A roughness study by modeling L-PBF surfaces

Olivier Poncelet, Camille van der Rest, Matthieu Marteleur and Aude Simar

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UCLouvain
Institute of Mechanics, Materials and Civil Engineering (iMMC)

Wallonia Clusters

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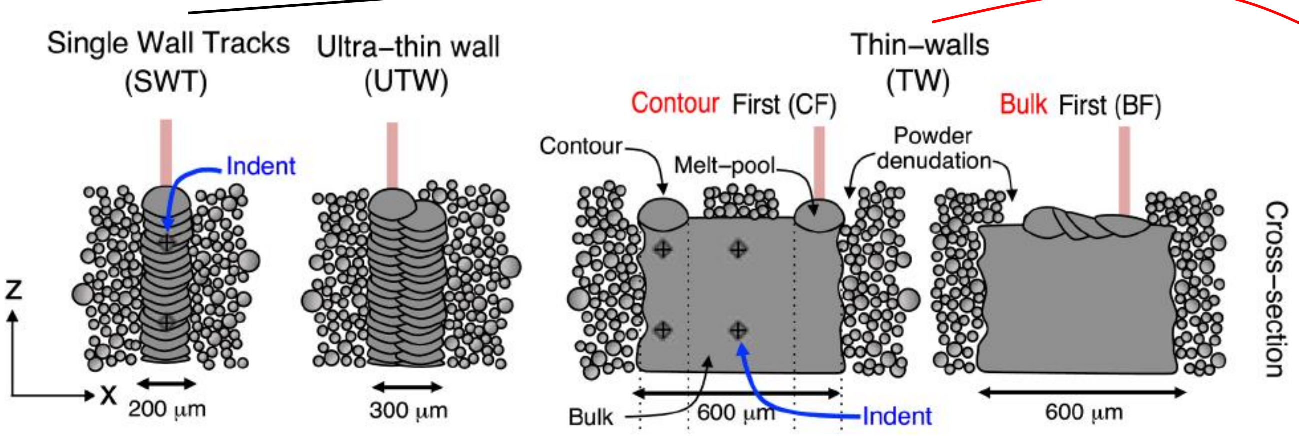
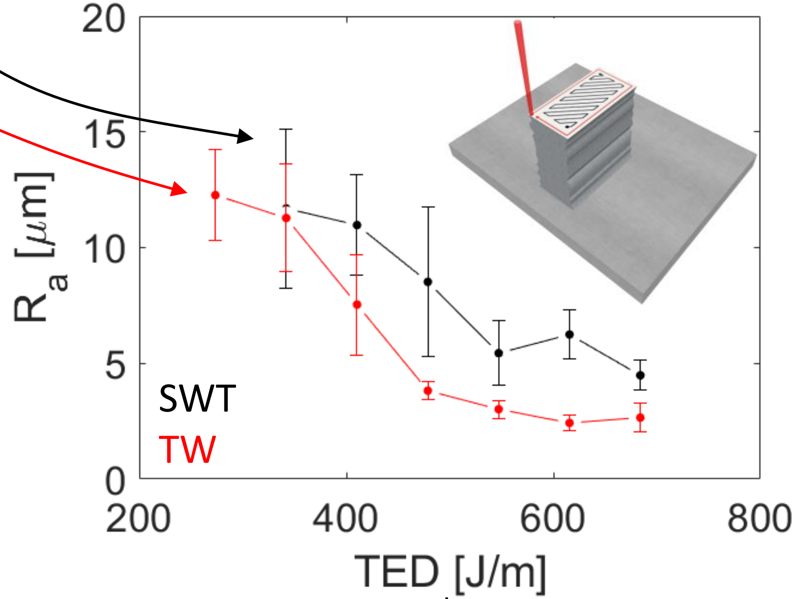
Critical assessment of the impact of process parameters on vertical roughness and hardness of thin walls of **AlSi10Mg** processed by laser powder bed fusion. *[Poncelet et al., Additive manufacturing, 2021]*

