Thermal history modelling to understand microstructures observed in repair technology of Ti-6Al-4V

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Outline

1. Introduction

2. Numerical model

3. Constant Track Length (CTL) results

4. Decrease Track Length (DTL) results

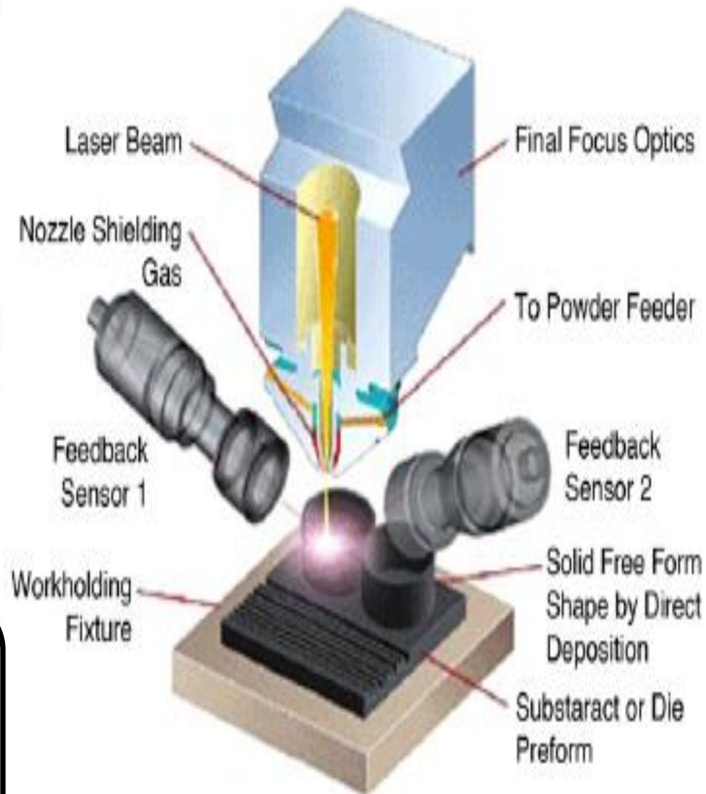
5. Conclusion & Perspectives

Innovative technology

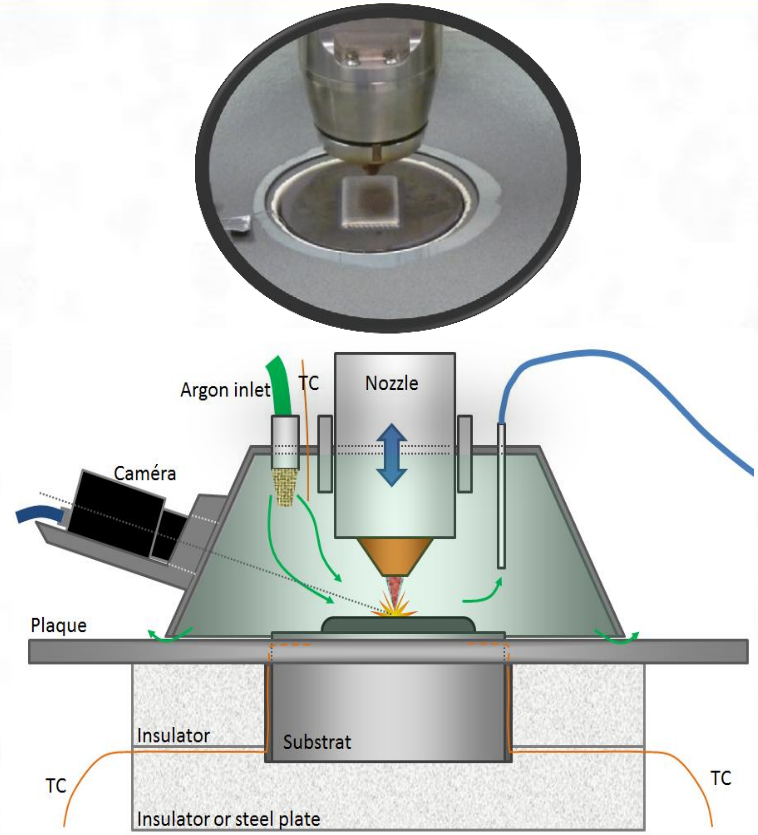
Production of dense parts

Multilayer metal deposit

Very high cooling rates (ultrafine grain microstructure)



Bhattacharya & al. (2011)



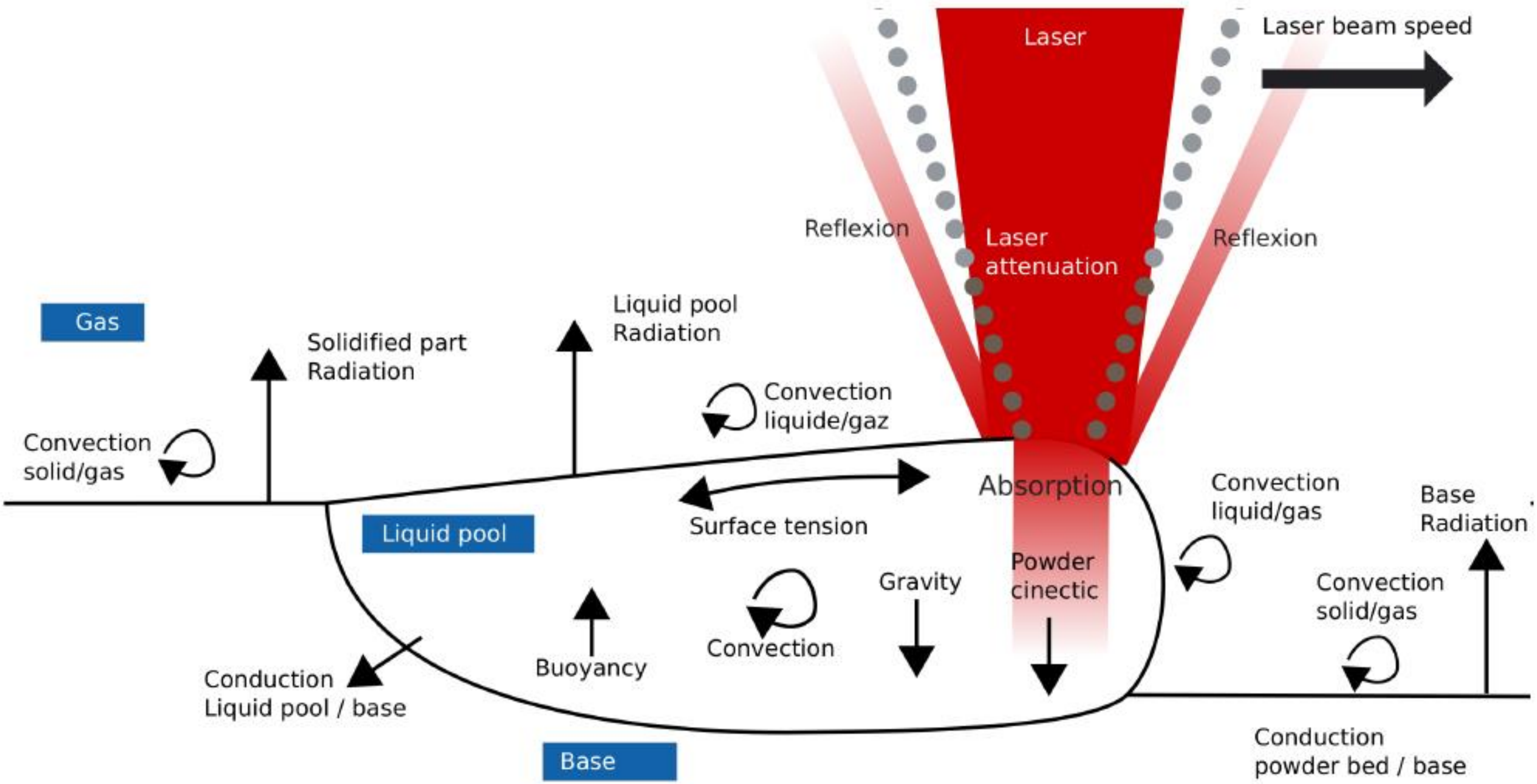
Sirris

Need of a thermal model:

Study of processing parameters:

- laser power
- powder flow
- preheating temperature (T°)
- laser beam velocity

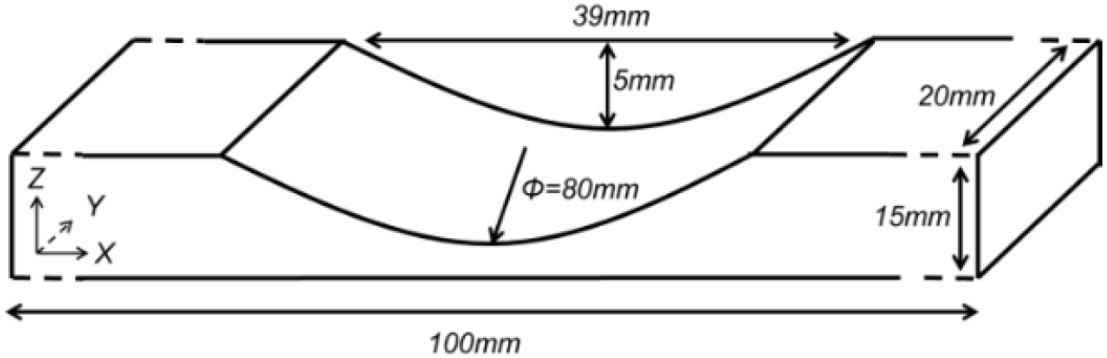
Interaction Laser - Material



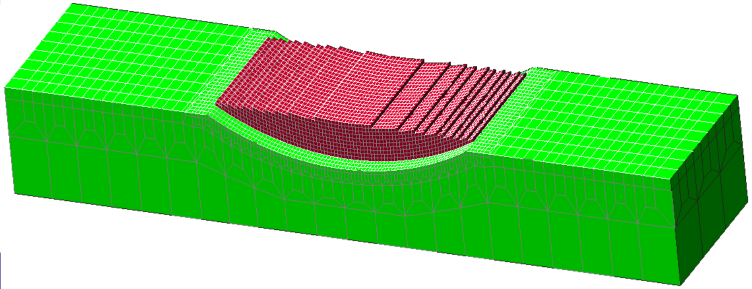
Marion et al.2015

Introduction

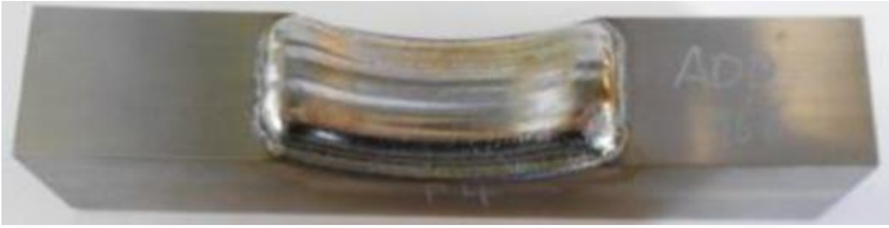
Laser cladding as a repair technology for Ti6Al4V alloy: influence of incident energy and building strategy on microstructure and hardness. H.Paydas,et al. Materials and Design 2015.

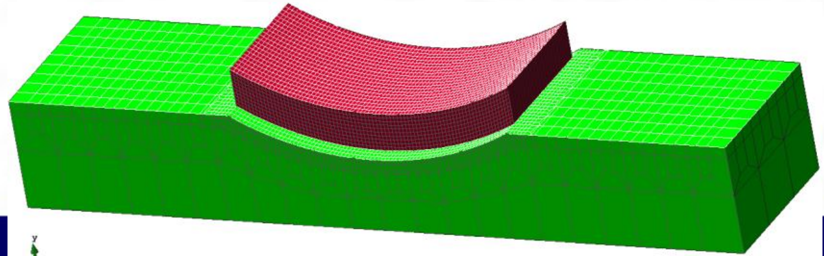


«MacroClad» & «Decrease Track Length (DTL)» strategy



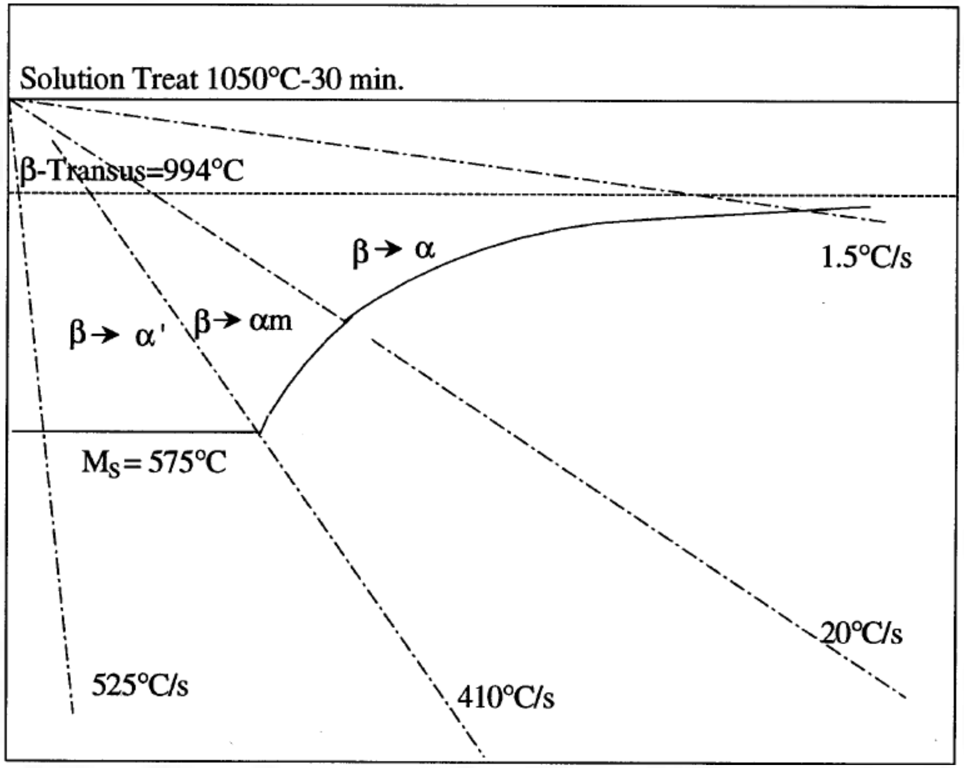
«MacroClad» & «Constant Track Length (CTL)» strategy





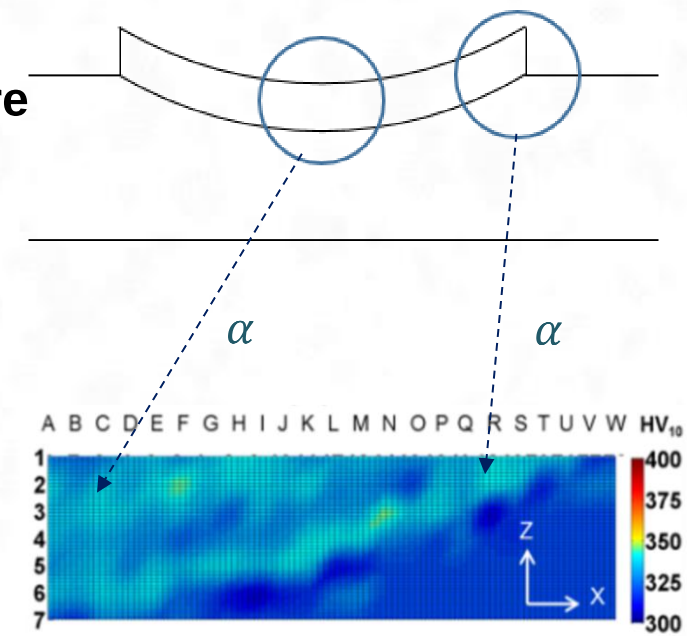
Material: Ti-6Al-4V

Éléments	Al	V	Fe max.	C max.	O max.	N max.	H max.	Ti
Composition %mass.	5.5 – 6.5	3.5 – 4.5	0.25	0.08	0.13	0.05	0.012	Bal.



