

Test report of TG3, describing the material, laminates and test

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Confidential



TG3

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Change record

Issue/revision	date	Pages	Summary of changes
draft		Na	na

1 Identification of extreme conditions relevant for wind turbines

Together with manufacturers and users the extreme conditions are identified. Especially the erection of wind turbines in hot regions (deserts), in arctic regions and in offshore positions necessitates a deeper understanding of the influences from environments. Temperature fluctuations, influences from humidity, chemical attacks, erosion and the combined effects are expected to be the main degradation factors.

Four environmental conditions are selected. The effect of these on the mechanical properties of both, reference and alternative materials will be experimentally investigated and compared. The work package, WP8, deals with characterization of reference material. The selected environmental conditions are listed in Table 1.

Table 1.

Extreme Conditions		
#	Environmental conditions	Remarks
1	Ambient room conditions	Reference
2	Temperature T=+60C	Extreme
3	Temperature T=-40C	Extreme
4	Humidity*	Extreme

* - Humidity – Test samples will be immersed in water and kept for 6 month and 12 month at ambient room temperature. The actual water take up will be measured by weight. The chemical composition of water and experimental procedure are according to standard ASTM D 1141-98, "Standard Practice for Substitute Ocean Water".

2 Test program

Types of tests that are used for each of the extreme conditions, listed in Table 1, are given in this section. Selected types of tests are given in Table 2. Each description of test type consists of test method, measurements, laminate used for test, and applicable standard. The geometries of test specimens are given in corresponding subsection of test method, such as "Static testing" and "Fatigue testing".

Table 2.

Types of tests						
#	Test method	Measurements	Laminate	Number of specimens	Applicable standards	Notes
1	Static tensile	EL, UTS, D(e)	[0]n	5	ISO 527/4(5)	Geometries of the specimens are given with description of test methods
2	Static tensile	EL, UTS, D(e)	[90]n	5	ISO 527/4(5)	
3	Static tensile	USS, D(e)	[30]n	5	ISO 527/4(5)	
4	Static tensile	Ex, D(e)	[0, ±45m]s	5	ISO 527/4(5)	
5	Static Iosipescu	GLT	[90]n	5	D 5379-93	
6	Static compression	UCS	[0]n	5	ISO 604	
7	Static compression	UCS	[90]n	5	ISO 604	
8	Fatigue, T-T (R=0.1)	S-N, D(N)	[0]n	15 (5)*	D 3479M-96	
9	Fatigue, T-T (R=0.1)	S-N, D(N)	[0, ±45m]s	15 (5)*	D 3479M-96	
10	Fatigue, T-C (R=-1.0)	S-N, D(N)	[0]n	15 (5)*	D 3479M-96	
11	Fatigue, T-C (R=-1.0)	S-N, D(N)	[0, ±45m]s	15 (5)*	D 3479M-96	
12	Fatigue, T-C (R=-1.0)	S-N, D(N)	[0]n	___ (5)*	D 3479M-96	
13	Fatigue, T-C (R=-1.0)	S-N, D(N)	[0, ±45m]s	___ (5)*	D 3479M-96	
14	Fatigue, C-C (R=10)	S-N, D(N)	[0]n	15 (5)*	D 3479M-96	
15	Fatigue, C-C (R=10)	S-N, D(N)	[0, ±45m]s	15 (5)*	D 3479M-96	

* - 15 specimens are tested for Reference conditions, and 5 specimens for following extreme conditions.

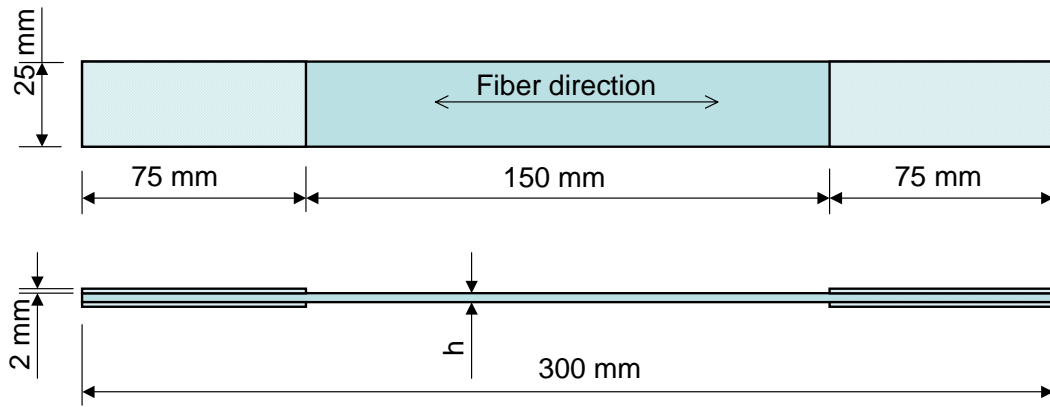
m,n- Number of layers used in laminates. Must be specified according to layer thickness and thickness of laminate for particular geometry.

