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Passenger car, truck, bus and motorcycle tyres — Methods of measuring rolling resistance

Pneumatiques pour voitures particulières, camions, autobus et motocycles — Méthodes de mesure de la résistance au roulement

Reference number
ISO 18164:2005(E)

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Foreword

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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.

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ISO 18164 was prepared by Technical Committee ISO/TC 31, *Tyres, rims and valves*.

This first edition represents a compilation of three individual standards (ISO 8767:1992, ISO 9948:1992 and ISO 13327:1998) into a consolidated, technically revised single document.

Passenger car, truck, bus and motorcycle tyres — Methods of measuring rolling resistance

1 Scope

This International Standard specifies methods for measuring rolling resistance, under controlled laboratory conditions, for new pneumatic tyres designed primarily for use on passenger cars, trucks, buses and motorcycles. The relationship between values obtained and the fuel economy of the vehicle is undetermined, and such values are not intended to be used to indicate levels of performance or quality.

This International Standard applies to all passenger car, truck, bus and motorcycle tyres.

Measurement of tyres using this method enables comparisons to be made between the rolling resistance of new tyres when they are free-rolling straight ahead, in a position perpendicular to the drum outer surface, and in steady-state conditions.

In measuring tyre rolling resistance, it is necessary to measure small forces in the presence of much larger forces. It is, therefore, essential that equipment and instrumentation of appropriate accuracy be used.

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 4223-1:2002, *Definition of some terms used in the tyre industry — Part 1: Pneumatic tyres*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4223-1 and the following apply.

3.1
rolling resistance
F_r
loss of energy (or energy consumed) per unit of distance travelled

NOTE The SI unit conventionally used for the rolling resistance is the newton metre per metre (N·m/m).This is equivalent to a drag force in newtons (N).

3.2
rolling resistance coefficient
C_r
ratio of the rolling resistance, in newtons, to the load on the tyre, in newtons

3.3
capped inflation
process of inflating the tyre and allowing the inflation pressure to build up, as the tyre is warmed up while running

3.4
regulated inflation
process of inflating the tyre to the required pressure independent of its temperature, and maintaining this inflation pressure while the tyre runs under load

NOTE This is most commonly done by using a regulated pressure source attached to the tyre through a rotating union.

3.5
parasitic loss
loss of energy (or energy consumed) per unit distance excluding internal tyre losses, and attributable to aerodynamic loss of the different rotating elements of the test equipment, bearing friction and other sources of systematic loss which may be inherent in the measurement

NOTE Depending on the method used, the aerodynamic loss of the tyre may or may not be included in the parasitic loss.

3.6
skim test reading
type of parasitic loss measurement, in which the tyre is kept rolling, without slippage, while reducing the tyre load to a level at which energy loss within the tyre itself is virtually zero

3.7
machine reading
type of parasitic loss measurement, involving losses of the test machine, exclusive of losses in the rotating spindle bearing, which carries the tyre and rim, and aerodynamic losses

3.8
moment of inertia
ratio of the torque applied to the tyre to the annular acceleration on the tyre

See Annex A.

4 Test methods

The following are alternative measurement methods. The choice of an individual method is left to the tester. For each method, the test measurements shall be converted to a force acting at the tyre/drum interface. The measured parameters are given below.

a) Force method: the reaction force measured at the tyre spindle. This measured value also includes the bearing losses of the tyre spindle and the aerodynamic losses of the tyre and the wheel.

b) Torque method: the torque input measured at the test drum (see NOTE).

c) Power method: the measurement of the power input to the test drum (see NOTE).

d) Deceleration method: the measurement of deceleration of the test drum and tyre assembly (see NOTE).

NOTE This measured value also includes the bearing and aerodynamic losses of the wheel, the tyre and the drum, losses that are also to be considered.

5 Test equipment

5.1 Drum specifications

5.1.1 Diameter

The test dynamometer shall have a cylindrical flywheel (drum)

— with a diameter of at least 1,5 m (reference drum diameter: 1,7 m) for passenger car and motorcycle tyres;

— with a diameter of at least 1,7 m for truck/bus tyres.

It should be noted that the results are different for different diameters; see 9.3 for drum diameter correction for comparisons, if necessary.

