UpWind

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Assessment of Fibre Bragg Grating optical strain sensors Fatigue of specimens with embedded and surface-mounted sensors

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1. INTRODUCTION

This report describes the optical fibre strain measurement system tested at WMC as a cross-cutting activity of UPWIND [1] Work Packages 7 and 3 (“Condition Monitoring” and “Rotor Structure and Materials”, respectively). Part of the assessment was performed at RISØ-DTU within the same project. The optical fibre strain sensing system, including sensors, was provided by Smartfibres Ltd. in the UK.

The objective of the assessment was to investigate the performance of embedded and surface mounted optical fibres for strain measurement, notably in fatigue.

To this end, optical fibres were embedded in UPWIND specimens at WMC. These specimens were tested in fatigue at different R-values at WMC and RISØ. The test results were compared to similar tests without optical strain gauges, to detect any potential influence of the presence of the optical fibre in the laminate.
In addition, optical fibres were surface-mounted on the sides of the specimens at Smartfibres and tested in the same testing regime.

Strain measurements were compared to measurements using more conventional technologies, such as extensometers and strain gauges.

2. BACKGROUND

Continuous strain measurement is useful both in operational and laboratory conditions. Extensive literature exists where strain-related parameters are used for life and strength predictions.

Acquisition of strain data to fine-tune these models from experiments, as well as operational data, is hampered because of shortcomings in strain measurement.
Strain measurement equipment is, in general, confined to measuring strains on the specimen surface. The commonly used strain gauges suffer from fatigue themselves and typically fail well before the specimen substrate (although most specimens used in determination of S-N curves are tested at higher strains than e.g. wind turbine blades). Extensometers are better suited for long-term strain data acquisition, but apart from their confinement to surface measurements, practical use is sometimes hampered by their size, errors introduced at higher test frequencies because of dynamic effects, and the chance of detaching from the specimen during the test.

Optical fibres offer the potential of long-term strain (and temperature) measurement, both on the surface and inside the laminate. Their properties are nominally identical to those of the glass fibres in the substrate, minimising their influence on the behaviour of the laminate, although, typically, the optical fibre is an order of magnitude thicker than a glass fibre in a wind turbine laminate (typically 65 μm versus 17 μm).

Moreover, they can be connected in series, allowing a single fibre to measure strains on multiple locations in a blade. Optical fibres can be co-cured with the laminate if they are embedded, allowing for tracking the development of residual strains in the laminate and performing internal temperature monitoring during the manufacturing process.

In operational applications, strain sensors applied on the inside of the blade, or embedded in the laminates, do not distort the aerodynamic profile of a rotor blade and allow for collection of load data and damage detection.
In the future, practical implementation of this type of measurement in blades can be useful for scheduling maintenance based on condition monitoring.

Downsides are, that the sensors are very sensitive to temperature fluctuations, and are currently more expensive than strain gauges.

Various literature exists on the principle of Fibre Bragg Grating (FBG) strain measurement, and application in wind turbines see e.g. [2][3].

Embedding the fibres and the influence of the (much thicker) optical fibre in the laminate at various loading conditions needs some research.

3. PRINCIPLE

Two different measurement principles exist: time division and wavelength division. For the current report, a wavelength division type system was used.

Its working principle can be explained as follows. A laser beam containing a range of wavelengths is sent into the optical fibre. At a certain point, a Fibre Bragg Grating has been etched into the fibre outer surface. The total length of this grating is typically in the order of ~1 mm. Essentially, the grating consists of a series of transverse lines at a fixed interval. The interval determines the wavelength of the light that is reflected. Thus, elongation of the fibre changes the interval and hence the reflected wavelength.

The laser beam is generated, and the reflection detected and processed, in an interrogator. This instrument can have different channels, each channel being capable of detecting multiple strains. The sensor interrogator measures the wavelength shift and calculates the elongation of the sensor. Since the elongation is a function of strain and temperature, the temperature at the measurement location needs to be accounted for in order to derive strain.

By combining FBGs with different intervals in a fibre, the strain can be measured at different locations using a single fibre. This was not explored in this report.

The amount of strains that can be measured simultaneously by an interrogator is determined by the number of channels, the data acquisition rate per channel.

4. SYSTEM SET-UP

A 4-channel 250 Hz interrogator (scaled down to 100 Hz) was used, type W3 4250 [5]. The interrogator can be connected to a network. Custom software was provided by Smartfibres to enable readout of fatigue signals. For Fatigue Monitoring the “Graphics” tab of the standard W3 SmartSoft interface has been replaced by a “Fatigue” tab [4].

As outlined in [5], the interrogator produces a digitally encoded strain signal. Since the data acquisition for strain gauges and extensometers at WMC is via analogue signals, a digital-to-analog conversion was implemented, enabling near-synchronised read-out of the optical fibre and other strain sensors. A procedure of setting up the system to enable interaction with the WMC in-house data acquisition software, using the protocols described in [5], is reported in [6].

An overview of FBG measurement system is shown in Figure 1. This figure shows the Schenck 100 kN test frame at WMC, and the Smartfibres interrogator.

Figure 1: Test machine and interrogator

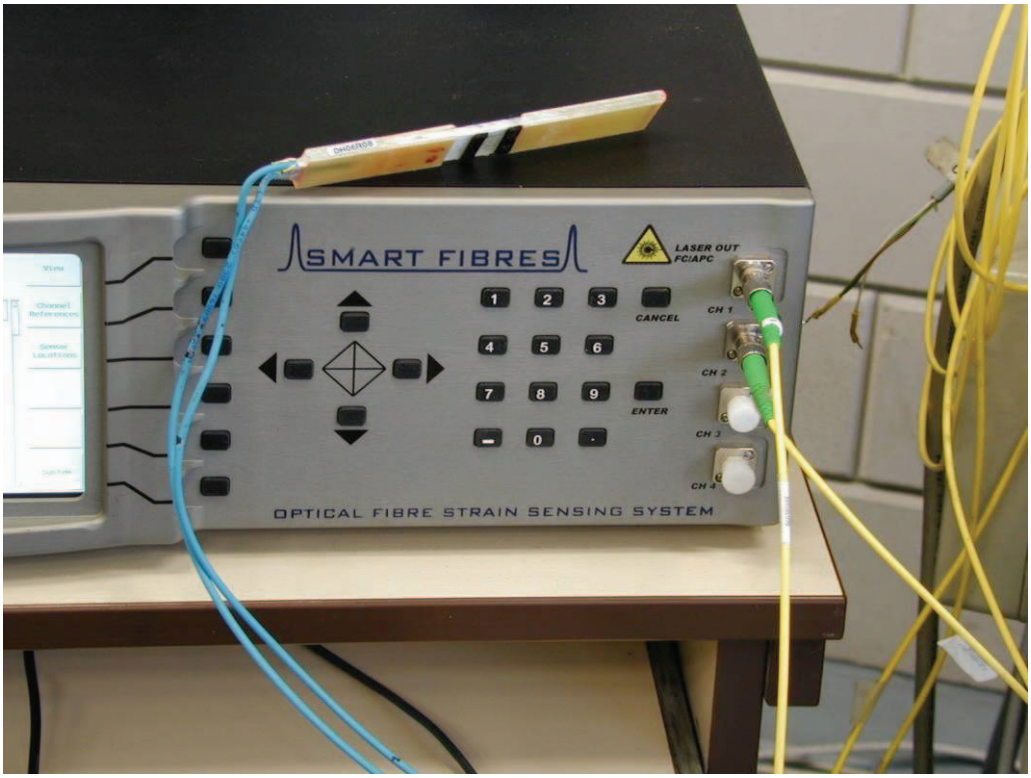

Figure 2: Close-up of interrogator input panel

5. EMBEDDING OF OPTICAL FIBRES

Specimens were embedded in unidirectional laminates of 4 layers and 6 layers thickness, viz. the R08, R07 and I01 geometries [7]. They were embedded between the middle layers. The laminate was manufactured using Vacuum Assisted Resin Transfer Moulding. Since the mantle of the sensor was not entirely airtight, the location where the mantle was stripped away from the actual sensor was closed with fast-curing 2-component epoxy adhesive (Araldite), see Figure 3.

In later plate manufacturing, the rather thick (blue, 3 mm diameter) protective mantle was replaced by a thinner, single-layered one (yellow, diameter 900 μm identical to the one used on the surface-mounted fibres), improving the sealing. Also the use of a less viscous 2-component epoxy adhesive for sealing the mantle decreased the chance of air leakage.
The same mould, resin and fibres, process temperature, etc. as used in the production of standard UPWIND specimens were used for FBG-specimen fabrication, Figure 4.

Figure 3: Sealing mantle with Araldite

For some of the manufactured plates containing embedded sensors the strain signal is monitored during the infusion process. In Figure 5 the measured strains and temperatures are plotted.

The measured temperatures are obtained from several sensors at the mould (T02 through T06), and sensor T01 measured the room temperature. W01 is the desired temperature and optical sensors 001O000 – 004O000 measured the strain.

Before the infusion process is started, the mould temperature is set to 30ºC and a vacuum check is performed. This vacuum check is performed between 35 and 50 minutes, which can clearly be seen in the results (Figure 5).

After 53 minutes the infusion process is started and the resin line is opened. At approximately 70 minutes the resin reached the other side of the mould. Several minutes later (at 73 minutes) the vacuum is removed and both the resin and the vacuum line are left open.

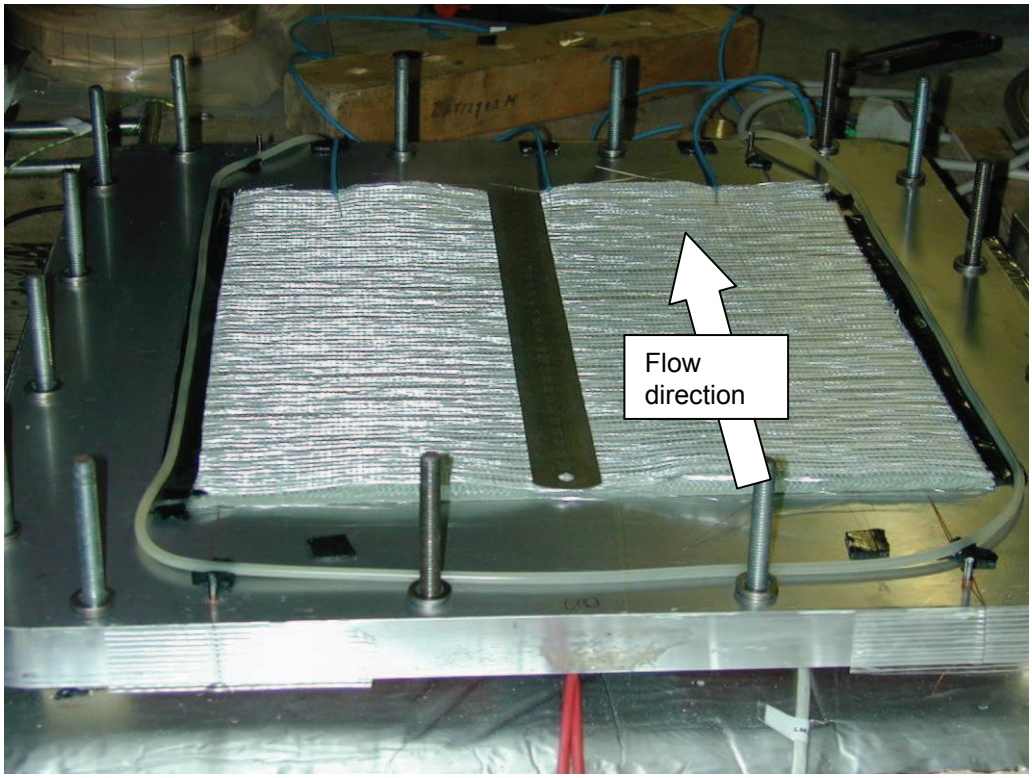

Figure 4: Three optical fibres positioned on first 2 layers of fabric

The laminate containing the embedded sensors is post-cured in the mould and again the temperatures and strains are monitored. This can be seen in Figure 6. At ~240 minutes a rise in strain can be seen where the temperature stays constant. This might indicate the curing of the laminate.
It would have been recommendable to include (temperature compensated) strain gauge measurements in these processes as well. This would have provided a 'second opinion' and facilitated an explanation of e.g. why the strains increase when a vacuum is applied on the mould.
In addition, it would have been interesting to re-heat the specimens in Figure 6 to ~85ºC after the curing cycle, to double-check if the optical fibre strain can be attributed to larger thermal contraction in the matrix material than in the optical fibre.

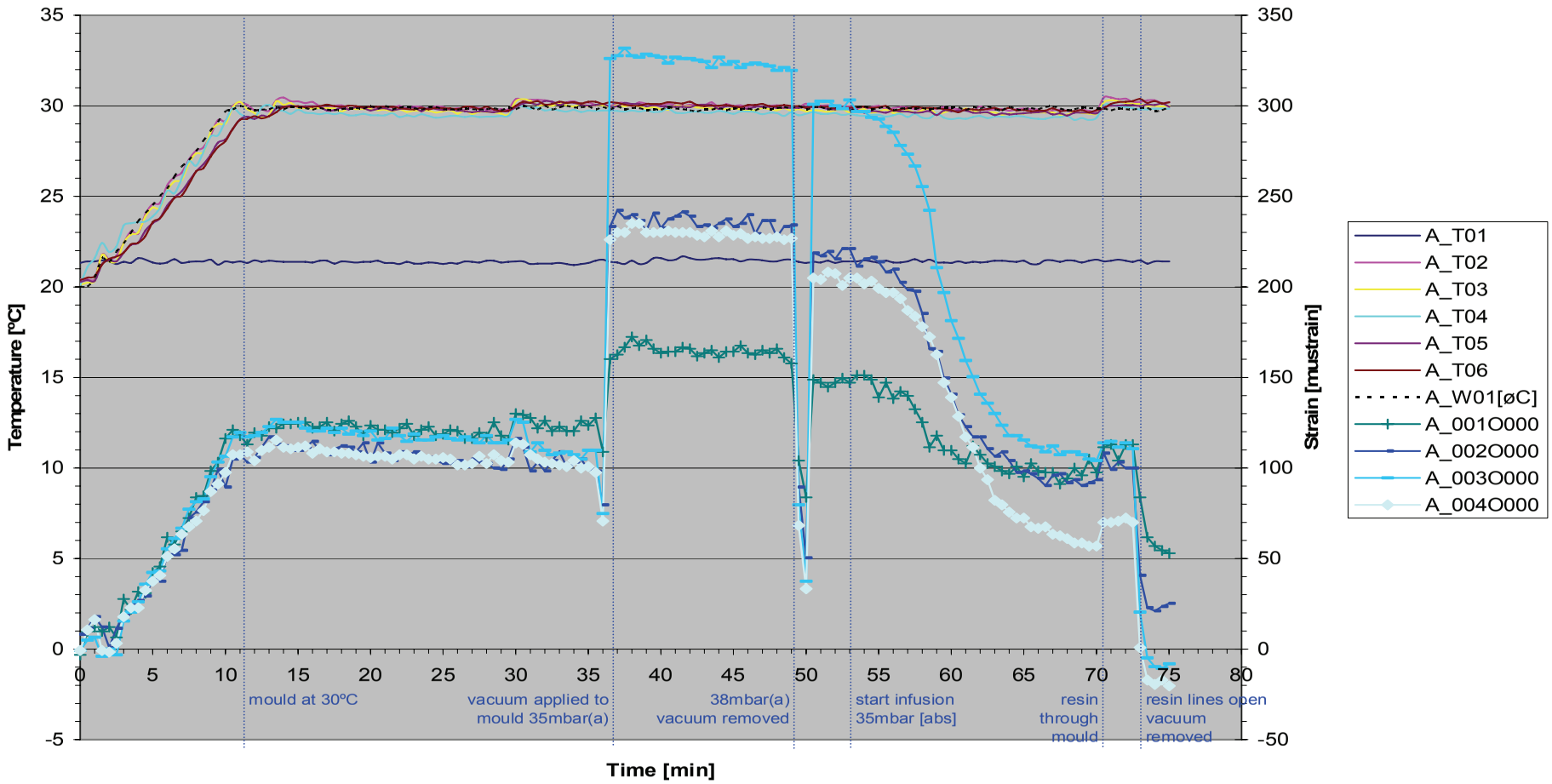

Figure 5: FBG and temperature measurements during infusion

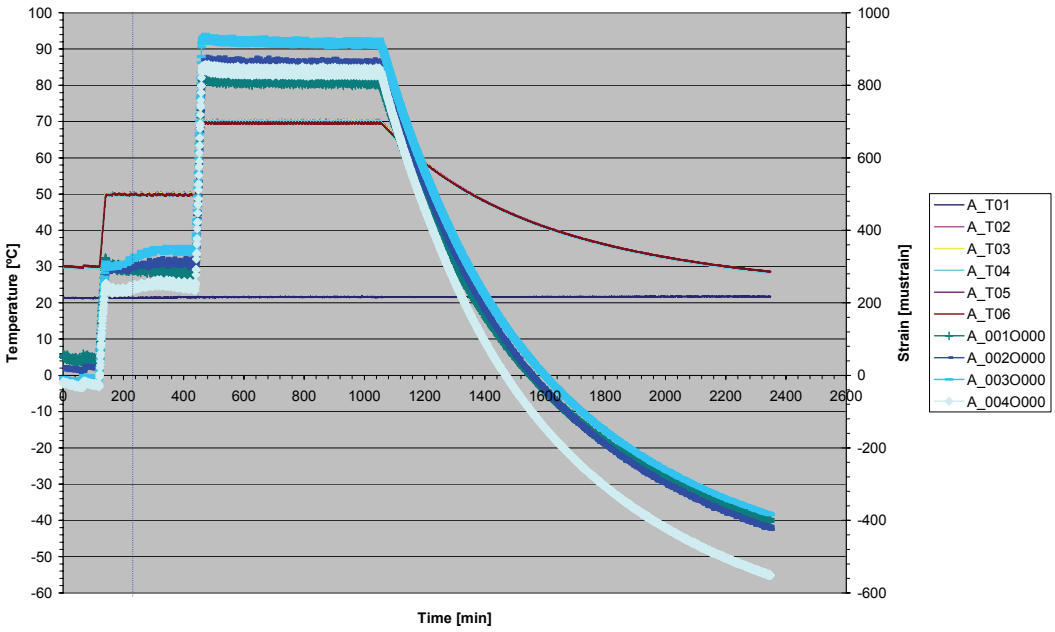

Figure 6: FBG and temperature measurements during post-curing

After curing in the mould, the plate was demoulded. A picture of an embedded fibre is shown in Figure 7.

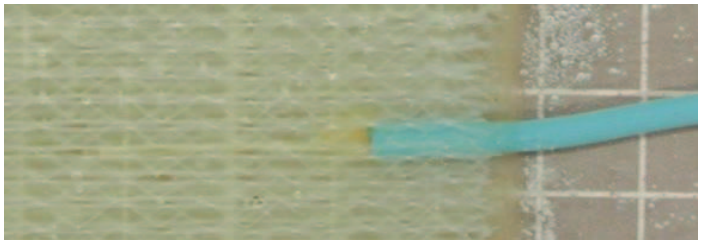

Figure 7: Embedded sensor before applying specimen tabs

Figure 8: Side view of reference geometry specimen with embedded fibre

The embedded fibre in the reference specimen exits the specimen from the top, see Figure 8. This poses some constraints on gripping of the specimen; the grips should allow for some free space above the specimen. At RISØ, an adaptation was made to the fixture to accommodate this.

6. SURFACE MOUNTING OF FIBRES

The strain sensors were mounted in axial direction on the side of the specimen by Smartfibres. For this lay-up, the strains are likely to be identical to those measured in the centre of the specimen. Moreover, this location is preferred because it facilitates gripping of the specimens without the need for smaller sensors or excessively small bending radii of the fibre. During the test programme it was decided to apply additional adhesive pre-treatment: these surface-mounted fibre specimens were post-cured for 2 hours at 65º at WMC. The adhesive bond between the bare optical fibre and specimen spanned the side of the gauge length, the rest of the sheathed cable was typically not bonded. A sensor-specimen assembly is shown in Figure 9.

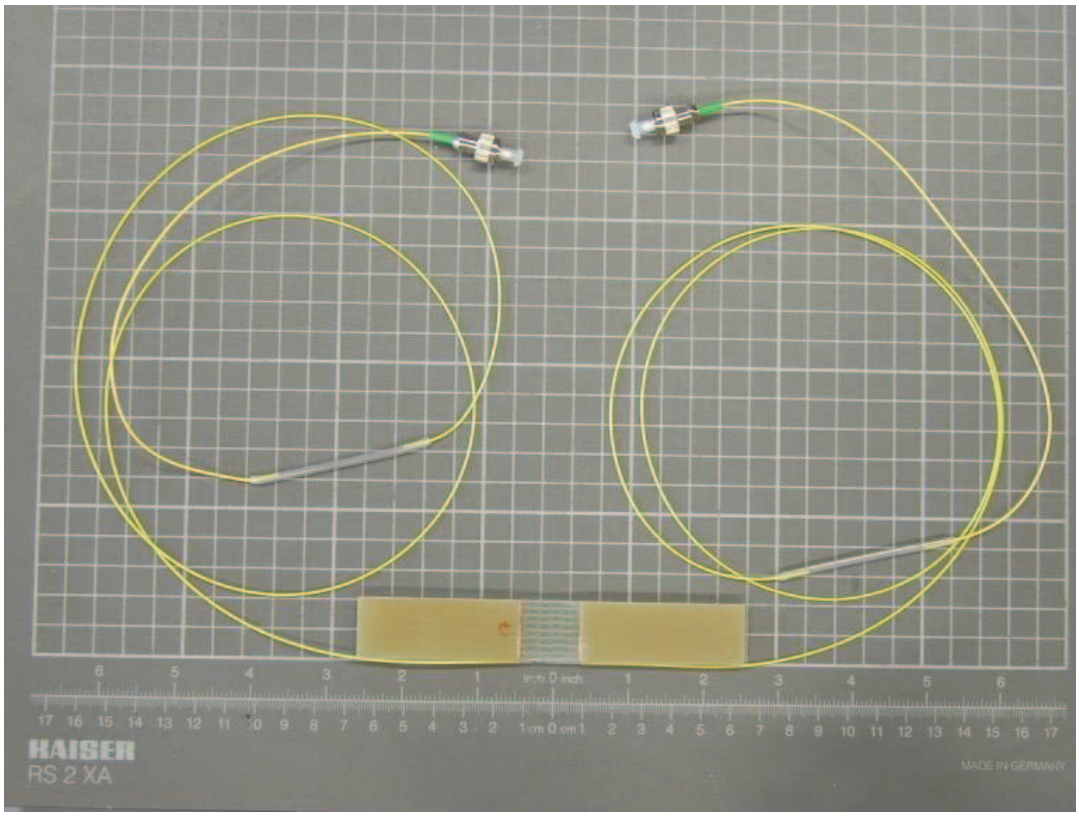

Figure 9: Reference geometry specimen with side-mounted optical fibre

7. TEST PROGRAMME

A test programme was set-up by members of WP3 and WP7. Different R-values and geometries were incorporated in this test programme. The laminate was unidirectional in all cases. The test programme and specimen geometries are shown in Table 1.

Two interrogators and sufficient sensors were made available, so that testing could be performed simultaneously at WMC and RISØ.

Table 1: Test programme

Static testing	**Surface mounted/embedded (between layers #/#)**	**Lab**	**Number of specimens**	**Length [mm]**	**Width [mm]**	**Tabs [mm]**	**Number of layers**
Tensile ISO 527	surface	RISØ	3	300	25	50	6 UD
Tensile ISO 527	embedded (3/4)	RISØ	3	300	25	50	6 UD
Compression R07	surface	RISØ	3	145	20	55	6 UD
Compression R07	embedded (3/4)	RISØ	3	145	20	55	6 UD
Fatigue testing*							
R=0.1 R08	surface	WMC	6	130	20	55	4 UD
R=0.1 R08	embedded (2/3)	WMC	6	130	20	55	4 UD
R=-1 R08	surface	WMC	6	130	20	55	4 UD
R=-1 R08	embedded (2/3)	WMC	6	130	20	55	4 UD
R=10 R07	surface	RISØ	6	145	20	55	6 UD
R=10 R07	embedded (3/4)	RISØ	6	145	20	55	6 UD
Total			36				

*R-value is used to typefy a class of fatigue loading, and equivalent to: F_{min}/F_{max}, e.g. R=0.1 is tension-tension fatigue

8. RESULTS AND DISCUSSION

To date, ca. 36 out of 48 tests are reported. The results are summarised in Table 2, and in Figure 10- Figure 13.

Any tests missing from the current report will be included in a later version of this report, or in a separate report.

8.1 EFFECT ON FATIGUE LIFE

From the S-N diagrams in Figure 10- Figure 13, it can be checked if a detrimental effect of embedding a fibre is obvious from the fatigue results. Also, the influence of pure tension versus tension-compression can be checked.

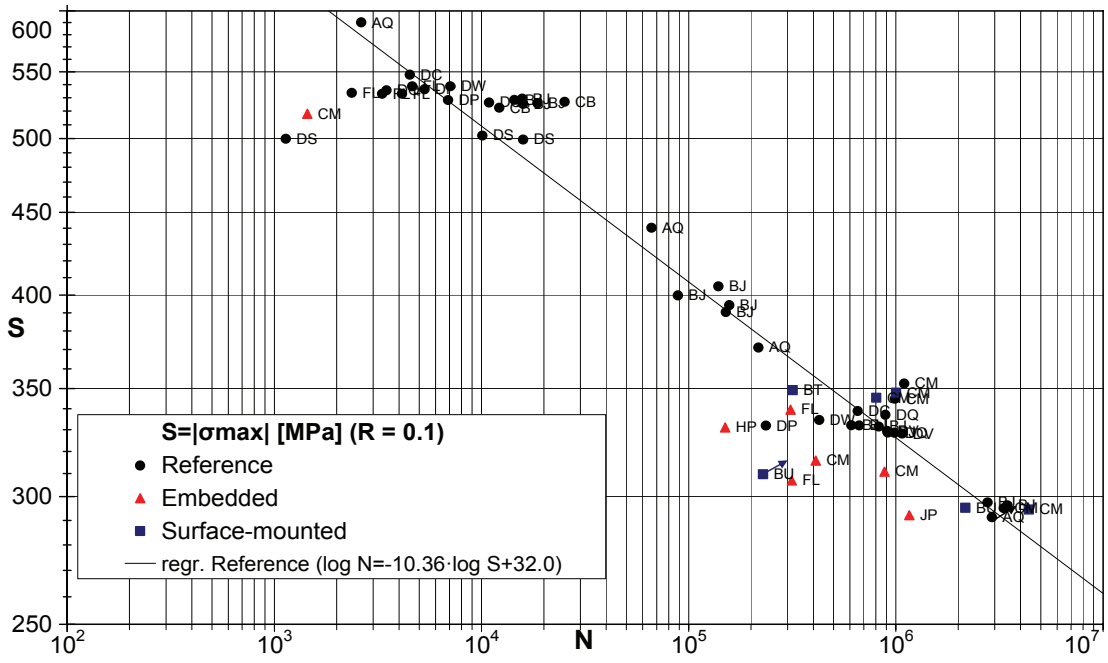

Figure 10: R=0.1 S-N diagrams with specimens labelled with plate number

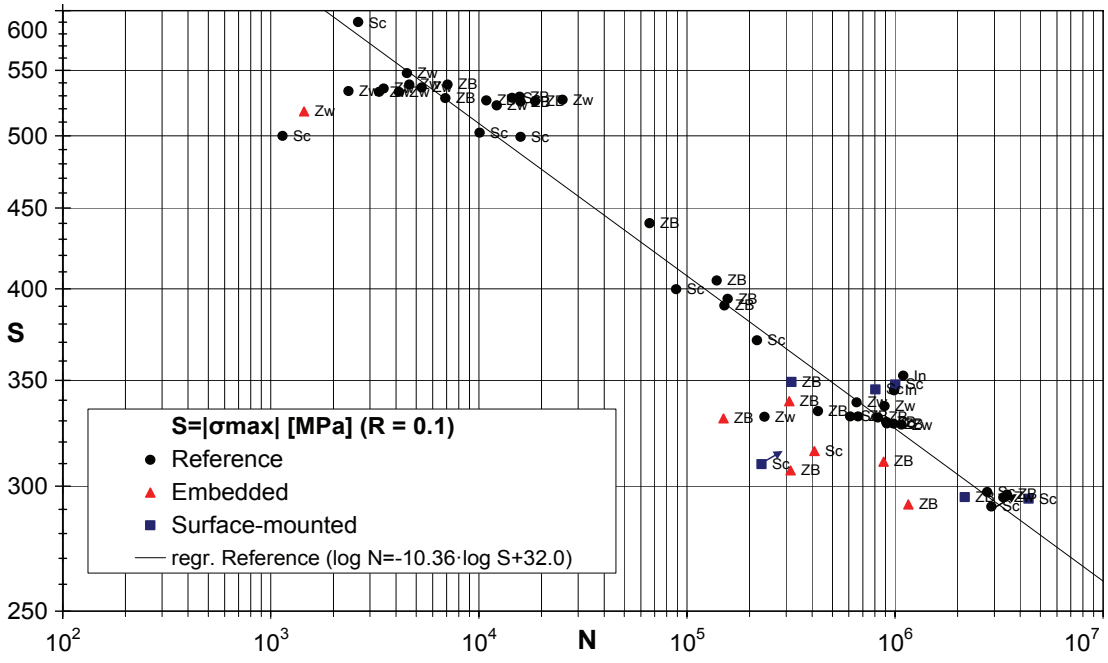

Figure 11: R=0.1 S-N diagrams with specimens labelled with test frame (Sc=Schenck 100kN, In=Instron 100kN, ZB=WMC homebuilt 100kN, Zw=Zwick 220kN)

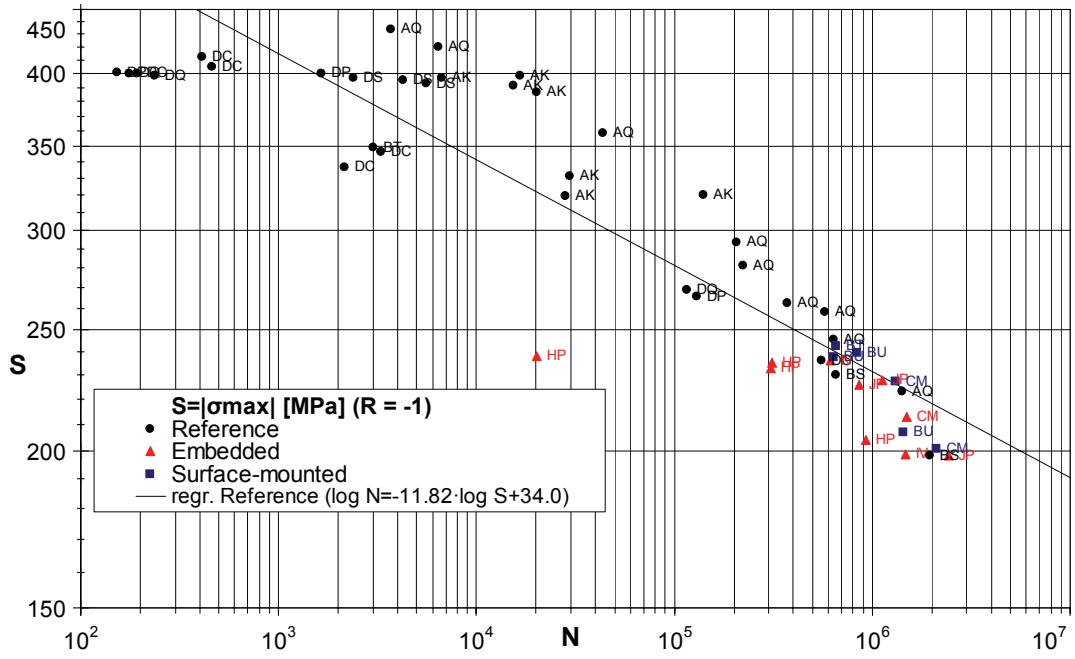

Figure 12: R = -1 S-N diagram with FBG specimens indicated

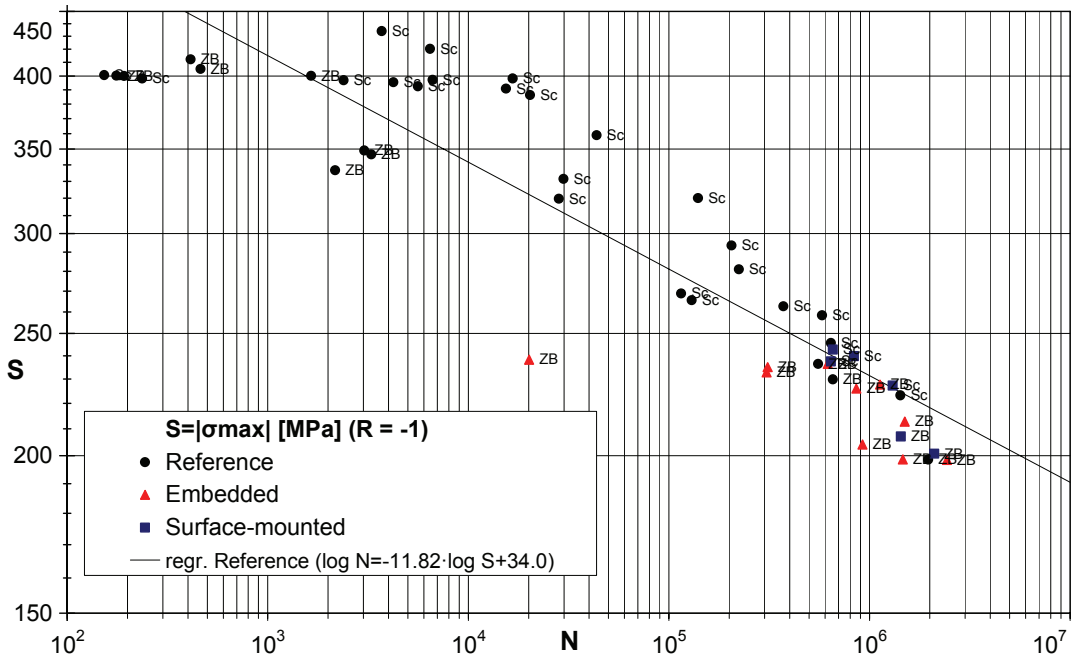

Figure 13: R = -1 S-N diagram with test frames indicated

However, potential plate-to-plate variations and test frame-to-test frame variations should be taken into account. Therefore, for each R-value, 2 plots are shown; one with the plate ID marked next to the data points, and one with the test frame indicated next to the data points.

One of the known plate-to-plate variations is for plate HP (manufactured using excess hardener).

A suspected frame-to-frame variation can be identified for the ZB machine in both R-values.

With the limited data available, no detrimental effect of applying optical fibres on the specimen surface on specimen fatigue life can be seen, see Figure 10- Figure 13.

For the embedded fibres, no detrimental effect can be identified from these figures in R=-1.
However, in R=0.1, suspicion of a small detrimental effect can be justified notwithstanding the abovementioned variations.

8.2 MEASUREMENT PERFORMANCE IN FATIGUE

The measurements during the initial slow cycle (which was done both in tension and compression to obtain tensile and compressive Young's modulus), and the measurements written at intervals during the fatigue tests are shown in Appendix B- Appendix E. Also, more detailed continuous measurements of a couple of cycles are plotted in these appendices. These are taken at logarithmic intervals. The first plot is after ca. 1000 cycles, the second after ca. 10000 cycles, etc.

For specimens where the optical fibre was destroyed during the manufacturing process, no signal was provided and only the strain- or clip gauge signals (if any) are plotted.

The plots contain recordings of load, displacement, temperature, strains, and stress-strain diagrams for determination of compression and tension Young's Modulus. Furthermore, they contain a table with a summary of the maximum, minimum and average values and the moduli.

The findings from these plots are also reported in Table 2.

Although the performance was not unanimously consistent for all cases, it can be concluded that optical fibres did not perform very well in R=0.1 surface mounted configuration; 5 out of 6 tests showed poor FBG sensor performance.

The embedded configuration showed poor performance for 2 out of 6 tests.

For R=-1 surface mounted fibres, problems were found in 4 out of 6 tests. For the embedded fibres, 5 out of 6 performed without significant problems.

Summarising, embedding the fibres gives better chances of successful measurements than bonding them to the specimen sides as performed in this project.

Furthermore, the plots in the appendices confirm poor measurement performance of standard strain gauges. These fail in ca. 1,000 fatigue cycles and are really only suited for initial stiffness measurements.

The clip gauges occasionally suffered from drift in the signal. This might be caused by gradual movement of the clip gauge contact points on the specimen surface. This might be avoided to some extent by not relying on friction alone, but also bonding the contact points to the specimen surface.

Table 2: Test results summary

		Surface mounted/Embedded (between layers #/#	Laboratory	Specimen ID	Load [kN]	σ [Mpa]	N	FBG performance	Remarks
Fatigue	R=0.1 R08	S	WMC	BU21R08	18.00	310	228504	ceases to achieve tensile strain early in life	Runout; fibre adhesive not postcured
				CM01R08	20.00	348	1003750	Good correlation with clip gauges throughout test	

		Surface mounted/Embedded (between layers ## Laboratory	Specimen ID	Load [kN]	σ [Mpa]	N	FBG performance	Remarks
			CM08R08	20.00	345	804542	ceases to achieve tensile strain early in life	fibre adhesive not postcured
			CM20R08	18.00	295	4383408	ceases to achieve tensile strain early in life	fibre adhesive not postcured
			BT05R08	20	349	318059	ceases to achieve tensile strain early in life	
			BU12R08	18	295	2163765	ceases to achieve tensile strain early in life	
	R=0.1 R08	E (2/3) WMC	CM02R08	18.00	311	880932	good correlation between all strain sensors	
			CM10R08	18.00	306	409913	reasonable correlation with clip gauge 1	clip gauge 2 no signal
			FL06R08	18.00	307	314741	Optical fibre broken from ~1000 cycles	
			FL07R08	20.00	340	309989	average and range decrease gradually during test w.r.t. clip gauges	
			HP02R08	20.00	331	150012	good correlation with all strain sensors	Fan not pointed at specimen, temp too high (35ºC max)
			DH06R08 invalid	18	330	87585	n.a.	Invalid; inferior laminate quality and error in measurement
			JP02R08	18.00	292	1160246	good correlation with all strain sensors	
			CM21R08	32	518	1444	n.a.	contains optical fibre (no FBG)
	R=-1 R08	S WMC	BT14R08	14.00	243	656885	average and range constant while clip gauge's decrease gradually	Postcured 2h@65°C at WMC
			BU03R08	14.00	240	837905	measured range decreases early	Postcured 2h@65°C at WMC
			BU17R08	14.00	238	642004	good correlation with clip gauge 2	Postcured 2h@65°C at WMC; clip gauge 1 average decreases w.r.t clip gauge 2
			CM04R08	13	227	1306001	FBG signal constant while clip gauge's range and average decrease gradually. Gradual distortion of signal	Optical fibre was not bonded properly at delivery
			BU04R08	12	207	1431975	ceases to achieve strains after ca. 50kcycles	

		Surface mounted/Embedded (between layers ## Laboratory	Specimen ID	Load [kN]	σ [Mpa]	N	FBG performance	Remarks
			CM14R08	12	201	2100631	ceases to achieve strains within 10kcycles	
			CM19R08	12	199	261255	ceases to achieve strains early in life	Premature failure due to power cut
	R=-1 R08	E (2/3) WMC	CM06R08	12.00	213	1498426	smaller range than clip gauges early in life; FBG constant while average and range of clip gauges decrease gradually	
			HP03R08*	14.00	233	306837	constant while average of clip gauges decreases gradually	
			HP04R08*	14.00	238	20090	good correlation with all strain sensors	
			HP08R08*	12.00	204	923486	constant while clip gauge signal decreases gradually	
			HP09R08*	14.00	235	310591	constant while clip gauge signal decreases gradually	
			JP01R08	12.00	198	2434770	reasonable correlation with clip gauges	clip gauges malfunctioned
			JP03R08	14	226	859781	not functioning from start	
			JP04R08	14	228	1128524	not functioning from start	
			IV02R08	12	199	1466120	not functioning from start	
			IV09R08	14	236	618290	not functioning from start	
	R=10 R07	S RISØ	BO02R07	-36.39	410	2788		
			BO07R07	-34.64	388	16751		
			BO10R07	-31.99	358	625343	Sensor signal strange from beginning	
			BO13R07	-31.6	355	1455600	Slow degradation of signal	
			BO14R07	-33.84	381	225664		
			BO15R07	-30.66	342	1283053		
			BO22R07	-32.37	364	859	Cancelled due to bad signal from sensor	
			BP07R07	-40.78	467	16350	Unstable signal from sensor	
			BP09R07	-31.53	357	1283		
			BP17R07	-34.24	386	175023	Sine-shaped curve but level wrong	
			BP18R07	-32.42	354	1238105	Drift in signal already from start	

*Plate HP was made with excess hardener; inferior fatigue results might be expected

9. CONCLUDING REMARKS

Embedding fibres in the UPWIND 4-layer and 6 layer laminates was successful after taking the necessary precautions against leakage via the cable protective mantle and ensuring proper alignment of the fibres in the mould. However, the optical fibres are quite sensitive to external loads, which resulted in some of the sensors being destroyed during the preparation of the plates and specimens.

Measurements could be taken for a selected plate of the infusion and curing of the plate with embedded fibres. This allows for evaluation of the (residual) stresses observed by the fibres during the process. It would have been recommendable to include (temperature compensated) strain gauge measurements in these processes as well.

No detrimental effect of surface-mounted fibres on fatigue life at any R-value is detected.

The possibility of a detrimental effect of embedded fibres on fatigue life at R=0.1 should be further evaluated.

No significant detrimental effect of embedding fibres was found for R=-1.

A larger and more balanced dataset might give more accurate conclusions; it is recommendable to test further specimens from the same plate on different test frames and R-values.

Embedded fibres gave relatively reliable measurements.

Surface mounted optical fibres seemed to suffer from the degradation of the adhesive bond between fibres and specimen surface. This resulted in progressive degradation of the sine-shaped character of the measurements during fatigue life: an alternative bonding method might give better performance, e.g. bonding over a longer length of the optical fibre.

Clip gauge measurements might be improved by using an adhesive to hold the contact points on the surface in place.

10. REFERENCES

[1] UPWIND DOW, via www.upwind.eu (participant area)

[2] Makaremi, S., 'Clipper's Design Approach to Improving Reliability and Integrated Condition Based Monitoring', presentation at 2nd wind turbine reliability workshop, September 17th-18th, 2007

[3] Hendriks, H.B., 'Application of optical fibres for blade load measurement and condition monitoring', presentation at 2004 blade workshop, Albuquerque, NM, February 2004.

[4] Smart Fibres Limited, 'Fatigue monitor instructions', in e-mail from Kevin Jones to WMC, 2007

[5] Smart Fibres Limited, 'W3 4250 Swept Laser Interrogator Instruction Manual' revision 1.4, 2007

[6] Kuiken, J.J., 'Digital to analog conversion of a Fibre Bragg Grating strain sensor signal', WMC-2008-60, December 2008

[7] OptiDAT database, via www.upwind.eu (participant area)

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APPENDIX A PICTURES OF THE SPECIMENS BEFORE/AFTER

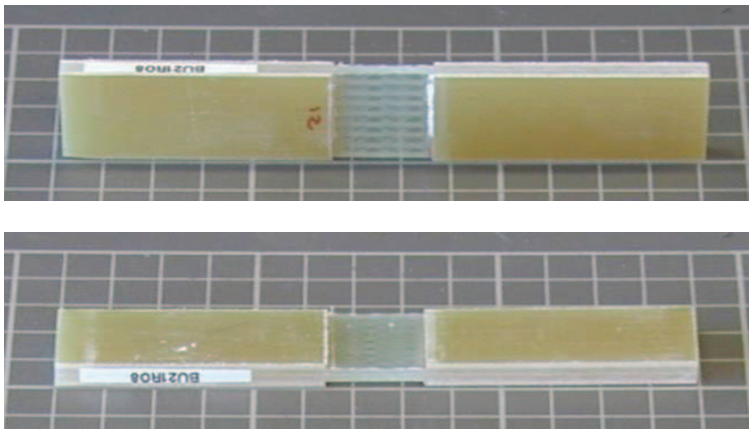


Figure A - 1: BU21R08 before testing

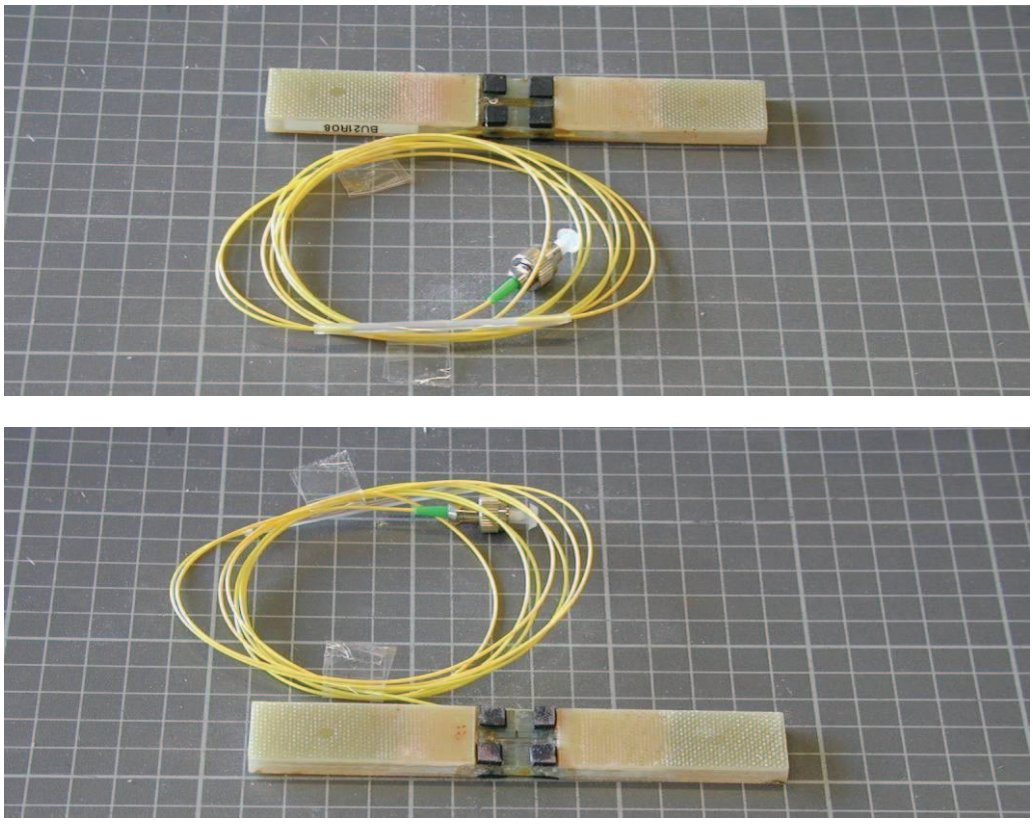


Figure A - 2: Specimen BU21R08 after testing

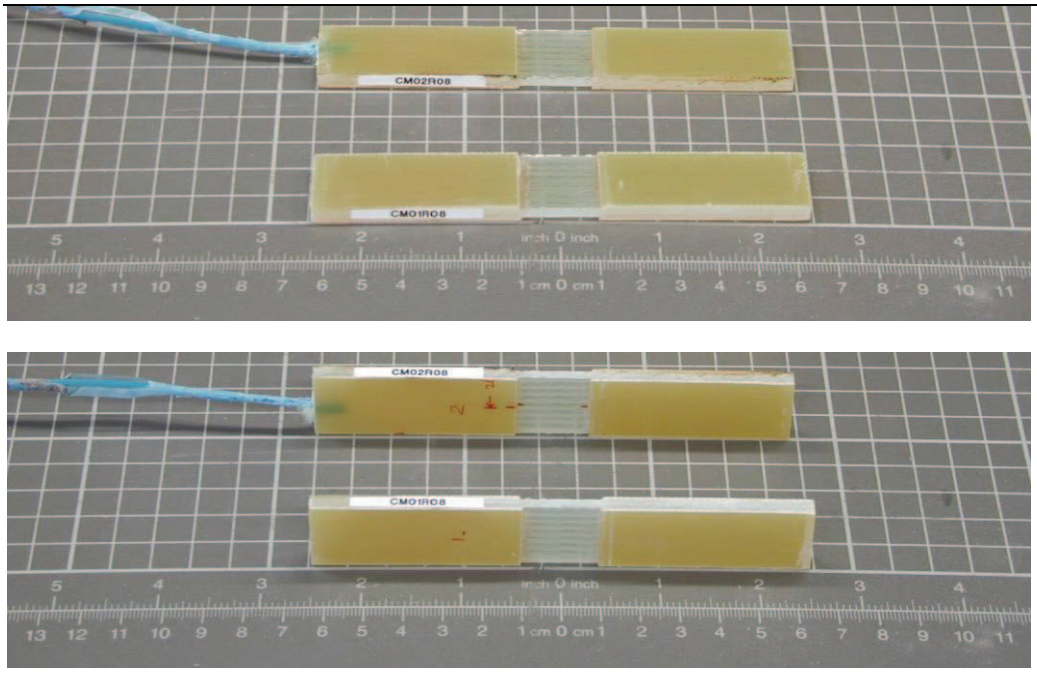


Figure A - 3: CM01R08 and CM02R08 before testing

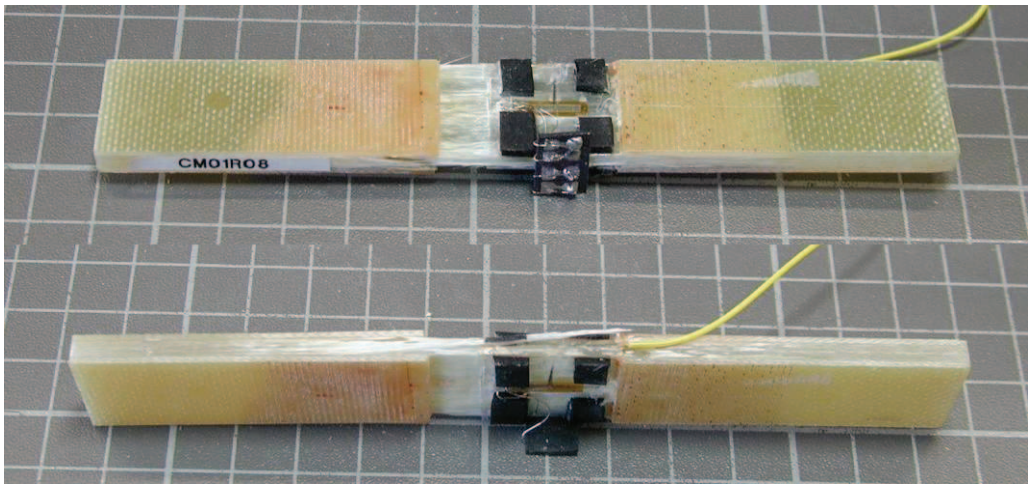


Figure A - 4: CM01R08 after testing

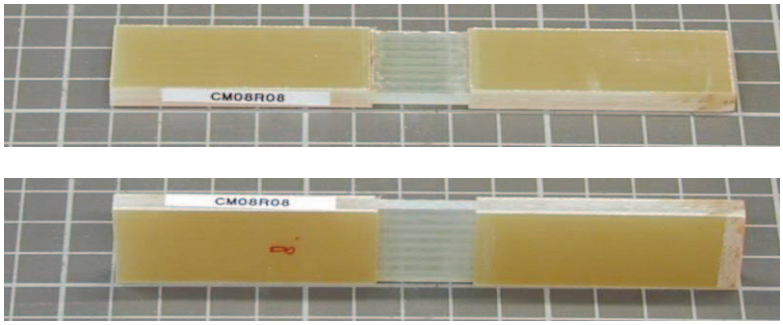


Figure A - 5: CM08R08 before testing

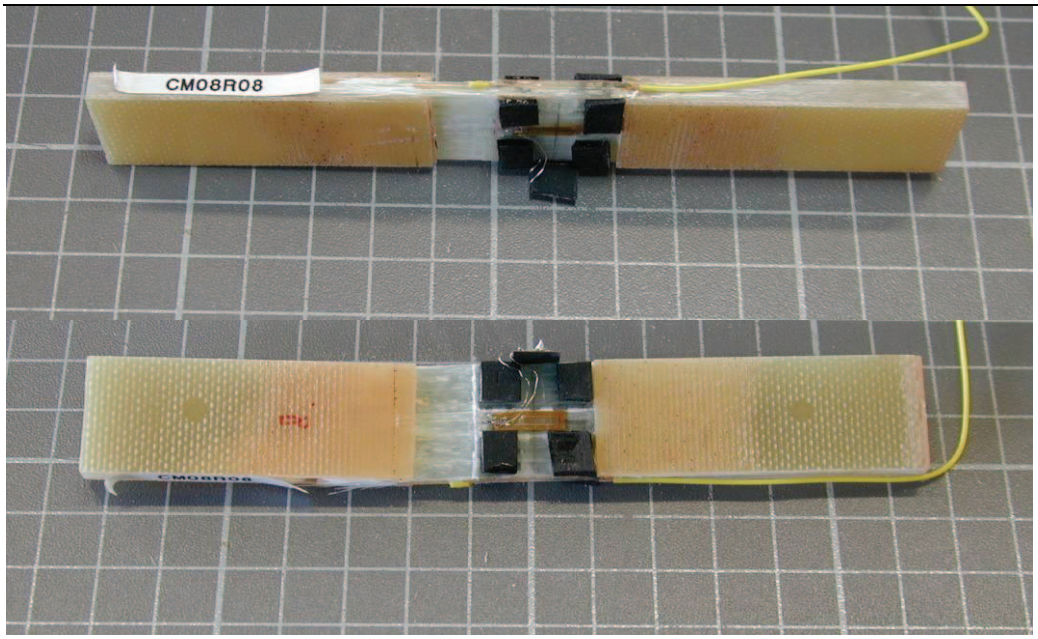


Figure A - 6: CM08R08 after testing

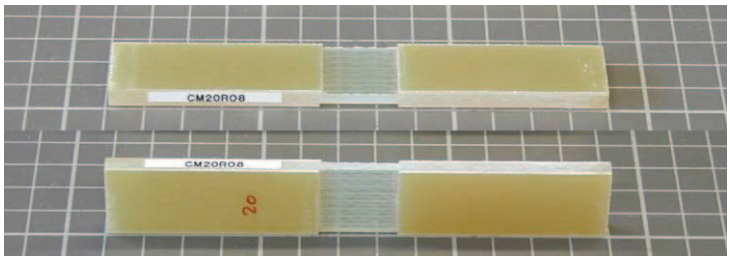


Figure A - 7: CM20R08 before testing

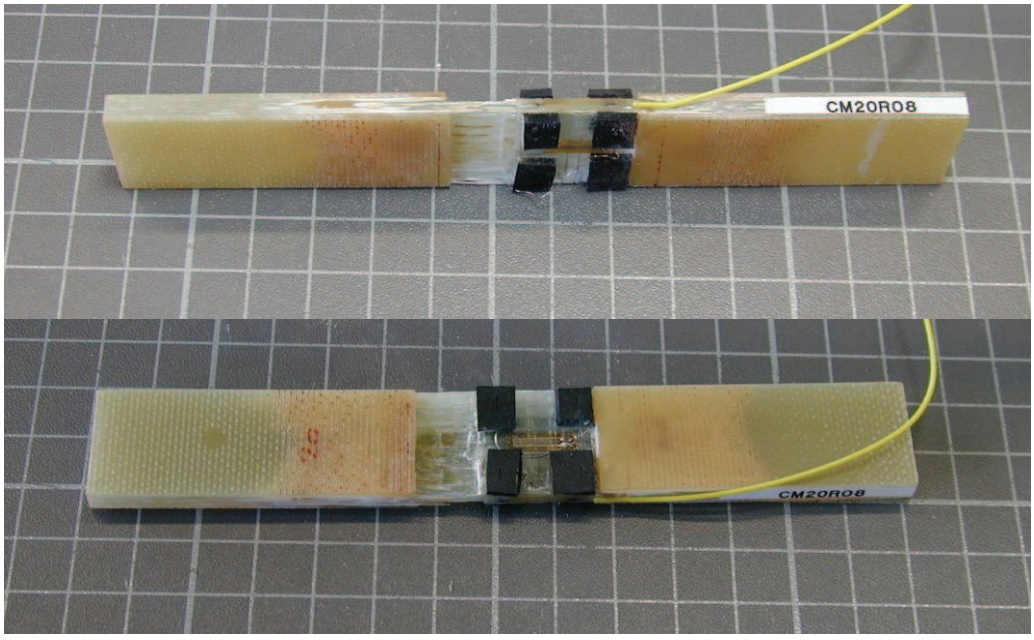


Figure A - 8: CM20R08 after testing

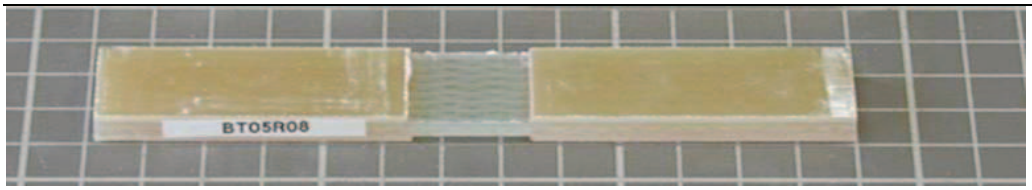


Figure A - 9: BT05R08 before testing

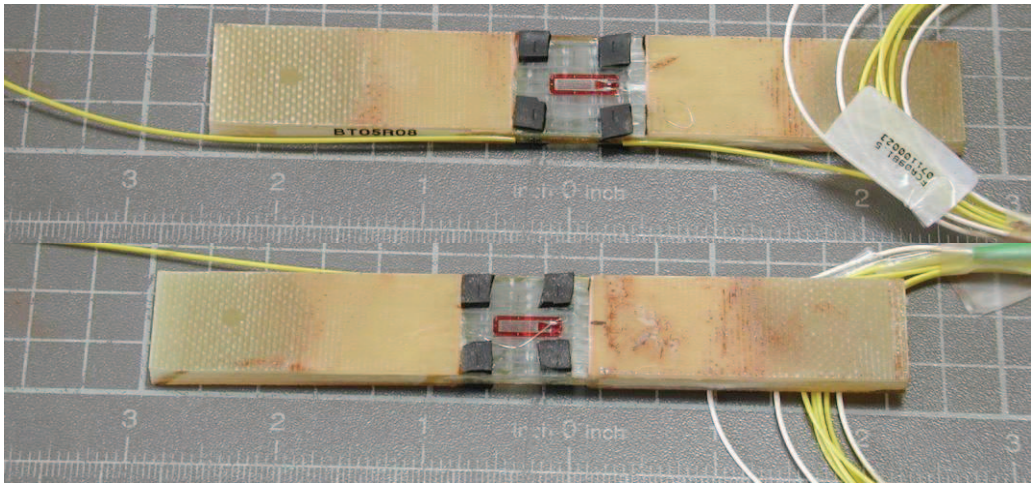


Figure A - 10: BT05R08 after testing

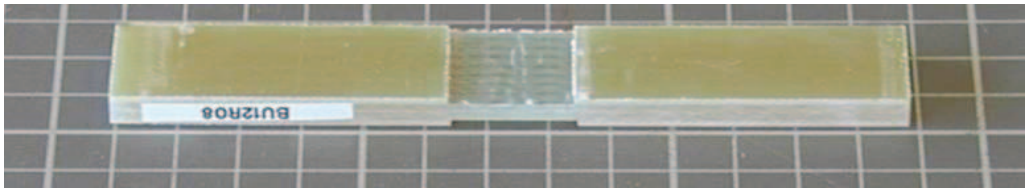


Figure A - 11: BU12R08 before testing

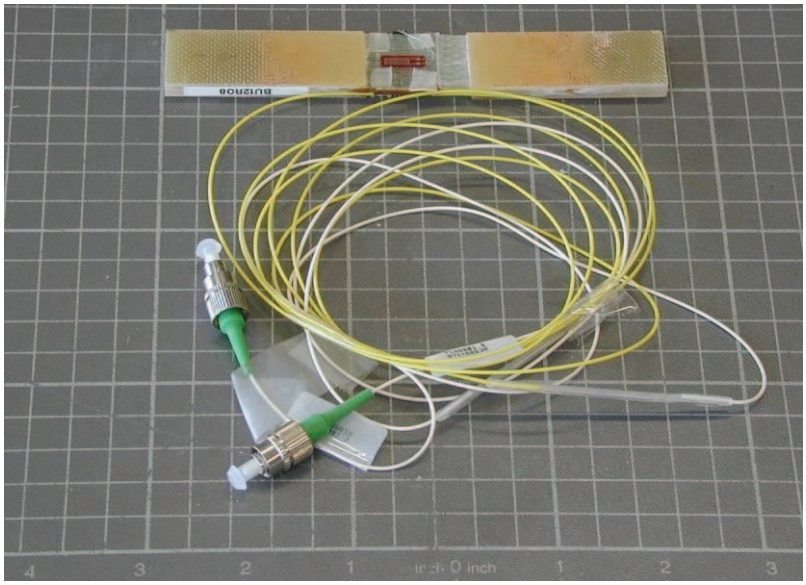


Figure A - 12: BU12R08 after testing

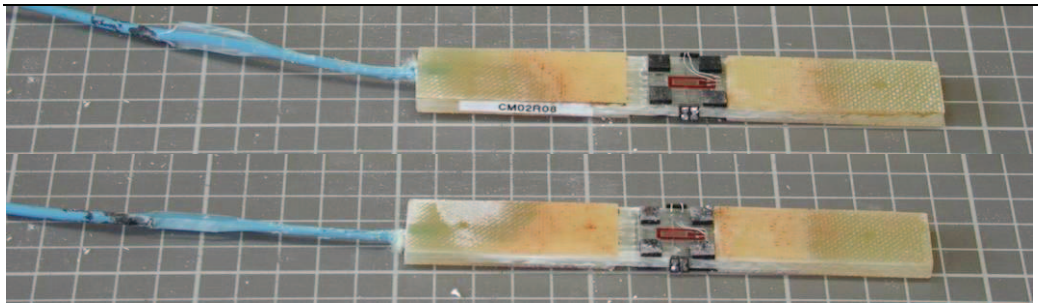


Figure A - 13: CM02R08 after testing

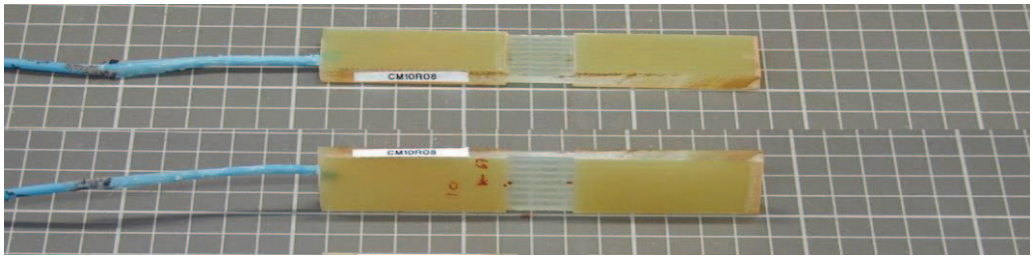


Figure A - 14: CM10R08 before testing

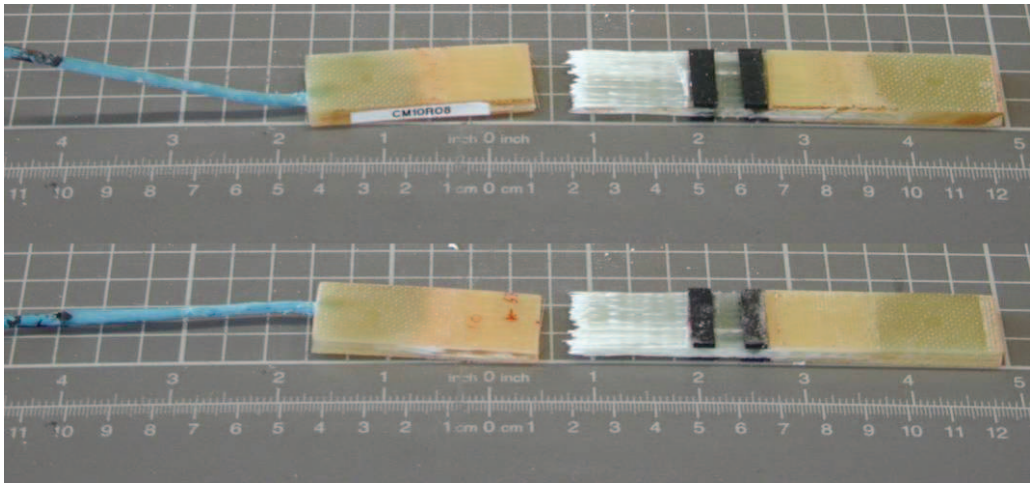


Figure A - 15: CM10R08 after testing

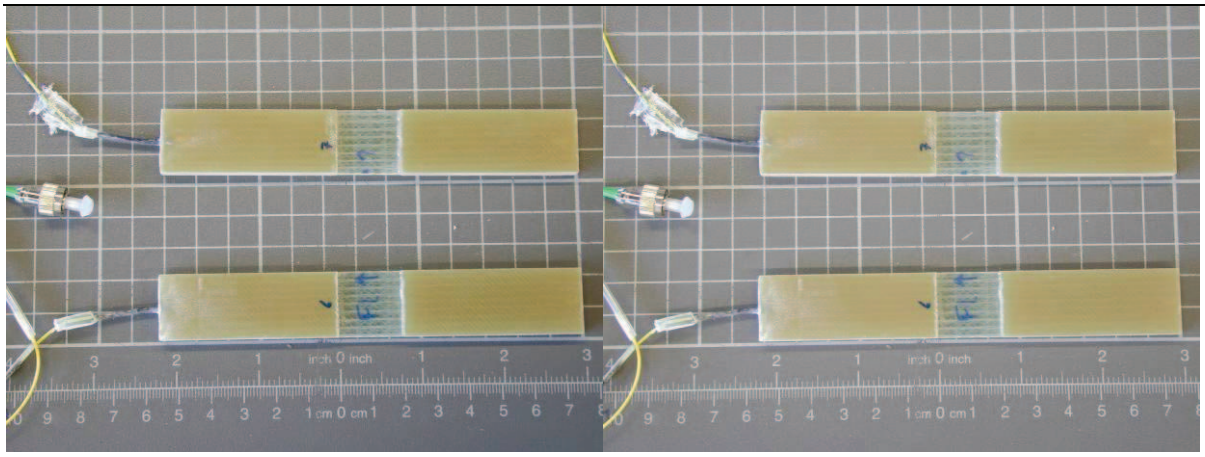
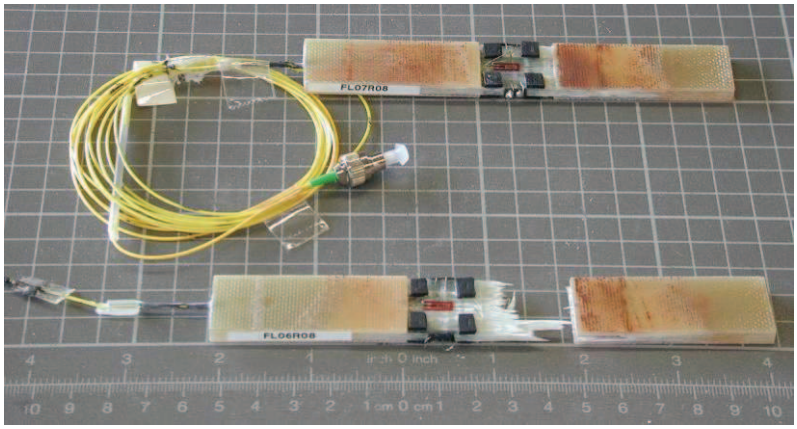


Figure A - 16: FL06R08 and FL07R08 before testing



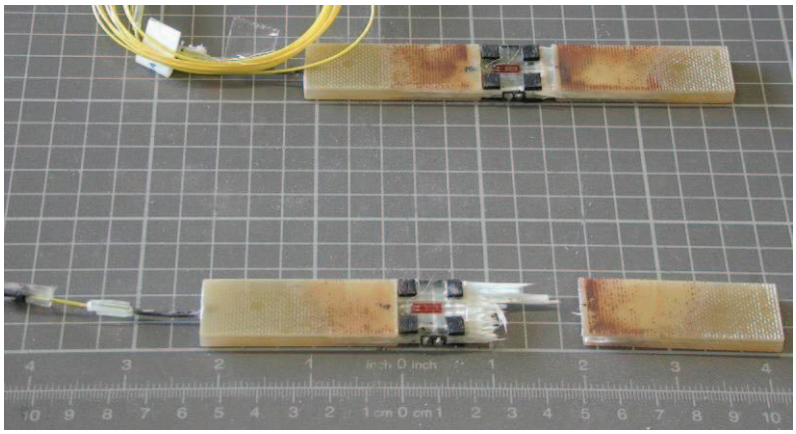


Figure A - 17: FL06R08 and FL07R08 after testing

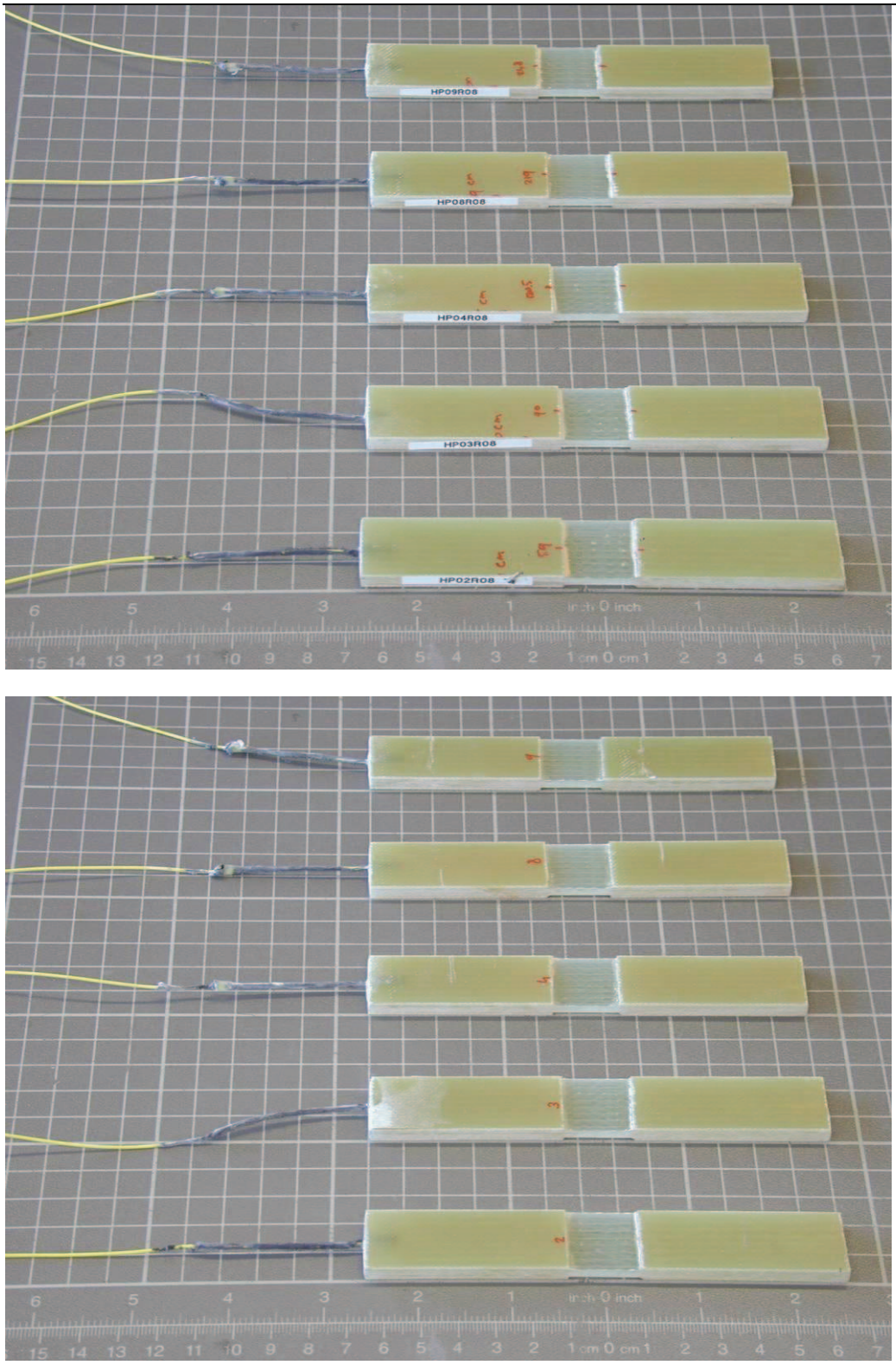


Figure A - 18: HP02, 03, 04, 08, 09 R08 before testing

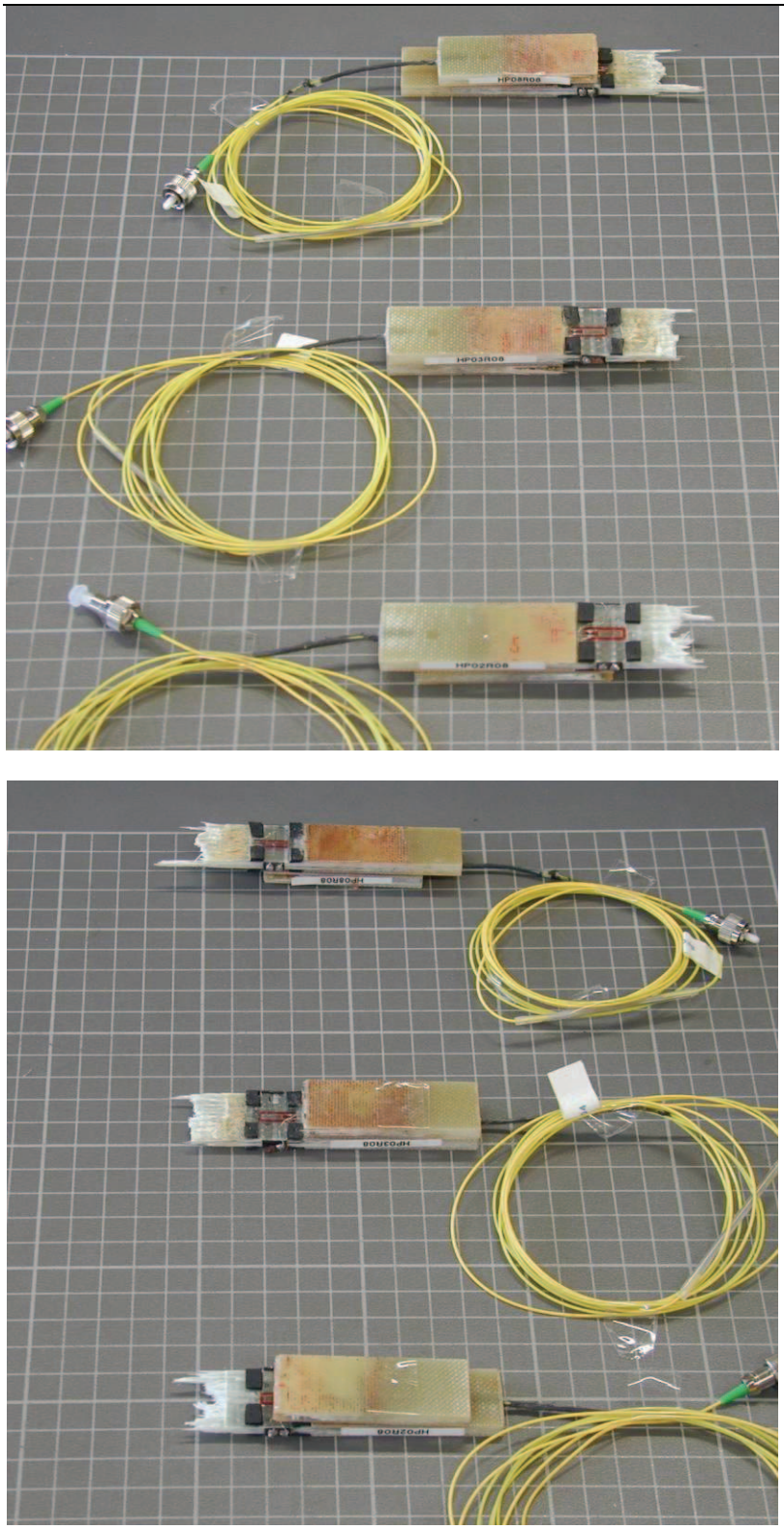
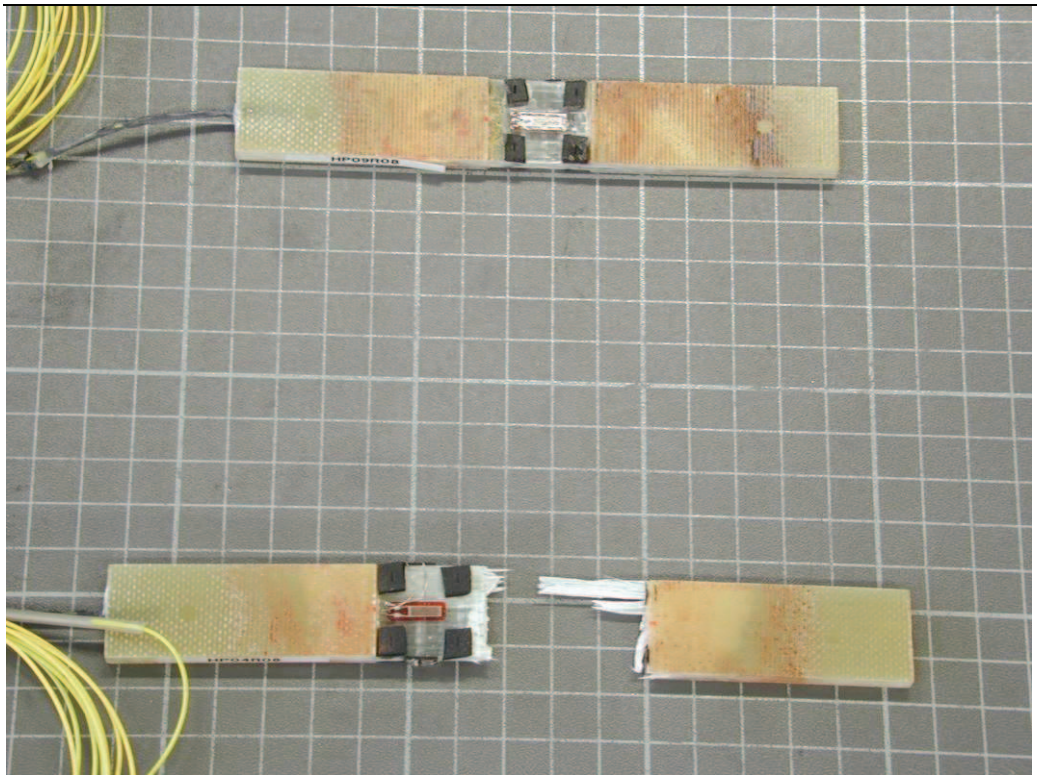