Continuous Cooling diagram– *Ahmed et al.1998*

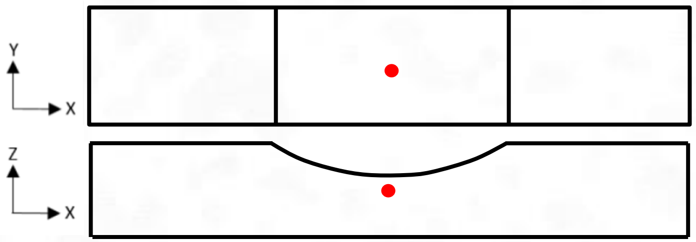
Microstructure evolution



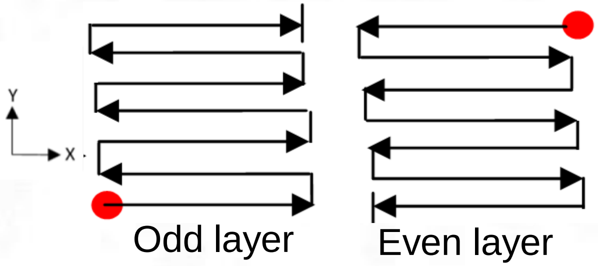
Hardness Map– CTL – Paydas et al.

Materials and Design 2015

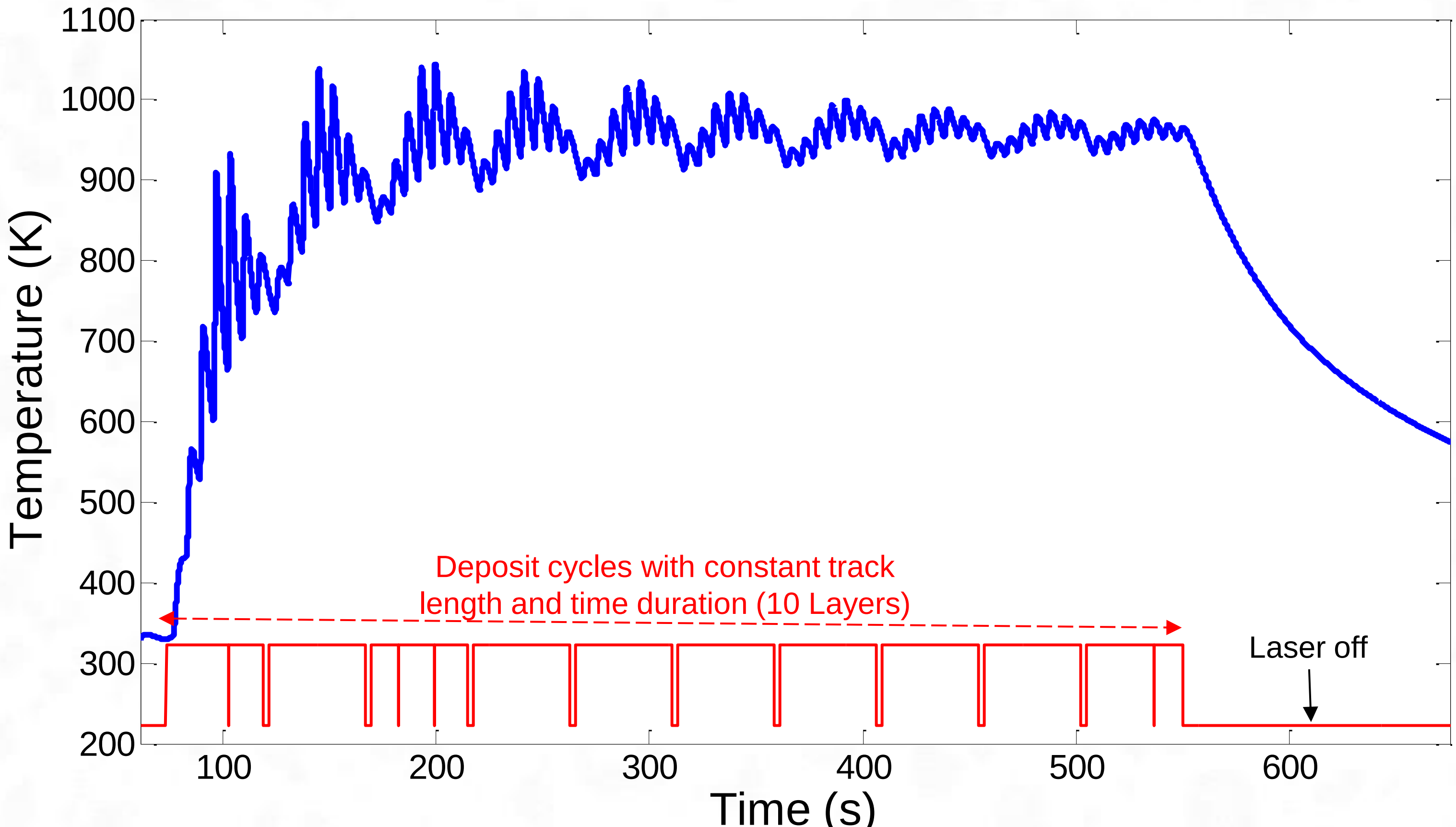
Experimental data



Geometry of the machined substrate

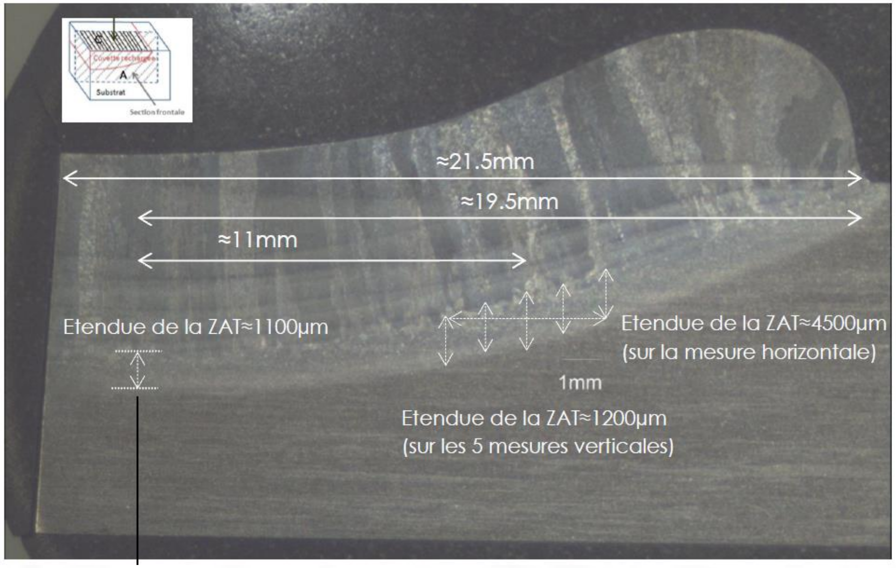


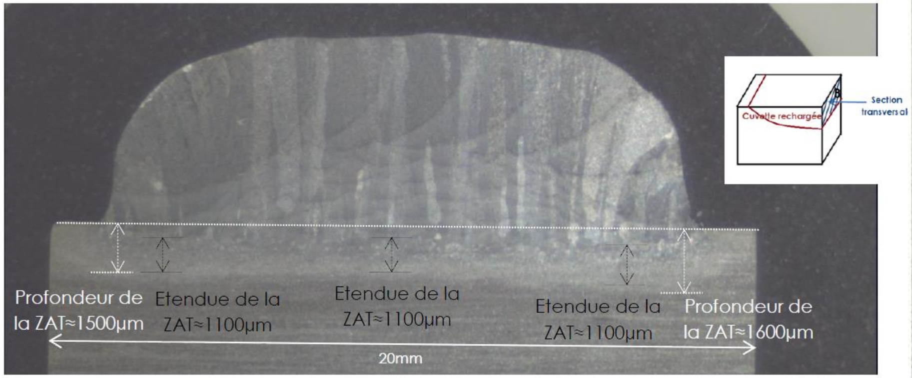
Path of laser beam (7 tracks/layer)

