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## Moped and moped-rider kinematics — Vocabulary

*Cinématique relative au cyclomoteur 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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

International Standard ISO 14722 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 23, *Mopeds*.

# Moped and moped-rider kinematics — Vocabulary

## 1 Scope

**1.1** This International Standard defines terms, symbols and conventions related to moped and moped-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 definitions in this International Standard apply to two-wheeled mopeds as defined in ISO 3833.

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

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC 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.*

## 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**
$\delta_H$
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 moped longitudinal plane

**3.1.3**
**wheel steer angle**
$\delta_W$
angle formed by the intersection with the road surface plane of the moped 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 moped-rider combination in a given state

NOTE When the moped-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 moped-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 moped-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 moped-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 moped-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 moped

**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**
$\tau$
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)

NOTE 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.

NOTE 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

See Figure 1.

### 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

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

NOTE 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**
$\varepsilon$
angle between the vertical and the wheel plane

**5.1.5**
**tyre slip angle**
$\alpha$
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⟩

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

**5.1.7**
**slip ratio**
$S$
⟨braking⟩

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

where

- $\upsilon_{tx}$ is the forward velocity of the conventional centre of the wheel;
- $\upsilon_{tc}$ is the peripheral velocity of the **conventional centre of tyre contact** (5.1.1) in reference to the centre of the wheel;
- $\alpha$ 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, when the **camber angle** (5.1.4) is 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, when the **camber angle** (5.1.4) is zero and a specified **tyre vertical load** (5.2.1) is 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 moped is described with respect to this earth fixed axis system.

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

NOTE The moped-rider combination axis system ($x'_{res}$, $y'_{res}$, $z'_{res}$) replaces the moped axis system in every corresponding definition when considering the moped-rider combination instead of the moped only.

## 6.2 Horizontal axis systems

**6.2.1**
**horizontal moped axis system**
($x$, $y$, $z$)
right-hand orthogonal axis system which has its origin at the centre of gravity of the moped and moves together with the moped 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 **moped 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, the 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**
**moped 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 moped

**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 moped

**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 moped

**6.4.4**
**angular orientation of the moped**
orientation of the **moped 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, $\Psi$, about the aligned $z'$- and $Z$-axis;

— pitch rotation, $\theta$, about the moped $y'$-axis;

— roll rotation, $\Phi$, about the moped $x'$-axis.

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

NOTE 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 moped or of the moped-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 moped or of the moped-rider combination about the $y'$-axis or $y'_{res}$-axis respectively

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

## 6.5 Moped masses and weight distribution

**6.5.1**
**moped mass**
mass of the moped under a given loading condition

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

**6.5.2**
**sprung mass**
mass corresponding to the load supported by the suspension

NOTE In cases where some of the masses of the propeller shaft, roller chain, suspension system, steering system, braking system, etc., constitute the sprung mass, such masses should be added to the corresponding masses according to the structure of the moped.

**6.5.3**
**unsprung mass**
mass which corresponds to the difference between moped mass and sprung mass

**6.5.4**
**weight distribution ratio**
percentage of weight distributed to each axle under well-defined loading conditions

## 6.6 Moments of inertia

**6.6.1**
**moment of inertia**
$I$
sum of the products of the elements of mass and the squares of their distances from an axis

NOTE This axis may be the axis that passes through the centre of gravity of the moped, the assembly or the component.

EXAMPLE Moments of inertia about the axes of the **moped axis system** (6.1.2) are indicated by $I_{x'x'}$, $I_{y'y'}$ or $I_{z'z'}$.

**6.6.2**
**product of inertia**
sum of the products of the elements of mass and their distances from two axes

NOTE The two axes should be clearly stipulated and indices used to indicate which axes are relevant.

EXAMPLE Product of inertia about $x'$-axis and $z'$-axis is indicated by $I_{z'x'}$.

## 6.7 Motion variables

**6.7.1**
**pitch angle**
$\theta$
angle formed between the $x_r$-axis and the $X$-$Y$ plane, which is positive when the $x_r$-axis is moving clockwise about the $Y$-axis seen in the positive sense of the $Y$-axis

**6.7.2**
**yaw angle**
$\Psi$
angle formed between the $x_{ru}$-axis projection on the road plane and the $X$-axis, which is positive when the $x_{ru}$-axis projection on the road plane is moving clockwise about the $Z$-axis seen in the positive sense of the $Z$-axis

**6.7.3**
**course angle**
$\nu$
angle between the horizontal moped speed and the $X$-axis which is positive when the moped velocity on the road plane is moving clockwise about the $Z$-axis seen in the positive sense of the $Z$-axis

**6.7.4**
**moped sideslip angle**
$\beta$
angle between the horizontal moped speed and the moped $x$-axis, which is equivalent to the difference between the course angle and the yaw angle

**6.7.5**
**roll angle**
**bank angle**
$\Phi$
angle between the $x'$-$z'$ plane and the $x$-$z$ plane which is positive for a right turn (clockwise as seen by the rider)

NOTE Other roll angles can be considered as the angles formed by the plane through the $x_{go}$ or $x_{gg}$ or $x_{ge}$-axis and the moped centre of gravity and the $z$-axis, these are defined in 6.7.5.1, 6.7.5.2 and 6.7.5.3.

**6.7.5.1**
**conventional roll angle**
$\Phi_{go}$
angle between the plane through the $x_{go}$-axis and the moped centre of gravity, which is positive for a right turn (clockwise as seen by the rider)

**6.7.5.2**
**geometrical roll angle**
$\Phi_{gg}$
angle between the plane through the $x_{gg}$-axis and the moped centre of gravity, which is positive for a right turn (clockwise as seen by the rider)

**6.7.5.3**
**effective roll angle**
$\Phi_{ge}$
angle between the plane through the $x_{ge}$-axis and the moped centre of gravity, which is positive for a right turn (clockwise as seen by the rider)

**6.7.6**
**resultant roll angles**
angles formed by the planes through either the $x_{go}$ or $x_{gg}$ or $x_{ge}$-axis and the moped-rider combination's centre of gravity and the $z$-axis; these are called respectively conventional ($\Phi_{go,res}$), geometrical ($\Phi_{gg,res}$) and effective ($\Phi_{ge,res}$) resultant force angle