Figure A - 19: HP02, 03, 08 after testing



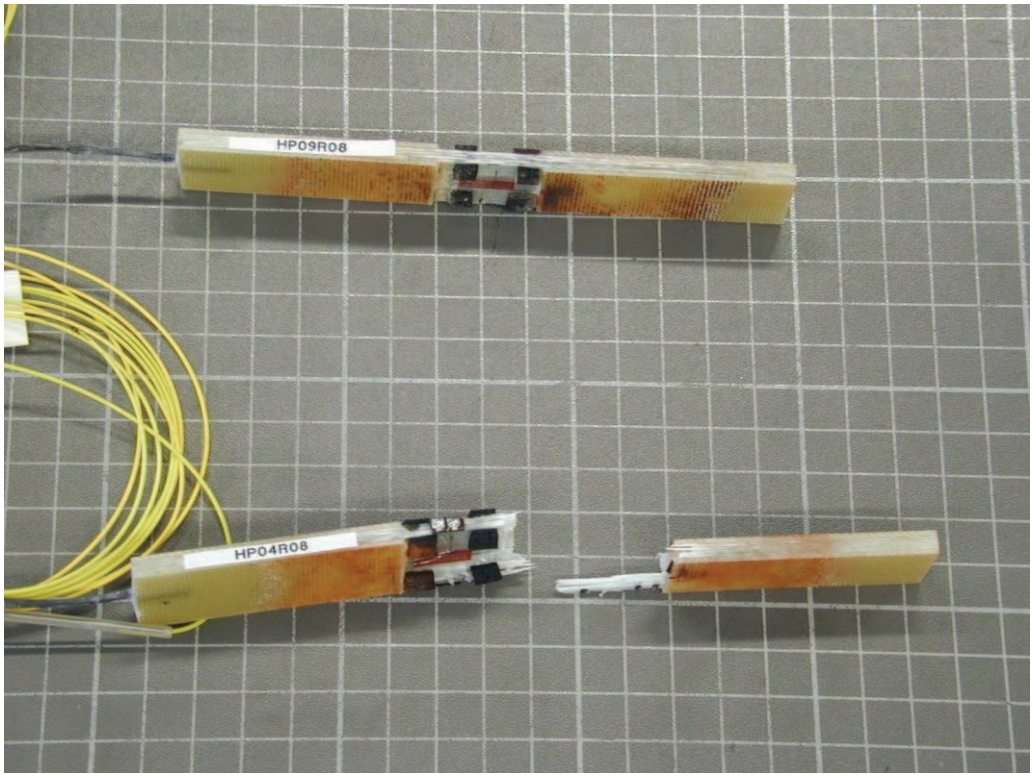


Figure A - 20: HP04, 09 R08 after testing

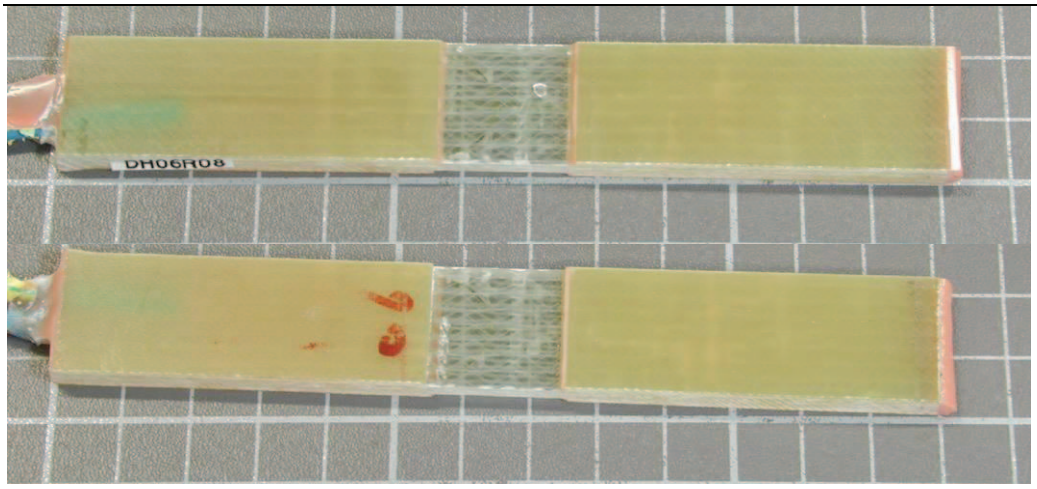


Figure A - 21: DH06R08 before testing

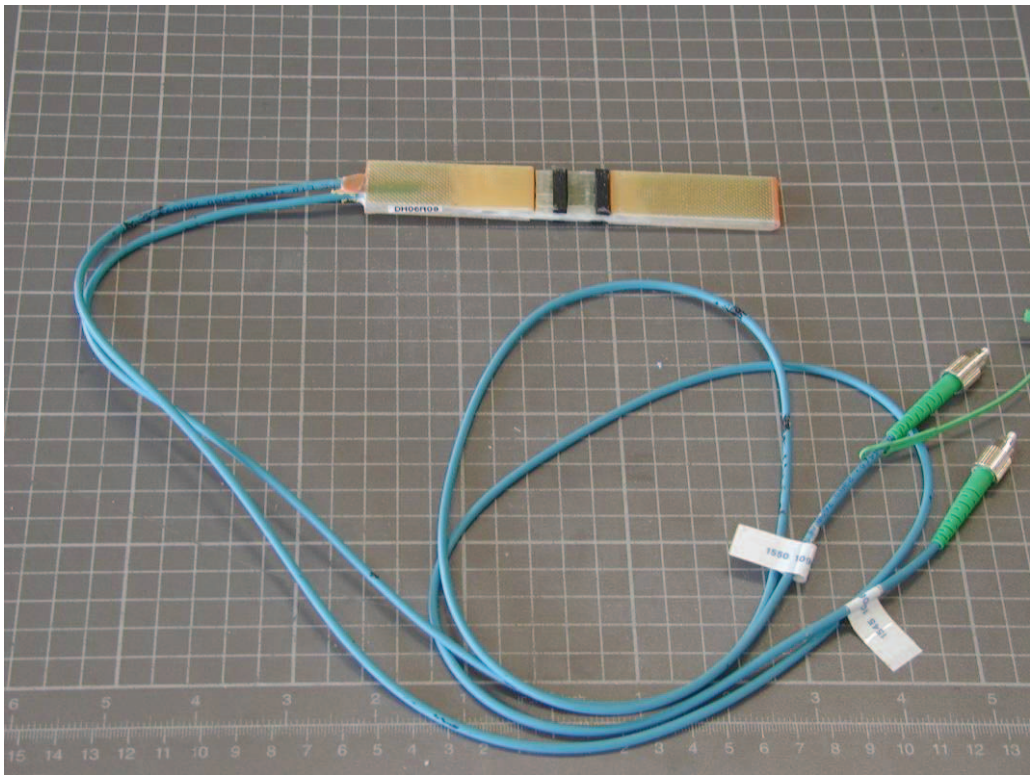


Figure A - 22: DH06R08 after testing

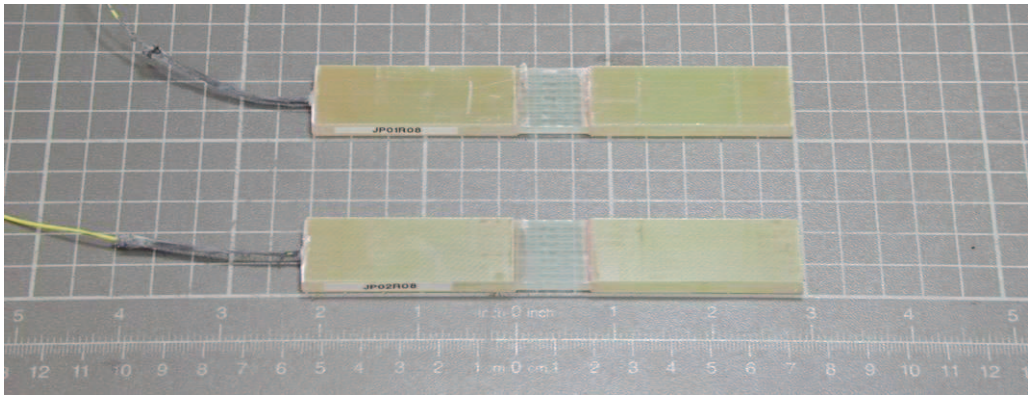


Figure A - 23: JP01R08 and JP02R08 before testing

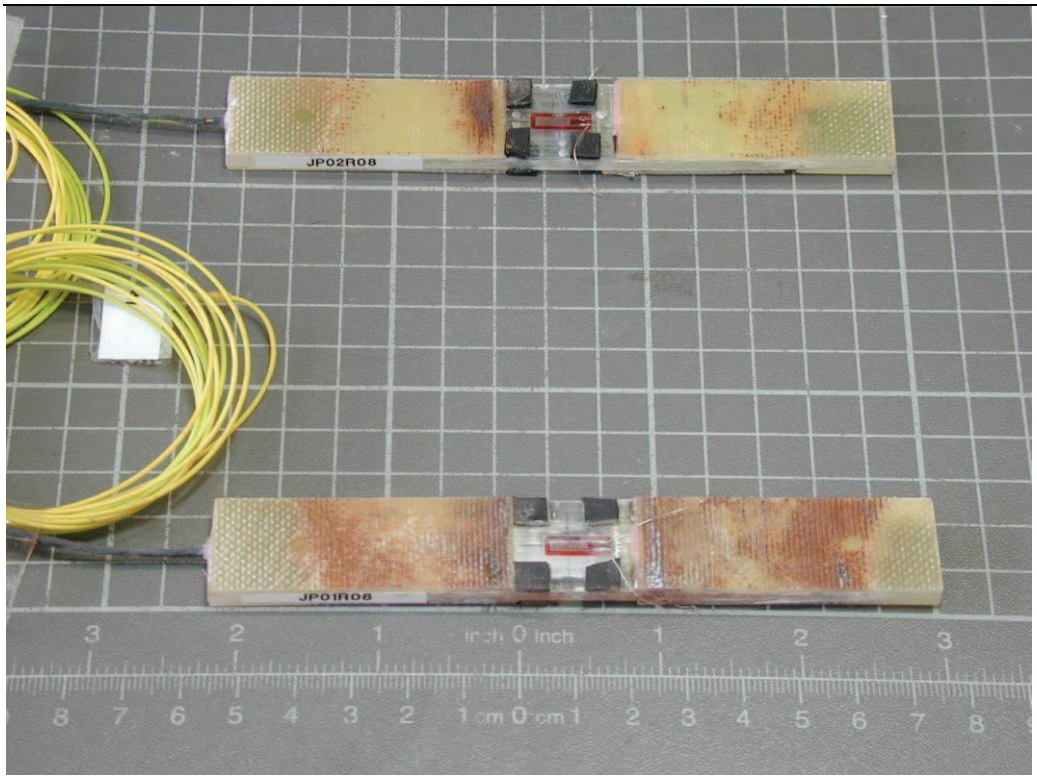


Figure A - 24: JP01R08 and JP02R08 after testing

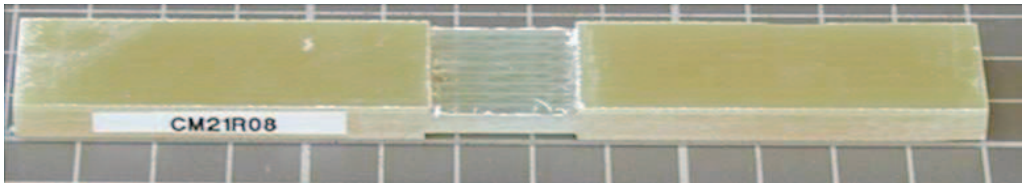


Figure A - 25: CM21R08 before testing

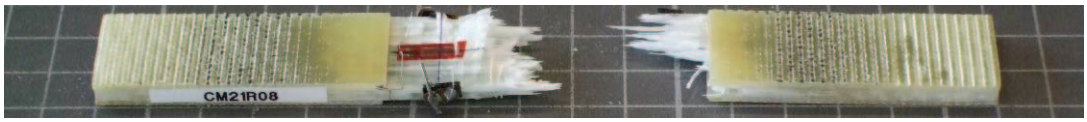


Figure A - 26: CM21R08 after testing

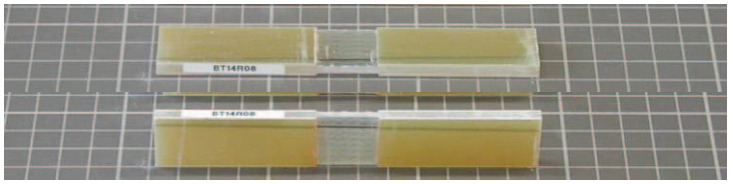


Figure A - 27: BT14R08 before testing

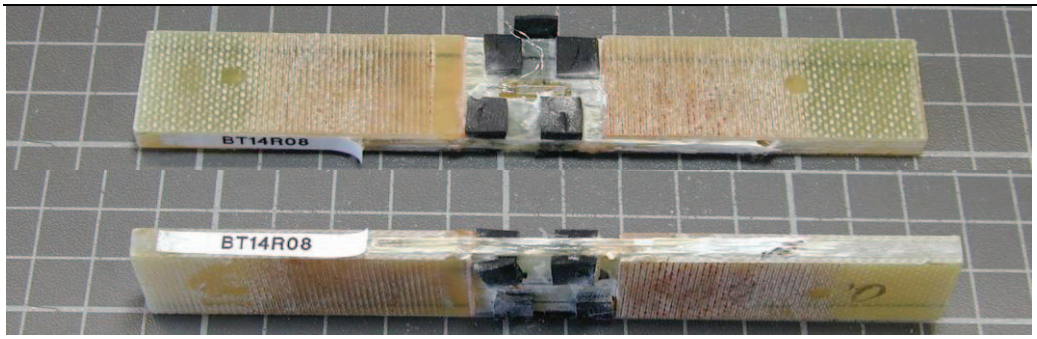


Figure A - 28: BT14R08 after testing

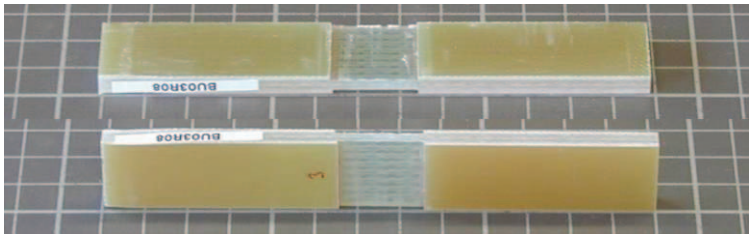


Figure A - 29: BU03R08 before testing

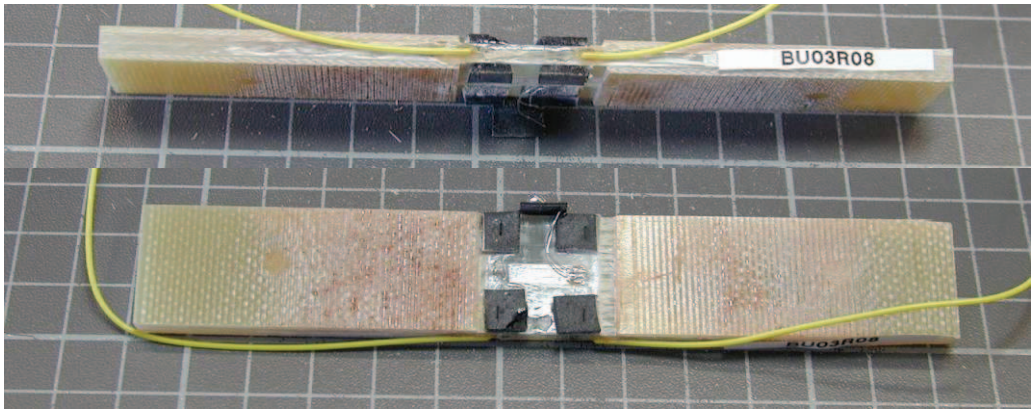


Figure A - 30: BU03R08 after testing

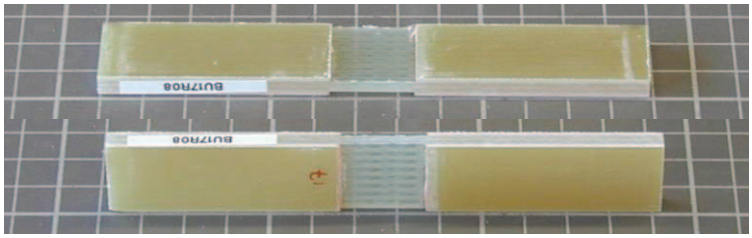


Figure A - 31: BU17R08 before testing

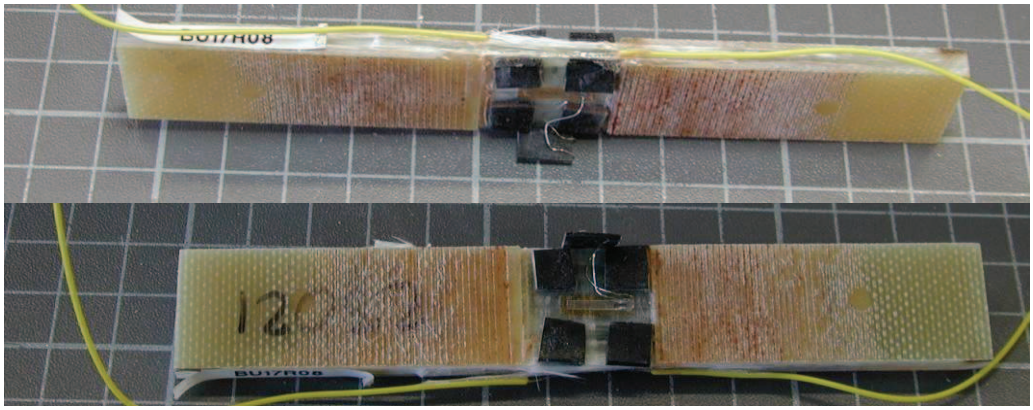
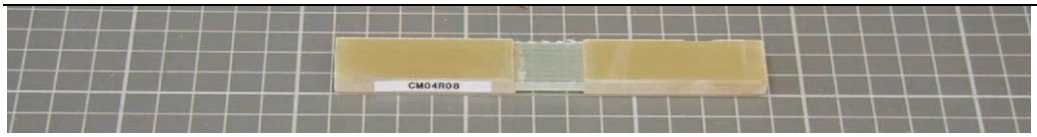


Figure A - 32: BU17R08 after testing



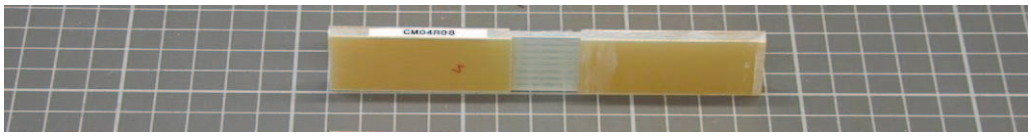
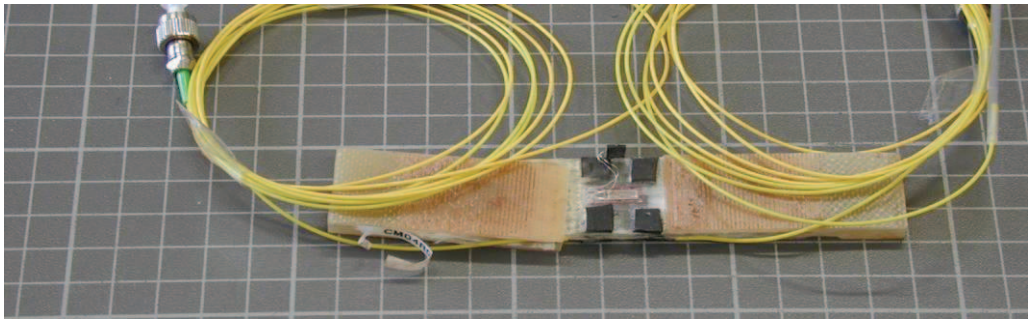


Figure A - 33: CM04R08 before testing



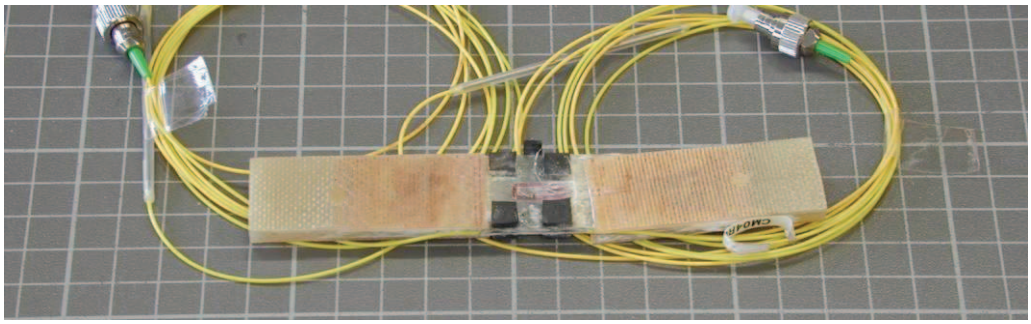


Figure A - 34: CM04R08 after testing

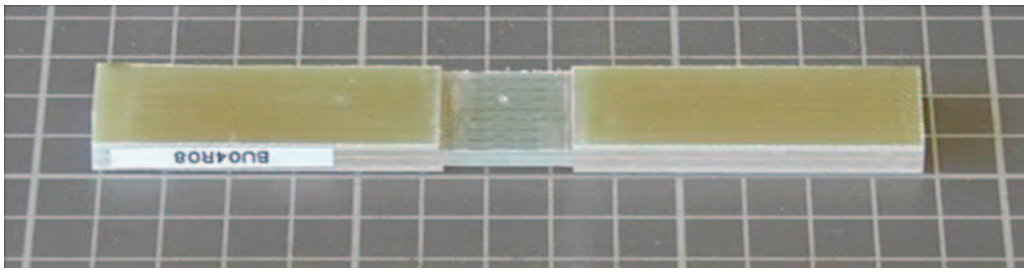


Figure A - 35: BU04R08 before testing

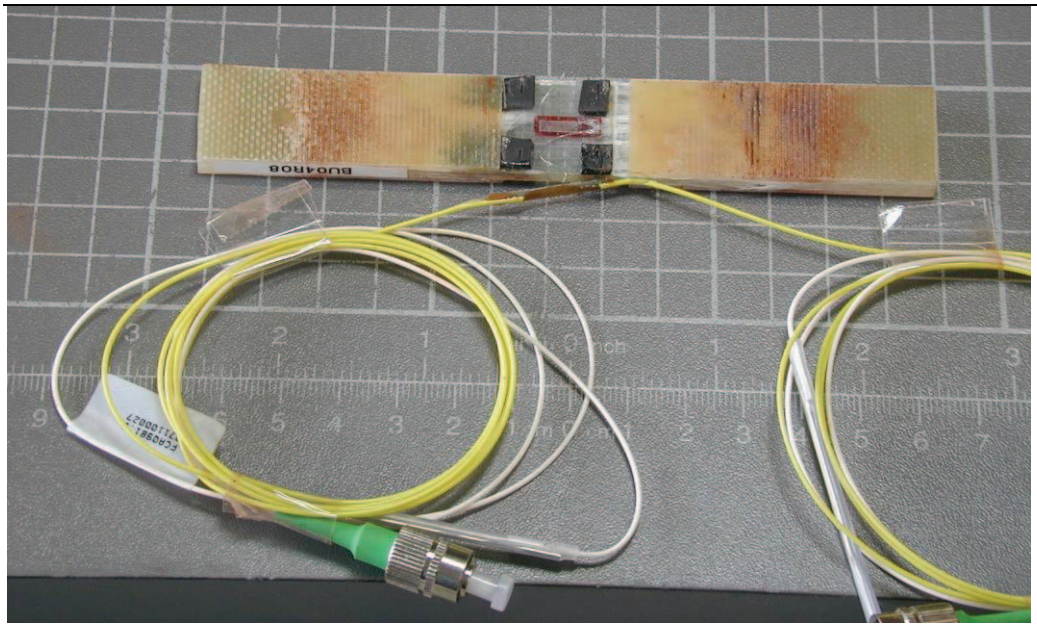


Figure A - 36: BU04R08 after testing

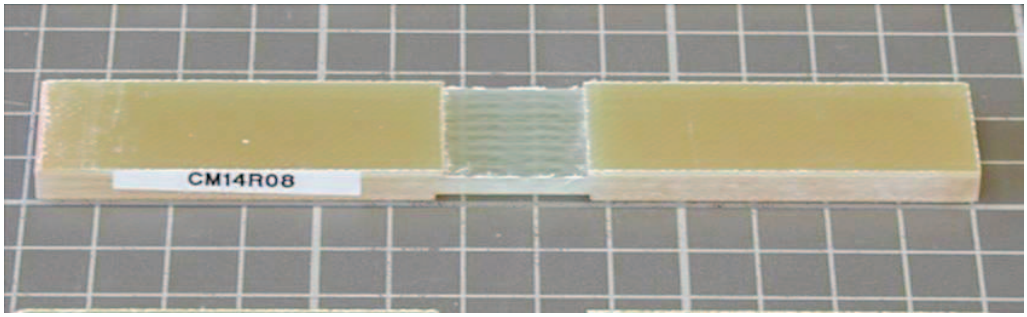


Figure A - 37: CM14R08 before testing

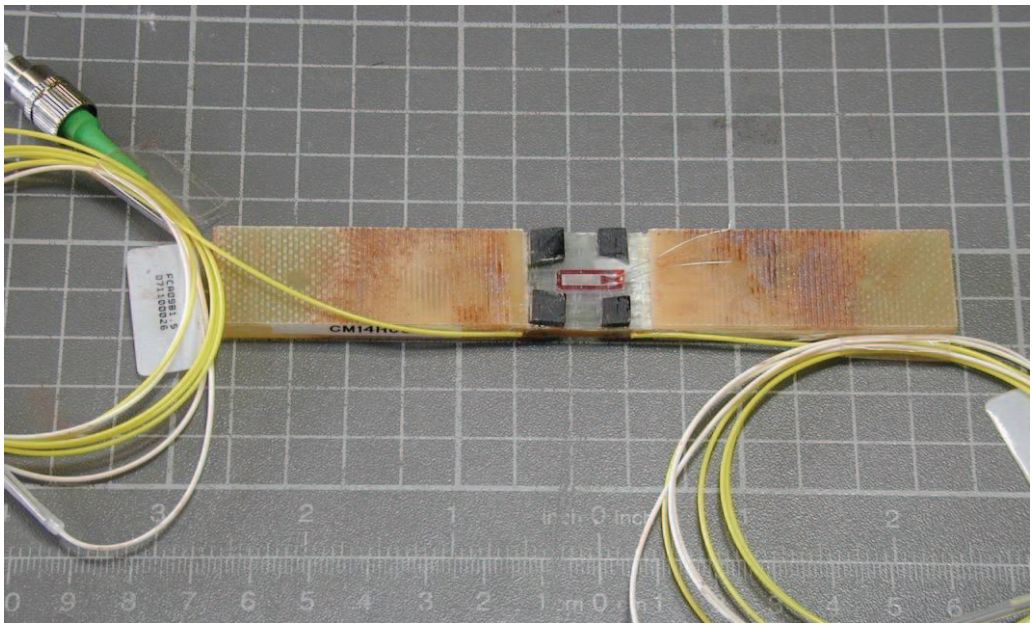


Figure A - 38: CM14R08 after testing

Figure A - 39: CM19R08 before testing

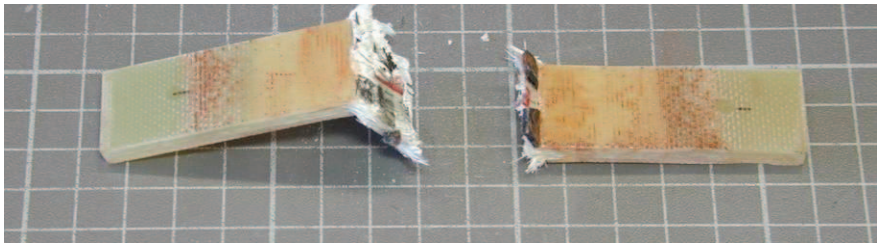


Figure A - 40: CM19R08 after testing

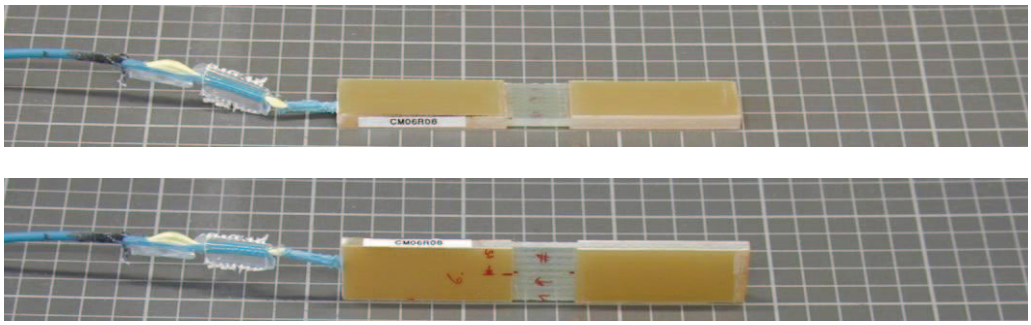


Figure A - 41: CM06R08 before testing

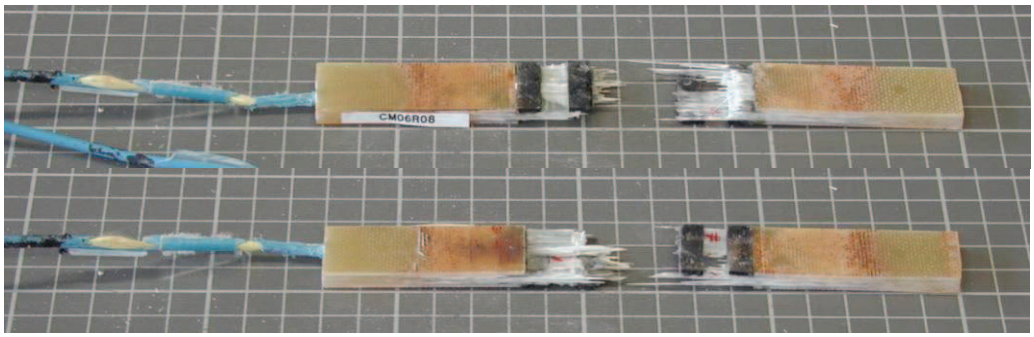


Figure A - 42: CM06R08 after testing

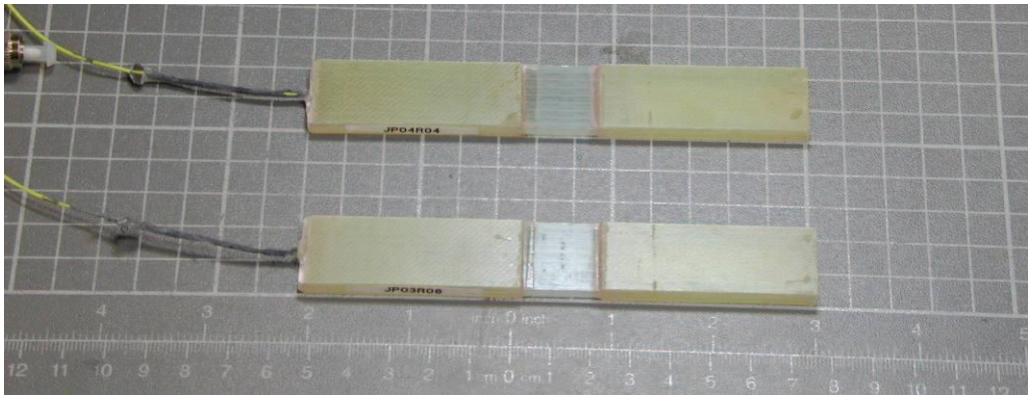


Figure A - 43: JP03R08 and JP04R08 before testing

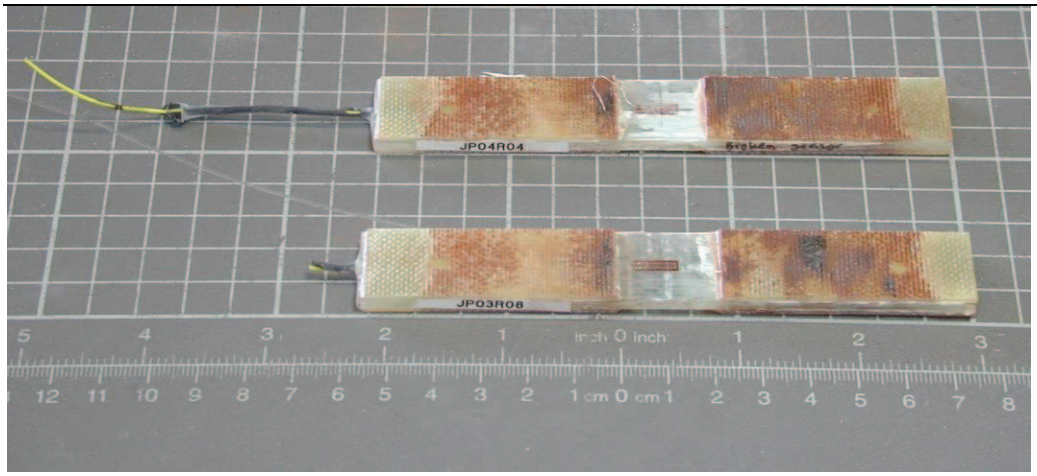


Figure A - 44: JP03R08 after testing

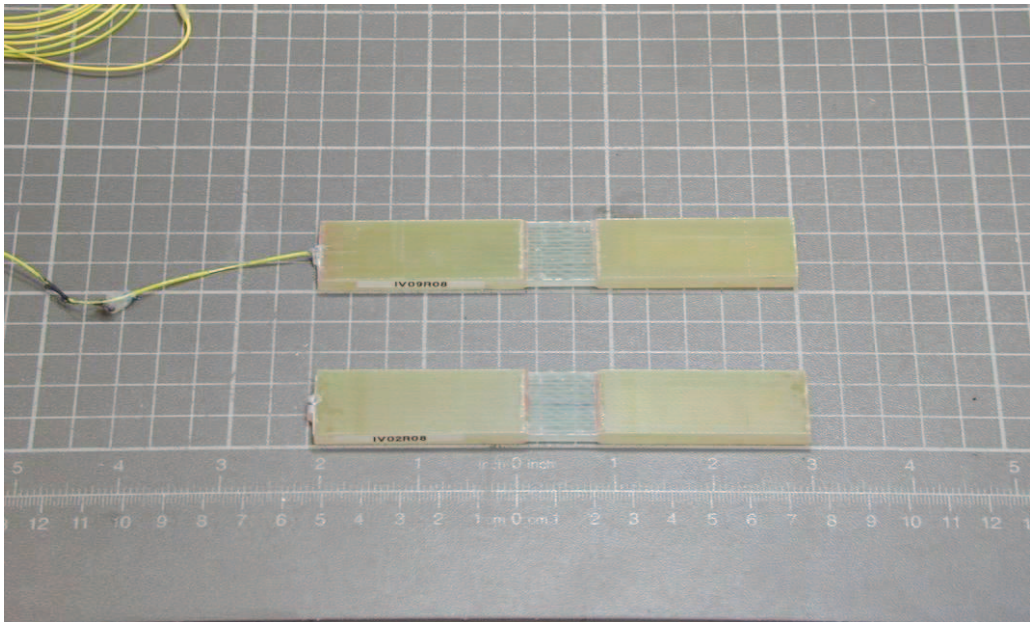


Figure A - 45: IV02R08 and IV09R08 before testing

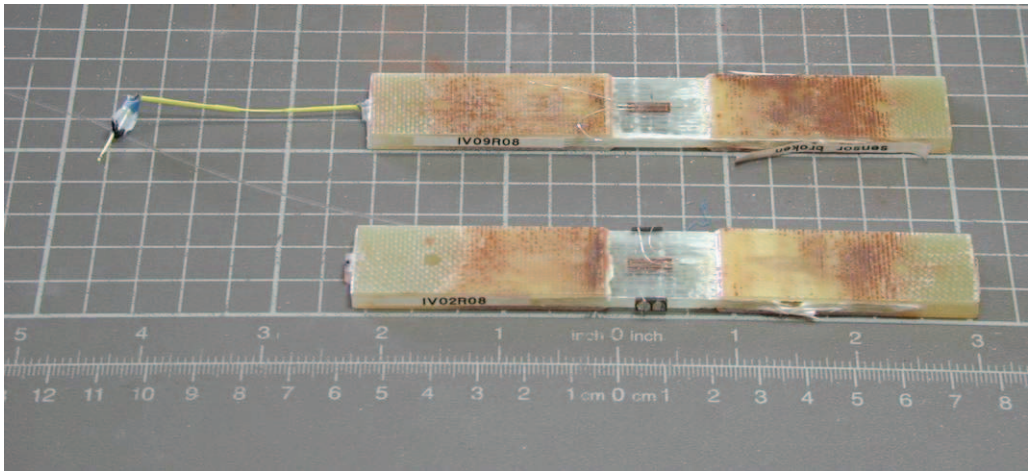


Figure A - 46: IV02R08 and IV09R08 after testing

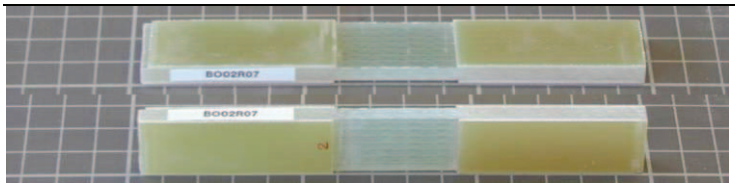


Figure A - 47: BO02R07 before testing

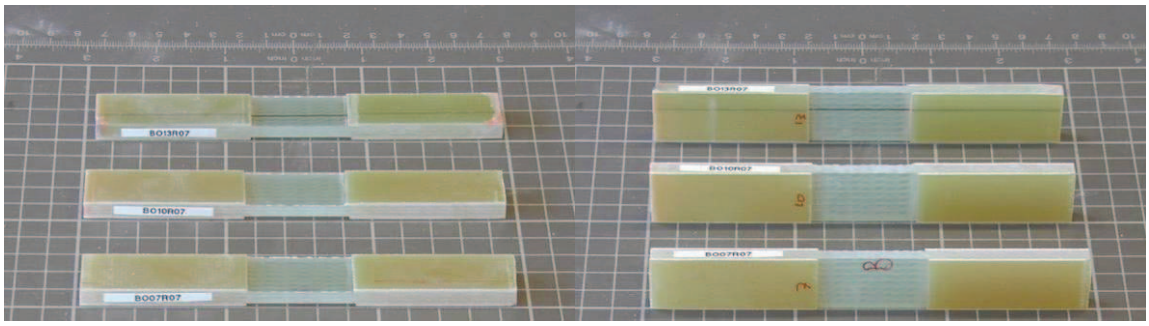


Figure A - 48: BO07, 10, 13 R07 before testing

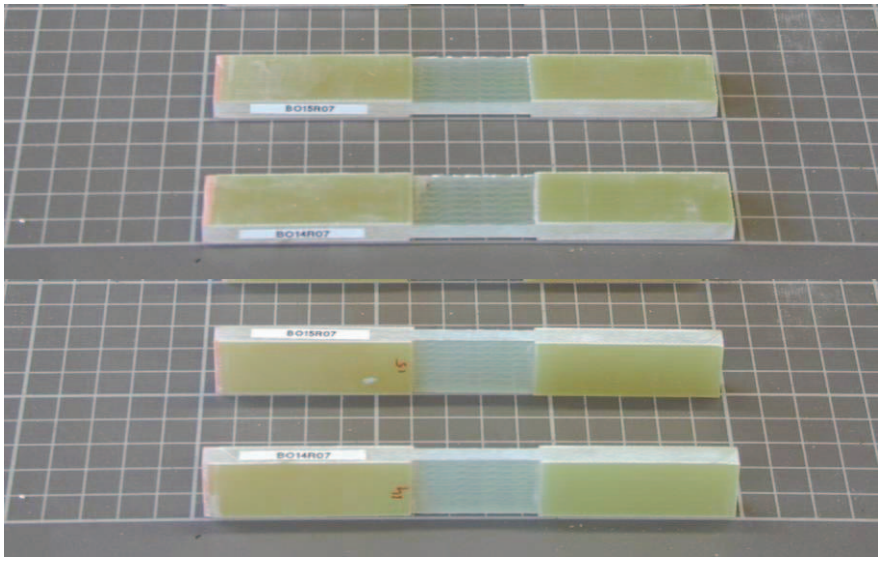


Figure A - 49: BO14, 15 R07 before testing

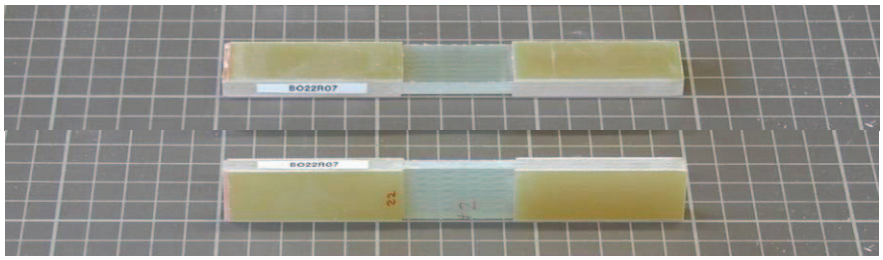


Figure A - 50: BO22R07 before testing

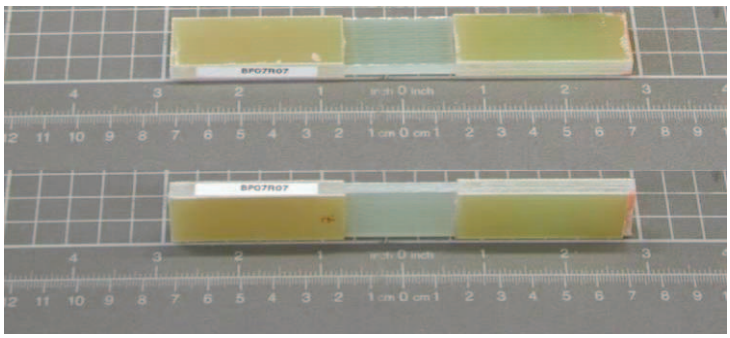


Figure A - 51: BP07R07 before testing

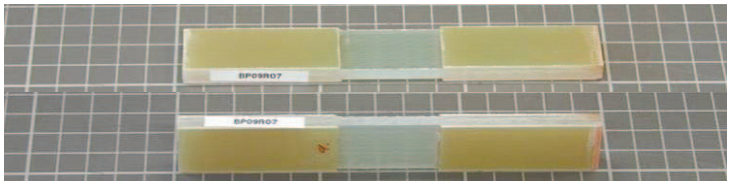


Figure A - 52: BP09R07 before testing

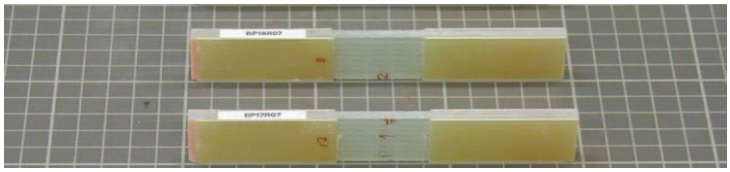


Figure A - 53: BP17, 18 R07 before testing

APPENDIX B MEASUREMENT SUMMARY R = -1 SURFACE MOUNTED

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	6.2	-7.3	-7.3		
Displ. [mm]	0.47	0.01	0.01		
$Clip_1$ [μ]	2515.	-3183.	-3183.	42242.	40505.
$Clip_2$ [μ]	2700.	-3344.	-3344.	40577.	38017.
$FBG_{1\ (0°)}$ [μ]	3054.	-3667.	-3212.	35772.	34989.
$\varepsilon_{1\ (0°)}$ [μ]	2926.	-3254.	-3254.	37481.	37936.
$\varepsilon_{2\ (0°)}$ [μ]	2707.	-3151.	-3151.	39929.	40033.
σ [MPa]	106.9	-126.9	-126.9		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	25.0	24.5	24.8

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BT14R08\BT14R08.SLW Nulled with:BT14R08.nul(Rec.1) E-moduli based on: TEST started at: 15-02-08 15:55:17

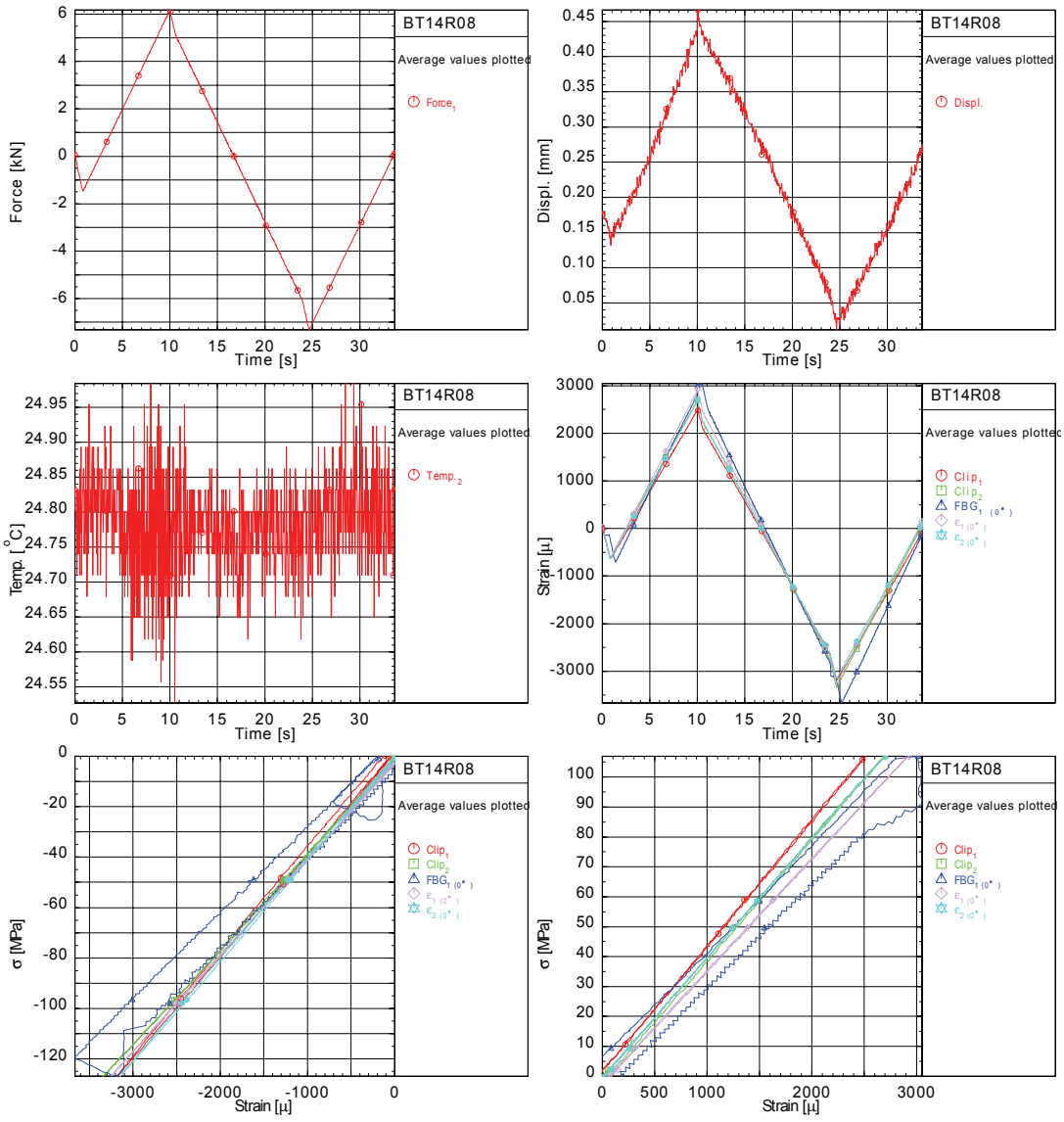


Figure B - 1: BT14R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
Force$_1$ [kN]	13.9	-14.0	14.1	-14.1	0.0
Displ. [mm]	1.17	-0.13	3.49	-0.29	1.86
Clip$_1$ [μ]	5287.	-7603.	10664.	-8794.	-1.
Clip$_2$ [μ]	5233.	-7250.	6061.	-8634.	4.
FBG$_{1\ (0^\circ)}$ [μ]	6154.	-4746.	6432.	-6954.	3.
$\varepsilon_{1\ (0^\circ)}$ [μ]	19053.	19037.	19056.	-5829.	1.
$\varepsilon_{2\ (0^\circ)}$ [μ]	18698.	18673.	18702.	-5684.	-1.
σ [MPa]	241.5	-242.3	243.8	-244.3	0.0

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	25.8	21.0	22.5

Number of Cycles	656895.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BT14R08\BT14R08.DFX Nulled with:BT14R08.nul(Rec.1) - TEST started at: 15-02-08 15:53:07

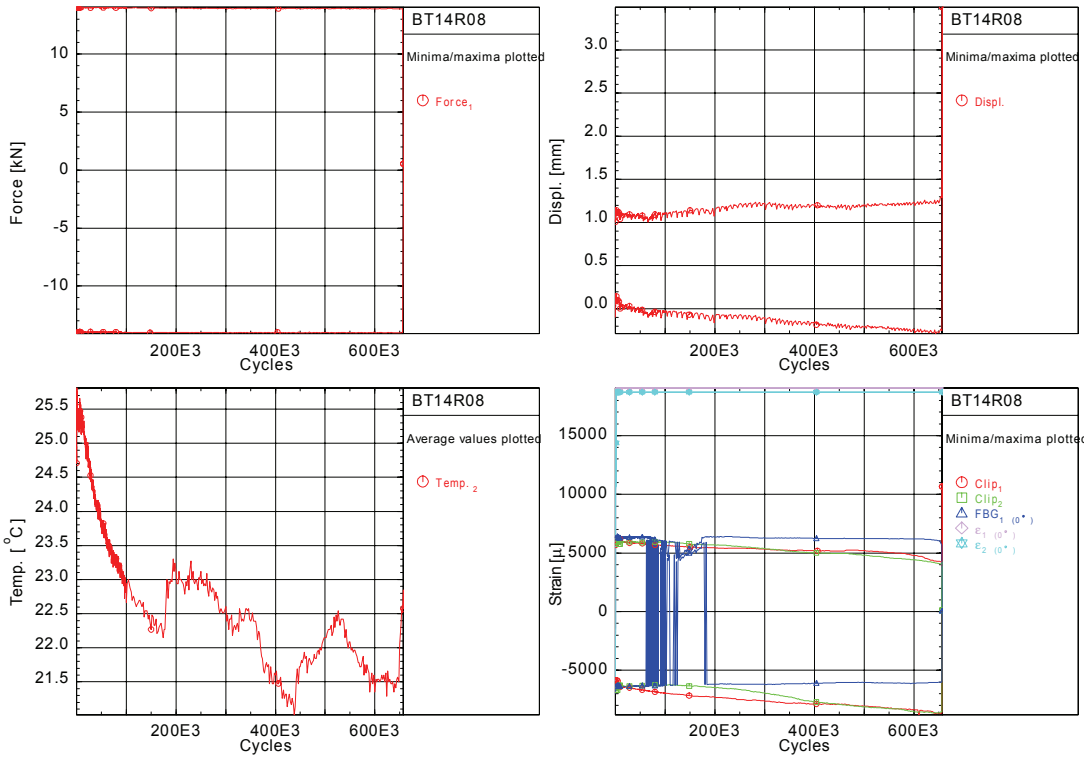


Figure B - 2: BT14R08 (fatigue summary)

Remarks: Jumps in signal may be attributed to D/A conversion software

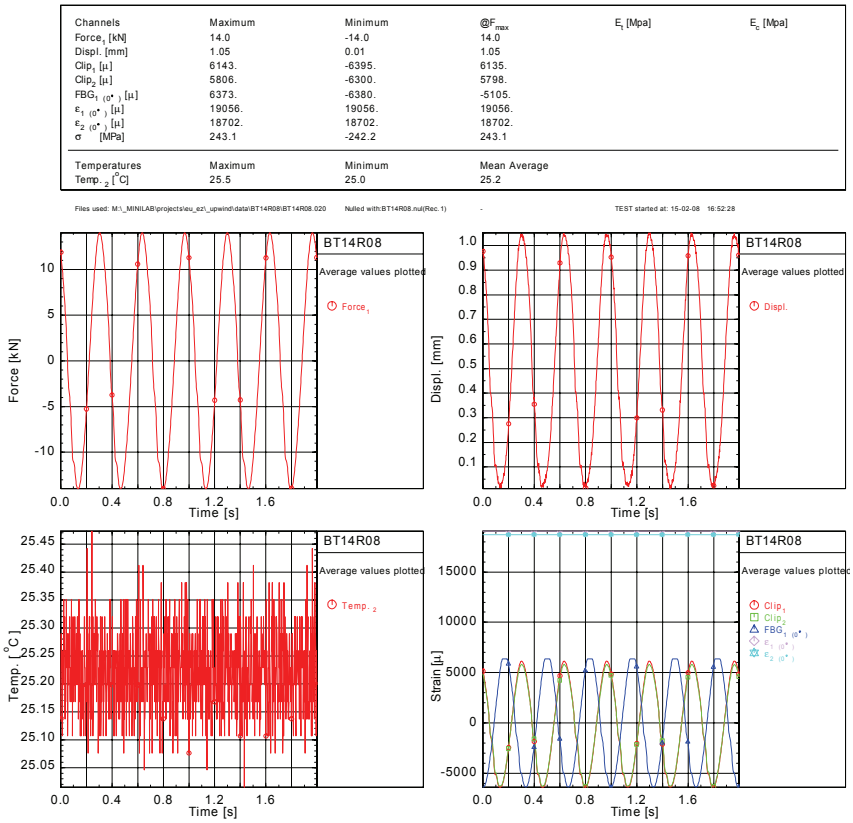


Figure B - 3: BT14R08 (ca. 1,000 cycles)

Remarks: Signals of FBG and Clip gauge are out-of-phase (likely due to D/A conversion)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	14.0	-13.9	14.0		
Displ. [mm]	1.11	-0.02	1.11		
$Clip_1$ [µ]	5669.	-6890.	5666.		
$Clip_2$ [µ]	5947.	-6246.	5928.		
$FBG_{1\ (0^\bullet)}$ [µ]	6084.	-6306.	-5092.		
$\varepsilon_{1\ (0^\bullet)}$ [µ]	19056.	19056.	19056.		
$\varepsilon_{2\ (0^\bullet)}$ [µ]	18702.	18702.	18702.		
σ [MPa]	243.1	-241.8	243.1		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	23.3	22.9	23.1

Files used: M:_MINILAB\projects\eu_ezi_upwind\data\BT14R08\BT14R08.028 Nulled with:BT14R08.nul(Rec. 1) - TEST started at: 16-02-08 00:15:03

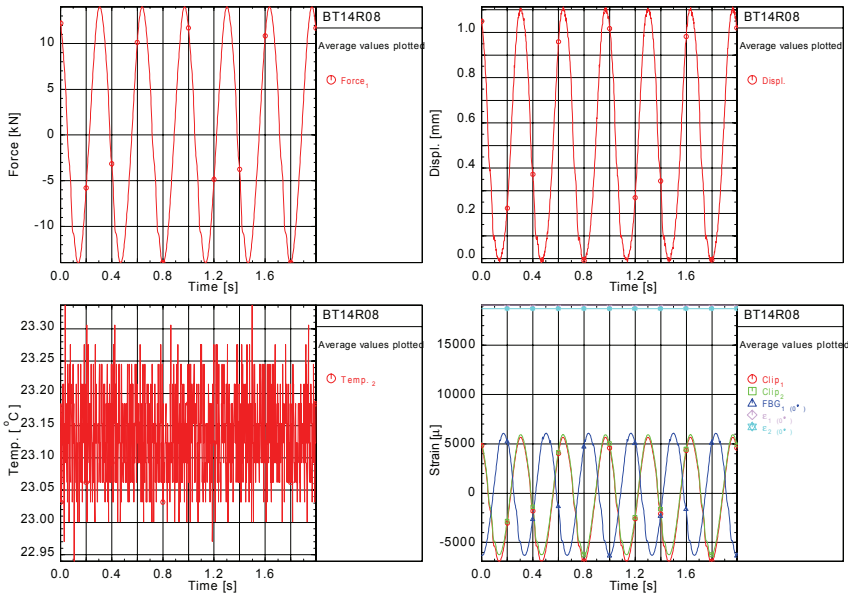


Figure B - 4: BT14R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	14.0	-14.0	14.0		
Displ. [mm]	1.11	-0.03	1.09		
$Clip_1$ [µ]	5643.	-6956.	5638.		
$Clip_2$ [µ]	5947.	-6235.	5937.		
$FBG_{1\ (0°)}$ [µ]	6022.	-6311.	-5082.		
$\varepsilon_{1\ (0°)}$ [µ]	19056.	19056.	19056.		
$\varepsilon_{2\ (0°)}$ [µ]	18702.	18702.	18702.		
σ [MPa]	242.9	-242.2	242.9		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	23.2	22.7	22.9

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BT14R08\BT14R08.029 Nulled with:BT14R08.nul(Rec.1) - TEST started at: 16-02-08 01:10:23

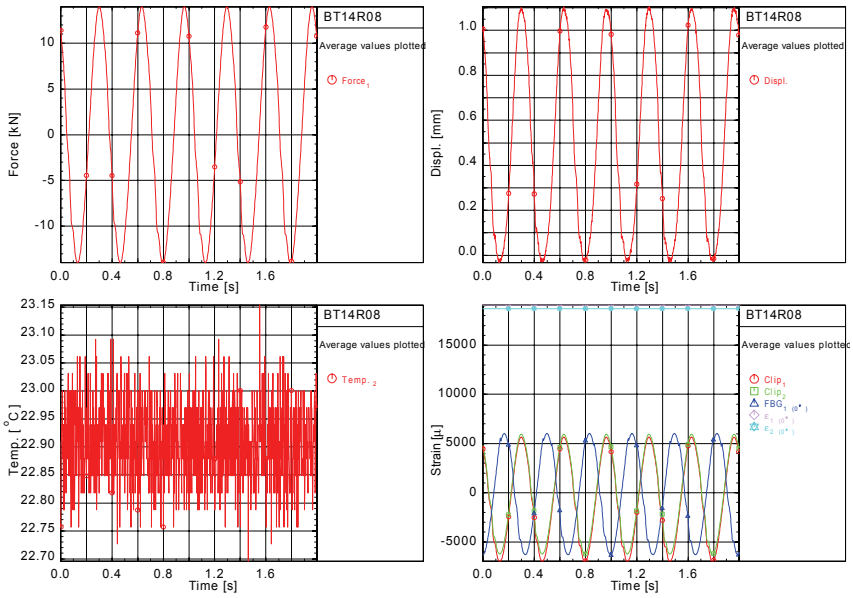


Figure B - 5: BT14R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	14.0	-14.0	-14.0		
Displ. [mm]	1.13	-0.10	-0.09		
$Clip_1$ [µ]	5450.	-7300.	-7293.		
$Clip_2$ [µ]	5701.	-6480.	-6469.		
$FBG_{1\ (0°)}$ [µ]	6337.	-6178.	4752.		
$\varepsilon_{1\ (0°)}$ [µ]	19056.	19056.	19056.		
$\varepsilon_{2\ (0°)}$ [µ]	18702.	18702.	18702.		
σ [MPa]	242.3	-242.6	-242.6		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	23.3	22.9	23.1

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BT14R08\BT14R08.030 Nulled with:BT14R08.nul(Rec.1) - TEST started at: 16-02-08 10:23:37

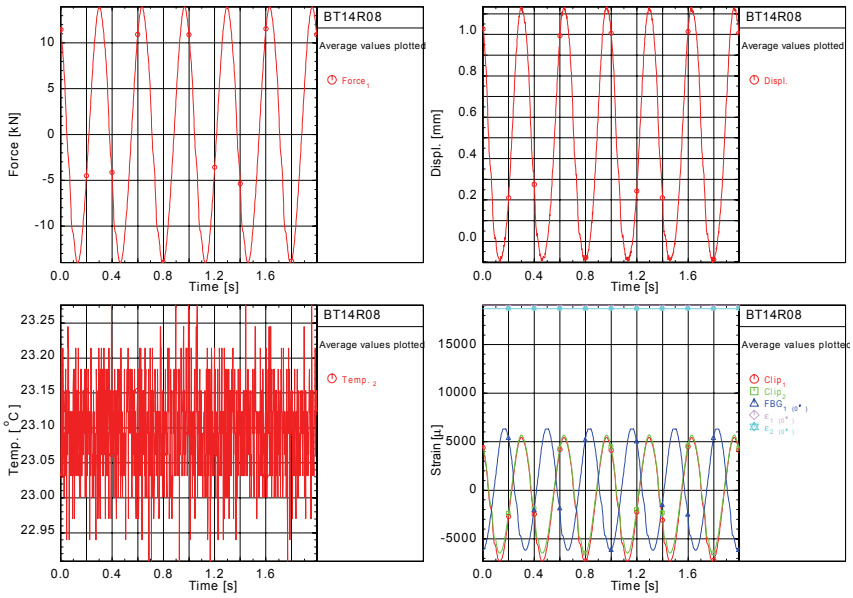


Figure B - 6: BT14R08 (ca. 1,000,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	6.1	-7.4	-7.4		
Displ. [mm]	0.34	-0.19	-0.18		
$Clip_1$ [μ]	2438.	-3265.	-3263.	41334.	40400.
$Clip_2$ [μ]	2289.	-3366.	-3366.	40849.	41131.
$FBG_{1\ (0°)}$ [μ]	2990.	-3099.	-2681.	37968.	38512.
$\varepsilon_{1\ (0°)}$ [μ]	2755.	-3197.	-3197.	38628.	39020.
$\varepsilon_{2\ (0°)}$ [μ]	2811.	-3407.	-3407.	36941.	37194.
σ [MPa]	104.8	-126.6	-126.6		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.1	23.7	23.9

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU03R08\BU03R08.SLW Nulled with:BU03R08.nul(Rec.1) E-moduli based on: TEST started at: 20-02-08 14:42:42

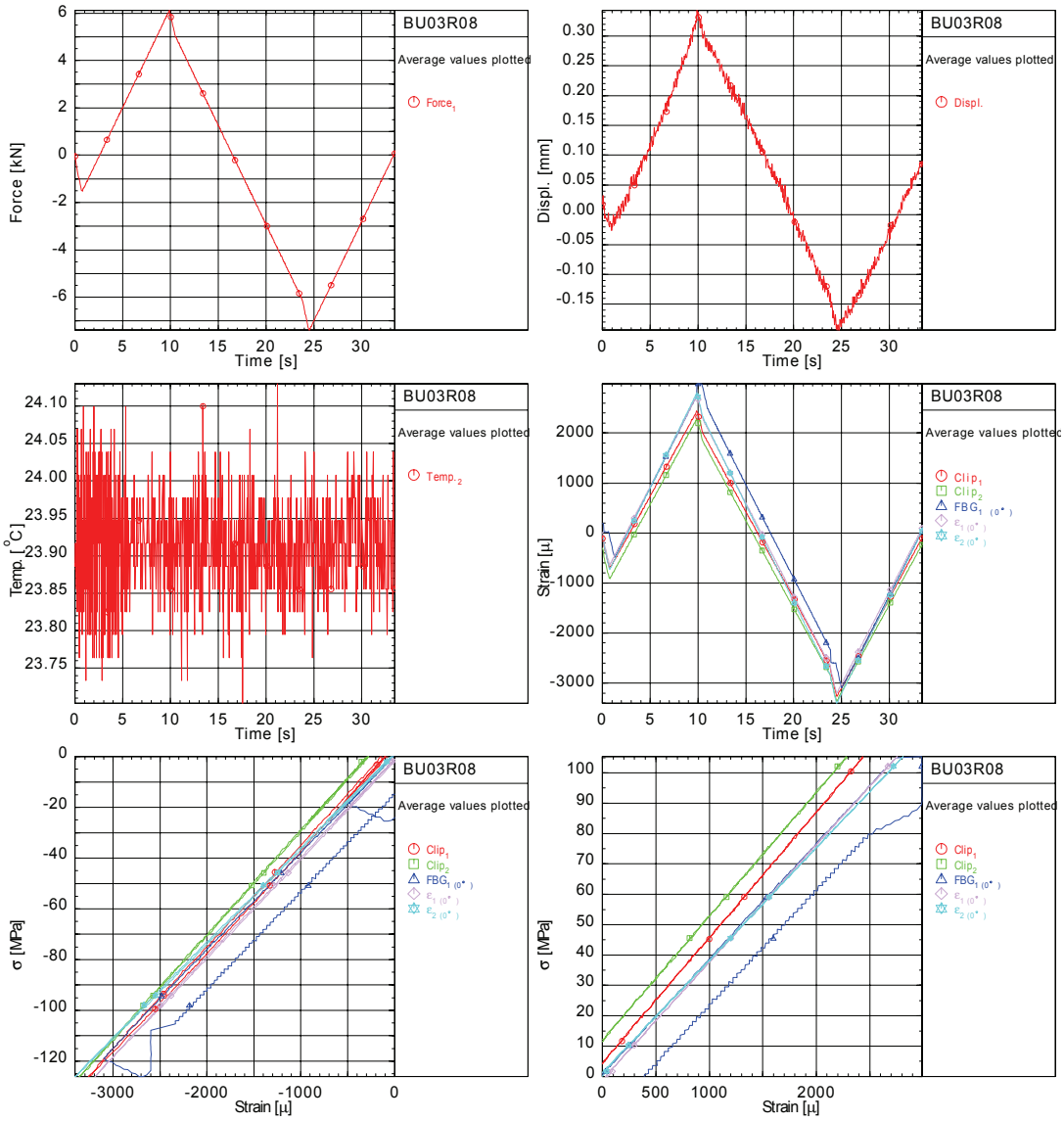


Figure B - 7: BU03R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
Force$_1$ [kN]	13.9	-14.0	14.5	-14.9	0.0
Displ. [mm]	1.02	-0.35	4.57	-0.52	0.27
Clip$_1$ [μ]	3826.	-7545.	5808.	-9241.	8.
Clip$_2$ [μ]	5846.	-6327.	6093.	-6691.	0.
FBG$_{1\ (0^\circ)}$ [μ]	4337.	1345.	8284.	-21431.	-1.
$\varepsilon_{1\ (0^\circ)}$ [μ]	19207.	19186.	19210.	-6009.	-2.
$\varepsilon_{2\ (0^\circ)}$ [μ]	19232.	19215.	19235.	-6305.	-2.
σ [MPa]	238.0	-240.1	249.1	-255.7	0.5

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	26.4	23.5	24.8

Number of Cycles	837905.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU03R08\BU03R08.DFX Nulled with:BU03R08.nul(Rec.1) - TEST started at: 20-02-08 14:39:16

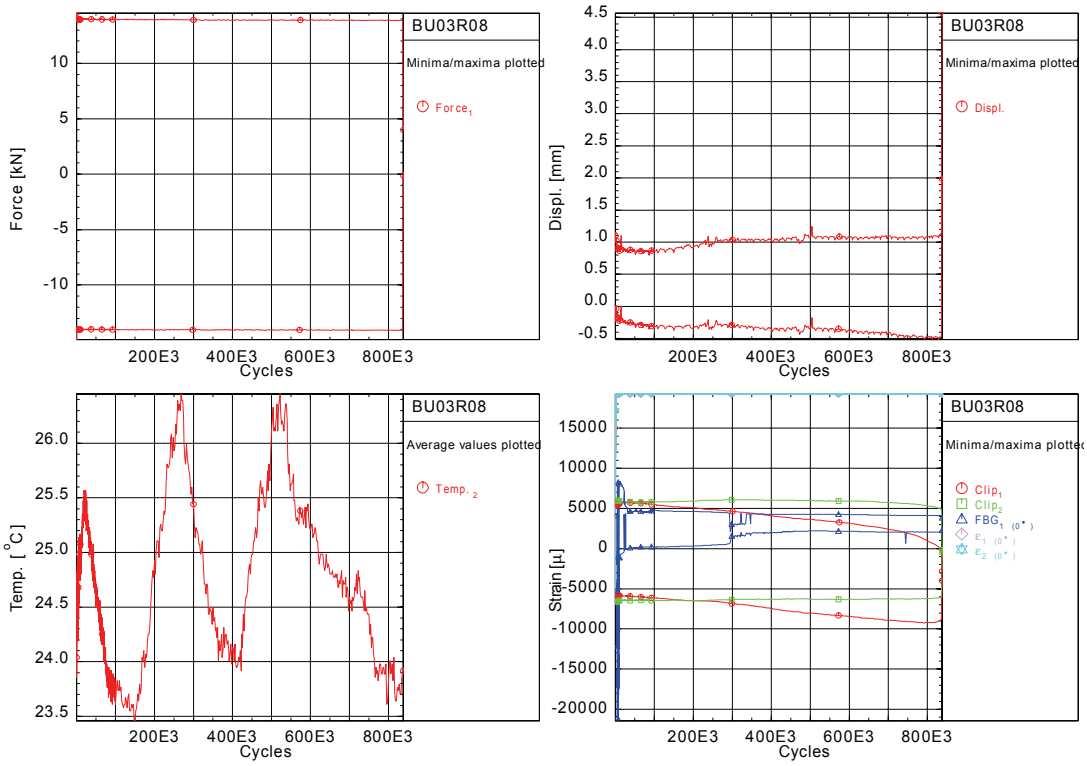


Figure B - 8: BT03R08 (fatigue summary)

Remarks: Front and rear clip gauges considerably different. FBG measured range decreases early

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	14.0	-14.0	14.0				
Displ. [mm]	1.05	-0.02	1.04				
$Clip_1$ [μ]	5511.	-5768.	5508.				
$Clip_2$ [μ]	5978.	-6514.	5977.				
$FBG_{1\ (0°)}$ [μ]	4158.	-5438.	-4417.				
$\varepsilon_{1\ (0°)}$ [μ]	19210.	10215.	19210.				
$\varepsilon_{2\ (0°)}$ [μ]	19235.	12153.	19235.				
σ [MPa]	239.6	-240.1	239.6				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.9	24.5	24.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU03R08\BU03R08.nul(Rec.1)

TEST started at: 20-02-08 14:52:45

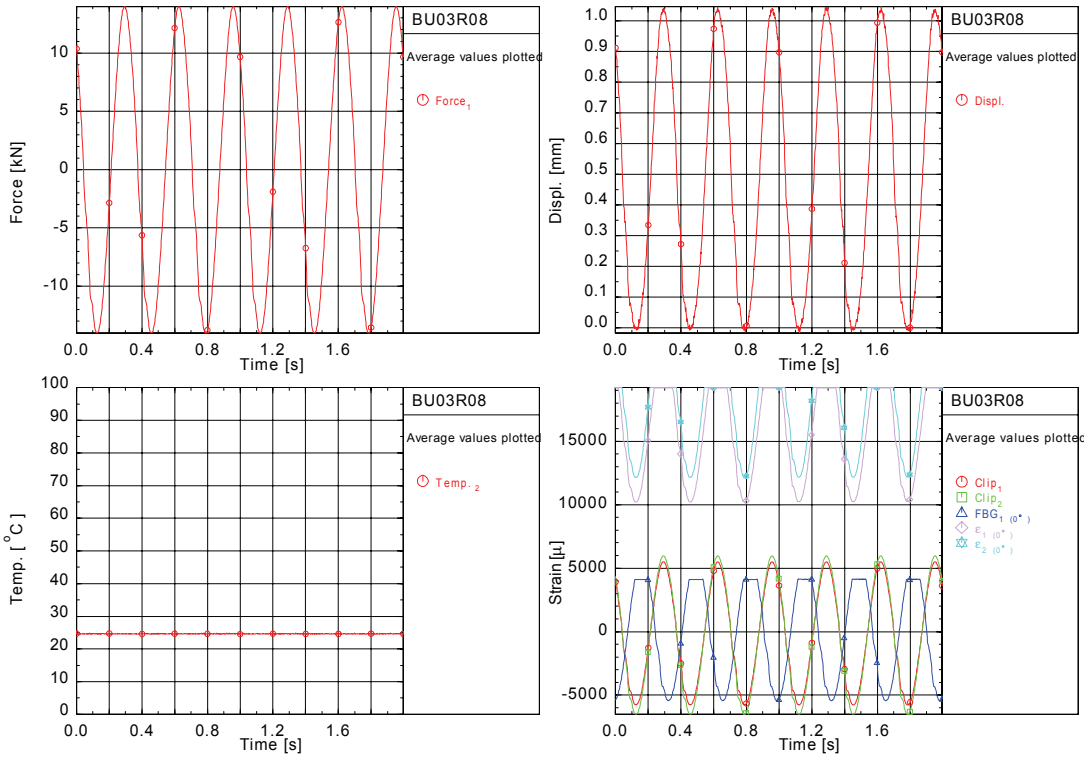


Figure B - 9: BU03R08 (ca. 1,000 cycles)

Remarks: Strain gauges starting to fail. FBG signals miss top (incorrect settings in interrogator?)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	14.0	-14.0	14.0				
Displ. [mm]	0.87	-0.28	0.86				
$Clip_1$ [μ]	5668.	-6003.	5658.				
$Clip_2$ [μ]	5801.	-6437.	5795.				
$FBG_{1\ (0^\circ)}$ [μ]	4649.	150.	340.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	19210.	19210.	19210.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19235.	19235.	19235.				
σ [MPa]	239.2	-240.0	239.2				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.6	24.1	24.4

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU03R08\BU03R08.nul(Rec.1)

TEST started at: 20-02-08 20:31:07

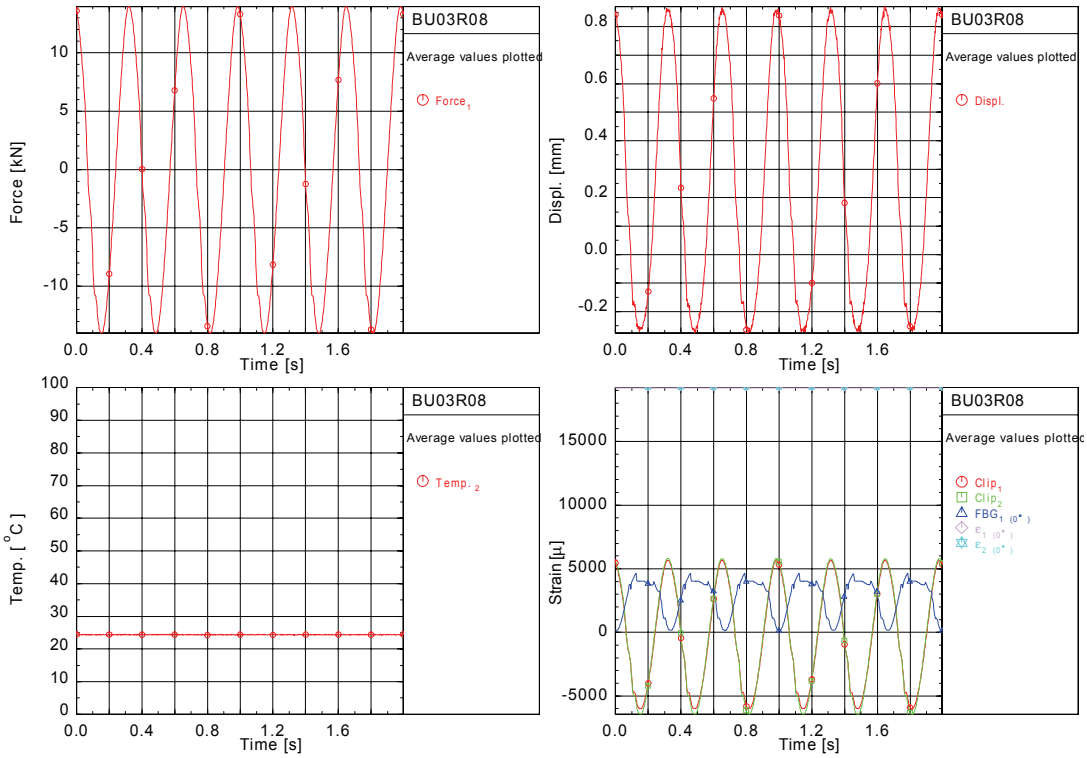


Figure B - 10: BU03R08 (ca. 10,000 cycles)

Remarks: Significant distortion of FBG signal

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	14.0	-14.1	-14.1				
Displ. [mm]	0.91	-0.35	-0.33				
$Clip_1$ [µ]	5095.	-6490.	-6473.				
$Clip_2$ [µ]	5929.	-6471.	-6453.				
$FBG_{1\ (0^\circ)}$ [µ]	4632.	312.	4097.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	19210.	19210.	19210.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	19235.	19235.	19235.				
σ [MPa]	239.2	-240.8	-240.8				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	25.0	24.7	24.8

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU03R08[illegible]R08.nul(Rec.1)

TEST started at: 21-02-08 09:25:39

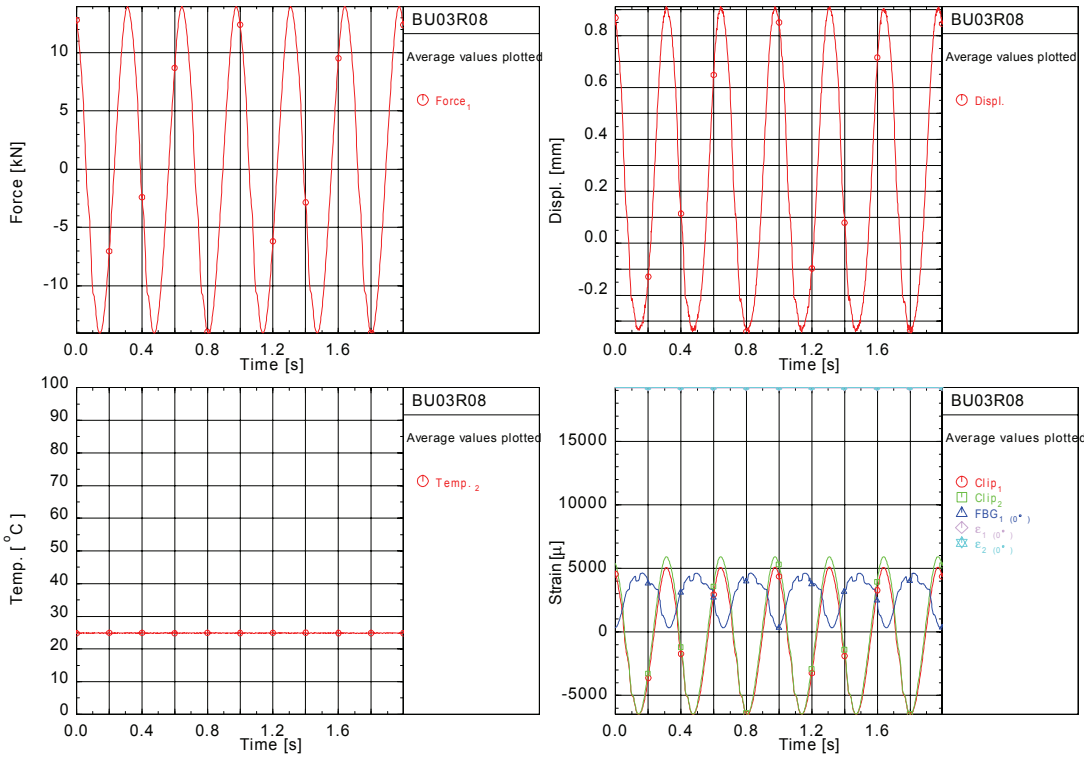


Figure B - 11: BU03R08 (ca. 100,000 cycles)

Remarks: Significant distortion of FBG signal

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	6.1	-7.1	-7.1		
Displ. [mm]	0.28	-0.17	-0.17		
$Clip_1$ [µ]	2448.	-2987.	-2987.	40780.	41489.
$Clip_2$ [µ]	2505.	-3058.	-3058.	40149.	40078.
$FBG_{1\ (0°)}$ [µ]	2780.	-2846.	-2402.	40386.	39390.
$\varepsilon_{1\ (0°)}$ [µ]	2773.	-3148.	-3148.	37323.	38123.
$\varepsilon_{2\ (0°)}$ [µ]	2866.	-3302.	-3302.	35934.	36341.
σ [MPa]	102.8	-120.8	-120.8		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	23.3	22.9	23.1

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU17R08\BU17R08.SLW Nulled with:BU17R08.nul(Rec.1) E-moduli based on: TEST started at: 11-02-08 16:30:25

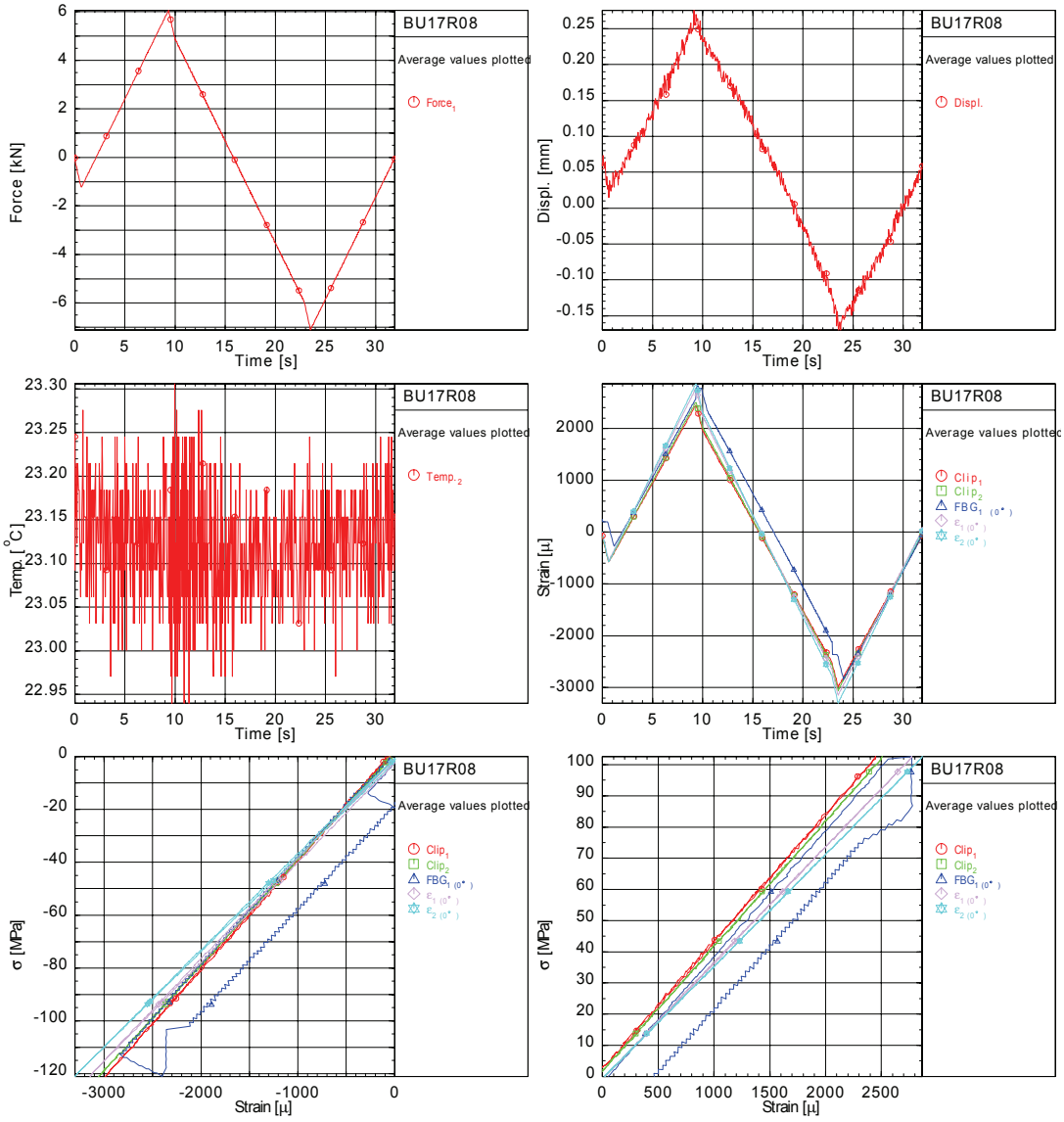


Figure B - 12: BU17R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
Force$_1$ [kN]	14.0	-13.9	14.1	-14.1	0.0		
Displ. [mm]	0.69	-0.57	2.14	-0.75	0.22		
Clip$_1$ [μ]	4644.	-7837.	6454.	-9788.	12.		
Clip$_2$ [μ]	5808.	-6126.	6296.	-6475.	14.		
FBG$_{1\ (0°)}$ [μ]	4975.	-6147.	6373.	-6572.	9.		
$\varepsilon_{1\ (0°)}$ [μ]	19449.	19424.	19501.	-15412.	-4.		
$\varepsilon_{2\ (0°)}$ [μ]	19337.	19315.	19400.	-15910.	3.		
σ [MPa]	236.9	-236.2	239.8	-238.5	-0.3		

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	27.0	23.0	25.0

Number of Cycles 642004.

