"On the influence of overheating in downfacing regions on the surface quality and geometrical accuracy"

Umberto Paggi[1,2,4], Rajit Ranjan[3],Lore Thijs[2], Can Ayas[3], Matthijs Langelaar[3], Fred van Keulen[3], Brecht van Hooreweder[1,4]

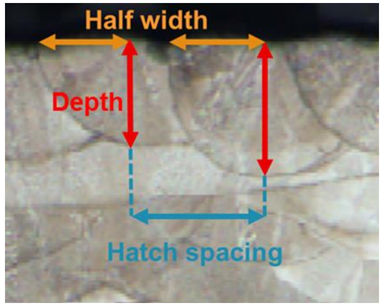
[1] KU Leuven, Department of Mechanical Engineering, Leuven, Belgium

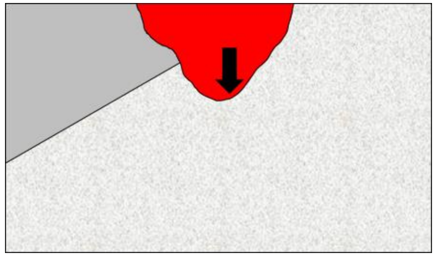
[2]3D Systems Leuven, Belgium

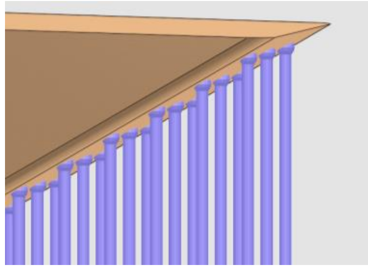
[3]TU Delft, Department of Precision and Microsystems Engineering (PME), Delft, the Netherlands

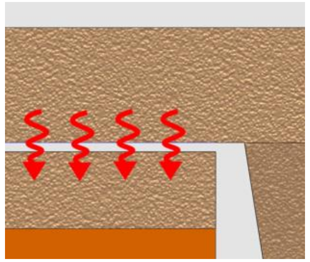
[4]Member of Flanders Make - Core lab PMA-P, KU Leuven, Leuven, Belgium

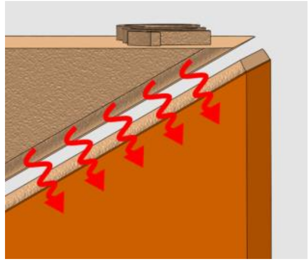
Table of content

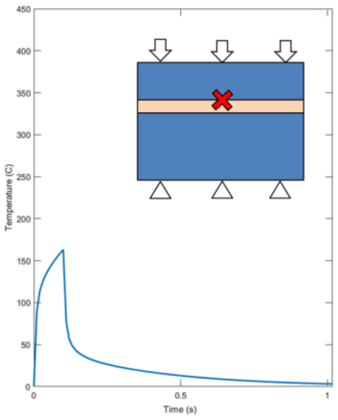


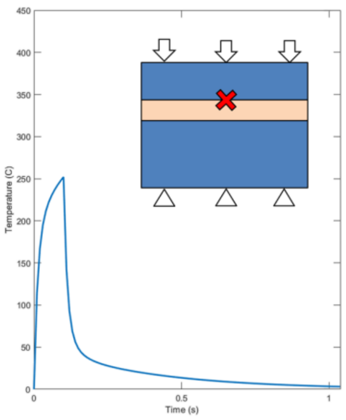


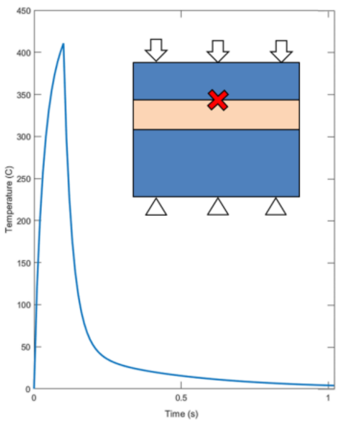




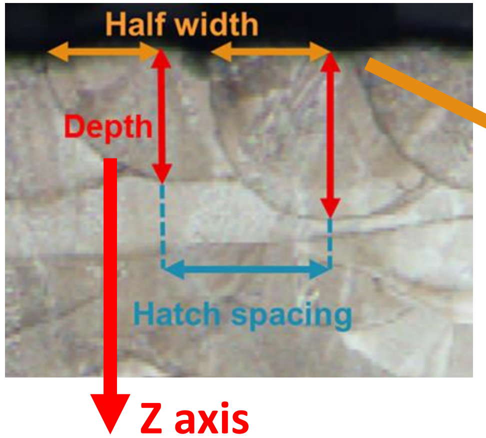


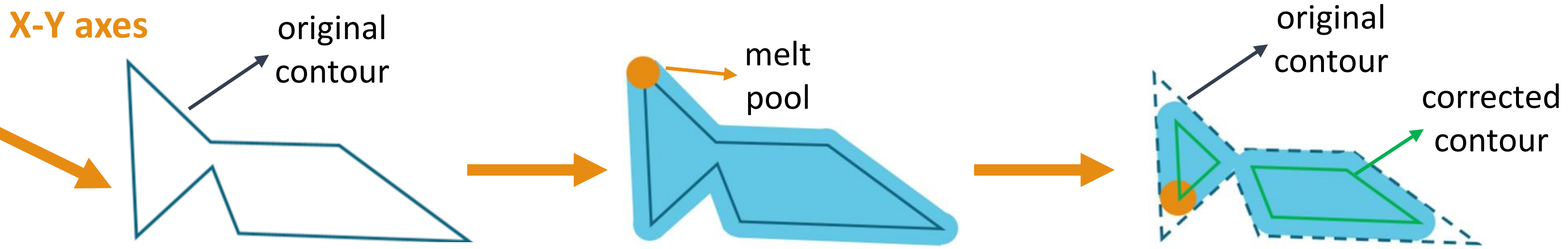






Melt pool and accuracy

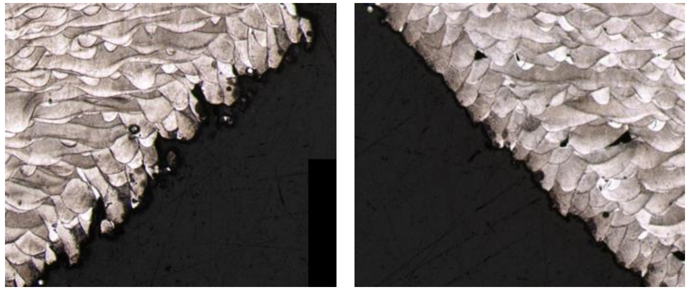




Cross section (no correction)

