

BS ISO 17288-2:2011



BSI Standards Publication

# Passenger cars — Free-steer behaviour

Part 2: Steering-pulse open-loop test  
method

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**National foreword**

This British Standard is the UK implementation of ISO 17288-2:2011. It supersedes BS ISO 17288-2:2004 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AUE/15, Safety related to vehicles.

A list of organizations represented on this committee can be obtained on request to its secretary.

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**Amendments issued since publication**

Date	Text affected
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**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*



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## Foreword

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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*.

This second edition cancels and replaces the first edition (ISO 17288-2:2004), of which it constitutes a minor revision.

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 main purpose of this part of ISO 17288 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.





# 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 15037-1:2006, *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 15037-1:2006, 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 ( $\delta_H$ ).

## 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	$\pm 0,3$ m/s
Lateral acceleration	$-15 \text{ m/s}^2$ to $+15 \text{ m/s}^2$	$\pm 0,1 \text{ m/s}^2$
Yaw velocity	$-50^\circ/\text{s}$ to $+50^\circ/\text{s}$	$\pm 0,3^\circ/\text{s}$
Steering-wheel angle	$-360^\circ$ to $+360^\circ$	$\pm 2^\circ$ for $ \delta_H  \leq 180^\circ$ $\pm 4^\circ$ 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 Annex A of ISO 15037-1:2006.

### 6.2 Transducer installation

#### 6.2.1 General

The transducer installation shall comply with ISO 15037-1:2006, 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 15037-1:2006, 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 15037-1:2006, 4.3, apply.

## 7 Test conditions

Test conditions shall be in accordance with ISO 15037-1:2006, Clause 5.

## 8 Test procedure

### 8.1 General

All details of the test shall be recorded in the test report specified in ISO 15037-1:2006, 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 15037-1:2006, 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 15037-1:2006, 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  $\pm 20$  km/h.

