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Tensile fatigue of standard OB specimens at 100% Relative Humidity -test results from WMC-

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Change record

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1. Introduction

In the framework of Task Group 3 (Extreme Conditions), material properties at ambient conditions are compared to properties at extreme conditions [1, 2]. The extreme conditions investigated in OPTIMAT are -40° [3], +60° (e.g. [4]), and 100% relative humidity (e.g. [5]).

This document contains details on the 5 UD and 5 MD R=0.1 fatigue tests at 100% Relative Humidity, carried out at WMC in summer 2005. The results can be compared to the results at ambient conditions, obtained throughout the project. The results can also be found in the project database OptiDAT [6].

2. Specimens and test set-up

The test specimens are standard OB specimens GEV206_R0300, and GEV207_R0400 specimens. The nominal dimensions of the standard specimens are found in OptiDAT. Thickness, width, length, and load length were measured, and the coupons were equipped with standard issue clip gauges in a back-to-back configuration.

The R=0.1 fatigue tests were carried out on the 100 kN Schenck test frame with hydraulic grips (grip pressure 200 bar). The load frame and load cell are depicted in Figure 1. An infra-red temperature sensor was installed, which measured the temperature, as prescribed in [7].

Figure 1 Test set-up for 100% relative humidity

Relative Humidity was achieved as depicted in Figure 1. Specimens were mounted dry, or preconditioned in tap water for a few days. The specimen gauge length and clip gauges was surrounded by a container. This container was filled with (tap) water and cotton wool. The water-drenched cotton wool provided a large vaporisation surface, which ensured maximum water content of the air in the closed container. Relative humidity was not measured. A fan was installed as part of the standard test set-up, but in this case the temperature limiting effect could be regarded as negligible, as the container hampered air-flow around the specimen.

The MD specimens were kept under 100% RH conditions prior to testing. The UD specimens were only subjected to 100% RH during the fatigue test.
All tests were done at a single load level, viz. level 3 (nominal life 10^6 cycles), at the frequency and load prescribed in [7]. Collecting results at a single load level ensures sufficient statistical significance to compare average life with that at dry conditions. Level 3 was chosen because these tests take the longest of all standard tests, and the potentially detrimental influence of humidity was expected to take effect only after some time in 100% RH conditions.

Prior to the fatigue loading, a ‘slow’ R=-1 cycle was performed at ±10 kN and 0.02 Hz. The initial tensile and compressive Young’s modulus were derived from this slow cycle. Strain measurements were continuously recorded throughout the fatigue test.

3. Results

All results are uploaded into the project database, OptiDAT. The test results are summarised in Table I. Back-to-back strain measurements are obviously more consistent for the MD specimens. The discrepancy in Young's modulus between front and back of the UD specimens can be attributed to bending/buckling of the specimen.

3.1. *General fatigue test results wet specimens*

In Figure 2 and Figure 3, the results are compared to S-N data at dry conditions.

The plots show the S-N data, and Young's Moduli (only shown if back-to-back measurements were within 10%, see Table I for full data). Figure 2 shows the 'wet' and 'dry' S-N data for coupons tested at WMC, on the same load frame. For the comparison in Figure 3, data were taken from OptiDAT and comprise other labs/test frames. There seems to be a minor detrimental effect of humidity on average fatigue life in MD. The average life for the wet coupons was 751078, the average life for standard OB coupons at level 3 is 1189042 cycles [8]. In addition, Young's modulus is approximately 10% lower for the 100% RH MD specimens than for the dry specimens.

