Rolling Resistance Measurement Procedure for Passenger Car Tires— SAE J1269 JUN84

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PREPRINT

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SAE Recommended Practice

Report of the Highway Tire Committee, approved November 1979, first revision, Rolling Resistance Subcommittee, June 1984.

1. Introduction—The rolling resistance of pneumatic tires results in a significant energy loss to motor vehicles. This recommended practice provides methods for determining rolling resistance of passenger car tires under controlled conditions. The procedure is intended to provide a way of gathering data on a uniform basis, to be used for various purposes (for example, tire comparisons, determination of load or pressure effects, comparison with test results from road tests, etc.).

At this time (June, 1984), there are no related ISO (International Standards Organization) Standards on rolling resistance.

A companion document, SAE Information Report J1270 JUN84, "The Measurement of Passenger Car Tire Rolling Resistance," expands on this subject and gives background information. The format of both documents is the same, with corresponding topics presented under the same headings.

2. Scope—This recommended practice applies to the laboratory measurement of rolling resistance of pneumatic passenger car tires designed primarily for normal highway service. The procedure applies only to the steady-state operation of free-rolling tires at zero slip and inclination angles; it includes the following three basic methods:

2.1 Force Method—Measures the reaction force at the tire spindle and converts it to rolling resistance.

2.2 Torque Method—Measures the torque input to the test machine and converts it to rolling resistance.

2.3 Power Method—Measures the power input to the test machine and converts it to rolling resistance.

3. Definitions—The following definitions apply wherever the terms and expressions are used in this recommended practice, and in SAE Information Report, J1270 JUN84.

3.1 Rolling Resistance—Rolling resistance of the free-rolling tire is the scalar sum of all contact forces tangent to the test surface and parallel to the wheel plane of the tire.

3.2 Rolling Resistance Coefficient—Rolling resistance coefficient is the ratio of the rolling resistance to the load on the tire.

3.3 Loaded Radius—Loaded radius is the perpendicular distance from the axis of rotation of the loaded tire to the surface on which it is rolling.

3.4 Maximum Load—Maximum load is molded on the tire sidewall and/or listed either in the tire load tables of the current Tire & Rim Association, Inc. (TRA) Yearbook, or in corresponding tables published by similar organizations concerned with standardization.

3.5 Maximum Inflation Pressure—Maximum inflation pressure is molded on the tire sidewall and listed in the tire load tables of the current TRA Yearbook or in corresponding tables published by similar organizations concerned with standardization.

3.6 Capped Inflation Pressure—The state of capped inflation pressure is achieved by inflating the tire to the required pressure prior to testing, while the tire is at ambient temperature of the test area, and then sealing the air in the tire during testing with a valve, cap, or some other seal.

3.7 Regulated Inflation Pressure—The state of regulated inflation pressure is achieved by inflating the tire to the required pressure independent of its temperature, and maintaining this inflation pressure during testing.

3.8 Ambient Temperature—The term ambient temperature refers to the temperature of the air measured during a rolling resistance test at a fixed location near the tire. The fixed location of ambient temperature measurement is defined at a lateral distance of 0.4 m (16 in) from the rim flange and an angle of 180 deg from the center of the tire footprint.

3.9 Ambient Reference Temperature—All rolling resistance data are referred to an ambient reference temperature of 24°C (75°F).

4. Test Equipment—The equipment most commonly used for this procedure is the laboratory test wheel.

4.1 Test Surface

4.1.1 TEST WHEEL DIAMETER— The diameter of the laboratory test wheel most commonly used is 1.708 m (67.23 in)[1].

4.1.2 WIDTH—The width of the test surface must exceed the tread width of the test tire.

4.1.3 TEXTURE—The surface must have a medium-coarse 80-grit texture. (See J1270 for discussion of the condition of the surface.)

4.2 Test Rims—Test rims must have an approved contour and width as specified by the TRA or similar organizations, for the size of the tire tested. The standard rim for testing is the design rim for a particular tire, although other approved rims may be used. The rim width and contour used must be reported with the test results. The rim runout must meet the specifications given for new rims.

4.3 Alignment and Control Accuracies—All test conditions must be maintained at their specified levels, because any deviation will affect the accuracy of rolling resistance data. The following alignment and control accuracies are specified such that their combined effect on rolling resistance does not surpass a standard error of 0.5 N (0.1 lbf). Except for special considerations discussed for each of the three methods in paragraphs 4.3.1, 4.3.2, and 4.3.3, the test parameters must be maintained within the following (+/−) limits:

Tire Load Fore-Aft Offset: 0.2 mm (0.01 in)
Tire Load Angular Offset: 0.3 deg
Tire Slip Angle: 0.1 deg
Tire Inclination Angle: 0.3 deg
Tire Load: 20 N (5 lbf)
Inflation Pressure: 1.5 kPa (0.2 psi)
Test Wheel Speed: 2 km/h (1 mph)
Ambient Temperature: see paragraph 5.5.

