INTERNATIONAL STANDARD

ISO 17288-2

First edition
2004-08-15

Passenger cars — Free-steer behaviour —

Part 2: Steering-pulse open-loop test method

Voitures particulières — Comportement volant libre —

Partie 2: Méthode d'essai en boucle ouverte avec impulsion au volant

Reference number
ISO 17288-2:2004(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 iv
Introduction v
1 Scope 1
2 Normative references 1
3 Terms and definitions 1
4 Principle 1
5 Variables 2
6 Measuring equipment 2
7 Test conditions 3
8 Test procedure 3
9 Data analysis 4
Bibliography 13

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 17288-2 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

ISO 17288 consists of the following parts, under the general title *Passenger cars — Free-steer behaviour*:

— *Part 1: Steering-release open-loop test method*

— *Part 2: Steering-pulse open-loop test method*

Introduction

The dynamic behaviour of road vehicles 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 dynamic behaviour is therefore very difficult since there is a significant interaction between these driver–vehicle–environment elements, and each element is individually complex itself. 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. Since they quantify only a small part of the whole handling field, 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 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 the free-steer behaviour tests be used as some of many tests which, taken together, will cover the field of vehicle dynamic behaviour.

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

Passenger cars — Free-steer behaviour —

Part 2: Steering-pulse open-loop test method

1 Scope

This part of ISO 17288 specifies a procedure for determining the free control stability of a passenger car as defined in ISO 3833, by measurement of the transient behaviour following steering pulse input, starting from a straight-ahead, steady-state status.

NOTE The open loop manoeuvre specified in this part of ISO 17288 is not representative of normal driving conditions, but is useful for obtaining a measure of vehicle transient behaviour.

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3833 and ISO 8855 apply.

4 Principle

This test is intended to evaluate the ability of the vehicle to return to a straight path following a steering pulse input from a straight-ahead, steady-state driving initial condition.

Oscillation of the vehicle is initiated by the application of a single pulse steering input. This is followed by release of the steering wheel and a period during which the steering wheel is free. The steering-wheel angle and the vehicle response are measured and recorded. From the recorded signals, characteristic values are calculated.

5 Variables

5.1 Reference system

The provisions given in ISO 15037-1:1998, 3.1, apply.

5.2 Measurement

Measure the following variables (see ISO 8855):

a) longitudinal velocity (v_X);

b) lateral acceleration (a_Y);

c) yaw velocity ($\dot{\psi}$);

d) steering-wheel angle (δ_H).

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 transducer and recording system, are given in Table 1.

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

Variable	Typical operating range	Recommended maximum error of the combined transducer and recorder system
Longitudinal velocity	0 m/s to + 50 m/s	± 0,3 m/s
Lateral acceleration	− 15 m/s^2 to + 15 m/s^2	± 0,1 m/s^2
Yaw velocity	− 50°/s to + 50°/s	± 0,3°/s
Steering-wheel angle	− 360° to + 360°	± 2° for $\lvert\delta_H\rvert \leqslant$ 180° ± 4° otherwise

Transducers for measuring some of the listed variables are not widely available and 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 given in ISO 15037-1:1998, Annex A.

6.2 Transducer installation

6.2.1 General

The transducer installation shall comply with ISO 15037-1:1998, 4.2. For the steering-wheel angle, the additional requirements given in 6.2.2, below, shall apply.

6.2.2 Steering-wheel angle

It is recommended that the steering-wheel angle be measured using transducers in conjunction with the original steering wheel of the vehicle. Alternatively, a replacement instrumented steering wheel may be used. In either event, care should be taken to avoid changing the mass centre, inertial properties or friction of the steering system. Any changes shall be recorded in the test report given in ISO 15037-1:1998, Annex B.

NOTE Free control behaviour is known to be sensitive to the friction and inertia characteristics of the steering system. In addition, it is sensitive to the mass and mass offset of the steering wheel.

6.3 Data processing

The provisions given in ISO 15037-1:1998, 4.3, apply.

7 Test conditions

Test conditions shall be in accordance with ISO 15037-1:1998, Clause 5.

8 Test procedure

8.1 General

All details of the test shall be recorded in the test report specified in ISO 15037-1:1998, Annexes A and B, under “General comments and/or other relevant details” and “Test method specific data”, respectively.

8.2 Warm-up

The warm-up shall be carried out in accordance with ISO 15037-1:1998, 6.1.

8.3 Starting conditions of the test

The starting condition for the test is steady-state straight-ahead running motion at a prescribed longitudinal velocity v_X. The steady-state straight-ahead running motion shall be in accordance with ISO 15037-1:1998, 6.2.1.