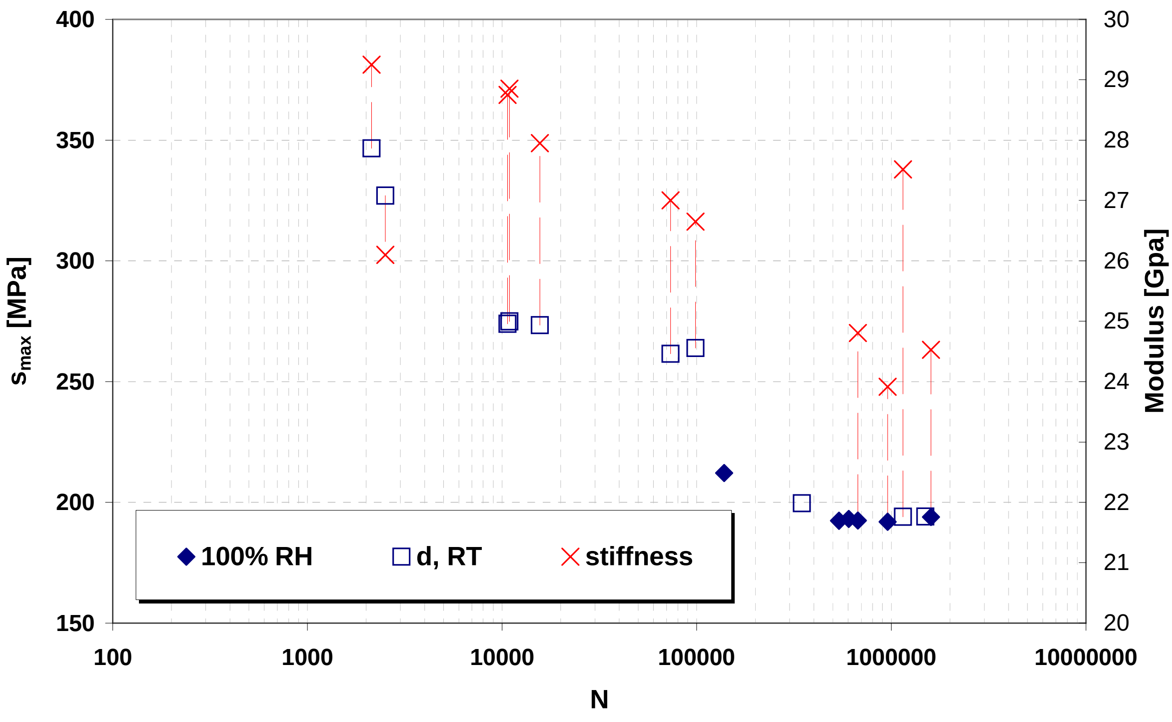

Figure 2 S-N data and stiffness of MD coupons, tested at WMC 100 kN Schenck frame

