Competence Centers for Excellent Technologies

ZCO-57

„Improving Galvanizing Bath Hardware“

European GAP Program Review Meeting,
28th May, 2019, Brest

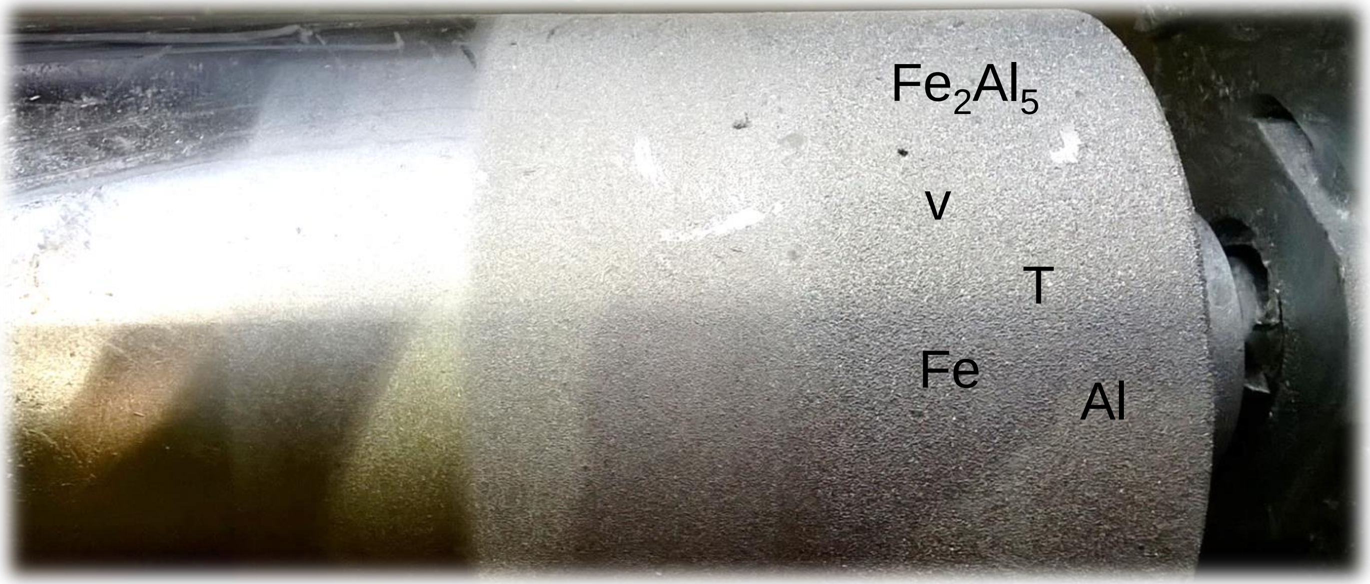
A. Kharicha[1], G. Reiss[2], M.Stefan-Kharicha[1], W. Eßl[2], A. Ludwig[1]

[1]Department Metallurgy, Montanuniversität Leoben, 8700 Leoben, Austria

[2]Materials Center Leoben Forschung GmbH, 8700 Leoben, Austria

Table of Contents

Project Overview

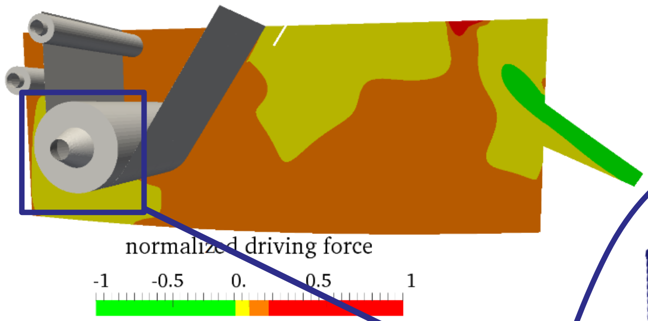


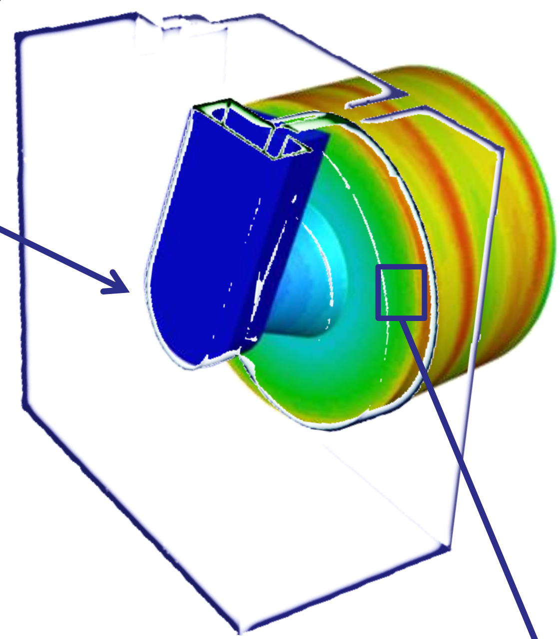
Problem: Build-ups on the roll → Inflexible production and downtimes

Aim: Predict temperatures, concentrations of Al, Fe, Fe_2Al_5 and $FeZn_7$ and flow near the hardware's surface to study its influence on the growth.

Project Overview: Method: Macro to Micro

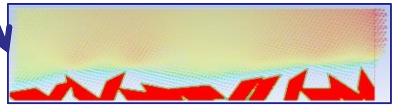
MCL full zinc bath results (metre)





Hydrodynamics near the roll (millimetre)

Project content ZCO-57



Growth model (micrometre)

Project Overview

Arbeitspakete / Work packages		Verantwortlichkeit / Responsibility	2017												2018												2019											
			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
WP1	Model development build-up growth	SMMP																																				
WP2	Hydrodynamics and multiphysics	MCL																																				
WP3	Interaction build-up growth hydrodynamics	MCL & SMMP																																				
WP4	Build-up analysis and reducing strategy	MCL & SMMP																																				

Completed Tasks:

WP1: Model Development of Build-up Growth

- Model development (crystal growth from the surfaces).

