
**Mopeds — Measurement method for
moments of inertia**

Cyclomoteurs — Méthode de mesure des moments d'inertie



Reference number
ISO 9043:2008(E)

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Published in Switzerland

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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.

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 9043 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 23, *Mopeds*.

This second edition cancels and replaces the first edition (ISO 9043:1991), which has been technically revised.

Introduction

The stability of a moped is a very important element of its active safety. The moped/rider combination and the environment in which this combination is used form a unique closed-loop system. However, the evaluation of moped/rider combination stability is extremely complex because of interaction of the intrinsic moped stability, the influence of the position of the rider and his response to continuously changing conditions.

In the evaluation of moped stability, the determination of the kinetic characteristics of the moped/rider combination is considered an important part of the design parameters of the vehicle itself.

The test procedure described in this International Standard deals with one aspect of the kinetic characteristics: the determination of the moments of inertia of the moped and of the moped/rider combination.

Mopeds — Measurement method for moments of inertia

1 Scope

This International Standard specifies a measuring method for determining the moments of inertia of the moped and of the moped/rider combination. It applies to two-wheeled mopeds.

Other measuring methods can be used if it is demonstrated that the results are equivalent.

Measurement results obtained exclusively by the method described in this International Standard (see Annex A) cannot be used for an evaluation of vehicle stability because they deal with only one aspect of this very complex phenomenon.

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 3779, *Road vehicles — Vehicle identification number (VIN) — Content and structure*

ISO 8705, *Mopeds — Measurement method for location of centre of gravity*

49 CFR Part 572 Subpart B [*Code of Federal Regulations*, issued by the National Highway Traffic Administration (NHTSA)]

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

moped-fixed axis system (x, y, z)

right-hand orthogonal axis system fixed in the moped, such that when the moped is moving in a straight line on a level road, the x-axis is substantially horizontal, points forwards and is in the longitudinal plane of symmetry of the moped, the y-axis points to the rider's left side and the z-axis points upwards

NOTE 1 This coordinate system performs translation motion and rotational motion together with the moped.

NOTE 2 Assuming that the moped is fixed to a platform, the coordinate system is also applied to the platform.

3.2

earth-fixed axis system (X, Y, Z)

right-hand orthogonal axis system fixed on the Earth, such that the X-axis and the Y-axis are in a horizontal plane and the Z-axis points upwards

4 Measurement conditions

4.1 Measurement conditions for a moped shall be as follows:

- a) the moped shall be quite clean and free from mud and deformation, and shall operate normally;
- b) the fuel shall be filled up to the top level specified in the operation manual;
- c) lubricating oil and cooling water, for water-cooled engines, shall be filled up to the level specified in the operation manual;
- d) tyre pressure shall be as specified in the operation manual;
- e) tools shall be provided at the regular storage positions;
- f) front and rear suspension systems shall be fixed at a static position;
- g) the front wheel shall be positioned along the x-axis.

If the conditions are to be modified depending on the object of measurement, the modified conditions shall be recorded in the measurement results (see Annex A).

4.2 Measurement conditions when a rider is on the moped shall be as follows:

- a) measurement conditions of the moped shall be as specified in 4.1;
- b) a test dummy as specified in 49 CFR Part 572 Subpart B (or equivalent), with a mass of 73,4 kg, or an equivalent human being, shall be used as the rider;
- c) the rider shall be positioned as follows:
 - 1) positioned on the vertical centre surface of the moped;
 - 2) sitting on the seat, holding the handle bar by both hands, with both feet placed on the foot rests;
 - 3) with an angle of posture formed by the line connecting the point S (indicating the centre of rotation of the torso and the arms of the rider) and point H (indicating the centre of rotation of the torso and femoral regions of the rider) and the x-axis;
 - 4) at a seating position that is the distance between the front axle and the point H along the x-axis.

However, if the conditions are to be modified depending on the object of measurement, the modified conditions shall be recorded in the measurement results (see Annex A).

5 Measuring instruments

Measuring instruments to measure the moments of inertia shall be as follows or shall have equivalent functions and accuracy:

- a) a precision square level that can measure up to 0,1 mm/1 m ($\approx 20''$);
- b) a steel tape measure with a tolerance of $\pm [0,3 + 0,1(L - 1)]$ mm at the length of L m;
- c) weighing stands with enough accuracy to weigh the object up to 0,1 kg;
- d) a stop watch that can measure up to 0,01 s, used for measuring the oscillation time;

- e) a platform with the highest possible rigidity, and of light weight;
- f) a knife edge, where the roundness at the edge shall be below 1 mm in radius, and an edge angle below 90 degrees is recommended;

NOTE The roundness at the edge is the form of the edge finished sharply when rounded with the load.

- g) weights, to incline the platform.

6 Measuring procedure

6.1 Measurement of location of centre of gravity

Calculate the mass and location of centre of gravity of the platform, moped, and the platform with the moped placed on it, in accordance with ISO 8705.

6.2 Roll moment of inertia about x-axis (physical pendulum principle)

6.2.1 Roll moment of inertia about AB-axis for empty platform

Inertia moment about the AB-axis for the empty platform shall be measured in the procedure described below (see Figure 1).

