Reliable optimal use of materials for wind turbine rotor blades

Optimat Blades
(ENK6-CT-2001-00552)

Test program for basic material under extreme conditions

(Detailed Plan of Actions, 1st draft)

Task group 3: Investigation of blade material behavior under extreme conditions

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Nomenclature

E_L - Young's modulus in fiber direction.
E_T - Young's modulus in transverse direction.
G_{LT} - Shear modulus
σ_L^+ - Tensile strength of UD in fiber direction
σ_T^+ - Tensile strength of UD in transverse direction
σ_L^- - Compression strength of UD in fiber direction
σ_T^- - Compression strength of UD in transverse direction
$\sigma_{LT}^{\pm}$ - Shear strength of UD
S-N - Fatigue life diagram S-N
$D(\varepsilon)$ - Damage tensor as a function of applied strain, defined as E_{x0} / E_x
$D(N)$ - Damage tensor as a function of number of cycles, defined as E_{x0} / E_x
R - Applied stress ratio, $R = \sigma_{\min} / \sigma_{\max}$

Selected extreme conditions and test program

Within the framework of "Task group 3", four environmental conditions are selected with respect to what the mechanical properties of basic material will be experimentally investigated and compared. There are four environmental conditions selected and corresponding test series are used as listed in Table 1. Each test series is represented by selected types of tests, listed in Table 2, in order to obtain all the mechanical and fatigue properties of interest.

Table 1. The list of environmental conditions.

#	Environmental conditions	Test series	Notes
1	Ambient room temperature and humidity	Test series-1	Reference conditions
2	Temperature T= +60 C	Test series-2	Extreme conditions
3	Temperature T= -40 C	Test series-3	Extreme conditions
4	Humidity*	Test series-4	Extreme conditions

* Humidity – Test samples will be immersed in water and kept for one year at room temperature. The actual humidity will be measured before test.

Each S-N curve will be represented with 15 measurements (experimental points on S-N curve) at different applied stress levels for Test series-1. The number of measurements is reduced to 5 for Test series 2-4. The targeted number of cycles for fatigue tests will be 10^4-10^7 cycles. The frequency of 5Hz-10Hz will be used. Strain and load will be measured throughout the fatigue test.

Table 2. List of test types and its description used for test series.

Test type	Test type description		Specimens			Number of specimens to be tested (**)	Number of specimens to manufacture	Applicable standards
	Test method	Measurements	Specimen type	Laminate	Geometry(*)			
1	Static tensile	E_L, σ_L^+, D(ε)	1	[0]n	1 (1)	5	7	ISO 527/4
2	Static tensile	E_T, σ_T^+, D(ε)	2	[90]n	1 (1)	5	7	ISO 527/4
3	Static tensile	σ_{LT}^+	3	[30]n	1 (1)	5	7	ISO 527/4
4	Static tensile	E_x, $D(\varepsilon)$	4	[0n ± θ m]s	1 (1)	5	7	ISO 527/4
5	Static Iosipescu	G_{LT}	5	[90]n	4 (4)	5	7	D 5379-93
6	Static compression	σ_L^-,	6	[0]n	2 (2)	5	7	ISO 604
7	Static compression	σ_T^-,	7	[90]n	2 (2)	5	7	ISO 604
Total in static tests for Test series-1			7			35	49	
Total in static tests for all Test series			7			140	196	
7	Fatigue T-T (R=0.1)	S-N, D(N)	8	[0]n	3 (3)	15 (5)	17 (7)	D 3479M - 96
8	Fatigue T-T (R=0.1)	S-N, D(N)	9	[0n ±θm]s	3 (3)	15 (5)	17 (7)	D 3479M - 96
9	Fatigue T-C (R=-1.0)	S-N, D(N)	8	[0]n	3 (3)	15 (5)	17 (7)	D 3479M - 96
10	Fatigue T-C (R=-1.0)	S-N, D(N)	9	[0n ±θm]s	3 (3)	15 (5)	17 (7)	D 3479M – 96
11	Fatigue C-C (R=10)	S-N, D(N)	8	[0]n	3 (3)	15 (5)	17 (7)	D 3479M - 96
12	Fatigue C-C (R=10)	S-N, D(N)	9	[0n ±θm]s	3 (3)	15 (5)	17 (7)	D 3479M – 96
Total in fatigue tests for Test series-1			2			90	102	
Total in fatigue tests for all Test series			2			120	144	

