

# Optimization of WLAM process Parameters for Metal Forming Tool Repair

Conférence AMS Senlis  
20-21 mars 2024

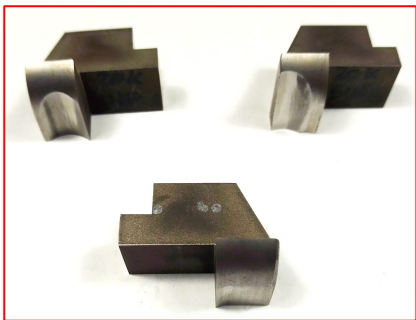
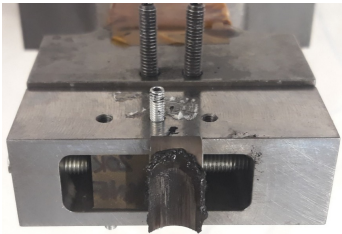
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# Context

## Context

- Tool wear



## Problems

- Wear
- Waste
- Environment



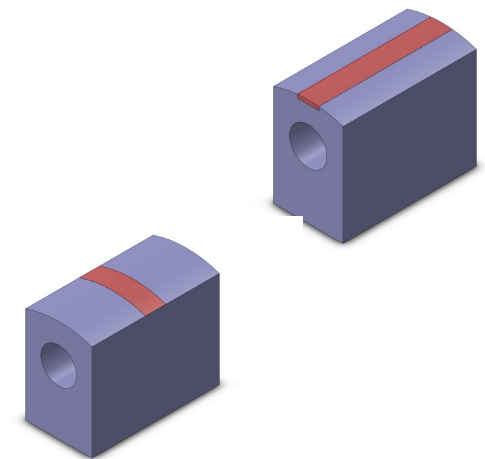
## New Approach

- Reload
- Restoration of tribo-mechanical functions



## Locks

- Optimization of laser parameters
- Preservation of matrices
- Improving tribo-mechanical



## Equipment used for reloading

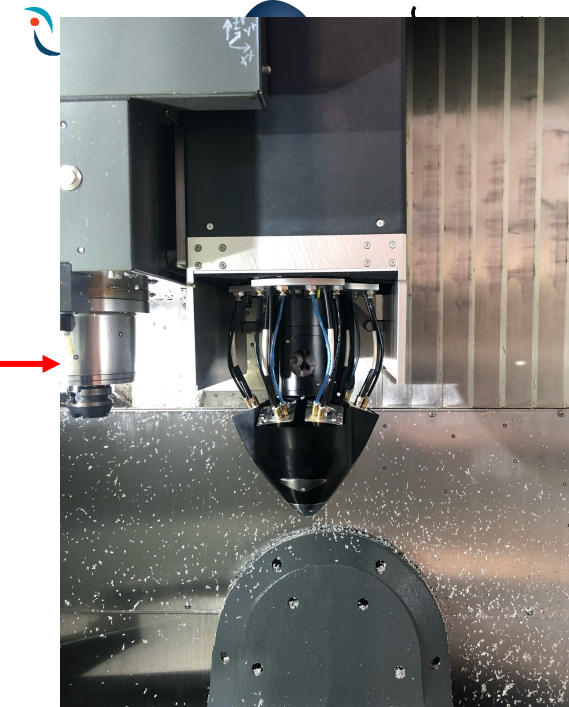
### DED WLAM + 5-axis machining centre : Why?

#### CNC

- HAAS 750 5-axis

#### 3D Printer

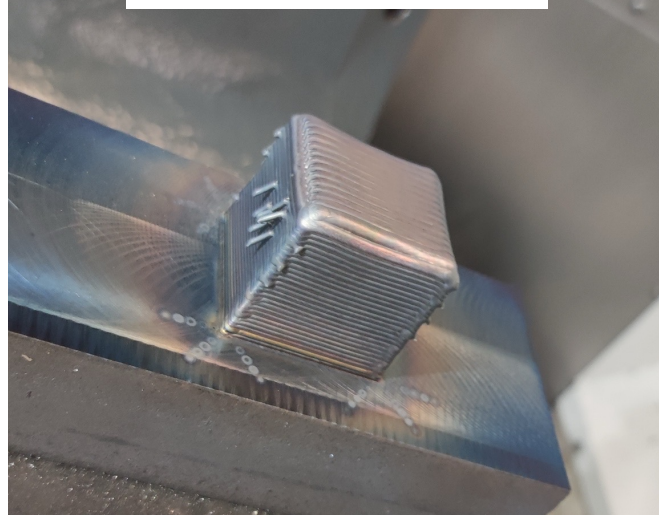
- Meltio M450 (Wire Laser)
- 6 Laser diode – Power max 1.2 kW



**Step1:** Impression of the part



**Step2:** End of the impression



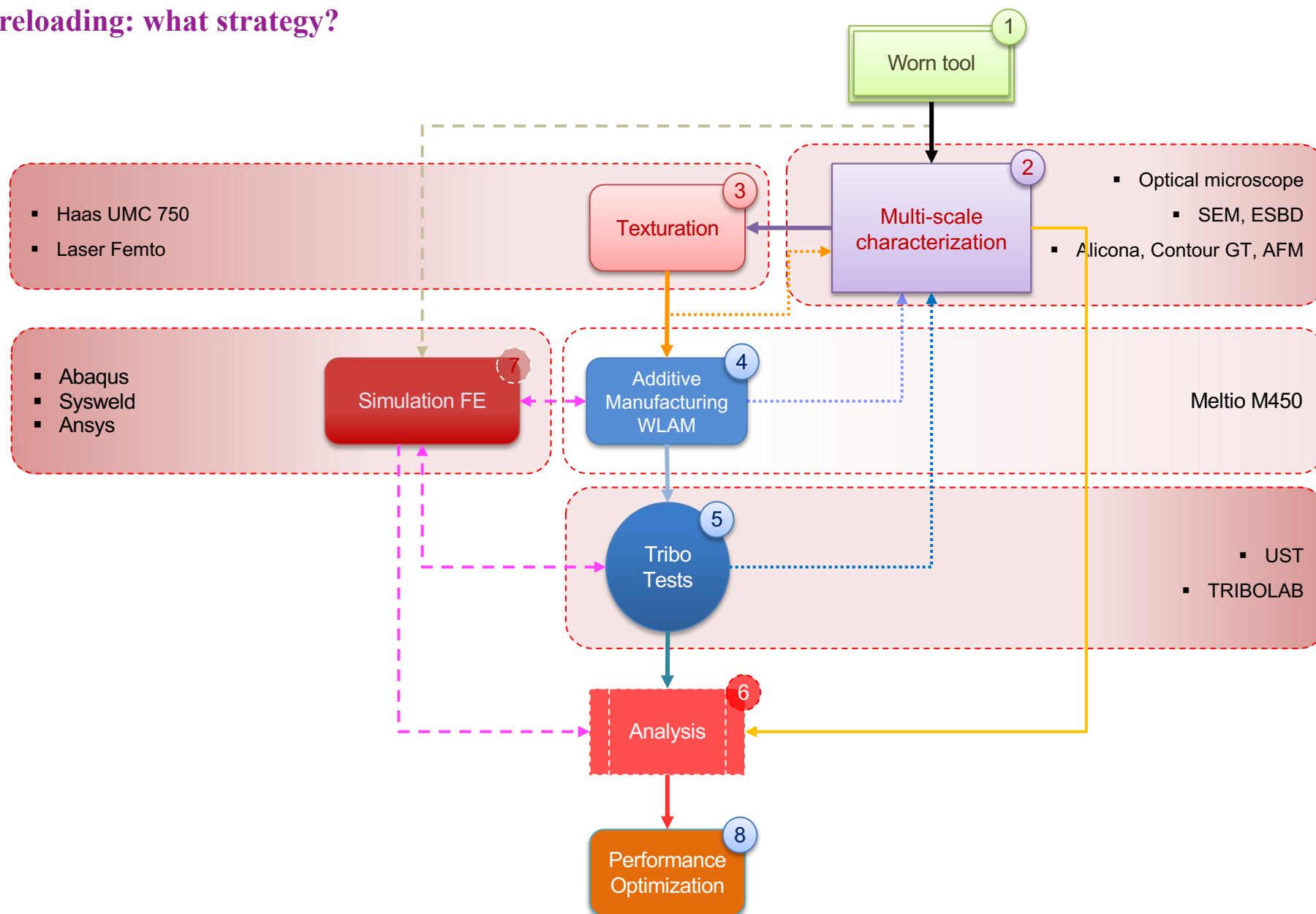
**Step3:** Machining



**Step4:** End of machining



## Tool reloading: what strategy?



## Parametric study

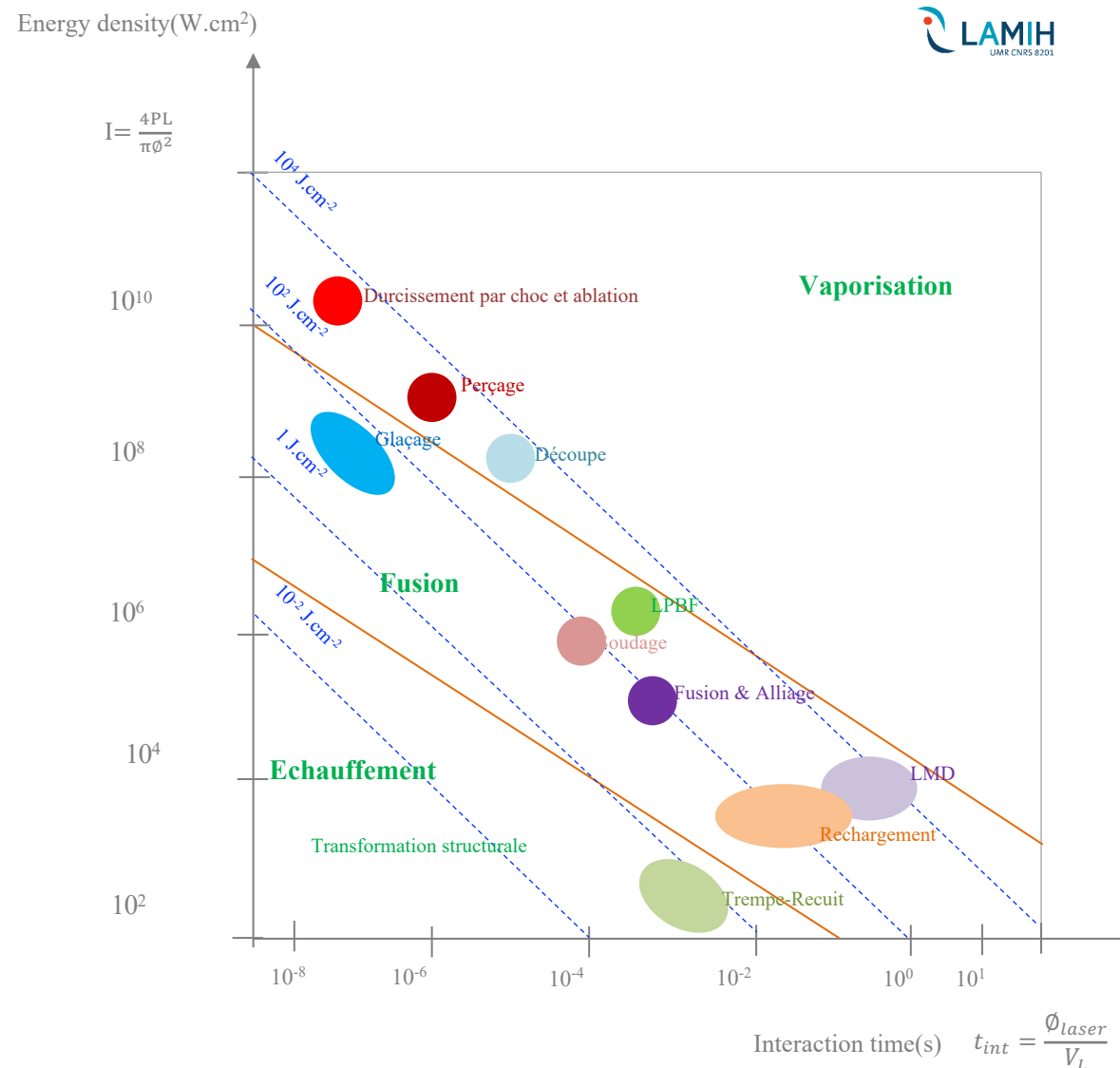
### Why?