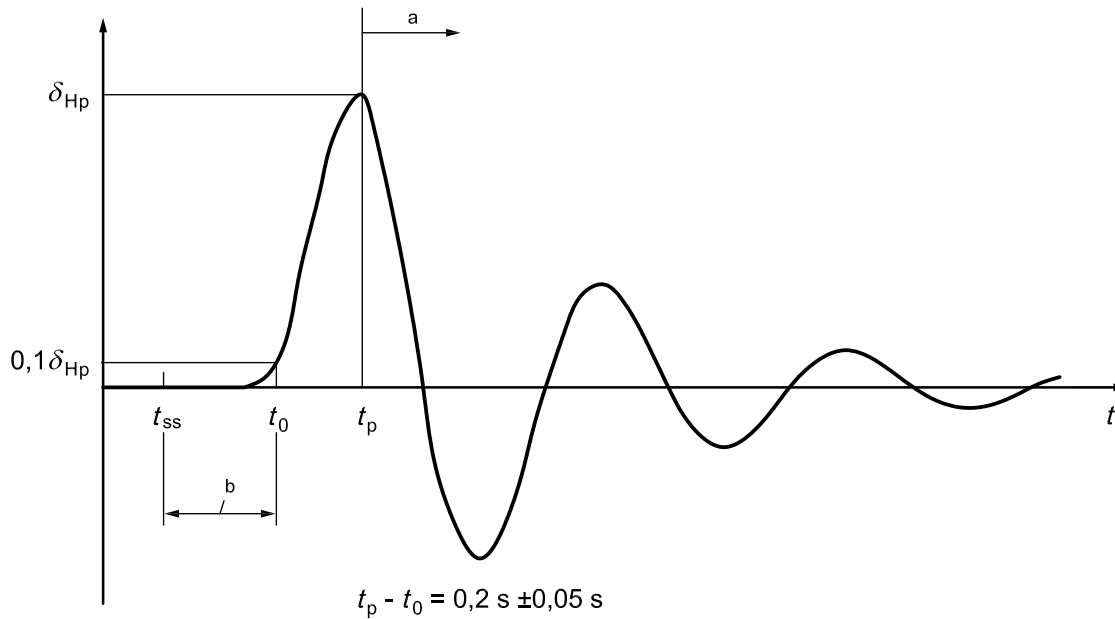
### 8.4 Test execution

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  $1 \text{ m/s}^2$ . The test shall be repeated with incremented amplitude of steering-wheel angle peak  $\delta_{HP}$ , such that lateral acceleration is incremented in steps of not more than  $0,5 \text{ m/s}^2$  up to a level of at least  $5 \text{ m/s}^2$ . 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  $\delta_{HP}$ , 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  $0,2 \text{ s} \pm 0,05 \text{ s}$ . Test data are recorded from time  $t_{SS} - 0,5 \text{ s}$  until 1 s after the steering oscillation is completely damped or until  $t_0 + 5 \text{ s}$ , whichever is shorter.

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



**Key**

- $t$  time, s
- $\delta_{Hp}$  maximum amplitude of steering-wheel angle
- $t_p$  time of maximum amplitude of steering-wheel angle (at which steering wheel is released)
- $t_{ss}$  point in time from which steady-state straight-ahead driving is recommended
- $a$  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 15037-1:2006, 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:

$$\dot{\beta}(t) = \frac{a_y(t)}{v_x(t)} - \dot{\psi}(t) \tag{1}$$

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;

$t$  is time.

## 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):

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

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:

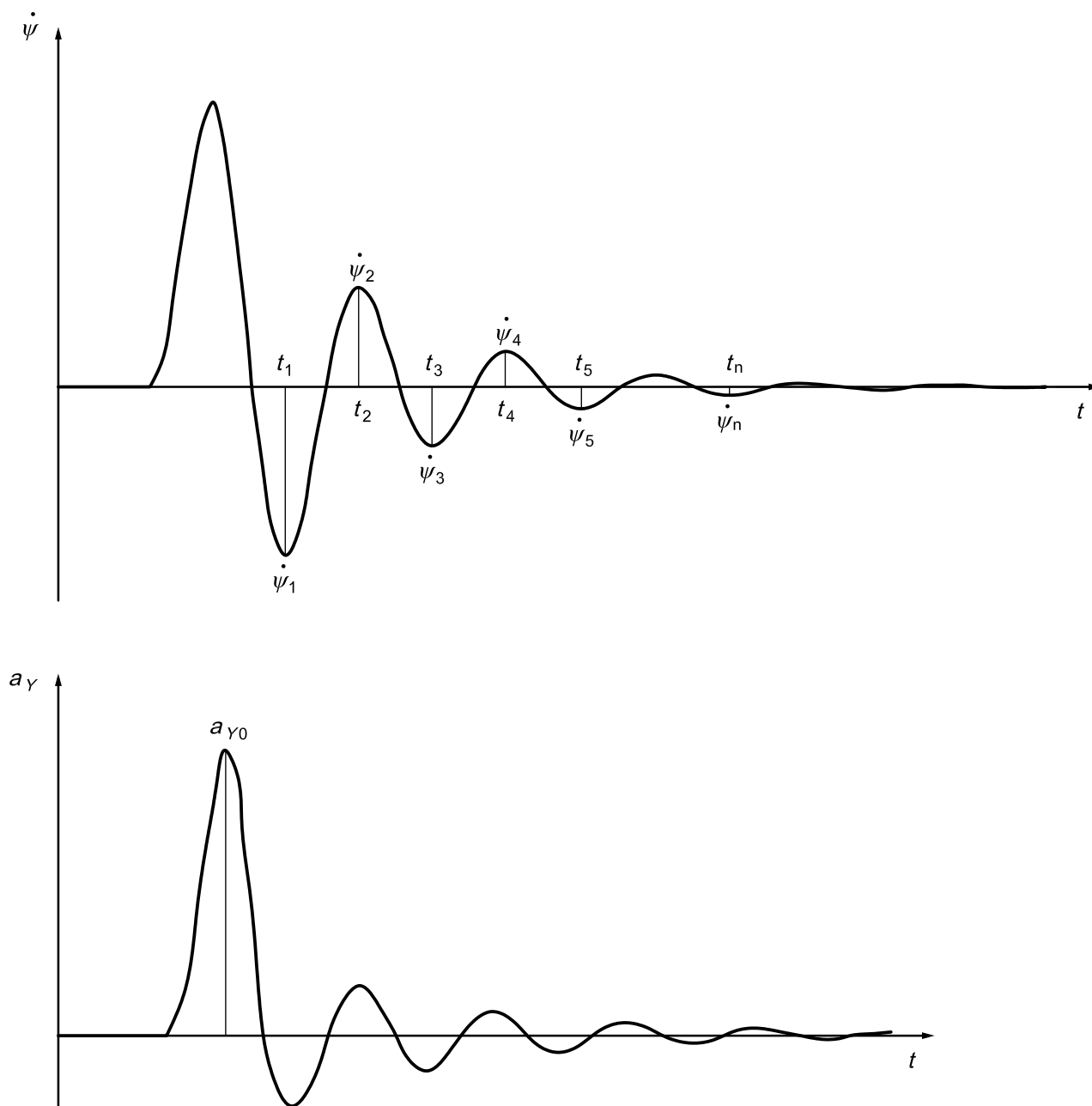
a) evaluate the functions  $f(a_{Y0}) = D$  and  $f(a_{Y0}) = T_{0,1}$ , at each level of initial lateral acceleration  $a_{Y0}$ ;

