Production & caracterisation of 316L stainless steel wire-arc additive manufacturing

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Laboratoire de Mécanique et Génie Civil

CFM 2019 - Brest

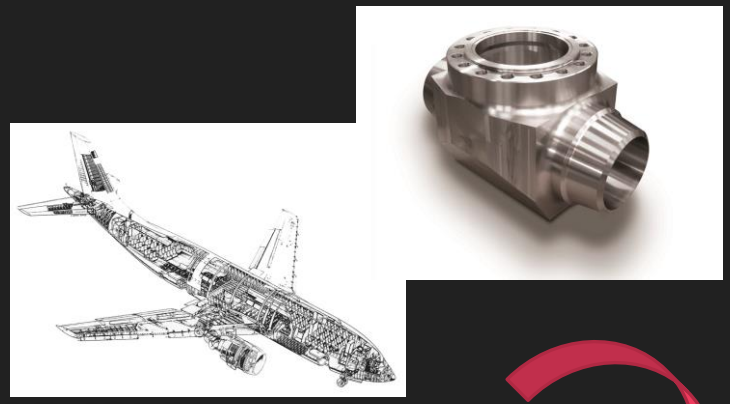
LMGC

- Laboratoire de Mécanique et Génie Civil
- UMR / Montpellier
- ~ 110 persons
- 7 teams

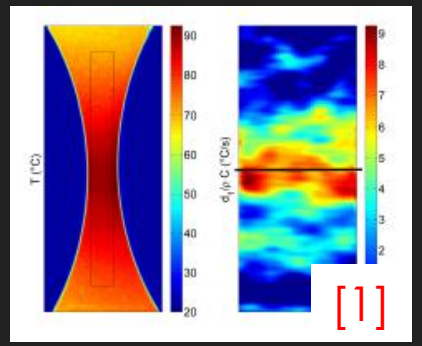
- Assemblages Soudés
- Biomécanique des Interactions et de l'Organisation des Tissus et des Cellules
- Bois
- Mathématiques et Modélisations en Mécanique
- Physique et Mécanique des Milieux Divisés
- Structures Innovantes, Géomatériaux, Ecoconstruction
- ThermoMécanique des Matériaux

MACCADAM project

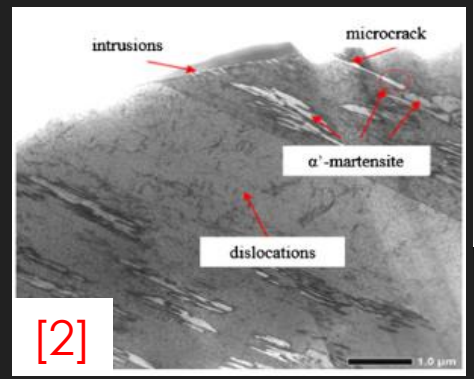
- « Matériaux à caractéristiques contrôlées élaborés par fabrication additive arc-métal »
- ANR
- ~ 4 years
- LMGC / ICA / ENIT / CEMEF / Poly-shape
- 3 goals
  1. Identify potential applications



  2. Define the impact of process parameters on 316L / TA6V regarding
     - Geometry
     - Mechanical caracteristics
     - Microstructure
     - Fatigue behaviour



[1]



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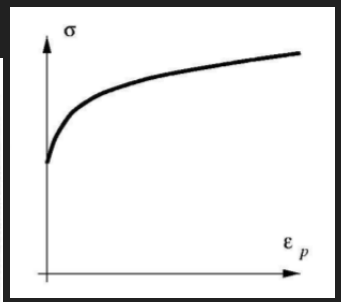
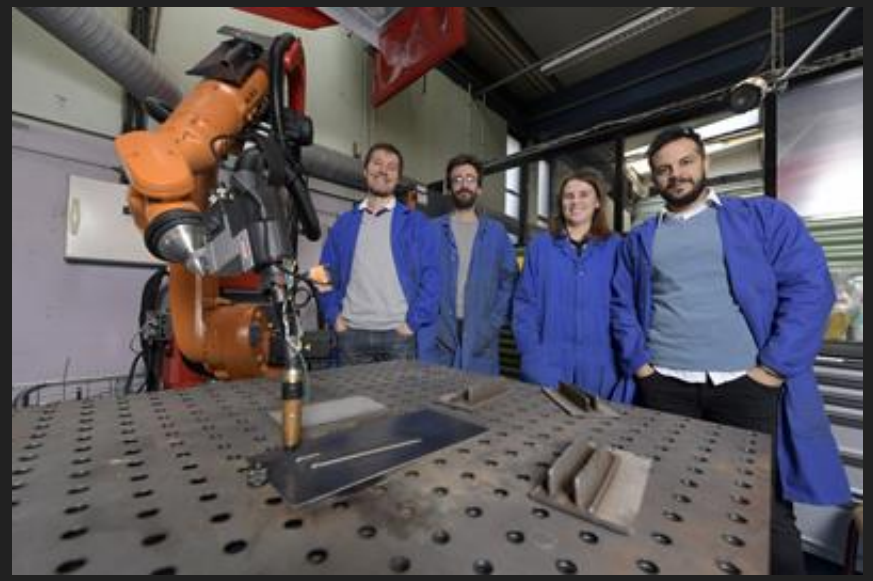


  3. Modelisation of the behaviour / microstructure

WAAM = process



- Wire-arc additive manufacturing
- ~~Powder~~ => Wire
- Welding torch + Motion (table, CNC, Robot …)

- Big parts
- Deposit rate (…5 Kg/h)
- Available means / wires

- Not accurate geometry
- Work in progress on … residual stresses, fatigue => bring confidence !

