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Road vehicles — Heavy commercial vehicles and buses — Lateral transient response test methods

Véhicules routiers — Véhicules utilitaires lourds et autobus — Méthodes d'essai de réponse transitoire latérale

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Contents

Page

Foreword

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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 14793 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 9, *Vehicle dynamics and road-holding ability*.

Introduction

Road-holding ability is a most important part of active vehicle safety. Any given heavy commercial vehicle, combination or bus, 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 since there is a significant interaction between these driver–motor-vehicle–(trailer)–environment elements, each of which is complex in itself. A complete and accurate description of the behaviour of such a vehicle must necessarily involve information obtained from a number of tests of different types. Since they quantify only a small part of the whole vehicle-handling field, the results of these tests can only be considered significant for a correspondingly small part of the overall handling behaviour of heavy vehicles, heavy-vehicle combinations and buses.

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 test methods and results for regulation purposes at present. The best that can be expected is that the transient response tests are used as some among many other (mostly transient) tests, which together cover the field of vehicle dynamic behaviour.

Road vehicles — Heavy commercial vehicles and buses — Lateral transient response test methods

1 Scope

This International Standard specifies test methods for determining the transient response behaviour of heavy commercial vehicles, heavy commercial vehicle combinations, buses and articulated buses, as defined in ISO 3833 for trucks and trailers above 3,5 t and buses above 5 t maximum weight, and in UNECE (United Nations Economic Commission for Europe) and EC vehicle classification, categories M3, N2, N3, O3 and O4.

NOTE The open-loop manoeuvres specified in this International Standard are not representative of real driving conditions, but are nevertheless useful for obtaining measures of vehicle transient behaviour — particularly with respect to that which the driver experiences — in response to several specific types of steering input under closely controlled test conditions. For combinations where the response of the last vehicle unit is of importance, see ISO 14791.

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 1176:1990, *Road vehicles — Masses — Vocabulary and codes*

ISO 3833:1977, *Road vehicles — Types — Terms and definitions*

ISO/TR 8725:1988, *Road vehicles — Transient open-loop response test method with one period of sinusoidal input*

ISO/TR 8726:1988, *Road vehicles — Transient open-loop response test method with pseudo-random steering input*

ISO 8855:1991, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ECE Regulation No. 30, *Uniform provisions concerning the approval of pneumatic tyres for motor vehicles and their trailers*

3 Terms and definitions

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

3.1
vehicle unit
unit of a vehicle combination which is connected with a yaw-articulation joint

EXAMPLE Tractor, semitrailer, dolly.

NOTE The number of vehicle units is one more than the number of articulation joints.

4 Principle

IMPORTANT — The method of data analysis in the frequency domain is based on the assumption that the vehicle has a linear response. Over the whole range of lateral acceleration this is unlikely to be the case, the standard method of dealing with such a situation being to restrict the range of the input so that linear behaviour can be assumed and, if necessary, to perform more than one test at different ranges of inputs which, together, cover the total range of interest.

The objective of these tests is to determine the transient response of a vehicle. Characteristic values and functions of both linear and nonlinear behaviour are considered necessary for fully characterizing vehicle transient response. Linear characteristic values and functions are determined with tests in the frequency domain and nonlinear characteristic values and functions with tests in the time domain. In the case of vehicle combinations, it is primarily the response of the first vehicle unit that is evaluated.

Important characteristics in the time domain are

- time lags between steering-wheel angle, lateral acceleration and yaw velocity,
- response times of lateral acceleration and yaw velocity (see 9.2.1),
- lateral acceleration gain (lateral acceleration divided by steering-wheel angle),
- yaw velocity gain (yaw velocity divided by steering-wheel angle), and
- overshoot values (see 9.2.3).

Important characteristics in the frequency domain are the transfer functions of

- lateral acceleration related to steering-wheel angle, and
- yaw velocity related to steering-wheel angle,

expressed as gain and phase functions between input and output variables.

There are several test methods for obtaining these characteristics in the time and frequency domains, as follows, the applicability of which depends in part on the size of the test track available.

a) Time domain:

   1) step input;

   2) sinusoidal input (one period).

a) Frequency domain:

   1) random input;

   2) pulse input;

   3) continuous sinusoidal input.

