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HIGH-SPEED DIGITAL IMAGE CORRELATION: APPLICATION TO BI- AXIAL FATIGUE

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ICCS17, Porto

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1) Bi-axial fatigue behaviour of composites

- Very few experiments have been done to determine the behavior of composite structures under multi-axial loading.
- Determination of the behavior under bi-axial fatigue loading.

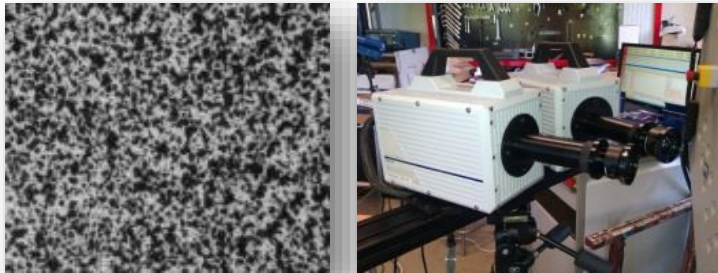


- Comparison with uni-axial datas.

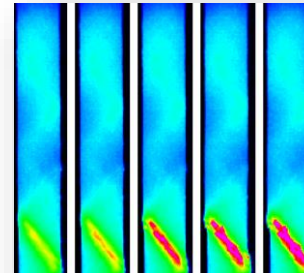
2) Automatic monitoring of fatigue experiments

- Development of a system for a complete monitoring of the test.

Strain measurements
using high-speed
stereo-DIC



Thermic measurements
using Infrared
thermography



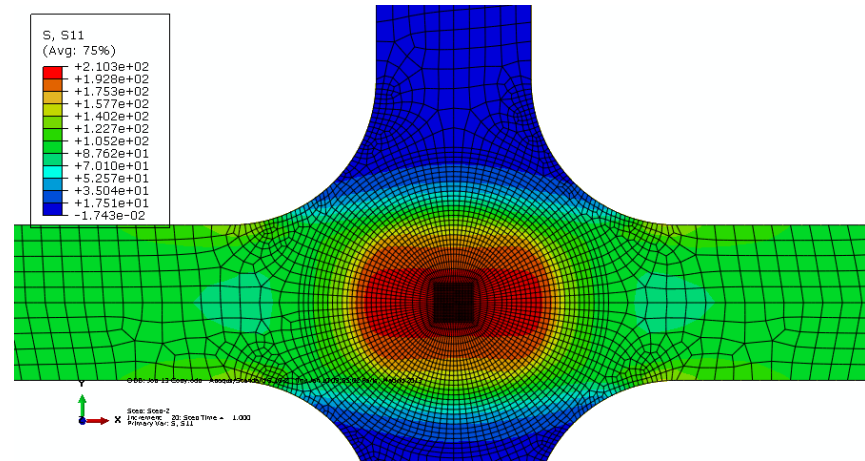
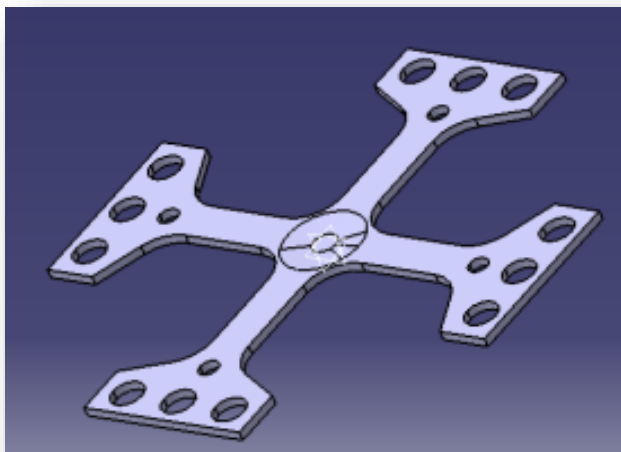
- Simultaneous use of both systems
- Cameras triggered using analogical signals sent from the machine