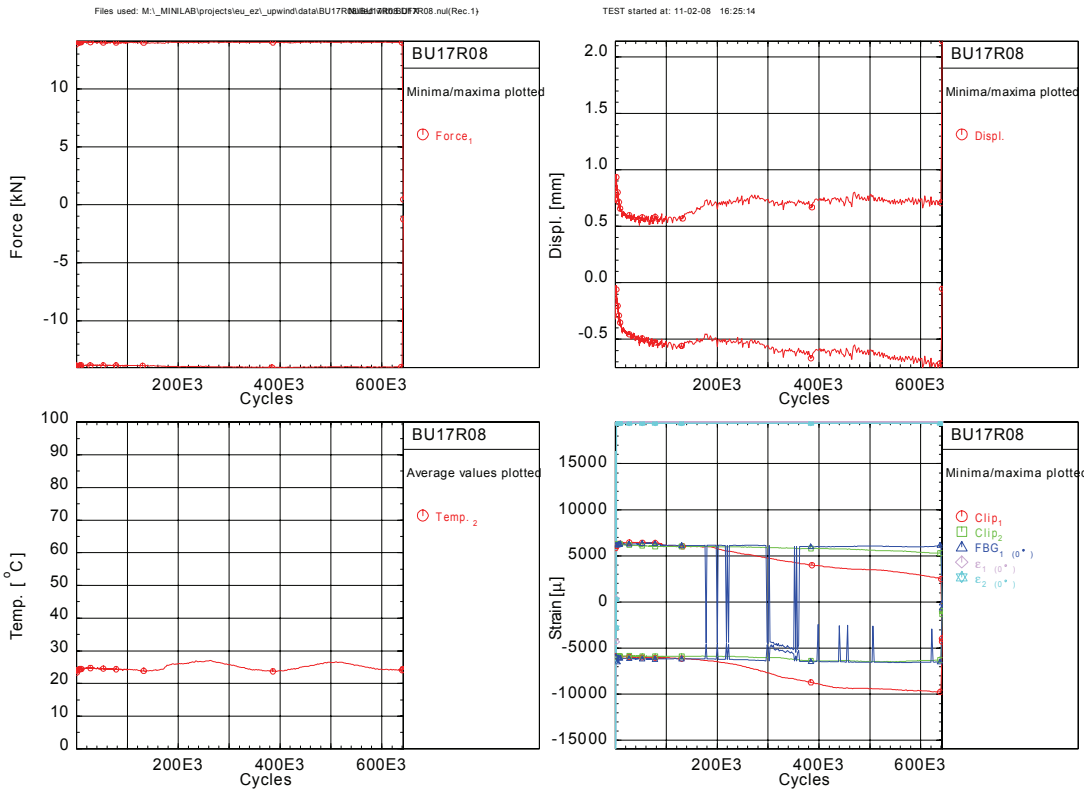


Figure B - 13: BU17R08 (fatigue summary)

Remarks: Jumps in signal may be attributed to D/A conversion software

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	14.0	-14.0	14.0				
Displ. [mm]	0.94	-0.04	0.93				
$Clip_1$ [μ]	6069.	-5886.	6061.				
$Clip_2$ [μ]	6227.	-5958.	6227.				
$FBG_{1\ (0°)}$ [μ]	6193.	-5893.	-4918.				
$\varepsilon_{1\ (0°)}$ [μ]	19501.	11361.	19501.				
$\varepsilon_{2\ (0°)}$ [μ]	19400.	13124.	19400.				
σ [MPa]	238.3	-237.0	238.3				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.3	23.8	24.1

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU17R08\BU17R08.nul(Rec.1)

TEST started at: 11-02-08 16:37:40

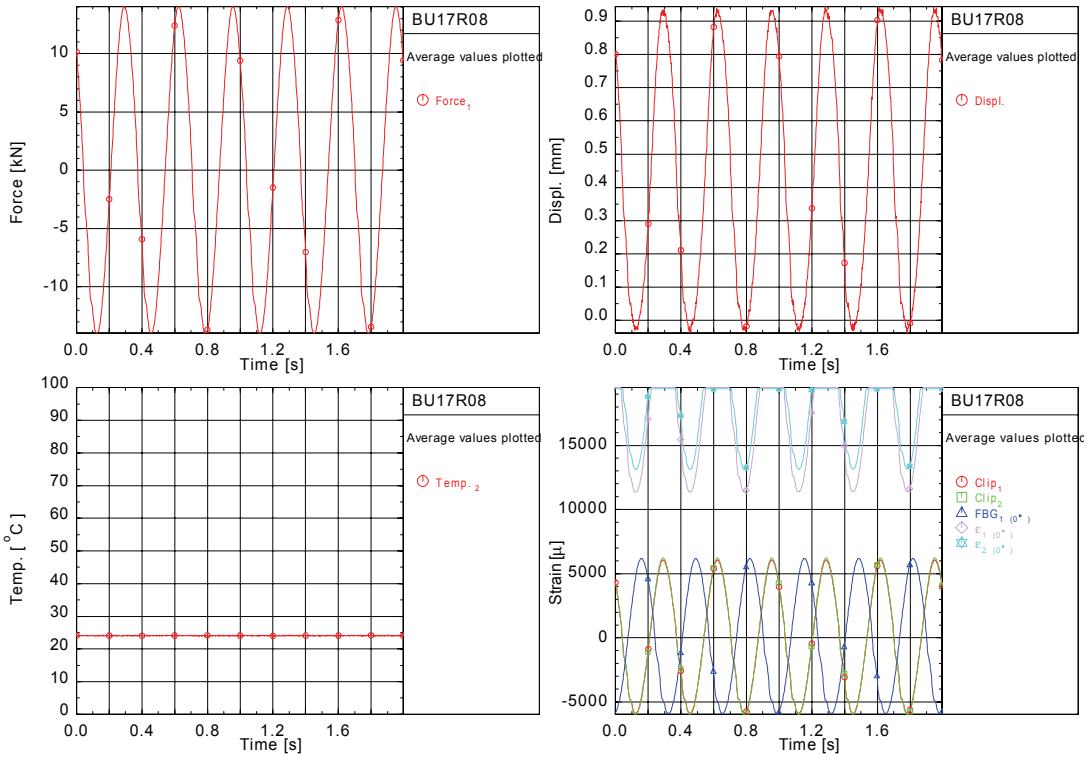


Figure B - 14: BU17R08 (ca. 1,000 cycles)

Remarks: Strain gauges starting to fail. FBG and clip gauge signals out of phase

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	14.0	-13.9	14.0				
Displ. [mm]	0.59	-0.46	0.57				
$Clip_1$ [μ]	6435.	-5954.	6430.				
$Clip_2$ [μ]	6204.	-5863.	6188.				
$FBG_{1\ (0^\circ)}$ [μ]	6295.	-6122.	-5050.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	19501.	19501.	19501.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19400.	19400.	19400.				
σ [MPa]	238.0	-235.4	238.0				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.9	24.5	24.7

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU17R08\BU17R08.nul(Rec.1)

TEST started at: 11-02-08 18:22:47

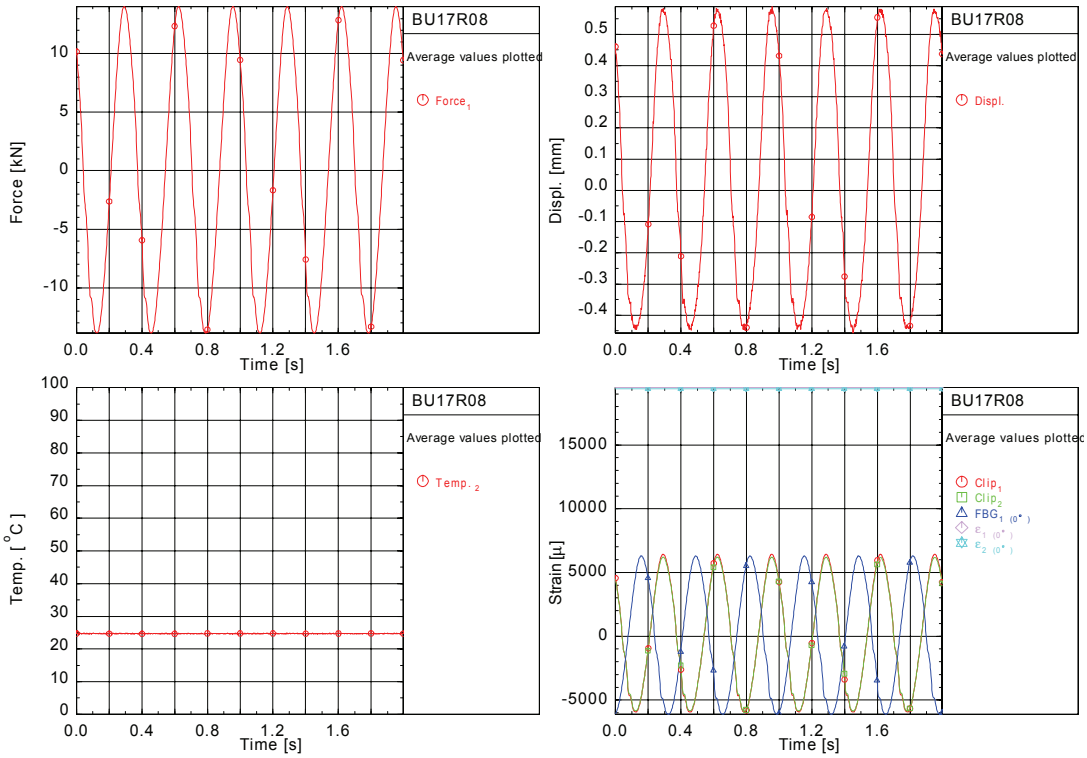


Figure B - 15: BU17R08 (ca. 10,000 cycles)

Remarks: Strain gauges failed. FBG and clip gauges out-of-phase

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	14.0	-14.0	-14.0				
Displ. [mm]	0.75	-0.55	-0.55				
$Clip_1$ [µ]	4770.	-7686.	-7675.				
$Clip_2$ [µ]	5910.	-6024.	-6020.				
$FBG_{1\ (0^\circ)}$ [µ]	6128.	-6380.	4765.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	19501.	19501.	19501.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	19400.	19400.	19400.				
σ [MPa]	238.0	-237.7	-237.7				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	26.0	25.6	25.8

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU17R08\BU17R08.nul(Rec.1)

TEST started at: 12-02-08 20:11:51

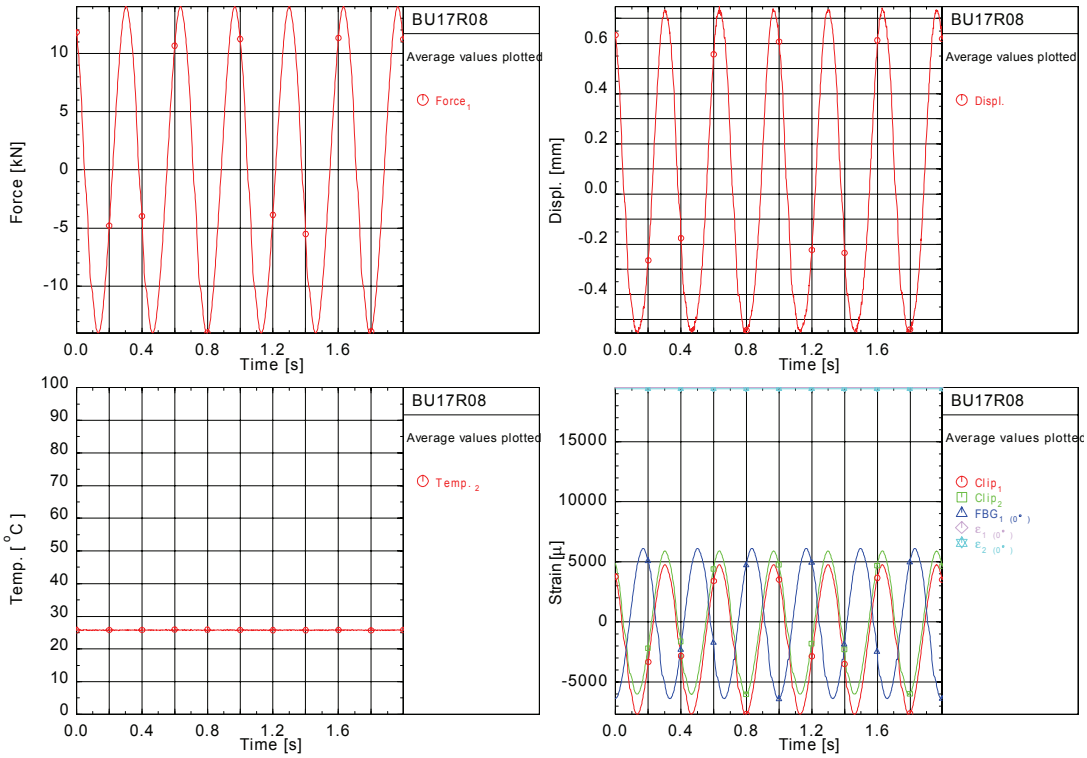


Figure B - 16: BU17R08 (ca. 100,000 cycles)

Remarks: Clip gauge signal shifted downward slightly

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	6.1	-7.4	-7.4		
Displ. [mm]	0.41	-0.11	-0.11		
$Clip_1$ [µ]	2400.	-3195.	-3195.	42436.	42654.
$Clip_2$ [µ]	2526.	-2825.	-2825.	44153.	44470.
$FBG_{1\ (0°)}$ [µ]	2567.	-2954.	-2597.	43426.	42779.
$\varepsilon_{1\ (0°)}$ [µ]	2666.	-3290.	-3290.	39487.	39717.
$\varepsilon_{2\ (0°)}$ [µ]	2826.	-3128.	-3128.	39504.	39527.
σ [MPa]	107.0	-129.0	-129.0		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	23.8	23.4	23.6

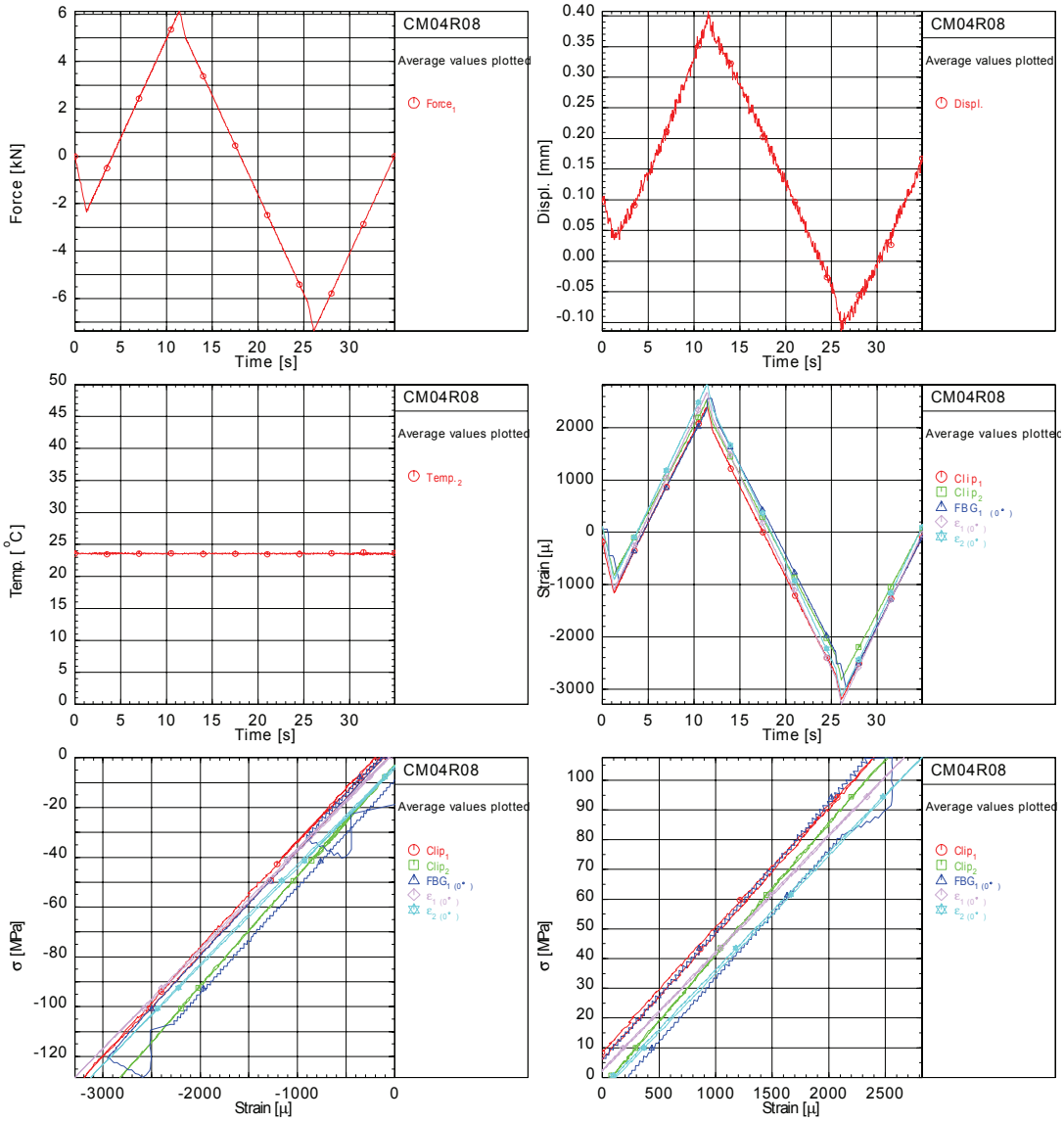


Figure B - 17: CM04R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
$Force_1$ [kN]	12.8	-13.0	13.1	-13.4	0.0		
Displ. [mm]	1.02	-0.22	2.41	-0.38	0.29		
$Clip_1$ [μ]	5498.	-6060.	6406.	-8085.	14.		
$Clip_2$ [μ]	4114.	-8111.	6107.	-10224.	-6.		
$FBG_{1\ (0^\circ)}$ [μ]	2999.	-4391.	5324.	-6203.	11.		
$\varepsilon_{1\ (0^\circ)}$ [μ]	19029.	18969.	19045.	-5230.	2.		
$\varepsilon_{2\ (0^\circ)}$ [μ]	19036.	18988.	19046.	-5348.	2.		
σ [MPa]	223.0	-226.8	229.6	-234.3	0.6		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	27.0	23.3	25.4

Number of Cycles 1306001.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM04R08.nul(Rec.1-)

TEST started at: 21-04-08 09:48:09

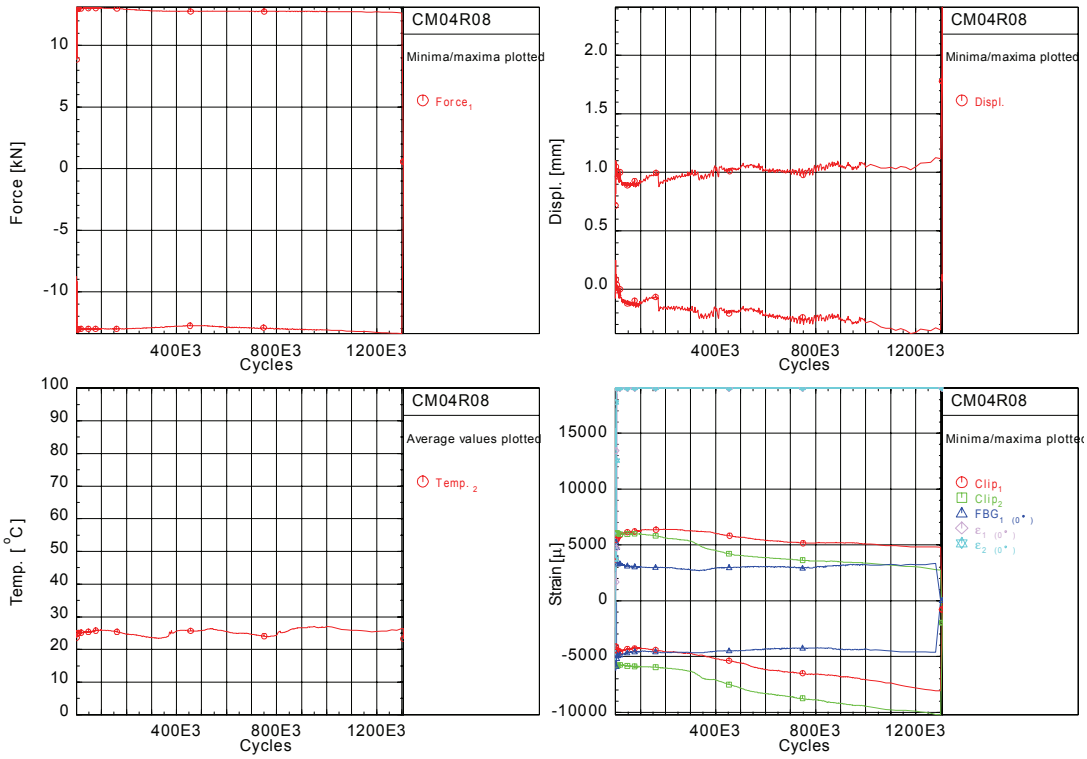


Figure B - 18: CM04R08 (fatigue summary)

Remarks: Front and back clip gauge signals differ. FBG signal correlates with temperature

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	13.0	-13.1	13.0				
Displ. [mm]	1.08	0.11	1.08				
Clip$_1$ [µ]	5343.	-4727.	5318.				
Clip$_2$ [µ]	5886.	-5950.	5884.				
FBG$_{1\ (0^\circ)}$ [µ]	3019.	-4336.	-3798.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	10796.	-224.	10786.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	13836.	1182.	13822.				
σ [MPa]	228.0	-229.0	228.0				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	24.6	24.2	24.4

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM04R08\CM04R08.nul(Rec.1)

TEST started at: 21-04-08 09:58:32

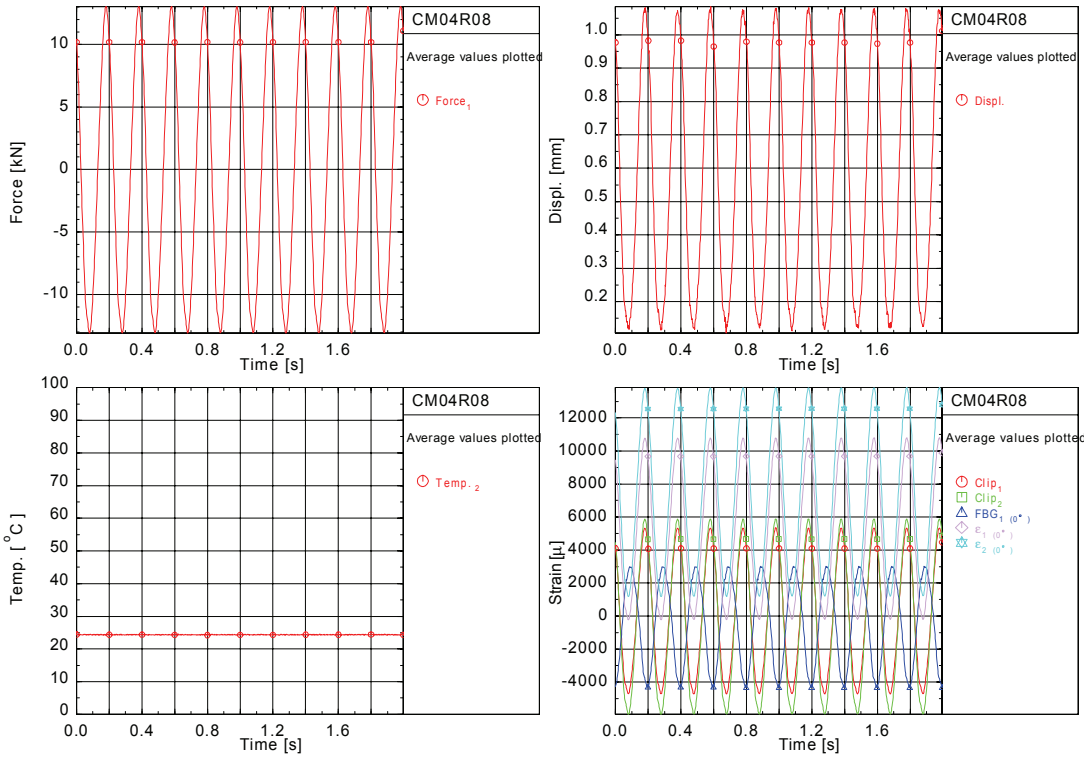


Figure B - 19: CM04R08 (ca. 1,000 cycles)

Remarks: Considerable difference between all types of strain measurement

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.0	-13.0	13.0				
Displ. [mm]	0.96	-0.05	0.95				
$Clip_1$ [μ]	5913.	-4578.	5893.				
$Clip_2$ [μ]	5966.	-5780.	5966.				
$FBG_{1\ (0^\circ)}$ [μ]	3327.	-4849.	1133.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	19045.	19045.	19045.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19045.	19045.	19045.				
σ [MPa]	227.7	-227.8	227.7				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	25.4	25.0	25.2

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM04R08\CM04R08.nul(Rec.1)

TEST started at: 21-04-08 11:06:07

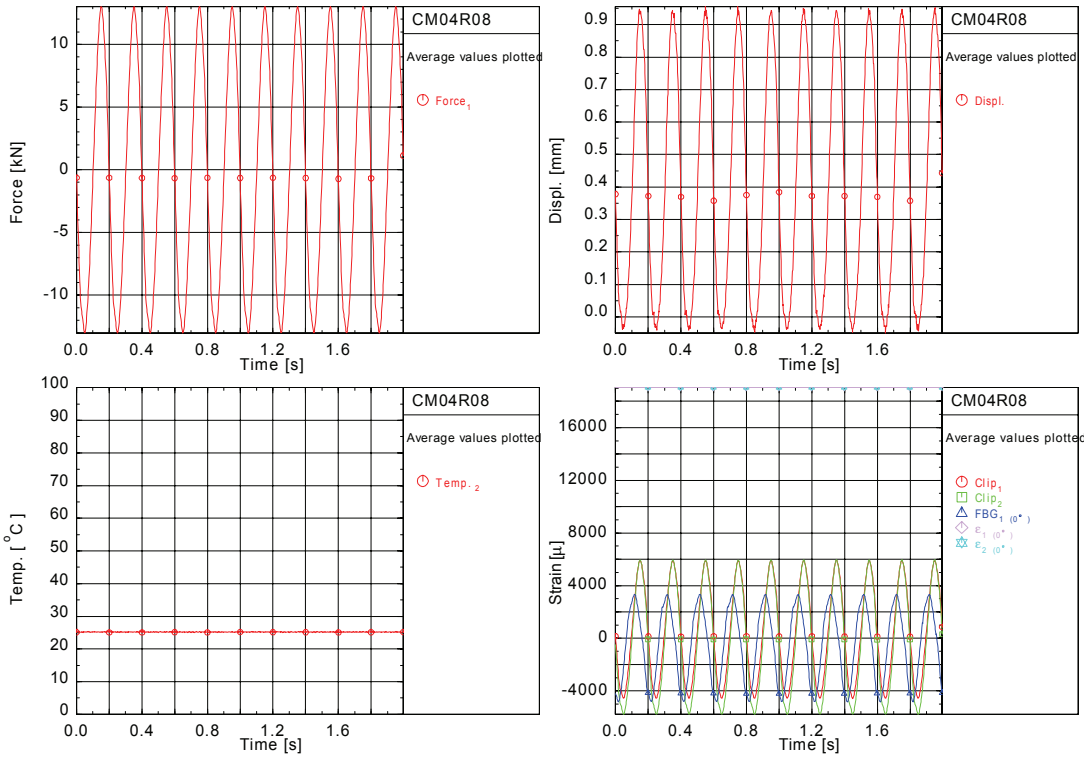


Figure B - 20: CM04R08 (ca. 10,000 cycles)

Remarks: FBG signal distorted near top and measures lower tensile strain than clip gauges

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	12.8	-12.9	-12.9				
Displ. [mm]	0.99	-0.18	-0.17				
Clip$_1$ [μ]	6278.	-4742.	-4732.				
Clip$_2$ [μ]	5348.	-6333.	-6328.				
FBG$_{1\ (0^\circ)}$ [μ]	2761.	-4665.	-1833.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	19045.	19045.	19045.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19045.	19045.	19045.				
σ [MPa]	224.5	-225.9	-225.9				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	23.8	23.4	23.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM04R08\CM04R08.nul(Rec.1)

TEST started at: 22-04-08 02:39:17

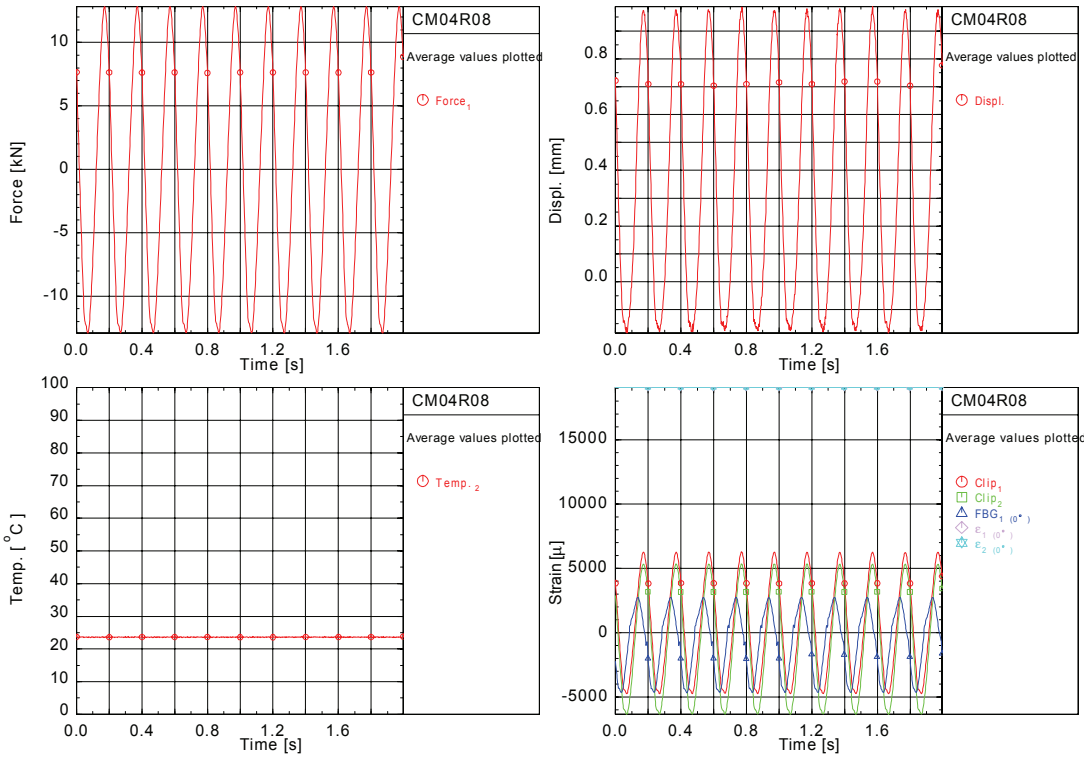


Figure B - 21: CM04R08 (ca. 100,000 cycles)

Remarks: FBG signal distorted (more than in previous plot)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.19	-12.07	12.19	-11.98		
$Force_3$ [kN]	12.18	-12.18	12.12	-12.00		
Displ. [mm]	-77.05	-78.09	-77.07	-78.08		
$Clip_1$ [μ]	6231.	-5662.	6231.	-5622.	35214.	0.
$Clip_2$ [μ]	5952.	-6402.	5937.	-6328.	34695.	0.
$FBG_{1\ (0°)}$ [μ]	5550.	-5401.	5378.	-5367.	38237.	0.
$\varepsilon_{1\ (0°)}$ [μ]	5663.	-5240.	5647.	-5208.	38426.	0.
$\varepsilon_{2\ (0°)}$ [μ]	10070.	-5478.	5943.	-5434.	31502.	0.
σ [MPa]	210.4	-208.3	210.4	-206.8		
Bending [μ/mm]	81.60	*******	-100.81	77.04		
Bending [μ/mm]	264.11	87.56	100.27	240.57		

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	22.3	21.7	22.0
Temp.$_2$ [°C]	20.7	20.2	20.5

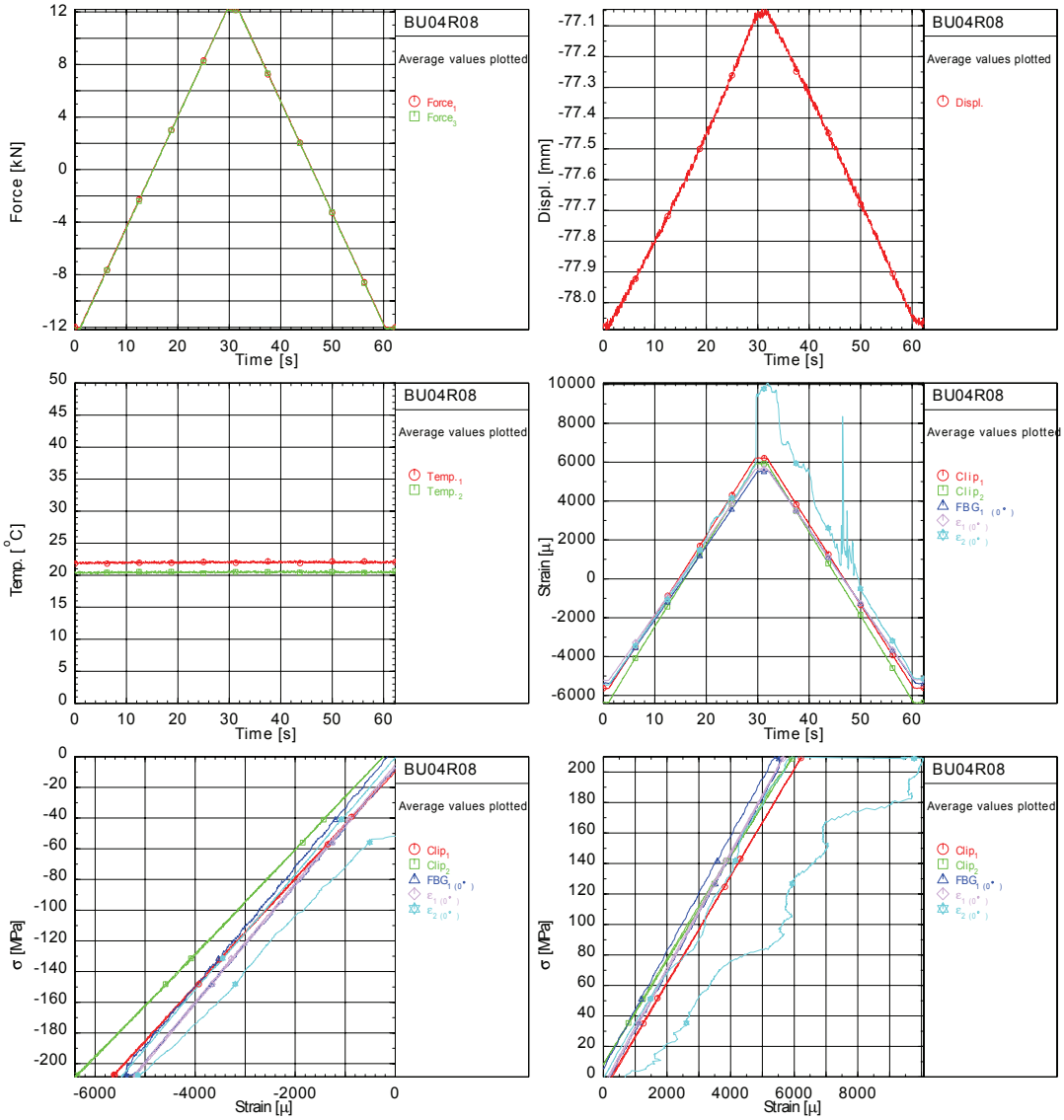


Figure B - 22: BU04R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
$Force_1$ [kN]	11.90	-11.87	12.48	-12.32	-0.02
$Force_3$ [kN]	11.87	-12.00	12.50	-12.44	0.03
Displ. [mm]	-77.35	-78.55	-75.98	-78.77	50.16
$Clip_1$ [μ]	5009.	-8425.	6886.	-17741.	-20.
$Clip_2$ [μ]	5483.	-7761.	23038.	-8465.	3.
$FBG_{1\ (0°)}$ [μ]	-905.	-1189.	5642.	-5525.	-5.
$\varepsilon_{1\ (0°)}$ [μ]	19309.	19268.	19324.	-5191.	0.
$\varepsilon_{2\ (0°)}$ [μ]	18608.	18594.	18631.	-4702.	6.
σ [MPa]	205.4	-204.8	215.4	-212.7	-0.4

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	27.8	20.8	24.0
$Temp._2$ [°C]	28.4	19.2	24.8

Number of Cycles	1431973.

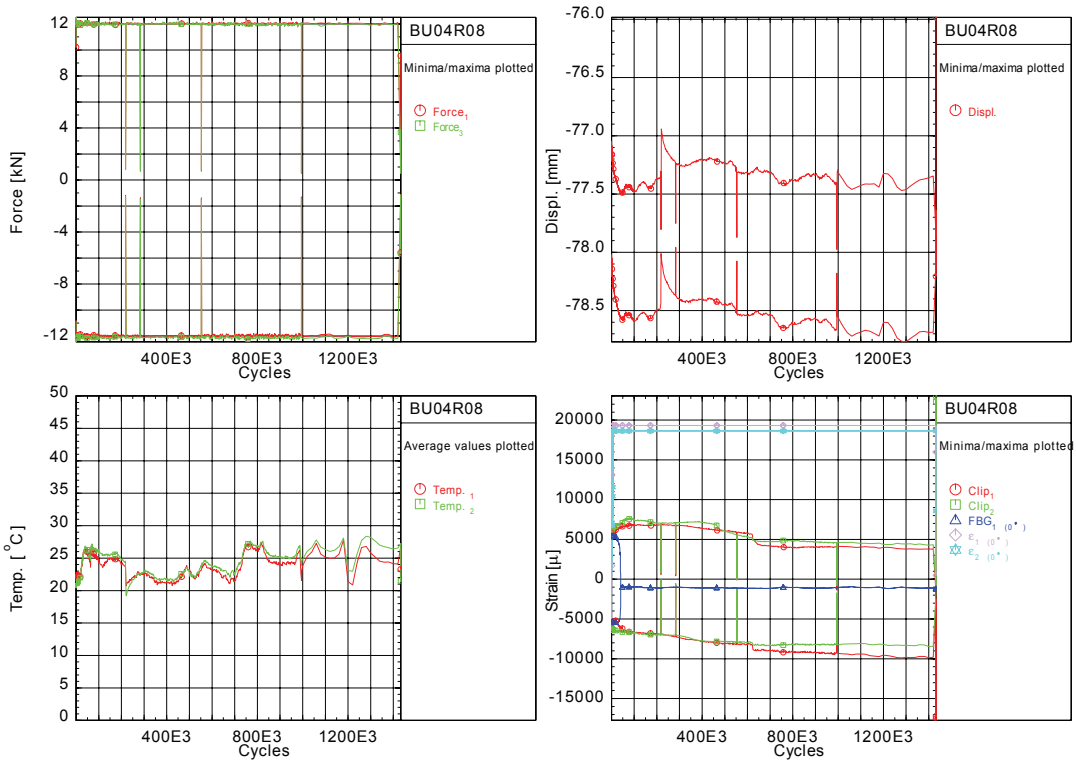


Figure B - 23: BU04R08 (fatigue summary)

FBG ceases to achieve strains after ca. 50kcycles

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.05	-12.00	12.05	11.72		
$Force_3$ [kN]	12.05	-12.10	11.97	11.64		
Displ. [mm]	-77.12	-78.10	-77.12	-77.14		
$Clip_1$ [µ]	6240.	-5567.	6213.	6136.		
$Clip_2$ [µ]	6143.	-6254.	6110.	6004.		
$FBG_{1\ (0°)}$ [µ]	5447.	-5384.	802.	1728.		
$\varepsilon_{1\ (0°)}$ [µ]	10547.	-260.	10522.	10430.		
$\varepsilon_{2\ (0°)}$ [µ]	18631.	-133.	18631.	18631.		
σ [MPa]	208.0	-207.2	208.0	202.5		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	22.6	22.0	22.3
$Temp._2$ [°C]	21.1	20.5	20.8

Area of cross-section 57.90

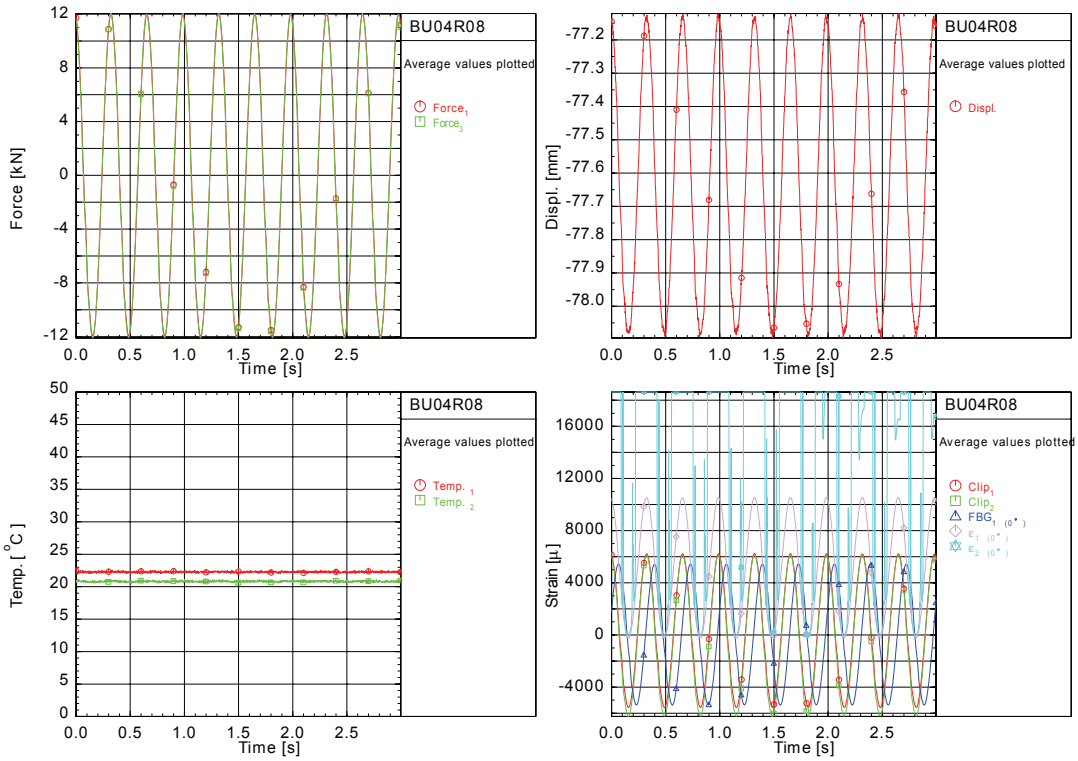


Figure B - 24: BU04R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.10	-12.04	12.10	11.80		
$Force_3$ [kN]	12.07	-12.13	12.04	11.68		
Displ. [mm]	-77.30	-78.33	-77.32	-77.33		
$Clip_1$ [μ]	6064.	-5318.	6063.	5954.		
$Clip_2$ [μ]	6712.	-6462.	6712.	6600.		
$FBG_{1\ (0°)}$ [μ]	5447.	-5400.	828.	1491.		
$\varepsilon_{1\ (0°)}$ [μ]	19324.	19324.	19324.	19324.		
$\varepsilon_{2\ (0°)}$ [μ]	18631.	18631.	18631.	18631.		
σ [MPa]	208.9	-207.9	208.9	203.9		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	22.5	21.9	22.2
$Temp._2$ [°C]	21.9	21.4	21.7

Area of cross-section 57.90

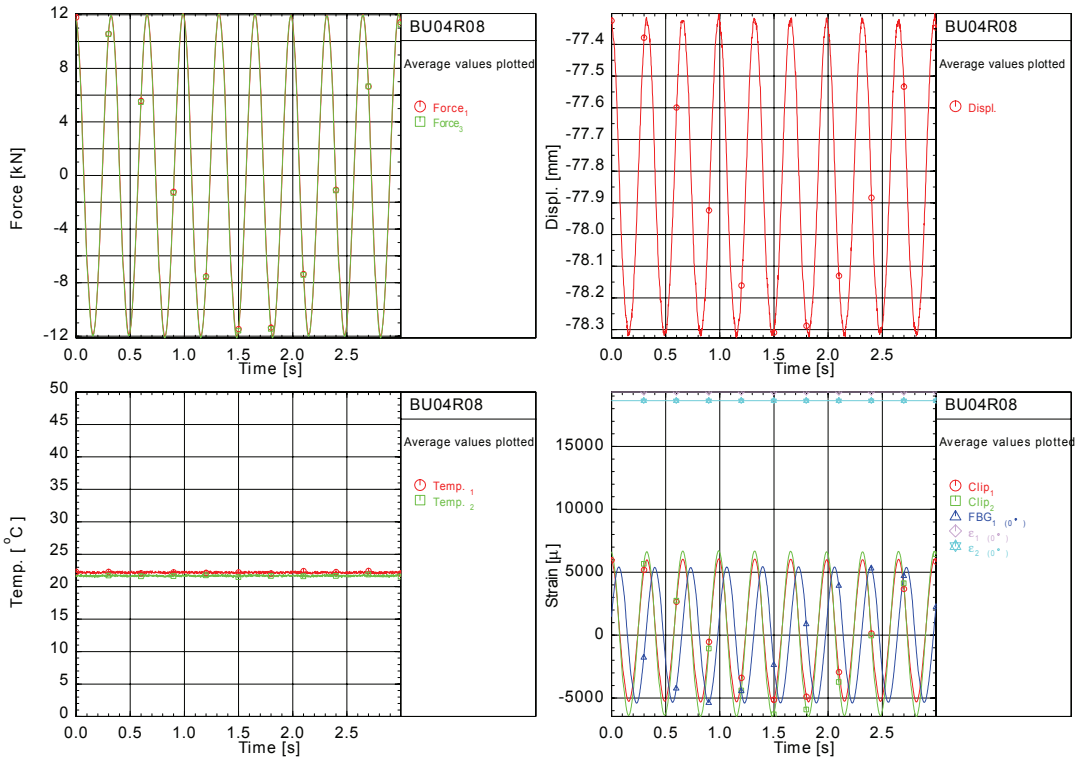


Figure B - 25: BU04R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.13	-12.06	12.13	11.93		
$Force_3$ [kN]	12.08	-12.21	12.06	11.70		
Displ. [mm]	-77.47	-78.59	-77.48	-77.48		
$Clip_1$ [µ]	6845.	-6764.	6827.	6787.		
$Clip_2$ [µ]	7479.	-6785.	7470.	7378.		
$FBG_{1\ (0°)}$ [µ]	-958.	-977.	-967.	-975.		
$\varepsilon_{1\ (0°)}$ [µ]	19324.	19324.	19324.	19324.		
$\varepsilon_{2\ (0°)}$ [µ]	18631.	18631.	18631.	18631.		
σ [MPa]	209.5	-208.4	209.5	206.0		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.9	24.4	24.6
$Temp._2$ [°C]	26.3	25.7	26.0

Area of cross-section 57.90

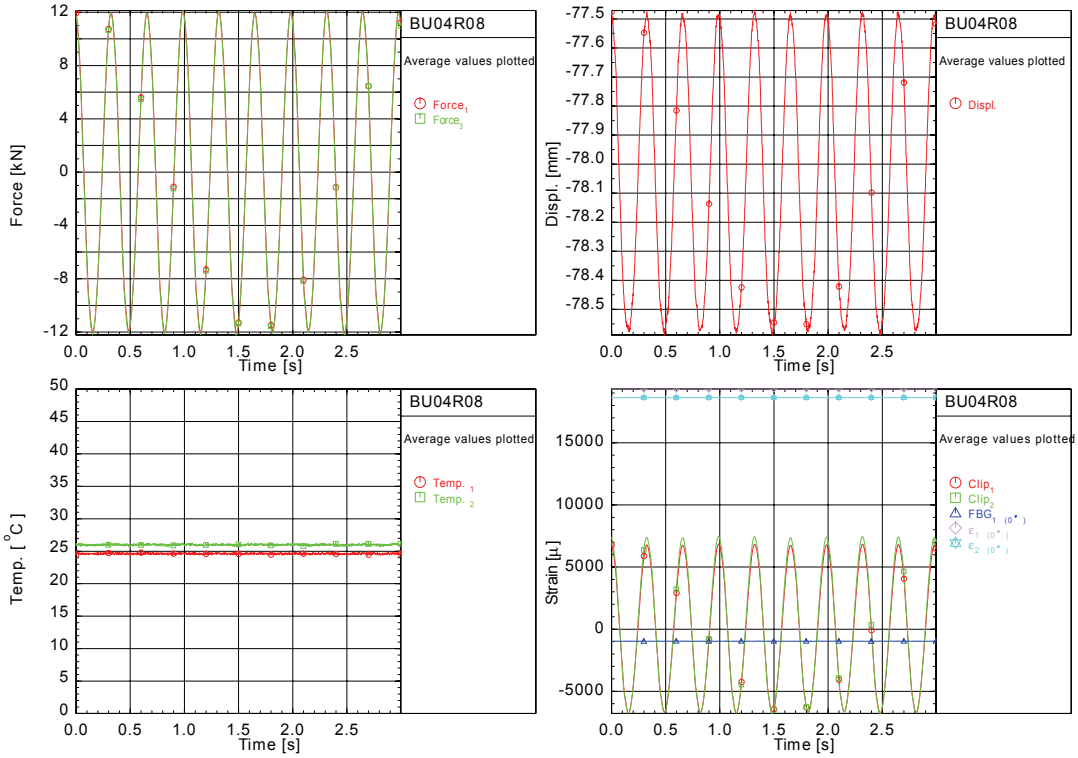


Figure B - 26: BU04R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	7.50	-7.59	-7.59	-2.67		
$Force_3$ [kN]	7.52	-7.71	-7.64	-2.47		
Displ. [mm]	-76.45	-78.11	-78.10	-77.92		
$Clip_1$ [μ]	-17194.	-18070.	-17206.	-17354.		
$Clip_2$ [μ]	23038.	22572.	23038.	23038.		
$FBG_{1\ (0°)}$ [μ]	-1106.	-1233.	-1149.	-1159.		
$\varepsilon_{1\ (0°)}$ [μ]	19324.	19324.	19324.	19324.		
$\varepsilon_{2\ (0°)}$ [μ]	18631.	18631.	18631.	18631.		
σ [MPa]	129.5	-131.1	-131.1	-46.2		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	23.6	23.0	23.3
$Temp._2$ [°C]	21.7	21.2	21.5

Area of cross-section 57.90

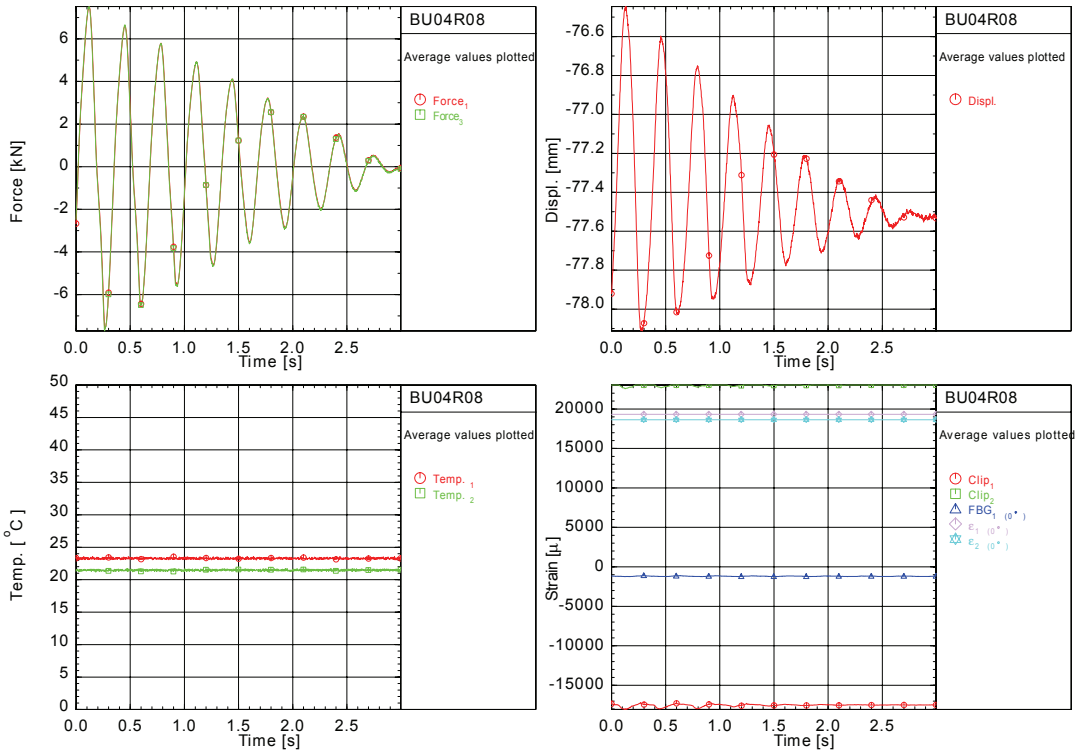


Figure B - 27: BU04R08 (failure)

Channels	Maximum	Minimum	@F_{max}	@start	E_1 [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.13	-0.09	12.13	-0.06		
$Force_3$ [kN]	12.11	-0.17	12.08	-0.12		
Displ. [mm]	-77.29	-77.82	-77.31	-77.82		
$Clip_1$ [μ]	5252.	89.	5252.	98.	36230.	0.
$Clip_2$ [μ]	4800.	-373.	4795.	-342.	39385.	0.
$FBG_{1\ (0^\circ)}$ [μ]	5035.	18.	5018.	25.	41680.	0.
$\varepsilon_{1\ (0^\circ)}$ [μ]	5610.	42.	5599.	47.	37957.	0.
$\varepsilon_{2\ (0^\circ)}$ [μ]	5482.	-47.	5482.	-42.	36480.	0.
σ [MPa]	202.9	-1.5	202.9	-1.1		
Bending [μ/mm]	62.27	-18.13	39.61	30.35		
Bending [μ/mm]	413.64	143.40	155.01	149.29		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.7	24.1	24.4
$Temp._2$ [°C]	21.5	20.8	21.1

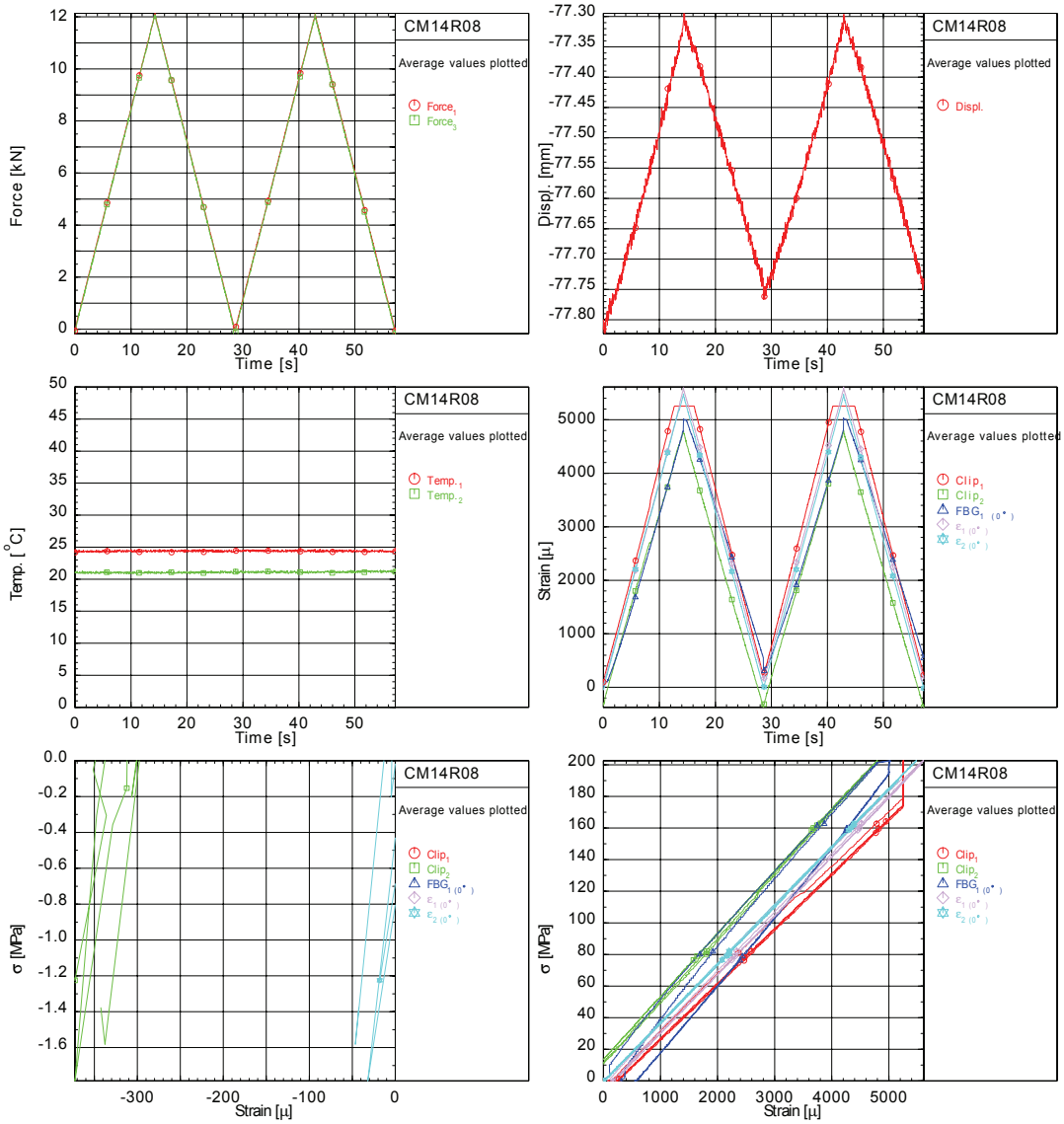


Figure B - 28: CM14R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
$Force_1$ [kN]	12.03	-11.97	13.16	-12.97	-0.02
$Force_3$ [kN]	11.98	-12.12	13.12	-13.09	0.01
Displ. [mm]	-77.52	-78.68	-75.92	-78.88	50.16
$Clip_1$ [μ]	-22527.	-27413.	5252.	-41208.	-18.
$Clip_2$ [μ]	12571.	8578.	16839.	-5881.	-11.
$FBG_{1\ (0°)}$ [μ]	-7063.	-7087.	5403.	-11649.	2.
$\varepsilon_{1\ (0°)}$ [μ]	19190.	19156.	19199.	-5445.	-2.
$\varepsilon_{2\ (0°)}$ [μ]	18948.	18908.	18960.	-5751.	5.
σ [MPa]	201.2	-200.2	220.1	-216.9	-0.3

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	27.4	18.2	24.7
$Temp._2$ [°C]	27.8	18.4	25.3

Number of Cycles	2100631.

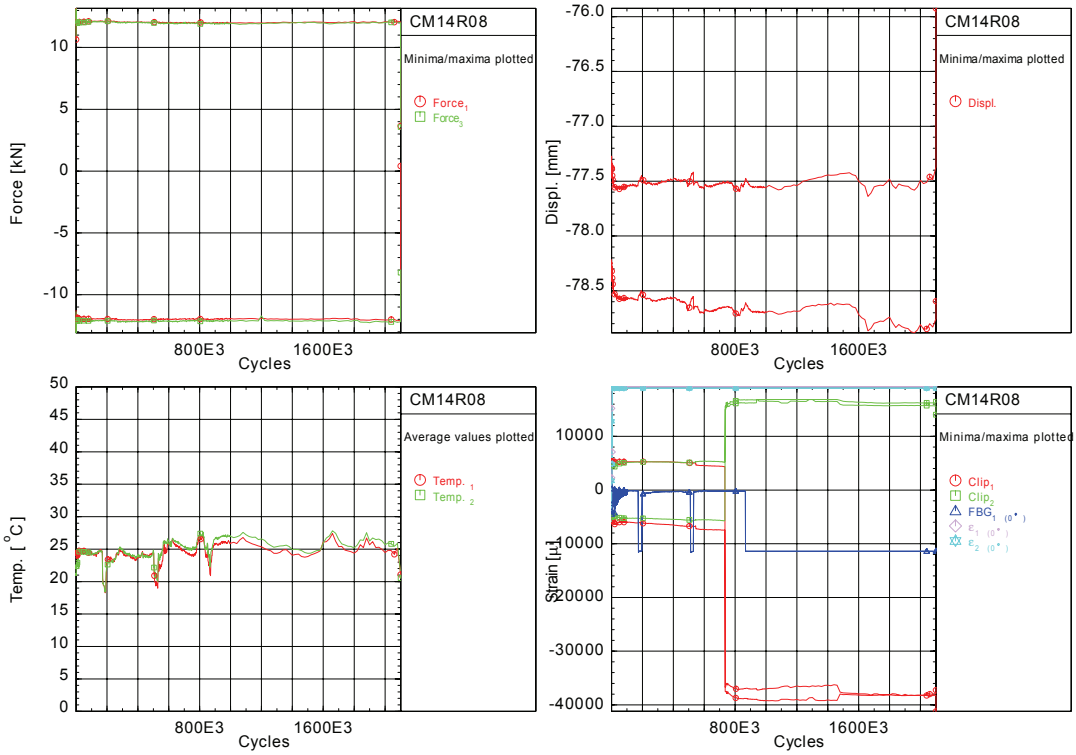


Figure B - 29: CM14R08 (fatigue summary)

FBG ceases to achieve strains within 10kcycles ; clip gauges malfunction after ca. 750kcycles (rubber rings that hold them in place broken)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.06	-12.02	12.06	11.89		
$Force_3$ [kN]	12.03	-12.16	12.01	11.73		
Displ. [mm]	-77.37	-78.29	-77.39	-77.39		
$Clip_1$ [µ]	5252.	-5584.	5252.	5252.		
$Clip_2$ [µ]	4561.	-5119.	4540.	4516.		
$FBG_{1\ (0°)}$ [µ]	4896.	-4520.	-4457.	-4265.		
$\varepsilon_{1\ (0°)}$ [µ]	10688.	-363.	10666.	10615.		
$\varepsilon_{2\ (0°)}$ [µ]	10175.	-580.	10164.	10031.		
σ [MPa]	201.6	-201.0	201.6	198.8		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.5	24.0	24.2
$Temp._2$ [°C]	22.7	22.0	22.3

Area of cross-section 59.80

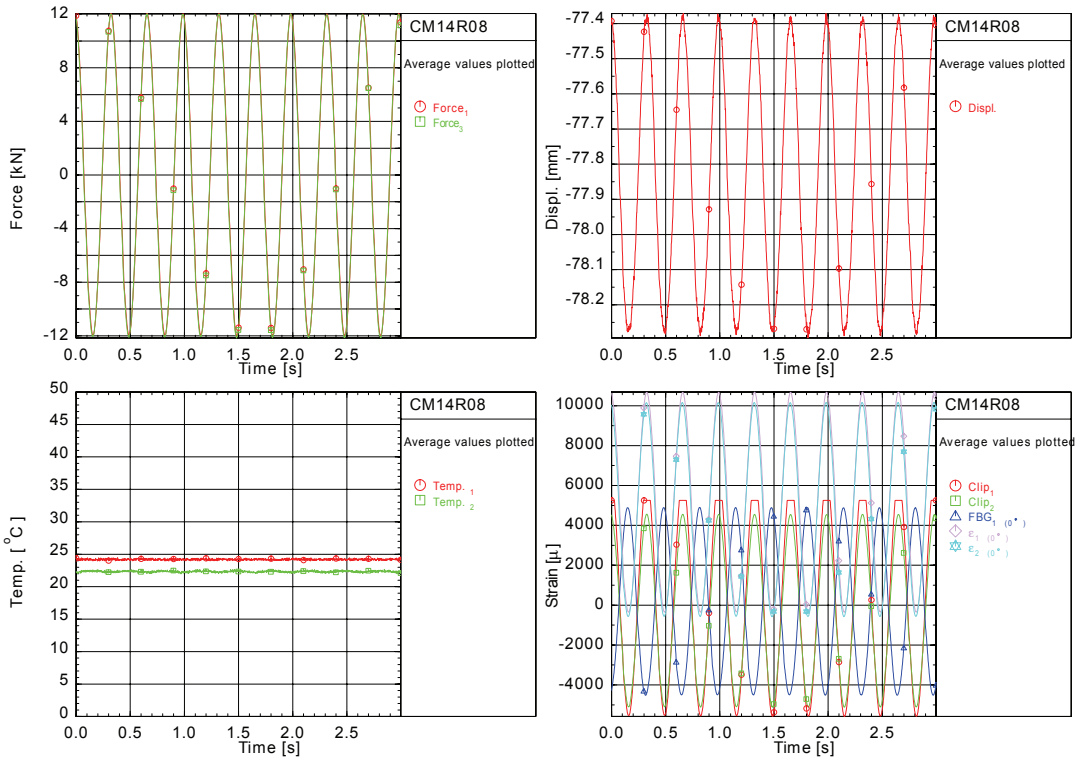


Figure B - 30: CM14R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.06	-12.01	12.06	11.85		
$Force_3$ [kN]	11.98	-12.16	11.92	11.71		
Displ. [mm]	-77.51	-78.47	-77.51	-77.53		
$Clip_1$ [µ]	5252.	-5902.	5252.	5252.		
$Clip_2$ [µ]	4645.	-4738.	4643.	4587.		
$FBG_{1\ (0°)}$ [µ]	163.	-2983.	-2867.	-2761.		
$\varepsilon_{1\ (0°)}$ [µ]	19199.	19199.	19199.	19199.		
$\varepsilon_{2\ (0°)}$ [µ]	18960.	18960.	18960.	18960.		
σ [MPa]	201.6	-200.9	201.6	198.2		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.8	24.3	24.6
$Temp._2$ [°C]	24.2	23.5	23.8

Area of cross-section 59.80

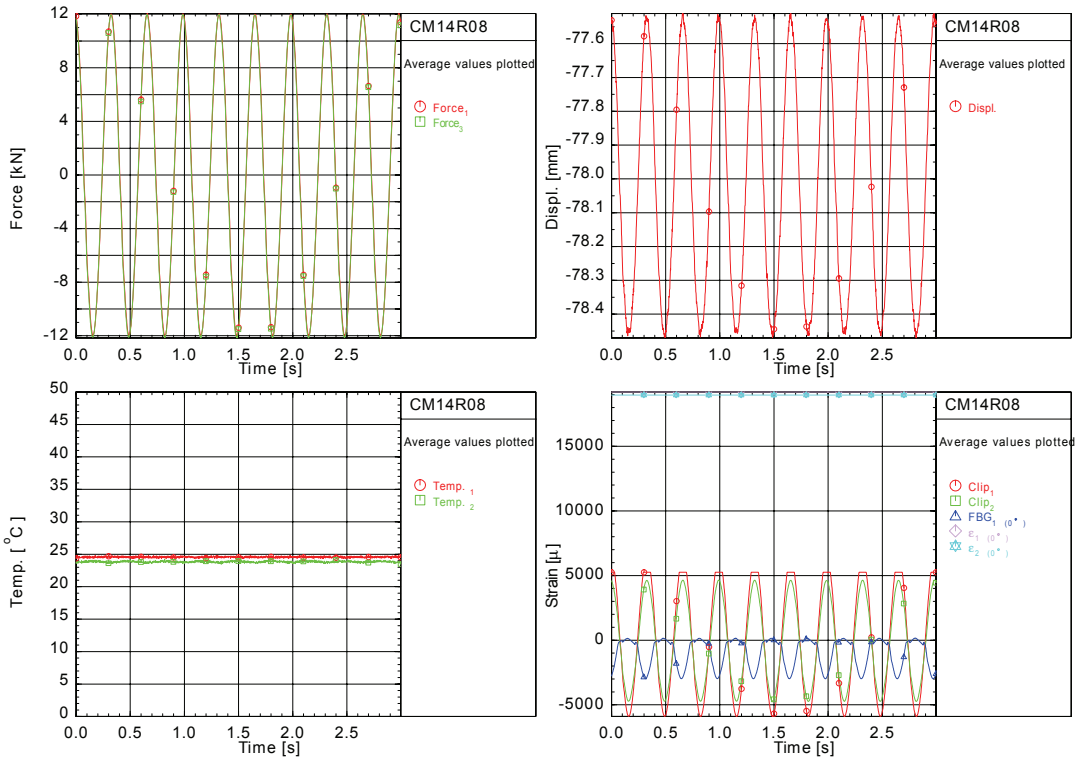


Figure B - 31: CM14R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.12	-11.96	12.12	11.87		
$Force_3$ [kN]	12.07	-12.14	12.01	11.65		
Displ. [mm]	-77.54	-78.57	-77.55	-77.55		
$Clip_1$ [µ]	5252.	-5995.	5252.	5252.		
$Clip_2$ [µ]	5148.	-5250.	5125.	5060.		
$FBG_{1\ (0°)}$ [µ]	140.	-981.	-728.	-730.		
$\varepsilon_{1\ (0°)}$ [µ]	19199.	19199.	19199.	19199.		
$\varepsilon_{2\ (0°)}$ [µ]	18960.	18960.	18960.	18960.		
σ [MPa]	202.7	-200.0	202.7	198.5		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.7	24.1	24.4
$Temp._2$ [°C]	24.9	24.2	24.5

Area of cross-section 59.80

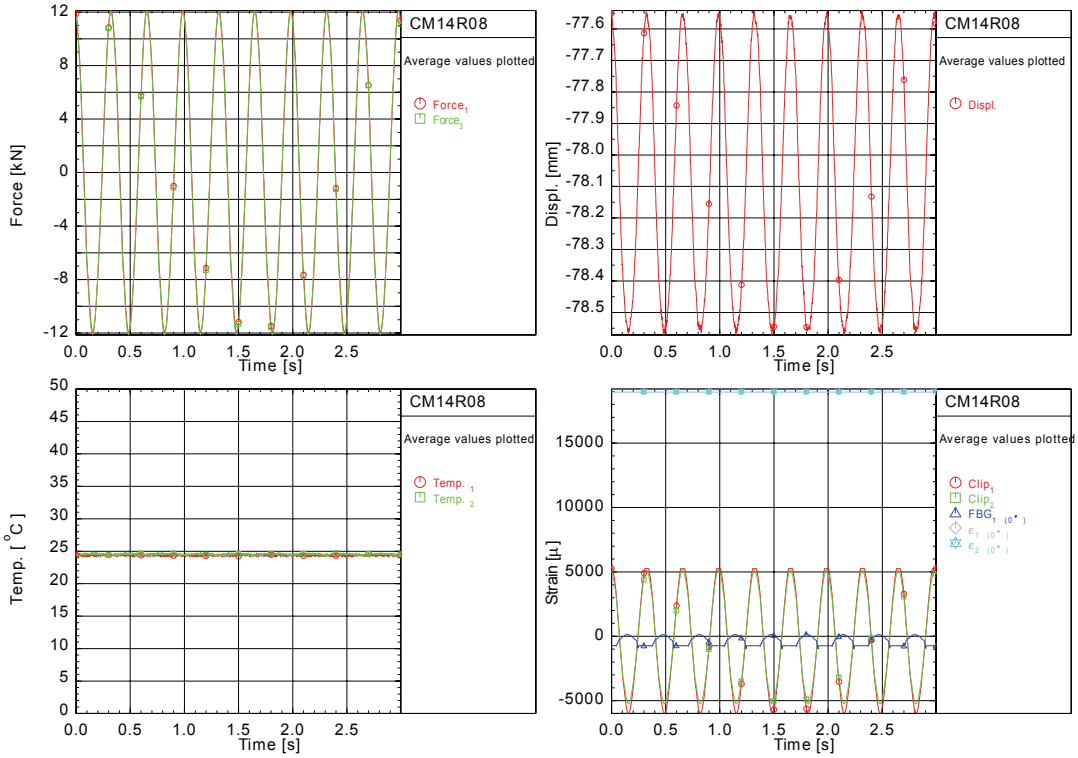


Figure B - 32: CM14R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.03	-11.98	12.03	11.82		
$Force_3$ [kN]	11.98	-12.14	11.90	11.66		
Displ. [mm]	-77.55	-78.70	-77.56	-77.55		
$Clip_1$ [μ]	-37021.	-39239.	-39230.	-39175.		
$Clip_2$ [μ]	16839.	16507.	16551.	16567.		
$FBG_{1\ (0°)}$ [μ]	-11388.	-11408.	-11401.	-11404.		
$\varepsilon_{1\ (0°)}$ [μ]	19199.	19199.	19199.	19199.		
$\varepsilon_{2\ (0°)}$ [μ]	18960.	18960.	18960.	18960.		
σ [MPa]	201.2	-200.4	201.2	197.7		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.2	25.8	26.0
$Temp._2$ [°C]	27.3	26.7	27.0

