Designation: D4975 – 14

Standard Test Methods for Single-Filament Tire Bead Wire Made from Steel[1]

This standard is issued under the fixed designation D4975; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover testing of single-filament steel wires that are components of tire beads used in the manufacture of pneumatic tires. By agreement, these test methods may be applied to similar filaments used for reinforcing other rubber products.

1.2 These test methods describe test procedures only and do not establish specifications and tolerances.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 These test methods cover the determination of the mechanical properties listed below:

Property	Section
Breaking Force (Strength)	7 – 13
Yield Strength	7 – 13
Elongation	7 – 13
Torsion Resistance	14 – 20
Diameter (Gage)	21 – 27

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D76 Specification for Tensile Testing Machines for Textiles

D123 Terminology Relating to Textiles

D4848 Terminology Related to Force, Deformation and Related Properties of Textiles

D6477 Terminology Relating to Tire Cord, Bead Wire, Hose Reinforcing Wire, and Fabrics

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms relating to tire cord, bead wire, hose wire, and tire cord fabrics, refer to Terminology D6477.

3.1.1.1 The following terms are relevant to this standard: percent elongation, tire bead, tire bead wire, torsion resistance, in tire bead wire, yield strength.

3.1.2 For definitions of terms related to force and deformation in textiles, refer to Terminology D4848

3.1.2.1 The following terms are relevant to this standard: breaking force.

3.1.3 For definitions of other textile terms, refer to Terminology D123.

4. Summary of Test Methods

4.1 A summary of the procedures prescribed for the determination of specific properties of tire bead wire is stated in the appropriate sections of the specific test methods that follow.

5. Significance and Use

5.1 The procedures for the determination of properties of single-filament bead wire made from steel are considered satisfactory for acceptance testing of commercial shipments of this product because the procedures are the best available and have been used extensively in the trade.

5.1.1 In case of a dispute arising from differences in reported test results when using these test methods for acceptance testing of commercial shipments, the purchaser and supplier should conduct comparative test to determine if there is a statistical bias between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens which are as homogeneous as possible and which are from a lot of material of the type in question. The test specimens then should be randomly assigned in equal number to each laboratory for testing. The average results from the two laboratories should be compared using Student's *t*-test for unpaired data and an acceptable probability level chosen by the two parties before testing is begun. If a bias is found, either its cause must be determined and corrected or the purchaser and the supplier must agree to interpret future test results with consideration to the known bias.

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[1] These test methods are under the jurisdiction of ASTM Committee D13 on Textiles and are the direct responsibility of Subcommittee D13.19 on Industrial Fibers and Metallic Reinforcements.

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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.

6. Sampling

6.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of reels, coils, spools, or other shipping units of wire directed in an applicable material specification or other agreement between the purchaser and the supplier. Consider reels, coils, spools, or other shipping units of wire to be the primary sampling units.

NOTE 1—A realistic specification or other agreement between the purchaser and the supplier requires taking into account the variability between and within primary sampling units so as to provide a sampling plan which at the specified level of the property of interest has a meaningful producer's risk, consumer's risk, acceptable quality level, and desired limiting quality level.

6.2 *Laboratory Sample*—Use the primary sampling units in the lot sample as a laboratory sample.

6.3 *Test Specimens*—For each test procedure, take the number of lengths of tire bead wire of the specified lengths from each laboratory sample as directed in the test procedure.

BREAKING FORCE, YIELD STRENGTH, AND ELONGATION

7. Summary of Test Method

7.1 The two ends of a specimen are clamped in a tensile testing machine; an increasing force is applied until the specimen breaks. The change in force is measured versus the increase in separation of the specimen clamps to form a force-extension curve. Breaking force is read directly from the curve and is expressed in newtons. Percent elongation at break is the extension at break divided by the original specimen length, × 100. The yield strength, the intersection of the force-extension curve with a line at 0.2 % elongation offset, is read from the force-extension curve and is expressed in newtons.

8. Significance and Use

8.1 The load-bearing ability of a reinforced rubber product such as a tire bead is related to the strength of the single-filament wire used as the reinforcing material. The breaking force and yield strength of tire bead wire is used in engineering calculations when designing this type of reinforced product.

8.2 Elongation of tire bead wire is taken into consideration in the design and engineering of tire beads because of its effect on uniformity and dimensional stability during service.

9. Apparatus

9.1 *Tensile Testing Machine,* CRE (Constant-Rate-of-Extension) tensile testing machine of such capacity that the maximum force required to fracture the wire shall not exceed 90 % nor be of less than 10 % of the selected force measurement range. The specifications and methods of calibration and verification for tensile testing machines shall conform to Specification D76.

9.2 In some laboratories, the output of CRE type of tensile testing machine is connected with electronic recording and computing equipment which may be programmed to calculate and print the results for each of these desired properties. Because of the variety of electronic equipment available and the various possibilities for recording test data, use of this type of equipment is not covered in this test method.

