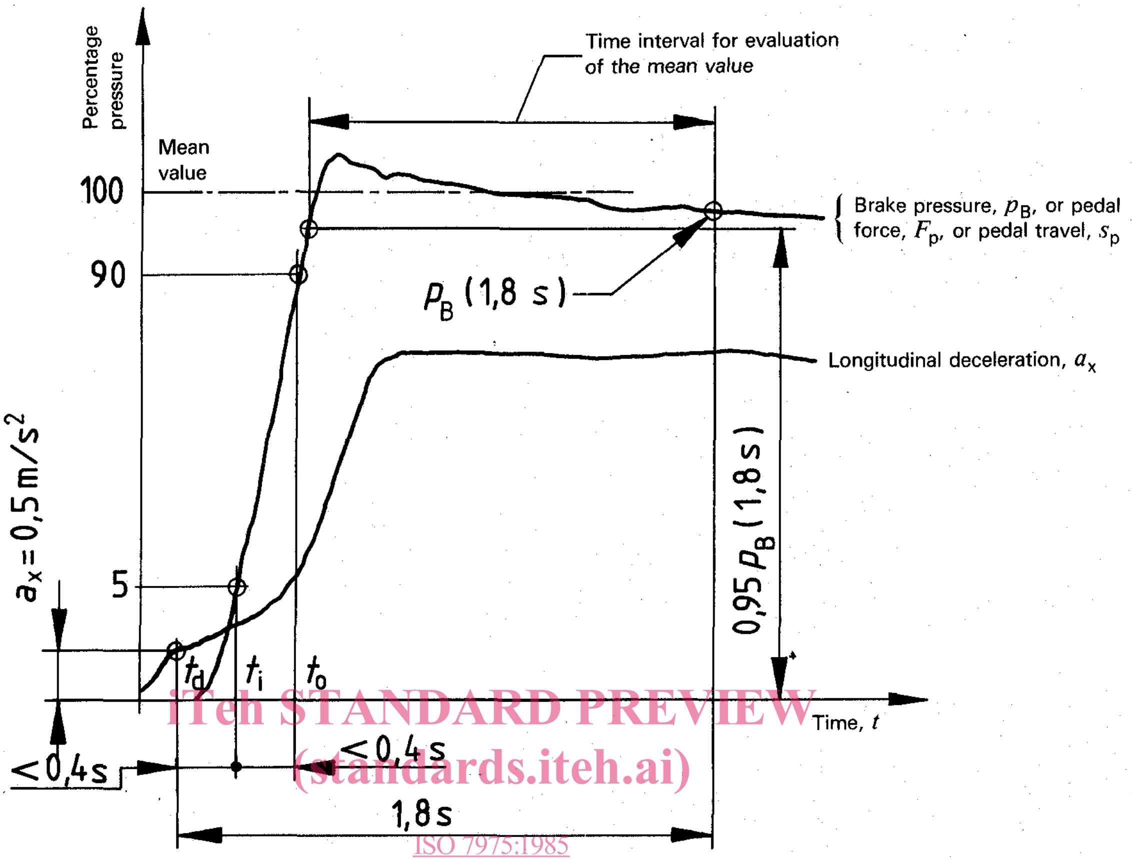

Figure 1

b) taking the mean value in the time interval t_i to t_f (see figure 2) of the output of the longitudinal deceleration transducer, suitably corrected when necessary.

6.2.2 Longitudinal deceleration at time t_n

The longitudinal deceleration at any time t_n after brake application (t_i) is considered to be the mean value during the period of $t_n \pm 0,1$ s.

7 Data presentation

7.1 General requirements

General data shall be presented on the summary form as shown in annex A for each loading condition.

Time histories of all quantities listed in 0.2 for each brake application shall be shown.

At the present state of the art it is still not known what variables can better describe the responses of vehicles which are safer and better accepted by users during in-turn brake application. The variables listed below hence do not comprise a complete list. The plots in annex B are therefore only examples.

7.2 Variables as a function of time

For each test run calculate and plot as a function of time :

a) the difference between the actual and reference yaw velocity according to the equation

$$\Delta\dot{\Psi}(t) = \dot{\Psi}(t) - v_x(t)/R_o$$

b) the difference between the actual and reference lateral acceleration according to the equation

$$\Delta a_y(t) = a_y(t) - \frac{[v_x(t)]^2}{R_o}$$

c) the difference between the actual and calculated yaw velocity according to the equation

$$\dot{\beta}'(t) = \dot{\Psi}(t) - \frac{a_y(t)}{v_x(t)}$$

where $\dot{\beta}'(t)$ is the sideslip angle velocity uncorrected for the effects of the sideslip angle itself and the deceleration. It gives information on the vehicle's yaw stability;

