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**Analyse thermographique des sources de chaleur
accompagnant la fatigue à grand nombre de cycles**
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Thermographie infrarouge appliquée à l'Automobile

Journée thématique SFT du 13 octobre 2004
PSA PEUGEOT CITROËN - POISSY

***Analyse thermographique des sources
de chaleur accompagnant
la fatigue à grand nombre de cycles***

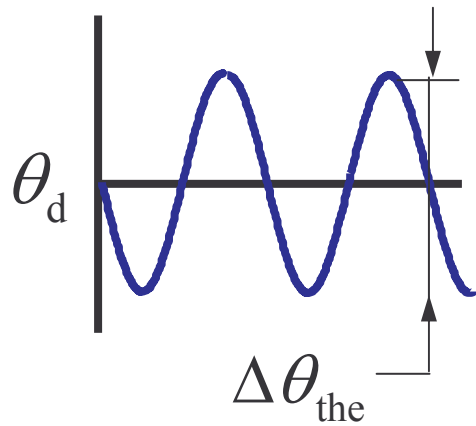
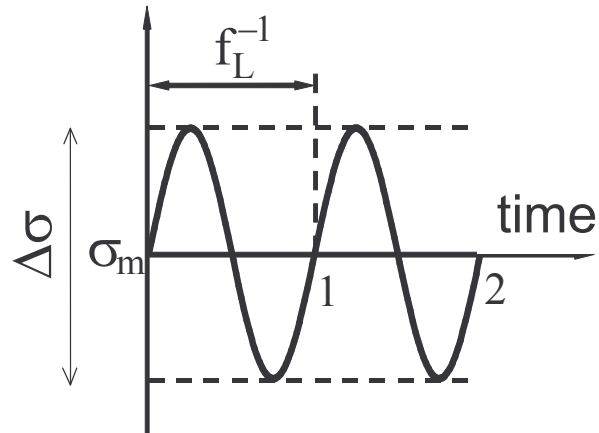
A. Chrysochoos*, O. Arnould*, T. Boulanger*, A. Galtier**