- a) Place the knife edges A and B on the stay so that they can freely oscillate around the AB-axis.
- b) Oscillate the platform gently around the AB-axis. It is desirable to keep total oscillating angle below 5°.
- c) Make sure that the platform oscillates in a stable way and measure the time required for the platform to oscillate 50 times by a stop watch. Repeat this process 3 times and obtain the average value of 3 average cycle times. The result shall be the period.
- d) Calculate the inertia moment of the platform about the AB-axis, I_{xp} , expressed in kgm^2 , using Equation (1):

$$I_{xp} = \left(\frac{T_{xp}}{2\pi} \right)^2 \sqrt{c_p^2 + y_p^2} m_p g \quad (1)$$

where

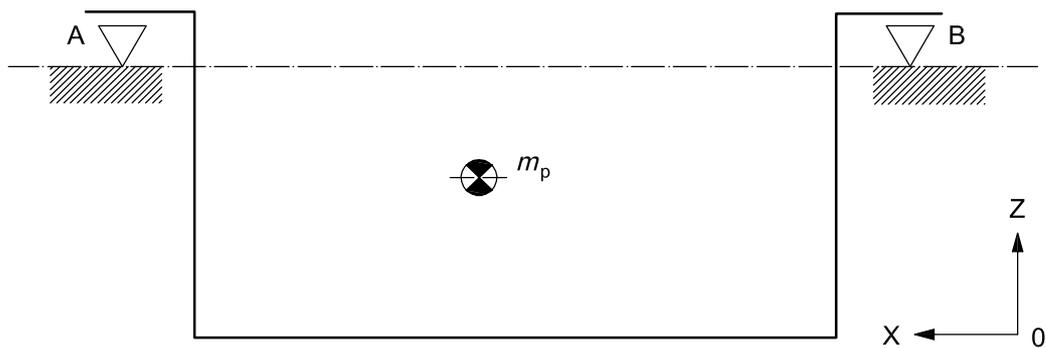
T_{xp} is the period for the platform to oscillate around the AB-axis, in s;

c_p is the distance along the z-axis from the knife edge to the centre of gravity of the platform, in m;

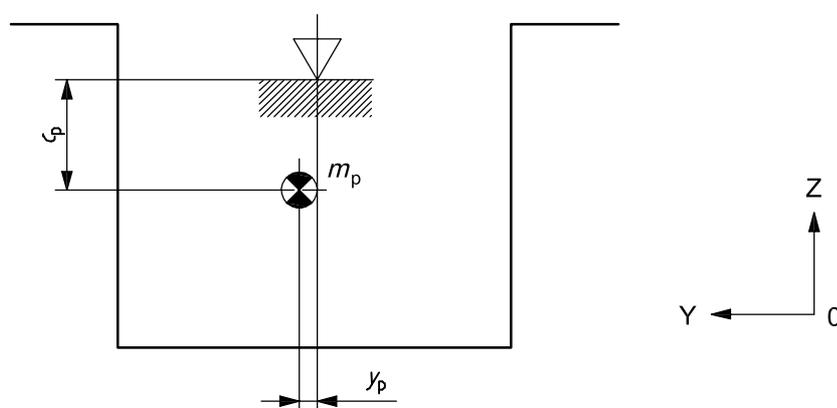
y_p is the distance along the y-axis from the knife edge to the centre of gravity of the platform, in m;

m_p is the mass of the platform, in kg;

g is acceleration due to gravity (9,81 m/s^2).



a) Side view



b) Rear view

Key

c_p distance along the z-axis from the knife edge to the centre of gravity of the platform

m_p mass of platform

y_p distance along the y-axis from the knife edge to the centre of gravity of the platform

Figure 1 — Measurement procedure for roll moment of inertia of empty platform (procedure with physical pendulum principle)

6.2.2 Roll moment of inertia of moped about x-axis

Roll moment of inertia of the moped about the x-axis shall be measured in the procedure described below (see Figure 2).

NOTE This measurement applies to both the empty moped and the moped with a rider.

- a) Place the moped on the platform and fix it so that it cannot move. The lateral inclination angle of the moped to the platform shall be $0^\circ \pm 0,5^\circ$.
- b) Place the knife edges A and B on the stay so that they can freely oscillate around the AB-axis.
- c) Oscillate the moped/platform combination gently around the AB-axis. It is desirable to keep total oscillating angle below 5° .
- d) Make sure that the platform oscillates in a stable way and measure the time required for the platform to oscillate 50 times by a stop watch. Repeat this process 3 times and obtain the average value of 3 average cycle times. The result shall be the period.
- e) Calculate the inertia moment of the moped about the x-axis, I_{xm} , expressed in kgm^2 , using Equation (2):

$$I_{xm} = \left(\frac{T_{xT}}{2\pi} \right)^2 \sqrt{c_T^2 + y_T^2} m_T g - I_{xp} - m_m (c_m^2 + y_m^2) \quad (2)$$

where

T_{xT} is the period for the platform with the moped on it to oscillate around the AB-axis, in s;

c_T is the distance along the z-axis from the knife edge to the centre of gravity of the moped/platform combination, in m;

y_T is the distance along the y-axis from the knife edge to the centre of gravity of the moped/platform combination, in m;

m_T is the mass of moped/platform combination, in kg;