Area of cross-section 59.80

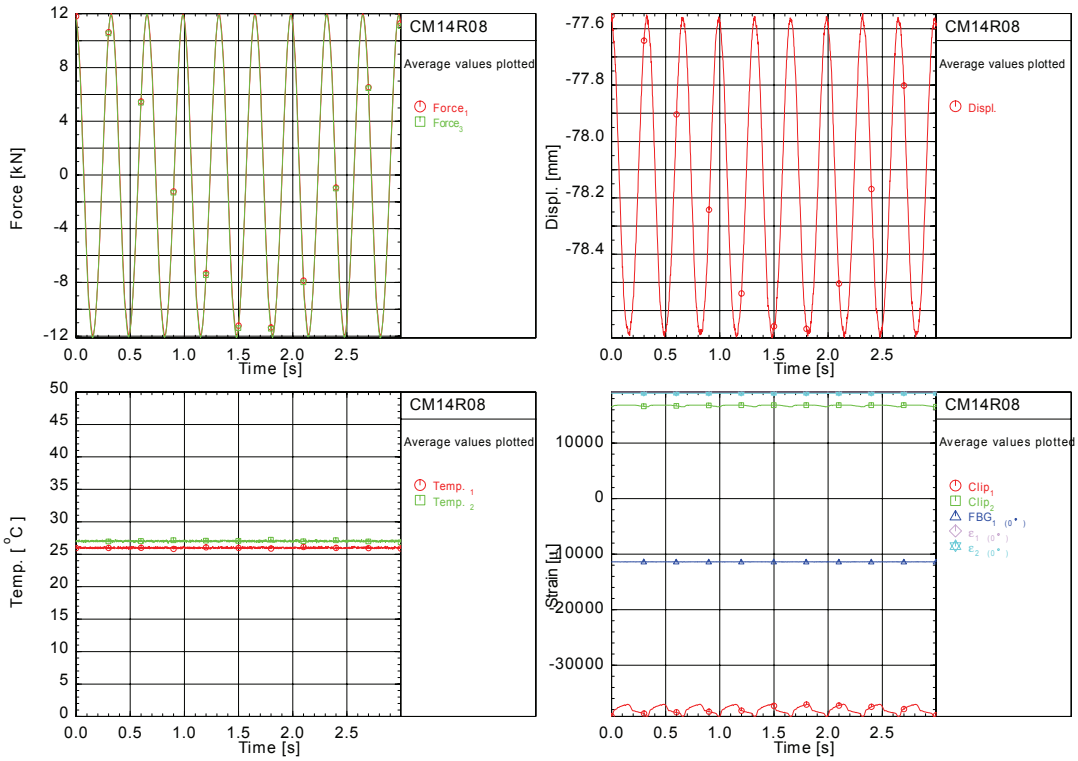


Figure B - 33: CM14R08 (ca. 1,000,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	7.38	-8.33	-8.33	5.63		
$Force_3$ [kN]	7.30	-8.42	-8.42	5.32		
Displ. [mm]	-77.39	-78.61	-78.59	-77.41		
$Clip_1$ [μ]	-37753.	-38281.	-37905.	-37819.		
$Clip_2$ [μ]	16328.	15673.	16193.	15755.		
$FBG_{1\ (0°)}$ [μ]	-11425.	-11445.	-11436.	-11435.		
$\varepsilon_{1\ (0°)}$ [μ]	19199.	19199.	19199.	19199.		
$\varepsilon_{2\ (0°)}$ [μ]	18960.	18960.	18960.	18960.		
σ [MPa]	123.4	-139.3	-139.3	94.2		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	21.7	21.1	21.4
$Temp._2$ [°C]	21.4	20.8	21.1

Area of cross-section 59.80

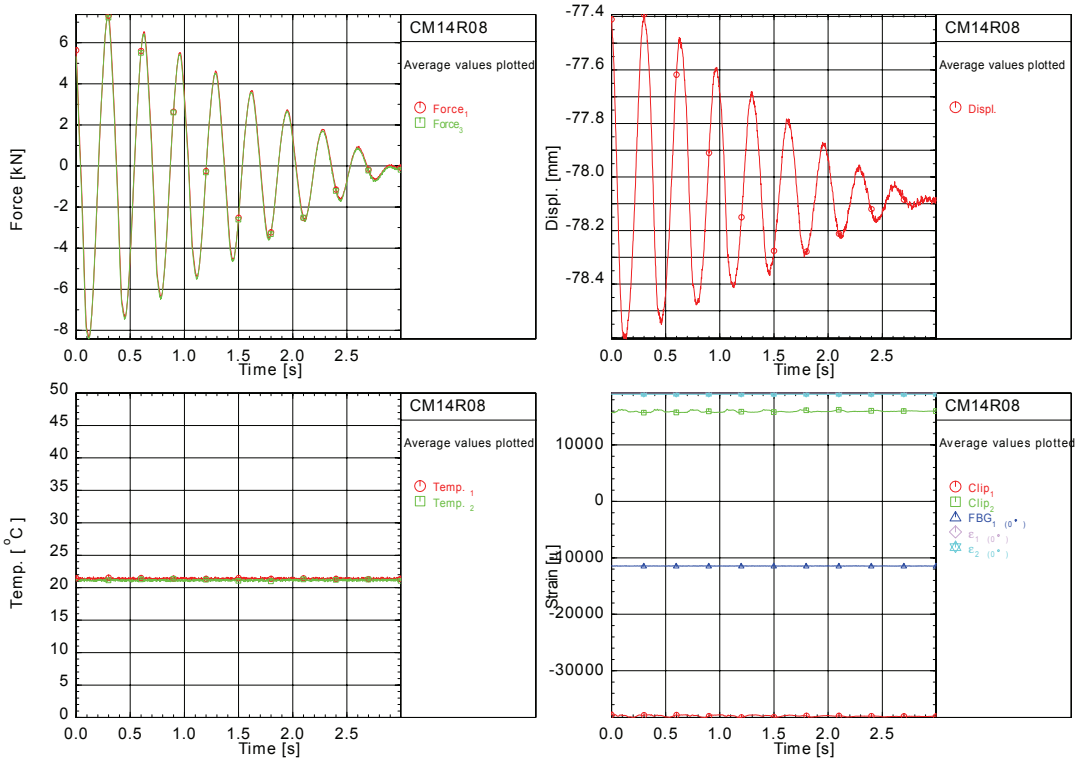


Figure B - 34: CM14R08 (failure)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	7.37	-6.45	7.37	-0.01		
$Force_3$ [kN]	7.23	-6.54	7.22	-0.15		
Displ. [mm]	-55.52	-56.06	-55.52	-55.81		
$Clip_1$ [µ]	3100.	-2735.	3100.	-12.	39005.	39435.
$Clip_2$ [µ]	3230.	-3379.	3209.	-352.	34539.	34944.
$FBG_{1\ (0°)}$ [µ]	3021.	-2850.	3014.	-152.	38322.	39364.
$\varepsilon_{1\ (0°)}$ [µ]	3065.	-2921.	3065.	-135.	38018.	38339.
$\varepsilon_{2\ (0°)}$ [µ]	3013.	-3051.	3005.	-261.	37764.	38083.
σ [MPa]	122.2	-106.9	122.2	-0.1		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	23.4	22.9	23.1
$Temp._2$ [°C]	21.8	21.3	21.5

Area of cross-section 60.30

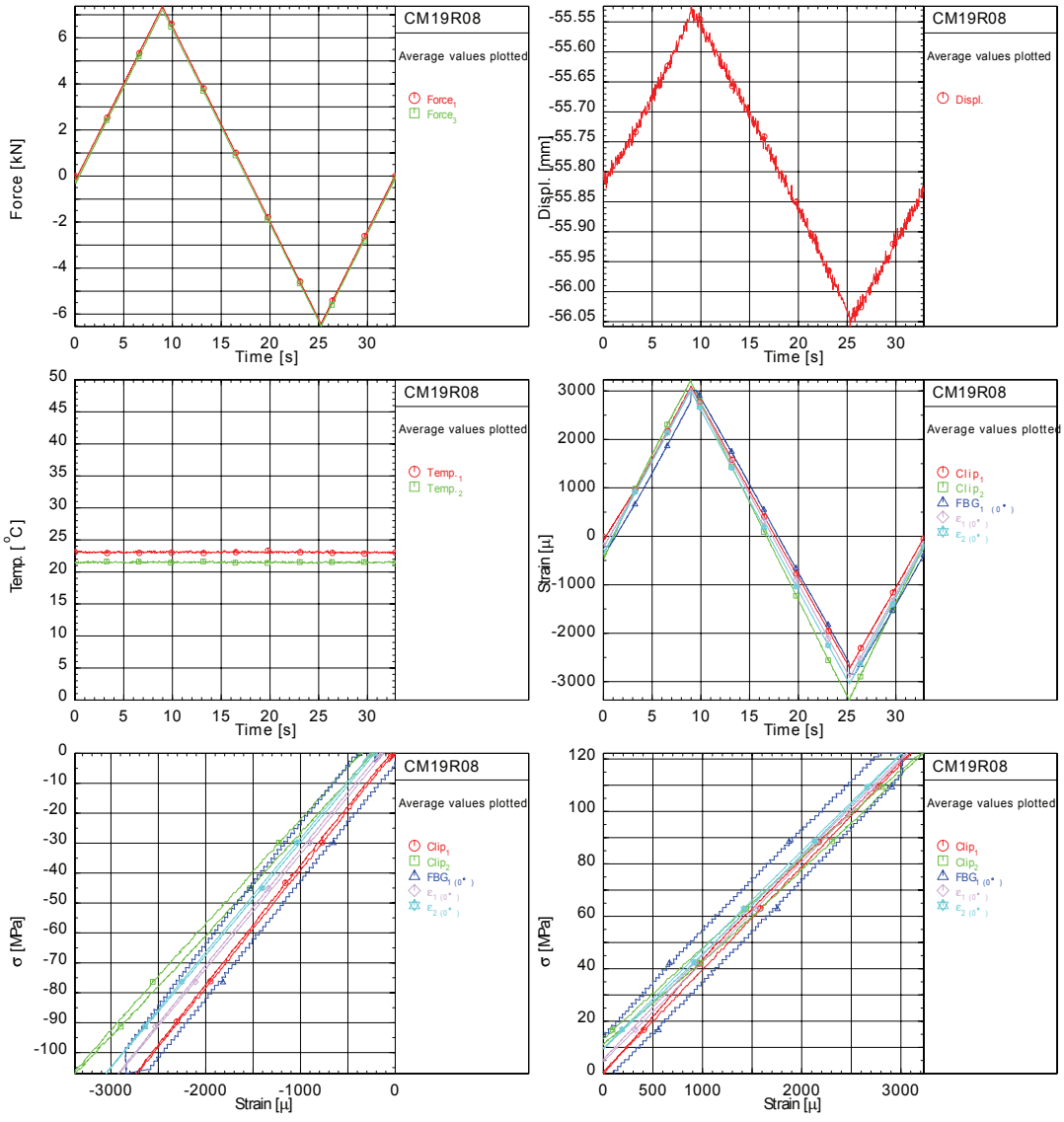


Figure B - 35: CM19R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum
$Force_1$ [kN]	12.06	-11.96	12.32	-12.01
$Force_3$ [kN]	11.87	-12.04	12.18	-12.15
Displ. [mm]	-55.54	-56.55	-55.27	-56.64
$Clip_1$ [μ]	4432.	-6640.	5518.	-7045.
$Clip_2$ [μ]	5568.	-5801.	5672.	-6044.
$FBG_{1\ (0°)}$ [μ]	-30.	-4517.	5290.	-5714.
$\varepsilon_{1\ (0°)}$ [μ]	18960.	18683.	19049.	-5221.
$\varepsilon_{2\ (0°)}$ [μ]	18968.	18687.	19062.	-5368.
σ [MPa]	200.0	-198.3	204.2	-199.1

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.2	21.0	22.7
$Temp._2$ [°C]	26.9	21.5	25.1

Number of Cycles	260002.
Area of cross-section	60.30

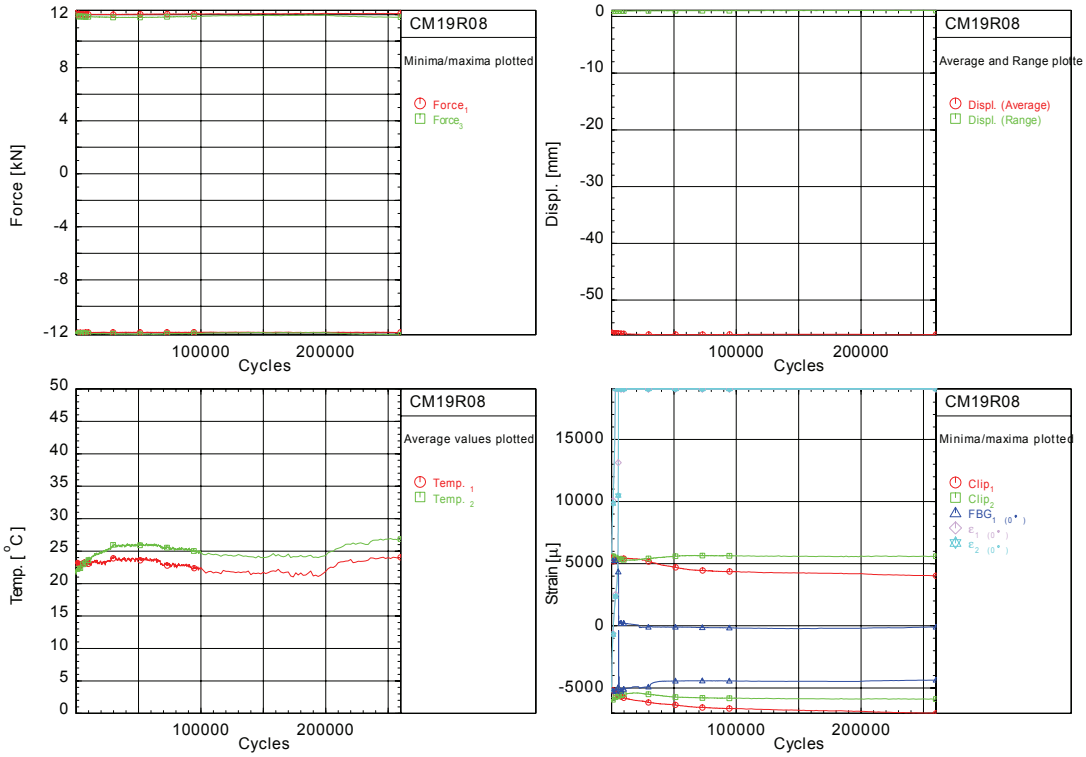


Figure B - 36: CM19R08 (fatigue summary)

FBG ceases to achieve strains early in life

APPENDIX C MEASUREMENT SUMMARY R = -1 EMBEDDED

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
Force [kN]	5.8	-5.7	5.8		
Displ. [mm]	-54.84	-55.33	-54.84		
$Clip_1$ [µ]	3033.	-2562.	3033.	36142.	36070.
$Clip_2$ [µ]	2832.	-3155.	2799.	34611.	34443.
$Clip_{AVG}$ [µ]	2848.	-2768.	2820.	36527.	36476.
smart [µ]	2732.	-2539.	1217.	38168.	38167.
σ [MPa]	103.0	-100.2	103.0		

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	26.2	24.9	25.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM06R08\CM06R08.SLWNulled with:CM06R08.nul(Rec.1) E-moduli based on:CM06R08.slw TEST started at: 29-10-07 15:38:33

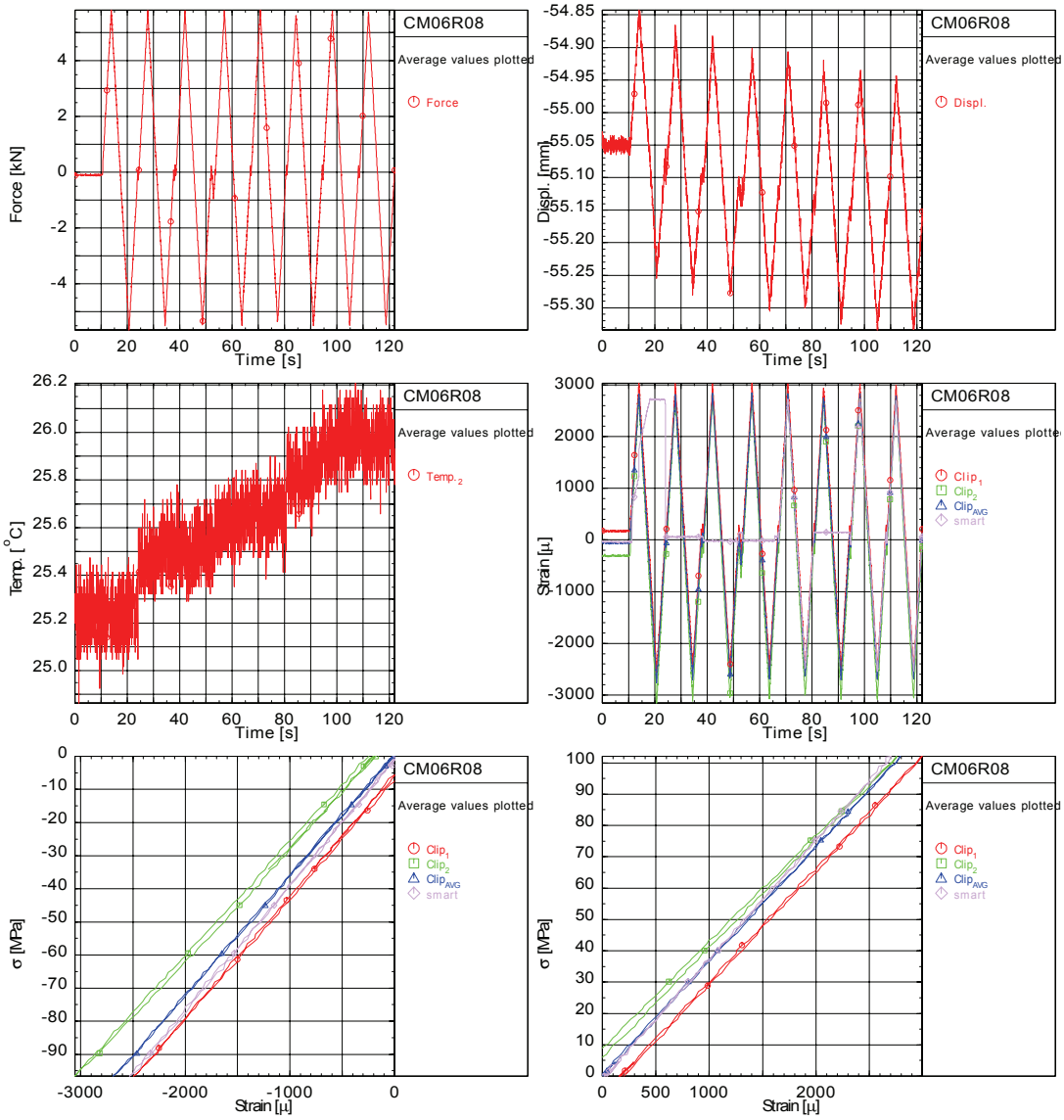


Figure C - 1: CM06R08 (slow cycle(s))

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
$Force_1$ [kN]	11.8	-11.9	12.1	-12.1	0.0		
Displ. [mm]	-4.49	-5.64	-3.68	-7.41	23.33		
$Clip_1$ [μ]	3731.	-8883.	20610.	-12068.	112.		
$Clip_2$ [μ]	4282.	-8934.	7669.	-10064.	-39.		
$Clip_{AVG}$ [μ]	3804.	-8801.	6902.	-17474.	16.		
smart1 [μ]	3662.	-5246.	7840.	-38991.	-2.		
σ [MPa]	209.8	-211.5	214.0	-215.2	0.3		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	29.9	25.6	28.1

Number of Cycles 1498426.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM06R08\CM06R08.nul(Rec.1)

TEST started at: 29-10-07 15:33:31

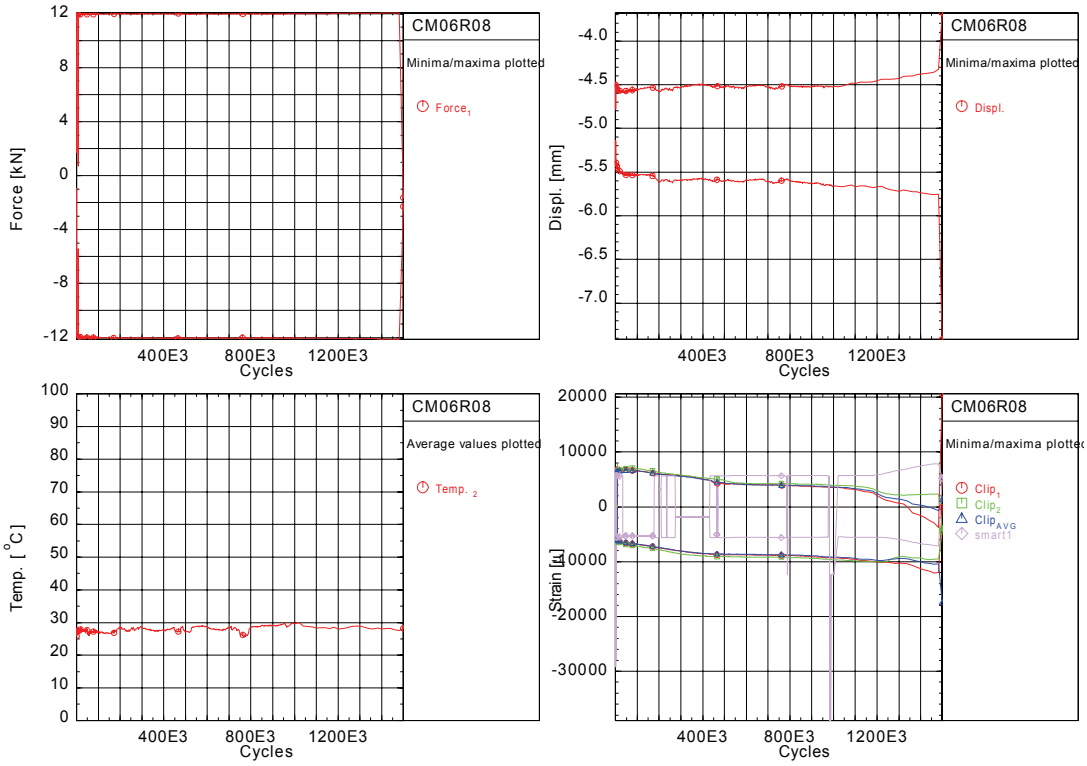


Figure C - 2: CM06R08 (fatigue summary)

Remarks: Jumps in signal may be attributed to D/A conversion software. Considerable difference between clip gauge and FBG signals

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	11.4	-10.5	11.4				
Displ. [mm]	-54.71	-55.49	-54.72				
$Clip_1$ [µ]	6327.	-5332.	6310.				
$Clip_2$ [µ]	5846.	-5399.	5846.				
$Clip_{AVG}$ [µ]	5900.	-5194.	5878.				
smart1 [µ]	5368.	-4835.	5207.				
σ [MPa]	202.6	-186.3	202.6				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	27.2	26.6	26.9

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM06R08\CM06R08.nul(Rec.1)

TEST started at: 29-10-07 16:16:20

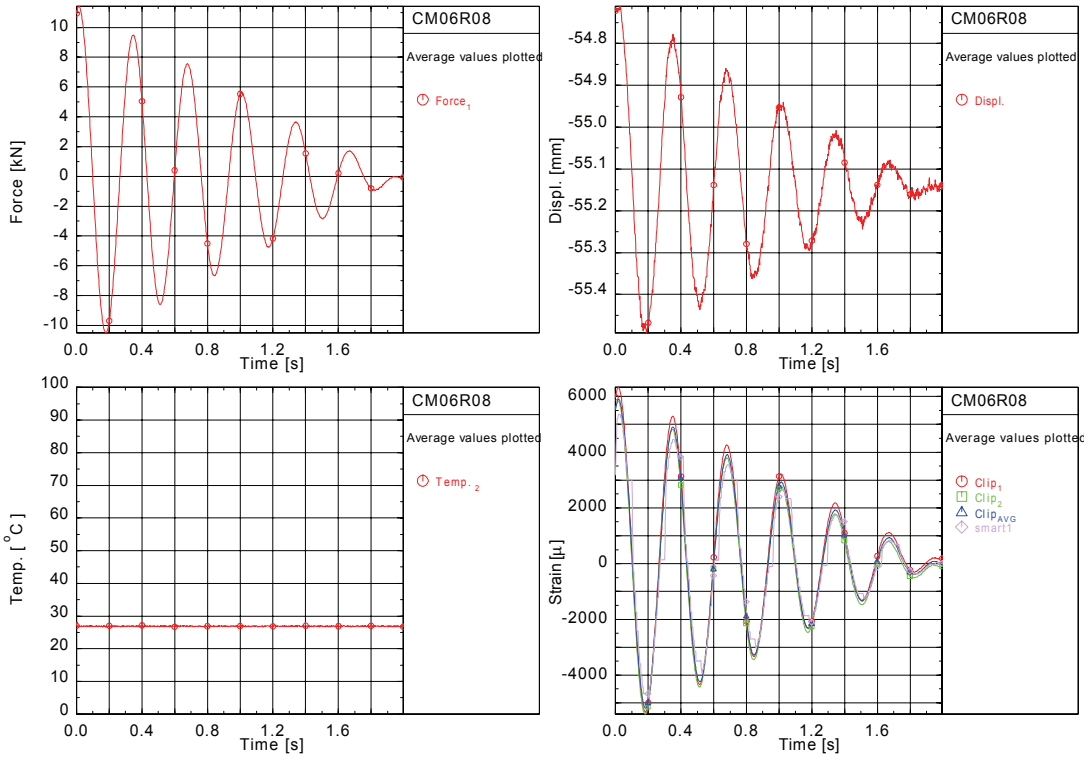


Figure C - 3: CM06R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	11.9	-12.0	-12.0				
Displ. [mm]	-54.71	-55.62	-55.60				
$Clip_1$ [μ]	6718.	-6265.	-6235.				
$Clip_2$ [μ]	6557.	-6385.	-6374.				
$Clip_{AVG}$ [μ]	6441.	-6120.	-6078.				
smart1 [μ]	5643.	-5537.	-4569.				
σ [MPa]	211.9	-212.6	-212.6				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	27.9	27.2	27.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM06R08\CM06R08.nul(Rec.1)

TEST started at: 29-10-07 17:04:53

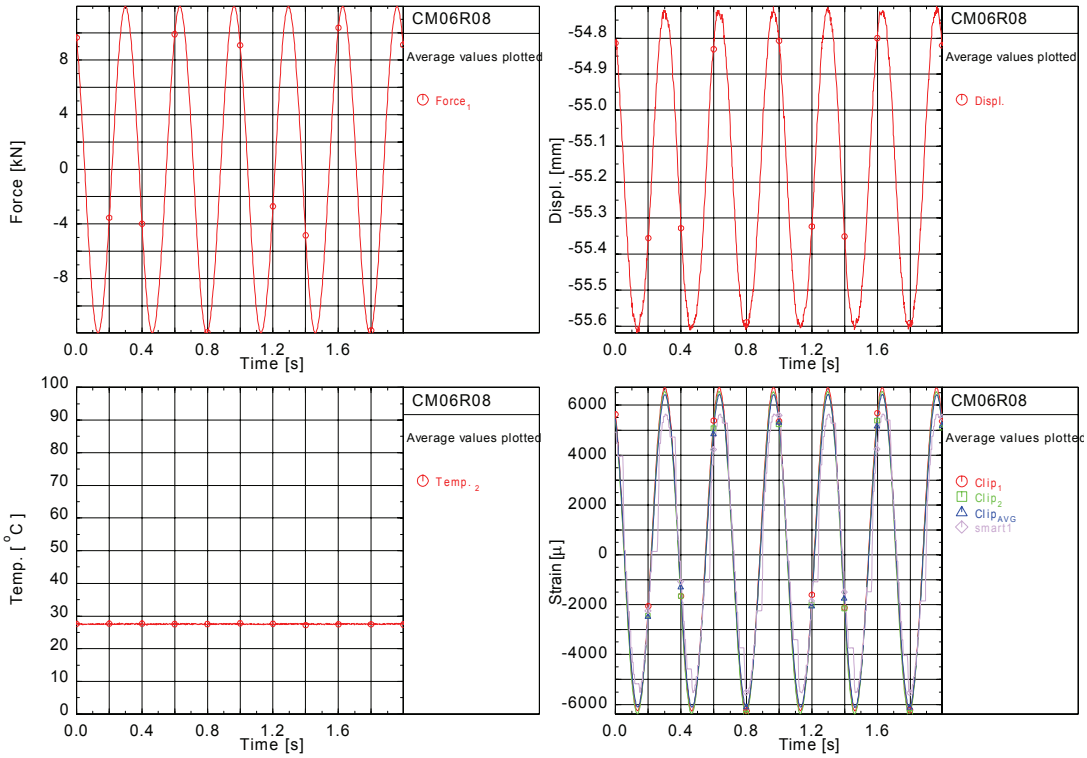


Figure C - 4: CM06R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	12.0	-12.0	-12.0				
Displ. [mm]	-54.71	-55.69	-55.68				
$Clip_1$ [μ]	6558.	-6889.	-6867.				
$Clip_2$ [μ]	6953.	-7210.	-7207.				
$Clip_{AVG}$ [μ]	6551.	-6815.	-6794.				
smart1 [μ]	-5290.	-5309.	-5298.				
σ [MPa]	212.4	-213.1	-213.1				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	27.3	26.7	27.0

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM06R08\CM06R08.nul(Rec.1)

TEST started at: 30-10-07 01:28:21

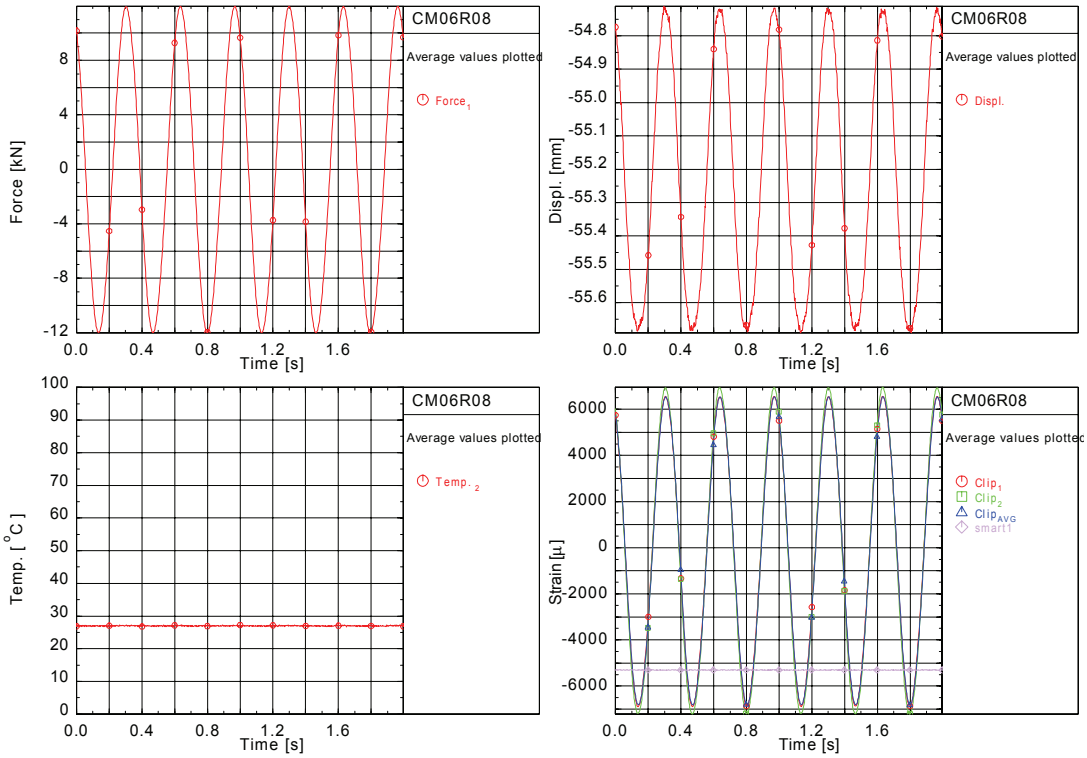


Figure C - 5: CM06R08 (ca. 100,000 cycles)

Remarks: FBG sensor no useful signal

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	12.0	-12.1	-12.1				
Displ. [mm]	-54.64	-55.81	-55.81				
$Clip_1$ [μ]	3154.	-9621.	-9621.				
$Clip_2$ [μ]	3761.	-9935.	-9935.				
$Clip_{AVG}$ [μ]	3351.	-9463.	-9453.				
smart1 [μ]	5697.	-5532.	-5374.				
σ [MPa]	213.1	-214.1	-214.1				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	28.8	28.3	28.5

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM06R08\CM06R08.nul(Rec.1)

TEST started at: 02-11-07 21:42:27

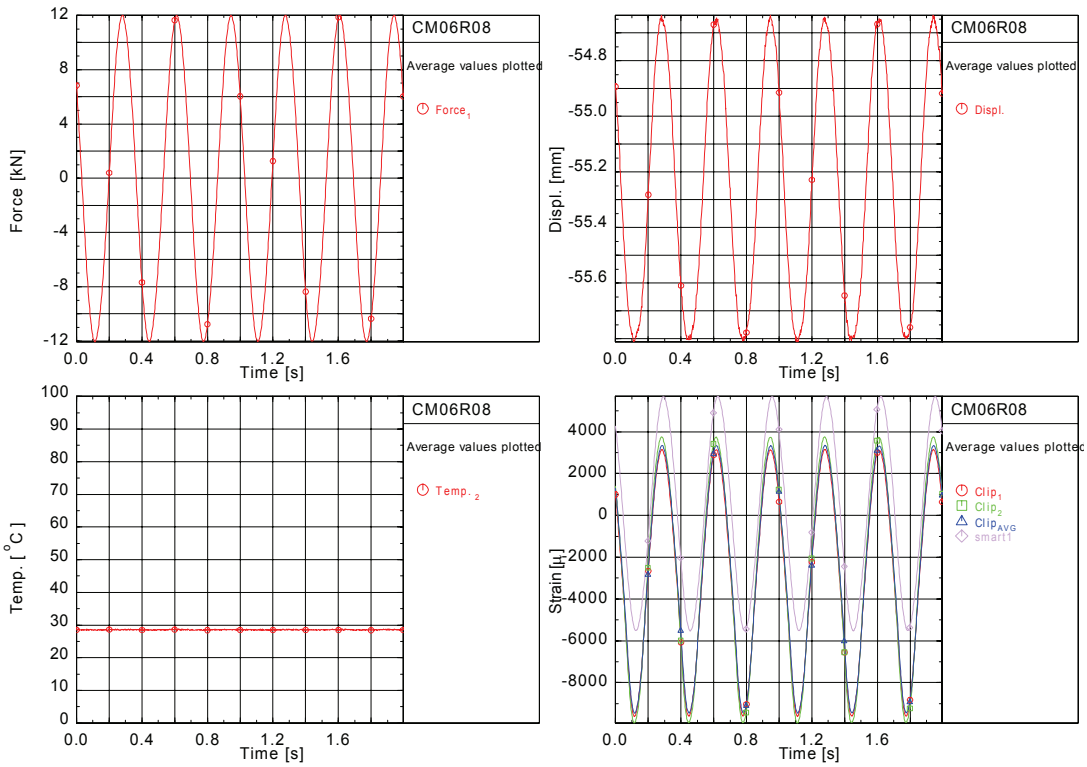


Figure C - 6: CM06R08 (ca. 1,000,000 cycles)

Channels	Maximum	Minimum	@F_{max}	G [GPa]
Force$_1$ [kN]	7.1	-0.3	7.1	
Force$_3$ [kN]	7.0	-0.4	7.0	
Displ. [mm]	-77.62	-77.90	-77.62	
Clip$_1$ [μ]	3542.	117.	3542.	
Clip$_2$ [μ]	2983.	-740.	2983.	
FBG$_{1\ (\varepsilon^*)}$ [μ]	2827.	-328.	2827.	
$\varepsilon_{1\ (\varepsilon^*)}$ [μ]	3023.	-116.	3023.	
$\varepsilon_{2\ (\varepsilon^*)}$ [μ]	2894.	-536.	2894.	
σ [MPa]	118.3	-5.4	118.3	

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	26.4	25.9	26.2
Temp.$_2$ [°C]	25.6	25.2	25.4

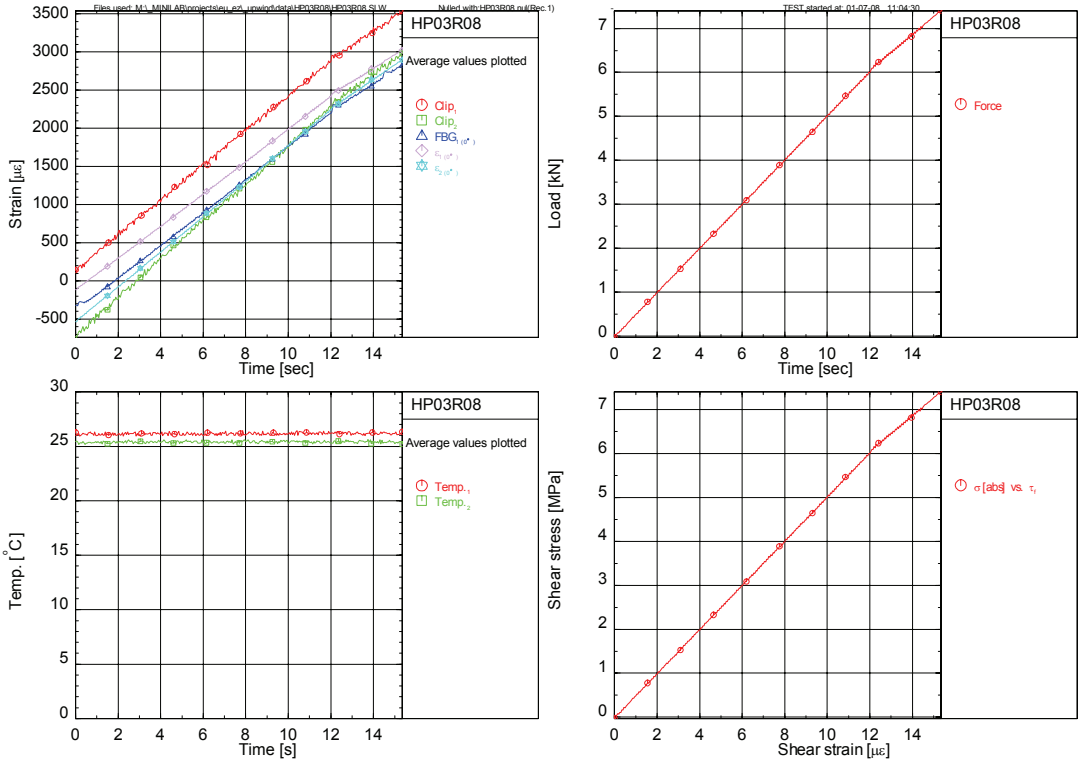


Figure C - 7: HP03R08 (slow ramp)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.7	-14.3	14.1	-14.4	0.3		
$Force_3$ [kN]	13.6	-14.3	14.2	-14.5	0.0		
Displ. [mm]	-77.61	-78.80	-73.34	-79.15	50.16		
$Clip_1$ [µ]	3394.	-9965.	6851.	-11326.	26.		
$Clip_2$ [µ]	2835.	-12685.	6959.	-14850.	26.		
$FBG_{1\ (0^\circ)}$ [µ]	5823.	-7020.	6258.	-7115.	-5.		
$\varepsilon_{1\ (0^\circ)}$ [µ]	18921.	18856.	18965.	-5579.	-3.		
$\varepsilon_{2\ (0^\circ)}$ [µ]	18840.	18688.	18865.	-6703.	3.		
σ [MPa]	228.1	-237.5	234.8	-238.8	4.9		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	29.3	24.5	26.6
$Temp._2$ [°C]	31.4	25.2	29.0

Number of Cycles 306835.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP03R08\HP03R08.nul(Rec.1)

TEST started at: 01-07-08 10:54:01

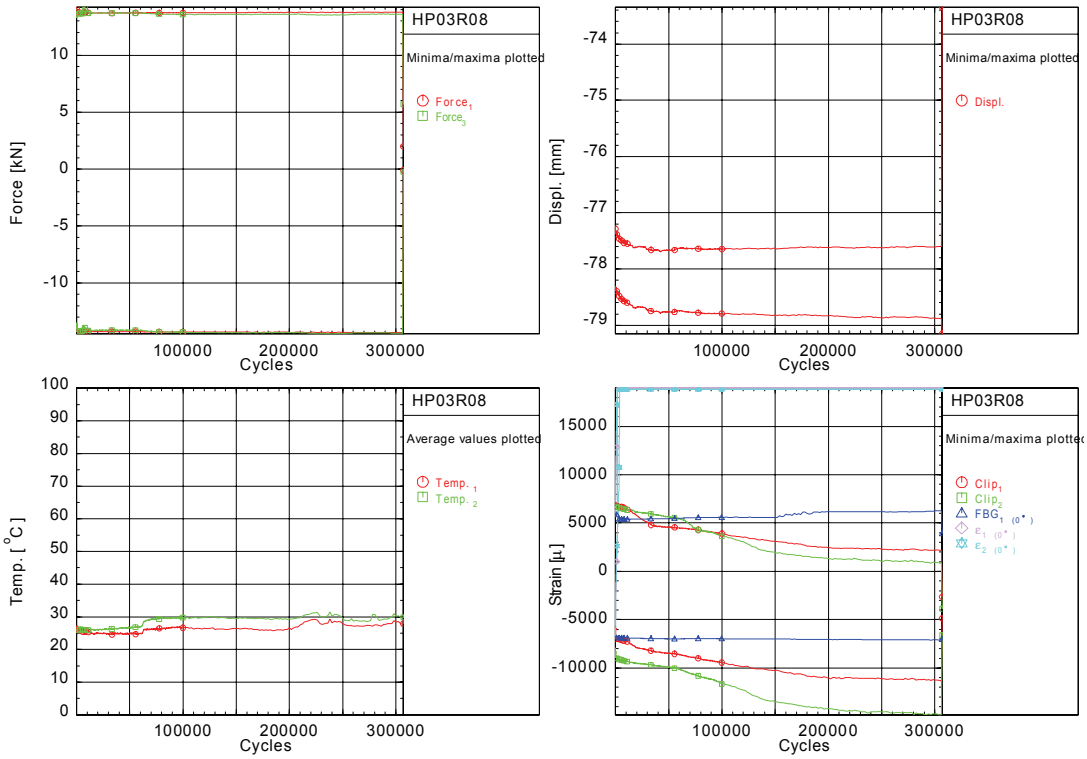


Figure C - 8: HP03R08 (fatigue summary)

Remarks: clip gauges and FBG considerably different

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.7	-14.3	-14.3				
$Force_3$ [kN]	13.6	-14.3	-14.3				
Displ. [mm]	-77.36	-78.38	-78.36				
$Clip_1$ [µ]	6769.	-7026.	-6999.				
$Clip_2$ [µ]	6733.	-8984.	-8977.				
$FBG_{1\ (0^\circ)}$ [µ]	5879.	-6907.	-6870.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	12112.	317.	317.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	15717.	1854.	1855.				
σ [MPa]	228.3	-238.1	-238.1				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.2	25.6	25.9
$Temp._2$ [°C]	26.3	25.7	25.9

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP03R08\HP03R08.nul(Rec.1)

TEST started at: 01-07-08 11:11:38

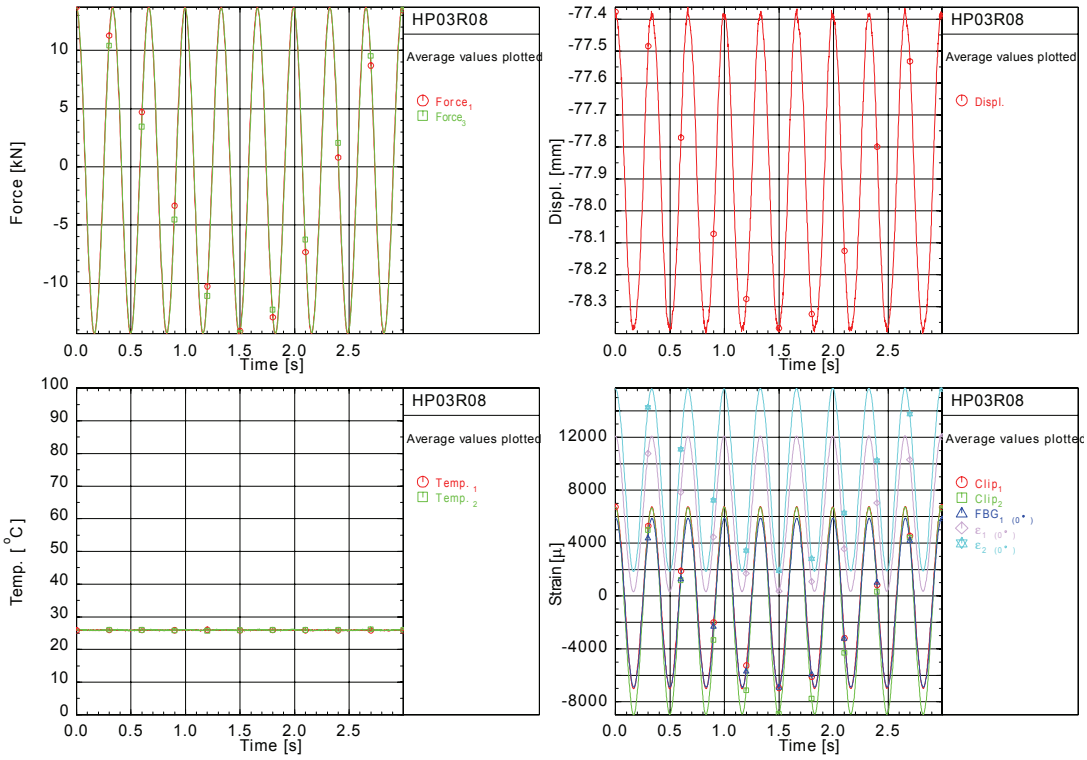


Figure C - 9: HP03R08 (ca. 1,000 cycles)

Remarks: Strain gauges drifted considerably

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.7	-14.3	13.7				
$Force_3$ [kN]	13.7	-14.2	13.7				
Displ. [mm]	-77.61	-78.69	-77.63				
$Clip_1$ [μ]	5798.	-7989.	5765.				
$Clip_2$ [μ]	6202.	-9539.	6132.				
$FBG_{1\ (0^\circ)}$ [μ]	5410.	-6931.	5375.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	18965.	18965.	18965.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	18865.	18865.	18865.				
σ [MPa]	228.2	-237.2	228.2				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	25.3	24.8	25.0
$Temp._2$ [°C]	26.3	25.6	25.9

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP03R08\HP03R08.nul(Rec.1)

TEST started at: 01-07-08 12:56:45

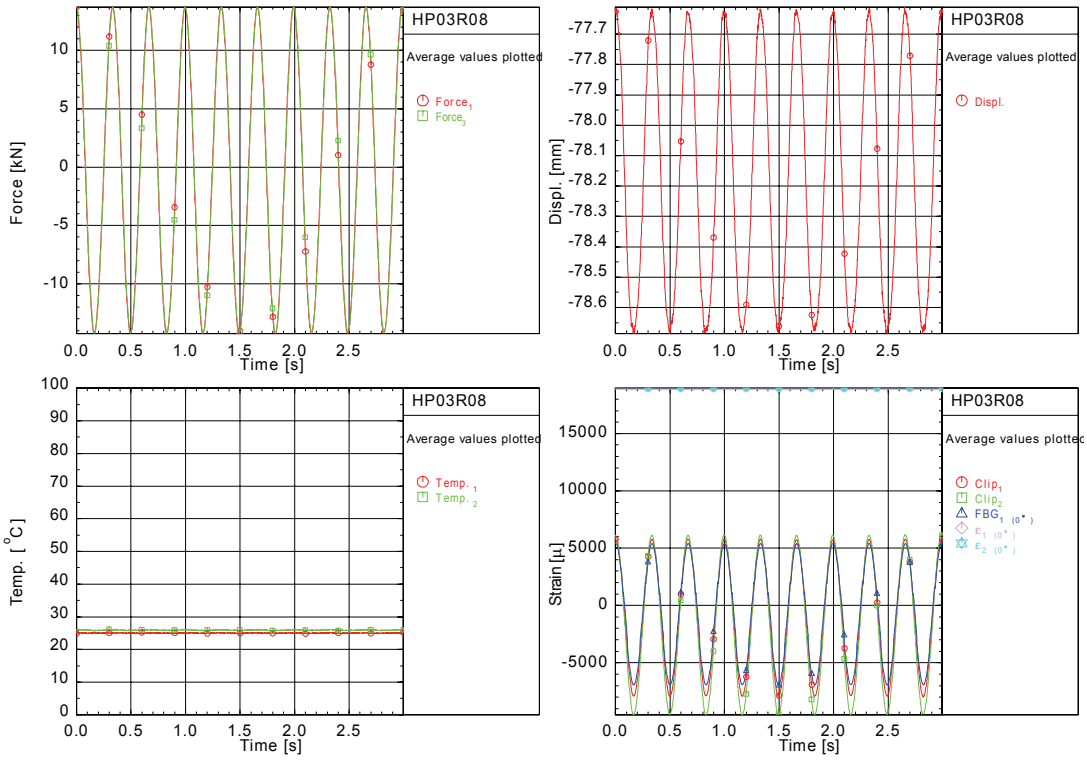


Figure C - 10: HP03R08 (ca. 10,000 cycles)

Remarks: Strain gauges failed

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.8	-14.3	13.8				
$Force_3$ [kN]	13.6	-14.4	13.6				
Displ. [mm]	-77.61	-78.88	-77.61				
$Clip_1$ [μ]	2231.	-11300.	2171.				
$Clip_2$ [μ]	873.	-14866.	794.				
$FBG_{1\ (0^\circ)}$ [μ]	6241.	-7111.	6219.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	18965.	18965.	18965.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	18865.	18865.	18865.				
σ [MPa]	229.2	-238.7	229.2				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	28.1	27.6	27.8
$Temp._2$ [°C]	29.8	29.3	29.5

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP03R08.nul(Rec.1)

TEST started at: 02-07-08 14:45:51

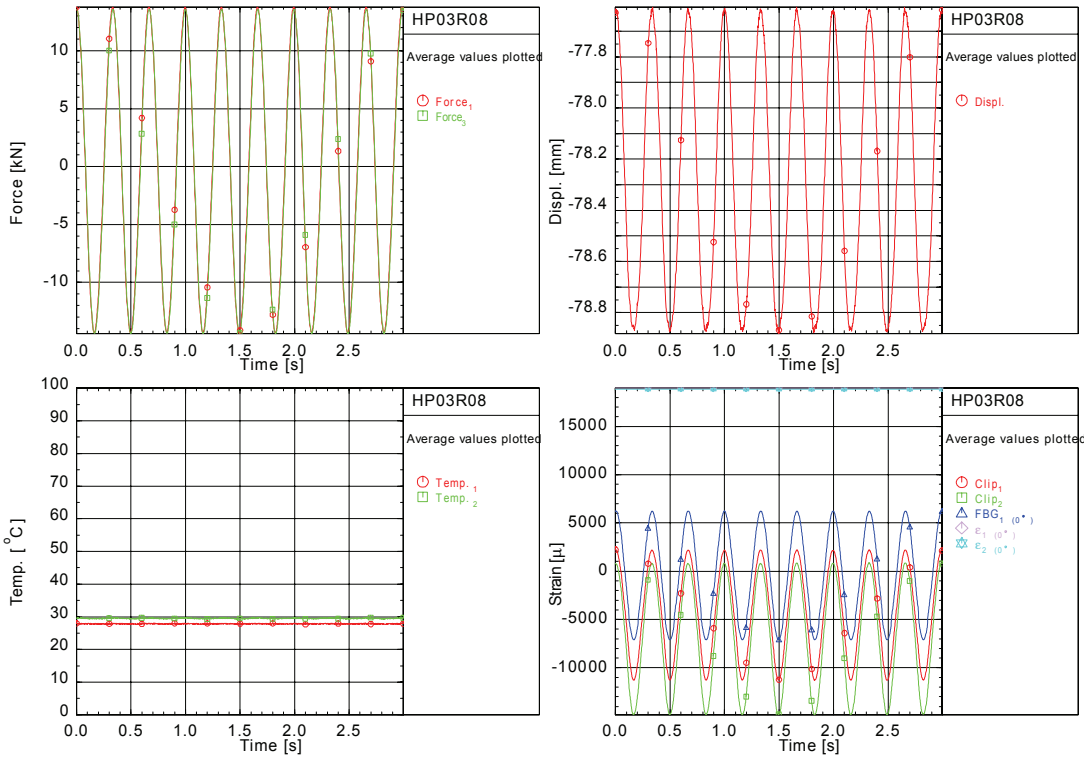


Figure C - 11: HP03R08 (ca. 100,000 cycles)

Remarks: Clip gauges drifted downwards

Channels	Maximum	Minimum	@F_{max}	G [GPa]
Force$_1$ [kN]	6.0	-6.0	6.0	
Force$_3$ [kN]	5.9	-5.8	5.9	
Displ. [mm]	-79.33	-79.74	-79.34	
Clip$_1$ [μ]	2332.	-3009.	2315.	
Clip$_2$ [μ]	2603.	-3639.	2596.	
FBG$_{1\ (\varepsilon^*_1)}$ [μ]	2439.	-2881.	2429.	
$\varepsilon_{1\ (\varepsilon^*_1)}$ [μ]	2444.	-2575.	2441.	
$\varepsilon_{2\ (\varepsilon^*_1)}$ [μ]	2504.	-3055.	2504.	
σ [MPa]	101.7	-101.7	101.7	

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	26.8	26.3	26.6
Temp.$_2$ [°C]	25.8	25.2	25.4

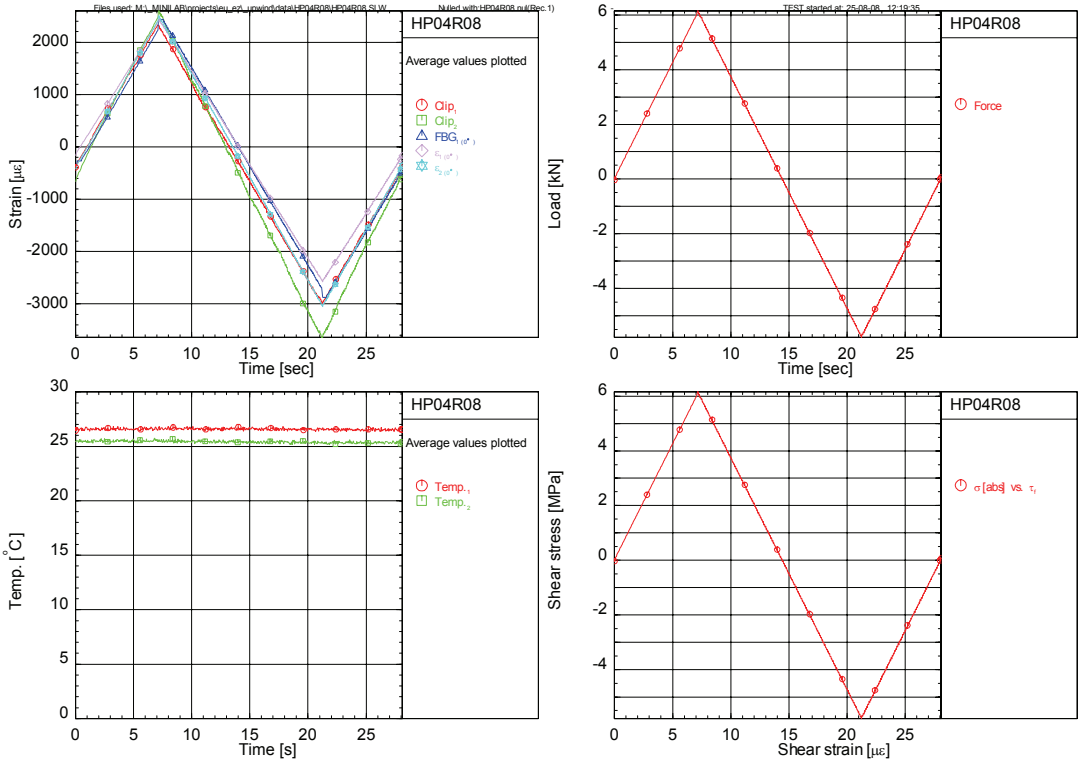


Figure C - 12: HP04R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.8	-14.1	14.4	-14.4	0.2		
$Force_3$ [kN]	13.7	-14.2	14.3	-14.4	0.0		
Displ. [mm]	-79.01	-80.11	-76.84	-80.45	50.16		
$Clip_1$ [µ]	6541.	-7240.	19113.	-7583.	13.		
$Clip_2$ [µ]	7651.	-9673.	8030.	-10307.	30.		
$FBG_{1\ (0^\circ)}$ [µ]	6094.	-6910.	6266.	-7121.	-7.		
$\varepsilon_{1\ (0^\circ)}$ [µ]	18329.	16028.	19010.	-5508.	-5.		
$\varepsilon_{2\ (0^\circ)}$ [µ]	18716.	17185.	19016.	-7161.	2.		
σ [MPa]	234.1	-240.4	244.8	-245.3	3.1		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.7	24.8	25.8
$Temp._2$ [°C]	29.0	25.1	27.5

Number of Cycles 20090.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP04R08\HP04R08.nul(Rec.1)

TEST started at: 25-08-08 12:07:12

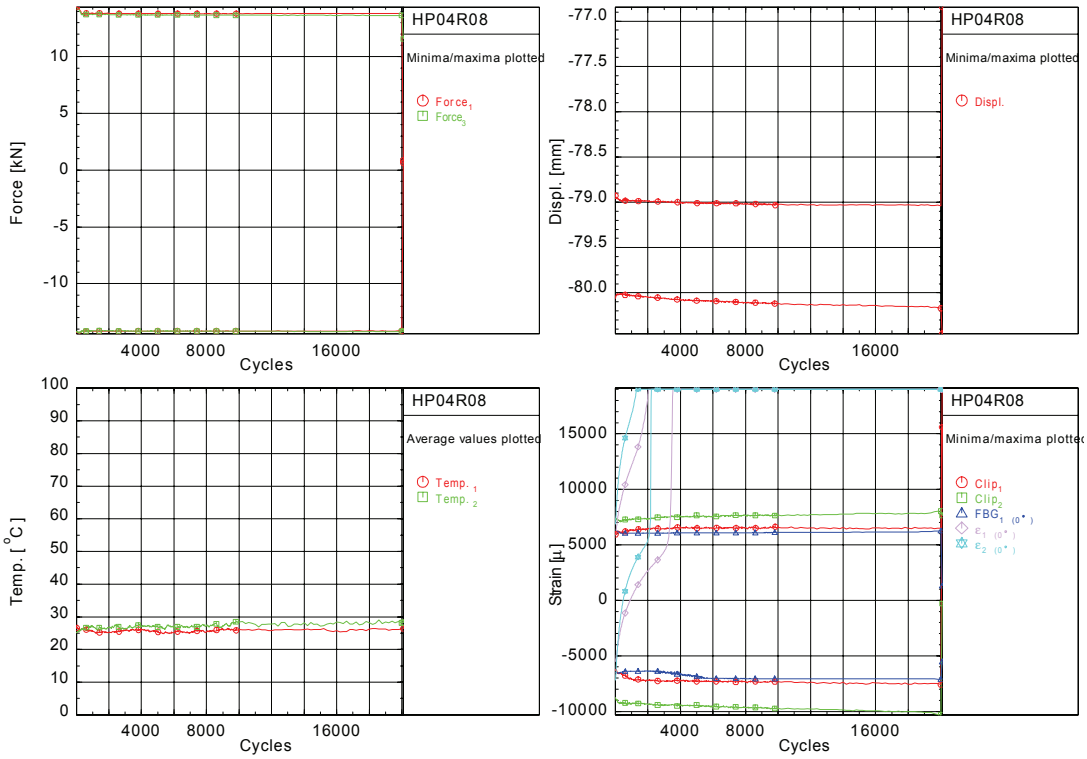


Figure C - 13: HP04R08 (fatigue summary)

Remarks: Clip gauge 1 and optical fibre very similar throughout test

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.8	-14.2	13.8				
$Force_3$ [kN]	13.7	-14.2	13.7				
Displ. [mm]	-78.98	-80.03	-78.98				
$Clip_1$ [μ]	6387.	-7008.	6333.				
$Clip_2$ [μ]	7262.	-9362.	7220.				
$FBG_{1\ (0^\bullet)}$ [μ]	6043.	-6381.	5799.				
$\varepsilon_{1\ (0^\bullet)}$ [μ]	11788.	-15.	11766.				
$\varepsilon_{2\ (0^\bullet)}$ [μ]	16302.	2332.	16276.				
σ [MPa]	235.4	-241.7	235.4				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.0	25.5	25.7
$Temp._2$ [°C]	27.3	26.7	27.0

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP04R08\HP04R08.nul(Rec.1)

TEST started at: 25-08-08 12:27:36

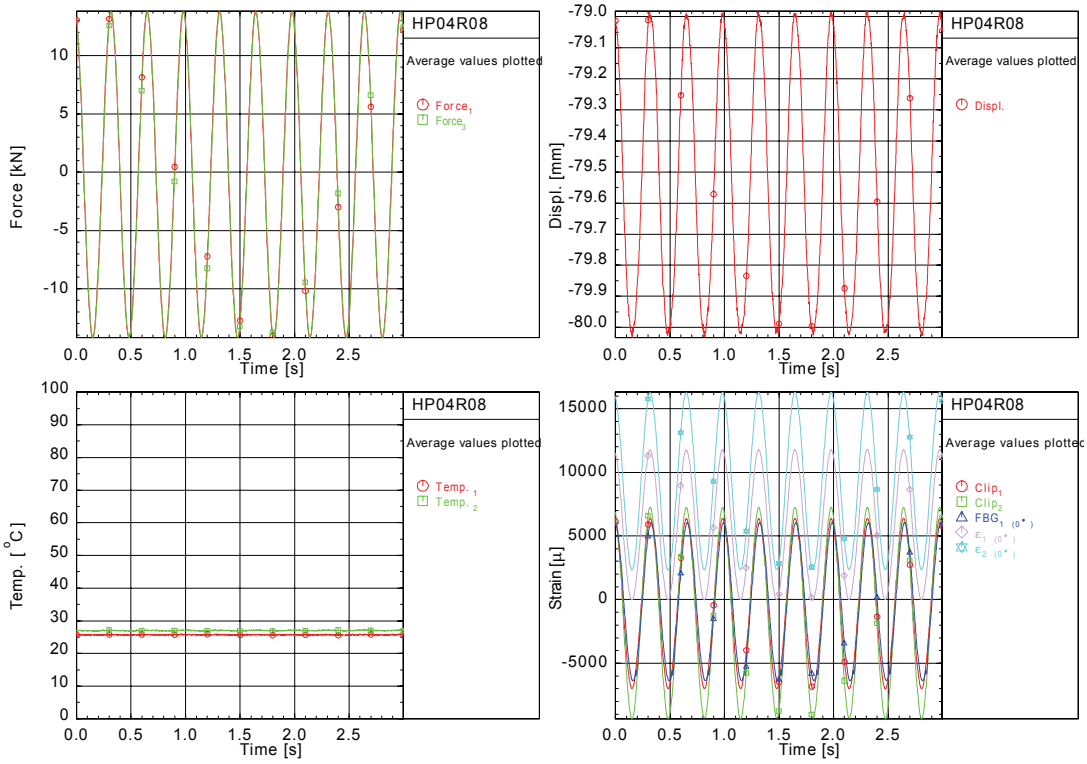


Figure C - 14: HP04R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.8	-14.2	-14.2				
$Force_3$ [kN]	13.7	-14.2	-14.2				
Displ. [mm]	-79.02	-80.12	-80.11				
$Clip_1$ [µ]	6586.	-7335.	-7275.				
$Clip_2$ [µ]	7677.	-9737.	-9703.				
$FBG_{1\ (0^\circ)}$ [µ]	6119.	-7054.	-6887.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	19010.	19010.	19010.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	19016.	19016.	19016.				
σ [MPa]	234.8	-241.4	-241.4				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.2	25.7	25.9
$Temp._2$ [°C]	28.6	28.0	28.3

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP04R08\HP04R08.nul(Rec.1)

TEST started at: 25-08-08 13:17:56

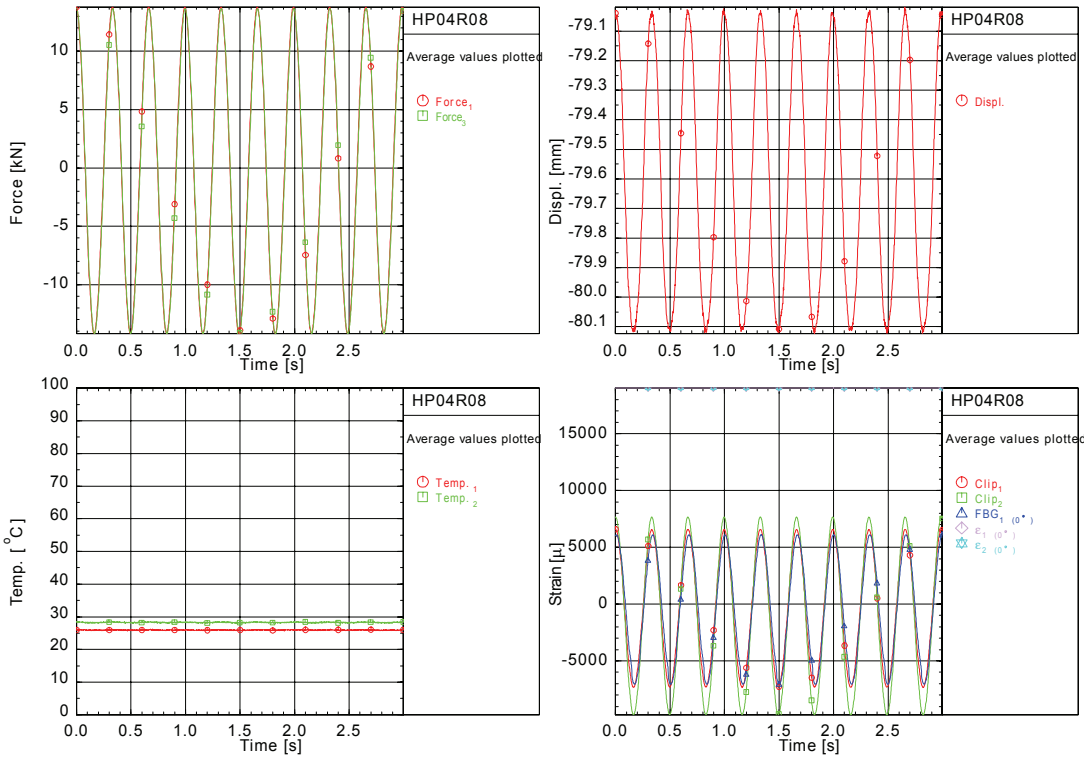


Figure C - 15: HP04R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	@F_{max}	G [GPa]
Force$_1$ [kN]	6.1	-5.9	6.1	
Force$_3$ [kN]	5.9	-6.0	5.9	
Displ. [mm]	-78.61	-79.04	-78.62	
Clip$_1$ [μ]	2643.	-2607.	2629.	
Clip$_2$ [μ]	2062.	-4012.	2014.	
FBG$_{1\ (\varepsilon^*_1)}$ [μ]	2590.	-2904.	2575.	
$\varepsilon_{1\ (\varepsilon^*_1)}$ [μ]	2659.	-2538.	2659.	
$\varepsilon_{2\ (\varepsilon^*_1)}$ [μ]	2362.	-3084.	2362.	
σ [MPa]	103.1	-100.0	103.1	

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [$^\circ$C]	26.3	25.7	26.0
Temp.$_2$ [$^\circ$C]	25.9	25.4	25.6

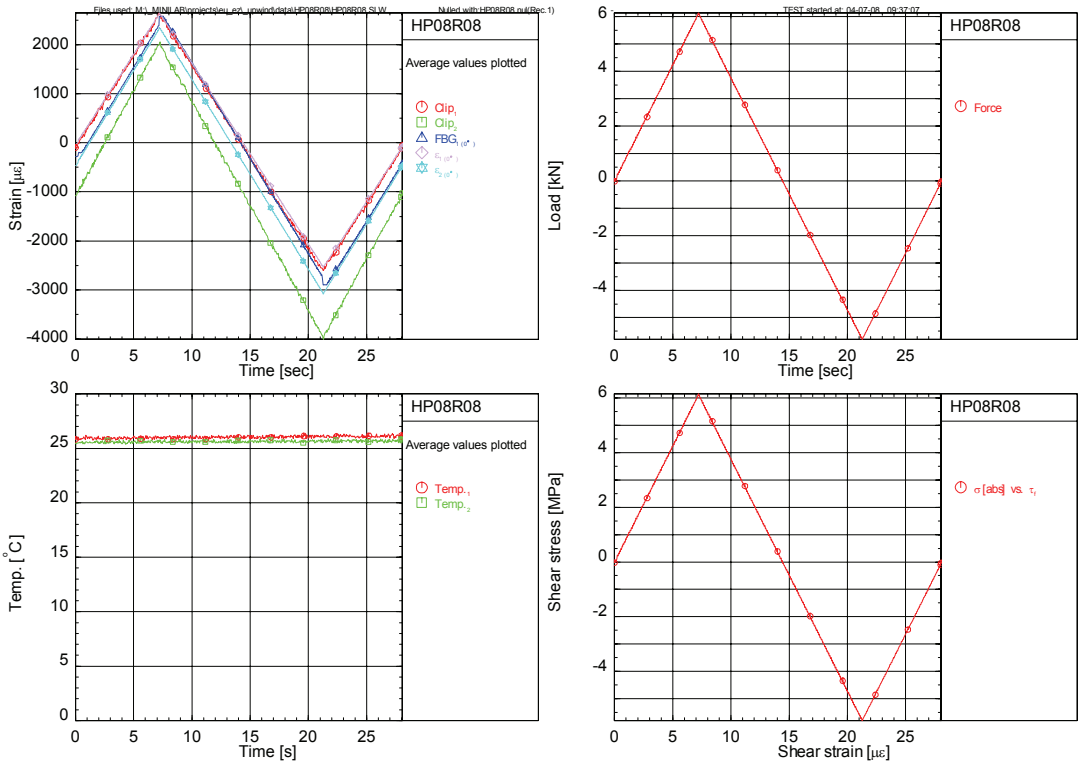


Figure C - 16: HP08R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
$Force_1$ [kN]	12.0	-12.1	12.1	-12.2	0.1		
$Force_3$ [kN]	11.8	-12.2	12.0	-12.3	0.0		
Displ. [mm]	-78.61	-79.67	-73.50	-79.79	50.16		
$Clip_1$ [µ]	3970.	-7111.	5443.	-7643.	-14.		
$Clip_2$ [µ]	3668.	-10041.	5974.	-11157.	-20.		
$FBG_{1\ (0^\circ)}$ [µ]	5299.	-5799.	5352.	-5926.	3.		
$\varepsilon_{1\ (0^\circ)}$ [µ]	18934.	18852.	18969.	-5013.	1.		
$\varepsilon_{2\ (0^\circ)}$ [µ]	18967.	18905.	18983.	-6085.	1.		
σ [MPa]	204.8	-205.0	205.7	-207.8	1.4		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	28.6	22.2	26.4
$Temp._2$ [°C]	30.2	24.6	28.0

Number of Cycles 923485.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP08R08[illegible]R08.nul(Rec.1)

TEST started at: 04-07-08 09:26:03

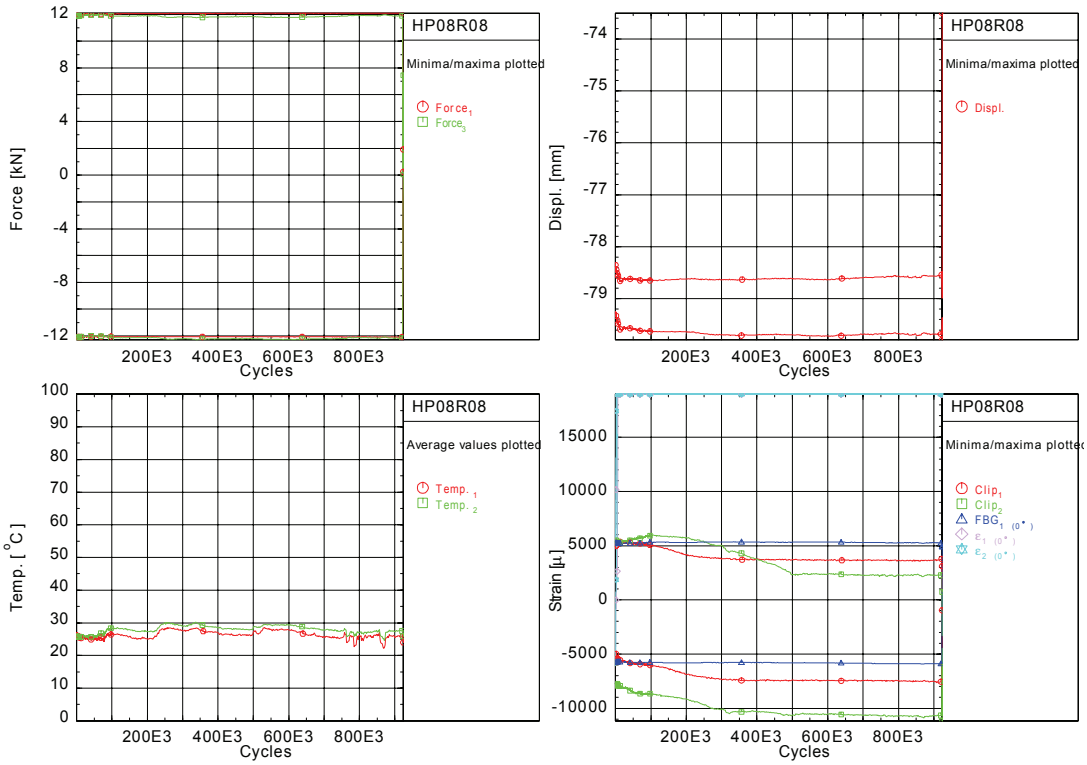


Figure C - 17: HP08R08 (fatigue summary)

FBG signal constant throughout life while clip gauge average decreases

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	12.0	-12.1	12.0				
$Force_3$ [kN]	11.9	-12.2	11.8				
Displ. [mm]	-78.41	-79.29	-78.41				
$Clip_1$ [μ]	4942.	-4988.	4909.				
$Clip_2$ [μ]	5510.	-7969.	5452.				
$FBG_{1\ (0^\circ)}$ [μ]	5294.	-5774.	5258.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	8583.	-1446.	8561.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	11747.	-173.	11712.				
σ [MPa]	204.0	-206.6	204.0				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.4	25.9	26.1
$Temp._2$ [°C]	26.3	25.8	26.0

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP08R08.nul(Rec.1)

TEST started at: 04-07-08 09:43:49

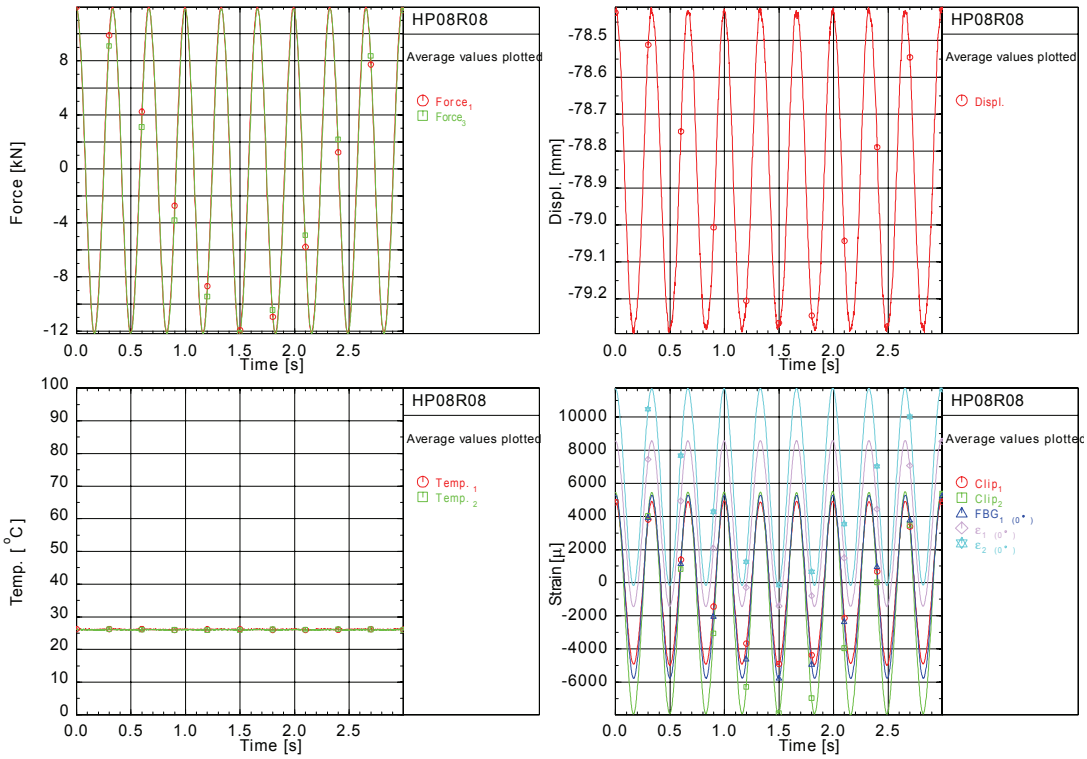


Figure C - 18: HP08R08 (ca. 1,000 cycles)

Remarks: Strain gauges drifted

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	12.0	-12.1	12.0				
$Force_3$ [kN]	11.9	-12.1	11.9				
Displ. [mm]	-78.65	-79.60	-78.66				
$Clip_1$ [µ]	5336.	-5728.	5336.				
$Clip_2$ [µ]	5379.	-8148.	5370.				
$FBG_{1\ (0^\circ)}$ [µ]	5216.	-5735.	5216.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	18969.	18969.	18969.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	18983.	18983.	18983.				
σ [MPa]	204.2	-205.5	204.2				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	25.5	24.9	25.2
$Temp._2$ [°C]	26.0	25.4	25.7

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP08R08\HP08R08.nul(Rec.1)