(*) LMGC, Université Montpellier II

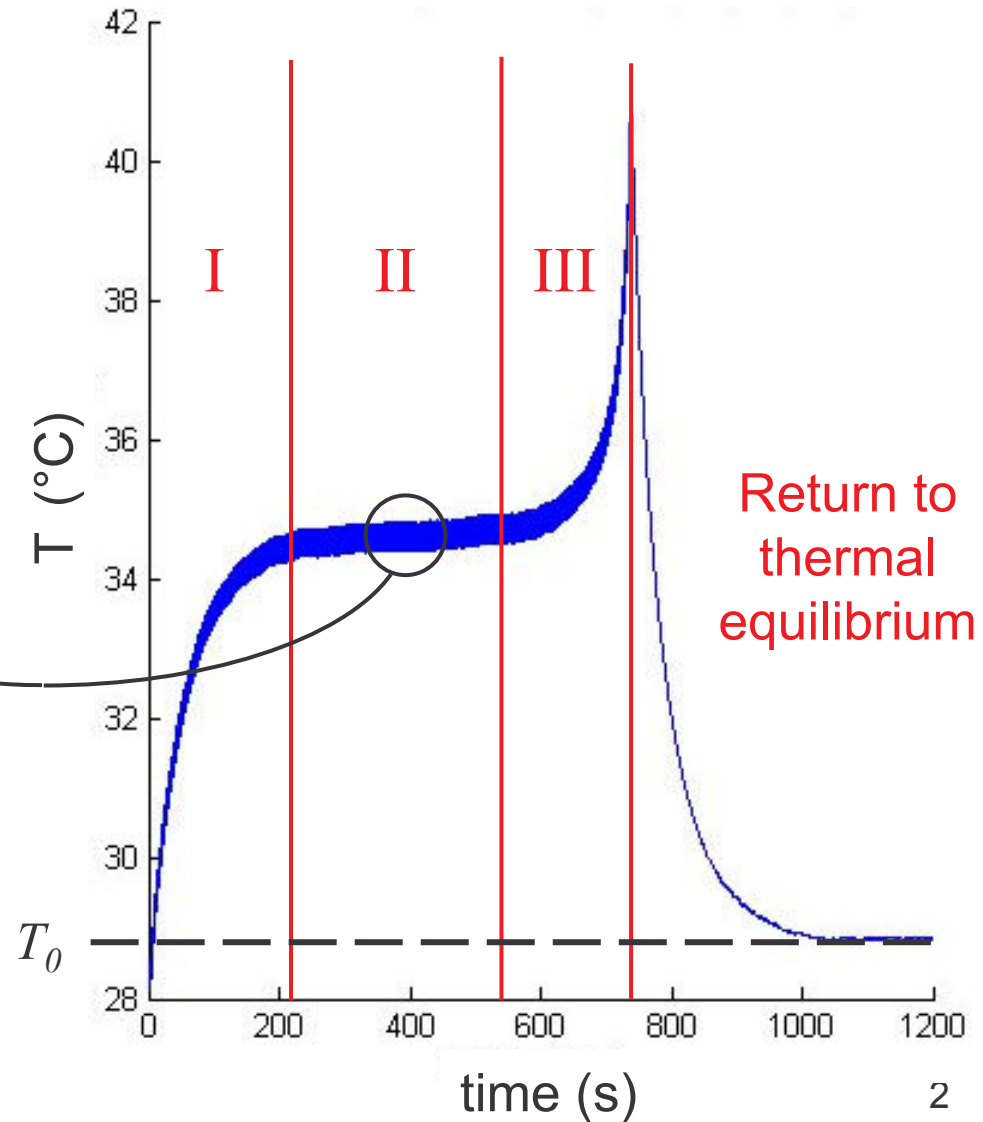
(**) IRSID-ARCELOR, Mézières-les-Metz

Introduction

Evolution of the temperature during a cyclic loading

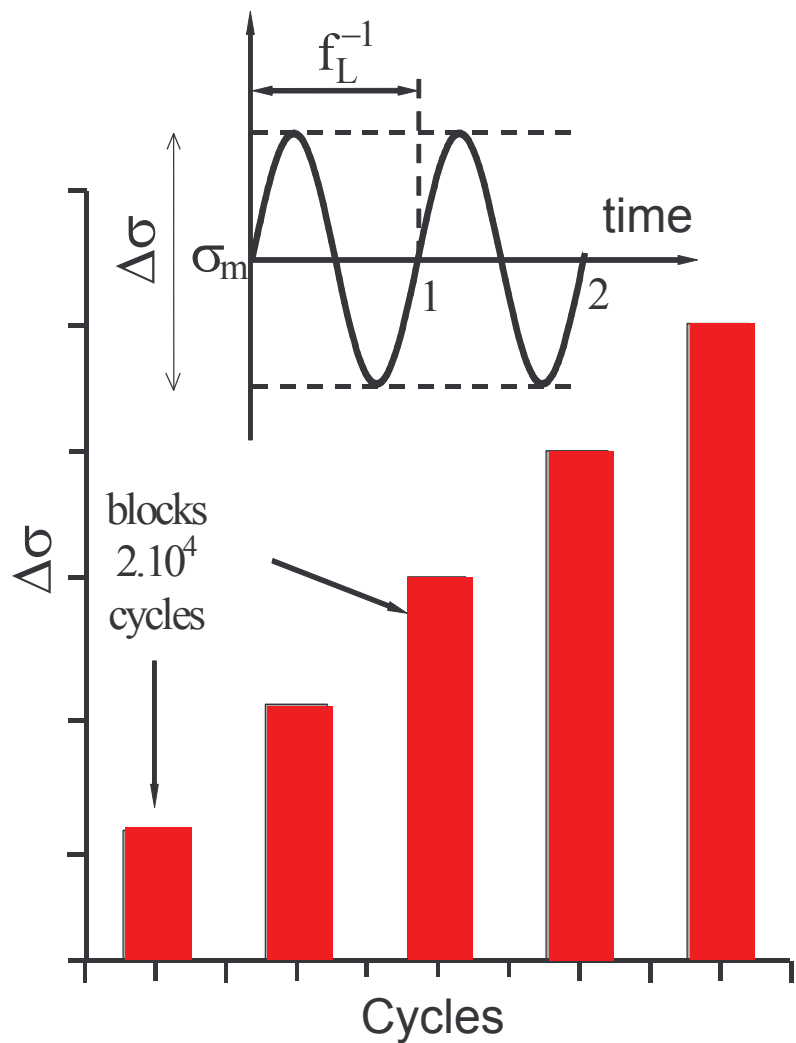


$$\theta = T - T_0 \text{ (}^\circ\text{C)}$$

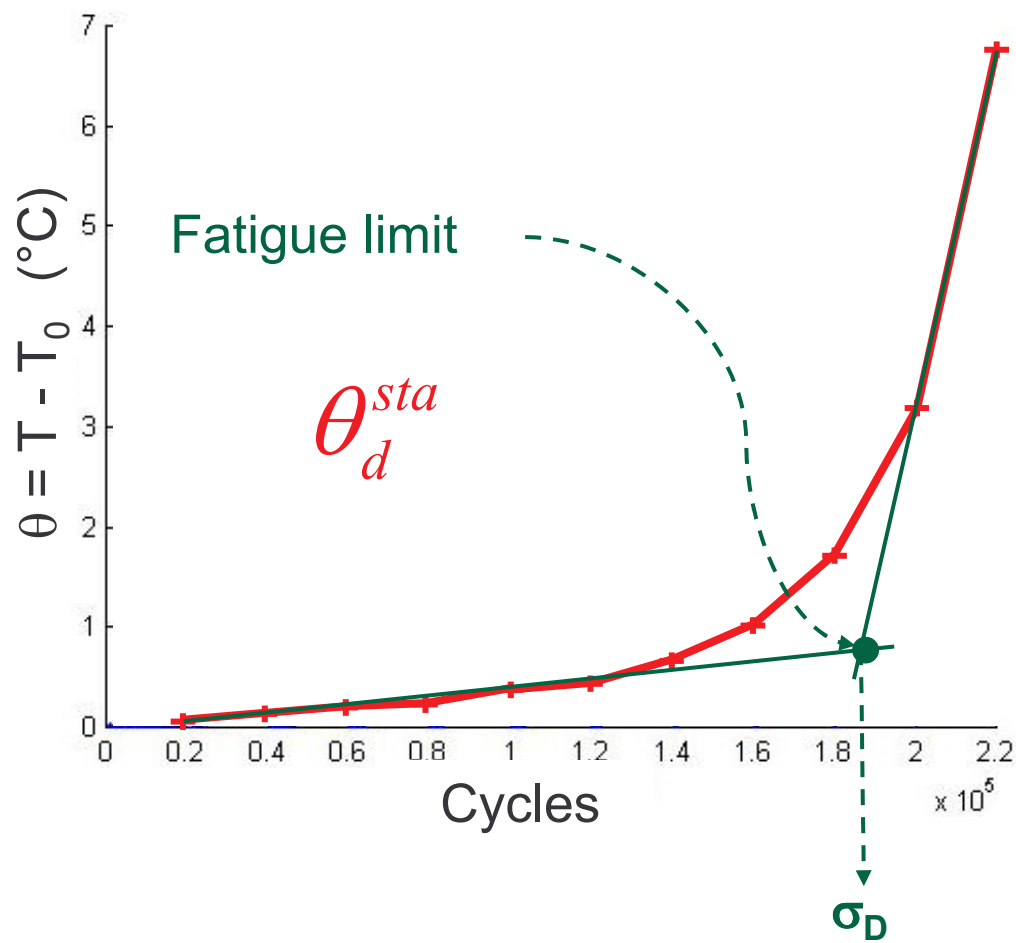


[Luong,1998], [Risitano, 2000], ...

Trend of the mean temperature drift