5 Reference system

The variables of motion used to describe the vehicle behaviour in a test-specific driving situation relate to the intermediate axis system (X, Y, Z) (see ISO 8855).

The location of the origin of the vehicle axis system (X_V, Y_V, Z_V) is the reference point and shall be thus defined.

6 Variables

The following variables shall be determined:

— yaw velocity, $\dot{\psi}$;

— lateral acceleration, a_Y;

— steering-wheel angle, δ_H;

— longitudinal velocity, v_X.

The following variables may be determined:

— lateral deviation, y;

— roll angle at relevant points, φ;

— steering-wheel torque, M_H;

— sideslip angle, β.

These variables, all but lateral deviation defined in ISO 8855, are not intended to comprise a complete list.

7 Measuring equipment

7.1 Description

The variables to be determined in accordance with Clause 6 shall be measured by means of appropriate transducers. Their time histories shall be recorded on a multi-channel recording system having a time base.

The typical operating ranges and recommended maximum errors of the transducers and the recording system are given in Table 1.

7.2 Transducer installation

The transducers shall be installed so that the variables corresponding to the terms and definitions of ISO 8855 can be determined.

If the transducer does not measure the variable directly, appropriate transformations into the reference system shall be carried out.

7.3 Data processing

7.3.1 General

The frequency range relevant for this test is between 0 Hz and the maximum utilized frequency of f_{max} = 2 Hz. Depending on the data processing method chosen (analog or digital data processing) the provisions of 7.3.2 or 7.3.3 shall be observed.

For lighter trucks it may be necessary to increase f_{max} to 3 Hz. In this case, the following requirements concerning the frequency f_{max} may be modified correspondingly.

7.3.2 Analog data processing

The bandwidth of the entire, combined transducer/recording system shall be no less than 8 Hz.

In order to execute the necessary filtering of signals, low-pass filters of order four or higher shall be employed. The width of the passband (from 0 Hz to frequency f_0 at –3 dB) shall be not less than 9 Hz. Amplitude errors shall be less than ± 0,5 % in the relevant frequency range of 0 Hz to 2 Hz. All analog signals shall be processed with filters having phase characteristics sufficiently similar to ensure that time delay differences due to filtering lie within the required accuracy for time measurement.

NOTE During analog filtering of signals with different frequency contents, phase shifts can occur. Therefore, a digital data processing method, as described in 7.3.3, is preferable.

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

Variable	Range	Recommended maximum error of combined transducer and recorder system
Yaw velocity	– 50°/s to + 50°/s	± 0,5°/s
Lateral acceleration	– 15 m/s² to + 15 m/s²	± 0,15 m/s²
Steering-wheel angle	– 360° to + 360°	± 2° for angles < 180° ± 4° for angles > 180°
Longitudinal velocity	0 m/s to 35 m/s	± 0,35 m/s
Roll angle	– 15° to + 15°	± 0,15°
Side slip angle	– 10° to + 10°	± 0,3°
Lateral velocity	– 10 m/s to + 10 m/s	± 0,1 m/s
Steering-wheel torque		
without power steering	– 50 N·m to + 50 N · m	± 0,5 N · m
with power steering	– 20 N·m to + 20 N · m	± 0,2 N · m
Transducers for some of the listed variables are not widely available and are 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 under general data in the test report (see Annex A).		

7.3.3 Digital data processing

7.3.3.1 General considerations

Preparation of analog signals includes consideration of filter amplitude attenuation and sampling rate in order to avoid aliasing errors, and filter phase lags and time delays. Sampling and digitizing considerations include pre-sampling amplification of signals so as to minimize digitizing errors, the number of bits per sample, the number of samples per cycle, sample and hold amplification, and timewise spacing of samples. Considerations for additional phaseless digital filtering include the selection of passbands and stopbands, and the attenuation and allowable ripple in each, as well as correction of anti-alias filter phase lags. Each of these factors shall be considered so that an overall data-acquisition accuracy of ± 0,5 % is achieved.