➡ Automatic monitoring of the tests

II) Design of a new cruciform specimen

1) Finite elements model

- Design using the ABAQUS software.
- 3D model, 1 element per ply.
- Design criterion:
 - Stress concentration nowhere else than at the center of the specimen
 - Failure should occur in the central zone due to bi-axial stress state
 - The central zone must be as flat as possible to allow DIC
 - Adaptability to the LRI process
 - Easy reproducibility
 - Adaptation to the machine (mechanical jaws)



II) Design of a new cruciform specimen

2) Manufacturing of the specimen

- Use of Liquid Resin Infusion process
- Development of a specific infusion strategy
- Reduced central area realized before the infusion part by pre-cutting the plies

→ Fibres are not damaged due to milling process in the critic area



- Stacking sequence:
 - 4 plies at 0° in the central area
 - 4 more plies on each side in the arms
- Process made on collaboration with

NIMITECH
Etudes

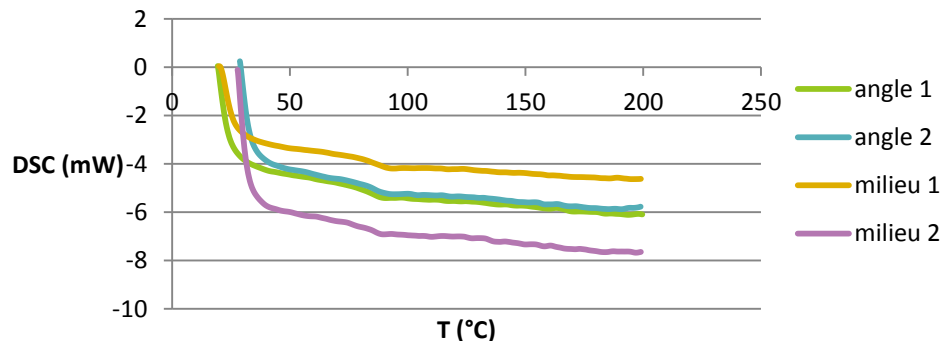
II) Design of a new cruciform specimen

3) Health control of the specimen

Control of the resin, fibers and porosity volumetric rates by dissolution of resin