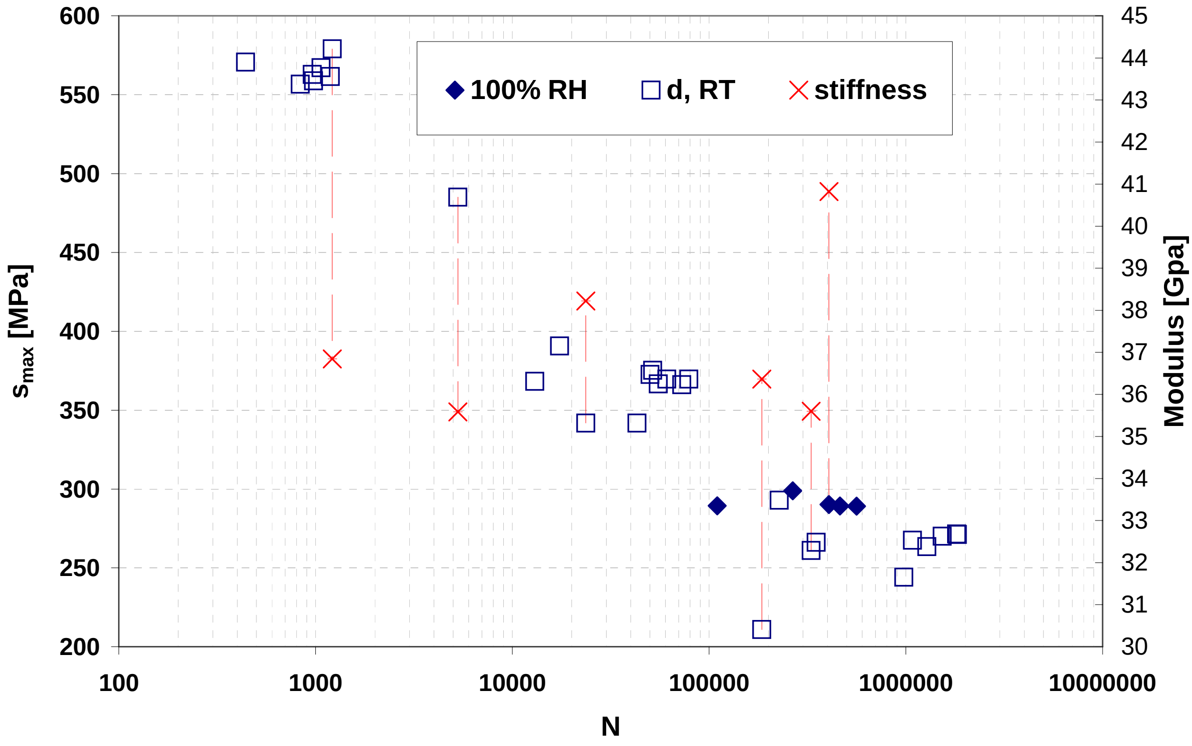

Figure 3 S-N data and stiffness of UD coupons (various machines)

3.2. *Influence of preconditioning*

There is no apparent correlation between the duration of the preconditioning and lifetime, see Figure 4. For UD, the detrimental effect, if any, is even less pronounced; 361327 for the wet specimens (424176, when 906 is excluded, see below) vs 438190 for the dry coupons [8].

Figure 4 Duration of preconditioning of MD specimens vs life and stiffness

Figure 5 to Figure 7 show an example of the ‘slow’ cycle, and the calculation of Young’s modulus through linear regression of the separate strain signals.

