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EXPERIMENTAL INVESTIGATION OF THE CRACK CLOSURE WITH APPLYING DYNAMIC ACOUSTO-ELASTIC TESTING ON A STEEL SAMPLE

Arthur Perrin

4th - 8th July 2022

Cédric Payan, Cécile Gueudré, Marie-Aude Ploix, Gilles Corneloup, Patrick Reclin





SUMMARY

1. Industrial context
2. Dynamic Acousto-Elastic Testing (DAET)
3. Bending test
4. DAET and bending test links



INDUSTRIAL CONTEXT

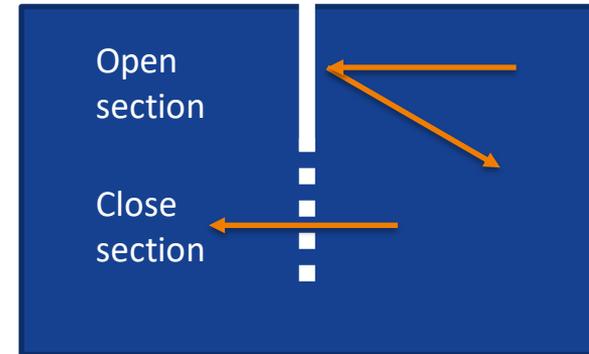
PROBLEMATIC



Cracks have been found on industrial **steel** components

Comparing destructive and non-destructive testing

➔ Underestimation of crack depth
caused by **crack closure**



Closure problematic

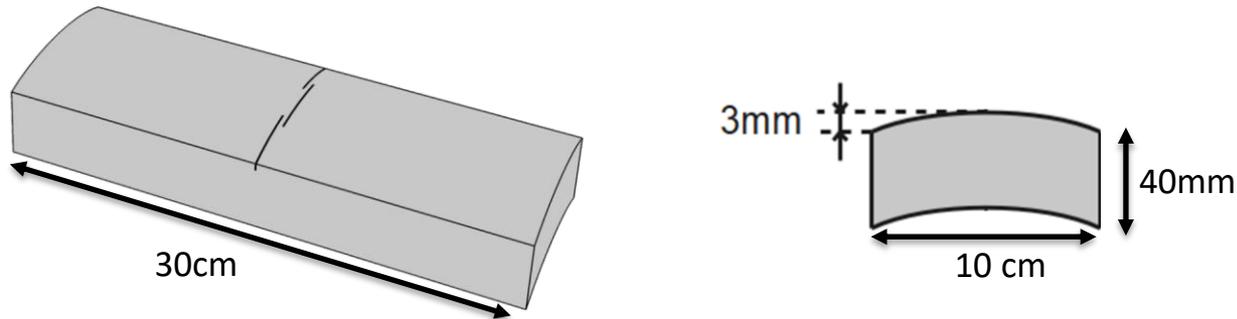
SAMPLE DESCRIPTION



Sample = cracked industrial part:

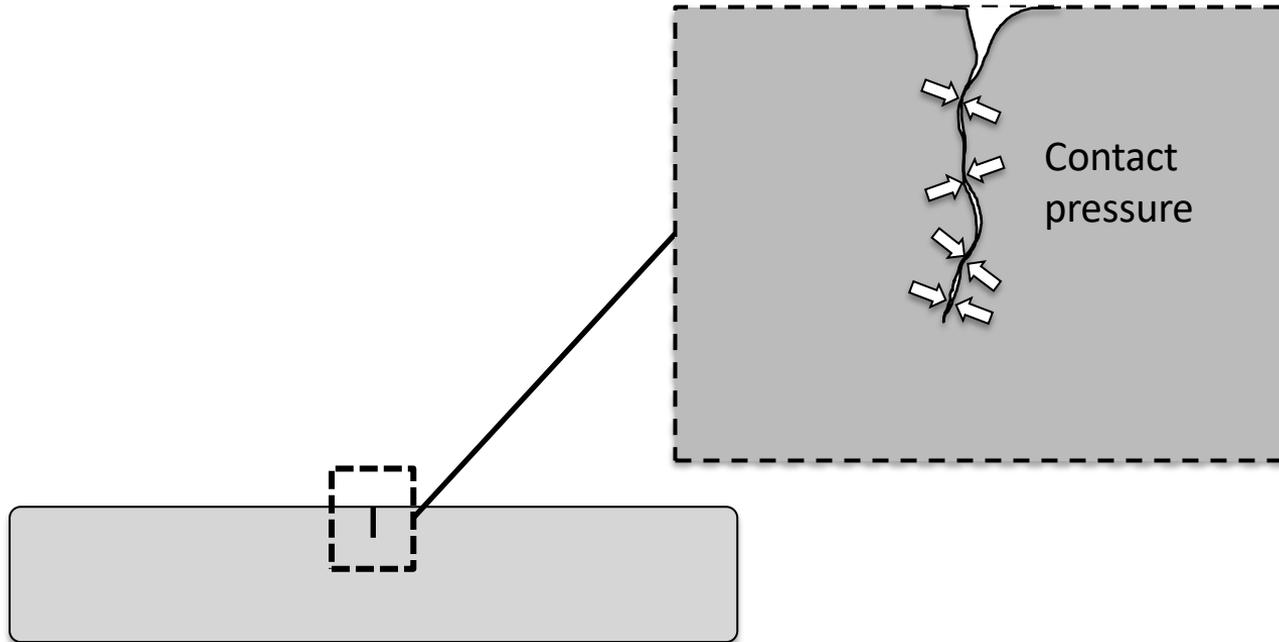
- Tube portion shape
- Real fatigue cracks

3 different cracks identified in the center of the sample



Sample 3D modeling

CRACK MODELING



DAET: good candidate to learn more about closed cracks

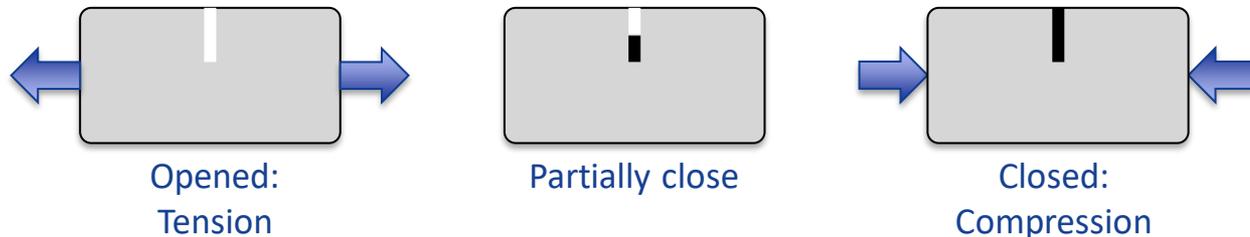


DYNAMIC ACOUSTO-ELASTIC TESTING (DAET)