[Luong, 1998] [Risitano, 2000]



Objectives

- Analysis of fatigue mechanisms in terms of heat rather than in terms of temperature
- Separate estimate of dissipative and thermoelastic sources (dissipation \ll thermoelasticity)
- Quantization of fatigue mechanisms (constitutive equations)
- New data and criteria for behaviour characterization and structure design

Thermodynamic aspects

1-Small Perturbation Hypothesis (SPH)

2-Fatigue : quasi-static process

GSM formalism

$$\rho C \dot{T} - \text{div}(k : \text{grad} T) = d_1 + s_{the} + \cancel{s_{ic}} + r_e$$

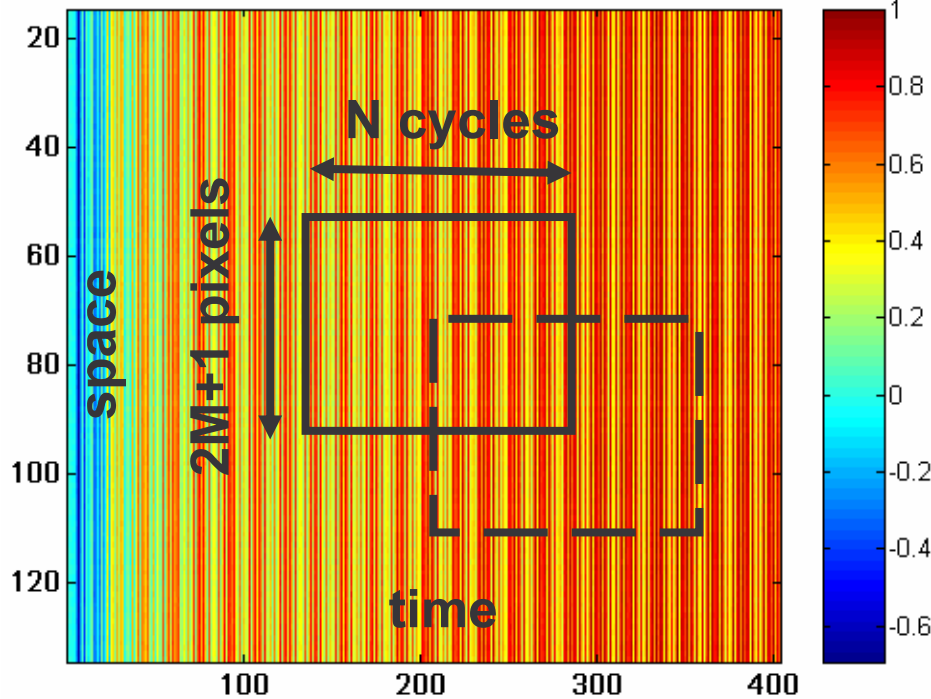
Thermal aspects

1D diffusion problem

$$s(x, t) \approx \rho C \left(\frac{\partial \theta}{\partial t} + \frac{\theta}{\tau_{th}^{1D}} - \delta_{th} \frac{\partial^2 \theta}{\partial x^2} \right)$$