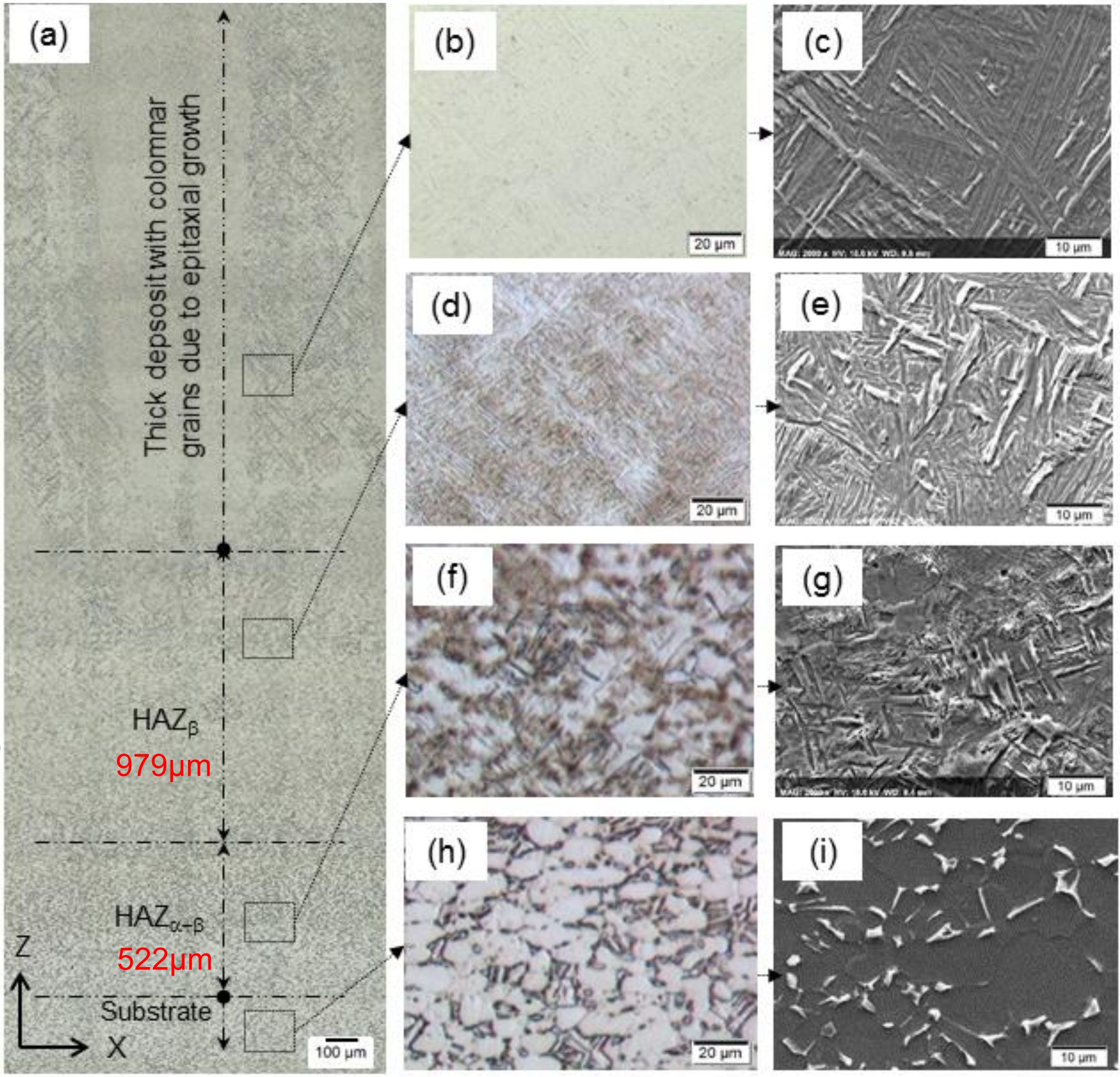


Temperature measured at the thermocouple

Experimental data

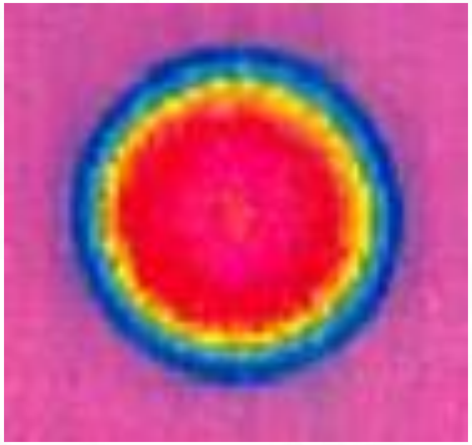




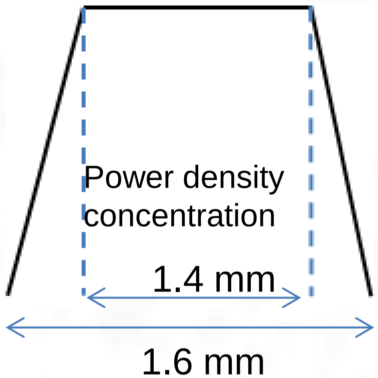


Microstructure of Constant Track Length

Numerical model

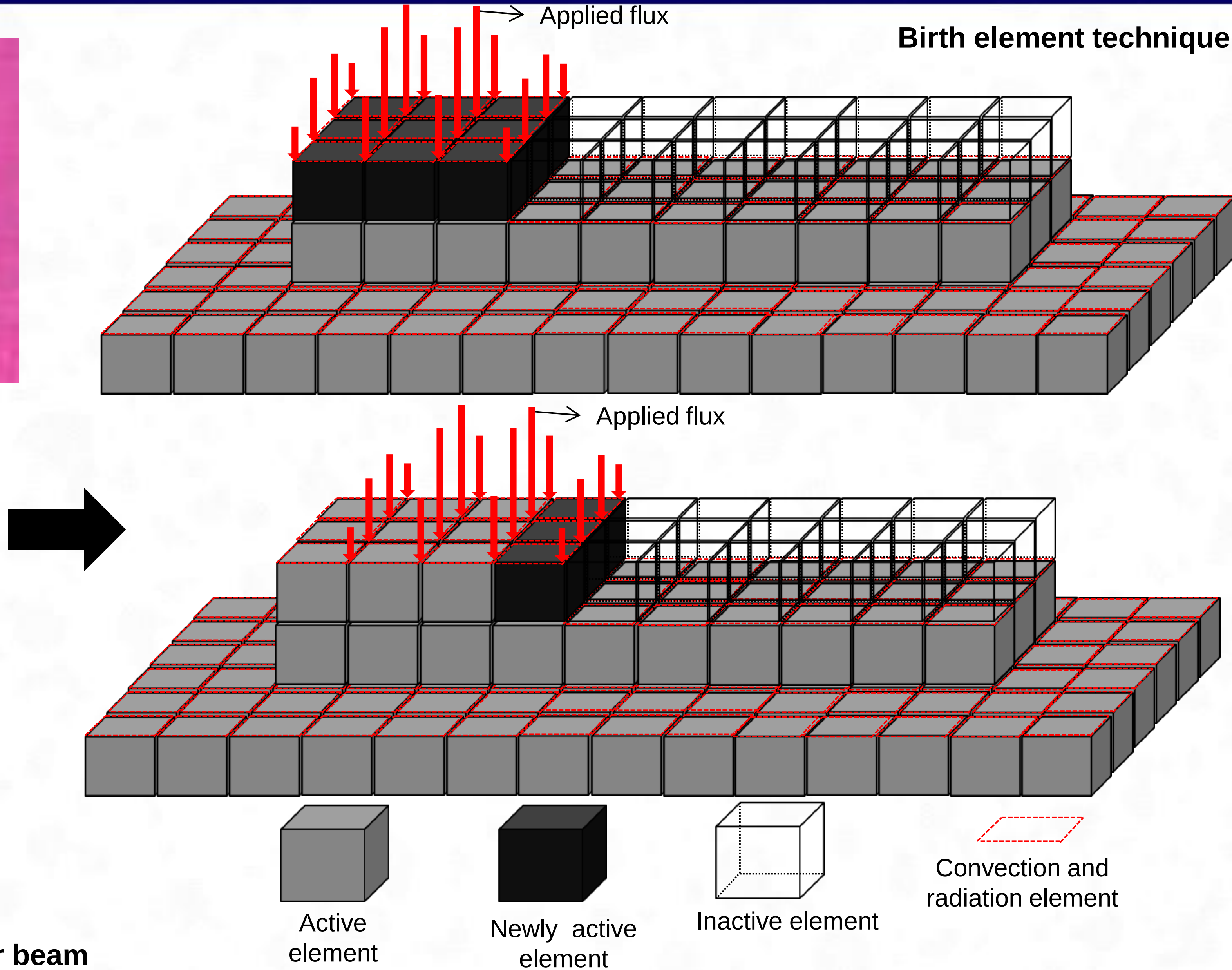


Laser used by Sirris



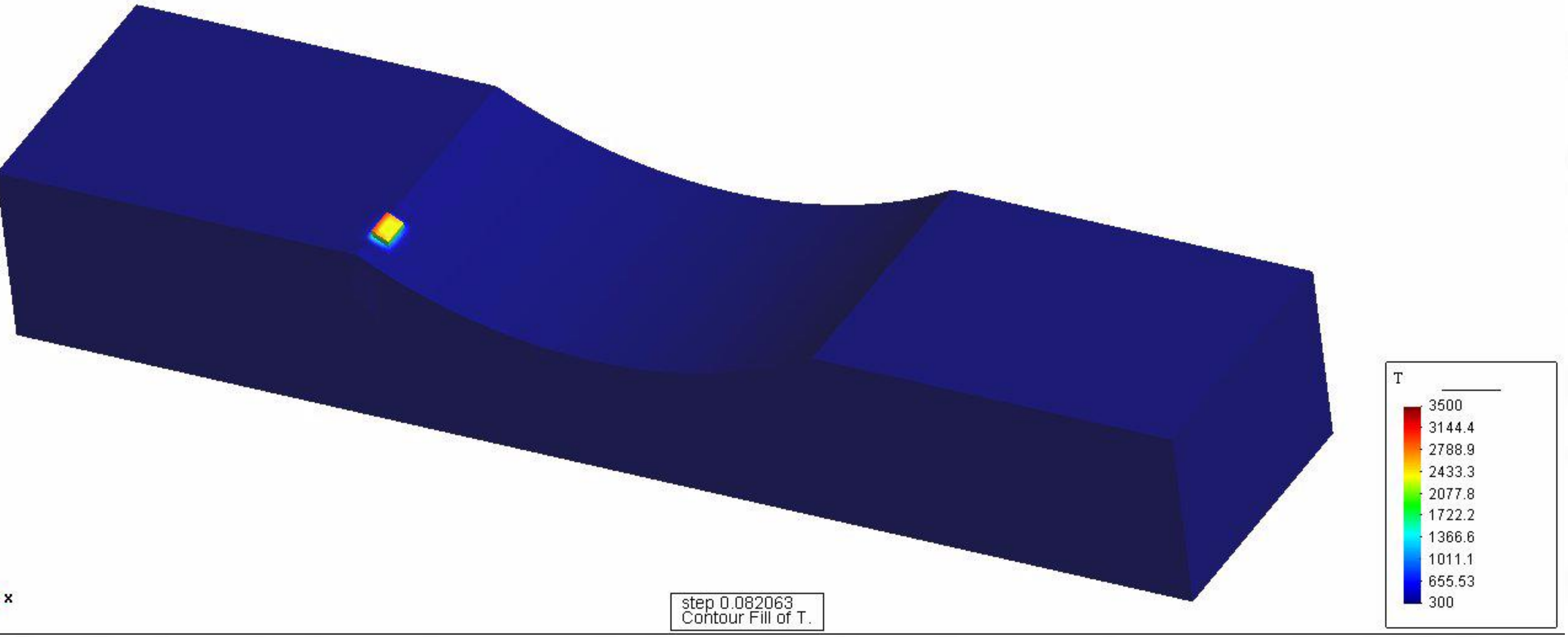
Top-hat profile of the laser beam energy

Birth element technique



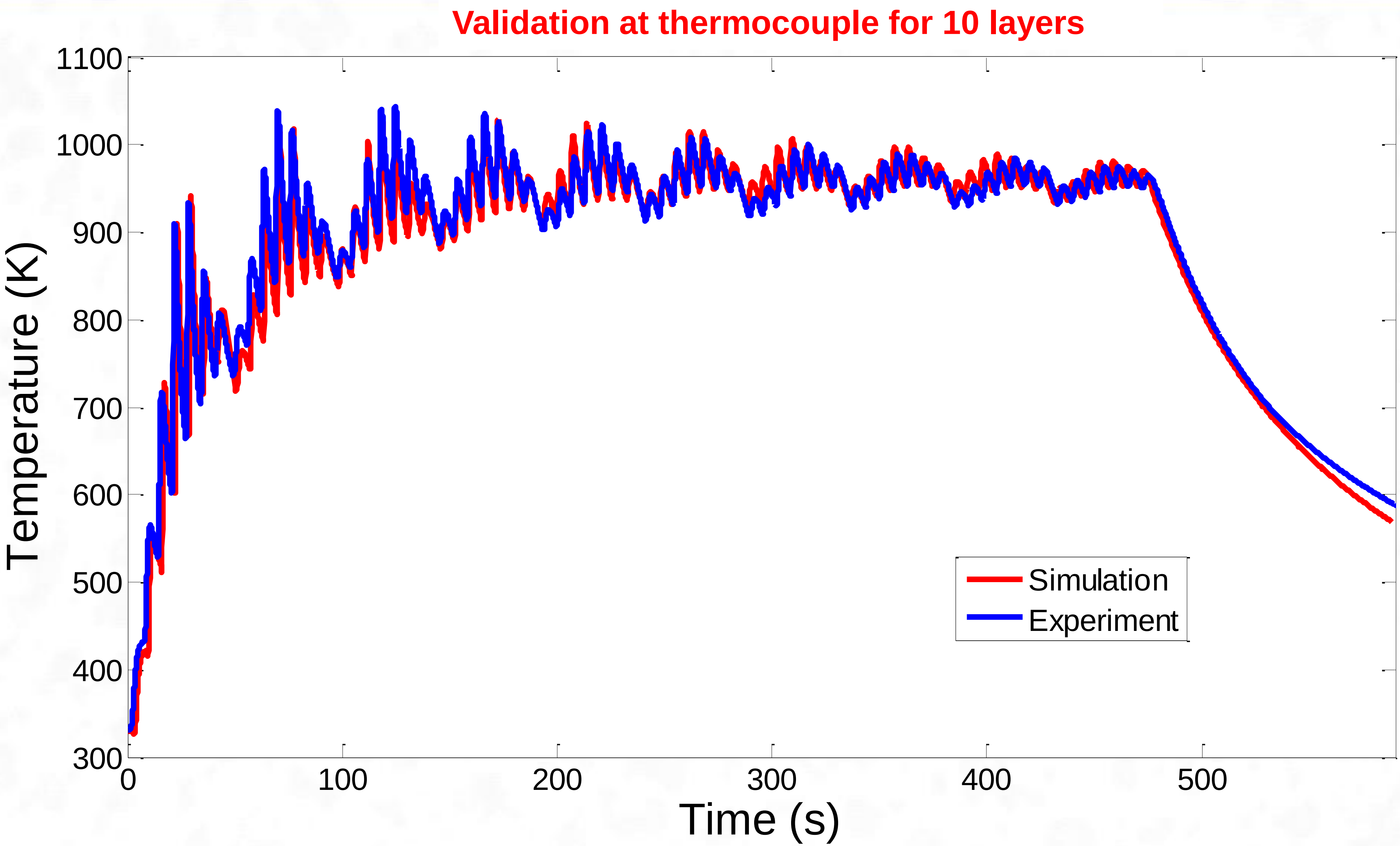
At each time step → Updated boundary conditions

Constant Track Length strategy



Temperature (K)
Red = 3500 K
Blue = 300 K

Constant Track length strategy

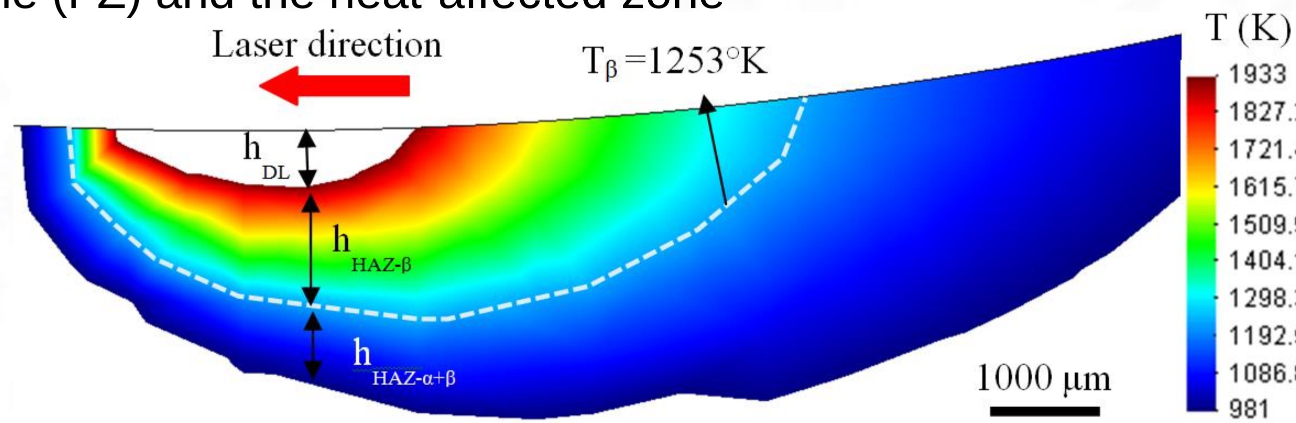


Comparison between the simulated and the experimental thermal history from the thermocouple

Constant Track length strategy

Fusion zone (FZ) and the heat-affected zone (HAZ)