NOTE Historically, the measurement of the fore and aft (longitudinal) force on a flat surface machine has been shown to be quite difficult since this force is very small relative to other forces being measured. If a flat surface machine is used, care should be taken to correlate the data with the reference drum diameter in order to assure accurate results.

5.1.2 Surface

The surface of the drum shall be smooth steel or textured and shall be kept clean. For the textured drum surface, see B.4.

5.1.3 Width

The width of the drum test surface shall exceed the width of the test tyre tread.

5.2 Test rim

The tyre shall be mounted on a test rim, as specified in Annex C.

5.3 Load, alignment, control and instrumentation accuracies

Measurement of these parameters shall be sufficiently accurate and precise to provide the required test data. The specific and respective values are shown in Annex C.

5.4 Thermal environment

5.4.1 Reference conditions

The reference ambient temperature, as measured on the rotational axis of the tyre, 1 m away from the plane touching the nearest tyre sidewall, shall be 25 °C.

5.4.2 Alternative conditions

If the reference temperature cannot be obtained, the rolling resistance measurement shall be corrected to standard temperature conditions in accordance with 9.2.

5.4.3 Drum surface temperature

Care should be taken to ensure that the temperature of the test drum surface is approximately the same as the ambient temperature at the beginning of the test.

6 Test conditions

6.1 General

The test consists of a measurement of rolling resistance in which the tyre is inflated and the inflation pressure is allowed to build up (i.e. "capped air").

6.2 Test speeds

6.2.1 Single test speed

The value shall be obtained at a drum speed as shown in Table 1.

Table 1 — Test speeds

Speed in kilometres per hour

Tyre type	Passenger car	Truck and bus			Motorcycle	
Load index	All	LI 121 and below	LI 122 and above		All	All
Speed symbol	All	All	F to J	K to M	L and below	Above L
Speed	80	80	60	80	50	80

6.2.2 Multiple test speed

Passenger car tyres: the values shall be obtained at drum speeds of 50 km/h, 90 km/h and 120 km/h.

Truck/bus tyres: for LI of 121 and below, the values shall be obtained at drum speeds of 80 km/h and, if required, 120 km/h.

6.3 Test load

The standard test load shall be computed from the values shown in Table 2 and shall be kept within the tolerances specified in Annex C.

Table 2 — Test loads and inflation pressures

Tyre type	Passenger car[a]		Truck and bus	Motorcycle	
	Light and standard load	Reinforced or extra load		Standard load	Reinforced or extra load
Load % of maximum load capacity	80	80	85 (% of single load)	65	80
Inflation pressure kPa	210	250	Corresponding to maximum load capacity for single application	200	250
NOTE The inflation pressure shall be capped with the accuracy specified in C.4.1.					
[a] For those passenger car tyres belonging to categories which are not shown in Annex B of ISO 4000-1:2001, the inflation pressure shall be the inflation pressure recommended by the tyre manufacturer, corresponding to the maximum tyre load capacity, reduced by 30 kPa.					

6.4 Test inflation pressure

The inflation pressure shall be in accordance with those shown in Table 2 and shall be capped with the accuracy specified in C.4.1.

6.5 Duration and speed

When the deceleration method is selected, the following requirements apply:

a) for duration, Δt, the time increments shall not exceed 0,5 s;

b) any variation of the test drum speed shall not exceed 1 km/h.

6.6 Optional conditions

If the sensitivities of load, inflation or speed are desired, the additional information given in Annex B should be consulted.

7 Test procedure

7.1 General

The test procedure steps described below shall be followed in the sequence given.

7.2 Break-in

To ensure repeatability of measurements, an initial break-in and cooling period is required prior to the start of the test. Such a break-in shall be carried out on a test drum of at least 1,5 m diameter (1,7 m for truck and bus tyres) for a period of at least 1 h, at a minimum speed as given in 6.2, per type of tyre, with the load and inflation pressure given in 6.3 and 6.4 respectively.

7.3 Thermal conditioning

Place the inflated tyre in the thermal environment of the test location for the time necessary to achieve thermal equilibrium, which is generally reached after 3 h for passenger car and motorcycle tyres and 6 h for truck and bus tyres.