WP2: Hydrodynamics and Multiphysics near the Hardware's Surfaces

- Evaluation of Multiphysics conditions near the hardware's surfaces
- Influence of roughness on hydrodynamics
- Dross particle movement through bath and interaction with hardware

WP3: Interaction of Growth with Hydrodynamics

- Growth on the surface influenced by hydrodynamics and roughness

WP4: Build-up analysis and reducing strategy

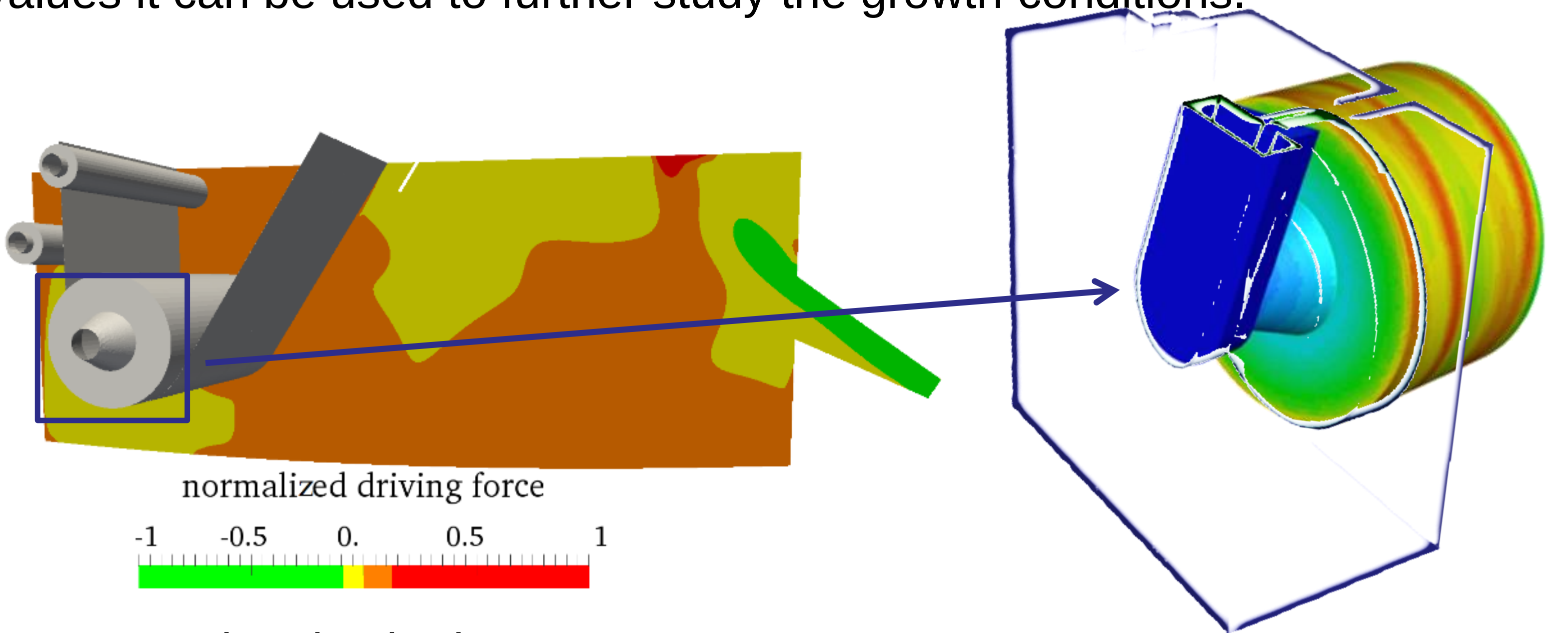
- Assessment of temperature, concentration and dross build-up tendency in sub-modell based on realistic operating conditions

WP 4: Analysis of dross build-up on bath hardware

Two realistic operating conditions in entire zinc bath were chosen to obtain starting boundary conditions for the more detailed hydrodynamic sub-models.

The results in the vicinity of the static (roll arm) and rotating (roll) bath hardware are compared and analysed, based on thermodynamics.

Once, the established growth kinetic model is validated with experimental values it can be used to further study the growth conditions.