Welding Technology

GMAW

CMT (cold metal transfert) - Fronius

Controlled short-circuit : electrically and mechanically

Warm ↘

residual stresses

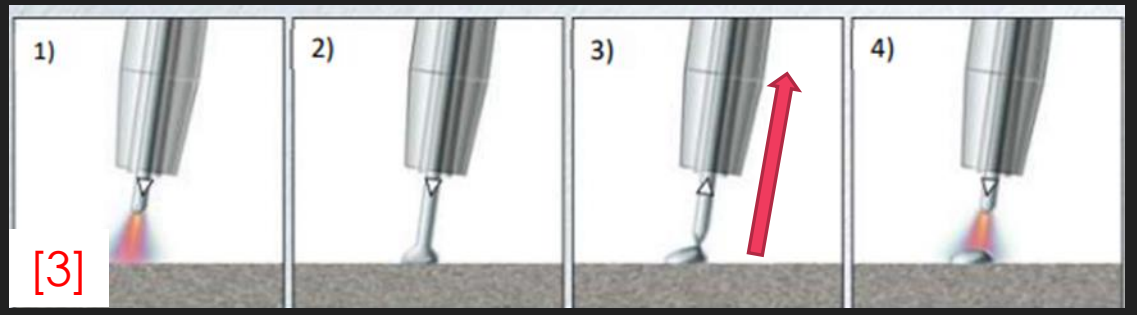
distortions

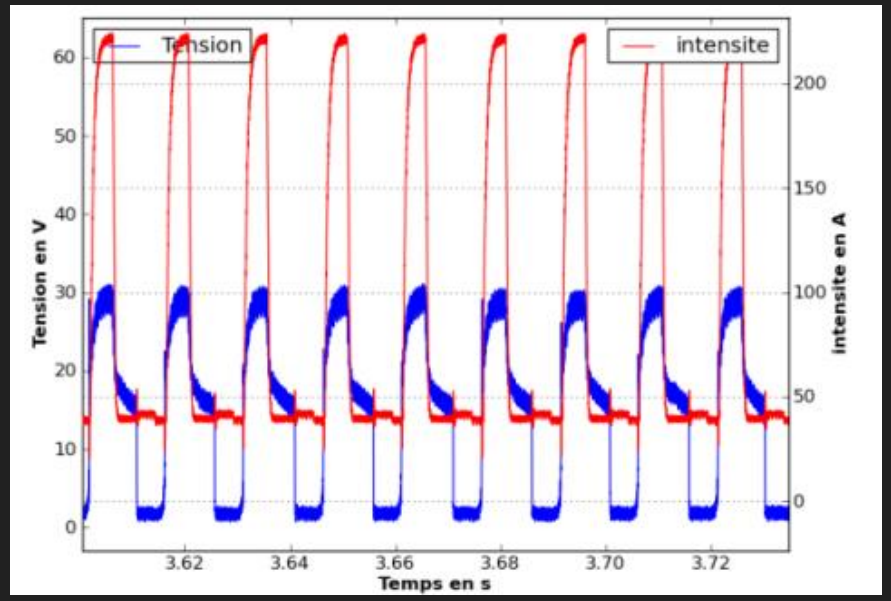
Spatters ↘

Good synergy

Repetability

Adaptability (ex : no increase a defect)





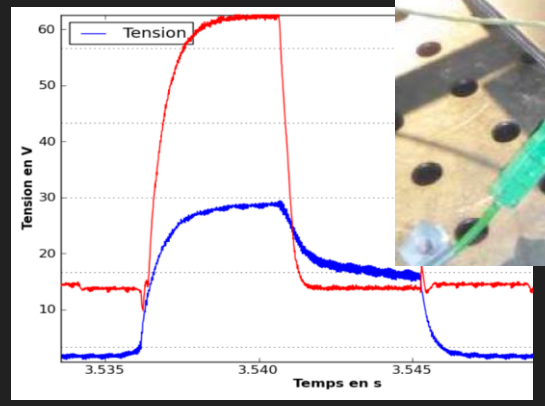
Process measurements

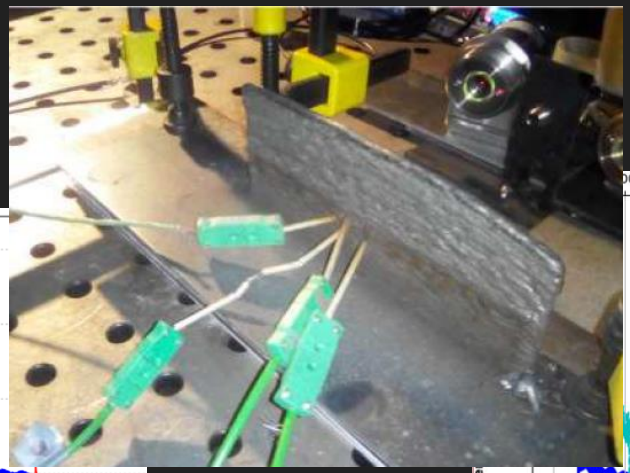
- Voltage / Intensity
- Temperatures

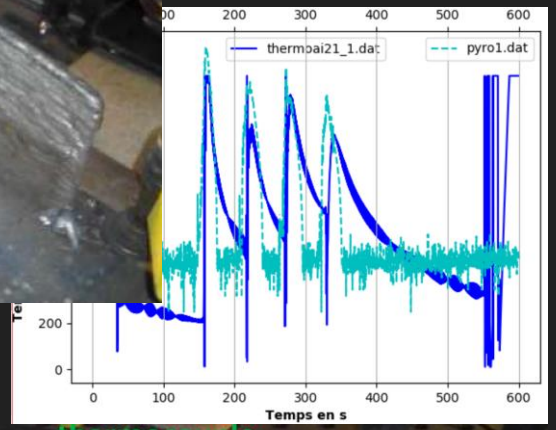
  Thermocouples, pyrometers (?), IR camera (?)