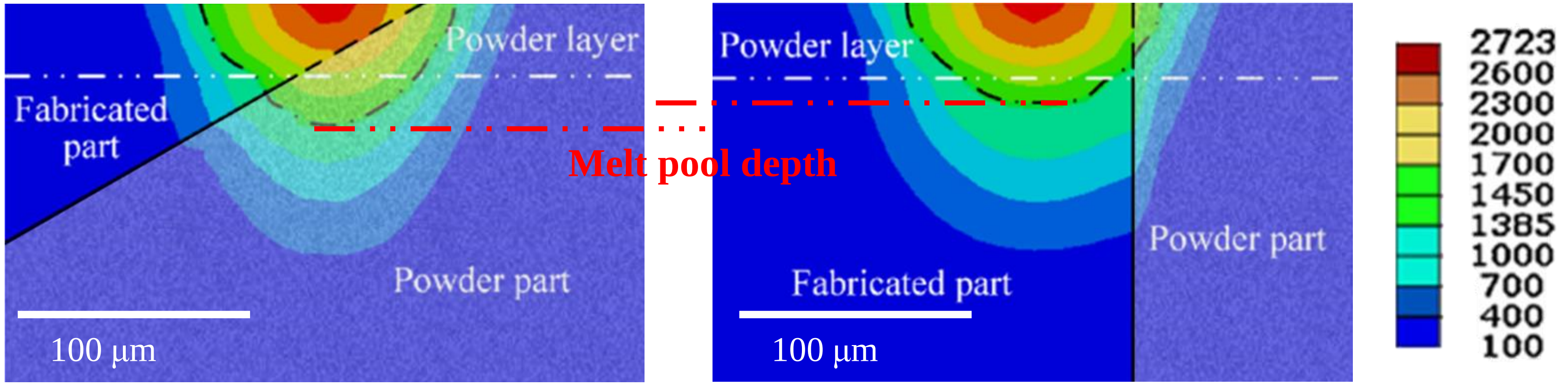
Printed part

Beam compensation



Non-optimal parameters

Optimal parameters

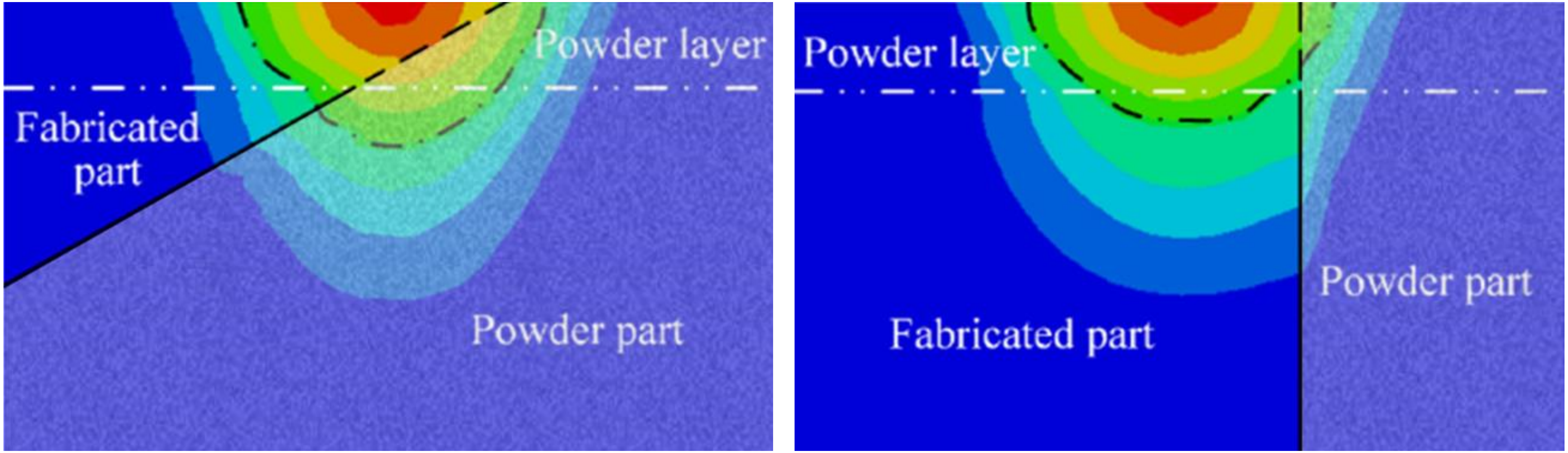


Overheating due to insulating effect of powder bed

[Analysis of the quality of slope surface in selective laser melting process by simulation and experiments, Xiang et al., 2019]

Overheating and fluid flow on downfacing regions

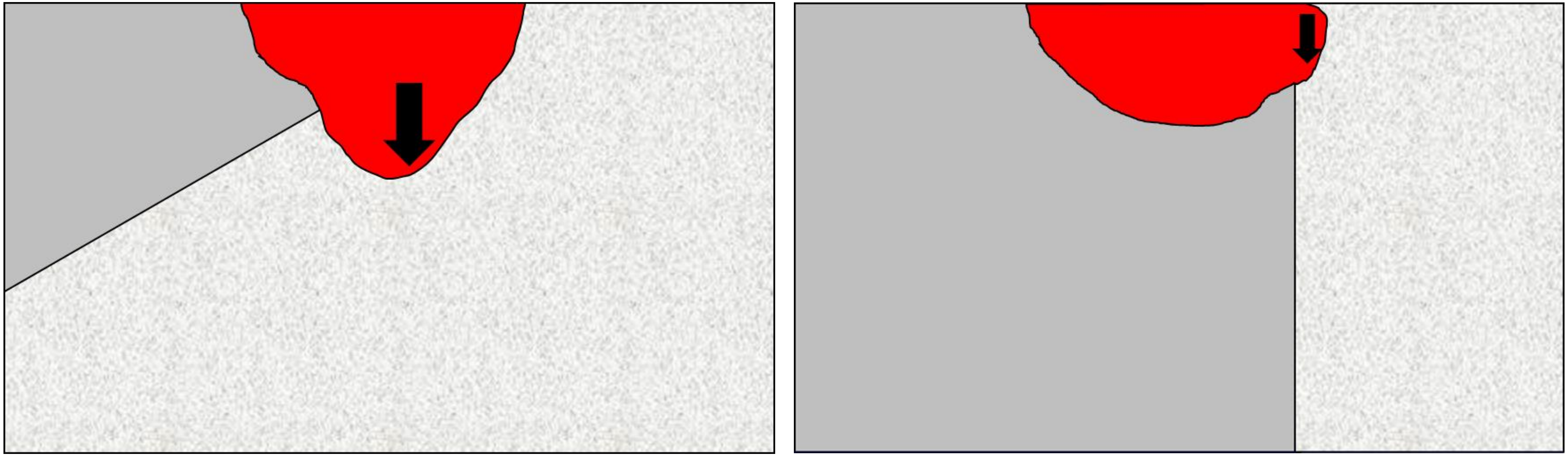
Laser scanning (overheating of the downfacing area)



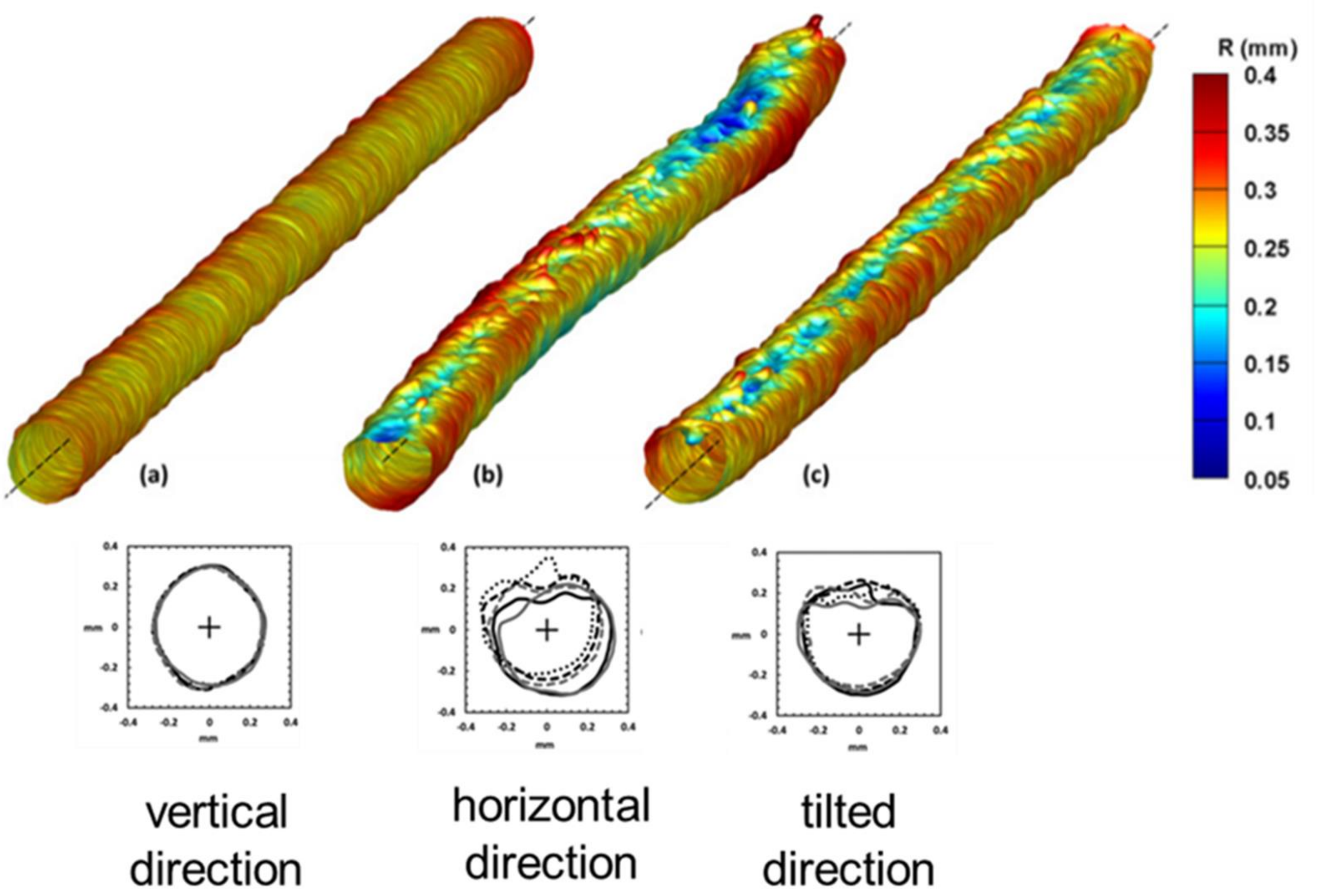
Overheating and fluid flow on downfacing regions

Fluid flow due to gravity, recoil pressure, capillarity, turbulent flow in the melt pool...

