



Tire Ride Modeling Tests for FTIRE using Flat-Trac Equipment

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 standard is written to describe, in general terms, all tests required for FTIRE tire modeling input, as specifically run on the Flat-Trac equipment (Light Truck Race Electric (LTRE), CT+, Flat Trac equipment, or equivalent model designation available from MTS Systems Corporation). The data generated by this test is used to create FTIRE models for vehicle simulations of loads and ride performance.

1.2 Applicability. This test is restricted to controlled laboratory tests on passenger and light truck tires.

1.3 Remarks.

1.3.1 The properties addressed in this test are important to various vehicle simulation groups since these tire properties will greatly dictate the vehicle's response to specific control inputs.

1.3.2 Tire properties addressed in this test are dependent upon almost every physical characteristic of a tire (e.g., tire structure, compounds, tread design, etc.) Tire properties addressed in this test are also dependent upon the usage environment such as the load, inflation pressure, rim width, speed, state of wear, ambient conditions, surface texture, temperatures, tire age, storage history, and usage history. This is pointed out to emphasize the need to be diligent in the selection of test tires, their storage conditions, and attention to detail in following good test practices outlined in this procedure.

1.3.3 The quantification of tire properties addressed in this test requires the measurement of the net resultant forces and moments from stresses within the tire footprint area. This implies the footprint dynamics on the measurement equipment must be similar to those experienced under actual vehicle operation. Therefore, a flat surface machine using a textured surface is required.

2 References

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

2.1 External Standards/Specifications.

SAE J670

2.2 GM Standards/Specifications.

GMW16590 GMW17360

2.3 Additional References.

European Tyre and Rim Technical Organization (ETRTO) Yearbook, Brussels, Belgium, (www.etrto.org/)

GNU Image Manipulation Program (GIMP), (<https://www.gimp.org/>)

Mathworks Incorporated, MATLAB, Natick, Massachusetts, (<https://www.mathworks.com>)

MTS Systems Corporation, Eden Prairie, Minnesota, (<http://www.mts.com/en/index.htm>)

Rubber Manufacturer's Association Sourcing Documents, Washington, DC, (<https://rma.org/>)

The Tire and Rim Association (T&RA) Yearbook, Copely, Ohio, (<http://www.us-tra.org/>)

Tyre Data Exchange Format (TYDEX),

(http://www.fast.kit.edu/download/DownloadsFahrzeugtechnik/TY100531_TYDEX_V1_3.pdf)

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3 Resources

3.1 Facilities. MTS LTRe, CT+, Flat Trac equipment, or equivalent, equipped test facility.

3.2 Equipment.

3.2.1 All of the tests described in this procedure must be performed with a Flat-Trac machine built to the specifications in 3.2.1.1.

3.2.1.1 Specifications of the machine are dependent on the range of the tires and fidelity of the data. If large truck tires are required, then higher load capacity is required. The stiffness of the equipment must be high enough to not significantly affect the model results.

3.2.2 Three (3) enveloping obstacles (cleats), built to the descriptions in Table 1, and shown in Figure 1 through Figure 3.

Table 1: Cleat Descriptions

Cleat	Size (Description)
Trapezoidal (orientated at 0 degrees and 45 degrees)	10 mm × 30 mm
Square	25 mm x 25 mm
Triangular Bottoming	75 mm x 415 mm

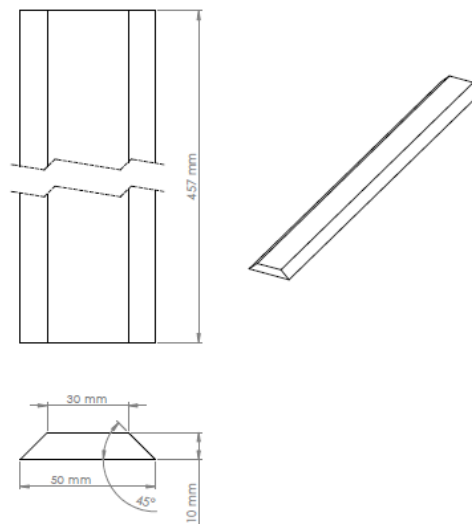


Figure 1: Trapezoidal Cleat

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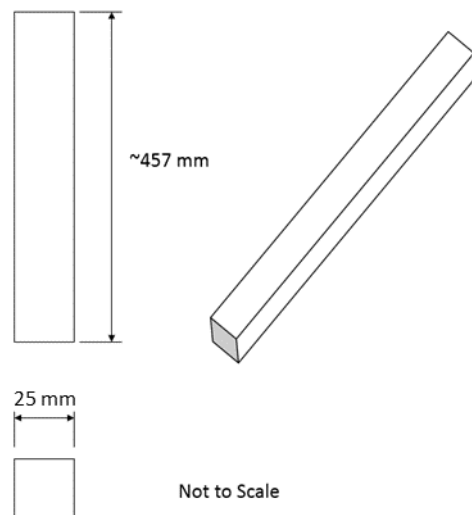