entire zinc bath

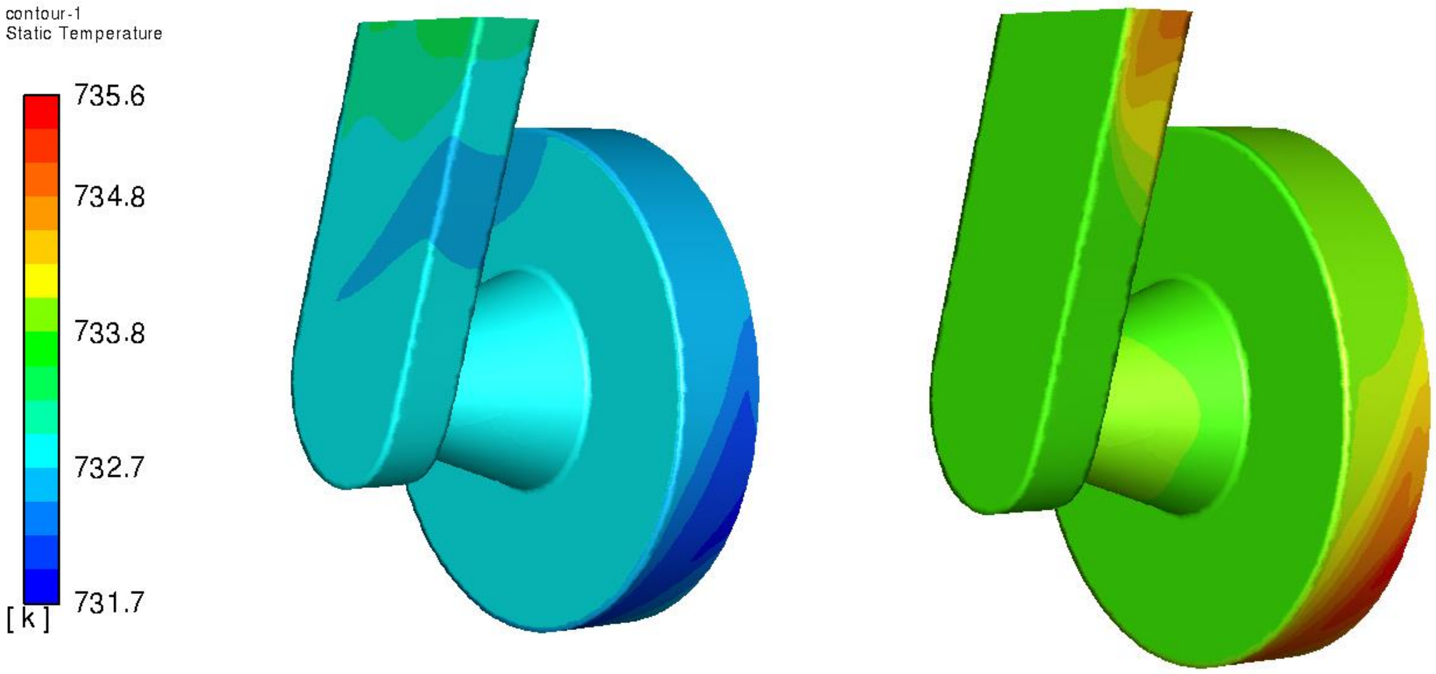
hydrodynamic sub-model

WP 4: Analysis of dross build-up on bath hardware

Comparison between temperature distribution

Case A

Case B

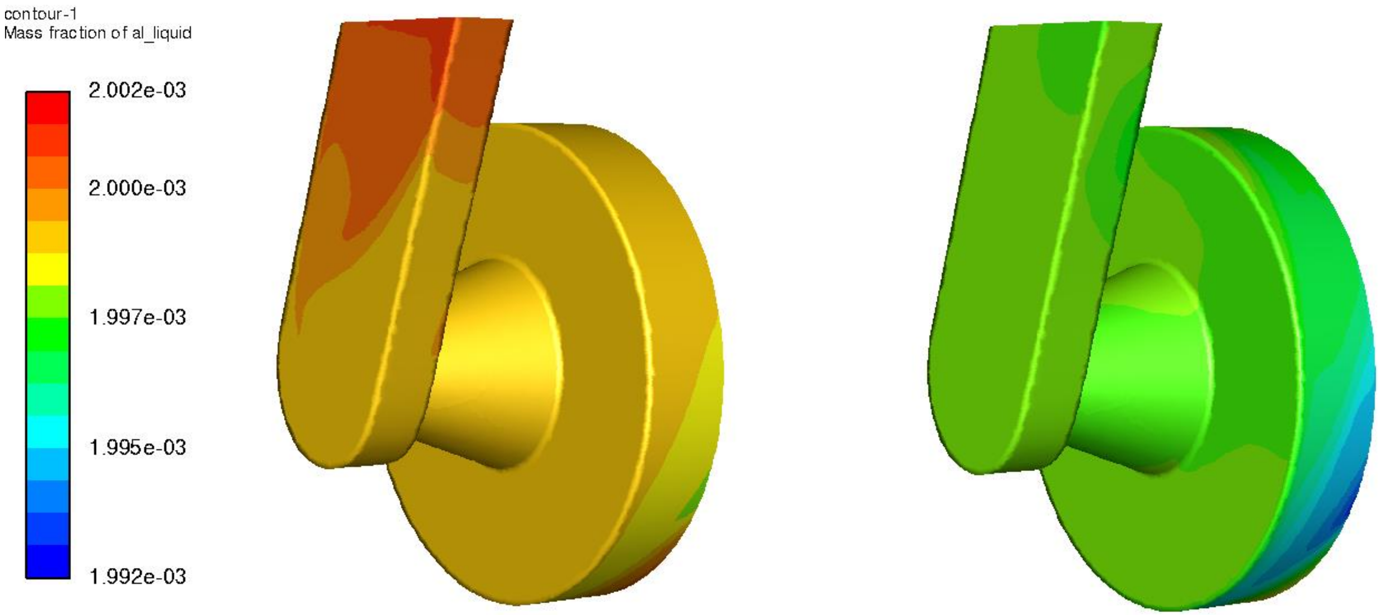


In general the mean zinc temperature around the bath hardware is cooler in case A. Case B shows areas with higher temperature