**6.7.7**
**speed of the centre of gravity**
$\mathbf{v}$
velocity vector which has its origin at the centre of gravity of a component, an assembly or a moped

**6.7.8**
**horizontal moped speed**
$v_h$
horizontal component of the speed of the centre of gravity of the moped frame

**6.7.9**
**moped velocity**
$v$
vector quantity expressing the velocity of a point in the moped relative to the **earth-fixed axis system** (6.1.1), of which the following motion variables are components of this vector, resolved with respect to the moving **moped axis system** (6.1.2)

**6.7.9.1**
**longitudinal velocity**
$v_{x'}$
magnitude of the component of the velocity vector of a point in the moped in the $x'$-direction

**6.7.9.2**
**side velocity**
$v_{y'}$
magnitude of the component of the velocity vector of a point in the moped in the $y'$-direction

**6.7.9.3**
**normal velocity**
$v_{z'}$
magnitude of the component of the velocity vector of a point in the moped in the $z'$-direction

**6.7.9.4**
**forward velocity**
$v_x$
magnitude of the component of the velocity vector of a point in the moped perpendicular to the $y$-axis and parallel to the $x$-axis

**6.7.9.5**
**lateral velocity**
$v_y$
magnitude of the component of the velocity vector of a point in the moped perpendicular to the $x$-axis and parallel to the $y$-axis

**6.7.9.6**
**vertical velocity**
$v_z$
magnitude of the component of the velocity vector of a point in the moped parallel to the $z$-axis

**6.7.9.7**
**roll velocity**
**bank velocity**
$\dot{\Phi}$
angular velocity about the $x'$-axis

NOTE Other roll velocities can be considered as the angular velocities about either the $x_{go}$ or $x_{gg}$ or $x_{ge}$-axis, these are defined in 6.7.9.7.1, 6.7.9.7.2 and 6.7.9.7.3.

**6.7.9.7.1**
**conventional roll velocity**
$\dot{\Phi}_{go}$
angular velocity about the $x_{go}$-axis

**6.7.9.7.2**
**geometrical roll velocity**
$\dot{\Phi}_{gg}$
angular velocity about the $x_{gg}$-axis

**6.7.9.7.3**
**effective roll velocity**
$\dot{\Phi}_{ge}$
angular velocity about the $x_{ge}$-axis

**6.7.9.8**
**pitch velocity**
$\dot{\Theta}$
angular velocity about the $y'$-axis

**6.7.9.9**
**yaw velocity**
$\dot{\Psi}$
angular velocity about the $z$-axis

**6.7.10**
**acceleration vector of the centre of gravity**
$\boldsymbol{a}$
acceleration vector with its origin at the centre of gravity of a component, an assembly or a moped

**6.7.11**
**moped acceleration**
$a$
vector quantity expressing the acceleration of a point in the moped relative to the **earth-fixed axis system** (6.1.1) of which the following motion variables are components of this vector, resolved with respect to the **moped axis system** (6.1.2)

**6.7.11.1**
**longitudinal acceleration**
$a_{x'}$
magnitude of the component of the acceleration vector of a point in the moped in the $x'$-direction

**6.7.11.2**
**side acceleration**
$a_{y'}$
magnitude of the component of the acceleration vector of a point in the moped in the $y'$-direction

**6.7.11.3**
**normal acceleration**
$a_{z'}$
magnitude of the component of the acceleration vector of a point in the moped in the $z'$-direction

**6.7.11.4**
**forward acceleration**
$a_x$
magnitude of the component of the acceleration vector of a point in the moped perpendicular to the $y$-axis and parallel to the road plane

**6.7.11.5**
**lateral acceleration**
$a_y$
magnitude of the component of the acceleration vector of a point in the moped perpendicular to the $x$-axis and parallel to the road plane

**6.7.11.6**
**vertical acceleration**
$a_z$
magnitude of the component of the acceleration vector of a point in the moped parallel to the $z$-axis

**6.7.11.7**
**centripetal acceleration**
$a_c$
magnitude of the component of the acceleration vector of a point in the moped perpendicular to the tangent to the path of that point and parallel to the road plane

## 6.8 Forces

NOTE The external forces acting on the moped can be summed into one force vector ***F*** having the components defined in 6.5.1, 6.5.2 and 6.5.3.

**6.8.1**
**longitudinal force**
$F_{x'}$
component of the force vector in the $x'$-direction

**6.8.2**
**side force**
$F_{y'}$
component of the force vector in the $y'$-direction

**6.8.3**
**normal force**
$F_{z'}$
component of the force vector in the $z'$-direction

## 6.9 Moments

NOTE The external moments acting on the moped can be summed into one moment vector ***M*** having the components defined in 6.9.1, 6.9.2 and 6.9.3.

**6.9.1**
**pitch moment**
$M_{y'}$
component of the moment vector tending to rotate the moped about the $y'$-axis, which is positive if clockwise when looking in the positive direction of the $y'$-axis

**6.9.2**
**yaw moment**
$M_{z'}$
component of the moment vector tending to rotate the moped about the $z'$-axis, which is positive if clockwise when looking in the positive direction of the $z'$-axis

**6.9.3**
**roll moment**
**bank moment**
$M_{x'}$
component of the moment vector tending to rotate the moped about the $x'$-axis, which is positive if clockwise when looking in the positive direction of the $x'$-axis

NOTE Other roll moments can be considered as the components of the moment vector tending to rotate the moped about either the $x_{go}$ or $x_{gg}$ or $x_{ge}$-axis, these are defined in 6.9.3.1, 6.9.3.2 and 6.9.3.3.

**6.9.3.1**
**conventional roll moment**
$M_{xgo}$
component of the moment vector tending to rotate the moped about the $x_{go}$-axis, which is positive if clockwise when looking in the direction of the $x_{go}$-axis

**6.9.3.2**
**geometrical roll moment**
$M_{xgg}$
component of the moment vector tending to rotate the moped about the $x_{gg}$-axis, which is positive if clockwise when looking in the direction of the $x_{gg}$-axis

**6.9.3.3**
**effective roll moment**
$M_{xge}$
component of the moment vector tending to rotate the moped about the $x_{ge}$-axis, which is positive if clockwise when looking in the direction of the $x_{ge}$-axis

# 7 Directional dynamics

## 7.1 Controls

**7.1.1**
**roll control**
control made by the rider in order to maintain, or to change, the **roll angle** (6.7.5) of the moped to an intended value

**7.1.2**
**directional control**
control made by the rider in order to maintain, or to change, the **course angle** (6.7.3) of the moped to an intended value

NOTE 1 For the controls of mopeds, 7.1.1 and 7.1.2 are correlated and should not be treated separately.

