Designation: D 6588 – 02

Standard Test Method for
Fatigue of Tire Cords (Disc Fatigue Test)[1]

This standard is issued under the fixed designation D 6588; 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 This test method covers the determination of fatigue of tire cords in rubber due to compression or extension, or both, using a disc fatigue tester. The fatigue is measured as a loss in strength.

1.2 The values stated in either SI units or other units (in parentheses) are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

1.3 *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 to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 76 Specification for Tensile Testing Machines for Textiles[2]

D 123 Terminology Relating to Textiles[2]

D 885 Methods of Testing Tire Cords, Tire Cord Fabrics, and Industrial Filament Yarns Made from Man-Made Organic-Base Fibers[2]

D 1776 Practice for Conditioning Textiles for Testing[2]

D 6477 Terminology Relating to Tire Cord and Fabrics

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms relating to tire cord and fabrics, see Terminology D 6477.

3.1.2 For definitions of other terms related to textiles, see Terminology D 123.

4. Summary of Test Method

4.1 disc fatigue is a measure of the strength loss of a tire cord, which is subjected to repeated stresses. The stresses are accomplished by subjecting the tire cords, after being cured in rubber, to repeated cycles of compression and extension.

4.2 The specimen of interest is the cord after it has been stressed and later removed from the rubber in which it was imbedded. Cord specimens are placed between strips of rubber compound and molded into blocks. The specimen block is then mounted between two rotating discs that are positioned in such a way that the specimen will undergo compression or extension, or both, as the discs rotate. After a specified number of cycles, the cords are removed from the blocks and their breaking force measured on a tensile testing machine. The fatigue, based on the unfatigued specimen strength, is expressed as a percent strength loss in fatigued specimens.

5. Significance and Use

5.1 This test method is not recommended for acceptance testing of commercial shipments in the absence of reliable information on between-laboratory precision.

5.1.1 If there are differences of practical significance between the reported test results for two laboratories (or more), a comparative test should be performed to determine if there is a statistical bias between them, using competent statistical assistance. As a minimum, test samples should be used that are as homogeneous as possible, that are drawn from a material from which the disparate test results were obtained, and that are randomly assigned in equal numbers to each laboratory for testing. Other fabrics with established test values may be used for this purpose. The test results from the two laboratories should be compared using a statistical test for unpaired data, at a probability level chosen prior to the testing series. If a bias is found, either its cause must be found and corrected, or future test results must be adjusted in consideration of the known bias.

6. Apparatus, Materials, and Reagents

6.1 *Disc Fatigue Tester* (see schematic drawing in Fig. 1), with capacity for 12 specimens. For actual dimensions, see patent US 2595069. Testers with different capacity are acceptable.

6.2 *Transducer*, with digital readout or dial gage for setting distance between disc fatigue flanges to the nearest 0.01 mm (0.004 in.).

6.3 *Mold*, top and bottom sections with cavities in each for 12 or 24 specimens with the dimensions of 10.8 by 12.7 by 76.2 mm (7⁄16 by ½ by 3 in.). (See schematic drawing in Fig. 2). All dimensions given require an accuracy of 0.1 mm (0.04 in.).

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[1] This test method is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.19 on Tire Cord and Fabrics
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[2] *Annual Book of ASTM Standards*, Vol 07.01.