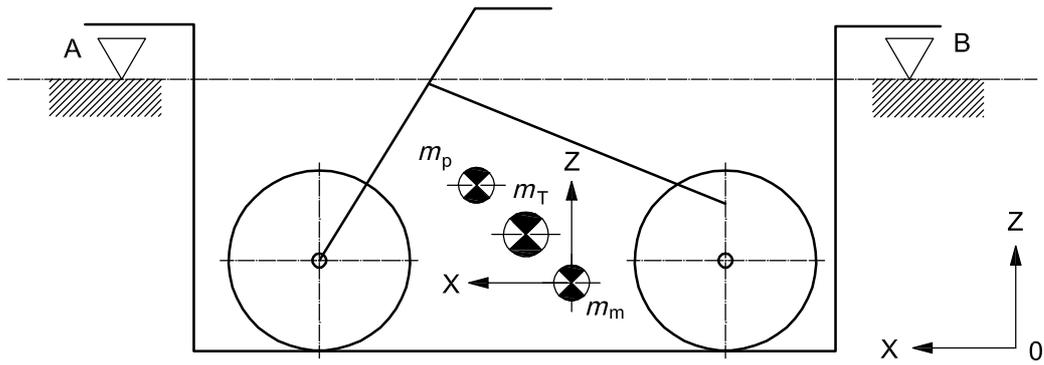
I_{xp} is the inertia moment of the platform about the AB-axis, in kgm^2 [see Equation (1)];

g is acceleration due to gravity ($9,81 \text{ m/s}^2$);

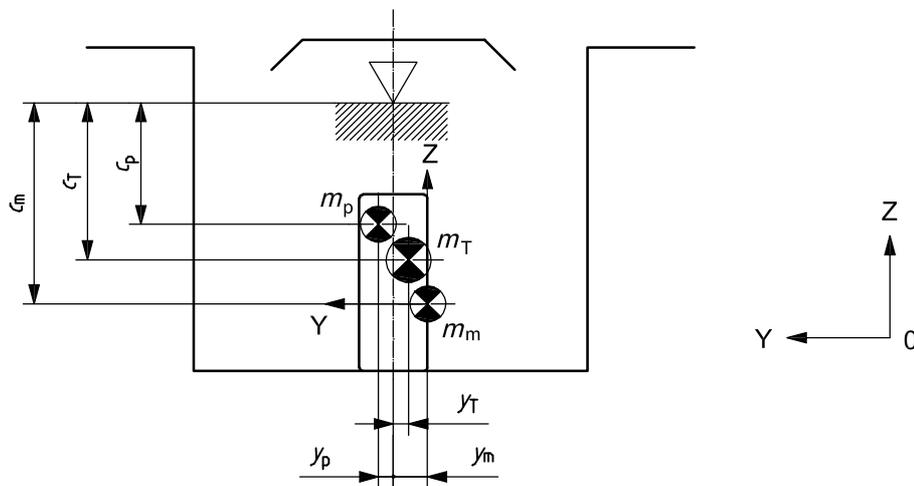
m_m is the mass of moped, in kg;

c_m is the distance along the z-axis from the knife edge to the centre of gravity of the moped, in m;

y_m is the distance along the y-axis from the knife edge to the centre of gravity of the moped, in m.



a) Side view



b) Rear view

Key

- c_m distance along the z-axis from the knife edge to the centre of gravity of the moped
- c_p distance along the z-axis from the knife edge to the centre of gravity of the platform
- c_T distance along the z-axis from the knife edge to the centre of gravity of the moped/platform combination
- m_m mass of moped
- m_p mass of platform
- m_T mass of moped/platform combination
- y_m distance along the y-axis from the knife edge to the centre of gravity of the moped
- y_p distance along the y-axis from the knife edge to the centre of gravity of the platform
- y_T distance along the y-axis from the knife edge to the centre of gravity of the moped/platform combination

Figure 2 — Measurement procedure for roll moment of inertia of the moped (procedure with physical pendulum principle using a platform)

6.3 Pitch moment of inertia about y-axis (physical pendulum principle)

6.3.1 Pitch moment of inertia about CD-axis for empty platform

Inertia moment about the CD-axis for the empty platform shall be measured in the procedure described below (see Figure 3).

- a) Place the knife edges C and D on the stay so that they can freely oscillate around the CD-axis.
- b) Oscillate the platform gently around the CD-axis. It is desirable to keep total oscillating angle below 5°.
- c) Make sure that the platform oscillates in a stable way and measure the time required for the platform to oscillate 50 times by a stop watch. Repeat this process 3 times and obtain the average value of 3 average cycle times. The result shall be the period.
- d) Calculate the inertia moment of the platform about the CD-axis, I_{yp} , expressed in kgm^2 , using Equation (3):

$$I_{yp} = \left(\frac{T_{yp}}{2\pi} \right)^2 \sqrt{c_p^2 + x_p^2} m_p g \quad (3)$$

where

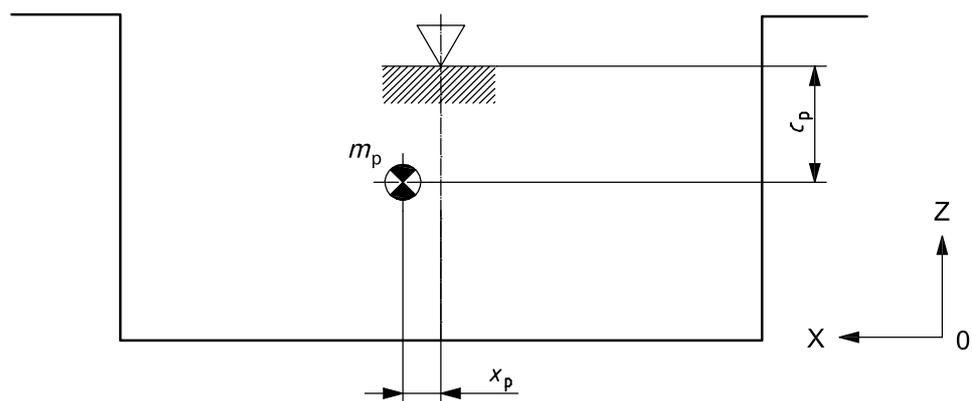
T_{yp} is the period for the platform to oscillate around the CD-axis, in s;

c_p is the distance along the z-axis from the knife edge to the centre of gravity of the platform, in m;