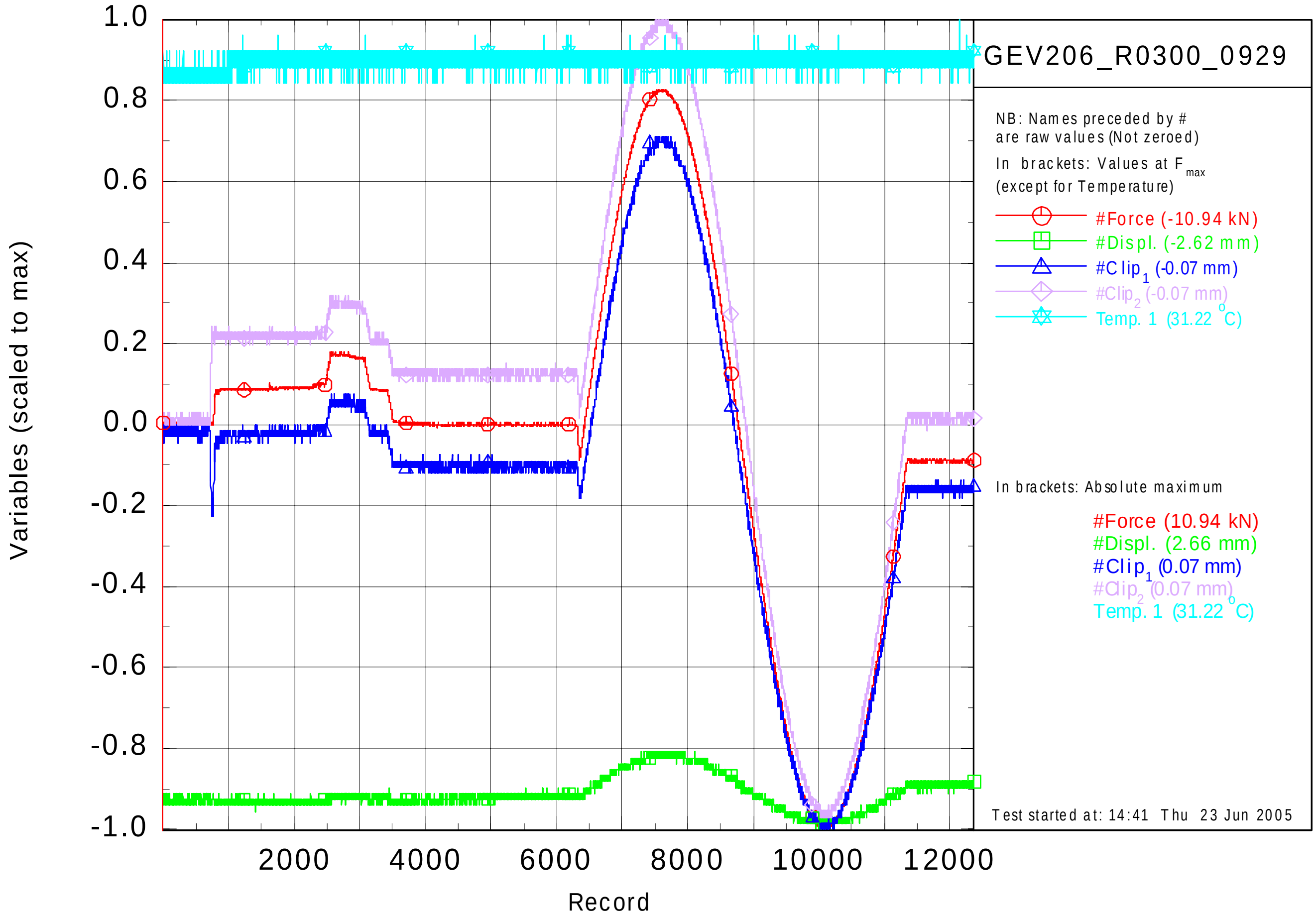

Figure 5 Slow cycle prior to fatigue

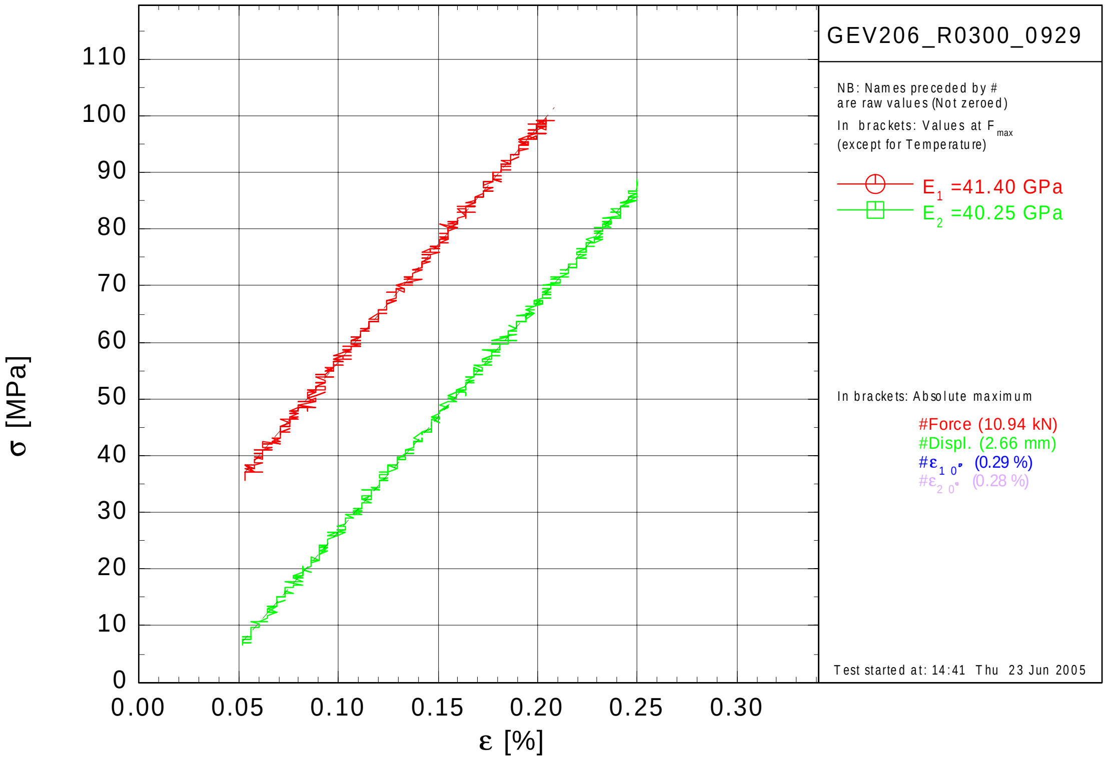

Figure 6 Measurement of tensile modulus during slow cycle prior to fatigue

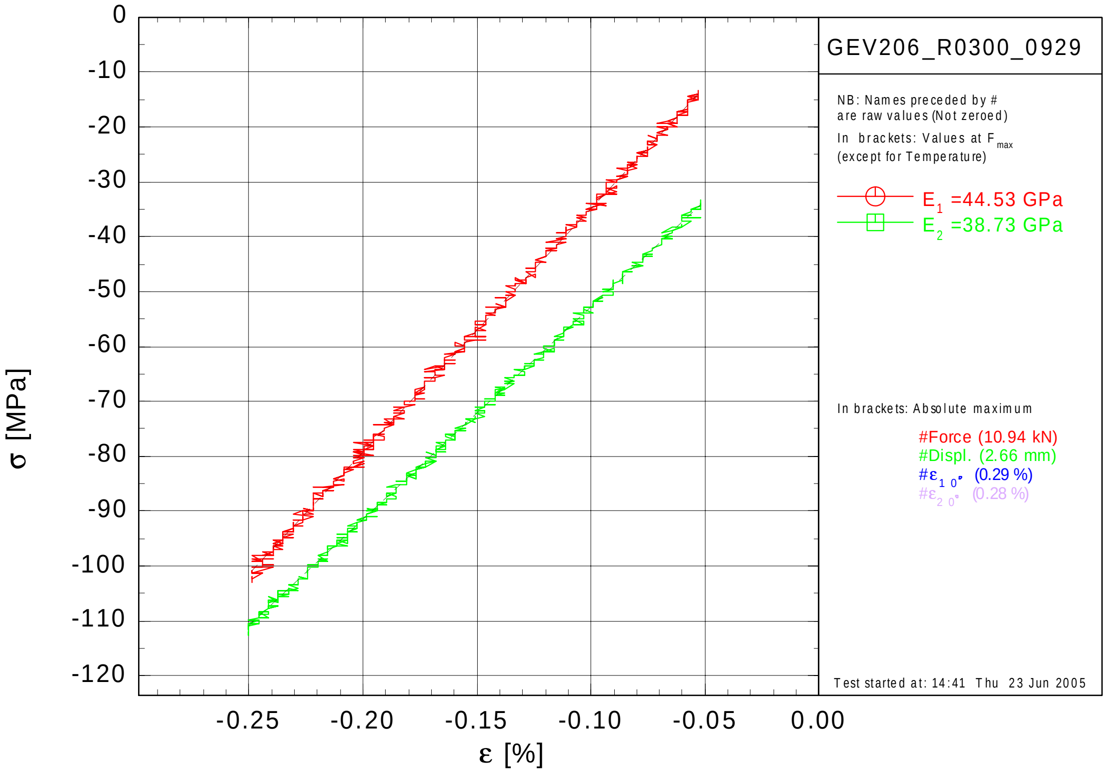

Figure 7 Measurement of compressive modulus during slow cycle prior to fatigue

3.3. *Analysis of the stiffness degradation*

Figure 8 gives an example of property degradation as a function of lifetime at both sides of the specimen. The maximums given in the figure are for raw data (not yet zeroed at the start of the test).