θ - To be gives by manufacturer.
m, n – Number of layers used in laminates. Must be specified according to layer thickness and thickness of laminate for particular geometry.
(*) - Number of Figure where the corresponding geometry of the specimen is given

(**) – Number of specimens used for Test series 2-4

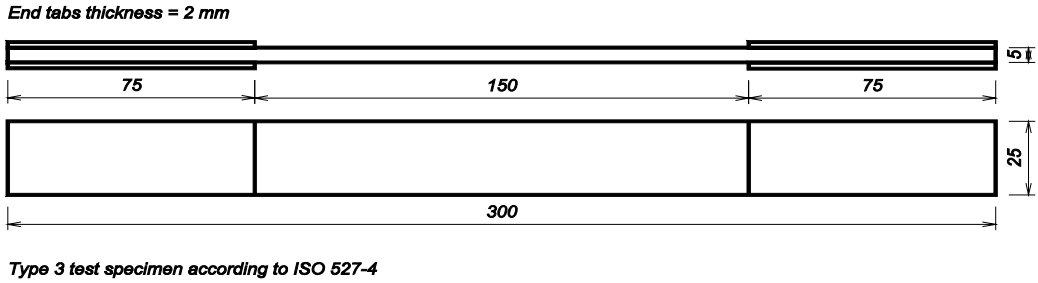

Figure 1. Tensile test specimen, ISO 527/4, (Geometry 1).

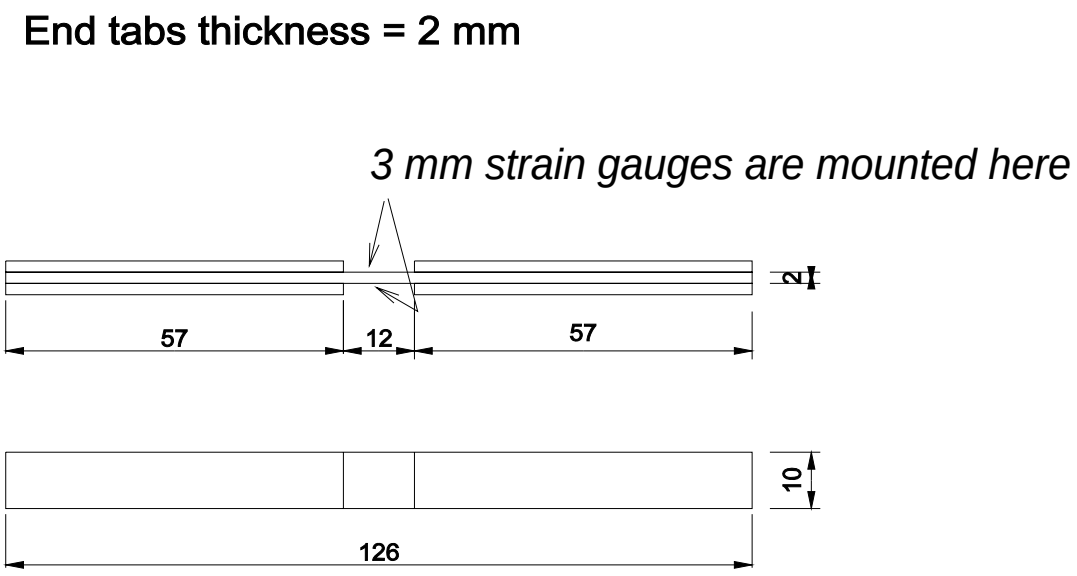

Figure 2. Compression test specimen, ISO 604 CFRP, Risø Fixture, (Geometry 2).