7.4 Pressure adjustment

After thermal conditioning, the inflation pressure shall be adjusted to the test pressure, and verified 10 min after the adjustment is made.

7.5 Warm-up

The tyre shall be run at constant test speed until reaching a stabilized steady-state value of rolling resistance. Recommendations for warm-up periods are given in Annex B.

7.6 Measurement and recording

The following shall be measured and recorded (see Figure 1):

a) test speed, U_n;

b) load on the tyre normal to the drum surface, L_m;

c) test inflation pressure:

1) initial, as defined in 7.4

2) final, for capped inflation;

d) the driving torque on the drive shaft, T_t, the tyre spindle force, F_t, the input power, $V \times A$, or the deceleration of the test drum/tyre/wheel assembly, $\Delta\omega/\Delta t$, depending on the method;

e) distance from the tyre axle to the drum outer surface under steady-state conditions, r_L (see 8.2.1);

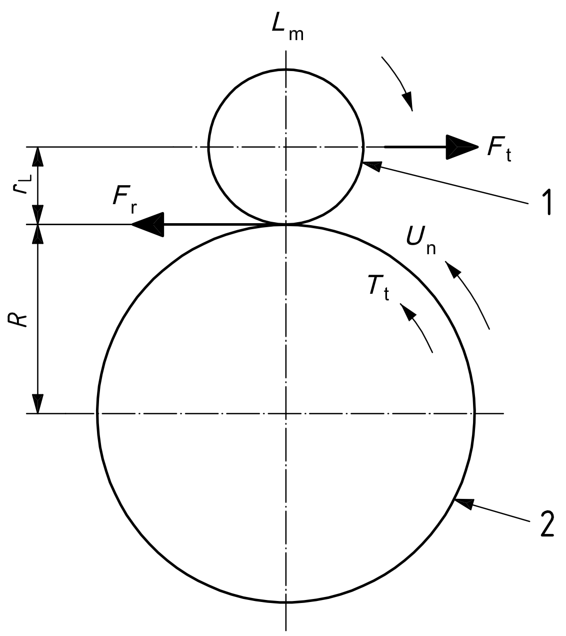
f) ambient temperature, t_{amb};

g) test drum radius, R;

h) rolling resistance force, F_r;

i) test method chosen;

j) test rim (designation and material).



Key

1 tyre

2 drum

Figure 1 — Free-body diagram of tyre/drum system, assuming no bearing and aerodynamic losses

7.7 Measurement of parasitic losses

7.7.1 General

Determine parasitic losses by one of the procedures given in 7.7.2 to 7.7.4.

7.7.2 Skim test reading

a) Reduce the load to maintain the tyre at the test speed without slippage.

b) Record the spindle force, F_t, input torque, T_t, or the power, whichever applies.

c) Record the load on the tyre normal to the drum surface, L_m.

NOTE The measured value includes the bearing and aerodynamic losses of the wheel, the tyre and the drum, losses that are also to be considered.

7.7.3 Machine reading

a) Remove the tyre from the drum surface.

b) At the test speed, U_n, record the input torque, T_t, the power, or the test drum deceleration, whichever applies.

NOTE The measured value includes the drum losses to be considered.

7.7.4 Deceleration method

a) Remove the tyre from the test surface.

b) Record the deceleration of the test drum, $\Delta\omega_o/\Delta t$, and that of the unloaded tyre, $\Delta\omega_{po}/\Delta t$.

NOTE The measured value includes the bearing and aerodynamic losses of the wheel, the tyre and the drum, losses that are also to be considered.

8 Data interpretation

8.1 Calculation of parasitic losses

8.1.1 General

The parasitic losses, F_{pl}, related to the tyre/drum interface expressed in newtons, shall be calculated from the force F_t, torque, power or the deceleration, as shown below.

8.1.2 Force method at tyre spindle

Calculate: $F_{pl} = F_t(1 + r_L/R)$

where

F_t is the tyre spindle force in newtons (see 7.7.2);

r_L is the distance from the tyre axis to the drum outer surface under steady state conditions, in metres;

R is the test drum radius, in metres.

8.1.3 Torque method at drum axis

Calculate: $F_{pl} = T_t/R$

where

T_t is the input torque in newtons metres as determined in 7.7.2 or 7.7.3;

R is the test drum radius, in metres.

