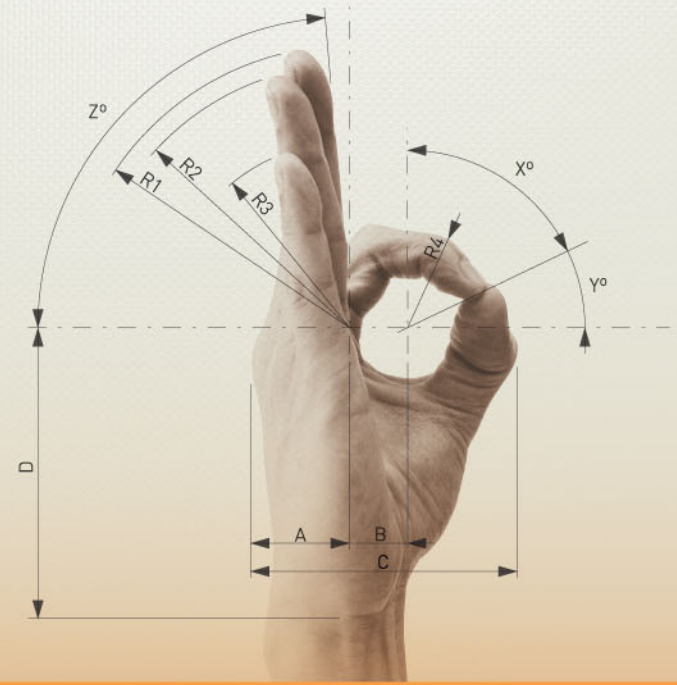


Determination of Crack Growth Rate Curves in Mode II Tests by Means of the Compliance Real Time Monitoring

J. Renart, L. Carreras, J. Costa, A. Turon
COMPTEST 2015, 9th of April 2015



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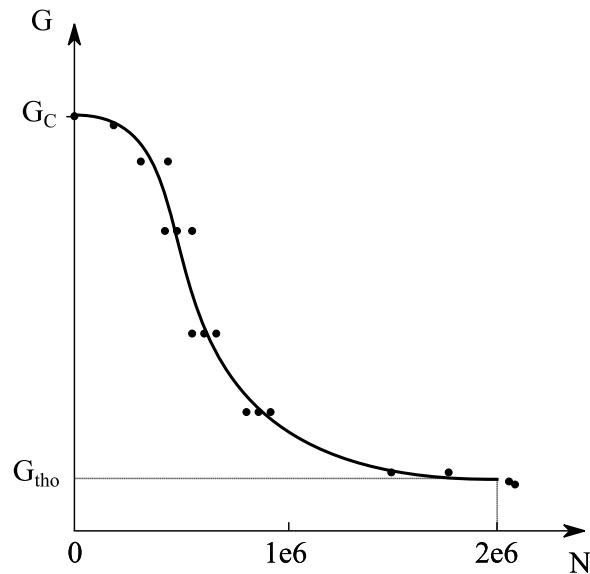
 2: Methodology

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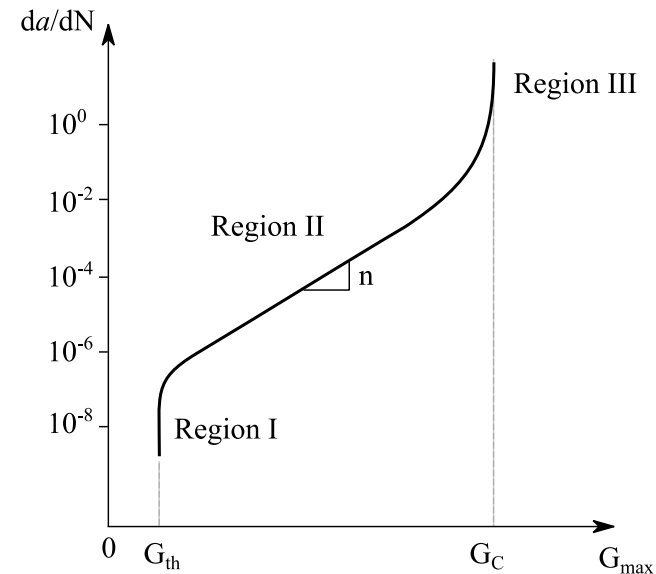
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Introduction: interlaminar fatigue tests

- Interlaminar fatigue tests are used to analyze the composite structures under service conditions
- Typical coupons: DCB, **ENF**, MMB



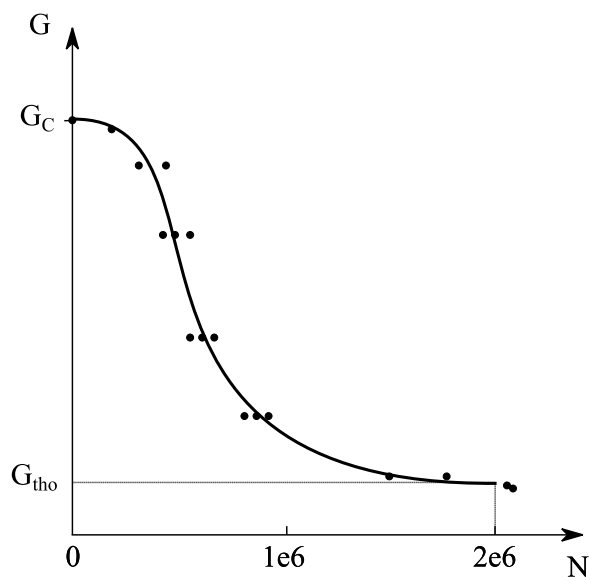
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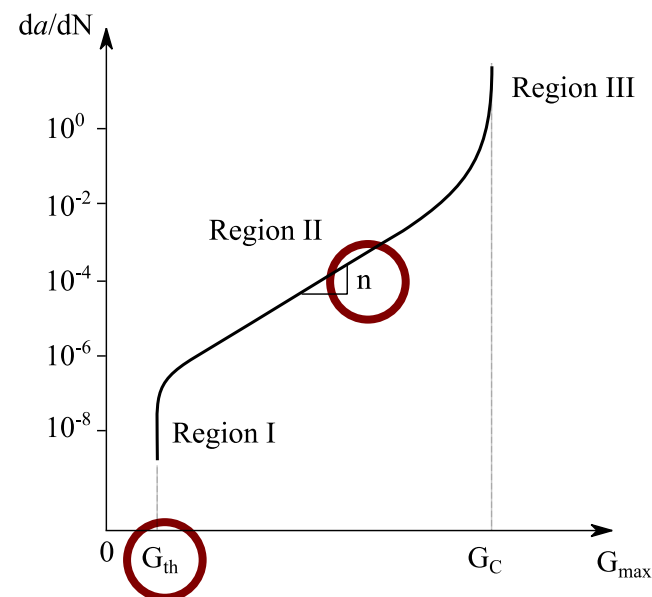
Crack growth rate curves

Introduction: interlaminar fatigue tests

- Interlaminar fatigue tests are used to analyze the composite structures under service conditions
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Onset curves