NOTE 2 In the related International Standard for automobiles, control is clearly understood as “directional control”.

NOTE 3 In the case of a moped the roll angle is to be controlled mainly to determine the direction.

## 7.2 Control modes

**7.2.1**
**steering position control**
mode of moped control wherein inputs or restraints are placed upon the steering system in the form of displacements at some control point in the steering system, independent from the force required

**7.2.2**
**force control**
mode of moped control wherein inputs or restraints are placed upon the steering system in the form of forces, independent from the displacement required

**7.2.3**
**rider lean control**
mode of moped control wherein inputs or restraints are placed upon the moped frame in the form of rider lean angle independent from the steering control

**7.2.4**
**free control**
mode of moped control wherein no inputs or restraints are placed upon the moped by the rider

NOTE This mode is not possible with a real rider but only with a riding machine.

**7.2.5**
**fixed control**
mode of moped control where the position of the steering system and the position of the rider or dummy is held fixed; this control does not exist in the case of a human rider

**7.2.6**
**open loop**
procedures to describe the performance of a moped without any control influence of the rider

NOTE This mode is only possible with a riding machine.

**7.2.7**
**closed loop**
procedures to describe the moped-rider system with respect to any kind of rider control

**7.2.8**
**steering**
inputs to a moped by means of either the position control, the force control or the rider lean control, or any combination thereof

**7.2.9**
**handling**
response of the moped to the rider's input in order to follow an intended change in the course

## 7.3 Moped response

Moped response is defined by the following terms or a combination thereof.

**7.3.1**
**steering response**
motion of the moped or the moped-rider combination resulting from the input to the steering assembly

**7.3.2**
**rider lean response**
motion of the moped or the moped-rider combination resulting from the input by the rider lean control

**7.3.3**
**disturbance response**
motion of the moped or the moped-rider combination resulting from external force or displacement inputs applied to the moped and/or the rider

**7.3.4**
**steady state conditions**
conditions under which periodic (or constant) moped responses to periodic (or constant) control and/or disturbance inputs do not change over an arbitrarily long time; the motion responses in steady state are referred to as steady state responses

NOTE This definition does not require the moped to be operated in a straight line or on a level road. For example, it can be in a turn of constant radius or on a cambered road.

**7.3.5**
**transient state**
state where the motion responses, the external forces relative to the moped or the control positions are changing with time

**7.3.6**
**trim**
steady state (that is, equilibrium) condition of the moped with constant input which is used as the reference state for analysis of dynamic moped stability and control characteristics

**7.3.7**
**steady state response**
response under steady state conditions

**7.3.8**
**steady state response gain**
ratio of change in the **steady state response** (7.3.7) of any motion variable with respect to change in input at a given trim

**7.3.9**
**transient response**
response under transient state

**7.3.10**
**yaw response**
moped motion related with yaw rotation resulting from an internal or external input to the moped

**7.3.11**
**roll response**
moped motion related with roll rotation resulting from an internal or external input to the moped

**7.3.12**
**steering angle response**
rotation of steering assembly resulting from an internal or external input to the moped

**7.3.13**
**steering torque response**
steering torque formed by the forces exerted on the rider's arms resulting from an internal or external input to the moped

**7.3.14**
**steering sensitivity**
**control gain**
change in lateral acceleration during cornering on a level road with respect to the change in the steering angle or the steering torque at a given trim

**7.3.15**
**road surface irregularity sensitivity**
disturbance response of the moped resulting from an input caused by road surface disturbances

**7.3.16**
**side wind sensitivity**
disturbance response of the moped resulting from an input caused by a variation of wind forces

**7.3.17**
**frequency response**
steady state response of the moped against any periodical input, from which the output gain against the input and phase characteristics can be obtained

## 7.4 Steer properties

**7.4.1**
**neutral steer**
property of a moped where steer angle is equal to the theoretical steer angle under which no side slip angles occur

**7.4.2**
**understeer**
property of a moped the steer angle is greater than the theoretical steer angle under which no side slip angles occur

**7.4.3**
**oversteer**
property of a moped where the steer angle is smaller than the theoretical steer angle under which no side slip angles occur

## 7.5 Stability

**7.5.1**
**asymptotic stability**
state of stability at a prescribed trim where, for any small temporary change in disturbance or control input, the moped motion variables approach the values aimed at by the trim

**7.5.2**
**neutral stability**
state of stability at a prescribed trim, for any small temporary change in disturbance or control input, the resulting motion variables of the moped remain close to, but do not approach, the values aimed at by the trim

**7.5.3**
**divergent instability**
state of instability at a prescribed trim where any small temporary disturbance or control input causes an ever increasing value of the moped variables

NOTE The states defined in 7.5.1, 7.5.2 and 7.5.3 can be reproduced by oscillations for which:

- in 7.5.1, the amplitude of the oscillation is decreasing;
- in 7.5.2, the amplitude of the oscillation is constant;
- in 7.5.3, the amplitude of the oscillation is increasing.

# 8 Moped motion characteristics

**8.1**
**maximum lateral acceleration**
maximum value of lateral acceleration that may be obtained when the moped-rider combination is making curvilinear motions

**8.2**
**maximum centripetal acceleration**
maximum value of centripetal acceleration that may be obtained when the moped-rider combination is making curvilinear motions

**8.3**
**minimum speed**
lowest speed that allows a moped-rider combination to run stably in the straight forward direction

**8.4**
**maximum roll angle**
maximum obtainable value of roll angle of a moped-rider combination under steady state cornering until the tyres are skidding to the side or until moped parts (e.g. footrests, side or centre stands) touch the ground in such a way that a greater roll angle is impossible for stable riding conditions

**8.5**
**skid**
situation where the entire tyre contact tread is sliding relative to the pavement surface

**8.6**
**spin out**
sudden increases in the yaw rate and rear **tyre slip angle** (5.1.5) and decrease in the turning radius