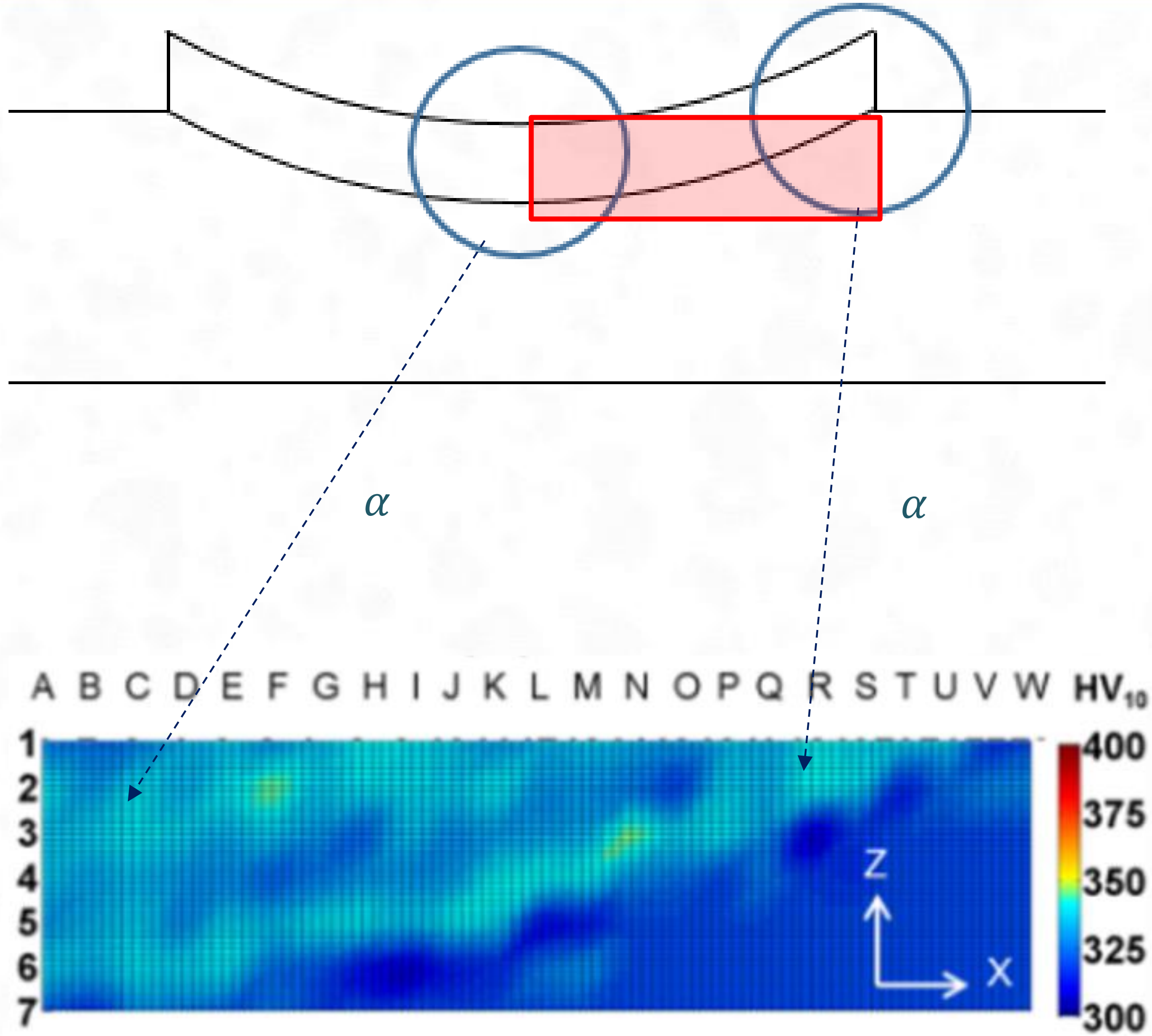
Depth of Fusion zone



2D view of thermal field within HAZ

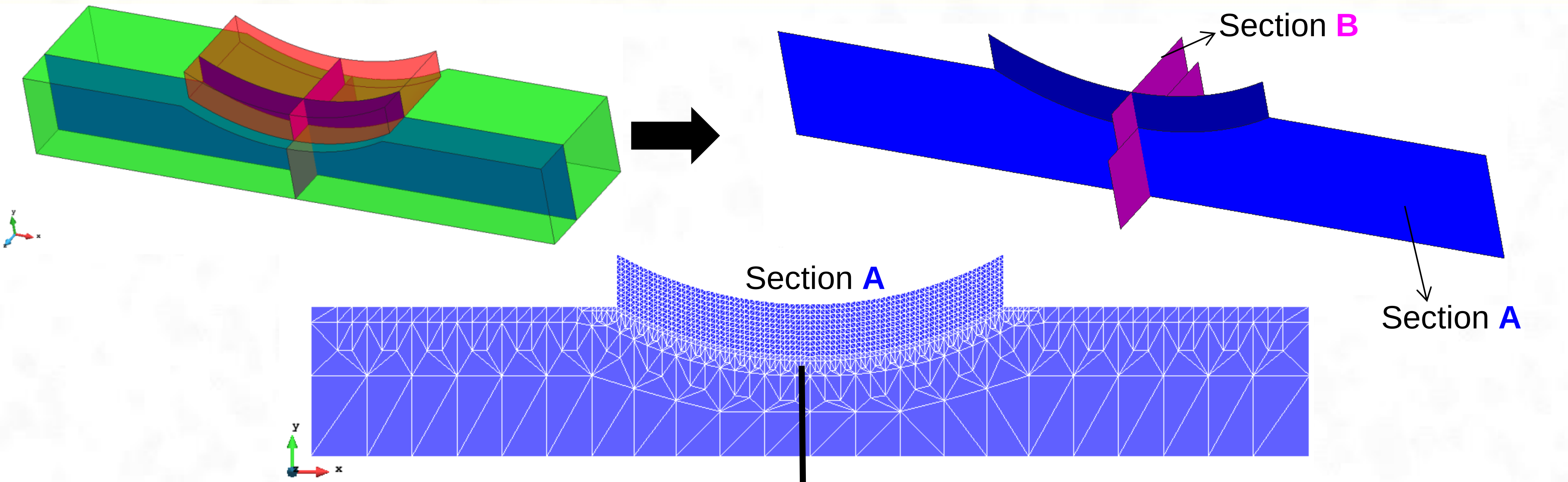
	Depth	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Simu result	h_{DL} (µm)	508	688	709	730	793
	h_{HAZ} (µm) $HAZ_\beta + HAZ_{\alpha+\beta}$	1618	1864	2174	2377	2605
Measured	h_{DL} (µm)	450	Not accessible, different zones cannot be recovered			
	h_{HAZ} (µm) $HAZ_\beta + HAZ_{\alpha+\beta}$	1501				

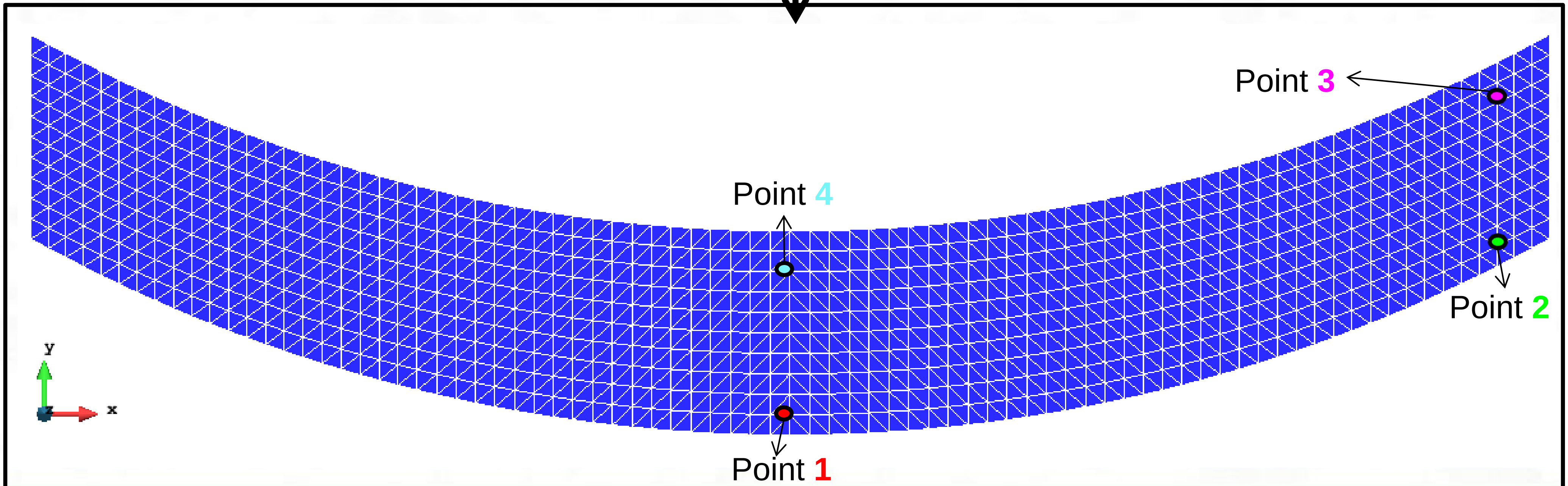
Constant Track length strategy



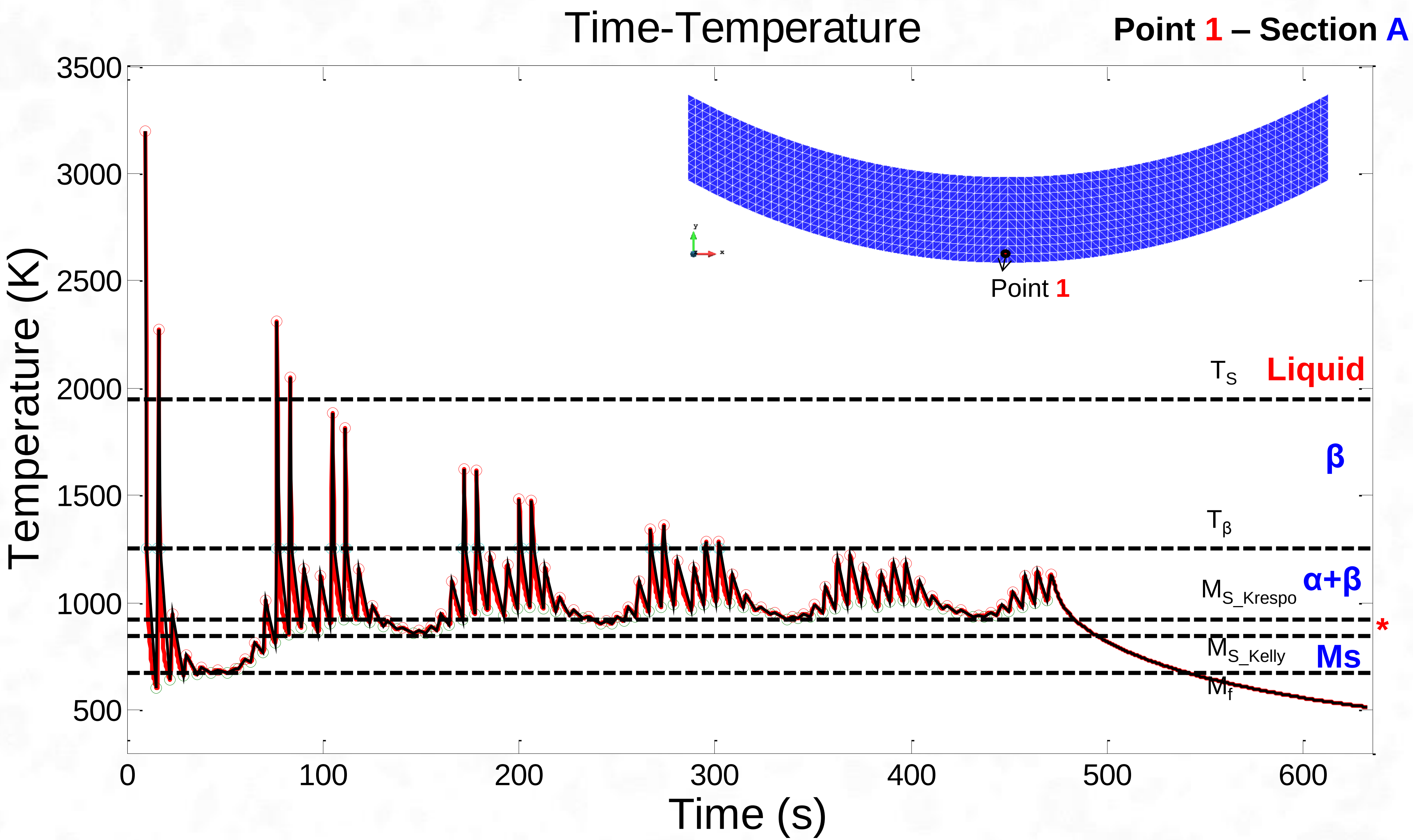
Hardness map – CTL – Laser cladding as a repair technology for Ti6Al4V alloy: influence of incident energy and building strategy on microstructure and hardness. H.Paydas,et al.; Materials and Design, 2015.