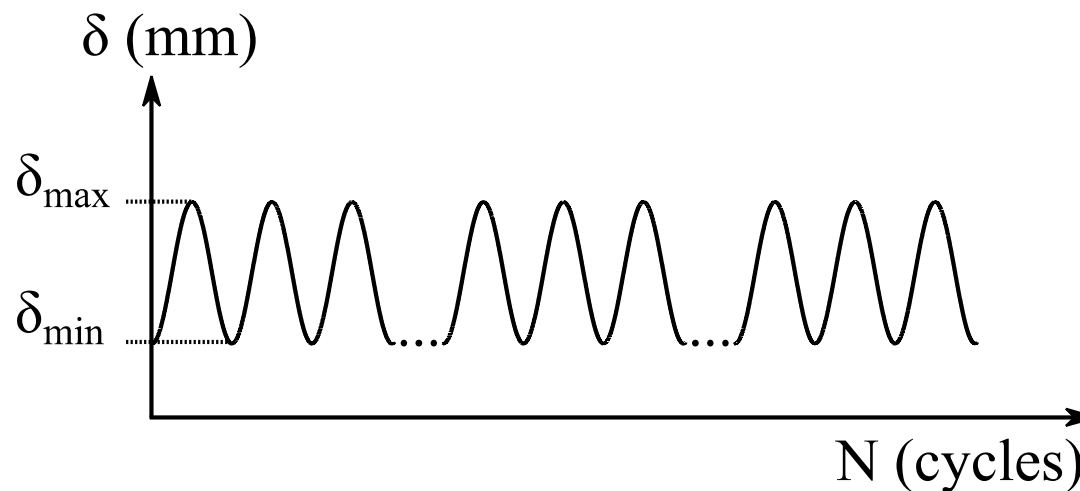
Crack growth rate curves

Introduction: fatigue test methodology

Initial conditions

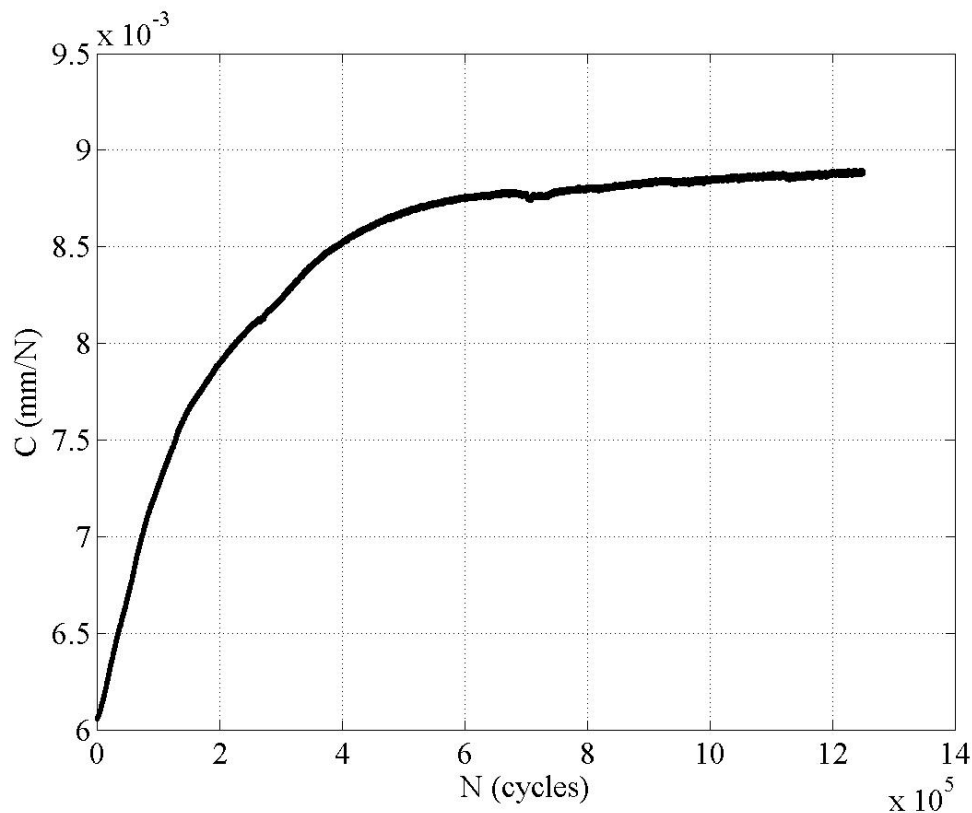
- Percentage of energy release rate, $\%ERR = G_{\max}/G_C$
- Load ratio ($R = P_{\max}/P_{\min} \cong \delta_{\max}/\delta_{\min}$)

Fatigue test under displacement control



Introduction: fatigue test methodology

🏠 The damage in the specimen is measured by an increase in the compliance (C)



🏠 The crack length is estimated with compliance calibration tests

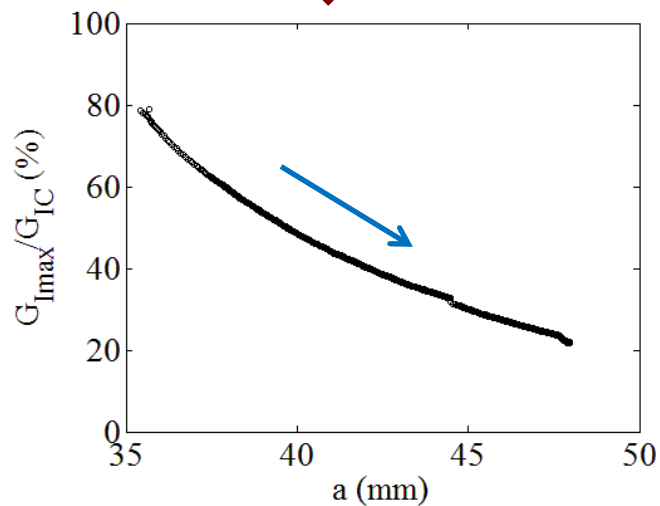
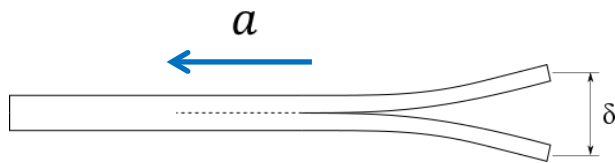
🏠 Real time monitoring of the compliance

- The compliance and the maximum load are monitored continuously at every cycle

Continuous da/dN curve

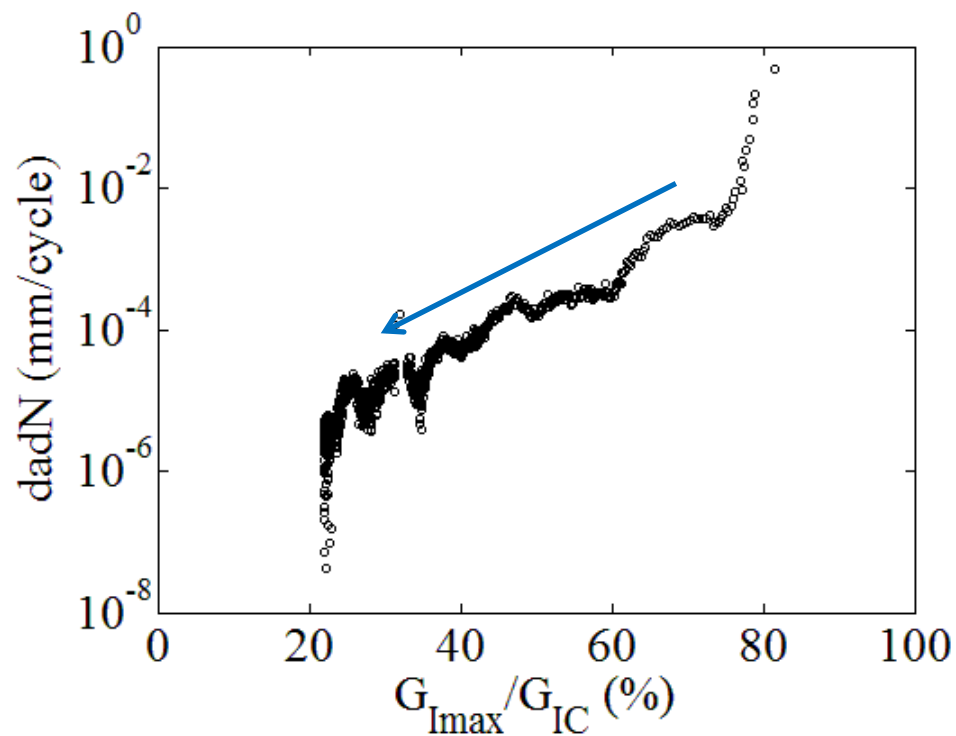
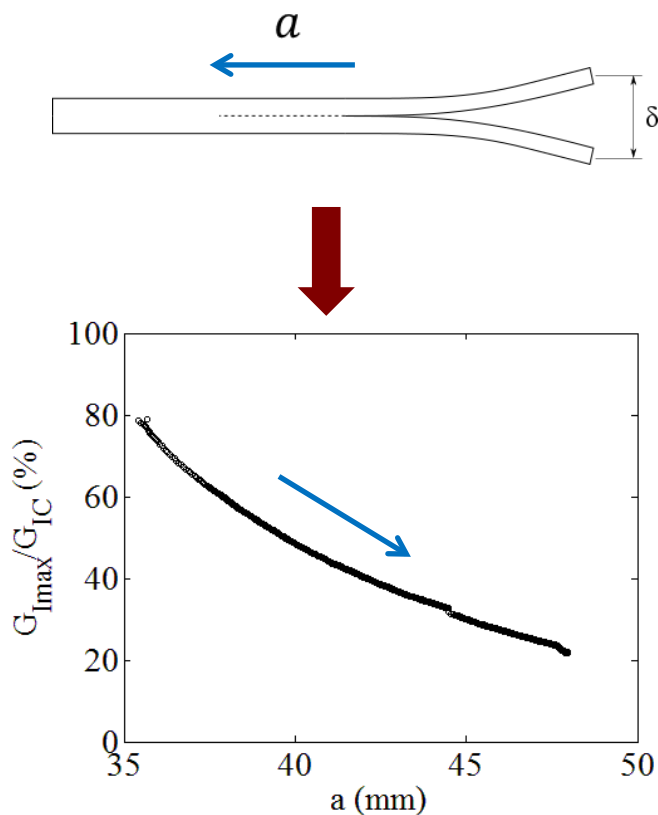
Introduction: fatigue test methodology

DCB fatigue test:



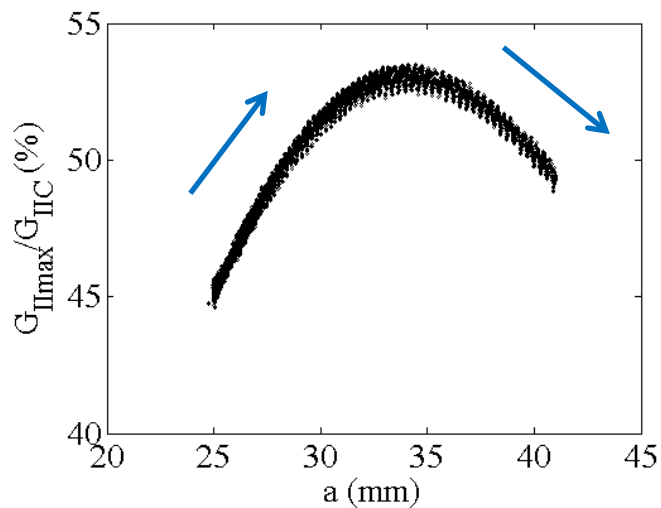
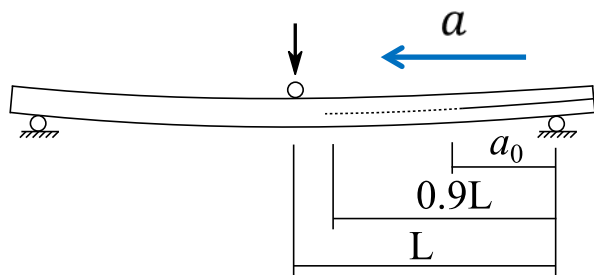
Introduction: fatigue test methodology

DCB fatigue test:



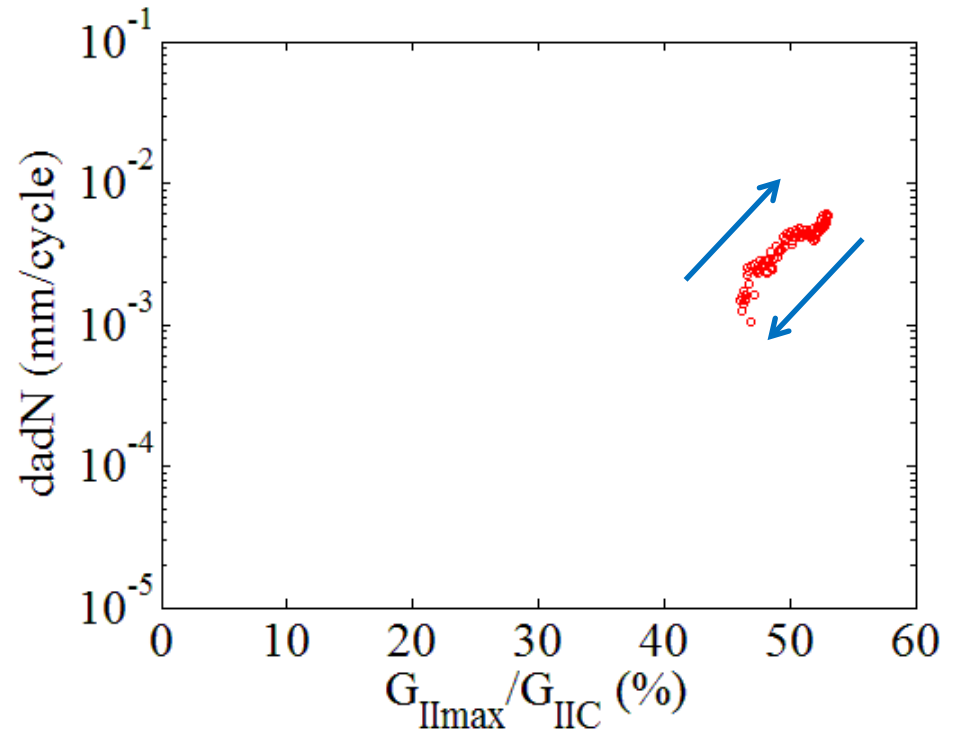
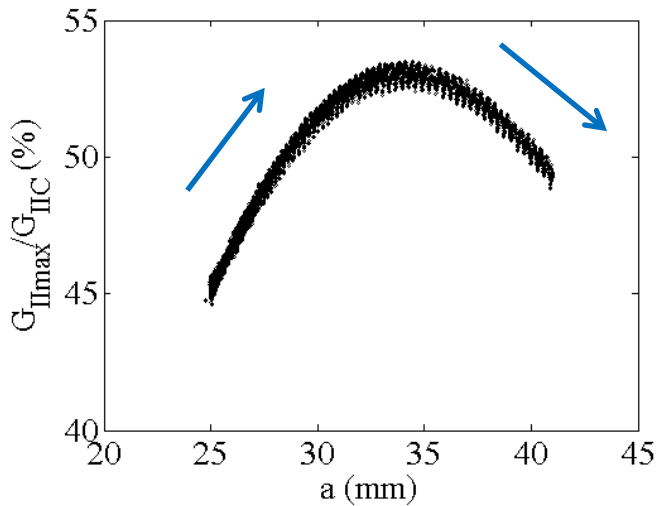
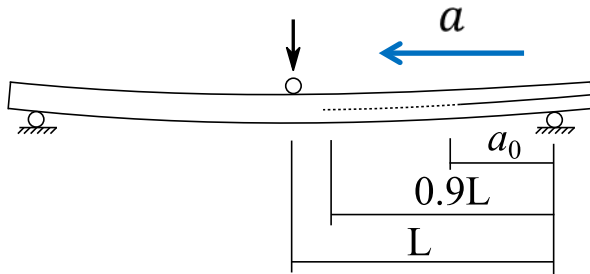
Introduction: fatigue test methodology

ENF fatigue test:



Introduction: fatigue test methodology

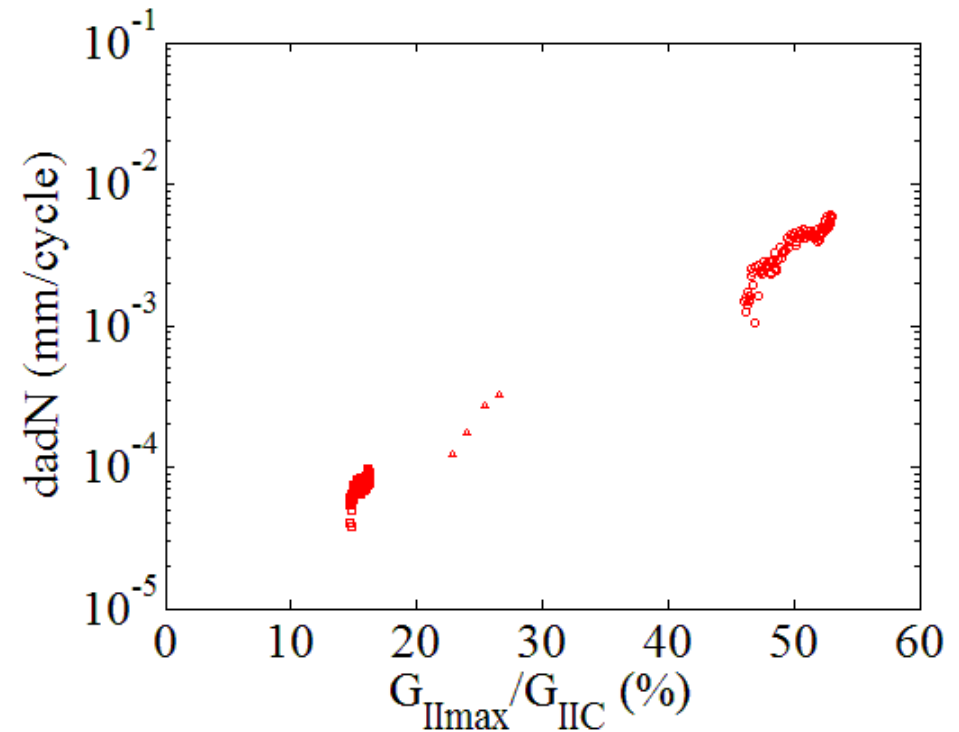
ENF fatigue test:



Introduction: fatigue test methodology

ENF fatigue test:

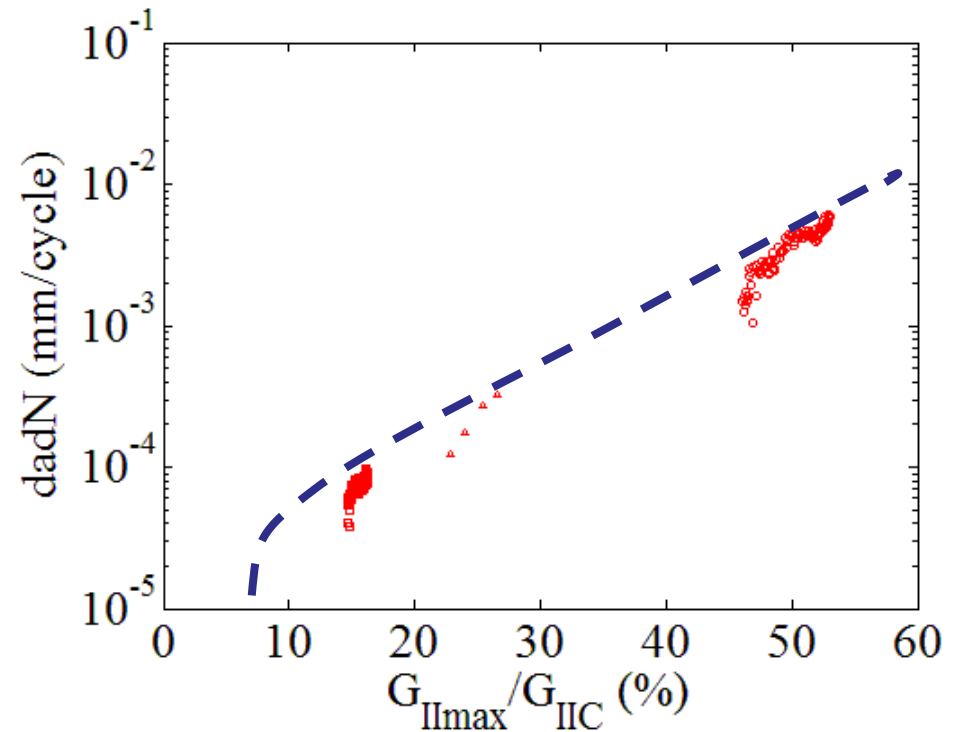
- In order to obtain a whole curve you need to perform a series of tests at different levels of %ERR
- As the data gets closer to the threshold the crack growth segment gets smaller