**8.7**
**drift out**
sudden increases in the turning radius and the front **tyre slip angle** (5.1.5) and decrease in the yaw rate

**8.8**
**tuck-in**
transient roll phenomenon that occurs when the rider closes the throttle or declutches when the moped is turning

**8.9**
**knifing in of the steering handle**
phenomenon of the steering handle which tends to rotate with a sudden and intensive force towards a direction that may reduce the turning radius of the moped while turning

**8.10**
**hydroplaning**
phenomenon of a sudden decrease in the friction between the tyres and the wet road surface due to the hydrodynamic effect

**8.11**
**hop**
vertical oscillation motion of a wheel between the road surface and the sprung mass

**8.12**
**bounce**
oscillatory motion of the sprung mass where each point of the sprung mass moves primarily along a vertical line

**8.13**
**pitch**
motion of the sprung mass where each point of the sprung mass moves primarily on a circular path about an axis which is parallel to the moped $y$-axis

**8.14**
**wave**
normally occurring combination of bounce and pitch

**8.15**
**weave**
combined roll and yaw motion of the moped which is generally well-damped with a natural frequency in the range of about 1 Hz to 4 Hz, depending on speed, moped, component properties, etc.

NOTE It is oscillatory and can even become unstable for some operating conditions or moped-rider combinations

**8.16**
**wobble**
motion of primarily the steering assembly about the steering axis which is generally well damped with a natural frequency in the range of about 6 Hz to 10 Hz, depending on speed, fork assembly properties, rider coupling behaviour, etc.

NOTE It is oscillatory and can even become unstable for some operating conditions or moped-rider combinations

**8.17**
**capsize**
steady state tendency of the moped-rider combination to roll from the upright position until the rider makes a roll or steer input as correction

**8.18**
**twist**
torsional vibration of the frame

**8.19**
**cornering weave**
combined pitch, yaw and roll motion which can occur in a turn

**8.20**
**kick back**
rapid change of the steering angle caused by a road irregularity

**8.21**
**surging**
kind of non-steady state longitudinal motion, normally occurring if a moped is driven in too high a gear, with low revolutions of the engine

NOTE In this case an oscillating longitudinal acceleration is occurring instead of a constant moped speed.

## 9 Aerodynamic characteristics of the moped-rider combination

In the following definitions the **steer angle** (3.1.2) is zero.

### 9.1 Winds

**9.1.1**
**steady wind**
wind having a flow speed and a direction which do not change according to time (substantially laminar)

**9.1.2**
**unsteady wind**
wind having a flow speed up to a maximum of 10 m/s in difference between maximum and minimum values of wind speed as measured for 10 min

**9.1.3**
**gust of wind**
wind having a flow speed of more than 10 m/s in difference between maximum and minimum values of wind speed as measured for 10 min

### 9.2 Aerodynamic variables

**9.2.1**
**ambient wind velocity**
horizontal component of the velocity of the wind relative to the road plane

See Figure 4.

**9.2.2**
**ambient wind angle**
angle formed between the $X$-axis of the **earth-fixed axis system** (6.1.1) and the projection of the wind velocity onto the road plane

See Figure 4.

**9.2.3**
**resultant wind velocity**
vector difference between the velocity of the wind and the velocity of the centre of gravity of the moped-rider combination

See Figure 4.

**9.2.4**
**aerodynamic sideslip angle**
angle formed between the projection of the $x'$-axis of the **moped axis system** (6.1.2) and the resultant wind velocity onto the road plane

See Figure 4.

**9.2.5**
**aerodynamic angle of attack**
angle formed between the $x'$-axis of the **moped axis system** (6.1.2) and the projection of the resultant wind velocity onto the vertical plane along the $x'$-axis

See Figure 4.

**9.2.6**
**centre of wind pressure**
intersection of the line of action of the wind pressure resultant force and the moped longitudinal plane

**9.2.7**
**frontal projected area**
area created by projecting the moped-rider combination onto the $y'$-$z'$ plane

**9.2.8**
**standard atmosphere**
atmosphere having a density of 1,225 kg/m$^3$ and a coefficient of kinematic viscosity of $1{,}466 \times 10^{-5}$ m$^2$/s at a temperature of 288 K (15 °C) and an atmospheric pressure of 101 325 kPa (1 atm)

## 9.3 Aerodynamic forces, moments and coefficients

**9.3.1**
**components of aerodynamic forces and moments**
forces and moments acting on the moped-rider combination in an air stream as divided into six components in relation to the axis system

**9.3.2**
**drag**
$x'$-component of the forces acting on the moped-rider combination in an air stream

**9.3.3**
**drag coefficient**
value obtained by dividing the **drag** (9.3.2) by the product of the dynamic pressure and the **frontal projected area** (9.2.7)

**9.3.4**
**lateral force**
$y'$-component of the forces acting on the moped-rider combination in an air stream

**9.3.5**
**lateral force coefficient**
value obtained by dividing the lateral force by the product of the dynamic pressure and the **frontal projected area** (9.2.7)

**9.3.6**
**lift**
$z'$-component of the forces acting on the moped-rider combination in an air stream

**9.3.7**
**lift coefficient**
value obtained by dividing the lift by the product of the dynamic pressure and the **frontal projected area** (9.2.7)

**9.3.8**
**aerodynamic roll moment**
moment about the $x'$-axis caused by the aerodynamic forces acting on the moped-rider combination

**9.3.9**
**aerodynamic roll moment coefficient**
value obtained by dividing the aerodynamic roll moment by the product of the dynamic pressure, the **frontal projected area** (9.2.7) and the standard length

NOTE The wheelbase is usually employed as the standard length.

**9.3.10**
**aerodynamic pitch moment**
moment about the $y'$-axis caused by the aerodynamic forces acting on the moped-rider combination

**9.3.11**
**aerodynamic pitch moment coefficient**
value obtained by dividing the **aerodynamic pitch moment** (9.3.10) by the product of the dynamic pressure, the **frontal projected area** (9.2.7) and the standard length

NOTE The wheelbase is usually employed as the standard length.

**9.3.12**
**aerodynamic yaw moment**
moment about the $z'$-axis caused by the aerodynamic forces acting on the moped-rider combination

**9.3.13**
**aerodynamic yaw moment coefficient**
value obtained by dividing the **aerodynamic yaw moment** (9.3.12) by the product of the dynamic pressure, the **frontal projected area** (9.2.7) and the standard length

NOTE The wheelbase is usually employed as the standard length.

