Load levels for CA testing

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Confidential

TC

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Change record

Issue/revision	date	pages	Summary of changes
draft	25-09-03	Na	Na
1	25-09-03	4 6	E=26.7 GPa for MD, instead of E=39 GPa). Decision for “initial strain” as “load level” definition made.

1. Introduction

In order to be testing at the same levels, without need for continuous temperature measurement, it is important that all TGs use the same load level and frequency. In order to determine the load level, preliminary S-N lines have been established. Now, we need to fix the load levels and load definitions.

1.1. Notation

A small note on notation first: I've noticed that various people use terms like "S-n line" or "s-n line". I believe the correct notation to be: "S-N line". Perhaps "S-n line" could be possible if your not referring to the total number of cycles somehow……

S stress level.

N number of cycles to failure

n number of cycles at a certain load

1.2. Pre-requisitions for testing

Geoff noted that: "we need a much more formal approach to" the S-N line. TG5 has concluded that continuous temperature monitoring on all coupons in the TG5 test matrix is not feasible….. so the S-N curve/load specification should also include the appropriate test frequencies to limit surface temperature rise to, say, < 10 degrees C. (since most partners cannot control their laboratory temperature, this effectively means that "at risk" tests should not be attempted if the laboratory temperature is > 25 degrees C. - these specific levels can be altered if necessary to fit your existing data, so long as the expected temperature rise is stated along with the load frequency).

A check-list of the "signed off" data (fitted curve, specific loads / lifetimes, confidence intervals) required by TG5 from TG1 is therefore the load/starin/frequency at four levels, corresponding to 10^3, $5{\cdot}10^4$, 10^6 and 10^7 cycles. Note that the specific load levels for 10^7 cycles lifetime can be supplied later, since the shorter lifetime tests will be performed first.

From TG1: UD 0° R = 0.1, -1, -10 and MD R = 0.1,-1,-10

From TG2: UD 90° R = 0.1, -1, -10

1.3. Approach

Olaf noted that" Looking at some email discussions in the past, there seems to be a little bit confusion about the provision of the necessary information for the fatigue testing programme. Originally, it was decided to determine the levels and frequencies with a preliminary S-N-curve (6 data points). For MD (R=-1) this was done by DLR and the results published by email on July 17th. One month later Geoff (TG5) stated, that in his opinion this procedure is not sufficient and proposed that the data should be authorized by TL/TC". Results of fatigue tests are summarized in [1] and [2].

2. Suggested load levels and frequencies

The following load levels are suggested by TG1 to be used for MD:

	N	F_{max}	$\varepsilon_{max}[\mu]$	σ_{max}[MPa]	f [Hz]	Remarks
MD	R=-1	TG1				LogS=2.7524-0.1036*log(N)
Level 1	10^3	45.8	10300	275	0.62	
Level 2	$5{\cdot}10^4$	31.3	6900	185	1.37	
Level 3	10^6	22.5	5100	135	2.57	
Level 4	10^7	17.5	3900	105	4.25	No test data
MD	R=0.1	TG1				LogS=????????????
Level 1	10^3	66.0	14600	390	1.52	
Level 2	$5{\cdot}10^4$	44.0	9700	260	3.42	
Level 3	10^6	32.8	7300	195	6.09	
Level 4	10^7	26.1	5800	155	9.63	No test data

Notice that the above use the Energy rule, discussed at the TC meeting in VUB [1]. Olaf used [4] with 3 Hz as reference frequency and 125 MPa as reference amplitude, this method is based on the energy method: $\Delta T = f(\varepsilon^2, f, c_d, t, T_{surface})$. Although Olaf suggested using 250 MPa for MD, R=-1, level 1, due to lower results in the low cycle area (see Figure 1), I feel it's better to stick to the straight S-N definition and use 275 MPa.

As for frequencies: Povl suggested at that same meeting (in line with TUD experience as well):
ε=1%(10000μ) ➔ 5Hz, ε=0.8%➔ 7Hz, ε=0.5% ➔20Hz, ε=1.6% 2Hz.
We can see here that MUCH lower frequencies seem necessary in this case [4]. Povl and Modris also checked the frequency effect for the Risø test specimen

Strains for MD were calculated from E=26.7 GPa: $\varepsilon\,[\mu] = \sigma\,[MPa]/0.0267$.