All test results will be reported in the database, OptiDat, as soon as the tests are accomplished. Test reports, including data, figures and photographs will be prepared after a complete set of tests has been finished.

3 Static testing

3.1 Tensile tests

Tensile tests are performed using two types of geometries in general, ISO standard geometry, used for all laminates, and Optimat Blade specimen, R03 for UD laminates and R04 for MD laminates. Two geometries are used in order to compare the performance of the Optimat Blade specimen with respect to standard test setup. The geometries of the test specimen are given in Figure 1 - Figure 3. Tests, regarding the loading conditions, are carried out according to ISO 527/4(5) standard. Strain in loading direction is measured with strain gauges or extensometers, and strain in transverse direction is measured with single strain gauge placed on one side of specimen, or with transverse extensometer. Successive loading and unloading with increasing applied strain for each step will be used in order to measure damage tensor, D(e). Elastic properties of undamaged material are measured within applied strain of 0.05%-0.25%. Standard test machines with standard hydraulic or mechanical grips are to be used.

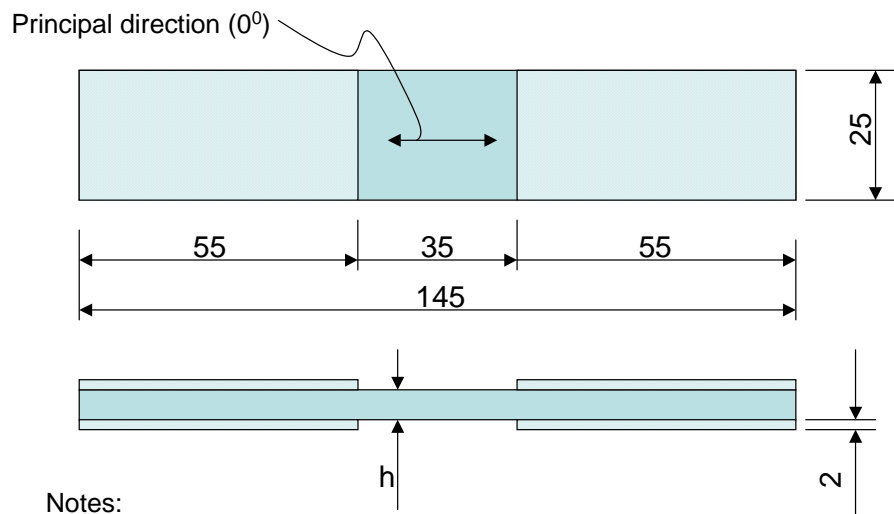


Notes:

ISO-527-5 / Riso / UD / 0 / T

- | Indicates on specimen with TABs
- | Fiber orientation with respect to applied load
- | Type of laminate used
- | Indicates that there are modifications made that deviate the specimen from ISO standard

Figure 1. Tensile test specimen, ISO-527-5/ Riso/ UD/ 0/ T.

