SURFACE VEHICLE RECOMMENDED PRACTICE

SAE International

J1106 AUG2012

Issued 1975-01
Stabilized 2012-08

Superseding J1106 JAN1975

Laboratory Testing Machines for Measuring the Steady State Force And Moment Properties of Passenger Car Tires

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE Highway Tire Forum Steering Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical/standards/J1106_201208

1. ***Scope***—This Recommended Practice describes some basic design requirements and operational procedures associated with equipment for laboratory measurement of tire force and moment properties of the full range of passenger car tires. These properties must be known to establish the tire's contribution to vehicle dynamic performance. Many factors influence laboratory tire force and moment measurements. This Recommended Practice was compiled as a guide for equipment design and test operation so that data from different laboratories can be directly compared and applied to vehicle design and tire selection problems.

It is recognized that laboratory measurements define performance in a controlled and idealized situation that may not correspond to conditions encountered in a vehicle's operating environment. Several decades of testing experience in different laboratories indicates, however, that these tests can provide a very useful bench mark for evaluation of tire performance. It is neither necessary nor practical to test under all possible conditions.

There are many factors which affect the forces and moments developed by rolling tires: surface, speed, temperature, water on the surface, dynamics of the changes in tire operating conditions, driving and braking torques, etc. A discussion of the effects of many of these factors as related to tire performance and testing is given in SAE Information Report, J1107, which provides the technical basis for this Recommended Practice.

This Recommended Practice is based on types of equipment and procedures that are used in several laboratories for routine tire evaluation. This limits the scope of this Recommended Practice to equipment and methodology for measuring the steady state properties of free-rolling tires. The procedures are intended to characterize the performance of the tire under operating conditions which are essentially invariant with time or which vary slowly enough so that dynamic effects are negligible (quasi-static rolling conditions). J1107 includes a discussion of some of the equipment design and methodology considerations for other kinds of force and moment tests.

This Recommended Practice includes specific recommendations for space, measuring system ranges and accuracy needed to measure the force and moment properties of the full range of passenger car tires. Because the range of tire sizes to be tested by a particular laboratory may be different from the full of range passenger car tires, a discussion of the space, measuring system ranges, and accuracy in terms of load capacities and the physical sizes of the tires to be tested will be included in J1107. These alternate recommendations should be used for any test machines which are designed to test a range of tires other than the full range of passenger car tires. It must be emphasized that the experience on which this Recommended Practice is based has been primarily obtained through testing of passenger car tires.

These recommendations are a set of design and procedural goals that will not be completely satisfied by most of the test equipment in use. Existing equipment can still be useful for comparison testing associated with product development. However, to insure that test results are comparable among laboratories, the equipment and procedures defined in this Recommended Practice must be followed.

Tire force and moment properties are most applicable to vehicle design and provide the best guidance for tire development if testing is done on flat rigid surfaces. Most flat surface laboratory tire testers in routine use incorporate simulated roadways translated at low speeds beneath fixed-axle dynamometers. Tests have shown that the force and moment properties are essentially independent of speed when the tire rolls without appreciable sliding in the contact area. On dry surfaces, tests have also shown that the effect of speed is small over a large range of slip angles. The methods described in this Recommended Practice are accordingly particularly suited for measuring the force and moment properties for dry surface conditions. A more complete discussion of the effects of speed and surface is presented in J1107.

2. References

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J670—Vehicle Dynamics Terminology

SAE J1107—Laboratory Testing Machines and Procedures for Measuring the Steady State Force and Moment Properties of Passenger Car Tires

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 17—

3. Basic Form of Measurement—A rolling tire may be considered to apply three orthogonal force and three orthogonal moment components that can be measured in a force and moment test. These force and moment components are affected mainly by the kinematic variables—vertical deflection of the tire, slip angle, and inclination angle. Because normal force is a primary consideration in tire application and is closely related to vertical deflection, it is usually considered as an independent variable rather than vertical deflection. These kinematic variables, considered to constitute the basic input, and output parameters for force and moment testing are defined with respect to the axis system shown in Figure 1 which was taken from the SAE J670, Vehicle Dynamics Terminology. Terminology and sign conventions consistent with Figure 1 should be used for all force and moment testing. In addition to these parameters, other properties of interest are tire spin velocity, road linear velocity, loaded radius, and effective rolling radius (J670).

