GE Energy *Materials and Processes Engineering*	PROCESS SPECIFICATION **P3C-WE-0001**
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INSPECTION PROCEDURES OF GLASS FABRIC FOR COMPOSITE STRUCTURES

DOCUMENT REVISION STATUS: DETERMINED BY THE LAST ENTRY IN THE "REV" AND "DATE" COLUMN

REV.	DESCRIPTION	SIGNATURE	REV. DATE
-	THIS SPECIFICATION PROVIDES THE INSPECTION PROCEDURES FOR GLASS FABRIC REINFORCEMENTS IN ORGANIC COMPOSITE STRUCTURAL COMPONENTS, SUCH AS IN WIND TURBINE BLADES; DCI NO. 0703708. (RM SUFFIELD)	CR TRIPEPI	

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ORIG. ISSUE DATE: October 17, 2007	

INSPECTION PROCEDURES OF GLASS FABRIC FOR COMPOSITE STRUCTURES

1. SCOPE

1.1. This specification provides the inspection procedures for glass fabric reinforcements in organic composite structural components, such as in wind turbine blades.

1.2. This specification contains an introduction and general guidelines (Section 5) and test methods for handling glass fabric materials, and for processing requirements.

NOTE: The following classes are for inspection criteria, and are not procurement specifications.

P3C-WE-0001 Class A – Unidirectional fabric

P3C-WE-0001 Class B – Biaxial fabric

P3C-WE-0001 Class C – Triaxial fabric

P3C-WE-0001 Class D – Woven fabric

2. APPLICABLE DOCUMENTS

2.1. The following documents shall form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue shall apply.

2.1.1. American Society for Testing and Materials

ASTM D 578 Standard Specification for Glass Fiber Strands

ASTM D 3776 Mass Per Unit Area (Weight) of Fabric

2.1.2. Society for Automotive Engineers

AIR4844 Composites and Metal Bonding Glossary

2.1.3. International Standards Organization

ISO 472 Plastics - Vocabulary

3. DEFINITIONS

3.1. Personnel

3.1.1. Purchaser - The GE Power Generation Operation (PGO), or its Business Associate.

3.1.2. External Supplier - The corporation, company, partnership, sole proprietorship or individual engaged to perform the process covered by this Specification.

3.1.3. Internal Supplier - Any GE Power Generation Manufacturing Department.

3.1.4. Supplier - As used herein, unless specifically designated, refers to either an External or an Internal Supplier.

3.2. Specification Deviation Documents

3.2.1. Applicable to External Supplier

3.2.1.1. Supplier Deviation Request (SDR) - A method for the documentation, approval and control of a waiver for materials, processes, or dimensions which deviate from Purchase Order documents (drawings, specifications, engineering instructions, etc.).

3.2.2. Applicable to Internal Supplier

3.2.2.1. Quality Control Report (QCR) - GE Manufacturing Department non-conformance report initiated during processing through the factory. The QCR used by Manufacturing to document non-conformance to governing documents and request disposition and corrective action.

3.3. Terms (References: SAE AIR4844 AND ISO 472)

3.3.1. Roving - A number of yarns, strands, tows, or ends collected into a parallel bundle with little or no twist. This term is applied most commonly to glass and Kevlar. See ISO 472.

3.3.2. Fabric - A material made of woven fibers or filaments.

3.3.3. Unidirectional - Filament orientation in the lengthwise direction only.

3.3.4. Woven Fabric - (i) A material (usually a planar structure) constructed by interlacing yarns, fibers, or filaments, to form such fabric patterns as plain, harness satin, or leno weaves. (ii) Fiber yarns woven into a fabric of any two-dimensional weave pattern. Warp and weft tracer fibers of another material may be incorporated into the fabric.

3.3.5. Layered Laminate (or Layered FABRIC) - When two or more plies, either of the same or different materials, are bonded and stacked one on top of the other to act as a single structural layered element, then this structural element is called a layered laminate.

3.3.6. Chopped Strand Mat - A mat formed of strands cut to a short length, randomly distributed, without intentional orientation, and held together by a binder.

3.3.7. Weft - The transverse threads or fibers in a woven fabric. Those fibers running perpendicular to the warp. Also called fill, filling yarn, or woof.

3.3.8 Warp - The yarn running lengthwise in a woven fabric. A group of yarns in long lengths and approximately parallel. Fabrics are tensioned in the warp direction during weaving. The weft is not tensioned.

3.3.9. Tex - A unit for expressing linear density equal to the mass or weight in grams of 1000 m of filament, fiber, yarn, or other textile strand.