9.3 *Grips,* of such design that failure of the specimen does not occur at the gripping point, and slippage of the specimen within the jaws (grips) is prevented.

10. Procedure

10.1 Thermally age the specimen by placing it in an oven for 60 ± 1 min, at 150 ± 3°C. Allow specimens to cool to room temperature before testing.

10.2 Select the proper force scale range on the tensile testing machine based on the estimated breaking force of the specimen being tested.

10.3 Adjust the distance between the grips of the testing machine, nip to nip, to a gage length of 250 mm.

10.4 Secure the specimen in the top clamp, exerting enough pressure to prevent the specimen from slipping when loaded. Place the other end of the specimen between the jaws of the bottom clamp.

10.5 Apply a pretension of 1 % of full scale to keep the specimen taut.

10.6 After setting the cross head speed at 25 mm/min and recorder chart speed at 250 mm/min, start the testing machine and record the force-extension curve generated.

10.6.1 If the specimen fractures within 5 mm of the gripping point, discard the result and test another specimen. If such jaw breaks continue to occur, insert a jaw liner such as an abrasive cloth between the gripping surface and the specimen in a manner so that the liner extends beyond the grip edge where it comes in contact with the specimen.

10.7 Conduct this test procedure on two specimens from each laboratory sampling unit.

10.8 Elongation, the increase in gage length of a tensile specimen, is usually expressed as a percentage of the original gage length and can be determined from the force-extension curve.

10.8.1 When a greater degree of accuracy is required in the determination of elongation, an extensometer can be attached to the specimen.

10.9 Yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. Determine the yield strength by the 0.2 % offset elongation method.

10.9.1 On the force-extension curve (Fig. 1) that has been generated (see 10.6) mark off Om equal to the specified value of the offset (0.2 % elongation); draw mn parallel to OA and locate r. This intersection of mn with the force-extension curve corresponds to force R which is the yield strength. Should the force-extension curve exhibit an initial nonlinear portion, extrapolate from the straight line portion to the base line. The intersection is point O used in this section.

11. Calculation

11.1 Calculate the average breaking force of the laboratory sample to the nearest 5 N.

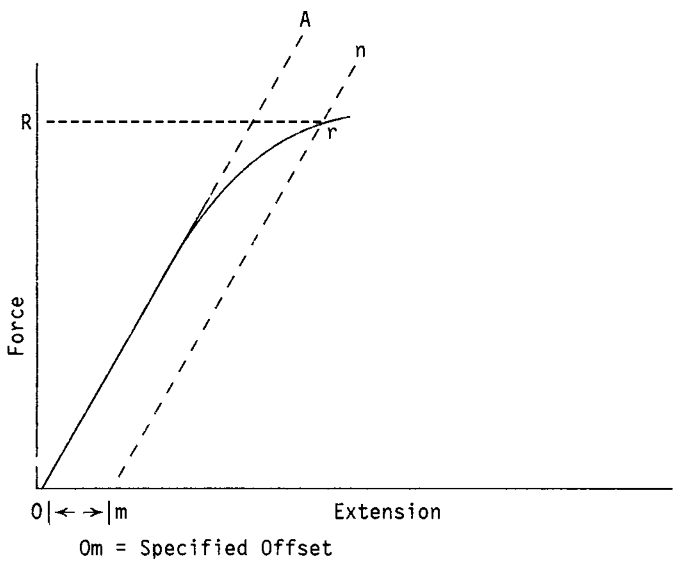

FIG. 1 Force-Extension Curve for Determination of Yield Strength by the Offset Method

11.2 Calculate the elongation to break from the force-extension curve to the nearest 0.1 %. Should the force-extension curve exhibit an initial nonlinear portion, extrapolate from the straight line portion of the curve to the base line. This intersection is the point of origin for the elongation determination. The extension from this point to the force at the point of break is the total elongation.

11.3 Calculate the average yield strength of each laboratory sample as directed in 10.9.1 to the nearest 5 N.

12. Report

12.1 State that the tests were performed as directed in Test Methods D4975, describe the material or product tested, and report the following:

12.1.1 The test results of each specimen and the laboratory sample average. Calculate and report any other data agreed to between the purchaser and the supplier,

12.1.2 Date of test,

12.1.3 Type of tensile test machine and rate of extension, and

12.1.4 Any deviation from the standard test procedure.

13. Precision and Bias

13.1 *Interlaboratory Test Data*—An interlaboratory test was run in 1990 in which randomly drawn samples of four materials were tested in 13 laboratories. Each laboratory used two operators, each of whom tested two specimens of each material on two separate days.