Figure 2: Square Cleat



Figure 3: Triangular Bottoming Cleat

3.3 Test Vehicle/Test Piece.

3.3.1 Tire Test Specimen. The new tires must be free of all tags, tape, or other foreign material in the tread area.

3.3.2 Test Wheel. The wheel must be selected properly to facilitate correct test results. The wheel must be the correct diameter, the width must match that requested on the test request, and the rim flange contour must be approved by the appropriate standardizing body (e.g., current year of either the European Tyre and Rim Technical Organization (ETRTO) Yearbook, or the Tire & Rim Association (T&RA) Yearbook). A General Motors approved wheel is preferred for testing.

3.3.3 Test Surface. The flat test surface must be free of foreign material including, but not limited to oils, rubber dust, and other deposits from previous usage. The flat surface abrasive material is to be 120-grit 3M-ite. The surface macro texture should be reduced prior to the initial use, requiring eight (8) passes of the stoning roller over the surface before use, or equivalent.

3.3.4 Sample Size. Total of five (5) (including a spare) are required for vehicle applications with a single placard pressure specified for the front and rear axles. If the vehicle utilizes significantly different pressures for the front and rear axles (i.e., a split placard) then four (4) additional tires are required. Typically, a split placard on a passenger car of 35 kPa or less, will not require the additional tires.

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3.4 Test Time.

Calendar time: 1 day

Test time: 6 h

Coordination time: 0.5 h

3.5 Test Required Information.

3.5.1 Record the following:

- Tire Size (be specific, prefix and suffix letters are important).
- Service Description (e.g., 98H, 120/124R).
- Construction Number (contact integration engineer, tire development engineer, or DRE).
- Load Rating (e.g., SL, XL, LL, C, D, E).
- Supplier (Tire Manufacturer).

Note: If a specific wheel is provided, the wheel part number should also be provided. Additional information required may vary by test site.

3.5.2 The inflation pressure will be the warm operating inflation pressure for the intended application vehicle. This will typically be 20 kPa above the placard pressure for passenger car tires and 35 kPa above placard for light truck or commercial tires. The test will generate data at multiple inflation pressure based off of the inflation pressure given on the Tire Test Request. For split pressure placards, multiple tests are required, one corresponding to each placard pressure.

3.5.3 Rim Width.

3.5.4 Nominal Load - Vehicle load on a front tire under normal loading conditions. For split pressure placards, the vehicle load for each test pressure is based on the corner load applicable to that pressure.

3.6 Personnel/Skills. Test operators must be trained in the safe operation of the measurement equipment. The measurement equipment, by necessity, involves moving parts and loading mechanisms which must be understood and operated using proper safety precautions. Operators must also be trained in the selection of test components and fixtures to facilitate the proper testing of the tires.

4 Procedure

4.1 Preparation.

4.1.1 Store the tires prior to test in a staging area with the ambient temperature within ± 5 °C of the test room temperature for at least 24 h prior to testing.

4.1.2 Inspect the tire bead and the bead seat of the wheel to ensure this interface is free of damage, defects, and foreign material. Clean or replace test pieces as necessary.

4.1.3 Use only a thin film of an approved mounting lubricant to facilitate proper tire mounting and bead seating. Excessive mounting lubricant can cause slippage at the tire and rim interface during testing.

4.1.4 Inspect the bead area of the mounted tire and wheel assembly to ensure the tire bead is firmly seated on the wheel.

4.1.5 Inflate the tire and wheel assembly 30 kPa above the required test inflation pressure and allow the tire to stabilize at room temperature prior to testing while the previous tire is being tested. Wait at least 1 h before running the test to let the tire pressure stabilize.

4.1.6 Using a paint pen or similar instrument, place an arrow on the sidewall of the tire pointing at the location of the valve stem of the wheel. The relative location of this mark to the valve stem is to be noted posttest.

4.2 Conditions.

4.2.1 Environmental Conditions. The ambient temperature in the room where the measurement equipment is operating shall be controlled to $21\text{ °C} \pm 3\text{ °C}$ to minimize the thermal gradients within the test equipment and instrumentation.

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.

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4.3 Instructions. Table 2 lists the tests that are performed on the tires.