3.3.10. Woven Fabric - Rovings woven in 0° and 90° direction.

3.3.11. Continuous Mat - Endless rovings or filaments that are glued together without a direction.

3.3.12. Chopped Strand Mat - Cut rovings or filaments that are glued together without a direction.

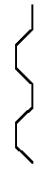
3.3.13. Gauge - The number of stitches per inch (25.4mm) in weft direction.

Example:

Gauge 10: stitches every 0.1 inch (2.5 mm)
Gauge 5: stitches every 0.2 inch (5 mm)

3.3.14. Length of Stitching - The distance between one cut and the next, in inches (or mm).

3.3.15. Kinds of Stitches - Common styles of stitches for layered fabrics are as follows. Other stitching combinations are possible. But the tricot and warp stitches are the most commonly used.

Tricot	Warp	Tricot & warp
Stitching in a zig-zag pattern	Stitching in a line	Stitching in line and then to the side
		

3.3.16. Areal Weight - The weight of fiber per unit area (width X length) of tape or fabric.

4. ENGINEERING REQUIREMENTS

4.1. Class A: Unidirectional fabric

Property	Requirement	Test Method
Gaps	(1)	5.2.1
Stitching:		
Style	Tricot	3.4.15
Gauge, stitches per inch weft	7	3.4.13
Length of missing stitches	(2)	5.2.3
Distortion, tolerance, percent		5.2.4
Length	– 0.1 %	
Width	+ 0.1 %	
Fraying	(6)	5.2.5

(1) The rovings must place together in 0° direction on an even surface without any gaps over the whole material. On one side of the material, chopped strands with a typical areal weight of 50g/m² are placed to stabilize the layered rovings.

(2) The discontinuity in one stitching line shall be less than 1 meter. Additionally the roving must be fixed on both sides at the beginning of the missing stitches. No more than one missing stitching over the whole width and on a length of 5 meter shall be allowed.
(6) In cutting a right angle from 0° direction of the layered fabric, fraying longer than 5 mm is not allowed. Fraying longer than 50 mm in a cutting angle between 0° and 90° is not allowed.

4.2. Class B: Biaxial fabric

Property	Requirement	Test Method
Gaps	No gaps allowed	5.2.1
Stitching:		
Style	Warp	3.4.15
Gauge, stitches per inch weft	(4)	3.4.13
Variation of fiber direction:		5.2.2
– 45° direction	± 2°	
+ 45° direction	± 2°	
Length of missing stitches	(2)	5.2.3
Distortion, tolerance, percent		5.2.4
Length	– 0.1 %	
Width	+ 1.0 %	
Fraying	(7)	5.2.5

(2) The discontinuity in one stitching line shall be less than 1 meter. Additionally the roving must be fixed on both sides at the beginning of the missing stitches. No more than one missing stitching over the whole width and on a length of 5 meter shall be allowed.
(4) A gap is the distance between 2 rovings bigger than 0.5 mm. The gap shall be less than 2.5mm. Not more than 7 gaps on a line of 0.5m in the width. The maximum sum of all gaps along the one-meter line must be less than 5mm.
(7) In cutting fabric, fraying longer than 10 mm is not allowed.

4.3. Class C: Triaxial Fabric

Property	Requirement	Test Method
Gaps	(5)	5.2.1
Stitching:		
Type 1:		
Style	Tricot-Warp	3.4.15
Gauge, stitches per inch weft	5	3.4.13
Type 2:		
Style	Tricot-Warp	
Gauge, stitches per inch weft	5	
or		
Style	Tricot	
Gauge, stitches per inch weft	9	
Variation of fiber direction:		5.2.2
– 45° direction	± 2°	
+ 45° direction	± 2°	
Length of missing stitches	(2)	5.2.3
Distortion, tolerance, percent		5.2.4
Length	– 0.1 %	
Width	+ 0.1 %	
Fraying	(6)	5.2.5

(2) The discontinuity in one stitching line shall be less than 1 meter. Additionally the roving must be fixed on both sides at the beginning of the missing stitches. No more than one missing stitching over the whole width and on a length of 5 meter shall be allowed.

(5) A gap is the distance between 2 rovings bigger than 1.0 mm. The gap shall be less than 0.5 mm. Not more than 15 gaps on a line of 1.0 m in the width. The maximum sum of all gaps along the one-meter line must be less than 20mm.

(6) In cutting a right angle from 0° direction of the layered fabric, fraying longer than 5 mm is not allowed. Fraying longer than 50 mm in a cutting angle between 0° and 90° is not allowed.