[Improving additive manufacturing processability of hard-to-process overhanging structure by selective laser melting, Cheng et al., 2017]

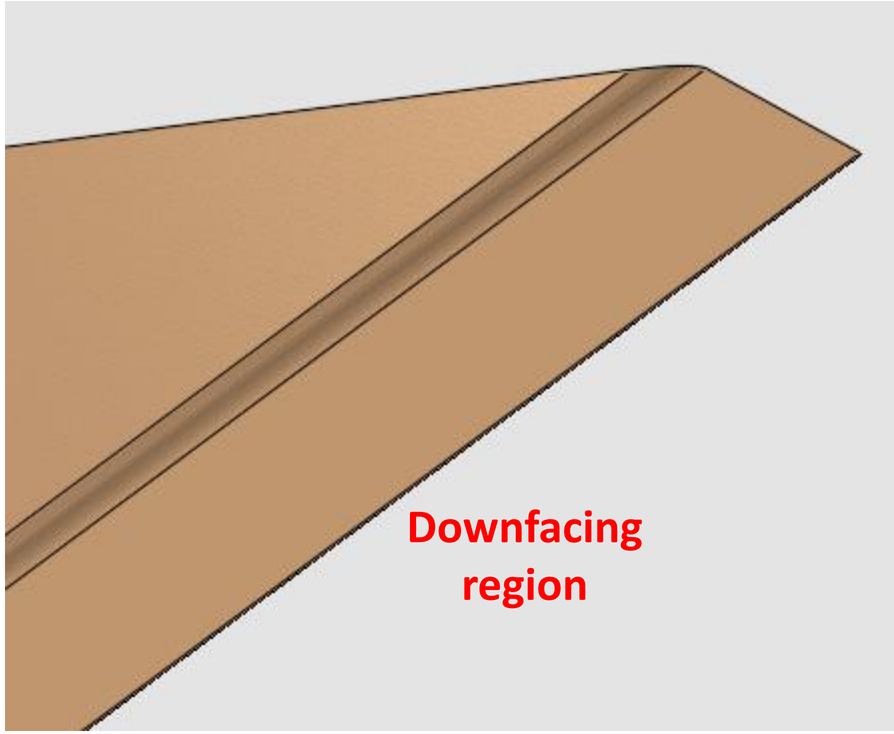


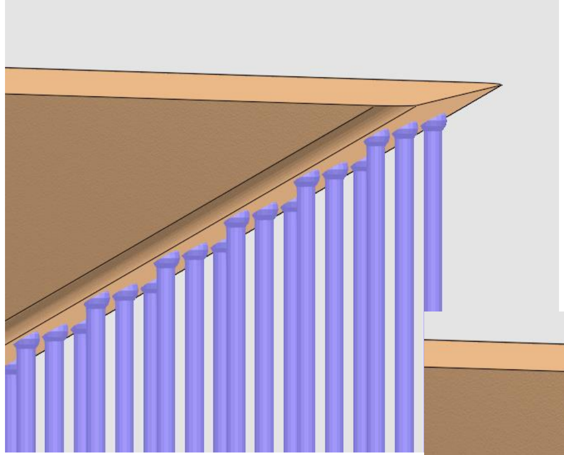
Overheating and fluid flow on downfacing regions



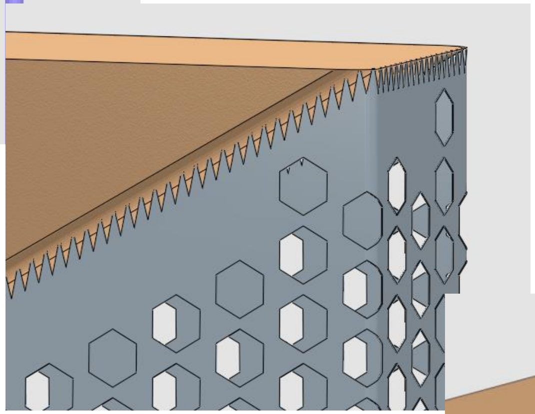
[Build Direction Effects on Microchannel Tolerance and Surface Roughness, Jacob C. Snyder et al., 2015]

Improving powder bed conduction: standard support strategies

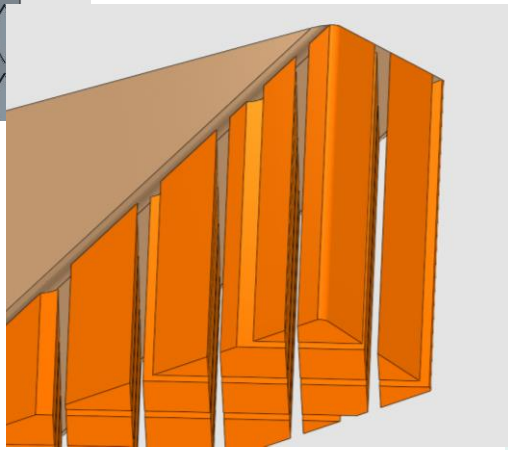




Cone support

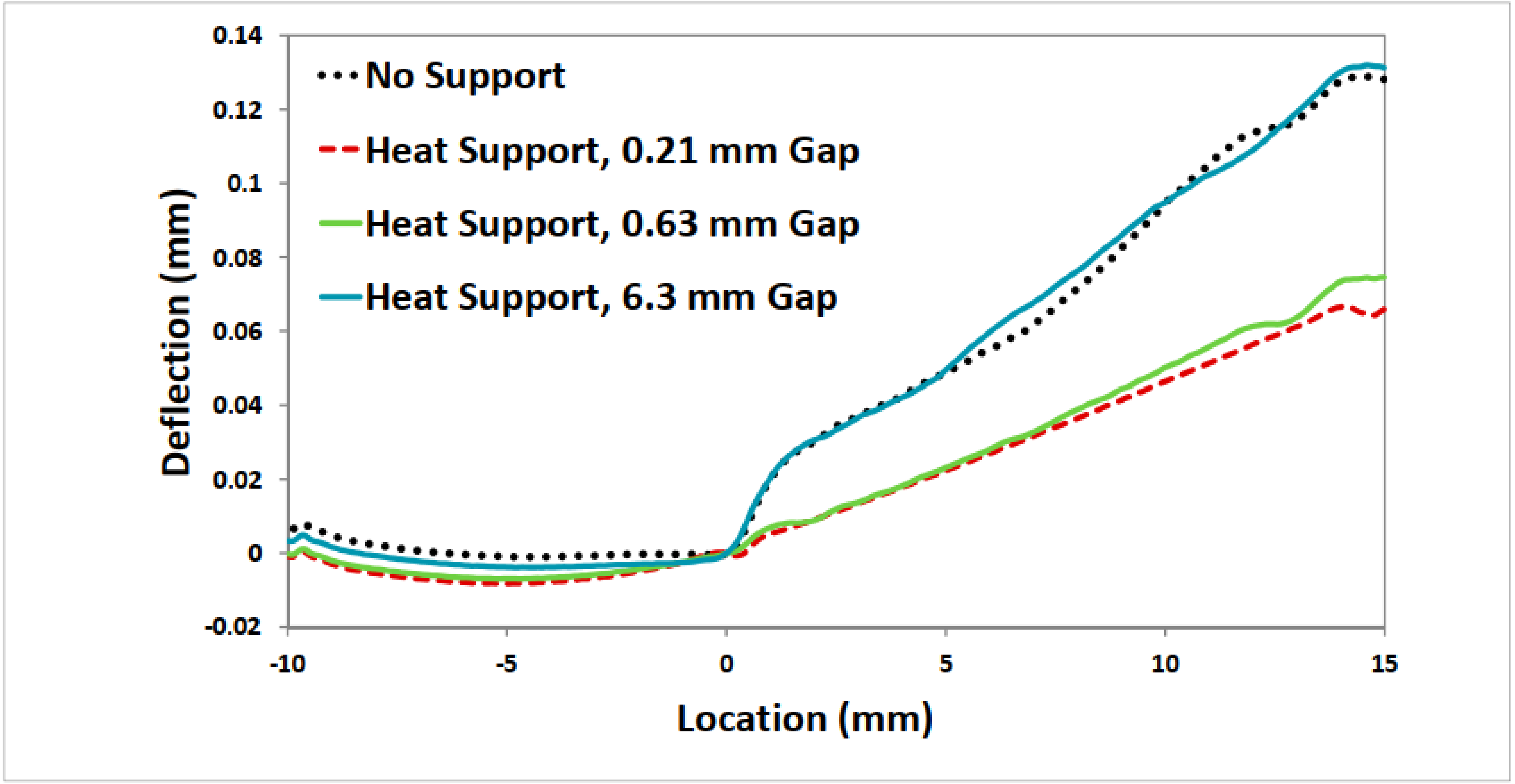


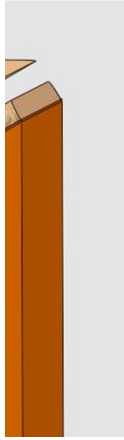
Wall support



Solid support

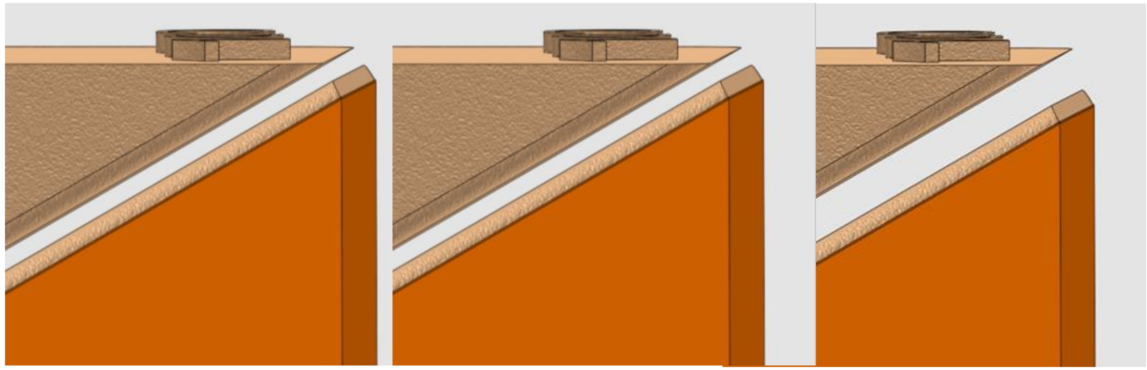
Improving powder bed conduction: contactless thermal support