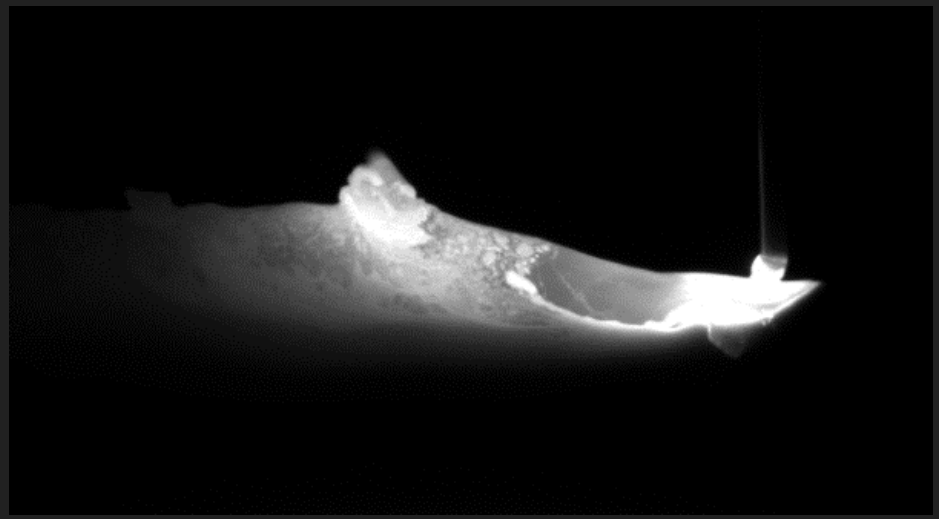
  Simulaltion (CEMEF)
- Visual pool camera

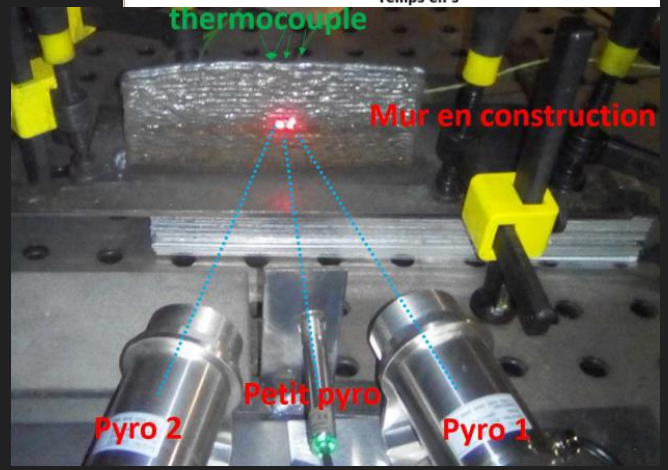
  isotherms, simulation (CEMEF)