4.4. Class D: Woven fabric

4.4.1. This glass fabric material is a combination of E-glass and polyester yarn.

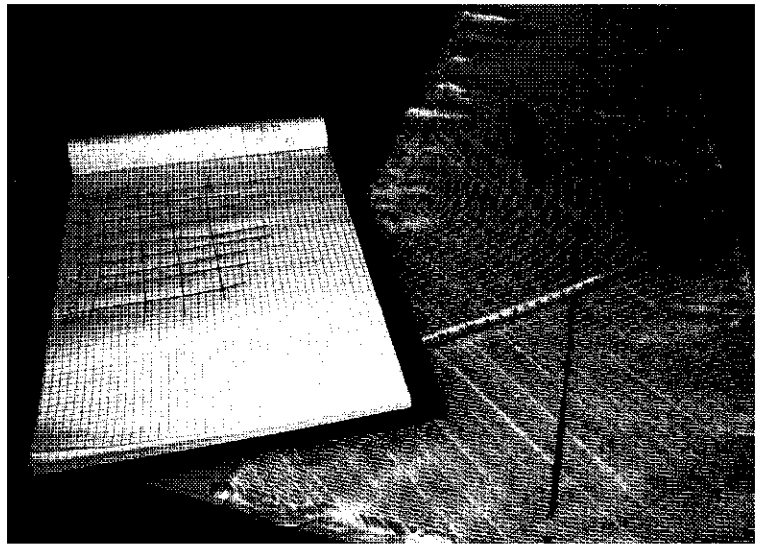
Property	Requirement	Test Method
Distortion, tolerance, percent		5.2.4
Length	– 0.1 %	
Width	+ 0.1 %	

5. TEST AND INSPECTION REQUIREMENTS

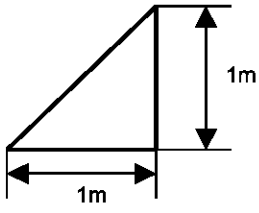
5.1. Introduction and General Guidelines - Glass fabrics are delicate materials, which require care in handling. Each handling step can be considered as a modification of the material. Wind turbine rotor blades are classified as structural components. Consequently, the glass fabric reinforcements in these glass epoxy composites must pass rigorous quality criteria. Control of material defects and allowable tolerances is essential. Many quality defects can arise merely as a result of incorrect cutting and handling of the glass fabrics.

5.2. Inspection Test Methods

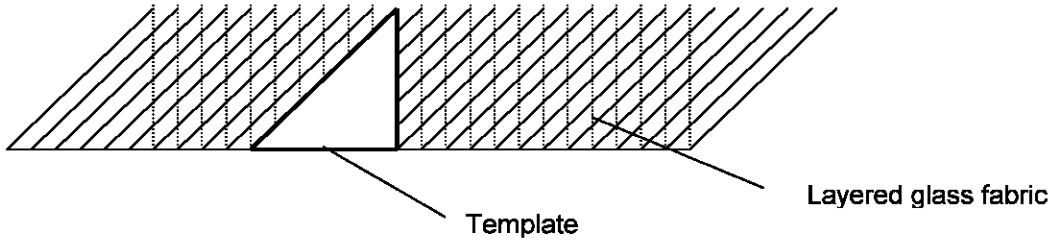
5.2.1. Gaps - To measure the quality and the quantity of gaps in a biaxial layered fabric, or in the biaxial part of a triaxial-layered fabric, draw a line across the fabric in the width in the area of the most gaps. The length of the gap is measured perpendicular to the direction of the fiberglass roving. Count all gaps, longer than 0.5mm or as defined by the specification. Measure perpendicular to the direction of the glass fabric, crossing the line.



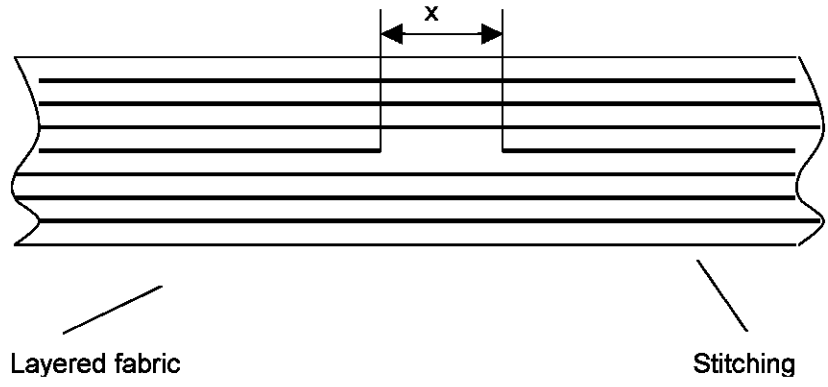
5.2.2. Fiber Direction - Only the biaxial and 90° fiber directions are necessary to be measured. Make a template in a form of a right-angle triangle with the length of sides as 1 meter.