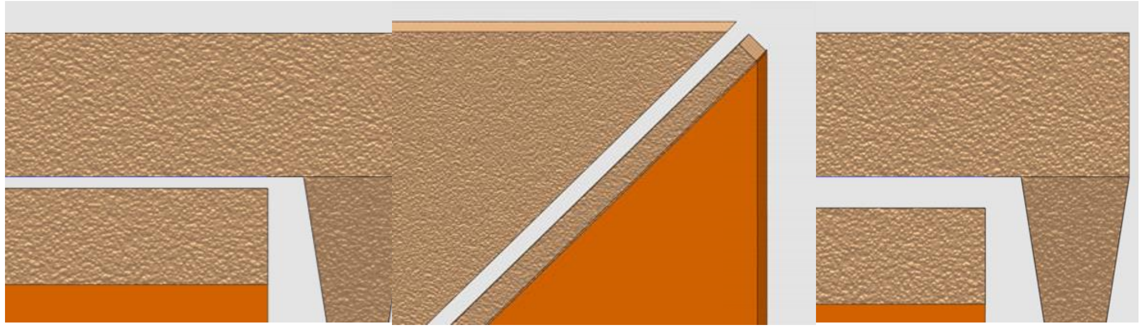


[Contact-Free Support Structures for Part Overhangs in Powder-Bed Metal Additive Manufacturing, Cooper et al., 2017
Deformation Evaluation of Part Overhang Configurations in Electron Beam Additive Manufacturing, Cheng and Chou, 2015]