The test shall be conducted for a minimum of three longitudinal velocities. These shall include the standard longitudinal velocity of 100 km/h, and other velocities varied in steps of ± 20 km/h.

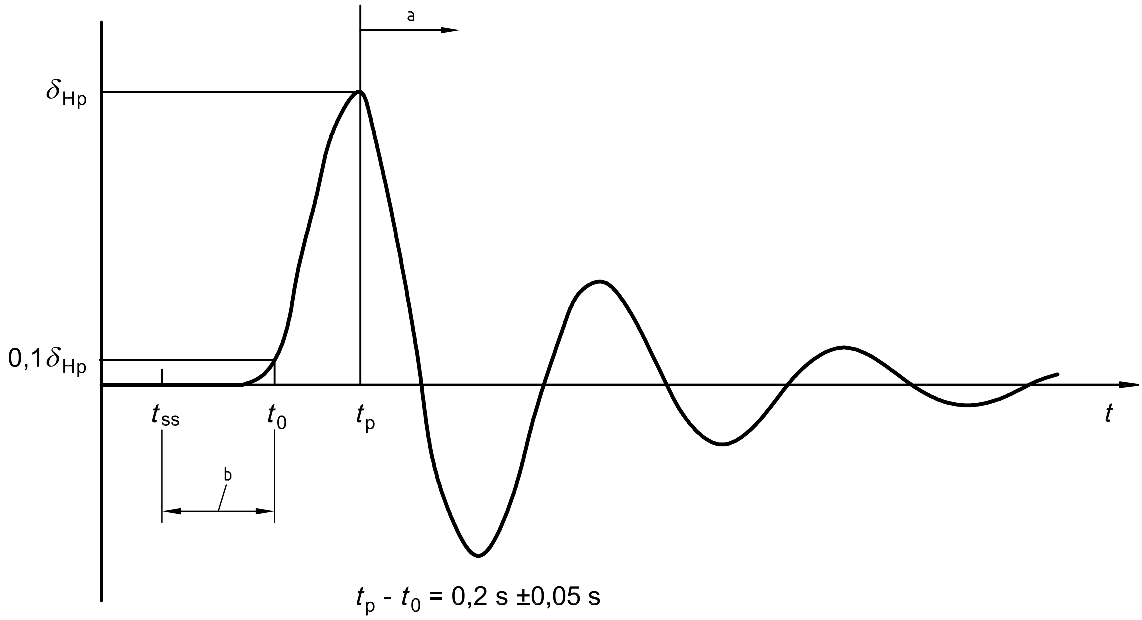
8.4 Test execution

From each starting condition, the driver shall apply the steering pulse input to a predetermined value and release the steering wheel immediately to place the vehicle in free control with its response determined by its dynamic characteristics. The throttle shall be maintained constant, even though velocity can decrease.

The test shall be conducted with an amplitude of steering-wheel angle sufficient to produce the initial lateral acceleration (a_{Y0}) of 1 m/s^2. The test shall be repeated with incremented amplitude of steering-wheel angle peak δ_{Hp}, such that lateral acceleration is incremented in steps of not more than 0,5 m/s^2 up to a level of at least 5 m/s^2. See Figures 1 and 2.

Referring to the example time history of steering-wheel angle shown in Figure 1, t_0 is the time, in seconds, at which the amplitude of steering wheel angle first exceeds 10 % of its maximum amplitude δ_{Hp}, and t_p is the time of maximum amplitude at which the steering wheel is released. The rise time of pulse input ($t_p - t_0$) shall be 0,2 s ± 0,05 s. Test data are recorded from time t_{ss} – 0,5 s until 1 s after the steering oscillation is completely damped or until t_0 + 5 s — whichever is shorter.

Where possible, the test should be conducted in both left and right turning directions.



Key

t time, s

δ_{Hp} maximum amplitude of steering-wheel angle

a Free steer control.

b 0,5 s to 0,8 s.

Figure 1 — Steering-wheel angle input

9 Data analysis

9.1 General

General data shall be presented in the test report given in ISO 15037-1:1998, Annexes A and B.

The recorded time history of the following variables shall be displayed and examined visually. Results not considered to be representative shall be discarded:

— yaw velocity;

— steering-wheel angle;

— sideslip angular velocity.

NOTE Sideslip angular velocity is usually calculated by the formula:

$$\dot{\beta}(t) = \frac{a_Y(t)}{v_X(t)} - \dot{\psi}(t) \quad (1)$$

where

v_X is the longitudinal velocity of the vehicle;

$\dot{\psi}$ is the yaw velocity of the vehicle;

a_Y is the lateral acceleration of the vehicle.