Use this template to measure fiber direction of rovings in the ±45° and 90° directions according to the following drawing.

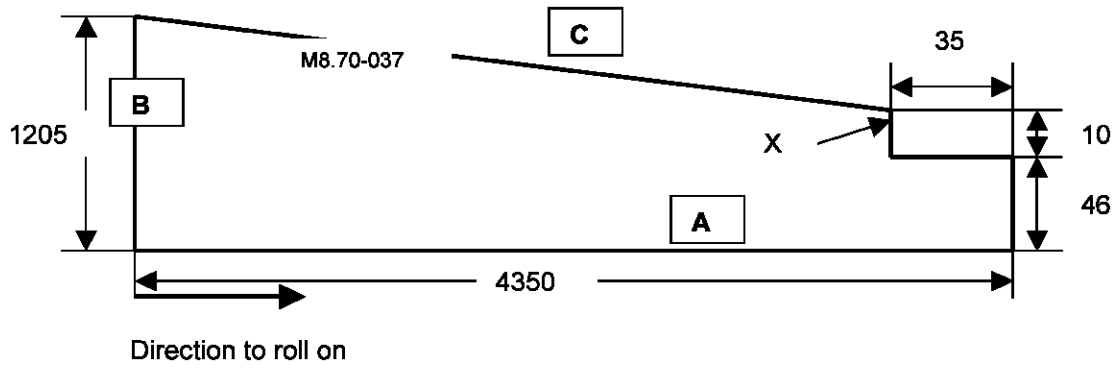


5.2.3. Length of Missing Stitches - Missing stitches are measured in the length direction of the roll from the layered fabric. The roving must be fixed on both sides at the beginning of the missing stitching. Count the number of missing stitches on a length of 5 meters of layered fabric.



5.2.4. Distortion - Cut the fabric layer by electrical hand cutter exactly to size, according to the following drawing (template) (tolerance ± 5mm). Side A of the template must be placed exactly on one edge of the glass fabric. Roll on the fabric layer after cutting. Begin with side B to roll on the layer.

(Dimensions in mm.)



Roll off the fabric layer 24 hours later and compare the dimensions given in the drawing with the sizes from the layered fabric. The X-Point is the fix point to start measuring in the length and the width.

5.2.5. Fraying - (This test is only for triaxial fabric layers with rovings in 0° direction.) Cut triaxial fabric layer as shown above, template M8.70-037. Roll the glass on a core with a diameter of 100mm. Roll off the glass, 24 hours later.

a. Count rovings in 0° direction that are protruding in longitudinally from the layered fabric.

b. Count rovings in 0° direction that are protruding from side C of the layered fabric.

5.2.6. Measurement of Width of Glass Fabric Roll

a. New manufactured glass fabric rolls:
Measure the width of a roll from stitching to stitching without fringes.

b. Cutting fiberglass rolls:
Measure the width of a roll from cut to cut.

6. NOTES

6.1. Roving

6.1.1. Roving Specifications - The weight, the filament diameter, the type of sizing and the type of the roving (E-glass, S-glass, AR-glass, etc.) is necessary to specify a roving. The weight of the roving is given in "tex", the weight in grams per kilometer. Filament diameter is specified in micrometers (μm).

On the surface of the glass filaments is a thin film of sizing or "finish". There are different sizings for different resin types. The sizing connects the filaments and aids in the bonding of fibers to the matrix resin. Additionally the sizing makes the filaments flexible and elastic. The mass of the sizing on a filament is given as a percentage of the weight of a roving.

6.2. Fabrics

6.2.1. Layered Fabric - Rovings are positioned in the desired direction and stitched together with a yarn. Directions from unidirectional to multi-axial are possible. Sometimes the fabric is stitched together with a chopped strand mat for a higher stability during handling.

6.2.1.1. Advantages:
- High mechanical properties
- Unidirectional fabrics are possible
- More different directions are possible

6.2.1.2. Disadvantages:
- More expensive than a woven fabric
- A stitching is used

6.3. Stitching in a Layered Fabric - To fix the layered rovings together in the different directions, a stitching is necessary. A polyester yarn is used for the stitching.

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