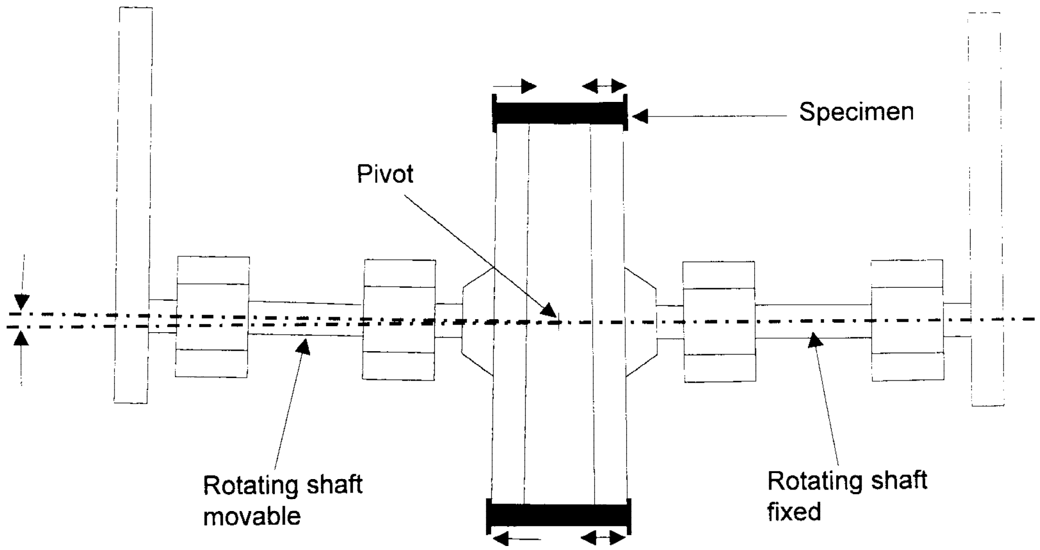

FIG. 1 Schematic Top View of the Disc Fatigue Tester with Two Specimens

The top of the mold may be coated with TFE-fluorocarbon to release the specimens easily. Molds with other numbers of cavities may be used.

6.4 *Weights*, having a mass of 50 ± 5 g or 100 ± 10 g, or both, for tensioning yarns or cords while building specimen blocks.

6.5 *Curing press*, capable of maintaining a minimum pressure of 3.5 MPa (500 psi) over the total area of the mold surface, and capable of a platen temperature control within ±3°C (±5°F) of the temperature specified for curing the rubber compound.

6.6 *Guillotine, Hand-operated*, capable of slicing the sample blocks (see 11.2.2).

6.7 *Tensile Testing Machine*, CRE type, in accordance with Specification D 76.

6.8 *Clamps*, air-actuated, flat, rubber-faced or bollard-type.

6.9 *Rubber Compound*, with a thickness of 6.0 ± 0.3 mm (0.24 ± 0.01 in.), rolled up in polyethylene liner and free from moisture and contamination.

NOTE 1—The rubber type used, especially rubber modulus, will affect the results.

6.10 *Gloves*, neoprene or other solvent-resistant rubber.

6.11 *Solvent*, 1.1.2.2 tetrachloroethylene, $CHCl_2$ $CHCl_2$ or 1.1.1 trichloroethane CCl_3CH_3) for removing cords from rubber.

6.12 *Tachometer or Strobotac*.

6.13 *Screwdriver*, or other tightening device.

7. Hazards

7.1 The manufacturer's material data sheets (MSDSs) shall be used to obtain information on handling, storage, use, and disposal of chemicals used in this test method.

8. Sampling and Test Specimens

8.1 *Primary Sampling Unit*—Consider one roll of dipped tire cord fabric or a cord package as the primary sampling unit.

8.2 *Laboratory Sampling Unit*—As a laboratory sampling unit, from each primary sampling unit prepare tabby samples by taking a sample equal to the length of cord between the regular tabby woven at the end of the roll and a special tabby woven a short distance from the end when the roll of fabric is manufactured. For rolls that do not have a special woven tabby, improvise a tabby by the use of gummed tape or strips of cemented fabric applied across a section of the cord fabric to give a tabby sample length at least 0.5 m (18 in.) long and at least one tenth of the roll width wide.

8.2.1 *Preparation of Tabby Samples*—The handling of the samples must be done with care. The person obtaining the sample should wear clean gloves. Cut the warp cords of the dipped fabric along the centerline of the special tabby for a distance equal to the width of the sample. If this distance is less than the full width of the fabric, cut the filling yarns of the sample and of the special and regular tabbies in the direction parallel with the warp cords. The resulting section of cord fabric is the tabby sample. Attach the tabby sample to a piece of cardboard or fiberboard, the length of which shall be equal to at least the length of the cord warp between tabbies. Fold the tabby portions of the sample over each end of the board, and secure the sample to the board with pressure-sensitive tape or staples. Use care to avoid contact of tape or staples with the area to be tested. Handle the sample carefully. Discard any specimen subjected to any bend with a diameter less than 10 times the yarn/cord thickness (or diameter). The board with the sample may be folded lengthwise and parallel with the warp for convenience. Place the board with the fabric sample in a black polyethylene bag, or wrap it with several layers of black polyethylene film to protect the sample from ultraviolet (UV) and ozone.

8.3 *Test Specimens*:

8.3.1 *Specimens Yarns or Cord*—From the laboratory sample, take the number of specimens needed for each block, multiplied by the number of blocks that have to be built as shown in Table 1. Take a duplicate number of specimens for unfatigued control testing.