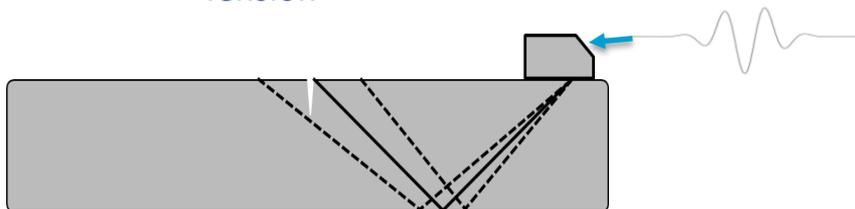
DAET PRINCIPLE



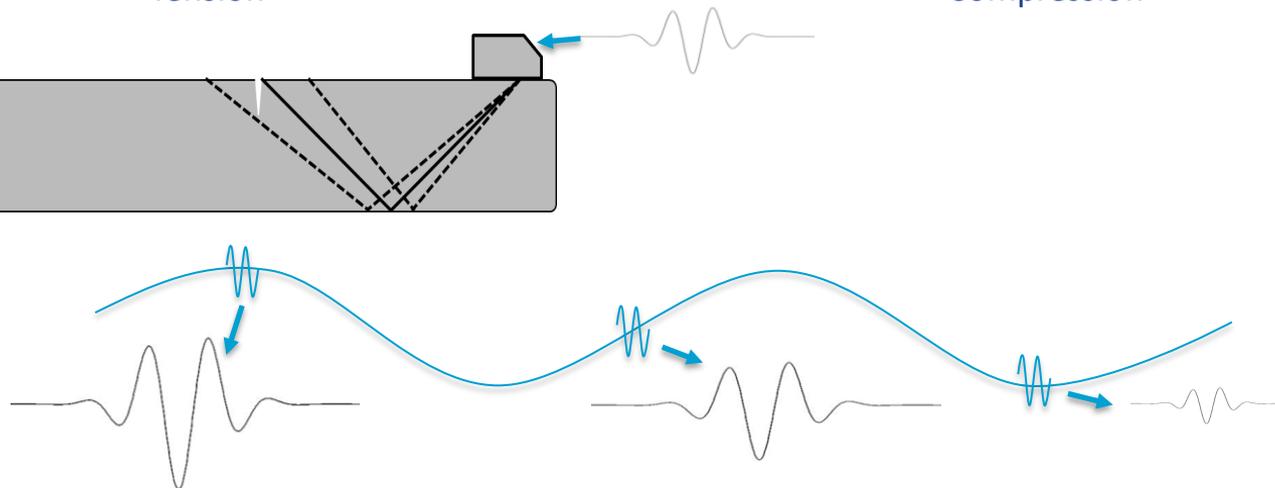
Pump wave
(Low frequency)



Prob wave
(High frequency)



→ **Modulated prob wave**



DAET SETUP: PUMP



Pump:

- 3cm diameter transducer
- 8kHz
- Laser vibrometer recording the lateral face displacements

For the following results:

Pump = Lateral faces displacements

2 pump amplitudes are used: $7\mu\text{m}$ and $3\mu\text{m}$



Pump transducer

DAET SETUP

Prob:

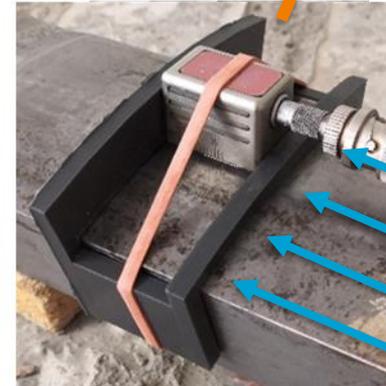
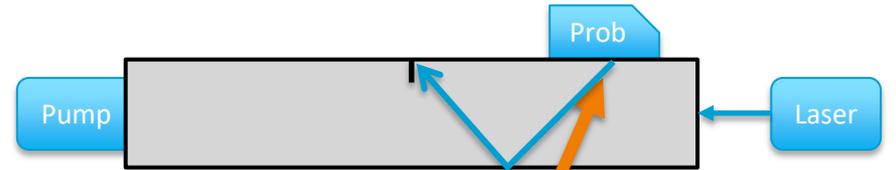
- 4MHz, 45°, Shear waves
- Reflection on the lower surface + **corner echo**

DAET Parameter:

$$\frac{A - A_{mean}}{A_{mean}}$$

$A =$ Echo amplitude

$A_{mean} =$ Mean echo amplitude



Prob transducer

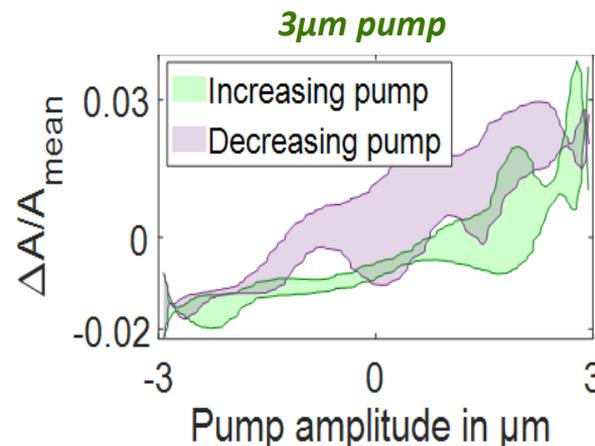
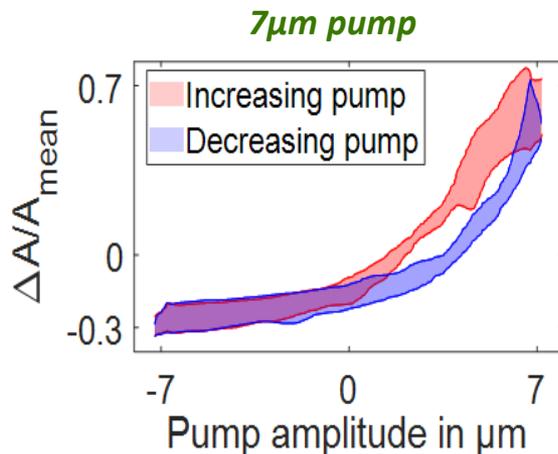
Evaluation
in different
positions

