



Tire Flat-Spot 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 procedure for testing passenger car and light truck tires for flat-spot.

1.2 Applicability. These procedures apply to the standard flat-spot testing of passenger car and light truck tires. Uniformity is measured on a Highway Speed Uniformity (HSU) machine at zero slip angle and zero inclination angle.

1.3 Remarks. Increased levels of tire non-uniformity caused by a tire flat-spotting may contribute to the vibrations experienced by the customer. Flat-spot test results may be used to evaluate a tire against component flat-spot specifications or it may also be used to help diagnose vehicle vibration issues.

1.3.1 Flat-spot testing measures the change in tire uniformity caused by extended periods of static loading at a defined temperature. It quantifies both the initial and permanent effects of a flat-spot.

1.3.2 The flat-spot result requires two (2) high speed uniformity measurements. The first measurement is taken before the static load application and is defined as initial time based uniformity. The second is taken after the static load application and is defined as post flat-spot time based uniformity. The flat-spot data is the decay of the vector differences between the uniformity measurements at equal times, for a period of 30 minutes.

1.3.3 The first two (2) harmonics of radial (F_z) and fore/aft (F_x) are of the forces of primary interest.

2 References

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

2.1 External Standards/Specifications.

SAE J332

2.2 GM Standards/Specifications.

GMW16590

3 Resources

3.1 Facilities.

3.2 Equipment. All details associated with the test apparatus are included in SAE J332.

3.2.1 The road wheel should be covered with either medium grit 3M Safety Walk or 80 grit Three-M-ite. The surface should be replaced at routine intervals to eliminate it as a source of testing variability.

3.3 Test Vehicle/Test Piece. A tire-wheel assembly is required to run a flat-spot test. The test requester will specify the width and rim flange of the wheel.

3.4 Test Time.

Calendar time: 1.5 days

Test time: 26 h

Coordination time: 1 h

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3.5 Test Required Information. Required information includes test temperature, tire size, construction number, load rating, service description, and wheel width. Additional information required may vary by test site.

3.6 Personnel/Skills. Test operator should have adequate training and be familiar with the local operator's procedure.

4 Procedure

4.1 Preparation.

4.1.1 Tires must be mounted on the appropriate wheels per 3.3.

4.1.2 All tires must be mounted in the proper orientation with respect to the front face of the test wheels. Whitewall tires must be mounted whitewall out with respect to the front face of the wheels. Black wall tires must be mounted with the cosmetic or intended outboard sidewall mounted out with respect to the front face of the test wheels.

4.1.3 Assemblies or individual tires and wheels should be at an ambient room temperature of $24\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ for a minimum of 2 h before a flat-spot test.

4.1.4 The assembly should always be mounted on the machine in the standard position, in which the valve stem is aligned with the zero mark on the spindle. If this is not possible because the spindle studs do not line up with the bolt holes, the assembly is rotated clockwise until the studs and bolt holes do line up. The angle through which the assembly was rotated is then used to correct the phase angles of the Fast Fourier Transform (FFT).

4.1.5 Minimizing the radial runout is very important to minimize mounting contribution to uniformity. Follow local mounting instructions using expandable collets and other mounting hardware in order to optimize the centering of the machine mounting.

4.2 Conditions.

4.2.1 Environmental Conditions. Ambient temperature of the uniformity machine test area must be kept at $24\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$. A method for monitoring ambient temperature must be in place.

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.

4.2.2.1 Load and Pressure. Tires must be tested at standard test conditions unless otherwise specified by the tire test request. Standard test conditions are defined in Table 1.

Table 1: Calculation of Standard HSU Test Conditions

Tire Type	Load Range	Test Load	Test Pressure (Capped)
Passenger Car	All	70% of maximum load	210 kPa
Light Truck or Commercial	All	70% of load capacity at 350 kPa	350 kPa

4.2.2.2 Speed. The standard test speed used to evaluate flat-spot performance is 120 km/h in the clockwise direction.

4.3 Instructions. The flat-spot test result requires two (2) high-speed uniformity measurements, one (1) before the stationary load application (initial time based uniformity) and one (1) after (post flat-spot time based uniformity).

4.3.1 Acquiring Initial Time Based Uniformity.

4.3.1.1 To acquire the initial time based uniformity, no break in or warm up is used.

4.3.1.2 Because the initial flat-spot decays quickly, the following steps should be used to reach the test conditions, with the interest of exercising the tire as little as possible before data acquisition.