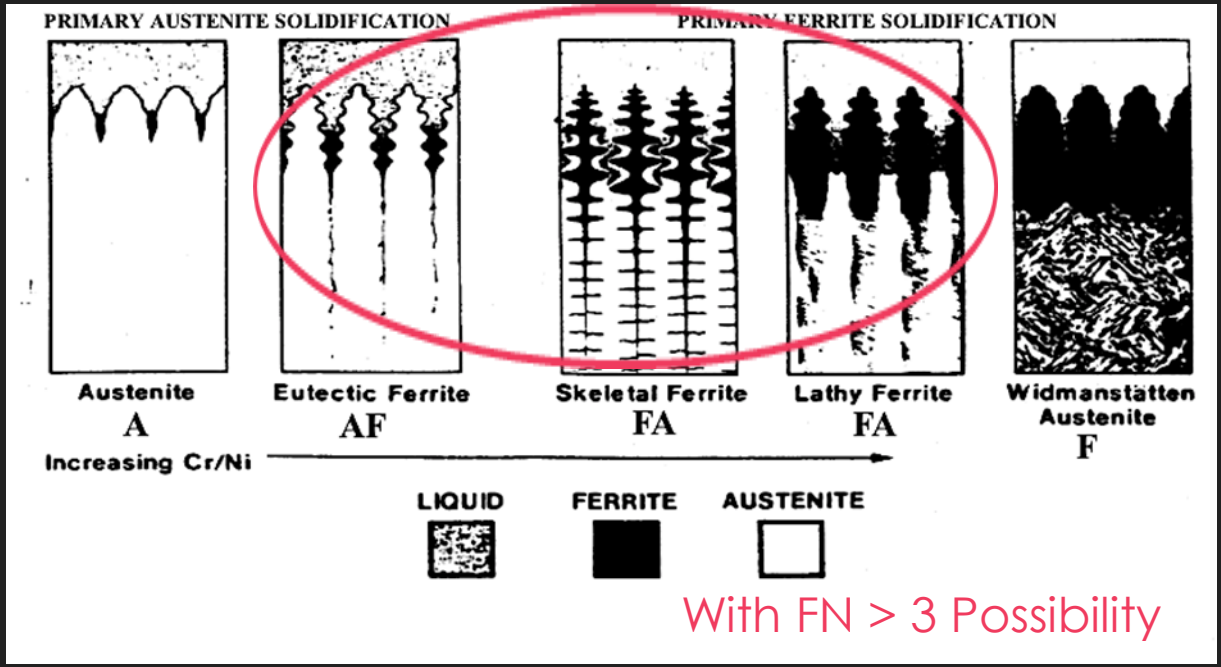




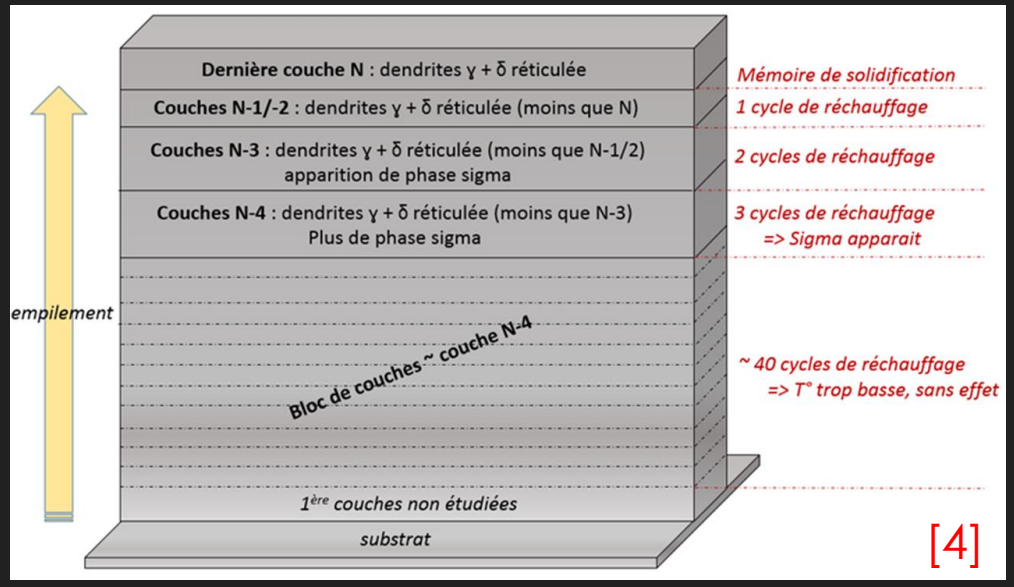


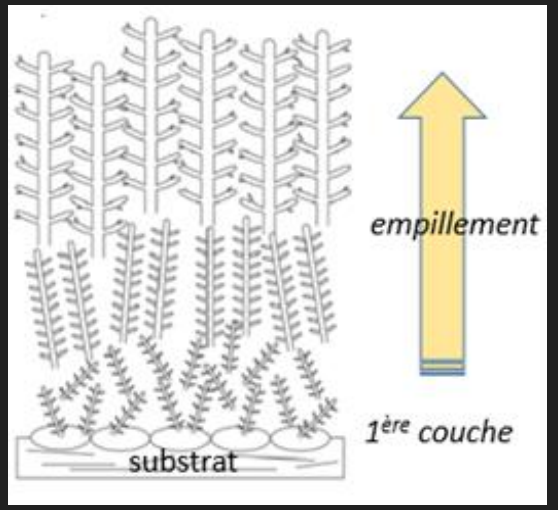
316L stainless steel

- Solidification welding microstructure



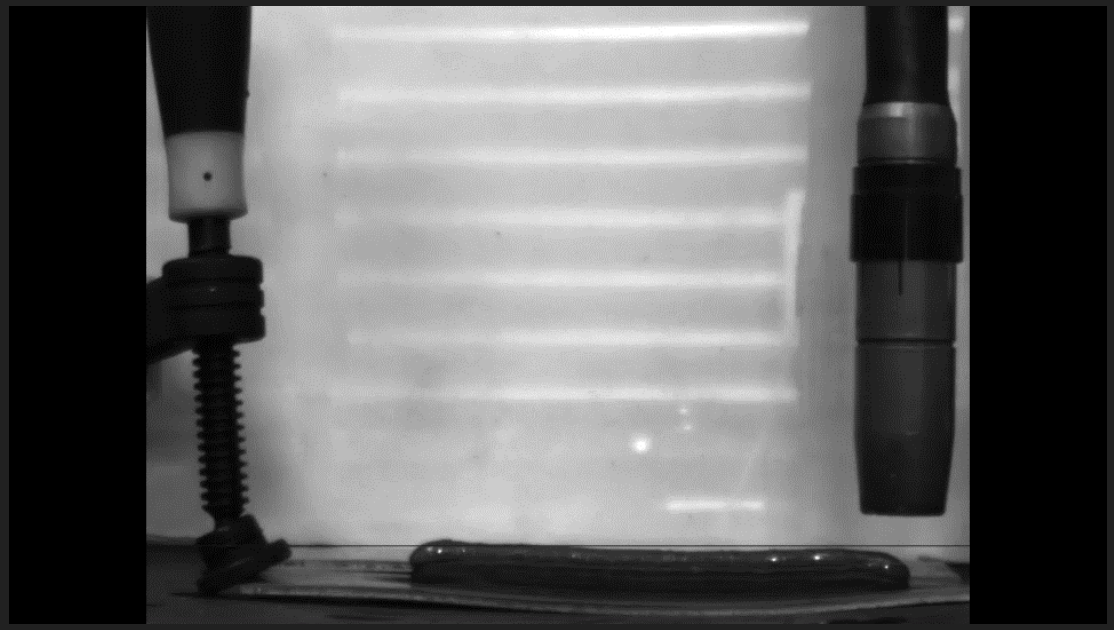
- WAAM microstructure



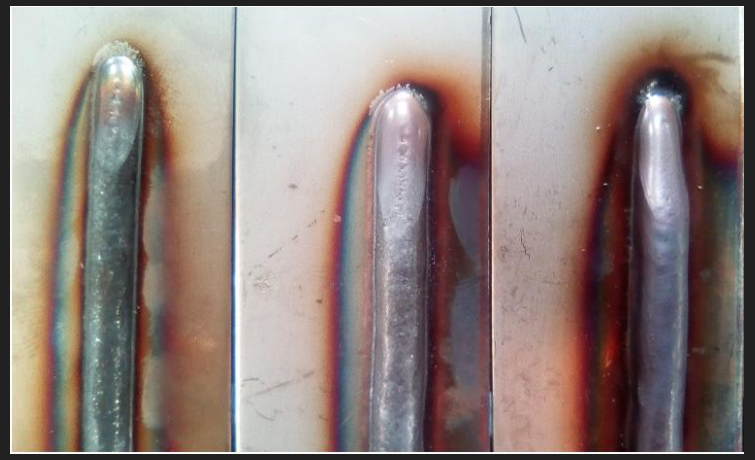


Manufacturing

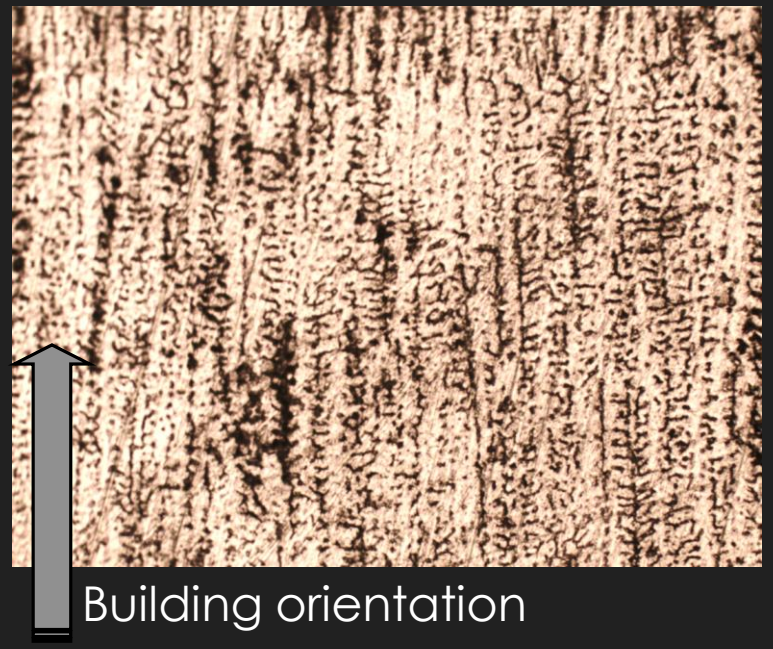
- Stick-out control (via camera)



- Stainless steel oxydation ?