8.1.4 Power method at drum axis

Calculate: $F_{pl} = \frac{3{,}6 V \times A}{U_n}$

where

V is the electrical potential applied to the machine drive, in volts;

A is the electric current drawn by the machine drive, in amperes;

U_n is the test drum speed, in kilometres per hour.

8.1.5 Deceleration method

Calculate the parasitic losses, F_{pl}, in newtons.

$$F_{pl} = \frac{I_D}{R}\left(\frac{\Delta\omega_{vo}}{\Delta t_o}\right) + \frac{I_T}{R_r}\left(\frac{\Delta\omega_{po}}{\Delta t_o}\right)$$

where

I_D is the test drum inertia in rotation, in kilogram metres squared;

R is the test drum surface radius, in metres;

ω_{vo} is the test drum angular speed, without tyre, in radians per second;

Δt_o is the time increment chosen for the measurement of the parasitic losses without tyre, in seconds;

I_T is the tyre and wheel inertia in rotation, in kilogram metres squared;

R_r is the tyre rolling radius, in metres;

ω_{po} is the tyre angular speed, unloaded tyre, in radians per second.

8.2 Rolling resistance calculation

8.2.1 General

Calculate the rolling resistance using the values obtained by testing the tyre to the conditions specified in this International Standard and by subtracting the appropriate parasitic losses, F_{pl}, obtained according to 8.1.

NOTE When the machine reading method is used to determine parasitic losses for the torque or power, the resulting rolling resistance includes aerodynamic losses of the tyre and wheel as well as the tyre-spindle friction.

8.2.2 Force method at tyre spindle

The rolling resistance, F_r, in newtons, is calculated using the equation

$$F_r = F_t[1 + (r_L/R)] - F_{pl}$$

where

F_t is the tyre spindle force in newtons;

F_{pl} represents the parasitic losses as calculated in 8.1.2;

r_L is the distance from the tyre axis to the drum outer surface under steady-state conditions, in metres;

R is the test drum radius, in metres.

8.2.3 Torque method at drum axis

The rolling resistance, F_r, in newtons, is calculated with the equation

$$F_r = \frac{T_t}{R} - F_{pl}$$

where

T_t is the input torque, in newton metres;

F_{pl} represents the parasitic losses as calculated in 8.1.3;

R is the test drum radius, in metres.

8.2.4 Power method at drum axis

The rolling resistance, F_r, in newtons, is calculated with the equation:

$$F_r = \frac{3{,}6 V \times A}{U_n} - F_{pl}$$

where

V is the electrical potential applied to the machine drive, in volts;

A is the electric current drawn by the machine drive, in amperes;

U_n is the test drum speed, in kilometres per hour;

F_{pl} represents the parasitic losses as calculated in 8.1.4.

8.2.5 Deceleration method

The rolling resistance, F_r, in newtons, is calculated using the equation:

$$F_r = \frac{I_D}{R}\left(\frac{\Delta\omega_v}{\Delta t_v}\right) + \frac{R I_T}{R_r^2}\left(\frac{\Delta\omega_v}{\Delta t_v}\right) - F_{pl}$$

where

I_D is the test drum inertia in rotation, in kilogram metres squared;

R is the test drum surface radius, in metres;

F_{pl} represents the parasitic losses as calculated in 8.1.5;

Δt_v is the time increment chosen for measurement, in seconds;

ω_v is the test drum angular velocity, loaded tyre, in radians per second;

I_T is the tyre and wheel inertia in rotation, in kilogram metres squared;

R_r is the tyre rolling radius, in metres.

NOTE Annex A gives guidelines and practical examples to measure the moments of inertia for the deceleration method.

9 Data analysis

9.1 Rolling resistance coefficient

The rolling resistance coefficient, C_r, is calculated by dividing the rolling resistance by the load on the tyre:

$$C_r = \frac{F_r}{L_m}$$

where

F_r is the rolling resistance, in newtons;

L_m is the test load, in newtons.

