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**Motorcycles — Measurement methods for  
moments of inertia**

*Motorcycles — Méthodes de mesure des moments d'inertie*

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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 9129 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 22, *Motorcycles*.

This second edition cancels and replaces the first edition (ISO 9129:1988), which has been technically revised.

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## Introduction

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

In the evaluation of motorcycle stability, the determination of the kinetic characteristics of the motorcycle/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 motorcycle and of the motorcycle/rider combination.

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# Motorcycles — Measurement methods for moments of inertia

## 1 Scope

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

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 9130, *Motorcycles — 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

#### **motorcycle-fixed axis system (x, y, z)**

right-hand orthogonal axis system fixed in the motorcycle, such that when the motorcycle 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 motorcycle, 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 motorcycle.

NOTE 2 Assuming that the motorcycle 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 motorcycle shall be as follows:

- a) the motorcycle 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 motorcycle shall be as follows:

- a) measurement conditions of the motorcycle 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 motorcycle;
  - 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, motorcycle, and the platform with the motorcycle placed on it, in accordance with ISO 9130.

### 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  $\text{kgm}^2$ , 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

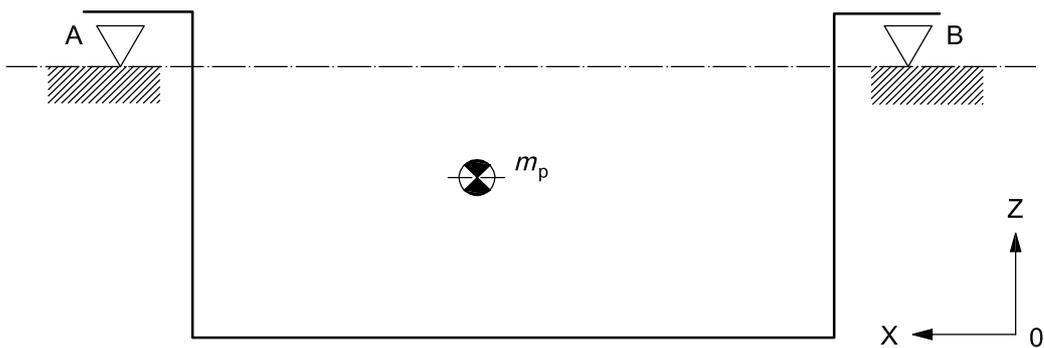
$T_{xp}$  is the period for the platform to oscillate around the AB-axis, in s;

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

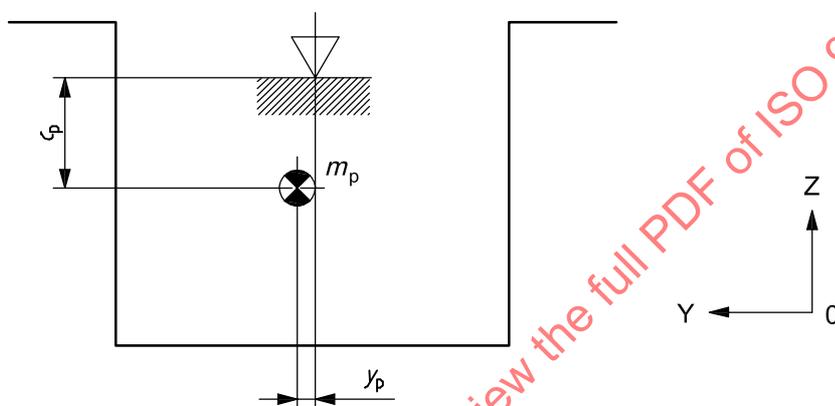
$y_p$  is the distance along the y-axis from the knife edge to the centre of gravity of the platform, in m;

$m_p$  is the mass of the platform, in kg;

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



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 motorcycle about x-axis

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

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

- a) Place the motorcycle on the platform and fix it so that it cannot move. The lateral inclination angle of the motorcycle 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 motorcycle/platform combination gently around the AB-axis. It is desirable to keep total oscillating angle below  $5^\circ$ .
- 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 motorcycle about the x-axis,  $I_{xm}$ , expressed in  $\text{kgm}^2$ , 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 motorcycle 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 motorcycle/platform combination, in m;