Comparison between Aluminum distribution

Case A

Case B



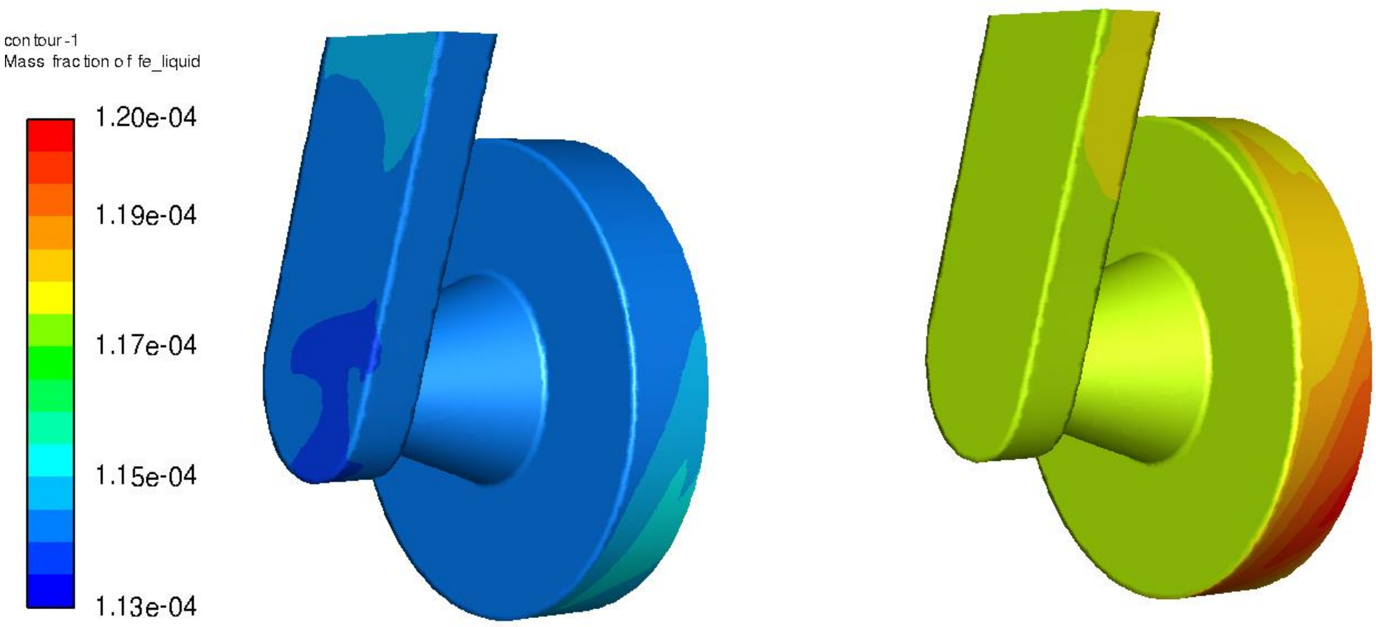
In general the mean Aluminum concentration is homogeneous with only slightly higher values on the roll arm for case A and slightly lower values for the rotating roll in case B. This is in accordance with the fact that the Aluminium uptake is higher at higher temperatures.

WP 4: Analysis of dross build-up on bath hardware

Comparison between Iron distribution

Case A

Case B

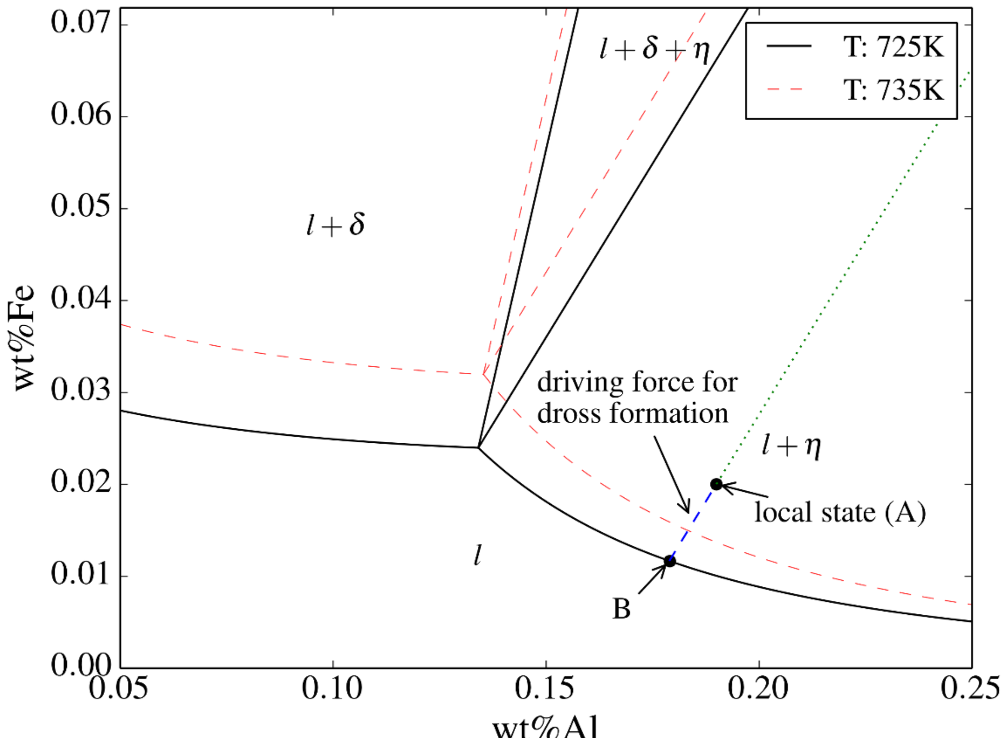


The Iron concentration in Case B is slightly higher. This is due the fact that the Iron dissolution is higher at higher temperatures.

WP 4: Analysis of dross build-up on bath hardware

In the hydrodynamic sub-model the driving force for dross build-up formation can be evaluated. The information of thermodynamics is used. The farther away the condition in the melt (point A) is from the equilibrium, the higher is the driving force.

The evaluation in the hydrodynamic sub-model is restricted to the conditions slightly away from the surface, as the laminar boundary layer is not resolved. This is done on the micro-meter scale in the growth model. However, the evaluation of the driving force gives a first valuable assessment of the conditions.