Table 2: Tests performed on tires for FTIRE modeling.

Test	Procedure
Rotational Inertia	Section 4.3.1
Peak Slip Angle (SA) and Slip Ratio (SR) Tune	Section 4.3.2
Loaded Radius	Section 4.3.3
Vertical Stiffness	Section 4.3.4
Bottoming	Section 4.3.5
Dynamic Vertical Stiffness	Section 4.3.6
Torsional Stiffness	Section 4.3.7
Slip Angle	Section 4.3.8
Slip Ratio	Section 4.3.9
Cleat Impact	Section 4.3.10
Footprint	Section 4.3.11
Static Stiffness	Section 4.3.12

4.3.1 Rotational Inertia Test.

4.3.1.1 General Information. The rotational inertia test is a fully automated loaded radius (RL) and Spindle Drive Velocity (VSD) controlled test. The test is located in the "Tire Models" tire definition and needs to be built with the current test tire. During the test, the spindle will move to an RL of 500 mm and then vary the spindle speed through a predetermined range of accelerations. The rotational inertia test is repeated with three (3) configurations shown in Table 3.

4.3.1.2 Procedure. Appendix B, Figure B1 illustrates the automated test and Table 3 shows the conditions need for testing.

Table 3: Rotational Inertia Test Parameters

Test Condition	Inertial Result	Desired Results
Spindle + Adapter	I_s (spindle and adaptor inertia)	I_s
Spindle + Adapter + Wheel	I_{sw} (spindle, adaptor, wheel inertia)	$I_w = I_{sw} - I_s$
Spindle + Adaptor + Wheel + Tire (nominal pressure)	I_{swt} (spindle, adaptor, wheel, tire inertia)	$I_t = I_{swt} - I_{sw}$

4.3.1.3 Data Collected. Appendix A, Table A1 describes the data channels collected during the tests.

4.3.1.4 Analysis. The data files from each of the test conditions listed in Table 3 are post processed in MATLAB to generate the inertia parameters. No Tyre Data Exchange (TYDEX) Format files are created.

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4.3.2 Peak SA and SR test.

4.3.2.1 General Information. The peak SA and SR tune test is a fully automated sequence which starts with three (3) SA sweeps and finishes with three (3) SR tests. A tire warmup test is run right before the Peak SA and SR Test to bring the tire to the correct thermal state.

4.3.2.2 Procedure. Appendices C, D, and G, respectively, illustrate the Tire Warmup, Peak SR, and SA Tests.

4.3.2.3 Data Collected. Appendix A describes the data channels collected during the tests.

4.3.3 Loaded Radius Test.

4.3.3.1 General Information. The loaded radius test is fully automated and Fz controlled. The loaded radius (RL) test starts at a roadway velocity (Vr) of 2.5 km/h, steps to 5 km/h, then continues to 130 km/h in 5 km/h steps. The test is performed at three (3) loads: 70%, 100%, and 130% of reference Fz (same loads as GMW17360 SWIFT test procedure). There are no camber, slip angles, or slip ratio conditions during the loaded radius test. In addition to model data, the loaded radius test is used to parameterize the Cleat Impact test velocity ramp for RL control. The tire pressure is regulated to prescribed test pressure.

4.3.3.2 Procedure. Appendices C and E, respectively, illustrate the prescribed channels as a function of time for both the Tire Warmup and Loaded Radius Tests.

4.3.3.3 Data Collected. Appendix A, Table A1 describes the data channels collected during the tests.

4.3.3.4 Analysis procedure. The Loaded Radius Test load is used to model how the radius of the tire changes with velocity. The test with the load closest to 50% of the load index of the tire should be used. Calculate the rolling circumference by dividing the belt velocity by the wheel rotation speed at 2.5 km/h and at the maximum test speed or tire speed index (whichever is lower). Calculate the percent difference between the high speed value and the low speed value. This is a parameter input to FTIRE belt extension at maximum velocity (Vmax). TYDEX files are created for the data measured in this test.

4.3.4 Vertical stiffness.

4.3.4.1 General Information. The vertical stiffness test is a manually generated end level test. There are six (6) vertical stiffness configurations each tested at 0 km/h:

- Flat surface: 0 degree Inclination Angle (IA).
- High pressure: (test pressure + 30 kPa) flat surface 0 degree IA.
- Flat surface: 6 degree IA.
- Transverse cleat: 0 degree IA.
- Transverse cleat: 6 degree IA.
- Longitudinal cleat: 0 degree IA.

Note: Cleat tests are done with a 25 mm square steel stock.