Improving powder bed conduction: contactless thermal support



Gap/layer thickness = 0.5 Downfacing angle 30° Gap/layer thickness = 6

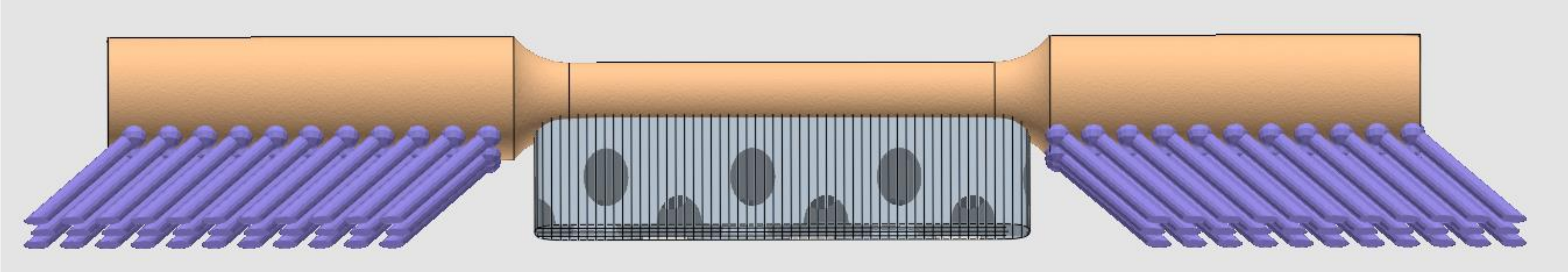


Downfacing angle 45°

ProX350 Flex

3DXpert™

Improving powder bed conduction: standard support strategies

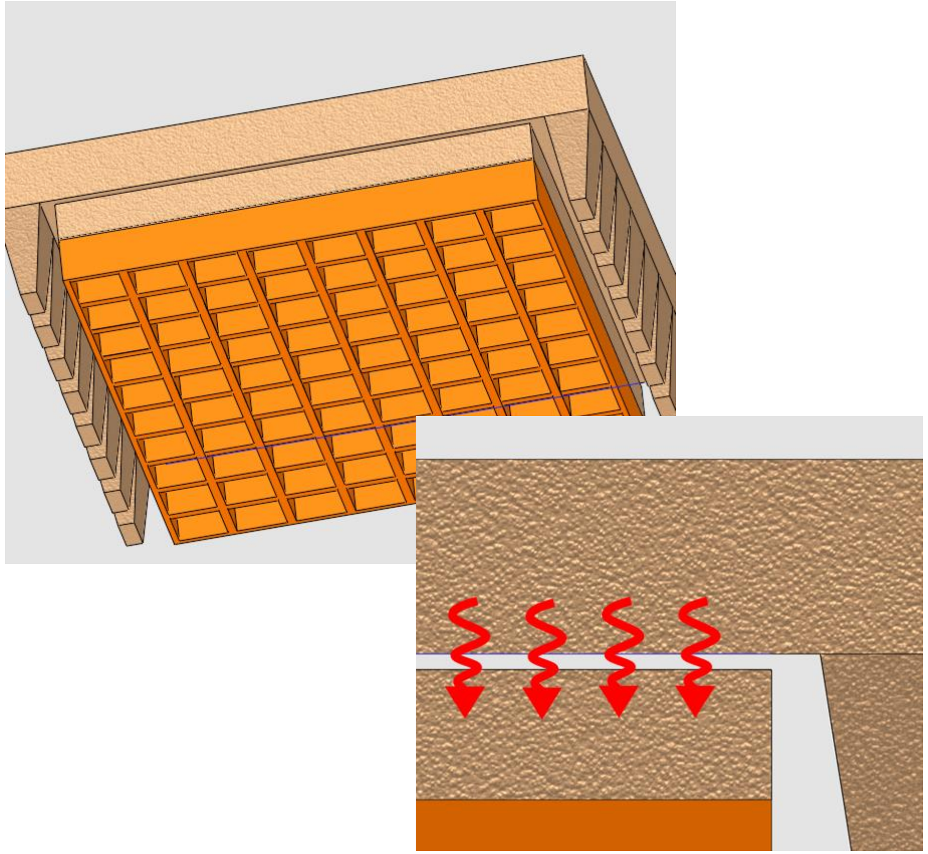


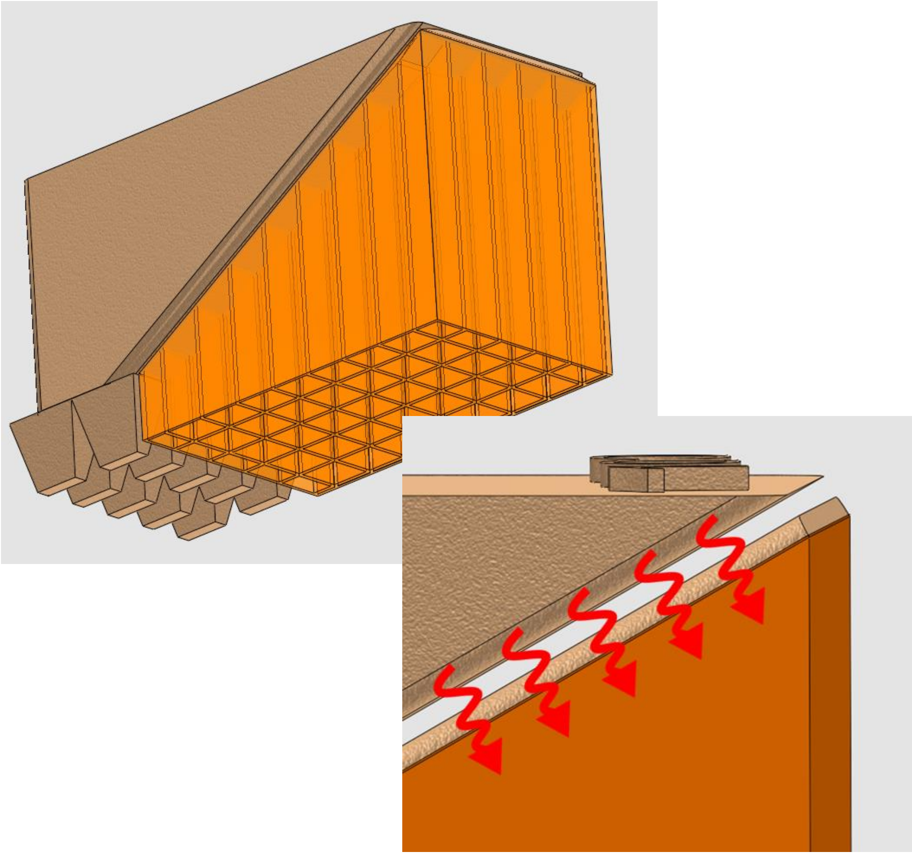
Manual support removal

Grinding

Polishing

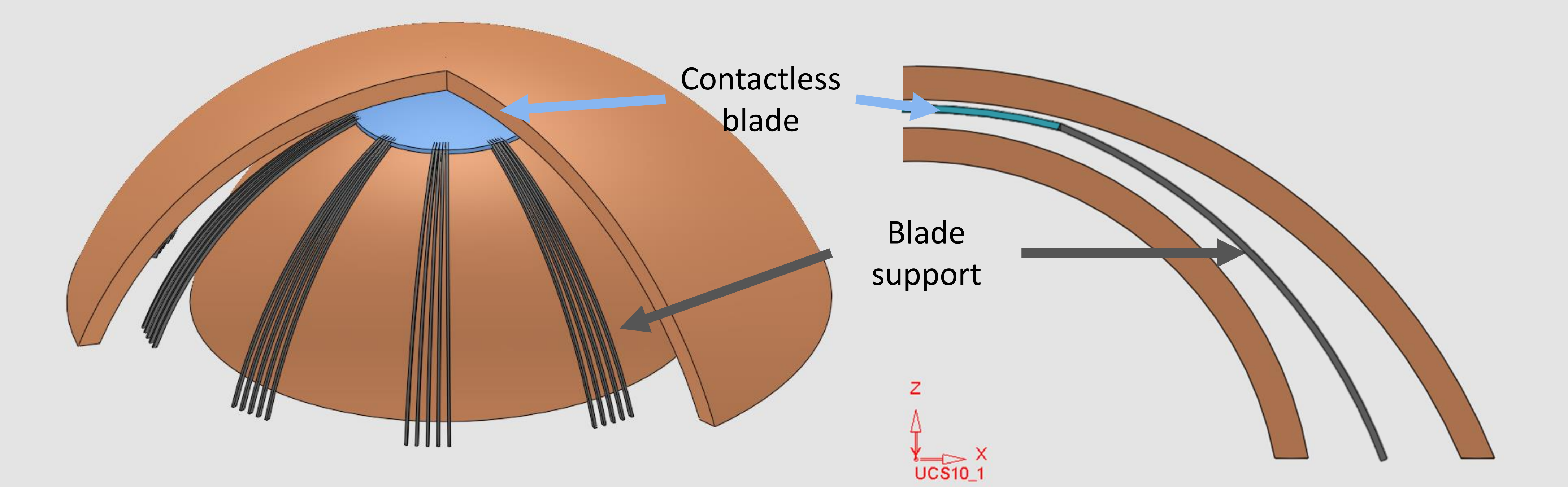
Improving powder bed conduction: contactless thermal support



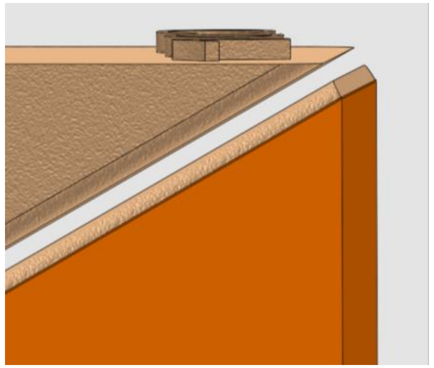


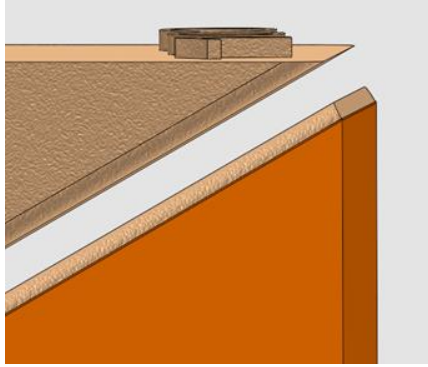
*[Contact-Free Support Structures for Part Overhangs in Powder-Bed Metal Additive Manufacturing, Cooper et al., 2017
Deformation Evaluation of Part Overhang Configurations in Electron Beam Additive Manufacturing, Cheng and Chou, 2015]*

Improving powder bed conduction: contactless thermal support

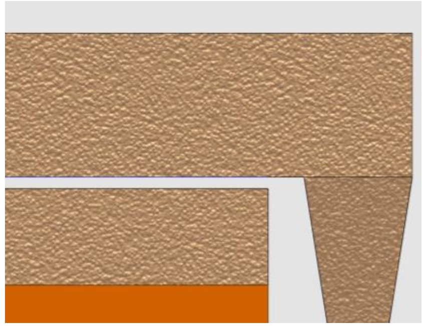


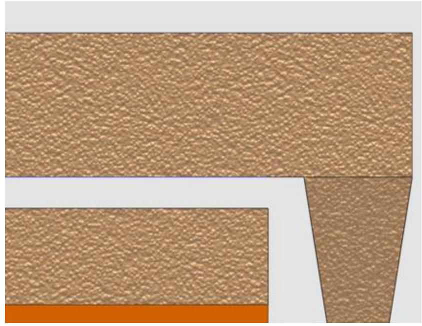
Improving powder bed conduction: contactless thermal support

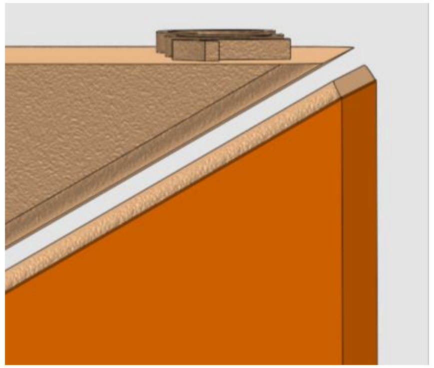




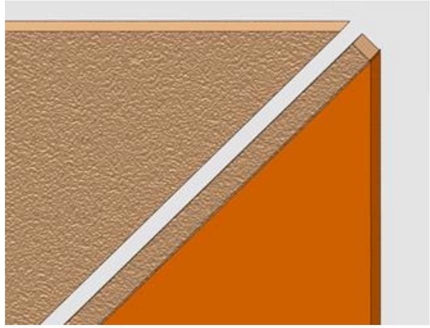
Gap/layer thickness = 0.5 → Gap/layer thickness = 6