## 10 Riding postures and behaviours

NOTE The terms defined in clause 10 are limited to rider's postures and behaviours which contribute to the riding stability of mopeds; they do not apply to passenger's postures and behaviours.

**10.1**
**normal position**
condition in which the rider puts his hands on the handlebar and his feet on the footrests or platform with his centre of gravity in the moped longitudinal plane

NOTE This position can differ according to the speed, riding time, moped specifications and human physical structure.

**10.2**
**lean forward**
condition in which the rider bends or inclines his upper torso more forwards than in the normal position

**10.3**
**lean over**
**lean forward** (10.2) in which the rider bends or inclines his upper torso to the maximum inclination of the upper torso

**10.4**
**lean back**
condition in which the rider leans or inclines his upper torso further backwards than in the normal position

**10.5**
**lean in**
condition in which the rider's centre of gravity is placed out of the moped longitudinal plane towards the centre of the curve

**10.6**
**lean out**
condition in which the rider's centre of gravity is placed out of the moped longitudinal plane towards the opposite side of the centre of the curve

**10.7**
**lean with**
condition in which the rider's centre of gravity is in the moped longitudinal plane during cornering

# 11 Tests

## 11.1 Constant environment influence

**11.1.1**
**straight forward running stability test**
test to evaluate the response to a certain input to the moped-rider combination by the kinematic damping characteristics when running straight forward at a constant speed

**11.1.2**
**braking stability and handling tests**
tests to evaluate the stability and/or the handling of the moped-rider combination while braking under straight forward running or cornering conditions

NOTE Lateral displacement of the moped, yaw angular velocity, etc. may be considered as characteristics for evaluation in this test.

**11.1.3**
**power on/off tests**
tests to evaluate the stability and/or handling of the moped-rider combination during accelerations and decelerations through the operation of the throttle grip while running in a straight or while cornering

**11.1.4**
**steady state circular tests**
tests to evaluate steering torque characteristics, steering angle characteristics, rolling characteristics, maximum centripetal acceleration, etc. by stepwise changing the centripetal acceleration

NOTE To vary the centripetal acceleration, there are two methods: one is under the condition that the radius of the circle is kept constant and the other is under the condition that the moped speed is kept constant.

**11.1.5**
**obstacle avoidance test**
closed loop test to evaluate the transient characteristics of the moped-rider combination and the performance to avoid traffic accidents when the rider changes the moped course to avoid obstacles in front of the moped while it is running straight forward at constant speed

NOTE Yaw angular velocity, roll angle, rider's behaviour, etc. may be considered as characteristics for evaluation in this test.

**11.1.6**
**lane changing test**
closed loop test to evaluate the transient response and behaviour of the moped-rider combination when it is changing from one lane to another

**11.1.7**
**slalom test**
closed loop test to evaluate the manoeuvrability, response, etc. of the moped-rider combination when it is running along a zigzag course marked out by poles

NOTE The maximum slalom speed, steering torque, yaw angular velocity, roll angular velocity, etc. may be considered as characteristics for evaluation in this test.

**11.1.8**
**eight figure test**
closed loop test to evaluate the steering torque, etc. by riding the moped along a lemniscate curve at low speed

NOTE A lemniscate curve is represented by the following equation

$$(x^2 + y^2)^2 = 2a^2(x^2 - y^2)$$

or by the polar equation

$$r^2 = 2a^2 \cos 2\theta$$

See Figure 5.

**11.1.9**
**transient response tests**
tests to evaluate transient response characteristics of the moped rider combination through application of transient steering inputs under the condition of acceleration, deceleration or constant speed

NOTE Yaw angular velocity, roll angular velocity, etc. may be considered as evaluation items.

**11.1.10**
**random response test**
transient response test with random steering inputs

**11.1.11**
**sinusoidal response test**
transient response test with sinusoidal steering inputs

**11.1.12**
**pulse response test**
transient response test with pulse steering inputs

## 11.2 Changeable environment influence

**11.2.1**
**irregular road surface stability tests**
tests to evaluate the sensitivity in response of the moped-rider combination against the irregularity of the road surface, under straight forward running or cornering conditions

**11.2.2**
**crosswind stability test**
test to evaluate the stability of the moped-rider combination when crosswind acts on the running moped