Introduction: fatigue test methodology

ENF fatigue test:

- In order to obtain a whole curve you need to perform a series of tests at different levels of %ERR
- As the data gets closer to the threshold the crack growth segment gets smaller



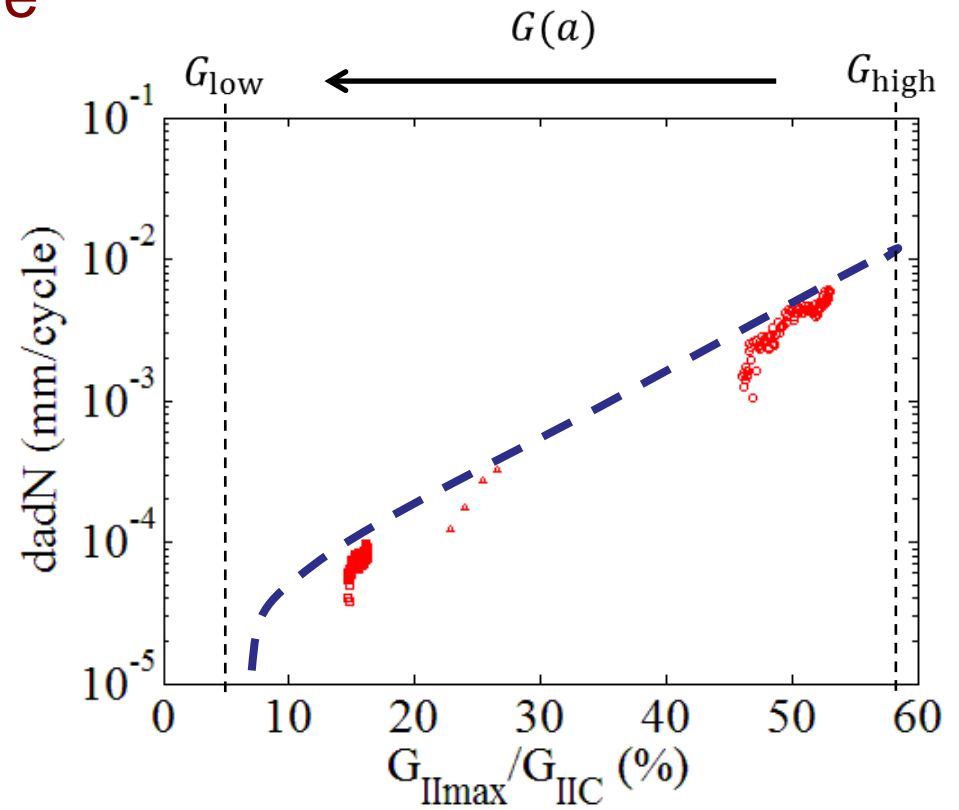
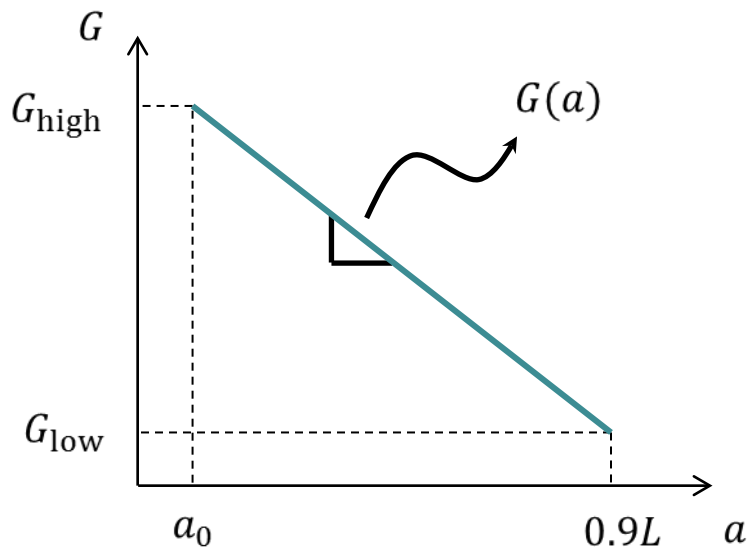
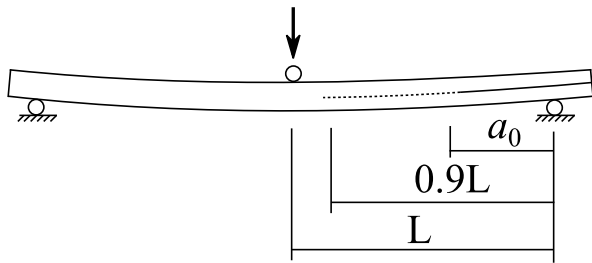
Objective

Cover the full range of the crack growth with a continuous curve
 Determination of the threshold energy release rate

} δ controlled with
 δ variable

Methodology: test procedure

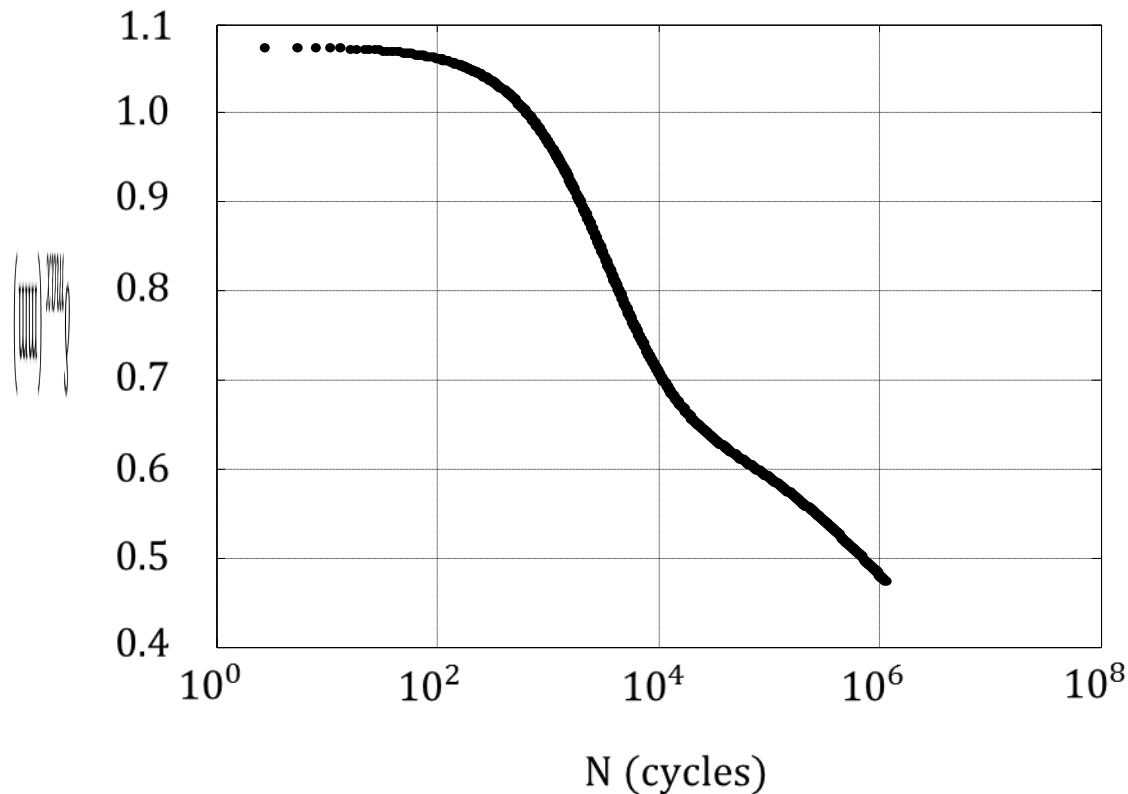
Impose a range of G to measure before the crack arrives to the loading arm.



