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SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

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TESTING MACHINES FOR MEASURING THE UNIFORMITY OF PASSENGER CAR AND LIGHT TRUCK TIRES

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1. ***Scope***—In recent years the comfort and fatigue of passengers in vehicles has become a major engineering consideration. Among the many factors involved are vibratory and auditory disturbances. Tires participate, among other elements of the vehicle, in exciting vibrations and noises. Furthermore, tires also may generate forces leading to lateral drift of the vehicle.

   This recommended practice describes the design requirements of equipment for evaluating some of the characteristic excitations of passenger car and light truck tires which may cause disturbance in vehicles. The kinds of excitations treated result from nonuniformities in the structure of the tire and have their effect when a vehicle bearing the tire travels on a smooth road.

   This recommended practice also describes some broad aspects of the use of the equipment and lists precautionary measures that have arisen out of current experience.

   The intention underlying these recommendations is to establish the best standardized measurement for use by the engineering community that our present state of knowledge allows.

   There is considerable body of evidence that supports the statistical relevance of data obtained from the type of equipment and the procedures described. However, the mechanical instability of the materials of a tire responding to the effects of temperature, storage conditions, and surface contamination, as well as the previous history of usage, etc., all produce variations in vibratory excitations. For these reasons, the measurements of individual tires are often cloaked in a degree of uncertainty. Nevertheless, larger values of vibratory excitations are usually well identified, and statistical evaluations of the data usually serve to indicate properly the quality and production lots of tires.

   Criteria of quality which might be based on measurements made under this recommended practice follow from the needs of individual engineering applications and are consequently not sufficiently general to be specified here.

2. ***Basic Form of Measurement***—The measurement detects the variations in force components produced by a mounted and inflated tire while the tire runs unsteered against a smooth road drum at constant axle height over that drum and at a constant speed.

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The varying and constant force components of the tire requiring evaluation are generally four in number. These components of force, as illustrated in Fig. 1, are termed:

(a) The variation in radial force.
(b) The variation in lateral force.
(c) The variation in tractive force.
(d) The constant component of the lateral force.

3. Apparatus

3.1 General—The equipment is essentially an axle or spindle supporting a rim on which tires may be readily mounted, a means for loading the tire against a drum at a specified load and for holding a fixed tire-to-drum center distance during measurements, and a system for measuring the excitation forces equivalent to those at the tire's spindle as the tire and drum are rotated at prescribed speeds. Rotation can be accomplished by driving either the tire or the drum. There should be provisions for both clockwise and counterclockwise directions of rotation to account for use of tires on left or right sides of the vehicle. The equipment also requires a means for rapid inflation and deflation of the tire, and for control of inflation pressure during rotation.

3.2 Structure—The supporting structure and components of the machine must be sufficiently rigid to insure that natural frequencies of the machine assemblies (which may be ultimately detected in the measurement of forces) are above 40 times the wheel rotational frequency used in the measurement. For special types of instrumentation that are matched to machine resonances, this requirement may be waived. The drum and wheel spindles are to be rigidly supported with no lash in radial, axial, or tractive directions.

ϕ The structure and rims are to accept tires of 22–36 in (559–914 mm) in diameter and 5–13 in (127–330 mm) in section width. The equipment is to be capable of rotating tires at a speed in the range of 15–60 rpm during the measuring operation and with the option of 300–400 rpm for stabilization before measurement. The design should be based on a maximum force between tire and drum of 2000 lb (8.9 kN) in the radial direction, 500 lb (2.22 kN) laterally, and 500 lb (2.22 kN) in the tractive direction.

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3.3 Drum, Axles and Rims—The drum is to be standardized at 33.625 ± 0.100 in (854.1 ± 2.5 mm) in diameter. The total indicator runout of this member as measured at a reference band is to be less than 0.001 in (0.025 mm). The maximum acceptable unbalance is 1 in-lb (0.113 N·m). The drum should feature a high-friction, textured surface, such as provided by knurling, sprayed tungsten carbide, adhered tungsten carbide crystals, etc. The surface texturing, however, must be sufficiently uniform so that the average radius of the drum per 2.0 in (51 mm) of circumference meets the specifications for runout. The parallelism of the rim axis and the drum axis while under 2000 lb (8.9 kN) of radial load and 100 lb (445 N) of lateral load should be within a tolerance of one part in 4000 (0.003 in/ft (0.25 mm/m)).