9.2 Temperature correction

If measurements at temperatures other than 25 °C are unavoidable (only temperatures not less than 20 °C nor more than 30 °C are acceptable), then a correction for temperature shall be made using the following equation, where F_{r25} is the rolling resistance at 25 °C, in newtons:

$$F_{r25} = F_r[1 + K(t_{amb} - 25)]$$

where

F_r is the rolling resistance, in newtons;

t_{amb} is the ambient temperature, in degrees Celsius;

K is equal to

0,008 for passenger and motorcycle tyres;

0,01 for truck and bus tyres with load index 121 and lower;

0,006 for truck and bus tyres with load index 122 and above.

9.3 Drum diameter correction

Test results obtained from different drum diameters may be compared by using the following theoretical formula:

$$F_{r02} \approx K F_{r01}$$

with

$$K = \sqrt{\frac{\left(R_1/R_2\right)\left(R_2 + r_\mathrm{T}\right)}{\left(R_1 + r_\mathrm{T}\right)}}$$

where

R_1 is the radius of drum 1, in meters;

R_2 is the radius of drum 2, in meters;

r_T is the nominal tyre radius, in meters;

$F_{\mathrm{r}02}$ is the rolling resistance value measured on drum 1, in newtons;

$F_{\mathrm{r}01}$ is the rolling resistance value measured on drum 2, in newtons.

Annex A
(informative)

Measurement methods of moment of inertia for drum and tyre assembly — Deceleration method

A.1 Limitation

The methods presented here should be considered only as guidelines or practical examples of methods used to measure moments of inertia by the deceleration method in order to achieve reliable test results.

A.2 Test drum inertia

A.2.1 Measurement method

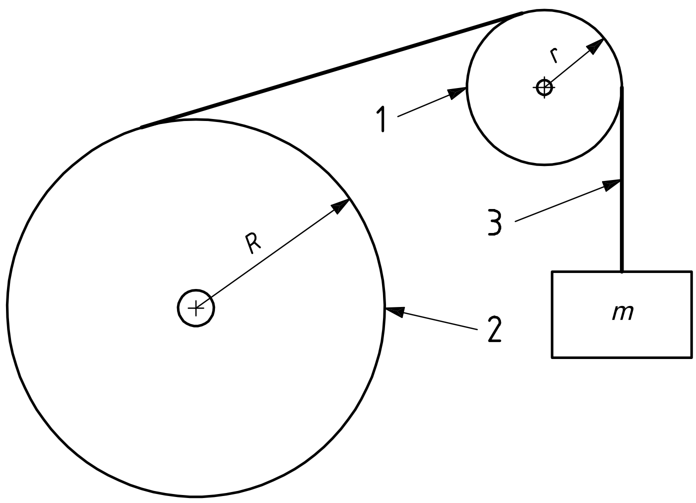
A.2.1.1 Equipment needed

The arrangement shown in Figure A.1 requires, in addition to the drum and its angular encoder:

— a lightweight pulley mounted on low-friction bearings;

— a weight of known mass, m, in the range 50 kg to 100 kg;

— suitable wire rope and attachments.



Key

1 tyre

2 drum

3 wire rope

m mass

r pulley radius

R drum radius

Figure A.1 — Test arrangement

A.2.1.2 Test arrangement

A.2.1.3 Theory

Application of laws of mechanics to the system shown in Figure A.1 leads to the following equation:

$$I_D = \frac{mgR - C}{(\Delta\omega_D / \Delta t)} - mR^2 - I_p \frac{R^2}{r^2}$$

where

m is the mass, in kilograms;

I_p is the pulley inertia, in kilogram metres squared;

r is the pulley radius, in metres;

R is the drum radius, in metres;

I_D is the drum inertia, in kilogram metres squared;

C is the friction torque of drum bearings, in newton metres;

g is acceleration due to gravity, equal to 9,81 m/s^2;

$\Delta\omega_D/\Delta t$ is the angular acceleration or deceleration.

NOTE The friction torque of pulley bearings, C, may be neglected.

A.2.1.4 Method

When the mass, m, is released, the angular acceleration is measured through the angular encoder fitted to the drum axle (and otherwise used to measure drum decelerations). The friction torque, C, of drum bearings can also be measured provided that the rope can be separated from the drum once mass, m, has given sufficient momentum to the drum, for the subsequent drum deceleration is directly related to C by:

$$C = I_D \left(\frac{\Delta\omega_D}{\Delta t} \right)$$

where the values are as defined under A.2.1.3.

