Fatigue tests of the MD reference material (GEV207-D02-00) using Risø geometry for the test coupons

21st November 2003

(CA fatigue at reference conditions, R=0.1)

Confidential

OB_TG3_R013_rev0[1]

OPTIMAT BLADES

TG3[2]

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[2]

Issue/revision	date	pages	Summary of change
0	Nov. 21, 2003	Na	Na

1 Introduction

The constant amplitude (CA) fatigue test of GEV207 system in, so called, longitudinal (fiber) direction is carried out, and results are reported in this document. The test has been carried out at ambient room conditions (OPTIMAT reference conditions). The results obtained by using RISOE dog bone shape specimens are presented at this point. The additional test, where the OPTIMAT standard specimens are used will be added, and results will be compared in the future.

This work is a part of the work package 8, OPTIMAT TG3, and is carried out according to DPA of TG3, [2].

2 Specimens and materials

The specimen geometry for the RISOE dog bone specimen is illustrated in Figure 1. The extensometer with the gauge length of $25\,[mm]$ was used to measure the strain through out the fatigue test. The strain-stress hysteresis loops were used later to calculate the stiffness degradation as a function of number of cycles.

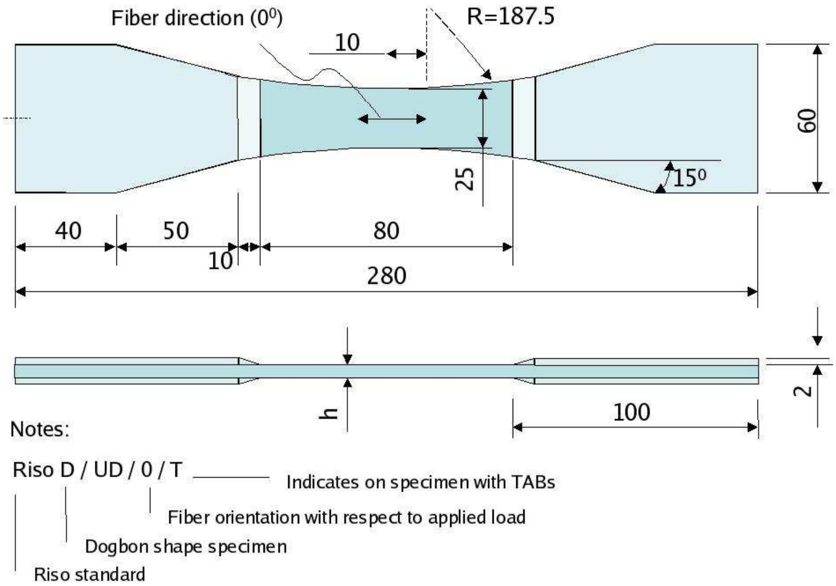

Figure 1: Geometry of the RISOE dog bone specimen.

2.1 Procedures and measurements

Load controlled CA fatigue test was carried out at ambient room temperature. The constant dissipated energy test conditions (constant hysteresis loop) were used. The whole cycle is periodically recorded, recording it more frequently at the end of the life time.

Strain, displacement and load are measured through out the test. The predefined stress or strain levels are irrelevant, but are helpful as they can serve as a guideline for planning and carry out the test. The irrelevance is because different approach is used in order to calculate S-N statistics.

3 Results and discussion

3.1 Static tests

The static tensile tests have been carried out using specimens with ISO geometry. The tests were carried out according to ASTM standard, and the results have been reported in OB_TG3_R007, [3]. The obtained results of the elastic properties and static strength are given in Table 1.

Table 1: Results of the static tensile test, GEV207-I01-00.

