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Standard Practice for Linear Tire Treadwear Data Analysis[1]

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ε[1] NOTE—Editorial corrections made throughout in June 2013.

1. Scope

1.1 This practice describes the elementary linear regression analysis of basic treadwear data as obtained according to Test Method F421 and Test Method F762.

1.2 The basic treadwear data are obtained as groove depth loss measurements by procedures described in Test Method F421 after a series of test cycles (test distances under specified conditions) according to Test Method F762.

1.3 A linear regression analysis is performed for the relationship between average tire tread depth and the test distance traveled by the test vehicle, on which the test tires are mounted. From this analysis a rate of wear is determined: groove depth loss per unit distance.

1.4 Linear treadwear is defined as an essentially constant rate of wear, after break-in, which results in a linear regression coefficient of determination, R^2, equal to or greater than 0.95 when obtained for a data set where the number of measurement intervals, n, is at least 3. Each measurement interval represents a specific test distance.

1.5 This practice is not applicable to the prediction of treadlife for tires that exhibit non-linear or irregular treadwear.

1.6 Evaluation parameters are given for both SI and inch-pound units; either may be used. The evaluation parameters as defined are ones typically used in the tire testing industry and no special claim is made for superiority of these parameters and terms over other terms and parameters that may be developed.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F421 Test Method for Measuring Groove and Void Depth in Passenger Car Tires

F538 Terminology Relating to the Characteristics and Performance of Tires

F762 Test Method for Determining Change in Groove (or Void) Depth With Distance Traveled for Passenger Car Tires

3. Terminology

3.1 *Definitions:*

3.1.1 *average tire tread depth,* [L], *n*—the average of all tire groove (void) depth measurements. **F538**

3.1.2 *break-in,* [L], *n*—one or more periods of initial standardized tire operation during which tire is brought to the state which will lead to more consistent test results. **F538**

3.1.3 *fastest wearing groove,* [L], *n*—the circumferential groove with the minimum life expectancy. **F538**

3.1.4 *fastest wearing location,* [L], *n*—that location which exhibits the highest percent tread (depth) loss as calculated in 6.1.1. **F538**

3.1.5 *groove, average depth,* [L], *n*—the average of all tire groove depth measurements in a single groove. **F538**

3.1.6 *projected treadlife,* [L], *n*—the test distance that gives h as the average tread depth; where h is the height of treadwear indicator above groove (or void) base. **F538**

3.1.7 *test distance,* [L], *n*—distance traveled by a vehicle after tire break-in. **F538**

4. Summary of Practice

4.1 This practice provides a calculation procedure for linear regression analysis of treadwear data to be used in the tire industry for assessing tire treadwear performance.

4.2 No specific mathematical formulas are given for the customary least-squares calculations used for linear regression parameter evaluation since these calculation algorithms are readily available with electronic hand calculators or statistical software for personal computers, or both. Terms are defined for slope, intercept, and coefficient of determination.

[1] This practice is under the jurisdiction of ASTM Committee F09 on Tires and is the direct responsibility of Subcommittee F09.30 on Laboratory (Non-Vehicular) Testing.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

5. Significance and Use

5.1 The purpose of this practice is to standardize the meaning and derivation of some terms and indexes that are commonly used to characterize treadwear.

5.1.1 There is no intent to recommend either of the two treadwear performance indexes: distance per unit loss of tread depth or loss of tread depth per distance unit.

6. Calculation

6.1 Use the following calculations and terms to report treadwear:

6.1.1 The percentage tread (depth) loss (PTL) expresses the loss of tread depth as a percent of the initial tread depth (to the tread-depth indicators), as follows:

$$PTL = \left[\frac{\bar{X}_i - \bar{X}_k}{\bar{X}_i - h} \right] \times 100 \quad (1)$$

where:

$\bar{X}_i$ = average tread depth after a break-in (see 3.1.1 or 3.1.2),
$\bar{X}_k$ = average tread depth at a given observation or test distance (see 3.1.1 or 3.1.7), and
h = height of treadwear indicator above groove (or void) base.

6.1.2 The percentage tread (depth) remaining (PTR) expresses the remaining tread depth as a percent of the initial tread depth (to the tread-depth indicators), as follows:

$$PTR = 100 - PTL \quad (2)$$

6.1.3 The rate of wear, *RW*, is obtained as the slope, *b* (either for SI or inch-pound units), of the regression line of average tire tread depth (*y*-variable) versus the test distance (*x*-variable). See 3.1.1 and 3.1.7 for definitions. The intercept of the regression line on the tread depth axis is defined by the term *a*.