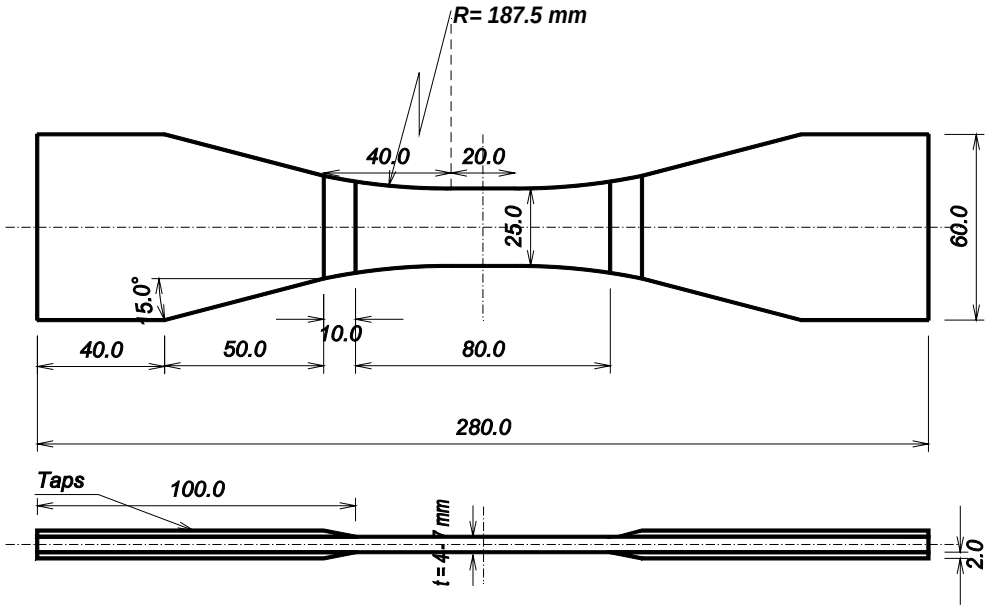

Figure 3. Fatigue test specimen, Long Risø Standard, (Geometry 3).

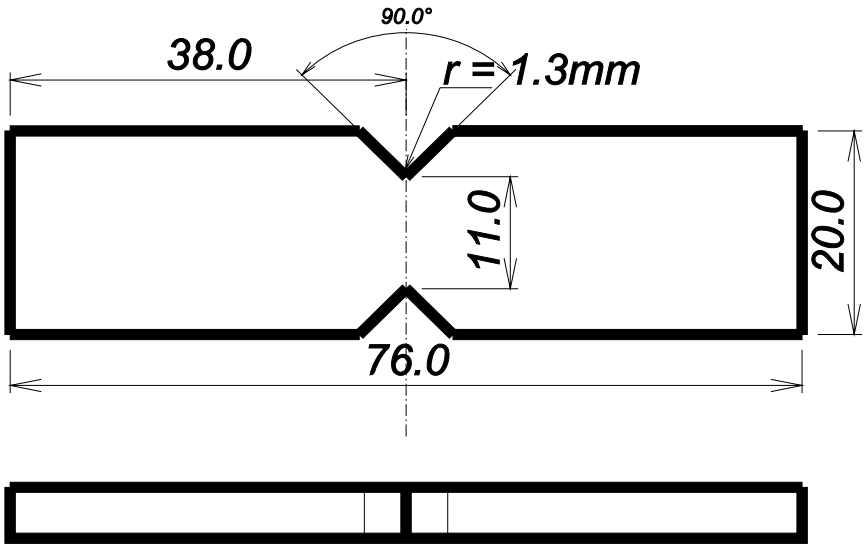

Figure 4. Iosipescu shear test specimen. (Geometry 4)