Specimen ID	w (mm)	h (mm)	ε_{max} $(\%)$	E_x (MPa)	σ_{max} (MPa)	P_{max} (kN)	P_{min} (kN)	f (Hz)	N_f	Notes
GEV207-I01 00-01	24.78	6.72	2.35	29.30	544.30	90.64	0	1	1	
GEV207-I01 00-02	24.76	6.78	2.54	28.85	555.91	93.32	0	1	1	
GEV207-I01 00-03	24.72	6.72	2.43	29.27	562.52	93.44	0	1	1	
GEV207-I01 00-04	24.69	6.73	2.46	28.00	519.75	86.36	0	1	1	
GEV207-I01 00-05	24.72	6.53	2.30	28.24	545.60	88.07	0	1	1	
GEV207-I01 00-06	24.64	6.64	2.47	30.80	571.89	93.57	0	1	1	
GEV207-I01 00-07	24.72	6.66	2.43	27.27	552.02	90.88	0	1	1	
GEV207-I01 00-08	24.6	6.66	2.57	28.88	584.88	95.82	0	1	1	
GEV207-I01 00-09	24.75	6.63	2.57	28.13	565.00	92.71	0	1	1	
GEV207-I01 00-10	24.71	6.76	2.00	28.31	536.03	89.54	0	1	1	

3.2 T-T fatigue, R=0.1

The number of specimens tested, the corresponding loading and results of fatigue lifetime are given in Table 2.

The fatigue lifetime diagram is presented as $\epsilon - N$ curve, and it is described by power law function, $N = K\varepsilon^{-m}$, also called model. The constants m and K are calculated by fitting the model in log-log scale. Also the 95 confidence limit (tolerance bound) is calculated. The approach proposed by Ronold and Echtermeyer [1] is used for calculating the tolerance bound. Both, the experimental data, and model fit with its tolerance bound is given in Figure 2.

Table 2: Results of the fatigue test, GEV207-D02-00, R=0.1, RT

Specimen ID	w (mm)	h (mm)	ε_{max} $(\%)$	E_x (MPa)	σ_{max} (MPa)	P_{max} (kN)	P_{min} (kN)	f (Hz)	N_f	Notes
GEV207-D02-00-04			0.40					10.0		
GEV207-D02-00-05			0.50					6.4		
GEV207-D02-00-06	24.90	6.70	0.60	26.90	161	26.93	2.69	5.0	2000000	
GEV207-D02-00-07			0.70					3.3		
GEV207-D02-00-08	25.10	6.42	0.80	29.20	204	32.94	3.29	2.5	317880	
GEV207-D02-00-9	25.10	6.40	0.90	29.30	220	35.30	3.53	2.0	159000	
GEV207-D02-00-10	24.90	6.41	1.00	29.50	236	37.67	3.77	1.6	49700	
GEV207-D02-00-11	25.50	6.50	1.10	28.80	245	40.58	4.06	1.3	41000	
GEV207-D02-00-12	24.93	6.58	1.20	28.74	259	42.43	4.24	1.1	16000	
GEV207-D02-00-13	24.80	6.46	1.30	30.20	287	45.96	4.60	0.9	9250	
GEV207-D02-00-14	24.90	6.56	1.40	28.30	283	46.23	4.62	0.8	8500	
GEV207-D02-00-15			1.50					0.7		

The procedure of the fitting the model to experimental data points is straight forward done by linear regression in "log-log" scale. The methodology is also detailed described and discussed in [1]. Nevertheless, for better consistency of this report, it is shortly outlined in section 5. The procedures that are used in order to calculate the tolerance bound are also given by [1] and shortly outlined in 5.