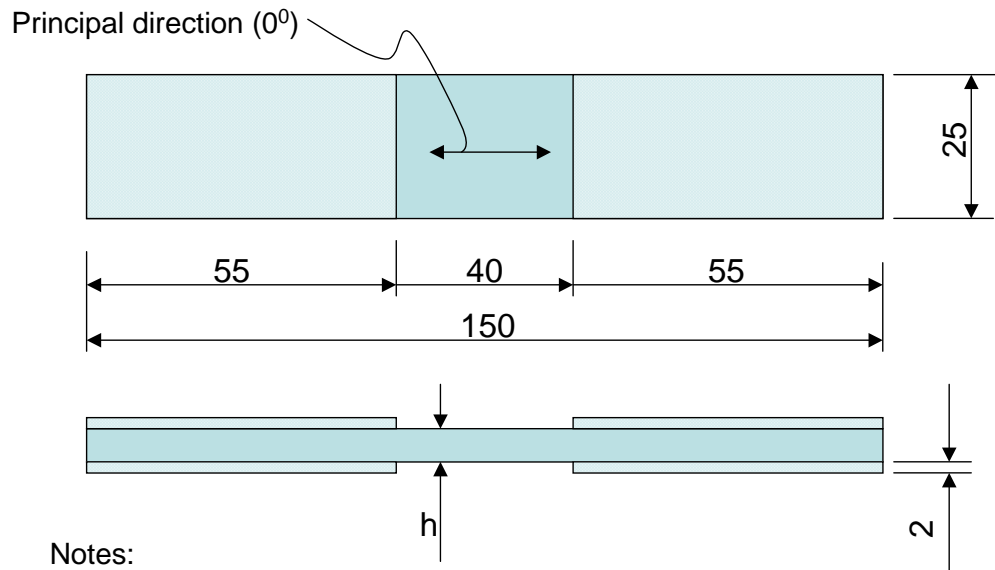


Notes:

R03 / UD / 0 / T

- | Indicates on specimen with TABs
- | Fiber orientation with respect to applied load
- | Type of laminate used
- | Optimat standard specimen

Figure 2. Optimat Blade specimen R03/ UD/ 0/ T.



Notes:

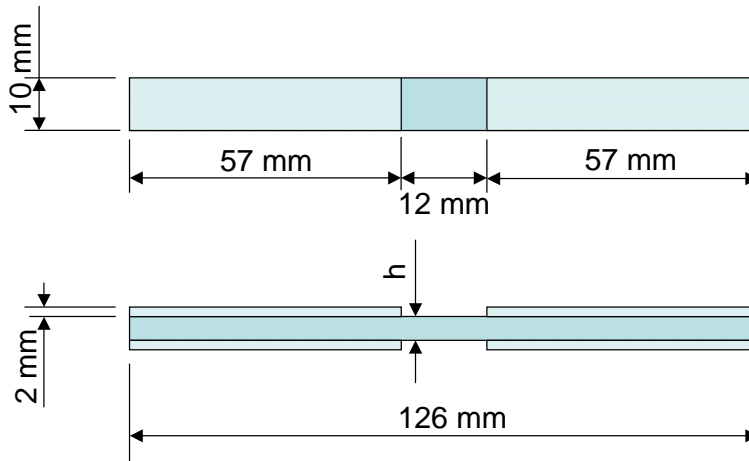
R04 / UD / 0 / T

| Indicates on specimen with TABs
 | Fiber orientation with respect to applied load
 | Type of laminate used
 | Optimat standard specimen

Figure 3. Optimat blade specimen R04/ UD/ 0/ T.

3.2 Compression tests

Compression tests, similarly as tensile test before, are performed on two geometries in general, given in Figure 2, Figure 3 for Optimat specimen, and Figure 4 for Riso standard specimen used for compression test. Special test fixture is used, which combine side and end loading of the specimen. Two strain gauges are placed buck to back on the sides of specimen, in order to measure strain and control the alignment of specimen during the test. Tests are carried out according to ISO 14126 standard. Elastic properties of undamaged material are measured within applied strain of 0.05%-0.25%.



Notes:

ISO- 14126 / Riso UD / 0 / T

| Indicates on specimen with TABs

| Fiber orientation with respect to applied load

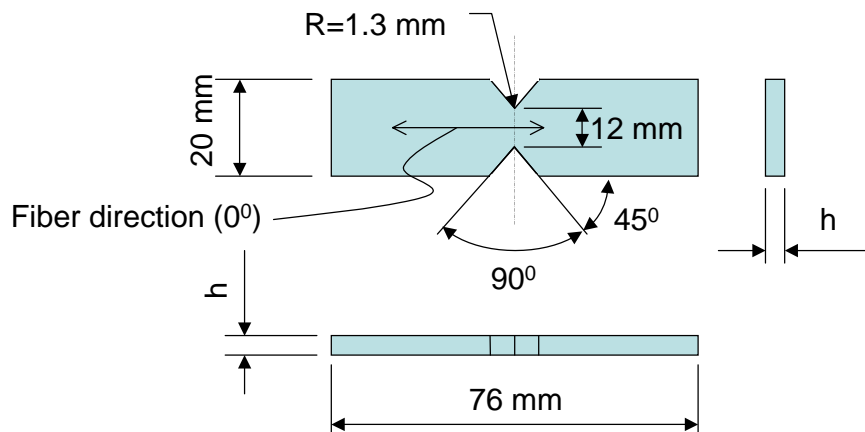
| Type of laminate used

| Indicates that there are modifications made that deviate the specimen from ISO standard regarding Riso fixtures

Figure 4. Compression test specimen, ISO 14126/ Riso/ UD/ 0/ T, Risø Fixture.