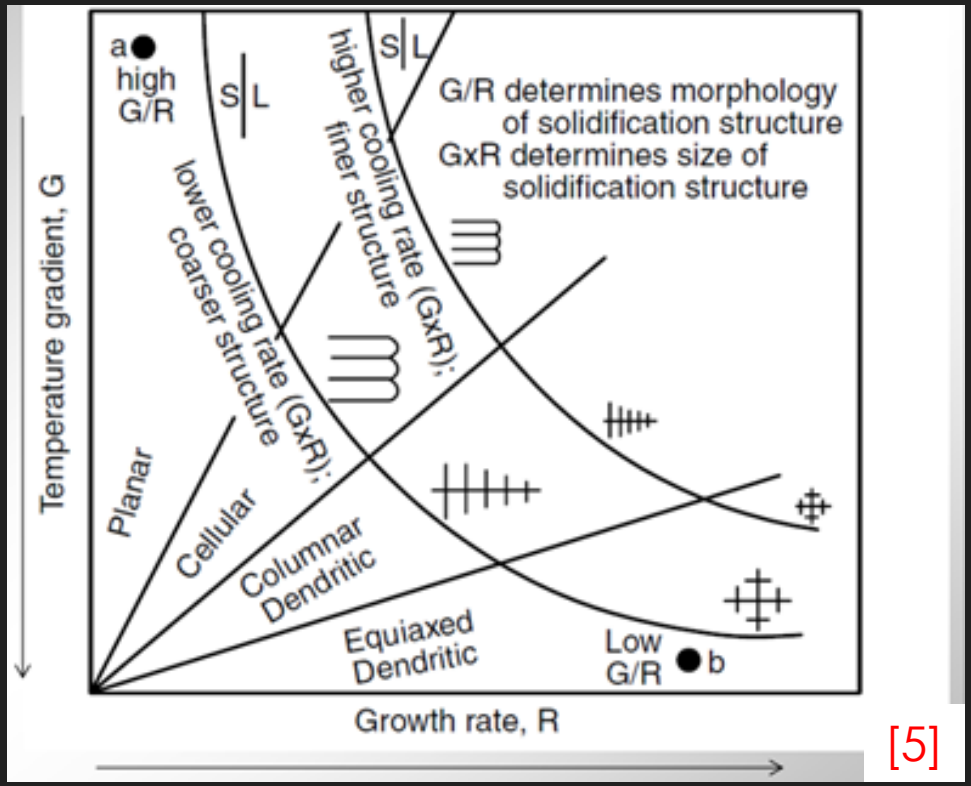
- First results -- > confirmation



Manufacturing

- Aim : having different samples
  - microstructure / texture
  - residual stresses

- Process parameters
  - fixed
    - Gaz : Ar+2%CO2
    - Stick-out : 15 mm
    - Process : CMT with fixed synergy
  - variable
    - Wire speed -- > U / I change
    - Welding speed (torch motion)
    - Idle time (between each bead)



[5]