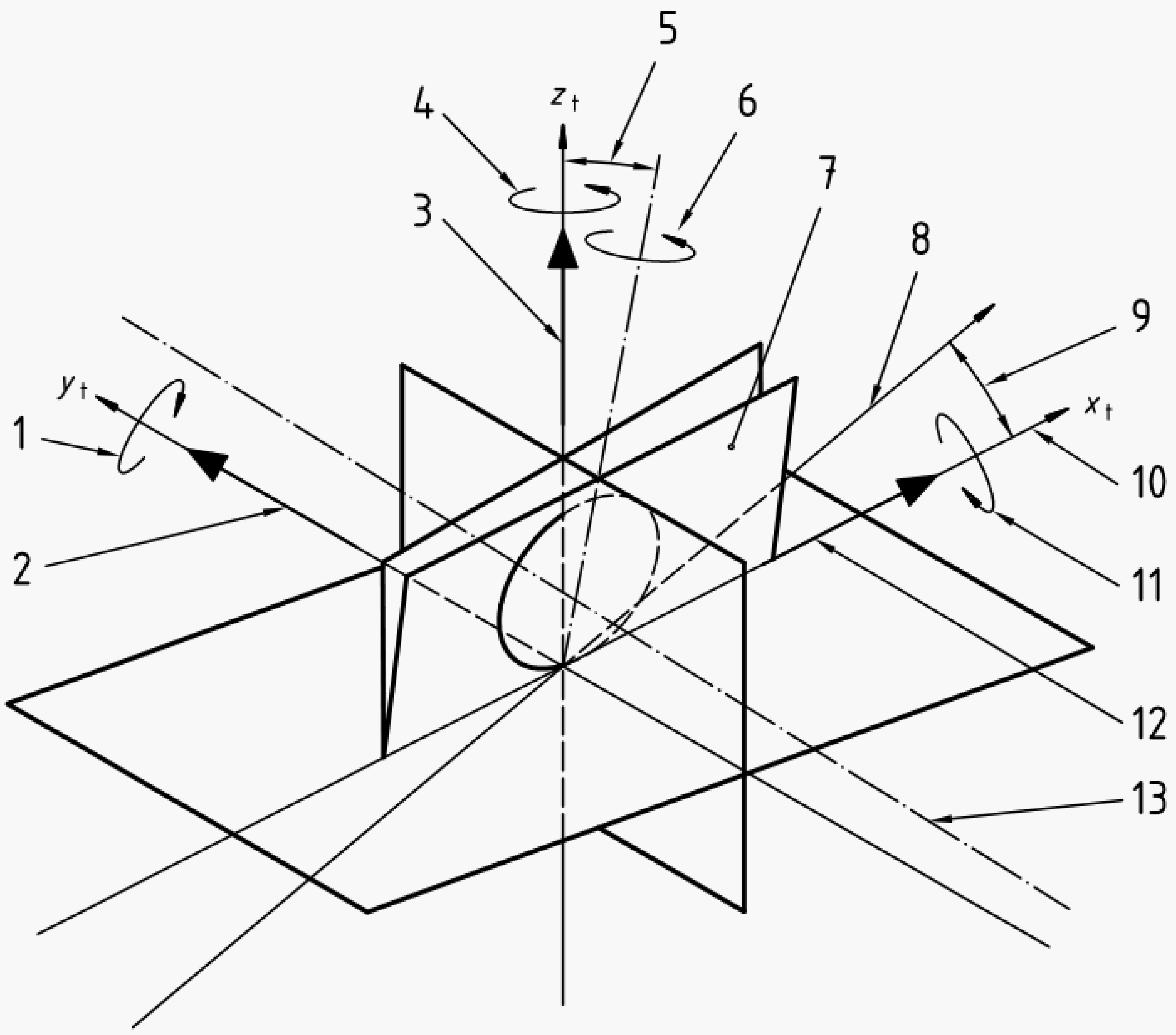
NOTE Lateral displacement, the time to reach such a lateral displacement, yaw angular velocity, etc., may be considered as evaluation items.

## 11.3 Other tests

**11.3.1**
**steering torque tests**
tests to evaluate the steer torque under certain conditions such as: the stationary condition of the moped, extremely low speed running, cornering, high speed running, etc.

**11.3.2**
**roll angle test**
test to measure the **roll angle** (6.7.5) and/or the **effective roll angle** (6.7.5.3) of the moped-rider combination when it is running with a constant speed on a circular path having a given radius

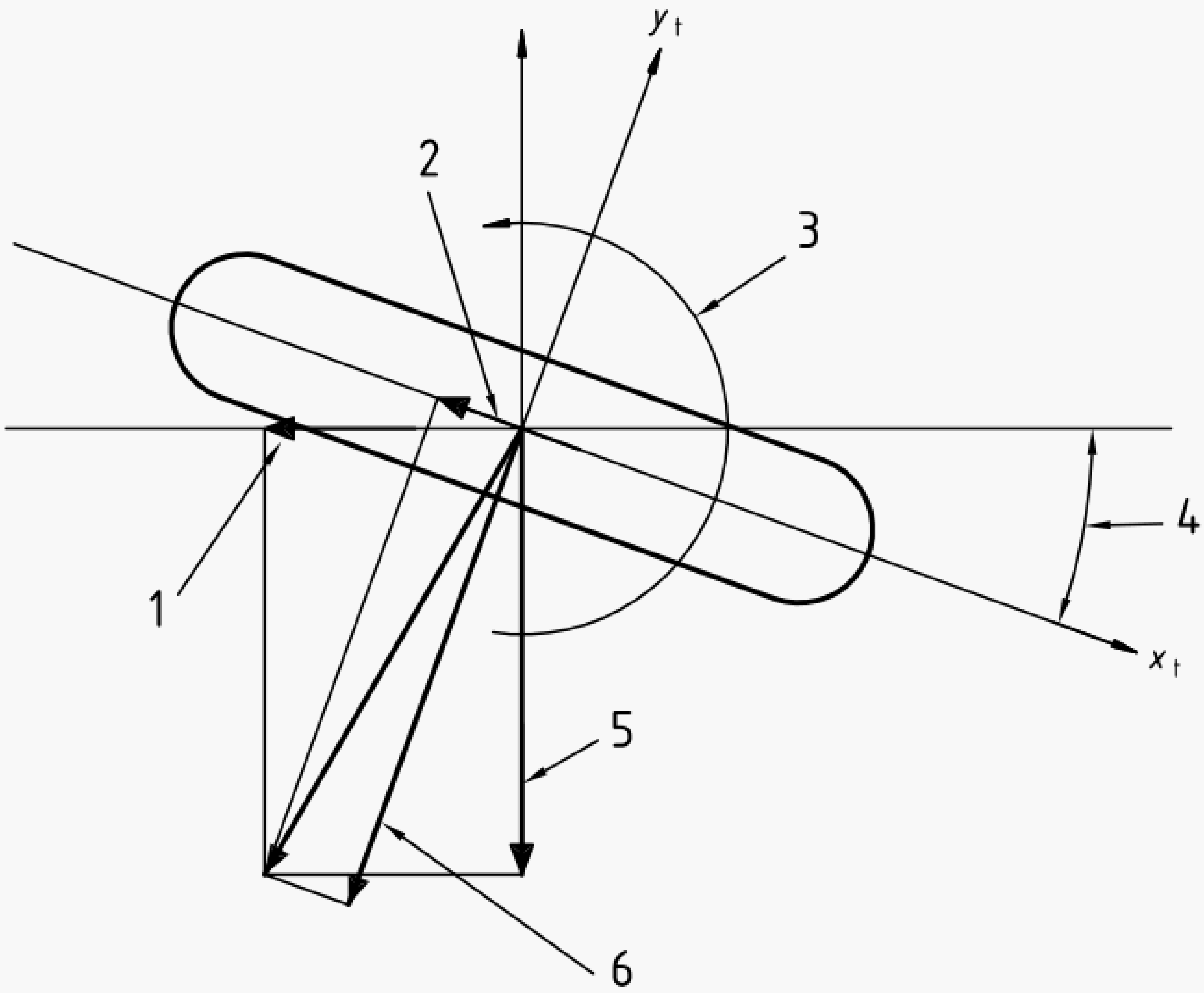
**11.3.3**
**minimum turning radius test**
test to measure the minimum turning radius of the moped when it is pushed forward with the moped being held upright and its steering handle being turned fully to the left or fully to the right