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

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

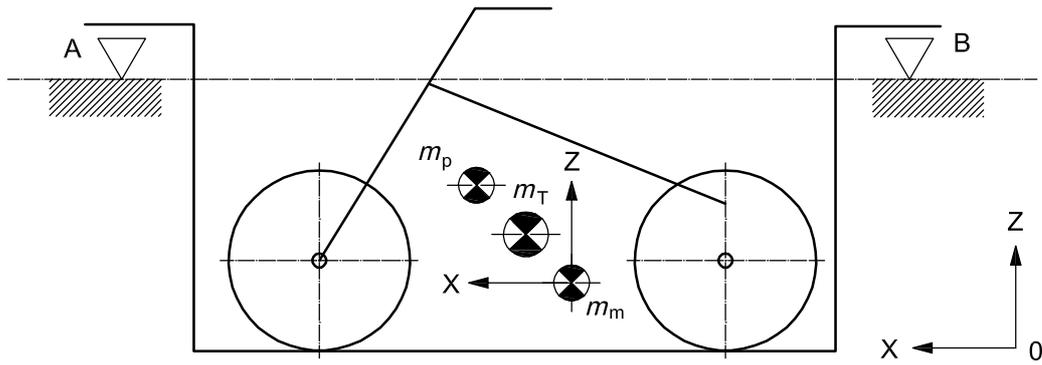
$I_{xp}$  is the inertia moment of the platform about the AB-axis, in  $\text{kgm}^2$  [see Equation (1)];

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

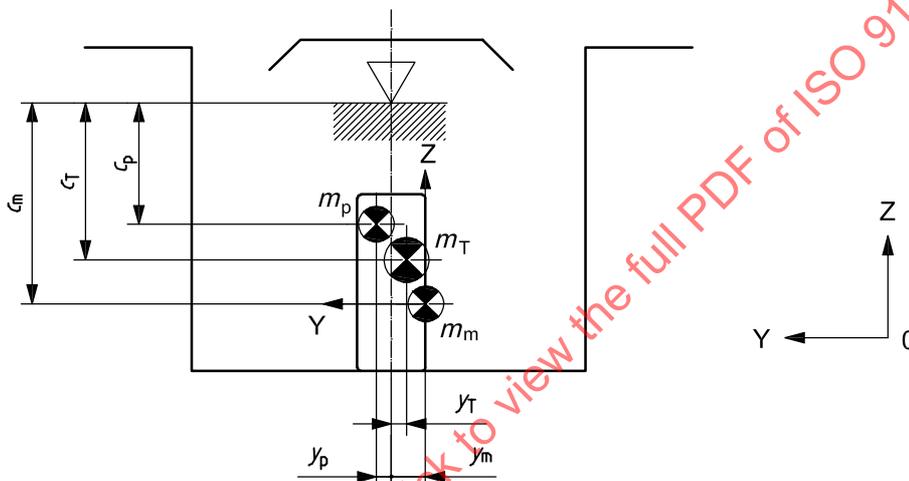
$m_m$  is the mass of motorcycle, in kg;

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

$y_m$  is the distance along the y-axis from the knife edge to the centre of gravity of the motorcycle, 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 motorcycle
- $c_p$  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 motorcycle/platform combination
- $m_m$  mass of motorcycle
- $m_p$  mass of platform
- $m_T$  mass of motorcycle/platform combination
- $y_m$  distance along the y-axis from the knife edge to the centre of gravity of the motorcycle
- $y_p$  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 motorcycle/platform combination

**Figure 2 — Measurement procedure for roll moment of inertia of the motorcycle (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).