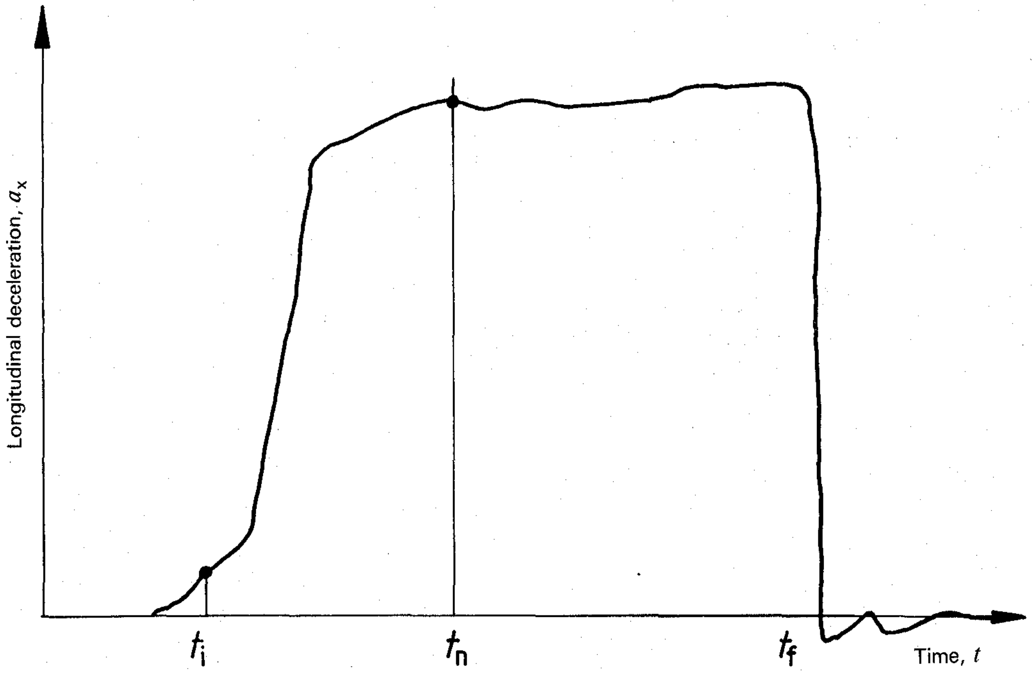

Figure 2

d) the difference between the nominal initial and the uncorrected calculated radius of turn according to the equation

$$\Delta R(t) = R_o - \frac{[v_x(t)]^2}{a_y(t)}$$

7.3 Variables as a function of longitudinal deceleration

For each set of initial conditions calculate and plot, as a function of mean longitudinal deceleration:

a) the ratio between the maximum value attained by yaw velocity during braking and the initial steady state value of yaw velocity :

$$\dot{\Psi}_{max}/\dot{\Psi}_o = f_1(\overline{a}_x)$$

b) the ratio between the maximum value attained by lateral acceleration during braking and the initial steady state value of lateral acceleration :

$$a_{y,\,max}/a_{y,\,o} = f_2(\overline{a}_x)$$

c) the ratio between the maximum value attained by the sideslip angle (if measured) during braking and the initial steady state value of sideslip angle :

$$\beta_{max}/\beta_o = f_3(\overline{a}_x)$$

d) the maximum value of the yaw velocity difference [calculated according to 7.2 a)] :

$$\Delta\dot{\Psi}_{max} = f_4(\overline{a}_x)$$

e) the ratio between the mean values of actual and reference yaw velocity according to the equation :

$$\frac{\overline{\dot{\Psi}}}{\overline{\dot{\Psi}}_{ref}} = \overline{\dot{\Psi}} / (\dot{\Psi}_o/2) = f_5(\overline{a}_x)$$

7.4 Variables as a function of longitudinal deceleration at time t_n

For each set of initial conditions calculate and plot, as a function of longitudinal deceleration at time t_n (1 s after brake application)[1] :

a) the ratio between the value of yaw velocity at time t_n and the initial steady state value of yaw velocity (normalized yaw velocity at actual time) (see figure 5 in annex B) :

$$\dot{\Psi}_{t_n} / \dot{\Psi}_o = f_6(a_{x,\,t_n})$$

b) the ratio between the value of lateral acceleration at time t_n and the initial steady state value of lateral acceleration (normalized lateral acceleration of actual time) (see figure 6 in annex B) :

$$a_{y,\,t_n}/a_{y,\,o} = f_7(a_{x,\,t_n})$$

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[1] t_n can also assume additional values.