Fibers	resin	porosity
Average (%)	Average (%)	Average (%)
60	38	2

Control of glass transition temperature by DSC



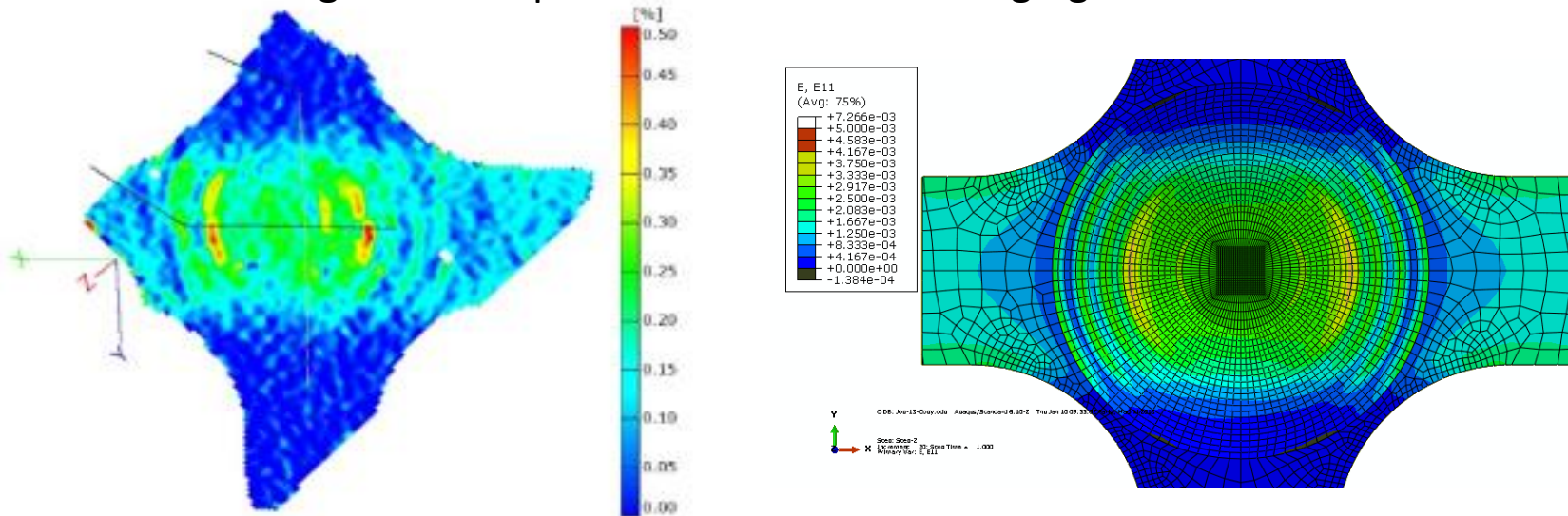
$T_g \approx 89^\circ\text{C}$



II) Design of a new cruciform specimen

4) Primary validation of the design

- Comparison of the measurements on a static bi-axial tensile test and the calculations
- $F = 5\text{kN}$ on each axis
- Strains along the x axis presented on the following figures:



Good match between the values:

➔ Validation of the linear elastic model

III) Monitoring of the fatigue experiments

1) High-speed digital image correlation

- Use of rapid cameras, capable of 5400 fps at 1Mp resolution
- 50 images per cycle for a 5Hz bi-axial fatigue experiment (250fps)
- Automatic trigger with a 10V signal sent from the machine
- Signal sent every 50 cycles
- Speckle pattern drawn on the specimen
- DIC done with the ARAMIS software

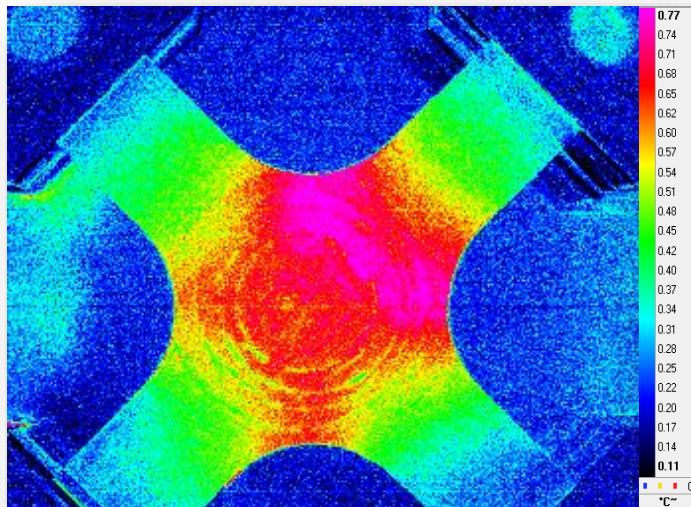


Goal is to detect a local loss of stiffness or delamination due to fatigue sollicitation

III) Monitoring of the fatigue experiments

2) Infrared thermography

- Use of a FLIR camera with a thermic resolution of 20 mK at 30°C
- Camera triggered permanently with a 3V signal sent from the testing machine.
- 1 image taken per cycle: permanent recording at 50fps, 1 image over 10 is conserved.
- Warming of the 2 spots taken into account
- Conditions of the room controlled

