



Tire Dimensions Test

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This document describes the test equipment requirements and test methodology for measuring static dimensions of a given tire to support the vehicle simulation models and the tire validation process.

1.2 Applicability. Passenger car, compact spare and light truck tires.

1.3 Remarks. Dimension parameters covered by this procedure include Section Width (SW), Overall Tire Width (OTW), Outer Diameter (OD), Loaded Section Width (LSW), Static Loaded Radius (SLR) and Static Spring Rate (SSR).

The dimensions of a tire, including SSR and SLR, are functions of tire construction, compound, and design. These properties may be found at various application conditions and influence tire/vehicle clearances, bumper heights and vehicle ride. The quantification of these properties is very important to both vehicle design and tire selection since these properties will indicate a tire's response to certain inputs on the road surface and are, therefore, required in meeting the demands of tire development process, vehicle simulation and integration of chassis systems.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW16590

2.3 Additional References.

Tire and Rim Association (T&RA) Yearbook

3 Resources

3.1 Facilities.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 The equipment is required for the Outer Diameter, Section Width, Overall Tire Width, Loaded Section Width, Static Spring Rate and Static Load Radius tests.

3.2.1.1 A π tape (Pi tape) for measuring the OD from a circumferential measurement, 0.1 mm incremental scale, non-contacting optical measurement device, or another suitable device.

3.2.1.2 Tire inflation gauge or regulated pressure system, accuracy of ± 2 kPa (± 0.3 psi).

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3.2.1.3 Vernier calipers, digital calipers, dial calipers or inside/outside joint caliper, non-contacting optical measurement device, or another suitable device.

3.2.1.4 A measuring rule to determine the caliper opening if using inside/outside joint calipers, smallest scale division shall be no greater than 0.5 mm incremental scale. Accuracy of the scale should be within 0.25 mm. These requirements also apply to vernier, digital and dial calipers.

3.2.2 Additional equipment is required for the Loaded Section Width, Static Spring Rate and Static Loaded Radius.

3.2.2.1 Load frame with displacement rate control accurate to ± 1 mm/minute. Displacement rate of machine used for testing should be documented.

3.2.2.2 Data acquisition system or X to Y recorder for recording force and displacement.

3.3 Test Vehicle/Test Piece.

3.3.1 Tires of specified nominal size, meeting dimensional requirements of T&RA or European Tyre and Rim Technical Organization (ETRTO).

3.3.2 The wheel must meet T&RA or ETRTO dimensional requirements for the specified tire.

3.4 Test Time.

Calendar time: 2 days

Test time: 26 hours

Coordination time: <1 hour

Note: Calendar time is the overall time from start to finish assuming the parts are available. Test hours are the actual time for test setup, test execution, and test breakdown. Coordination time is the time for coordinating the test request, part procurement, part modification, analysis, and part disposition.

3.5 Test Required Information. Wheel width information is required.

3.6 Personnel/Skills. Test technician shall be qualified on the basis of appropriate education, training, experience, and/or demonstrated skills.

4 Procedure

4.1 Preparation. Use the preparation for all tests; 4.3.3 Section Width, Overall Tire Width and Outer Diameter of the Unloaded Tire, 4.3.4 Loaded Section Width, and 4.3.5 Static Loaded Radius and Static Spring Rate.

4.1.1 Sample Preparation. The test tire must be free of all tags, tape, stones and other foreign objects.

4.1.2 The tire bead must be lubricated prior to mounting.

4.1.3 Mount the tire on the wheel using Rubber Manufacturers Association (RMA) recommended practice. Never inflate a tire over 275 kPa (40 psi) to seat the beads.

4.1.4 Inflate to the first test inflation pressure shown in Table A1, Appendix A. The order in which pressures are tested is unimportant.

4.1.5 Mark reference position on the tire sidewall.

4.1.5.1 For tires with Department of Transportation (DOT) mark, select and mark the **O** in the **DOT** as the reference point.

4.1.5.2 If the tire does not have a DOT mark, select a location that can easily be found as the reference point.

4.1.6 Mark additional measurement locations at equally spaced intervals around the tire circumference. A minimum of four (4) measurement locations are required.

4.1.7 Allow inflated tire to stand at least 24 h at ambient test temperature.

4.2 Conditions.

4.2.1 Environmental Conditions. Ambient temperature: $24^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.3 Tires standardized by an organization other than T&RA and ETRTO are to be tested at the same inflation pressure as the equivalent T&RA and ETRTO size.