- Place the knife edges C and D on the stay so that they can freely oscillate around the CD-axis.
- Oscillate the platform gently around the CD-axis. It is desirable to keep total oscillating angle below 5°.
- 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.
- Calculate the inertia moment of the platform about the CD-axis,  $I_{yp}$ , expressed in  $\text{kgm}^2$ , 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

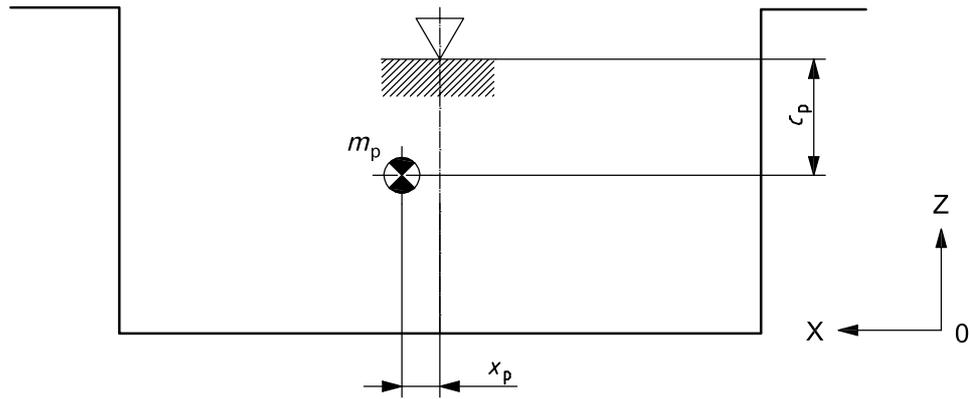
$T_{yp}$  is the period for the platform to oscillate around the CD-axis, in s;

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

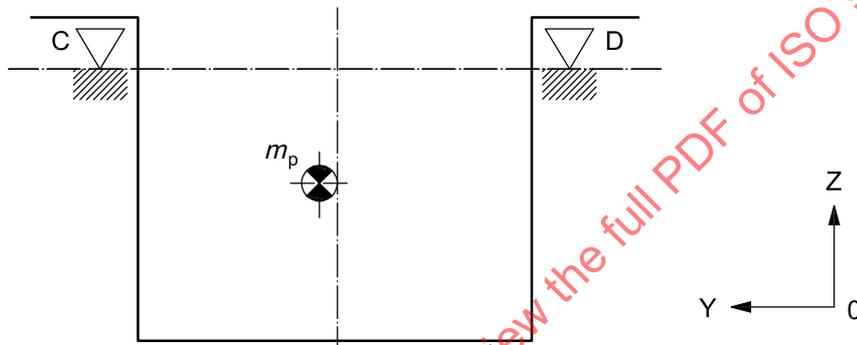
$x_p$  is the distance along the x-axis from the knife edge to the centre of gravity of the platform, in m;

$m_p$  is the mass of the platform, in kg;

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



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 motorcycle about y-axis

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

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

- a) Place the motorcycle on the platform and fix it so that it cannot move. The lateral inclination angle of the motorcycle 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 motorcycle/platform combination gently around the CD-axis. It is desirable to keep total oscillating angle below  $5^\circ$ .
- 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 motorcycle about the y-axis,  $I_{ym}$ , expressed in  $\text{kgm}^2$ , 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 motorcycle 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 motorcycle/platform combination, in m;