A.2.2 Determination method

The drum inertia is estimated by calculation.

The drum inertia, I_D, is determined by the summation of the inertia of each drum part (flange, disc, reinforced rib):

$$I_D = I_f + I_d + I_r$$

where

I_f is the drum flange inertia;

I_d is the drum disc inertia;

I_r is the reinforced rib inertia;

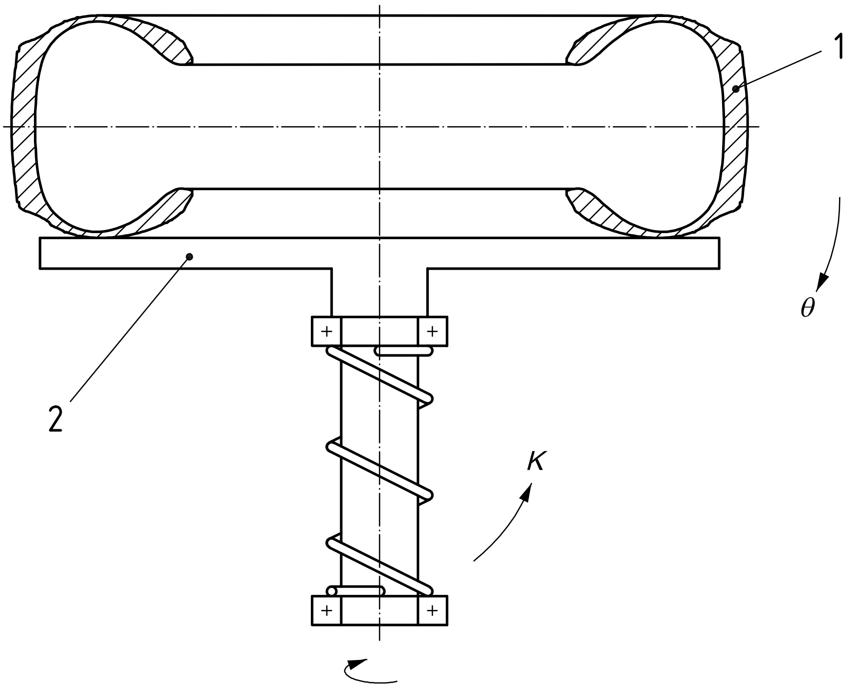
all values being expressed in kilogram metres squared.

A.3 Tyre assembly inertia

A.3.1 Spring method

A.3.1.1 Equipment needed

Torsion pendulum of inertia, I_o, and spring constant, K (see Figure A.2).



Key

1 tyre

2 torsion pendulum

θ angle of oscillation, in radians

K spring constant

Figure A.2 — Spring method

A.3.1.2 Theory

The equation of free movement of pendulum, if θ is the angle from equilibrium, is:

$$I_o \frac{d^2\theta}{dt^2} + K\theta = 0$$

Natural oscillation period, T_o;

$$T_o = 2\pi\sqrt{\frac{I_o}{K}}$$

where

θ is the angle of oscillation, in radians;

t is the period of time, in seconds;

I_o is the torsion pendulum inertia, in kilogram metres squared;

K is the spring constant.

A.3.1.3 Method

Measurement of oscillation periods, with the tyre assembly, T_1, and without T_o can be used to give the tyre assembly inertia, I_t.

$$I_t = \frac{K}{4\pi^2}\left(T_1^2 - T_o^2\right)$$

A.3.2 Bifilar pendulum (rope) method

Tyre inertia can be obtained by the period time of twisted oscillation of a tyre hanging from two steel ropes of exactly the same length (See Figure A.3)

A.3.2.1 Theory

The tyre inertia, I_t, is determined by

$$I_t = \tau^2 \times \frac{Wab}{4\pi^2 h}$$

where

τ is the oscillation period, in seconds;

W is the tyre and wheel weight, in newtons;