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4.2.4 Test Inflation Pressures.

4.2.4.1 Table A1 in Appendix A outlines the inflation pressures for testing based on tire type, load range and the maximum inflation pressure molded on the tire sidewall.

4.2.4.2 Capped Inflation Pressure. All tests under load should use an inflation pressure set as per 4.2.4.2.1 or 4.2.4.2.2 as appropriate given the test equipment available. 4.2.4.2.2 is the preferred method if available.

4.2.4.2.1 To set the capped inflation pressure, load the tire to 80% of the tire load limit (TLL) and then inflate the tire to test inflation pressure.

4.2.4.2.2 Instead of preloading the tire to set the inflation pressure, the actual pressure in the tire can be recorded during the test and the measured pressure at 80% of the TLL is reported as the actual test inflation pressure. For Data Analysis, the recorded pressure channel would be used for increased accuracy. This measured pressure must be within ± 5 kPa of the intended test inflation pressure.

4.2.5 Test Loads.

4.2.5.1 Appendix A, Table A2 outlines the test loading conditions.

4.3 Instructions.

4.3.1 Preloading. For LSW, SLR, and SSR measurements, the tire must be preloaded prior to taking measurements.

4.3.1.1 Align the reference location against the loading platform.

4.3.1.2 Load tire from zero to 140% of the test load for the highest test inflation pressure and unload as a preconditioning step.

4.3.1.3 Repeat preloading sequence at least one more time.

4.3.2 The remaining instructions are broken up into three (3) segments that can be performed individually or in conjunction with each other.

4.3.3 Section Width (SW), Overall Tire Width (OTW), and Outer Diameter (OD) of the Unloaded Tire.

4.3.3.1 Set the inflation pressure as stated in 4.1.4, and cap the pressure as stated in 4.2.4.2.

4.3.3.2 Measure and record the OD of the tire.

4.3.3.3 Measure and record the SW of the tire at locations specified in 4.1.6. The SW is the widest cross section of the tire excluding raised letters, protective side ribs, bars, other sidewall decorations, or rim flange protectors. This measurement should be taken at $50\% \pm 10\%$ of the section height of the tire.

4.3.3.4 Measure and record the OTW of the tire at locations specified in 4.1.6. The OTW is the widest cross section of the tire including raised letters, protective side ribs, bars, other sidewall decorations, or rim flange protectors.

4.3.3.5 Repeat the measurements for each test inflation pressure.

4.3.4 Loaded Section Width (LSW): Not commonly requested. For reference when needed.

4.3.4.1 Mount the tire/wheel assembly in the load frame with reference location nearest the loading surface.

4.3.4.2 Set the inflation pressure as stated in 4.1.4, and cap the pressure as stated in 4.2.4.2 and preload the assembly as stated in 4.3.1.

4.3.4.3 Load the assembly to the tire load limit.

4.3.4.4 Measure and record the loaded section width of the tire at the original reference point $\pm 45^\circ$.

4.3.4.5 Repeat the LSW measurement for each remaining test inflation pressure.

4.3.5 Static Loaded Radius and Static Spring Rate.

4.3.5.1 Mount the tire/wheel assembly in the load frame with reference location nearest the loading surface.

4.3.5.2 Set the inflation pressure as stated in 4.1.4, and cap the pressure as stated in 4.2.4.2 and preload the assembly as stated in 4.3.1.

4.3.5.3 Measure and record OD with the pressure set at the test inflation pressure.

4.3.5.4 Use an approved method to zero the load and deflection of the tire. Zero deflection should coincide with zero load. This can be done at the time of the test or in the data processing.

4.3.5.5 If a visual or manual method is used to determine when the tire begins to touch the loading surface, the load on the tire at zero deflection should not exceed 10 N.

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4.3.5.6 Alternatively, start recording the load and deflection data a short distance above the contact surface (10 mm through 200 mm) and determine the contact point mathematically as described in 5.1.4.2. Continue loading the tire until the applied load is greater than 140% of the Tire Load Limit (TLL) while recording load and deflection measurements simultaneously. The displacement rate of either the tire spindle or the load platform shall be 30 mm/minute $\pm$ 1 mm/minute.