TEST started at: 04-07-08 11:28:56

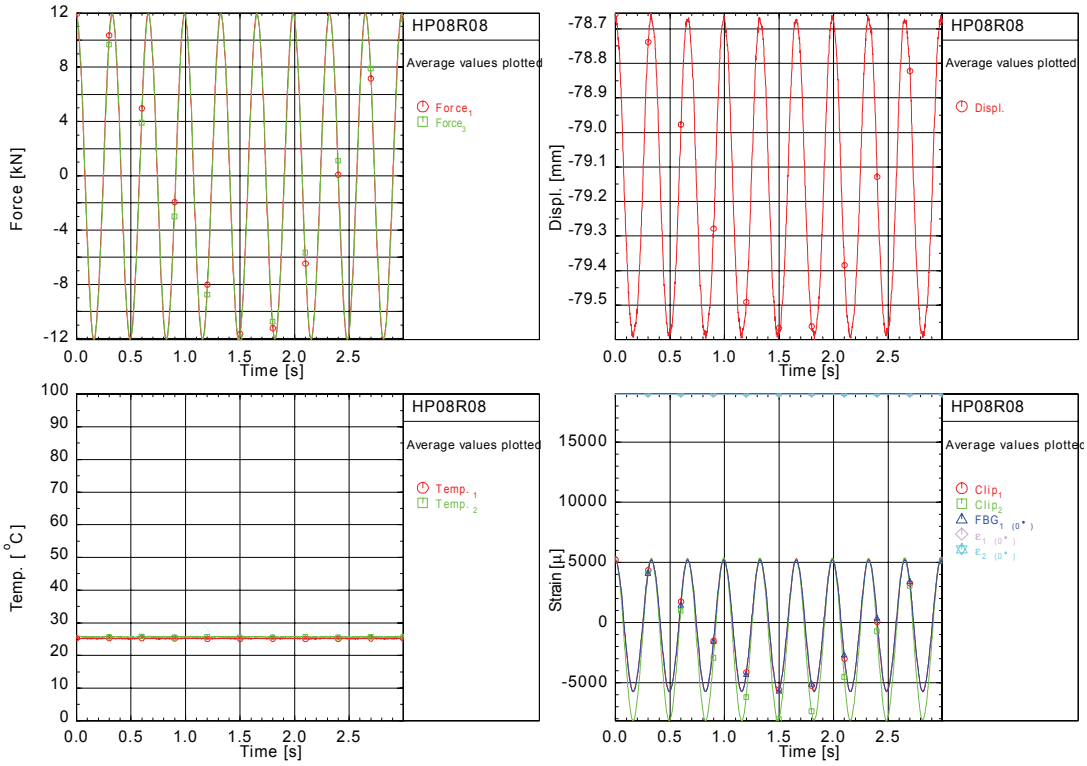


Figure C - 19: HP08R08 (ca. 10,000 cycles)

Remarks: Clip gauge 2 larger range; Strain gauges failed

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	12.1	-12.1	12.1				
$Force_3$ [kN]	11.8	-12.2	11.8				
Displ. [mm]	-78.63	-79.69	-78.64				
$Clip_1$ [µ]	3847.	-7340.	3813.				
$Clip_2$ [µ]	5005.	-10099.	4972.				
$FBG_{1\ (0°)}$ [µ]	5332.	-5799.	5309.				
$\varepsilon_{1\ (0°)}$ [µ]	18969.	18969.	18969.				
$\varepsilon_{2\ (0°)}$ [µ]	18983.	18983.	18983.				
σ [MPa]	205.3	-205.2	205.3				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	27.8	27.3	27.5
$Temp._2$ [°C]	29.3	28.7	29.0

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP08R08\HP08R08.nul(Rec.1)

TEST started at: 05-07-08 13:18:02

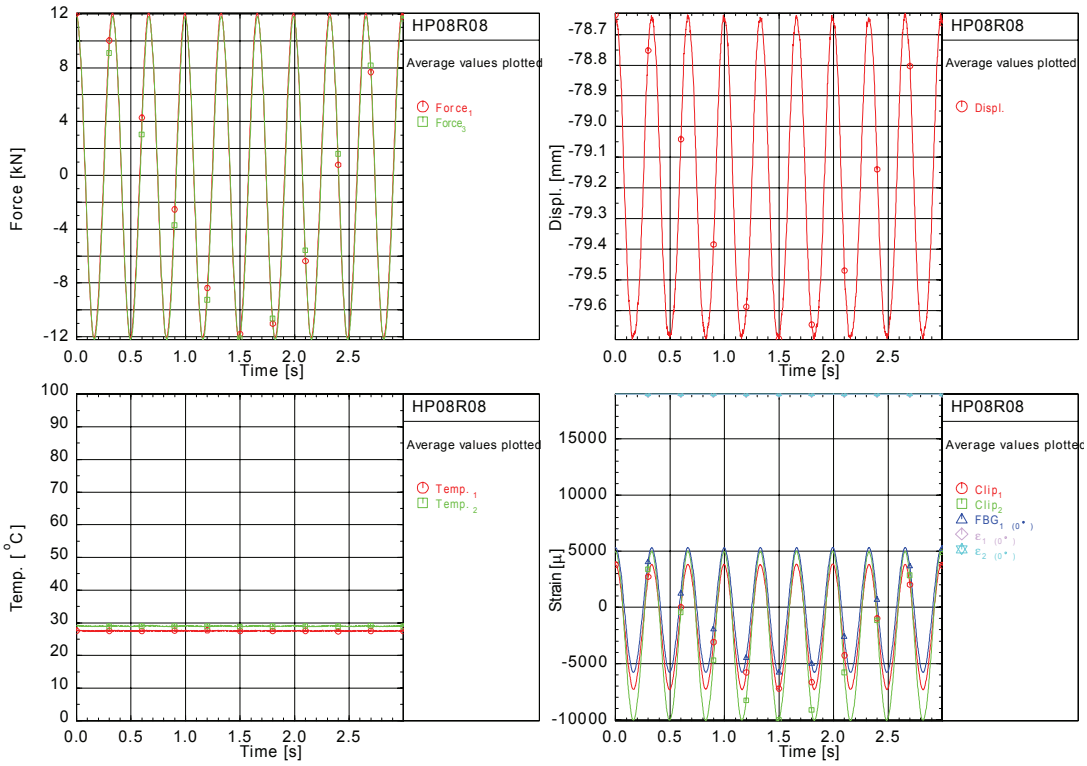


Figure C - 20: HP08R08 (ca. 100,000 cycles)

Remarks: Clip gauge 1 drifted (?) down

Channels	Maximum	Minimum	@F_{max}	G [GPa]
Force$_1$ [kN]	6.0	-5.9	6.0	
Force$_3$ [kN]	5.9	-6.0	5.9	
Displ. [mm]	-79.59	-80.04	-79.59	
Clip$_1$ [μ]	2807.	-2190.	2807.	
Clip$_2$ [μ]	1862.	-4164.	1859.	
FBG$_{1\ (\sigma^*_1)}$ [μ]	2380.	-2752.	2380.	
$\varepsilon_{1\ (\sigma^*_1)}$ [μ]	2716.	-2497.	2716.	
$\varepsilon_{2\ (\sigma^*_1)}$ [μ]	2103.	-3057.	2101.	
σ [MPa]	100.6	-98.4	100.6	

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [$^\circ$C]	25.0	24.4	24.7
Temp.$_2$ [$^\circ$C]	23.3	22.6	22.9

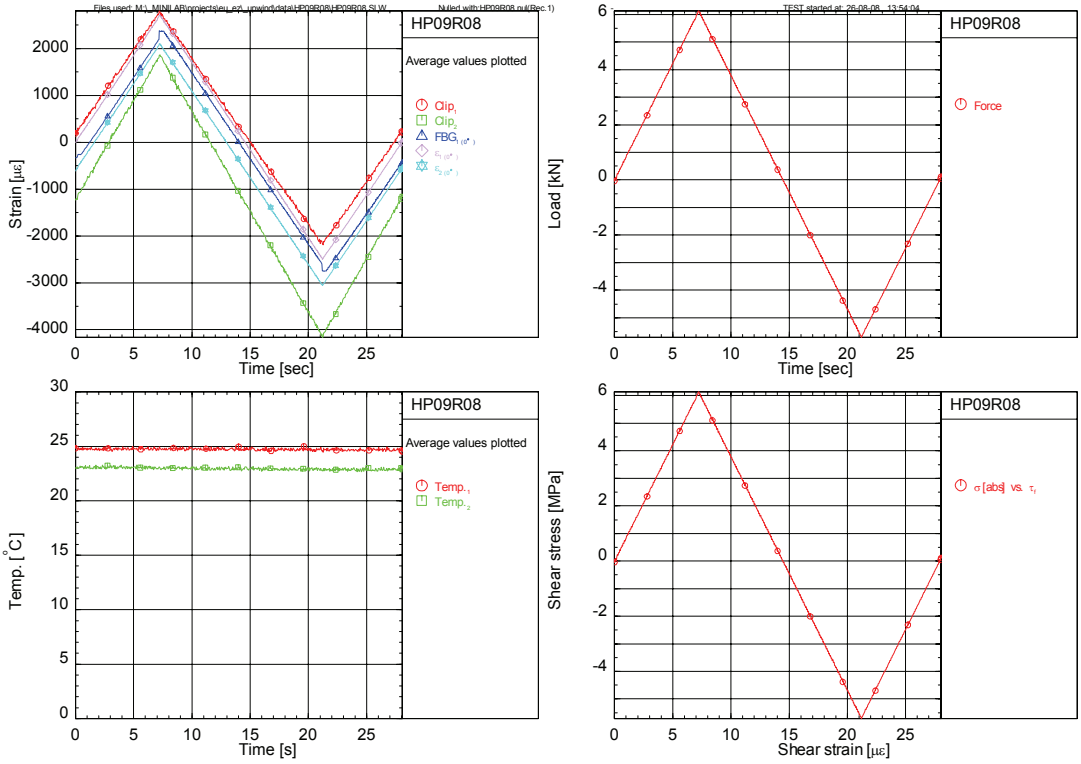


Figure C - 21: HP09R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.9	-14.2	14.0	-14.2	0.1		
$Force_3$ [kN]	13.7	-14.2	13.9	-14.4	0.0		
Displ. [mm]	-79.40	-80.66	-76.83	-80.83	50.16		
$Clip_1$ [µ]	4074.	-8866.	6082.	-9697.	-30.		
$Clip_2$ [µ]	3264.	-12492.	6551.	-13942.	1.		
$FBG_{1\ (0^\circ)}$ [µ]	6144.	-6906.	6230.	-7017.	-4.		
$\varepsilon_{1\ (0^\circ)}$ [µ]	18900.	18181.	18989.	-19106.	1.		
$\varepsilon_{2\ (0^\circ)}$ [µ]	19334.	19207.	19361.	-6580.	1.		
σ [MPa]	233.2	-237.7	234.3	-238.8	2.5		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	27.8	23.8	25.7
$Temp._2$ [°C]	27.1	22.9	25.2

Number of Cycles 310591.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP09R08\HP09R08.nul(Rec.1)

TEST started at: 26-08-08 13:44:51

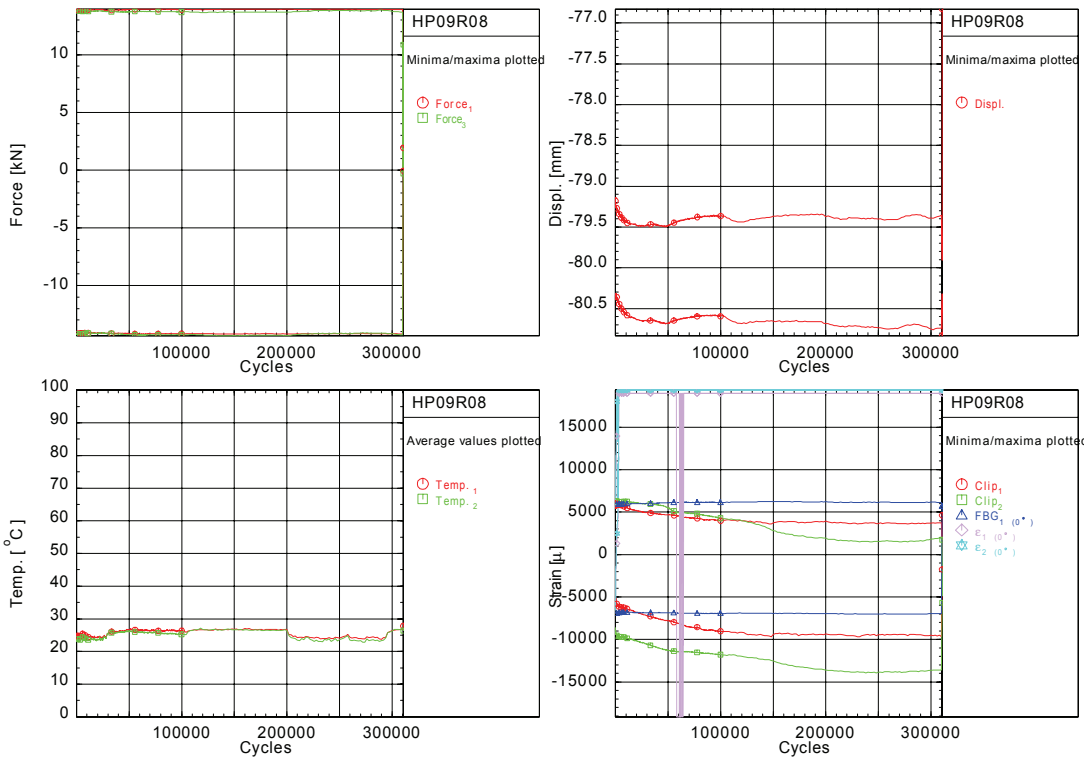


Figure C - 22: HP09R08 (fatigue summary)

Remarks: similar to HP08R08

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.9	-14.2	13.9				
$Force_3$ [kN]	13.8	-14.2	13.8				
Displ. [mm]	-79.26	-80.36	-79.28				
$Clip_1$ [μ]	5733.	-5712.	5703.				
$Clip_2$ [μ]	6414.	-9498.	6370.				
$FBG_{1\ (0^\circ)}$ [μ]	5941.	-6907.	5785.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	12783.	671.	12783.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	15829.	1724.	15829.				
σ [MPa]	233.5	-238.2	233.5				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	25.2	24.7	24.9
$Temp._2$ [°C]	24.0	23.3	23.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP09R08\HP09R08.nul(Rec.1)

TEST started at: 26-08-08 14:00:41

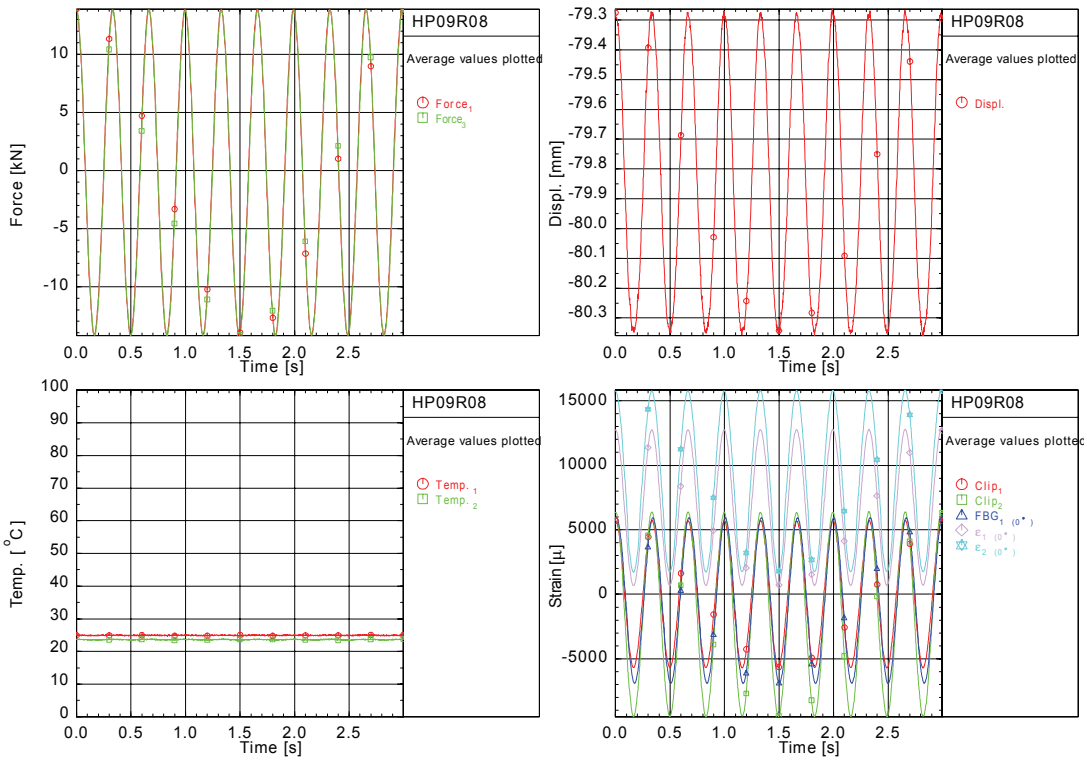


Figure C - 23: HP09R08 (ca. 1,000 cycles)

Remarks: Strain gauges drifted

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.9	-14.1	13.9				
$Force_3$ [kN]	13.8	-14.1	13.8				
Displ. [mm]	-79.48	-80.64	-79.48				
$Clip_1$ [µ]	5190.	-6808.	5146.				
$Clip_2$ [µ]	6107.	-10229.	6076.				
$FBG_{1\ (0^\circ)}$ [µ]	6011.	-6851.	5793.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	18989.	18989.	18989.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	19361.	19361.	19361.				
σ [MPa]	233.5	-237.5	233.5				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.5	24.0	24.3
$Temp._2$ [°C]	23.8	23.1	23.4

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP09R08 HP09R08.nul(Rec.1)

TEST started at: 26-08-08 15:45:48

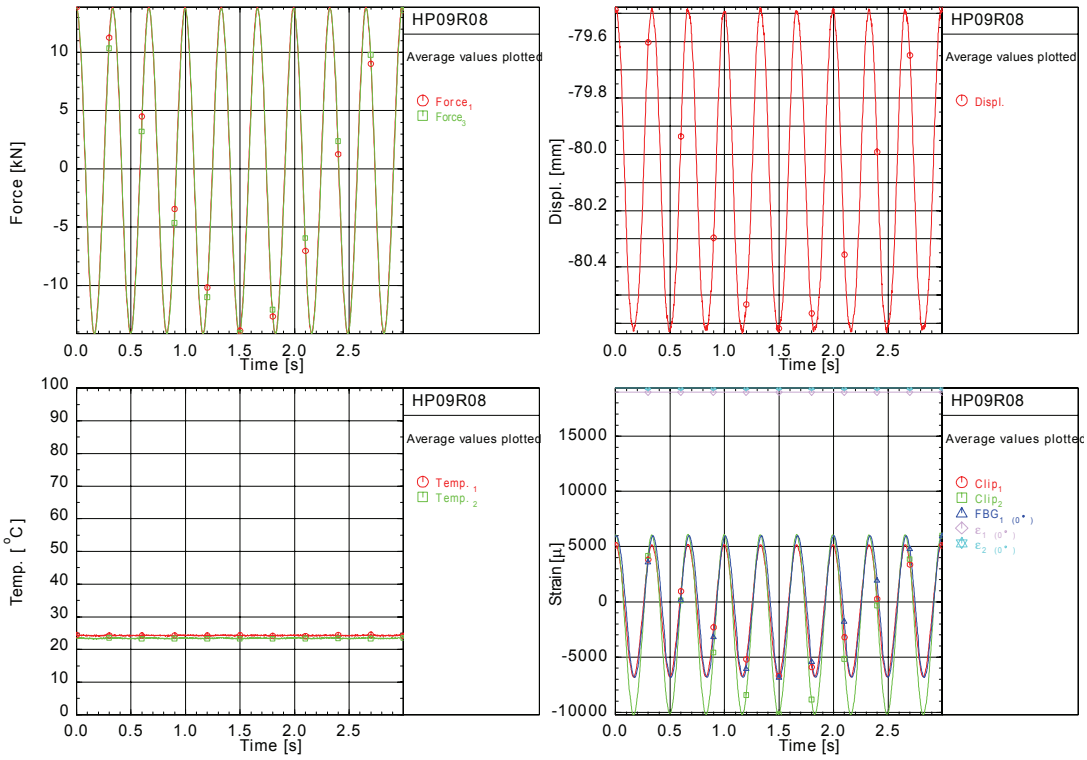


Figure C - 24: HP09R08 (ca. 10,000 cycles)

Remarks: Strain gauges failed

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	13.9	-14.2	13.9				
$Force_3$ [kN]	13.8	-14.2	13.7				
Displ. [mm]	-79.39	-80.76	-79.41				
$Clip_1$ [μ]	3750.	-9570.	3709.				
$Clip_2$ [μ]	1827.	-13702.	1811.				
$FBG_{1\ (0^\circ)}$ [μ]	6172.	-6976.	5962.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	18989.	18989.	18989.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19361.	19361.	19361.				
σ [MPa]	233.7	-238.2	233.7				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.5	26.0	26.3
$Temp._2$ [°C]	26.5	25.9	26.1

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP09R08\HP09R08.nul(Rec.1)

TEST started at: 27-08-08 17:34:54

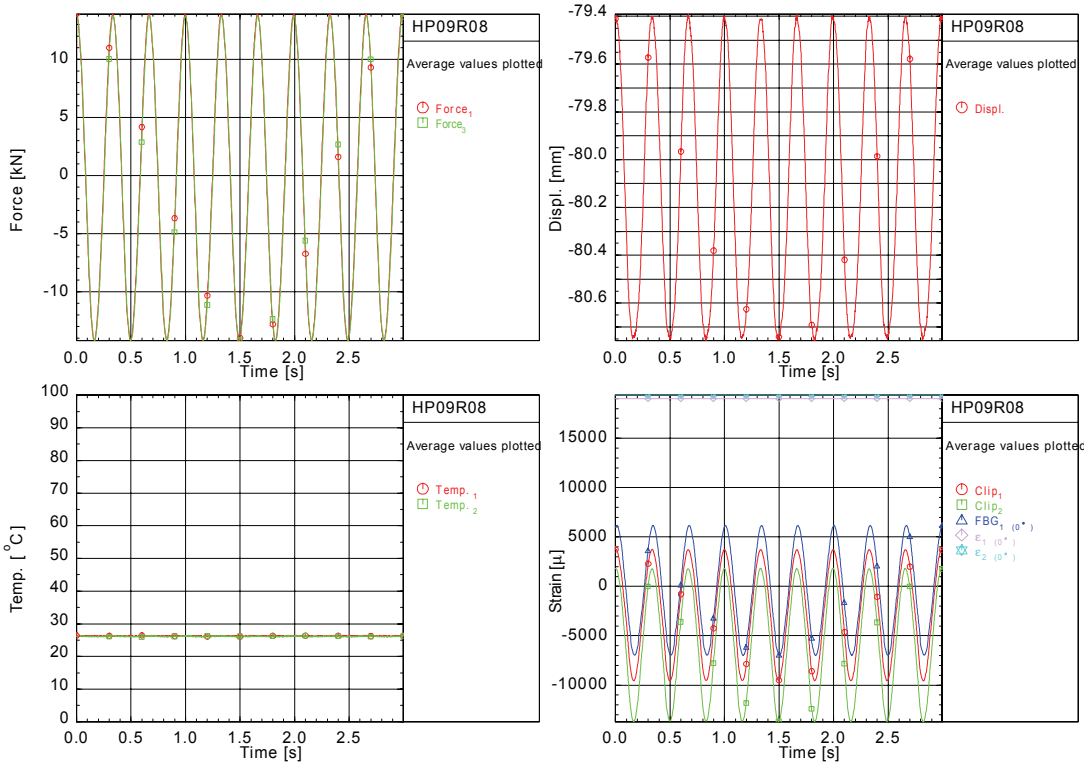


Figure C - 25: HP09R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	6.956	-6.944	-6.944		
$Force_3$ [kN]	6.9	-7.0	-7.0		
Displ. [mm]	-78.83	-79.39	-79.38		
$Clip_1$ [μ]	3227.	-2668.	-2668.	41653.	38791.
$Clip_2$ [μ]	2812.	-3348.	-3348.	37411.	37293.
$FBG_{1\ (0°)}$ [μ]	2993.	-2982.	-2980.	37726.	38403.
$\varepsilon_{1\ (0°)}$ [μ]	3038.	-2870.	-2870.	39281.	38622.
$\varepsilon_{2\ (0°)}$ [μ]	2949.	-3097.	-3094.	37199.	37777.
σ [MPa]	115.0	-114.8	-114.8		
Bending [μ/mm]	77.89	25.90	71.75		
Bending [μ/mm]	230.23	111.29	220.92		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.8	24.3	24.6
$Temp._2$ [°C]	26.1	25.6	25.9

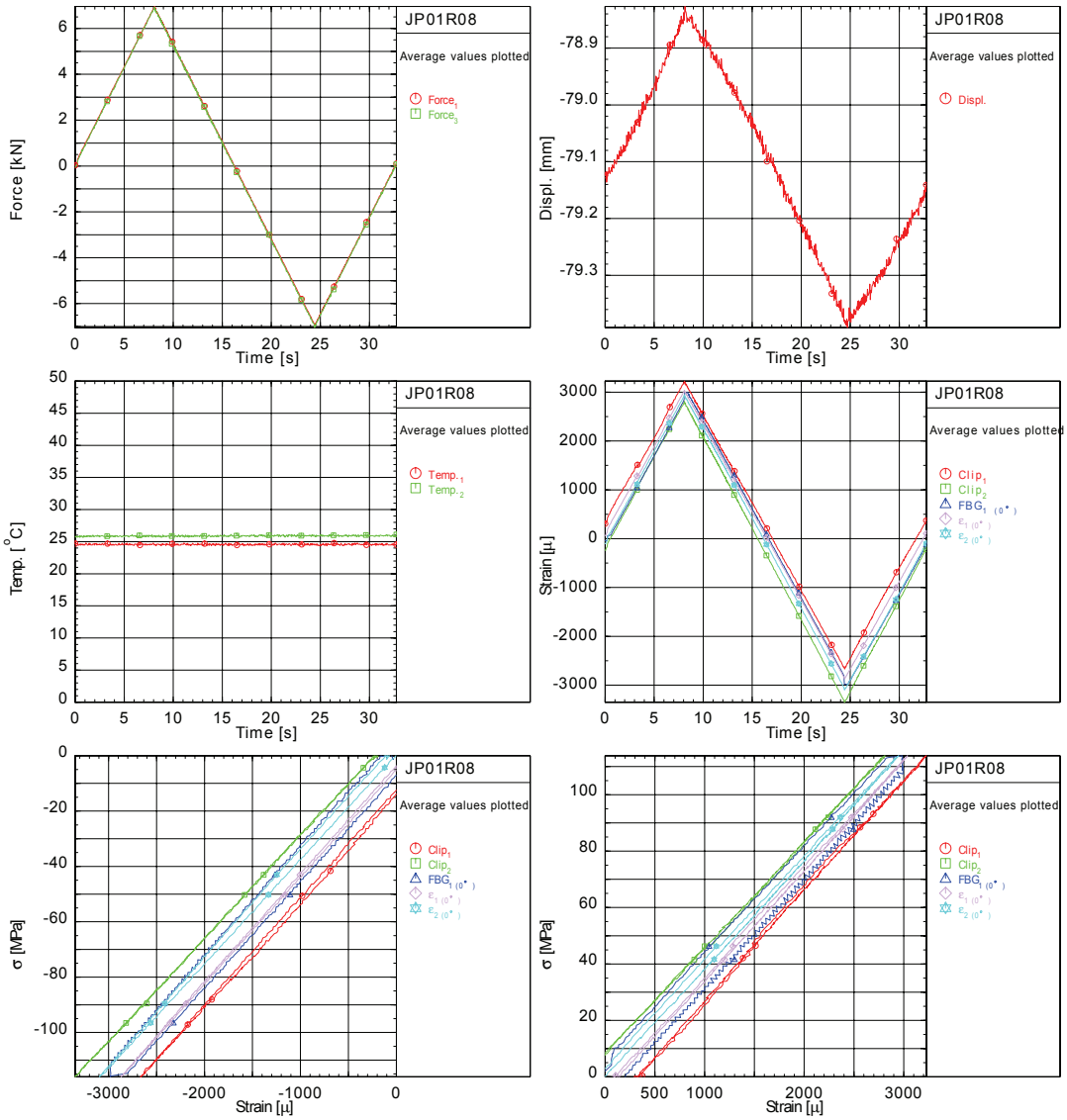


Figure C - 26: JP01R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
$Force_1$ [kN]	12.02	-11.83	12.37	-12.16	-0.07
$Force_3$ [kN]	12.0	-11.9	12.4	-12.3	0.0
Displ. [mm]	-78.57	-79.73	-76.61	-79.89	50.16
$Clip_1$ [µ]	-4785.	-10314.	6202.	-15860.	-15.
$Clip_2$ [µ]	12884.	7108.	20819.	-8590.	-5.
$FBG_{1\ (0°)}$ [µ]	5448.	-5244.	5845.	-5533.	-5.
$\varepsilon_{1\ (0°)}$ [µ]	19042.	19017.	19053.	-4997.	-3.
$\varepsilon_{2\ (0°)}$ [µ]	19028.	19009.	19036.	-5274.	4.
σ [MPa]	198.7	-195.7	204.6	-201.1	-1.2

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	25.8	19.1	21.8
$Temp._2$ [°C]	26.9	22.0	24.2

Number of Cycles	2434769.

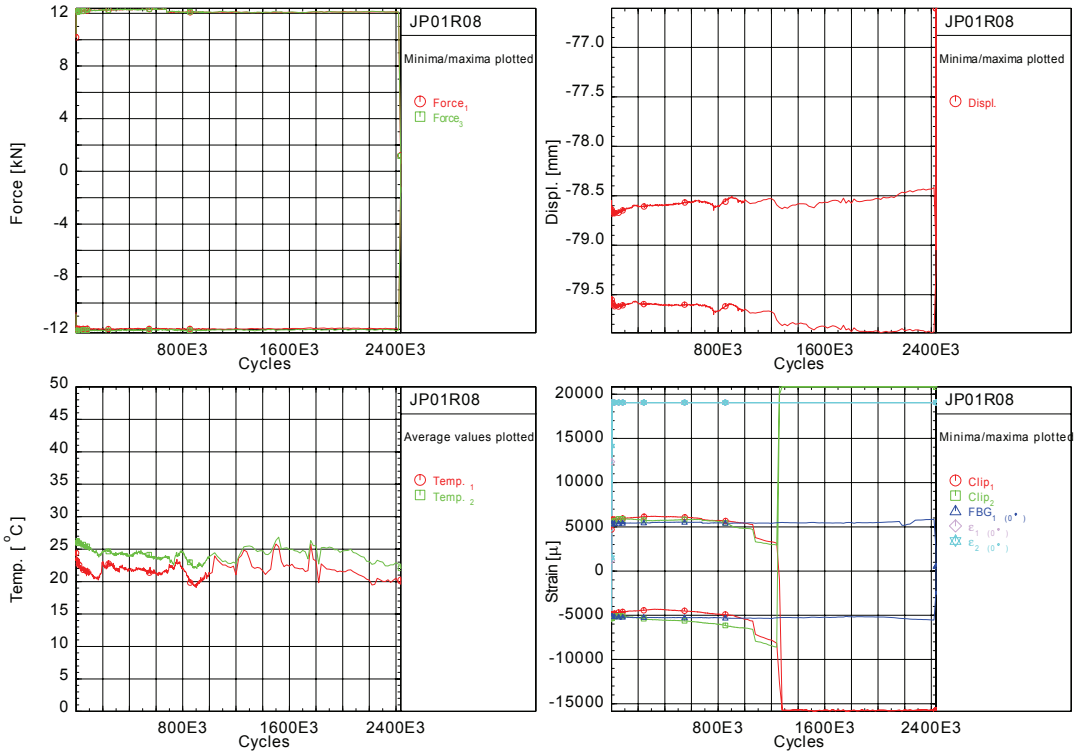


Figure C - 27: JP01R08 (fatigue summary)

FBG reasonable correlation with clip gauges until clip gauges malfunctioned (rubber rings broken)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.16	-12.01	12.16	11.98		
$Force_3$ [kN]	12.16	-12.12	12.10	11.81		
Displ. [mm]	-78.62	-79.54	-78.65	-78.63		
$Clip_1$ [µ]	5744.	-4931.	5715.	5704.		
$Clip_2$ [µ]	5293.	-5428.	5280.	5239.		
$FBG_{1\ (0°)}$ [µ]	5328.	-5118.	5145.	5311.		
$\varepsilon_{1\ (0°)}$ [µ]	9604.	-863.	9589.	9530.		
$\varepsilon_{2\ (0°)}$ [µ]	10042.	-639.	10035.	9903.		
σ [MPa]	201.1	-198.4	201.1	198.1		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.6	24.0	24.3
$Temp._2$ [°C]	26.4	25.8	26.1

Area of cross-section 60.50

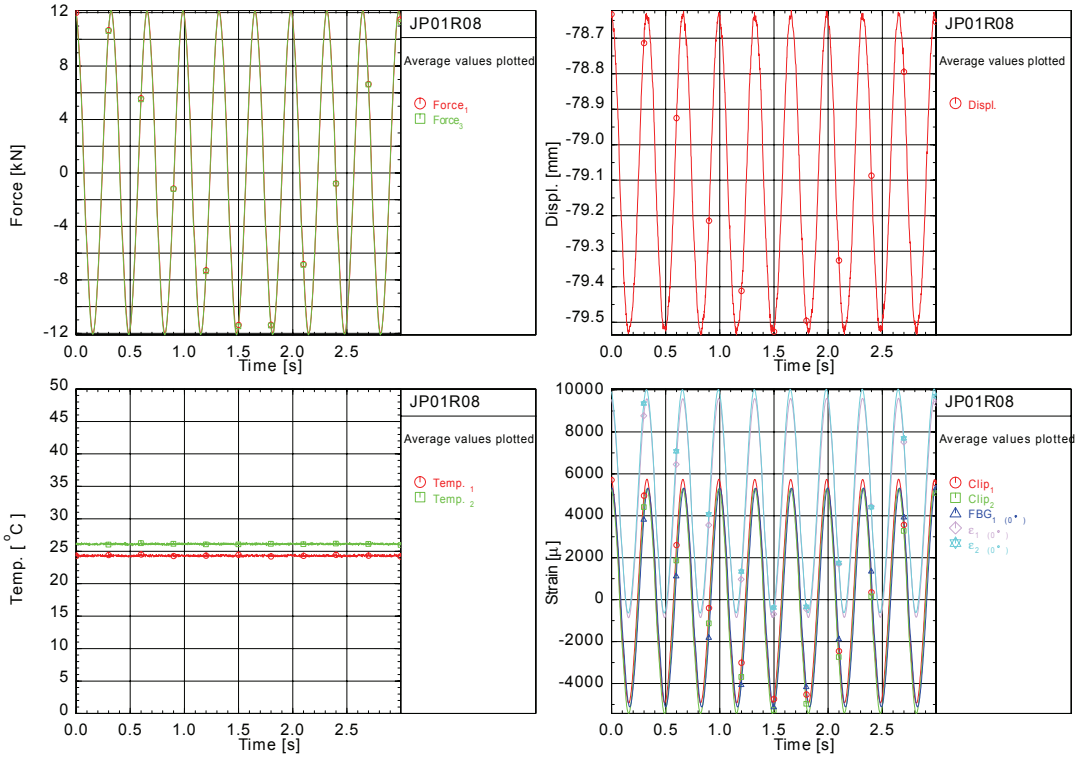


Figure C - 28: JP01R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.15	-11.98	12.15	12.01		
$Force_3$ [kN]	12.15	-12.12	12.07	11.85		
Displ. [mm]	-78.67	-79.60	-78.68	-78.68		
$Clip_1$ [µ]	5823.	-4888.	5776.	5793.		
$Clip_2$ [µ]	5542.	-5196.	5504.	5507.		
$FBG_{1\ (0°)}$ [µ]	5371.	-5141.	5096.	5336.		
$\varepsilon_{1\ (0°)}$ [µ]	19053.	19053.	19053.	19053.		
$\varepsilon_{2\ (0°)}$ [µ]	19036.	19036.	19036.	19036.		
σ [MPa]	200.9	-198.0	200.9	198.5		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	23.2	22.6	22.9
$Temp._2$ [°C]	26.5	25.9	26.2

Area of cross-section 60.50

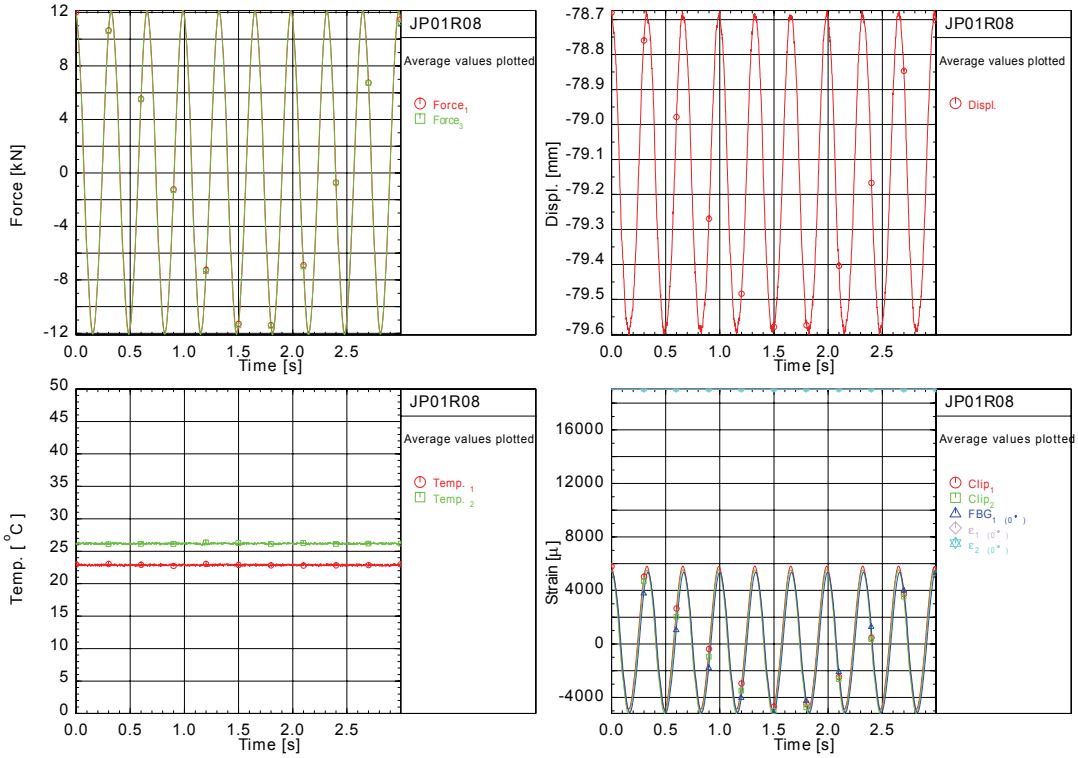


Figure C - 29: JP01R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.23	-11.97	12.23	12.00		
$Force_3$ [kN]	12.23	-12.12	12.21	11.90		
Displ. [mm]	-78.63	-79.61	-78.64	-78.66		
$Clip_1$ [μ]	5960.	-4614.	5924.	5934.		
$Clip_2$ [μ]	5886.	-5139.	5864.	5827.		
$FBG_{1\ (0°)}$ [μ]	5429.	-5219.	5167.	5412.		
$\varepsilon_{1\ (0°)}$ [μ]	19053.	19053.	19053.	19053.		
$\varepsilon_{2\ (0°)}$ [μ]	19036.	19036.	19036.	19036.		
σ [MPa]	202.1	-197.9	202.1	198.4		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	21.7	21.1	21.4
$Temp._2$ [°C]	25.3	24.7	25.0

Area of cross-section 60.50

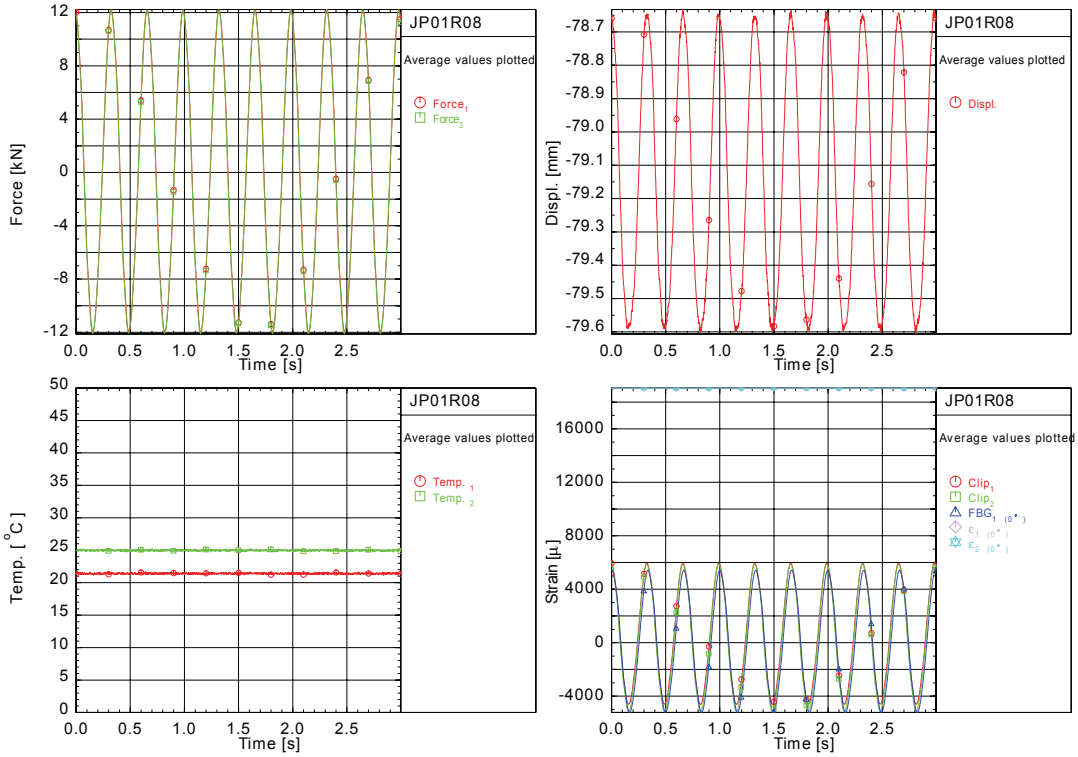


Figure C - 30: JP01R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.09	-12.01	-12.01	11.81		
$Force_3$ [kN]	12.11	-12.10	-12.00	11.72		
Displ. [mm]	-78.54	-79.65	-79.63	-78.57		
$Clip_1$ [µ]	5420.	-5462.	-5439.	5367.		
$Clip_2$ [µ]	4835.	-6453.	-6453.	4764.		
$FBG_{1\ (0°)}$ [µ]	5443.	-5332.	-1733.	2355.		
$\varepsilon_{1\ (0°)}$ [µ]	19053.	19053.	19053.	19053.		
$\varepsilon_{2\ (0°)}$ [µ]	19036.	19036.	19036.	19036.		
σ [MPa]	199.8	-198.4	-198.4	195.2		

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	21.3	20.8	21.0
Temp.$_2$ [°C]	24.2	23.6	23.9

Area of cross-section 60.50

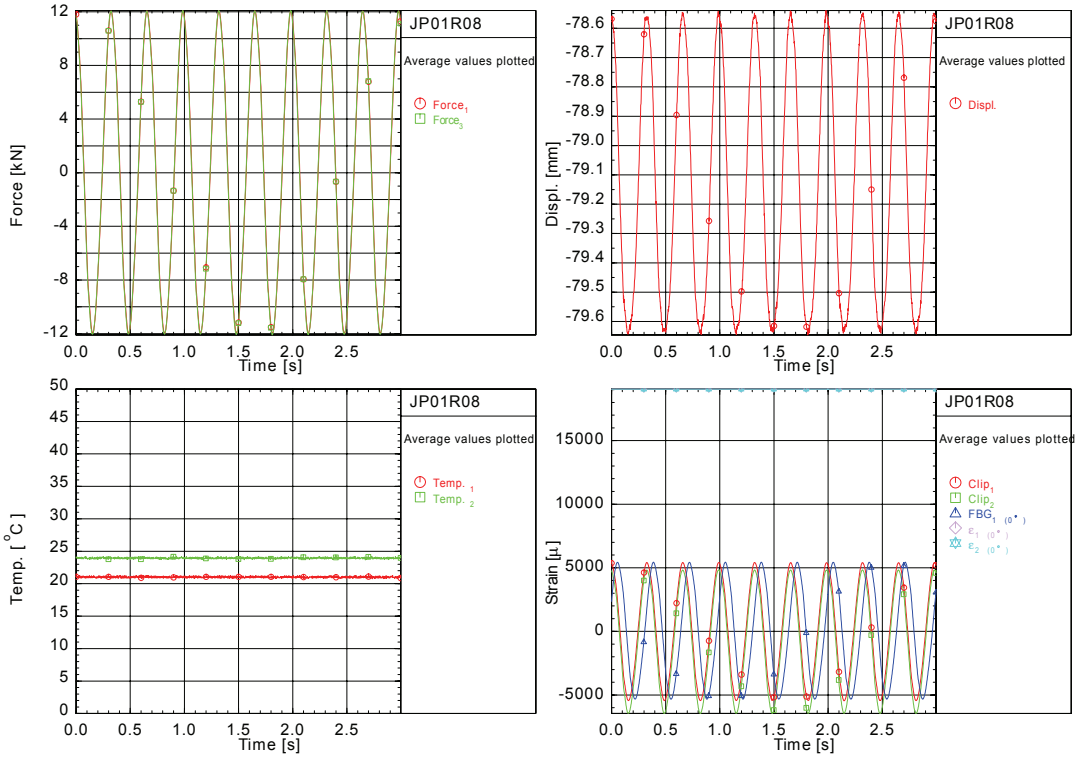


Figure C - 31: JP01R08 (ca. 1,000,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_1 [Mpa]	E_c [Mpa]
$Force_1$ [kN]	14.02	-14.17	14.02	-0.06		
$Force_3$ [kN]	14.10	-14.20	14.01	-0.04		
Displ. [mm]	-79.42	-80.64	-79.45	-80.09		
$\varepsilon_{1\ (0^\bullet)}$ [μ]	6117.	-5523.	6116.	174.	38619.	39073.
$\varepsilon_{2\ (0^\bullet)}$ [μ]	5701.	-6769.	5690.	-647.	35831.	36633.
σ [MPa]	226.4	-228.9	226.4	-0.9		
Bending [μ/mm]	405.07	132.90	137.76	265.06		

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	26.2	25.6	25.9
Temp.$_2$ [°C]	23.7	23.2	23.4

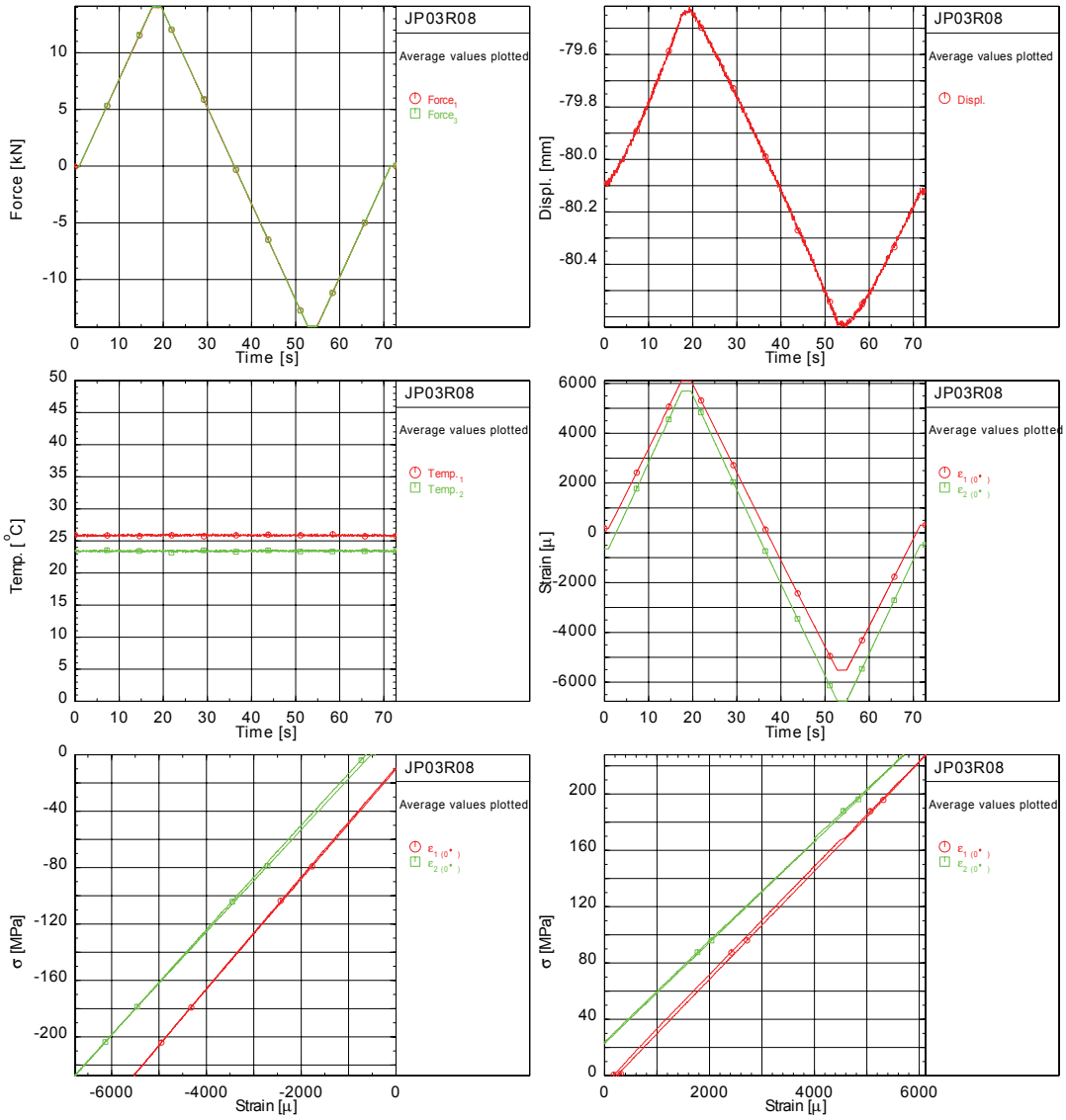


Figure C - 32: JP03R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum
$Force_1$ [kN]	13.88	-14.05	14.49	-14.25
$Force_3$ [kN]	13.92	-14.12	14.55	-14.35
Displ. [mm]	-79.63	-80.97	-77.59	-81.09
$\varepsilon_{1\ (0^\bullet)}$ [μ]	18512.	18498.	18515.	-4900.
$\varepsilon_{2\ (0^\bullet)}$ [μ]	18763.	18752.	18765.	-5979.
σ [MPa]	224.2	-226.9	234.0	-230.1

Temperatures	Maximum	Minimum	Mean Average
Temp. $_1$ [°C]	29.1	19.5	25.6
Temp. $_2$ [°C]	31.0	23.4	28.7

Number of Cycles	859781.

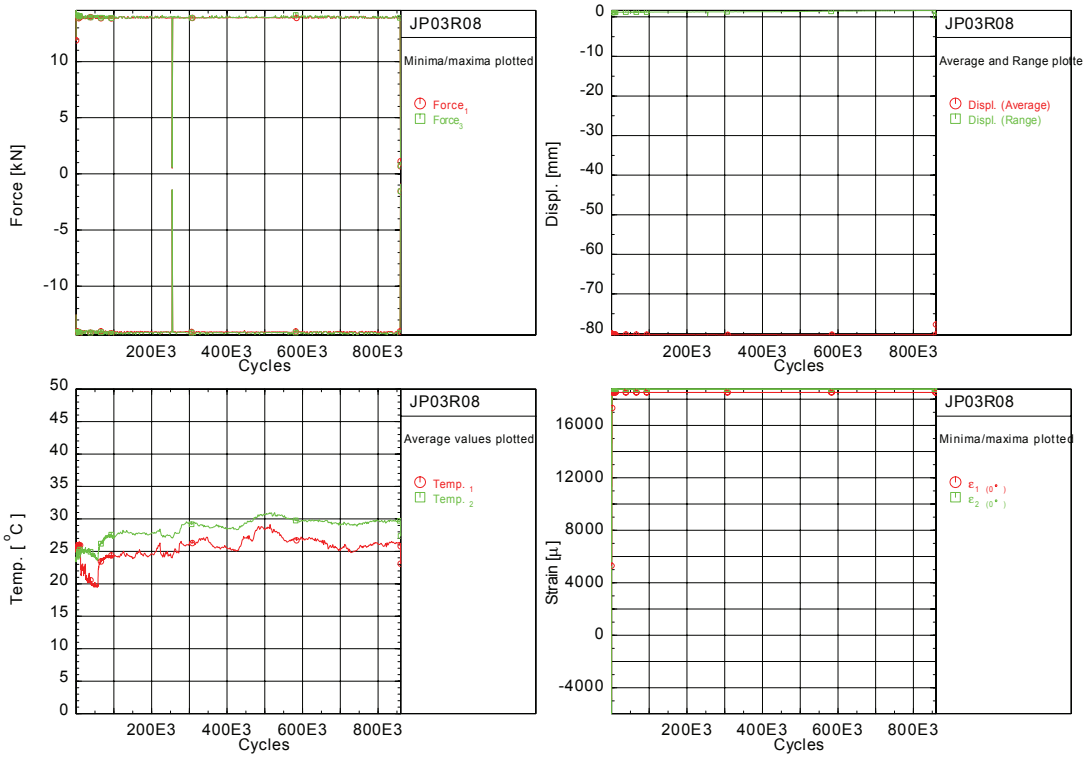


Figure C - 33: JP03R08 (fatigue summary)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	13.97	-14.24	-14.24	-0.11		
$Force_3$ [kN]	14.08	-14.26	-14.26	-0.09		
Displ. [mm]	-80.16	-81.31	-81.29	-80.77		
$\varepsilon_{1\ (0^\bullet)}$ [μ]	6057.	-5733.	-5733.	101.	38750.	38717.
$\varepsilon_{2\ (0^\bullet)}$ [μ]	5961.	-6088.	-6088.	-187.	38029.	37894.
σ [MPa]	227.2	-231.6	-231.6	-1.8		
Bending [μ/mm]	128.12	29.35	115.71	93.69		

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	22.0	21.4	21.7
Temp.$_2$ [°C]	21.7	21.2	21.4

Area of cross-section 61.47

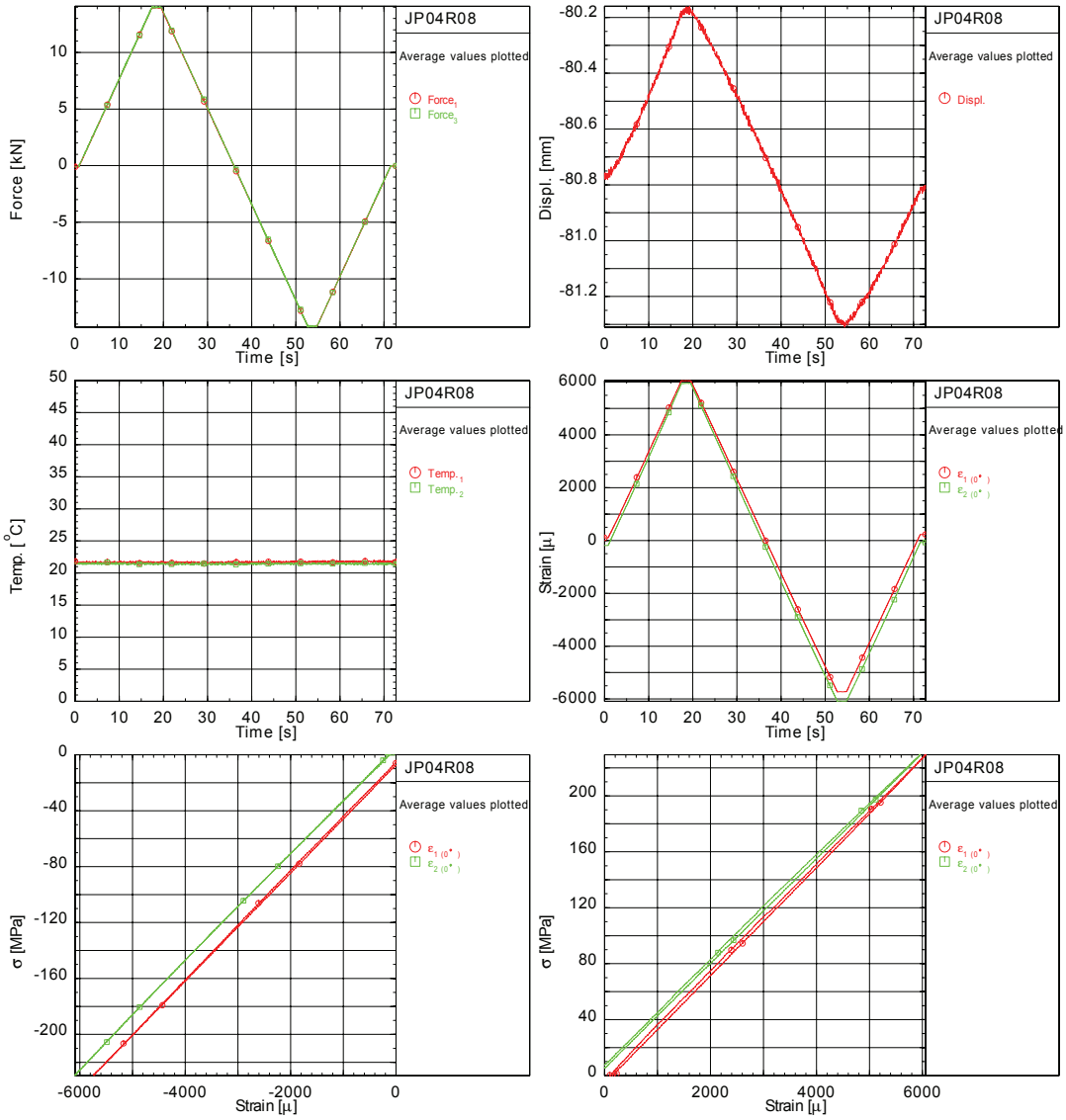


Figure C - 34: JP04R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum
$Force_1$ [kN]	13.75	-14.00	14.47	-14.27
$Force_3$ [kN]	13.78	-14.07	14.53	-14.36
Displ. [mm]	-80.35	-81.73	-80.15	-81.93
$\varepsilon_{1\ (0^\circ)}$ [μ]	18971.	18960.	18973.	-5121.
$\varepsilon_{2\ (0^\circ)}$ [μ]	19550.	19539.	19552.	-5346.
σ [MPa]	223.7	-227.8	235.4	-232.2

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	27.6	19.9	24.9
$Temp._2$ [°C]	30.0	21.4	28.0

Number of Cycles	1128524.
Area of cross-section	61.47

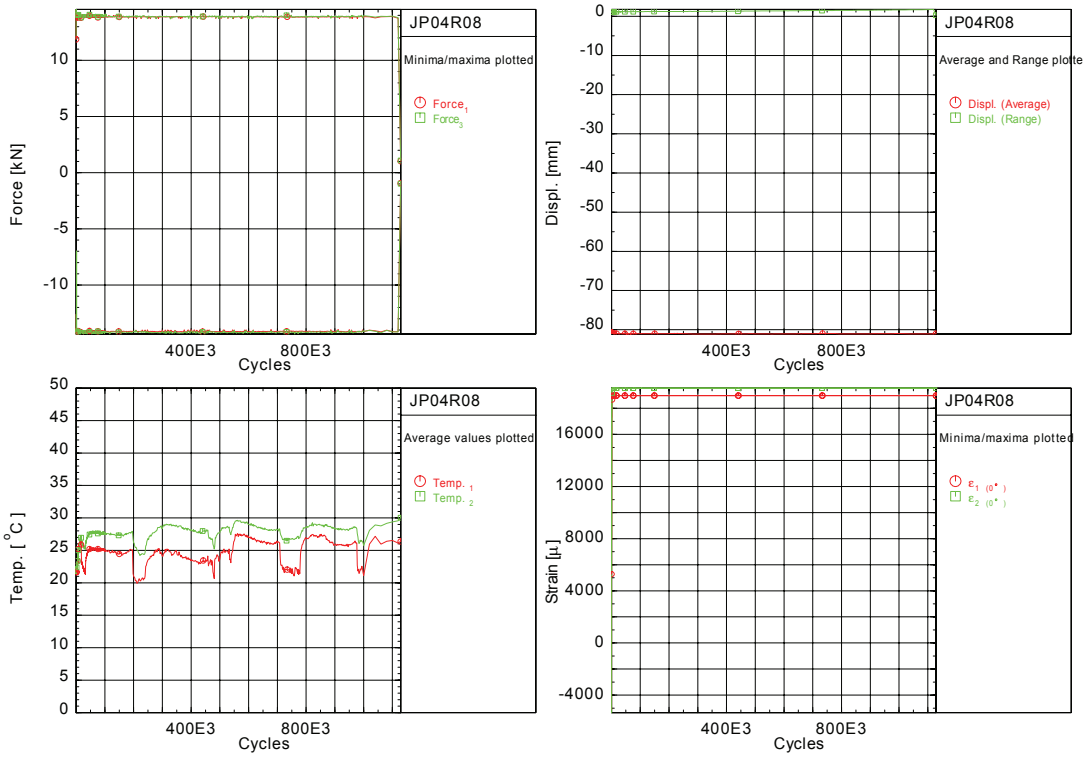


Figure C - 35: JP04R08 (fatigue summary)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	12.21	-12.08	12.21	0.02		
$Force_3$ [kN]	12.20	-12.17	12.17	-0.07		
Displ. [mm]	-61.01	-62.00	-61.02	-61.52		
$\varepsilon_{1\ (0^\bullet)}$ [μ]	5799.	-4701.	5795.	433.	37989.	38408.
$\varepsilon_{2\ (0^\bullet)}$ [μ]	4961.	-5575.	4961.	-350.	37941.	37856.
σ [MPa]	202.1	-199.9	202.1	0.4		
Bending [μ/mm]	291.94	251.46	275.33	258.53		

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	27.0	26.4	26.7
Temp.$_2$ [°C]	24.8	24.3	24.5

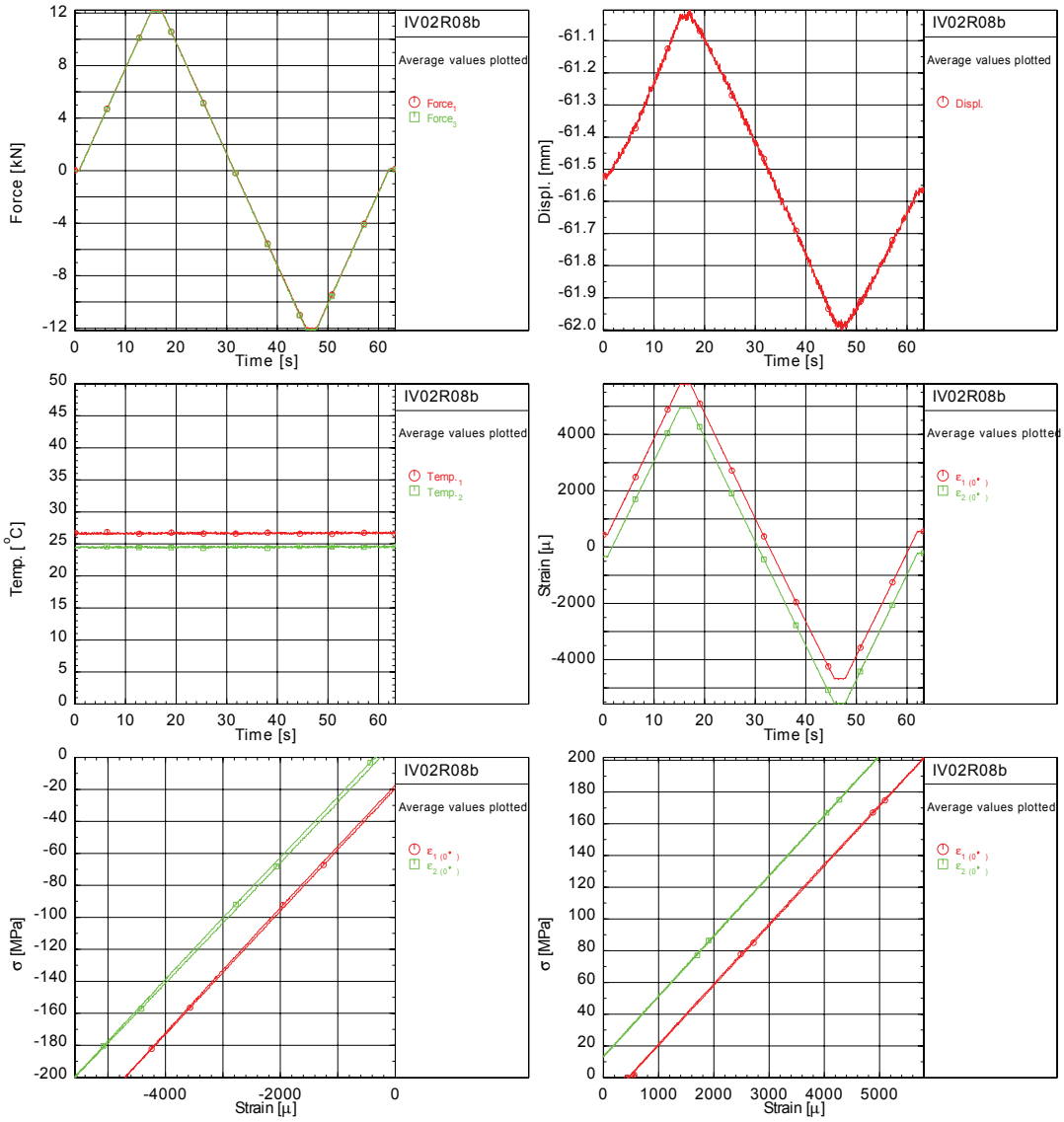


Figure C - 36: IV02R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum
$Force_1$ [kN]	11.97	-11.93	12.22	-12.16
$Force_3$ [kN]	11.95	-12.04	12.44	-12.36
Displ. [mm]	-61.32	-62.42	-57.73	-62.61
$\varepsilon_{1\ (0^\bullet)}$ [μ]	18938.	18924.	18941.	-4243.
$\varepsilon_{2\ (0^\bullet)}$ [μ]	18977.	18964.	18980.	-5108.
σ [MPa]	198.2	-197.4	202.3	-201.3

Temperatures	Maximum	Minimum	Mean Average
Temp. $_1$ [°C]	30.7	16.0	26.4
Temp. $_2$ [°C]	33.3	21.3	29.0

Number of Cycles	1466120.

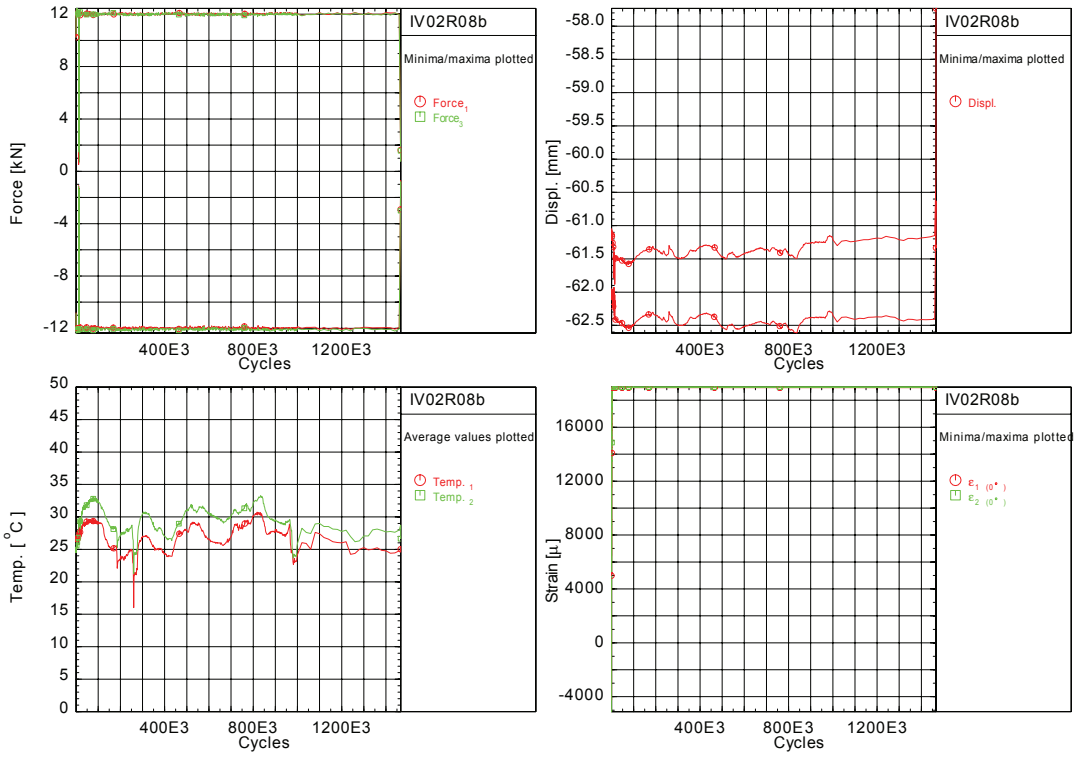


Figure C - 37: IV02R08 (fatigue summary)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	14.18	-14.18	14.18	-0.03		
$Force_3$ [kN]	14.27	-14.32	14.22	-0.02		
Displ. [mm]	-78.46	-79.65	-78.48	-79.09		
$\varepsilon_{1\ (0^\bullet)}$ [μ]	6148.	-5810.	6142.	12.	38795.	40212.
$\varepsilon_{2\ (0^\bullet)}$ [μ]	6448.	-6465.	6446.	-55.	36979.	37014.
σ [MPa]	239.5	-239.4	239.5	-0.5		
Bending [μ/mm]	219.76	-102.70	-101.92	22.52		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	25.4	24.6	25.0
$Temp._2$ [°C]	25.0	24.5	24.8

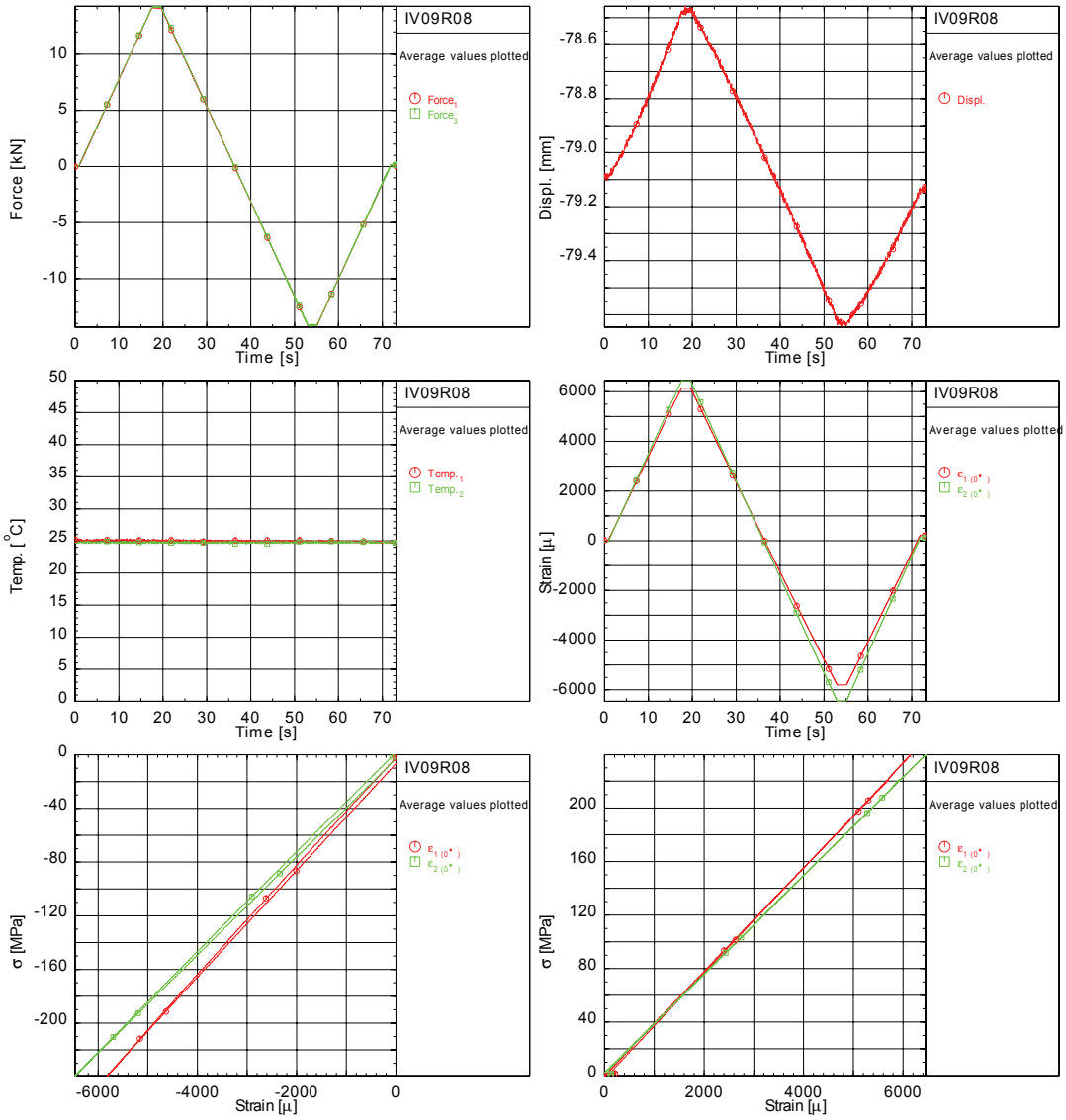


Figure C - 38: IV09R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum
$Force_1$ [kN]	13.98	-14.01	14.54	-14.27
$Force_3$ [kN]	14.04	-14.04	14.63	-14.26
Displ. [mm]	-78.57	-79.94	-76.66	-80.04
$\varepsilon_{1\ (0^\bullet)}$ [μ]	18891.	18876.	18894.	-5082.
$\varepsilon_{2\ (0^\bullet)}$ [μ]	19340.	19324.	19342.	-5573.
σ [MPa]	236.1	-236.6	245.5	-240.9

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	28.9	20.4	25.2
$Temp._2$ [°C]	31.4	24.7	29.4

Number of Cycles	618290.