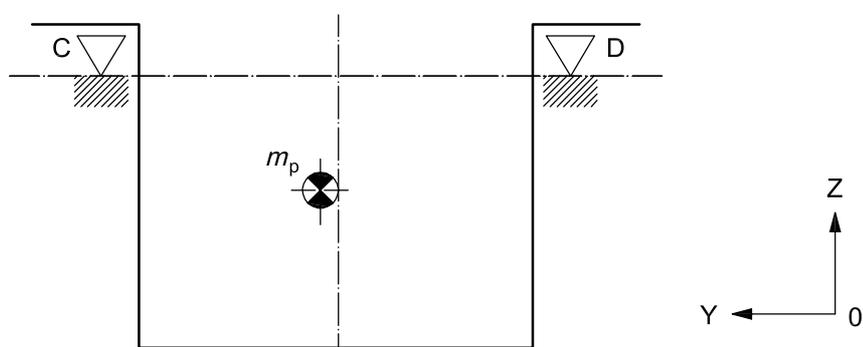
x_p is the distance along the x-axis from the knife edge to the centre of gravity of the platform, in m;

m_p is the mass of the platform, in kg;

g is acceleration due to gravity (9,81 m/s^2).



a) Side view



b) Rear view

Key

c_p distance along the z-axis from the knife edge to the centre of gravity of the platform

m_p mass of platform

x_p distance along the x-axis from the knife edge to the centre of gravity of the platform

Figure 3 — Measurement procedure for pitch moment of inertia of empty platform (procedure with physical pendulum principle)

6.3.2 Pitch moment of inertia about moped about y-axis

Pitch moment of inertia of the moped about the x-axis shall be measured in the procedure described below (see Figure 4).

NOTE This measurement applies to both the empty moped and the moped with a rider.

- a) Place the moped on the platform and fix it so that it cannot move. The lateral inclination angle of the moped to the platform shall be $0^\circ \pm 0,5^\circ$.
- b) Place the knife edges C and D on the stay so that they can freely oscillate around the CD-axis.
- c) Oscillate the moped/platform combination gently around the CD-axis. It is desirable to keep total oscillating angle below 5° .
- d) Make sure that the platform oscillates in a stable way and measure the time required for the platform to oscillate 50 times by a stop watch. Repeat this process 3 times and obtain the average value of 3 average cycle times. The result shall be the period.
- e) Calculate the inertia moment of the moped about the y-axis, I_{ym} , expressed in kgm^2 , using Equation (4):

$$I_{ym} = \left(\frac{T_{yT}}{2\pi} \right)^2 \sqrt{c_T^2 + x_T^2} m_T g - I_{yp} - m_m (c_m^2 + x_m^2) \quad (4)$$

where

T_{yT} is the period for the platform with the moped on it to oscillate around the CD-axis, in s;

c_T is the distance along the z-axis from the knife edge to the centre of gravity of the moped/platform combination, in m;

x_T is the distance along the x-axis from the knife edge to the centre of gravity of the moped/platform combination, in m;

m_T is the mass of the moped/platform combination, in kg;

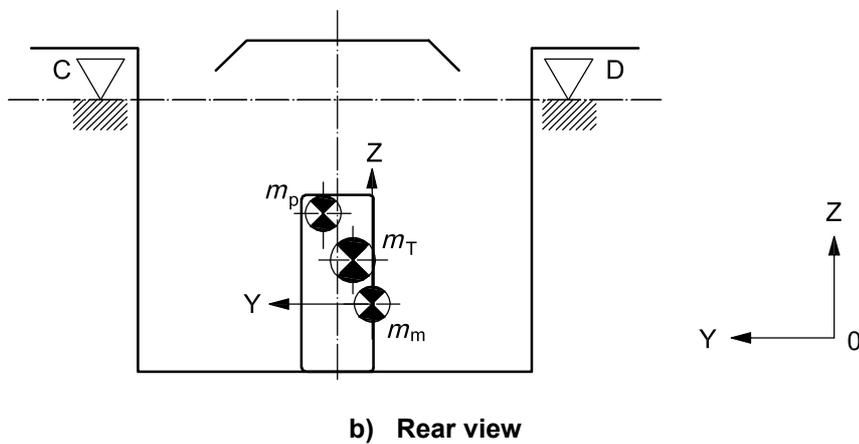
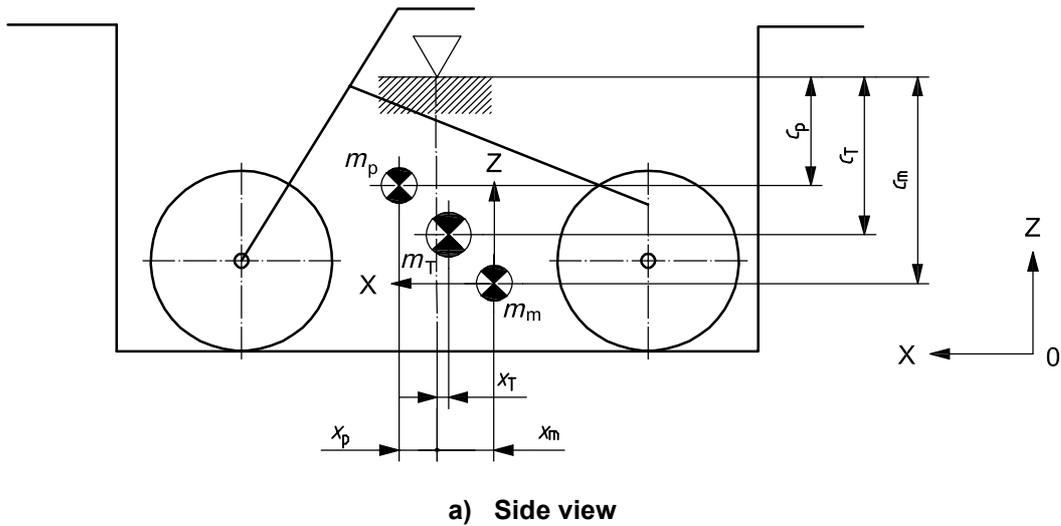
I_{yp} is the inertia moment of the platform about the CD-axis, in kgm^2 [see Equation (3)];