4.3.5.7 Unload the assembly.

4.3.5.8 Repeat the SLR and SSR measurements for each remaining test inflation pressure.

5 Data

5.1 Calculations.

5.1.1 The calculations are provided as an example process to obtain the reported parameters shown in Appendix C, Table C1. However, to increase the certainty of correlation to GM, it is recommended the calculations are made as specified in this document.

5.1.2 OD, SW, and OTW of an Unloaded Tire and LSW of a Loaded Tire. Calculate the mean of the SW, OTW, and LSW measurements taken at each measurement location at each pressure. The calculated means are to be the reported data values for each measured pressure. Since the OD is a single measurement, the mean is not calculated and it is reported as measured.

5.1.3 Michelin-Haas Model. The Michelin-Haas equation is used in modeling tire load-deflection behavior over the range of operating loads and pressures. The Michelin-Haas equation is fitted to the recorded load-deflection data taken in 4.3.5. The fit yields the A, B, and C coefficients for the equation and load-deflection behavior of the measured tire. Michelin-Haas equation is given as follows:

$$\text{load}(x, p) = Ax + Bpx^C$$

Where:

A, B, C are coefficients of the Michelin-Haas equation.
 load = Vertical Load (N)
 p = Inflation Pressure (kPa)
 x = Deflection (mm)

5.1.3.1 The slope of Michelin-Haas equation gives the rate of change of load per unit distance, or the tire SSR.

$$\frac{d(\text{load})}{dx} = \text{SSR}(x, p) = A + BCpx^{(C-1)}$$

Where:

load = Vertical Load (N)
 x = Deflection (mm)
 p = Inflation Pressure (kPa)
 SSR = Static Spring Rate (N/mm)

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5.1.3.2 The Static Loaded Radius (SLR) is given by:

$$SLR(x) = \frac{OD}{2} - x$$

Where:

x = Deflection (mm)

OD = Measure OD (mm)

SLR = Static Loaded Radius (mm)

5.1.4 Data Conditioning (Optional). Data conditioning is only done if necessary to provide results that correlate to GM. If data is already smooth and if the True Origin of the load-deflection cycle is already known, these steps are not required.

5.1.4.1 Filter the Measured Data. Measured data may need to be filtered to insure accuracy of data calculations. Filtering, if required, can either be done during the data acquisition or during data processing.

5.1.4.2 Determine the True Origin. The True Origin is to be determined with an accuracy of ± 0.5 mm.

5.1.4.3 Translate Data to the True Origin. Subtract the load and deflection values of the True Origin found in 5.1.4.2 from each measured data point equal to or greater than the True Origin. The measured data that is less than the values of the True Origin are excluded for the remaining analysis.

5.1.5 Determine Michelin-Haas Coefficients. Coefficients of the Michelin-Haas Equation are determined using an appropriate non-linear regression technique operating on all the translated load-deflection data. The translated load-deflection data from all test inflation pressure values are fitted to a single set of coefficients.

5.1.5.1 Trim the translated load-deflection data set at each inflation pressure to only include data where the applied load is between 30% and 140% of the TLL for the test inflation pressure.

5.1.5.2 Select an equal number of evenly spaced data points for each test inflation pressure with respect to load. The number of data points for each inflation pressure, m, is arbitrary, but should be at least 56.

5.1.5.3 Determine values for the coefficients A, B, and C using the data selected in 5.1.5.2.

5.1.5.4 Calculate the mean fit error using the following equation:

$$error_{mean} = \left(\frac{100}{m(np)} \right) \sum_{n=1}^{n=np} \sum_{i=1}^m \left(\frac{ABS(L_{calc,i} - L_{meas,i})}{L_{meas,i}} \right)$$

Where:error_{mean} = Mean fit error (%)L_{calc} = Predicted load at each deflection (N)L_{meas} = Measured load at each deflection (N)

np = Number of test inflations pressures

m = Number of data points chosen in 5.1.5.2

5.1.5.5 SLR and SSR of a Loaded Tire. Calculate the SLR and SSR at each test inflation pressure per Appendix A, by using the Michelin-Haas equations with coefficients calculated in 5.1.5.

5.1.5.5.1 In order to calculate SSR and SLR for a given load and pressure, the deflection at the desired load and pressure must be known. Since load is given as function of deflection and pressure, deflection must be iterated until the desired load is achieved with an accuracy of 0.001 N. Use the Newton-Raphson method to calculate deflection at a given load and pressure which is given as:

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