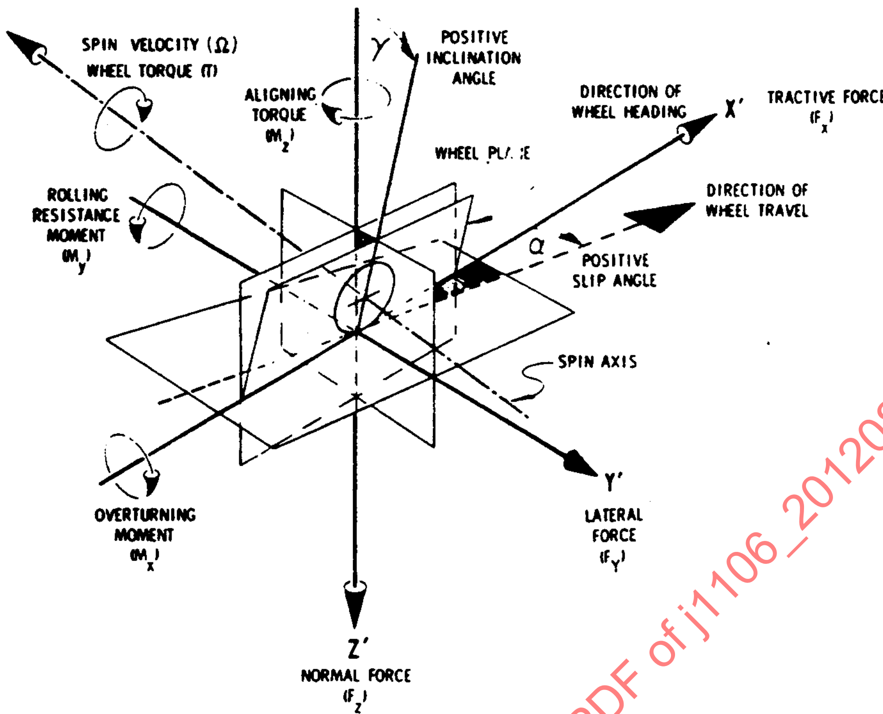

FIGURE 1—TIRE AXIS SYSTEM

4. Apparatus

4.1 General—A tire force and moment machine consists of three major components: A flat moving surface that is used to simulate the road; a mechanism for positioning the tire-wheel assembly and allowing for adjustment of normal force, slip angle, and inclination angle; and a weighing system to facilitate measurements of force and moment components.

4.2 Road Simulation—The road simulation mechanism should provide a flat and rigid surface in the region of the tire contact. The surface should be at least 18 in (460 mm) wide. The test length should be at least 1.5 times the circumference of the largest tire to be tested. To test the full range of passenger car tires, at least 150 in (4 m) of test length is required. The speed of the road system should be equal to or greater than 1 mph (1.6 km/h). Both directions of motion of the road surface should be provided. The road surface material should be textured to provide forces and moments near the maximum of those encountered on actual roads. A material manufactured by the 3M Company called "Medium Grit Safety Walk" is used by many laboratories. Equivalent surfaces can be developed. Any material used for the road surface should be insensitive to minor amounts of contamination and should provide lateral force levels of 170 lb (760 N) ± 3% and 610 lb (2710 N) ± 3% at 1 deg and 6 deg slip angle respectively for testing with an ASTM E-17 Traction Test Tire operating at an 800 lb (3560 N) load and inflated to 28 psi (190 kPa).

An alternative to the moving road system is a mechanism for translating the tire over a stationary road surface. While this approach has been used in a few cases, the accuracy is more difficult to achieve with moving dynamometer systems than with the moving road surface systems.

4.3 Tire Positioning Mechanism—The machine should be designed to provide for testing of the full range of passenger car tires. The tire diameter will be up to 32 in (800 mm) with section width from 5 in (125 mm) to at least 11.5 in (300 mm). The machine should accommodate rims from 10 in (250 mm) to 16 in (400 mm) in diameter and 4 in (100 mm) to 8 in (200 mm) in width. The space envelope should permit slip angles of ±30 deg and inclination angles of ±15 deg or any combination of angles in these ranges. An axle height variation from 7.5 in (190 mm) to 16 in (400 mm) is required for all load conditions of the range of tires to be included.

Wheels for tire testing are to be sufficiently rigid to insure that rim compliance is not a factor in the tire performance measurements. Wheels should be at least as stiff as those used on vehicles. The bead seats and rim flanges should conform with the recommendations of the Tire and Rim Association. Rims, as installed, should have radial and lateral total indicator runout at the bead seats of less than 0.002 in (0.05 mm). Wheels capable of continuous operation at high vertical and lateral loads are recommended.