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

- c) compute the linear regression between 3 m/s<sup>2</sup> and 5 m/s<sup>2</sup> (see Figures 3 and 4);
- d) calculate  $q$ , the value of the linear regression, at a lateral acceleration of 4 m/s<sup>2</sup>;
- e) calculate  $m$ , the gradient of the linear regression, using Equation (7):

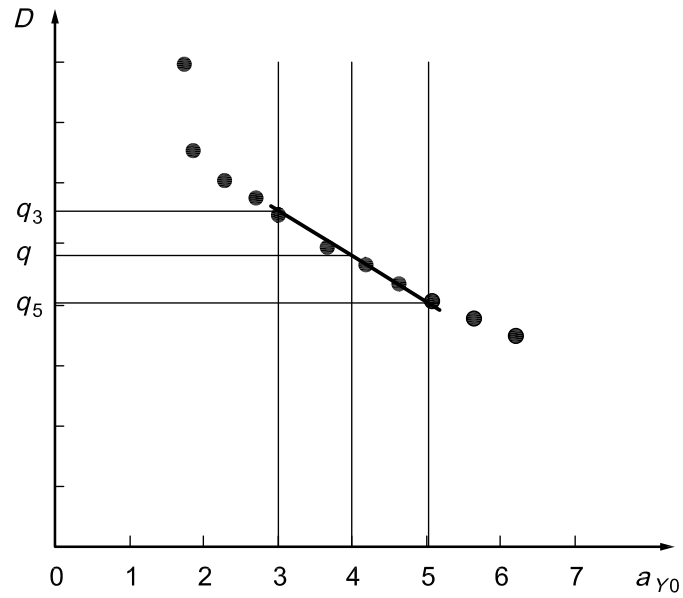
$$m = (q_5 - q_3)/2 \tag{7}$$

- 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

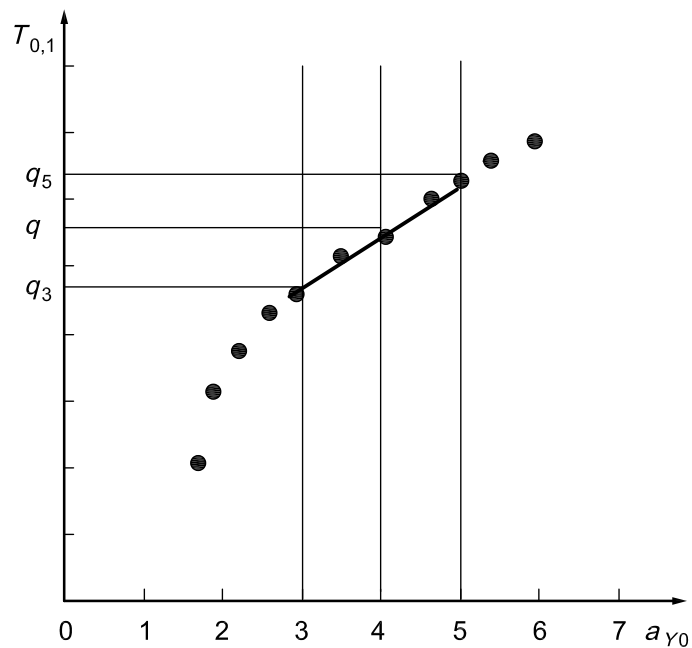
Figure 2 — Determination of amplitude



**Key**

- $a_{y0}$  lateral acceleration,  $m/s^2$
- $D$  damping of yaw velocity
- $q$  value of linear regression