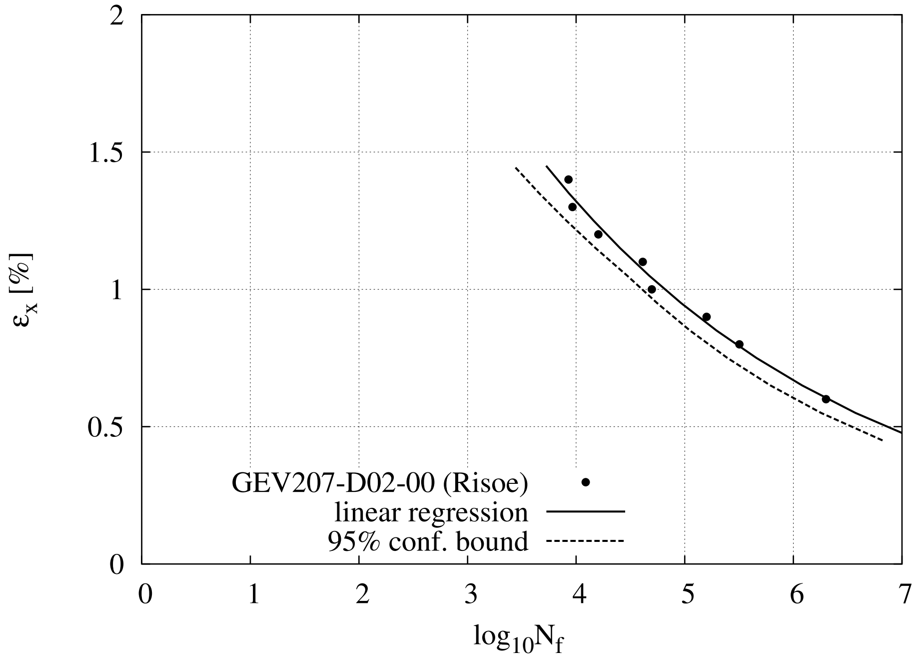

Figure 2: T-T fatigue, R=0.1. Material, GEV206-00. The constants for model are calculated as $N = 4.8153e + 04\varepsilon^{-6.7639}$.

4 Concluding remarks

The CA fatigue tests are carried out for MD of GEV207 at ambient room conditions. The fatigue life diagram is presented as $\epsilon - N$ curve represented with 8 points. Two more points will be added in the future.

The stiffness degradation is measured as function of number of cycles for corresponding applied strain level, but data are yet to bee added to this report.

5 Data reduction

In general the fatigue data can be presented in strain formulation, $\varepsilon - N$ as schematically shown in Figure 3

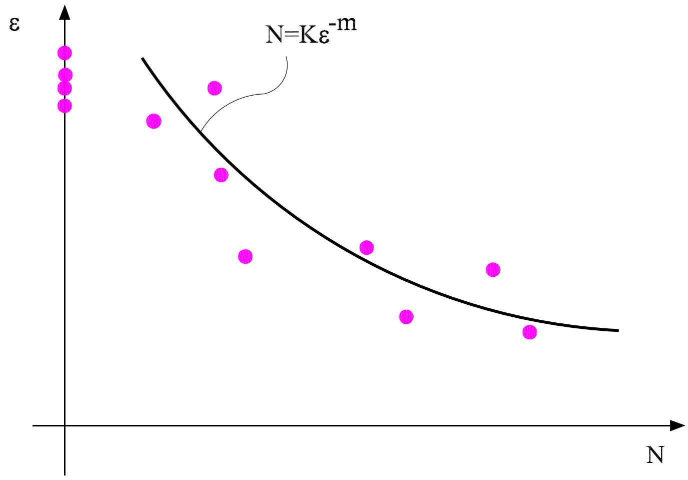

Figure 3: $\epsilon - N$ model.

The relationship between applied strain and number of cycles to failure are assumed to follow a power low function (it is also called, "model")

$$N = K\varepsilon^{-m} \tag{1}$$

where K and m are supposed to characterize material properties. These constants are calculated by using least squares method, fitting (1) as a straight line to experimental data of $\varepsilon - N$ in double "log-log" domain

$$\lg_{10} N = \lg_{10} K - m \lg_{10} \varepsilon. \tag{2}$$

It is easy to see that (2) describes straight line of form

$$y = b - mx, \tag{3}$$

where, $y = \lg_{10} N$, $b = \lg_{10} K$, and $x = \lg_{10} \varepsilon$.
The linear fit of (2) or (3) is shown schematically in Figure 6