$\delta(a)$

Methodology: test procedure

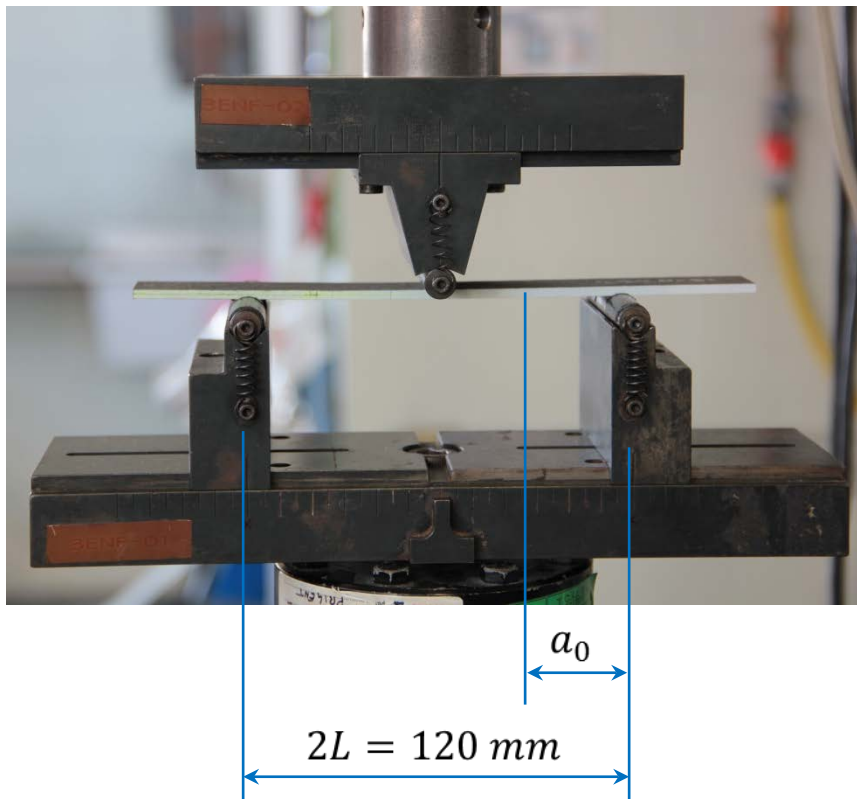
From the estimation of the Paris law slope we obtain $\delta(N)$



The displacement control is performed by an internal variable and the calculated channels option of MTS Test Star software

Results: experimental test set-up

- 🏠 A series of displacement controlled ENF fatigue tests were performed with UD CRFP specimens. Test frequency: 5 Hz
- 🏠 Specimen dimensions (length, width, thickness): 200 x 25 x 3 mm
- 🏠 The half span length was set to $L = 60$ mm



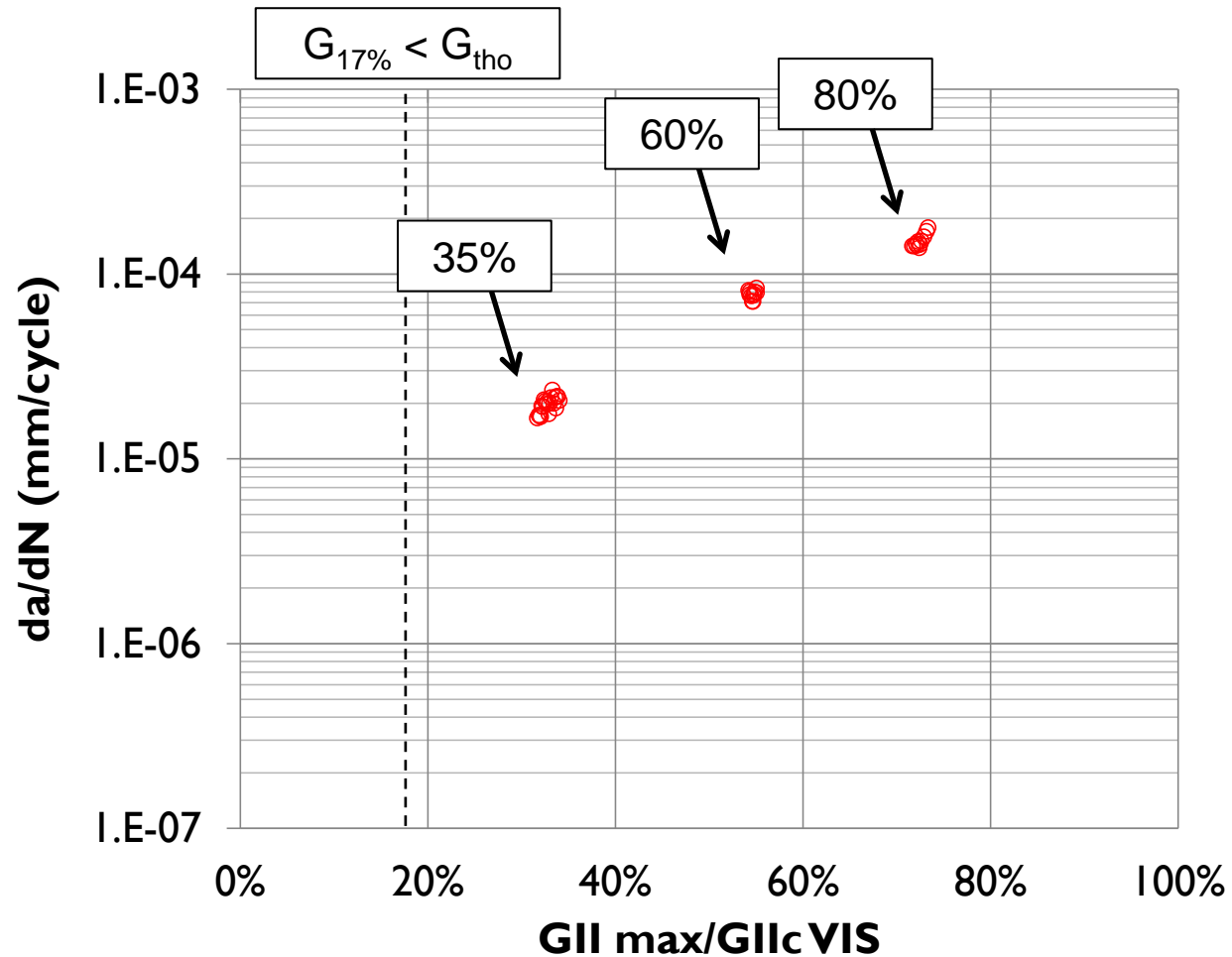
	Constant δ ($a_0 = 45$ mm)	Variable δ ($a_0 = 35$ mm)
% ERR	80% 60% 35% 17%**	80 to 10%* 50 to 10%