4.3.1.2.1 With the roadwheel stationary, load the tire to 500 N.

4.3.1.2.2 Accelerate the roadwheel to 120 km/h as quickly as possible.

4.3.1.2.3 Adjust the tire load to the test load.

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4.3.1.2.4 Steady-state conditions must be reached within 90 s of road-to-wheel contact. Within 60 s is preferred.

4.3.1.3 Begin data acquisition as soon as steady-state conditions are met. Data points should be gathered at 30 s intervals (60 s intervals are allowed). Continue capturing data for 30 minutes, where time zero begins once the tire has reached the steady-state test conditions. As a current GM practice, eight (8) consecutive revolutions of data are captured every 30 s for a period of 30 minutes. This group of 60 data sets is called the initial time based uniformity.

4.3.2 Inducing the Flat-Spot. Immediately after the first data collection is completed (< 10 minutes), place the assembly on a loading fixture in a climate controlled room at the correct test temperature. Keep the assembly loaded at the test load and test temperature for the specified times.

4.3.2.1 Location. The location for the flat-spot load is not specified. Flat-spot results have been shown to be independent of the flat-spot location.

4.3.2.2 Method. The load control method is the preferred method of inducing the flat-spot. Deflection control may be acceptable if the temperature verses deflection/load relationship is known and can be accommodated for sufficiently.

4.3.2.3 Temperature and Duration. The standard flat-spot test temperature is the 43.3 °C (110 °F) test. Other temperature conditions may also be run as required. The temperature conditions defined for testing flat-spot are as follows:

- 43.3 °C ± 2.8 °C (110 °F ± 5 °F) for 22 h, then
- 21.1 °C ± 2.8 °C (70 °F ± 5 °F) for 2 h.

In the case of the standard test procedure of 43.3 °C (110 °F), the tire is first loaded in the 43.3 °C (110 °F) environment for 22 h. The tire is then moved to ambient temperature conditions of 21.1 °C ± 2.8 °C (70 °F ± 5 °F) while maintaining the applied load at the same location on the tire. The tire is allowed to cool for 2 h in the ambient temperature environment.

4.3.2.3.1 Ambient Temperature. An ambient temperature test of 21.1 °C ± 2.8 °C (70 °F ± 5 °F) would have the tire loaded and in the ambient temperature environment for the full 24 h.

4.3.3 Acquiring Post Flat-Spot Time Based Uniformity.

4.3.3.1 Transfer the test assembly from the loading fixture to the uniformity machine. It is important to complete the transfer quickly (< 10 minutes), avoiding extraneous loading and handling.

4.3.3.2 When acquiring the post flat-spot time based uniformity measurements, there is again no break in or warmup period.

4.3.3.3 Because the initial flat-spot decays quickly, the following steps should be used to reach the test conditions, with the interest of exercising the tire as little as possible before data acquisition.

4.3.3.3.1 With the roadwheel stationary, load the tire to 500 N.

4.3.3.3.2 Accelerate the roadwheel to 120 km/h as quickly as possible.

4.3.3.3.3 Adjust the tire load to the test load.

4.3.3.3.4 Steady-state conditions must be reached within 90 s of road-to-wheel contact. Within 60 s is preferred.

4.3.3.4 Begin data acquisition as soon as steady-state conditions are met. Data points should be gathered at 30 s intervals (intervals of 60 s are allowed). Continue capturing data for 30 minutes, where time zero begins once the tire has reached the steady-state test conditions. As a current GM practice, eight consecutive revolutions of data are captured every 30 s for a period of 30 minutes. This group of 60 data sets is called the post flat-spot time-based uniformity.

Note: The unbalance data is not captured at the end of the 30 minutes in flat-spot testing as is done in HSU.

5 Data

5.1 Calculations. Radial (F_z) and fore/aft (F_x) are the forces of primary interest for flat-spot.

Note: These same calculations can be applied to any of the measured forces and moments.

Individual data sets, within both initial time based uniformity and post flat-spot time based uniformity are analyzed in the following manner:

5.1.1 All eight (8) revolutions of the acquired data are averaged into one representative revolution.

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5.1.2 The magnitudes and phase angles of radial and fore/aft forces are calculated based on the following formulations.

5.1.2.1 Radial.

$$F_z(i) = \sum_{j=1}^n R_{jH} * \cos\left(\frac{2 * \pi}{j * T} * \frac{i}{m} + R_{jP}\right)$$

Where:

$F_z(i)$ is measured as an eight (8) revolution averaged radial force in SAE International (SAE) coordinate system at each sample point in one (1) revolution.

i is variable index of sample points (i.e., $i = 1, 2, \dots, m$).

m is number of sample points per revolution (i.e., as 64 256).

j is variable index of harmonic (i.e., $j = 1, 2, \dots, n$)

n is number of harmonic (i.e., 16, 32).

