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Road vehicles — Heavy commercial vehicles and buses – Mass moment of inertia measurement

Véhicules routiers — Véhicules utilitaires lourds et autobus — Mesure du moment d'inertie de masse

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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.

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

Methods are presented for determining the roll (I_{xx}), pitch (I_{yy}), and yaw (I_{zz}) mass moments of inertia (MOI) and roll-yaw (I_{xz}) product of inertia (POI) of an individual vehicle unit about the vehicle unit axis system and centre of gravity reference point. I_{xx}, I_{yy}, I_{zz}, and I_{xz} are fundamental mass properties that provide information on a vehicle's mass distribution and rotational acceleration responses to applied forces. The I_{xy} and I_{yz} components of the inertia tensor are less significant to vehicle dynamics and are not addressed in this document. The MOIs are determined using a pendulum device with measurements of oscillation period and reaction forces. The location of the vehicle unit's centre of gravity (CG) reference point is required beforehand. Knowledge of a vehicle unit's mass moments of inertia supports vehicle modelling work, design validation, and planning for other dynamic tests yet to be performed.

Performing measurements for MOI determination of heavy commercial vehicles and buses may be challenging in practice due to the wide variety of vehicles that vary significantly in terms of weight, size, and number of axles. Adaptability of a heavy vehicle MOI facility's layout is an important attribute.

Road vehicles — Heavy commercial vehicles and buses – Mass moment of inertia measurement

1 Scope

This document provides standard methods for determining a vehicle's roll, pitch, and yaw mass moments of inertia (MOI) and roll-yaw product of inertia (POI). It applies to heavy vehicles, that is commercial vehicles and buses as defined in ISO 3833 (trucks and trailers with maximum weight above 3,5 tons and buses and articulated buses with maximum weight above 5 tons, according to ECE and EC vehicle classification, categories M3, N2, N3, O3 and O4). Mass moment of inertia measurements are performed separately for each single unit.

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 612, *Road vehicles — Dimensions of motor vehicles and towed vehicles — Terms and definitions*

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
stable pendulum
pendulum apparatus for supporting a vehicle on a nominally planar surface where the combined vehicle and pendulum CG height is below the pivot point

3.2
unstable pendulum
pendulum apparatus for supporting a vehicle on a nominally planar surface where the combined vehicle and pendulum CG height is above the pivot point

3.3
torsional pendulum
pendulum apparatus where the restoring force is torsion

3.4
multi-filar torsional pendulum
torsional pendulum (3.3) with multiple vertical wires, cables or chains supporting the vehicle and test *platform* (3.5) where the torsional restoring force is due to gravity and spring force in twisting cables

3.5
platform
nominally planar surface of the pendulum on which the vehicle unit or trailer is parked

3.6
vehicle restraint
device used to restrain vehicle motion on the test *platform* (3.5)

3.7
tare MOI
MOI determined for the test fixture only, with no test vehicle

3.8
vehicle MOI
I_v
MOI determined for the vehicle only

3.9
platform MOI
I_p
MOI determined for the *platform* (3.5) only

3.10
roll MOI
I_{xx}
mass MOI about the vehicle X_V axis

3.11
pitch MOI
I_{yy}
mass MOI about the vehicle Y_V axis

3.12
yaw MOI
I_{zz}
mass MOI about the vehicle Z_V axis

3.13
roll-yaw POI
I_{xz}
mass product of inertia coupling between the X_V and Z_V axes

3.14
radius of gyration
k_r
distance from the axis of rotation to a point where the total mass of the body may be concentrated, so that the MOI about the axis remains the same

4 Principles

This document specifies methods to determine the vehicle's roll, pitch, and yaw MOIs and roll-yaw POI about the vehicle axis system originating from the vehicle CG reference point. Based on the vehicle axis system defined in ISO 8855, the MOI determinations described in this document include I_{xx}, I_{yy}, I_{zz}, and I_{xz}.

The I_{xx} and I_{yy} MOIs are determined using a stable or unstable pendulum fixture, where the period of oscillation of the fixture and fixture with the vehicle are measured to calculate the MOIs. The I_{zz} MOI is determined using a torsional or multi-filar torsional pendulum, where again the period of oscillation is measured. The I_{xz} POI is determined using a torsional pendulum with an integrated roll axis, where the roll axis is constrained and the roll reaction moment is measured.

The accuracy of MOI measurements is dependent on vehicle condition during measurement, measurement equipment accuracy, potential movement of heavy sprung or unsprung masses within the vehicle, such as engine and transmission assemblies and suspensions, and movement of the vehicle on the platform during the measurement process. Potential movement of fuel, coolants, and oils will also affect measurement accuracy.

5 Variables

5.1 Reference system

The reference system specified in ISO 15037-2 shall apply.

5.2 Variables to be measured

With the vehicle at the load condition specified for the test, measure and record the following in accordance with the dimensions given in ISO 612 and ISO 8855:

— W_v total vehicle load (or weight);

— W_p load of the platform including the restraint components;

— h pivot height from the platform surface;

— h_p platform plus restraints vertical CG distance below (or above) the pivot axis, including the roll pivot axis for I_{xz} measurement;

— h_v vehicle vertical CG distance below (or above) the pivot axis, including the roll pivot axis for I_{xz} measurement;

— h_t system (platform, restraints, and vehicle) vertical CG distance below (or above) the pivot axis;

— θ_p pitch angle of the platform relative to the gravity vector (positive for the front of the vehicle pitched down);

— $\theta_{p,\ static}$ static pitch angle of the platform relative to the gravity vector (positive for the front of the platform pitched down);

— $\varphi_{p,\ static}$ static roll angle of the platform relative to the gravity vector (positive for the platform rolled to the left);