Image processing (1D)

$$\rho C \left(\frac{\partial \theta}{\partial t} + \frac{\theta}{\tau_{th}} - \delta_{th} \frac{\partial^2 \theta}{\partial x^2} \right) = d_1 + s_{the}$$



In phase with the loading

$$w_{the} = \oint_{Cycle} s_{the} d\tau = 0$$

Slow evolution of mean dissipation

$$\oint_{Cycle} f_L \cdot d_1 d\tau = \bar{d}_1$$

Local least-squares fitting

$N \approx 5, 30$ cycles

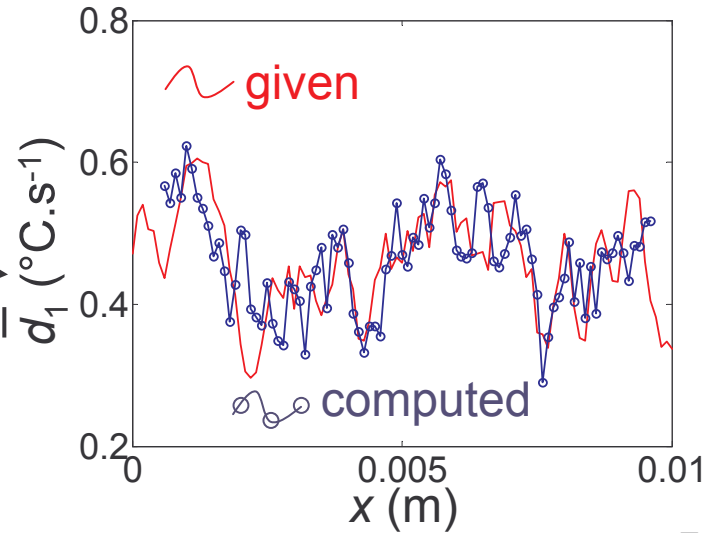
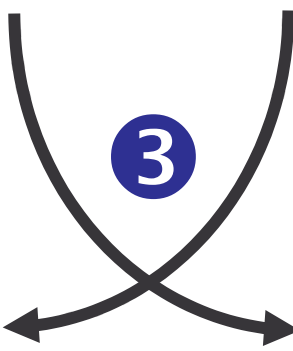
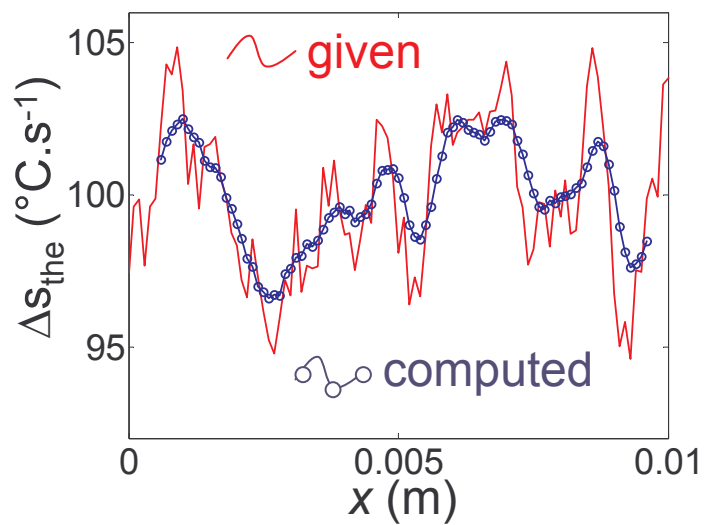
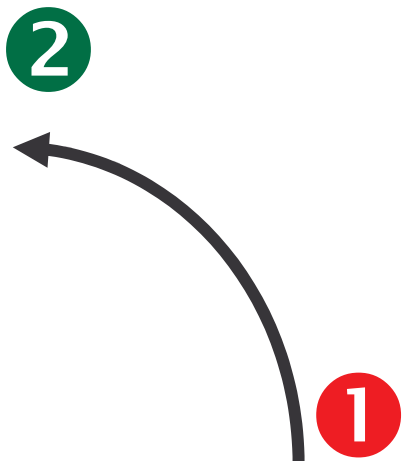
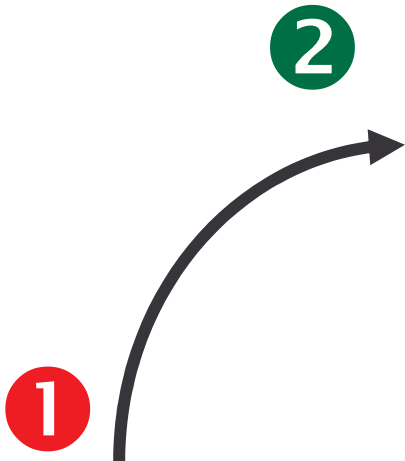
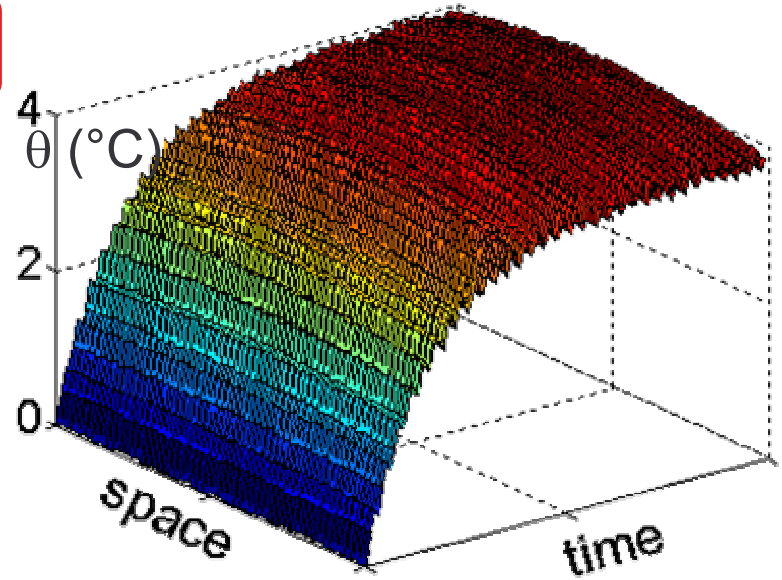
$M \approx 3, 15$ pixels