9.2 Damping and damping time of yaw velocity

Referring to the example time history of yaw velocity shown in Figure 2, all amplitudes starting with the second peak shall be determined. Calculate the mean value of the amplitude ratios, $\bar{r}$, using Equation (2):

$$\bar{r} = \frac{1}{n-2}\left\{\frac{\dot{\psi}_1 + \dot{\psi}_2}{\dot{\psi}_2 + \dot{\psi}_3} + \frac{\dot{\psi}_2 + \dot{\psi}_3}{\dot{\psi}_3 + \dot{\psi}_4} + \frac{\dot{\psi}_3 + \dot{\psi}_4}{\dot{\psi}_4 + \dot{\psi}_5} + \ldots + \frac{\dot{\psi}_{n-2} + \dot{\psi}_{n-1}}{\dot{\psi}_{n-1} + \dot{\psi}_n}\right\} \quad (2)$$

NOTE Each amplitude, $\dot{\psi}_n$, is an absolute value.

$\dot{\psi}_{n-1} + \dot{\psi}_n$ shall be at least 10 % of $\dot{\psi}_1 + \dot{\psi}_2$, or $\dot{\psi}_n$ shall be the last amplitude of the recorded time period of 5 s.

When the amplitude of third peak, $\dot{\psi}_3$, is too small to be determined clearly, or $\dot{\psi}_2$ is smaller than 10 % of $\dot{\psi}_1$, calculate $\bar{r}$ using Equation (3):

$$\bar{r} = \frac{\dot{\psi}_1}{\dot{\psi}_2} \quad (3)$$

Calculate the damping of yaw velocity, D, using Equation (4):

$$D = \frac{\ln \bar{r}}{\sqrt{\pi^2 + (\ln \bar{r})^2}} \quad (4)$$

Calculate the damping time of yaw velocity, $T_{0,1}$ — which indicates the duration of yawing oscillation (i.e. the time period required to decrease the yaw velocity within 10 % level of peak 1) — using Equation (5):

$$T_{0,1} = \frac{\ln 10}{D \times \omega} \quad (5)$$

where

$$\omega = \frac{\pi(n-1)}{(t_n - t_1)\sqrt{1-D^2}} \quad (6)$$

For each of the variables

— damping of yaw velocity, and

— damping time of yaw velocity:

a) evaluate the functions $f(a_{Y0}) = D$ and $f(a_{Y0}) = T_{0,1}$, at each level of initial lateral acceleration a_{Y0};

b) plot the functions $f(a_{Y0})$ vs a_{Y0};

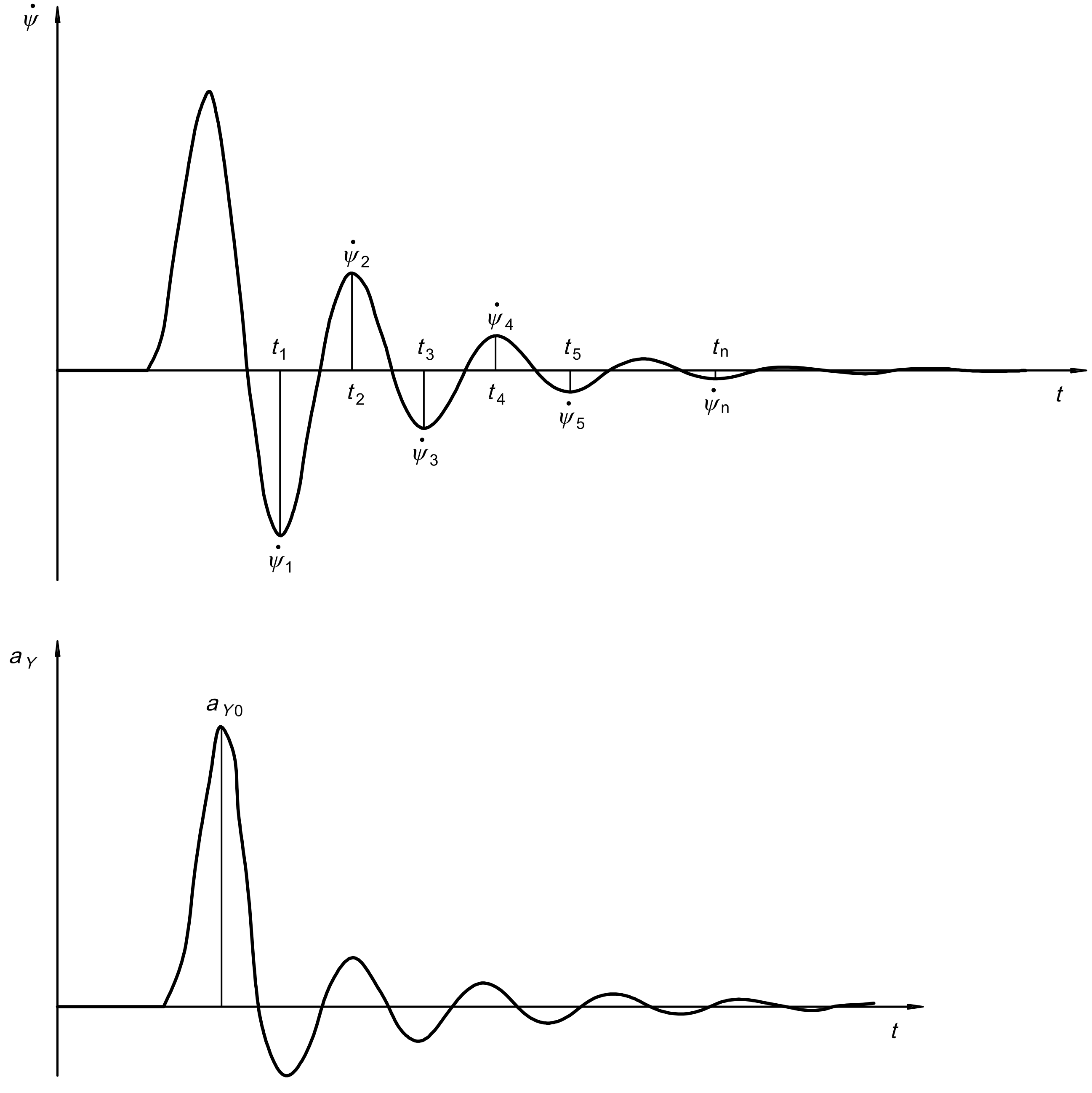
c) compute the linear regression between 3 m/s^2 and 5 m/s^2 (see Figures 3 and 4);