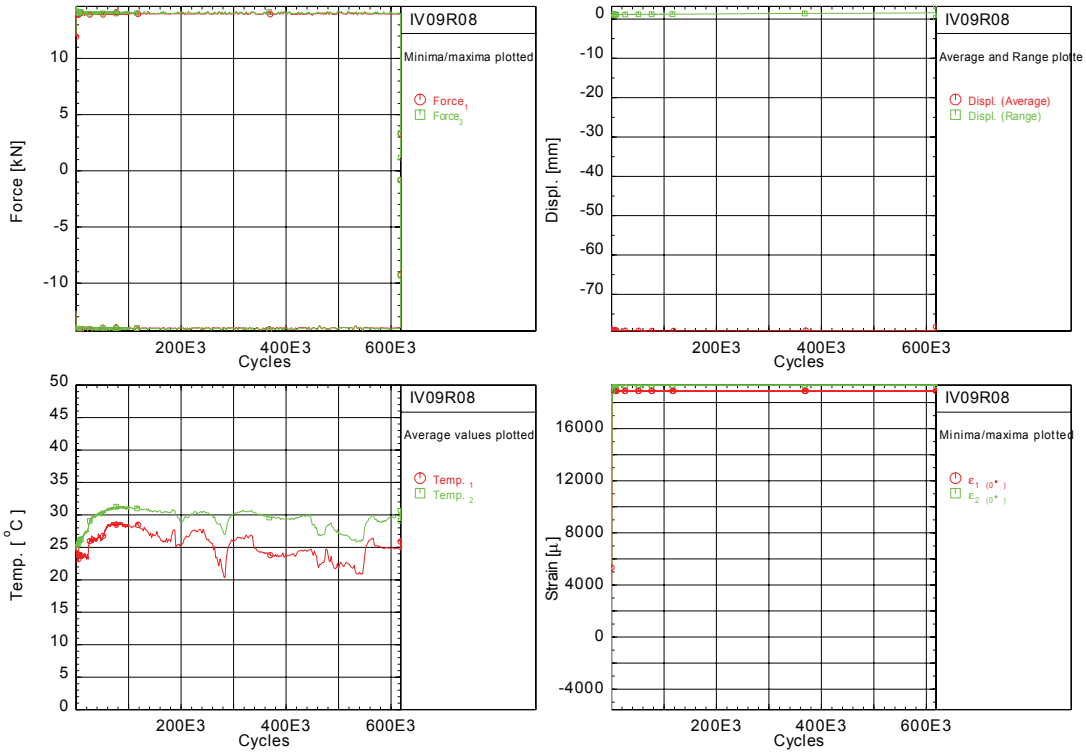


Figure C - 39: IV09R08 (fatigue summary)

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APPENDIX D MEASUREMENT SUMMARY R = 0.1 SURFACE MOUNTED

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	6.1	-7.2	-7.2		
$Force_{calc}$ [kN]	6.1	-7.2	-7.2		
Displ. [mm]	0.32	-0.09	-0.09		
$Clip_1$ [µ]	2483.	-3415.	-3415.	38411.	38923.
$Clip_2$ [µ]	2905.	-2775.	-2775.	39973.	40685.
$FBG_{1\ (0°)}$ [µ]	2594.	-2863.	-2526.	40725.	42206.
$\varepsilon_{1\ (0°)}$ [µ]	2834.	-3427.	-3427.	36560.	36660.
$\varepsilon_{2\ (0°)}$ [µ]	2769.	-3044.	-3044.	39305.	39527.
σ [MPa]	105.0	-124.3	-124.3		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.4	24.0	24.2

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU21R08\BU21R08.SLW Nulled with:BU21R08.nul(Rec.1) E-moduli based on: TEST started at: 24-01-08 16:11:14

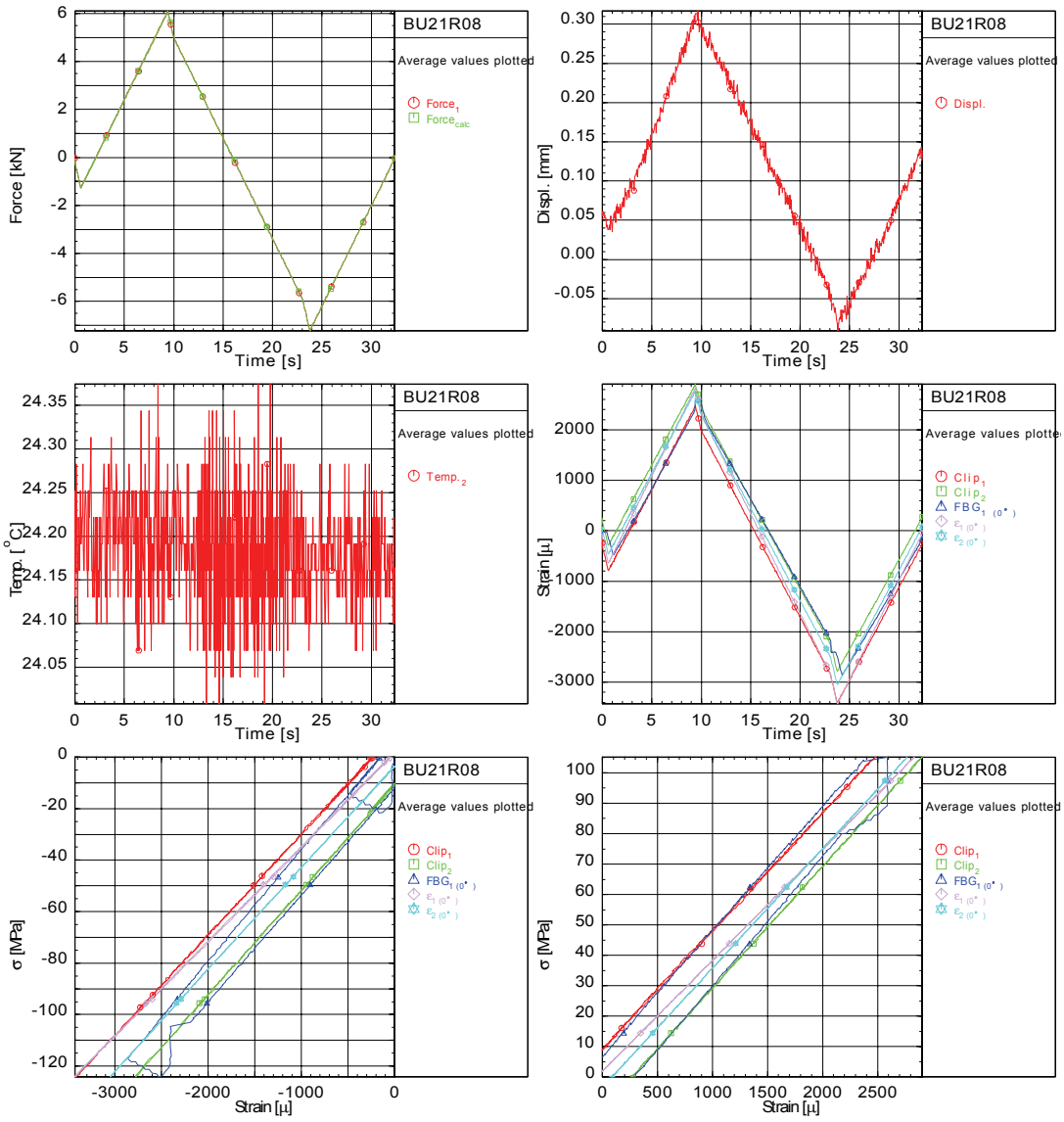


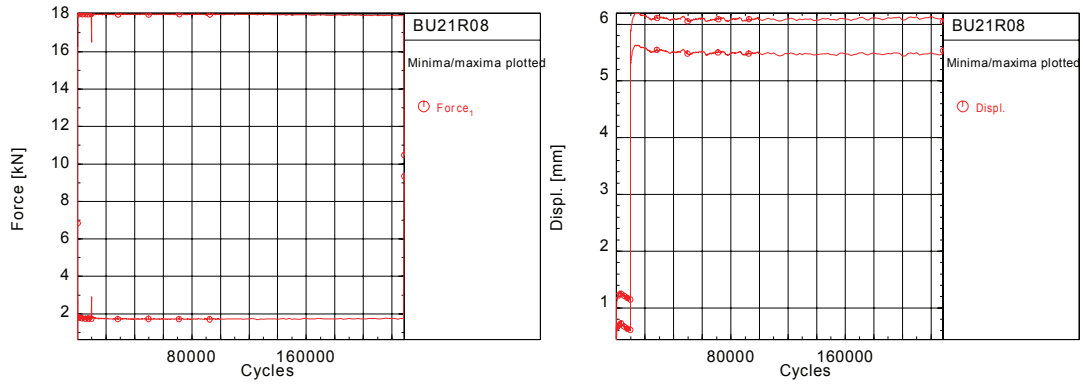
Figure D - 1: BU21R08 (slow cycle)

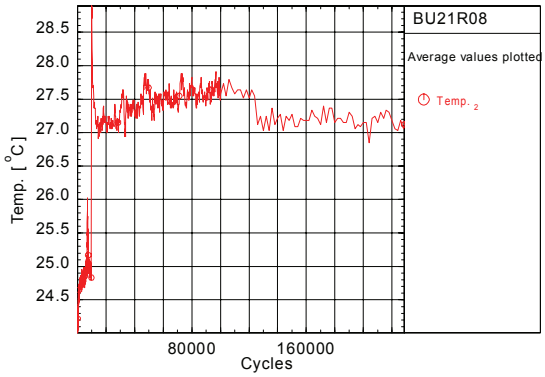
Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
$Force_1$ [kN]	18.0	1.8	18.1	0.6	0.0
Displ. [mm]	5.89	5.29	6.20	0.44	0.27
$Clip_1$ [μ]	8466.	1014.	8714.	116.	-3.
$Clip_2$ [μ]	7902.	571.	8286.	414.	-9.
$FBG_{1\ (0^\circ)}$ [μ]	-18.	-617.	6990.	-972.	-1.
$\varepsilon_{1\ (0^\circ)}$ [μ]	-17653.	-17726.	19089.	-19188.	-4.
$\varepsilon_{2\ (0^\circ)}$ [μ]	18639.	18303.	19102.	-14052.	1.
σ [MPa]	308.9	30.1	310.8	10.7	0.2

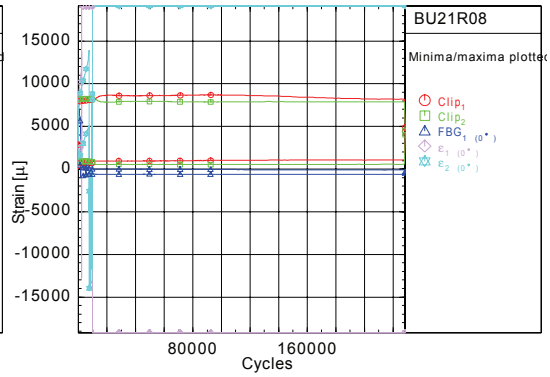
Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	28.9	24.0	27.2

Number of Cycles	228501.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU21R08\BU21R08.DFX Nulled with:BU21R08.nul(Rec.1) - TEST started at: 24-01-08 16:09:43







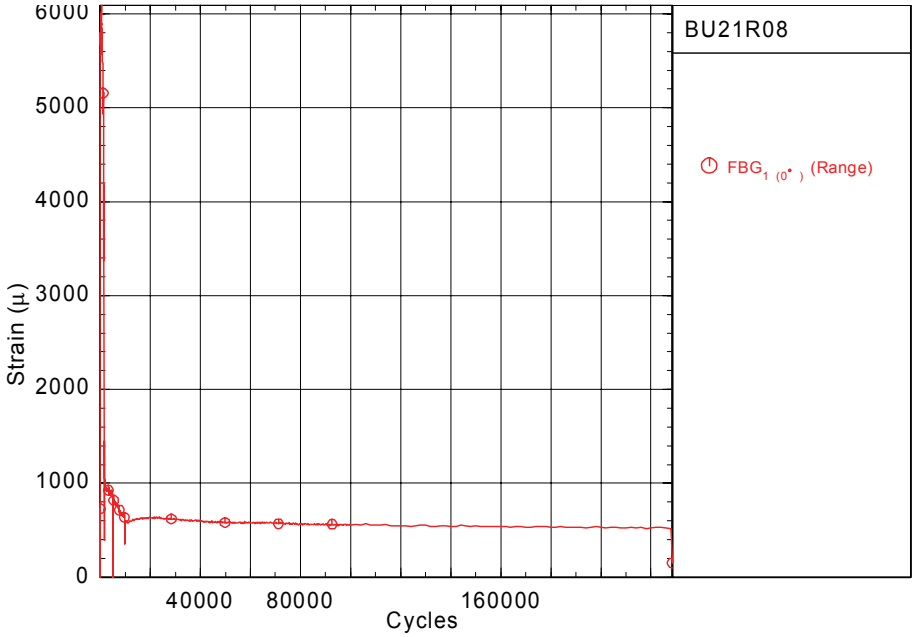


Figure D - 2: BU21R08 (fatigue summary)

Remarks: FBG signal ceases to achieve tensile strain early in life

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	18.0	1.7	18.0				
Displ. [mm]	1.21	0.67	1.20				
$Clip_1$ [μ]	7960.	646.	7948.				
$Clip_2$ [μ]	8205.	859.	8190.				
$FBG_{1\ (0^\circ)}$ [μ]	6417.	715.	6119.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	9749.	2038.	9741.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	8667.	1354.	8663.				
σ [MPa]	310.2	30.0	310.2				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.7	24.3	24.5

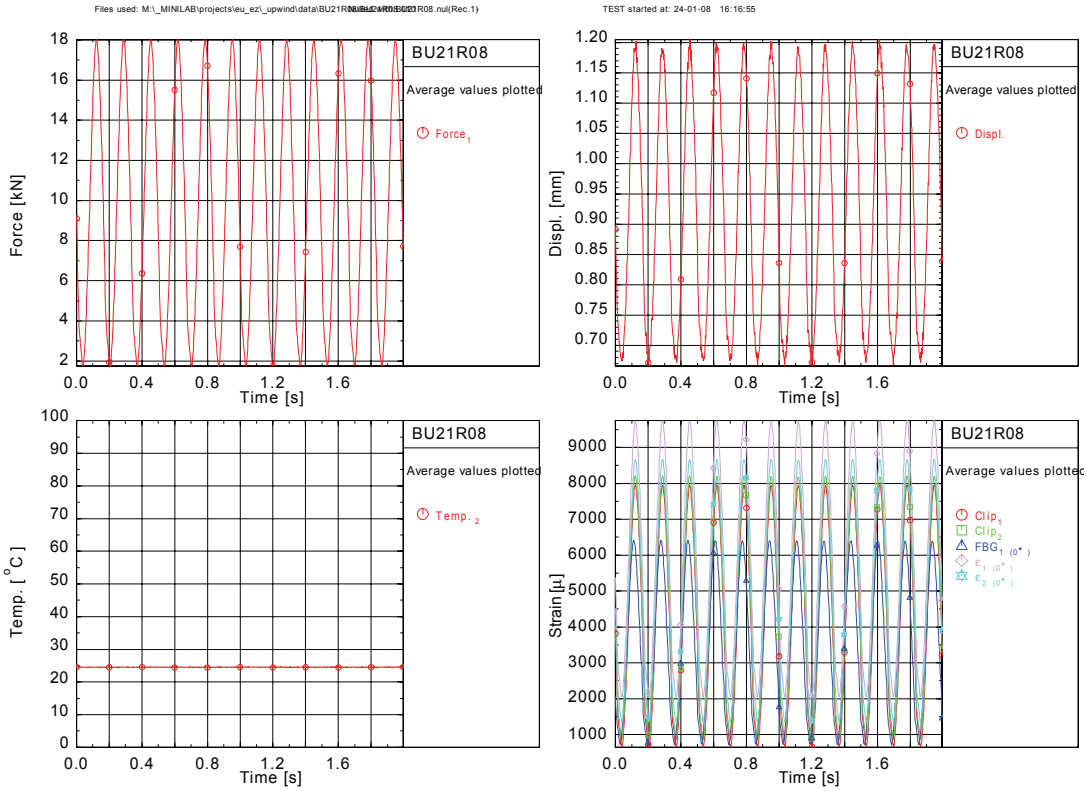


Figure D - 3: BU21R08 (ca. 1,000 cycles)

Remarks: Strain gauges start to fail

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	18.0	0.0	18.0				
Displ. [mm]	76.36	-0.27	1.17				
Clip$_1$ [µ]	15000.	-23.	8146.				
Clip$_2$ [µ]	8201.	-124.	8193.				
FBG$_{1\ (0^\circ)}$ [µ]	2619.	-650.	-130.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	19089.	-50.	19089.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	19102.	-185.	19102.				
σ [MPa]	310.1	-0.2	310.1				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	83.7	-10.8	24.9

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU21R08\BU21R08.nul(Rec.1)

TEST started at: 24-01-08 16:39:36

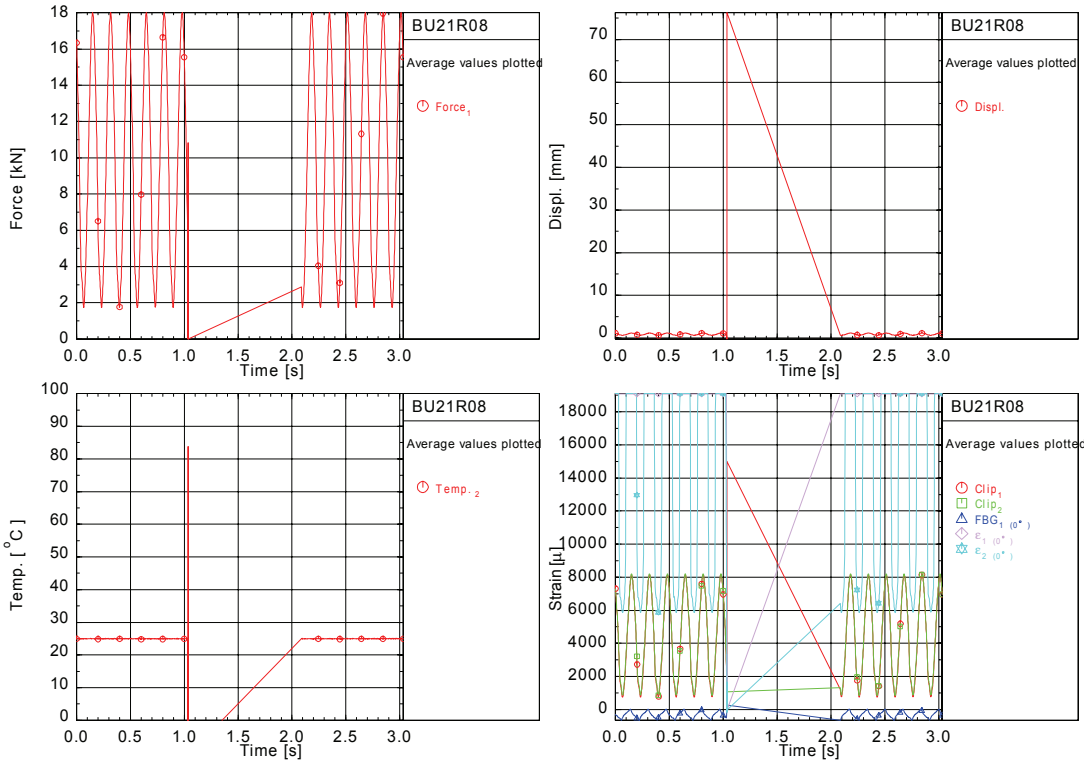


Figure D - 4: BU21R08 (ca. 10,000 cycles)

Remarks: Discontinuity caused by interrupted measurement

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	18.0	1.7	18.0				
Displ. [mm]	6.07	5.47	6.06				
$Clip_1$ [µ]	8694.	994.	8691.				
$Clip_2$ [µ]	7873.	528.	7867.				
$FBG_{1\ (0°)}$ [µ]	-54.	-622.	-280.				
$\varepsilon_{1\ (0°)}$ [µ]	-19188.	-19188.	-19188.				
$\varepsilon_{2\ (0°)}$ [µ]	19102.	19102.	19102.				
σ [MPa]	309.8	29.4	309.8				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	27.8	27.4	27.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\BU21R08\BU21R08.nul(Rec.1)

TEST started at: 24-01-08 20:48:35

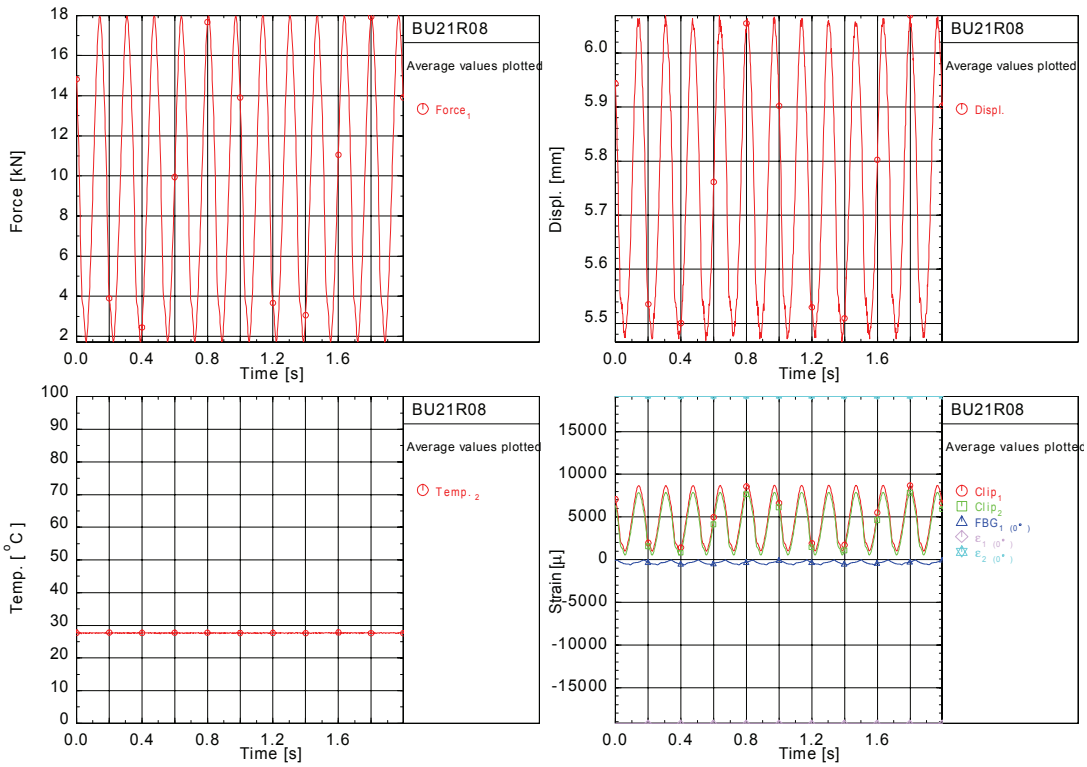


Figure D - 5: BU21R08 (ca. 100,000 cycles)

Remarks: FBG signal almost absent

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	6.0	-7.2	-7.2		
Displ. [mm]	0.18	-0.26	-0.24		
$Clip_1$ [μ]	2465.	-2435.	-2435.	46023.	47412.
$Clip_2$ [μ]	2141.	-3473.	-3473.	41295.	40668.
$FBG_{1\ (0°)}$ [μ]	2745.	-2959.	-2559.	39748.	40867.
$\varepsilon_{1\ (0°)}$ [μ]	2737.	-2759.	-2759.	41107.	42051.
$\varepsilon_{2\ (0°)}$ [μ]	2544.	-3592.	-3592.	37224.	37130.
σ [MPa]	103.8	-125.0	-125.0		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	556.4	556.1	556.2

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM01R08\CM01R08.SLW Nulled with:CM01R08.nul(Rec.1) E-moduli based on: TEST started at: 07-02-08 14:41:12

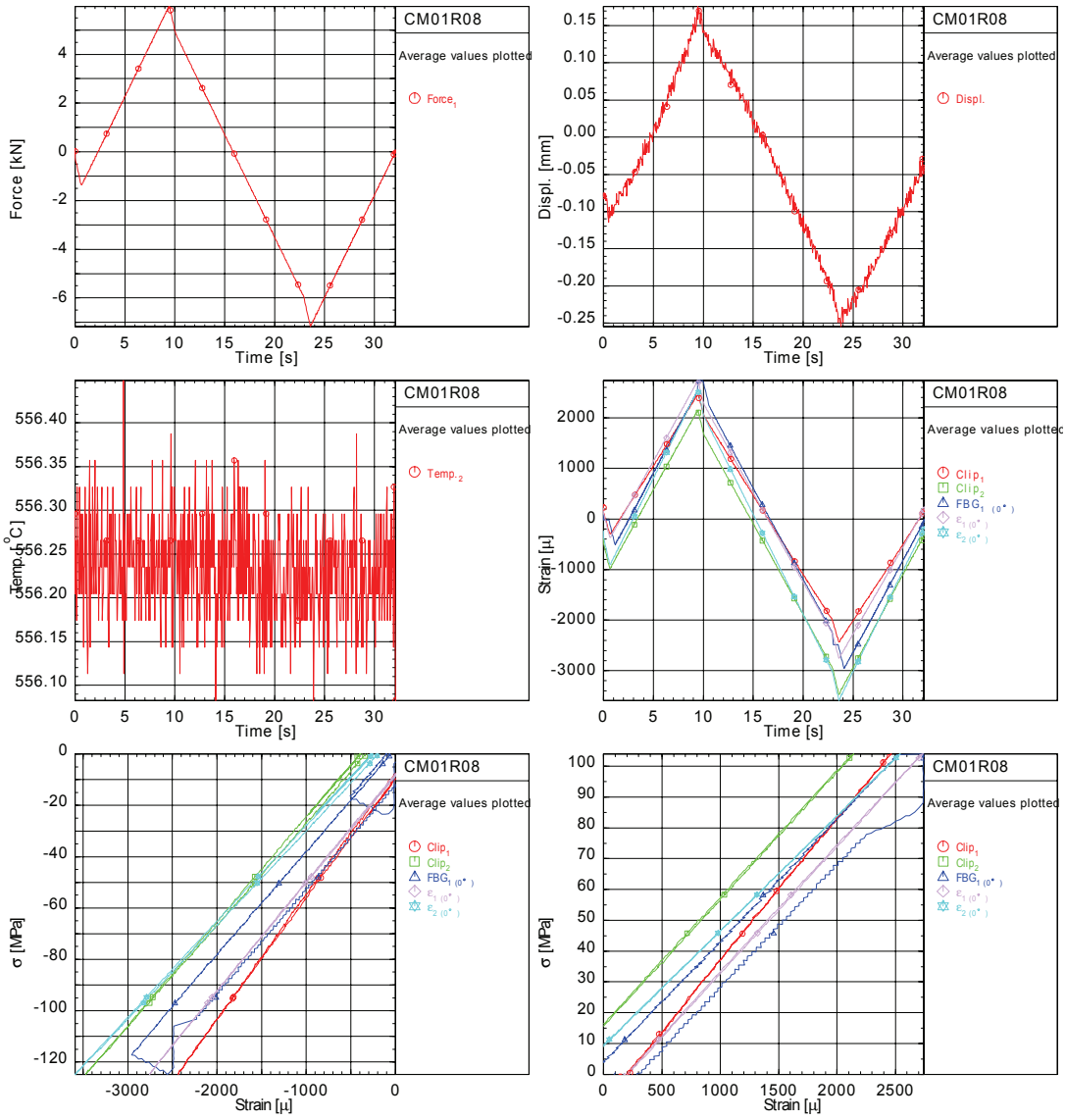


Figure D - 6: CM01R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
$Force_1$ [kN]	19.8	1.9	20.1	1.9	0.0
Displ. [mm]	0.97	0.28	1.58	0.22	0.43
$Clip_1$ [µ]	8254.	1091.	9264.	807.	-1.
$Clip_2$ [µ]	7929.	492.	8803.	333.	11.
$FBG_{1\ (0^\circ)}$ [µ]	8298.	878.	9138.	546.	16.
$\varepsilon_{1\ (0^\circ)}$ [µ]	19190.	19143.	19278.	-13472.	2.
$\varepsilon_{2\ (0^\circ)}$ [µ]	19108.	19083.	19147.	-13729.	-2.
σ [MPa]	344.9	33.9	349.6	32.5	0.1

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	556.6	553.5	555.8

Number of Cycles	1003750.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM01R08\CM01R08.DFX Nulled with:CM01R08.nul(Rec.1) - TEST started at: 07-02-08 14:37:56

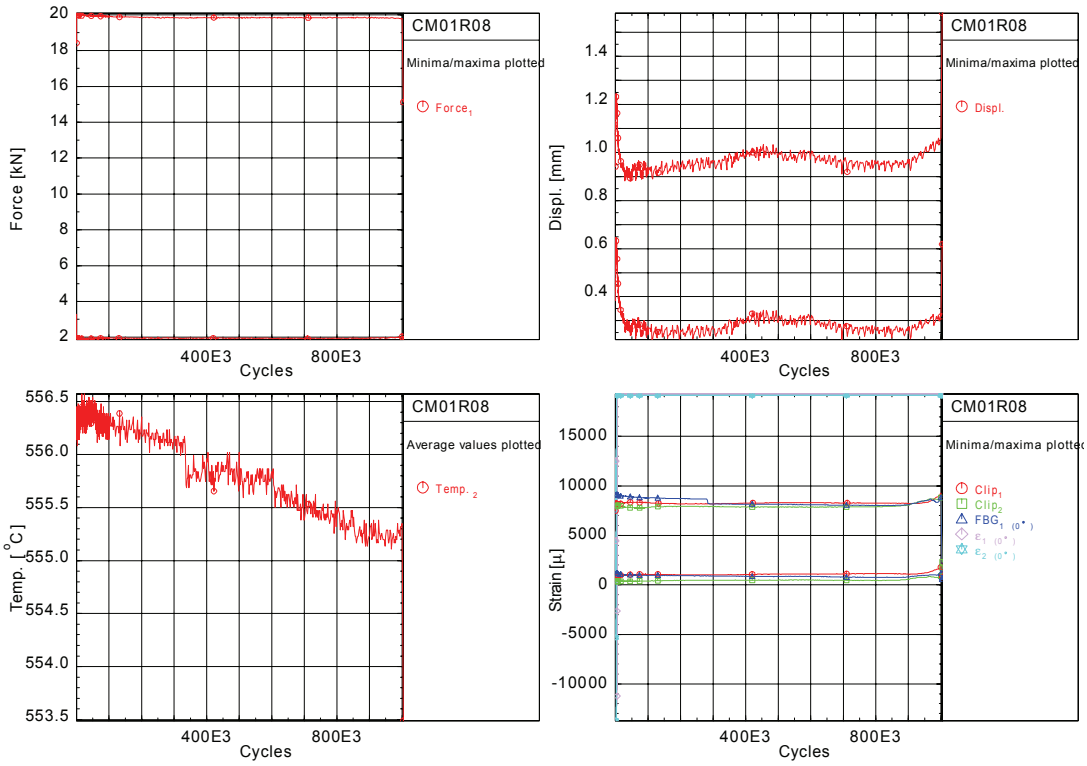


Figure D - 7: CM01R08 (fatigue summary)

Remarks: Good correlation between optical and clip gauges throughout test. Temperature sensor defect

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	20.0	1.9	20.0				
Displ. [mm]	1.20	0.60	1.19				
$Clip_1$ [µ]	8272.	163.	8255.				
$Clip_2$ [µ]	7905.	219.	7896.				
$FBG_{1\ (0°)}$ [µ]	9077.	1122.	6240.				
$\varepsilon_{1\ (0°)}$ [µ]	11112.	3079.	11093.				
$\varepsilon_{2\ (0°)}$ [µ]	11993.	8.	11972.				
σ [MPa]	347.9	33.6	347.9				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	556.5	556.0	556.3

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM01R08\CM01R08.nul(Rec.1)

TEST started at: 07-02-08 14:45:26

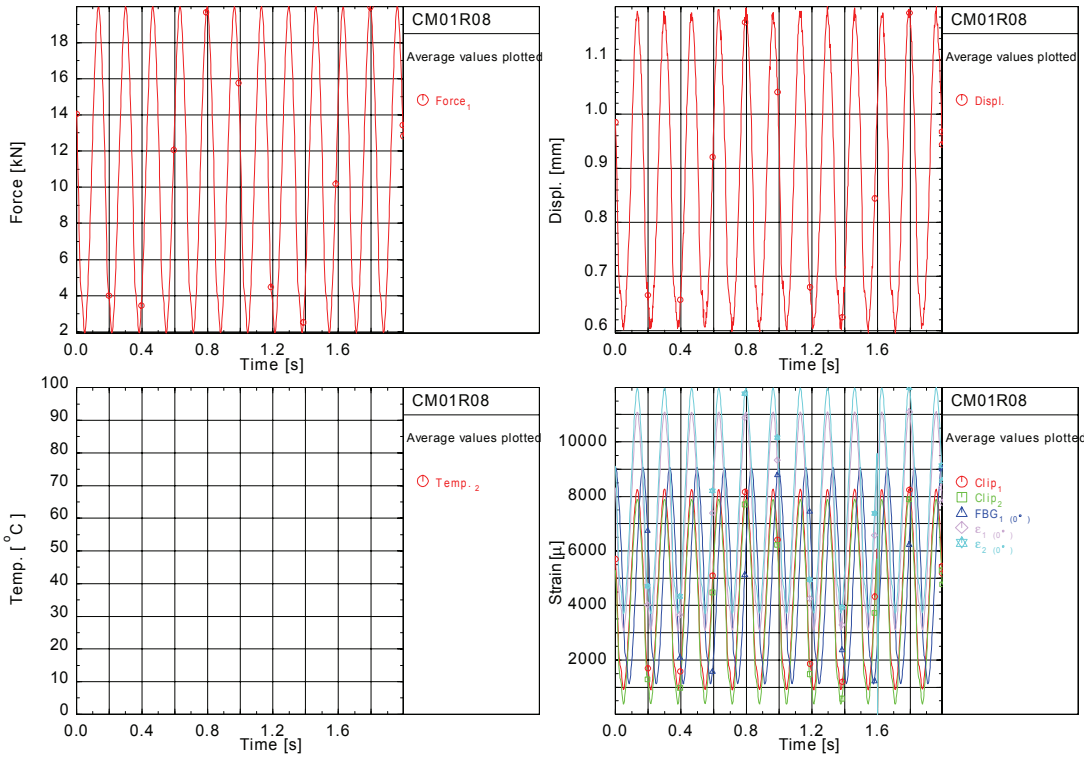


Figure D - 8: CM01R08 (ca. 1,000 cycles)

Remarks: Strain gauges start to fail

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	20.0	1.9	20.0				
Displ. [mm]	0.95	0.32	0.95				
Clip$_1$ [μ]	8248.	961.	8248.				
Clip$_2$ [μ]	7926.	365.	7920.				
FBG$_{1\ (0^\circ)}$ [μ]	8979.	1051.	6041.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	19278.	19278.	19278.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19147.	19147.	19147.				
σ [MPa]	347.6	33.2	347.6				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	556.6	556.2	556.4

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM01R08\CM01R08.nul(Rec.1)

TEST started at: 07-02-08 15:37:59

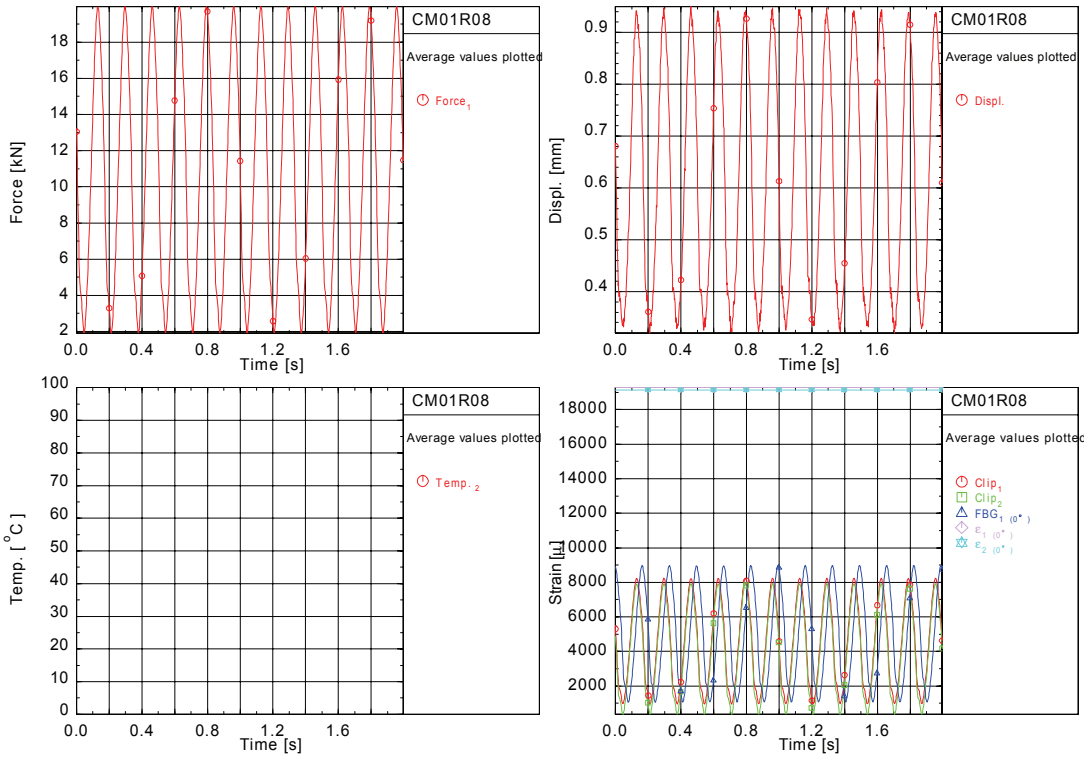


Figure D - 9: CM01R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	19.8	1.9	19.8				
Displ. [mm]	0.97	0.26	0.96				
$Clip_1$ [μ]	8203.	1004.	8203.				
$Clip_2$ [μ]	7912.	462.	7912.				
$FBG_{1\ (0^\circ)}$ [μ]	8183.	889.	5837.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	19278.	19278.	19278.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19147.	19147.	19147.				
σ [MPa]	345.1	33.4	345.1				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	556.3	555.9	556.1

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM01R08\CM01R08.nul(Rec.1)

TEST started at: 08-02-08 04:32:31

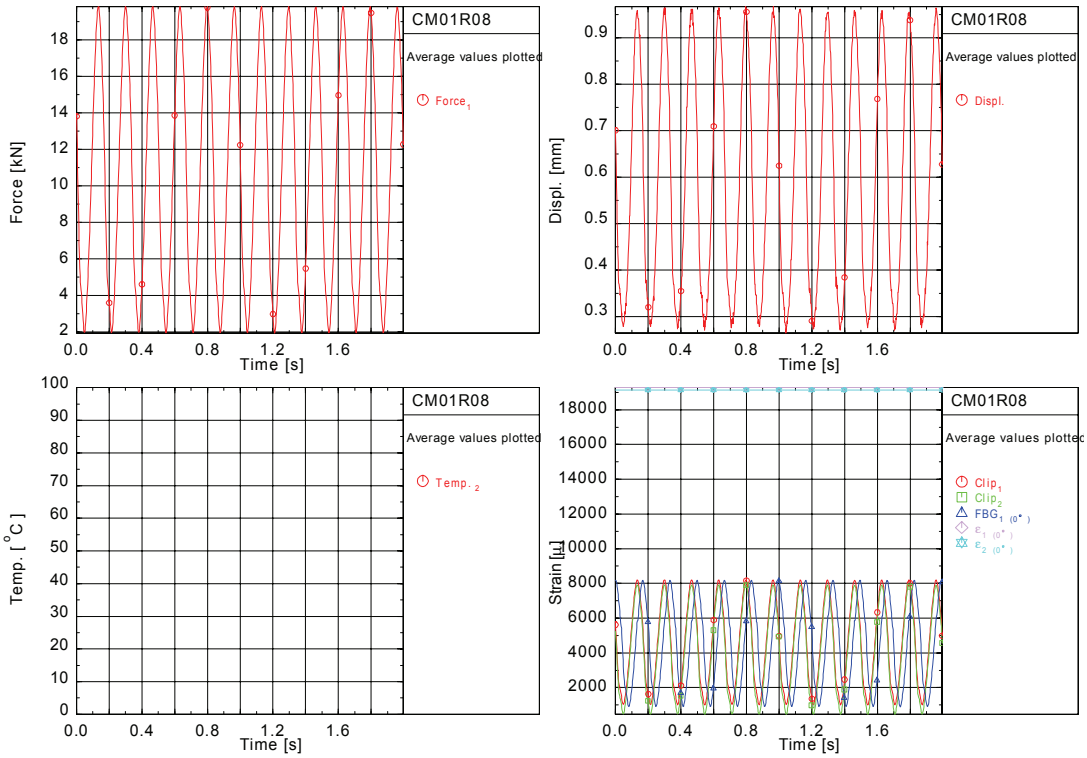


Figure D - 10: CM01R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	6.0	-7.2	-7.2		
Displ. [mm]	0.27	-0.14	-0.14		
$Clip_1$ [µ]	2459.	-3160.	-3160.	40230.	40915.
$Clip_2$ [µ]	2769.	-3096.	-3096.	38847.	38687.
$FBG_{1\ (0°)}$ [µ]	2667.	-3006.	-2591.	40132.	40158.
$\varepsilon_{1\ (0°)}$ [µ]	2778.	-3205.	-3205.	37780.	38280.
$\varepsilon_{2\ (0°)}$ [µ]	2595.	-3220.	-3220.	38865.	39316.
σ [MPa]	103.0	-124.8	-124.8		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	23.6	23.2	23.3

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM08R08\CM08R08.SLW Nulled with:CM08R08.nul(Rec.1) E-moduli based on: TEST started at: 05-02-08 11:49:43

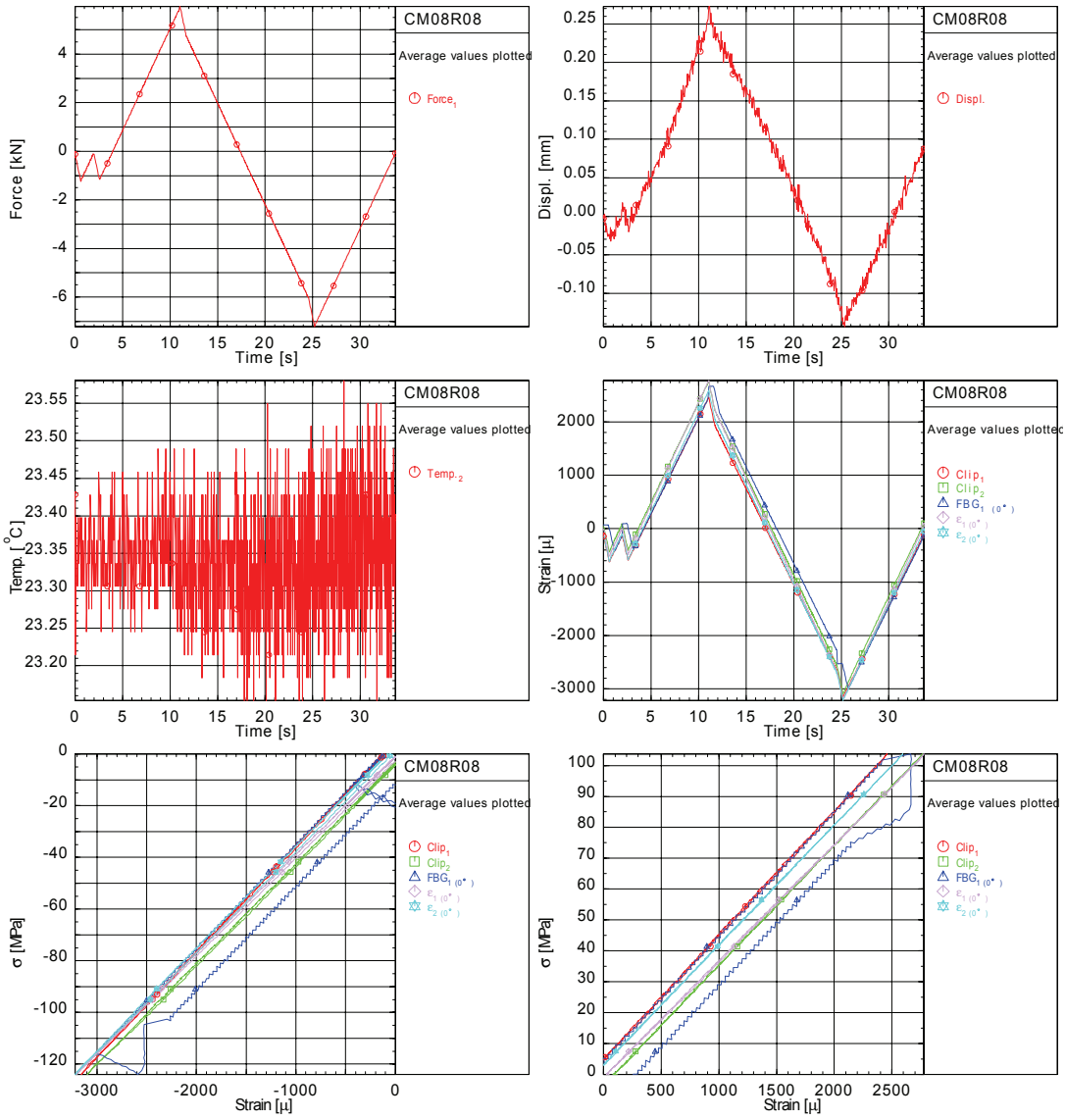


Figure D - 11: CM08R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
$Force_1$ [kN]	19.9	1.9	20.0	0.0	0.0
Displ. [mm]	1.45	0.75	17.46	0.53	0.28
$Clip_1$ [μ]	8617.	736.	9062.	-326.	-19.
$Clip_2$ [μ]	9173.	851.	9647.	741.	7.
$FBG_{1\ (0^\circ)}$ [μ]	3188.	781.	8828.	-1237.	-4.
$\varepsilon_{1\ (0^\circ)}$ [μ]	19053.	19002.	19142.	-13773.	-6.
$\varepsilon_{2\ (0^\circ)}$ [μ]	14535.	6124.	19130.	-19147.	1.
σ [MPa]	343.7	33.2	346.2	0.2	0.8

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	563.5	23.3	25.3

Number of Cycles	804542.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM08R08\CM08R08.DFX Nulled with:CM08R08.nul(Rec. 1) - TEST started at: 05-02-08 11:45:36

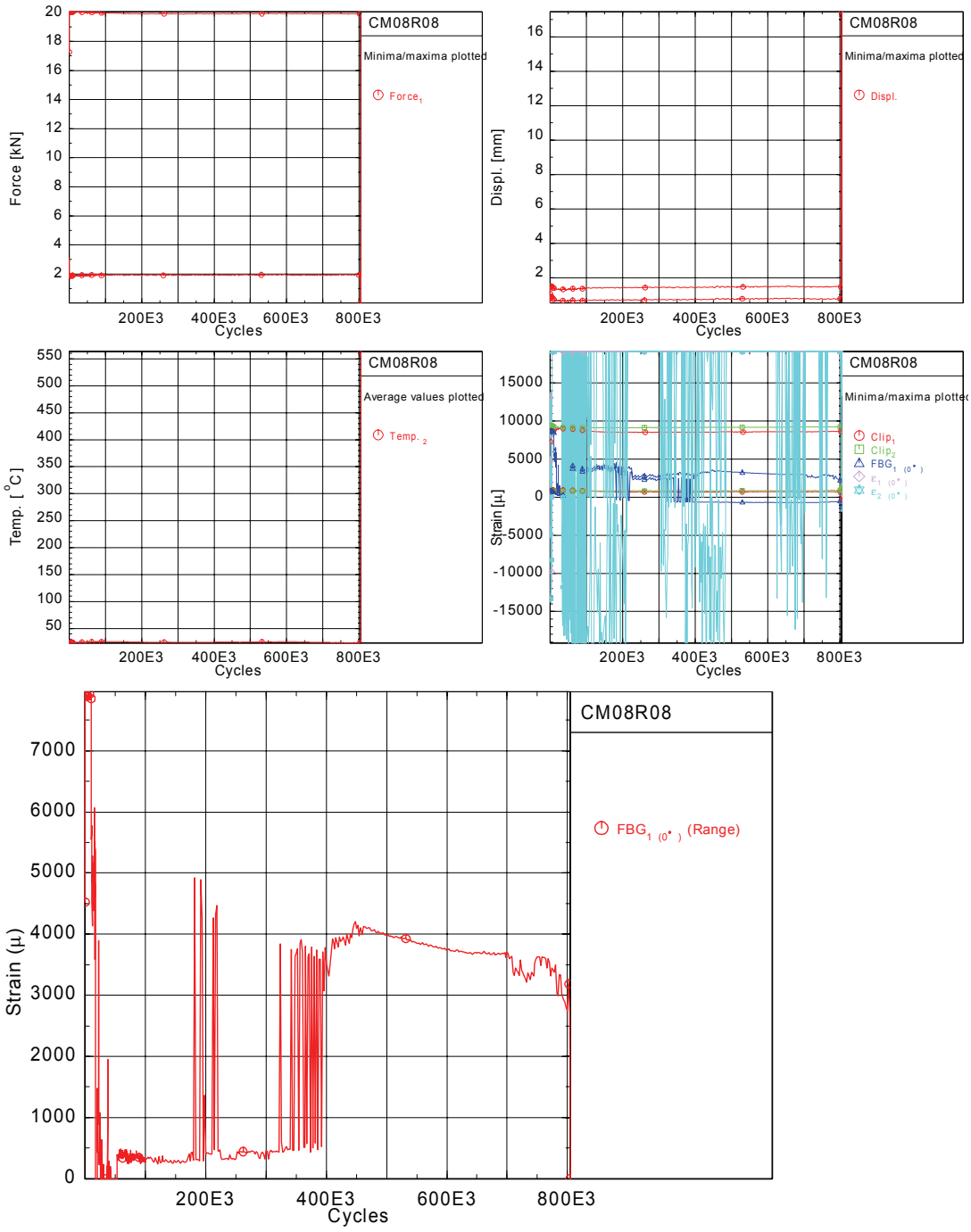


Figure D - 12: CM08R08 (fatigue summary)

Remarks: FBG signal ceases to achieve tensile strain early in life (jumps due to cross-talk with failed strain gauge 2?); good correlation between clipgauges

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	20.0	1.9	20.0				
Displ. [mm]	1.44	0.82	1.44				
$Clip_1$ [µ]	8532.	855.	8520.				
$Clip_2$ [µ]	9597.	813.	9594.				
$FBG_{1\ (0^\circ)}$ [µ]	8806.	872.	5955.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	11568.	3319.	11549.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	12605.	4055.	12583.				
σ [MPa]	345.7	32.8	345.7				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.3	23.9	24.0

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM08R08[illegible]R08.nul(Rec.1)

TEST started at: 05-02-08 11:54:17

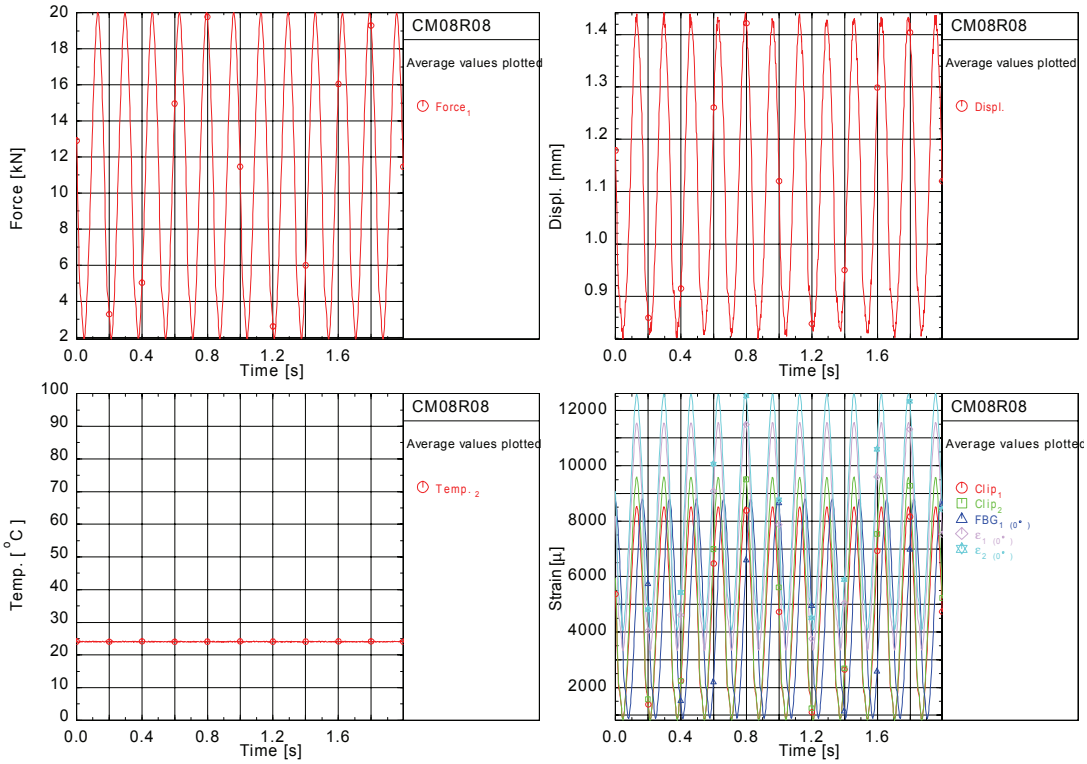


Figure D - 13: CM08R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	20.0	1.9	20.0				
Displ. [mm]	1.34	0.69	1.34				
$Clip_1$ [µ]	8944.	883.	8941.				
$Clip_2$ [µ]	9173.	751.	9161.				
$FBG_{1\ (0°)}$ [µ]	309.	290.	302.				
$\varepsilon_{1\ (0°)}$ [µ]	19142.	19142.	19142.				
$\varepsilon_{2\ (0°)}$ [µ]	19130.	19130.	19130.				
σ [MPa]	345.5	32.2	345.5				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.8	24.4	24.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM08R08[illegible]R08.nul(Rec.1)

TEST started at: 05-02-08 12:46:51

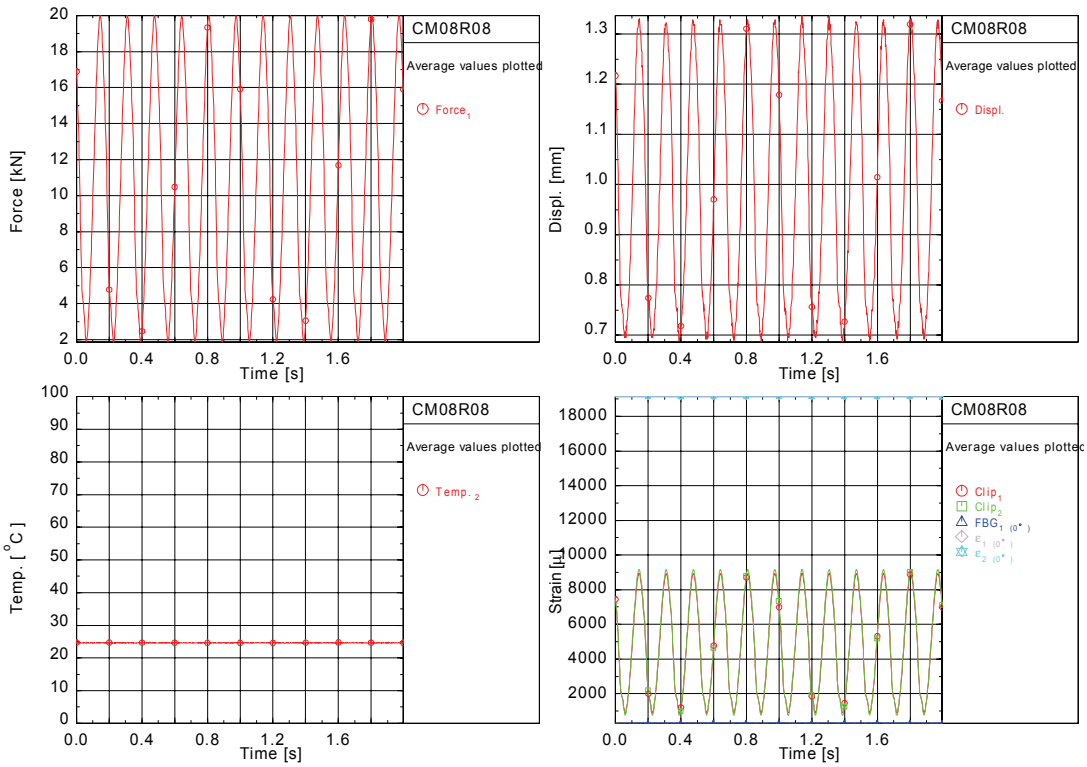


Figure D - 14: CM08R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	19.9	1.9	19.9				
Displ. [mm]	1.41	0.69	1.41				
Clip$_1$ [µ]	8558.	701.	8558.				
Clip$_2$ [µ]	9165.	832.	9165.				
FBG$_{1\ (0^\circ)}$ [µ]	3681.	-569.	2398.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	19142.	19142.	19142.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	19130.	19130.	19130.				
σ [MPa]	343.9	33.1	343.9				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	24.8	24.4	24.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM08R08[illegible]R08.nul(Rec.1)

TEST started at: 06-02-08 01:41:23

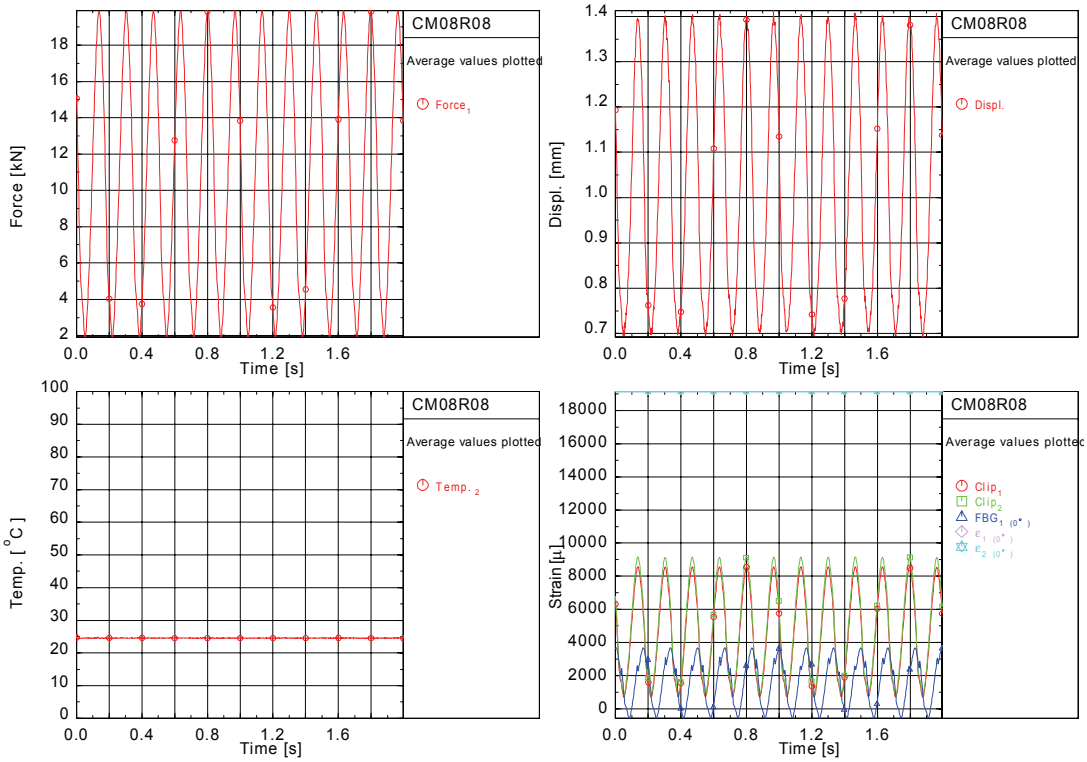


Figure D - 15: CM08R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	6.6	-7.9	-7.9		
Displ. [mm]	0.35	-0.10	-0.09		
$Clip_1$ [μ]	2331.	-3462.	-3462.	41103.	41330.
$Clip_2$ [μ]	2882.	-3018.	-3018.	40396.	40277.
$FBG_{1\ (0°)}$ [μ]	2936.	-3267.	-2867.	38616.	38708.
$\varepsilon_{1\ (0°)}$ [μ]	2910.	-3734.	-3734.	35442.	36073.
$\varepsilon_{2\ (0°)}$ [μ]	3195.	-3320.	-3320.	36380.	36500.
σ [MPa]	108.6	-129.4	-129.4		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	23.5	23.0	23.3

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM20R08\CM20R08.SLW Nulled with:CM20R08.nul(Rec.1) E-moduli based on: TEST started at: 25-01-08 12:23:20

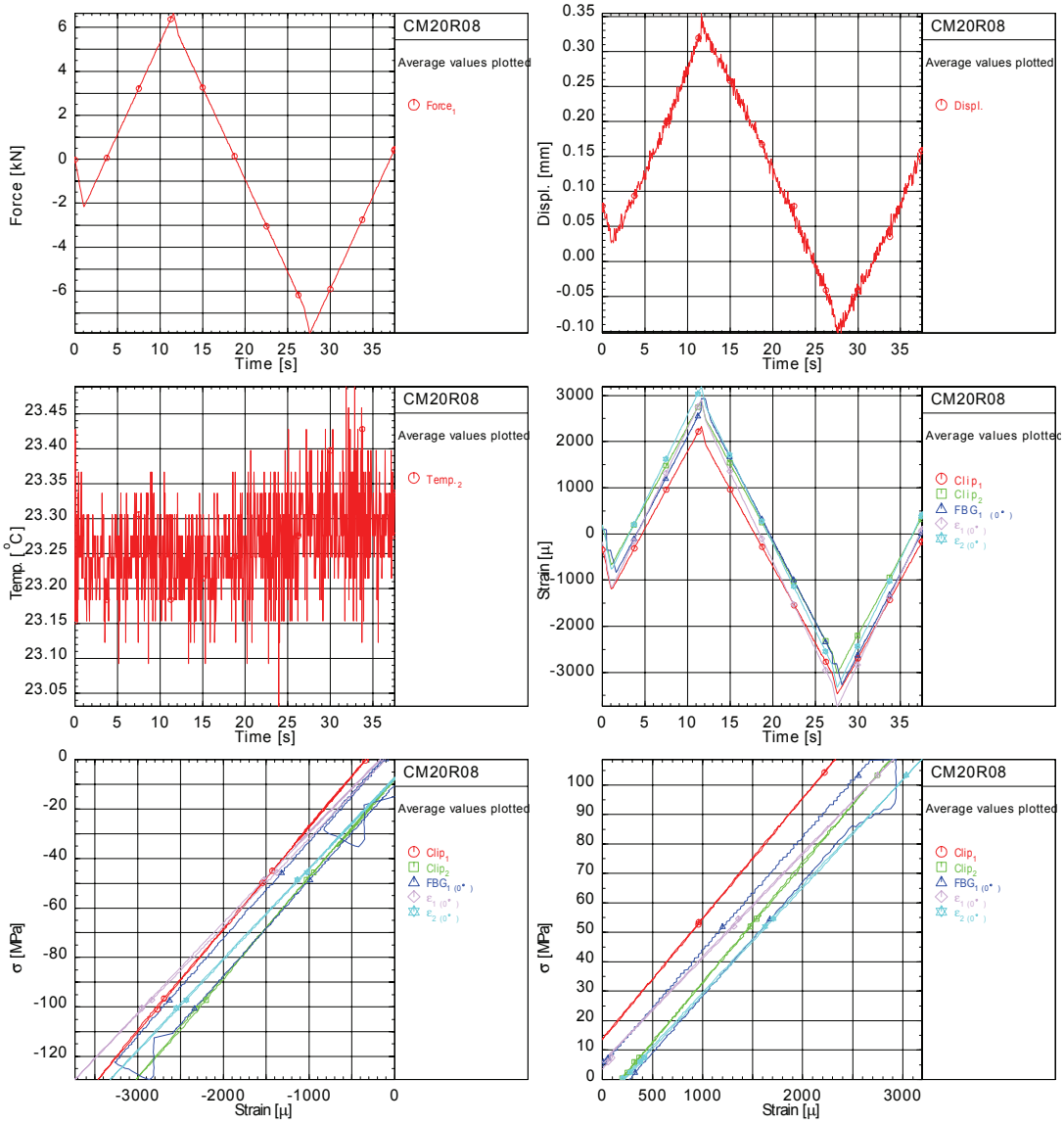


Figure D - 16: CM20R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
Force$_1$ [kN]	17.9	1.9	18.1	0.3	0.0
Displ. [mm]	1.20	0.58	1.98	0.43	2.06
Clip$_1$ [μ]	7240.	673.	7558.	-14.	-13.
Clip$_2$ [μ]	7282.	515.	7455.	418.	23.
FBG$_{1\ (0^\circ)}$ [μ]	-18.	-122.	7832.	-844.	-2.
$\varepsilon_{1\ (0^\circ)}$ [μ]	19315.	19311.	19319.	-12921.	-11.
$\varepsilon_{2\ (0^\circ)}$ [μ]	19250.	19230.	19282.	-14004.	12.
σ [MPa]	293.3	30.3	295.4	4.3	0.0

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	25.6	20.7	23.2

Number of Cycles	4383408.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM20R08\CM20R08.DFX Nulled with:CM20R08.nul(Rec.1) - TEST started at: 25-01-08 12:19:27

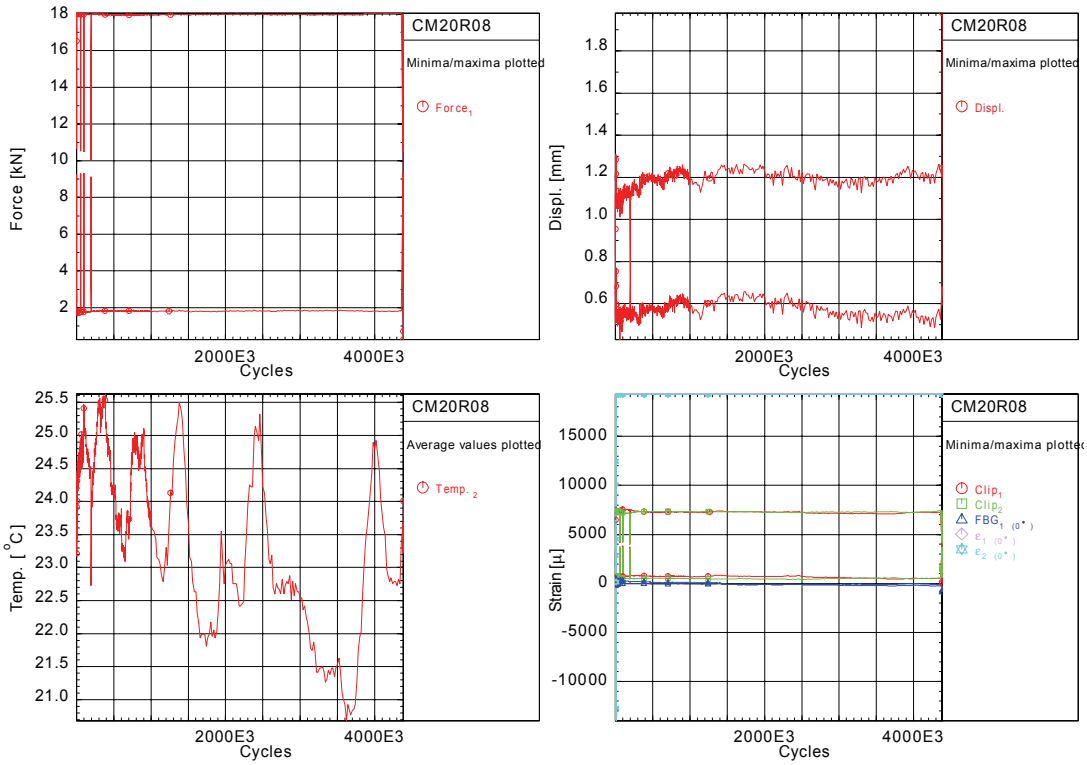


Figure D - 17: CM20R08 (fatigue summary)

Remarks: Good correlation between clip gauges. FBG signal lost early in life

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	18.0	1.8	18.0				
Displ. [mm]	1.24	0.70	1.22				
$Clip_1$ [µ]	7279.	448.	7269.				
$Clip_2$ [µ]	7335.	775.	7335.				
$FBG_{1\ (0^\circ)}$ [µ]	7781.	897.	5402.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	9680.	1977.	9671.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	8915.	1658.	8911.				
σ [MPa]	294.9	29.5	294.9				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	23.9	23.5	23.7

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM20R08\CM20R08.nul(Rec.1)

TEST started at: 25-01-08 12:28:22

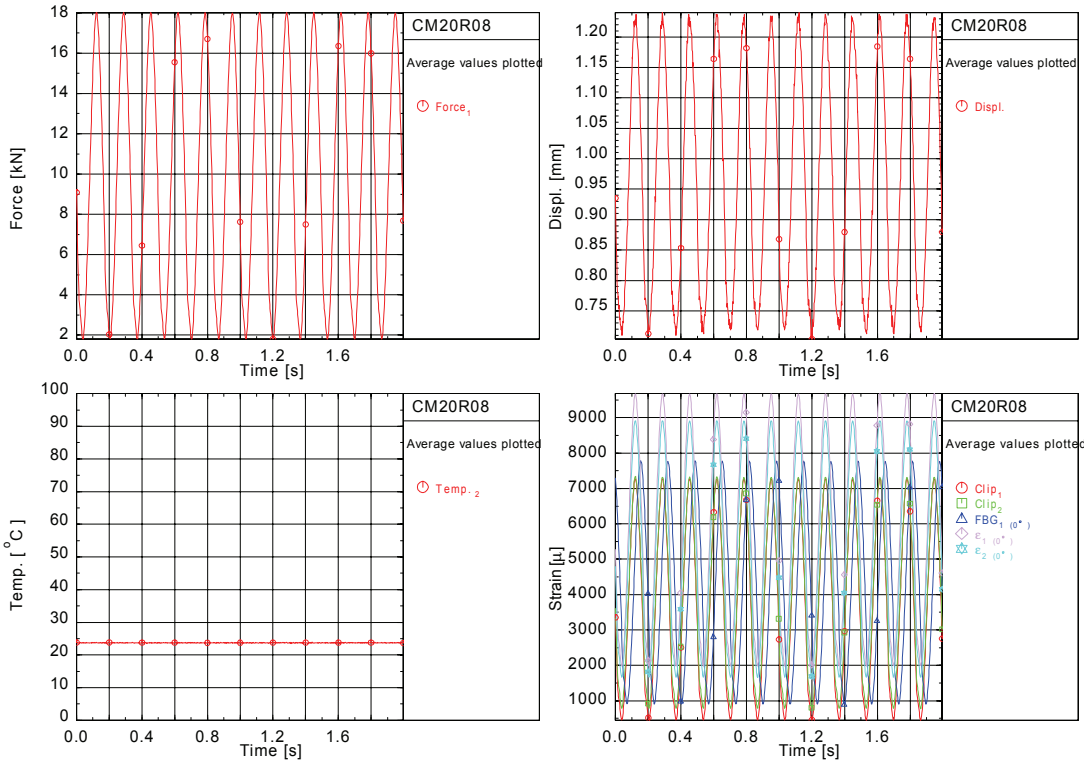


Figure D - 18: CM20R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	18.0	1.7	18.0				
Displ. [mm]	1.16	0.62	1.15				
$Clip_1$ [μ]	7397.	525.	7397.				
$Clip_2$ [μ]	7332.	694.	7330.				
$FBG_{1\ (0^\circ)}$ [μ]	331.	-111.	203.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	19319.	19319.	19319.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19282.	5732.	19282.				
σ [MPa]	295.1	28.5	295.1				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.4	24.0	24.2

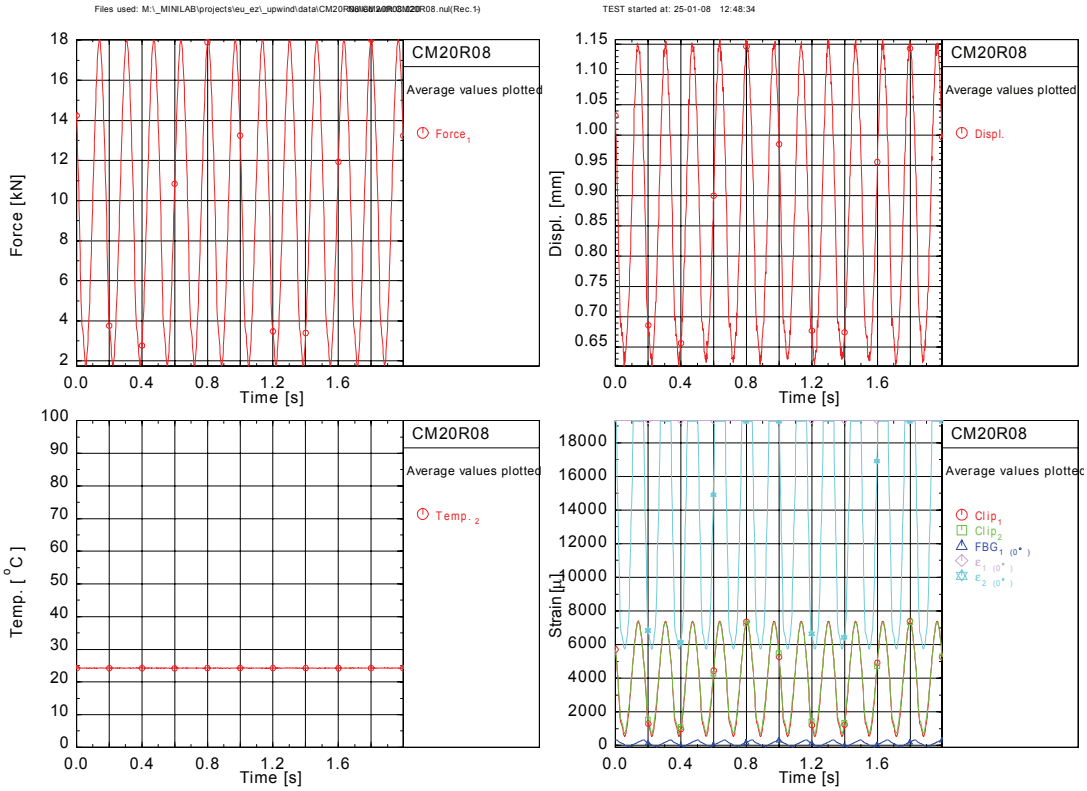


Figure D - 19: CM20R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	18.0	1.8	18.0				
Displ. [mm]	1.13	0.56	1.13				
$Clip_1$ [µ]	7461.	680.	7454.				
$Clip_2$ [µ]	7287.	570.	7281.				
$FBG_{1\ (0°)}$ [µ]	283.	-20.	167.				
$\varepsilon_{1\ (0°)}$ [µ]	19319.	19319.	19319.				
$\varepsilon_{2\ (0°)}$ [µ]	19282.	19282.	19282.				
σ [MPa]	294.9	28.9	294.9				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	24.9	24.6	24.7

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM20R08\CM20R08.nul(Rec.1)

TEST started at: 25-01-08 16:07:58

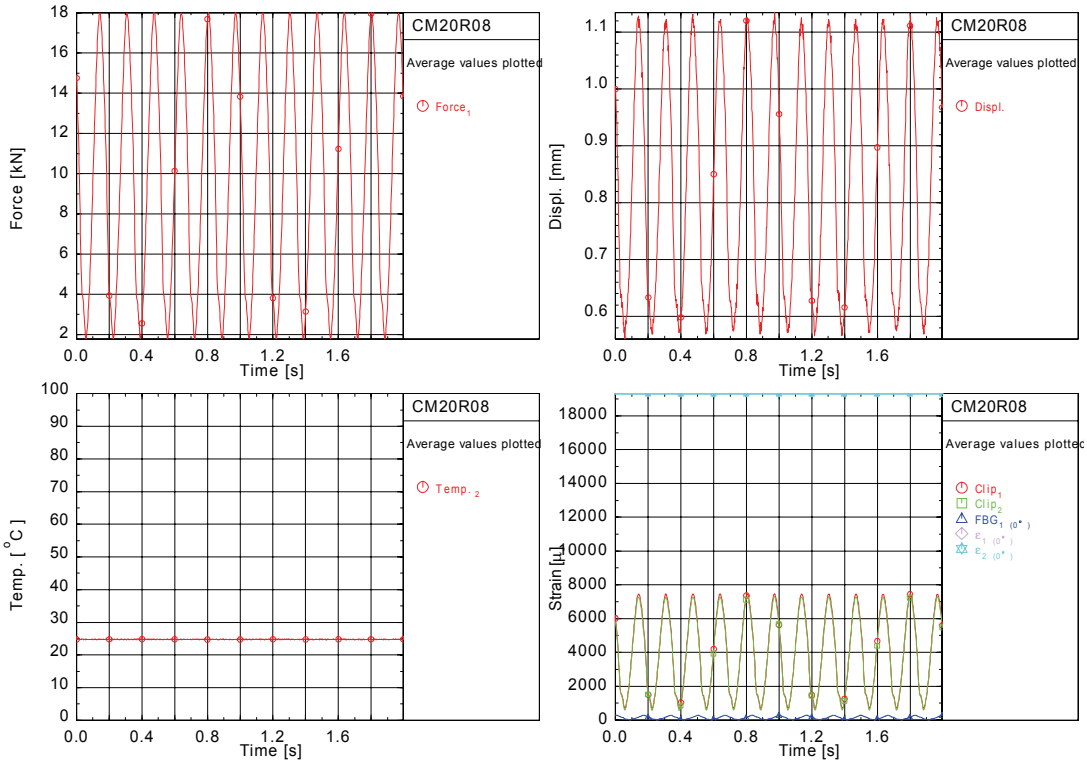


Figure D - 20: CM20R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	18.0	1.8	18.0				
Displ. [mm]	1.20	0.58	1.20				
Clip$_1$ [μ]	7305.	716.	7293.				
Clip$_2$ [μ]	7355.	527.	7355.				
FBG$_{1\ (0^\circ)}$ [μ]	115.	-46.	42.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	19319.	19319.	19319.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19282.	19282.	19282.				
σ [MPa]	294.0	29.6	294.0				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	23.7	23.2	23.5

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM20R08[illegible]R08.nul(Rec.1)

TEST started at: 29-01-08 07:33:27

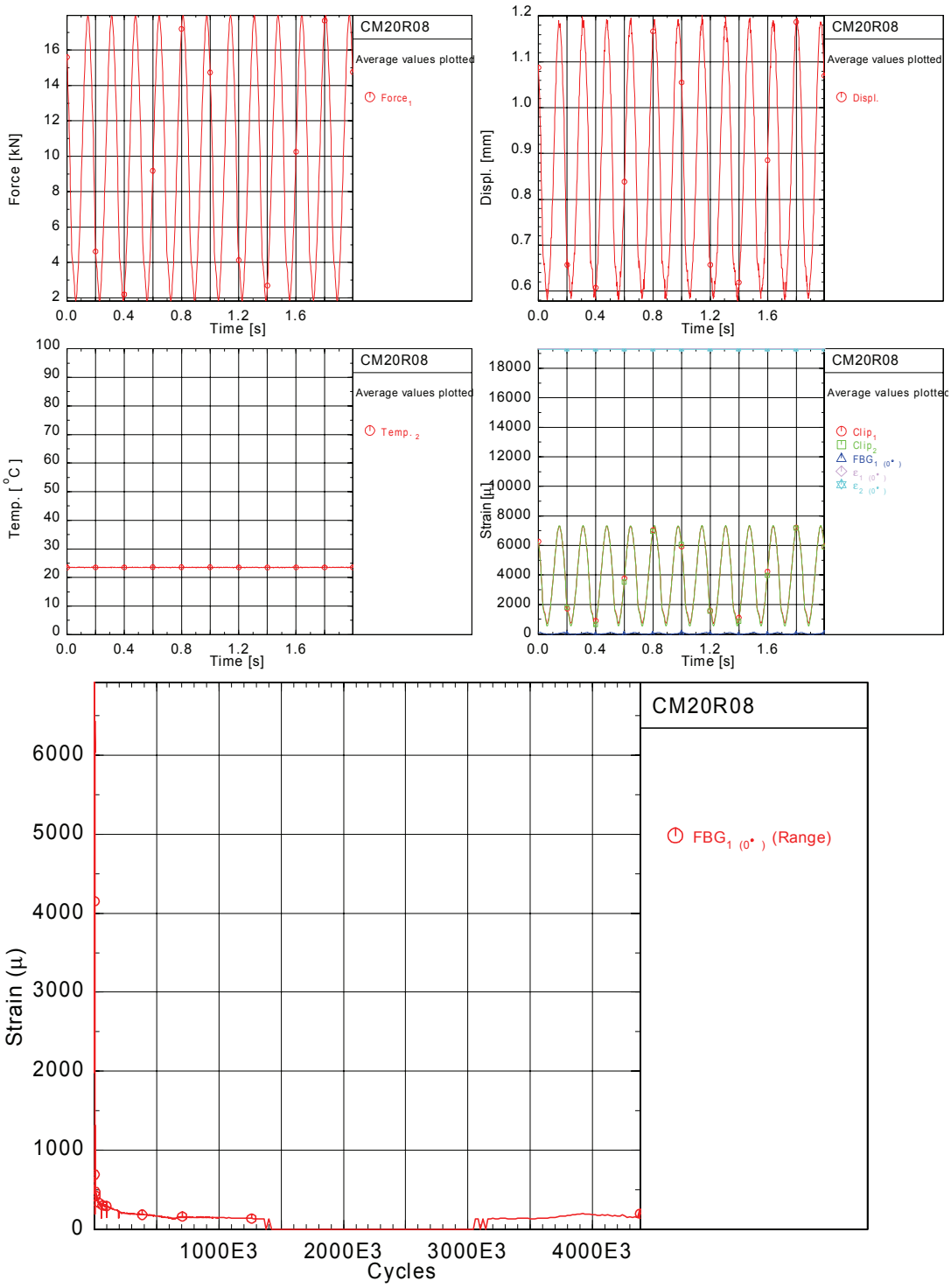


Figure D - 21: CM20R08 (ca. 1,000,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start
$Force_1$ [kN]	20.216	1.815	20.216	2.151
$Force_3$ [kN]	20.3	1.8	20.2	2.1
Displ. [mm]	-77.14	-78.04	-77.15	-78.03
$Clip_1$ [µ]	9702.	573.	9683.	685.
$Clip_2$ [µ]	10094.	861.	10081.	1026.
$FBG_{1\ (0°)}$ [µ]	8028.	823.	8024.	836.
$\varepsilon_{1\ (0°)}$ [µ]	13657.	1003.	10854.	1015.
$\varepsilon_{2\ (0°)}$ [µ]	9330.	939.	9330.	948.
σ [MPa]	353.0	31.7	353.0	37.6

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.4	24.0	24.2
$Temp._2$ [°C]	22.6	22.0	22.3

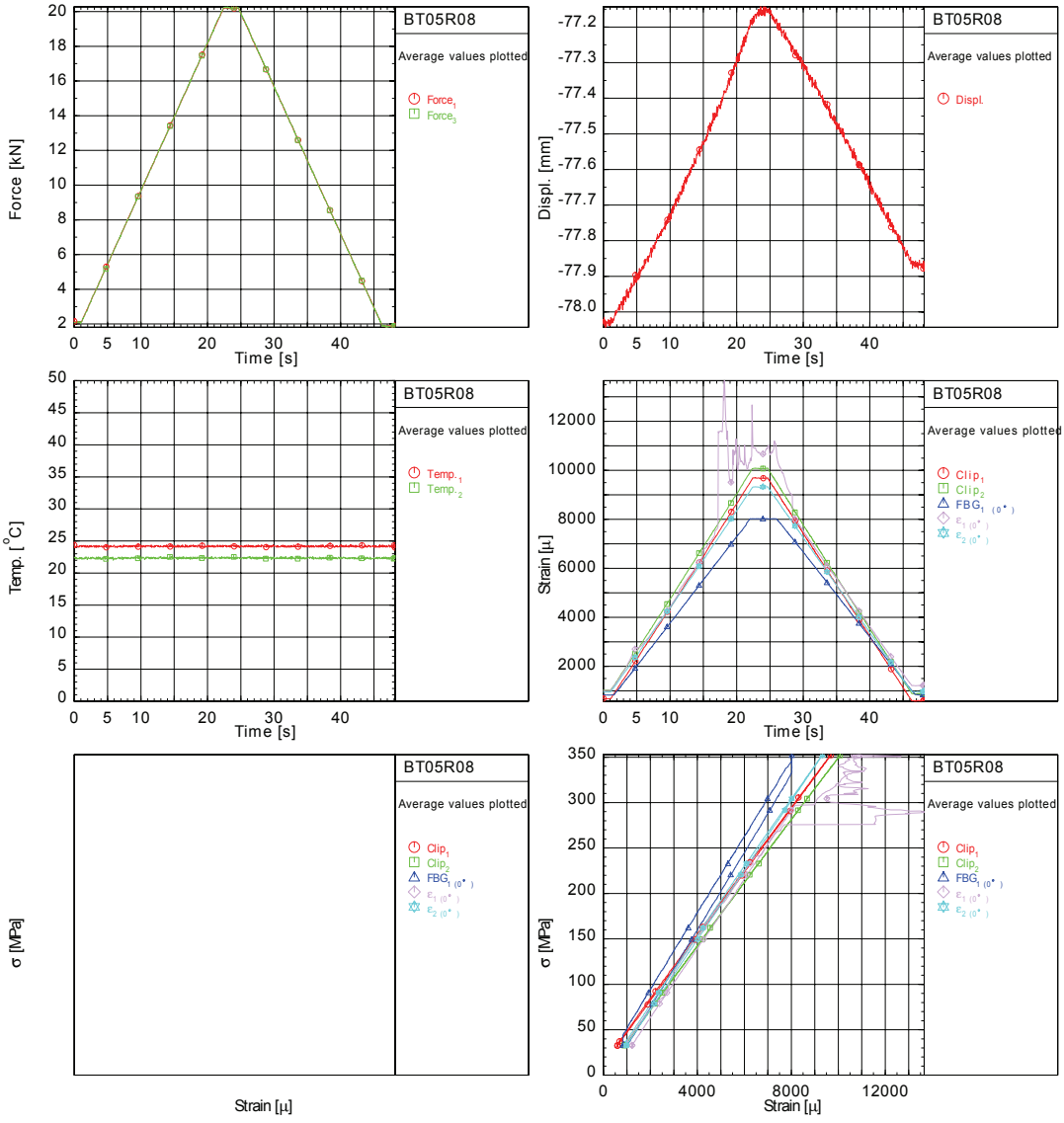


Figure D - 22: BT05R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
$Force_1$ [kN]	20.014	2.017	20.217	0.616	-0.015
$Force_3$ [kN]	20.1	2.0	20.3	1.8	0.0
Displ. [mm]	-77.32	-78.10	-76.78	-78.15	50.16
$Clip_1$ [μ]	10078.	1182.	10635.	650.	6.
$Clip_2$ [μ]	10403.	1028.	11479.	846.	-3.
$FBG_{1\ (0°)}$ [μ]	-149.	-214.	8032.	-1498.	2.
$\varepsilon_{1\ (0°)}$ [μ]	18803.	18780.	18828.	1240.	0.
$\varepsilon_{2\ (0°)}$ [μ]	18822.	18551.	18909.	1113.	-5.
σ [MPa]	349.5	35.2	353.0	10.8	-0.3

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	25.0	20.3	23.6
$Temp._2$ [°C]	25.2	20.9	24.1

Number of Cycles	318058.