ϕ The machine should be adaptable for accommodating different sizes of tires. This is best accomplished through interchangeable rims. Rims for force variation measurement should be based on the recommended contour of the Tire and Rim Association for that size and type tire. Some modifications to this contour may be required to facilitate mounting, dismounting, and proper seating of the bead for repeatable data. These modifications will depend upon tire bead dimensions, mounting technique, and warmup procedure. The inner spacing between flanges (for both passenger cars and light truck tires) should be the Tire and Rim Association design rim width ±0.5 in (±13 mm).

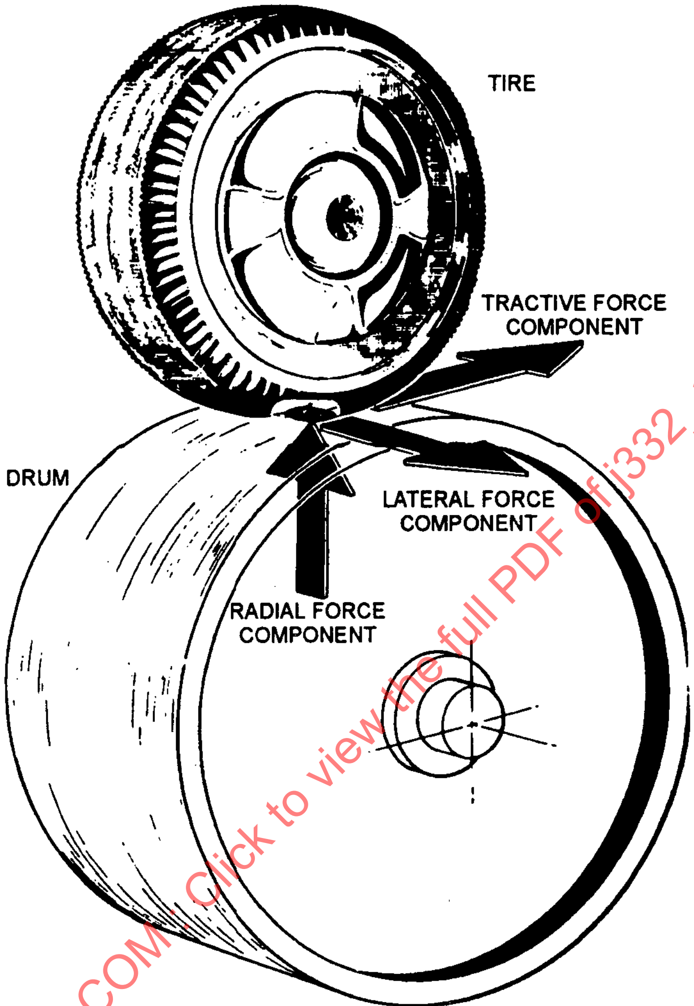

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FIG. 1

These rims are to have a total indicator runout at the bead seats of less than 0.001 in (0.025 mm). This limitation refers to both radial and axial directions and pertains to rims as installed with normal piloting on the machine. The design of the rims should enable rapid mounting and dismounting of the tires. The rims are to be sufficiently rigid to insure that deflection in any direction at the bead set operating under loads is less than 0.005 in (0.127 mm).

4. ***Measuring System***—A mechanical system of appropriate design which includes transducers for the development of output signals is required to isolate and detect the aforementioned components of force variation and mean force. The transducers may be either between the structure supporting the tire and the tire, or between the structure supporting the drum and the drum. For either alternative, the precaution should be observed that the torque for providing rotation does not pass through the spindle at which the transducers are located.

In accordance with the resonance requirements already indicated, the minimum natural frequency of the force measuring system shall be at least 40 times the frequency of tire rotation that prevails during measurement.

The resolution of force components by the measuring system shall be 1 lb (4.4 N) or less, including the effects of static friction. The deviations from true values of force within the 100 lb (445 N) range of excursion shall be less than 1 lb (4.4 N).

Errors in measurement of lateral force due to mechanical interaction from the radial force shall be less than 0.1% of the radial force. Spurious components of radial force due to mechanical interaction from the lateral force shall be less than 1% of the lateral force. Addition removal of interaction, where required, shall be accomplished in the signal processing circuitry or other instrumentation.

The mechanical isolation of the machine or of the force measuring system shall be such that vibratory interferences from exterior and internal sources will not exceed 0.5 lb (2.2 N) root mean square in any of the force component measuring systems.