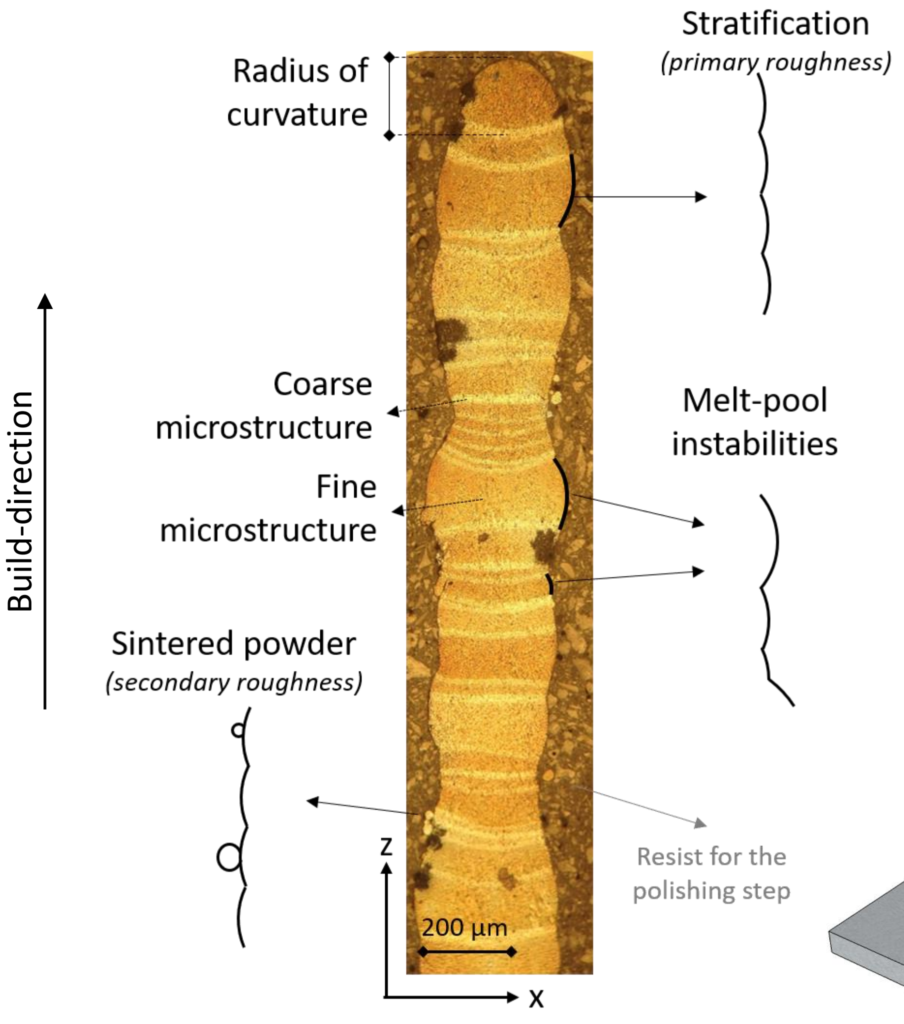




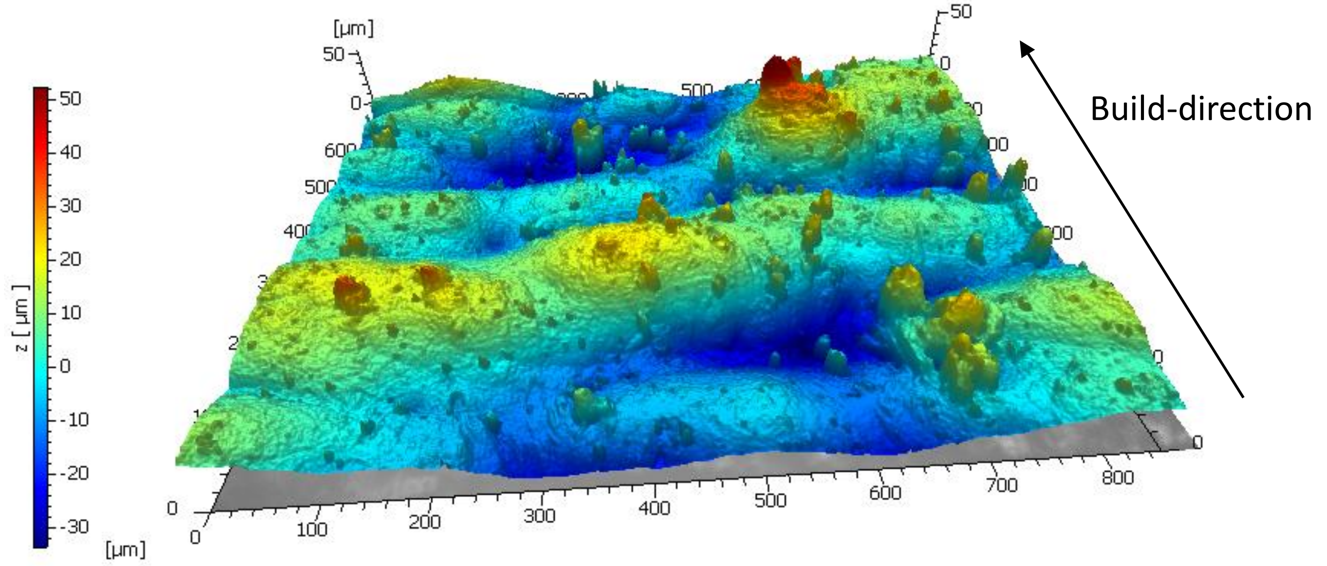
*TED = Track Energy Density [J/m] = **Power** [W] / **Scan speed** [m/s]*

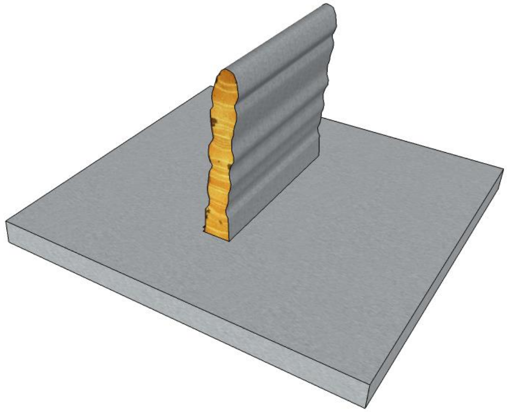
Increasing energy for contouring reduces roughness

Contribution of defects to roughness



SWT in AlSi10Mg



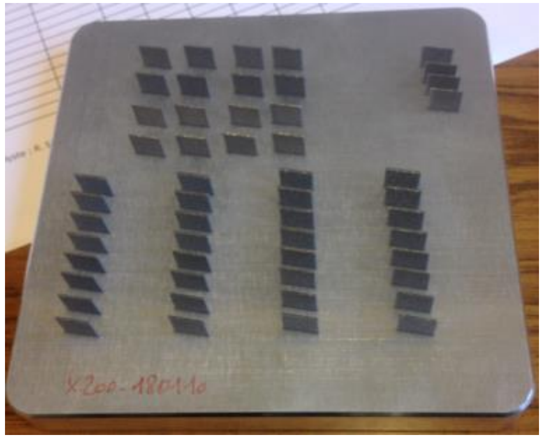


-How do defects impact roughness?

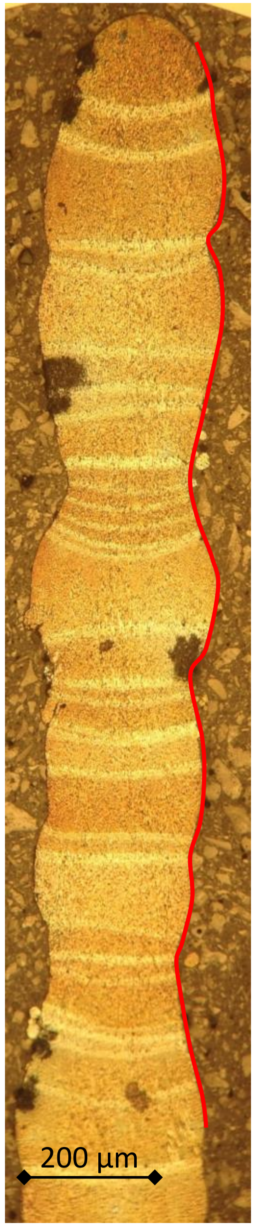
-What is the contribution of each defect to roughness?

-Other roughness indicators: R_p, R_v, R_{sk}, R_{ku},…

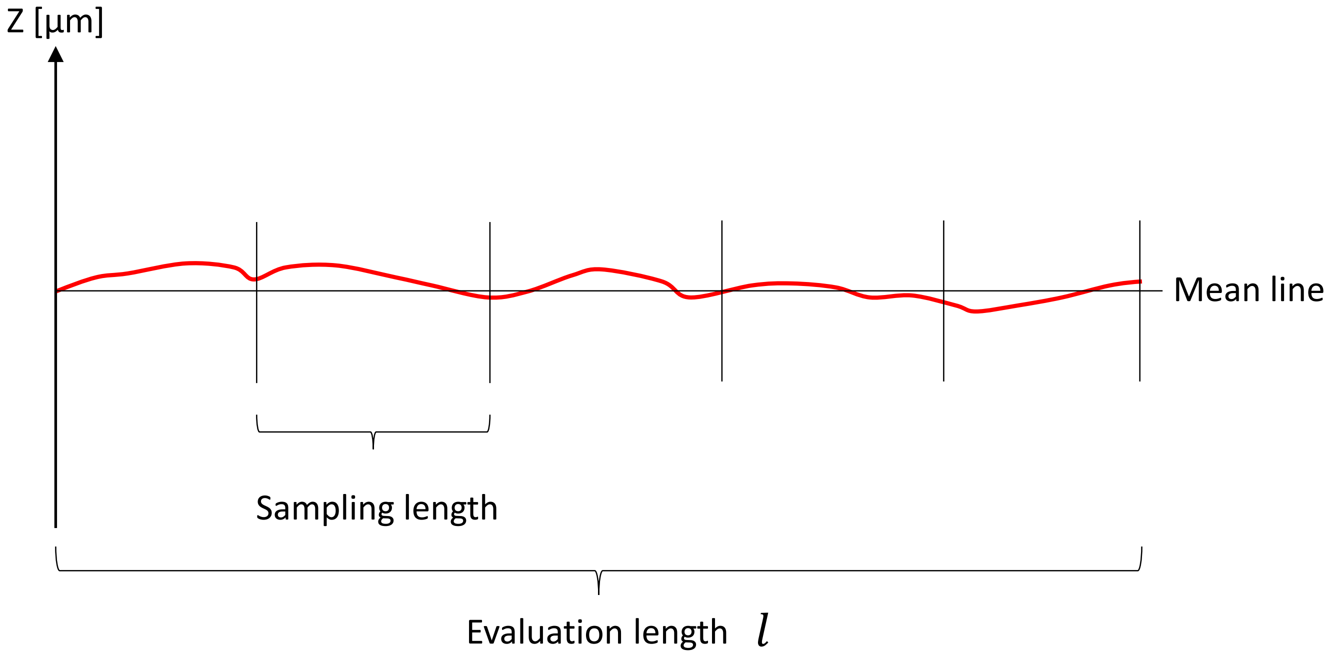
Roughness is a topographical measurement of the contouring melt-pools



