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400 COMMONWEALTH DRIVE WARRENDALE PA 15096

# AEROSPACE MATERIAL SPECIFICATION

AMS 3892 A
Superseding AMS 3892

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## FIBERS, CARBON (GRAPHITE), TOW AND YARN, For Structural Composites

1. SCOPE:

1.1 Form: This specification and its supplementary detail specifications cover carbon (graphite) fibers in the form of continuous multifilament tow and yarn.

1.2 Application: Primarily for use as reinforcements in composites for structural applications.

1.3 Classification: The fibers shall be as specified in the applicable detail specifications, wherein each material is defined by form and property characteristics. An example is shown in 8.2. The product covered by each detail specification appears as part of the title.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM C613 - Resin Content of Carbon and Graphite Prepregs by Solvent Extraction
ASTM D792 - Specific Gravity and Density of Plastics by Displacement
ASTM D1423 - Twist in Yarns by the Direct-Counting Method
ASTM D1505 - Density of Plastics by the Density-Gradient Technique
ASTM D2344 - Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short Beam Method
ASTM D2734 - Void Content of Reinforced Plastics
ASTM D3039 - Tensile Properties of Fiber-Resin Composites
ASTM D3171 - Fiber Content of Resin-Matrix Composites by Matrix Digestion
ASTM D3800 - Density of High Modulus Fibers
ASTM D4018 - Tensile Properties of Continuous Filament Carbon and Graphite Yarns, Strands, Rovings, and Tows

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Standards:

MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

3. TECHNICAL REQUIREMENTS:

3.1 Detail Specifications: The requirements for a specific material shall consist of all requirements specified herein in addition to the requirements specified in the applicable detail specification. In case of conflict between the requirements of this basic specification and an applicable detail specification, the requirements of the detail specification shall govern.

3.2 Material:

3.2.1 Construction: Carbon (graphite) tow and yarn shall be formed from parallel lays of carbon (graphite) filaments, lightly stranded when required, to produce a product that may be handled with care without material or property degradation.

3.2.2 Finish: A finish or treatment may be applied to the tow or yarn during or after tow or yarn manufacture to improve the handling qualities of the tow or yarn for impregnation processing or to improve the coupling of the matrix to the fiber filaments in the resultant composite structure. The finish or treatment shall reduce the tendency of the tow or yarn to fuzz or break when handled and shall not require removal prior to impregnation with resin.

3.2.3 Tow or Yarn Splicing:

3.2.3.1 Unless otherwise specified, tow or yarn splices shall be formed by joining the opposing fiber ends with an appropriate splicing compound in an overlapping joint in a manner such that the splice will not interfere with subsequent processing or by taping the opposing ends to a piece of paper, in which case a 25 ft (7.5 m) "tell tale" indicator shall be attached and wound with the new length of yarn or tow.

3.2.3.2 The distance between splices shall be not less than 500 ft (150 m).

3.2.4 Bending: Tow or yarn shall withstand bending through an angle of 180 deg around a 1-in. (25-mm) diameter mandrel with the fiber direction perpendicular to the axis of bend without visible fiber damage; 10X magnification shall be used in examination for damage.

3.2.5 Oxidation Resistance: When required by the detail specification, the tow or yarn shall meet the weight loss requirements specified therein, determined as in 4.5.10.

3.2.6 Storage Life: A laminate made from yarn or tow shall meet the interlaminar shear strength requirements of the applicable detail specification after storage of the yarn or tow as specified in the detail specification.

3.3 Properties: The product, as received by purchaser, shall conform to the requirements of this specification and the applicable detail specification. Tests shall be performed on the product supplied and in accordance with applicable test procedures of this specification as follows:

| Property | Number of Specimens per Test min | Test Procedure |
|---|---|---|
| Tensile Strength and Modulus of Elasticity | | |
| Strand Method | 5 | 4.5.1.1 |
| Coupon Method | 3 | 4.5.1.2 |
| Interlaminar Shear Strength | 5 | 4.5.3 |
| Length per Unit Weight | 1 | 4.5.4 |
| Weight of Fiber Finish | 1 | 4.5.5 |
| Density | 2 | 4.5.7 |
| Yarn Twist | 3 | ASTM D1423 |

3.4 Quality: The product, as received by purchaser, shall be uniform in quality Ø and condition, clean, and free from foreign materials and from internal and external imperfections detrimental to usage of the product.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of the product shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.6. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for construction (3.2.1), splicing (3.2.3), bending (3.2.4), quality (3.4), and Ø properties in accordance with 3.3 or as specified in the applicable detail specification are classified as acceptance tests and shall be performed on each lot.