Downfacing angle 30°



Downfacing angle 45°

ProX350 Flex

3DXpert™

Experimental results: 30° samples

ref supp

10 mm

30 µm

Ra = 15.22± 1.12 µm Ra = 17.90± 1.18 µm

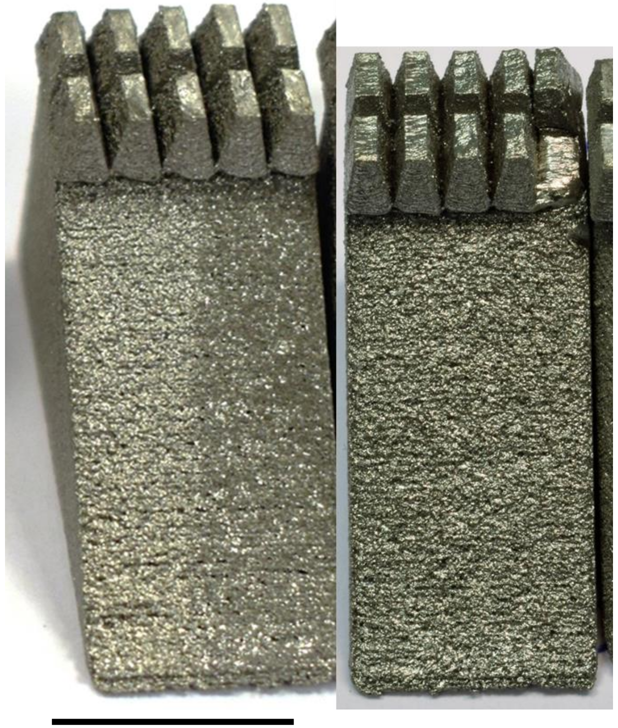
ref supp

10 mm

60 µm

Ra = 18.13± 0.79µm Ra = 20.06± 1.32 µm

ref supp

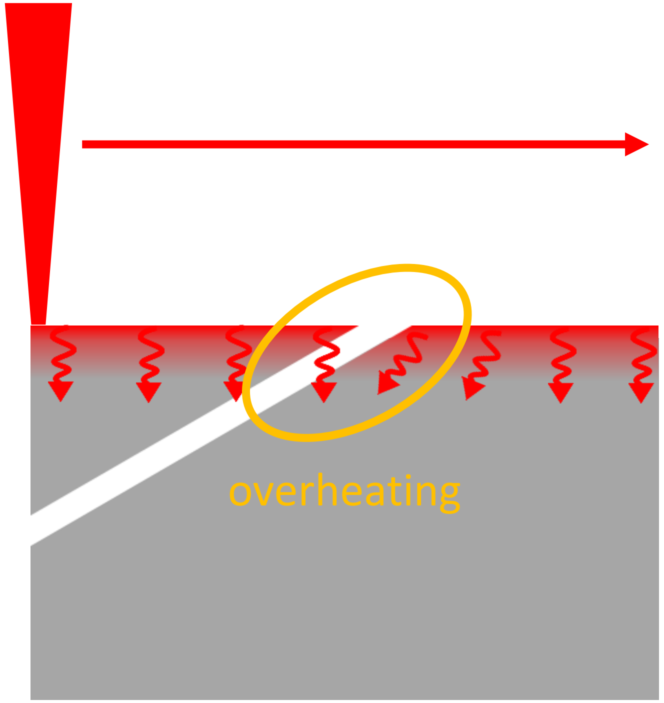


10 mm

90 µm

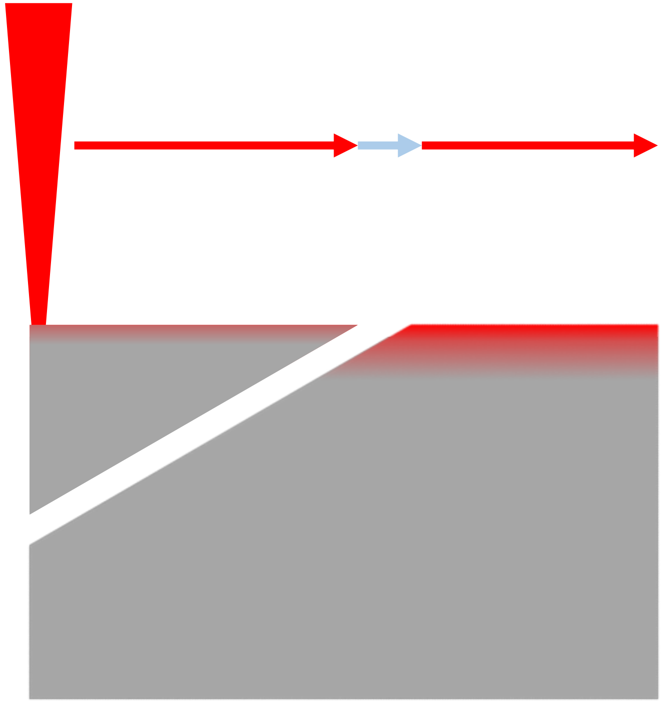
Ra = 21.99± 1.22 µm Ra = 24.66± 2.03µm

Experimental results: 30° samples



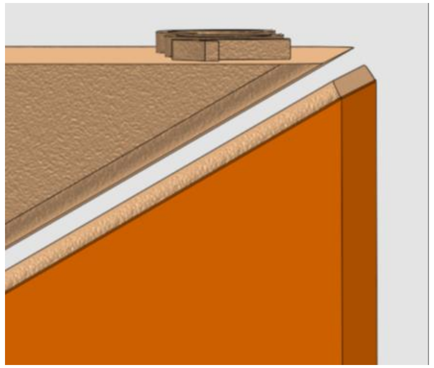
Standard strategy

[The influence of heat accumulation on the surface roughness in powder-bed additive manufacturing, Mahdi Jamshidinia and Radovan Kovacevic, 2015]