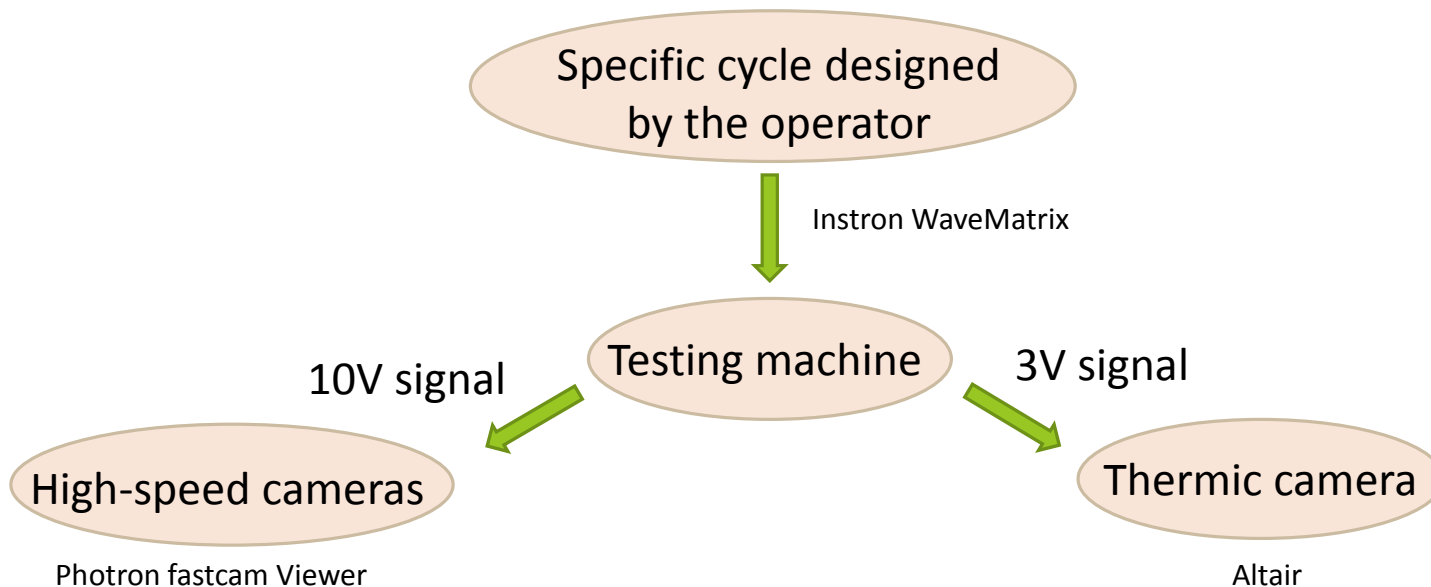


Goal is to detect a local warming which could be a sign of damage

3) Simultaneous use of the systems

- Possible relations between the datas obtained during the tests.
Ex: warming could be a sign of local damage which increases the local strains
- Both of the systems can be triggered using analogical signals sent from the testing machine

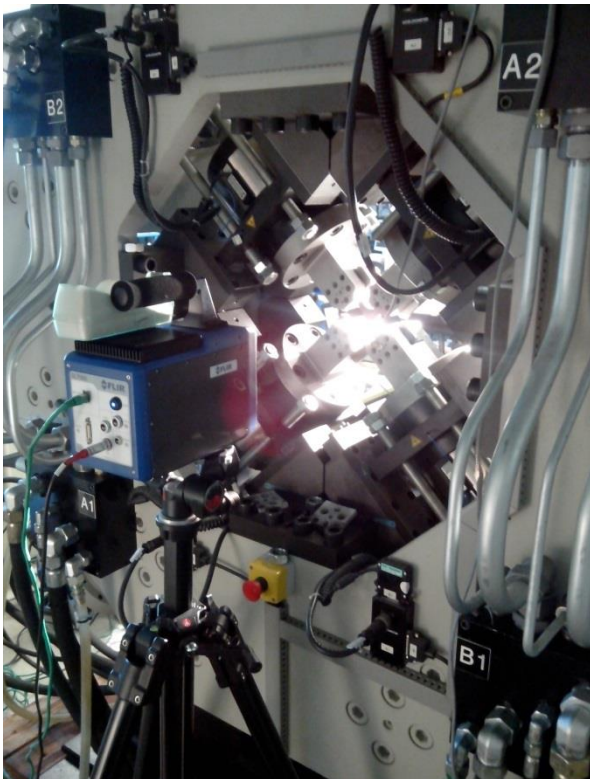
→ Use of those signals to make the monitoring automatic