#### Input parameters:

- Laser power (W)
- Wire flow (mm/s) (Fixed parameter)
- Feed speed (mm/min) (Fixed parameter)
- **Energy density ( $W.cm^{-2}$ )**

#### Output Settings:

- Geometric stability of the cords
- Evolution of the geometry of the cords
- Evolution of temperature
- Evolution of microstructure
- Evolution of hardness



Laser-matter interaction regimes as a function of power densities ( $W/cm^2$ ) and interaction times (s) involved

## Parametric study

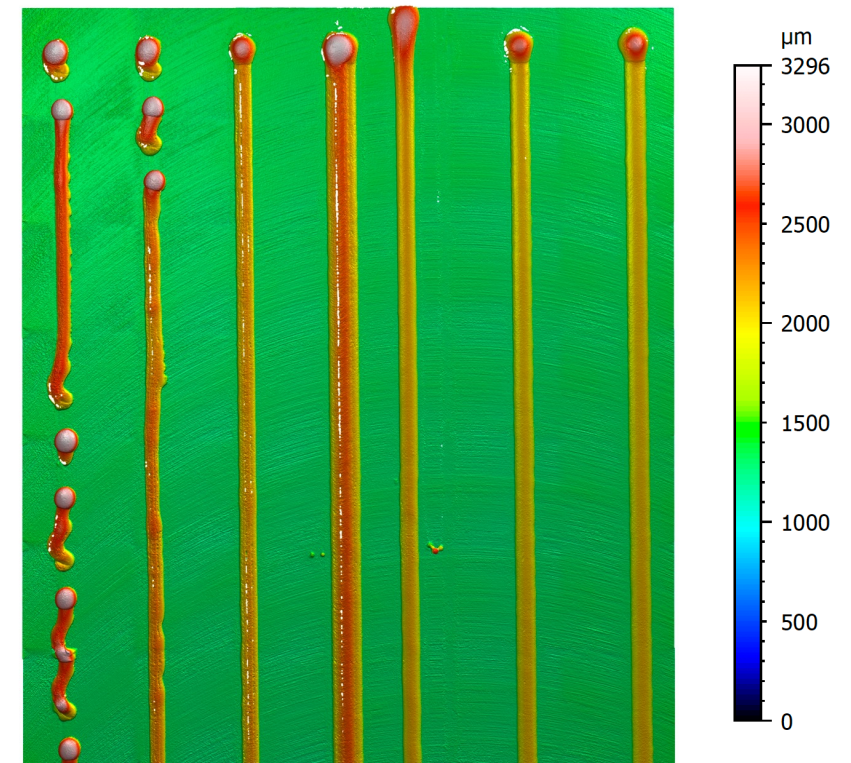
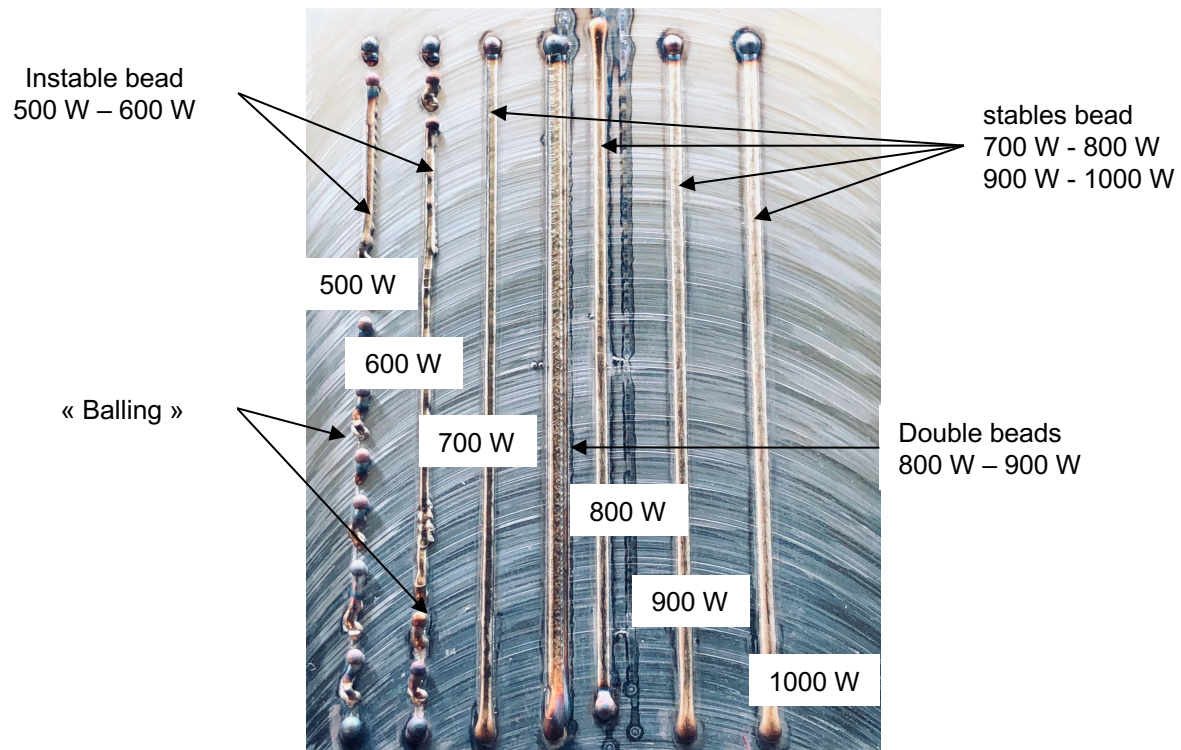
### ■ Bath Stability Parameters: Bead Morphologies

#### ■ Manufacturing parameters

- Laser power: from 500 W to 1000 W
- Feed rate: 15.2 mm/s

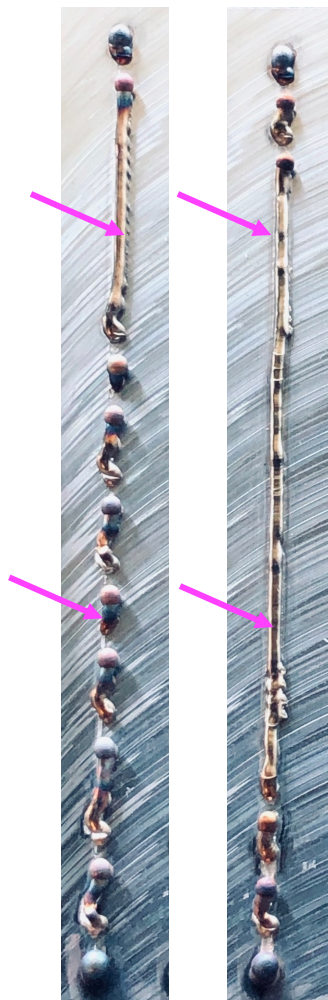
#### ■ Unstable beads between 500W - 600W

- “Balling” phenomenon
- Reducing the machine feed increases the laser/material interaction time



## Some defects

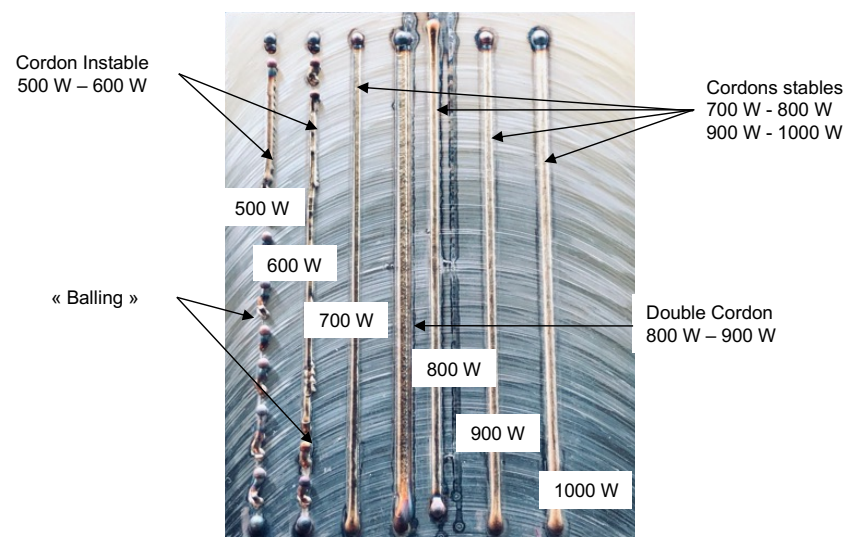
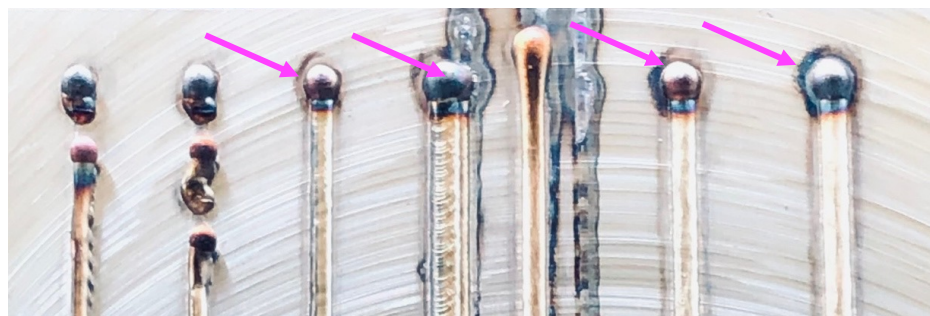
### ■ Denting phenomenon