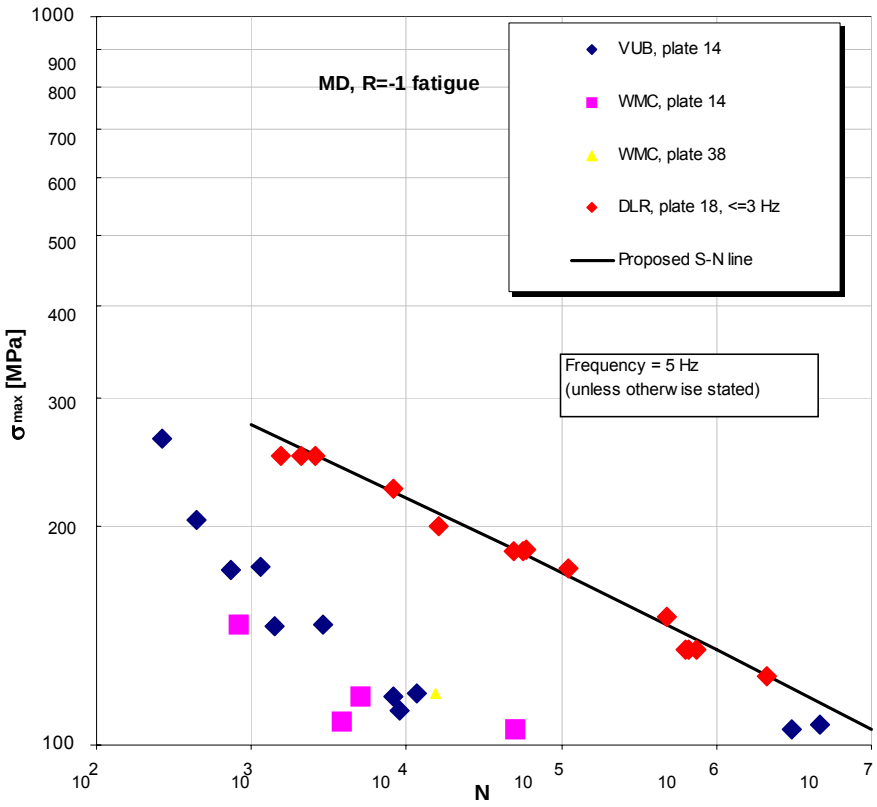

Figure 1 results of MD tests at R=-1

3. Definition of "load" level

In principle, there are four ways to specify the load level:

a. Force levels. This approach is slightly less labour intensive, as one can test a whole series of test specimens at a level. Also testing at a specific force is often easier to accomplish. On the other hand, it includes one source of scatter by failing to take the variation of cross sectional area into account.
b. Stress levels (essentially force levels, but taking variations of cross-sectional area into account).
c. Initial strain levels (which can directly be measured by strain gauges). Strains tend to be useful in laminate theory…
d. Strain levels: during the test, the force range would decrease with the variation of the Young's modulus. However, earlier on we decided to carry out fatigue tests with force control [5].

Since laminate design with plies in different directions is rather simpler than a stress based design and since strains can be directly measured, I favour strains over stresses. Since rotor blades are typically loaded by forces, I'd prefer to use the initial strain method (2c), rather than lowering the load when the Young's modulus decreases.

The TLs of TG1,TG3, TG4 and TG5 expressed support for the concept of initial strain as level to set for tests and as format for presenting results.

4. References

1. OB_TG2_R013, “Static and Fatigue tests on the standard OB UD coupon”, UP http://www.ecn.nl/optimat/optimat-docs/10135_000.pdf
2. OB_TG1_R06, “Benchmark Tests Standard OPTIMAT UD Specimen”, DLR http://www.ecn.nl/optimat/optimat-docs/10139_000.pdf
3. OB_TC_M005, “Minutes of 5th Technical Committee Meeting”, WMC http://www.ecn.nl/optimat/optimat-docs/10133_000.doc
4. OB_TC_N003, “Frequency effects on lifetime”, DLR http://www.ecn.nl/optimat/optimat-docs/10061_001.pdf
5. OB_TC_M002, “Minutes of 2nd Technical Committee Meeting”, WMC http://www.ecn.nl/optimat/optimat-docs/10040_003.doc