d) calculate q, the value of the linear regression at a lateral acceleration of 4 m/s^2;

e) calculate m, the gradient of the linear regression, using Equation (7):

$$m = (q_5 - q_3)/2 \quad (7)$$

f) plot q and m vs longitudinal velocity (see Figures 5, 6, 7 and 8)



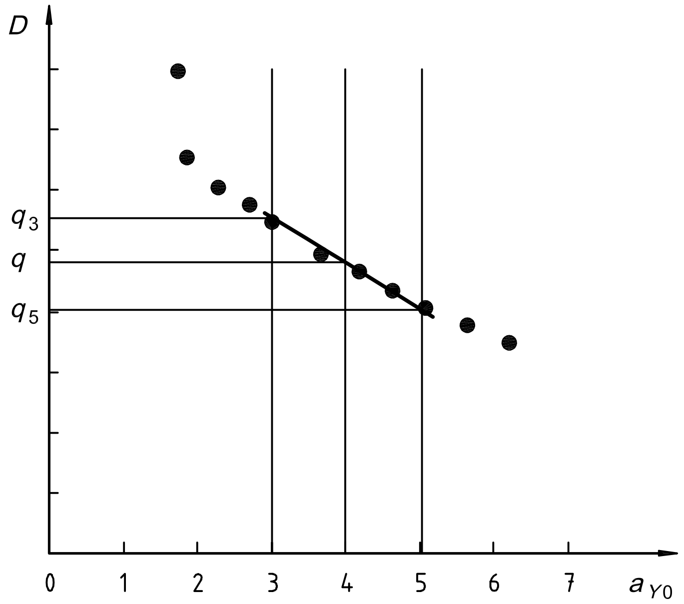
Key

t time, s

$\dot{\psi}$ yaw velocity

a_Y lateral acceleration

Figure 2 — Determination of amplitude



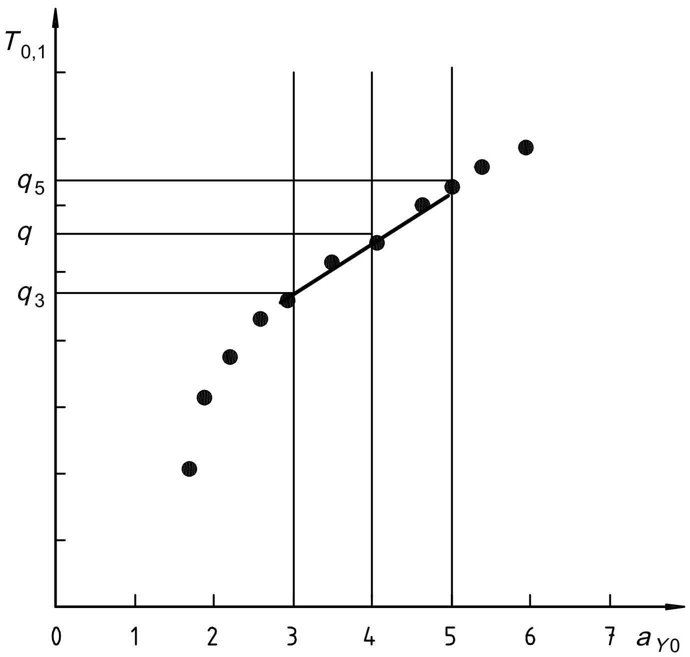
Key

a_{Y0} lateral acceleration, m/s^2

D damping of yaw velocity

q value of linear regression

Figure 3 — Typical aspect of damping vs a_{Y0}



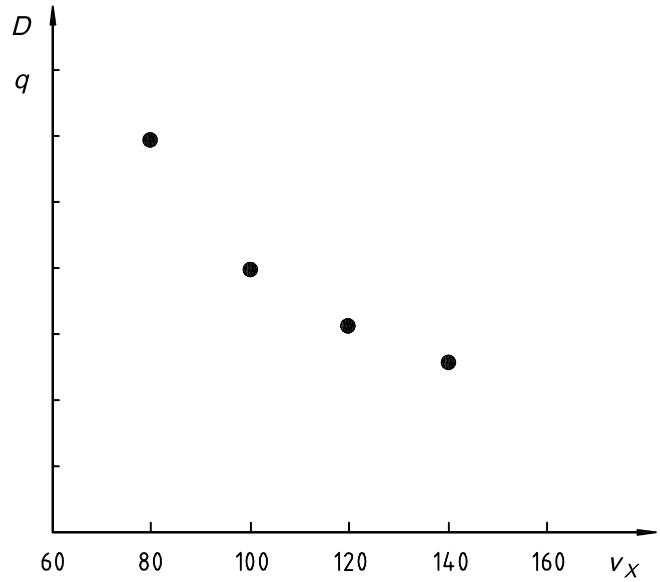
Key

a_{Y0} lateral acceleration, m/s^2

$T_{0,1}$ damping time of yaw velocity

q value of linear regression