g is acceleration due to gravity ($9,81\text{m/s}^2$);

m_m is the mass of the moped, in kg;

c_m is the distance along the z-axis from the knife edge to the centre of gravity of the moped, in m;

x_m is the distance along the x-axis from the knife edge to the centre of gravity of the moped, in m.



Key

- c_m distance along the z-axis from the knife edge to the centre of gravity of the moped
- c_p distance along the z-axis from the knife edge to the centre of gravity of the platform
- c_T distance along the z-axis from the knife edge to the centre of gravity of the moped/platform combination
- m_m mass of moped
- m_p mass of platform
- m_T mass of moped/platform combination
- x_m distance along the x-axis from the knife edge to the centre of gravity of the moped
- x_p distance along the x-axis from the knife edge to the centre of gravity of the platform
- x_T distance along the x-axis from the knife edge to the centre of gravity of the moped/platform combination

Figure 4 — Measurement procedure for pitch moment of inertia of the moped (procedure with physical pendulum principle using a platform)

6.4 Yaw moment of inertia about z-axis (bifilar pendulum principle)

6.4.1 Yaw moment of inertia about vertical central axis for empty platform

Inertia moment about the vertical axis passing through the centre, E, of the bottom surface of the empty platform shall be measured in the procedure described below (see Figure 5).

- a) Set up a weight of mass m_{d1} so that the centre of gravity of the platform is on the perpendicular line passing the centre, E, of the platform. Calculate the weight set-up position by using Equation (5):

$$\begin{aligned}x_{d1} &= \frac{m_p x_p}{m_{d1}} \\y_{d1} &= \frac{m_p y_p}{m_{d1}}\end{aligned}\quad (5)$$

where

- x_{d1} is the distance along the x-axis from the centre of the platform to the weight of mass m_{d1} , in m;
- y_{d1} is the distance along the y-axis from the centre of the platform to the weight of mass m_{d1} , in m;
- m_p is the mass of the platform, in kg;
- x_p is the distance along the x-axis from the centre of the platform to the centre of gravity of the platform, in m;
- y_p is the distance along the y-axis from the centre of the platform to the centre of gravity of the platform, in m;
- m_{d1} is the mass of the weight provided for adjusting the location of the centre of gravity of the platform, in kg.

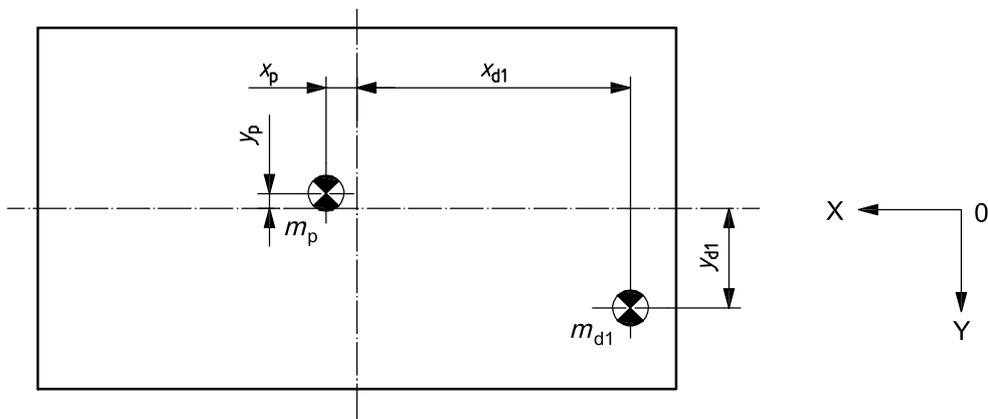
NOTE When the centre, E, and the centre of gravity of the platform coincide with each other, the value of all the distances is zero.

- b) Suspend the platform with 2 wires of the same length.
- c) Oscillate the entire platform around the vertical axis passing point E. It is desirable to keep total oscillating angle below 5° .
- d) Make sure that the platform oscillates in a stable way and measure the time required for the platform to oscillate 50 times by a stop watch. Repeat this procedure 3 times and obtain the average value of 3 average cycle times. The result shall be the period.
- e) Calculate the inertia moment of the platform about the z-axis, I_{zp} , expressed in kgm^2 , using Equation (6):

$$\begin{aligned}l_p^2 &= x_p^2 + y_p^2 \\l_{d1}^2 &= x_{d1}^2 + y_{d1}^2 \\I_{zp} &= \left(\frac{T_{zp}}{2\pi}\right)^2 \frac{ab}{h} (m_p + m_{d1})g - m_p l_p^2 - m_{d1} l_{d1}^2\end{aligned}\quad (6)$$