A matching calibration system is required for use with the force measuring system. The resolution of the loads applied by the calibrating system should be within 0.25 lb (1.1 N) for both lateral and tractive force components. The calibration system for the mean radial force measurement requires tare loads up to 2000 lb (8.9 kN) with resolutions of applied force of 10 lb (44 N). There should as well be an additional provision for calibrating radial force variations from the tare load with forces up to 200 lb (890 N) and with resolutions of applied force within 0.25 lb (1.1 N).

The measuring system shall contain a position marker to indicate the angular orientation of the tire relative to the force signals that it produces.

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5. Instrumentation—Instrumentation shall be provided to convert the variations in force components into analog signals or into a numerical form suitable for engineering evaluation. This subsystem shall have such properties as to enable the uniformity testing machine to produce data within the specifications under the paragraph on Ranges and Accuracies of the Uniformity Testing Machine.

The instrumentation should contain an integral means for testing (both statically and dynamically) its scaling and the interaction among channels.

5.1 Optional Instrumentation—According to the usage intended several kinds of auxiliary instrumentation may be provided with the Uniformity Measuring Machine. Two types that have found considerable application are listed below:

(a) Equipment for indicating peak-to-peak measurements and time averages of components of force variations.

(b) Equipment for measuring the amplitude and phase of the first ten harmonics of components of force variation. Phase is designated by the angular orientation of the rotating tire.

6. Ranges and Accuracies of the Uniformity Testing Machine

6.1 The machine is to provide output signals corresponding to the following ranges of force components:

Mean radial load from 0 to +2000 lb (0 to 8.9 kN).
Mean lateral force from –200 to +200 lb (–890 to +890 N).
Mean tractive force from –200 to +200 lb (–890 to +890 N).
Radial force variation from –100 to +100 lb (–445 to +445 N).
Lateral force variations from –100 to +100 lb (–445 to +445 N).
Tractive force variations from –100 to +100 lb (–445 to +445 N).

6.2 The complete machine shall be capable of measuring the various force variations to within ±1/2 lb (2.2 N) and to measure and set the mean radial force to within 5% of the prescribed value.

6.3 Error in the measurement of force components due to the presence of other components of force (applied in other transducer channels) shall be less than 0.5% of full-scale reading of that channel.

6.4 Output impedances shall be at the 600 ohm level or less.

6.5 Random errors in force measurements for any varying component shall be less than ±1 lb (4.4 N) over the frequency range from zero to the tenth harmonic of wheel rotation frequency.

6.6 The frequency response of the total measurement relative to input force shall be within ±2% of the static response at 100 lb (445 N) peak to peak of excitation force from the first to the tenth harmonic. The maximum allowable phase shift for frequency contents over this range is given by the quantity θ. It is required that θ be less than ±6, where θ is defined as phase shift in degrees of the signal frequency divided by the harmonic number of the frequency.

*7. **Operating Schedule***—The schedule consists of the following key steps. Numerous auxiliary actions are not listed.

(a) Tire mounting and inflation of the tire.
(b) A warmup procedure which insures that distortions in the structure of the tire due to packaging and shipping are reduced to an acceptable level.
(c) The adjustment of the inflation pressure and the rotation of the tire at a constant angular velocity for measurement.
(d) The adjustment of the axle-to-axle spacing of the rolling tire and drum to provide a predetermined value of mean radial load.
(e) The measurement of the force components generated by rotating the tire.
(f) Where desired, the reversal of the direction of rotation and a repeated measurement of force components.

7.1 Precautions and Conditions—Specific precautions and conditions that are recommended for the various phase of operation are as follows:

(a) Care should be taken that both the tire and drum are free of surface contamination such as labels, oil, and dirt.
(b) Proper bead seating should be assured by use of a suitable lubricant and/or low friction bead surface, by suitable mounting methods, and by the subsequent warmup procedure.
ϕ (c) A suitable warmup procedure is required to insure that local distortions due to packaging and shipping have been removed from the tire. This procedure consists of rolling the tire against the drum at some combination of speed, inflation pressure, mean radial load, and running time. The particular combination of conditions has to be established for each plant or location and typical state of the tires. The warmup procedure is considered sufficient when it guarantees that the change in peak-to-peak force variations for a group of 20 tires selected at random when run against the drum for an additional time period at the "nominal" conditions of load and inflation specified for that size and type tire is less than 1.5 lb (6.67 N) from the value measured after the warmup procedure.
ϕ (d) "Nominal" loads and inflations for the measuring operation are found in Table 1. The allowable variation in inflation pressure during the measuring operation is ±0.02 psi (0.14 kPa).

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