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

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

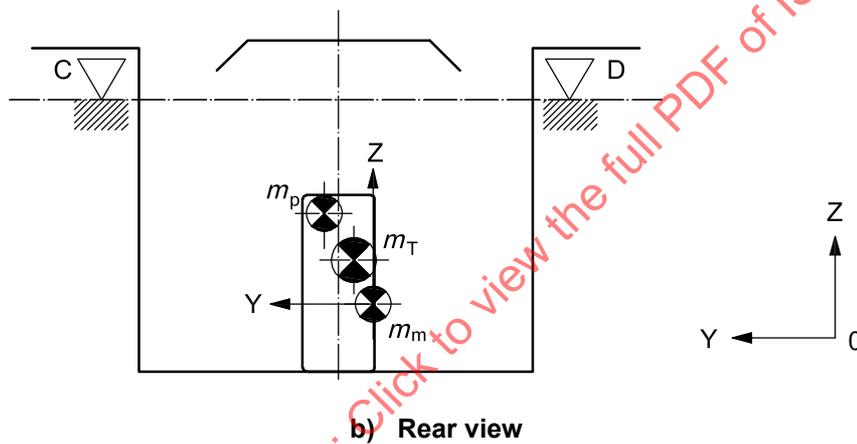
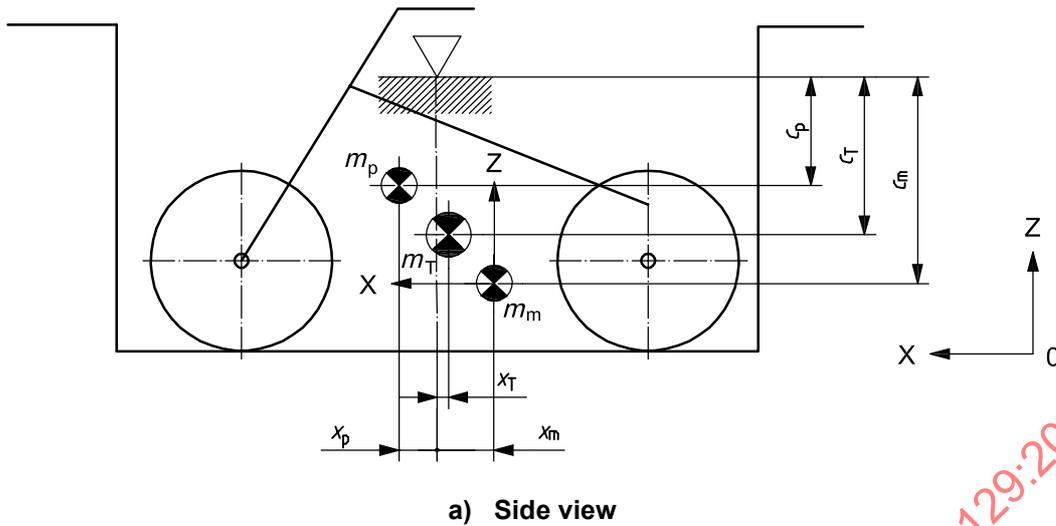
$I_{yp}$  is the inertia moment of the platform about the CD-axis, in  $\text{kgm}^2$  [see Equation (3)];

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

$m_m$  is the mass of the motorcycle, in kg;

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

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



**Key**

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

**Figure 4 — Measurement procedure for pitch moment of inertia of the motorcycle (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  $5^\circ$ .
- 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  $\text{kgm}^2$ , 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 (9,81m/s<sup>2</sup>).