1) Description of the experiment

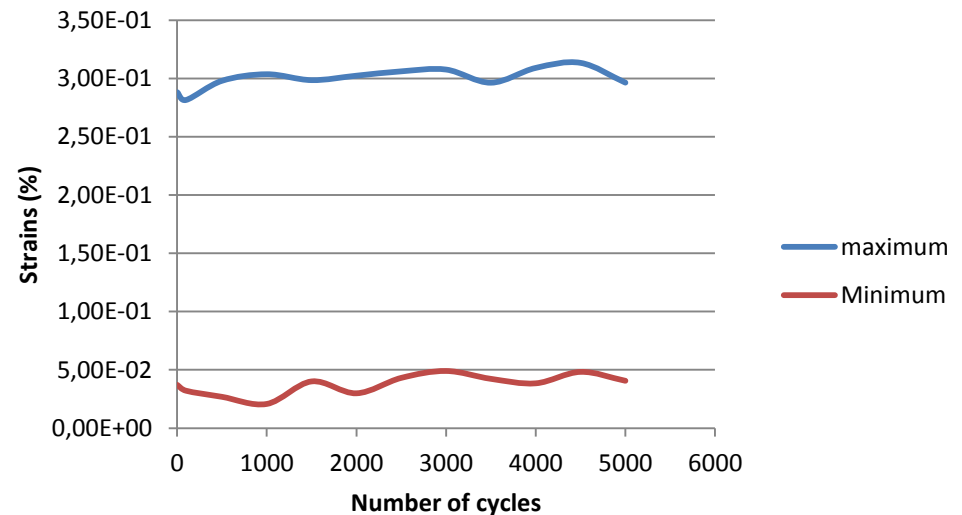
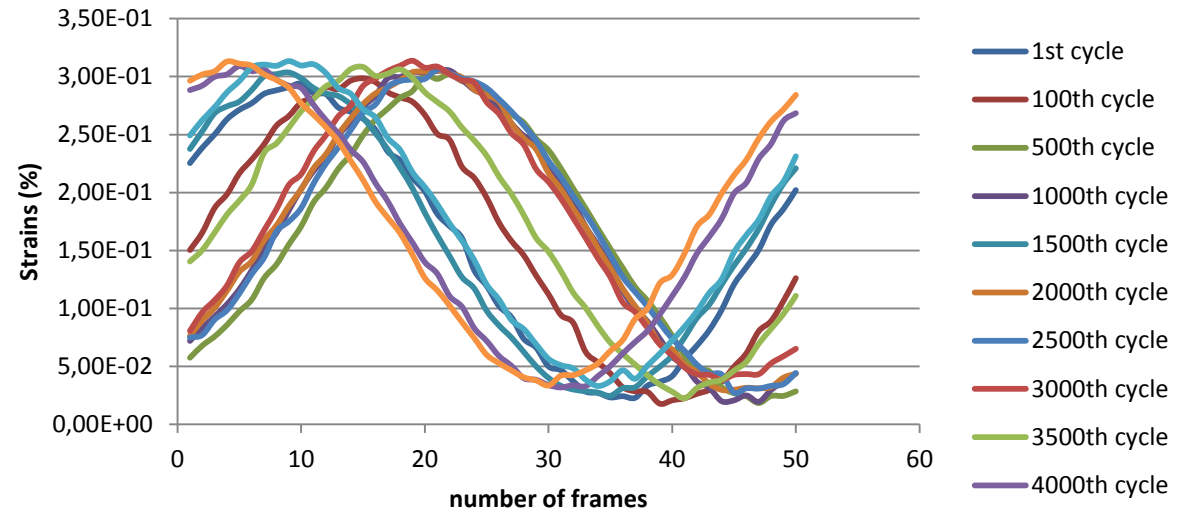
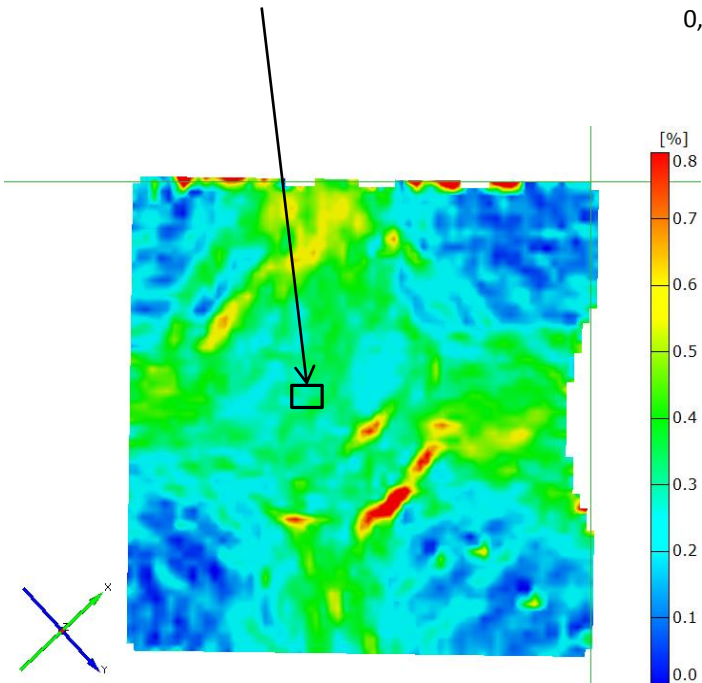
Bi-axial fatigue testing, 5000 cycles, 5Hz