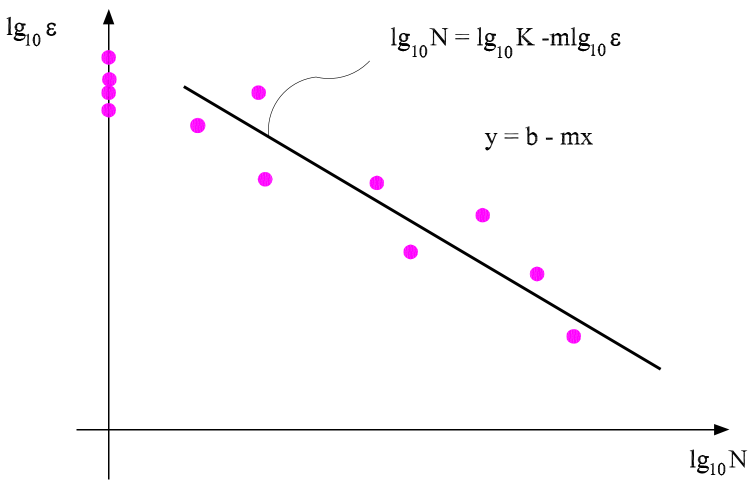

Figure 4: Linear fit in lg-lg domain.

The constants b and m are calculated directly by fitting the (2) or (3) to the data by least squares method, from where constant, K, for the model is calculated as, $K = 10^b$. Further these constants are used back into (1).

The statistical tolerance bound (illustrated in Figure 5) is constructed as for random normal variable

$$Y_i = y\left(x_i\right) \pm c^i_{1-\alpha,\gamma} s, \tag{4}$$

where $y\left(x_i\right) = \lg_{10} N_i$ is given by (2), and the coefficient $c^i_{1-\alpha,\gamma}$ is calculated for any Δx_i as

$$c^i_{1-\alpha,\gamma} = 1.645 + 2.567\left(n-2\right)^{-0.71} + \frac{5.588}{\sqrt{n-2}} \frac{\Delta x_i}{L_x}. \tag{5}$$

The deviation of current value x_i from mean $\overline{x}$ of all data, Δx_i is defined as

$$\Delta x_i = \left|x_i - \overline{x}\right|, \tag{6}$$

and length of the interval within which the all considered data are uniformly distributed is given by

$$L_x = \left|x_{\max} - x_{\min}\right|. \tag{7}$$

The standard deviation used in (4) is calculated according to

$$s = \sqrt{\frac{\sum\limits_i^n \left(y_i - y\left(x_i\right)\right)^2}{\left(n-1\right)}}. \tag{8}$$

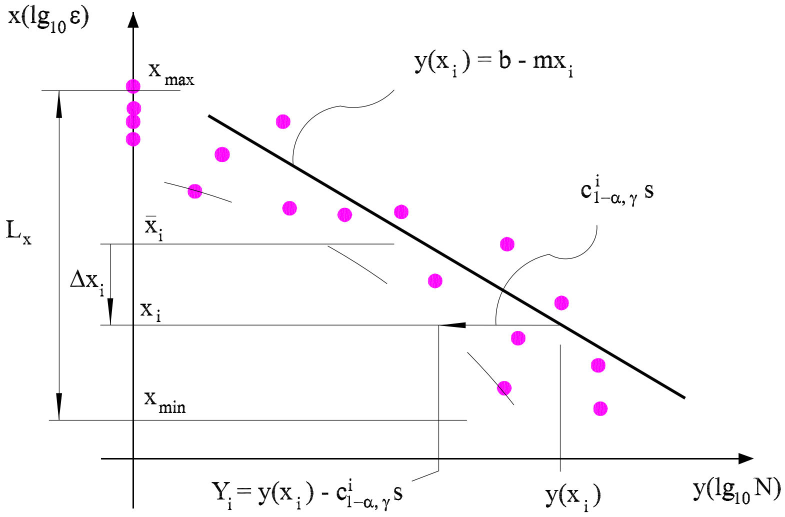

Figure 5:

References

[1] Ronold, K.O. and Echtermeyer, A.T. (1996), "Estimation of fatigue curves for design of composite laminates", Composites Part A, 27A, pp.489-491

[2] OB_TG3_R003, Detailed Plan of Action WP8 and WP9, documen number: 10048.

[3] OB_TG3_R007, Test report, TG3., Static tests of UD and MD using ISO geometries.