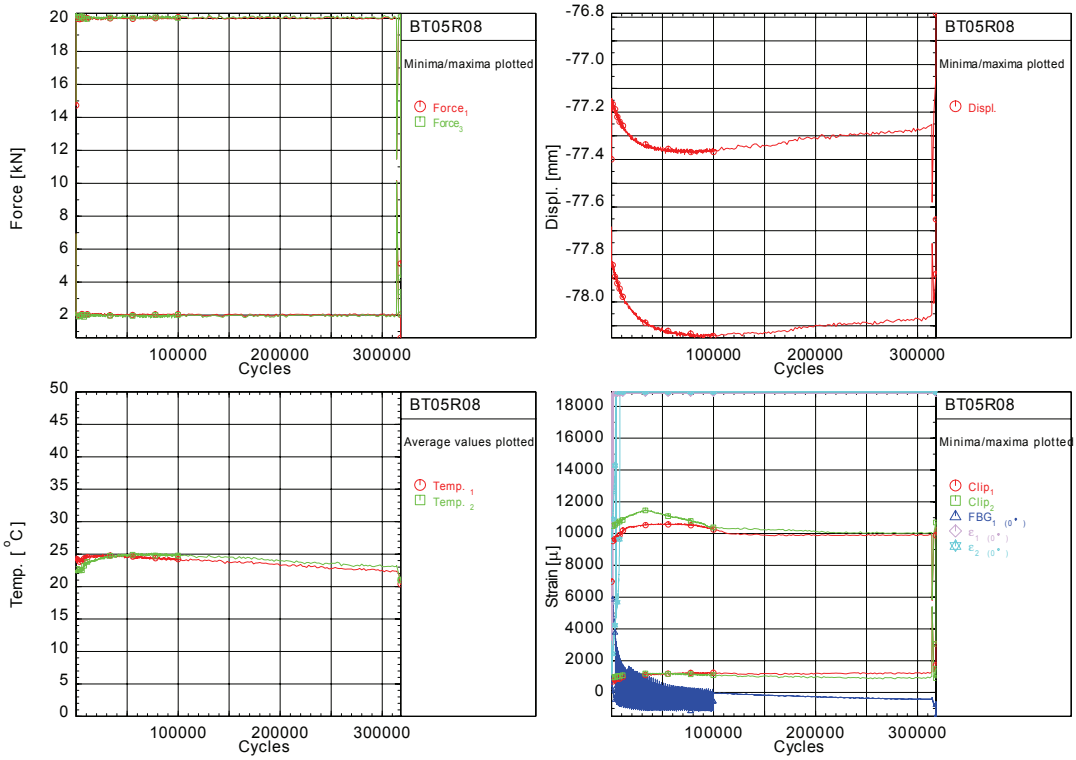


Figure D - 23: BT05R08 (fatigue summary)

FBG ceases to achieve tensile strain early in life ; reasonable correlation between clip gauges

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	20.10	1.94	20.10	16.02		
$Force_3$ [kN]	20.18	1.89	20.07	15.31		
Displ. [mm]	-77.15	-77.85	-77.17	-77.31		
$Clip_1$ [μ]	9617.	671.	9588.	7961.		
$Clip_2$ [μ]	10387.	936.	10363.	8553.		
$FBG_{1\ (0°)}$ [μ]	6780.	279.	6300.	3818.		
$\varepsilon_{1\ (0°)}$ [μ]	18828.	4315.	12109.	10281.		
$\varepsilon_{2\ (0°)}$ [μ]	10525.	2093.	10489.	8288.		
σ [MPa]	350.8	33.8	350.8	279.5		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.4	23.9	24.2
$Temp._2$ [°C]	22.7	22.1	22.4

Area of cross-section 57.30

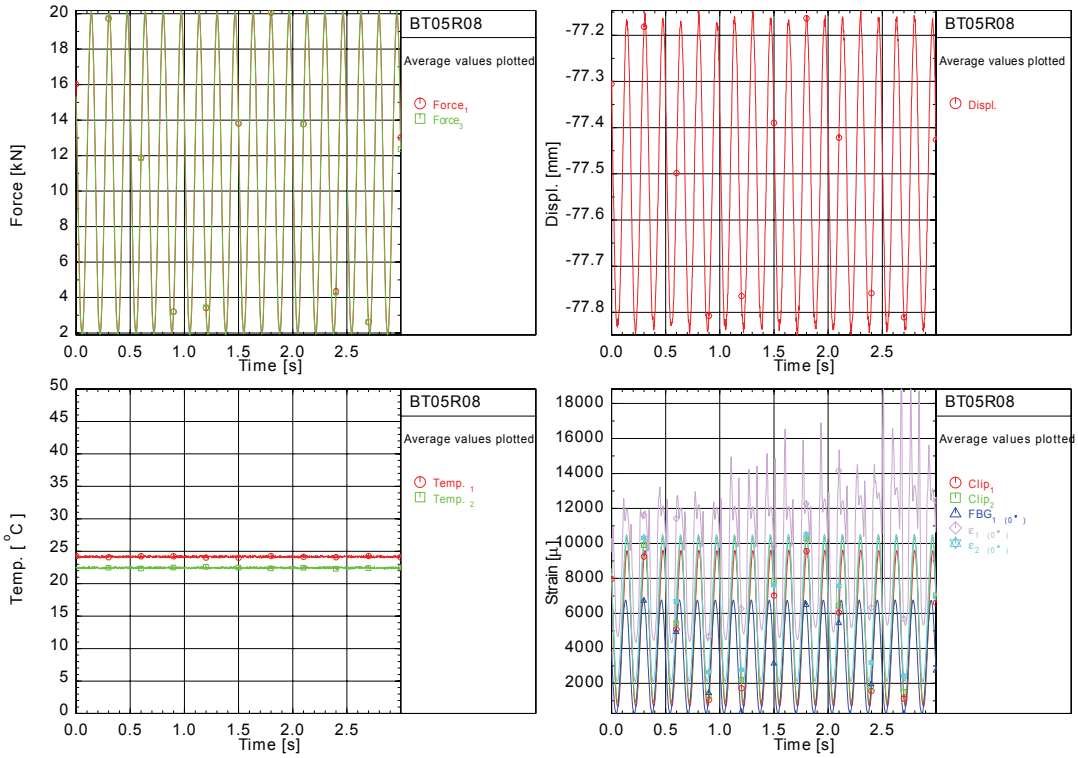


Figure D - 24: BT05R08 (ca. 1,000 cyles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	20.10	1.95	20.10	9.03		
$Force_3$ [kN]	20.17	1.91	20.05	8.38		
Displ. [mm]	-77.25	-77.98	-77.27	-77.69		
$Clip_1$ [μ]	10109.	908.	10083.	4959.		
$Clip_2$ [μ]	10894.	1016.	10890.	5247.		
$FBG_{1\ (0°)}$ [μ]	1874.	-923.	1556.	-359.		
$\varepsilon_{1\ (0°)}$ [μ]	18828.	18828.	18828.	18828.		
$\varepsilon_{2\ (0°)}$ [μ]	18909.	18909.	18909.	18909.		
σ [MPa]	350.8	34.0	350.8	157.6		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.9	24.4	24.6
$Temp._2$ [°C]	23.8	23.3	23.6

Area of cross-section 57.30

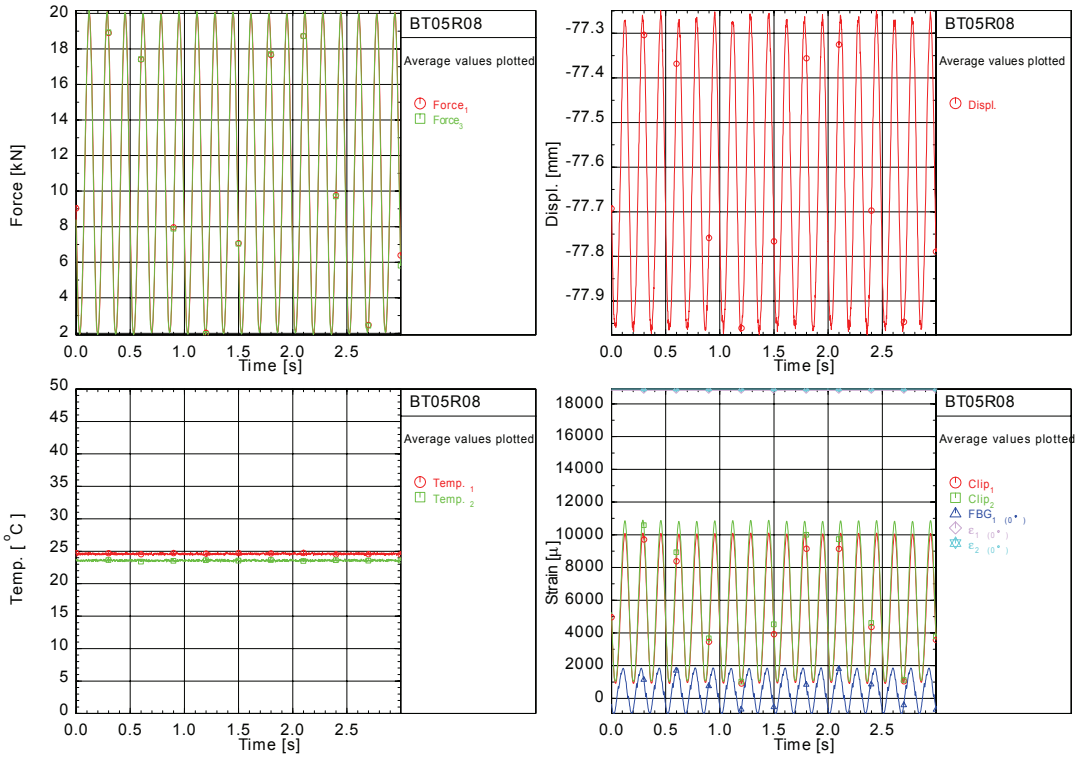


Figure D - 25: BT05R08 (ca. 10,000 cyles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	20.11	1.92	20.11	19.98		
$Force_3$ [kN]	20.17	1.88	20.10	19.94		
Displ. [mm]	-77.35	-78.14	-77.37	-77.37		
$Clip_1$ [µ]	10311.	1175.	10270.	10259.		
$Clip_2$ [µ]	10417.	1007.	10387.	10357.		
$FBG_{1\ (0°)}$ [µ]	320.	-1193.	72.	15.		
$\varepsilon_{1\ (0°)}$ [µ]	18828.	18828.	18828.	18828.		
$\varepsilon_{2\ (0°)}$ [µ]	18909.	18909.	18909.	18909.		
σ [MPa]	350.9	33.5	350.9	348.8		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.4	23.9	24.1
$Temp._2$ [°C]	25.1	24.5	24.8

Area of cross-section 57.30

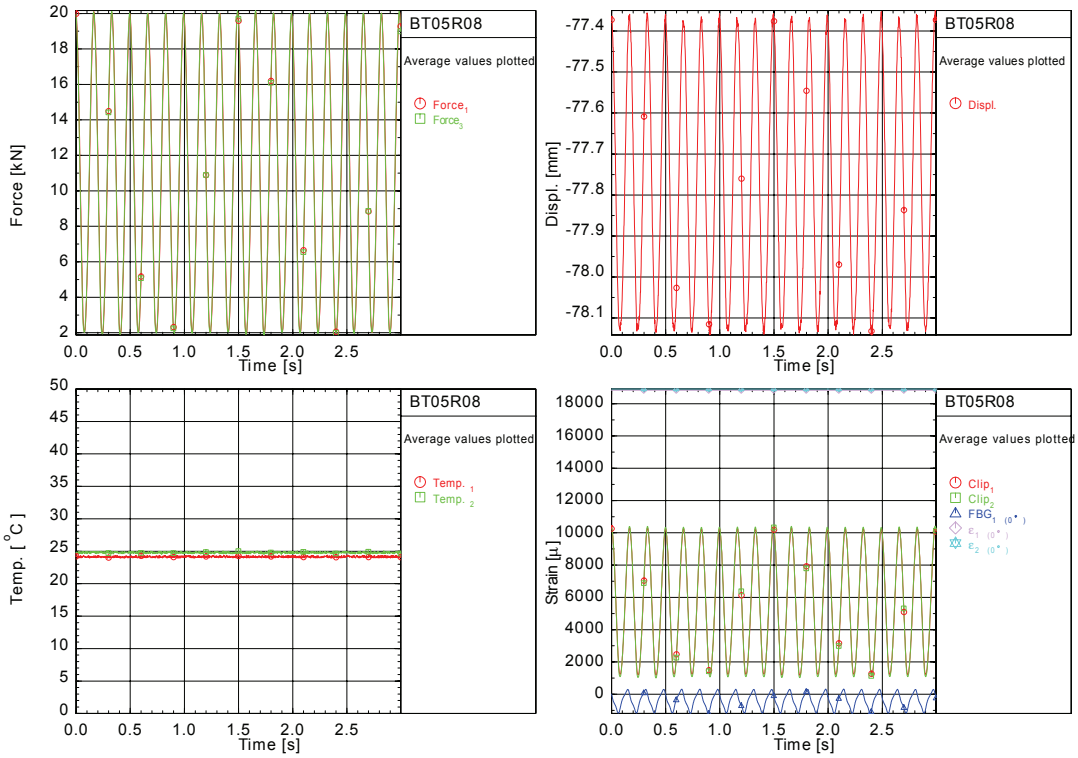


Figure D - 26: BT05R08 (ca. 100,000 cyles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	7.144	-6.420	7.144		
$Force_3$ [kN]	7.1	-6.5	7.0		
Displ. [mm]	-54.26	-54.84	-54.26		
$Clip_1$ [μ]	2180.	-2840.	2180.	41674.	46640.
$Clip_2$ [μ]	2915.	-2977.	2906.	37818.	38240.
$FBG_{1\ (0°)}$ [μ]	2880.	-2867.	2871.	38124.	38975.
$\varepsilon_{1\ (0°)}$ [μ]	3101.	-3086.	3098.	35794.	35958.
$\varepsilon_{2\ (0°)}$ [μ]	2987.	-2987.	2987.	36888.	37373.
σ [MPa]	117.2	-105.3	117.2		
Bending [μ/mm]	40.02	0.00	38.50		
Bending [μ/mm]	237.67	0.17	228.02		

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	22.8	22.3	22.5
Temp.$_2$ [°C]	24.0	23.5	23.7

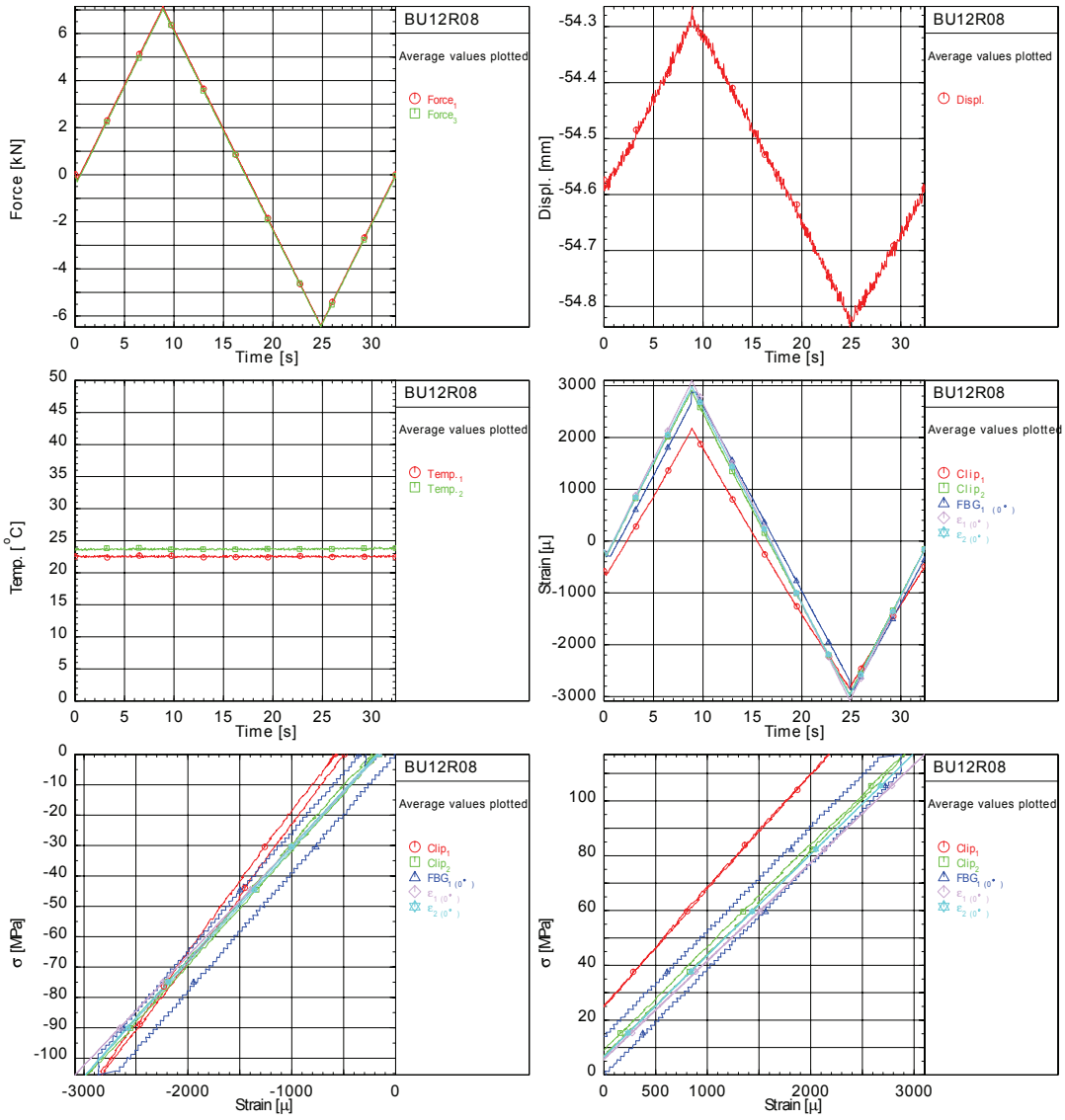


Figure D - 27: BU12R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum
$Force_1$ [kN]	18.03	1.78	18.09	0.21
$Force_3$ [kN]	17.84	1.65	18.02	0.01
Displ. [mm]	-50.12	-50.89	-50.00	-54.25
$Clip_1$ [μ]	7680.	276.	7966.	-1382.
$Clip_2$ [μ]	7551.	279.	7657.	167.
$FBG_{1\ (0°)}$ [μ]	858.	-469.	8019.	-791.
$\varepsilon_{1\ (0°)}$ [μ]	19008.	18964.	19039.	741.
$\varepsilon_{2\ (0°)}$ [μ]	19018.	18949.	19071.	537.
σ [MPa]	295.5	29.2	296.5	3.5

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	25.6	20.9	23.0
$Temp._2$ [°C]	28.0	23.6	26.3

Number of Cycles	2163765.
Area of cross-section	61.00

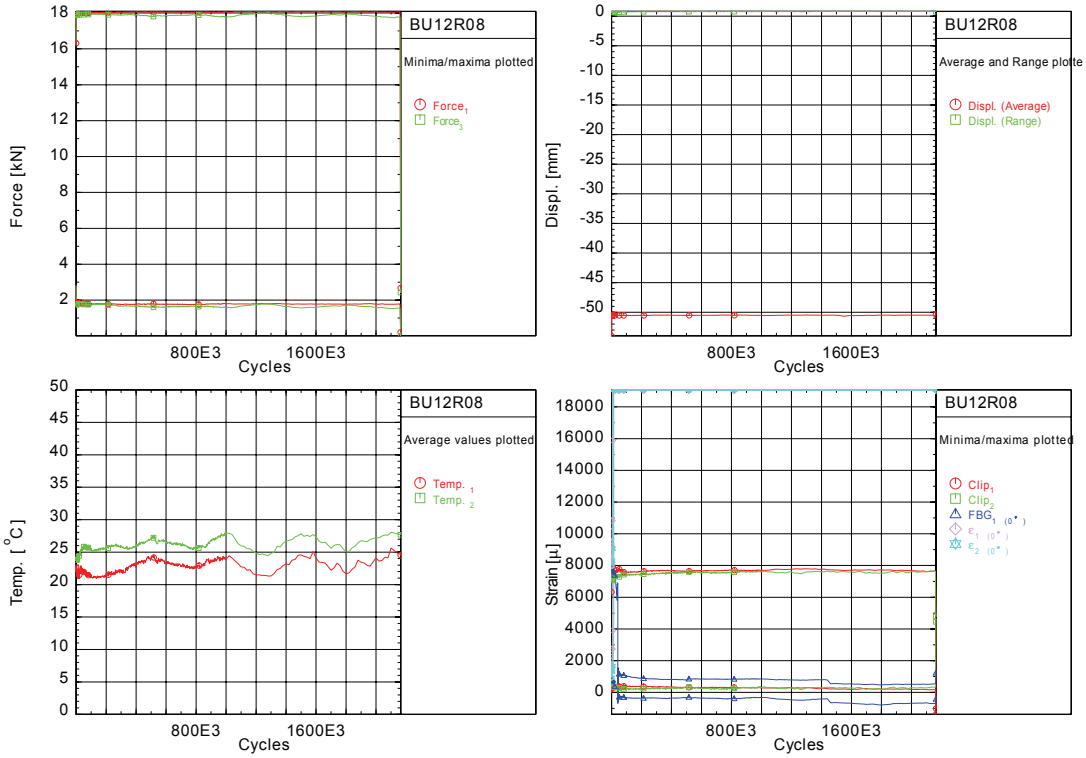


Figure D - 28: BU12R08 (fatigue summary)

FBG ceases to achieve tensile strain early in life

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	18.02	1.78	18.02	16.10		
$Force_3$ [kN]	17.92	1.74	17.87	16.52		
Displ. [mm]	-50.14	-50.82	-50.16	-50.22		
$Clip_1$ [µ]	7368.	177.	7341.	6791.		
$Clip_2$ [µ]	7489.	385.	7470.	6747.		
$FBG_{1\ (0°)}$ [µ]	7776.	649.	3790.	1568.		
$\varepsilon_{1\ (0°)}$ [µ]	8667.	1098.	8650.	7917.		
$\varepsilon_{2\ (0°)}$ [µ]	7854.	711.	7840.	7142.		
σ [MPa]	295.3	29.2	295.3	263.9		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	22.5	22.0	22.2
$Temp._2$ [°C]	24.1	23.5	23.8

Area of cross-section 61.00

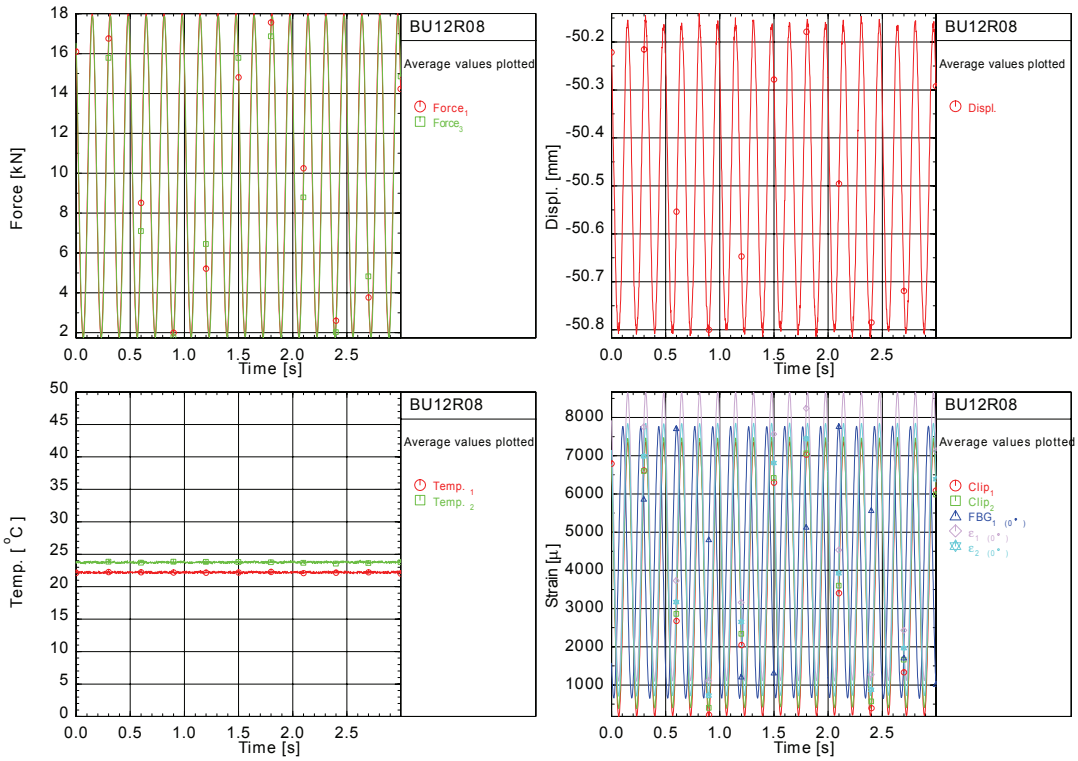


Figure D - 29: BU12R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	18.02	1.78	18.02	18.02		
$Force_3$ [kN]	17.93	1.74	17.86	17.86		
Displ. [mm]	-50.18	-50.87	-50.20	-50.20		
$Clip_1$ [μ]	7924.	307.	7890.	7890.		
$Clip_2$ [μ]	7160.	362.	7121.	7121.		
$FBG_{1\ (0°)}$ [μ]	7701.	663.	3532.	3532.		
$\varepsilon_{1\ (0°)}$ [μ]	19039.	9463.	19039.	19039.		
$\varepsilon_{2\ (0°)}$ [μ]	10825.	1881.	10801.	10801.		
σ [MPa]	295.5	29.1	295.5	295.5		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	22.2	21.7	21.9
$Temp._2$ [°C]	24.2	23.6	23.9

Area of cross-section 61.00

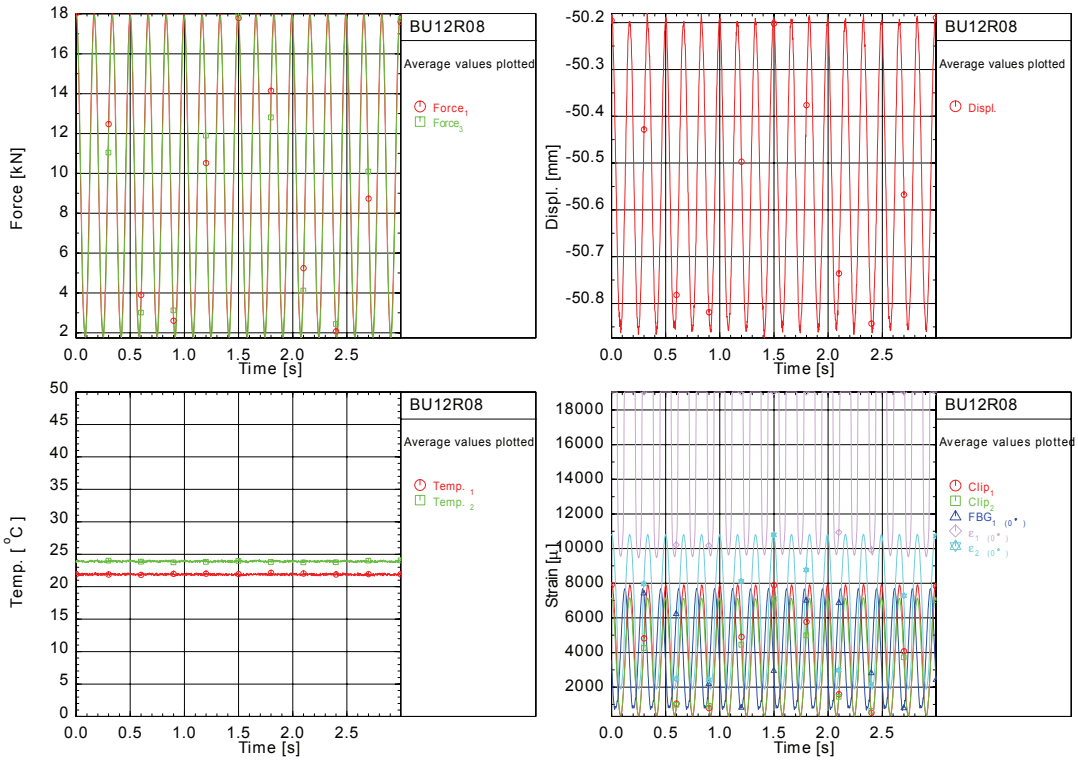


Figure D - 30: BU12R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	18.04	1.78	18.04	18.03		
$Force_3$ [kN]	17.94	1.73	17.85	17.85		
Displ. [mm]	-50.15	-50.90	-50.18	-50.15		
$Clip_1$ [μ]	7606.	371.	7560.	7565.		
$Clip_2$ [μ]	7422.	183.	7382.	7378.		
$FBG_{1\ (0°)}$ [μ]	1030.	-345.	130.	91.		
$\varepsilon_{1\ (0°)}$ [μ]	19039.	19039.	19039.	19039.		
$\varepsilon_{2\ (0°)}$ [μ]	19071.	19071.	19071.	19071.		
σ [MPa]	295.7	29.2	295.7	295.6		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	21.5	21.0	21.2
$Temp._2$ [°C]	25.7	25.1	25.4

Area of cross-section 61.00

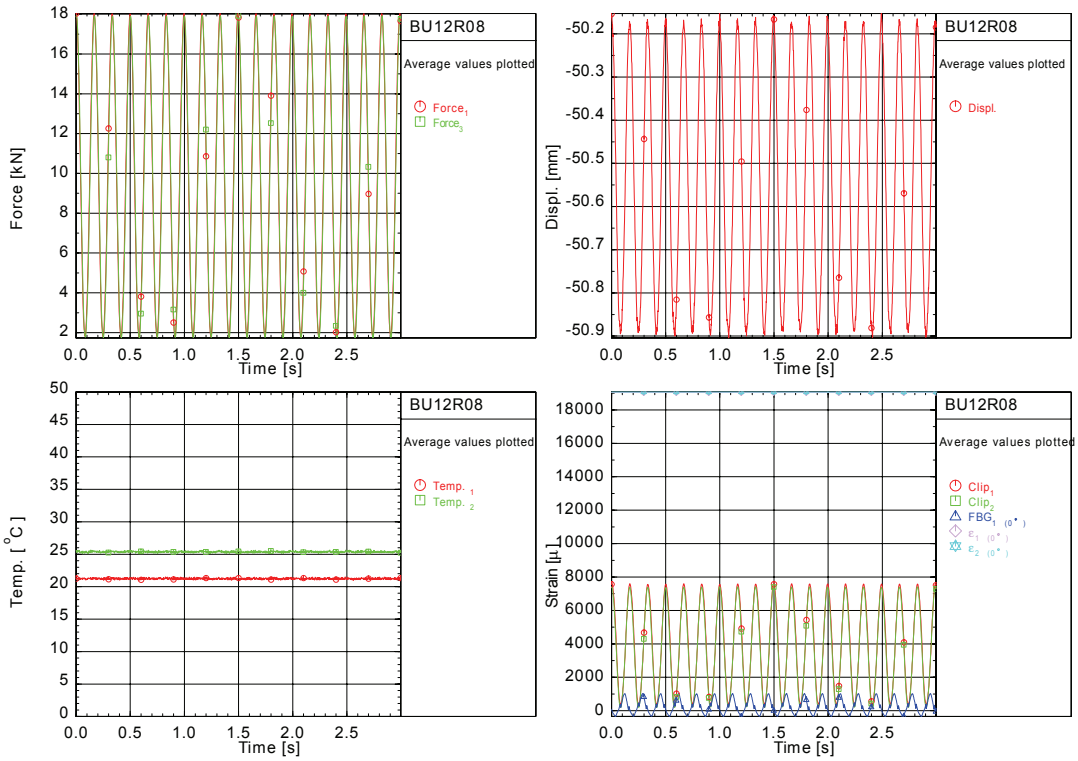


Figure D - 31: BU12R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	17.94	0.21	17.94	10.25		
$Force_3$ [kN]	17.64	0.01	17.58	9.24		
Displ. [mm]	-42.95	-50.85	-50.03	-50.48		
$Clip_1$ [μ]	8448.	-2273.	7839.	3870.		
$Clip_2$ [μ]	7948.	515.	7798.	4063.		
$FBG_{1\ (0°)}$ [μ]	1224.	-708.	93.	-401.		
$\varepsilon_{1\ (0°)}$ [μ]	19039.	19039.	19039.	19039.		
$\varepsilon_{2\ (0°)}$ [μ]	19071.	19071.	19071.	19071.		
σ [MPa]	294.1	3.5	294.1	168.0		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.9	24.4	24.6
$Temp._2$ [°C]	28.1	27.6	27.8

Area of cross-section 61.00

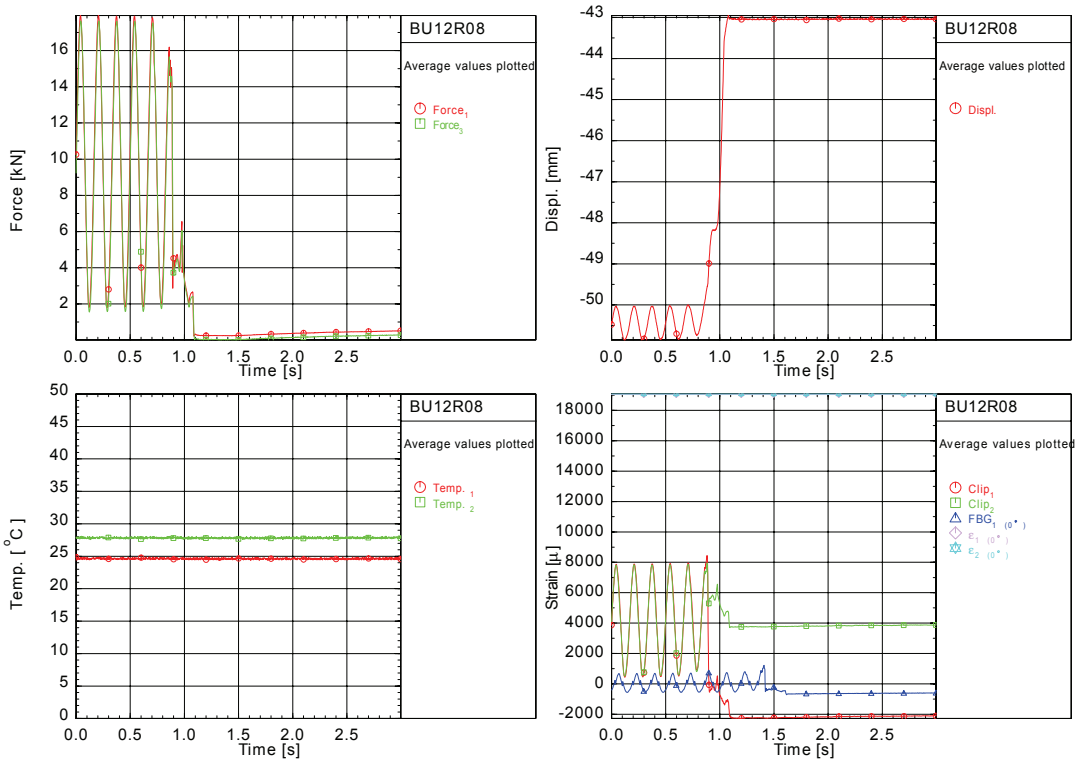


Figure D - 32: BU12R08 (failure)

APPENDIX E MEASUREMENT SUMMARY R = 0.1 EMBEDDED

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	7.2	-5.8	7.2		
$Force_{calc}$ [kN]	7.2	-5.8	7.2		
Displ. [mm]	-53.30	-53.72	-53.31		
$Clip_1$ [µ]	3523.	-2795.	3523.	36167.	35670.
$Clip_2$ [µ]	3366.	-2357.	3366.	38670.	39351.
$Clip_{AVG}$ [µ]	3335.	-2507.	3335.	38543.	38542.
smart1 [µ]	3276.	-2624.	3262.	37101.	38403.
$\varepsilon_{1\ (0^\circ)}$ [µ]	3377.	-2559.	3377.	37914.	37970.
$\varepsilon_{2\ (0^\circ)}$ [µ]	3138.	-2505.	3138.	39352.	40075.
σ [MPa]	124.7	-99.4	124.7		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	25.5	25.0	25.2

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM02R08b\CM02R08b.SLN filled with:CM02R08b.nul(Rec.1) E-moduli based on: TEST started at: 05-11-07 15:56:12

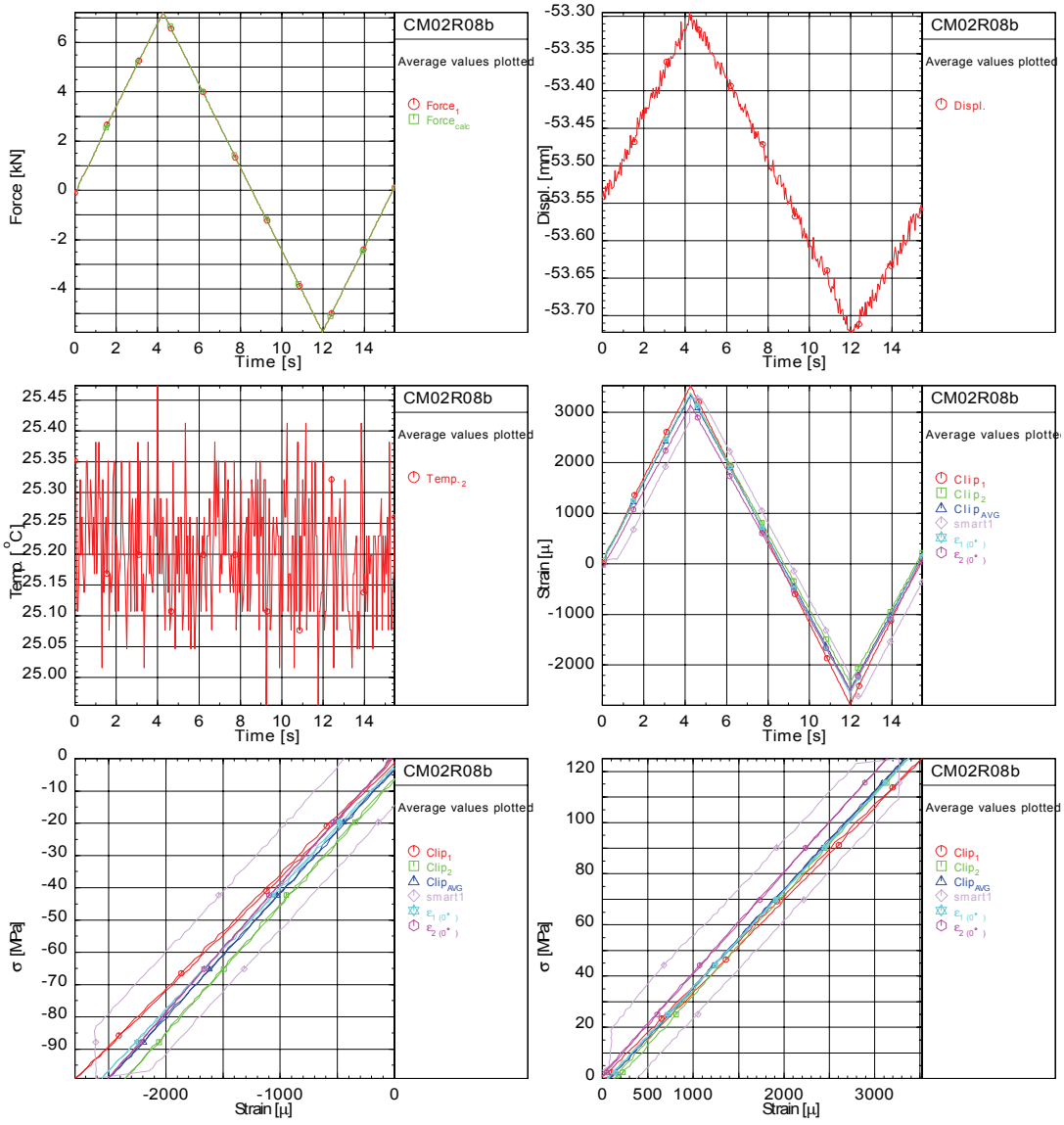


Figure E - 1: CM02R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
$Force_1$ [kN]	17.9	1.8	18.0	1.5	0.0
$Force_{calc}$ [kN]	17.9	1.8	18.0	1.5	0.0
Displ. [mm]	-2.80	-3.41	-1.88	-3.45	21.93
$Clip_1$ [μ]	8093.	516.	8676.	349.	-397.
$Clip_2$ [μ]	8321.	788.	8941.	-109.	-527.
$Clip_{AVG}$ [μ]	7945.	633.	8502.	-446.	-460.
smart1 [μ]	6451.	1167.	8280.	-923.	-2.
$\varepsilon_{1\ (0^\circ)}$ [μ]	18760.	18572.	18992.	-15484.	-8.
$\varepsilon_{2\ (0^\circ)}$ [μ]	18788.	18616.	19002.	-15991.	3.
σ [MPa]	310.0	30.7	311.3	26.5	0.3

Temperatures	Maximum	Minimum	Mean Average
Temp. $_2$ [°C]	27.5	25.0	26.7

Number of Cycles	880932.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM02R08b\CM02R08b.DAT Filled with:CM02R08b.nul(Rec.1) - TEST started at: 05-11-07 15:52:30

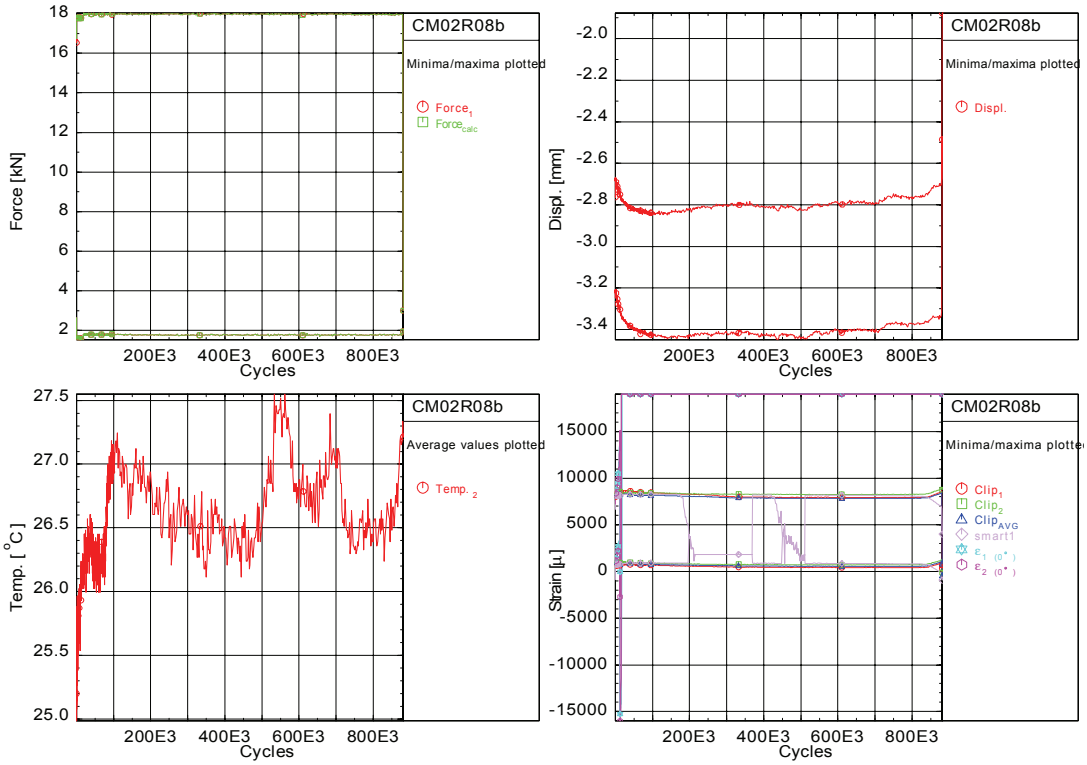


Figure E - 2: CM02R08 (fatigue summary)

Remarks: D/A conversion software causes jumps; good correlation between all strain sensors

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	17.8	1.6	17.8				
Displ. [mm]	-52.82	-53.38	-52.85				
Clip$_1$ [μ]	8387.	663.	8361.				
Clip$_2$ [μ]	8552.	956.	8525.				
Clip$_{AVG}$ [μ]	8199.	787.	8139.				
smart1 [μ]	8133.	736.	4707.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	8496.	1121.	8475.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	8127.	902.	8112.				
σ [MPa]	307.3	27.3	307.3				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	25.8	25.1	25.5

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM02R08b\CM02R08b.nul(Rec:1)

TEST started at: 05-11-07 16:00:08

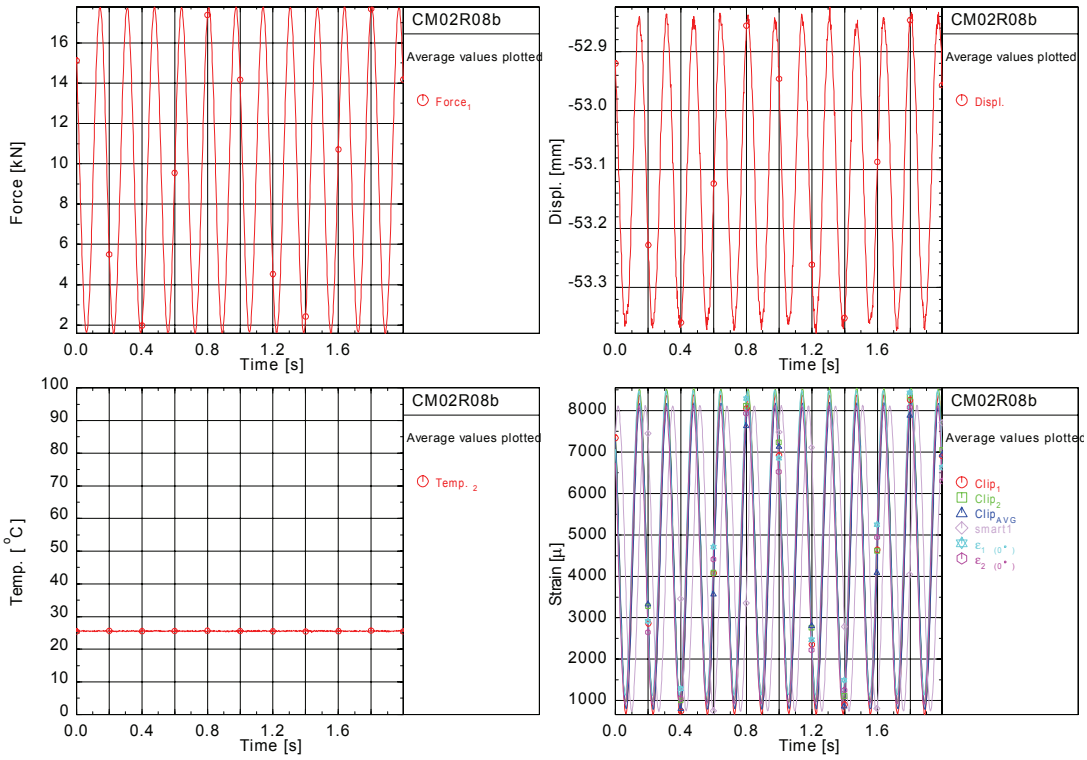


Figure E - 3: CM02R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	17.8	1.6	17.8				
Displ. [mm]	-52.89	-53.46	-52.92				
Clip$_1$ [μ]	8460.	670.	8428.				
Clip$_2$ [μ]	8572.	941.	8519.				
Clip$_{AVG}$ [μ]	8250.	782.	8174.				
smart1 [μ]	8157.	757.	4825.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	12623.	3259.	12576.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	12178.	2669.	12140.				
σ [MPa]	307.5	26.8	307.5				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	26.2	25.5	25.9

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM02R08b\CM02R08b.nul(Rec:1)

TEST started at: 05-11-07 16:25:19

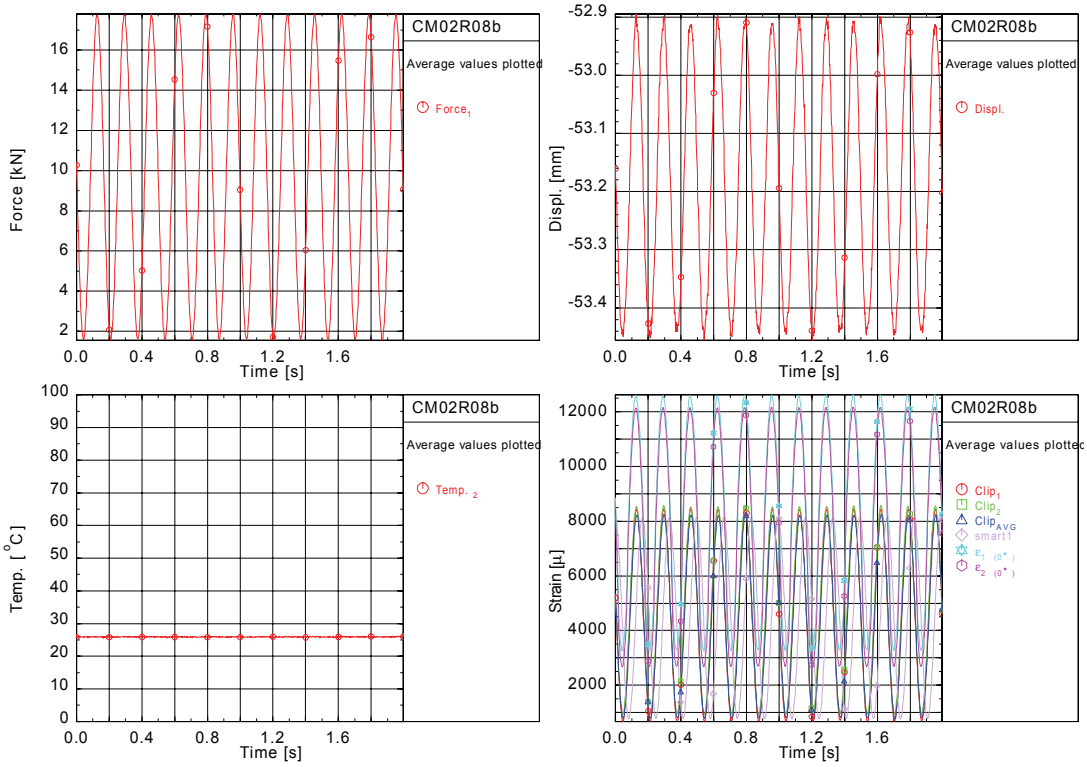


Figure E - 4: CM02R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	18.0	1.7	18.0				
Displ. [mm]	-52.97	-53.59	-53.00				
$Clip_1$ [μ]	8290.	569.	8250.				
$Clip_2$ [μ]	8345.	806.	8314.				
$Clip_{AVG}$ [μ]	8053.	670.	7982.				
smart1 [μ]	3798.	900.	3786.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	18992.	18992.	18992.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	19002.	19002.	19002.				
σ [MPa]	310.5	30.1	310.5				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	27.0	26.4	26.8

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM02R08b.nul(Rec:1)

TEST started at: 06-11-07 01:10:54

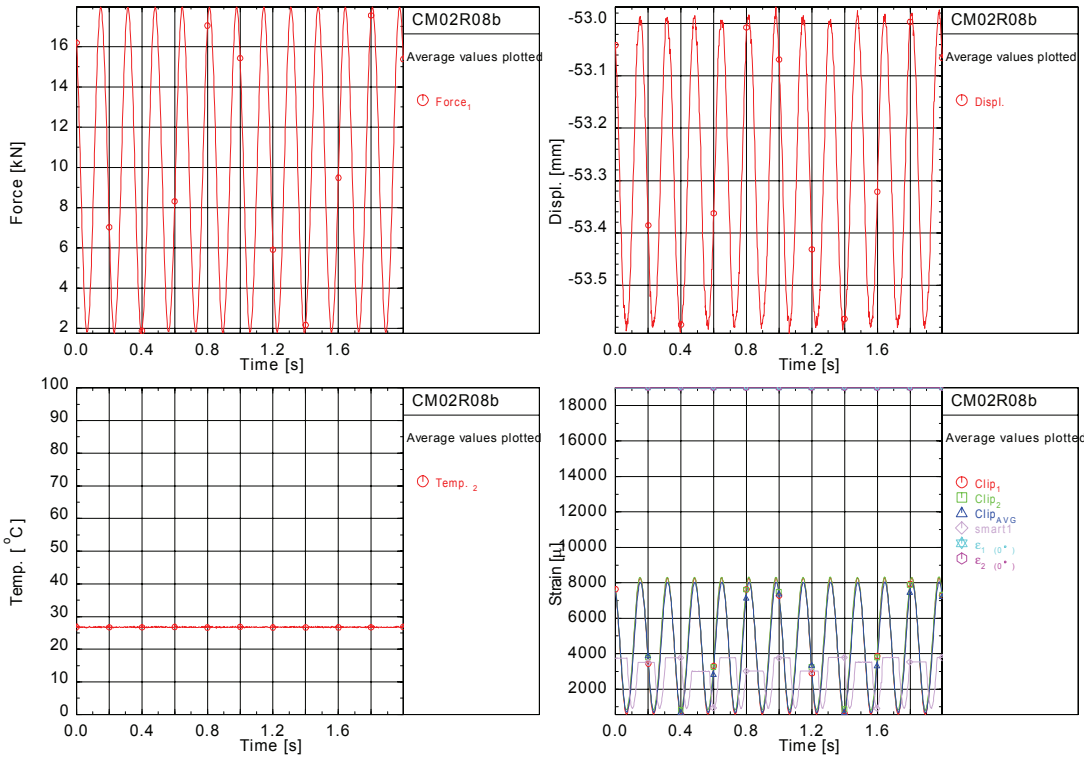


Figure E - 5: CM02R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	G [GPa]
Force, [kN]	8.5	-9.1	-9.1	
Displ. [mm]	0.63	-0.15	-0.14	
Clip, [μ]	0.	-2564.	-2547.	
Clip$_2$ [μ]	3402.	-4534.	-4523.	
smart1 [μ]	3891.	-4130.	-4111.	
σ [MPa]	144.5	-154.0	-154.0	

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	22.4	21.8	22.1

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM10R08\CM10R08.SLW Nulled with:CM10R08.nul(Rec.1) - TEST started at: 14-11-07 12:33:26

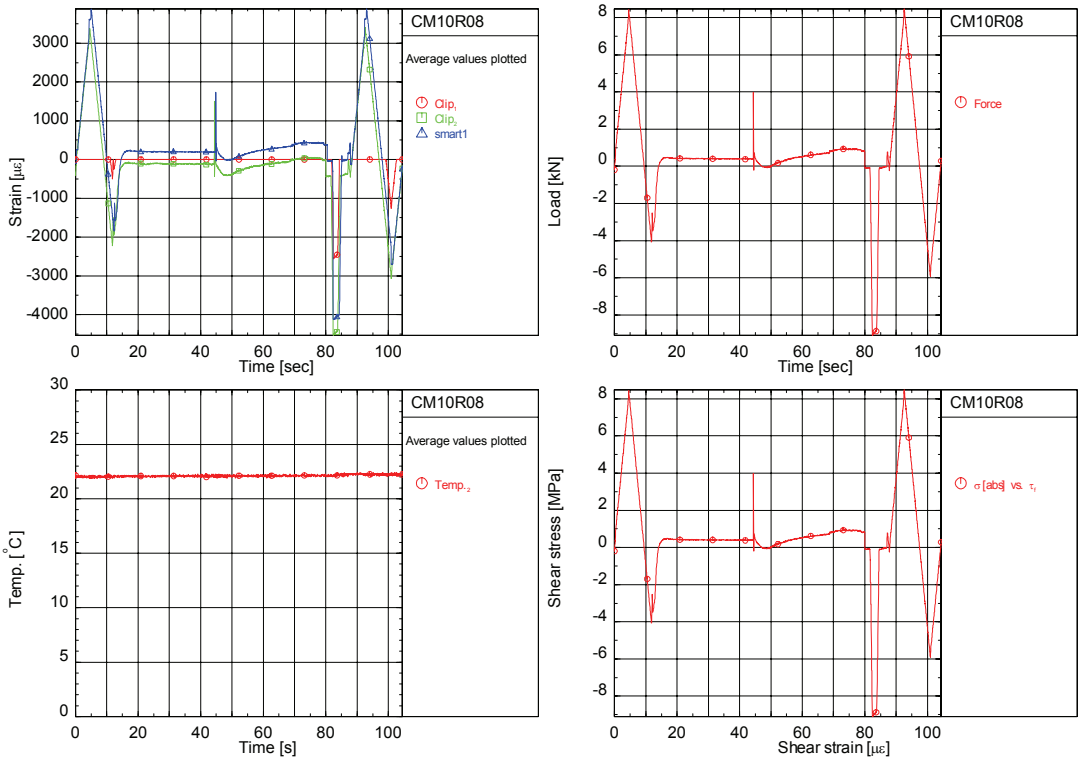


Figure E - 6: CM10R08 (slow cycle(s))

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	18.6	2.6	18.6				
Displ. [mm]	1.35	0.72	1.33				
Clip$_1$ [µ]	0.	0.	0.				
Clip$_2$ [µ]	8083.	753.	8063.				
smart1 [µ]	8477.	1215.	5879.				
σ [MPa]	315.2	44.6	315.2				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	22.7	22.3	22.5

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM10R08\CM10R08.nul(Rec.1)

TEST started at: 14-11-07 12:41:23

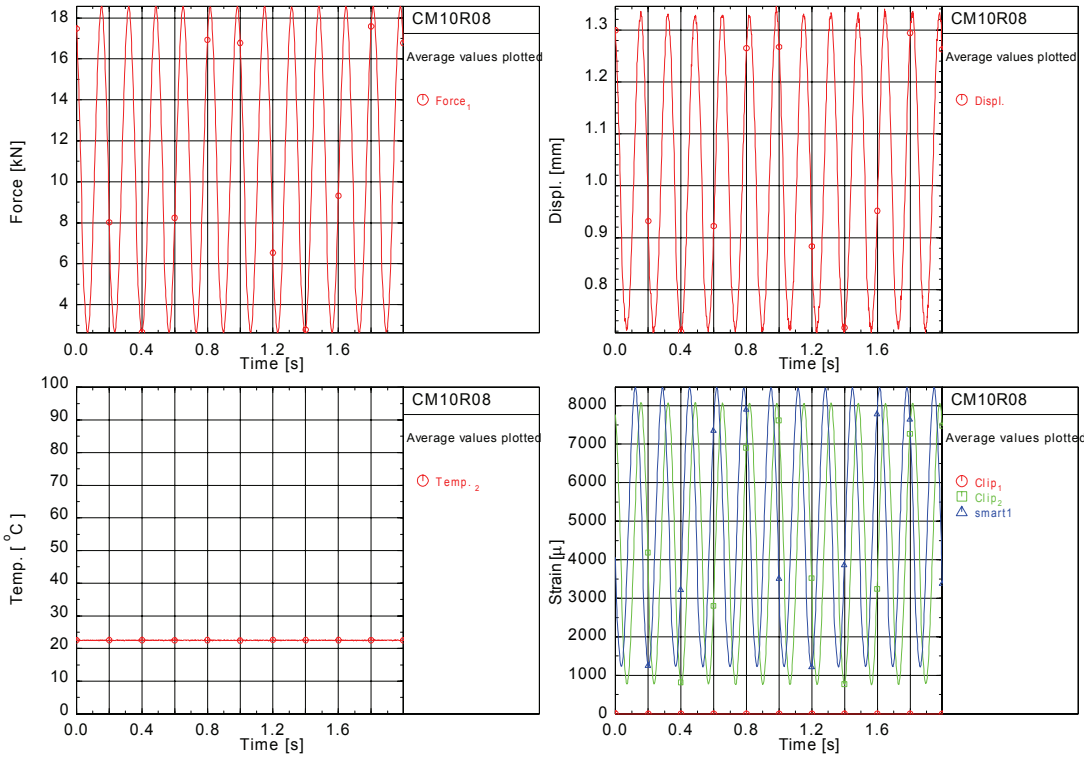


Figure E - 7: CM10R08 (ca. 1,000 cycles)

Remarks: Clip gauge 1 does not function; FBG reasonable correlation with clip gauge 1

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	18.6	2.6	18.6				
Displ. [mm]	1.40	0.77	1.39				
Clip$_1$ [µ]	0.	0.	0.				
Clip$_2$ [µ]	8207.	741.	8200.				
smart1 [µ]	8534.	1224.	5924.				
σ [MPa]	315.7	44.4	315.7				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	23.0	22.6	22.8

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM10R08 CM10R08.nul(Rec.1)

TEST started at: 14-11-07 12:46:55

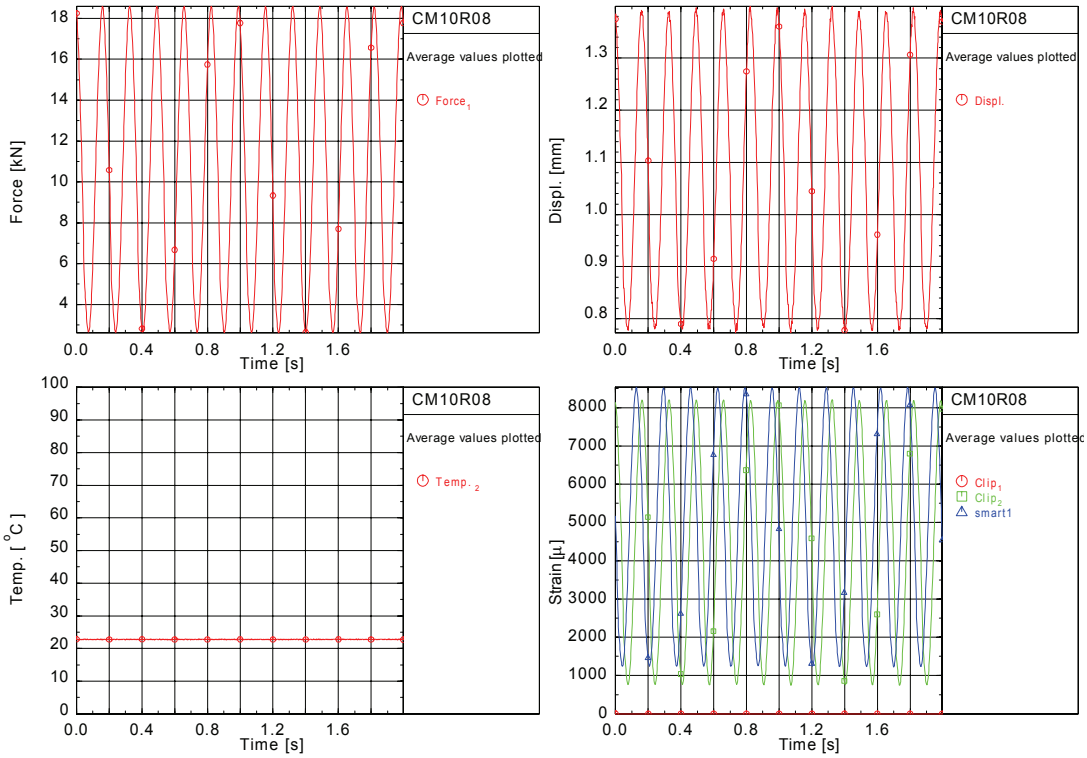


Figure E - 8: CM10R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	18.6	2.6	18.6				
Displ. [mm]	1.42	0.79	1.42				
$Clip_1$ [μ]	0.	0.	0.				
$Clip_2$ [μ]	8349.	747.	8330.				
smart1 [μ]	8546.	1236.	5937.				
σ [MPa]	315.6	44.7	315.6				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	23.2	22.8	23.0

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM10R08\CM10R08.nul(Rec.1)

TEST started at: 14-11-07 12:52:27

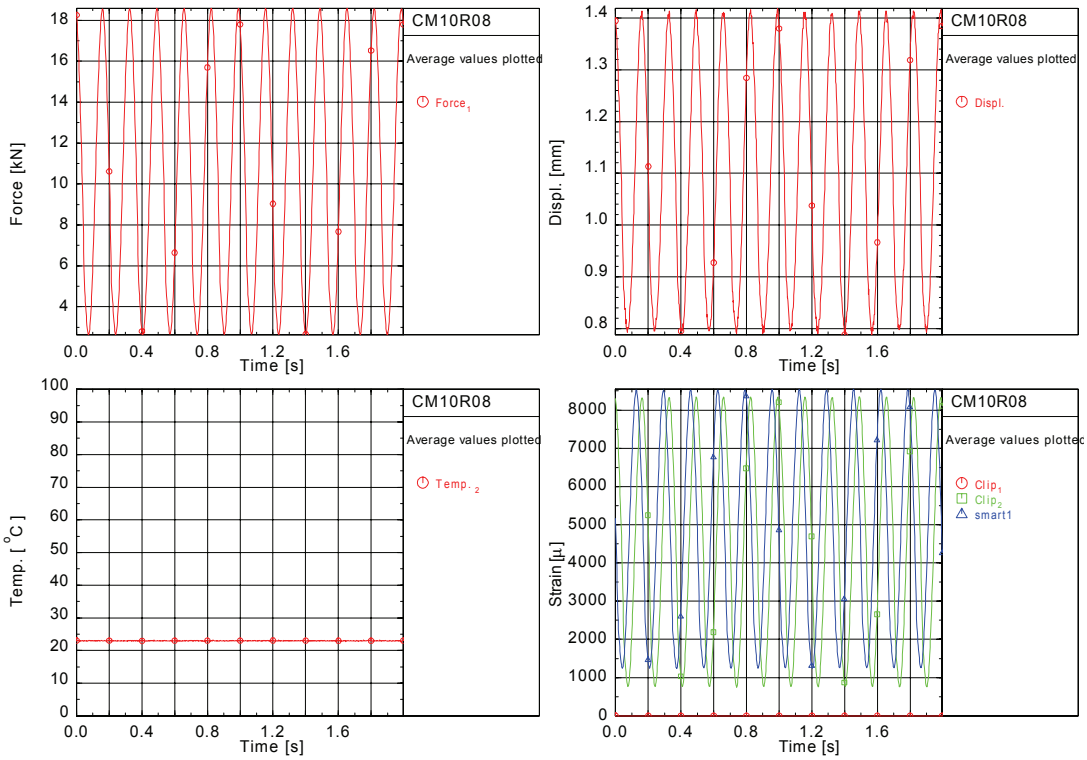


Figure E - 9: CM10R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
Force$_1$ [kN]	18.6	2.6	18.6				
Displ. [mm]	1.43	0.79	1.41				
Clip$_1$ [μ]	0.	0.	0.				
Clip$_2$ [μ]	8357.	740.	8331.				
smart1 [μ]	8523.	1252.	5911.				
σ [MPa]	315.3	44.7	315.3				

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	23.2	22.8	23.0

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM10R08\CM10R08.nul(Rec.1)

TEST started at: 14-11-07 12:57:59

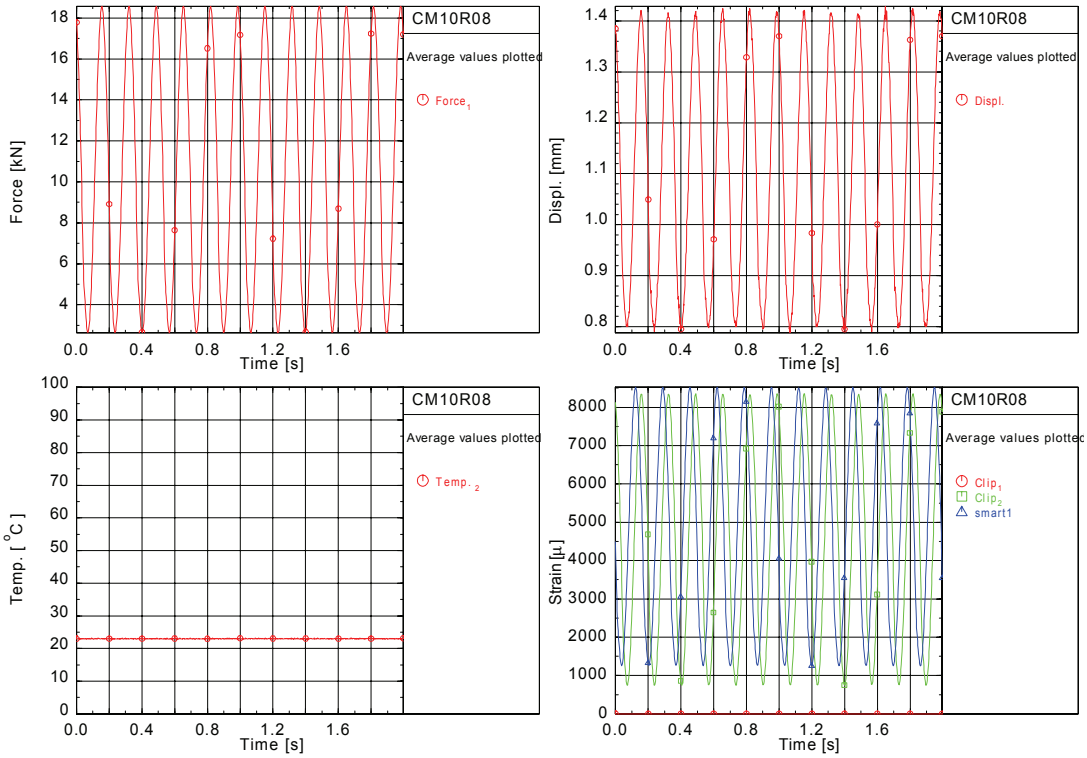


Figure E - 10: CM10 R08 (ca. 1,000,000 cycles)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	18.6	2.6	18.6				
Displ. [mm]	1.42	0.78	1.42				
$Clip_1$ [µ]	0.	0.	0.				
$Clip_2$ [µ]	8389.	714.	8365.				
smart1 [µ]	8560.	1246.	5932.				
σ [MPa]	315.4	44.4	315.4				

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	22.8	22.5	22.7

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM10R08.nul(Rec.1)

TEST started at: 14-11-07 13:03:31

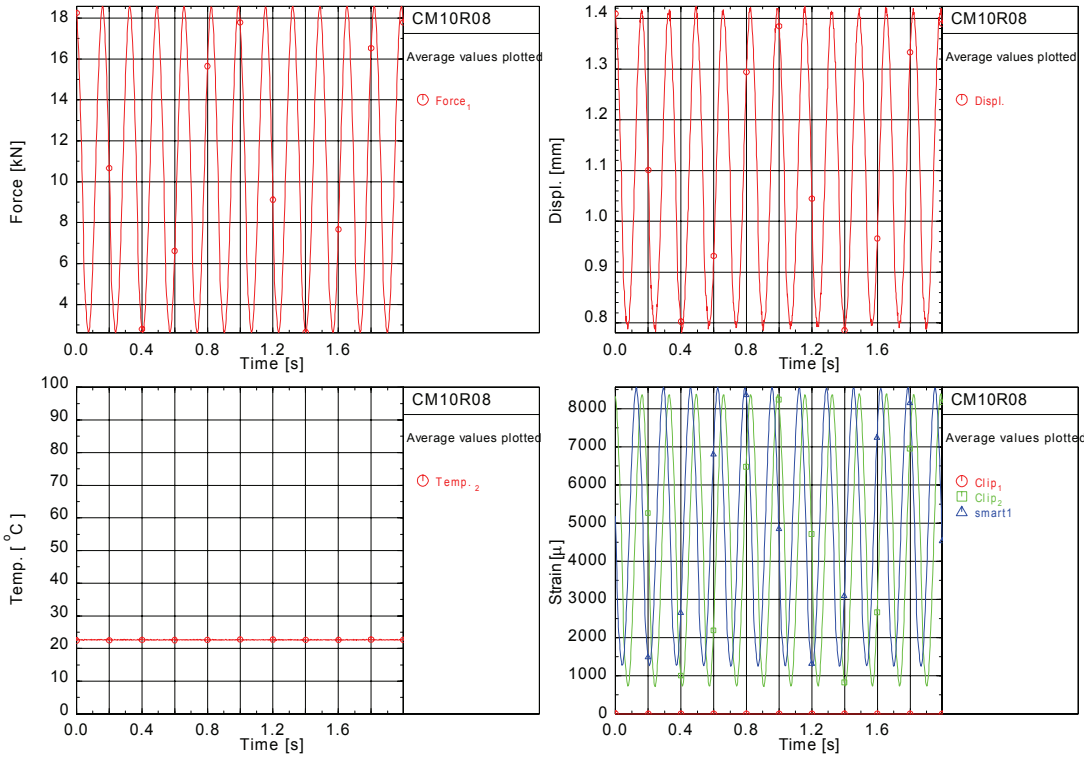


Figure E - 11: CM10R08 (ca. 10,000,000 cycles)

Channels	Maximum	Minimum	@F_{max}	G [GPa]
Force$_1$ [kN]	2.9	-3.2	2.9	
Force$_3$ [kN]	2.9	-3.2	2.9	
Displ. [mm]	-78.59	-78.80	-78.60	
Clip$_1$ [μ]	1700.	-1078.	1683.	
Clip$_2$ [μ]	383.	-2222.	383.	
FBG$_{1\ (\varepsilon^*_1)}$ [μ]	1115.	-1592.	1108.	
$\varepsilon_{1\ (\varepsilon^*_1)}$ [μ]	1384.	-1239.	1384.	
$\varepsilon_{2\ (\varepsilon^*_1)}$ [μ]	921.	-1751.	921.	
σ [MPa]	50.3	-54.2	50.3	

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	21.3	20.7	21.0
Temp.$_2$ [°C]	21.2	20.7	21.0

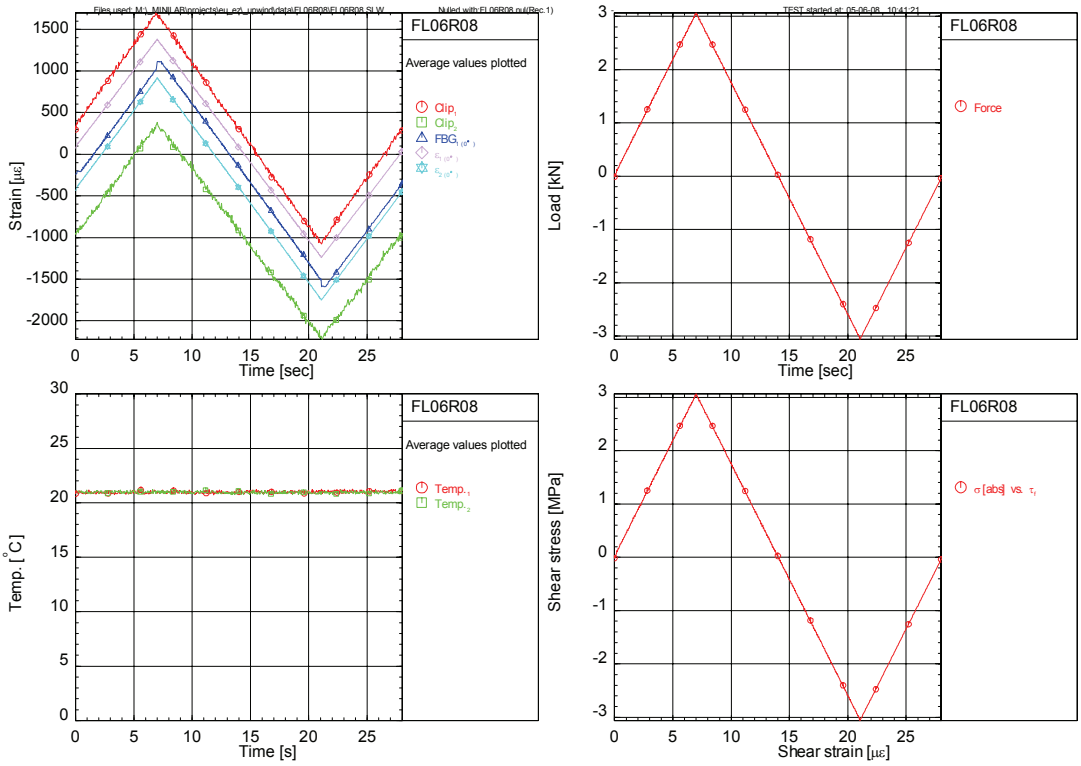


Figure E - 12: FL06R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
$Force_1$ [kN]	17.9	1.7	18.6	0.5	0.1		
$Force_3$ [kN]	17.8	1.6	18.5	1.4	0.0		
Displ. [mm]	-77.73	-78.39	-72.63	-78.45	50.16		
$Clip_1$ [µ]	8119.	1050.	8861.	805.	41.		
$Clip_2$ [µ]	7519.	352.	9826.	-172.	13.		
$FBG_{1\ (0^\circ)}$ [µ]	995.	979.	8220.	524.	-3.		
$\varepsilon_{1\ (0^\circ)}$ [µ]	18656.	18321.	18841.	919.	-1.		
$\varepsilon_{2\ (0^\circ)}$ [µ]	18576.	18100.	18845.	482.	-2.		
σ [MPa]	304.5	28.7	316.5	9.0	2.0		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.7	20.7	23.4
$Temp._2$ [°C]	28.2	20.9	24.7