$$\theta(x,t) = \underbrace{p_1(x)t + p_2(x)}_{\text{drift}} + \underbrace{p_3(x)\cos(2\pi f_L t) + p_4(x)\sin(2\pi f_L t)}_{\text{periodic response}}$$

Data processing validation (1D)

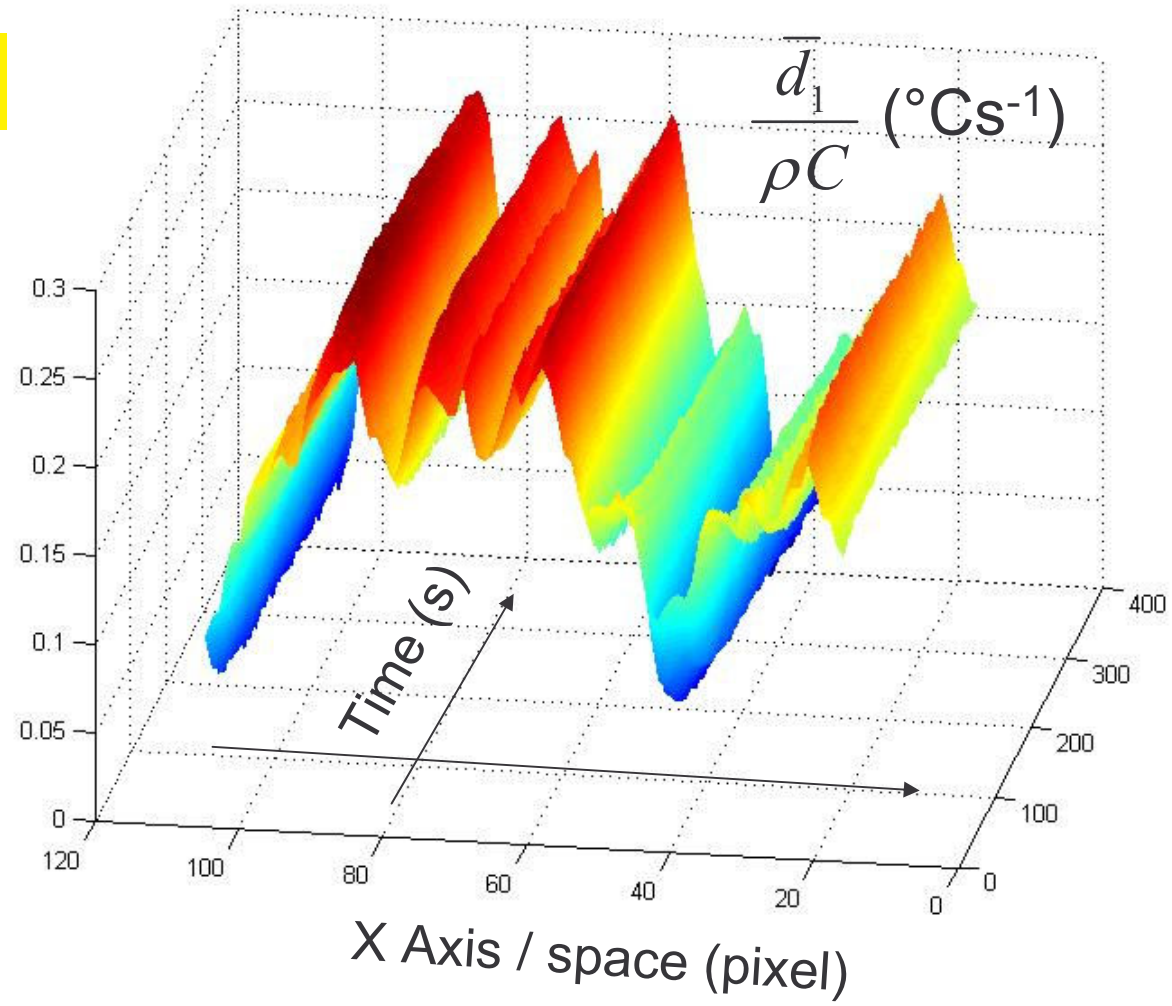
$$\Delta s_{\text{the}}(x), d_1(x) = \bar{d}_1$$