Constant Track length strategy



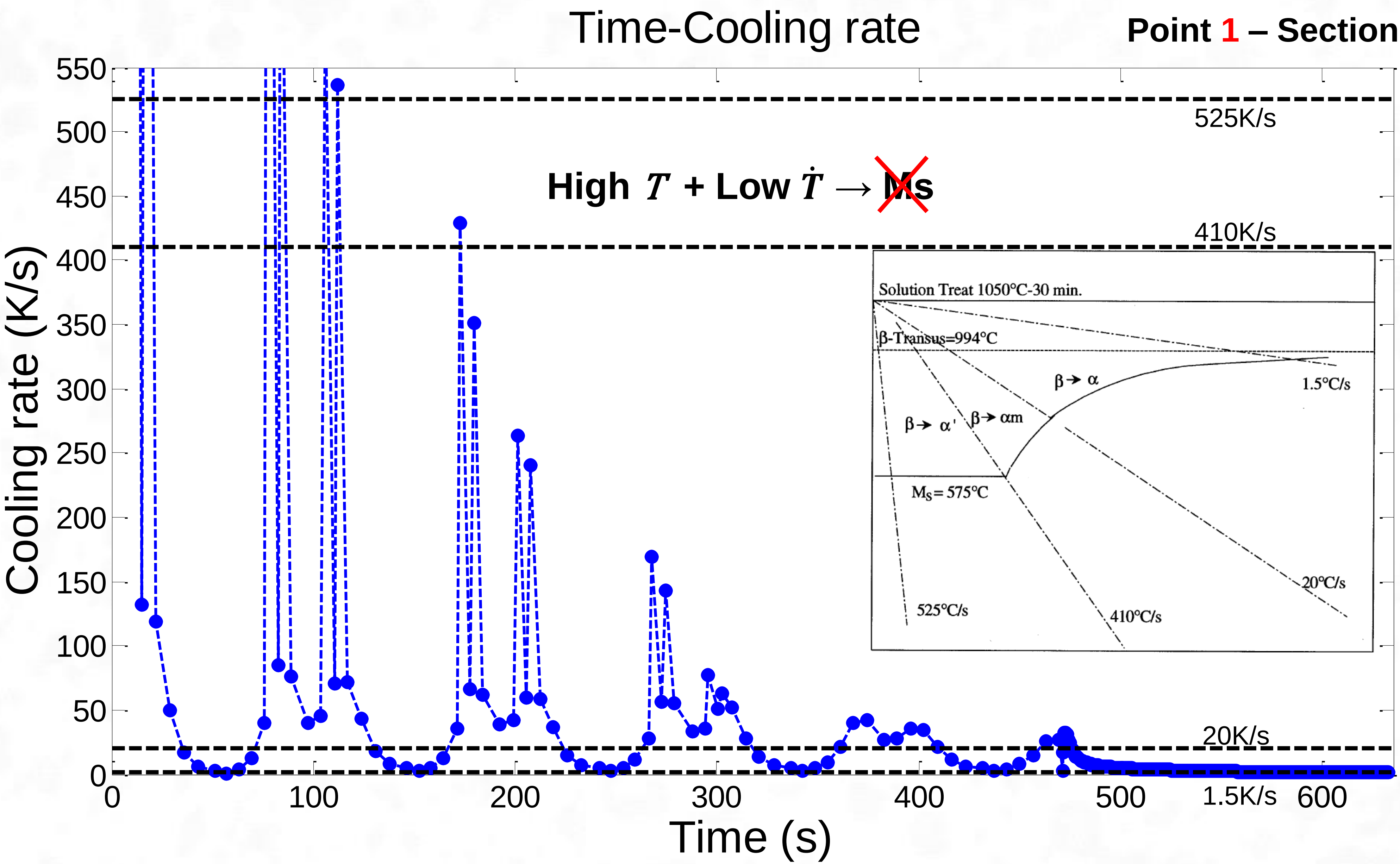


Constant Track length strategy

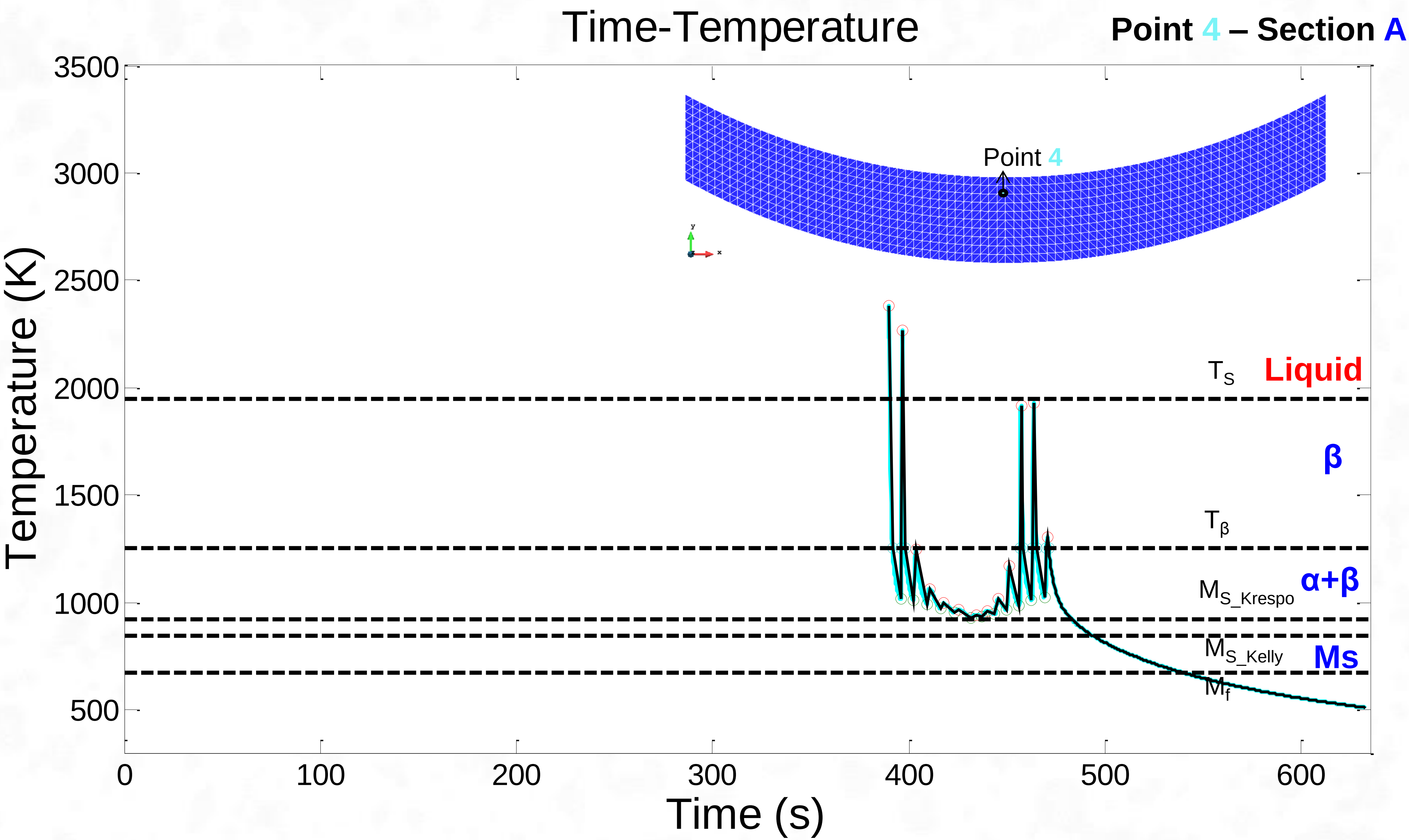


Constant Track length strategy

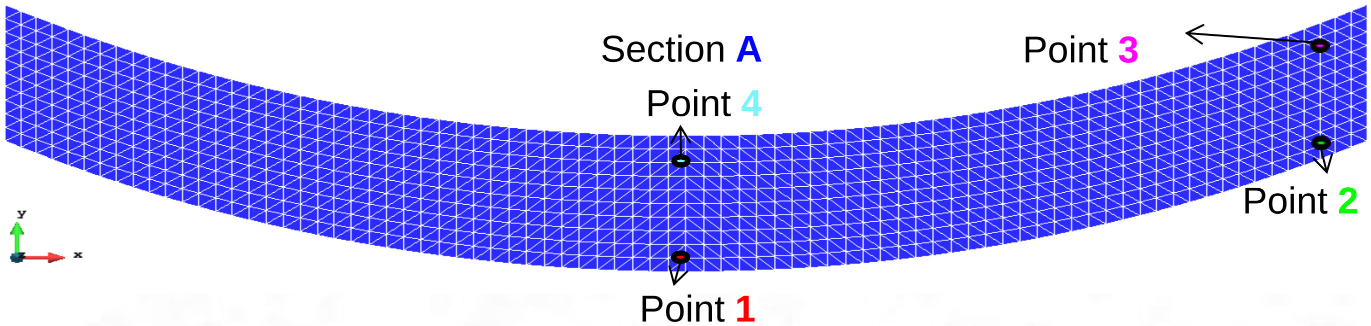
Point 1 – Section A



Constant Track length strategy



Conclusion



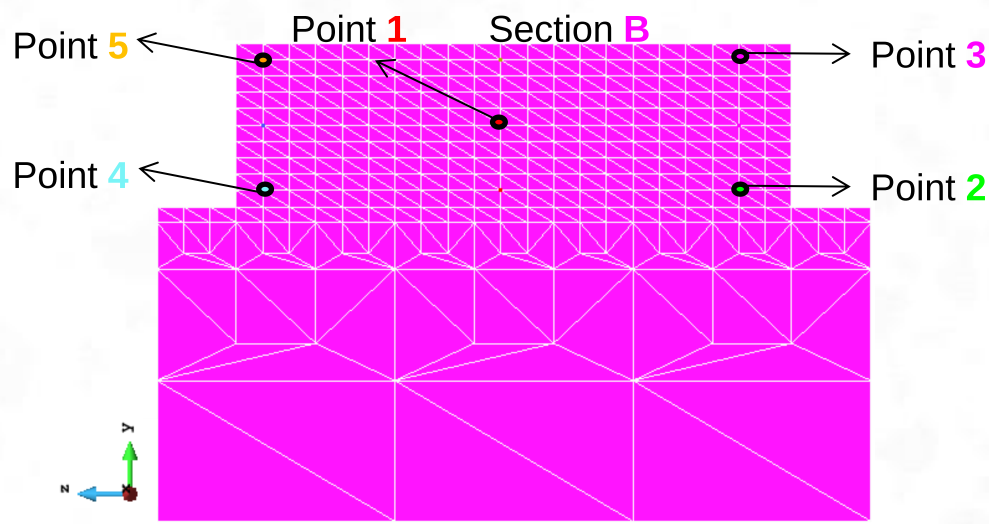
Prediction in Section A:

- Identical T° history
- $T_{average}$ > Ms
- $\dot{T}$ at the end low

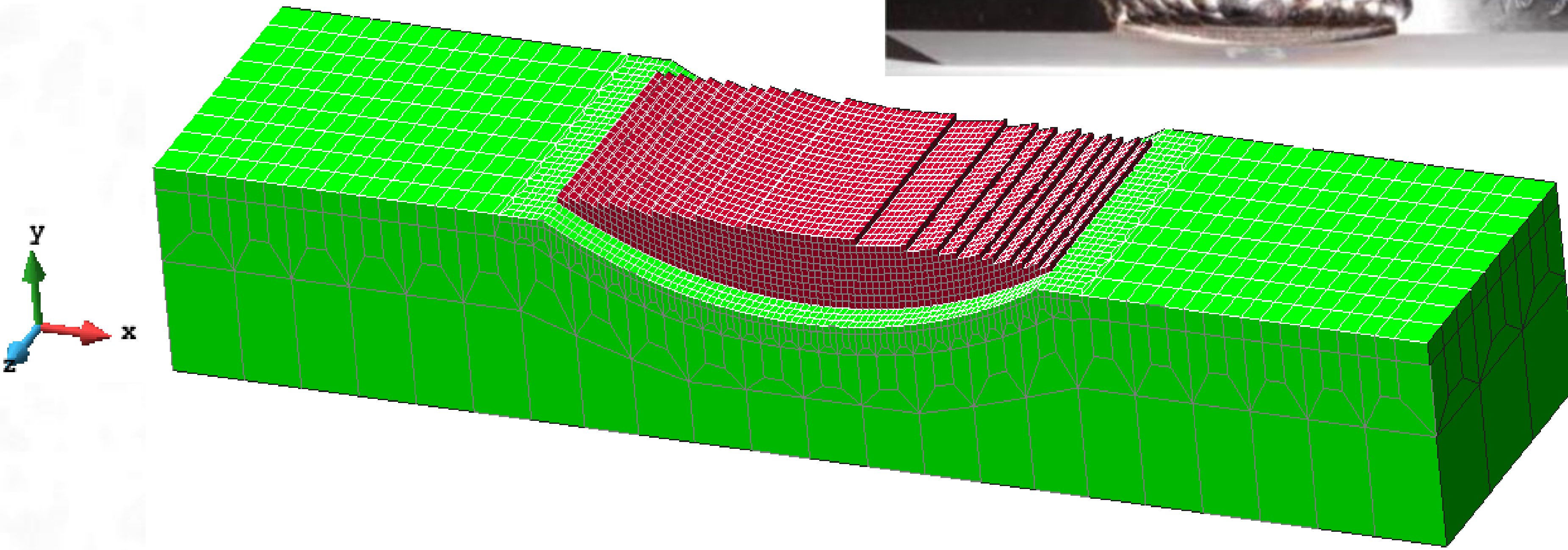
→ basket-weave Widmanstätten structure

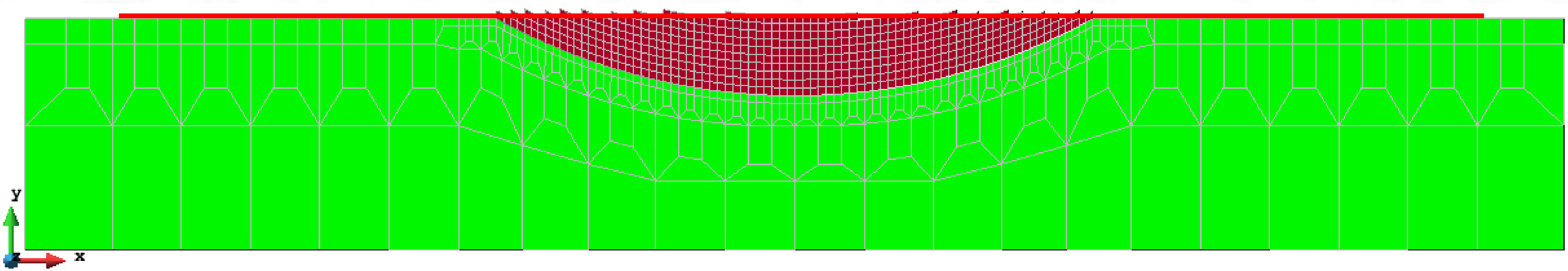
Prediction in Section B:

- T° History of five nodes identical
- Same microstructure

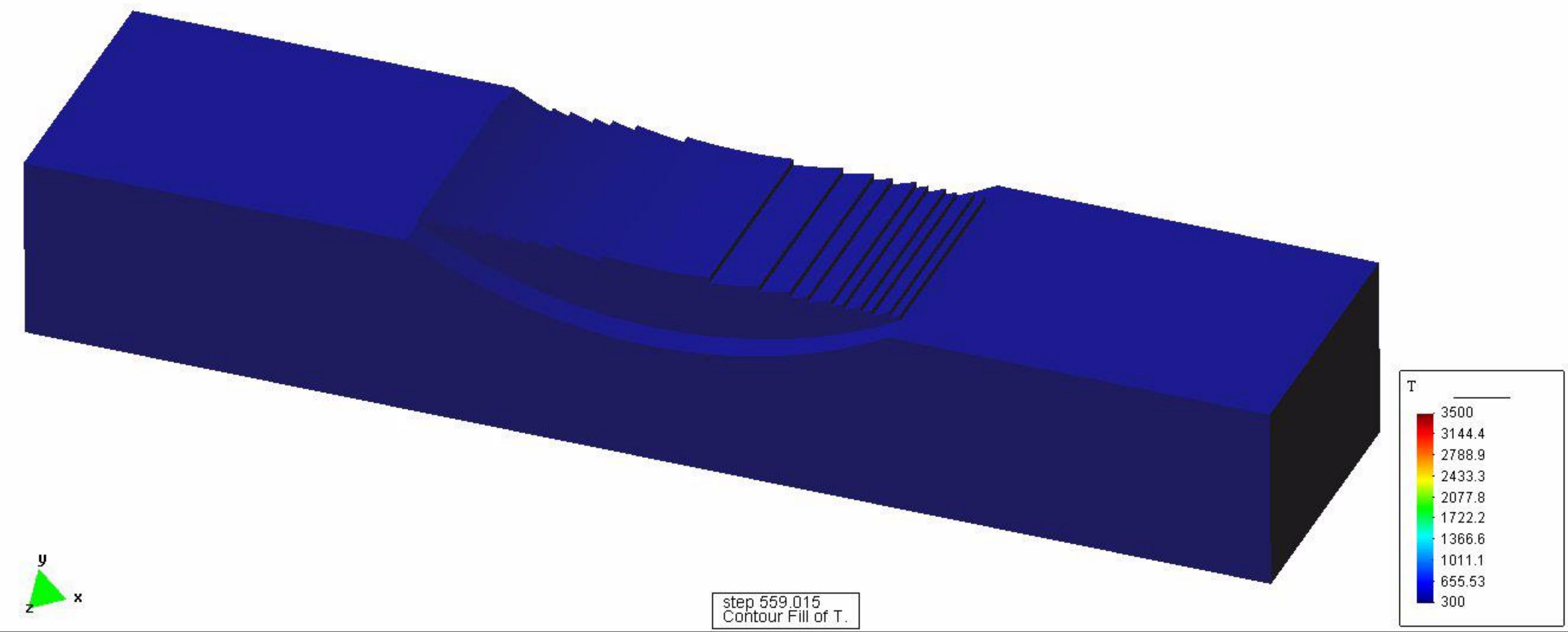


DTL strategy





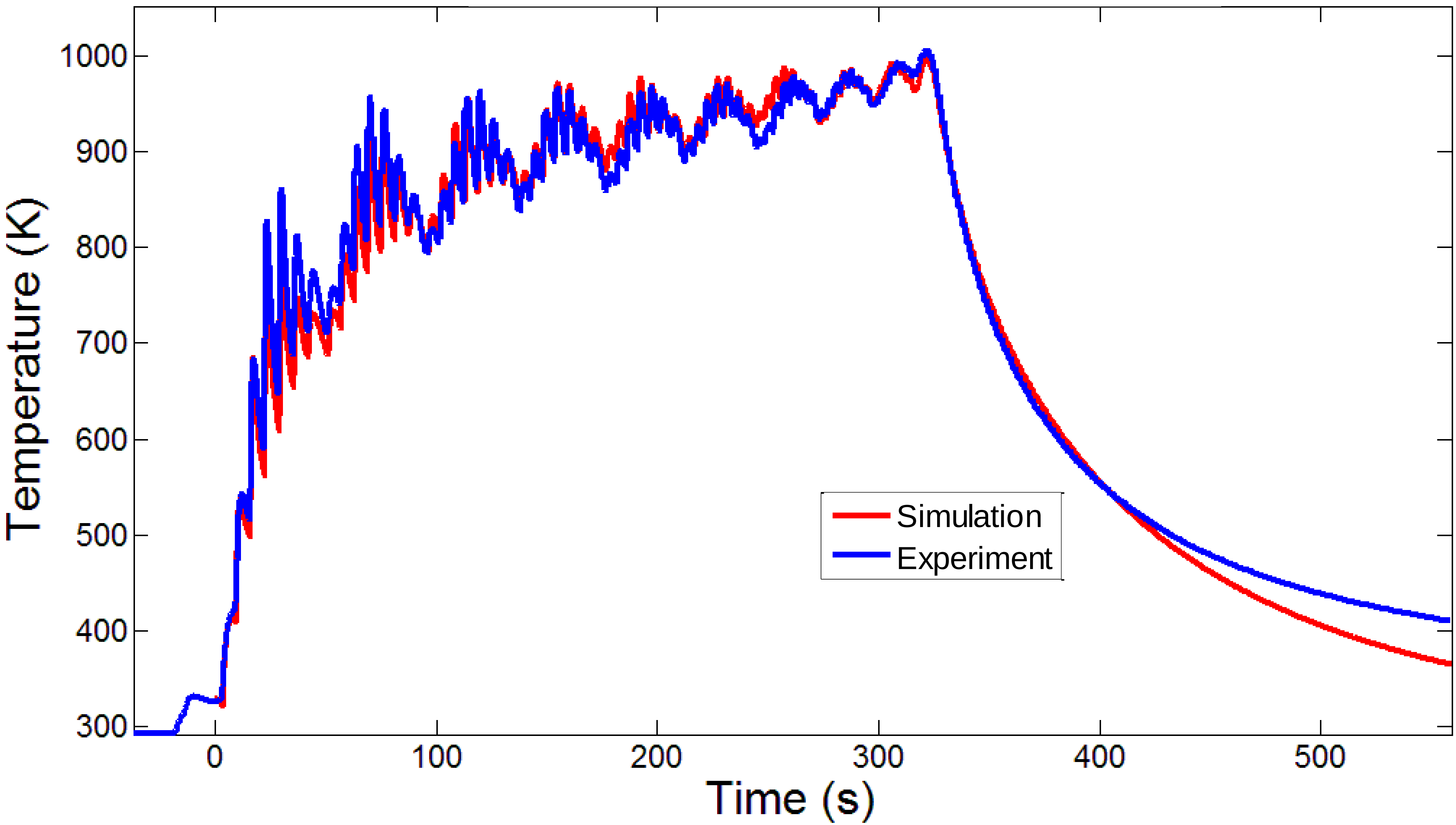
Decrease Track Length strategy



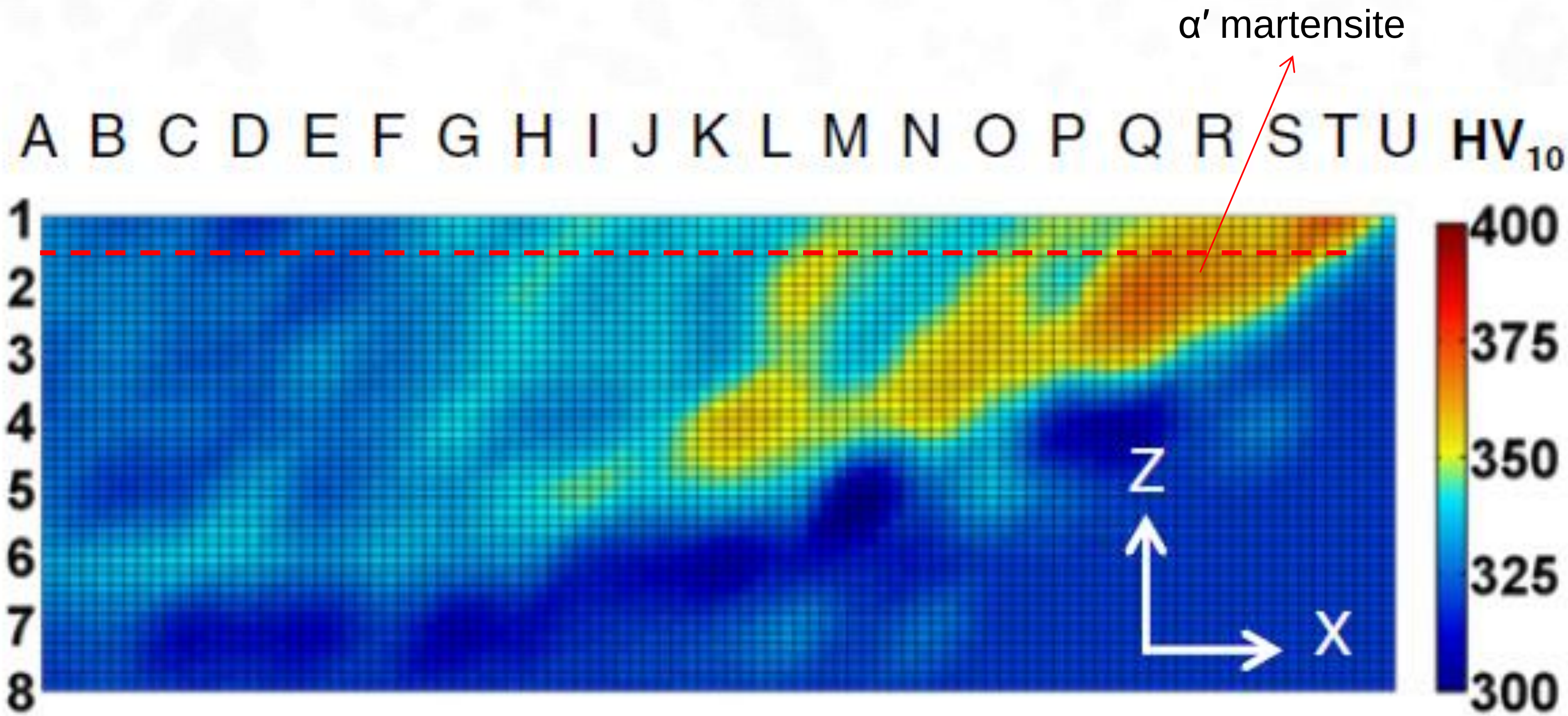
Temperature (K)
Red = 3500 K
Blue = 300 K

Decrease Track Length strategy

Validation at thermocouple for 10 layers

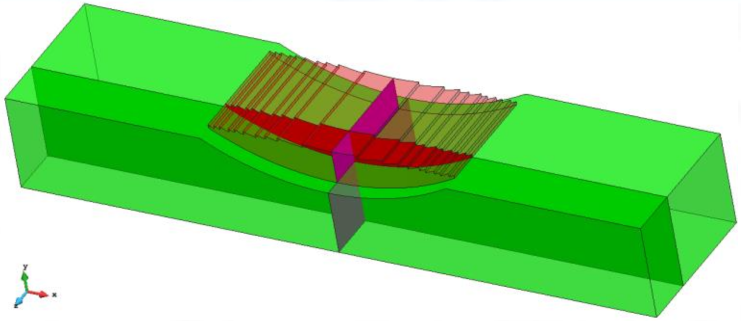


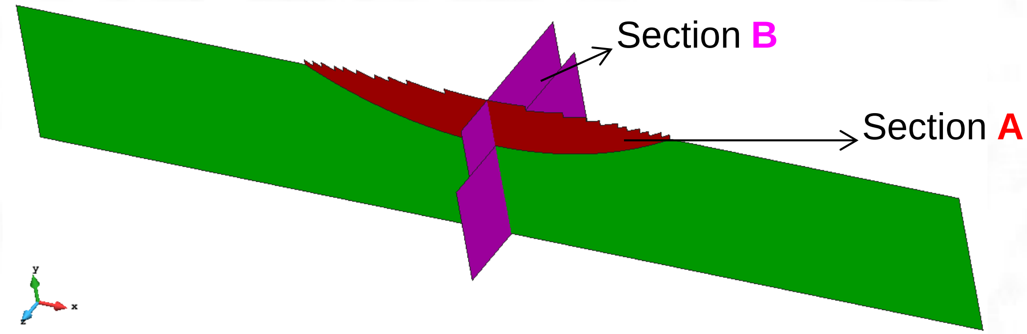
Decrease Track Length strategy



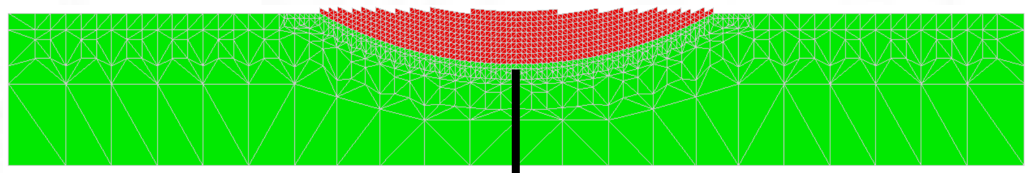
Hardness measurement (Hakan et al. 2015)