Figure 4 — Typical aspect of damping time vs a_{Y0}



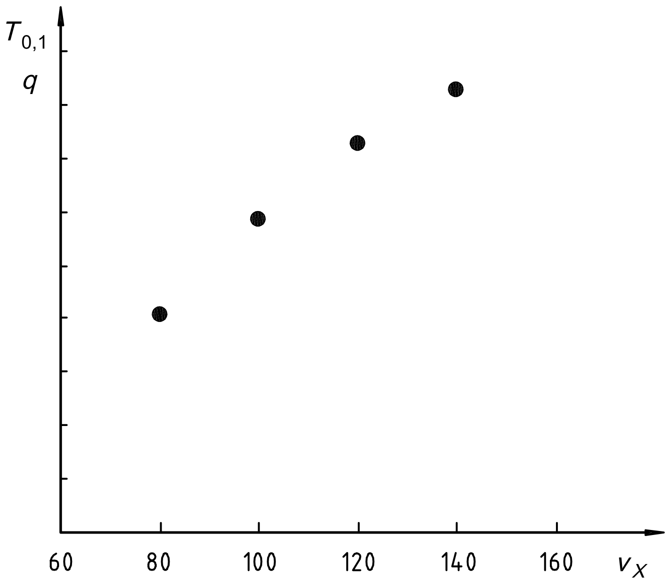
Key

v_X longitudinal velocity, km/h

D damping of yaw velocity

q value of linear regression

Figure 5 — q of damping value vs longitudinal velocity



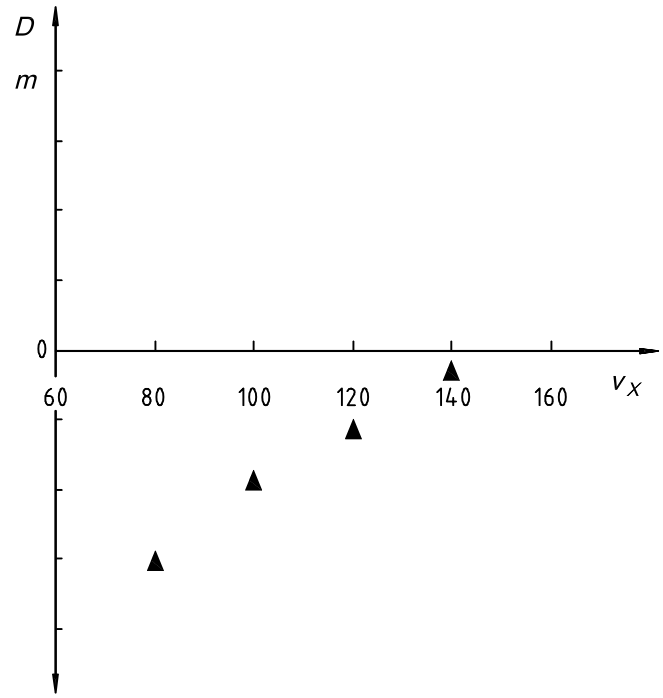
Key

v_X longitudinal velocity, km/h

$T_{0,1}$ damping time of yaw velocity

q value of linear regression

Figure 6 — q of damping time vs longitudinal velocity



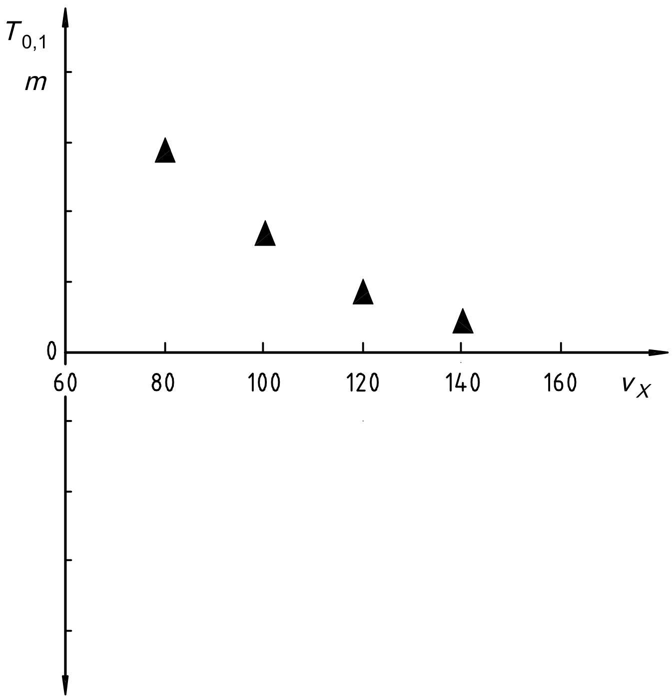
Key

v_X longitudinal velocity, km/h

D damping of yaw velocity

m gradient of linear regression

Figure 7 — m of damping value vs longitudinal velocity



Key

v_X longitudinal velocity, km/h

$T_{0,1}$ damping time of yaw velocity

m gradient of linear regression

Figure 8 — m of damping time vs longitudinal velocity