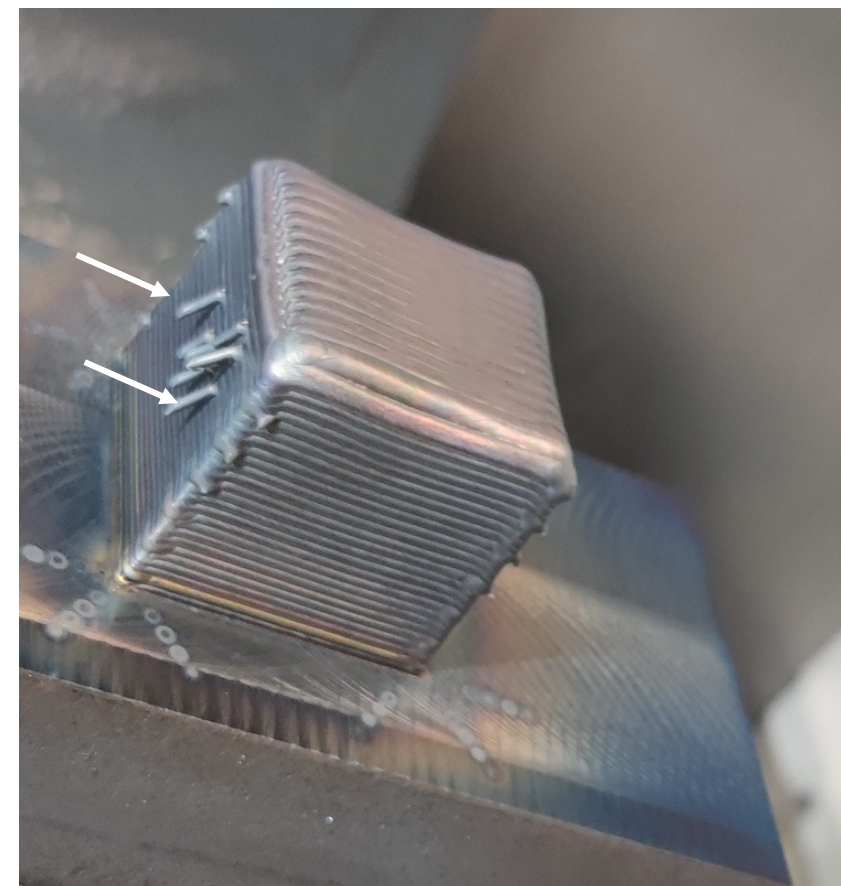
500W

600W

### ■ Bumps at the beginning and end of printing

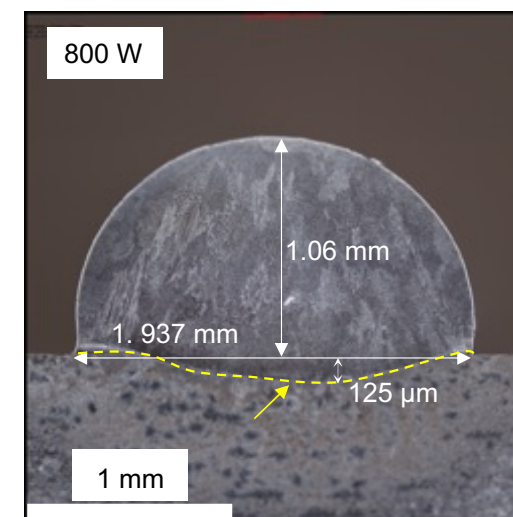
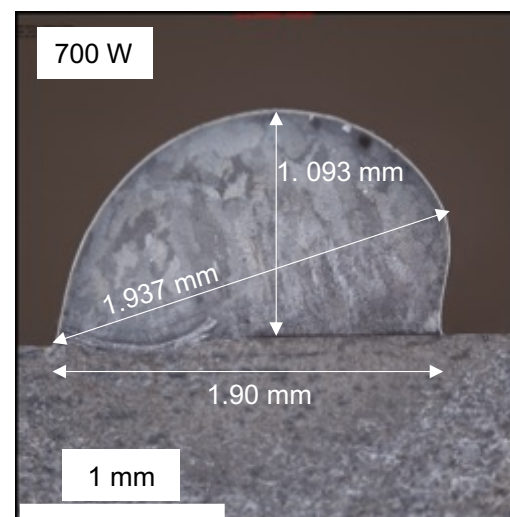
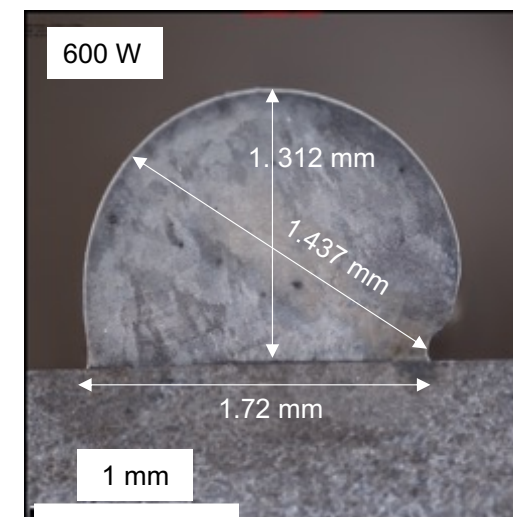
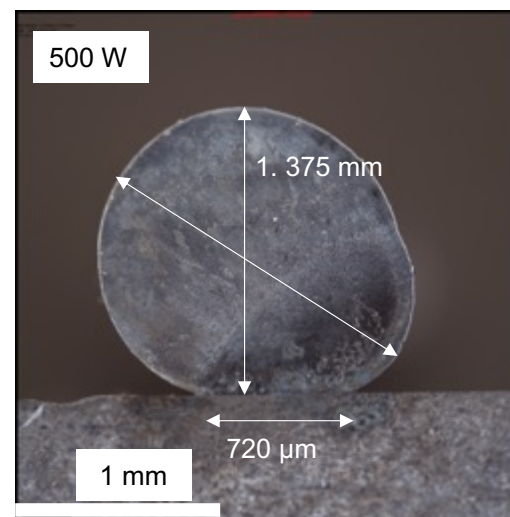
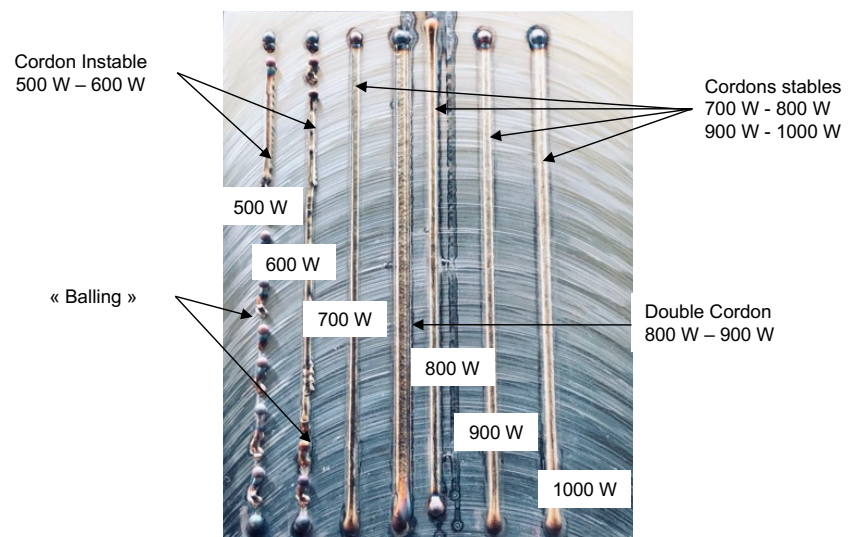


### ■ Early wire breakage



## Some defects

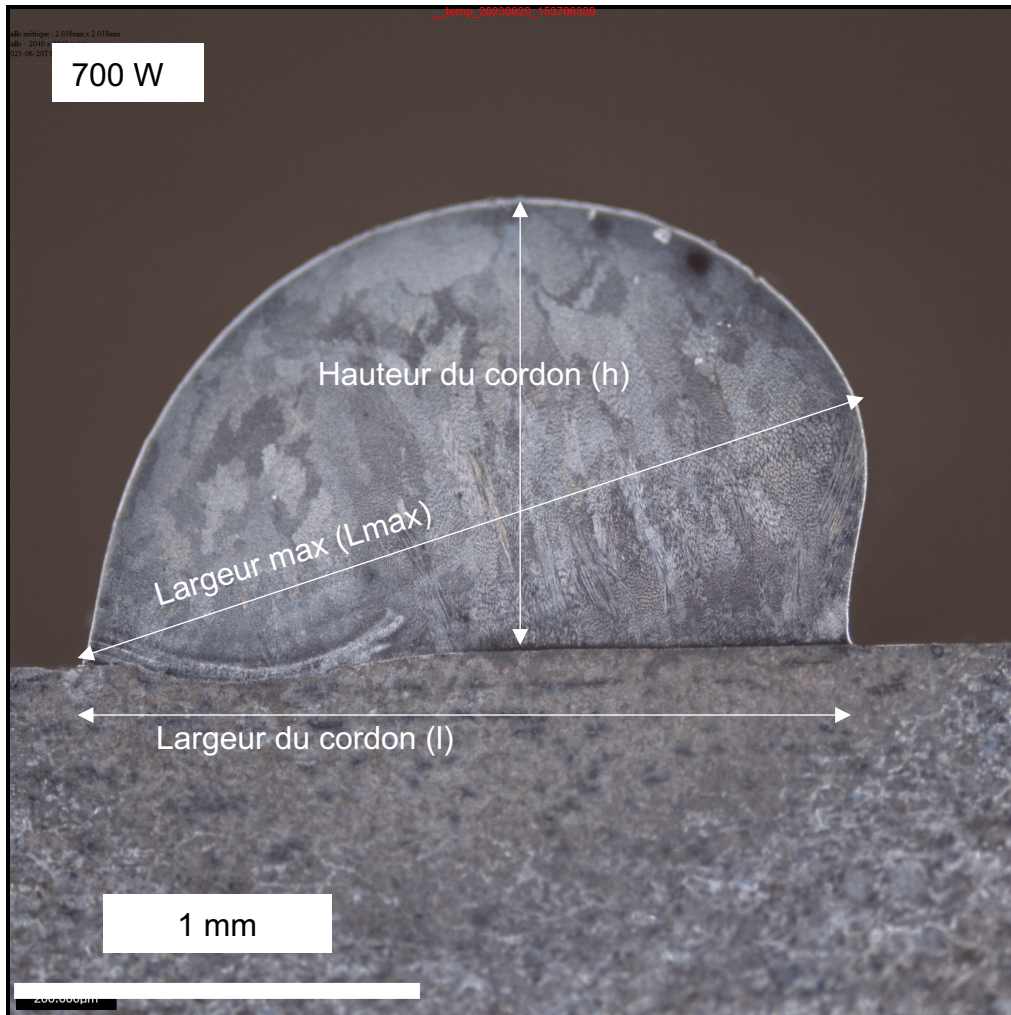
### ■ Unsymmetric geometry



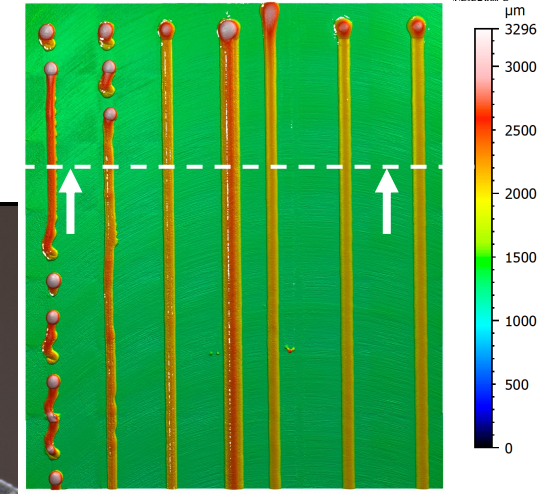
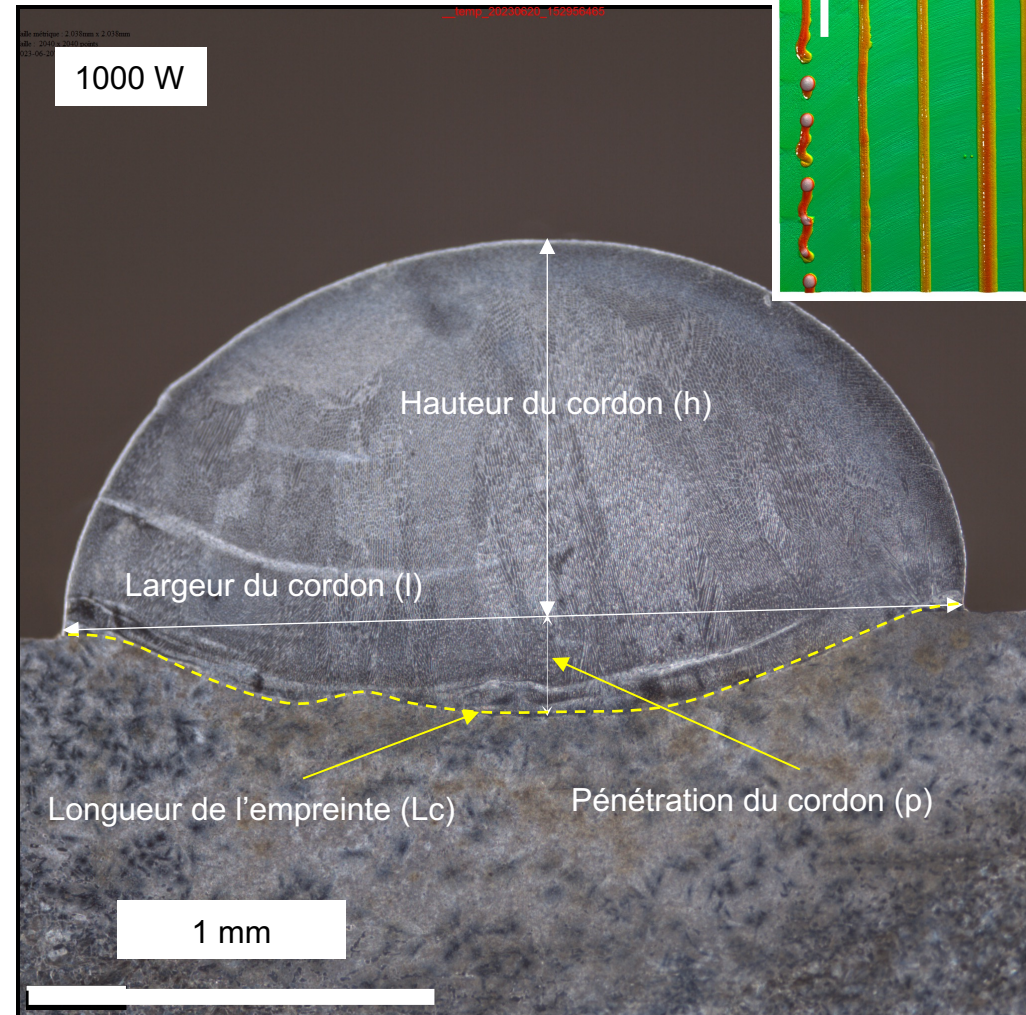


# Bead morphology and geometric measurements

## Unstable or non-uniform beads



## Homogeneous stable beads



## Conclusion on Parametric study

### Parameters selection:

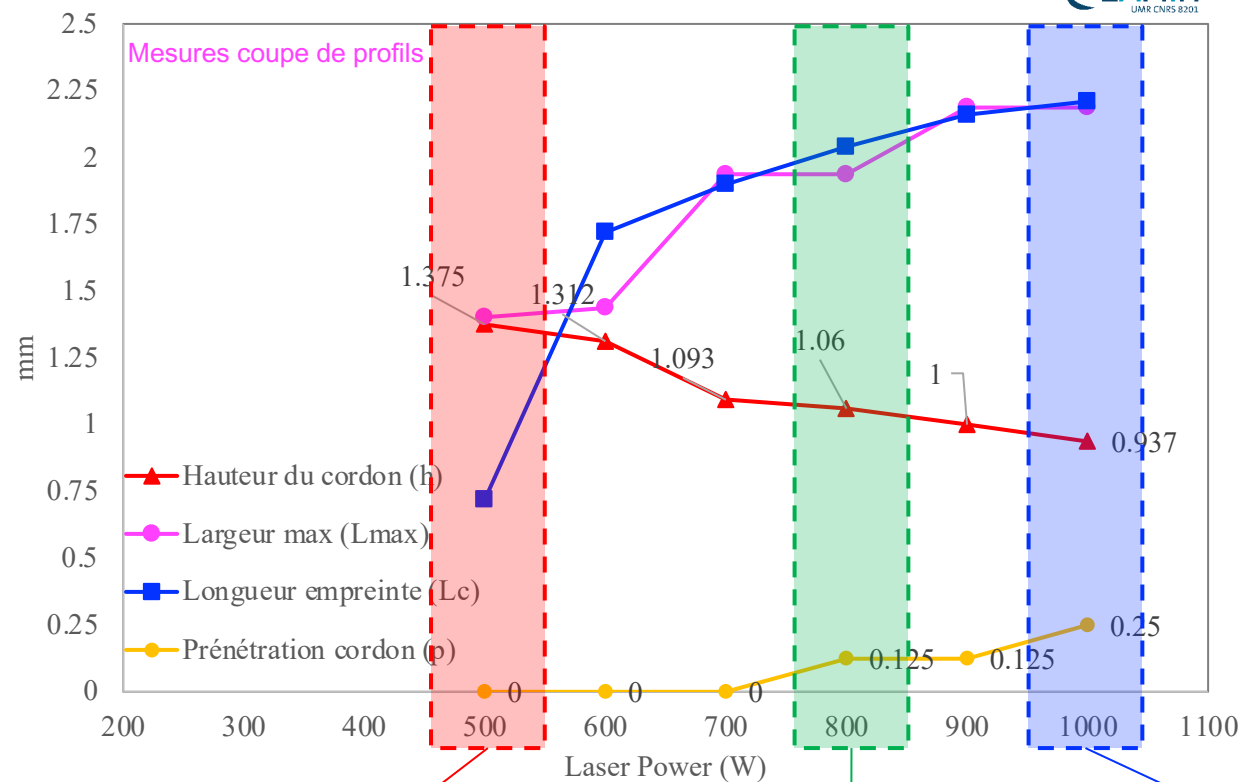
#### Minimal energy vs Optimal morphology