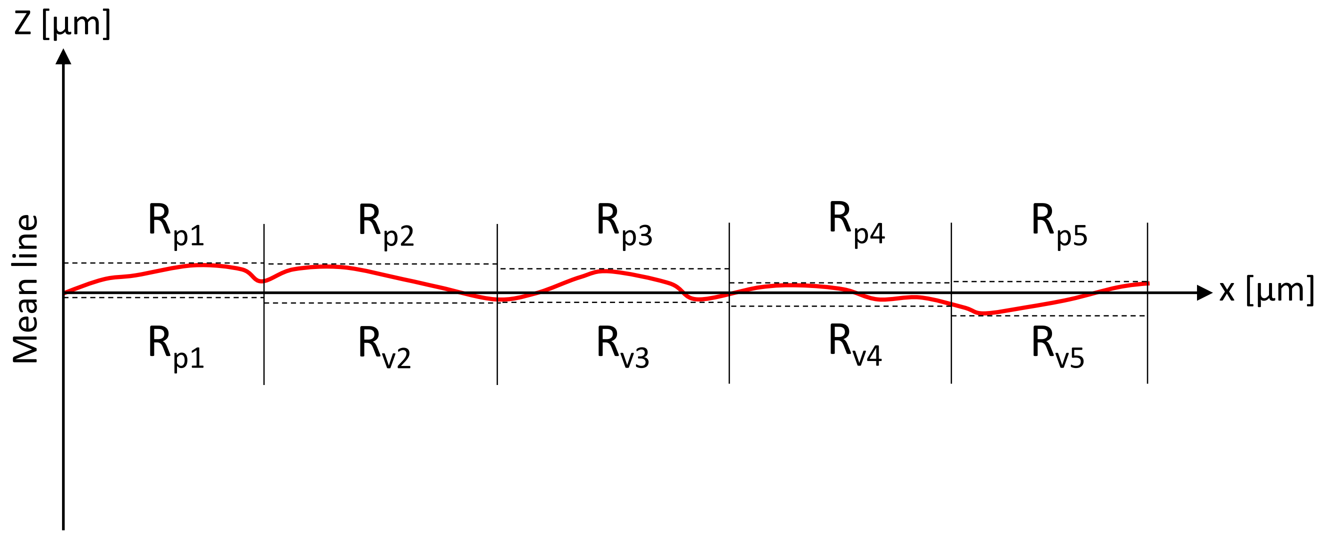
141x141 mm build plate
10x10 mm samples



SWT in AlSi10Mg



There are many interesting surface height parameters



R_p: the maximum profile peak height: $R_p = \frac{1}{5}\sum_{i=1}^{5} R_{pi}$

R_v: the maximum profile valley depth: $R_v = \frac{1}{5}\sum_{i=1}^{5} R_{vi}$

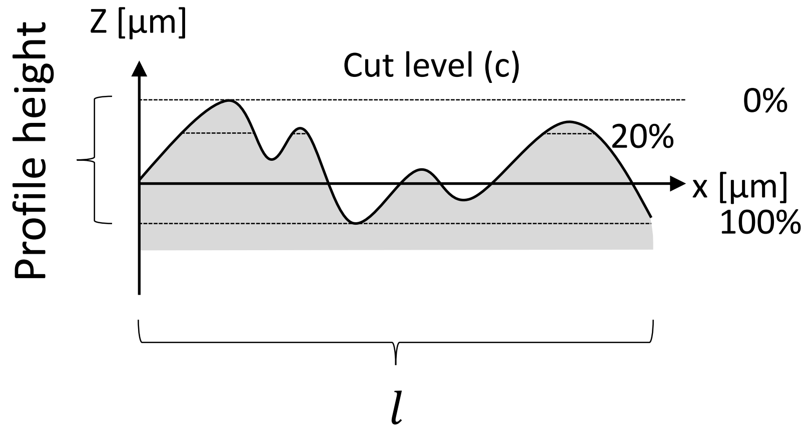
R_a : the roughness average, the arithmetic average of the absolute values of the profiles: $R_a = \frac{1}{l}\int_0^l |Z(x)|dx$

R_q: the root mean square roughness average: $R_q = \left[\frac{1}{l}\int_0^l Z(x)^2 dx\right]^{1/2}$

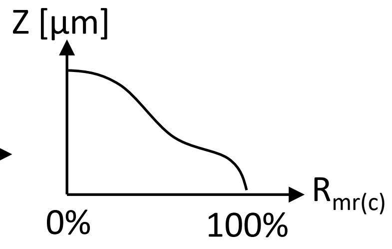
R_{sk}: the profile skewness, a measure of the asymmetry of the profile about the mean line: $R_{sk} = \frac{1}{l}\frac{1}{R_q^3}\int_0^l Z(x)^3 dx$

R_{ku}: the profile kurtosis, a measure of the peakedness of the profile about the mean line: $R_{ku} = \frac{1}{l}\frac{1}{R_q^4}\int_0^l Z(x)^4 dx$

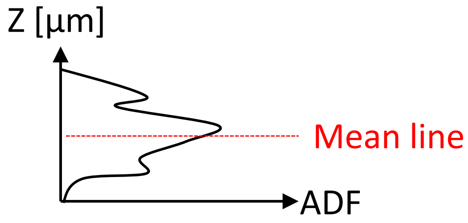
Shape of the profile height distribution



Profile

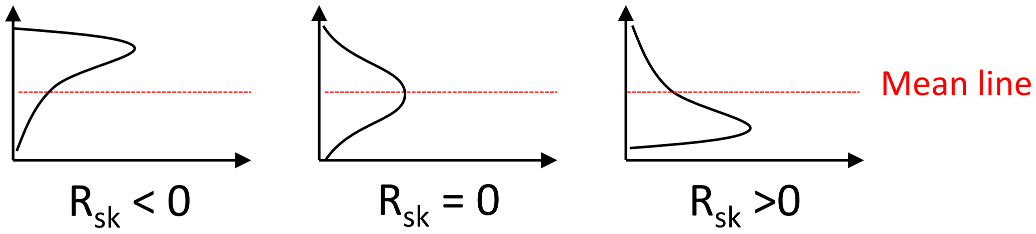


Material ratio curve

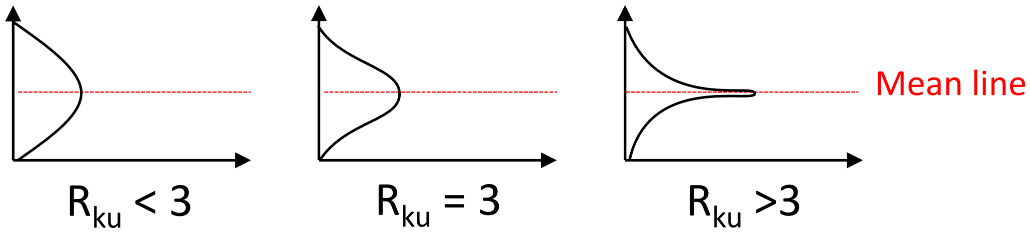


Amplitude density function (ADF)