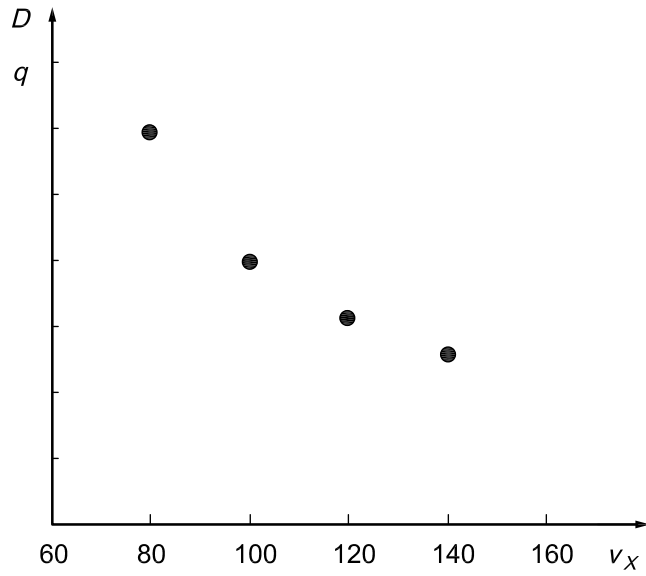
**Figure 3 — Typical aspect of damping vs  $a_{y0}$**



**Key**

- $a_{y0}$  lateral acceleration,  $m/s^2$
- $T_{0,1}$  damping time of yaw velocity
- $q$  value of linear regression

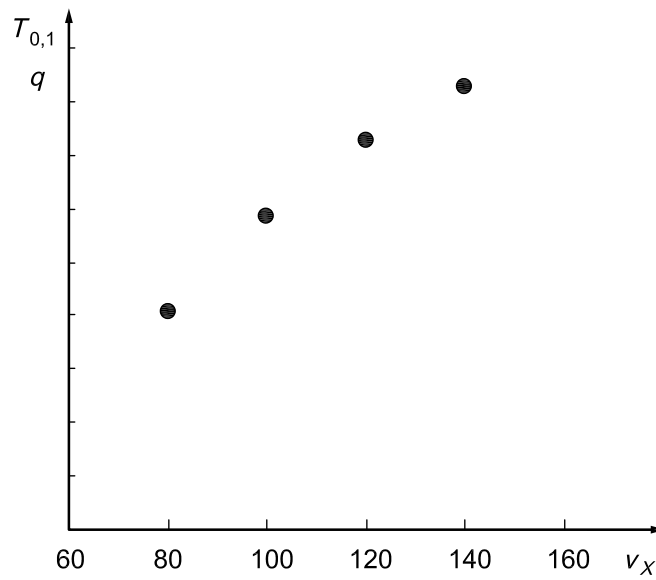
**Figure 4 — Typical aspect of damping time vs  $a_{y0}$**