9.3 Ratio between second and first peak of a given variable after steering wheel release

This method of data analysis may be used when observed free control behaviour is not oscillatory enough to calculate the damping.

EXAMPLE Test at low longitudinal velocity.

For each of the variables

— yaw velocity,

— steering-wheel angle, and

— sideslip angular velocity

(see Figures 9 and 10):

a) evaluate the function $f(a_{Y0})$ = peak 2/peak 1, at each level of initial lateral acceleration a_{Y0};

b) plot the function $f(a_{Y0})$ vs a_{Y0};

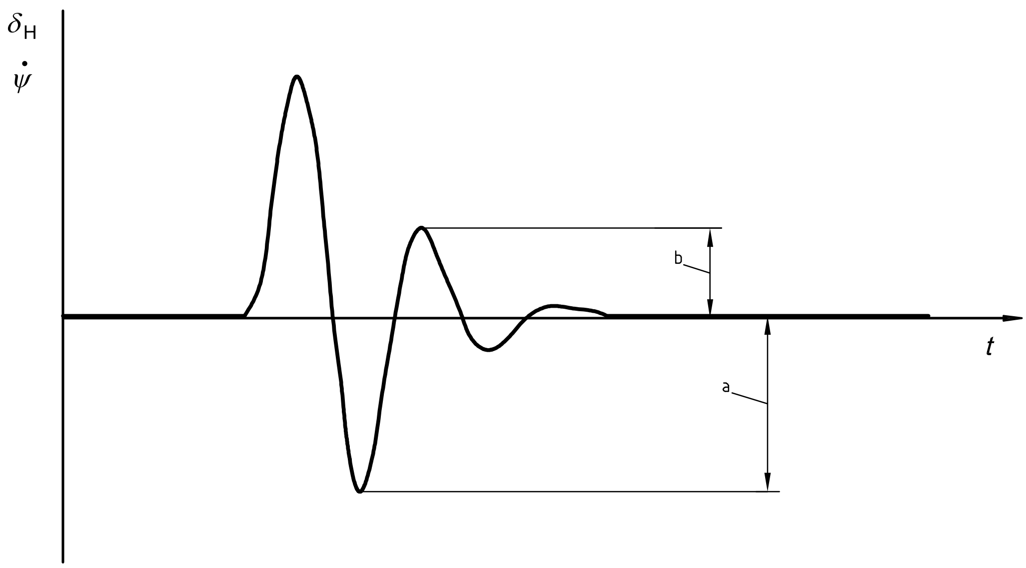
c) compute the linear regression between 3 m/s² and 5 m/s² (see Figure 11);

d) calculate "q", the value of the linear regression at a lateral acceleration of 4 m/s².

