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Heavy commercial vehicles and buses — Definitions of properties for the determination of suspension kinematic and compliance characteristics

Véhicules utilitaires lourds et autobus — Définitions des propriétés pour la détermination des caractéristiques cinématiques et de conformité des suspensions

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics and chassis components*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

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 shall necessarily involve information obtained from a number of different tests.

Static properties of the vehicle and its systems can have an important impact on the vehicle dynamic behaviour and a driver's or automation's ability to generate the desired motion. Test conditions have a strong influence on test results. Therefore, only vehicle dynamic and static properties obtained under virtually identical test conditions are comparable to one another.

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, it is important for any application of this test method for regulation purposes the proven correlation between test results and accident statistics.

Heavy commercial vehicles and buses — Definitions of properties for the determination of suspension kinematic and compliance characteristics

1 Scope

This document applies to heavy vehicles—that is, to commercial vehicles and buses as defined in ISO 3833—that are covered by the categories M3, N2, N3, O3, and O4 of ECE and EC vehicle regulations. These categories pertain to trucks and trailers with maximum weights above 3,5 tonnes and to buses with maximum weights above 5 tonnes.

Vehicle suspension kinematic and compliance (K&C) properties that impact vehicle stability and dynamic behaviour are described in this document and common methods of measurement are outlined. These methods are applicable to heavy vehicles. The measurements are performed on a single unit and typically one or two axles at a time.

This document will define or reference the key suspension kinematic and compliance parameters necessary for characterizing and simulating vehicle suspension performance. These parameters also provide system-level descriptions of quasi-static behaviour that can be cascaded into subsystem and component performance targets. The suspension variables required for determining suspension characterization of one vehicle end, i.e. for a single axle or for multiple axles inter-related through suspension configuration (for example, walking-beam), are provided. Metrics pertaining to the chassis connection between the front and rear suspensions are not included. Some typical methods of measurement will be discussed, however detail on how the measurements are executed is not within the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 8855, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ISO 15037-2, *Road vehicles — Vehicle dynamics test methods — Part 2: General conditions for heavy vehicles and buses*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
side view swing centre
point in a plane parallel to the X_V-Z_V plane that intersects the wheel centre and locates the instantaneous centre of rotation of the wheel centre resulting from a displacement in the Z_V direction

3.2
side view swing arm angle
angle from a horizontal line parallel to the X_V-Z_V plane that intersects the *side view swing centre* (3.1) and the line that intersects the side view swing centre and wheel centre

3.3
longitudinal force compliance, with suspension torque
$x_{\vec{F}_X}{}'$
rate of change of the wheel centre displacement in the X_V direction with respect to a force exerted on the geometric centre of the tyre contact patch in the X_V direction

3.4
longitudinal force compliance, without suspension torque
$x_{\vec{F}_{XW}}{}'$
rate of change of the wheel centre displacement in the X_V direction with respect to a force exerted on the wheel centre in the X_V direction

3.5
longitudinal force camber compliance, with suspension torque
$\varepsilon_{V\vec{F}_X}{}'$
rate of change of camber angle with respect to a force exerted on the geometric centre of the tyre contact patch in the X_V direction

3.6
longitudinal force camber compliance, without suspension torque
$\varepsilon_{V\vec{F}_{XW}}{}'$
rate of change of camber angle with respect to a force exerted on the wheel centre in the X_V direction

3.7
longitudinal force steer compliance, with suspension torque
$\delta_{\vec{F}_X}{}'$
rate of change of steer angle with respect to a force exerted on the geometric centre of the tyre contact patch in the X_V direction

3.8
longitudinal force steer compliance, without suspension torque
$\delta_{\vec{F}_{XW}}{}'$
rate of change of steer angle with respect to a force exerted on the wheel centre in the X_V direction

3.9
longitudinal force windup compliance, with suspension torque
$\tau_{\vec{F}_X}{}'$
rate of change of the axle or hub assembly angle about the Y_V axis with respect to a force exerted on the geometric centre of the tyre contact patch in the X_V direction

3.10
longitudinal force windup compliance, without suspension torque
$\tau_{\vec{F}_{XW}}{}'$
rate of change of the axle or hub assembly angle about the Y_V axis with respect to a force exerted on the wheel centre in the X_V direction

3.11
lateral force compliance at the wheel centre
$y_{\vec{F}_{\mathrm{YW}}}{}'$
rate of change of wheel centre displacement in the Y_{V} direction with respect to a force exerted on the geometric centre of the tyre contact patch in the Y_{V} direction

3.12
lateral force compliance at the contact centre
$y_{\vec{F}_{\mathrm{Y}}}{}'$
rate of change of geometric centre of the tyre contact patch displacement in the Y_{V} direction with respect to a force exerted on the geometric centre of the tyre contact patch in the Y_{V} direction

3.13
lateral force camber compliance
$\varepsilon_{\mathrm{V}\vec{F}_{\mathrm{Y}}}{}'$
rate of change of camber angle with respect to a force exerted on the geometric centre of the tyre contact patch in the Y_{V} direction

3.14
lateral force steer compliance
$\delta_{\vec{F}_{\mathrm{Y}}}{}'$
rate of change of steer angle with respect to a force exerted on the geometric centre of the tyre contact patch in the Y_{V} direction

3.15
aligning moment camber compliance
$\varepsilon_{\mathrm{V}\vec{M}_{\mathrm{Z}}}{}'$
rate of change of camber angle with respect to a moment exerted on the tyre contact patch about the Z_{V} axis