8.3.2 *Number of Blocks for Fatigue and Control Testing*—Prepare the number of blocks to be fatigue tested as shown in

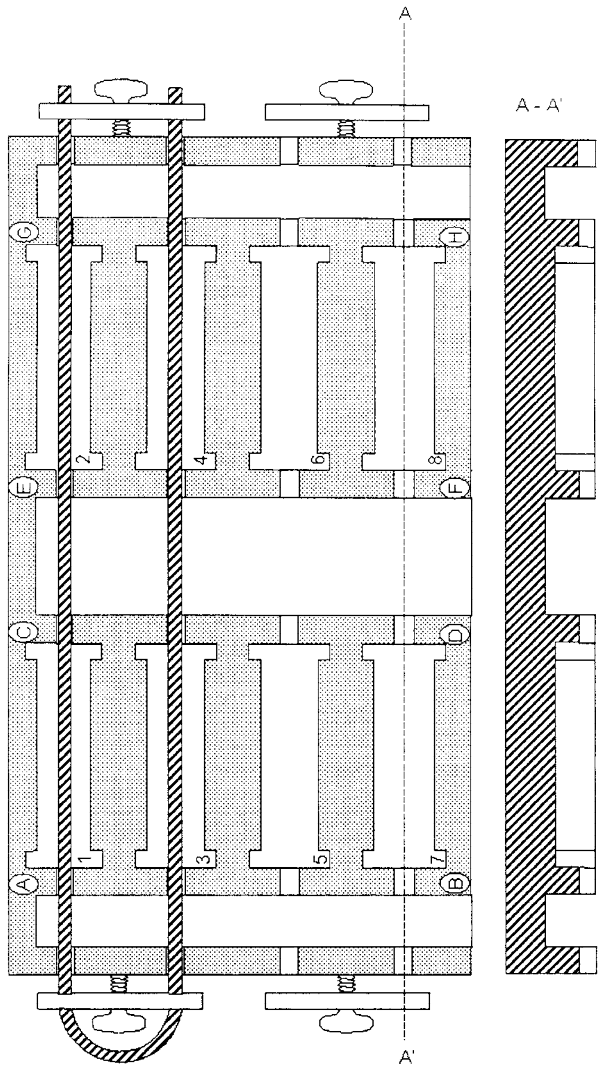

FIG. 2 Schematic View of the Mold

TABLE 1 Number of Specimens (Cords) per Block

Material	Nominal Linear Density, Dtex	Number of Specimens (Cords) per Block	Number of Blocks
Nylon	≤2200	5	3
	>2200	3	3
Polyester	≤2200	5	3
	>2200	3	3
Rayon	all	1	6
Aramid	all	1	6
Twisted yarn of any material	all	1	6

Table 1. Prepare a duplicated number of blocks for unfatigued control testing. The number of blocks specified is the minimum needed to constitute a valid test.

8.3.3 Label both yarn/cord specimens and block specimens to maintain specimen identity.

8.4 *Building Test Specimen Blocks*—Prepare test specimen blocks in accordance with the directions in 8.4.1 through 8.4.5

8.4.1 Cut a piece of rubber stock large enough to cut two strips of 6.0 ± 0.3 mm (0.24 ± 0.01 in.) for each cavity in the mold. Cut sufficient number of strips with the long direction parallel to the calendering direction of the rubber stock. Remove polyethylene backing from one side of rubber strips just prior to using. Place a strip in each of the cavities of the two halves of the mold with the polyethylene side up. Press the rubber firmly into the cavities. A cold press may be used. Remove the polyethylene backing from the top of the rubber, leaving the rubber surface free of contamination and fingerprints.

8.4.2 For packages, discard the outer layer of cord. Cut approximately 1 m (1 yd) of dipped cord. Simultaneously load two adjacent cavities in the bottom mold by one end of a single cord at the first clamp. Position the cord in the center of the first cavity, loop it through the second clamp at the end of the mold (hang a tensioning mass on the loop to ease loading) then down the center of the second cavity and back through the first clamp. Tighten the first clamp on the two cord ends. Tension each cord with a tensioning mass of 50 g by hanging 100 g on the loop end. Multiple cords are loaded in the same manner as a single cord, however, they are loaded and clamped simultaneously. Tension each cord with a tensioning mass of 50 g by hanging 100 g on each cord loop. Examine rear and front cord slots to be certain that all cords are properly aligned. Adjust cords as necessary then hold in position with masking tape at the ends of each block. Once the cords have been tensioned and aligned, close the second clamp and remove the mass. Put an identification tag on the ends of each cord. Continue filling the remaining cavities in the bottom of the mold (see schematic drawing in Fig. 2). Place top half of the mold on the bottom half.

8.4.3 Place the mold assembly in the press, preheated to the specified temperature and apply a minimum pressure of 3.5 MPa (500 psi) over the total area of the mold surface. Vulcanize for the specified time at the temperature.

8.4.4 Reduce the pressure and remove the mold.

8.4.5 Open the mold and remove the specimen blocks. Mark each block with identification. Trim the rubber overflow and cut the cords so that the total length in rubber and length extending on each side will be not less than 150 mm (6 in.). Condition the specimen blocks for at least 16 h at ambient room temperature

9. Preparation of Apparatus

9.1 *Disc Fatigue Tester*:

9.1.1 Set disc in the tester parallel and 25.40 ± 0.02 mm (1 ± 0.001 in.) apart. Do this by setting the angle of the right disc at 0 rad (0°) and adjusting the left disc to the proper distance.

9.1.2 Set the tester for compression and extension conditions using Table 2 or Eq 1 or Eq 2.

$$M = D_O\,(E-C)/2 \tag{1}$$

$$D_t = D_O + M \tag{2}$$

where:

M = change of the original distance, mm (in.), if M is negative, the distance is decreased by that amount and if M is positive, the distance is increased,
D_O = original distance, (25.4 mm) (1 in.),
D_t = parallel testing distance of the discs,
E = percent elongation/100, and
C = percent compression/100.

9.1.3 Make the appropriate M change in the distance between each pair of discs by moving the left disc in a straight line toward, or away from, the right disc until the specified parallel distance between the two discs has been achieved.

9.1.4 Next, set the left disc to the required compression and extension settings as obtained from Table 2, Eq 1 , Eq 2 or by changing the angle of the left disc. Read (and record) the maximum and minimum distances between the discs.

9.2 *Tensile Testing Machine Setup*:

9.2.1 Set the gage length at 30 mm (1.2 in.), except for aramid where a gage length of 250 mm (10.0 in.) is required.

9.2.2 For nylon, polyester, and rayon, use flat or bollard type clamps and set the crosshead speed at 100 or 50 % of the gage length per minute. For aramid, use suitable bollard type clamps and set the crosshead speed at 50 or 25 % of the gage length per minute.

10. Conditioning

10.1 Rubber compound properties are best maintained by storage in a cool, dry atmosphere. Excessive rubber compound moisture may lower adhesion of some fiber/rubber composites.

10.2 Store samples (tabbies) or adhesive-treated cord in moisture-proof, UV, and ozone protective bags (aluminum-coated or black polythene bags may be sufficient) at temperatures below 24°C (75°F).

10.3 Condition fatigued cords and non-fatigued control cords for at least 16 h in the standard atmosphere for testing textiles, as described for tire cords (see Practice D 1776) prior to determining breaking force.

11. Procedure

11.1 *Flexing Specimen Blocks*:

11.1.1 Determine the 25.4-mm (1.0-in.) position (loading position) for the discs and load the specimens (blocks) in this position. Place the specimens in slots in the discs and slip ends of cords under the disc enclosure. Do not allow the ends to become damaged during tester operation. Screw the holding clamps on top of the block ends in each disc and tighten with air driven screwdriver or other tightening device.

NOTE 2—If the blocks are loaded position, the elongation and compression will be different from the calculated values.

11.1.2 Adjust the tester to run at a speed of 2 300 to 2 700 rpm (3 600 000 cycles/24 h per 24 h) using a tachometer. Other speeds in the range of 2 300 to 2 700 can be selected. Run the tester for the desired time (see Note 3).

NOTE 3—Usual running times are 6, 24, 48, and 72 h. The strength loss is not linear with the running time. Retained strength values between 90 and 40 % are recommended.

11.1.3 Stop the tester at the completion of flexing time required and promptly remove the specimen blocks (see Note 4).

NOTE 4—The clamps can be removed while in the top position and the samples pulled from the front position. Pull one end of sample at a time from slots.

11.2 *Cord Preparation for Breaking Force*:

11.2.1 Prepare the multiple cords per block for breaking force testing by soaking the block in a solvent and pulling the cords from the rubber. Cut the block on one side and soak in a solvent for 24 ± 4 h. Soaking and sample removal should be

TABLE 2 Common Values for Compression and Elongation of the Different Cords

Fiber	Compression [C], (%)	Elongation [E], (%)	Compression, (mm (in.))	Extension, (mm (in.))	Correction [M], (mm (in.))	Parallel, D_t (mm (in.))
Nylon	12.5	6.3	3.18 (0.875)	1.60 (1.063)	−.79 (0.031)	24.61 (0.969)
Polyester	12.5	6.3	3.18 (0.875)	1.60 (1.063)	−.79 (.031)	24.61 (0.969)
Rayon	12.5	6.3	3.18 (0.875)	1.60 (1.063)	−.79 (.031)	24.61 (0.969)
Aramid	14	2	3.56 (0.86)	.51 (1.020)	−1.52 (.06)	23.88 (0.940)
Twisted yarn of any material	6	2	1.52 (0.940)	.51 (1.060)	–.51 (.02)	24.89 (0.980)

performed in a fume hood using gloves appropriate for the solvent used. Carefully pull the cords, one at a time, out of the rubber and attach identifying tags. Air dry the specimens in the hood. Do not trim any remaining rubber from the specimens after removal from the block. Oven dry the air-dried rayon cord specimens in an explosion proof oven for 4 ± 0.5 h at 105 ± 3°C (220 ± 6°F).

11.2.2 Prepare the single cord or yarn per block for breaking force testing by either cutting away the excess rubber or by soaking in a solvent and pulling the cord from the rubber in accordance with 11.2.1. To use the cutting procedure, place a block in the guillotine sample cutter and cut the block on all four sides as close as possible to the cord, without cutting the cord. Test them as cut from the block.

11.3 *Breaking Force*:

11.3.1 Test the test specimens in the standard atmosphere for testing textiles, as described for tire cords in Practice D 1776.

11.3.2 Determine the breaking force of the specimens (fatigued cords) in accordance with Methods D 885, except the machine setup in accordance with 9.2. Mount the specimen in the tensile testing machine clamps with that portion which was embedded in the rubber midway between the clamps.

11.3.2.1 Record the type of break for all fatigue-tested cords as: fatigue break (specimens that break during fatiguing), tensile break in rubber-embedded area or outside this area.

11.3.3 Determine the breaking force of eight specimens of control (specimens from unfatigued blocks) from each laboratory sampling unit to the nearest 0.05 N (0.01 lbf).

12. Calculation

12.1 Calculate the average breaking force of the fatigued cords. Do not include in the calculation results for any cord that breaks outside the area that was cured in rubber. Include the fatigue breaks as zero in the calculated average.

12.2 Calculate the average breaking force of the control (unfatigued) cord.

12.3 Calculate for each laboratory sampling the force loss for the fatigued cords using Eq 3.

$$FL = ((B - A)/B) \times 100 \quad (3)$$

where:
FL = force loss, %,
A = average breaking force of fatigued cords, mN (lb), and
B = average breaking force of unfatigued cords, mN (lb).

13. Report

13.1 State that the specimens were tested as in accordance with Test Method D 6588. Describe the material sampled and the method of sampling used.

13.2 Report the following information:

13.2.1 The breaking force for the fatigued cord for each laboratory sampling unit.

13.2.2 The breaking force for the control (unfatigued) cord for each laboratory sampling unit.

13.2.3 The force loss due to fatigue for each laboratory sampling unit.

13.2.4 The type of break for all fatigue specimens.

13.2.5 The rubber used.

13.2.6 The fatigue testing conditions.

13.2.7 Any modifications to the test.

14. Precision and Bias

14.1 *Precision*—From a standard spool with impregnated nylon cord, the disc fatigue has been tested in a single laboratory over a four-month time period. Each test result represents the average of eight specimen measurements, and is expressed as percent retained breaking force. A statistical analysis was used to quantify intralaboratory variability for this property. The process appeared stable over the test period. Results are shown as follows:

Property	Average	s_r	Repeatability	S_R	Reproducibility
Force loss, %	16.6	4.57	12.7	NA	NA

14.1.1 The intralaboratory standard deviation is s_r. The total standard deviation, S_R, is formed by taking the square root of the sum of intralaboratory and interlaboratory variance components. The standard deviation, S_R, cannot be determined from these data.

14.1.2 Method repeatability is defined as the "maximum difference" that can "reasonably" be expected between two test results obtained on the same material when the test results are obtained in the same laboratory. Method reproducibility is defined as the "maximum difference" that can "reasonably" be expected between two test results obtained on the same material when the test results are obtained from different laboratories.

14.2 *Bias*—The procedure of this test method produces a test value that can be defined only in terms of a test method. There is no independent, referee method by which bias may be determined. This test method has no known bias.

15. Keywords

15.1 cord; disc; fatigue; tire; tire cord

APPENDIX

(Nonmandatory Information)

X1. BIBLIOGRAPHY FOR FATIGUE OF TIRE CORDS

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