~ welding speed

Manufacturing

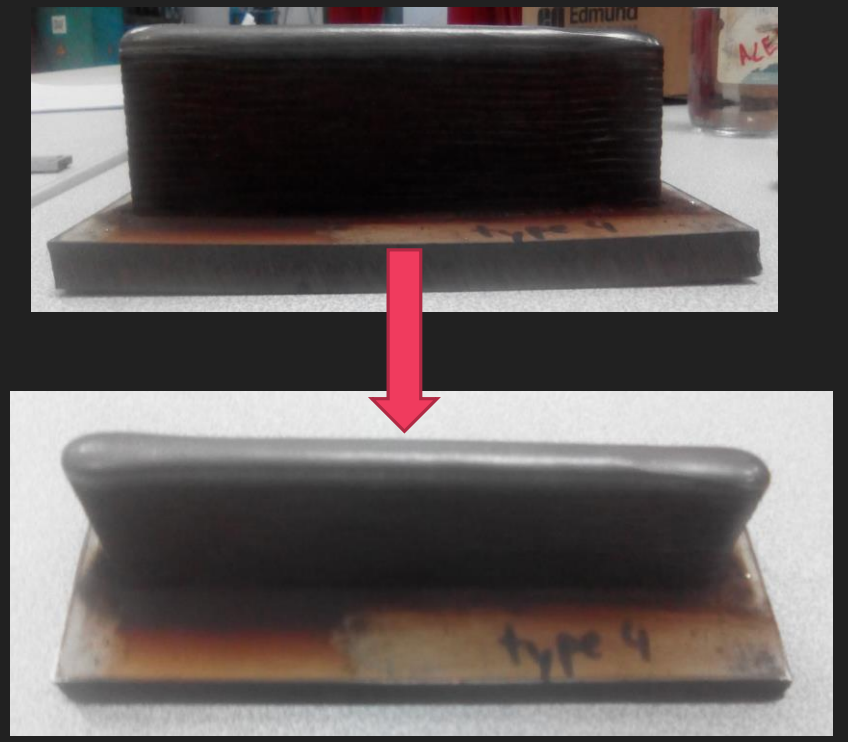
- 5 walls produced

Strategy : mono-bead

Wire speed : from 1 to 6,7 m/min

Torch speed : from 10 to 67 cm/min

Tickness : 5 mm



Tickness : 14 mm

Manufacturing (work in progress)

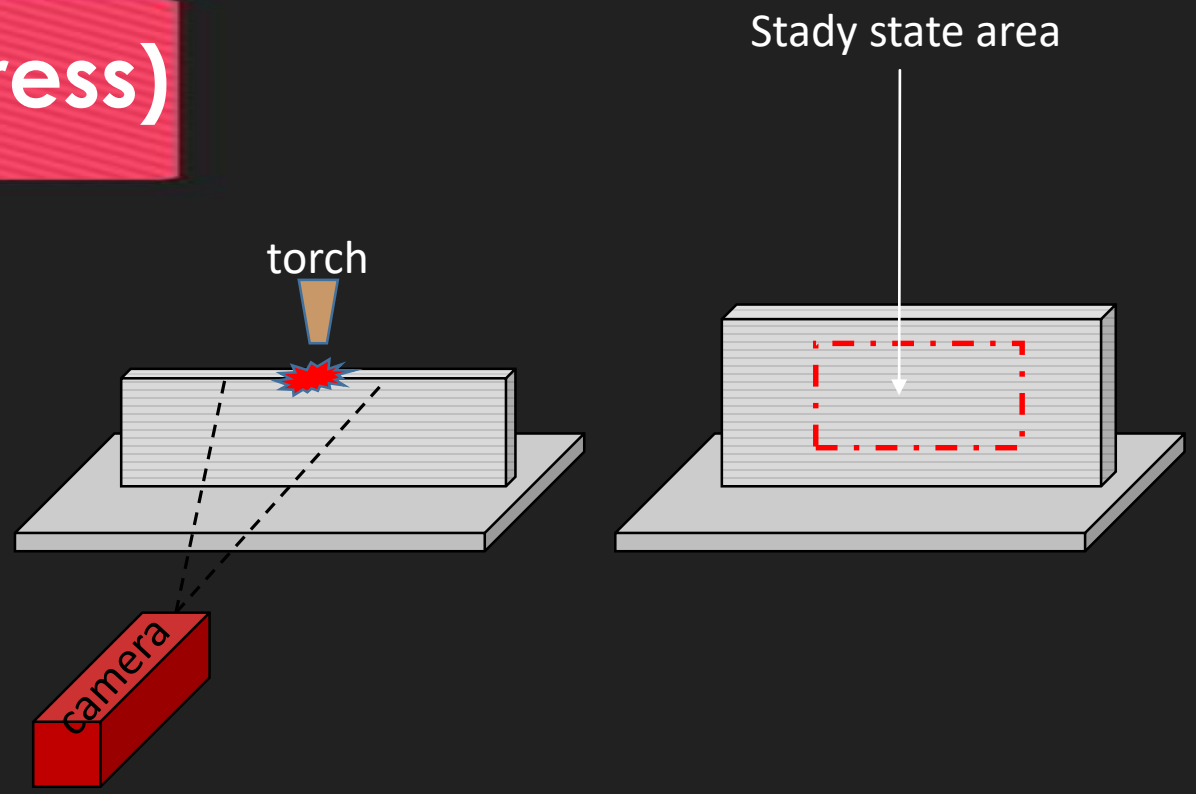
- 5 walls produced

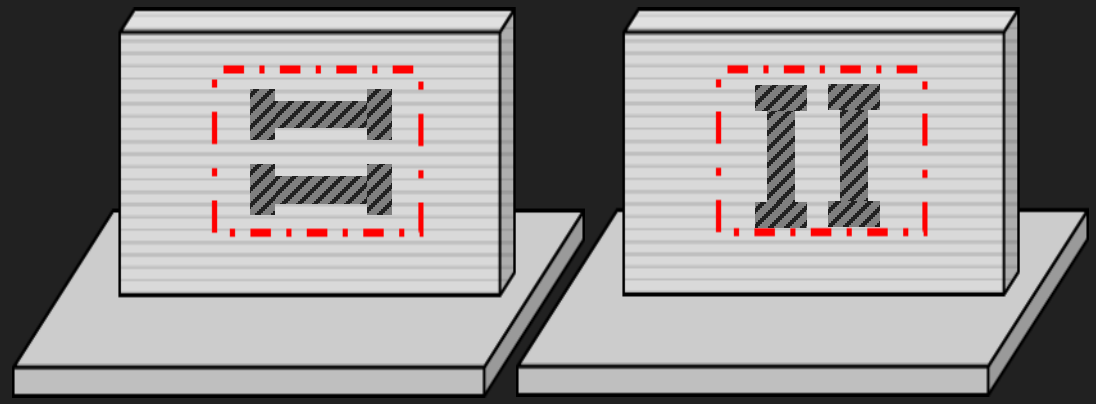
-- > pre-analysis ---- > choice of 2-3 walls