4.3.4.2 Procedure.

- a. Load the current test tire into the MTS software.
- b. Perform a tare/re-zero.
- c. Set and cap the internal tire pressure to the requested warm pressure. Do not proceed with test until the pressure is stable at the desired pressure and capped.
- d. Set up for the desired test surface configuration and IA.
- e. Find the RL value where the tire first makes contact with the belt or cleat and the RL corresponding to 130% Fz.
- f. Record the point of first contact and the target RL in the run log.
- g. Create an end level sinusoidal input that begins with an unloaded tire, moves to the target RL, and ends with an unloaded tire. The period of the sine wave should be about 20 s.
- h. Execute the test from the unloaded condition through one (1) complete cycle.
- i. Repeat steps a through f for all the listed configurations.

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4.3.4.3 Data Collected. Appendix A, Table A1 describes the data channels collected during the tests.

4.3.4.4 Analysis procedure. The data is converted into TYDEX format for processing in FTIRE. The TYDEX file should start before the tire begins loading and end shortly after the tire fully unloads. If there is an offset in the load channels it must be corrected. A tire deflection channel is created using the point of initial contact.

4.3.5 Bottoming test.

4.3.5.1 General Information. The bottoming test is an end level test generated following a manual investigation. It is very similar in construction to the Vertical Stiffness tests. It is performed on a flat surface and a 145 degree cleat with 0 degrees of IA. The tire is taken to an extreme load and deflection to simulate misuse conditions and to determine rim and flat tire stiffness.

4.3.5.2 Procedure.

4.3.5.2.1 Load the current test tire into MTS software.

4.3.5.2.2 Perform a tare/re-zero.

4.3.5.2.3 Set the tire to the standard test inflation pressure in capped pressure mode.

4.3.5.2.4 Set up for the desired test surface configuration (flat or cleat).

4.3.5.2.5 Find the RL value where the tire first makes contact with the belt or cleat.

4.3.5.2.6 Record the RL of first contact in the run log.

4.3.5.2.7 Manually increase the vertical load until a hook in the load vs. deflection curve becomes visible and the hook's slope has stabilized (about 5000 N past the initial change is desired) and record the target RL in the run log.

4.3.5.2.8 If the Fz or RL limits are reached before the hook forms, perform steps listed in sections 4.3.5.2.9 through 4.3.5.2.11 to the maximum safe load and record the data. Then, reduce the tire pressure to 10 kPa and repeat steps 4.3.5.2.3 through 4.3.5.2.7 and 4.3.5.2.9 through 4.3.5.2.11. If the hook cannot be attained at 100 kPa, reduce the tire pressure to 20 kPa.

4.3.5.2.9 Create a cosine shaped input that begins with an unloaded tire, moves to the target RL, and ends with an unloaded tire. The sinusoidal input should have a period of about 2 minutes.

4.3.5.2.10 Execute the test from the unloaded condition through one (1) complete cycle.

4.3.5.2.11 After the test is complete, allow the posttest internal tire pressure to stabilize and record any pressure loss in the run log.

4.3.5.3 Data Collected. Appendix A, Table A1 describes the data channels collected during the tests.

4.3.5.4 Analysis procedure. The data is converted into TYDEX format for processing in FTIRE. The TYDEX file should start before the tire begins loading and end shortly before the tire fully unloads (do not allow the force to reach zero). If there is an offset in the load channels it must be corrected. A tire deflection channel is created using the point of initial contact noted in the run log.

4.3.6 Dynamic vertical stiffness.

4.3.6.1 General Information. The dynamic vertical stiffness test is a manual test performed by the LTR operator. This test is performed at a single load and is tested at three (3) roadway velocities, 0 km/h, 50 km/h and 100 km/h. The load should be selected such that the 15 mm single amplitude in RL does not cause the tire to lift off the belt or the Fz to exceed 150% of the tires rated load. If the ± 15 mm of RL travel cannot be attained in the tire lift off to 150% of load index window, the amplitude may be reduced until the test can be performed.

4.3.6.2 Procedure.

4.3.6.2.1 Load the current test tire into the MTS software.

4.3.6.2.2 Perform a tare/re-zero.

4.3.6.2.3 Set the tire pressure and use controlled pressure mode.

4.3.6.2.4 Find the RL values where the tire first makes contact with the belt, where the Fz is 500 N, and where either the 30 mm peak to peak amplitude or 150% of load index is reached.

4.3.6.2.5 Record the RLs for touch, 500 N, and the end point and the Fz at the end point in the run log. Land the tire.

4.3.6.2.6 Set the roadway velocity (0 km/h, 50 km/h, or 100 km/h).

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