Skewness of the distribution



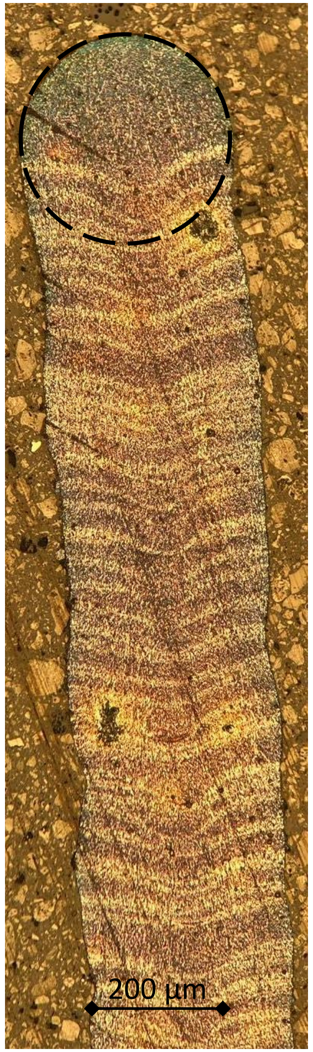
Kurtosis of the distribution



A geometrical model is used to study the impact of defects on R_a, R_p, R_v, R_{sk} and R_{ku}

Real sample

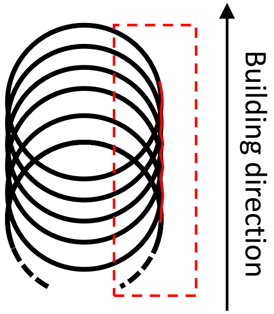
SWT



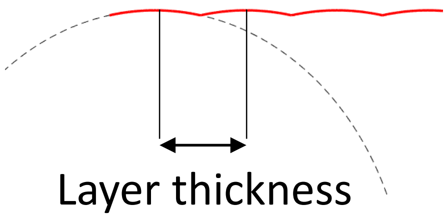
SWT in AlSi10Mg

Model

Perfect case

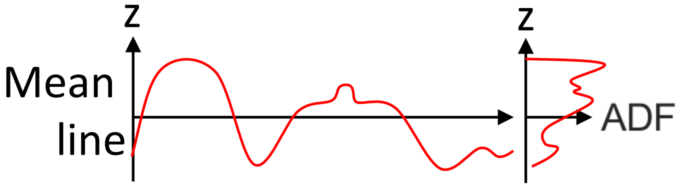


Profiles



Roughness computation

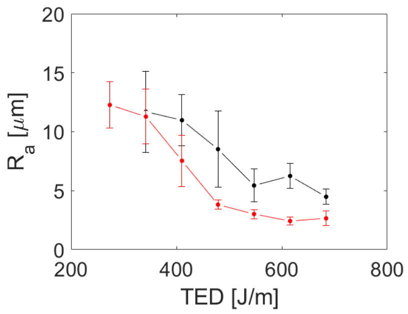
$R_a, R_v, R_p, R_{sk,\ldots}$



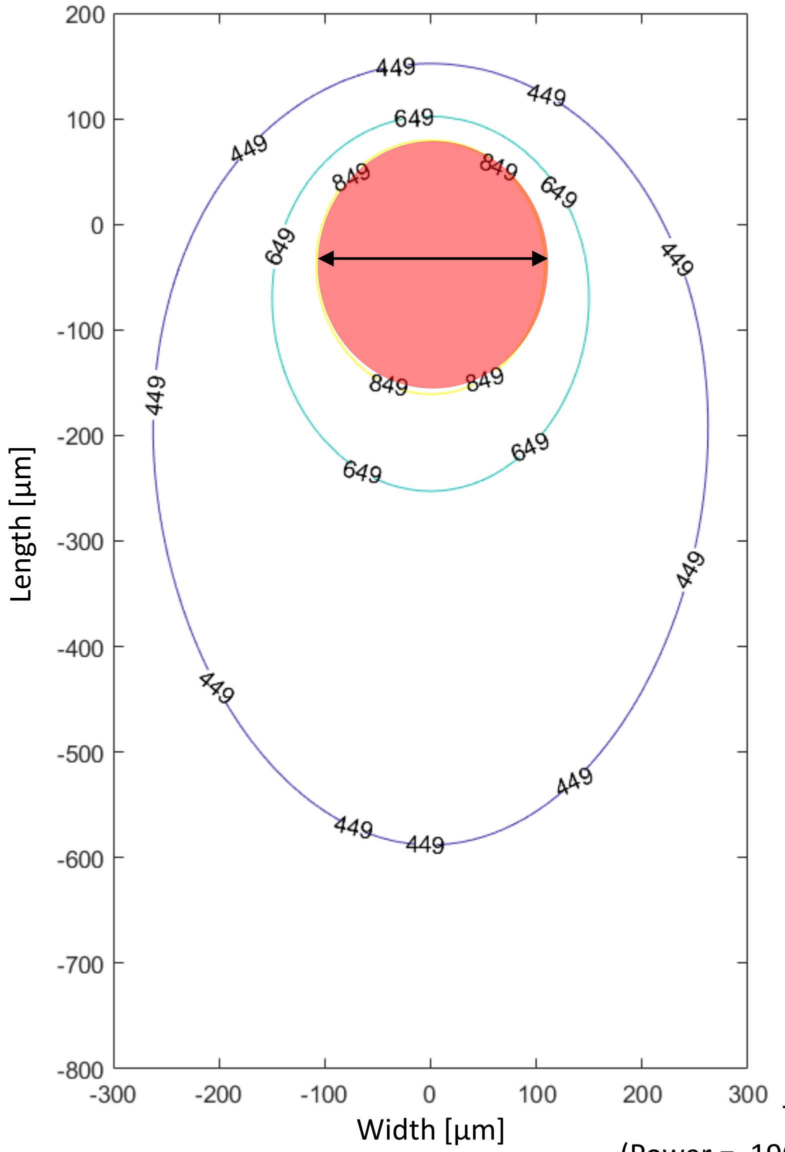
Input parameters: layer thickness and melt-pool size