**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**

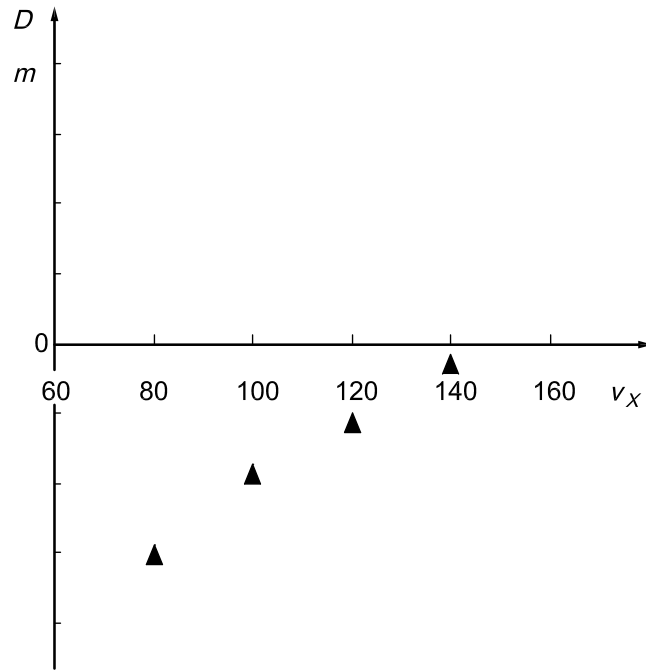


**Key**

- $v_x$  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**





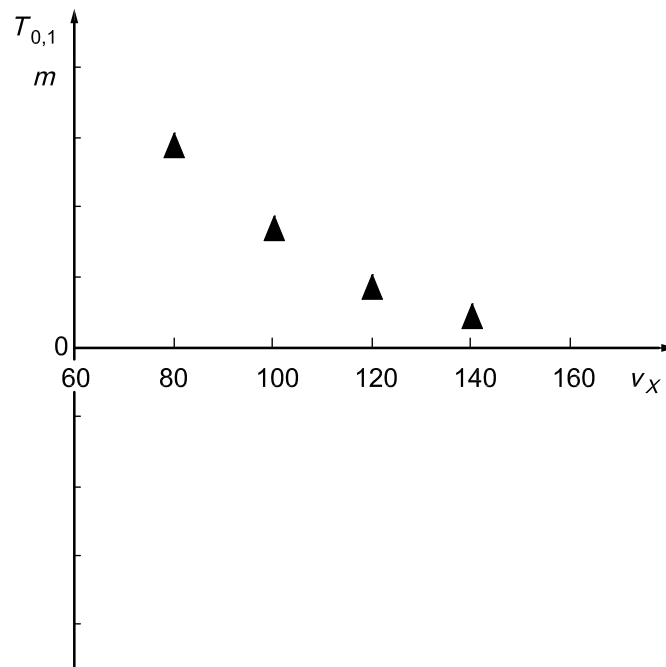
**Key**

$v_X$  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

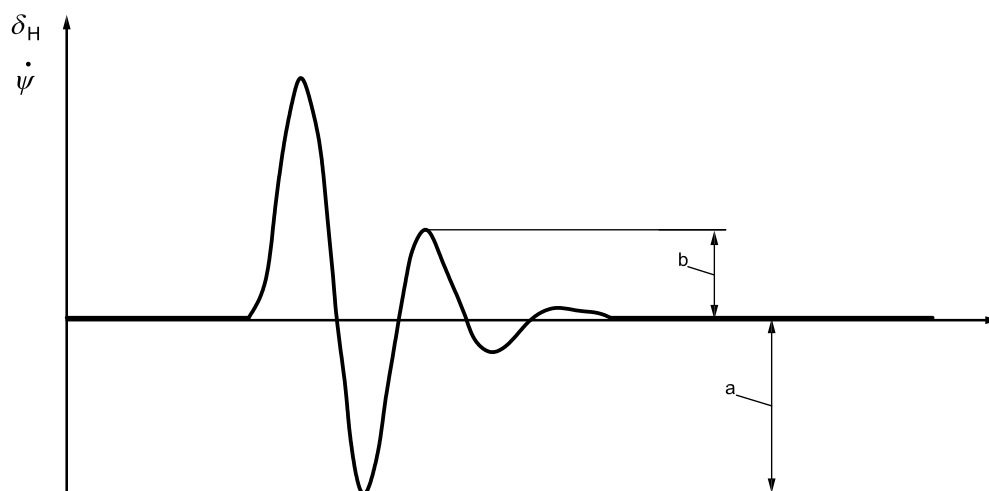
- yaw velocity,
- steering-wheel angle, and
- sideslip angular velocity

(see Figures 9 and 10):

- a) evaluate the function  $f(a_{y0}) = \text{peak 2}/\text{peak 1}$ , 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/s<sup>2</sup> and 5 m/s<sup>2</sup> (see Figure 11);
- d) calculate “ $q$ ”, the value of the linear regression at a lateral acceleration of 4 m/s<sup>2</sup>;
- e) calculate “ $m$ ”, the gradient of linear regression, using Equation (8):

