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Motorcycle and motorcycle-rider kinematics — Vocabulary

Cinématique relative au motocycle et à son conducteur — Vocabulaire

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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.

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.

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International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
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Motorcycle and motorcycle-rider kinematics — Vocabulary

1 Scope

1.1 This International Standard specifies symbols, definitions and conventions related to motorcycle and motorcycle-rider motions and kinematics and to the modelling thereof.

1.2 It does not deal with methods of measurement, nor with the units used in reporting the results, nor with accuracy.

1.3 The provisions of this International Standard apply to two-wheeled motorcycles as defined in ISO 3833.

1.4 This International Standard does not cover road motorcycles which are controlled by a pedestrian or which are used for the carriage of goods to the exclusion of persons.

1.5 This International Standard specifies terms, definitions and symbols for the following systems, parts and aspects:

steering system (clause 3)

suspension system (clause 4)

tyres and wheels (clause 5)

basic principles of axis systems and kinematics (clause 6)

directional dynamics (clause 7)

motorcycle motion characteristics (clause 8)

aerodynamic characteristics of the motorcycle-rider combination (clause 9)

riding postures and behaviours (clause 10)

tests (clause 11).

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

ISO 6725:1981, *Road vehicles — Dimensions of two-wheeled mopeds and motorcycles — Terms and definitions.*

ISO 6726:1988, *Mopeds and motorcycles with two wheels — Masses — Vocabulary.*

3 Steering system

3.1 Axis and angles of the steering assembly

3.1.1
steer axis
z_H
rotational axis of the steering assembly for steering control which coincides with the axis of the steering stem and with the axis of the steering head pipe

3.1.2
steer angle
δ_H
angle of motion of the steering assembly about the **steer axis** (3.1.1) which is zero when the front wheel plane is parallel to the motorcycle longitudinal plane

3.1.3
wheel steer angle
δ_W

angle formed by the intersection with the road surface plane of the motorcycle longitudinal plane and the front wheel plane

3.2 Dynamic quantities of the steering assembly

3.2.1
steering velocity
$\dot{\delta}$
angular velocity of the sprung part of the steering assembly about the z_f-axis

3.2.2
steering velocity of the handlebars
$\dot{\delta}_H$
angular velocity of the handlebars about the z_H-axis

3.2.3
steer torque
torque about the **steer axis** (3.1.1)

3.2.4
steer force
value obtained from dividing the **steer torque** (3.2.3) and the effective rotational radius of the steering handle

NOTE — The effective rotational radius of the steering handle is the distance between the **steer axis** (3.1.1) and the centre point of the steering handlegrip projected on the plane perpendicular to the steer axis.

3.2.5
steady state steer torque
torque applied to the steering handle in order to maintain the motion of the motorcycle-rider combination in a given state

NOTE — When the motorcycle-rider combination is turning, this torque is classified as **positive steer torque** (3.2.5.1), **neutral steer torque** (3.2.5.2) or **negative steer torque** (3.2.5.3).

3.2.5.1
positive steer torque
steady state steer torque (3.2.5) applied in the direction equal to that in which the motorcycle-rider combination is turning

3.2.5.2
neutral steer torque
amount of **steady state steer torque** (3.2.5) equal to zero, required when the motorcycle-rider combination is turning

3.2.5.3
negative steer torque
steady state steer torque (3.2.5) applied in the direction opposite to that in which the motorcycle-rider combination is turning

3.2.6
steady state steer force
value obtained from dividing the **steady state steer torque** (3.2.5) and the effective rotational radius of the steering handle

3.2.7
stiffness of the steering assembly
resistance against the deformation caused by the loads applied to the steering assembly

NOTE — There are torsional and bending stiffnesses.

3.2.8
friction torque of the steering assembly
torque about the **steer axis** (3.1.1) required to initiate the motion of the steering assembly which does not include the friction between the tyre and the road surface

3.2.9
damping torque of the steering assembly
damping torque about the **steer axis** (3.1.1) at a certain **steering velocity** (3.2.1) which does not include the damping between the tyre and the road surface

3.2.10
moment of inertia of the steering assembly
moment of inertia of the steering assembly about the **steering axis** (3.1.1) under defined load conditions

3.3 Steering characteristics of the steering assembly

3.3.1
steering under stationary conditions
steering operation of the motorcycle-rider combination under stationary conditions

3.3.2
counter steering
positive action on the steering handle in order to compensate (cancel out) the change in the state of the motorcycle

3.3.3
disturbed steer
very short and quick rotation of the steering handle caused by an outside disturbance

3.3.4
loss of control in steering
uncontrollable rotation of the steering handle caused by a disturbance

4 Suspension system

4.1 Suspension geometry

4.1.1
wheel plane
centre plane of the wheel which is perpendicular to the wheel spin axis

4.1.2
wheel centre
intersection of the wheel spin axis and the **wheel plane** (4.1.1)

4.1.3
front and rear wheel alignment
position of the front and the rear wheel planes relative to some reference frame planes

4.1.4
steering system alignment
relation between the wheel(s) and the body or the road surface

NOTE — This term is often applied to the **fork off-set** (4.1.8), **castor** (4.1.7), **castor angle** (4.1.6).