$\underbrace{\text{melt-pool size}}_{\text{Linked to the TED}}$

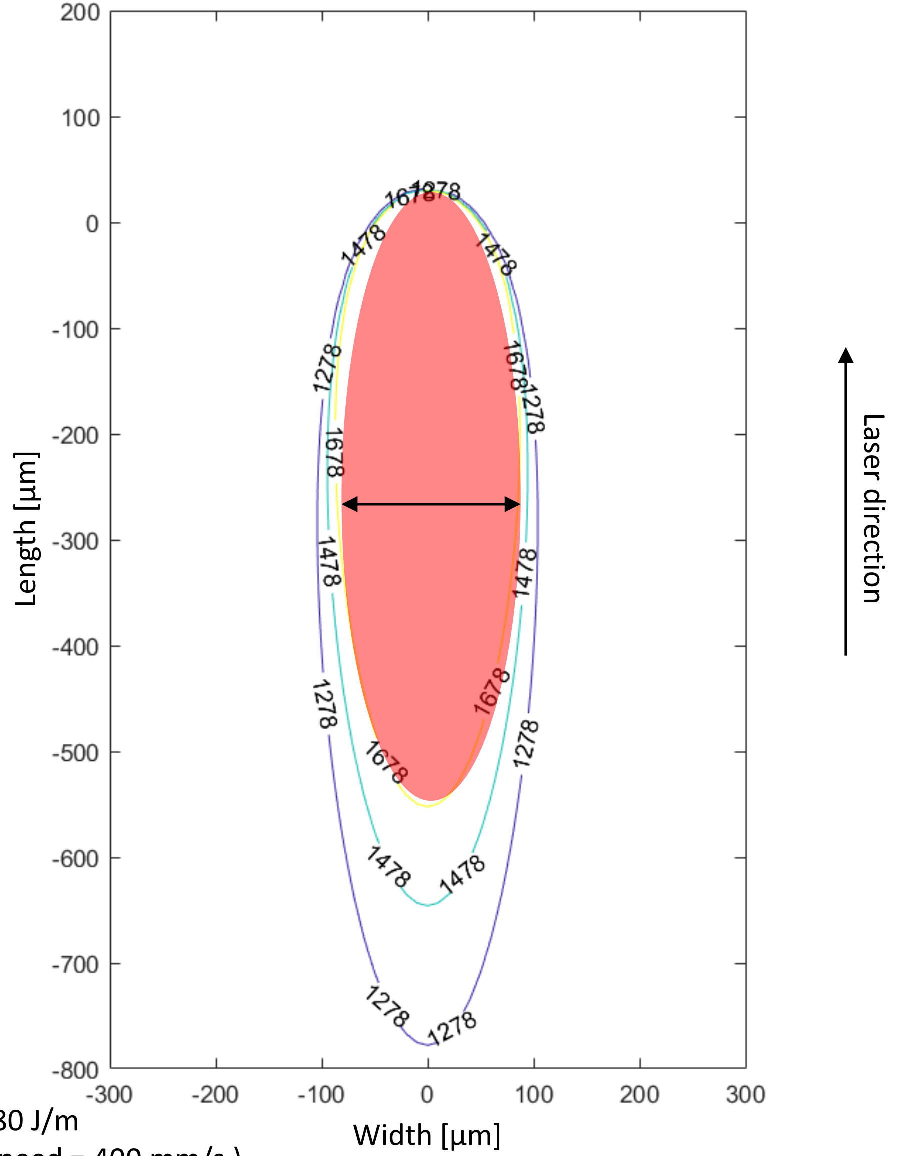
Rosenthal equation is used to obtain melt-pool size as a function of TED



AlSi10Mg



Stainless Steel 316L



TED = 480 J/m
(Power = 190 J/s – Speed = 400 mm/s)

A geometrical model is used to study the impact of defects on R_a, R_p, R_v, R_{sk} and R_{ku}