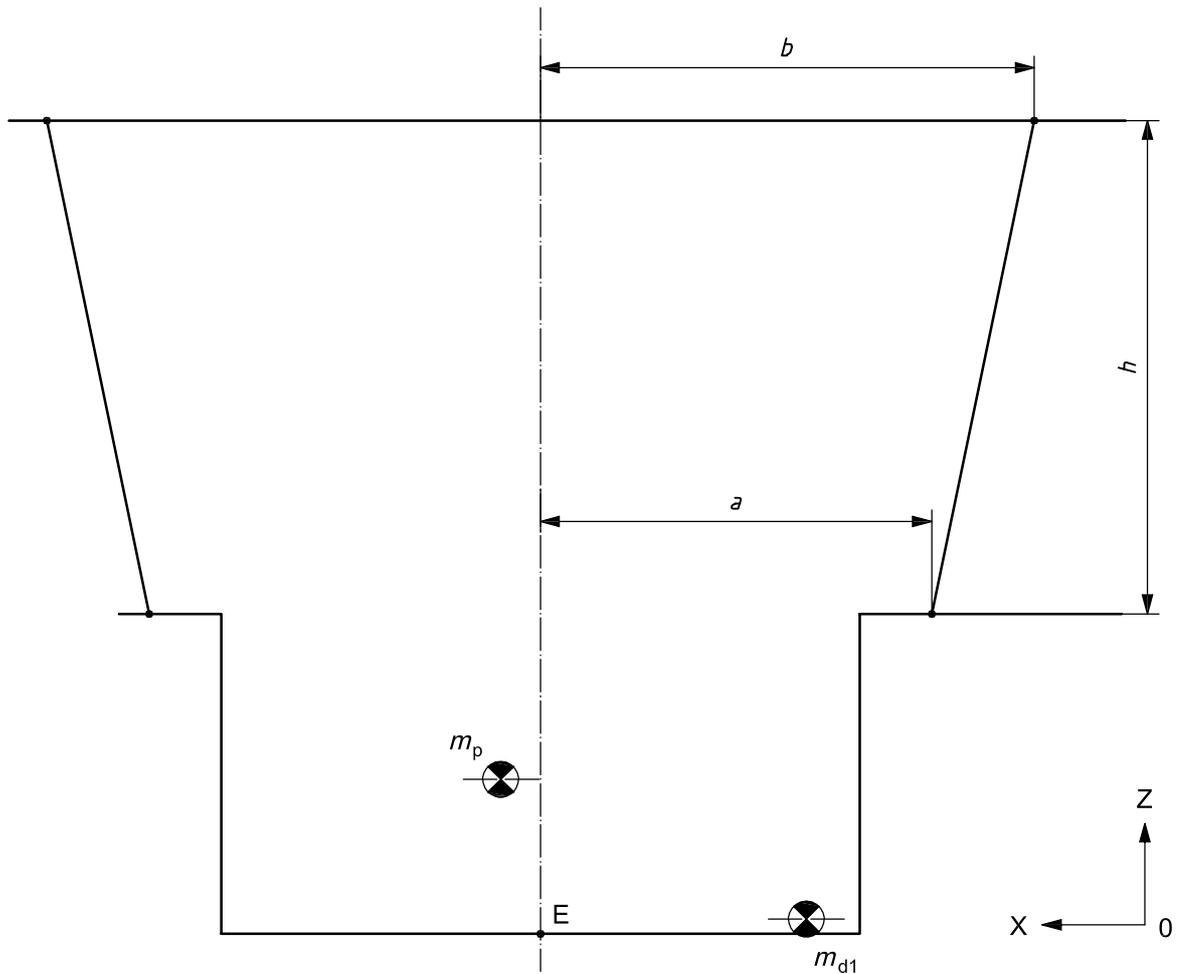
where

- l_p is the distance from the centre of the platform to the centre of gravity of the platform only, in m;
- l_{d1} is the distance from the centre of the platform to weight m_{d1} , in m;
- T_{zp} is the period for the platform to oscillate around the vertical axis passing point E, in s;
- a is half the distance between the lower fixing points of the wires suspending the platform, in m;
- b is half the distance between the upper fixing points of the wires suspending the platform, in m;
- h is the distance along the z-axis between the upper and lower fixing points of the wires suspending the platform, in m;
- g is acceleration due to gravity (9,81 m/s²).



a) Top view

Figure 5 (continued)



b) Side view

Key

- a half the distance between the lower fixing points of the wires suspending the platform
- b half the distance between the upper fixing points of the wires suspending the platform
- h distance along the z-axis between upper and lower fixing points of the wires suspending the platform
- m_{d1} mass of weight provided for adjusting the location of the centre of gravity of the platform
- m_p mass of the platform
- x_{d1} distance along the x-axis from the centre of the platform to the weight of mass m_{d1}
- x_p distance along the x-axis from the centre of the platform to the centre of gravity of the platform
- y_{d1} distance along the y-axis from the centre of the platform to the weight of mass m_{d1}
- y_p distance along the y-axis from the centre of the platform to the centre of gravity of the platform
- E centre of the bottom surface of the empty platform

**Figure 5 — Measurement procedure for yaw moment of inertia of empty platform
(procedure with bifilar pendulum principle)**

6.4.2 Yaw moment of inertia of moped about z-axis

Yaw moment of inertia of the moped about the z-axis shall be measured in the procedure described below (see Figure 6).

NOTE This measurement applies to both the empty moped and the moped with a rider.