* The 10% could not be reached, the crack propagation was greater than expected

** No crack propagation occurred during the test

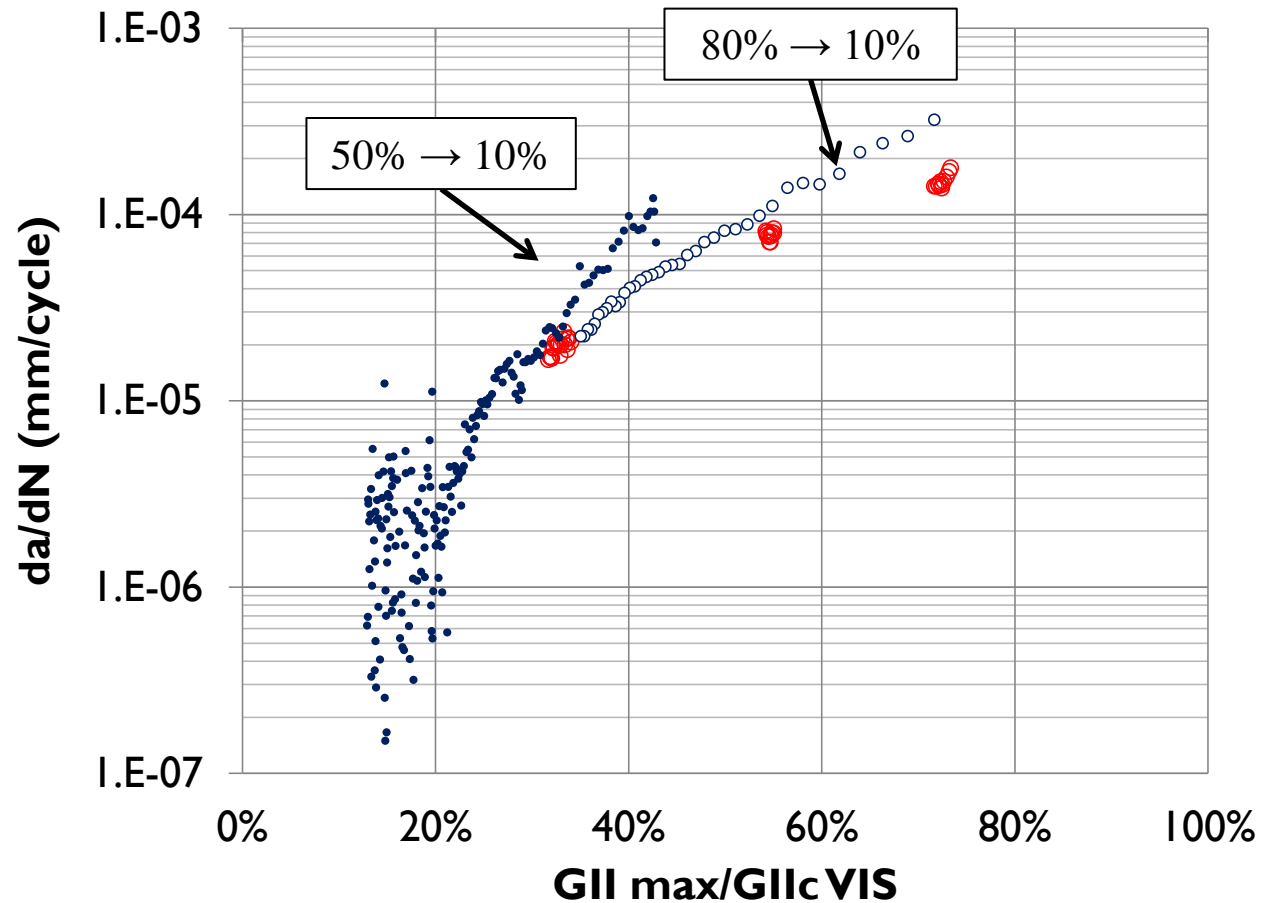
Results: crack growth rate curves

Curves obtained from the fatigue tests at constant displacement



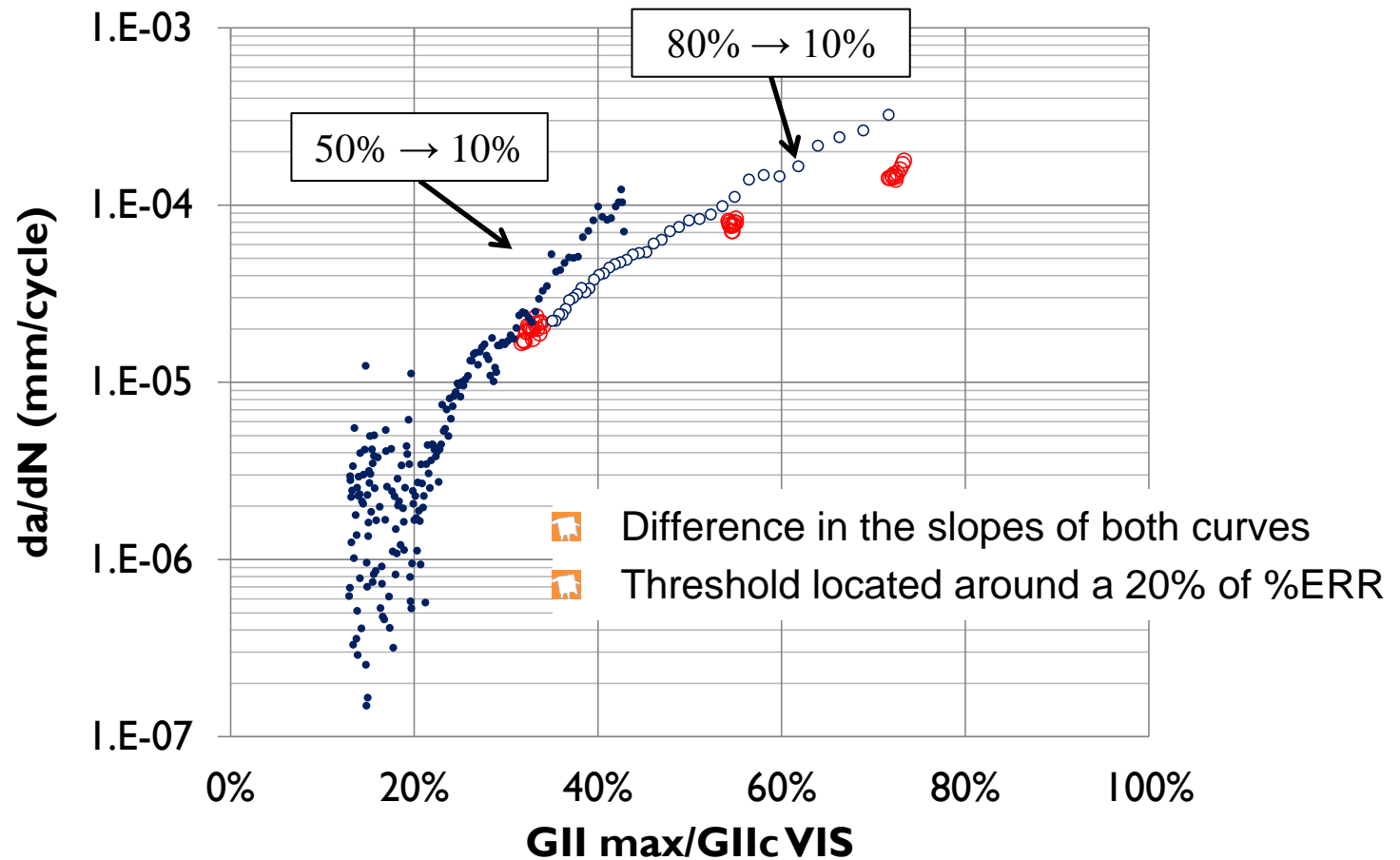
Results: crack growth rate curves

Results of the fatigue tests with δ variable



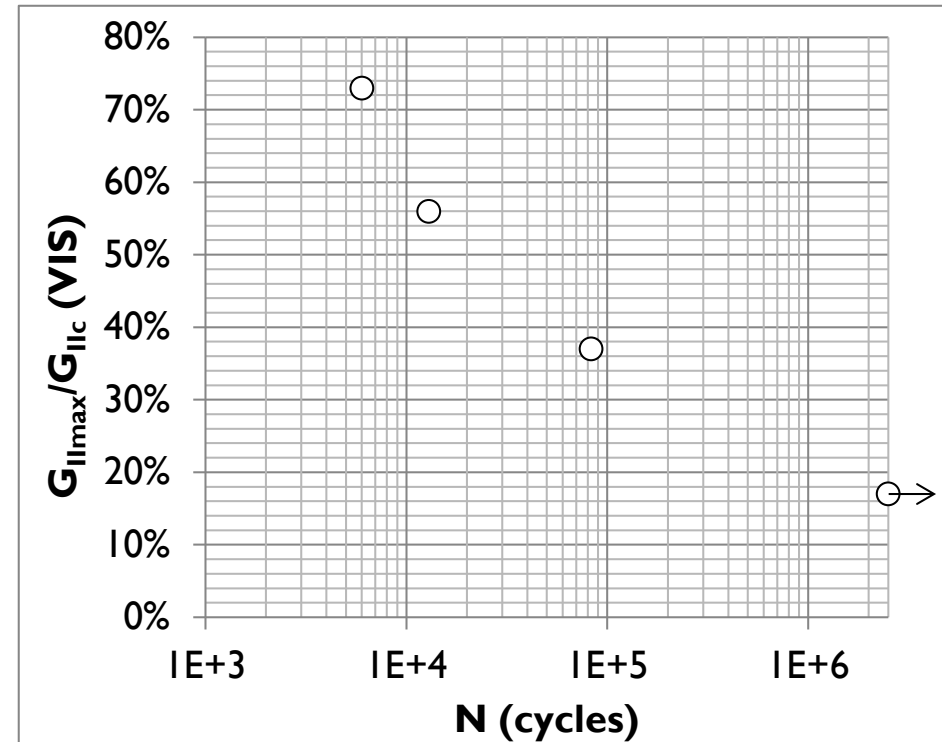
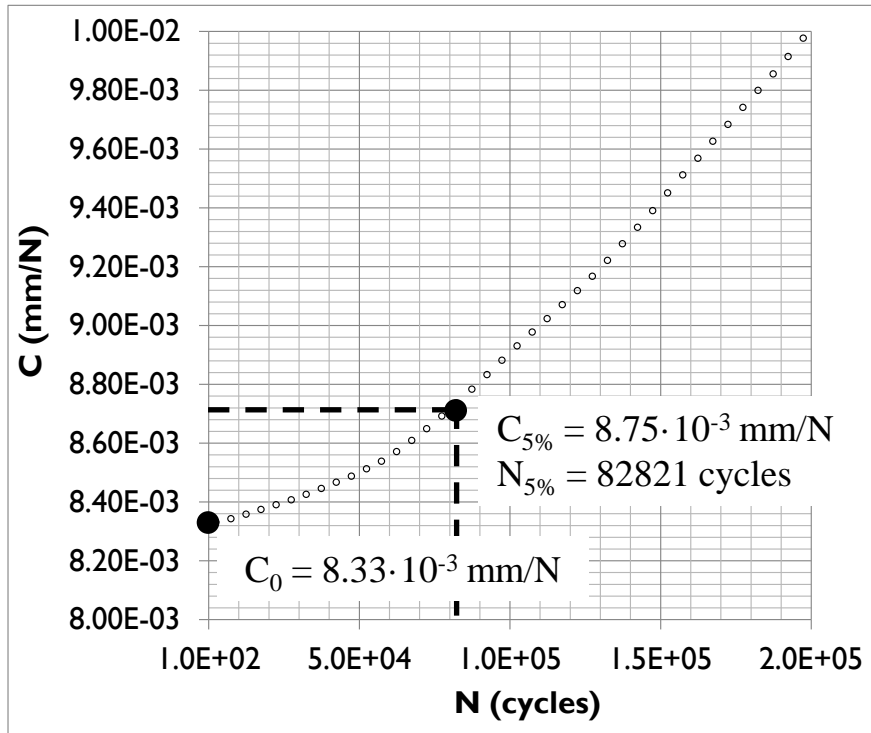
Results: crack growth rate curves