#### Beads

Laser power: de 500 W à 1000 W

Feed rate : 15.2 mm/s

- Cord height  $\searrow$  if Energy  $\nearrow$
- $L_c$ ,  $L_{max}$  of the bead  $\nearrow$  si Energy  $\nearrow$
- Penetration of the bead  $\nearrow$  si Energy  $\nearrow$ 
  - $p=0$  de 500W - 700W
  - $p=125 \mu\text{m}$  de 800W - 900W
  - $p=250 \mu\text{m}$  à 1000W



### Best choice :

#### Minimal energy vs Optimal morphology

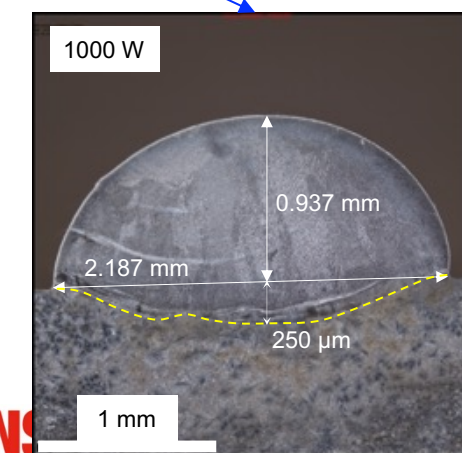
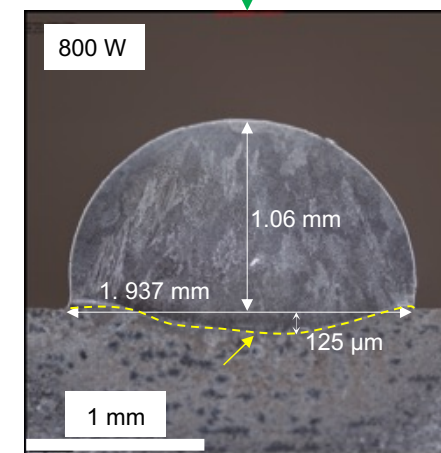
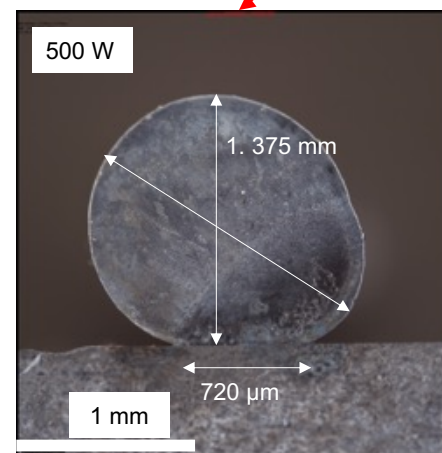
Laser power : 800 W

Feed rate : 15.2 mm/s

Penetration of the bead: 125  $\mu\text{m}$

Bead width: 1.937 mm

Bead height : 1.06 mm

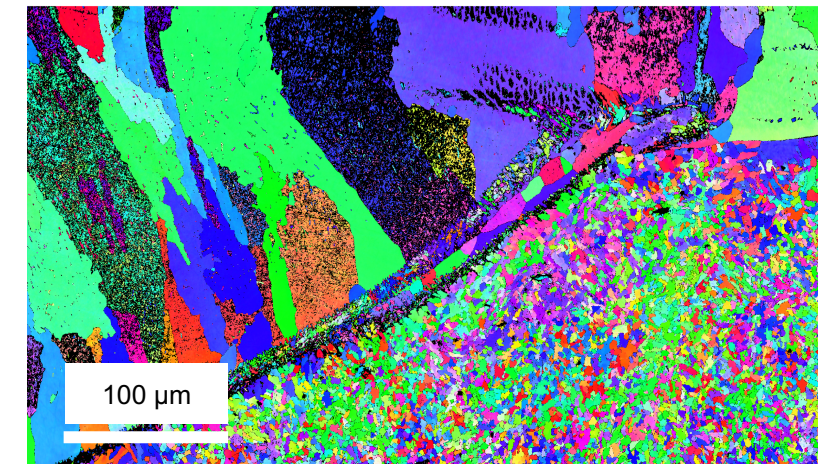
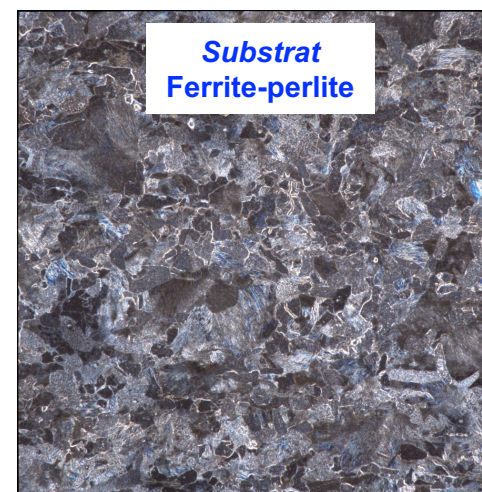
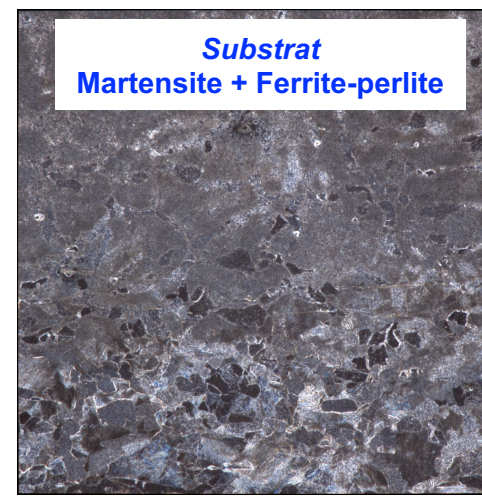
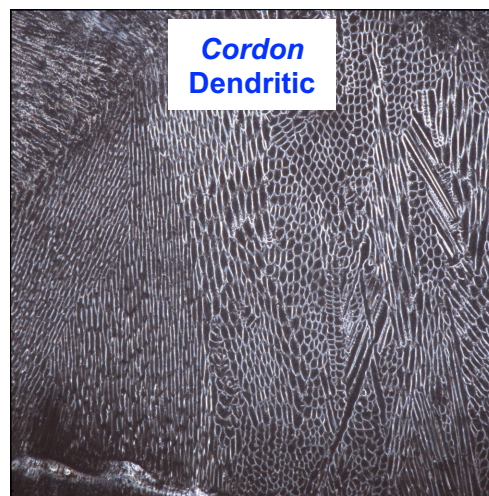
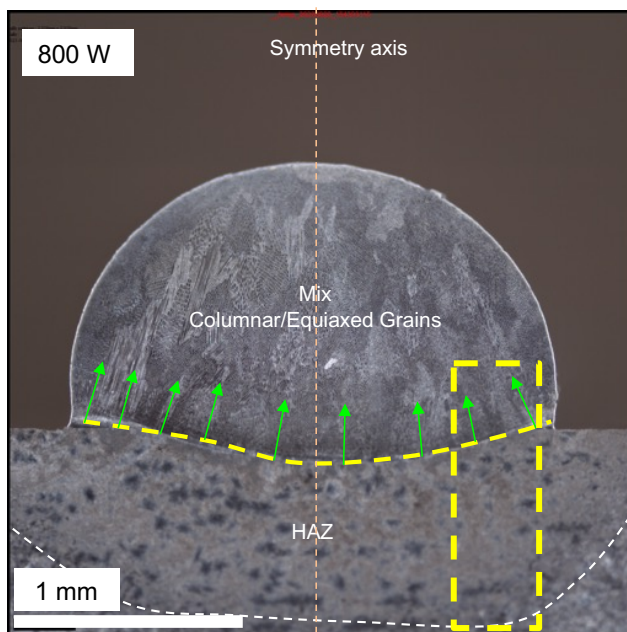


## Multi-scale characterization

### ▪ Bead and substrate microstructures

Homogeneous bead - Laser power : from 800 W to 1000 W

- Growth of columnar/equiaxed grains
- Homogeneous HAZ
- Ferrite-pearlitic



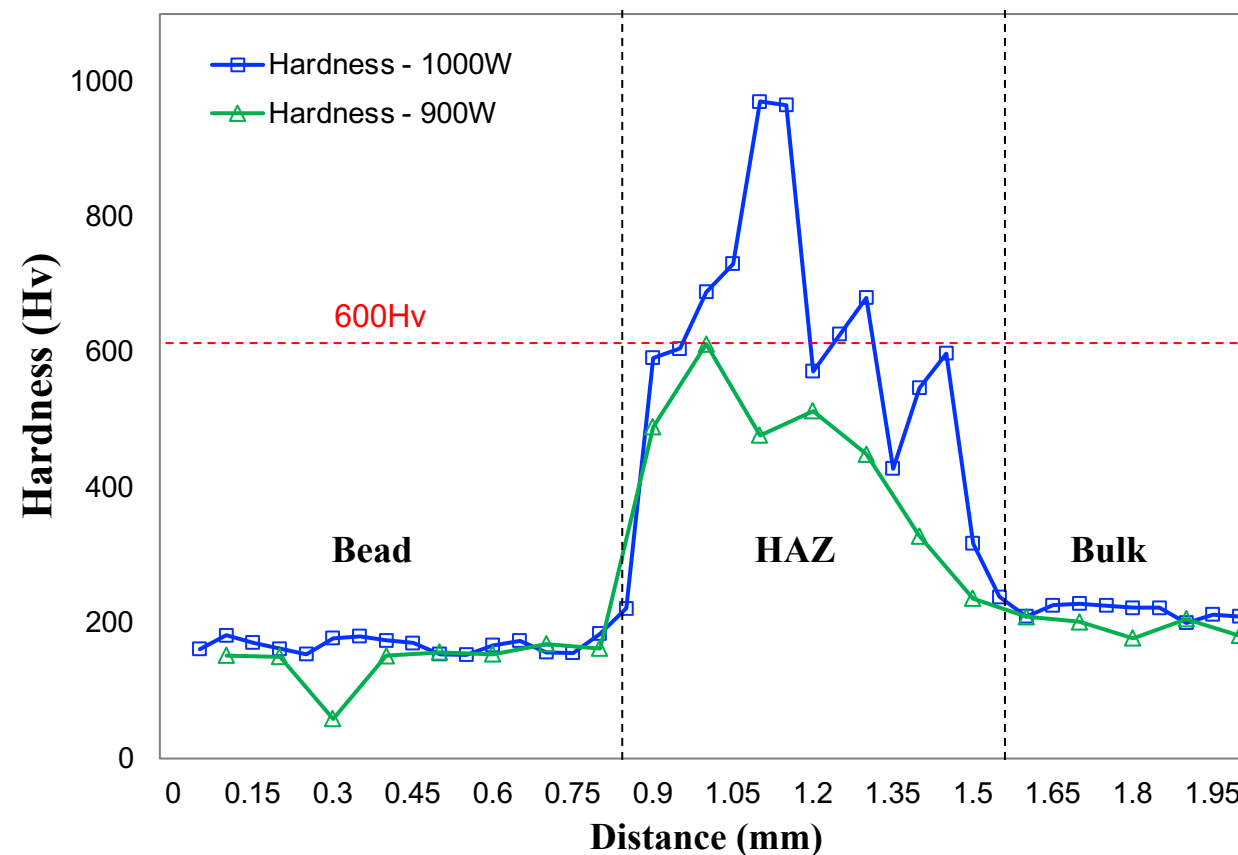
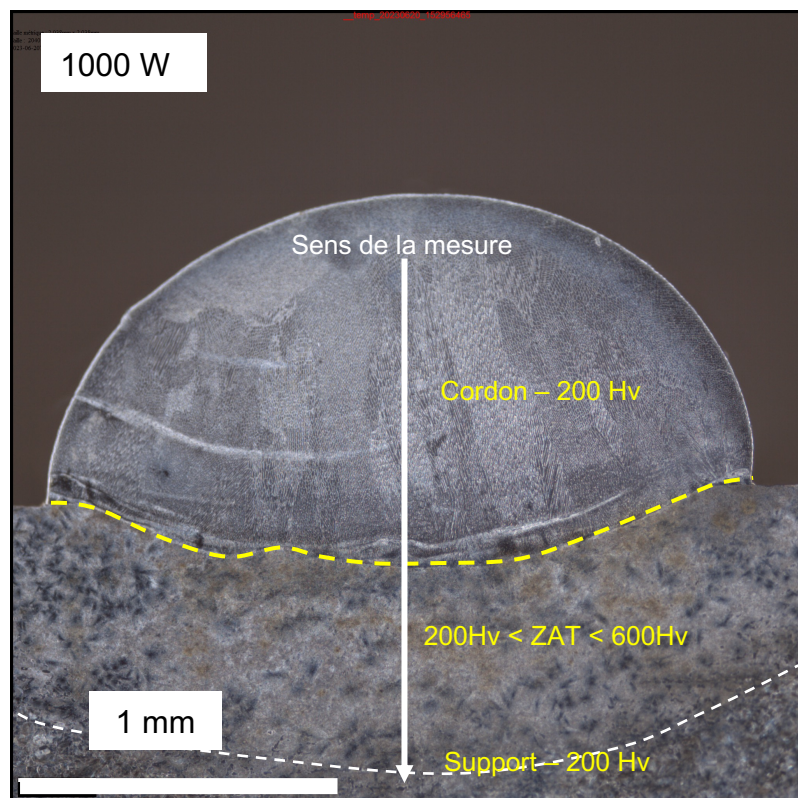
*Interface bead-substrat  
Dendritic + Martensite. EBSD*