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

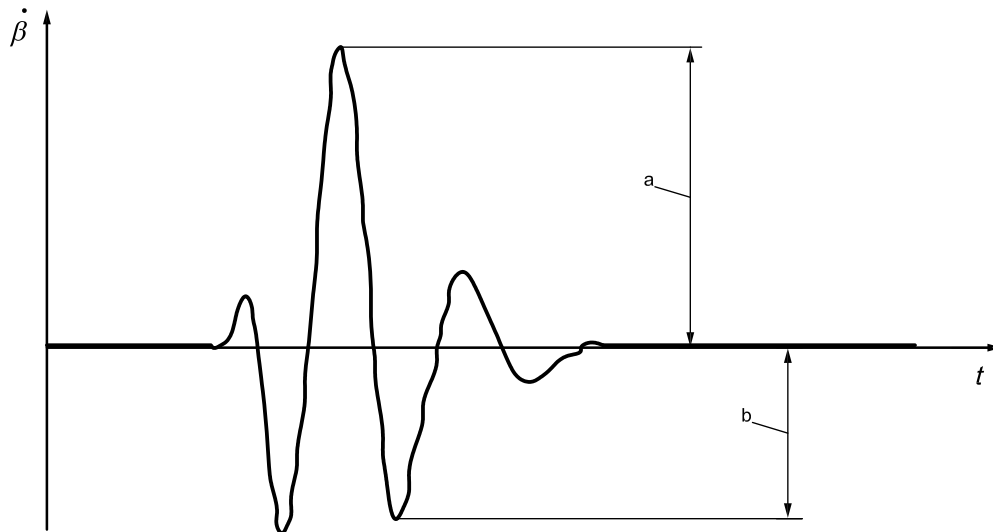
- f) plot  $q$  and  $m$  vs longitudinal velocity (see Figures 12 and 13).



**Key**

- $t$  time, s
- $\dot{\psi}$  yaw velocity
- $\delta_H$  steering-wheel angle
- a Peak 1.
- b Peak 2.

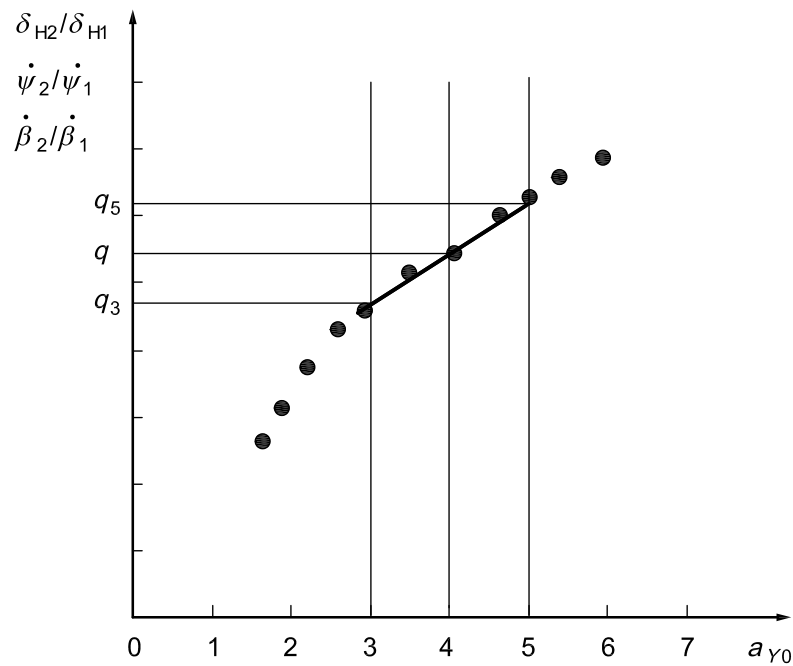
**Figure 9 — Peaks of variable after steering-wheel release — Steering-wheel angle, yaw velocity**



**Key**

- $t$  time, s
- $\dot{\beta}$  sideslip angular velocity
- a Peak 1.
- b Peak 2.