$$\Delta s_{\text{the}} \gg \bar{d}_1$$

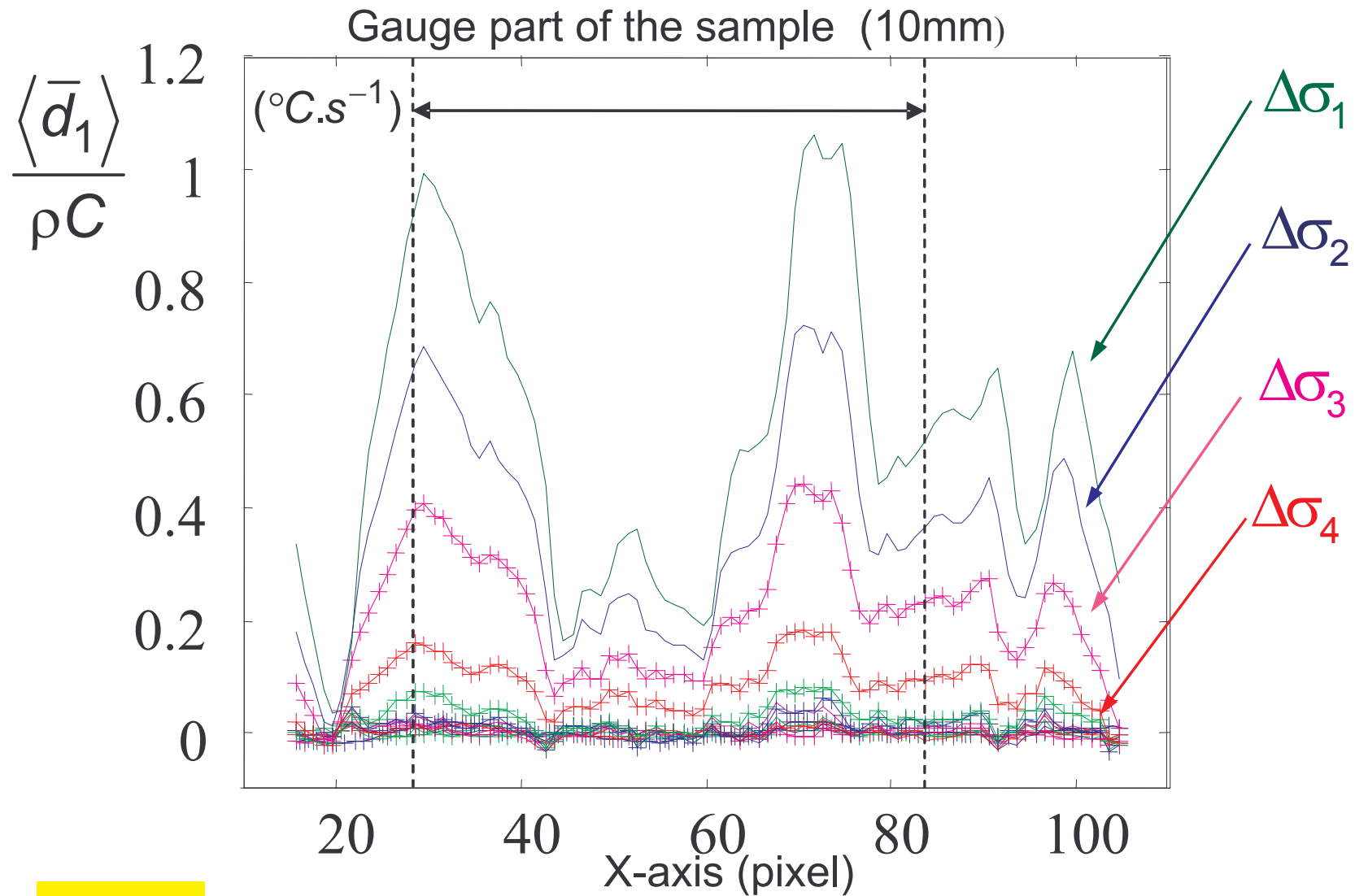


Distribution of \bar{d}_1 during a loading block

Steel



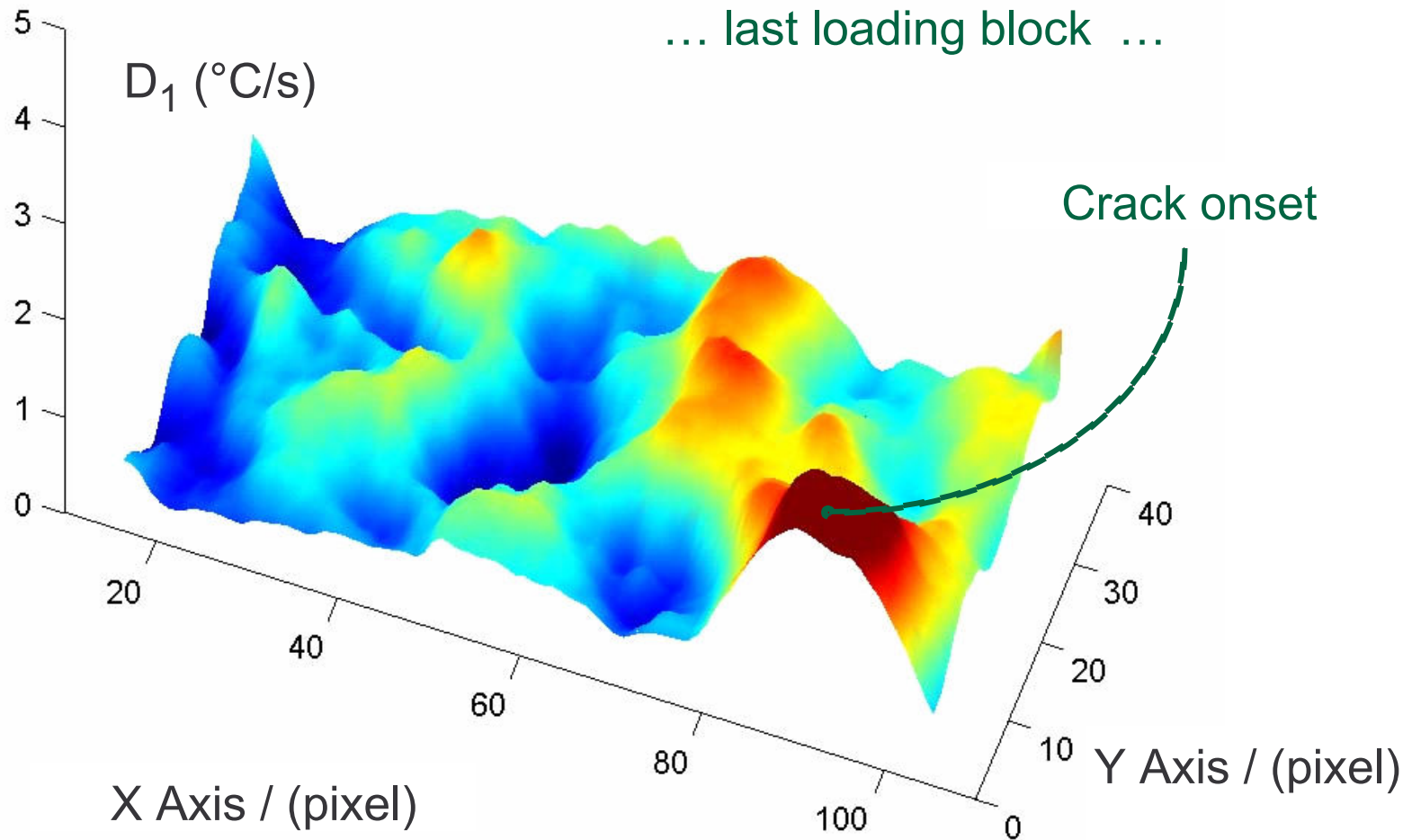
Mean profiles of $\langle \bar{d}_1 \rangle$ for different loading blocks



Steel

$$\Delta\sigma_1 > \Delta\sigma_2 > \Delta\sigma_3 > \Delta\sigma_4$$

First trial of 2D distribution of dissipation 1D^{1/2} !!