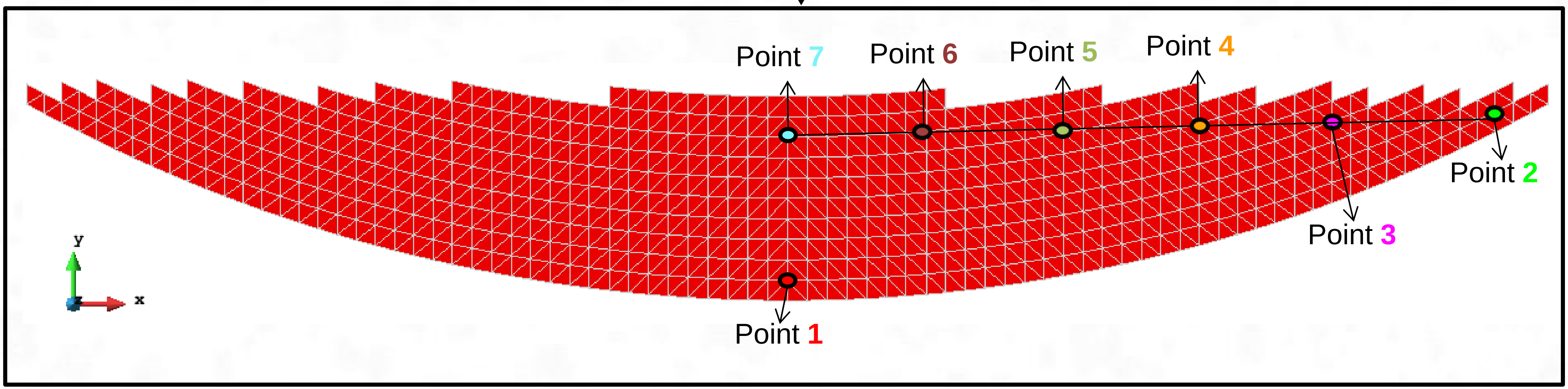
Decrease Track Length strategy



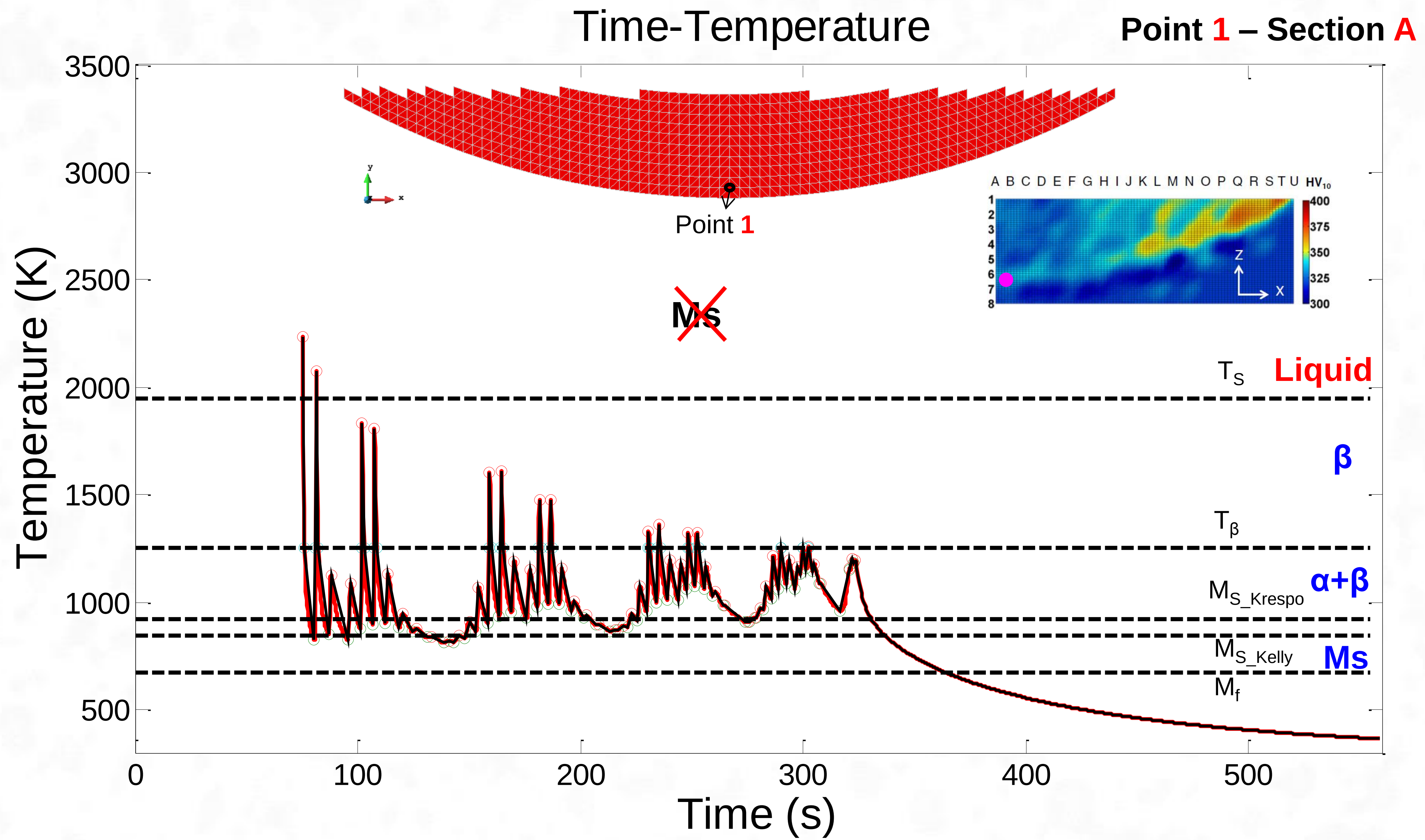


Section A

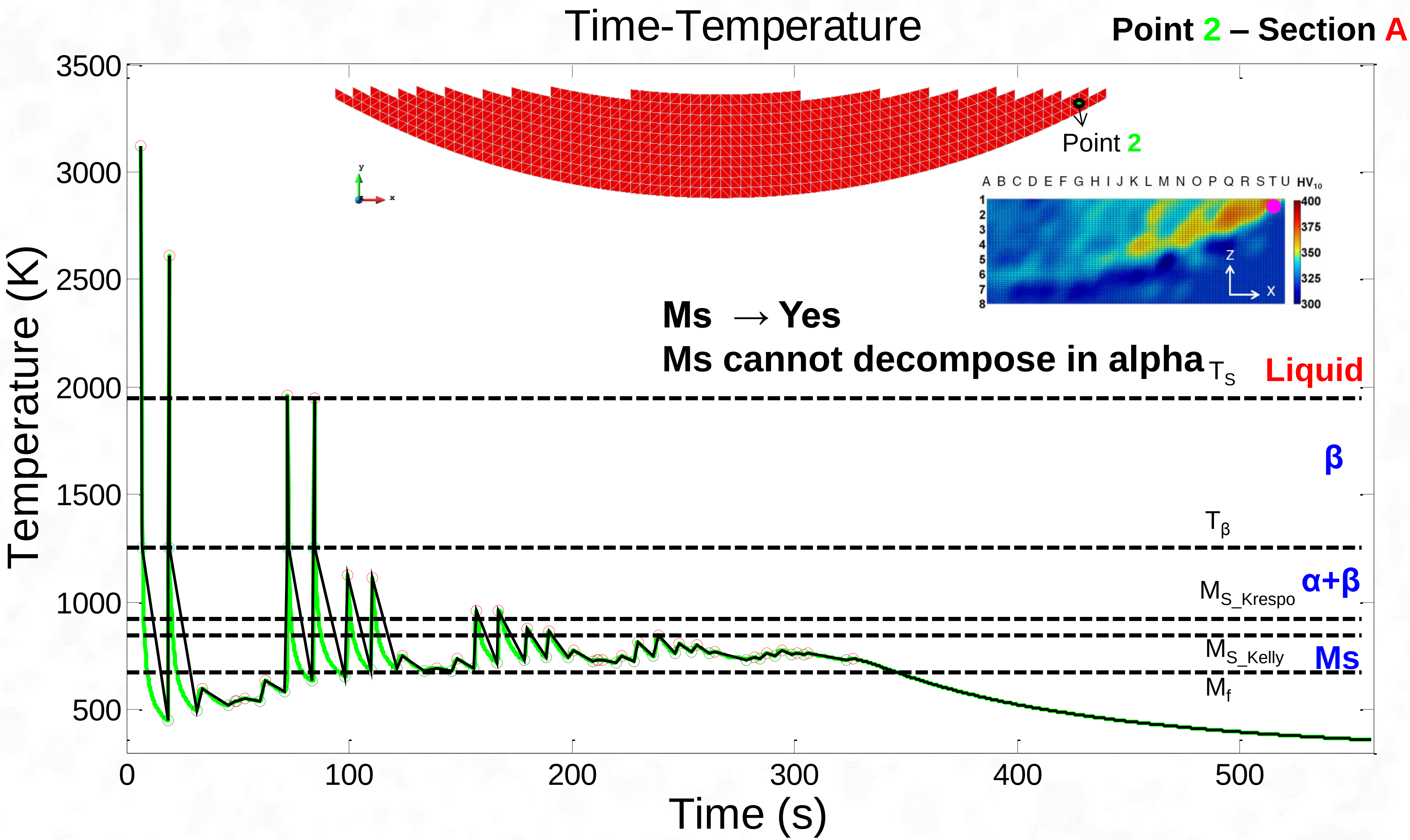




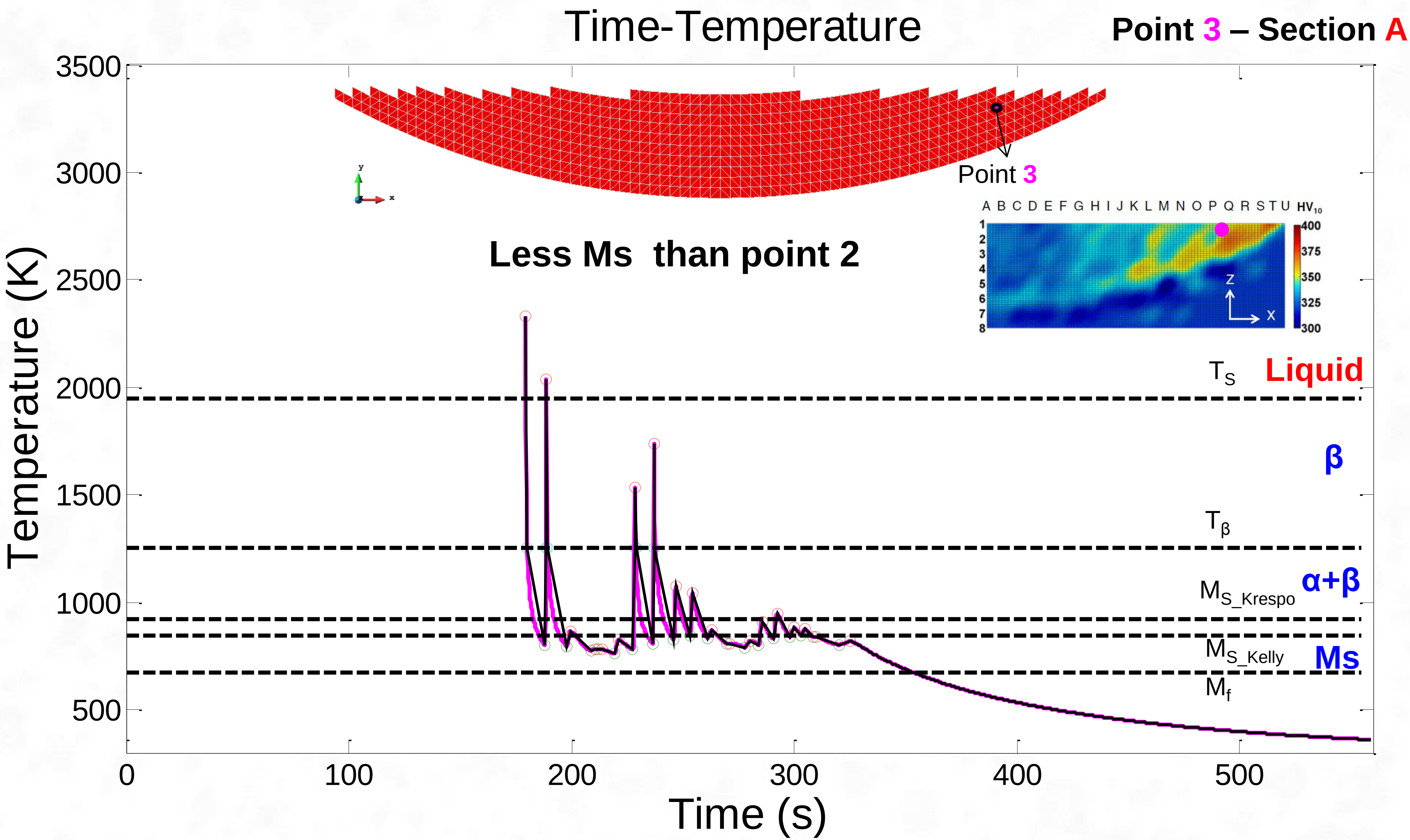
Decrease Track Length strategy



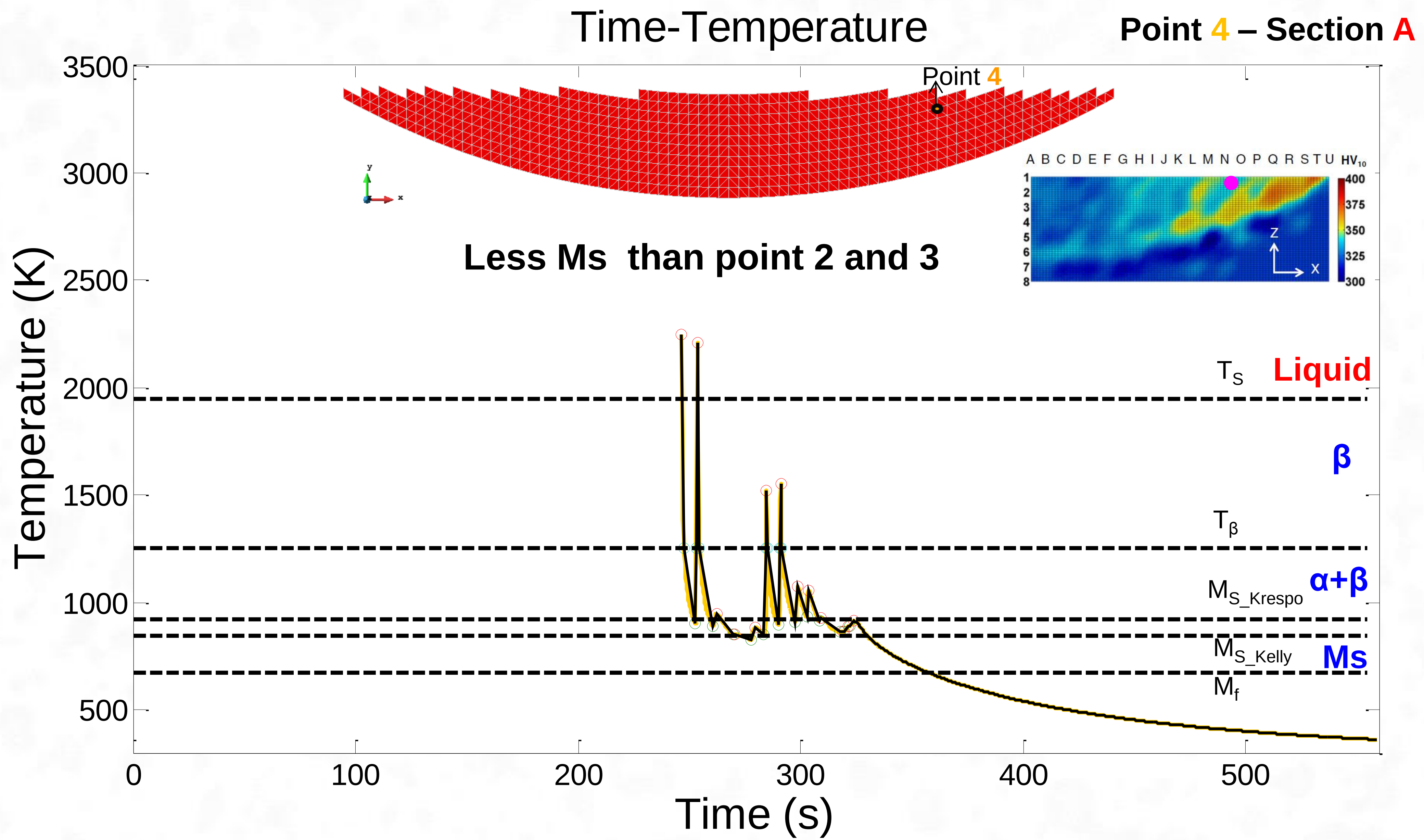
Decrease Track Length strategy



Decrease Track Length strategy

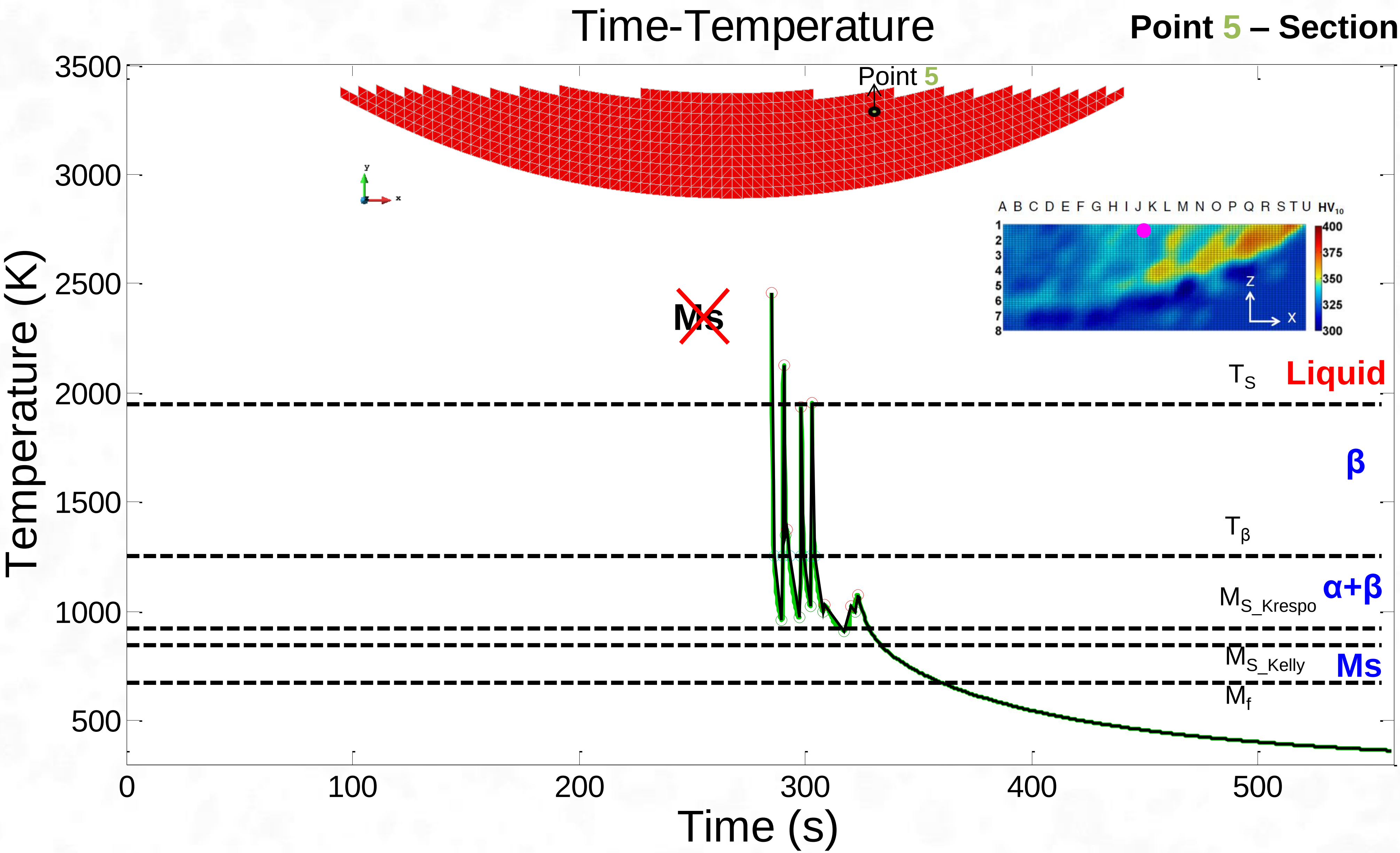


Decrease Track Length strategy



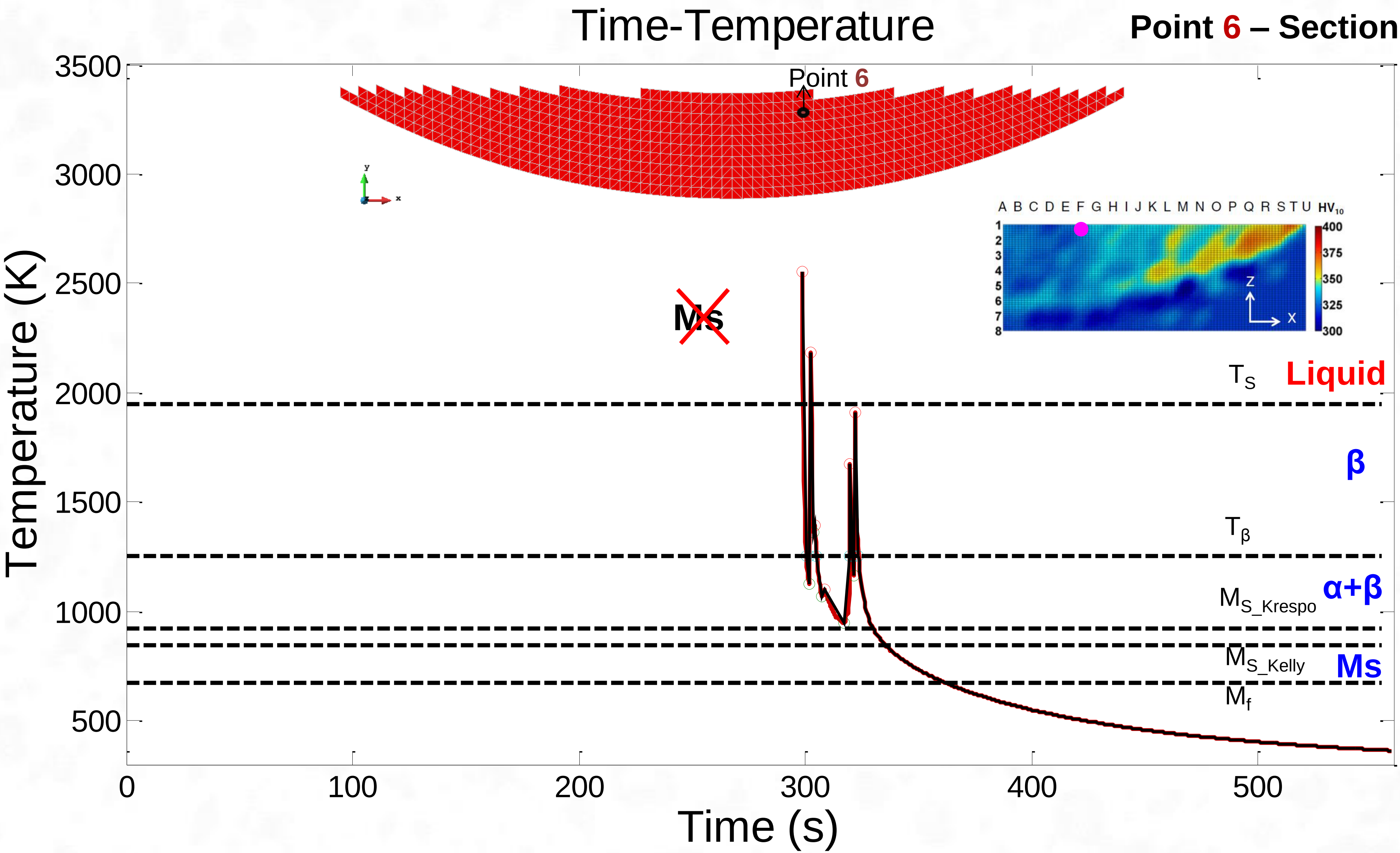
Decrease Track Length strategy

Point 5 – Section A

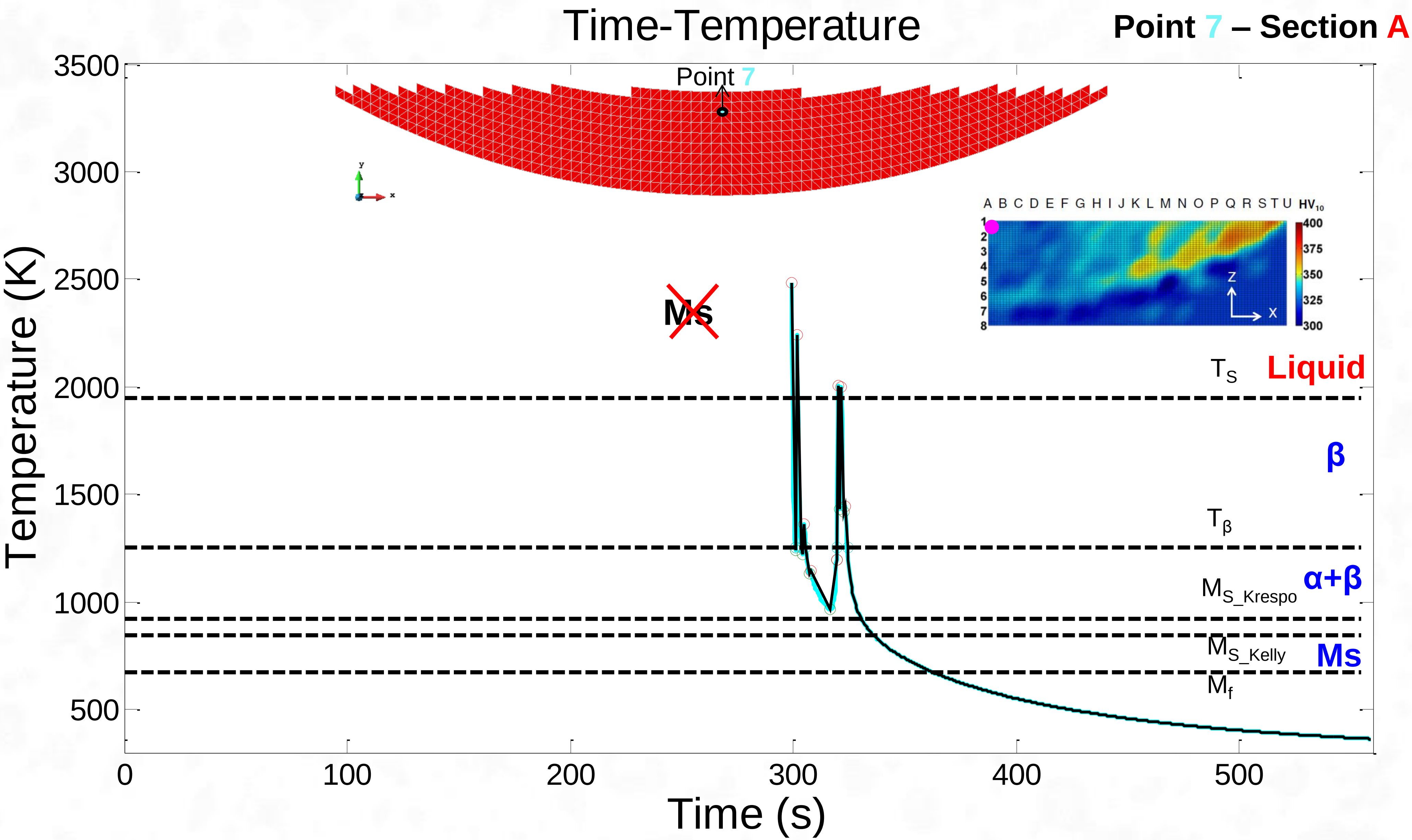


Decrease Track Length strategy

Point 6 – Section B



Decrease Track Length strategy



Conclusion & Perspectives

Done

Qualitative prediction // experience

HAZs size within substrate Melt pool size

Prediction in Constant Track Length:

- Homogeneous T° history
- $T_{average}$ > Ms
- $\dot{T}$ at the end low

➡ basket-weave Widmanstätten structure

Prediction in Decrease Track Length:

- Heterogeneous T° history
- At some location : $T_{average}$< Ms and $\dot{T}$ high

➡ basket-weave Widmanstätten structure + α’ Martensite

On going

Fully couple thermo-mechanical-metallurgical analysis, % phase

Thank you for your attention!