It is necessary that the tire's slip and inclination angle be known to within ±0.05 deg for all test conditions. This position transducer accuracy should include the effects of friction, lash, and structural compliances in the mechanism. Control of tire position may be less precise if the position is measured and considered in the processing of data. The positioning mechanism should also be designed to minimize movement of the center of gravity of the mass supported by the load transducers. Movement of the center of gravity and/or compensation for its effect should be such that measurement accuracies as defined in Table 2 can be realized.

4.4 Measuring System—The ranges and accuracy recommendations for the transducer system are stated below for measuring the full range of passenger car tires. Experience has shown that the accuracy can be obtained with the measuring range indicated, but that careful attention must be given to transducer sensitivity, linearity and interactions.

Transducers should be provided for all six force and moment components, loaded radius, effective rolling radius, slip angle and inclination angle with the full-scale capability shown in Table 1.

Output signals should be of a magnitude sufficient for analog recording and digital conversion of data for processing and plotting.

An overall accuracy that is 1% of full scale for the most significant test data is the goal applied to the design of this equipment. To achieve this goal, subsystem accuracy has to be better than 1%. The overall measuring system accuracy and resolution after signal filtering and interaction compensation required is shown in Table 2.

For a nominal test accuracy of 2% for the tire being tested, the rated load of the tire must be greater than 800 lb (3600 N).

Calibration of the system should be achieved by the application of at least six force vectors of known location, magnitude, and direction sufficient to exercise each transducer component through its full range. These vectors are to be applied with a system that will minimize friction forces between the wheel mounting axle and the force ground. Each transducer component should be checked for linearity and channel interactions determined. A daily calibration check should consist of the application of a known force vector chosen to exercise all system components. The occasional testing of a standard reference tire is also recommended. Reference tire data should be used to determine when the road surface is no longer suitable. Changes in reference tire data in excess of 3% of reading should be investigated.

TABLE 1—TRANSDUCER RANGES REQUIRED TO MEASURE FULL RANGE OF PASSENGER CAR TIRES

Normal Force (Negative of vertical load)	0 to –4000 lb (18000 N)
Lateral Force	±4000 lb (18000 N)
Longitudinal Force (free rolling)	±200 lb (900 N)
Aligning Torque	±500 lb-ft (700 Nm)
Overturning Moment	±1000 lb-ft (1400 Nm)
Rolling Resistance Moment (free rolling)	±200 lb-ft (270 Nm)
Loaded Radius	7.5 (200 mm) to 16 in (400 mm)
Effective Rolling Radius	7.5 (200 mm) to 16 in (400 mm)
Slip Angle	±30 deg
Inclination Angle	±15 deg

TABLE 2—ACCURACIES REQUIRED TO MEASURE FULL RANGE OF PASSENGER CAR TIRES

Normal Force	10 lb (50 N)
Lateral Force	10 lb (50 N)
Longitudinal Force	1 lb (5 N)
Aligning Torque	2 lb-ft (3 Nm)
Overturning Moment	10 lb-ft (15 Nm)
Rolling Resistance Moment	1 lb-ft (2 Nm)
Loaded Radius	0.05 in (2 mm)
Effective Rolling Radius	0.05 in (2 mm)
Slip Angle	0.05 deg
Inclination Angle	0.05 deg

5. Test Procedure—The test procedure can be divided into four parts: tire preparation, tire selection, routine testing, and precautions.

5.1 Tire Preparation—Tire preparation is necessary to achieve a level of performance that will persist during extensive series of tests such as a complete set of force and moment tests for one inflation pressure. The tire should be mounted with conventional procedures and lubricants to insure bead seating. The tire and test surface should be free from contamination. The inflation pressure of the unloaded tire should be adjusted to within ±0.5 psi (3.5 kPa) of that specified for the test. Since this type of testing does not normally produce any increase in inflation pressure due to temperature, tires are usually inflated to 4 psi (28 kPa) above the cold inflation specification of interest to simulate the pressure increase that is encountered in road operation. Both the tire structure and the tread surface must be conditioned to achieve a stable level of performance during a reasonable series of tests. The tire should be exercised to remove local distortions, residual stresses, and insure bead seating. The tread should be conditioned on the test surface by running the tire sufficient to result in stable force and moment properties.

5.2 Tire Selection—Tire force and moment properties are usually associated with design variables rather than production variables. However, some procedure should be followed to insure selection of a typical tire from a particular design lot. Current practice is to run a brief set of tests on a number of tires from the lot to determine the consistency in force and moment performance that exists in the lot and provide data for the selection of typical tires to be used in complete tests. Four or more tires should be checked during the selection process. A satisfactory, brief test consists of runs at ±6 deg slip angle and loads ranging up to 160% of the rated load for the tire. Attention should be directed to lateral force and aligning torque data for selection of typical tires.