If these levels cannot be achieved, corrections must be applied, particularly for alignment (paragraph 7.2) or temperatures (paragraph 7.4).

4.3.1 FORCE METHOD—Load misalignment, as well as interactions between load and spindle force transducers ("crosstalk"), can introduce severe errors of the spindle force reading. Such errors must be minimized (see paragraph 7.2).

4.3.2 TORQUE METHOD—Torque variations due to speed-hunting oscillations may cause significant rolling resistance errors. Machine induced torque variations must be kept small and averaged over several complete oscillation periods.

4.3.3 POWER METHOD—Because rolling resistance calculation requires a constant value of speed during the measurement interval, variations in surface speed can cause significant errors. Therefore, the following speed accuracy is required for this method: Test wheel speed: ± 0.3 km/h (0.2 mph).

4.4 Instrumentation Accuracy—The instrumentation used for readout and recording of test data must be sufficiently accurate and precise to provide rolling resistance measurements with a standard error of 0.5 N (0.1 lbf) or less. To achieve this accuracy, measurements common to all three methods of rolling resistance determination must be maintained within the following (+/−) accuracies:

Tire Load: 10 N (2 lbf)
Inflation Pressure: 1 kPa (0.1 psi)
Temperature: 0.2°C (0.5°F)
Speed: 1 km/h (0.5 mph)

4.4.1 FORCE METHOD—In addition to the common accuracies specified above, the use of this method requires the following (+/−) accuracies:

Spindle Force: 0.5 N (0.1 lbf)
Loaded Radius: 1 mm (0.04 in)

4.4.2 TORQUE METHOD—In addition to the common accuracies specified above, the use of this method requires the following (+/−) accuracy:

Torque Input: 0.3 N·m (3 lbf·in)

4.4.3 POWER METHOD—In addition to the common accuracies specified above, the use of this method requires the following (+/−) accuracies:

Power: 10 W
Test Wheel Speed: 0.2 km/h (0.1 mph)

5. Test Conditions—The recommended test consists of four test points at which the equilibrium rolling resistance and the equilibrium inflation pressure are determined.

5.1 Load and Inflation Pressure—Standard Test—The initial measurement of rolling resistance is taken at capped inflation pressure, where the pressure is allowed to rise as it would in service. This measurement is followed by three consecutive measurements at regulated inflation pressures. The loads and pressures appear in the following table.

[1] Conversion of SI units to U.S. customary units is handled with regard to the intended precision of the quantity in question.

Test Point No.	Tire Load–% of Max Load	Tire Inflation Pressure–Max. Pressure (+/−) Increment
1	90	−50 kPa (−7.3 psi) Capped
2	90	+70 kPa (+10.2 psi) Regulated
3	50	−30 kPa (−4.4 psi) Regulated
4	50	+70 kPa (+10.2 psi) Regulated

5.2 Load and Inflation Pressure–Alternate Test—All four test points are taken at regulated pressure. The loads and pressures appear in the following table.

Test Point No.	Tire Load–% of Max Load	Tire Inflation Pressure–Max. Pressure (+/−) Increment
1A	90	−30 kPa (−4.4 psi) Regulated
2	90	+70 kPa (+10.2 psi) Regulated
3	50	−30 kPa (−4.4 psi) Regulated
4	50	+70 kPa (+10.2 psi) Regulated

Note that points 2, 3, and 4 of the alternate test are identical with points 2, 3, and 4 of the standard test. Exchanging point 1 of the standard test by point 1A of the alternate test does not affect the overall accuracy of the test, if the object of the test is to determine the load or pressure sensitivity of the tire.

5.3 Test Sequence—It is recommended that the measurements be made in a sequence resulting in steadily decreasing values of rolling resistance. For most tires, the sequence shown in paragraphs 5.1 and 5.2 accomplishes this objective.

5.4 Test Speed—The test speed is 80 km/h (50 mph).

5.5 Ambient Temperature—The ambient temperature surrounding the test tire should be held between 20°C (68°F) and 28°C (82°F). An average ambient temperature is recorded for each of the four test points. All rolling resistance values must be adjusted to the Ambient Reference Temperature of 24°C (75°F) (see paragraph 7.4).

6. Test Procedure

6.1 Break-In—Tires that undergo significant permanent change in their dimensions or material properties upon first operation, require a break-in and cooling period prior to the start of the test. Break-in is accomplished by operating the tire at test point 1 (paragraph 5.1) for a period of 1 h, followed by a cool-down period to ambient test room temperature of at least 2 h.