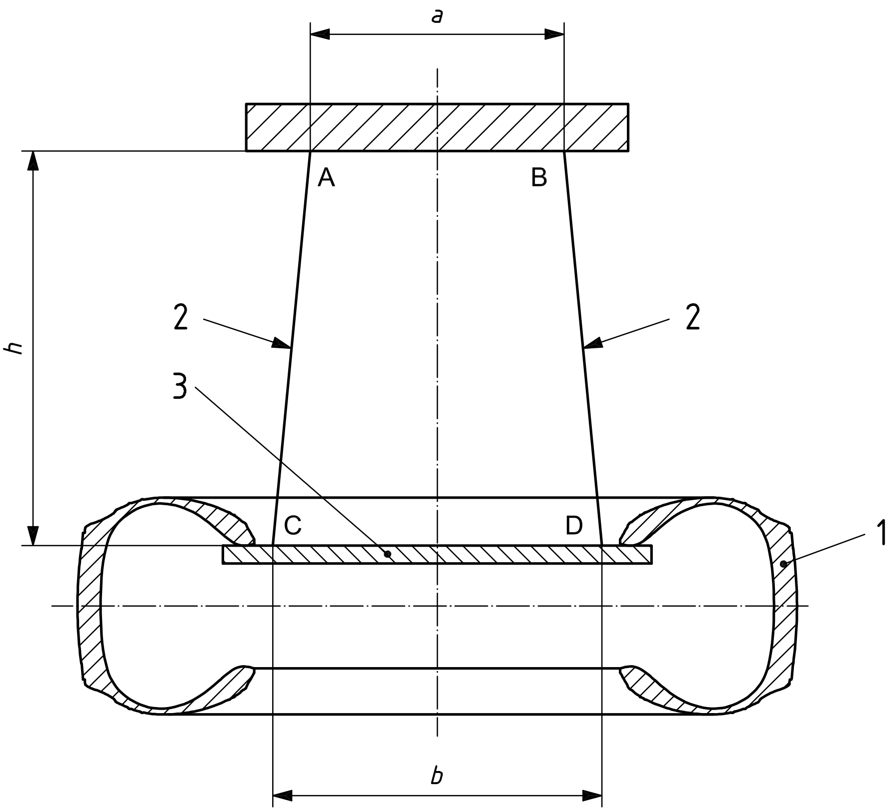
a is the distance between points A and B, in metres;

b is the distance between points C and D, in metres;

h is the vertical distance between lines AB and CD, in metres.

A.3.2.2 Method

The time period, τ, of the twisted oscillation of a tyre is measured, and tyre inertia can be calculated from the equation given in A.3.2.1.



Key

1 tyre

2 steel rope

3 tyre support platform

a distance between points A and B

b distance between points C and D

h vertical distance between lines AB and CD

Figure A.3 — Bifilar pendulum (rope) method

Annex B
(informative)

Optional test conditions

B.1 Purpose

The rolling resistance of a tyre will vary with speed, load and inflation pressure, as well as other factors. Depending upon the circumstances of particular tyre applications, it can be useful to determine the effect of these tyre-related parameters for the individual tyre to be tested. If such information is desired, the options indicated in B.2 and B.3 are recommended. Unless otherwise noted, all aspects of the standard test conditions apply.

B.2 Speed sensitivity

B.2.1 Passenger car tyres

Tests are carried out at 50 km/h, 90 km/h and 120 km/h in sequence (see 6.2.2). A warm-up period of at least 30 min for the first speed and at least 20 min for each successive speed is required.

B.2.2 Truck and bus tyres

Tests are carried out in accordance with speeds specified in 6.2. A warm-up period of at least 90 min for capped pressure conditions and at least 30 min for regulated pressure conditions is required.

B.3 Load and inflation sensitivity

B.3.1 General

If load and inflation sensitivity is required, test in accordance with Table B.1.

B.3.2 Passenger car tyres

A warm-up period of at least 30 min for the first data point and at least 10 min for each successive data point is required.

B.3.3 Truck and bus tyres

Test in a sequence thar results in steadily decreasing values of rolling resistance. For most tyres, the sequence shown accomplishes this objective.

A warm-up period of at least 90 min for the first data point and at least 30 min for each successive data point is required.

B.3.4 Motorcycle tyres

The tyre shall be run at constant test speed until reaching a stabilized steady-state value of rolling resistance. A warm-up period of at least 30 min at the test speed is required.

B.4 Textured surface

In cases where a textured drum surface is used instead of a smooth steel surface, this fact shall be noted in the test report. The surface texture shall then be 180 µm deep (80 grit).