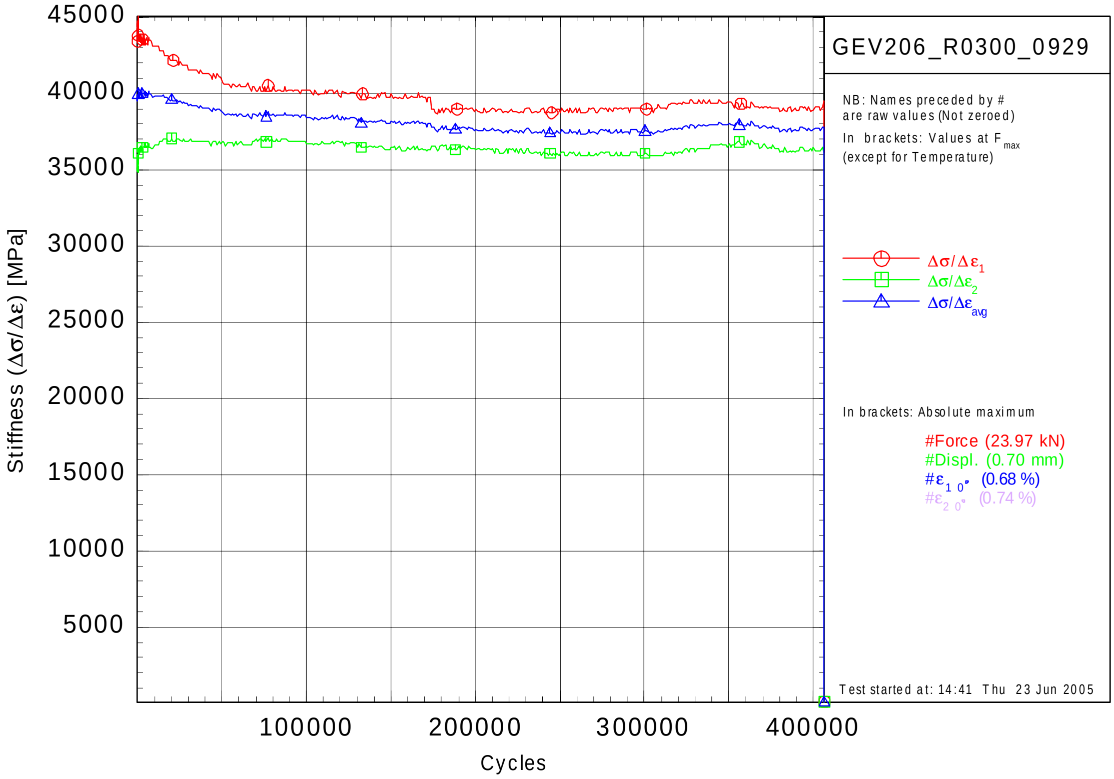

Figure 8 stiffness degradation during fatigue

3.4. *Failures observed*

The photos in Figure 9 show a selection of the failed specimens. There was no obvious predisposition of the specimens to fail at a specific side of the coupon. All failures are grip failures. Note, that specimen GEV206_R0300_0906 failed exceptionally close to the coupon bottom. This was the first specimen to be tested of this series, and compared to the other tests, relatively much water leaked from the container into the tab area. We suspect, that this water has aided in accelerating damage between the tabs, resulting in early failure (this coupon had the shortest life of all).