3.3 Iosipescu shear tests

Iosipescu shear tests are performed according to D 5379-93 standard. The specimen geometry that will be used for the test is given in Figure 3.



Notes:

ASTM D-5379M-93 / 0

| Fiber orientation with respect to applied load

Figure 5. Iosipescu shear test specimen, D 5379M-93/ 0.

3.4 Fatigue testing

Fatigue tests also are performed using two geometries. Mentioned already before, Optimat specimens, R03 and R04, given in Figure 2 and Figure 3 respectively, and Riso dog-bone specimen, Figure 4. Riso carries out tests with Riso specimen, and rest of the partners are using the Optimat specimen, so that the performance of the Optimat specimen in fatigue can be compared with Riso specimen, with which Riso has an extensive experience of testing and obtaining good, reliable results. Important to mention here, that the geometry of the tested volume is approximately the same for all geometries. Load and displacement are measured throughout the fatigue test. Thereby any stiffness degradation as function of number of cycles, $D(N)$, can be monitored during the tests.

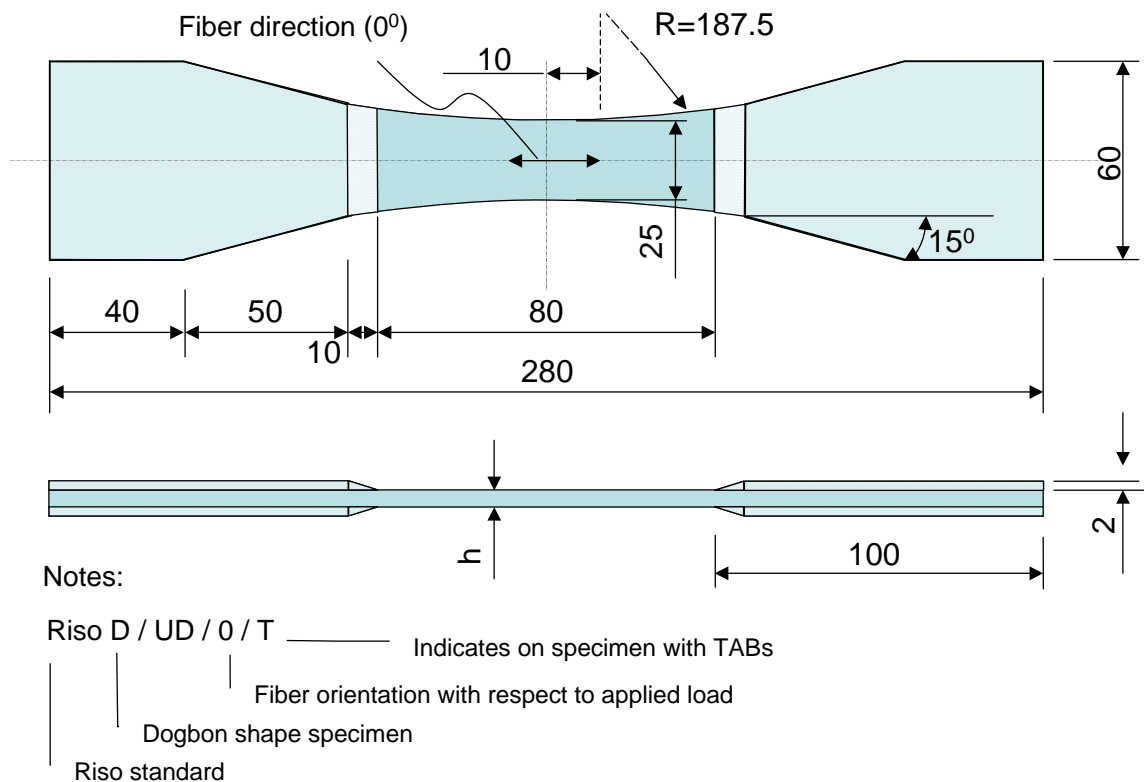


Figure 6. Fatigue test specimen, Riso D/ UD/ 0/ T, for grips with anti-buckling support, Risø Standard.

4 Evaluation

The results for extreme conditions are compared with results of reference conditions, and effects of environmental conditions on mechanical properties are identified.