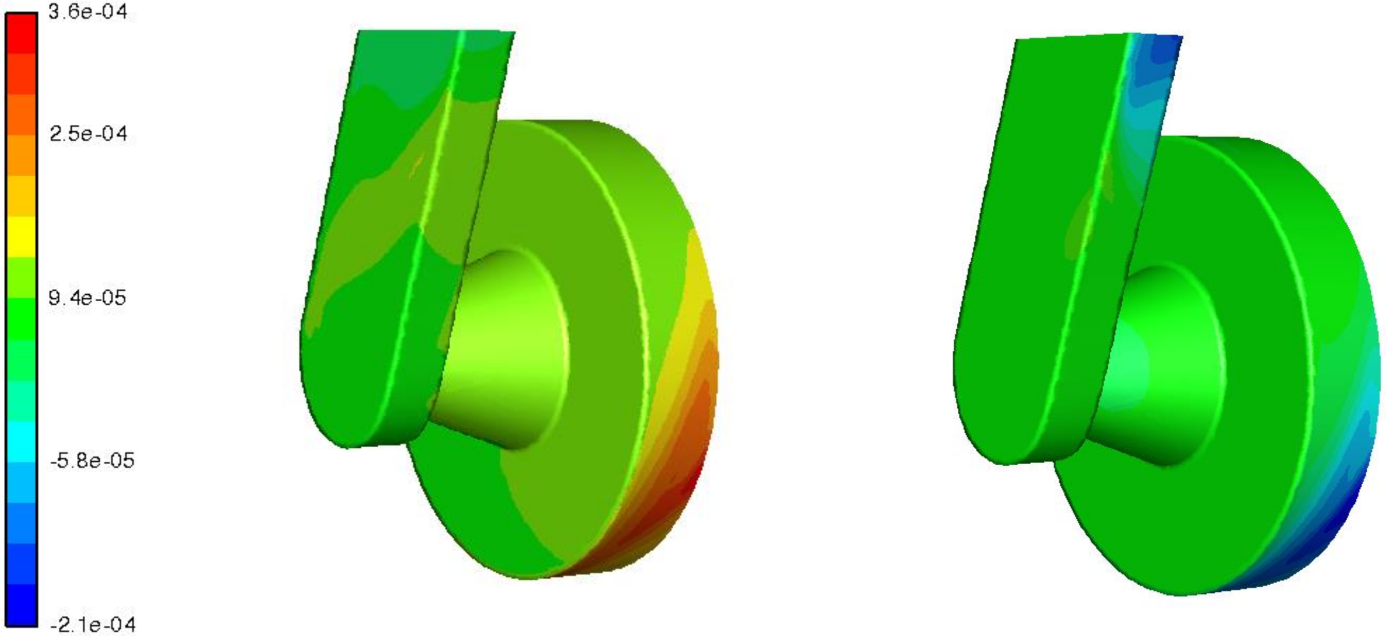
Reiss et. al. 2019

WP 4: Analysis of dross build-up on bath hardware

Comparison between tendency of dross build-up formation

Case A

Case B



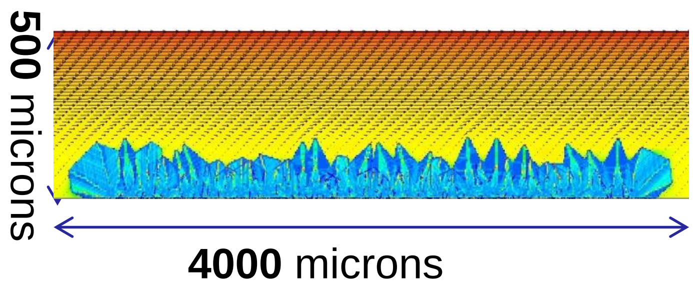
positive values refer to formation of dross build-up
negative values refer to a dissolution of dross build-up

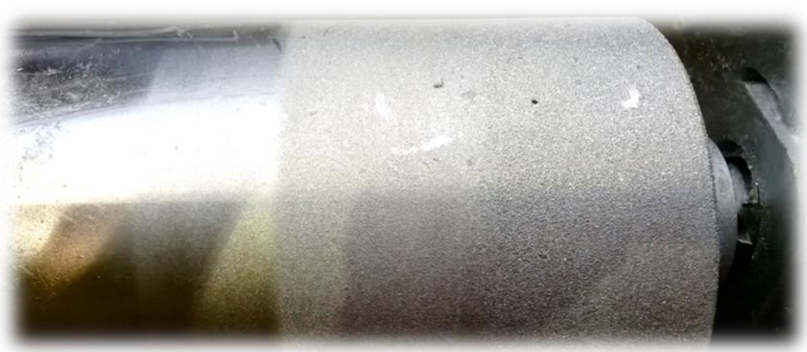
The prevailing conditions in Case A lead to conditions which favours the formation of dross-up on the roll surface. In Case B however the tendency of dissolution can be expected.

Table of Contents

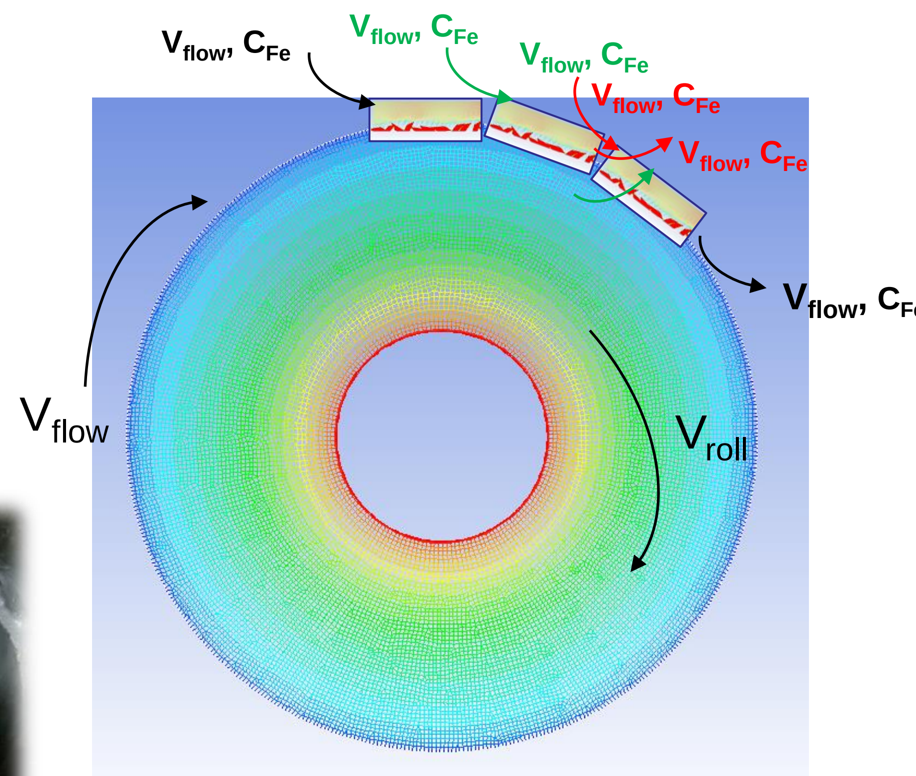
Growth model set-up: Boundary conditions