## Multi-scale characterization

### Hardness of beads and substrate

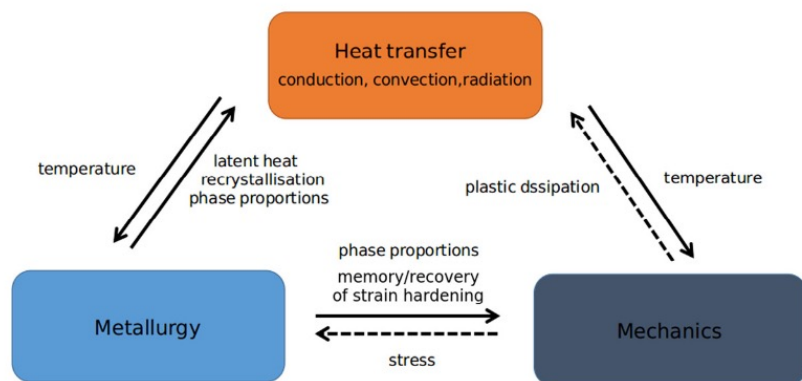
#### Bead/substrate hardness

- Bead/substrate hardness : Hv ~ 200Hv
- HAZ :  $200\text{Hv} < \text{Hv} < 600\text{Hv}$
- Microstructure not easily identifiable
- Transformation Ferrite/Perlite + Martensite

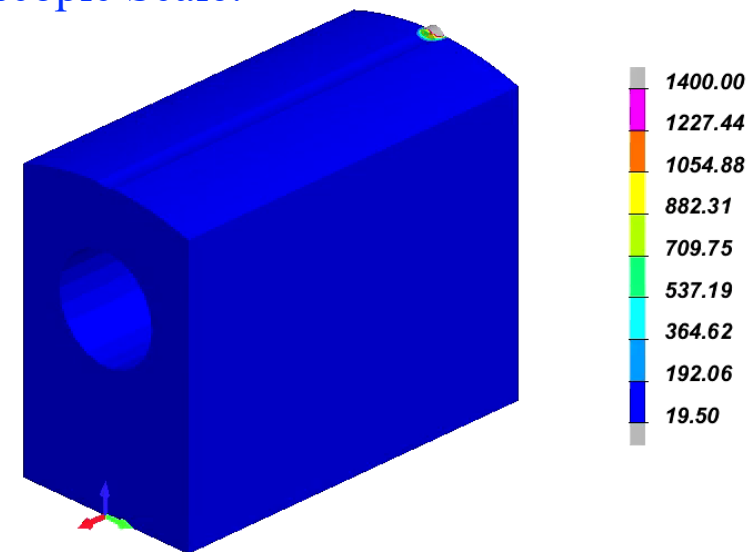


## Numerical approach

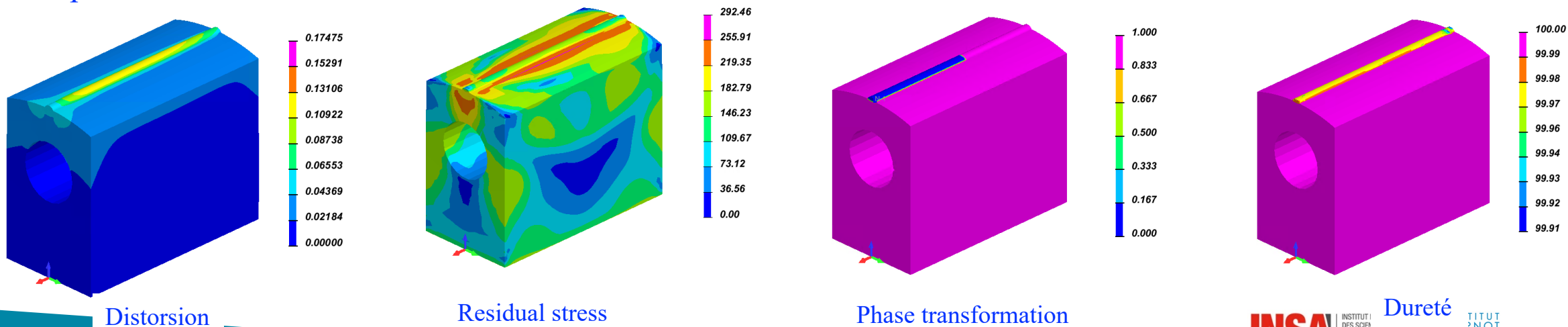
### ▪ Multiphysics and multi-scale coupling:



### Macroscopic Scale:



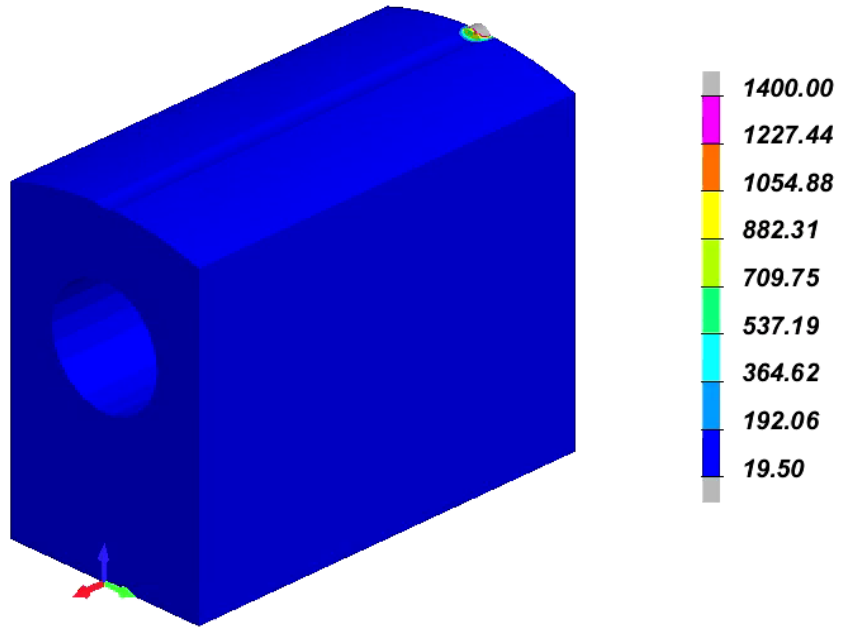
### Macro prediction after reload:



## Numerical approach

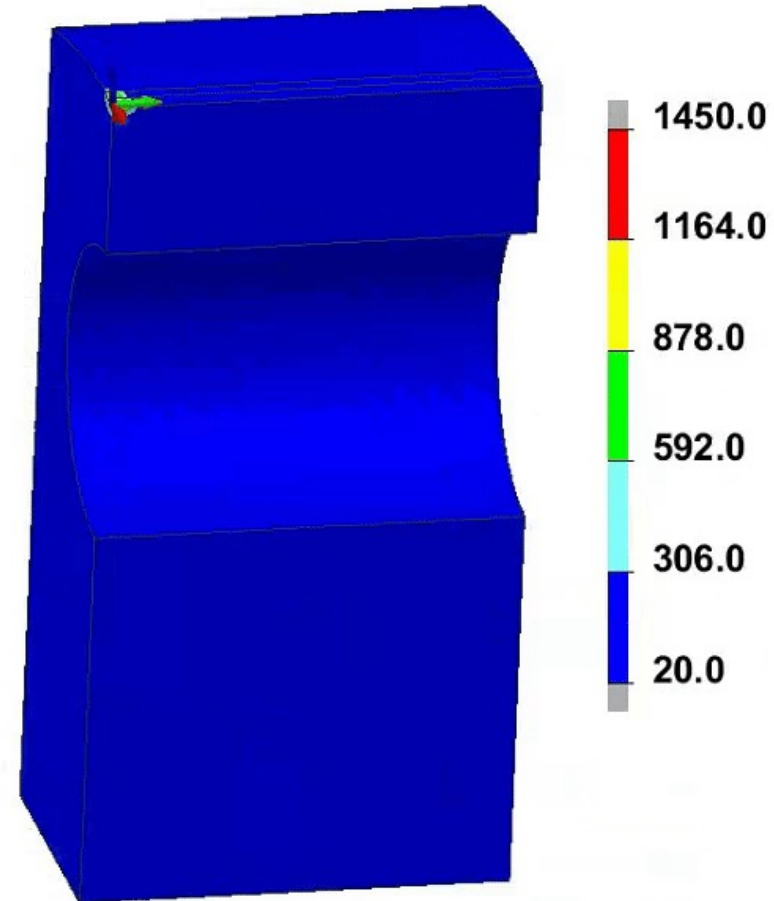
- Multiphysics and multi-scale coupling:

### Macroscopic Scale:



Geometry pre-defined

### Microscopic Scale:

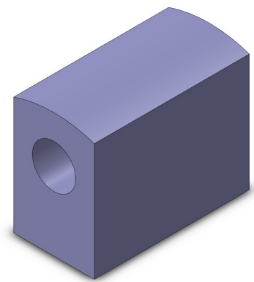
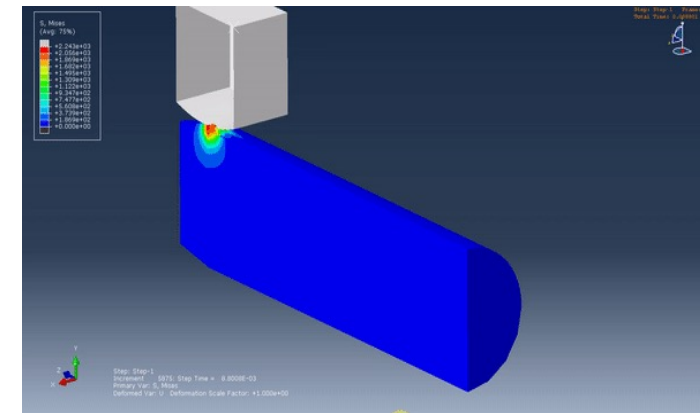
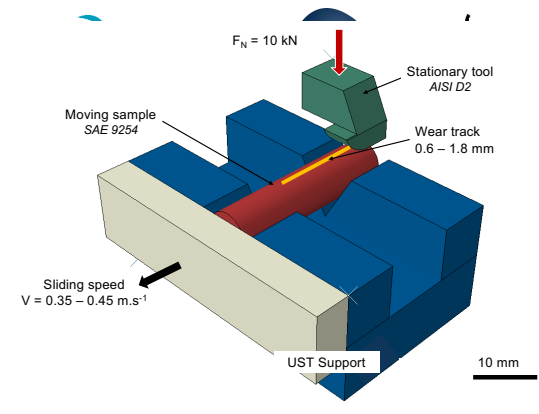


Prediction of the geometry

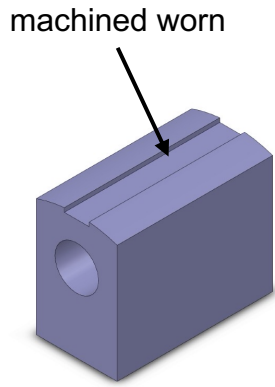
## Composite tools and tribo testing

### Materials choice

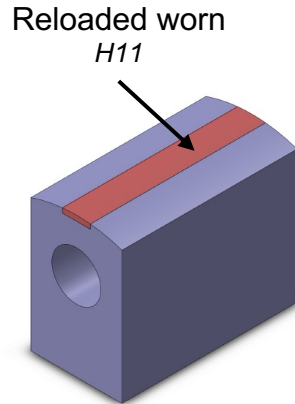
	Materials tested	Materials to come
Wire	316L	Acier outils H11
Tool repaired	Acier 38CrMoV5	Acier 38CrMoV5
Friction sample	Acier	Alu 7050 7075 7475