Results of the fatigue tests with δ variable



Results: onset curves

The onset points are considered as an increment of 5% in the compliance

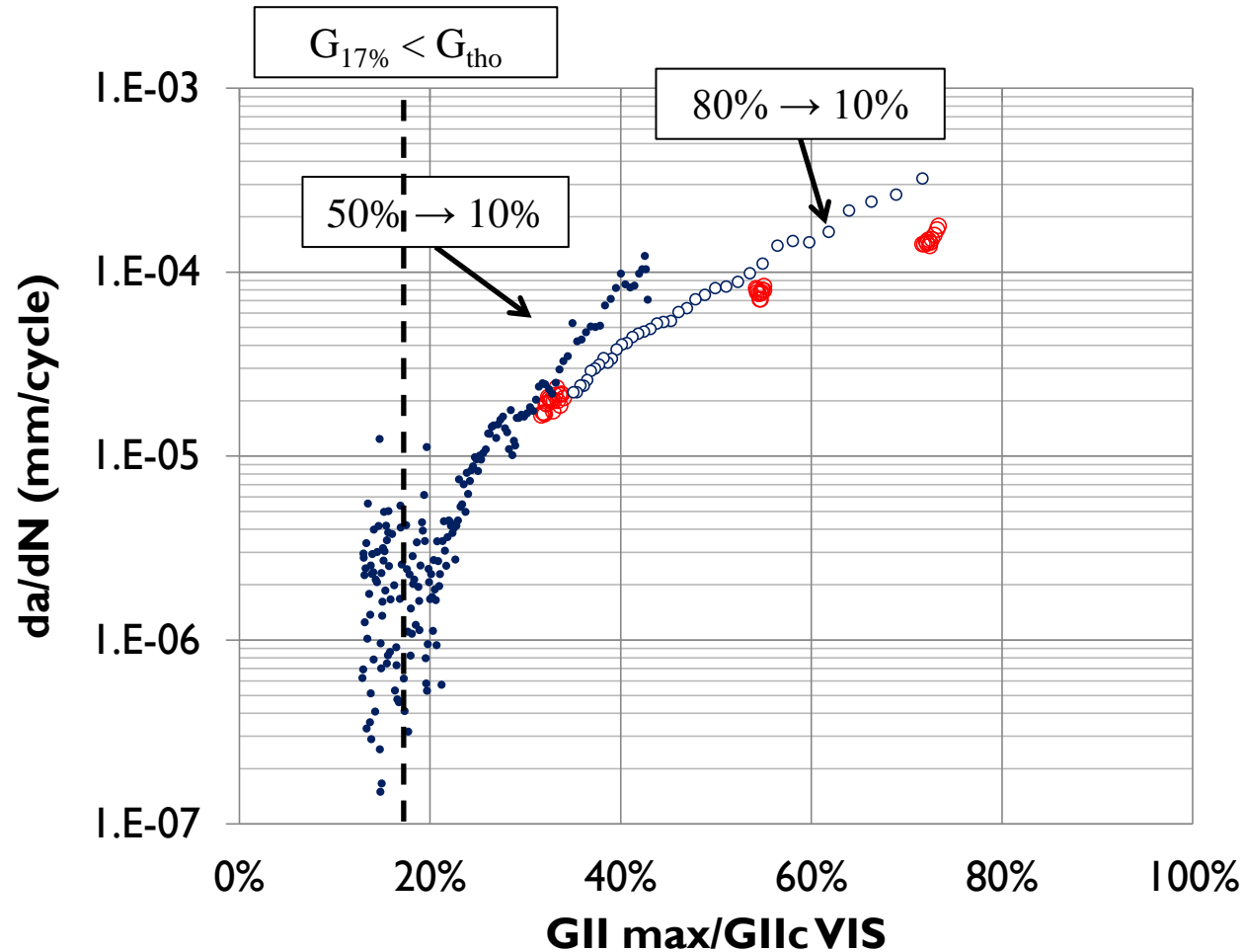


Onset fatigue test at 35% of %ERR

Run-out number of cycles: $2.5 \cdot 10^6$

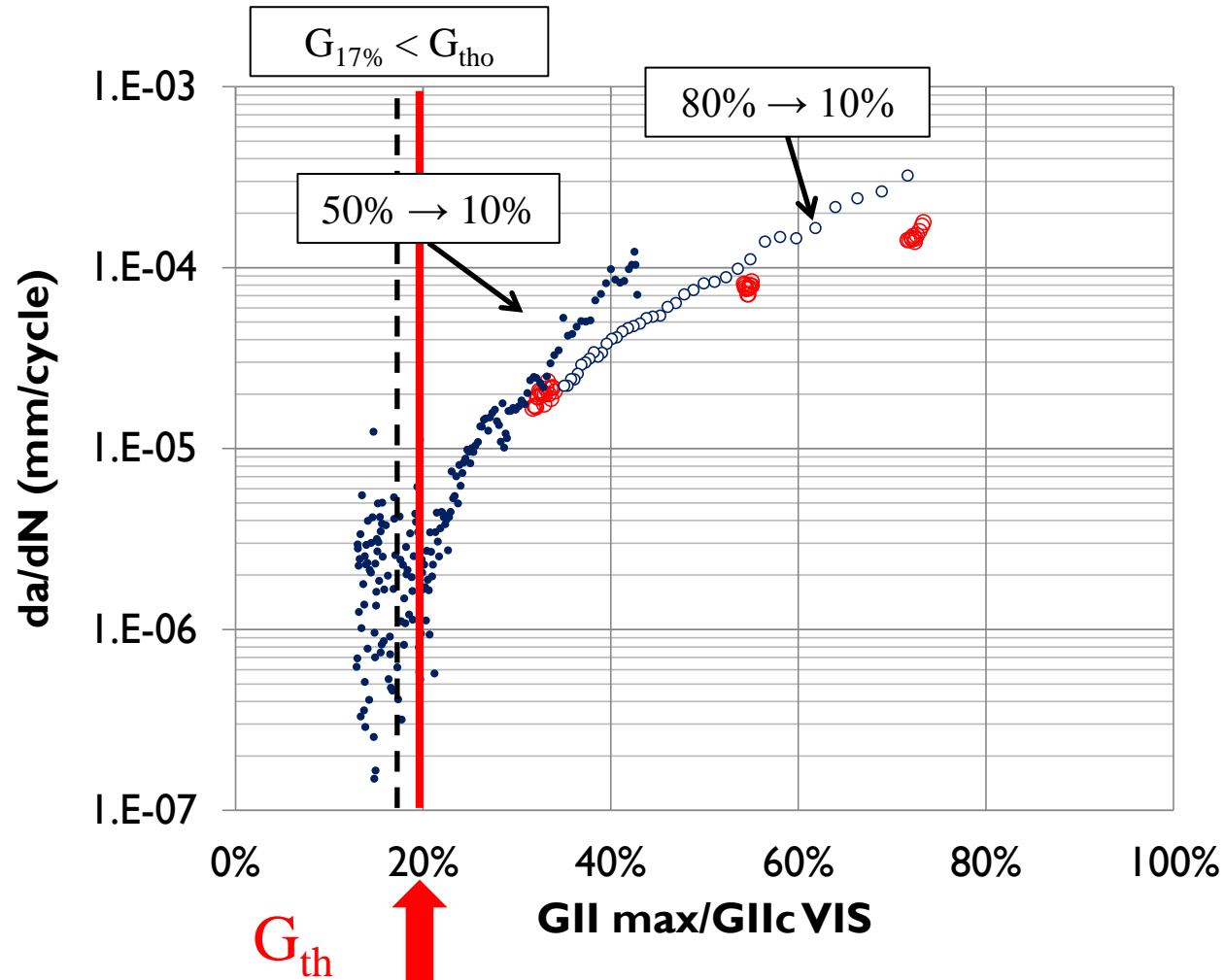
Results: crack growth rate curves

Results of the fatigue tests with δ variable



Results: crack growth rate curves

Results of the fatigue tests with δ variable



Conclusions

- A methodology to obtain full crack growth rate curves has been developed for the mode II ENF test. A variable displacement is applied during the fatigue test.
- An experimental testing campaign has been performed in which the crack growth rate curve is covered by only two tests.
- Differences have been obtained in the slopes of these curves, more tests are required in order to determine if it is caused by the uncertainty of the material or by the crack propagation speed.
- The method allows the determination of the threshold value that is in agreement with the results of the onset curves.