7.3.3.2 Aliasing errors

In order to avoid uncorrectable aliasing, the analog signals shall be appropriately filtered before sampling and digitizing. The order of the filters used and their passband shall be chosen according to both the required flatness in the relevant frequency range and the sampling rate. The minimum filter characteristics and sampling rate shall be such that

— within the relevant frequency range of 0 Hz to f_{max} = 2 Hz the attenuation is less than the resolution of the data acquisition system, and

— at one-half the sampling rate (i.e. the *Nyquist* or “folding” frequency) the magnitudes of all frequency components of signal and noise are reduced to less than the system resolution.

For 12-bit data acquisition systems with a resolution of 0,05 % the filter attenuation shall be less than 0,05 % to 2 Hz, and the attenuation shall be greater than 99,95 % at all frequencies greater than one-half the sampling frequency.

NOTE For a Butterworth filter the attenuation is given by

$$A^2 = \frac{1}{1 + \left(\frac{f_{max}}{f_0}\right)^{2n}}$$

and

$$A^2 = \frac{1}{1 + \left(\frac{f_N}{f_0}\right)^{2n}}$$

where

n is the order of the filter;

f_{max} is the relevant frequency range (2 Hz);

f_0 is the filter cut-off frequency;

f_N is the Nyquist or "folding" frequency;

f_s is the sampling frequency = $2 \times f_N$

For example, for a fourth-order filter:

— for A = 0,9995, $f_0 = 2{,}37 \times f_{max} = 4{,}74$ Hz;

— for A = 0,0005, $f_s = 2 \times (6{,}69 \times f_0) = 63{,}4$ Hz.

7.3.3.3 Phase shifts and time delays for anti-aliasing filtering

Excessive analog filtering shall be avoided, and all filters shall have sufficiently similar phase characteristics to ensure that time delay differences lie within the required accuracy for the time measurement.

Phase shifts are especially significant when measured variables are multiplied together to form new variables. This is because, while amplitudes multiply, phase shifts and associated time delays add. Phase shifts and time delays are reduced by increasing f_0. Whenever equations describing the presampling filters are known, it is practical to remove their phase shifts and time delays by simple algorithms performed in the frequency domain.

NOTE In the frequency range in which the filter amplitude characteristics remain flat, the phase shift, φ, of a Butterworth filter can be approximated by

— $\varphi = 81° (f/f_0)$ for 2nd order,

— $\varphi = 150° (f/f_0)$ for 4th order,

— $\varphi = 294° (f/f_0)$ for 8th order.

The time delay for all filter orders is $t = (\varphi/360°) \times (1/f_0)$

7.3.3.4 Data sampling and digitizing

At 2 Hz the signal amplitude changes by up to 1,25 %/ms. To limit dynamic errors caused by changing analog inputs to 0,1 %, sampling or digitizing time shall be less than 80×10^{-6} s. All pairs or sets of data samples to be compared shall be taken simultaneously or over a sufficiently short time period.

In order not to exceed an amplitude error of 0,5 % in the relevant frequency range from zero to f_{max}, the sampling rate, f_s, shall be at least 30 f_{max}.

7.3.3.5 Data acquisition system requirements

The data acquisition system shall have a resolution of 12 bits or more (± 0,05 %) and an accuracy of 2 LSB ± 0,1 %. Anti-aliasing filters shall be of order four or higher and the relevant frequency range shall be from 0 Hz to f_{max}.

For fourth-order filters, f_0 shall be greater than 2,37 f_{max} if phase errors are subsequently adjusted in digital data processing, and greater than 5 f_{max} otherwise; data sampling frequency f_s shall be greater than 13,4 f_0.

For filters of orders other than the fourth order, f_0 and f_s shall be selected for adequate flatness and prevention of alias error.

Amplification of the signal before digitizing shall be such that in the digitizing process the additional error is less than 0,2 %. Sampling and digitizing time for each data channel sampled shall be less than 80×10^{-6} s.

7.3.3.6 Digital filtering

For filtering of sampled data in data evaluation, phaseless (zero-phase-shift) digital filters shall be used, in accordance with the following (see Figure 1):

— the passband shall range from 0 Hz to 2 Hz;

— the stopband shall begin at < 6 Hz;

— the filter gain in the passband shall be 1 ± 0,005 (100 ± 0,5) %;

— the filter gain in the stopband shall be ⩽ 0,01 (⩽ 1 %);

— the filter gain shall fall within the unshaded area of Figure 1.