Rectangular domain:4000*500 microns
Mesh refined: 2 000 000 cells
Cell size: 0.5 microns



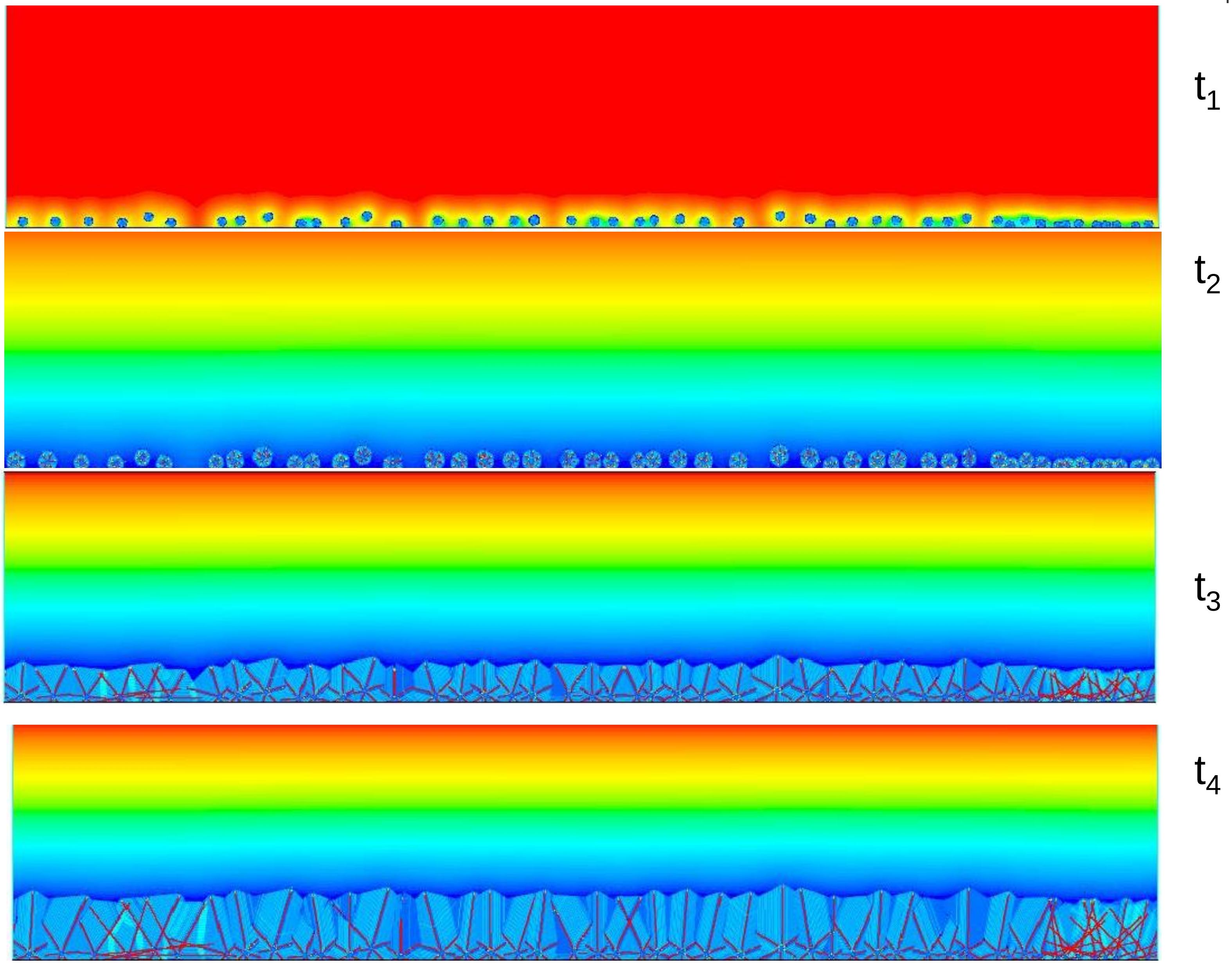


Current Boundary Condition: Periodic Flow

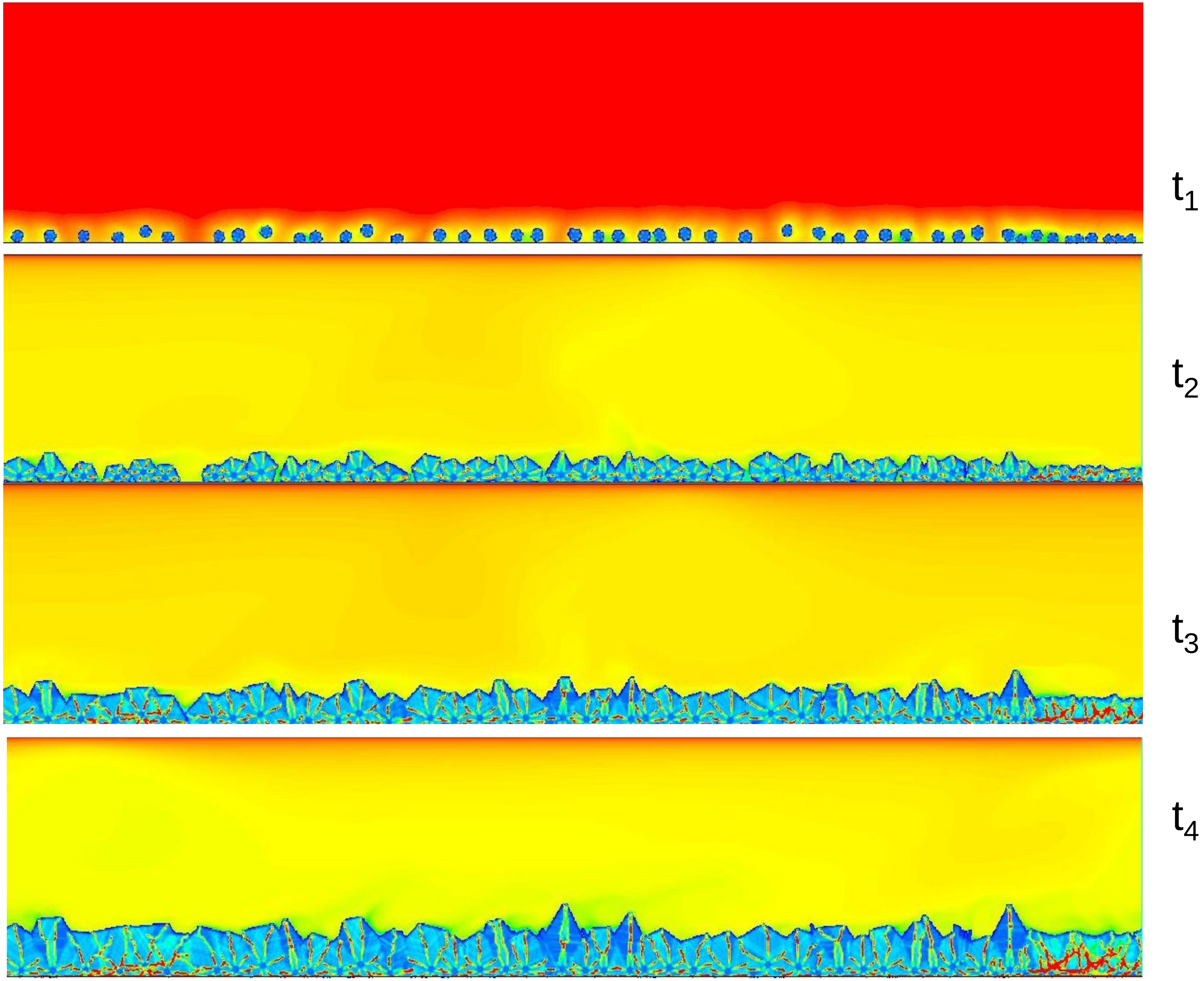


Periodic BC: outlet conditions become the inlet conditions.