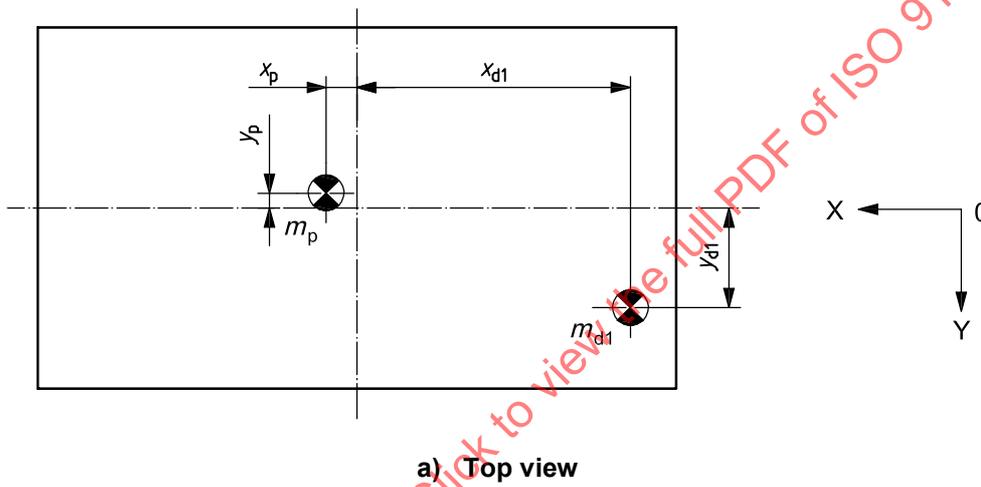
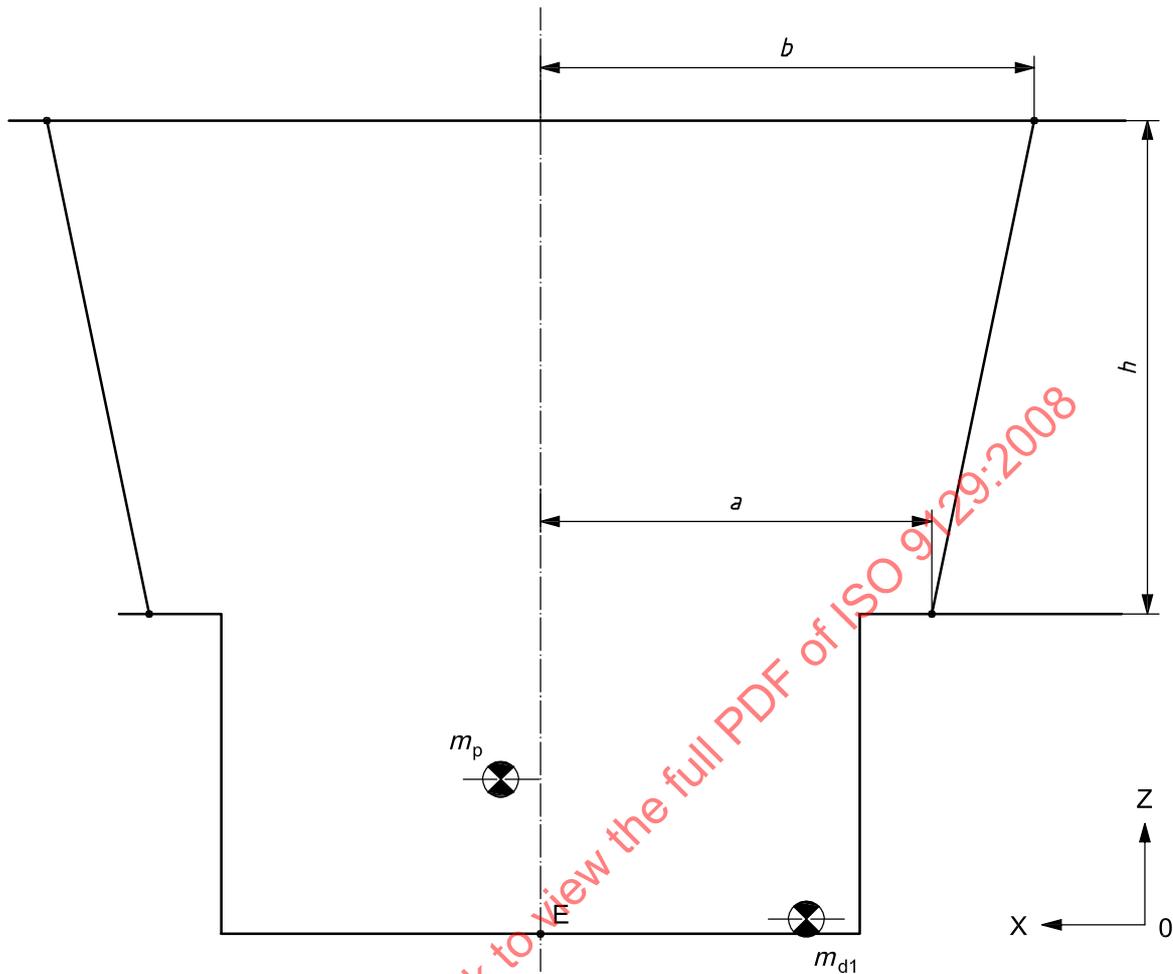


Figure 5 (continued)



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)**