NOTE 2—The bead wire products used in the interlaboratory evaluation were of the following diameter and strength levels:

Material	Diameter	Strength
1	0.965 mm	regular
2	0.965 mm	high
3	1.295 mm	regular
4	1.295 mm	high

13.2 *Precision*—For the property of interest, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences given in Table 1.

NOTE 3—The tabulated values of the critical differences should be considered to be a general statement, particularly with respect to between laboratory precision. Before a meaningful statement can be made concerning any two specific laboratories, the amount of statistical bias, if any, between them must be established, with each comparison being based on recent data obtained on specimens taken from a lot of material of the type being evaluated so as to be as nearly homogeneous as possible and then assigned randomly in equal numbers to each of the laboratories.

13.3 *Bias*—The procedures in this test method for measuring breaking force, elongation, and yield strength have no known bias because the value of these properties can be defined only in terms of a test method.

TORSION RESISTANCE

14. Summary of Test Method

14.1 A single-filament of wire is tested in torsion by either holding one end of the wire fixed while rotating the other or by rotating both ends in opposite directions at the same time until fracture occurs.

15. Significance and Use

15.1 Complex stress and strain conditions, sensitive to variations in materials, occur in a wire specimen during torsion testing. The torsion test is a useful tool in assessing wire ductility under torsional loading. Defective wire lowers torsion resistance.

16. Apparatus

16.1 *Torsion Test Machine,* an automated drive apparatus that allows a single-filament wire under light tension to be tested in torsion. A counter is provided that registers the number of wire rotations to wire fracture.

17. Procedure

17.1 Thermally age the specimen by placing it in a suitable oven for 60 ± 1 min. at 150 ± 3°C. Allow specimens to cool to room temperature before testing.

17.2 Cut the test specimen to the appropriate length so that a gage length of 200 mm between chuck or jaw edges is obtained.

17.3 Certain test equipment requires that a 90° bend be put in each end of the test specimen; if that is required, measure approximately 25 mm from each end and bend the wire 90° with both bends in the same direction.

17.4 Place the specimen in the clamping fixtures and tighten the jaws while keeping the wire in a straight alignment. A pretension 25 ± 5 N shall be applied to the specimen in the longitudinal direction to aid in keeping the wire straight during testing.

17.5 Set the rotation counter to zero.

17.6 Start the equipment and run until the specimen fractures. For wire sizes below 1.40 mm, use a rotation speed of 60

TABLE 1 Critical Differences for Conditions Noted

Name of Property	Number of Observations	Single Operator Precision		Within-Laboratory Precision		Between-Laboratory Precision	
				Single-Material Comparisons			
Breaking force, N	1	17		17		27	
	2	12		12		25	
	4	9		9		23	
	8	6		6		22	
	16	4		4		22	
				Multi-Material Comparisons			
	1	17		17		31	
	2	12		12		28	
	4	9		9		27	
	8	6		6		26	
	16	5		5		26	
				Single-Material Comparisons			
Yield strength, N		Group 1[A]	Group 2[B]	Group 1	Group 2	Group 1	Group 2
	1	19	57	20	61	28	81
	2	14	40	14	46	24	71
	4	10	28	11	36	22	65
	8	7	20	8	30	21	61
	16	5	14	7	26	21	60
				Multi-Material Comparisons			
	1	19	57	20	61	29	92
	2	14	40	14	46	26	83
	4	10	28	11	36	24	78
	8	7	20	8	30	23	75
	16	5	14	7	26	22	74
				Single-Material Comparisons			
Elongation,%	1	0.54		0.64		1.37	
	2	0.38		0.51		1.32	
	4	0.27		0.44		1.29	
	8	0.19		0.39		1.28	
	16	0.13		0.37		1.27	
				Multi-Material Comparisons			
	1	0.55		0.65		1.43	
	2	0.39		0.52		1.37	
	4	0.29		0.45		1.35	
	8	0.22		0.41		1.33	
	16	0.17		0.38		1.33	
				Single-Material Comparisons			
Torsion resistance, turns to fracture	1	9		10		11	
	2	6		8		9	
	4	4		6		8	
	8	3		6		8	
	16	2		5		7	
				Multi-Material Comparisons			
	1	9		10		15	
	2	7		8		14	
	4	5		7		13	
	8	4		6		12	
	16	4		6		12	
				Single-Material Comparisons			
Diameter, mm	1	0.007		0.010		0.015	
	2	0.005		0.009		0.014	
	4	0.004		0.008		0.014	
	8	0.002		0.007		0.013	
	16	0.002		0.007		0.013	
				Multi-Material Comparisons			
	1	0.007		0.010		0.020	
	2	0.005		0.009		0.020	
	4	0.004		0.008		0.019	
	8	0.002		0.007		0.019	
	16	0.002		0.007		0.019	

[A] Group 1 = Materials 1 and 2 (0.965-mm regular and high-strength products).
[B] Group 2 = Materials 3 and 4 (1.295-mm regular and high-strength products).