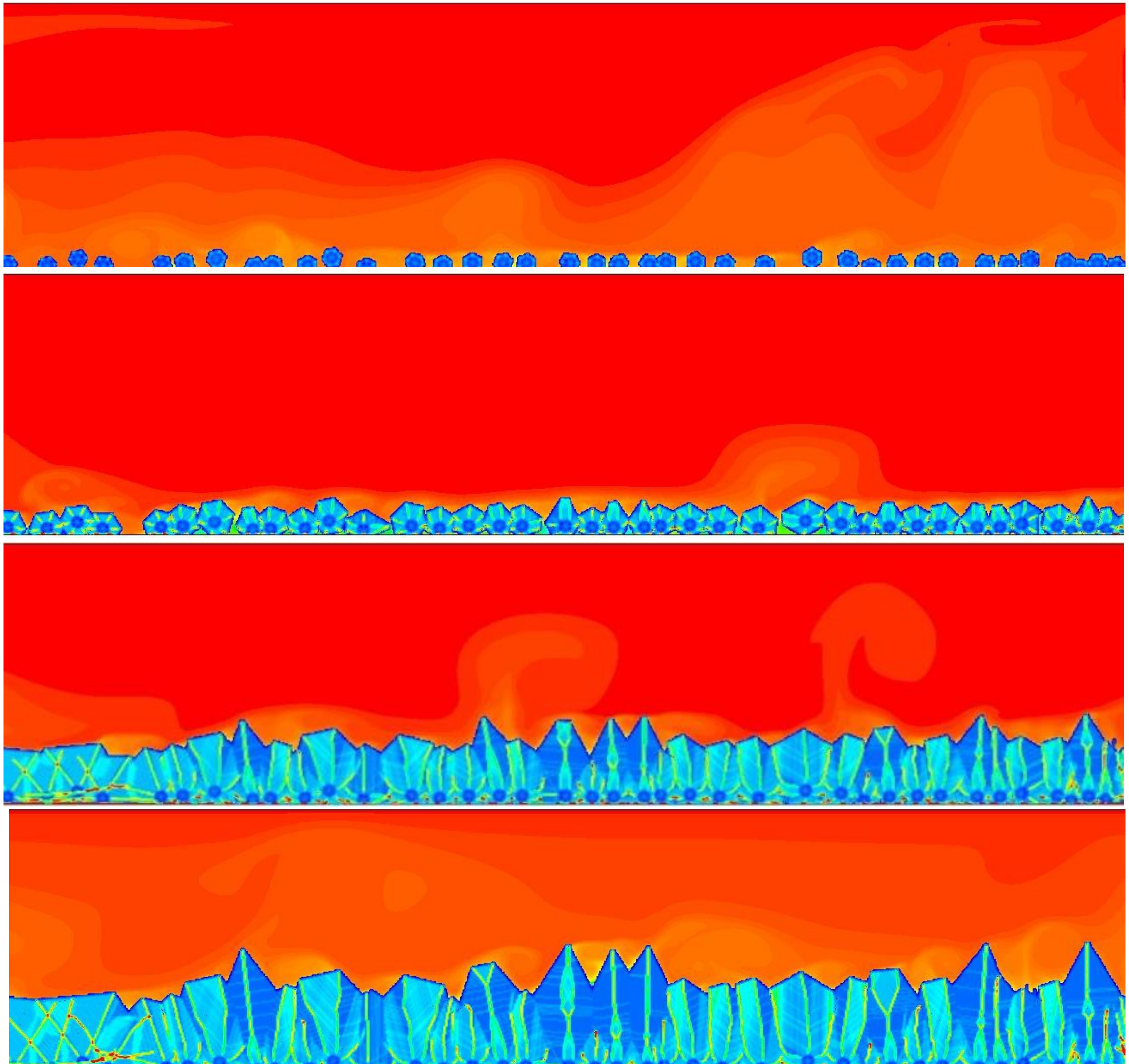
Build-up : Velocity 0.001 m/s



Build-up : Velocity 0.1 m/s



Build-up : Velocity 0.5 m/s



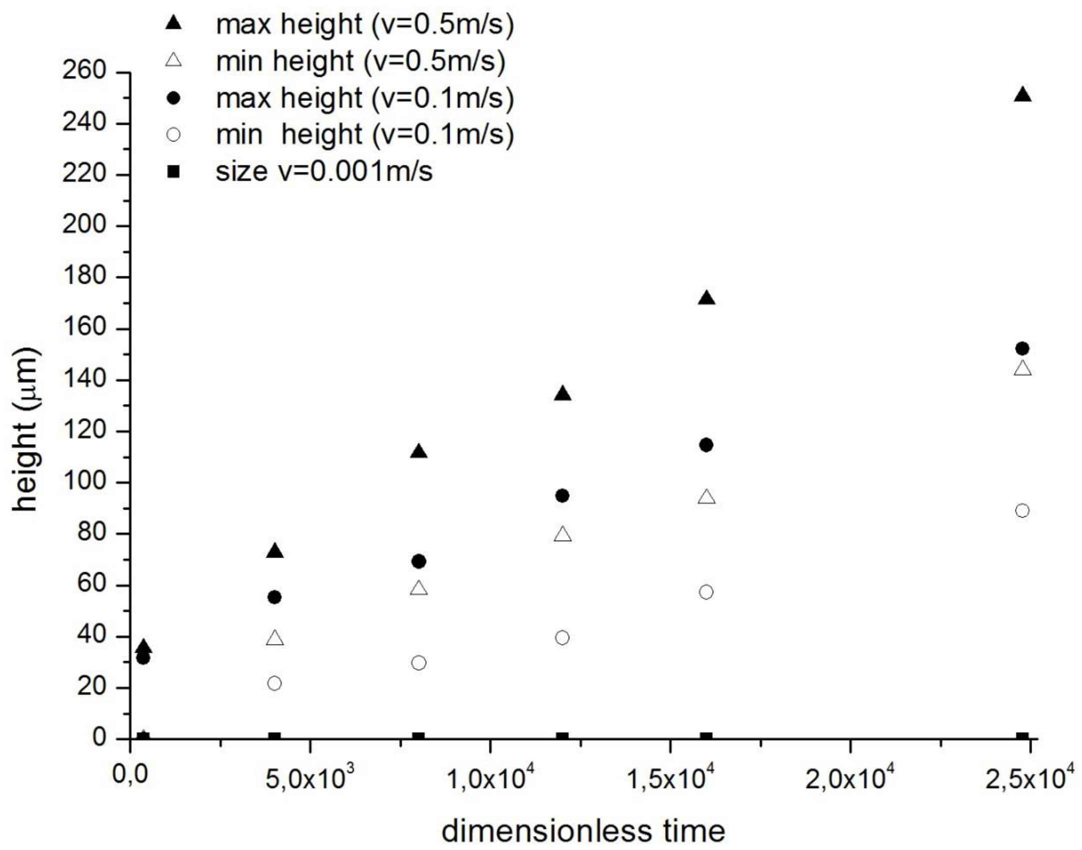
t_1

t_2

t_3

t_4

Evolution of the Build-up with time