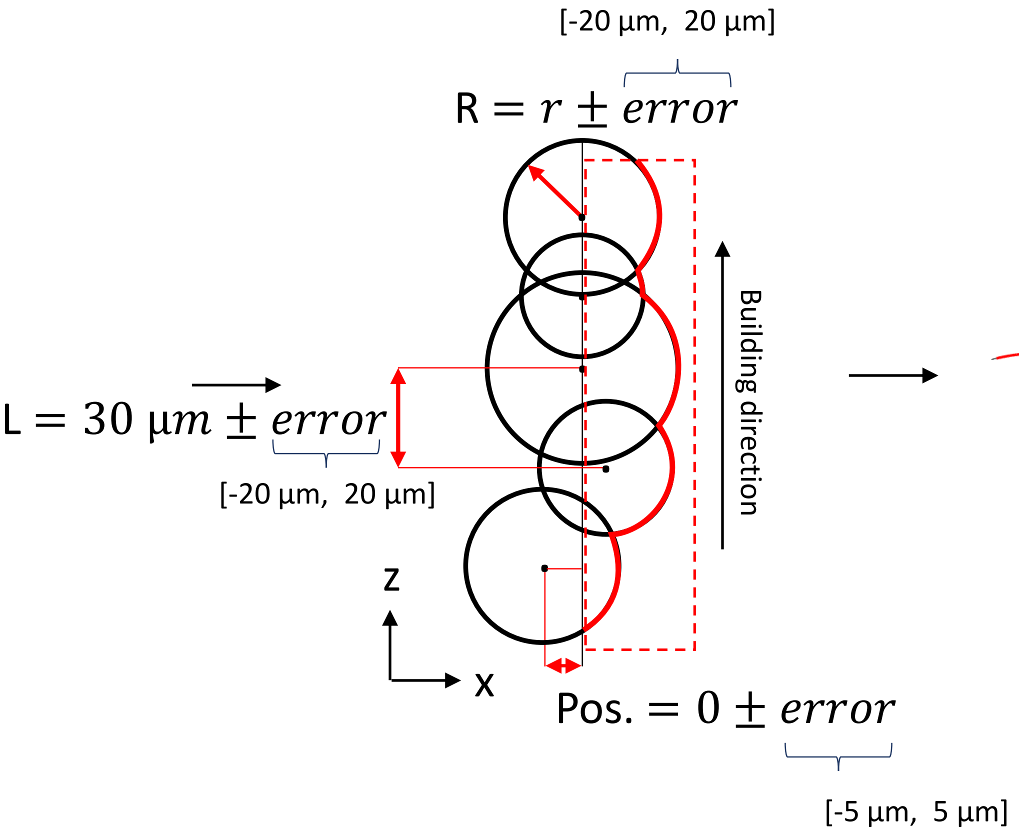
Real sample

SWT

SWT in AlSi10Mg

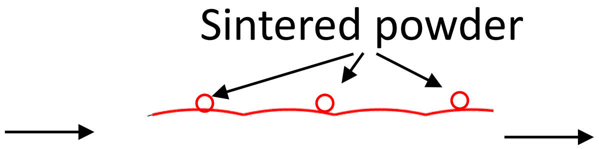
Model

Realistic case

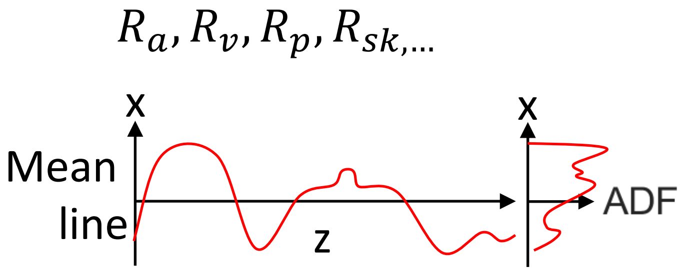


Profile length generated: 12.5 mm (ISO 4288) +- 400 melt-pools stacked

Addition of particles

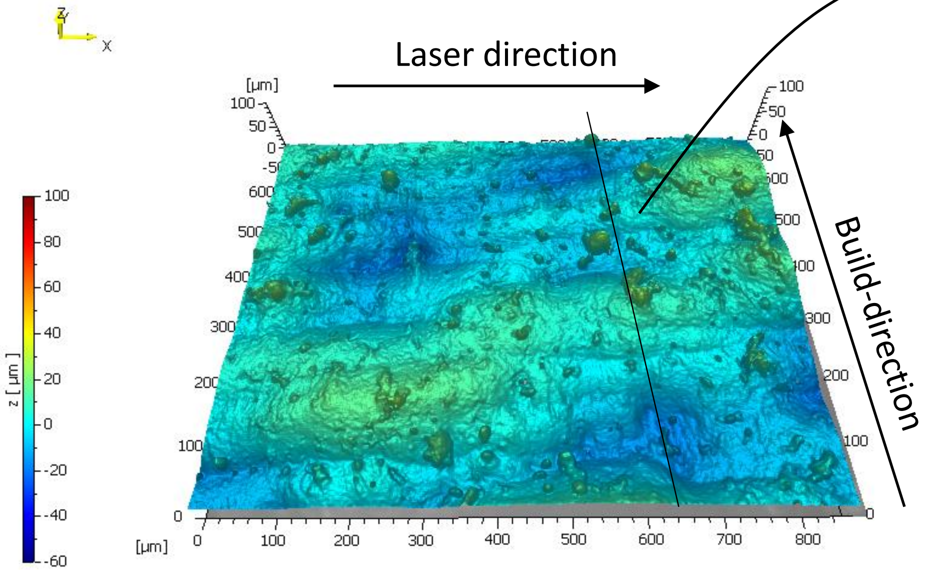


Roughness computation

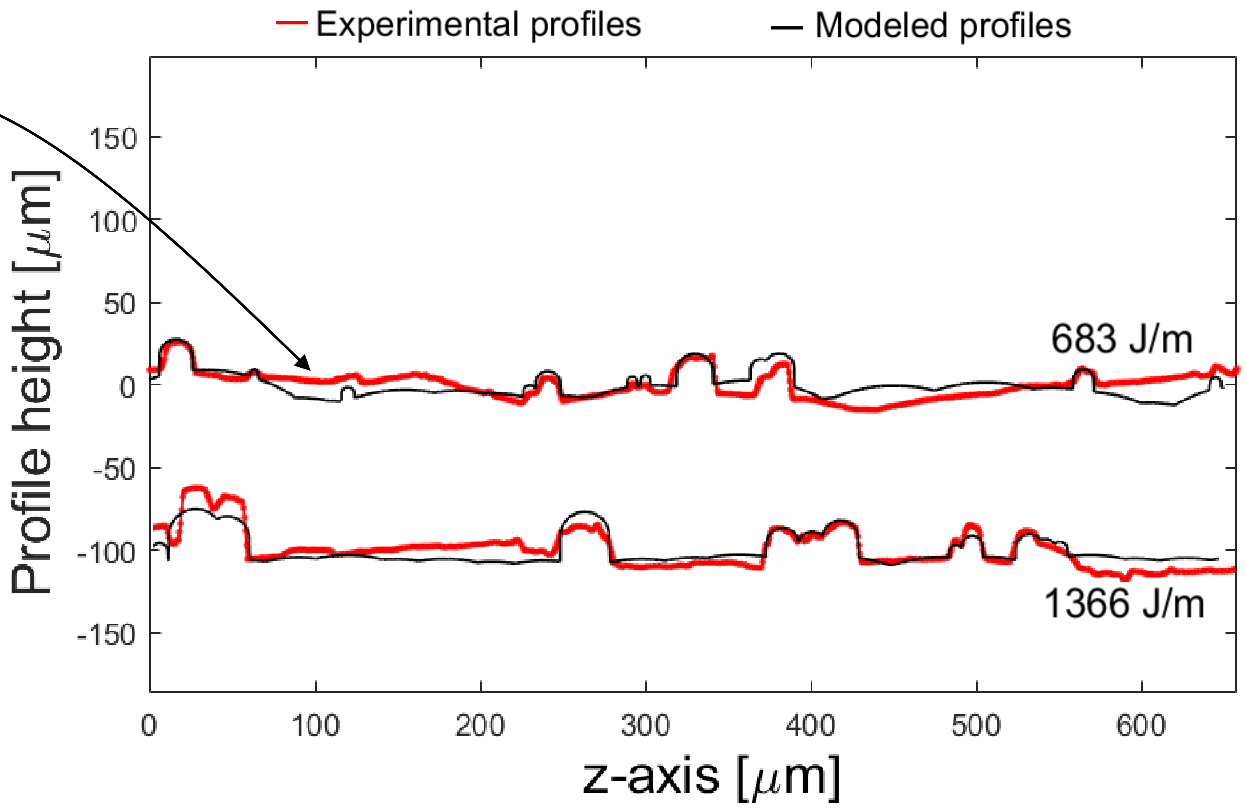


The model matches well experimental profiles

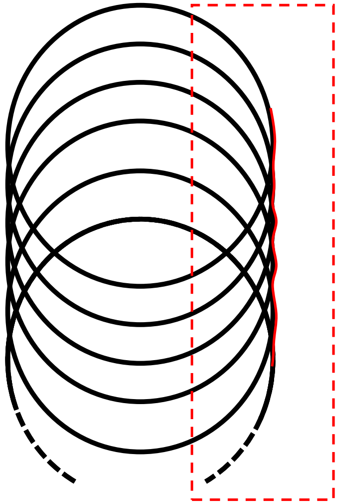
Compared with real profiles perpendicular to the melt-pool tracks, to capture the stratification