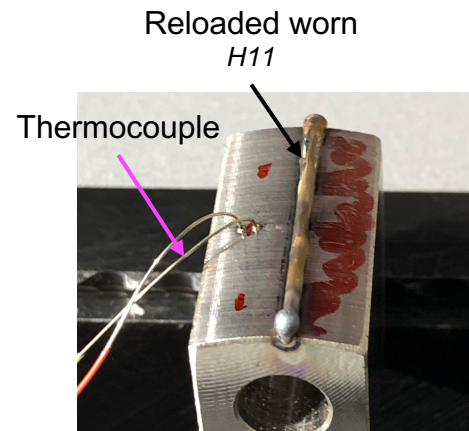
Step 1: Sliding tool  
38CrMoV5



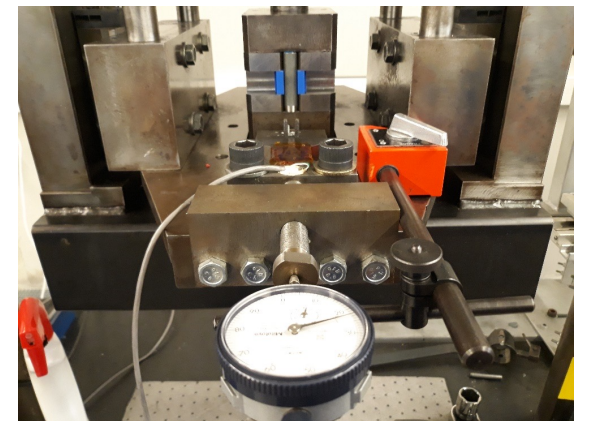
Step 2: Sliding tool  
with simulated worn  
38CrMoV5



Step 3: Sliding tool  
with reload  
38CrMoV5  
H11



Step 4: Sliding tool with  
reload before machining



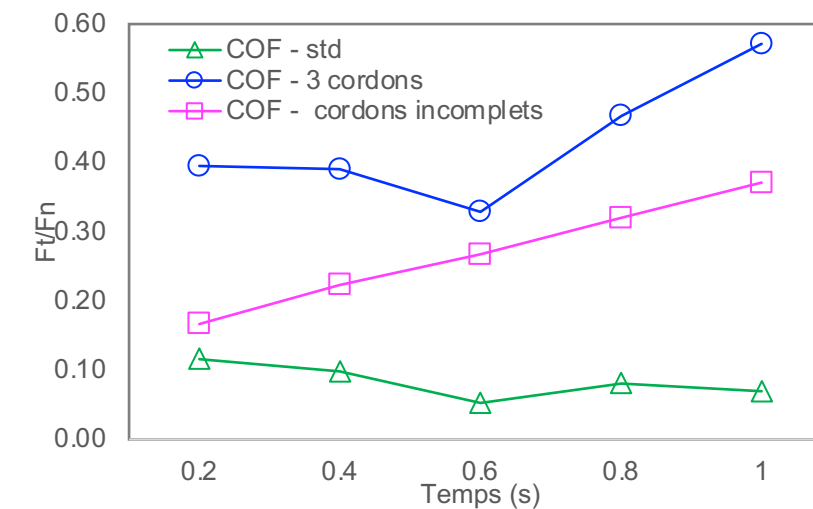
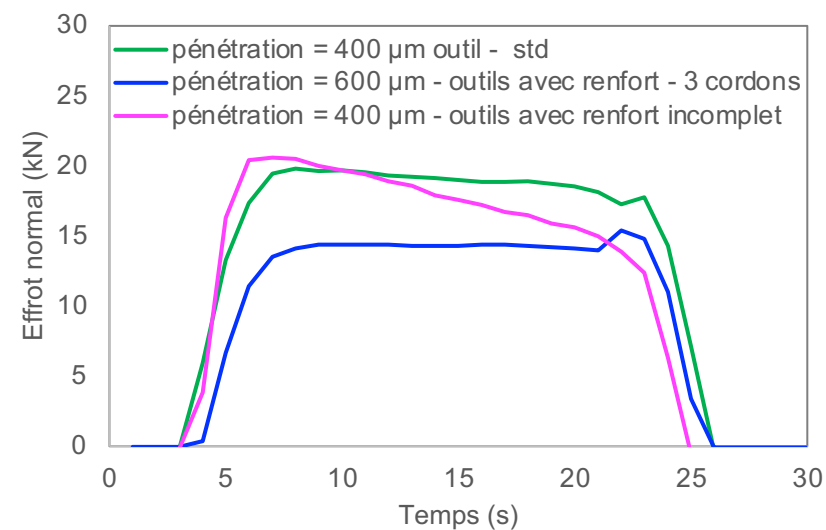
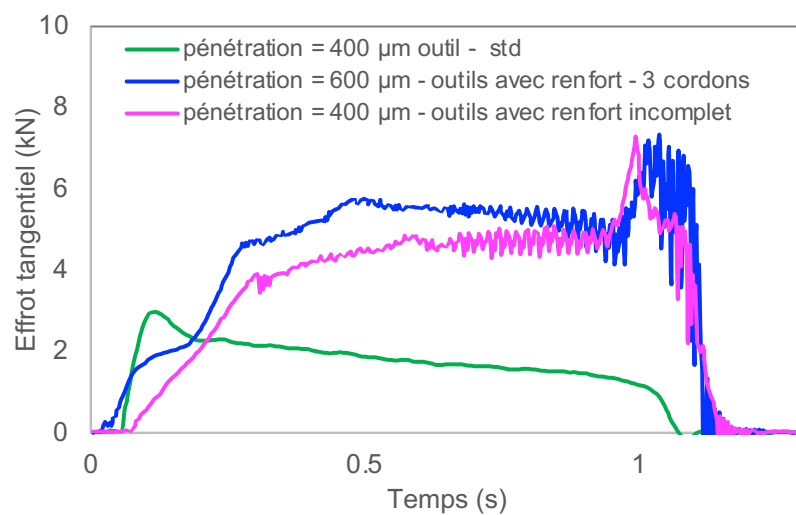
## Preliminary results of tribo tests

### Friction “composite tool” / “steel specimen”

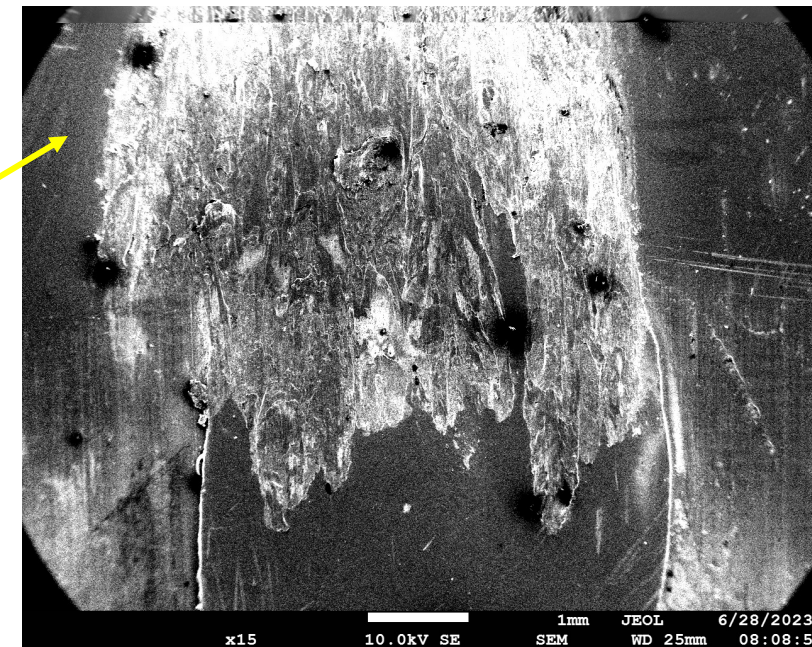
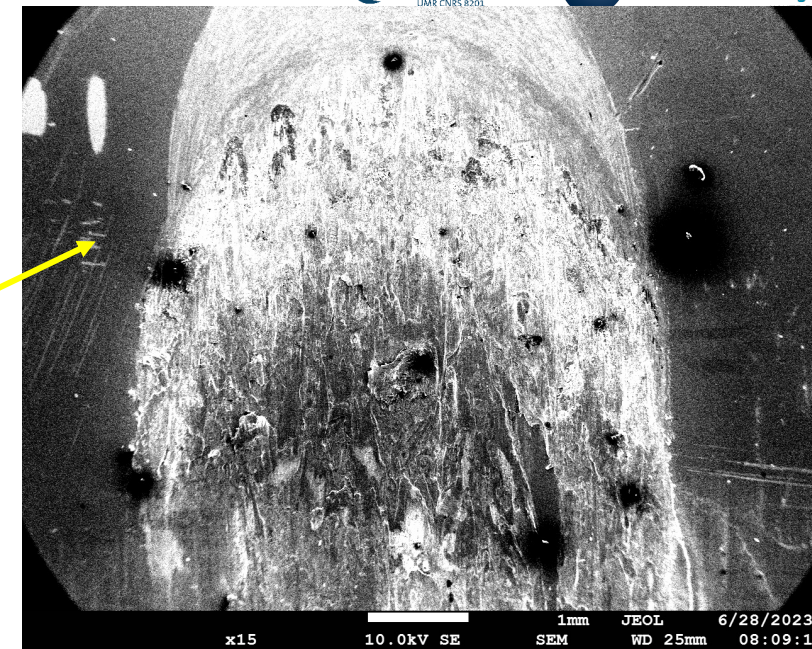
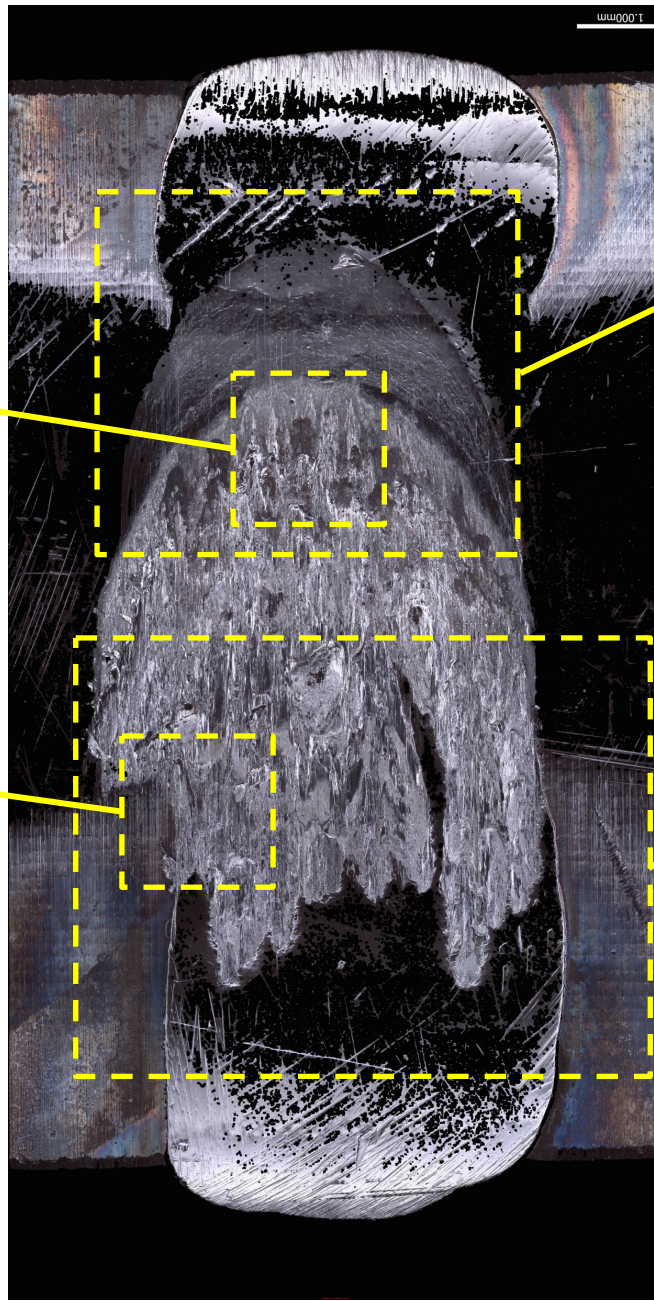
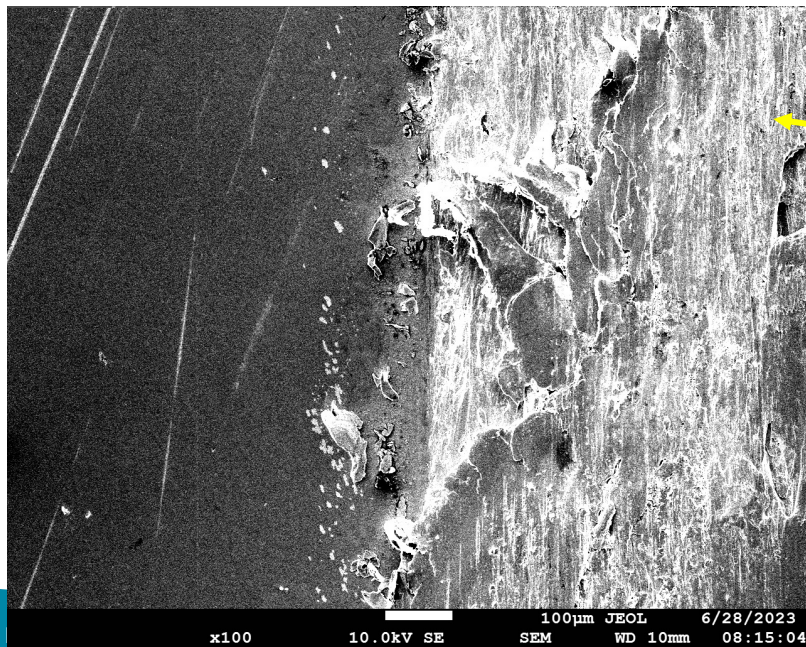
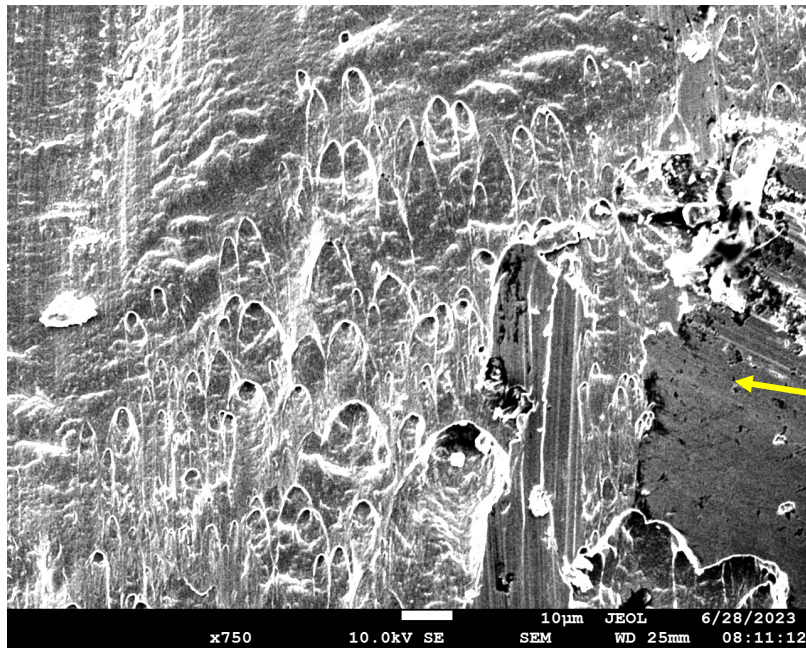
- **Matrix** : acier X38CrMoV5 (AISI H11)
- **Bead** : 316L
- **Sample** : steel