DAET RESULTS



7 μ m pump: Repeatability measurements + various measurement positions
➔ good reproducibility

With 3 μ m pump : Different curve shape and much smaller variations
➔ **Different physical phenomena** must be at play



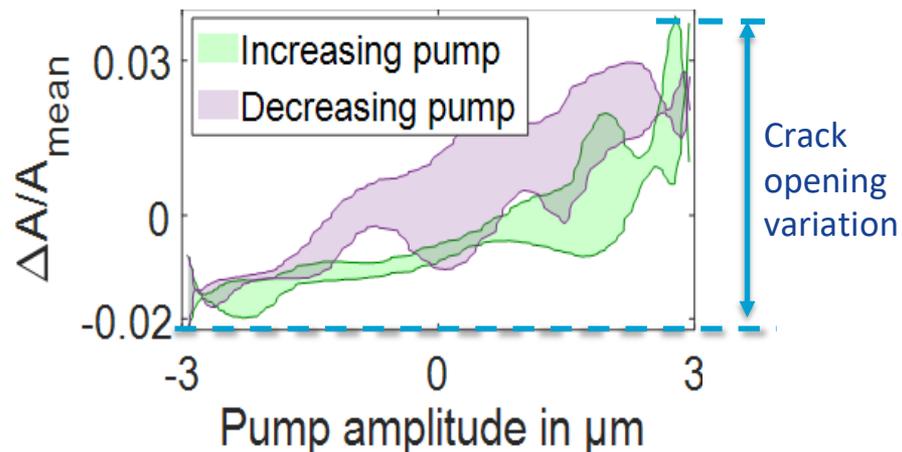
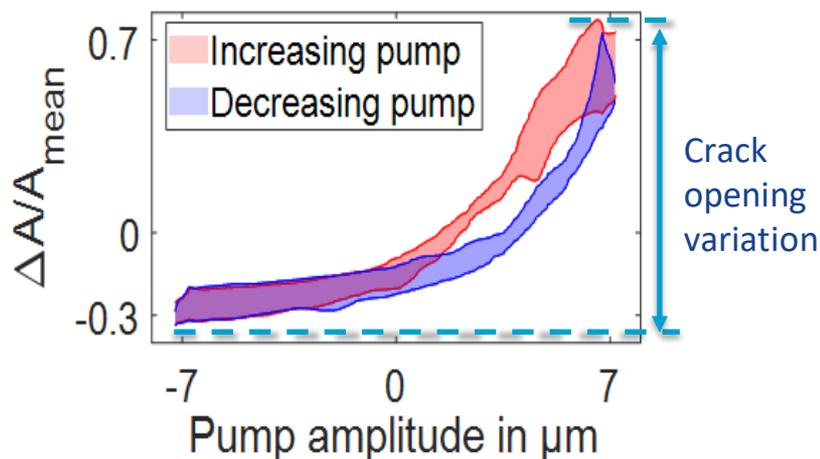
Areas including all DAET curves (repeatability at 1 position)

EXTRACTION OF A DAET PARAMETER



A parameter is needed to compare DAET curves after bending test:

Crack opening variation



Extracted DAET parameter description



BENDING TEST

BENDING TEST SETUP



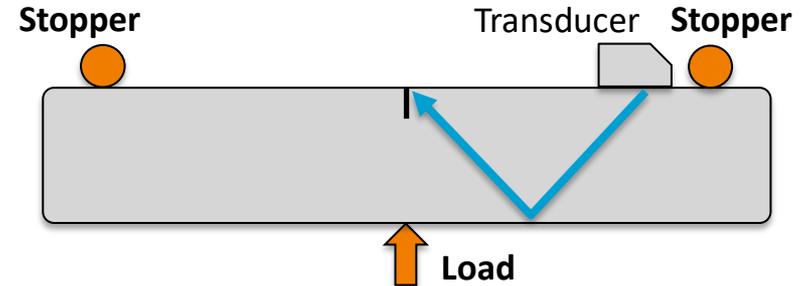
Cracks in the center of the sample

➔ 3-point bending test open them

+ **Monitoring** of the relative corner echo
amplitude $\frac{A}{A_0}$

A = Echo amplitude

A_0 = Initial echo amplitude



Bending test description



BENDING TEST RESULTS

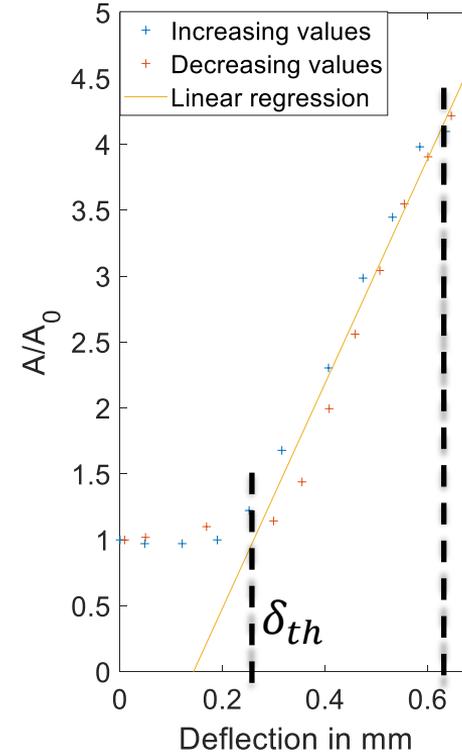
Similar behaviors for each transducer position:

- **Threshold** constraint below which crack does not open (**initial constant amplitude**)
- The echo reaches a **maximal constant value** at the end of the test → crack is totally opened

Deflection threshold δ_{th}



Contact pressure between the crack faces





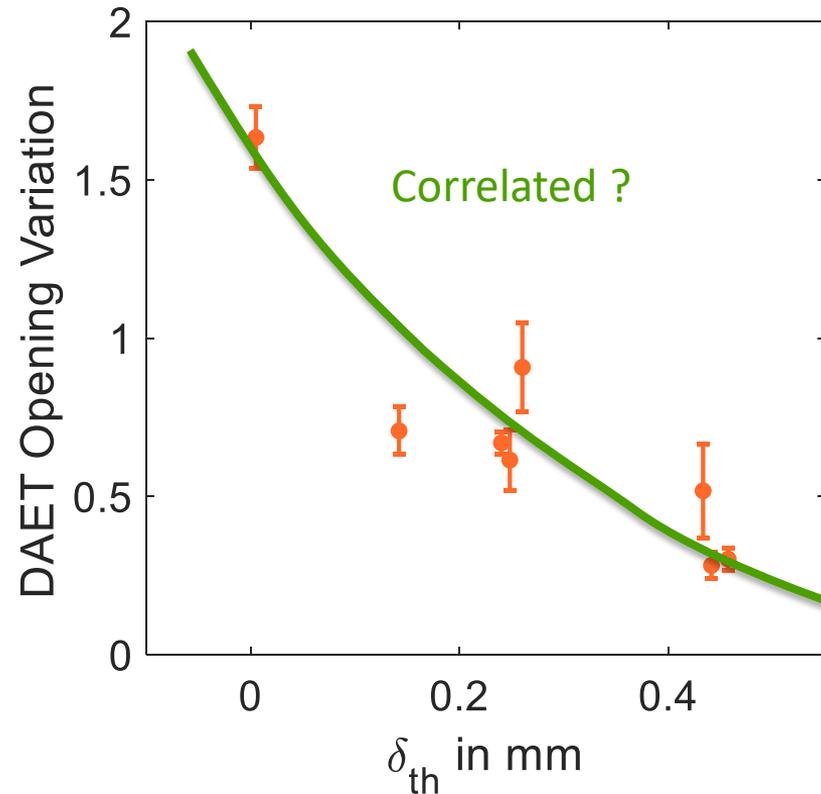
DAET AND BENDING TEST LINKS

7 μ m pump:

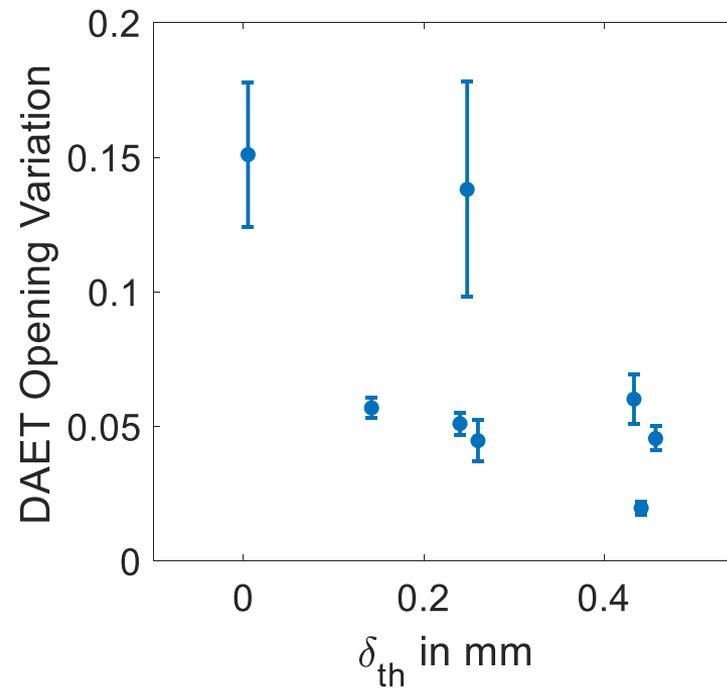
DAET opening variation $\Leftrightarrow \delta_{th}$?

Low standard deviation

=> **Correlation to further investigate**



3 μm pump:
Observations are less clear

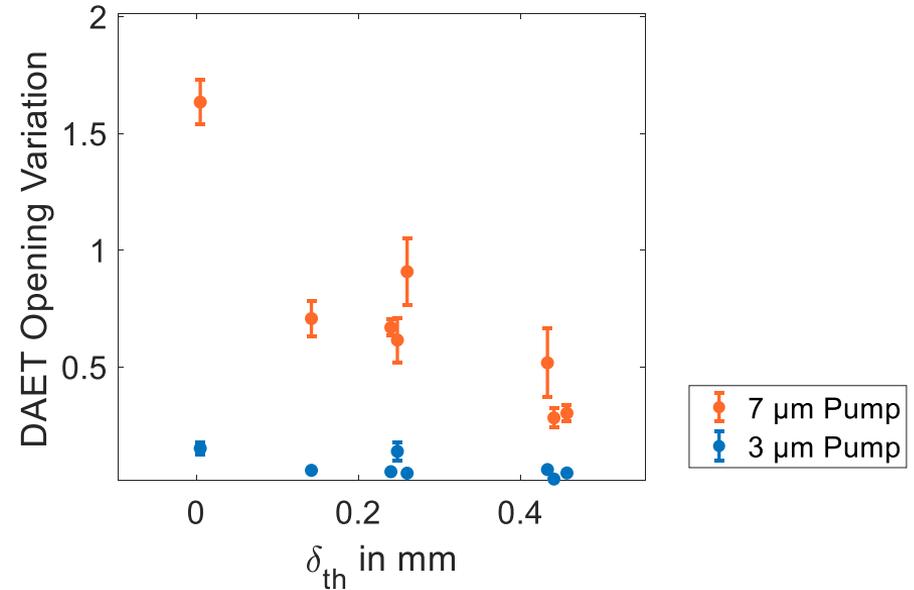


CLOSURE/ ECHO VARIATION RELATIONSHIP



DAET opening variations:
 $7\mu\text{m} > 3\mu\text{m}$

➔ A minimum pump amplitude is mandatory to observe correlations



*DAET result against deflection threshold
for $7\mu\text{m}$ and $3\mu\text{m}$ pump*



CONCLUSION

CONCLUSIONS AND PERSPECTIVES



Conventional US performance are limited on closed part of cracks

DAET seems to be sensitive to the crack closure:

- A minimum pump amplitude is mandatory to observe correlations
- Correlation to further investigate

Bending test = reliable experience to access the crack opening



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