Table B.1 — Load and Inflation at optional test

Passenger car		Truck and bus	
Tyre load as a percentage of maximum load	Test inflation pressure: standardized pressure, modified	Tyre load as a percentage of maximum load	Test inflation pressure as a percentage of rated pressure
50	+ 70 kPa, regulated	100	100 capped
50	– 30 kPa, regulated	100	95 regulated
90	+ 70 kPa, regulated	75	70 regulated
90	– 30 kPa, regulated	50	120 regulated
—	—	25	70 regulated

Annex C
(normative)

Test equipment tolerances

C.1 Purpose

The limits specified in this annex are necessary in order to achieve suitable levels of repeatable test results, which can also be correlated among various test laboratories. These tolerances are not meant to represent a complete set of engineering specifications for test equipment; instead, they should serve as guidelines for achieving reliable test results.

C.2 Test rims

C.2.1 Width

The test rim width shall be equal to the standardized measuring rim. If this is not available, then the next wider rim may be chosen. It should be noted that a change in rim width will result in different test results.

C.2.2 Run-out

Run-out shall meet the following criteria:

— maximum radial run-out: 0,5 mm;

— maximum lateral run-out: 0,5 mm.

C.3 Alignment

C.3.1 General

Angle deviations are critical to the test results.

C.3.2 Load application

The direction of tyre loading application shall be kept normal to the test surface and shall pass through the wheel centre within

— 1 mrad for the force and deceleration methods;

— 5 mrad for the torque and power methods.

C.3.3 Tyre alignment

C.3.3.1 Camber angle

The plane of the wheel shall be normal to the test surface within 2 mrad for all methods.

C.3.3.2 Slip angle

The plane of the tyre shall be parallel to the direction of the test surface motion within 1 mrad for all methods.

C.4 Control accuracy

C.4.1 General accuracy

Exclusive of perturbations induced by the tyre and rim non-uniformity, the test equipment shall be capable of checking the test variables within the following limits:

- tyre loading:
  - ± 20 N for load index 121 and below;
  - ± 45 N for load index 122 and above;
- inflation pressure: ± 3 kPa;
- surface speed:
  - ± 0,2 km/h for the power, torque and deceleration methods;
  - ± 0,5 km/h for the force method;
- time: ± 0,02 s;
- angular velocity: ± 0,2 %.

C.4.2 Optional compensation for load/spindle force interaction and load misalignment

NOTE This compensation applies for the force method only.

Compensation of both load/spindle force interaction (“cross talk”) and load misalignment, may be accomplished either by recording the spindle force for both forward and reverse tyre rotation or by dynamic machine calibration. If spindle force is recorded for forward and reverse directions (at each test condition), compensation is achieved by subtracting the “reverse” value from the “forward” value and dividing the result by two. If dynamic machine calibration is intended, the compensation terms may be easily incorporated in the data reduction.

C.5 Instrumentation accuracy

The instrumentation used for readout and recording of test data shall be accurate within the tolerances stated in Table C.1.

Table C.1 — Instrumentation accuracy

Parameter	Load index 121 and below	Load index 122 and above
Tyre load	± 10 N	± 30 N
Inflation pressure	± 1 kPa	± 1,5 kPa
Spindle force	± 0,5 N	± 1,0 N
Torque input	± 0,5 N·m	± 1,0 N·m
Distance	± 1 mm	± 1 mm
Electrical power	± 10 W	± 20 W
Temperature	± 0,2 °C	
Surface speed	± 0,1 km/h	
Time	± 0,01 s	
Angular velocity	± 0,1 %	

C.6 Test surface roughness

The roughness, measured laterally, of the smooth steel drum surface shall have a maximum centreline average height value of 6,3 µm.

NOTE In cases where a textured drum surface is used instead of a smooth steel surface, this fact shall be noted in the test report. The surface texture shall then be 180 µm deep (80 grit).

C.7 Tyre spindle bearing friction

When using the machine reading as a method for determining the parasitic losses, tyre spindle bearing friction shall be regularly verified as being sufficiently small as to be considered negligible (e.g. a coast-down from 80 km/h to 0 km/h in not less than 5 min with a freely rotating tyre).

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