**Key**

1 Rolling resistance moment (5.3.2)
2 Tyre lateral force (5.2.2)
3 Tyre vertical load (5.2.1)
4 Aligning torque (5.3.4)
5 Camber angle (5.1.4)
6 Camber torque (5.3.3)
7 Wheel plane
8 Direction of wheel travel
9 Tyre slip angle (5.1.5)
10 Direction of wheel heading
11 Overturning moment (5.3.1)
12 Tyre longitudinal force (5.2.3)
13 Spin axis

**Figure 1 — Tyre axis system**




**Key**

1 Drag force (5.2.14)

2 Rolling resistance (5.2.15)

3 Aligning torque (5.3.4)

4 Tyre slip angle (5.1.5)

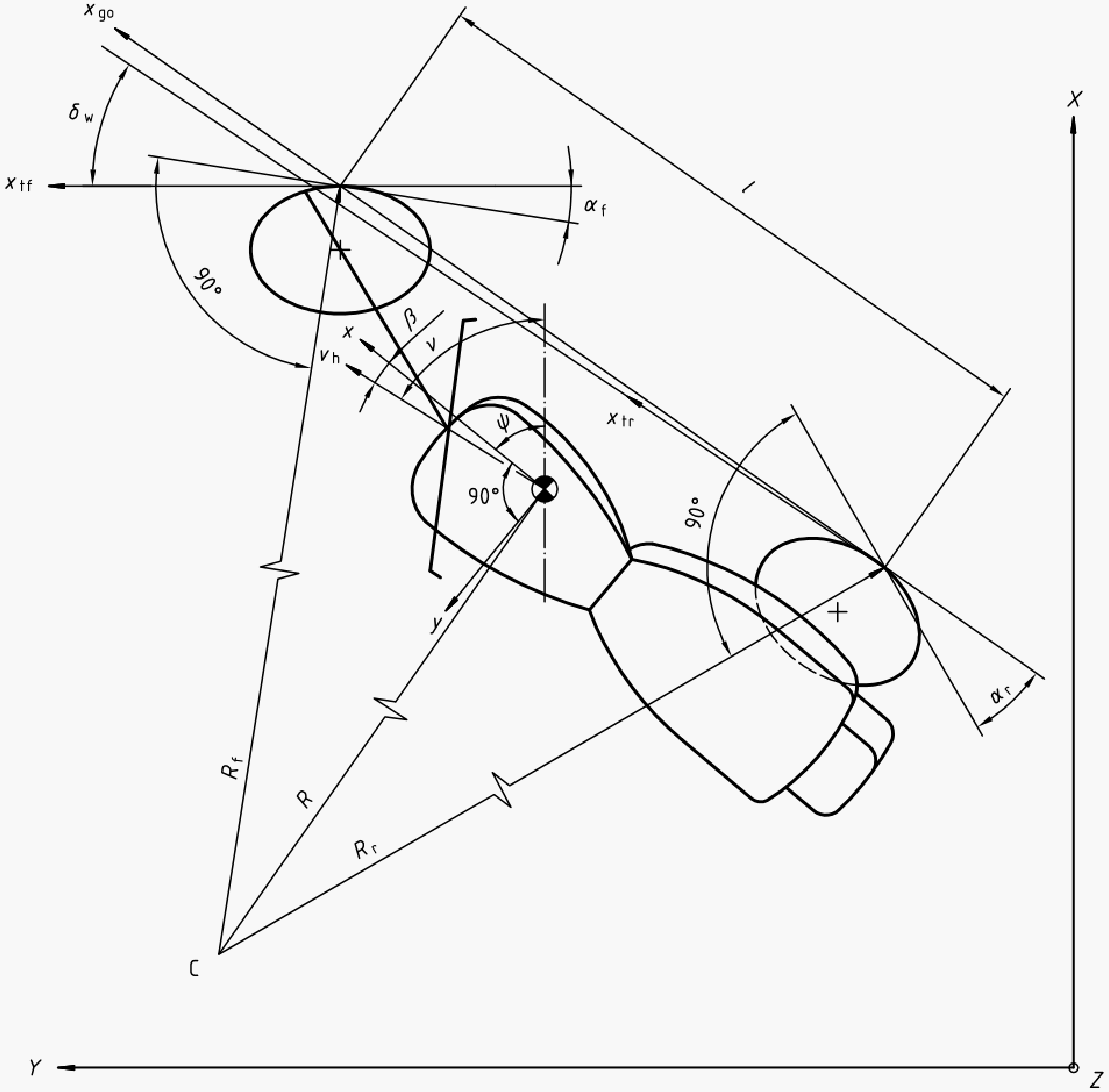
5 Cornering force (5.2.11)

6 Tyre side force (5.2.12)

NOTE  Positive tyre slip angles generate negative tyre side forces.