- a) Place the moped on the platform and fix it so it cannot move. Lateral inclination of the moped to the platform shall be $0^\circ \pm 0,5^\circ$.
- b) Position the moped so that the point of its centre of gravity is on the perpendicular line of point E of the platform. If it cannot be adjusted, set up the weight of mass m_{d2} as shown in Figure 6.
- c) Calculate the weight set-up position using Equation (7):

$$\begin{aligned}
 x_{d2} &= \frac{m_m x_m}{m_{d2}} \\
 y_{d2} &= \frac{m_m y_m}{m_{d2}}
 \end{aligned}
 \tag{7}$$

where

- x_{d2} is the distance along the x-axis from the centre of the platform to the weight of mass m_{d2} , in m;
- y_{d2} is the distance along the y-axis from the centre of the platform to the weight of mass m_{d2} , in m;
- m_m is the mass of the moped, in kg;
- x_m is the distance along the x-axis from the centre of the platform to the centre of gravity of the moped, in m;
- y_m is the distance along the y-axis from the centre of the platform to the centre of gravity of the moped, in m;
- m_{d2} is the mass of the weight provided for adjusting the location of the centre of gravity of the moped, in kg.

NOTE When the centre, E, and the centre of gravity of the moped coincide with each other, the value of all the distances is zero.

- d) Oscillate the moped/platform combination around the perpendicular axis passing point E. It is desirable to keep the total oscillating angle below 5° .
- e) Make sure that the platform is oscillating in a stable way and measure the time required for the platform to oscillate 50 times by a stop watch. Repeat this process 3 times and obtain the average value of 3 average cycle times. The result shall be the period.
- f) Calculate the inertia moment of the moped about the z-axis, I_{zm} , expressed in kgm^2 , using Equation (8):

$$\begin{aligned}
 l_m^2 &= x_m^2 + y_m^2 \\
 l_{d2}^2 &= x_{d2}^2 + y_{d2}^2 \\
 I_{zm} &= \left(\frac{T_z T}{2\pi} \right)^2 \frac{ab}{h} (m_p + m_{d1} + m_m + m_{d2}) g - I_{zp} - m_m l_m^2 - m_{d2} l_{d2}^2
 \end{aligned}
 \tag{8}$$

where

l_m is the distance from the centre of platform to the centre of gravity of the moped, in m;

l_{d2} is the distance from the centre of the platform to weight m_{d2} , in m;

T_{zT} is the period that the platform with the moped placed on it takes to oscillate, in s;

a is half the distance between the lower fixing points of the wires suspending the platform, in m;

b is half the distance between the upper fixing points of the wires suspending the platform, in m;

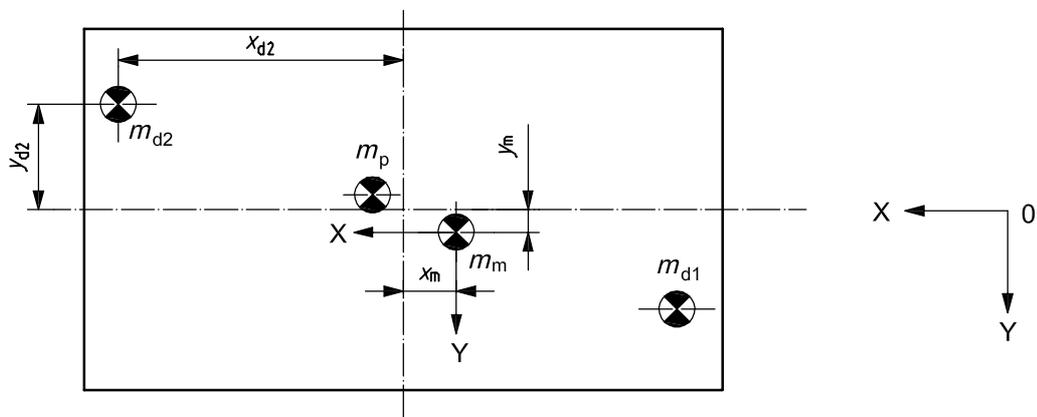
h is the distance along the z-axis between the upper and lower fixing points of the wires suspending the platform, in m;

m_p is the mass of the platform, in kg;

m_{d1} is the mass of the weight provided for adjusting the location of the centre of gravity of the platform, in kg;