6.2 Thermal Conditioning—Test tire and rim must be placed in the thermal environment of the test location to achieve thermal equilibrium before testing. A minimum of 2 h is needed for the tire. If the standard test is used (paragraph 5.1), the tire must be inflated on the test rim at least 1 h before testing.

6.3 Warm-Up—The tire must be run on the test surface under each set of conditions long enough to achieve a steady-state value of rolling resistance. A minimum period of 30 min is required for the first condition, and at least 10 min for each of the three following conditions. The achievement of steady-state conditions can be verified by monitoring the rolling resistance.

6.4 Measurement and Recording

6.4.1 Identification—The following information for the identification of each test should be recorded, if applicable:

6.4.1.1 Tire Identification

(a) Manufacturer
(b) Brand name
(c) Tire size
(d) Tire maximum load
(e) Tire maximum pressure
(f) Serial number
(g) Break-in information
(h) Use–history of tire
(i) Other pertinent information

6.4.1.2 Test Machine Identification

(a) Test wheel diameter
(b) Test wheel surface texture and general condition
(c) Tire mounting configuration
(d) Method of parasitic loss determination
(e) Other pertinent information

6.4.1.3 Test Conditions

(a) Date and time
(b) Rim width and contour
(c) Rotational direction (clockwise or counter-clockwise) determined for the tire side with serial number.
(d) Test operator

6.4.2 Test Variables—The following test data must be recorded immediately following warm-up for each load-pressure combination:

(a) Warm-up time
(b) Speed
(c) Load
(d) Inflation pressure
(e) Spindle force, input torque, or input electrical power, as appropriate
(f) Loaded radius (required for force method)
(g) Ambient temperature (see paragraph 5.5)

6.5 Measurement of Parasitic Losses—Parasitic losses can be determined by different techniques. Two commonly used methods for estimating parasitic losses are:

6.5.1 Skim Reading—Load on the tire must be reduced to a value just sufficient to maintain rotation at test speed without slippage. A skim load of 100 N (20 lbf) is recommended. Spindle force, input torque, or input electrical power (whichever applies) is read at the skim load.

6.5.2 Machine Offset Reading—The tire and wheel assembly is removed from the test surface. At test speed, input torque or input electrical power is read (whichever applies). Note that this method does not apply if the force method is used. Note also that the parasitic losses of the rotating tire and wheel assembly are not measured and must be determined separately.

7. Data Reduction

7.1 Net Readings via Subtraction of Parasitic Readings—Parasitic losses must be subtracted from the gross readings to yield net spindle force, net torque, or net electrical power (whichever applies). Two commonly used techniques for estimating the effect of parasitic losses are:

7.1.1 Skim Reading (for Force, Torque, and Power Method)—Substract the skim reading from the reading for each test condition.

7.1.2 Machine Offset Reading (for Torque and Power Method—Subtract the machine offset reading and, in addition, the tire spindle bearing loss from the reading for each test condition.

7.2 Compensation for Load-Spindle Force Interaction and Load Misalignment—Compensation for both load-spindle force interaction ("crosstalk") and load misalignment must be determined for each of the four test points (paragraph 5.1 or 5.2). This is accomplished either by recording the spindle force for both forward and reverse tire rotation, or by dynamic machine calibration. If spindle force is recorded for forward and reverse direction (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 elected, the compensation terms may be easily incorporated in the data reduction process.

7.3 Rolling Resistance Calculation—Rolling resistance must be calculated by using a formula appropriate to the measuring method.

7.3.1 Force Method

$$F_R = F_X\,(1 + R_L/R)$$

where: F_R = rolling resistance, N (lbf)
F_X = Magnitude of net tire spindle force, N (lbf)
R_L = Loaded radius, m (in)
R = Test wheel radius, m (in)

7.3.2 Torque Method

$$F_R = T/R$$

where: F_R = Rolling resistance, N (lbf)
T = Net input torque, N·m (lbf·in)
R = Test wheel radius, m (in)

7.3.3 Power Method

$$F_R = c \cdot P/v$$

where: F_R = rolling resistance, N (lbf)
c = 0.360 for speed in km/h
c = 0.503 for speed in mph
P = net power input, W
v = test surface speed, km/h (mph)

7.4 Data Adjustment to Ambient Reference Temperature—Individual values of rolling resistance must be adjusted to the reference temperature of 24°C (75°F) by use of the relation:

$$F_{RR} = F_R\,[1 + k\,(T_A - T_R)],\ \text{N (lbf)}$$

where: F_{RR} = rolling resistance at Ambient Reference Temperature, N (lbf)
F_R = rolling resistance measured at a test point, N (lbf)
T_A = average ambient temperature measured at a test point, °C (°F)
T_R = Ambient Reference Temperature
k = temperature adjustment factor, $(°C)^{-1}$ or $(°F)^{-1}$.

The factor k is determined empirically; current results (see Ref. 1 of