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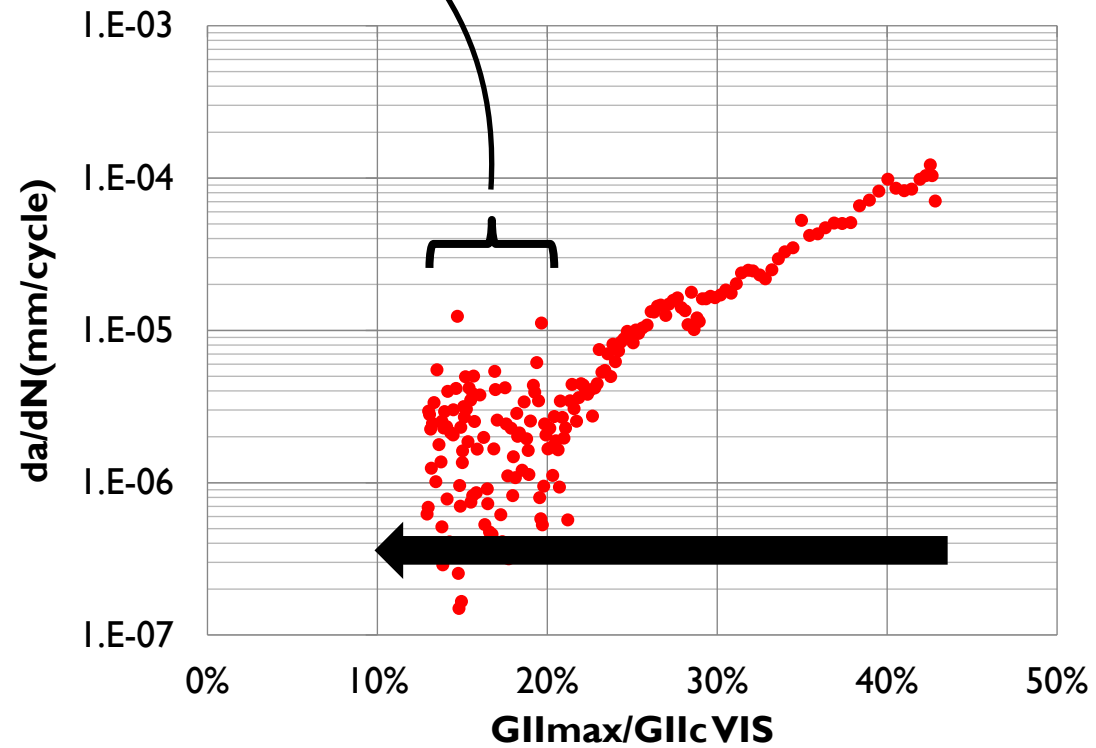
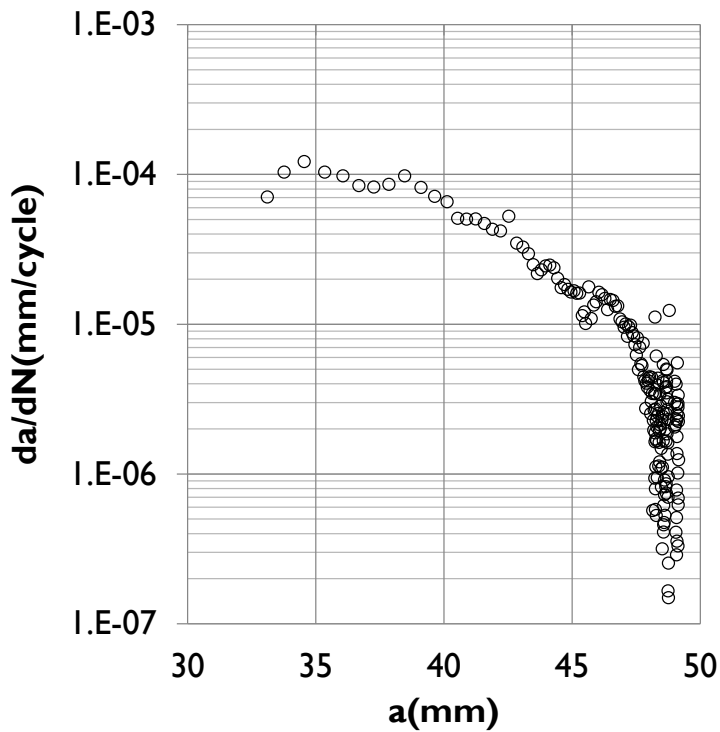
ANÀLISI I MATERIALS AVANÇATS PER AL
DISSENY ESTRUCTURAL



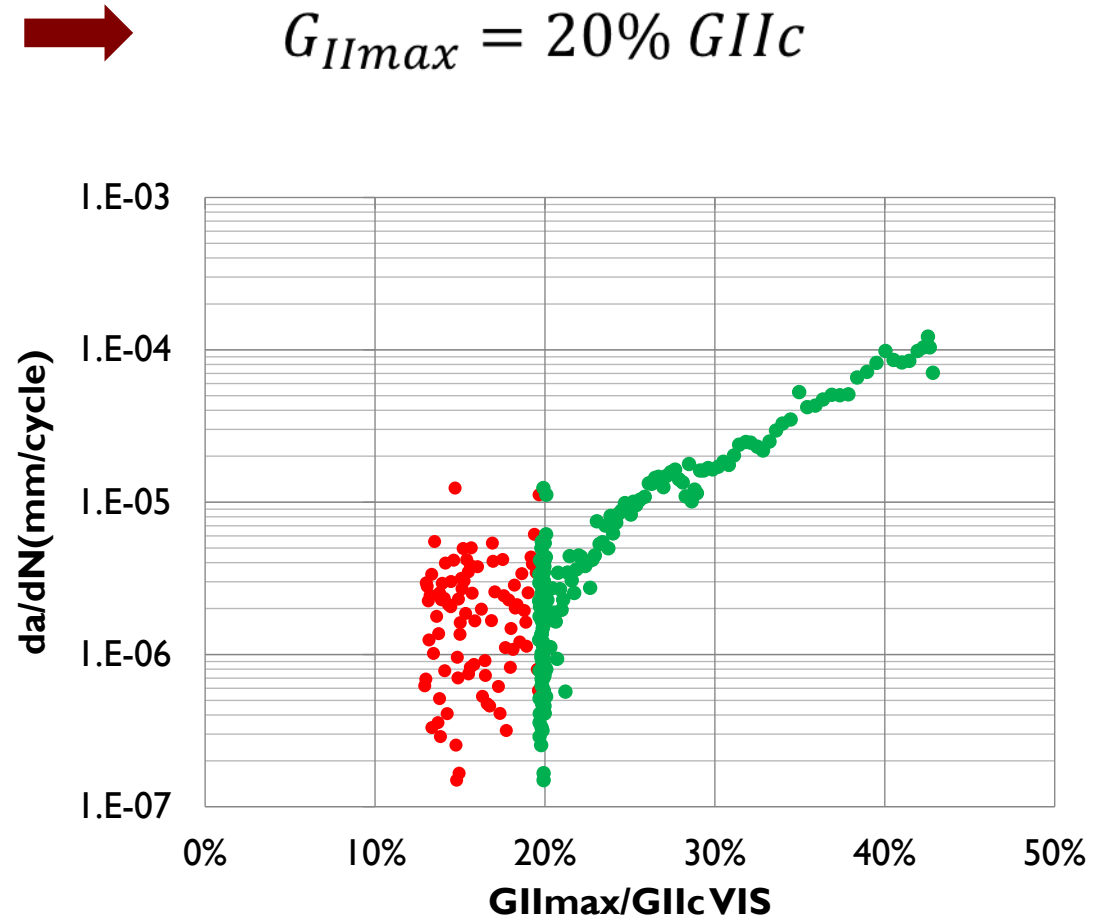
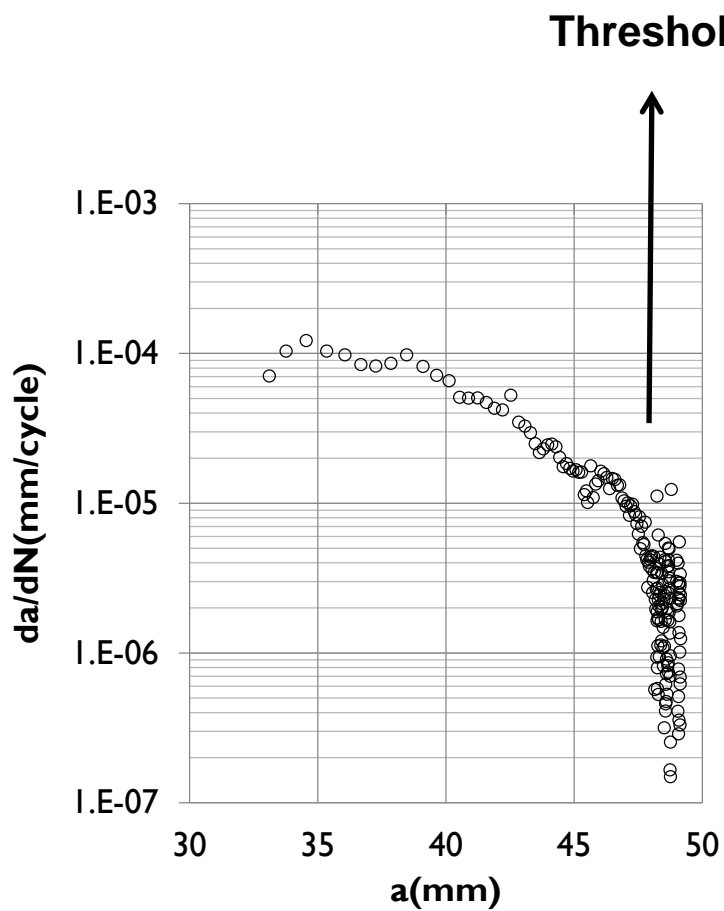
Universitat de Girona

Results: location of the threshold

$$G_{II\max} = \frac{3 k_c a^2 \delta^2}{2 B C^2}$$



Results: location of the threshold



$$G_{II\max} = 20\% G_{IIc}$$