**Figure 2 — Forces applied to tyre when camber angle is zero**

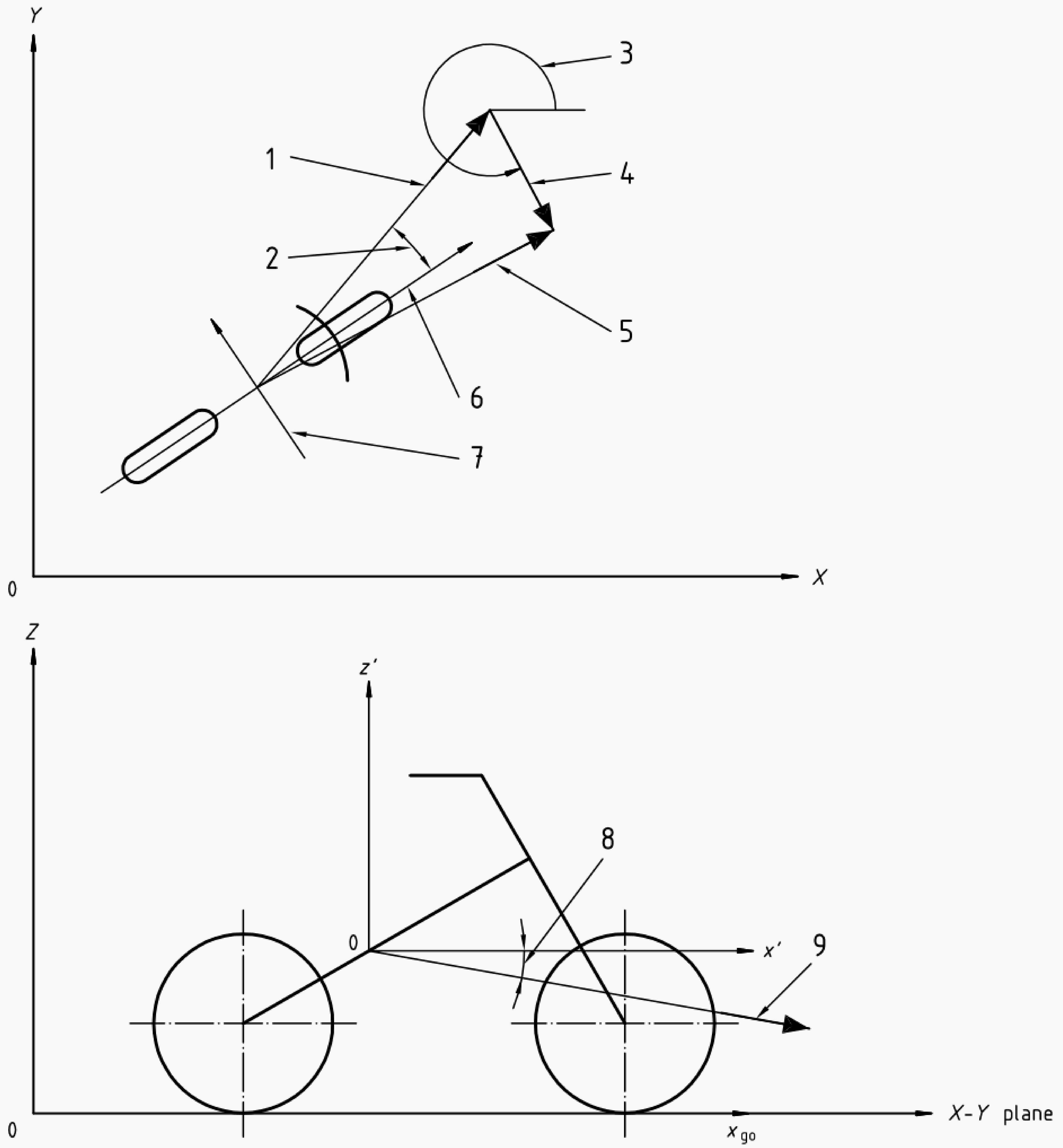
 




NOTE $R$, $R_f$, $R_r \gg l$

| | | | |
|---|---|---|---|
| $(X, Y, Z)$ | Earth-fixed axis system (6.1.1) | $\nu$ | Course angle (6.7.3) |
| $(x, y, z)$ | Horizontal moped axis system (6.2.1) | $\psi$ | Yaw angle (6.7.2) |
| $x_{go}$ | Conventional ground contact axis (6.4.1) | $\beta$ | Moped side slip angle (6.7.4) |
| $x_{tf}$, $x_{tr}$ | Horizontal tyre axis system (6.2.2) | $v_h$ | Horizontal moped speed (6.7.8) |
| $R$, $R_f$, $R_r$ | Radius of turning | $\delta_w$ | Wheel steer angle (3.1.3) |
| ⊗ | Centre of gravity | $\alpha_f$, $\alpha_r$ | Tyre slip angle (5.1.5) |
| C | Instantaneous centre of turning | $l$ | Distance between conventional centres of front and rear tyre contact (see 5.1.1) |

**Figure 3 — Definition of angles**




**Key**

1 Resultant wind velocity (9.2.3) projection
2 Aerodynamic sideslip angle (9.2.4)
3 Ambient wind angle (9.2.2)
4 Ambient wind velocity (9.2.1)
5 Moped velocity
6 *x*′-axis projection
7 *y*′-axis projection
8 Aerodynamic angle of attack (9.2.5)
9 Resultant wind velocity (9.2.3) projection

**Figure 4 — Aerodynamic variables**

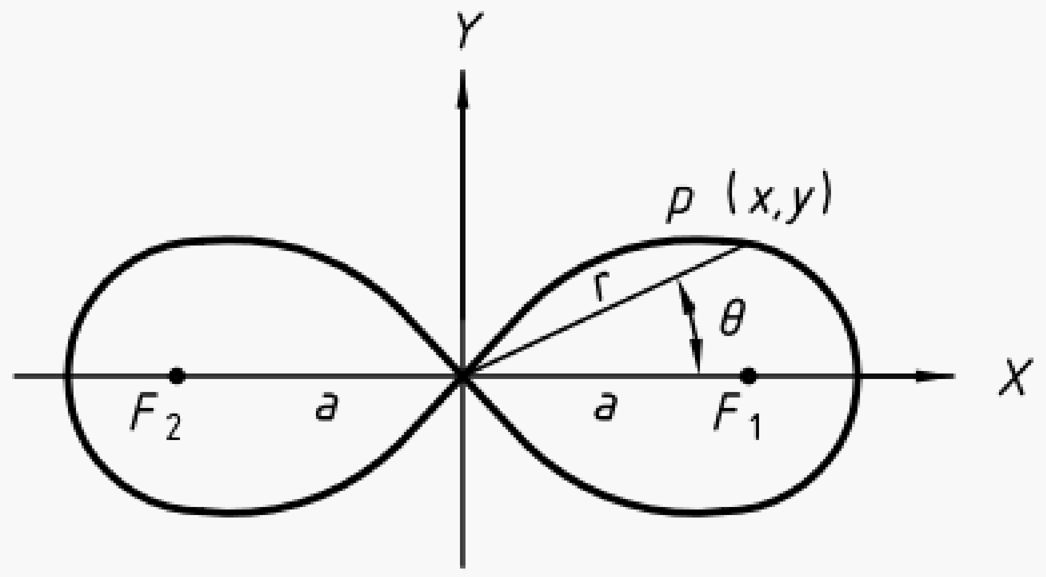



**Figure 5 — Lemniscate curve**

# Bibliography

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

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