± 15 r/min. For wire sizes greater than 1.40 mm, use a rotation speed of 45 ± 15 r/min.

NOTE 4—Speeds in excess of these cause excessive specimen heating and can cause inaccurate results.

17.6.1 If the specimen fails within twice its diameter from the jaw edge it is considered to be a jaw break, and the result should be discarded and another specimen tested.

17.7 Conduct this test procedure on two specimens from each laboratory sampling unit.

18. Calculation

18.1 Torsion resistance is expressed as the number of full rotational turns of the wire to fracture.

19. Report

19.1 State that the tests were performed as directed in Test Methods D4975, describe the material or product tested, and report the following:

19.1.1 The results of each specimen and the laboratory sample average,

19.1.2 Date of test,

19.1.3 Type of torsion tester and the rate of rotation, and

19.1.4 Any deviation from the standard test procedure.

20. Precision and Bias

20.1 *Summary*—In comparing two averages of two observations, the difference should not exceed the following critical differences in 95 out of 100 cases when all of the observations are taken by the same well-trained operator using the same piece of test equipment and specimens randomly drawn from the same sample of material and tested on the same day:

Torsion resistance, 6 turns

The magnitude of the differences is likely to be affected adversely by different circumstances. The true values of torsion resistance can be defined only in terms of specific test methods. Within this limitation, the procedure given in this test method for determining this property has no known bias. Paragraphs 20.2 – 20.4 explain the basis for this summary and for the evaluations made under other conditions.

20.2 *Interlaboratory Test Data*—An interlaboratory test was run in 1990 in which randomly drawn samples of four materials were tested in 12 laboratories. Each laboratory used two operators, each of whom tested two specimens of each material on two separate days (see Note 2).

20.3 *Precision*—For the property of interest, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences given in Table 1 (see Note 3).

20.4 *Bias*—The procedure given in this test method for measuring torsional resistance has no known bias because the value of this property can be defined only in terms of a test method.

DIAMETER (GAGE)

21. Summary of Test Method

21.1 A length of the single-filament specimen is held between two circular shaped, flat faced anvils of a micrometer. The movable anvil is closed gradually and gently until it is in contact with the specimen. The wire diameter is determined by reading the micrometer scale. The roundness is determined by a comparison of diameter measurements made at one single location on the specimen.

22. Significance and Use

22.1 Diameter is one of the basic mechanical properties of single-filament wire. Tire bead dimensions and tensile properties are dependent on the wire diameter.

23. Apparatus

23.1 *Micrometer,* precision micrometer with a vernier capable of measuring to the nearest 0.01 mm and with circular shaped, flat anvil faces that are parallel within 0.015 mm.

23.1.1 Non-contact optical measuring systems are available, allowing for greater precision and ease of measurement, and may be used as an optional method of diameter determination.

24. Procedure

24.1 Verify that the measuring instrument reads 0.000 mm when the anvils are closed. Determine the maximum and minimum diameter by measurements to the nearest 0.005 mm in approximately the middle of one specimen from each laboratory sampling unit.

25. Calculation

25.1 Determine the diameter (gage) of the laboratory sample by calculating the arithmetic average of the minimum and maximum values. The minimum and maximum values should both fall within the product specification limits.

25.2 Determine the out-of-roundness for each laboratory sample as the difference between the maximum and minimum diameter.

26. Report

26.1 State that the test specimens were tested as directed in Test Methods D4975, describe the material or product tested, and report the following:

26.1.1 The average laboratory sample diameter to the nearest 0.005 mm,

26.1.2 The out-of-roundness for the laboratory sample as determined in 25.2, and

26.1.3 Date of test.

27. Precision and Bias

27.1 *Summary*—In comparing two averages of two observations, the difference should not exceed the following critical differences in 95 out of 100 cases when all of the observations are taken by the same well-trained operator using the same piece of test equipment and specimens randomly drawn from the same sample of material and tested on the same day:

Diameter, 0.007 mm

The magnitude of the differences is likely to be affected adversely by different circumstances. The true value of diameter can be defined only in terms of specific test methods. Within this limitation, the procedure given in this test method for determining this property has no known bias. Paragraphs 27.2 – 27.4 explain the basis for this summary and for evaluations made under other conditions.

27.2 *Interlaboratory Test Data*—An interlaboratory test was run in 1990 in which randomly drawn samples of four materials were tested in 13 laboratories. Each laboratory used two operators, each of whom tested one specimen of each material on two separate days (see Note 4).

27.3 *Precision*—For the property of interest, two averages of observed values should be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences given in Table 1 (see Note 3).

27.4 *Bias*—The procedure given in this test method for measuring diameter has no known bias because the value of this property can be defined only in terms of a test method.

28. Keywords

28.1 diameter; elongation; strength; tire bead wire; torsion