Designation: D6507 – 16

Standard Practice for Fiber Reinforcement Orientation Codes for Composite Materials[1]

This standard is issued under the fixed designation D6507; 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 practice establishes orientation codes for continuous-fiber-reinforced composite materials. Orientation codes are explicitly provided for two-dimensional laminates and braids. The laminate code may also be used for filament-wound materials. A method is included for presenting subscript information in computerized formats that do not permit subscript notation.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D3518/D3518M Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a ±45° Laminate

D3878 Terminology for Composite Materials

2.2 *Other Documents:*

CMH-17-2G, *Polymer Matrix Composites*, Volume 2 Materials Properties, Section 1.6.1[3]

ISO 1268-1 *Fibre-reinforced Plastics—Methods of Producing Test Plates—Part 1: General Conditions*, Annex Stacking Designation Systems[4]

3. Terminology

3.1 *Definitions*—Definitions in accordance with Terminology D3878 shall be used where applicable.

4. Significance and Use

4.1 The purpose of a laminate orientation code is to provide a simple, easily understood method of describing the lay-up of a laminate. The laminate orientation code is based largely on a combination of industry practice and the codes used in the *NASA/DOD Advanced Composites Design Guide*,[5] CMH-17-2G, and ISO 1268-1.

4.2 The braiding orientation code provides similar information for a two-dimensional braid, based largely on *Standard Test Methods for Textile Composites*.[6]

5. Reference System

5.1 A reference plane and direction are selected before writing the orientation code. The reference plane is selected as the bottom or top layer for the laminate orientation code. For laminates symmetric about their midplane, the orientation code using the top layer as the reference plane is identical to the orientation code using the bottom layer as the reference plane; selection of the reference plane effectively determines the positive *z*- or three-axis of the laminate. The reference direction (0°) is somewhat arbitrarily selected for convenience and relevance to the application. Often, a dominant fiber direction is defined to be 0°. An example in which relevance to testing determines the reference direction is the D3518/D3518M in-plane shear specimen configuration for which the loading direction is selected as 0°.

6. Laminate Orientation (Lay-up) Code

6.1 The following information and the examples in Fig. 1 describe the laminate orientation code. Ply directions and number of layers are indicated using the laminate orientation code as follows:

[1] This practice is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.01 on Editorial and Resource Standards.

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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.

[3] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] NASA/DOD Advanced Composites Design Guide, Vol. 4, Section 4.0.5, Air Force Wright Aeronautical Laboratories, Day, OH, prepared by Rockwell International Corp., 1983(distribution limited).

[6] Masters, J. E., and Portanova, M. A., Standard Test Methods for Textile Composites, NASA CR-4751, NASA Langley Research Center, 1996