6.1.3.1 Specifically, rate of wear *RW* is defined as follows:

$$RW\,(\text{in mm/1000 km}) = 1000 \times b(M) \quad (3)$$

where b(M) = slope of regression line (metric units), mm/km and

$$RW\,(\text{in mils/1000 miles}) = 1000 \times b(E) \quad (4)$$

where b(E) = slope of regression line (English units), mils per mile (1 mil = 0.001 in.).

NOTE 1—For the rate of wear in this practice, the selected SI unit for test distance is 1000 km. The selected unit for tread depth is the millimetre. For strict SI use the metre (m) should be used. If this is used, then tread depths should be expressed in terms of nanometres (mm) (10–9 m) to produce roughly equivalent magnitude numbers to the mil/1000 miles inch-pound units usage. The use of the nanometres per metre expression presents difficulties in conceptualization of treadwear rates that is, it is easier to think in terms of millimetres/1000 km than nanometres/metre.

6.1.4 The inverse rate of wear (IRW) is the test distance traveled after break-in per unit loss in tread depth, as given in (Eq 5) in SI units and in (Eq 6) in inch-pound units as follows:

$$IRW(1000\ \text{km/mm}) = \frac{1}{RW(\ \text{mm/1000 km})} \quad (5)$$

$$IRW(1000\ \text{mi/mil}) = \frac{1}{RW(\ \text{mils/1000 mi})} \quad (6)$$

where *RW* = absolute loss in tread depth per unit test distance after break-in.

6.1.5 The wear performance index, a calculated value that relates the wear performance of a candidate tire to that of a control tire tested in the same test, may alternatively be calculated on the basis of either percent loss or tread depth ((Eq 7)) to give TLI, a treadlife index, or on the basis of rate of wear ((Eq 8)) to give TWI, a treadwear index. The two are equivalent if the initial tread depth of the candidate tire is equal to that of the control tire.

$$TLI = \frac{\%\ \text{loss in control tire}}{\%\ \text{loss in candidate tire}} \times 100 \quad (7)$$

$$TWI = \frac{RW\ \text{of control tire}}{RW\ \text{of candidate tire}} \times 100 \quad (8)$$

6.1.5.1 The inverse of each of these expressions may also be used.

7. Projected Treadlife Considerations

7.1 Projected treadlife is usually calculated for each tire in a set so that tire-to-tire variances, as well as overall means, may be considered.

7.2 If wear rates are linear, a knowledge of the wear rate permits a prediction of the travel distance to wear-out, that is, to the wear indicators. In the inch-pound system of units this is often called the projected mileage.

7.3 Different ribs or blocks on a tread surface often wear at different rates. When this happens the end point for treadwear may be determined from that at the fastest wearing location.

7.4 *Types of Projected Treadlife*

7.4.1 *Uniform Treadwear:*

7.4.1.1 Projected Tread Life (TL) of tires demonstrating linear treadwear and uniform tread depths around the circumference of the tire (uniform within 10 % of the mean tread depths for each groove) is calculated in (Eq 9) in kilometers and (Eq 10) in miles:

$$TL(\text{km}) = 1000\,\frac{h\,(\text{mm}) - a}{RW(\text{mm/1000 km})} + \text{break-in}\ (\text{km}) \quad (9)$$

where:

h = height of tread wear indicator, mm,
a = intercept (on tread depth axis) of the regression line for regression of loss in mm and test distance in km, and
RW = rate of wear, mm/1000 km.

$$TL(\text{mi}) = 1000\,\frac{h\,(\text{mils}) - a}{RW(\ \text{mils/1000 mi})} + \text{break-in}\ (\text{mi}) \quad (10)$$

where:

h = height of tread wear indicator, mils,
a = intercept (on tread depth axis) of the regression line for regression of loss in mils and test distance in miles, and
RW = rate of wear, mils/1000 miles.

7.4.1.2 Alternatively, the depth loss at the fastest wearing location or groove may be used instead of the average tire tread depth, as defined in 3.1.1, for calculating the rate of wear. Under these conditions *RW* would refer to the rate of wear of the fastest wearing groove or other location and *TL* would represent the projected treadlife of the tire on the basis of this rapid wearing location.

7.4.1.3 Normally *h* is 1.59 mm or 63 mils (0.063 in.) for passenger car tires, and tread depth is the mean distance to the bottom of the groove at locations apart from the treadwear indicators.

7.4.2 *Non-Uniform Treadwear*—If the tread depths are linear with traveled distance but not uniform to within 10 % of the mean tread depths around the circumference of the tire, the treadlife projection should be made for the fastest wearing location. This is accomplished by using the groove depth loss at this location rather than the average tire tread depth.

8. Keywords

8.1 groove depth; linear; linear tire treadwear; tread depth; treadwear; wear-out