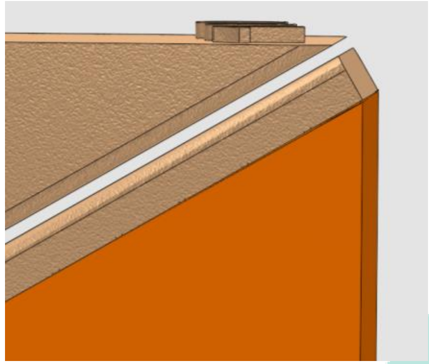


Buffer time between part and support

Support blade thickness



Thin



Thick

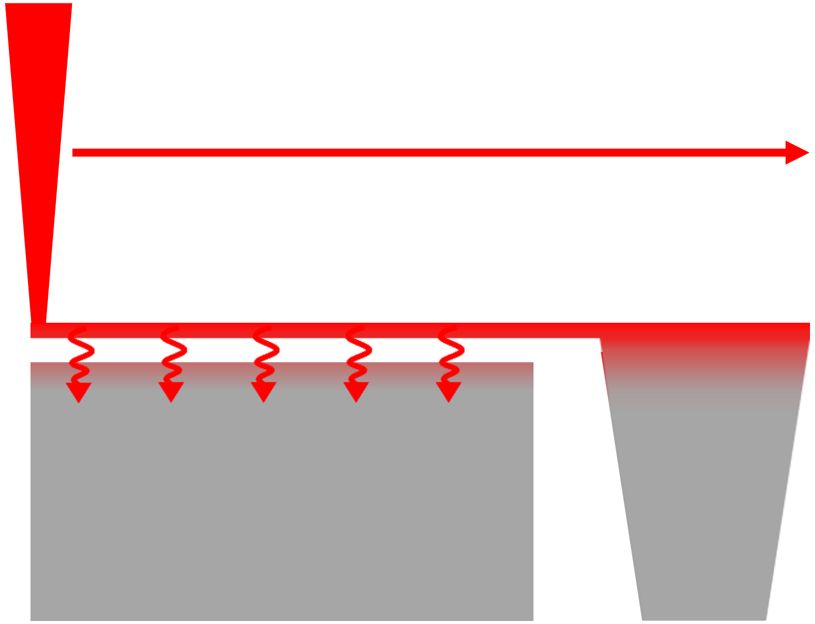
Understanding the gap behavior

unsuported

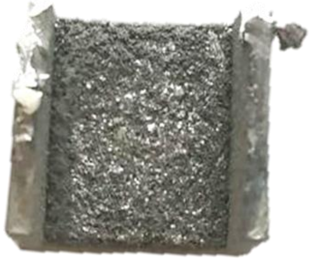
suported

30 µm

Ra = 16.98 ± 1.54 µm



Ra = 19.83 ± 1.45 µm

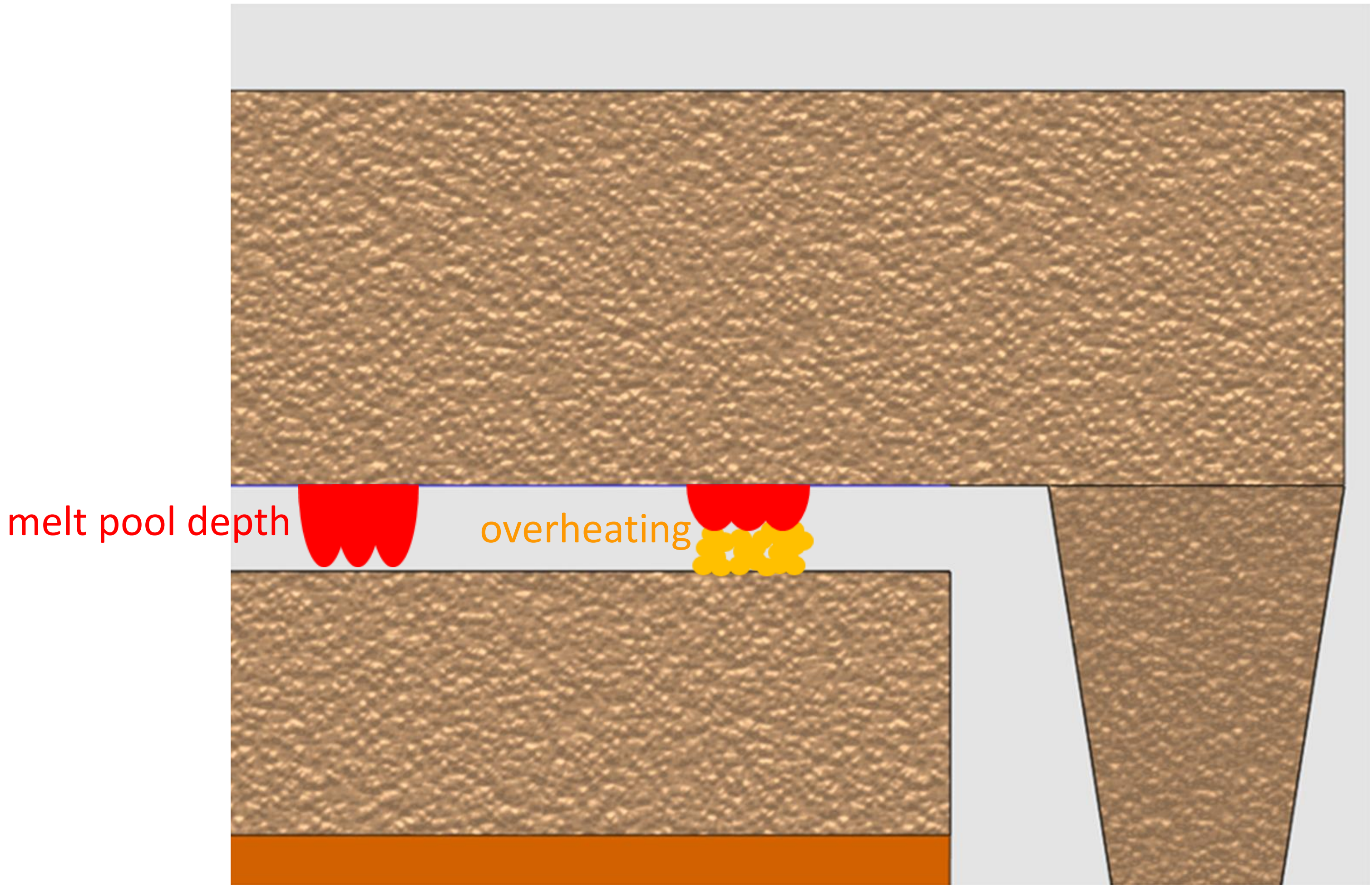


60 µm

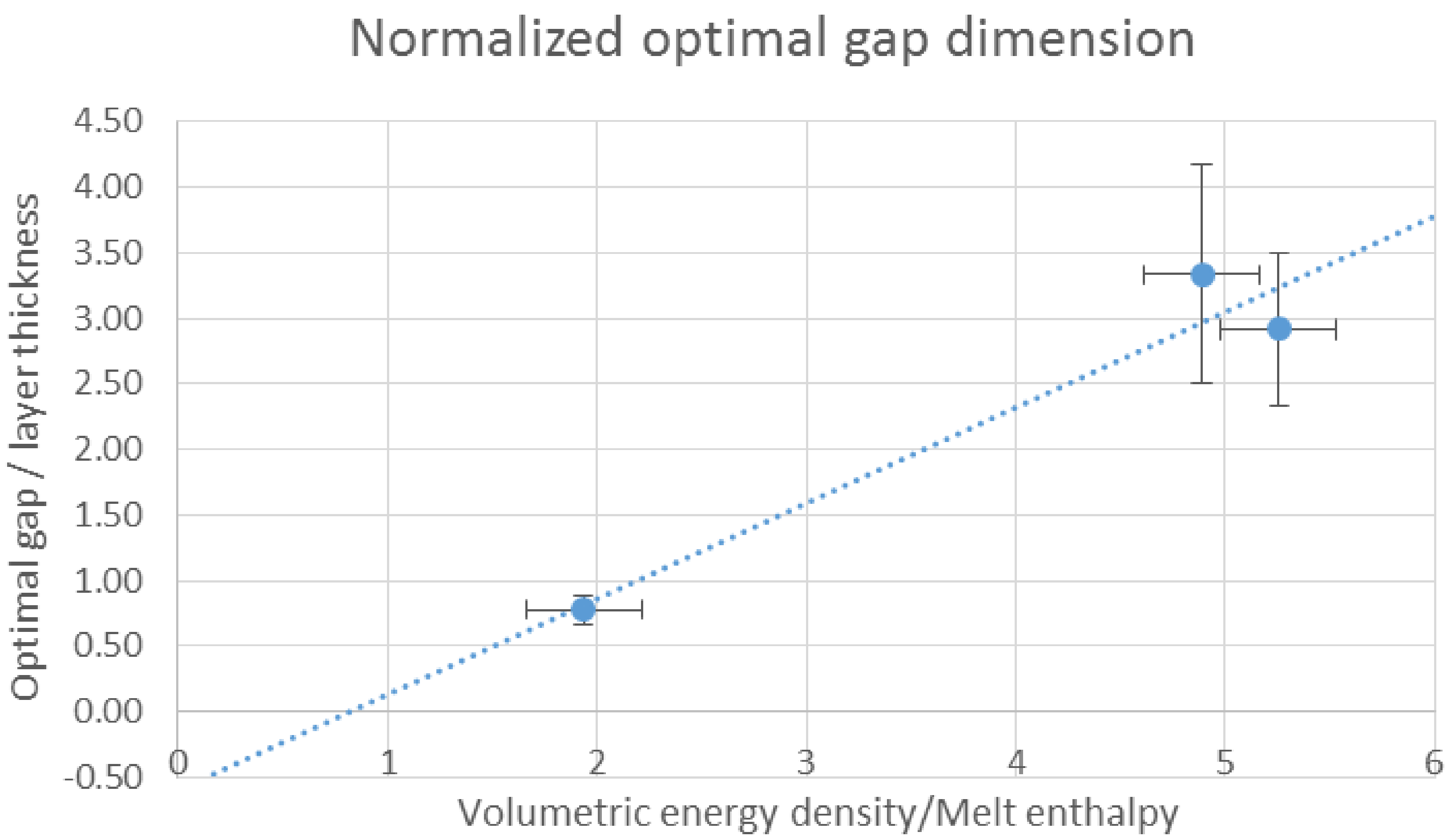
Ra = 25.02 ± 2.12 µm

90 µm

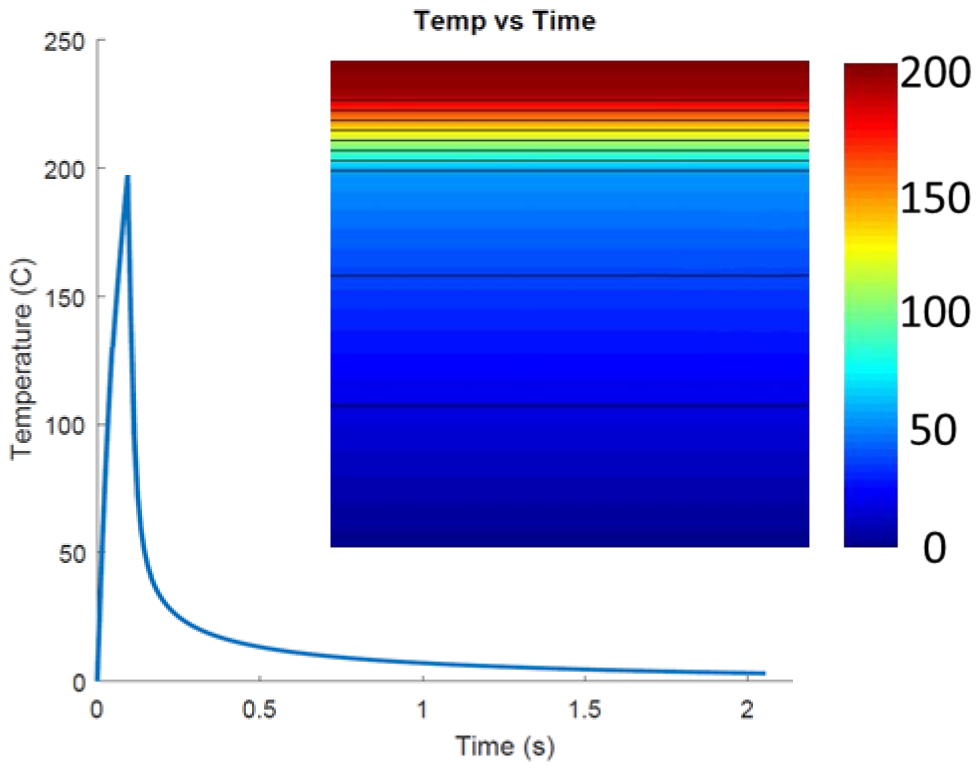
Root cause analysis

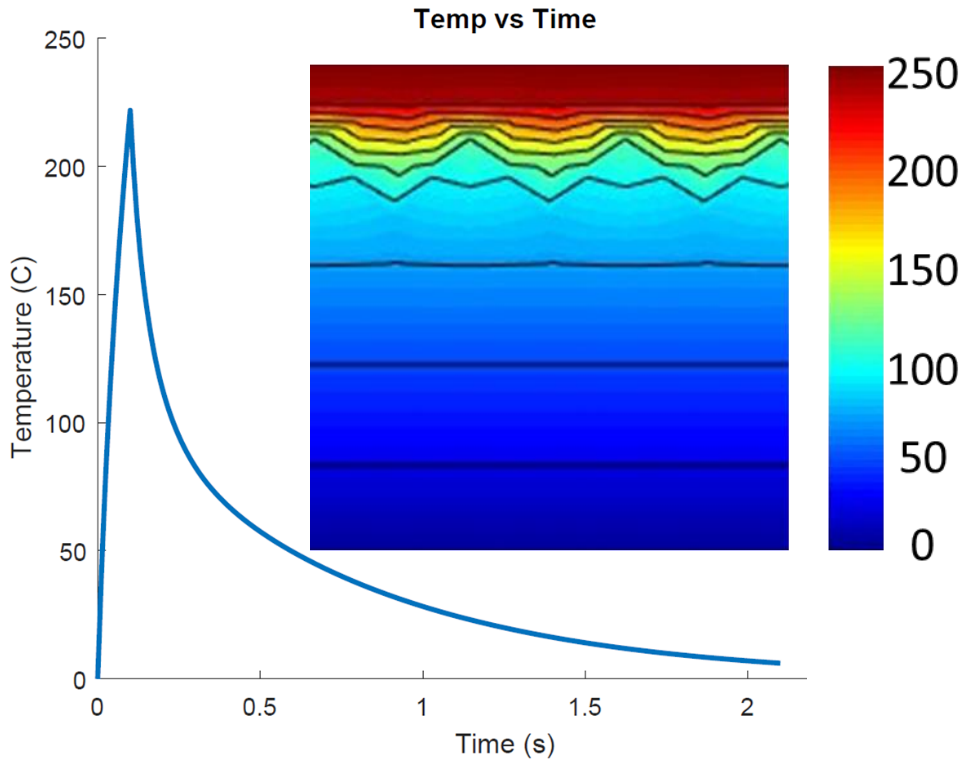


Root cause analysis

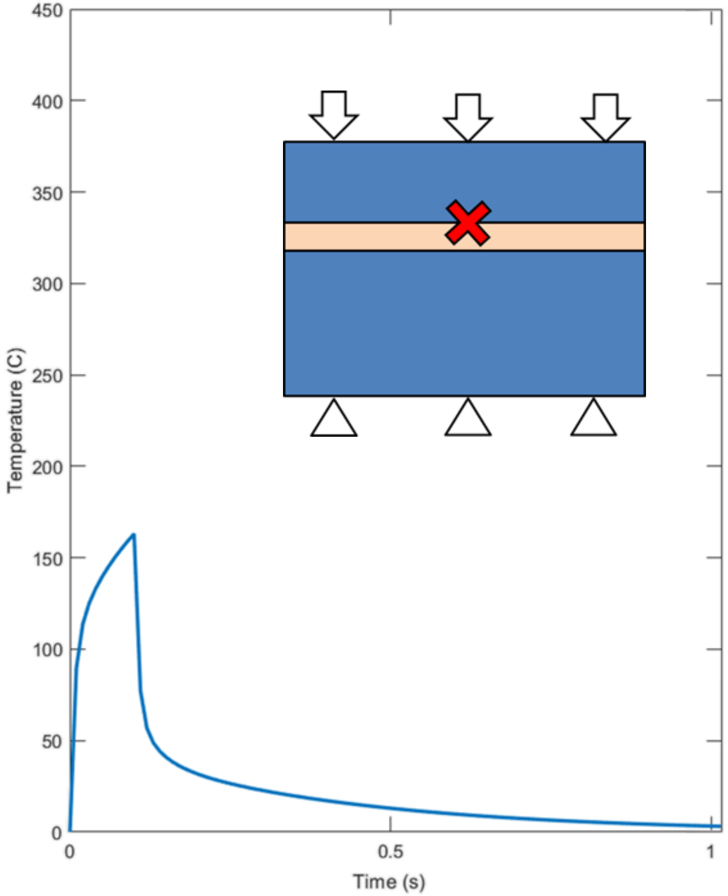


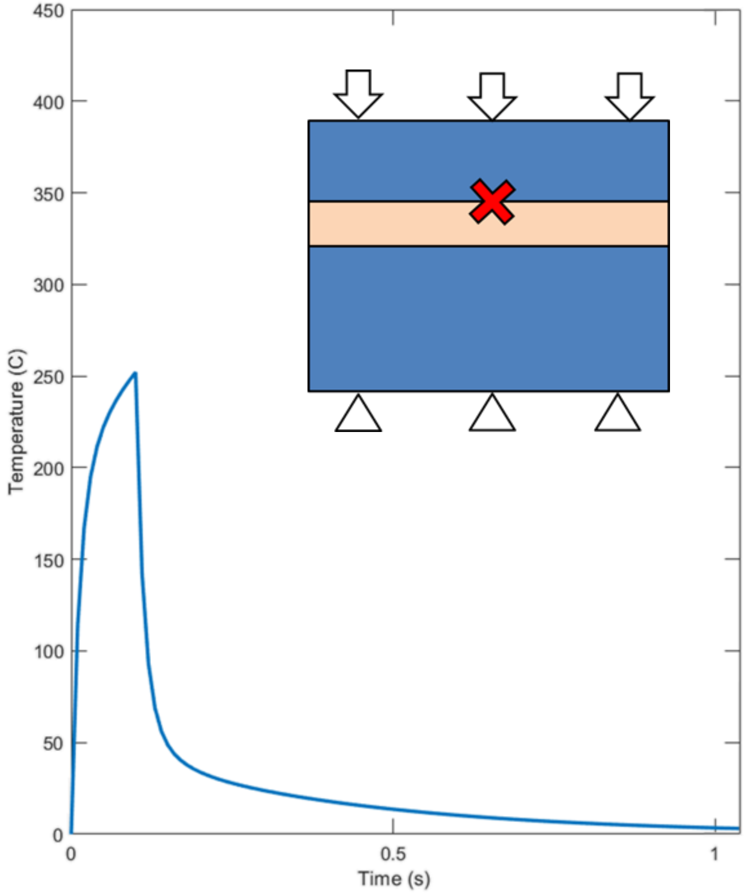
Thermal simulation

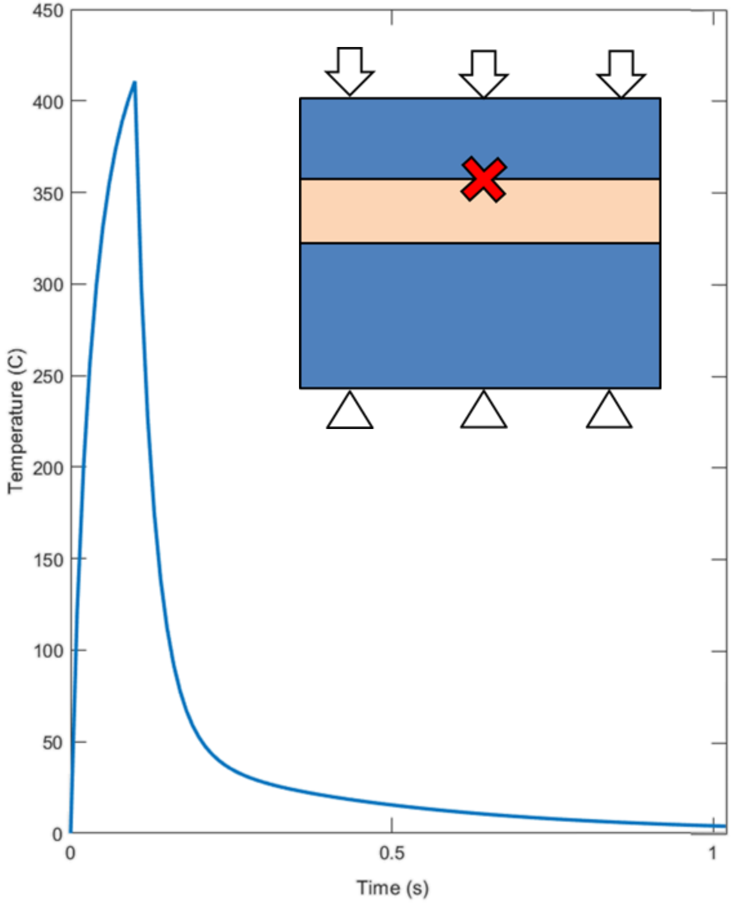