— T_p platform (plus restraints) undamped period of oscillation;

— T_t total system (platform, restraints and vehicle) undamped period of oscillation;

— X longitudinal offset displacement of the vehicle CG relative to the platform centreline (positive for forward vehicle displacement);

— Y lateral offset displacement of the vehicle CG relative to the platform centreline;

— n number of oscillations of the platform;

— R radial distance on a multi-filar pendulum from the yaw axis centroid to the vertical support cables;

— L length of the multi-filar pendulum vertical support cables;

— ψ_p platform yaw angle amplitude;

— ψ_v vehicle yaw angle amplitude;

— L_u unstable pendulum moment arm length from reaction spring to pivot;

— K_u unstable pendulum reaction spring stiffness (force/displacement);

— K_p torsional pendulum reaction spring stiffness (moment/angle);

— M_x roll reaction moment for the torsional pendulum used for I_{xz} determination;

— M_{meas} measured roll reaction moment for the torsional pendulum used for I_{xz} determination.

6 Measuring equipment

The measuring equipment, transducer installation, data processing, and typical operating ranges shall be in accordance with ISO 15037-2.

Table 1 — Variables, typical operating ranges and recommended maximum errors of variables not listed in ISO 15037-2 for MOI measurement

Variable	Typical operating range	Recommended maximum errors of the combined transducer and recorder system
Suspension air-spring inflation pressure	(500–1 000) kPa	15 kPa
Vehicle, axle or track load	Up to 40 000 kg (392 400 N)	0,2 %
Distance	≤2 000 mm	±2 mm
	>2 000 mm	±0,05 %
Angles	±5°	±0,05°
Static distance X, Y	±20 mm	±3,0 mm
Dynamic Distance X(t), Y(t)	±10 mm	±0,5 mm
Time period	2 min	±1,0 ms
Roll moment	(0–1 500) N-m	0,5 %

7 Test conditions

7.1 General

The limits and specifications indicated below shall be maintained during the test. Any deviations shall be identified in the test report.

7.2 Ambient conditions

The surface shall be clean and dry. If the test is conducted outdoors, the ambient wind speed is recommended to be less than 1 m/s. Ambient temperature shall be recorded if the test is conducted outdoors.

7.3 Test surface

The test surface, when applicable, should be in accordance with ISO 15037-2 and the surface should be stiff enough to avoid surface deformation when measuring the vehicle.

7.4 Test vehicle

The load condition shall be reported as described in ISO 15037-2. Tyre pressures, suspension setting (if applicable) and load condition shall be recorded.

On vehicles with multiple adjustable seats or other devices such as beds, adjust the items to a mid-travel position (longitudinal and vertical) and adjust the seat back torso angle to the manufacturers designated specification or as close as possible to 15°. The positions shall be reported.

On vehicles with steering wheel reach and rake, the position shall be reported.

7.5 Operating and other liquids

The fuel tanks shall be completely full or empty, including the urea tanks. Fuel motion within an unfilled fuel tank can have an adverse effect on the results. If the displacement of other liquids carried on the vehicle (operating and otherwise), such as engine oil, is expected to influence the results, precautions should be taken to fill the fluid tanks, drain the fluids, or note the potential issue. Tank conditions (empty or full) and locations shall be reported.

Note any leaking fluids during vehicle inclination.

7.6 Loading conditions, suspension and mechanical parts

Vehicle payload shall be held in place to avoid displacement due to inclination or yawing of the vehicle.

If the vehicle has a suspended cab or semi-suspended cab, the cab shall be locked at its standard height when the vehicle is in a horizontal plane with no driver in the cab. Other components with flexible mounting may need to be constrained as well, if deflection will adversely influence the results.

Immediately prior to each test event, all self-regulating suspensions shall be adjusted such that they are at the proper ride height or, in the case of the suspensions for certain auxiliary axles, at the prescribed inflation pressure. Initial ride height of each suspension shall be reported.

Tyre condition and pressure shall be in accordance with vehicle manufacturer recommendations and ISO 15037-2. In case a range is specified for tyre pressure, the highest-pressure value should be selected to minimize tyre deflection.

Suspended components such as the engine, gearbox, and axles may move laterally and /or longitudinally when tilting or yawing the vehicle. Such displacements may influence measurement accuracy and should be noted accordingly.

8 Determination of the I_{xx}, I_{yy}, I_{zz}, and I_{xz} mass moments of inertia

8.1 General

Two methods are presented for measuring the parameters needed to calculate each of the I_{xx}, I_{yy}, and I_{zz} MOIs. The methods vary by the type of pendulum device used. A single method is presented for determining the I_{xz} POI. In general, the pendulum fixtures are mechanically re-configurable to enable measurement of various MOIs. Reconfiguration might include simply repositioning the vehicle on the platform to align the vehicle longitudinal or lateral axis with the pendulum rotational axis and adjusting pivot and spring hardware to facilitate different MOI and POI measurements.

8.1.1 Platform levelness

The platform's empty, static equilibrium position, $\theta_{p,\ static}$ and $\varphi_{p,\ static}$, should be checked via inclinometers to verify its levelness. It is recommended that the empty platform is level within 0,1° for best results and no more than 0,5°.

8.1.2 Platform weight and stiffness

It is recommended that the platform be as light as possible compared to the weight of the vehicle under test, while providing sufficient stiffness to avoid measurement errors due to deflection. When loaded with the test vehicle, it is recommended that the platform deflection is less than 2,5 mm at the vehicle's CG (as measured from the pivot when compared to the unloaded platform). Significant measurement errors are introduced when the deflection is greater than this, although corrections for deflection can be made. In general, a stiff platform is more important than a light platform.