Simultaneous monitoring with stereo-DIC and IR thermography.



2) Stereo-DIC

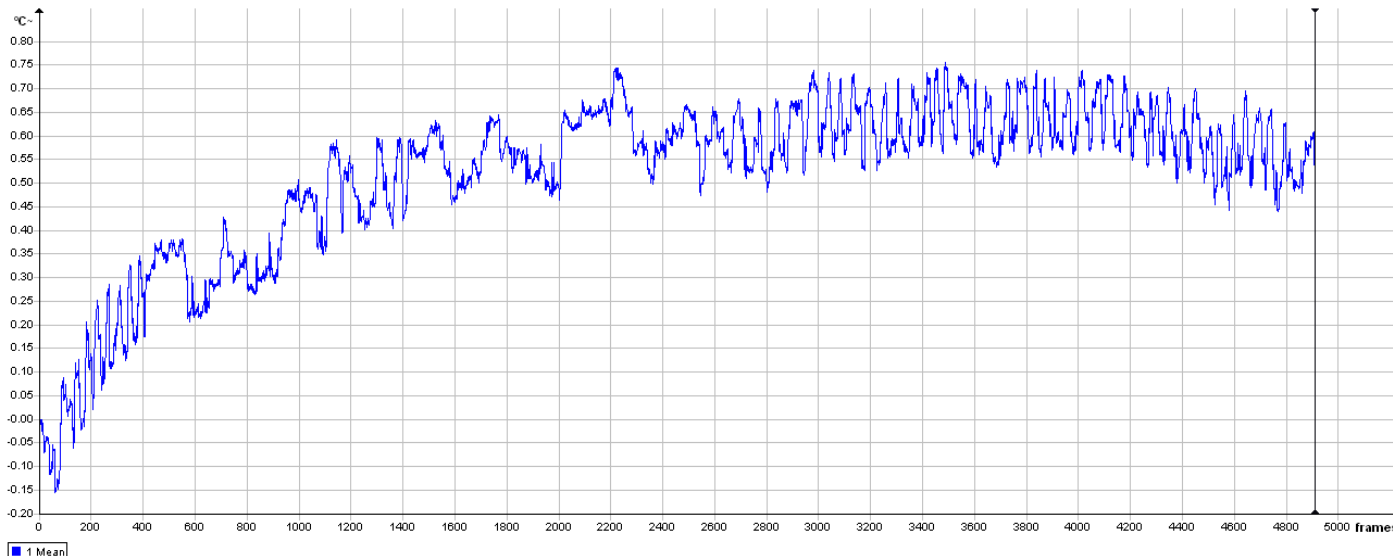
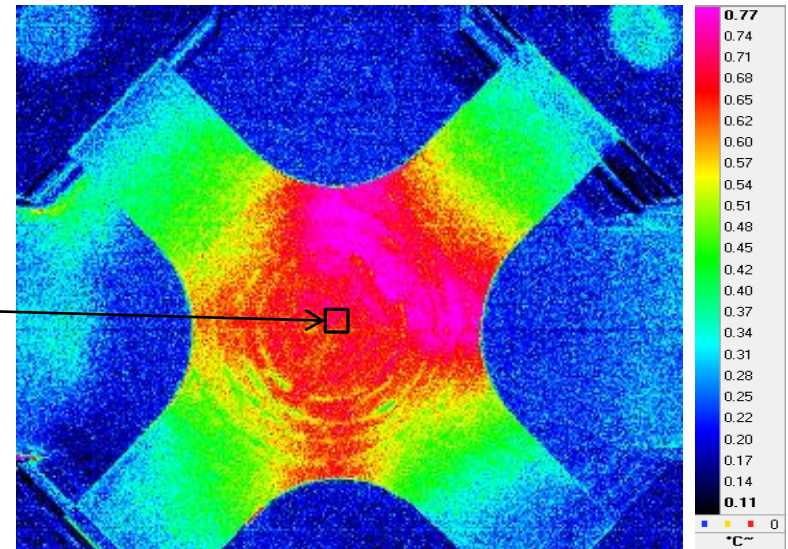
- 50 images per cycle
- Strains along X axis
- Mean strain on a small area on the central part



3) IR thermography

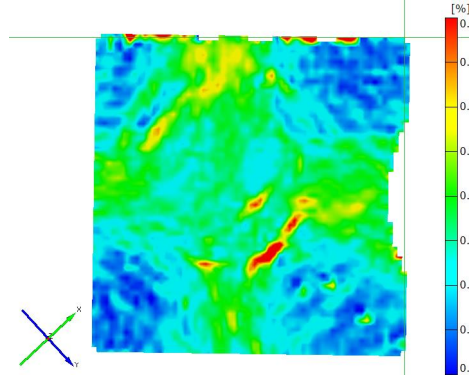
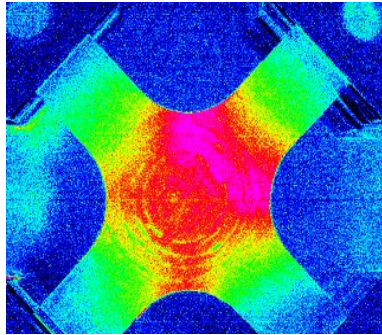
One image per cycle

Mean temperature on a small area on the central part



V) Perspectives and conclusion

- New kind of specimen manufactured with LRI process
- Specific approach for fatigue experiments monitoring



Perspectives:

- Improvement of the monitoring more
 - images with the IR thermography
- Monitoring of a complete fatigue testing until fracture, ability to detect damage with both systems:
 - local warming with thermography
 - Local loss of stiffness with stereo-DIC
 - correlation between both systems
- Correlation with uni-axial data

Thank you for your attention