### 3 Tests

- standard tool without reload  $\rightarrow 0.05 < F_t/F_n < 0.12$
- standard tool with reload  $\rightarrow 0.33 < F_t/F_n < 0.57$
- standard tool with uncompleted reload  $\rightarrow 0.17 < F_t/F_n < 0.37$

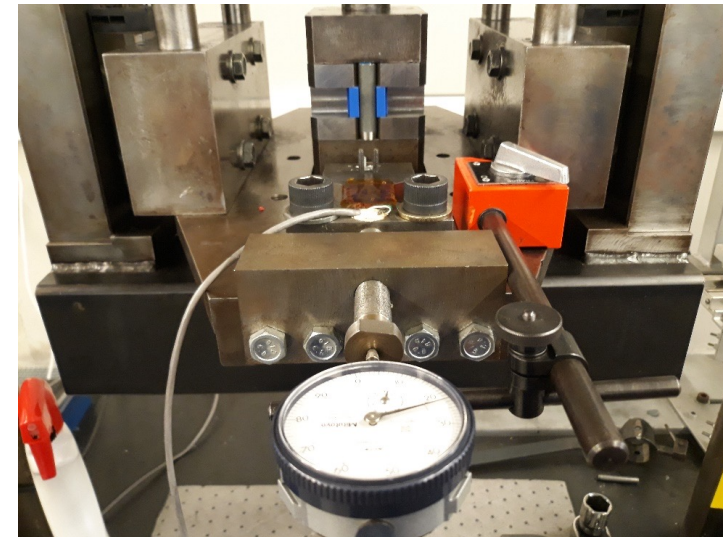
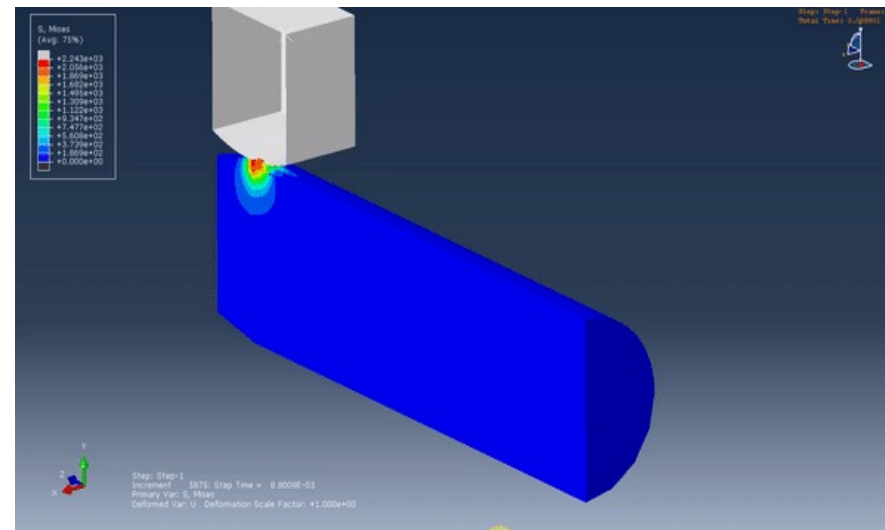
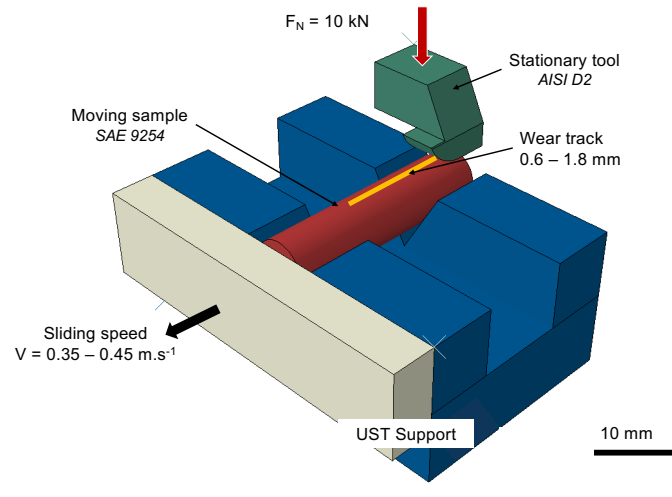






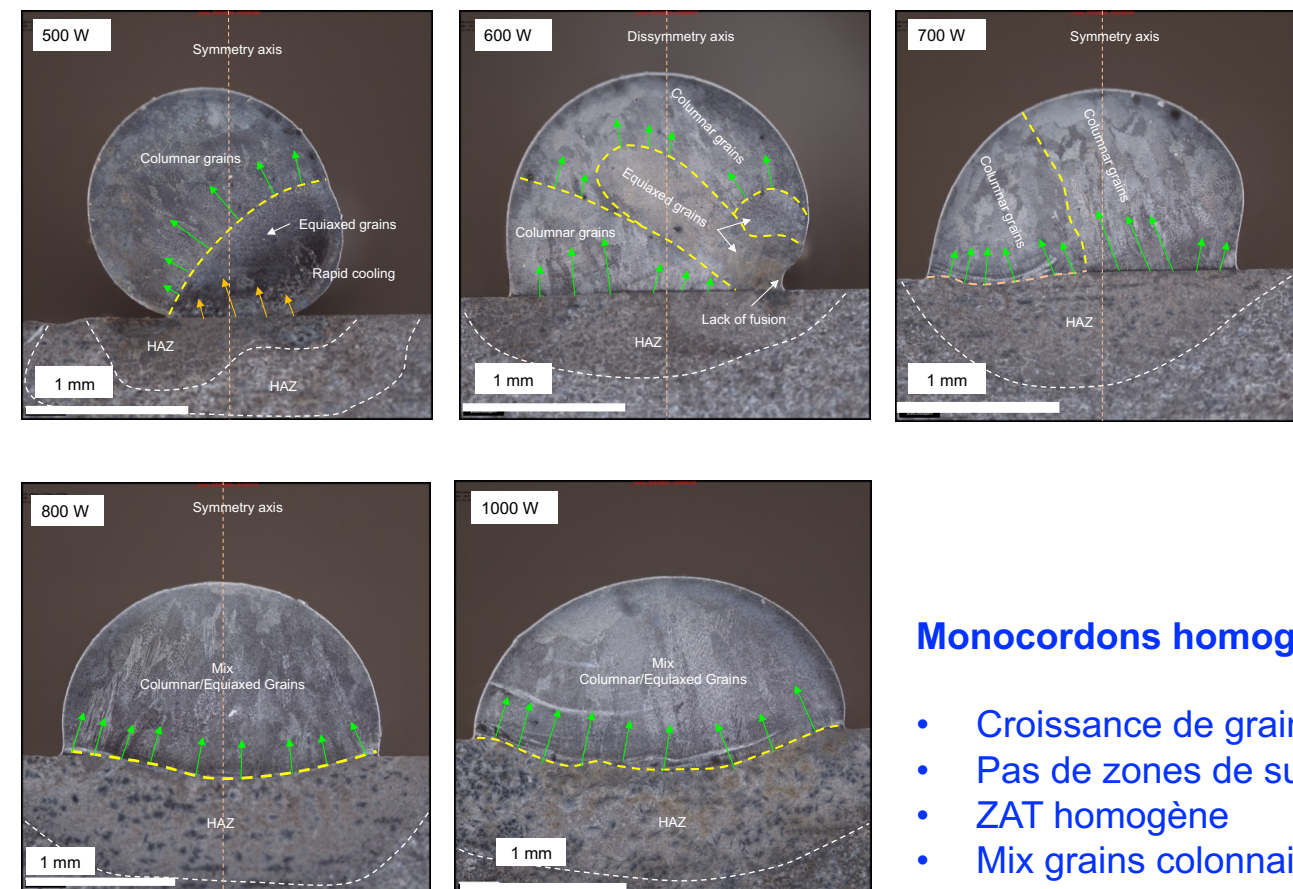
Merci de votre attention !