e) calculate "m", the gradient of linear regression, using Equation (8):

$$m = (q_5 - q_3)/2 \tag{8}$$

f) plot q and m vs longitudinal velocity (see Figures 12 and 13).



Key

t time, s

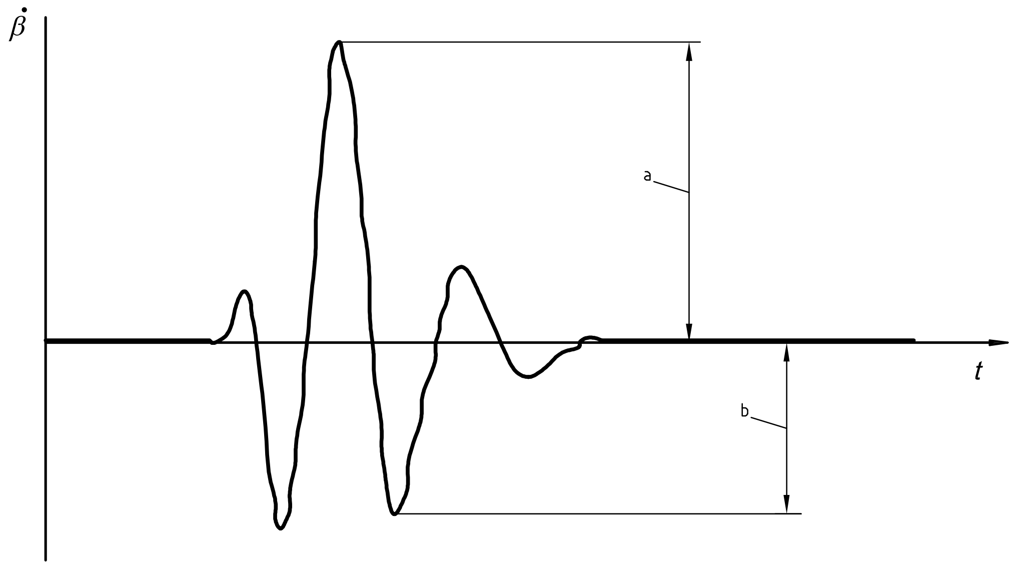
$\dot{\psi}$ yaw velocity

δ_H steering-wheel angle

a Peak 1.

b Peak 2.

Figure 9 — Peaks of variable after steering-wheel release — Steering-wheel angle, yaw velocity



Key

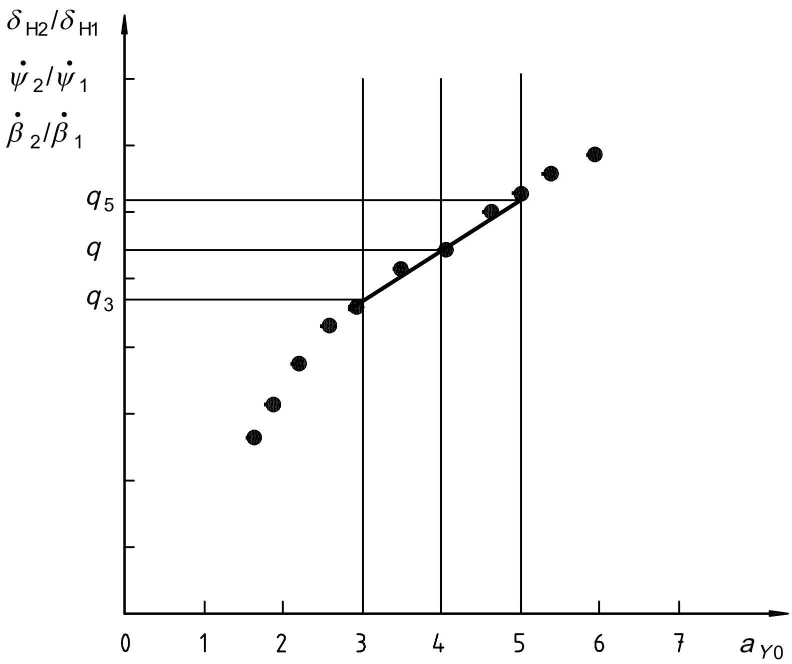
t time, s

$\dot{\beta}$ sideslip angular velocity

a Peak 1.

b Peak 2.