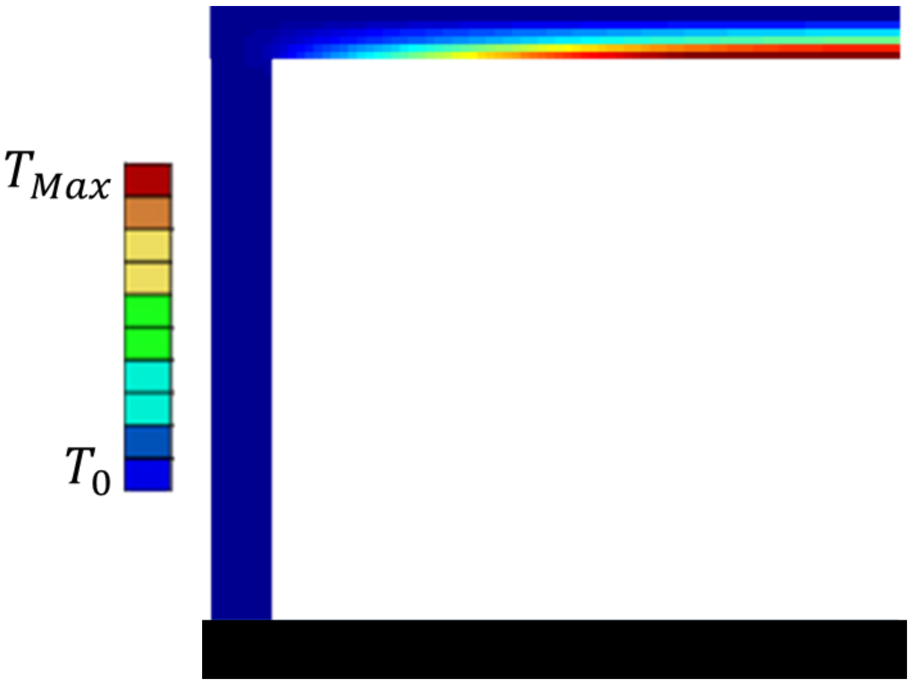
Thermal simulation

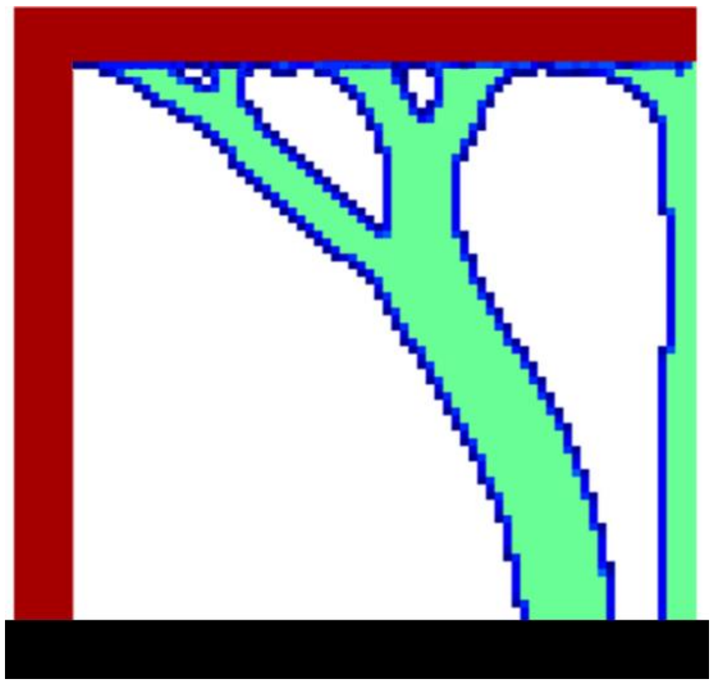






Thermal simulation





1. On sloped downfacing the powder is overheated by the part and the support which are scanned simultaneously in the same layer. Slightly better results are obtained if a buffer time is applied between the printing of the two regions.

2. On flat overhangs the thermal support (printed several layers before the part) efficiently dissipate the incoming heat. A sensible increase in geometrical accuracy is observed.

3. The thermal simulation suggest that the main feature that defines the optimal gap distance in the flat overhangs is the melt pool depth and not the overheating of the powder in the gap.