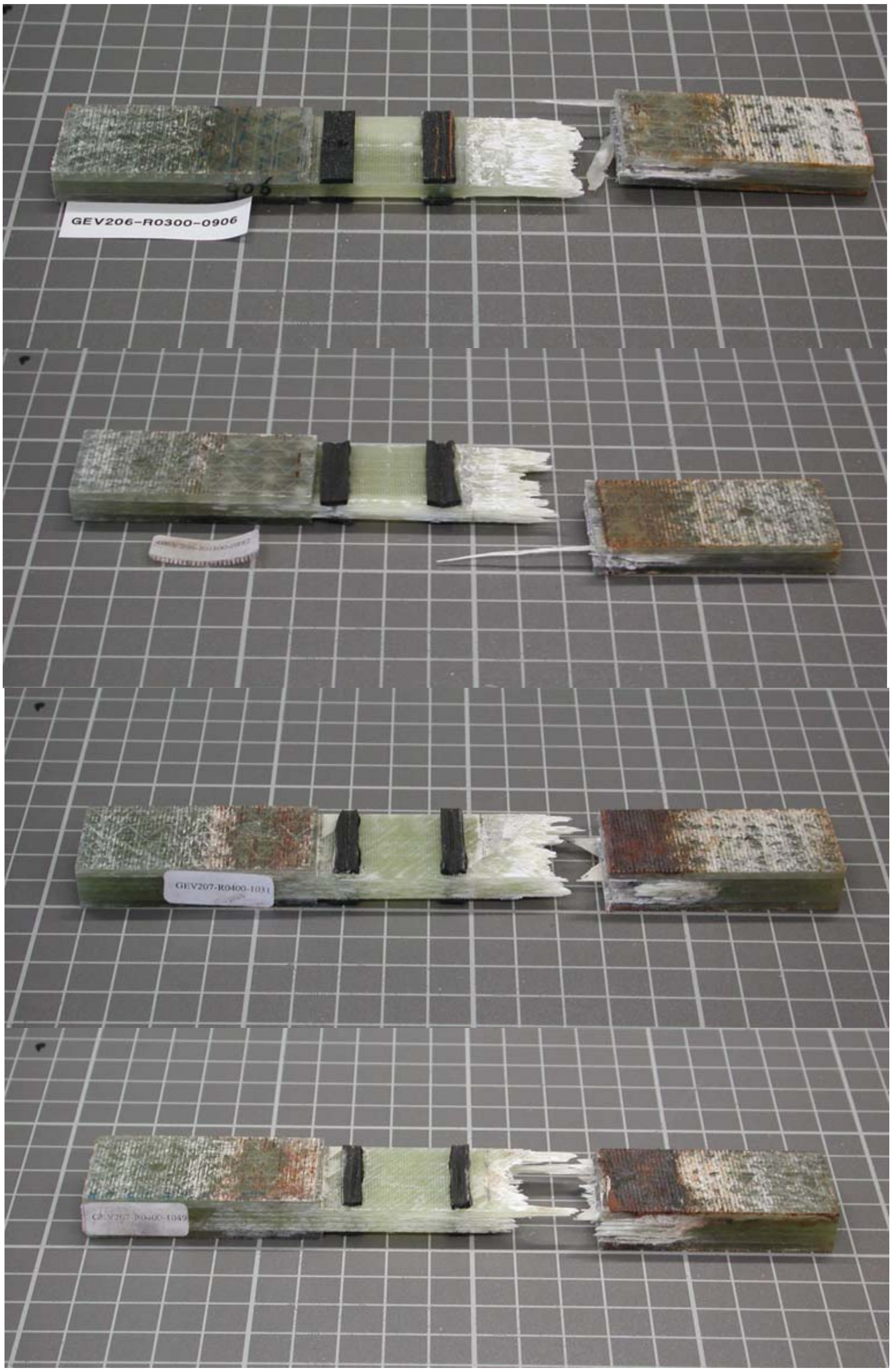

Figure 9 Selected failed specimens

4. Conclusions

From R=0.1 constant amplitude fatigue tests on 5 UD and 5 MD standard specimens at load level 3 (Nominal life 10^6) under 100% Relative Humidity, there is no significant effect of humidity on fatigue life of un-preconditioned specimens. The MD specimens, which had been slightly preconditioned in 100% RH conditions for a few days prior to testing, do show a minor detrimental effect in fatigue life, as well as a ca. 10% lower modulus of elasticity. There is no apparent correlation between the duration of the preconditioning and lifetime.

5. Acknowledgement

The authors thank Danny Mahieu and Maicel Dijkman for their testing efforts.

6. Tables and Figures

Table I: Summary of the results

	Name	Pre-cond. *	σ_{max}	N	$E_{1,t}$	$E_{2,t}$	E_t	$E_{1,c}$	$E_{2,c}$	E_c	T
MD	*GEV207_R0400_1080*	0	212	138477	25.9	33.0	29.4	27.3	34.2	30.7	26.3
	GEV207_R0400_1024	7	192	538691	22.2	28.4	25.3	23.7	28.2	26.0	27.6
	GEV207_R0400_1063	18	192	956670	24.7	23.1	23.9	26.9	23.6	25.3	28.8
	GEV207_R0400_1031	33	192	672311	24.3	25.3	24.8	24.6	25.0	24.8	
	GEV207_R0400_1049	35	193	603609	22.2	26.4	24.3	21.7	26.4	24.1	
	GEV207_R0400_0956	36	194	1596710	23.5	25.6	24.5	24.7	25.8	25.2	
UD	*GEV206_R0300_0882*		289	462698	36.5	42.9	39.7	36.3	42.6	39.4	30.0
	GEV206_R0300_0891		299	266028	36.4	32.8	34.6	37.4	31.5	34.5	27.6
	GEV206_R0300_0894		289	561392	43.3	38.0	40.7	40.5	39.2	39.8	27.6
	GEV206_R0300_0906		289	109929	38.7	44.9	41.8	37.1	42.4	39.8	27.6
	GEV206_R0300_0929		290	406588	41.4	40.3	40.8	44.5	38.7	41.6	31.2

*MD specimens were preconditioned in water for ... number of days

7. References

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Figure 7: selected failed specimens