4.2.2 Preproduction Tests: Tests to determine conformance to all technical Ø requirements of this specification and the applicable detail specification are classified as preproduction tests and shall be performed prior to or on the initial shipment of the product to a purchaser, when a change in material or processing, or both, requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.2.1 For direct U.S. Military procurement, substantiating test data and, Ø when requested, preproduction test material shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be as follows:

4.3.1 For Acceptance Tests: Sufficient product shall be taken at random from Ø each lot to perform all required tests. The number of determinations for each requirement shall be as specified in 3.3 or, if not specified therein, not less than three.

4.3.1.1 A lot shall be all product produced from the same batches of raw Ø materials in a continuous series of operations and presented for vendor's inspection at one time. An inspection lot shall not exceed 2500 lb (1135 kg), and may be packaged in small quantities under the basic lot approval provided lot identification is maintained.

4.3.1.2 When a statistical sampling plan and acceptance quality level (AQL) Ø have been agreed upon by purchaser and vendor, sampling shall be in accordance with such plan in lieu of sampling as in 4.3.1 and the report of 4.6.1 shall state that such plan was used.

4.3.2 For Preproduction Tests: As agreed upon by purchaser and vendor.
Ø

4.4 Approval:

4.4.1 Sample material shall be approved by purchaser before material for
Ø production use is supplied, unless such approval be waived by purchaser. Results of tests on production material shall be essentially equivalent to those on the approved samples.

4.4.2 Vendor shall use ingredients, manufacturing procedures, and methods of
Ø inspection on production material which are essentially the same as those used on the approved sample material. If necessary to make any change in ingredients, in type of equipment for processing, or in manufacturing procedures, vendor shall submit for reapproval a statement of the proposed changes in material or processing, or both, and, when requested, sample material. Production material made by the revised procedures shall not be shipped prior to receipt of reapproval.

4.5 Test Methods:

4.5.1 Tensile Strength and Modulus of Elasticity: Unless otherwise specified
Ø either of the following methods, strand or coupon, may be used:

4.5.1.1 Strand Method: Tensile strength and modulus of elasticity for the
Ø strands shall be determined in accordance with ASTM D4018.

4.5.1.2 Coupon Method:

4.5.1.2.1 Procedure: The tensile strength and modulus of elasticity for the
Ø coupons shall be determined in accordance with ASTM D3039. The test shall be performed on specimens taken from a laminate panel prepared with a suitable resin system containing unidirectionally oriented fibers with a fiber volume of 62% ± 3 and a void content not exceeding 3%.

4.5.1.2.2 Calculation of Fiber Strength and Modulus of Elasticity: The
Ø equivalent fiber properties shall be determined as follows:

$$\text{Tensile Strength (fibers)} = \frac{\text{coupon tensile strength x 100}}{\text{\% Fiber Volume in laminate (See 4.5.6)}}$$

$$\text{Modulus of Elasticity (fibers)} = \frac{\text{coupon Modulus of Elasticity x 100}}{\text{\% Fiber Volume in Laminate (See 4.5.6)}}$$

4.5.1.3 Reporting: Calculate the arithmetic mean of the required 3 or 5 determinations for each test as tensile strength and modulus of elasticity of the sample. Report both the individual test results and the arithmetic mean.

4.5.2 Ultimate Elongation: The ultimate elongation shall be determined from the tensile test specimens and may be obtained directly from the strain gauge or extensometer, or calculated as follows:

$$\text{Ultimate strain, \%} = \frac{\text{Ultimate Tensile Strength} \times 100}{\text{Modulus of Elasticity}}$$

4.5.3 Interlaminar Shear Strength: Shall be determined in accordance with ASTM D2344 on specimens taken from a laminate panel prepared with a suitable resin system containing unidirectionally oriented fibers with a fiber volume of 62% ± 3 and a void content not exceeding 3%.

4.5.3.1 Reporting: Calculate the arithmetic mean of 5 determinations for each test as the interlaminar shear strength of the sample. Report the individual test results and the arithmetic mean.