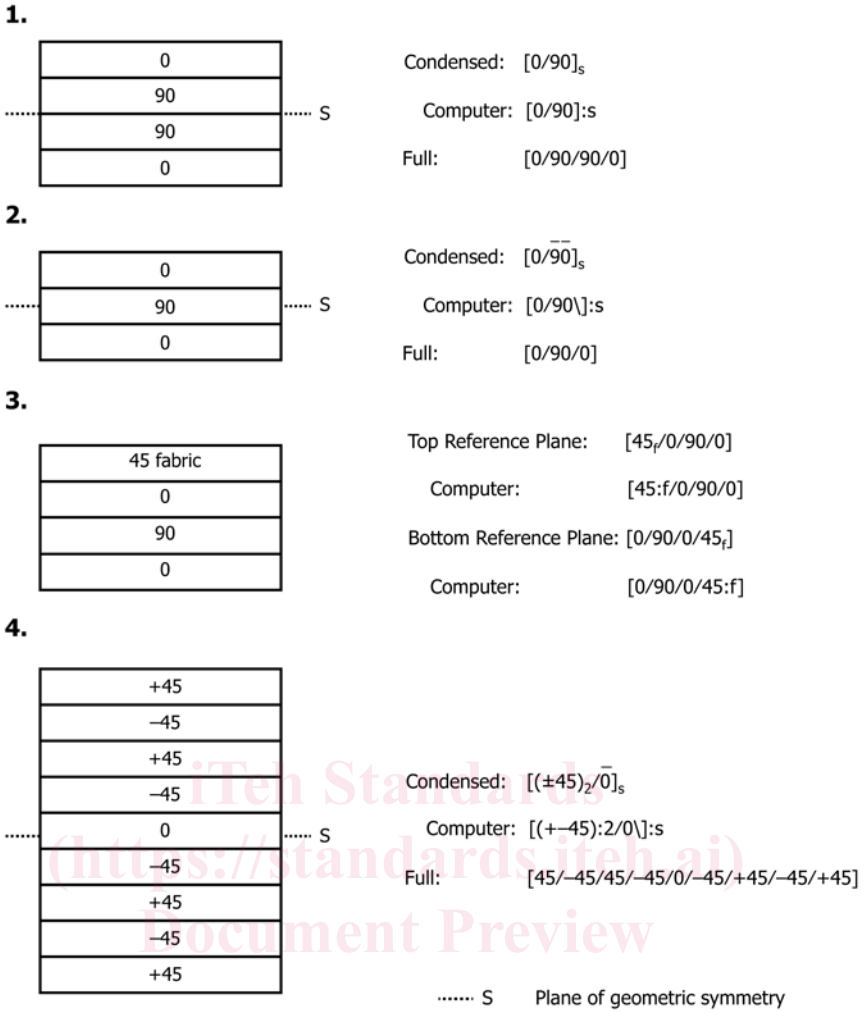

FIG. 1 Examples of Laminate Orientation Code

$$[\theta_1 m_1 b_1 / \theta_2 m_2 b_2 \ \ldots]_{nsb} \text{ notes} \quad (1)$$

where:

θ_1, θ_2 = ply orientations (degrees) of the laminate stacking sequence (see 6.1.2),

m_1, m_2 = number of plies at each particular orientation θ_1, θ_2, . . . (not used for a single ply) (see 6.1.3),

b_1, b_2 = material type and form, or both, (if required) at each particular orientation θ_1, θ_2, . . . (see 6.1.5),

n = number of repetitions of the bracketed group of plies (see 6.1.4),

s = indication of geometric symmetry (see 6.1.6), and

b = indicator of material type and form, or both, (if required) for an abbreviated group of plies.

All subscripts are lowercase with the exception of '*T*' for total (see 6.1.6).

6.1.1 Laminae are listed in order from the reference plane to the opposite side of the laminate. Square brackets are used to indicate the beginning and the end of the code.

6.1.2 The orientation of each lamina with respect to the reference direction is indicated by the angle between the principal fiber direction of that lamina and the reference direction. When indicating the lay-up of a weave, the angle is measured between the warp direction and the reference direction. Positive angles are measured counter-clockwise from the reference direction when looking toward the lay-up surface (right-hand rule). A consistent range of angles is used with all angles in the range $90 \geq \theta > -90$. Orientations of successive laminae with different values are separated by a virgule (/). Pairs of plies of equal and opposite angle may be indicated by plus-minus (±) and minus-plus (∓) symbols, where the top of the symbol indicates the direction of the first ply. For example, [+45/–45/–45/+45] is the same as [±45/∓45].

6.1.3 Ply symbols for two or more adjacent laminae with the same orientation and material system can be condensed by writing the common angle (and material form, if necessary) followed by a subscript equal to the number of identical plies. See Example 4 in Fig. 1.

6.1.4 When a laminate contains repeated and adjacent subsets of laminae, the code can be shortened by enclosing each subset in parentheses with the closing parentheses followed by *n, s*, and *b* subscripts that apply to the entire subset, as appropriate. As many subsets as necessary to describe the laminate may be used within the square brackets. The entire set of laminae within the square brackets may be repeated as