4.1.5
alignment variation
displacements and deformations of the suspension system caused by forces applied to the wheels

4.1.6
castor angle
τ

SEE ISO 6725:1981, 6.12.

4.1.7
castor

SEE ISO 6725:1981, 6.11.

4.1.8
fork off-set
distance between the steering shaft centreline and the front wheel spin axis

4.1.9
vertical wheel travel
vertical distance between the wheel spin axis position when the suspension is fully stretched and when it is fully compressed according to the manufacturer's indication

4.1.10
spring and/or damper stroke
displacement between the spring and/or damper unit positions when fully stretched and when fully compressed according to the manufacturer's indication

4.2 Suspension dynamic rates

4.2.1
suspension rate
increase of ground contacting load necessary to approximate the wheel spin axis and the sprung mass projected on the vertical line passing through the wheel centre by the unit distance under the designated load

4.2.2
ride rate
increase of ground contacting load necessary to approximate the road plane and the sprung mass projected on the vertical line passing through the wheel centre by the unit distance under the designated load

4.2.3
link ratio of spring and/or damper
ratio of the **vertical wheel travel** (4.1.9) and the **spring and/or damper stroke** (4.1.10)

NOTES

1 The link ratio can be more or less than 1, depending on the location and the way of geometrical linking of the spring and/or damper in relation to the position of the wheel axis.

2 The link ratio can be a function of the wheel travel.

4.2.4
damping characteristics
relation between the damping force occurring at the damper unit and the damper piston speed

NOTE — The sign is positive when the damper is compressed, it is negative when the damper is stretched.

5 Tyres and wheels

5.1 Tyre axis system and variables

5.1.1
conventional centre of tyre contact
intersection of the wheel plane and the vertical projection of the spin axis of the wheel onto the road plane

5.1.2
geometrical centre of tyre contact
geometrical centre of the contact area between the tyre and the road plane

5.1.3
effective centre of tyre contact
centre of pressures in the contact area of the tyre and the road plane

NOTES

1 When the wheel is cambered, the effective centre of tyre contact can be displaced in the direction of the camber.

2 The effective centre of tyre contact may not be the **geometrical centre of tyre contact** (5.1.2) area due to distortion of the tyre produced by applied forces.

5.1.4
camber angle
ε
angle between the vertical and the wheel plane

5.1.5
tyre slip angle
α
angle between the x_t-axis and the direction of wheel travel in the **conventional centre of tyre contact** (5.1.1)

See figure 2.

5.1.6
slip ratio
S
⟨driving⟩

$$S = \frac{v_{tx} \cos \alpha - v_{tc}}{v_{tc}}$$

5.1.7
slip ratio
S
⟨braking⟩

$$S = \frac{v_{tx} \cos \alpha - v_{tc}}{v_{tx} \cos \alpha}$$

where

v_{tx} is the forward velocity of the conventional centre of the wheel;

v_{tc} is the peripheral velocity of the **conventional centre of tyre contact** (5.1.1) in reference to the centre of the wheel;

α is the **tyre slip angle** (5.1.5).

5.2 Forces applied to tyres and their coefficients

5.2.1
tyre vertical load
z_t-component of the force applied from the road plane to the tyre

5.2.2
tyre lateral force
y_t-component of the force applied from the road plane to the tyre

5.2.3
tyre longitudinal force
x_t-component of the force applied from the road plane to the tyre

5.2.4
tyre vertical stiffness
variation in the vertical load required to shift the distance between the **conventional centre of tyre contact** (5.1.1) and the **wheel centre** (4.1.2) in the vertical direction by the length, with the **camber angle** (5.1.4) being zero

5.2.5
tyre lateral stiffness
variation in the **tyre lateral force** (5.2.2) required to vary the **wheel centre** (4.1.2) in the y_t-direction by the length relative to the supporting surface, with the **camber angle** (5.1.4) being zero and a specified **tyre vertical load** (5.2.1) being applied

5.2.6
driving force
positive **tyre longitudinal force** (5.2.3) caused by application of driving torque in the x_t-direction

5.2.7
braking force
negative **tyre longitudinal force** (5.2.3) caused by application of braking torque in the y_t-direction

5.2.8
conicity force
tyre lateral force (5.2.2) which changes sign [with respect the **horizontal tyre axis system** (6.2.2)] with a change in direction of rotation when the **tyre slip angle** (5.1.5) and the **camber angle** (5.1.4) are zero

5.2.9
plysteer force
tyre lateral force (5.2.2) which does not change sign [with respect to the **horizontal tyre axis system** (6.2.2)] with a change in direction of rotation when the **tyre slip angle** (5.1.5) and the **camber angle** (5.1.4) are zero

5.2.10
camber force
camber thrust
tyre lateral force (5.2.2) applied to the tyre having some **camber angle** (5.1.4) when the **tyre slip angle** (5.1.5) is zero and the **plysteer force** (5.2.9) and **conicity force** (5.2.8) have been subtracted

5.2.11
cornering force
horizontal component, in the direction perpendicular to the direction of wheel travel, of the force applied from the road plane to the wheel having some **tyre slip angle** (5.1.5) when the **camber angle** (5.1.4) is zero

See figure 2.

5.2.12
tyre side force
tyre lateral force (5.2.2) when the **camber angle** (5.1.4) is zero and the **plysteer force** (5.2.9) and **conicity force** (5.2.8) have been subtracted

See figure 2.

5.2.13
tractive force
component of the tyre force vector in the direction of wheel travel of the **effective centre of tyre contact** (5.1.3), is equal to the **tyre lateral force** (5.2.2) times the sine of the **tyre slip angle** (5.1.5) plus the **tyre longitudinal force** (5.2.3) times the cosine of the **tyre slip angle** (5.1.5)

5.2.14
drag force
negative **tractive force** (5.2.13)

See figure 2.

5.2.15
rolling resistance
force opposite to the direction of wheel heading mainly resulting from deformation of a rolling tyre

5.2.16
rolling resistance coefficient
ratio between the rolling resistance and the **tyre vertical load** (5.2.1)

5.2.17
camber stiffness
rate of change of **tyre lateral force** (5.2.2) with respect to the change in **camber angle** (5.1.4), usually evaluated at zero camber angle and at zero **tyre slip angle** (5.1.5)

5.2.18
camber stiffness coefficient
ratio of **camber stiffness** (5.2.17) of a free straight-rolling tyre to the **tyre vertical load** (5.2.1)

5.2.19
cornering stiffness
rate of change of **tyre lateral force** (5.2.2) with respect to the change in **tyre slip angle** (5.1.5), usually evaluated at zero tyre slip angle and at zero **camber angle** (5.1.4)

5.2.20
cornering stiffness coefficient
ratio of **cornering stiffness** (5.2.19) of a free straight-rolling tyre to the **tyre vertical load** (5.2.1)

5.2.21
pneumatic trail
horizontal distance between the point of action of the **tyre side force** (5.2.12) and the **conventional centre of tyre contact** (5.1.1)

NOTE — This is a way of defining the aligning torque relative to the **tyre side force** (5.2.12).

5.2.22
tyre lag
delay that occurs in the change of the **tyre lateral force** (5.2.2) resulting from a change in **tyre slip angle** (5.1.5) or **camber angle** (5.1.4)

5.2.23
relaxation length
distance covered during the **tyre lag** (5.2.22)

NOTE — Normally, the relaxation length is defined as the distance rolled by the tyre until a value of 63,2 % of the normal value of **tyre lateral force** (5.2.2) is obtained when the **tyre slip angle** (5.1.5) and/or the **camber angle** (5.1.4) change(s) in steps from zero.

5.3 Moments applied to tyres

5.3.1
overturning moment
component about x_t-axis of moments applied from the road plane to the tyres

5.3.2
rolling resistance moment
component of the tyre moment vector about the y_t-axis resulting from the **rolling resistance** (5.2.15)

5.3.3
camber torque
component about the z_t-axis of moments applied from the road plane to the wheel having some **camber angle** (5.1.4) when the **tyre slip angle** (5.1.5) is zero

5.3.4
aligning torque
component of the tyre moment vector tending to rotate the tyre about the z_t-axis

5.4 Phenomena related with tyres

5.4.1
standing wave
phenomenon that occurs when the tyre peripheral speed exceeds a given peripheral velocity while it is rotating at a high speed

NOTE — Deformations caused by the tyre contact tend to remain without recovery even after the deformed portions of the tyre have left the road surface, which results in steady standing waves on the tyre surface.

6 Basic principles of axis systems and kinematics

6.1 Axis systems

See figure 3.

6.1.1
earth-fixed axis system
(X, Y, Z)
right-hand orthogonal axis system fixed on the earth, in which the X- and Y-axis are in a horizontal plane and the Z-axis is directed upwards

NOTE — The trajectory of the motorcycle is described with respect to this earth fixed axis system.

6.1.2
motorcycle axis system
(x', y', z')
right-hand orthogonal axis system which has its origin at the centre of gravity of 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 parallel to the motorcycle longitudinal plane, the y'-axis points to the rider's left and the z'-axis points upwards.

NOTE — Use the motorcycle-rider combination axis system (x'_{res}, y'_{res}, z'_{res}) which substitutes the motorcycle axis system in every corresponding definition when considering the motorcycle-rider combination instead of the motorcycle only.

6.2 Horizontal axis systems

6.2.1
horizontal motorcycle axis system
(x, y, z)
right-hand orthogonal axis system which has its origin at the centre of gravity of the motorcycle and moves together with the motorcycle body such that the x-y plane is always parallel to the X-Y plane of the **earth-fixed axis system** (6.1.1); the x-axis is the projection of the x'-axis of the **motorcycle axis system** (6.1.2) on the x-y plane and points forwards and the z-axis is parallel to the Z-axis of the **earth-fixed axis system** and points upwards

6.2.2
horizontal tyre axis system
(x_t, y_t, z_t)
right-hand orthogonal axis system which has its origin at the **conventional centre of tyre contact** (5.1.1); the x_t-axis is the intersection of the **wheel plane** (4.1.1) and the road plane with a positive direction forward, the z_t-axis is perpendicular to the road plane with a positive direction upward and the y_t-axis is in the road plane

NOTE — In order to differentiate between front and rear horizontal tyre axis systems, indices "f" and "r" are used.

6.3 Component and assembly axis systems

The following component and assembly axis systems are right-hand orthogonal axis systems which have an origin at the centre of gravity of the component or the assembly.

6.3.1
steering assembly axis system
(x'_{fu}, y'_{fu}, z'_{fu})
axis system of the steering assembly in which the z'_{fu}-axis is parallel to the steering head pipe axis and points upwards and the x'_{fu}-axis points forwards and is parallel to the **wheel plane** (4.1.1)

6.3.2
frame fixed axis system
(x_{ru}, y_{ru}, z_{ru})
horizontal axis system of the frame without the steering assembly

6.3.3
steering assembly sprung part fixed axis system
(x'_f, y'_f, z'_f)
assembly axis system which applies to the sprung part of the steering assembly and is parallel to the **steering assembly axis system** (6.3.1) and has axes pointing in the same directions

6.3.4
frame sprung part fixed axis system
(x_r, y_r, z_r)
horizontal assembly axis system which applies to the sprung part of the frame without the steering assembly

6.3.5
motorcycle longitudinal plane
plane that passes through the steering head pipe axis and that is parallel to the rear wheel plane

6.4 Ground contact axes

6.4.1
conventional ground contact axis
(x_{go})
axis through both **conventional centres of tyre contact** (5.1.1) of the front and rear tyres; the direction of this axis is positive in the forward direction of the motorcycle

6.4.2
geometrical ground contact axis
(x_{gg})
axis through both **geometrical centres of tyre contact** (5.1.2) of the front and rear tyres; the direction of the axes is positive in the forward direction of the motorcycle

6.4.3
effective ground contact axis
(x_{ge})
axis through both **effective centres of tyre contact** (5.1.3) of the front and rear tyres; the direction of the axis is positive in the forward direction of the motorcycle

6.4.4
angular orientation of the motorcycle
orientation of the **motorcycle axis system** (6.1.2) with respect to the **earth-fixed axis system** (6.1.1) which is given by the following sequence of three angular rotations starting from a condition in which the two sets of axes are initially aligned:

— yaw rotation, Ψ, about the aligned z'- and Z-axis;

— pitch rotation, θ, about the motorcycle y'-axis;

— roll rotation, Φ, about the motorcycle x'-axis.

NOTES

1 Roll rotations can also be considered about axes x_{go}, x_{gg} and x_{ge}. The respective angles will then be Φ_{go}, Φ_{gg} and Φ_{ge}.

2 Angular rotations are positive if clockwise when looking in the positive direction of the axis about which the rotation occurs.

6.4.5
rolling
banking
angular rotation of the motorcycle or of the motorcycle-rider combination about the x'-axis or x'_{res}-axis respectively

NOTE — Rolling can also be considered about the axes x_{go}, x_{gg} and x_{ge}, as defined in 6.4.5.1, 6.4.5.2 and 6.4.5.3.

6.4.5.1
conventional rolling
rolling (6.4.5) about the x_{go}-axis

6.4.5.2
geometrical rolling
rolling (6.4.5) about the x_{gg}-axis

6.4.5.3
effective rolling
rolling (6.4.5) about the x_{ge}-axis

6.4.6
pitching
angular rotation of the motorcycle or of the motorcycle-rider combination about the y'-axis or y'_{res}-axis respectively

6.4.7
yawing
angular rotation of the motorcycle or of the motorcycle-rider combination about the z'-axis or z'_{res}-axis respectively

6.5 Motorcycle masses and weight distribution

6.5.1
motorcycle mass
mass of the motorcycle under a given loading condition

NOTE — Some particular conditions of motorcycle mass are defined in ISO 6726.