3.16
aligning moment steer compliance
$\delta_{\vec{M}_{\mathrm{Z}}}{}'$
rate of change of steer angle with respect to a moment exerted on the tyre contact patch about the Z_{V} axis

3.17
auxiliary roll stiffness
$K_{\varphi_{\mathrm{V}},\mathrm{aux}}$
contribution to roll stiffness beyond that which results from ride rate and symmetric vertical tyre contact patch-to-body displacement

3.18
auxiliary suspension roll stiffness
$K_{\varphi_{\mathrm{K}},\mathrm{aux}}$
contribution to suspension roll stiffness beyond that which results from suspension ride rate and symmetric vertical wheel-to-body displacement

3.19
total ride toe
$\delta_{\mathrm{z(R\text{-}L)}}$
change in the difference of the left steer angle from the right steer angle observed in *ride mode* (3.22)

3.20
total ride toe gradient
$\delta_{z(R\text{-}L)}'$
differential of *total ride toe* (3.19) with suspension travel as observed in *ride mode* (3.22)

3.21
wheel pad
surface of the kinematic and compliance measurement facility that supports each tyre contact patch and is typically capable of applying forces at the geometric centre of the tyre contact patch in the *X* and *Y* directions, moments at the tyre contact patch about the *Z* axis, and optionally displacements in the *Z* direction

Note 1 to entry: The wheel pads are assumed to represent the ground plane. If the vehicle sprung mass is not rolled relative to the wheel pads, it can be assumed that the intermediate axis system and vehicle axis system coincide.

3.22
ride mode
motion of vehicle suspension produced by near-equal Z_T displacements of the wheel centres on a single axle relative to the vehicle body, with *wheel pad* (3.21) *X* and *Y* forces and Z_T moments controlled to as near-zero as practicable, and preferably with the change in $\vec{M}_X$ held as near to zero as practicable

3.23
roll mode
motion of single axle produced by a pure roll moment, $\vec{M}_X$, resulting from equal and opposite change in the forces applied to the left and right tyre contact centres of each axle in the Z_T direction, with *wheel pad* (3.21) *X* and *Y* forces and Z_T moments controlled to as near-zero as practicable

4 Principle

This document defines the common suspension kinematic and compliance (K&C) properties of suspensions that relate to the change in orientation of the road wheel and tyre to the road surface as a result of, and relative to, forces, moments and displacements input to the tyre contact patches. The forces, moments and displacements are intended to reflect those encountered in real-world manoeuvres. Characterization of these properties is essential to modelling the ride and handling behaviour of road vehicles as the motion of the tyre contact patch relative to the sprung mass is determined by both the sprung mass to tyre orientation and the tyre to road surface orientation.

The intent of K&C measurements is to isolate the change in ground and wheel planes to vehicle sprung mass orientation that result from each of the relevant primary forces, moments and displacements. For instance, lateral force steer compliance is measured by suppressing other inputs that steer angle is sensitive to, such as change in longitudinal force or steer moment. The lateral force steer compliance is isolated by controlling the wheel pad longitudinal force and steer moment to zero and constraining the vertical position of the contact patch to avoid introducing kinematic effects resulting from trim height change. Similarly, other measurements are made with constraints defined to isolate the change resulting from particular forces, moments or displacements to facilitate the principle of superposition when used in a vehicle simulation.

While it is essential to isolate the reactions to specific forces, moments or displacements, the inputs shall be representative of naturally occurring inputs. For example, when measuring the roll characteristics of a suspension, it is strongly preferred to simulate the sprung mass roll relative the ground plane. This may be achieved using asymmetric vertical displacement of the wheel pads or by rolling the vehicle body relative to the wheel pads. In either case, the sum of the normal forces exerted on the axle shall remain constant. This is more representative of on-road behaviour than the input of equal and opposite vertical displacements at the tyre contact patches.

5 Variables

5.1 Reference system

Variables used to characterize vehicle suspension K&C properties are typically determined in the following manner:

— the change in wheel orientation as defined by the wheel axis system (X_W, Y_W, Z_W) resulting from a displacement, force, or moment aligned to the intermediate axis system (X, Y, Z) (see ISO 8855);

— the displacement of the wheel centre as defined by the intermediate coordinate system (x, y, z) resulting from a force aligned to the intermediate axis system (X, Y, Z) (see ISO 8855);

— the change in vehicle sprung mass orientation as defined by the vehicle axis system (X_V, Y_V, Z_V) resulting from a displacement, force, or moment aligned to the intermediate axis system (X, Y, Z) (see ISO 8855).

NOTE Ideally the changes in wheel orientation due to tyre forces and moments would be determined relative to the tyre forces and moments in the tyre axis system (X_T, Y_T, Z_T), since this is the reference system in which tyre force and moment properties are provided. However, it typically is not practical to maintain contact patch shear force alignment with the tyre axis system in a K&C machine and so, the shear forces are normally aligned with the intermediate axis system. For the small angles that normally result during compliance measurements, the differences can be neglected.

5.2 Variables to be determined

Variable definitions not found in ISO 8855 can be found in Clause 3. To describe the relative suspension motions resulting from external forces and moments, the principal relevant variables are the following:

5.2.1 Vehicle geometry

— wheel centre

— contact centre

— contact patch

— tandem axle spacing

— b, track

5.2.2 Motion variables

— φ_V, vehicle roll angle

— φ_K, suspension roll angle

— ride displacement

— bogie orientation variables (pitch, roll, twist)

5.2.3 Forces and moments

— $\vec{F}_X$, longitudinal force

— $\vec{F}_Y$, lateral force

— $\vec{F}_Z$, vertical force

— $\vec{M}_X$, roll moment