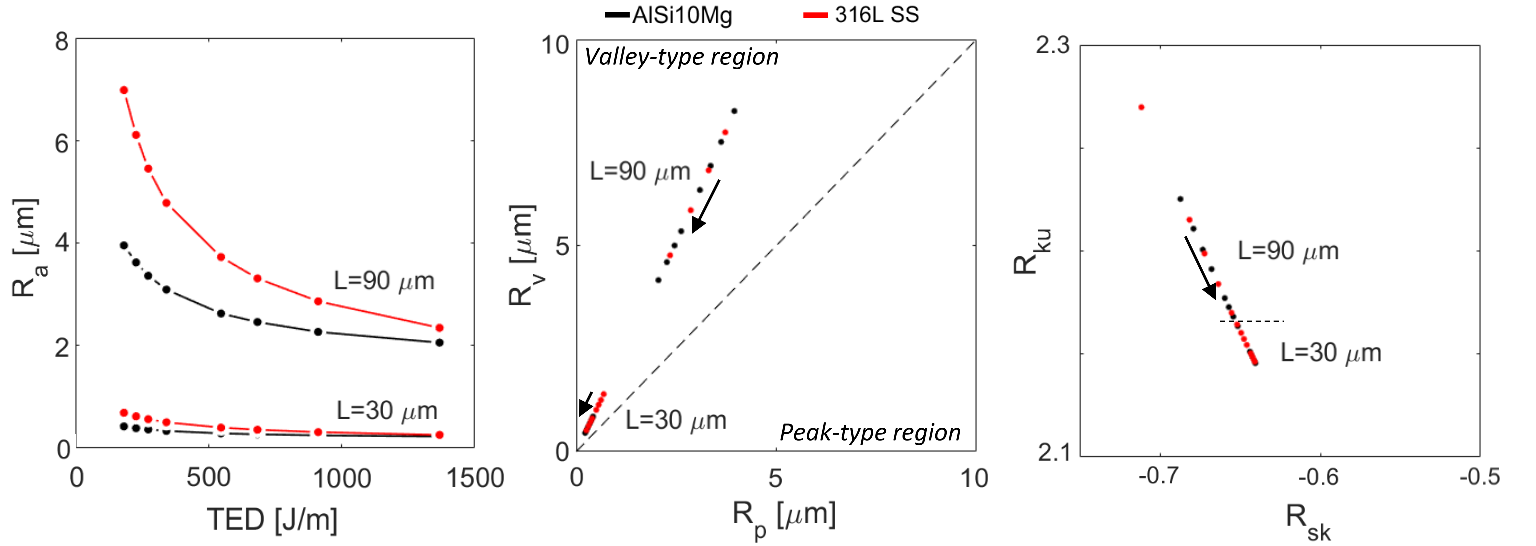


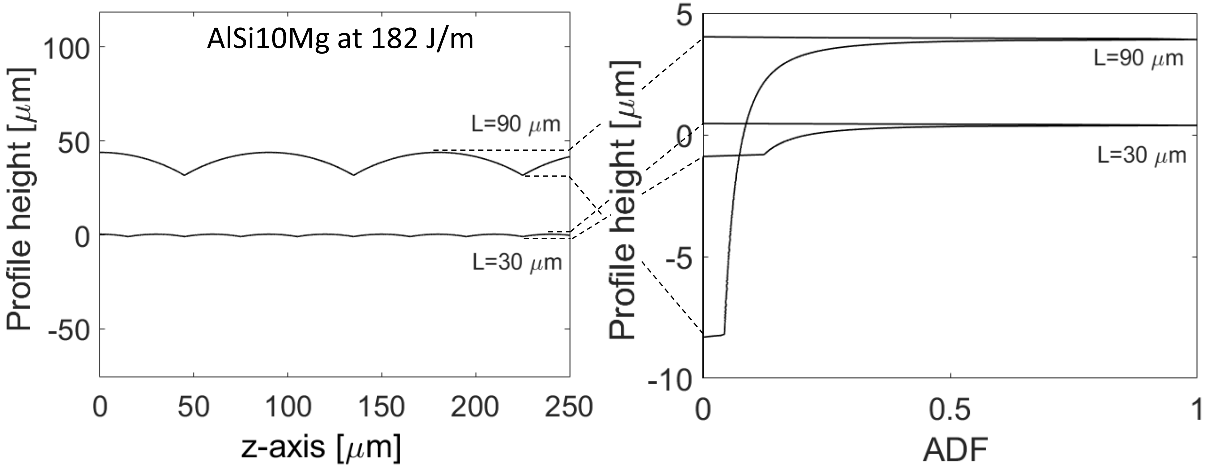
SWT in AlSi10Mg at 683 J/m



Perfect cases – Stratification increases with the layer thickness





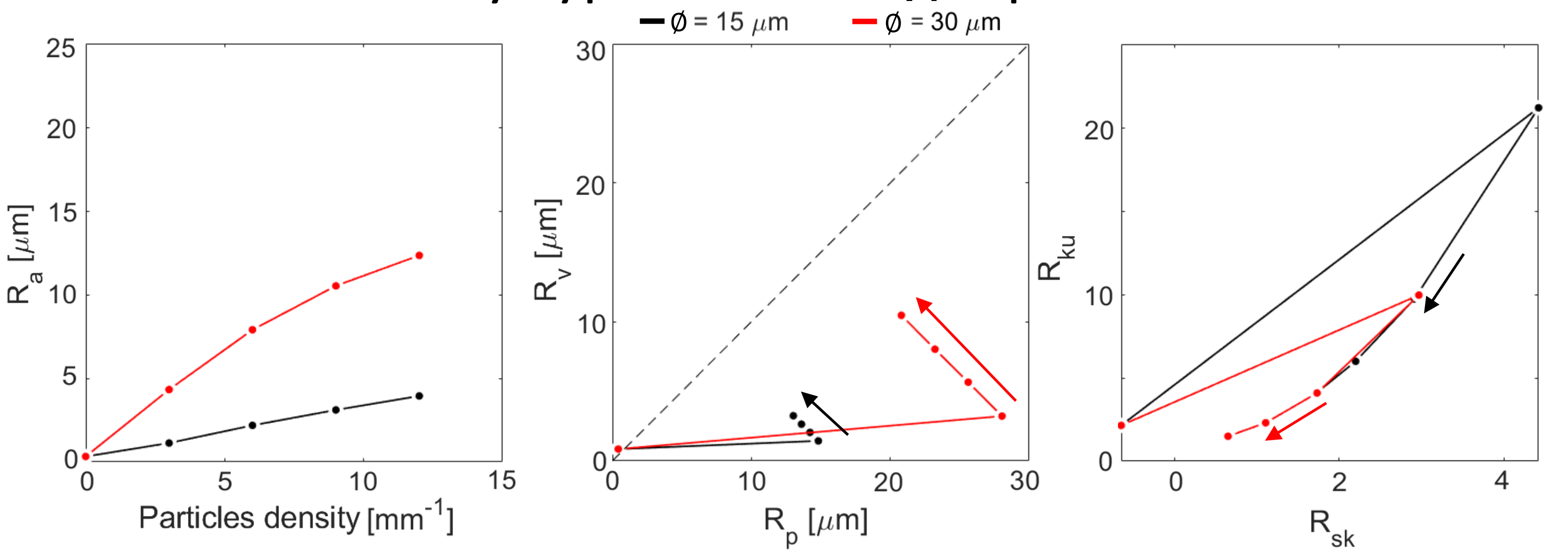


Outcomes Roughness due to stratification is weak but increases with the layer thickness or by decreasing melt-pool (MP) size

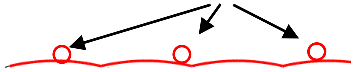
Profiles are Valley-type

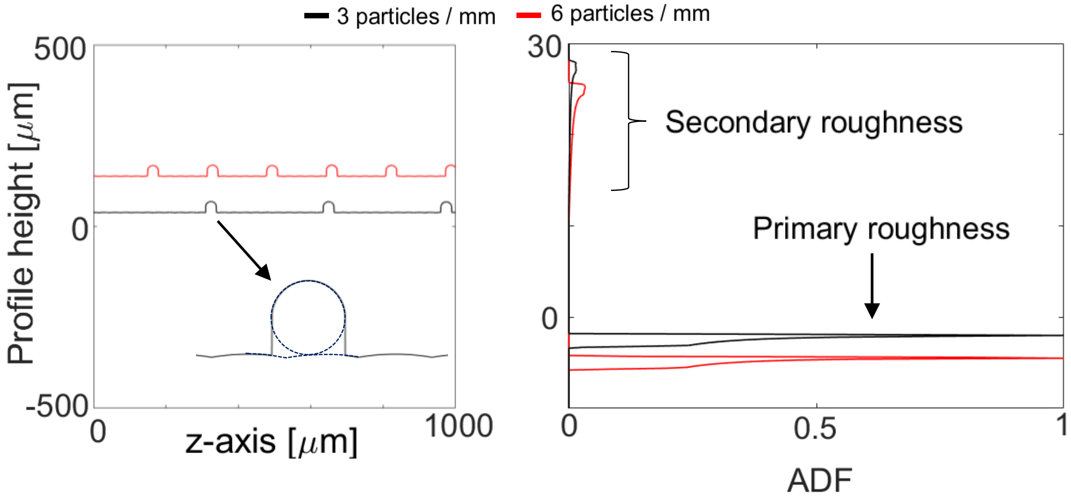
Perfect cases with particles – from valley-type to peak-type profiles