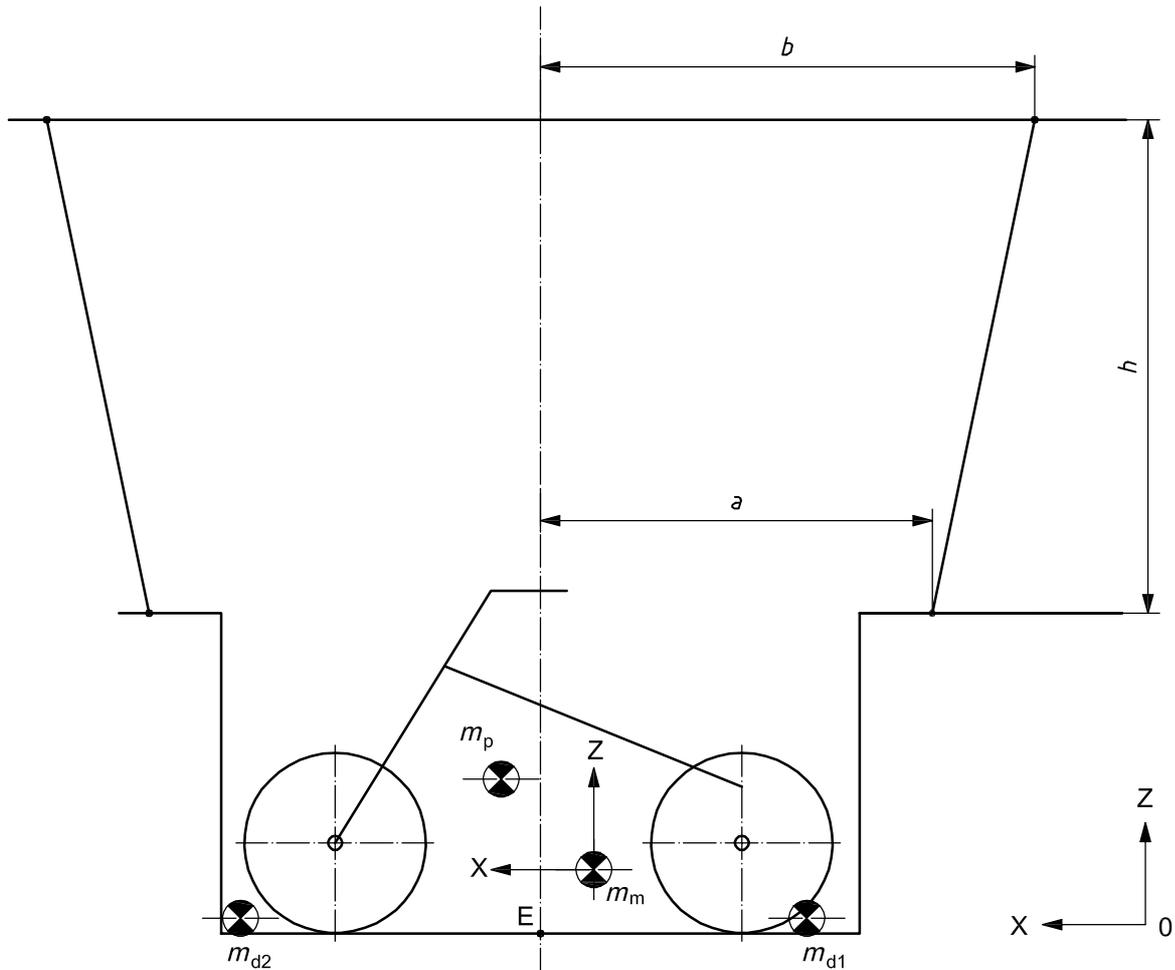
g is acceleration due to gravity (9,81 m/s²);

I_{zp} is the inertia moment of the platform about the z-axis, in kgm² [see Equation (6)].



a) Top view

Figure 6 (continued)



b) Side view

Key

- a half the distance between the lower fixing points of the wires suspending the platform
- b half the distance between the upper fixing points of the wires suspending the platform
- h distance along the z -axis between upper and lower fixing points of the wires suspending the platform
- m_{d1} mass of the weight provided for adjusting the location of the centre of gravity of the platform
- m_{d2} mass of the weight provided for adjusting the location of the centre of gravity of the moped
- m_m mass of the moped
- m_p mass of the platform
- x_{d2} distance along the x -axis from the centre of the platform to the weight of mass m_{d2}
- x_m distance along the x -axis from the centre of the platform to the centre of gravity of the moped
- y_{d2} distance along the y -axis from the centre of the platform to the weight of mass m_{d2}
- y_m distance along the y -axis from the centre of the platform to the centre of gravity of the moped
- E centre of the bottom surface of the empty platform

Figure 6 — Measurement procedure for yaw moment of inertia of the moped (procedure with bifilar pendulum principle using a platform)

7 Test results

Record the measurement results in the report as shown in Annex A. Round the measurement values of the inertia moment to 3 significant digits.

Annex A
(normative)

Format for measurement results

The format shown in this annex shall be used to record the measurement results of moments of inertia for mopeds, calculated in accordance with this International Standard.

Moped – Moments of inertia – Measurement results calculated in accordance with ISO 9043	
1 Vehicle identification	
1.1	Make, model, type:
1.2	Year model:
1.3	Vehicle Descriptor Section (VDS) (see ISO 3779):
1.4	Tyre pressure: front: kPa / rear: kPa
1.5	Suspension setting (if adjustable):
1.6	Suspension fixing position: front ^a : rear ^b :
1.7	Other conditions ^c :
2 Test conditions	
2.1	Date of test:
2.2	Place of test:
2.3	Measured by:
2.4	Rider ^d : None / Dummy / Human being.....
2.5	Dummy reference (if applicable):
2.6	Seating position ^e : mm
2.7	Posture angle ^f : degrees
2.8	Measuring condition of period ^g : degrees
3 Test results	
3.1	Roll moment of inertia of the moped about the x-axis, I_{xm} : kgm ²
3.2	Pitch moment of inertia of the moped about the y-axis, I_{ym} : kgm ²
3.3	Yaw moment of inertia of the moped about the z-axis, I_{zm} : kgm ²
<p>^a Distance from the centre of the head pipe to the ground. If this distance cannot be measured, record the reference point on the springing portion of the moped front side and measure the distance from this point to the ground.</p> <p>^b Distance from the centre of the bolt mounting the upper side of the rear suspension to the ground. If this distance cannot be measured, record the reference point on the springing portion of the rear side of the moped and measure the distance from this point to the ground.</p> <p>^c See Clause 4: record the added or changed measuring conditions.</p> <p>^d Delete from the list (“None”, “Dummy”, or “Human being”) those which are not applicable.</p> <p>^e Distance from the front axle to the point H along the x-axis. The point H is the centre of rotation of the trunk of the body and femoral region of the rider.</p> <p>^f Angle formed by the line connecting the point S and the point H and the x-axis. Point S is the centre of rotation of the trunk of the body and arms of the rider.</p> <p>^g If period was measured by a different method from the one described in ISO 9043, record those conditions.</p>	

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Price based on 17 pages