- Manufacturing

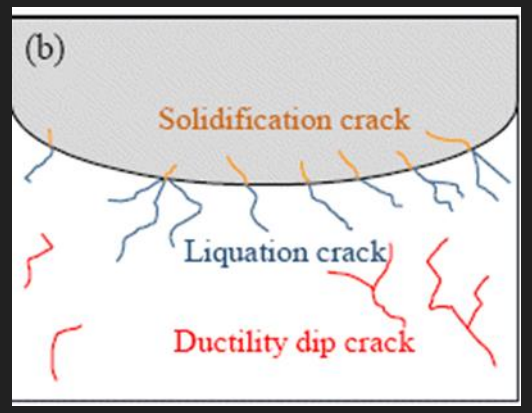
Without heat-treatment

With heat-treatment (550°C or 1100°C)

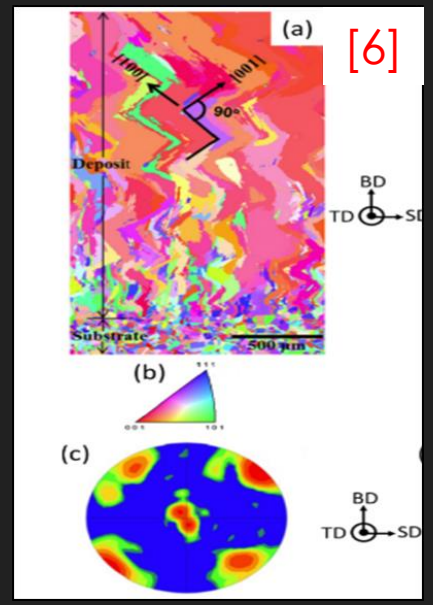


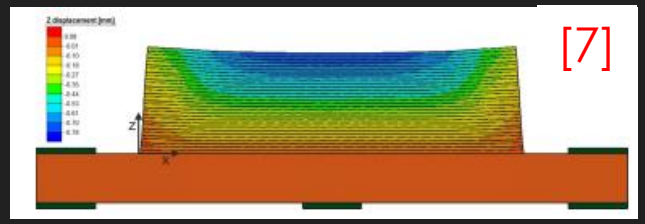


Analysis (futur work)



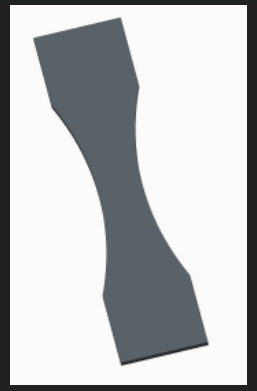
- O and S.E microscopies (ICA)
- EBSD- SEM / DRX cristallography (ICA)
- Scanner distortion measurements (ICA)
- Residual stresses measurements and simulation (All / CEMEF)

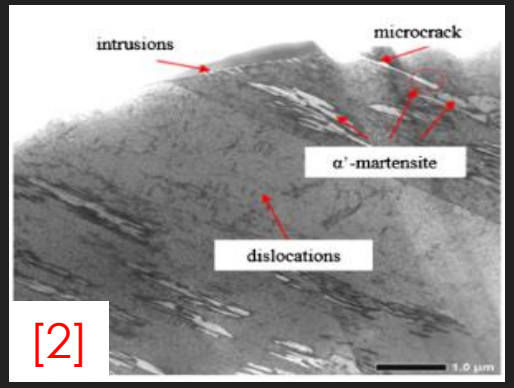


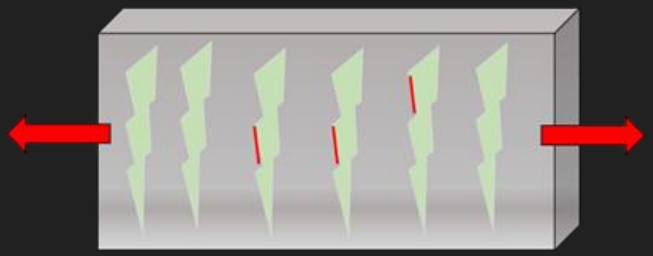


Fatigue (futur work - LMGC)