AlSi10Mg at 182 J/m (90 µm witdh MP)
and layer thickness = 30 µm



Sintered powder





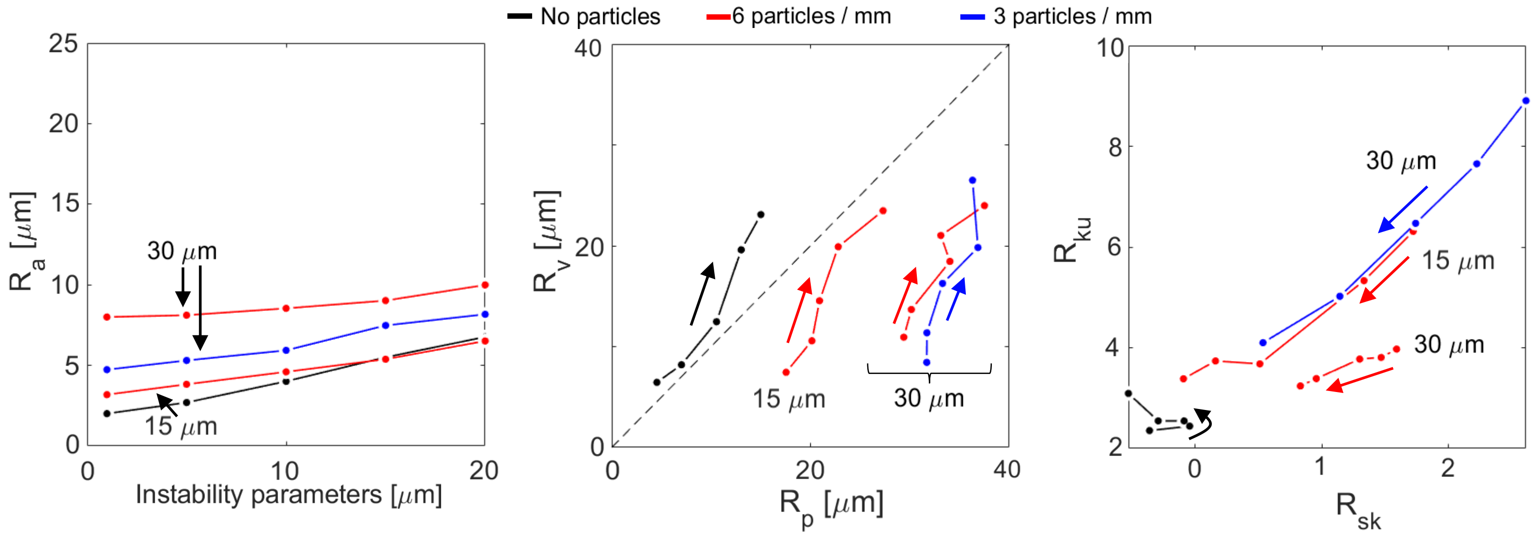
Outcomes Sintered particles increase roughness proportionally to their size and density

Profiles are turned into Peak-type (R_p greatly increases)

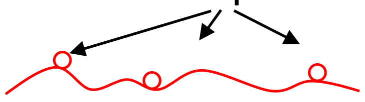
A small amount of particles on a flat surface greatly increases R_{ku} and R_{sk}

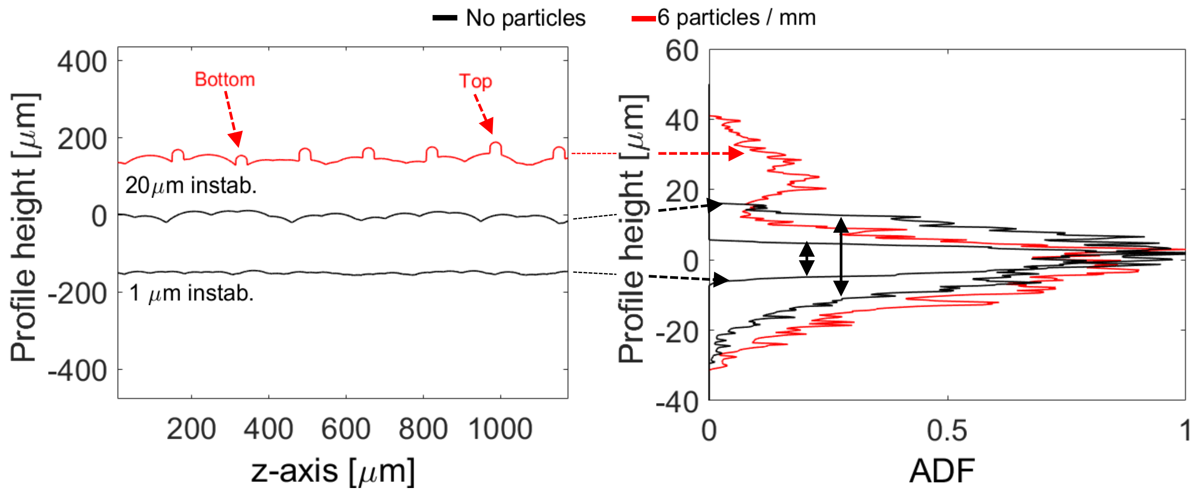
Realistic cases

AlSi10Mg at 182 J/m (180 µm-witdh MP)
and layer thickness = 30 µm



Sintered powder

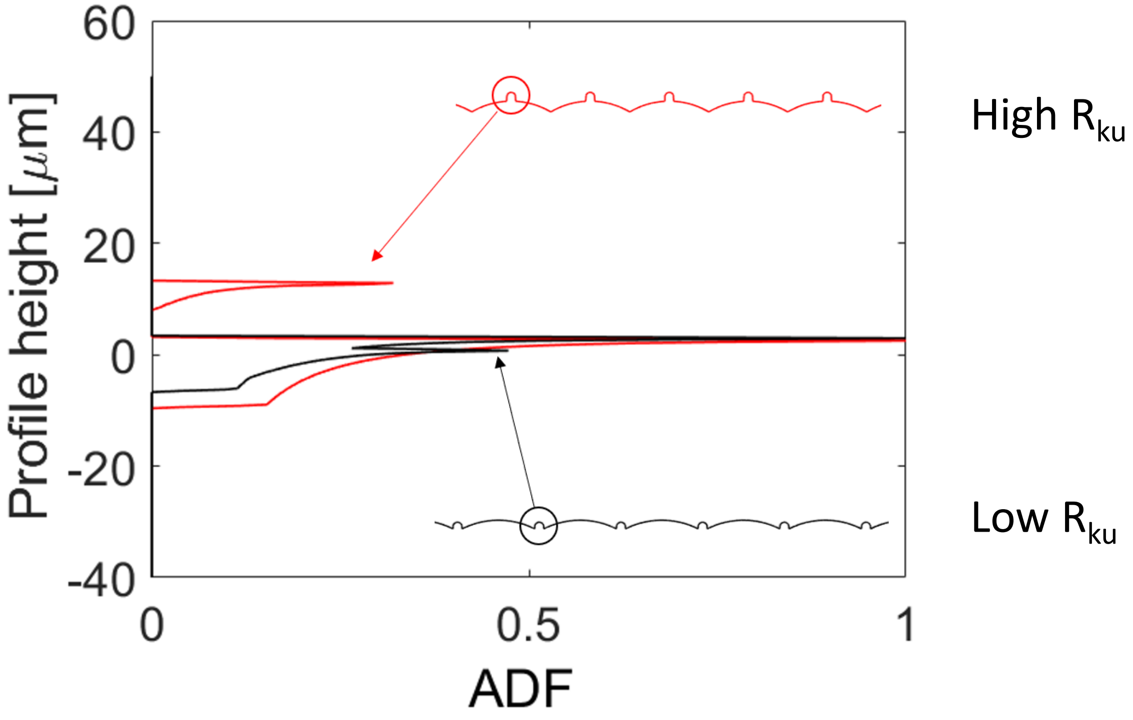




Outcomes Melt-pool instability increases roughness and the valley-ness of the profiles.

Particles direclty change profiles to peak-type and also increase the roughness

The way particles are sintered also has an impact



Outcome Effect of particles depends on their localisation

The model help to provide a better understanding of the R_a optimisation curves

Experimental data on SWT of three materials