Number of Cycles 314737.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\FL06R08\FL06R08.nul(Rec.1)

TEST started at: 05-06-08 10:30:40

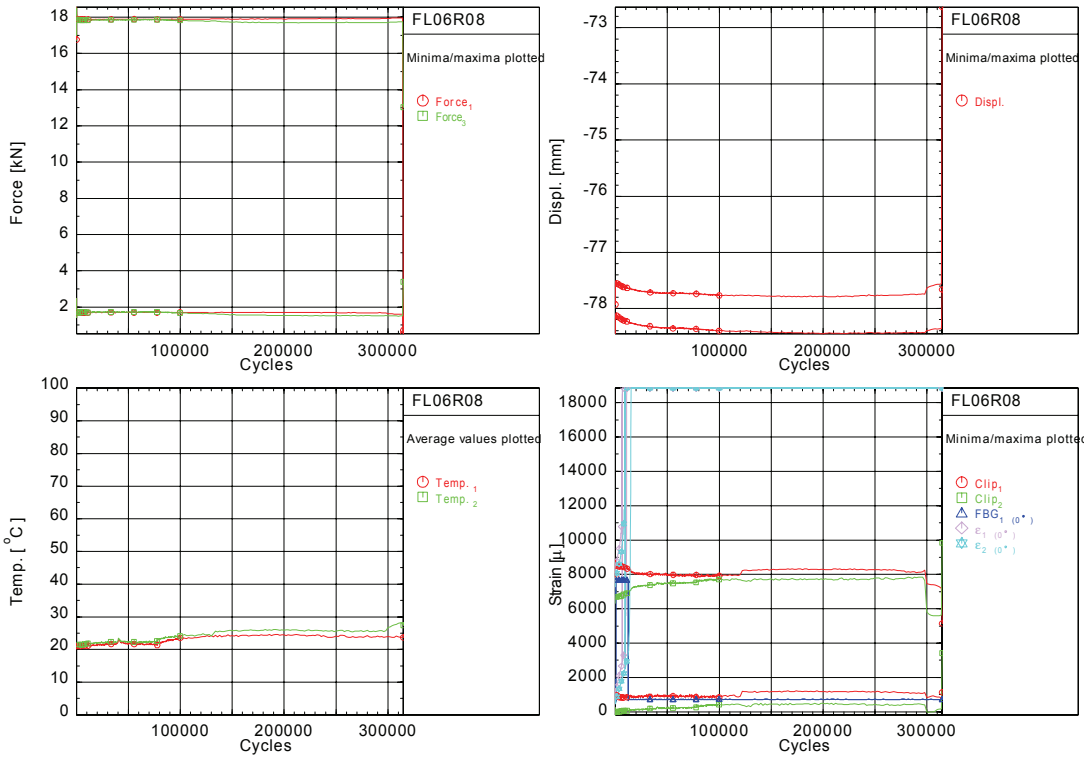


Figure E - 13: FL06R08 (fatigue summary)

Remarks: Good correlation between strain measurements, FBG lost early

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	17.9	1.7	17.9				
$Force_3$ [kN]	17.9	1.7	17.8				
Displ. [mm]	-77.54	-78.13	-77.56				
$Clip_1$ [µ]	8627.	908.	8540.				
$Clip_2$ [µ]	6740.	-20.	6677.				
$FBG_{1\ (0^\circ)}$ [µ]	7689.	7661.	7682.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	8715.	1399.	8692.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	8025.	845.	8006.				
σ [MPa]	305.4	28.6	305.4				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	21.3	20.7	21.0
$Temp._2$ [°C]	21.6	21.0	21.3

Files used: M:_MINILAB\projects\eu_ez_upwind\data\FL06R08\FL06R08.nul(Rec.1)

TEST started at: 05-06-08 10:46:21

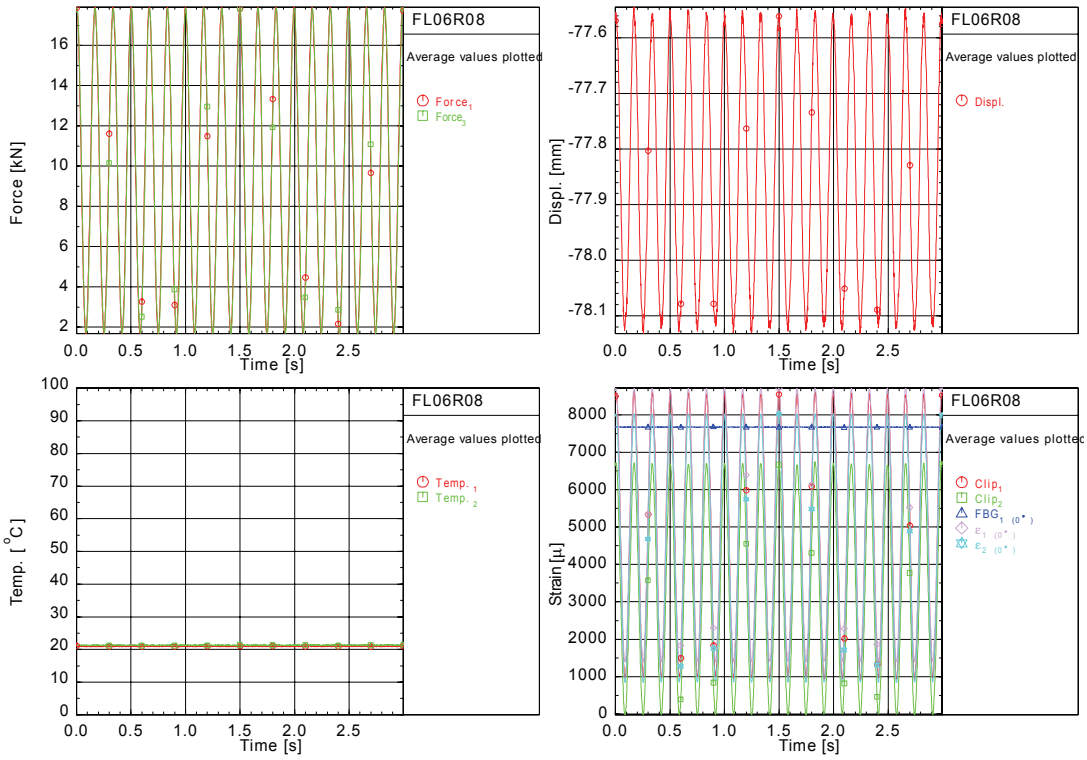


Figure E - 14: FL06R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	17.9	1.7	17.9				
$Force_3$ [kN]	17.9	1.7	17.8				
Displ. [mm]	-77.67	-78.28	-77.67				
$Clip_1$ [μ]	8104.	859.	7997.				
$Clip_2$ [μ]	7319.	108.	7284.				
$FBG_{1\ (0^\circ)}$ [μ]	737.	712.	717.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	18841.	18841.	18841.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	18845.	18845.	18845.				
σ [MPa]	304.9	28.7	304.9				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	21.6	21.1	21.3
$Temp._2$ [°C]	22.2	21.6	21.9

Files used: M:_MINILAB\projects\eu_ez_upwind\data\FL06R08\FL06R08.nul(Rec.1)

TEST started at: 05-06-08 11:38:54

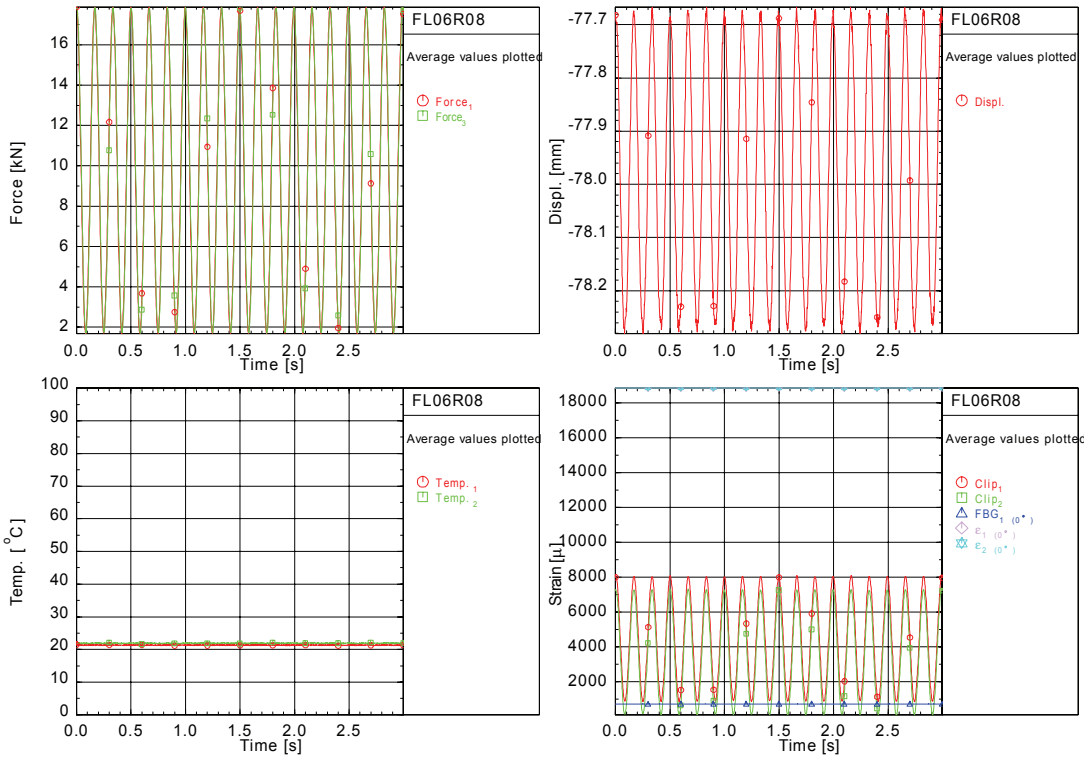


Figure E - 15: FL06R08 (ca. 10,000 cycles)

Remarks: FBG and strain gauges failed

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	17.9	1.6	17.9				
$Force_3$ [kN]	17.7	1.5	17.7				
Displ. [mm]	-77.63	-78.40	-77.64				
$Clip_1$ [µ]	7488.	815.	7459.				
$Clip_2$ [µ]	5858.	-87.	5852.				
$FBG_{1\ (0^\circ)}$ [µ]	737.	714.	731.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	18841.	18841.	18841.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	18845.	18845.	18845.				
σ [MPa]	306.0	27.7	306.0				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.1	23.5	23.7
$Temp._2$ [°C]	27.0	26.5	26.7

Files used: M:_MINILAB\projects\eu_ez_upwind\data\FL06R08\FL06R08.nul(Rec.1)

TEST started at: 06-06-08 00:33:28

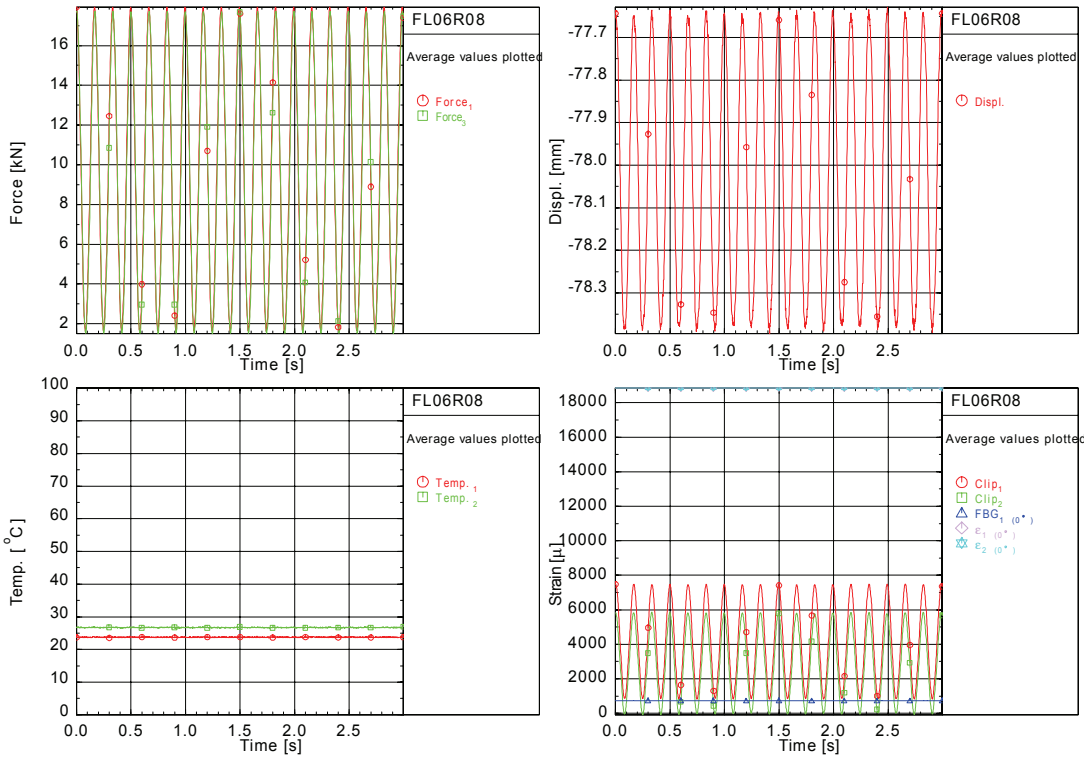


Figure E - 16: FL06R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	G [GPa]
Force$_1$ [kN]	3.1	-3.0	3.1	
Force$_3$ [kN]	3.0	-3.2	2.9	
Displ. [mm]	-76.87	-77.09	-76.88	
Clip$_1$ [μ]	2474.	-130.	2457.	
Clip$_2$ [μ]	193.	-2502.	165.	
smart1 [μ]	1209.	-1486.	1203.	
$\varepsilon_{1\ (\sigma^+)}$ [μ]	1506.	-1142.	1506.	
$\varepsilon_{2\ (\sigma^+)}$ [μ]	943.	-1663.	943.	
σ [MPa]	52.4	-51.7	52.4	

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [$^\circ$C]	24.4	23.9	24.1
Temp.$_2$ [$^\circ$C]	26.3	25.7	26.0

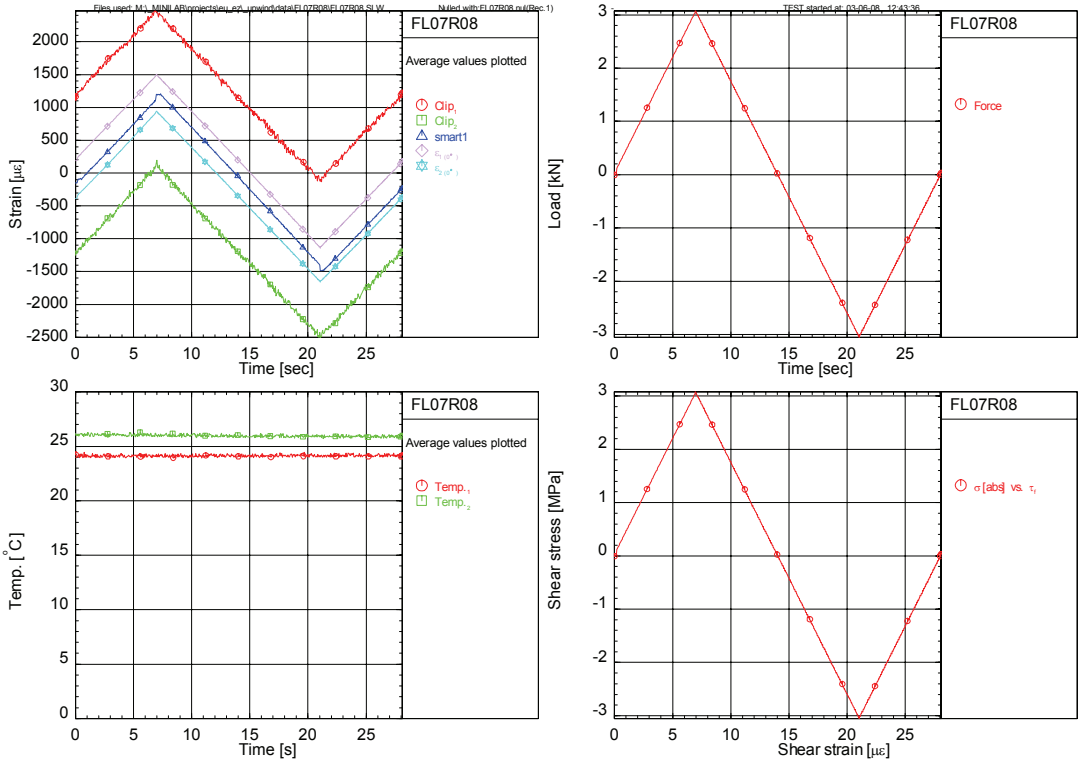


Figure E - 17: FL07R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
$Force_1$ [kN]	19.8	2.0	20.5	-1.5	0.0		
$Force_3$ [kN]	19.8	1.9	20.4	-1.3	0.0		
Displ. [mm]	-75.78	-76.54	-75.26	-76.70	50.16		
$Clip_1$ [µ]	10284.	2624.	11469.	1447.	96.		
$Clip_2$ [µ]	8334.	134.	9119.	-1202.	103.		
smart1 [µ]	6096.	-408.	9033.	-2570.	2.		
$\varepsilon_{1\ (0^\circ)}$ [µ]	18211.	17910.	18309.	1085.	-1.		
$\varepsilon_{2\ (0^\circ)}$ [µ]	18362.	18127.	18479.	562.	-4.		
σ [MPa]	335.8	33.2	348.9	-24.6	-0.1		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.2	22.2	24.7
$Temp._2$ [°C]	28.0	23.3	26.6

Number of Cycles 309987.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\FL07R08\FL07R08.nul(Rec.1)

TEST started at: 03-06-08 12:26:32

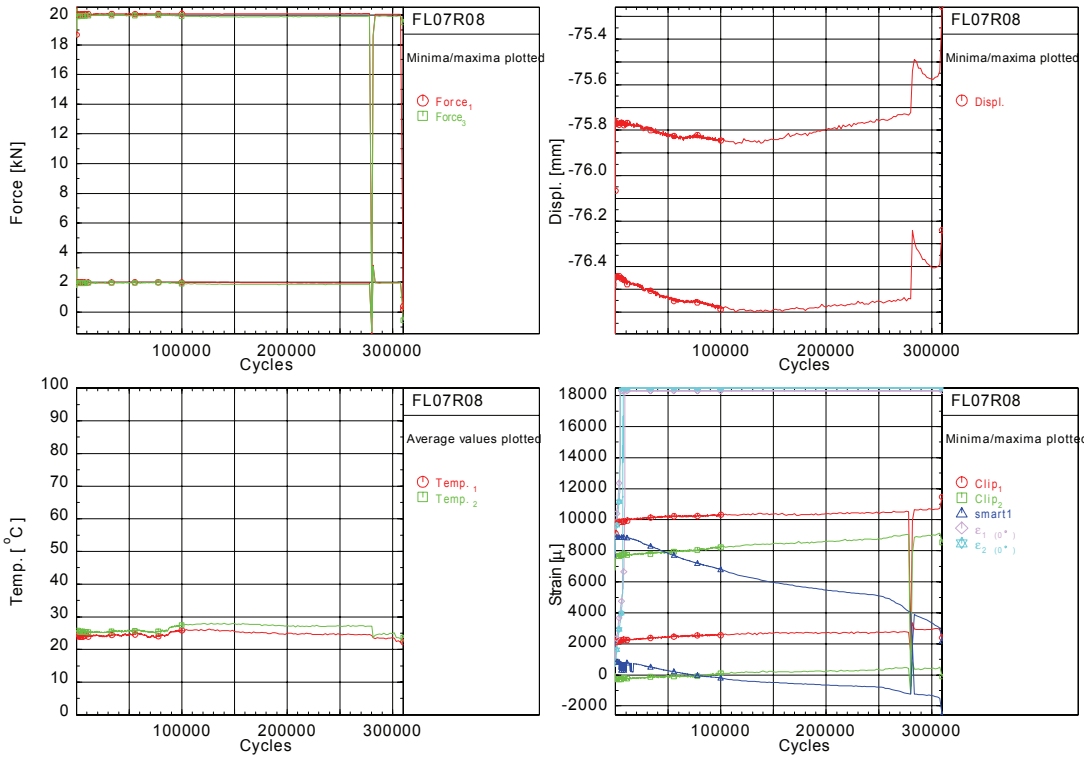


Figure E - 18: FL07R08 (fatigue summary)

Remarks: FBG lost gradually

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	20.0	2.0	20.0				
$Force_3$ [kN]	19.9	1.9	19.9				
Displ. [mm]	-75.77	-76.45	-75.78				
$Clip_1$ [μ]	9822.	2095.	9805.				
$Clip_2$ [μ]	7698.	-339.	7563.				
smart1 [μ]	8850.	828.	8464.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	10218.	2187.	10201.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	9474.	1461.	9450.				
σ [MPa]	340.2	34.2	340.2				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.3	23.8	24.0
$Temp._2$ [°C]	26.0	25.4	25.7

Files used: M:_MINILAB\projects\eu_ez_upwind\data\FL07R08\FL07R08.nul(Rec.1)

TEST started at: 03-06-08 12:49:48

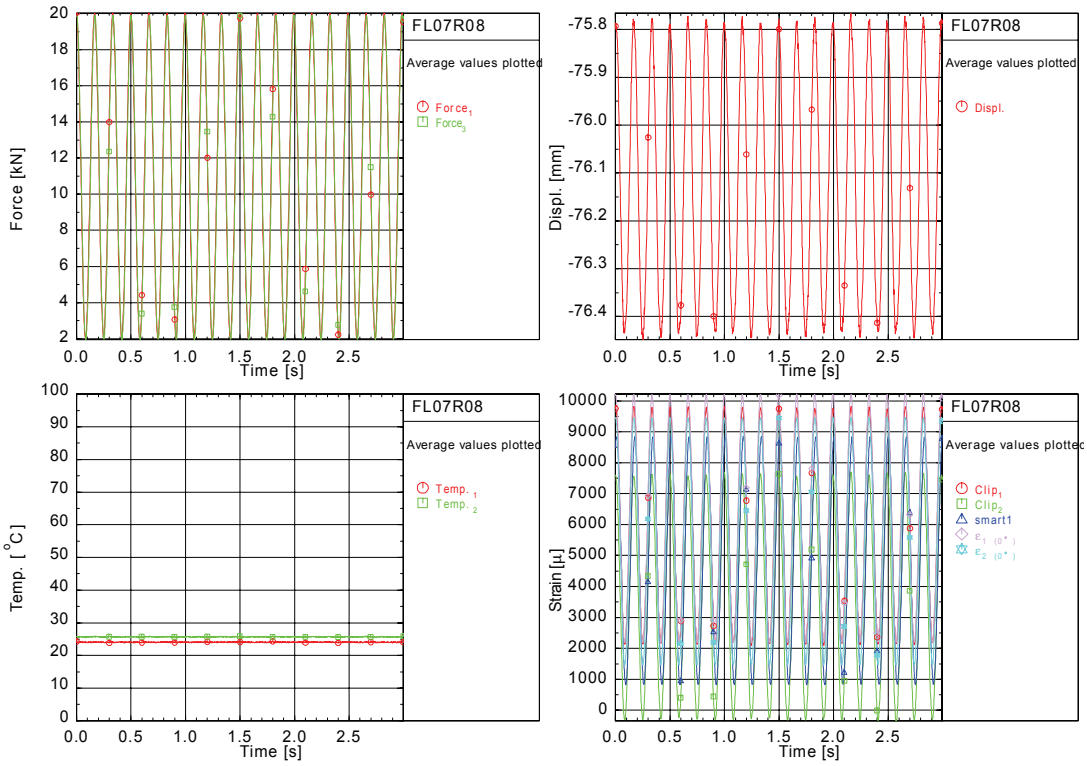


Figure E - 19: FL07R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	20.1	2.0	20.1				
$Force_3$ [kN]	20.0	1.9	19.9				
Displ. [mm]	-75.78	-76.48	-75.79				
$Clip_1$ [μ]	10075.	2244.	10050.				
$Clip_2$ [μ]	7811.	-233.	7775.				
smart1 [μ]	8685.	689.	8237.				
$\varepsilon_{1\ (0^\circ)}$ [μ]	18309.	18309.	18309.				
$\varepsilon_{2\ (0^\circ)}$ [μ]	18479.	18479.	18479.				
σ [MPa]	340.9	33.6	340.9				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.5	24.0	24.3
$Temp._2$ [°C]	25.5	25.0	25.3

Files used: M:_MINILAB\projects\eu_ez_upwind\data\FL07R08\FL07R08.nul(Rec.1)

TEST started at: 03-06-08 13:42:21

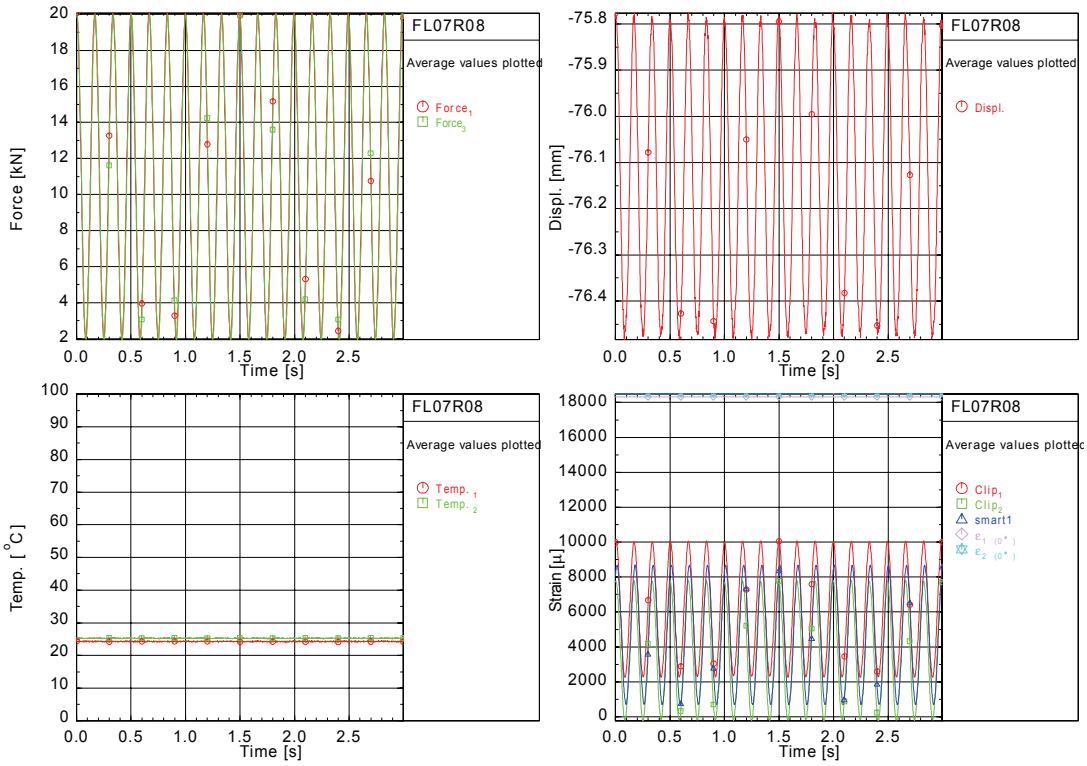


Figure E - 20: FL07R08 (ca. 10,000 cycles)

Remarks: Strain gauges failed

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	20.1	-2.2	20.1				
$Force_3$ [kN]	19.9	-1.3	19.9				
Displ. [mm]	-75.72	-76.72	-75.74				
$Clip_1$ [µ]	10601.	1447.	10557.				
$Clip_2$ [µ]	9110.	-1201.	9094.				
smart1 [µ]	4027.	-3045.	3773.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	18309.	18309.	18309.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	18479.	18479.	18479.				
σ [MPa]	341.6	-37.9	341.6				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.7	24.1	24.4
$Temp._2$ [°C]	27.4	26.9	27.1

Files used: M:_MINILAB\projects\eu_ez_upwind\data\FL07R08\FL07R08.nul(Rec.1)

TEST started at: 04-06-08 01:40:04

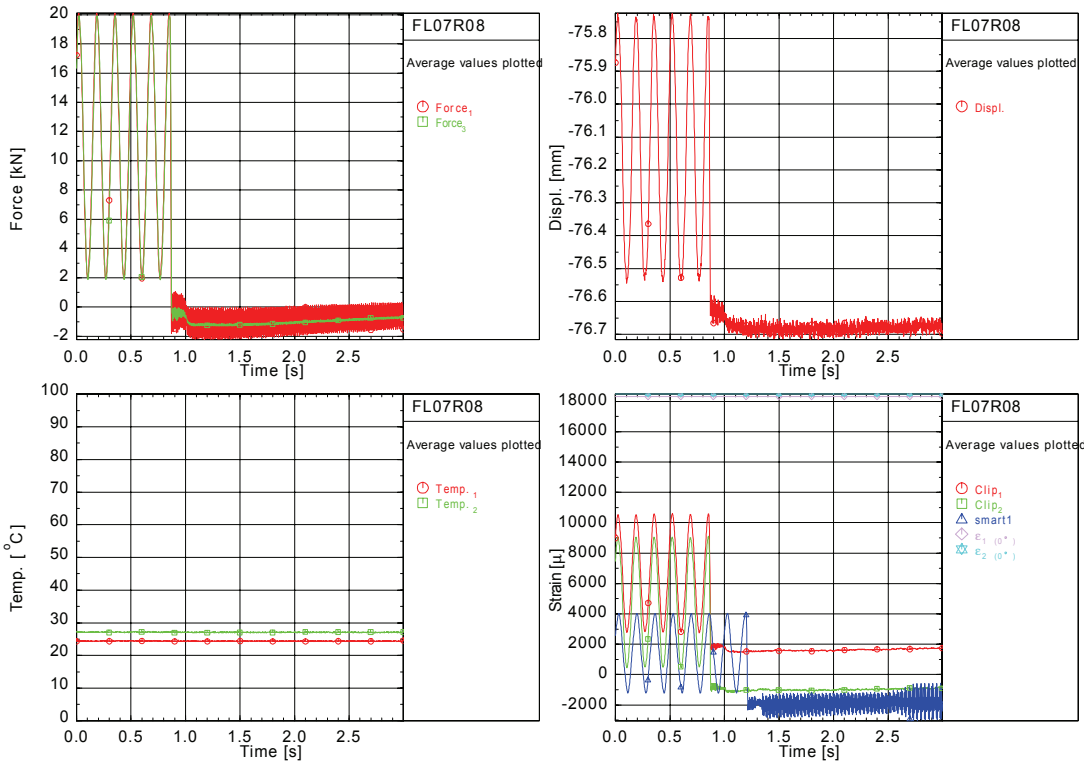


Figure E - 21: FL07R08 (ca. 100,000 cycles)

Remarks: Test interrupted here (280266 cycles)

Channels	Maximum	Minimum	@F_{max}	G [GPa]
Force$_1$ [kN]	8.5	-0.3	8.5	
Force$_3$ [kN]	8.4	-0.4	8.4	
Displ. [mm]	-76.37	-76.72	-76.37	
Clip$_1$ [μ]	3625.	40.	3625.	
Clip$_2$ [μ]	3583.	-729.	3583.	
FBG$_{1\ (\varepsilon^*)}$ [μ]	3528.	-328.	3528.	
$\varepsilon_{1\ (\varepsilon^*)}$ [μ]	3484.	-104.	3484.	
$\varepsilon_{2\ (\varepsilon^*)}$ [μ]	3691.	-578.	3691.	
σ [MPa]	141.0	-4.6	141.0	

Temperatures	Maximum	Minimum	Mean Average
Temp.$_1$ [°C]	26.0	25.5	25.7
Temp.$_2$ [°C]	27.7	27.3	27.4

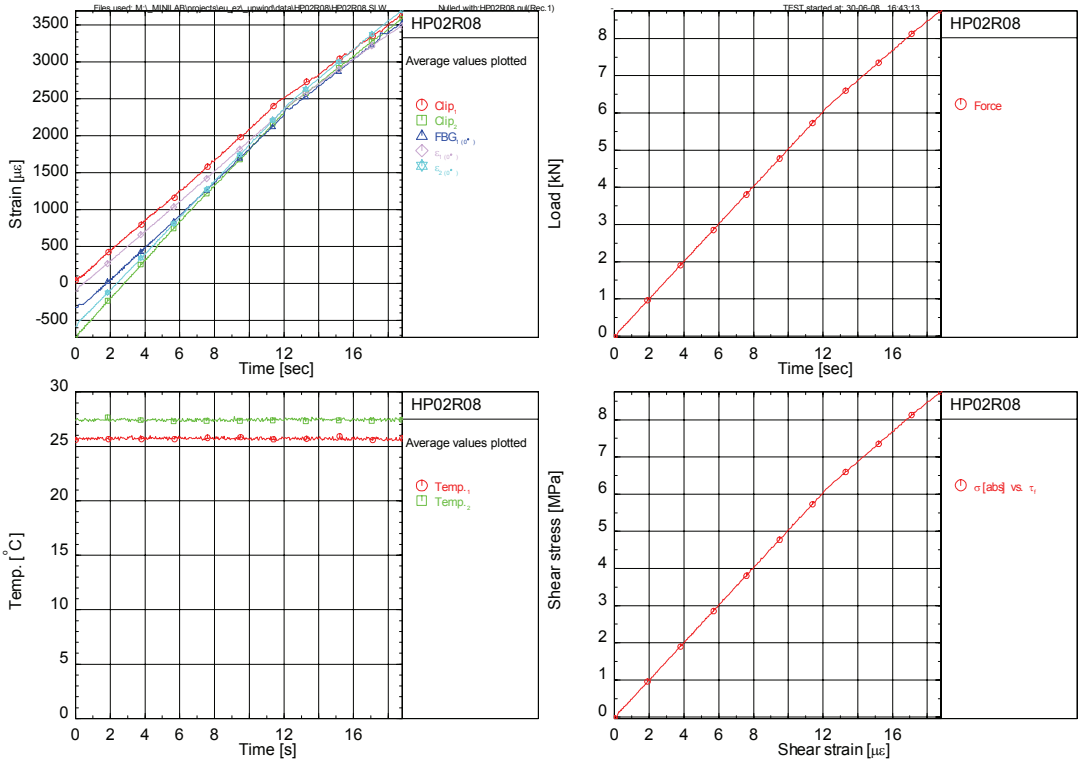


Figure E - 22: HP02R08 (slow ramp)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
$Force_1$ [kN]	19.7	1.8	19.9	0.5	0.2		
$Force_3$ [kN]	19.5	1.6	19.8	1.5	0.0		
Displ. [mm]	-75.87	-76.56	-68.87	-76.60	50.16		
$Clip_1$ [µ]	8468.	908.	8739.	642.	18.		
$Clip_2$ [µ]	9741.	1068.	10622.	-789.	-11.		
$FBG_{1\ (0^\circ)}$ [µ]	9329.	991.	11292.	598.	8.		
$\varepsilon_{1\ (0^\circ)}$ [µ]	17593.	16961.	18011.	745.	2.		
$\varepsilon_{2\ (0^\circ)}$ [µ]	19340.	19046.	19535.	552.	-3.		
σ [MPa]	326.8	29.7	330.0	8.9	4.0		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.8	25.2	26.2
$Temp._2$ [°C]	35.0	27.0	33.7

Number of Cycles 150012.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP02R08\HP02R08.nul(Rec.1)

TEST started at: 30-06-08 16:32:35

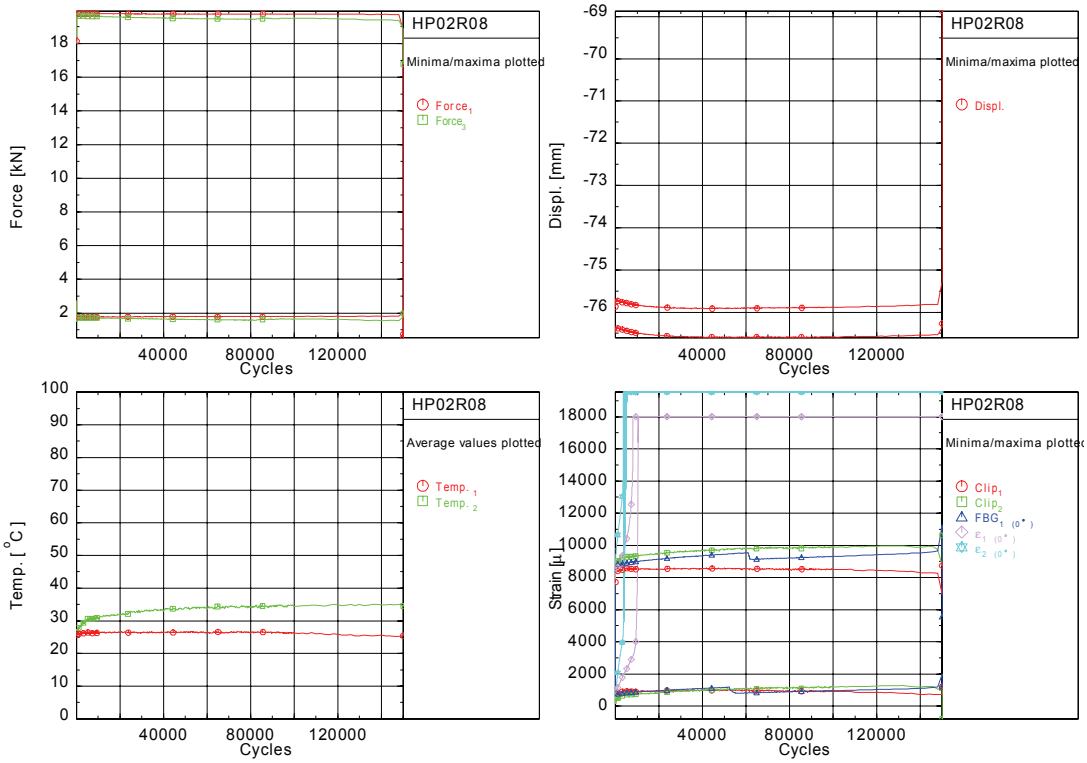


Figure E - 23: HP02R08 (fatigue summary)

FBG good correlation with clip gauge measurements

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	19.8	1.8	19.8				
$Force_3$ [kN]	19.6	1.7	19.6				
Displ. [mm]	-75.72	-76.39	-75.74				
$Clip_1$ [µ]	8460.	802.	8393.				
$Clip_2$ [µ]	8889.	322.	8869.				
$FBG_{1\ (0^\circ)}$ [µ]	8815.	734.	8759.				
$\varepsilon_{1\ (0^\circ)}$ [µ]	8600.	1096.	8586.				
$\varepsilon_{2\ (0^\circ)}$ [µ]	10464.	1875.	10432.				
σ [MPa]	327.4	29.1	327.4				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.3	25.8	26.0
$Temp._2$ [°C]	27.9	27.3	27.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP02R08\HP02R08.nul(Rec.1)

TEST started at: 30-06-08 16:48:26

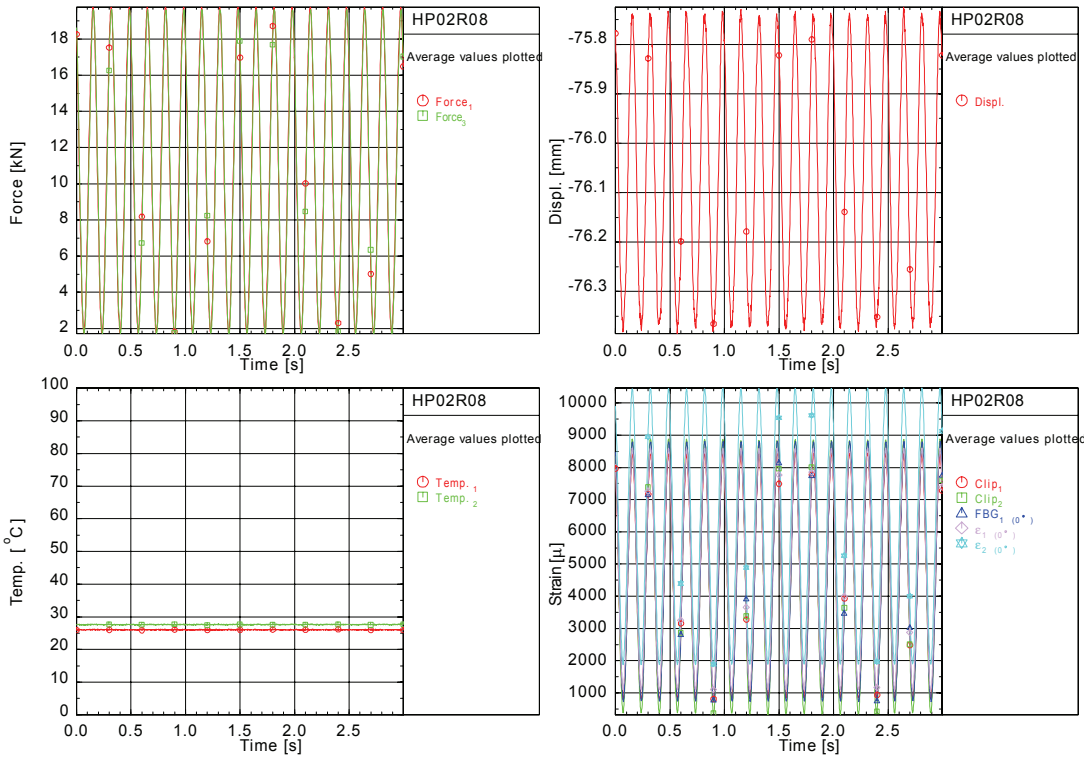


Figure E - 24: HP02R08 (ca. 1,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	19.8	1.8	19.8				
$Force_3$ [kN]	19.6	1.7	19.6				
Displ. [mm]	-75.83	-76.50	-75.84				
$Clip_1$ [µ]	8543.	896.	8506.				
$Clip_2$ [µ]	9351.	738.	9338.				
$FBG_{1\ (0°)}$ [µ]	9010.	865.	8921.				
$\varepsilon_{1\ (0°)}$ [µ]	18011.	7742.	18011.				
$\varepsilon_{2\ (0°)}$ [µ]	19535.	19535.	19535.				
σ [MPa]	327.5	29.2	327.5				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.6	26.1	26.3
$Temp._2$ [°C]	31.0	30.5	30.7

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP02R08\HP02R08.nul(Rec.1)

TEST started at: 30-06-08 17:13:36

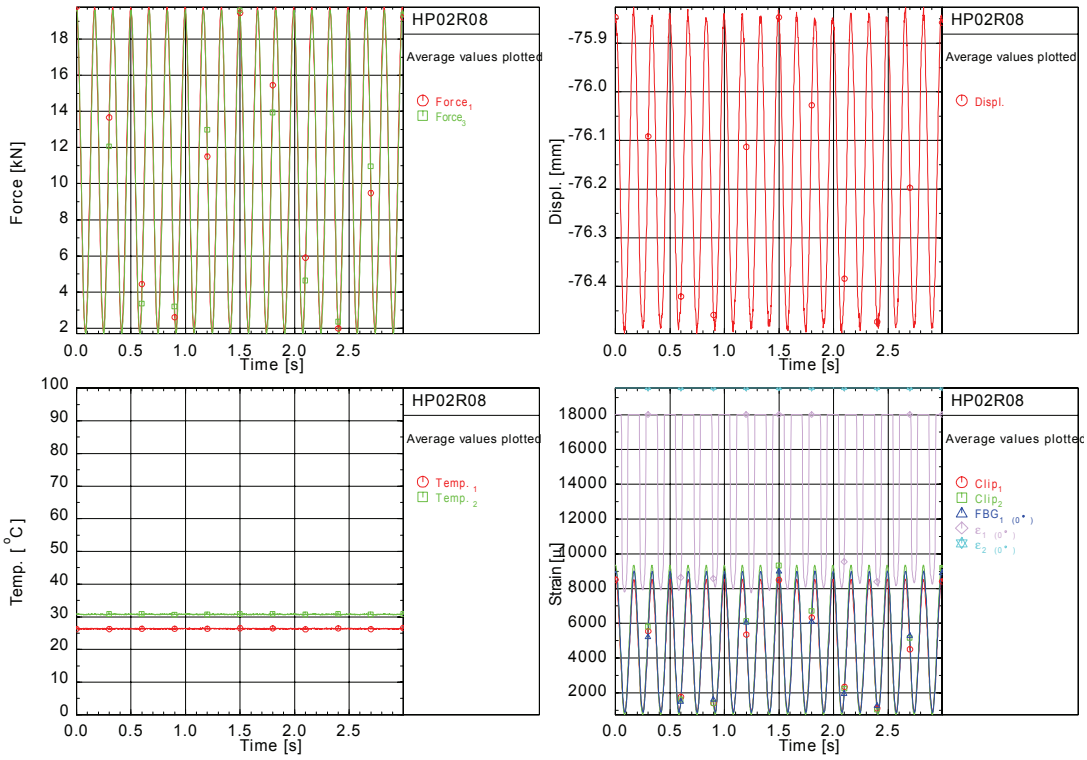


Figure E - 25: HP02R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	$@F_{max}$	E_t [Mpa]	E_c [Mpa]	ν_t [-]	ν_c [-]
$Force_1$ [kN]	19.3	0.4	19.3				
$Force_3$ [kN]	19.0	0.1	18.9				
Displ. [mm]	-68.88	-76.38	-75.35				
$Clip_1$ [µ]	8740.	544.	6738.				
$Clip_2$ [µ]	10622.	-788.	8340.				
$FBG_{1\ (0°)}$ [µ]	13099.	-326.	12579.				
$\varepsilon_{1\ (0°)}$ [µ]	18011.	18011.	18011.				
$\varepsilon_{2\ (0°)}$ [µ]	19535.	19535.	19535.				
σ [MPa]	319.0	6.5	319.0				

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	25.6	25.1	25.3
$Temp._2$ [°C]	34.9	34.3	34.6

Files used: M:_MINILAB\projects\eu_ez_upwind\data\HP02R08.nul(Rec.1)

TEST started at: 30-06-08 23:40:53

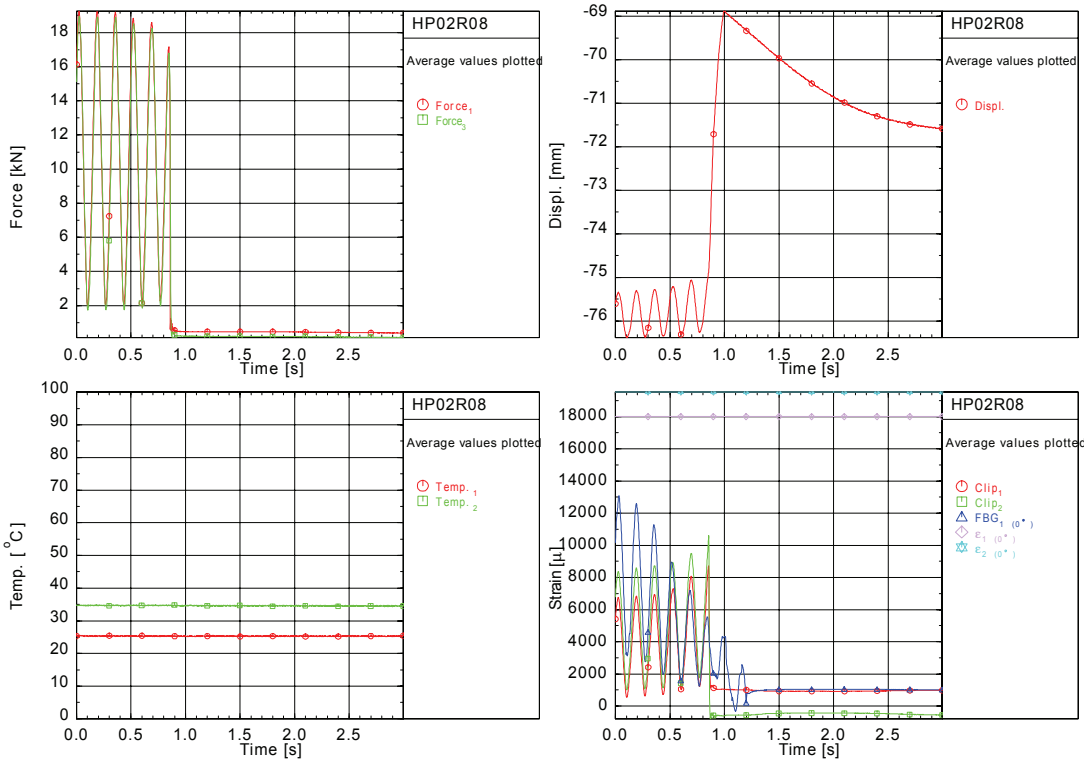


Figure E - 26: HP02R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	18.153	-0.055	18.153	-0.055		
$Force_3$ [kN]	18.2	0.0	18.2	0.0		
Displ. [mm]	-76.95	-78.02	-76.99	-78.01		
$Clip_1$ [µ]	8262.	355.	8262.	377.	40067.	0.
$Clip_2$ [µ]	7177.	-1402.	7177.	-1366.	36710.	0.
$FBG_{1\ (0°)}$ [µ]	7757.	-14.	7757.	-14.	38987.	0.
$\varepsilon_{1\ (0°)}$ [µ]	7935.	77.	7935.	79.	38560.	0.
$\varepsilon_{2\ (0°)}$ [µ]	8107.	-194.	8107.	-191.	36629.	0.
σ [MPa]	294.6	-0.9	294.6	-0.9		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.9	24.3	24.6
$Temp._2$ [°C]	23.2	22.6	22.9

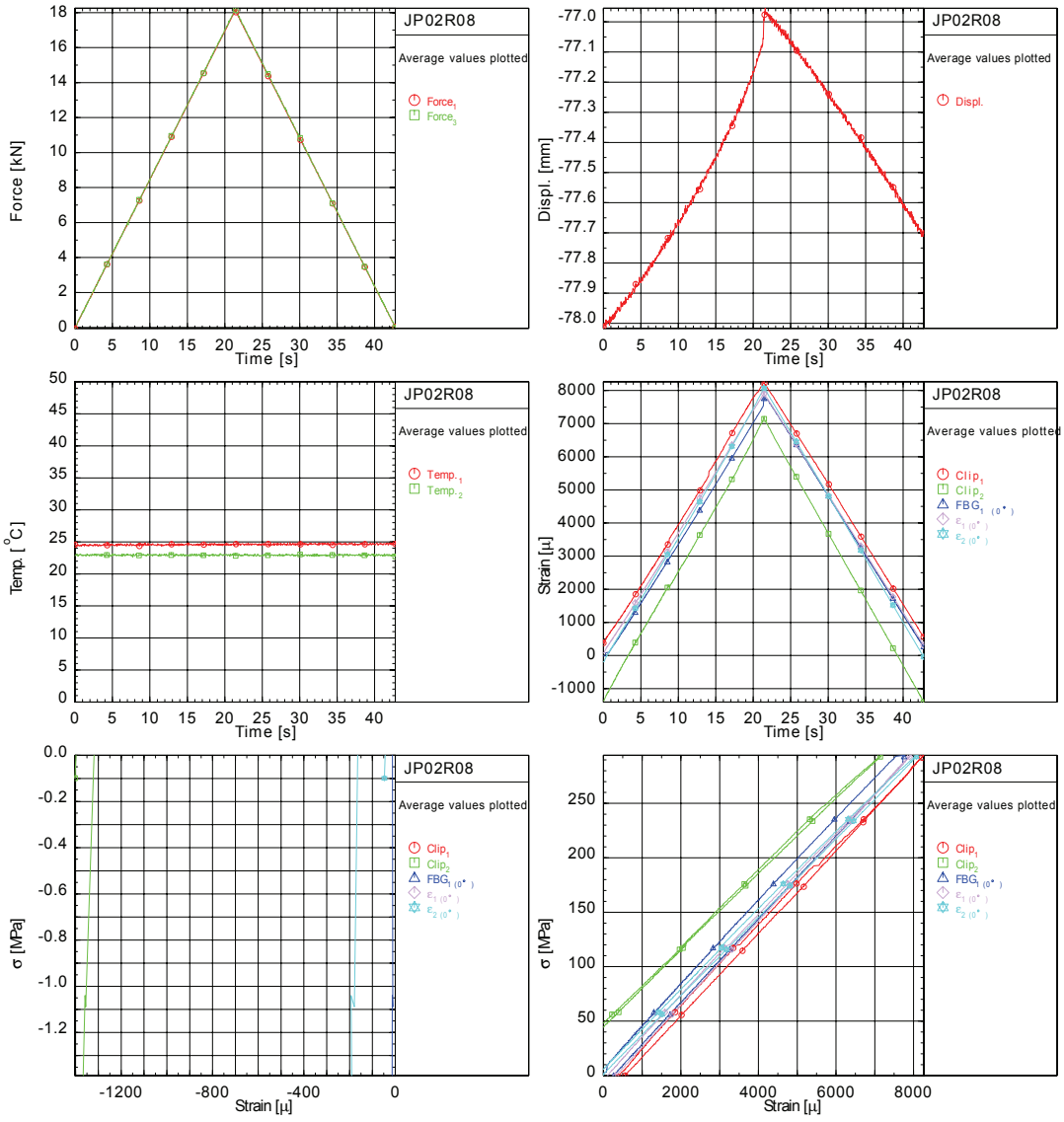


Figure E - 27: JP02R08 (slow cycle)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record
$Force_1$ [kN]	18.033	1.800	18.134	-1.016	-0.031
$Force_3$ [kN]	18.1	1.8	18.3	0.4	0.0
Displ. [mm]	-77.05	-77.79	-74.25	-77.89	50.16
$Clip_1$ [μ]	7833.	966.	8621.	-524.	-3.
$Clip_2$ [μ]	7281.	-432.	8039.	-1135.	-1.
$FBG_{1\ (0°)}$ [μ]	7631.	777.	7922.	-33.	2.
$\varepsilon_{1\ (0°)}$ [μ]	18586.	18498.	18652.	1135.	0.
$\varepsilon_{2\ (0°)}$ [μ]	18853.	18738.	18920.	816.	1.
σ [MPa]	292.6	29.2	294.3	-16.5	-0.5

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	26.2	20.9	22.9
$Temp._2$ [°C]	26.2	21.9	23.5

Number of Cycles	1160246.

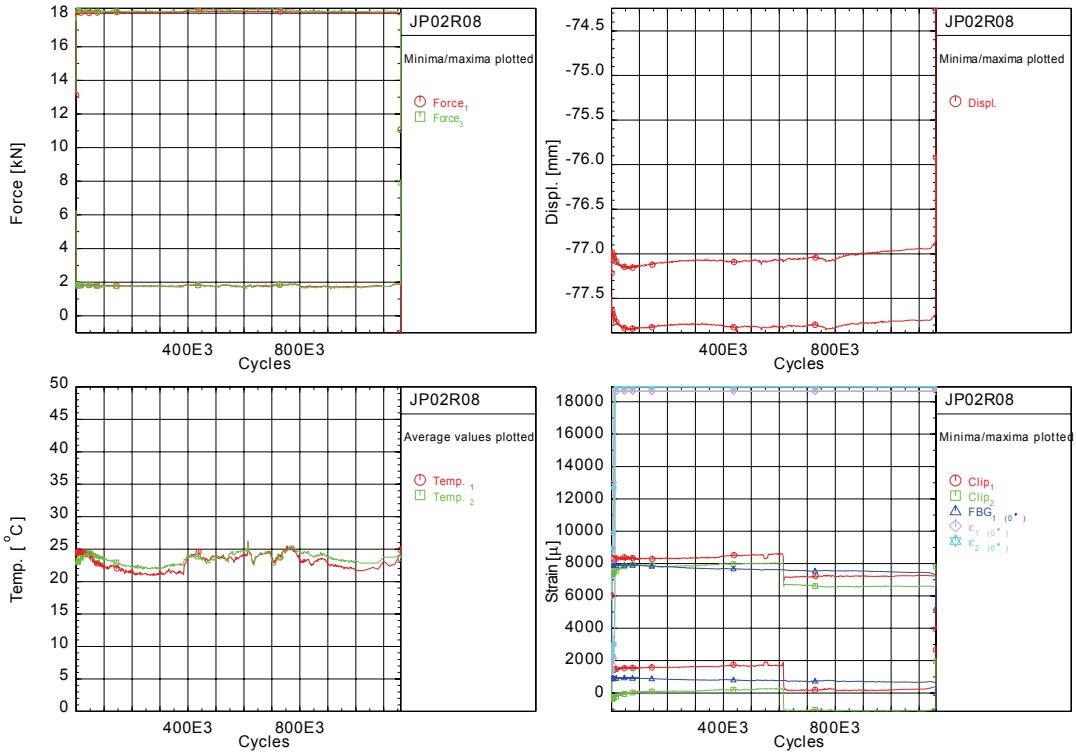


Figure E - 28: JP02R08 (fatigue summary)

FBG good correlation with clip gauges (clip gauges shifted at 6Mcycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	18.08	1.80	18.08	17.91		
$Force_3$ [kN]	18.19	1.77	18.09	17.90		
Displ. [mm]	-76.97	-77.63	-76.98	-76.98		
$Clip_1$ [µ]	8334.	1360.	8316.	8313.		
$Clip_2$ [µ]	7247.	-419.	7213.	7223.		
$FBG_{1\ (0°)}$ [µ]	7871.	873.	4767.	4265.		
$\varepsilon_{1\ (0°)}$ [µ]	8091.	1269.	8080.	8065.		
$\varepsilon_{2\ (0°)}$ [µ]	8472.	1125.	8452.	8341.		
σ [MPa]	293.6	29.3	293.6	290.8		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.5	24.0	24.3
$Temp._2$ [°C]	23.2	22.7	23.0

Area of cross-section 61.60

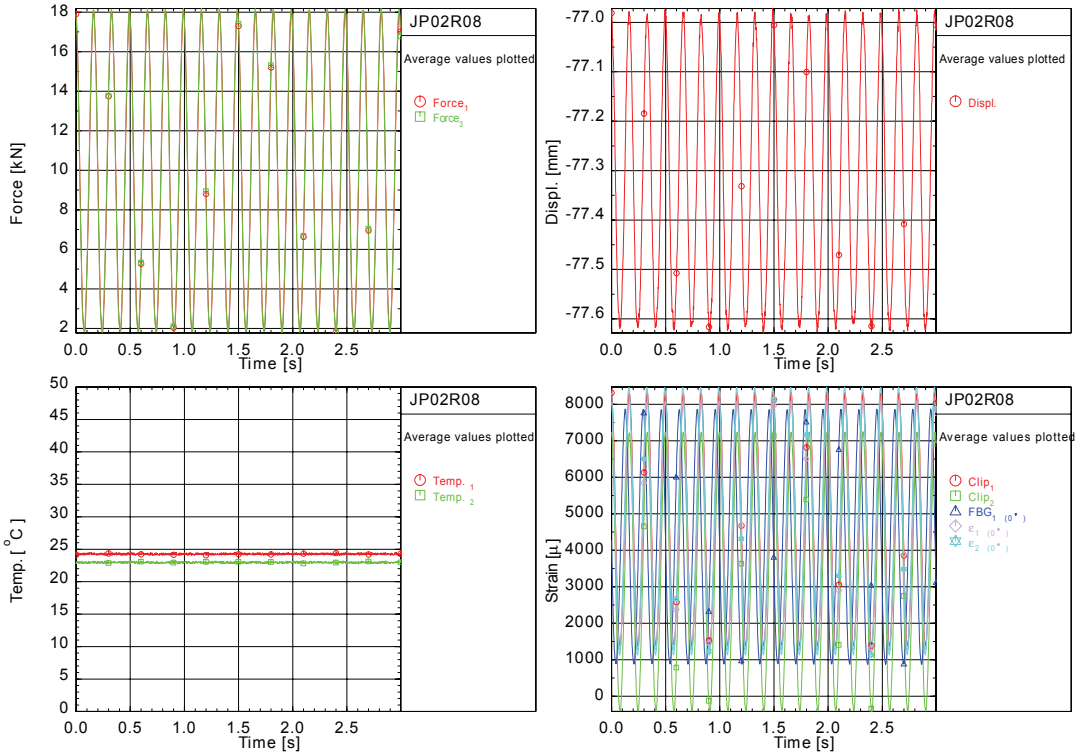


Figure E - 29: JP02R08 (ca. 1000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	18.10	1.81	18.10	17.92		
$Force_3$ [kN]	18.19	1.79	18.14	17.90		
Displ. [mm]	-77.05	-77.73	-77.06	-77.07		
$Clip_1$ [μ]	8372.	1399.	8317.	8280.		
$Clip_2$ [μ]	7488.	-271.	7451.	7470.		
$FBG_{1\ (0°)}$ [μ]	7893.	893.	4869.	4345.		
$\varepsilon_{1\ (0°)}$ [μ]	18652.	2886.	18652.	18652.		
$\varepsilon_{2\ (0°)}$ [μ]	18920.	3611.	18920.	18920.		
σ [MPa]	293.8	29.3	293.8	291.0		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	24.7	24.2	24.4
$Temp._2$ [°C]	23.5	22.9	23.3

Area of cross-section 61.60

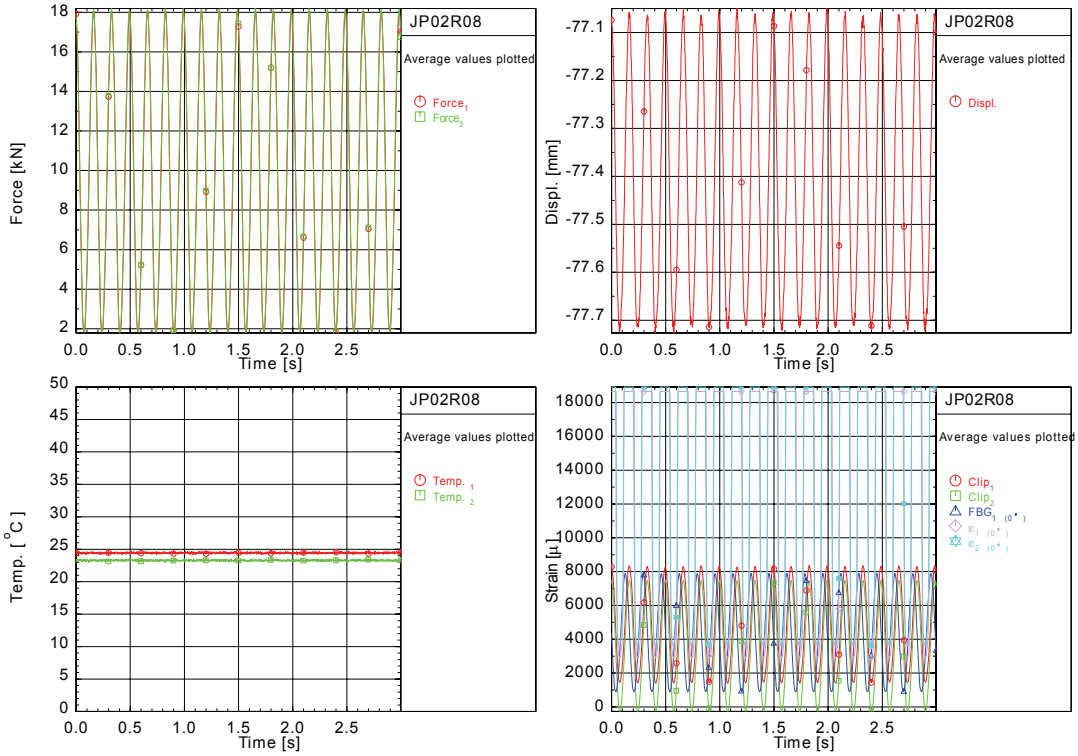


Figure E - 30: JP02R08 (ca. 10,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	18.06	1.77	18.06	18.01		
$Force_3$ [kN]	18.11	1.72	18.05	17.93		
Displ. [mm]	-77.14	-77.84	-77.14	-77.14		
$Clip_1$ [µ]	8330.	1531.	8296.	8303.		
$Clip_2$ [µ]	7922.	60.	7872.	7908.		
$FBG_{1\ (0°)}$ [µ]	7885.	898.	5002.	4724.		
$\varepsilon_{1\ (0°)}$ [µ]	18652.	18652.	18652.	18652.		
$\varepsilon_{2\ (0°)}$ [µ]	18920.	18920.	18920.	18920.		
σ [MPa]	293.2	28.7	293.2	292.3		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	22.4	21.9	22.2
$Temp._2$ [°C]	23.7	23.2	23.5

Area of cross-section 61.60

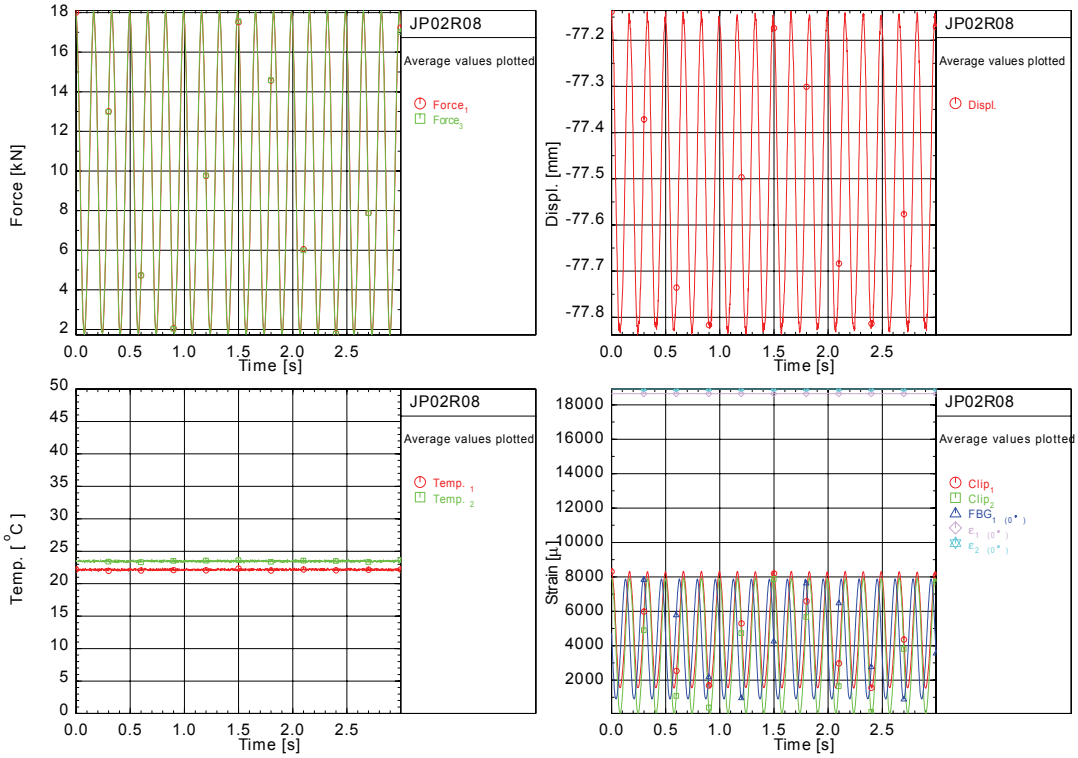


Figure E - 31: JP02R08 (ca. 100,000 cycles)

Channels	Maximum	Minimum	@F_{max}	@start	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	18.05	1.70	18.05	17.90		
$Force_3$ [kN]	18.14	1.67	18.03	17.83		
Displ. [mm]	-76.95	-77.76	-76.97	-76.97		
$Clip_1$ [µ]	7223.	146.	7198.	7199.		
$Clip_2$ [µ]	6608.	-1096.	6547.	6592.		
$FBG_{1\ (0°)}$ [µ]	7492.	659.	4845.	4274.		
$\varepsilon_{1\ (0°)}$ [µ]	18652.	18652.	18652.	18652.		
$\varepsilon_{2\ (0°)}$ [µ]	18920.	18920.	18920.	18920.		
σ [MPa]	293.0	27.5	293.0	290.6		

Temperatures	Maximum	Minimum	Mean Average
$Temp._1$ [°C]	22.0	21.5	21.7
$Temp._2$ [°C]	23.2	22.7	22.9

Area of cross-section 61.60

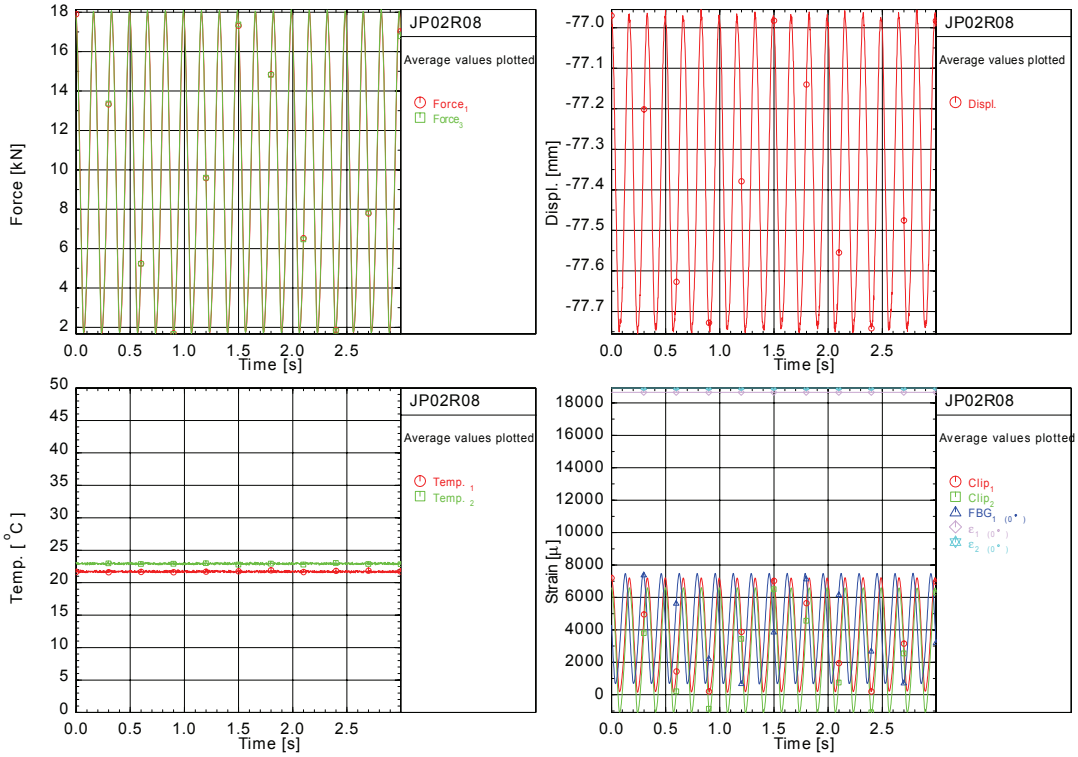


Figure E - 32: JP02R08 (ca. 1,000,000 cycles)

Channels	Maximum	Minimum	@F_{max}	E_t [Mpa]	E_c [Mpa]
$Force_1$ [kN]	5.507	******	******		
Displ. [mm]	0.35	-0.60	-0.53		
$\varepsilon_{1\ (0^\circ)}$ [μ]	8099.	0.	4091.	0.	0.
$\varepsilon_{2\ (0^\circ)}$ [μ]	2205.	-5673.	-5672.	35051.	33996.
σ [MPa]	89.2	-184.1	-184.1		
Bending [μ/mm]	3281.41	0.38	3210.85		

Temperatures	Maximum	Minimum	Mean Average
$Temp._2$ [°C]	60.2	59.6	59.9

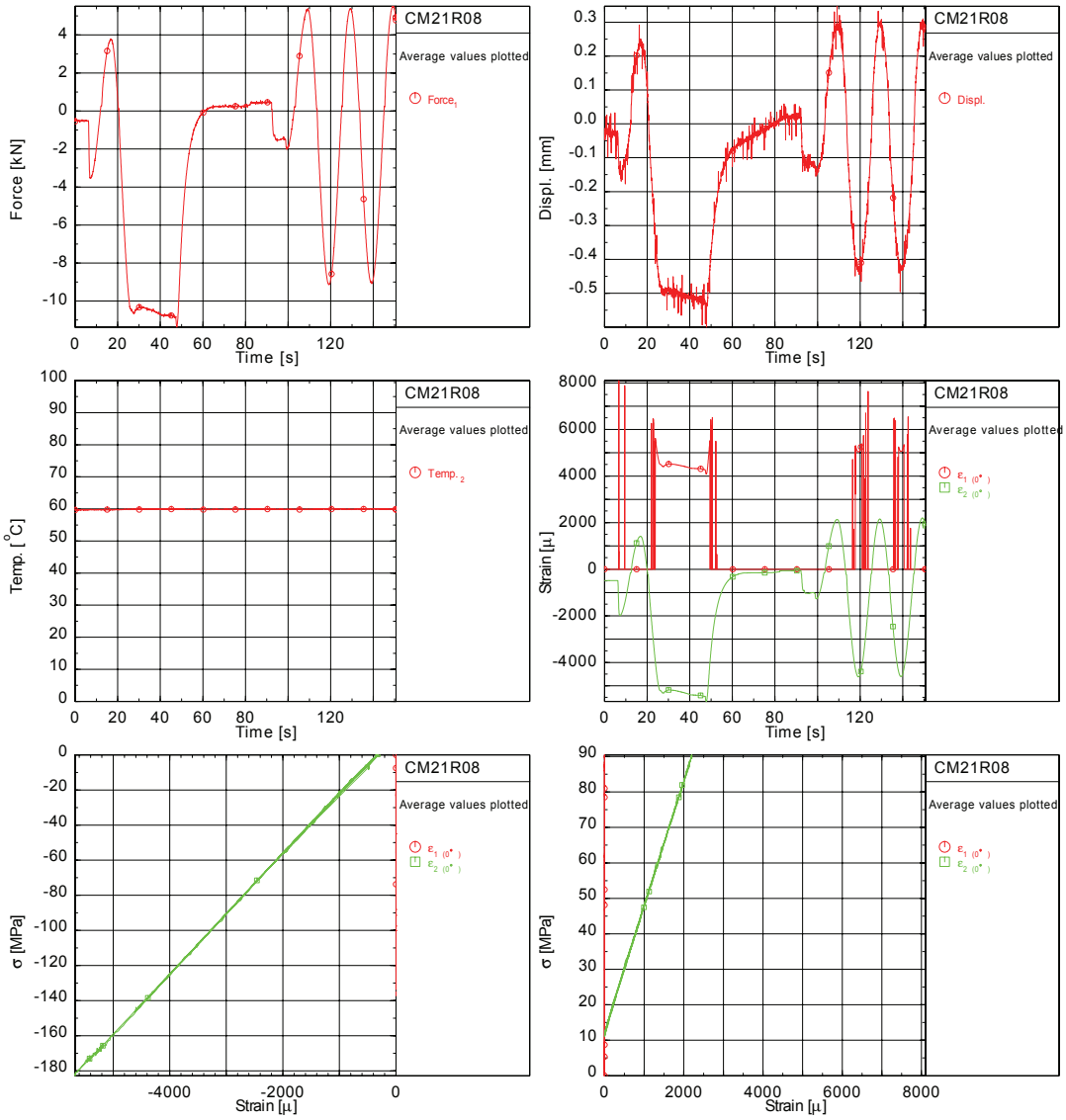


Figure E - 33: CM21R08 (slow cycles)

Channels	Mean maximum	Mean minimum	Maximum	Minimum	Null record	ν_t [-]	ν_c [-]
Force$_1$ [kN]	31.4	3.4	32.0	3.1	0.1		
Displ. [mm]	3.04	1.49	3.29	1.03	6.81		
$\varepsilon_{1\ (0^\circ)}$ [μ]	4482.	3292.	38095.	0.	0.		
$\varepsilon_{2\ (0^\circ)}$ [μ]	24881.	18821.	28902.	1758.	2.		
σ [MPa]	508.1	55.1	518.8	49.6	1.3		

Temperatures	Maximum	Minimum	Mean Average
Temp.$_2$ [°C]	63.0	60.1	61.5

Number of Cycles	1426.

Files used: M:_MINILAB\projects\eu_ez_upwind\data\CM21R08\CM21R08.nul(Rec.1)

TEST started at: 15-10-08 09:09:59

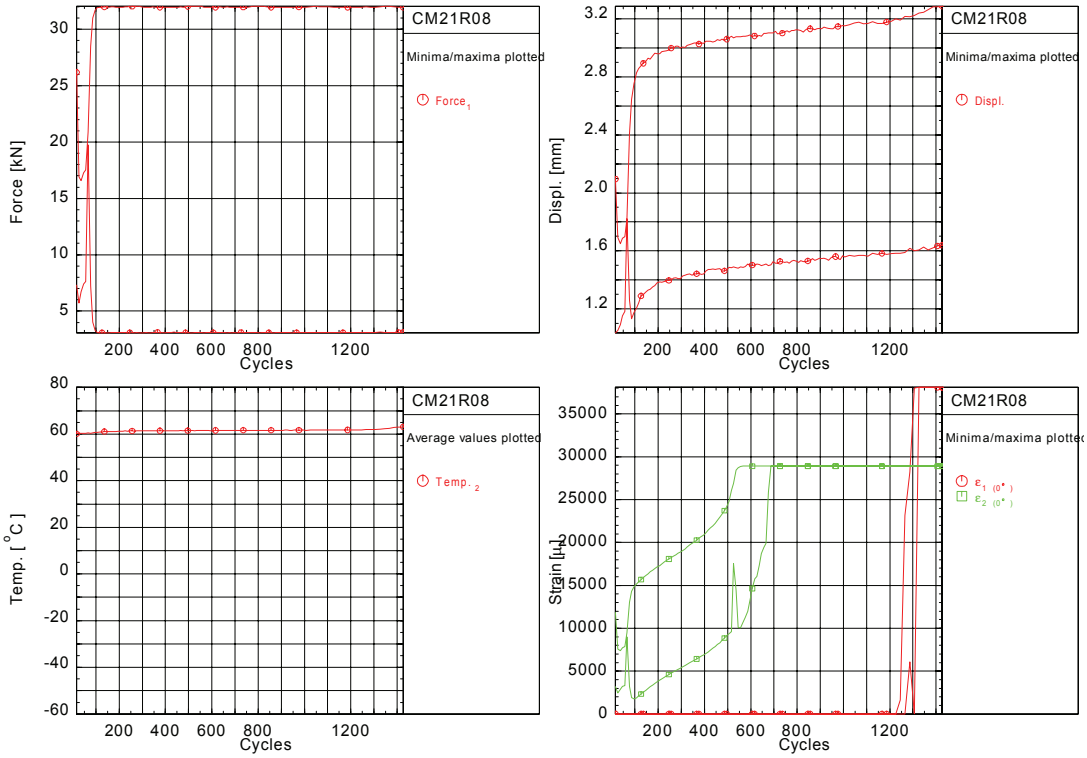


Figure E - 34: CM21R08 (fatigue summary)