Figure 10 — Peaks of variable after steering-wheel release — Sideslip angular velocity



Key

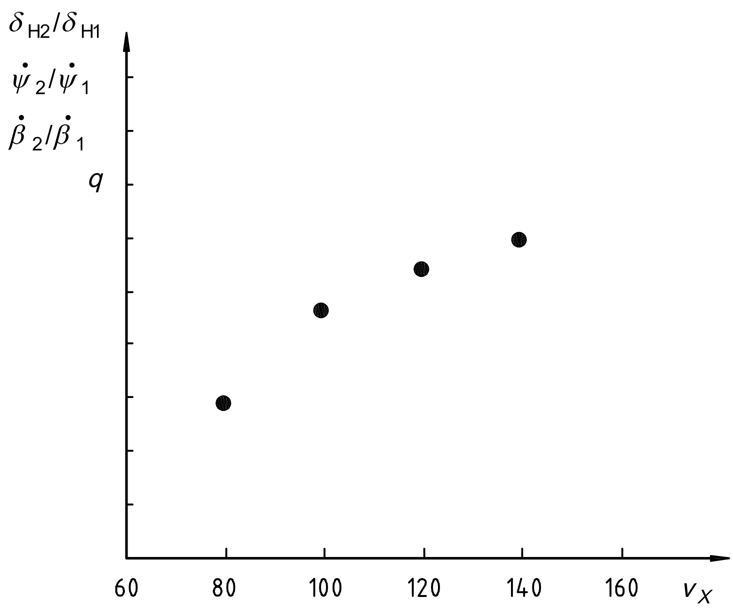
a_{Y0} lateral acceleration, m/s^2

δ_H steering-wheel angle

$\dot{\psi}$ yaw velocity

$\dot{\beta}$ sideslip angular velocity

Figure 11 — Typical aspect of functions of lateral acceleration vs a_{Y0}



Key

v_X longitudinal velocity, km/h

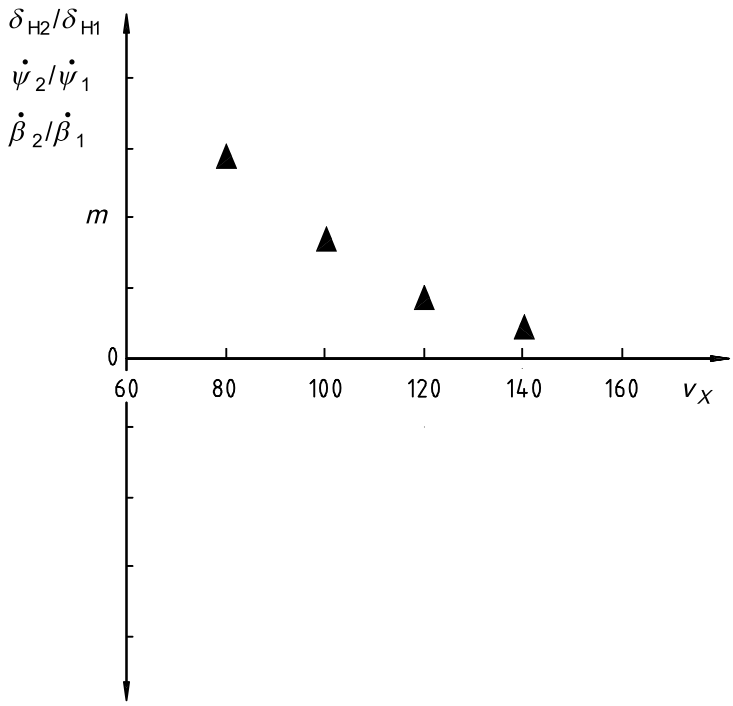
δ_H steering-wheel angle

$\dot{\psi}$ yaw velocity

$\dot{\beta}$ sideslip angular velocity

q value of linear regression

Figure 12 — q of ratio between the second and first peak vs longitudinal velocity — Steering-wheel angle, yaw velocity, sideslip angular velocity



Key

v_X longitudinal velocity, km/h

δ_H steering-wheel angle

$\dot{\psi}$ yaw velocity

$\dot{\beta}$ sideslip angular velocity

m gradient of linear regression

Figure 13 — m of ratio between the second and first peak vs longitudinal velocity — Steering-wheel angle, yaw velocity, sideslip angular velocity

Bibliography

[1] ISO 1176:1990, *Road vehicles — Masses — Vocabulary and codes*

[2] ISO 2416:1992, *Passenger cars — Mass distribution*

ICS 43.100

Price based on 13 pages