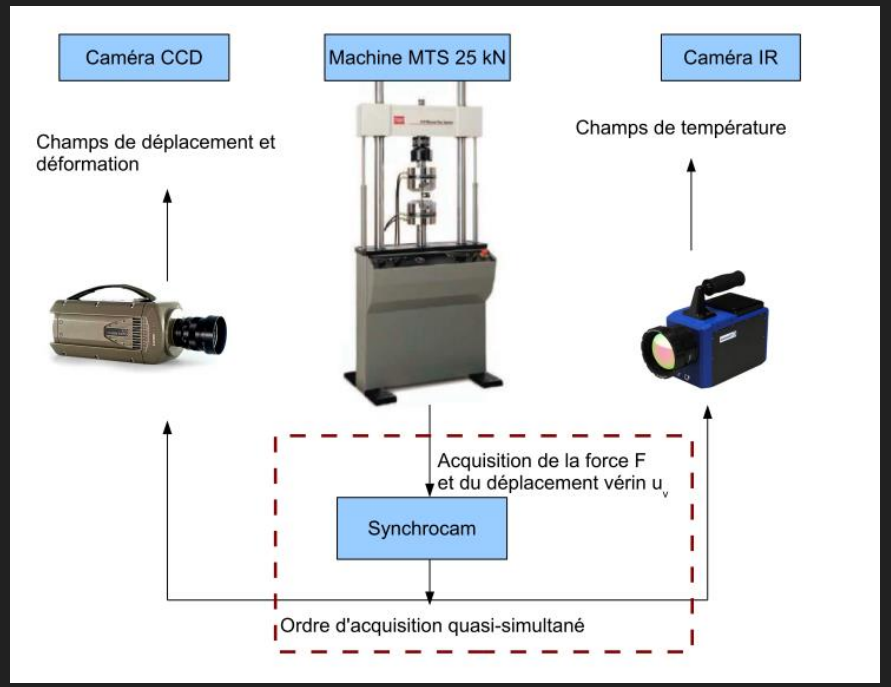
- Sheet reference samples
- WAAM samples







- Fatigue tests (LMGC) -- > self-heating
  - 1 thermal camera
  - 1 visual camera



Fatigue (futur work - LMGC)

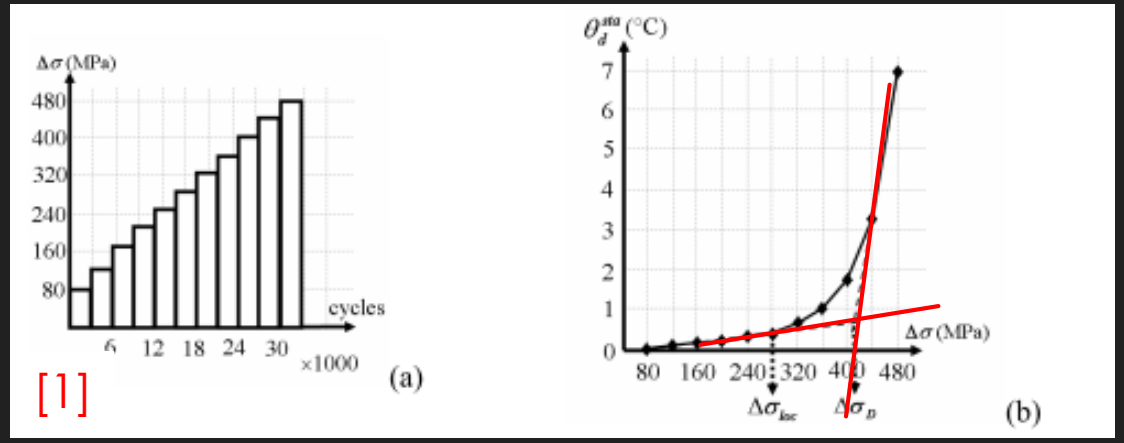
- 1 thermal camera -- > temperature fields

  localy or not :

  quick determination of limit fatigue

  localisation of defect/weakness

  thermoelasticity and dissipation sources evaluation

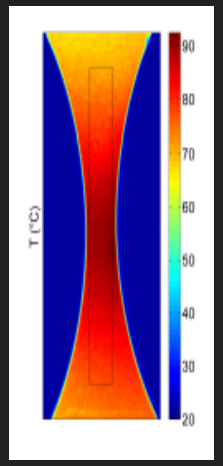


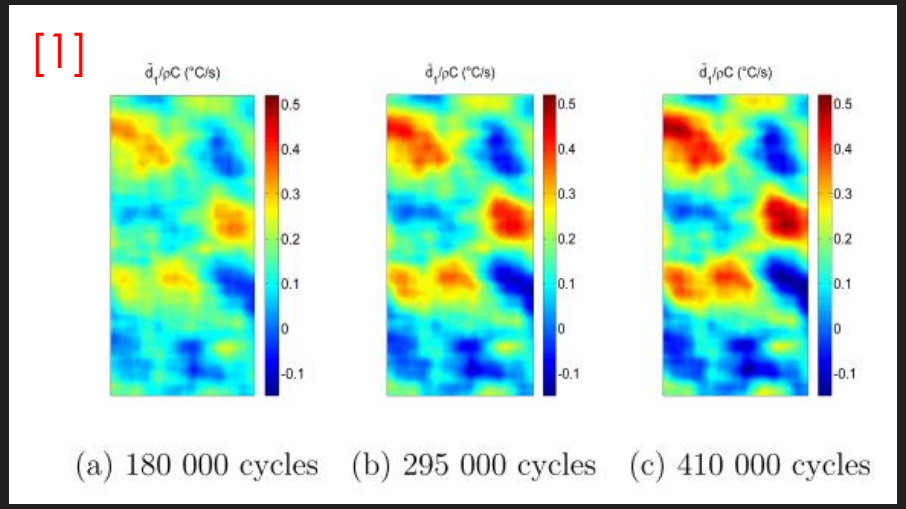
- 1 visual camera -- > displacement fields

  localy or not :

  estimation of strain / stress fields

  localisation of defect/weakness





-- > combinaison of cameras

Local energy balances ---- > access to stored energy

References

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Effets dissipatifs en fatigue à grand et très grand nombre de cycles
LMGC – UM PhD 2011

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Int. J. Fatigue, vol. 93, pp. 250–260, 2016

[3] : www.Fronius.com

[4] : X. Chen, J. Li, X. Cheng, B. He, H. Wang, and Z. Huang, "Microstructure and mechanical properties of the austenitic stainless steel 316L fabricated by gas metal arc additive manufacturing," *Mater. Sci. Eng. A*, vol. 703, pp. 567–577, Aug. 2017

[5] : R. W. Messler, Principles of Welding. Wiley, 1999.

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Merci de votre attention