# Simulation des essais tribo



## Caractérisation multi-échelle

### Microstructures des cordons et du substrat



### Monocordons non homogènes - Puissance laser : de 500 W à 700 W

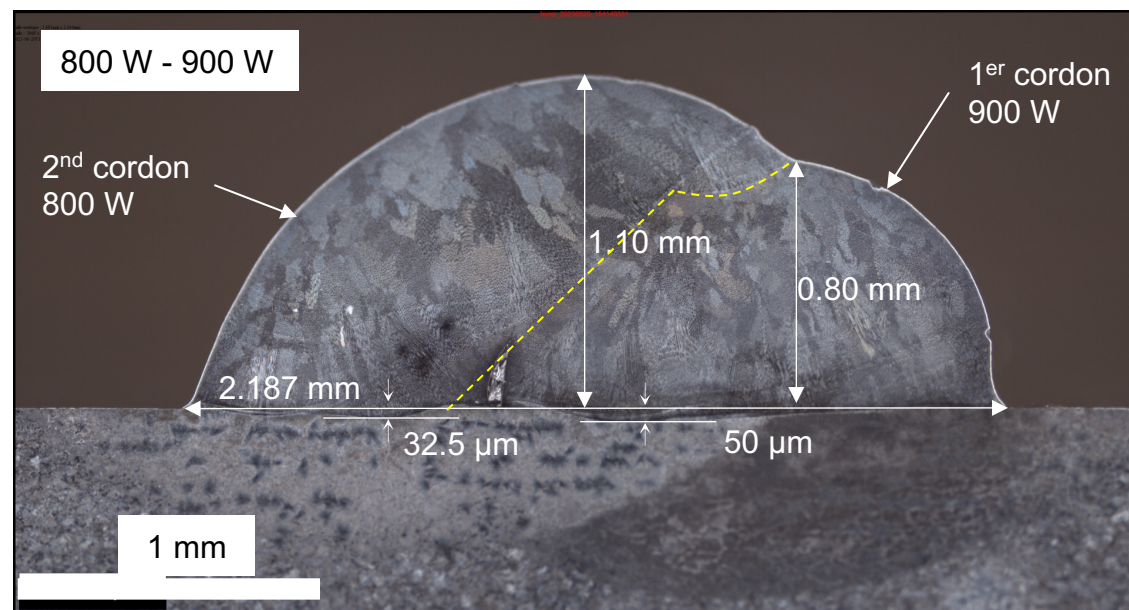
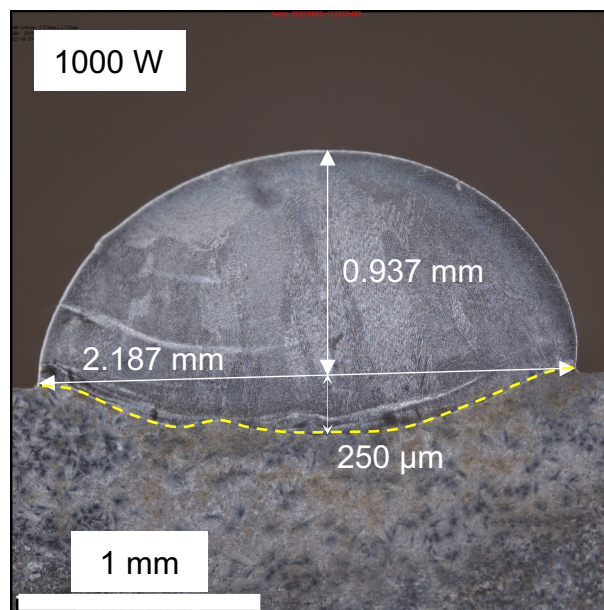
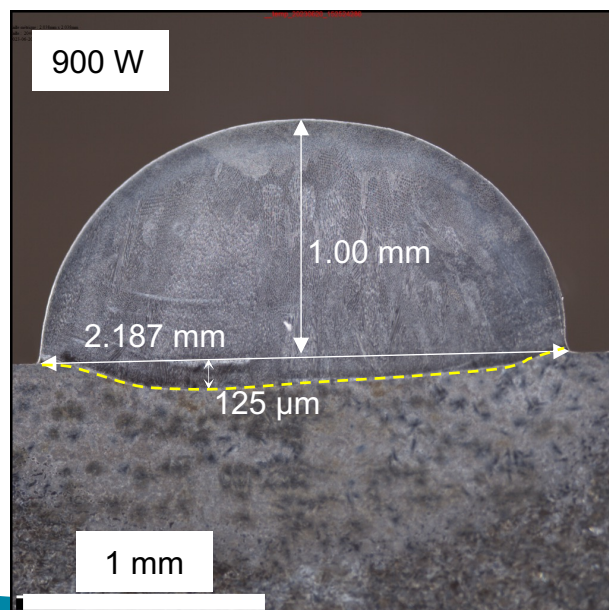
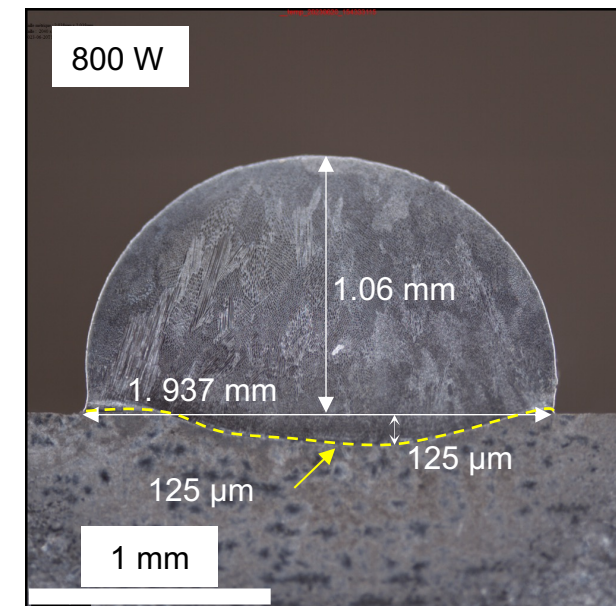
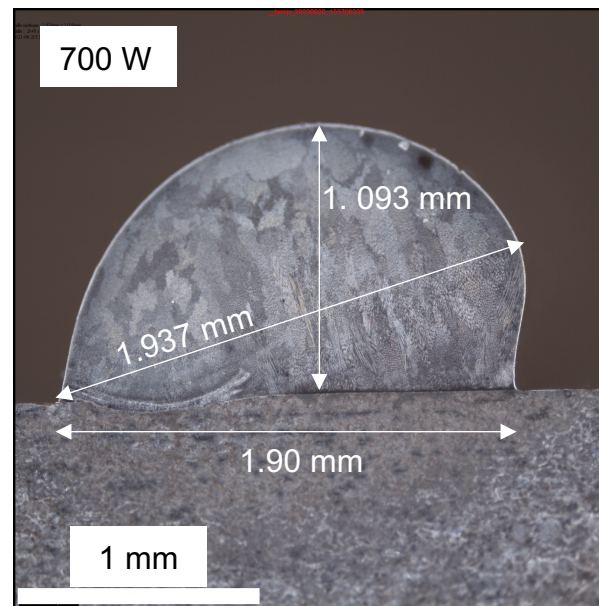
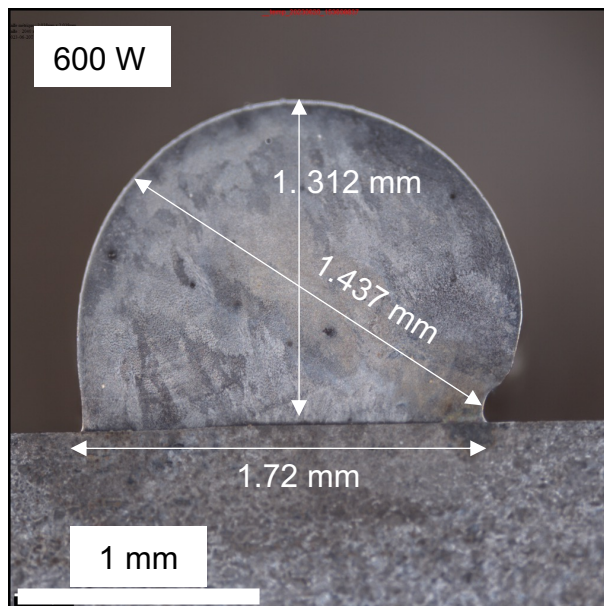
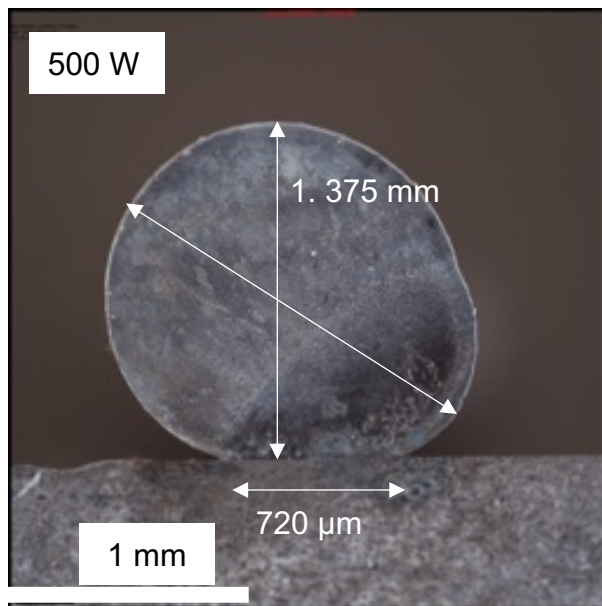
- Zone de refroidissement rapide
- Croissance de grains colonnaires
- Cordons créant du « balling »

Possible dissymétrie de focalisation des faisceaux lasers ?

- Zones de surfusion
- ZAT importante
- Mix grains colonnaires/équiaxes

### Monocordons homogènes - Puissance laser : de 800 W à 1000 W

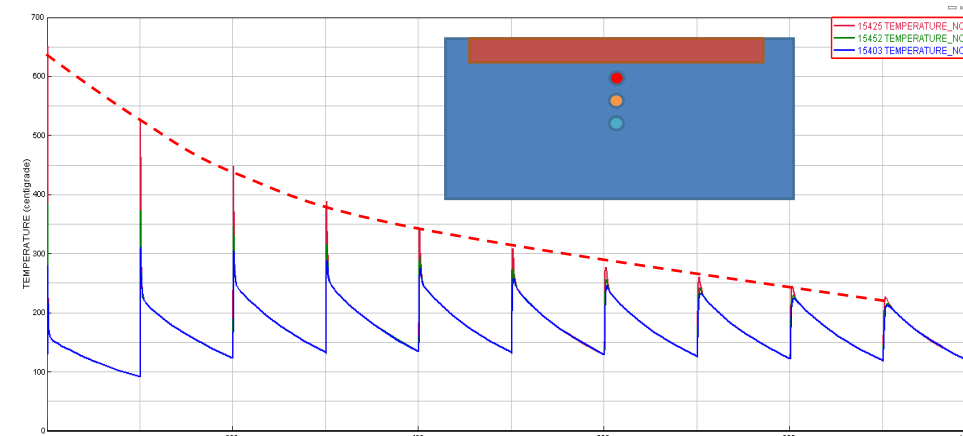
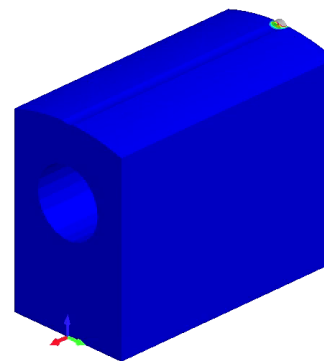
- Croissance de grains colonnaires/équiaxes
- Pas de zones de surfusion
- ZAT homogène
- Mix grains colonnaires/équiaxes



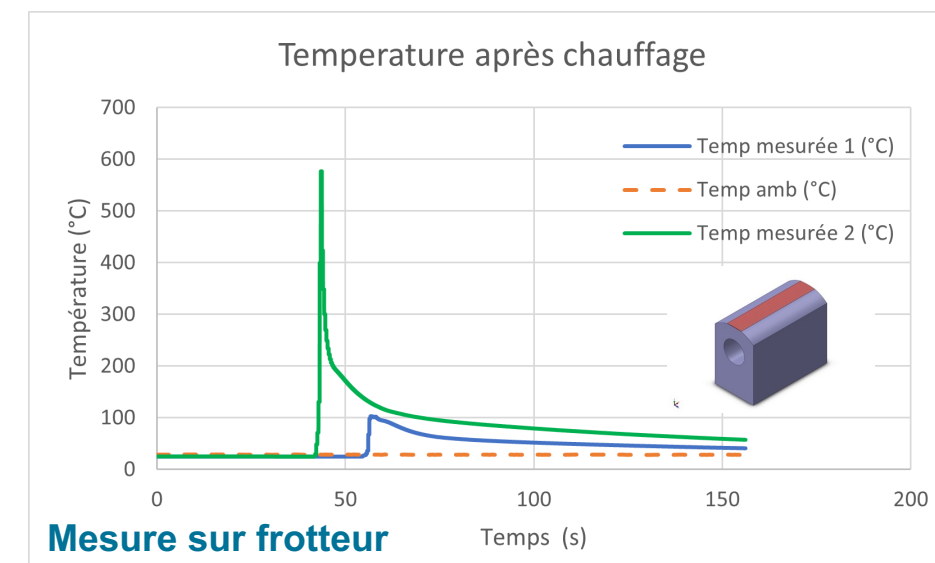
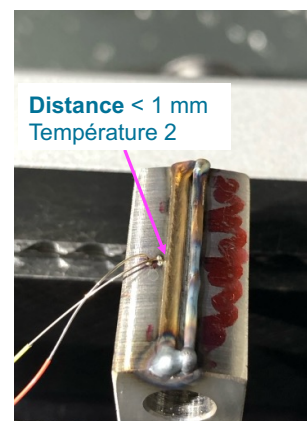
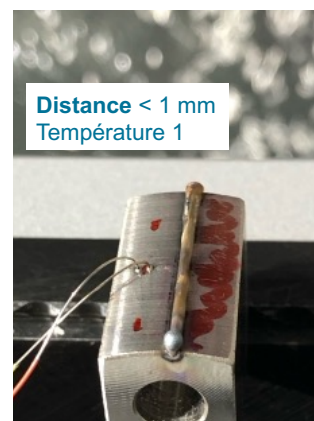
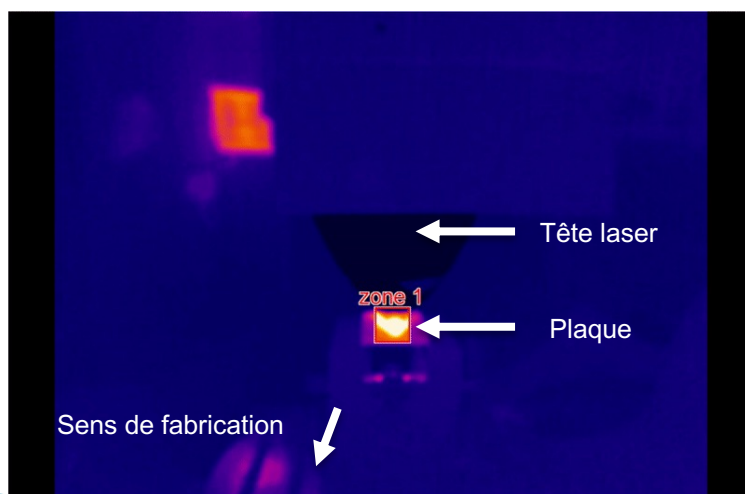
## Caractérisation multi-échelle

### Mesure des températures

	Distance thermocouple	Température max
<b>Simulation</b>	< 3 mm	650°C
<b>Mesure sur plaque</b>	2.9 mm	250°C
<b>Mesure sur frotteur</b>	< 1 mm	580°C



Simulation



Mesure sur frotteur