4.5.4 Length Per Unit Weight:

4.5.4.1 Measure a 100 in. (3 m) length of tow or yarn to the nearest 0.1 in. (2.0 mm).

4.5.4.2 Weigh the tow or yarn to the nearest 10 milligrams.

4.5.4.3 Calculate the length per unit weight using inch/pound units of measure as follows:

$$\text{Length per Unit Weight, ft/lb} = \frac{454{,}000L}{12W}$$

where, L = Tow or yarn length, in.

W = Tow or yarn weight, mg

4.5.4.4 Calculate the length per unit weight using SI units of measure as follows:

$$\text{Length per Unit Weight, m/kg} = \frac{L}{W} \times 10^6$$

where, L = Tow or yarn length, m

W = Tow or yarn weight, mg

4.5.5 Fiber Finish Content: Fiber finish or sizing content shall be determined by soxhlet extraction in accordance with ASTM C613 using an appropriate solvent or, if approved by purchaser, by other appropriate method which quantitatively indentifies the amount of finish without affecting the fiber.

4.5.6 Laminate Fiber Volume: The fiber content of the laminate used for the interlaminar shear strength test shall be determined in accordance with ASTM D3171. Calculate the arithmetic mean of 3 determinations as the fiber volume of the test laminate. Report the individual test results and the arithmetic mean.

4.5.7 Fiber Density Measurement: The density of the fibers shall be determined in accordance with ASTM D3800. Calculate the arithmetic mean of 2 determinations as the fiber density. Report the individual test results and the arithmetic mean.

4.5.8 Density of Test Laminate: The density of the test laminates used for interlaminar shear strength and tensile strength shall be determined in accordance with ASTM D792 using a suitable nonaqueous liquid or in accordance with ASTM D1505.

4.5.9 Void Content: The void content of the laminates used for the interlaminar shear strength and tensile strength shall be determined in accordance with ASTM D2734.

4.5.10 Oxidation Resistance of Fiber: The oxidation resistance shall be determined by the following test method. If the fiber contains a sizing, the test shall be conducted on the sized fiber and the weight of sizing, determined in 4.5.5, shall be subtracted from the weight determined herein. Samples shall be run in duplicate.

4.5.10.1 Specimen Preparation: Form approximately 2 g of yarn or tow into a loop approximately 2 in. (50 mm) in diameter, dry in a suitable oven at 75°C ± 1 (170°F ± 2) for not less than 16 hr, and weigh ($W_d$) to the nearest 0.1 milligram.

4.5.10.2 Procedure: Place the dry specimen in a circulating-air oven, with one change of air per minute, in a manner to prevent physical damage to the specimen, and expose for the time and temperature specified in the applicable detail specification. After hot air exposure, weigh the specimen to the nearest 0.1 mg ($W_a$).

4.5.10.3 Calculation: Determine the weight percent loss under the specified conditions as follows:

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$$W_{1a} \text{ (unsized fiber)} = \frac{W_d - W_a}{W_d} \times 100$$

$$W_{1a} \text{ (sized fiber)} = \frac{W_d - W_a}{W_d} \times 100 - \text{wt \% of sizing (See 4.5.5)}$$

Where, $W_{1a}$ = percent weight loss in hot air due to oxidation

$W_d$ = fiber weight after drying (mg)

$W_a$ = fiber weight after hot air exposure (mg)

4.6 Reports:

4.6.1 Ø The vendor of the product shall furnish with each shipment a report showing the results of tests to determine conformance to the acceptance test requirements and stating that the product conforms to the other technical requirements of this specification and the applicable detail specification. This report shall include the purchase order number, AMS 3892/*, vendor's material designation, treatment finish (if used), date of manufacture, lot number, spool number, and, for each spool, the net weight.

4.6.2 The vendor of finished or semi-finished parts shall furnish with each shipment a report showing the purchase order number, AMS 3892/*, contractor or other direct supplier of material, supplier's material designation, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and the applicable detail specification and shall include in the report either a statement that the material conforms or copies of laboratory reports showing the results of tests to determine conformance.

* Insert applicable detail specification number and revision letter.

4.7 Resampling and Retesting: If the average results in the above tests fail to meet the specified requirements, disposition of the product may be based on the results of testing three additional specimens for each original nonconforming specimen. Specimens shall be taken from the same test panel, or an additional test panel prepared and cured the same as the original panel. Failure of any retest specimen to meet specified requirements shall be cause for rejection of the product represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY: