



Designation: D4018 – 23

Standard Test Methods for Properties of Continuous Filament Carbon and Graphite Fiber Tows¹

This standard is issued under the fixed designation D4018; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 These test methods cover the preparation and tensile testing of resin-impregnated and consolidated test specimens made from continuous filament carbon and graphite yarns, rovings, and tows to determine their tensile properties.

1.2 These test methods also cover the determination of the density and mass per unit length of the yarn, roving, or tow to provide supplementary data for tensile property calculation.

1.3 These test methods include a procedure for sizing removal to provide the preferred desized fiber samples for density measurement. This procedure may also be used to determine the weight percent sizing.

1.4 These test methods include a procedure for determining the weight percent moisture adsorption of carbon or graphite fiber.

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

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

¹ These test methods are under the jurisdiction of ASTM Committee D30 on Composite Materials and are the direct responsibility of Subcommittee D30.03 on Constituent/Precursor Properties.

Current edition approved Sept. 1, 2023. Published September 2023. Originally approved in 1981. Last previous edition approved in 2017 as D4018 – 17. DOI: 10.1520/D4018-23.

2. Referenced Documents

2.1 ASTM Standards:²

D70 Test Method for Specific Gravity and Density of Semi-Solid Asphalt Binder (Pycnometer Method)

D1193 Specification for Reagent Water

D3800 Test Method for Density of High-Modulus Fibers

D5550 Test Method for Specific Gravity of Soil Solids by Gas Pycnometer

E4 Practices for Force Calibration and Verification of Testing Machines

E83 Practice for Verification and Classification of Extensometer Systems

2.2 Other Document:

CRC Handbook of Chemistry and Physics³

3. Terminology

3.1 Definitions:

3.1.1 *sizing, n*—a generic term for compounds which, when applied to yarn or fabric, form a more or less continuous solid film around the yarn and individual fibers.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *desized fiber, n*—fiber which has had a sizing removed from it.

3.2.2 *fiber, n*—continuous filament carbon or graphite yarn, roving, or tow.

3.2.3 *sized fiber, n*—a fiber with a sizing applied to it.

3.2.4 *unsized fiber, n*—fiber which has never had a sizing applied to it.

3.3 Symbols:

3.3.1 *A*—Unit conversion factor for tensile strength

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.

³ CRC Press Inc., Boca Raton, Ann Arbor, London, Tokyo, 73rd Edition, 1992–1993.

- 3.3.2 B —Unit conversion factor for tensile modulus
- 3.3.3 E —fiber chord modulus
- 3.3.4 ϵ_l —Lower strain limit
- 3.3.5 ϵ_u —Upper strain limit
- 3.3.6 k_c —correction factor for density of sizing
- 3.3.7 L —specimen length
- 3.3.8 MUL —the mass per unit length of the sized fiber
- 3.3.9 MUL_I —the mass per unit length of the impregnated and consolidated fiber
- 3.3.10 P —maximum load
- 3.3.11 P_l —tensile load at lower strain limit
- 3.3.12 P_u —tensile load at upper strain limit
- 3.3.13 ρ_f —density of the fiber
- 3.3.14 ρ_{sf} —density of the fiber with sizing
- 3.3.15 RC —weight percent of resin (resin content)
- 3.3.16 W_I —specimen mass

4. Summary of Test Methods

4.1 These test methods include procedures for determining the tensile strength and modulus of a resin-impregnated and consolidated carbon fiber tow. Also included are procedures to measure the mass per unit length and density of the carbon fiber and the resin content of the resin-impregnated and consolidated specimens.

4.2 MUL —The MUL of the fiber is determined by dividing the mass of a sample of sized fiber by its length.

4.3 *Density*—The density of the fiber is determined using Archimedes' method or a pycnometer method. The recommended specimen is desized or unsized fiber. The ideal immersion fluid is one that completely wets the specimen and provides minimum toxicity or environmental hazard.

4.4 *Resin Content*—The resin content (weight percent) of the resin-impregnated and consolidated fiber is determined by comparing the mass per unit length of the impregnated and consolidated specimen to the fiber mass per unit length.

4.5 *Tensile Properties*—The tensile strength and tensile chord modulus of the fiber are determined by the tensile loading to failure of the resin-impregnated and consolidated fiber. The chord modulus is determined between defined strain limits. The purpose of the impregnating resin is to provide the fiber, when consolidated, with sufficient mechanical strength to produce an easily handled test specimen capable of sustaining uniform loading of the individual filaments in the specimen. The resin shall be compatible with the fiber and any sizing applied to it. The strain capability of the consolidated resin shall be at least twice the strain capability of the fiber.

5. Significance and Use

5.1 The properties determined by these test methods are of value in material specifications, qualifications, data base generation, certification, research, and development.

5.2 These test methods are intended for the testing of fibers that have been specifically developed for use as reinforcing

agents in advanced composite structures. The test results of an impregnated and consolidated fiber should be representative of the strength and modulus that are available in the material when used as intended. The performance of fibers in different resin systems can vary significantly so that correlations between results using these test methods and composite testing may not always be obtained.

5.3 The reproducibility of test results is dependent upon precise control over all test conditions. Resin type, content and distribution, curing process, filament alignment, gripping in the testing machine, and alignment in the testing machine are of special importance.

5.4 The measured strengths of fibers are not unique quantities and test results are strongly dependent on the test methods used. Therefore the test method described here will not necessarily give the same mean strengths or standard deviations as those obtained from single filaments, dry fibers, composite laminas, or composite laminates.

6. Apparatus

6.1 Three sets of apparatus are required. One set is for resin impregnation of the fiber. A second set is for curing the resin-impregnated specimens. A third set is for tensile testing the resin-impregnated and consolidated specimens. Optional apparatus may be used for applying end tabs to the specimens and removing sizing.

6.1.1 *Resin Impregnation*—The goal of the resin-impregnation apparatus is to apply and uniformly impregnate resin into the fiber. This is normally achieved by dipping the fiber into the resin and then working the wet fiber over rolls or through a die, or both. While automated apparatuses are preferred for consistency, any apparatus which achieves uniform impregnation of 35 % to 60 % resin by weight and does not damage the fiber is acceptable.

6.1.2 *Consolidation*—An apparatus to hold the impregnated specimens under tension during consolidation is required.

6.1.3 *Optional End Tabs*—An apparatus to cast resin end tabs on specimens may be used. Apparatuses to apply and align other forms of end tabs such as bonded on cardboard or metal tabs may also be used.

6.1.4 *Testing*—A tensile testing machine and recorder meeting the requirements of Practices E4 at the maximum expected test load are required. The load recording device shall be coordinated with the extensometer and strain recorder to assure that the corresponding load and elongation of the specimen are recorded at essentially the same time. The testing machine shall also have the following features:

6.1.4.1 *Grips*—Grips suitable for loading the tabbed or untabbed specimen without damaging it are required. For resin tabbed specimens a custom grip is generally required. For untabbed or cardboard tabbed specimens pneumatic or hydraulically powered grips are typically used. Different grip pressure settings may be required for different fibers.

6.1.4.2 *Jaws*—Jaws compatible with the grips and capable of holding a specimen without damaging it are required. For untabbed specimens, flat jaws with rubber or other compliant materials bonded to the face are generally used. Sandpaper may also be placed on the grips to reduce slippage. For