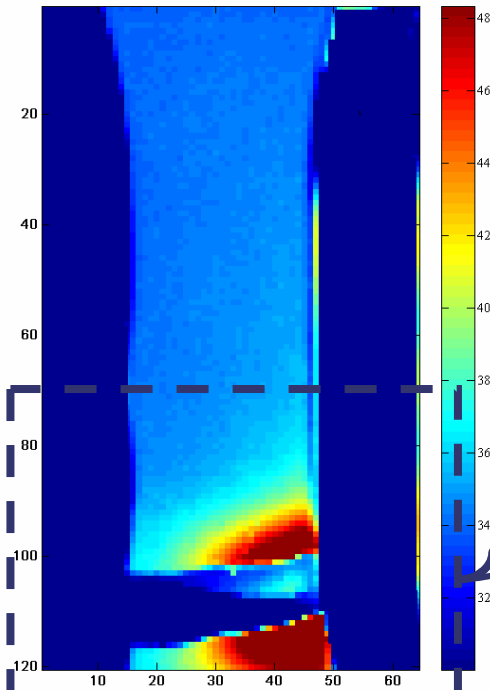
Steel

2D distribution of thermoelastic source

« True » 2D !

A. E. Morabito, UMII
+ Lecce, Italy

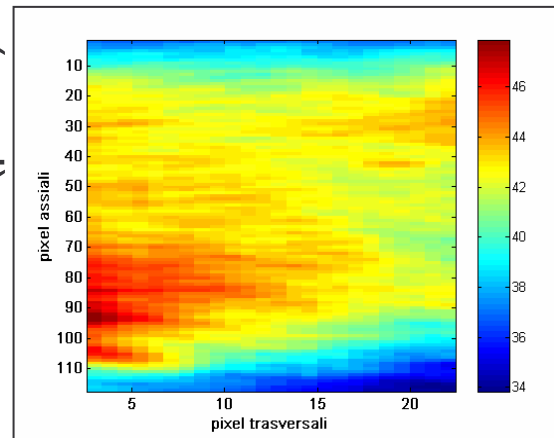
Failure ; block # 15



Pre-localization of crack onset

Aluminium

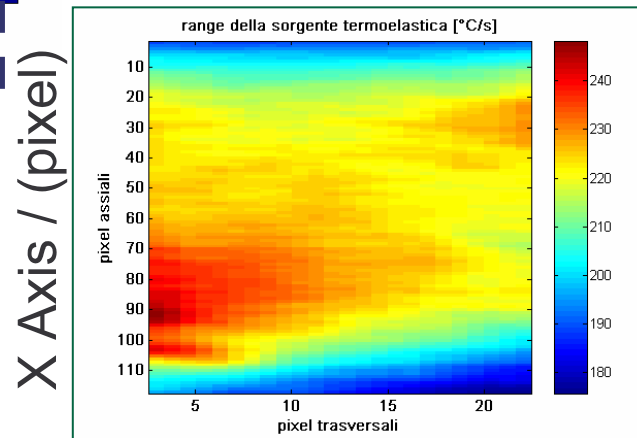
Block 3



[°C/s]

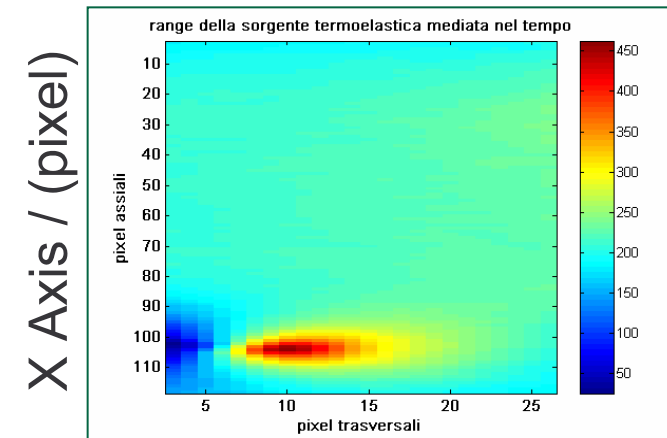
$$\frac{\Delta S_{the}}{\rho C}$$

Block 15



Y Axis / (pixel)

Block 15: failure



Y Axis / (pixel) 11

Concluding comments

- **Image processing** : s_{the} , \vec{d}_1 separately identified ($|s_{the}| \gg \vec{d}_1$)
- **Thermoelastic coupling** \Leftrightarrow state equation
- **Dissipation** \Leftrightarrow evolution equation
- **Fatigue limit** : **???**

heterogeneous fatigue tests
1D, 2D (near future)
(0D : *Int. J. of Fatigue* 2004)

Local analysis : material/structure

DIC + IRT : combined image processing