R_{jH} is decomposed magnitude (newtons) of radial force at harmonic j^{TH} or frequency of $1/(j * T)$.

R_{jP} is decomposed phase angle (degrees) of radial force at harmonic j^{TH} or frequency of $1/(j * T)$.

T is time taken for tire to rotate one cycle at specific speed and load.

5.1.2.2 Fore/Aft.

$$F_x(i) = \sum_{j=1}^n F_{jH} * \cos\left(\frac{2 * \pi}{j * T} * \frac{i}{m} + F_{jP}\right)$$

Where:

$F_x(i)$ is measured as an eight (8) revolution averaged fore/aft force in SAE coordinate system at each sample point in one revolution.

F_{jH} is decomposed magnitude (newtons) of fore/aft force at harmonic j^{TH} or frequency of $1/(j * T)$.

F_{jP} is decomposed phase angle (degrees) of fore/aft force at harmonic j^{TH} or frequency of $1/(j * T)$.

5.1.3 Typically, the first two (2) harmonics are of primary interest for flat-spot.

5.1.4 Phase angle is always reported as a physical spot on the tire measured clockwise from the zero mark of the spindle. The phase angle is always positive, so the n^{th} harmonic phase angle can be only from zero to 360 degrees/n.

5.1.5 Calculate the flat-spot results. The results of the initial time based uniformity are subtracted from the results of post flat-spot time based uniformity at each time step. A FFT will be performed on the difference between post flat-spot time based uniformity and initial time based uniformity to obtain both magnitudes and angles of force variations.

5.1.5.1 Polar charts are plotted for the resulting force vectors for the first two (2) harmonics. Generally, the radial (F_z) and fore/aft (F_x) vectors are of interest.

5.1.5.2 The magnitudes of time based uniformity vector differences for a given parameter can be fit with an exponential decay function of the form:

$$Mag(\vec{U}_{corr}) = A + B \cdot e^{-Ct}$$

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Where:

A is the permanent flat-spot.

A + B is the initial flat-spot, and

C is the time constant where **t** has units of minutes.

5.1.5.3 The magnitudes of the time based uniformity vector differences for each parameter of interest are generally plotted on a time scale and presented along with the exponential decay function above.

5.2 Interpretation of Results. The requester of the test will review the measured data, according to the specific needs.

5.2.1 Flat-spot values at $t = 2$ and $t = 30$ are called out specifically.

5.2.2 When evaluating the flat-spot values at $t = 2$ and $t = 30$ for the two (2) individual tires, it is preferred that the values are within 25 N of each other. For differences between 25 N and 50 N, it is a judgment call whether to test a third tire. If the difference in the values is greater than 50 N, a third tire should be tested. After the third tire is tested, all three (3) tires are reviewed, and the outlying tire is removed from the data set.

5.3 Test Documentation. The test results documentation should include:

- Test results report (generated by Global Tire-Wheel Test System (GTWTS) if submitting extensible markup language (XML) files)
- Test result data files (XML format) including a composite XML.
- *.dat files (ASCII format).

The list of required test data parameters is given in Appendix A, Table A1. A sample test system report is given in Appendix B, Data Sheet B1. In Appendix C, Data Sheet C1 is an example of the Excel report that can be found in the attachments section of the test system. This Excel report form is most convenient for copying data from the report.

Note: For data being loaded into the GTWTS, submit electronically the test results data files (XML format) and other supporting files listed above. GMW16590 defines the electronic file details (e.g., file types, file naming convention, and detailed file formats) for the GTWTS.

6 Safety

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

7 Notes

7.1 Glossary.

Applied Load: The force existing between the tire and the roadwheel during an HSU test.

Composite Data: The data acquired while the tire is run in a steady-state condition loaded against the road wheel.

Composite Magnitude: The peak-to-peak magnitude of the force variation over one complete 360 degree tire rotation.

First Harmonic: The peak-to-peak magnitudes of the lowest or fundamental frequency of the force variation signal over one complete 360 degree tire rotation.

Flat-Spot: The tendency of a tire to change in uniformity when it is loaded statically for a period of time. The degree of flat-spotting is dependent on the duration for which the tire remains static and the conditions to which it is exposed (i.e., load, temperature, pressure, etc).

Inflation Pressure: The capped tire inflation pressure during an HSU test.

Machine Contribution: A measure of the machine's contribution to the non-uniformity that appears in the test data. Machine contributions can come from an out of balance spindle and eccentricities of the assembly when it

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