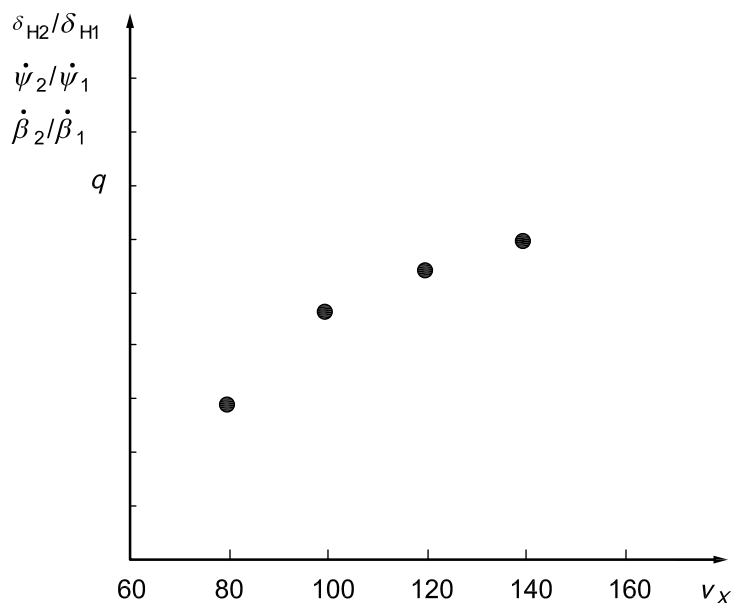
**Figure 10 — Peaks of variable after steering-wheel release — Sideslip angular velocity**



**Key**

- $a_{\gamma 0}$  lateral acceleration,  $m/s^2$
- $\delta_H$  steering-wheel angle
- $\dot{\psi}$  yaw velocity
- $\dot{\beta}$  sideslip angular velocity

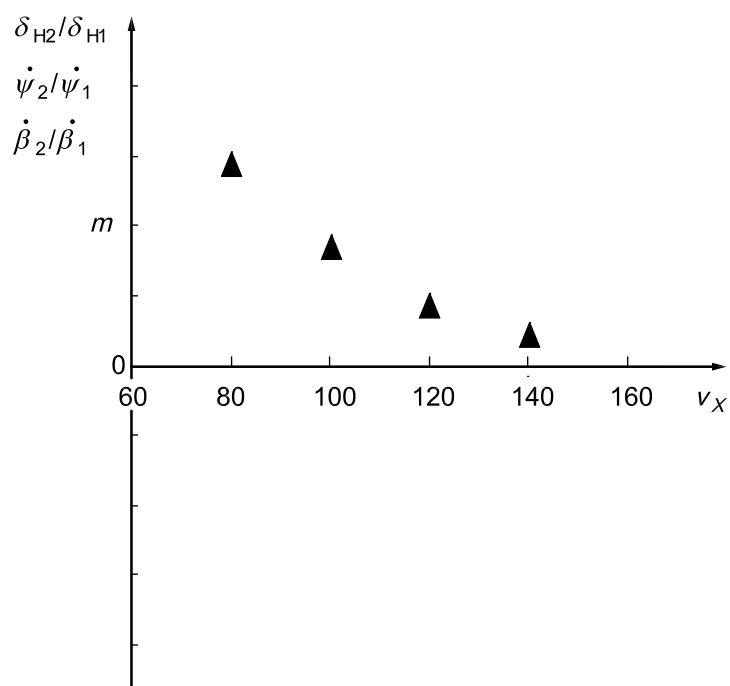
**Figure 11 — Typical aspect of functions of lateral acceleration vs  $a_{\gamma 0}$**



**Key**

- |                                   |   |
|-----------------------------------|---|
| $v_x$ longitudinal velocity, km/h | $\dot{\beta}$ sideslip angular velocity |
| $\delta_H$ steering-wheel angle   | $q$ value of linear regression          |
| $\dot{\psi}$ yaw velocity         |   |

**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 | $\dot{\beta}$ sideslip angular velocity |
| $\delta_H$ steering-wheel angle   | $m$ gradient of linear regression       |
| $\dot{\psi}$ yaw velocity         |   |

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

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