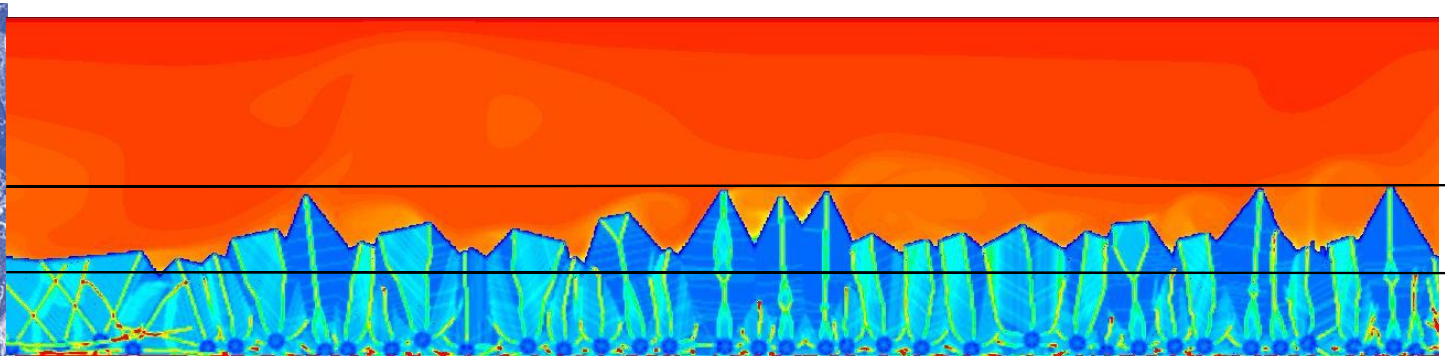
Maximum and minimum evolve with different velocity

=>

Crystal tips grow faster

=>

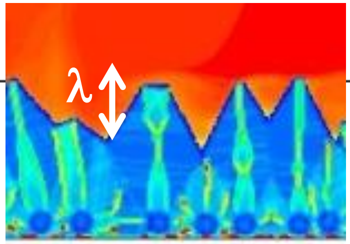
Depressions



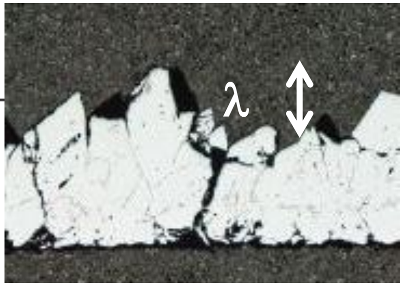
Max height

Min height

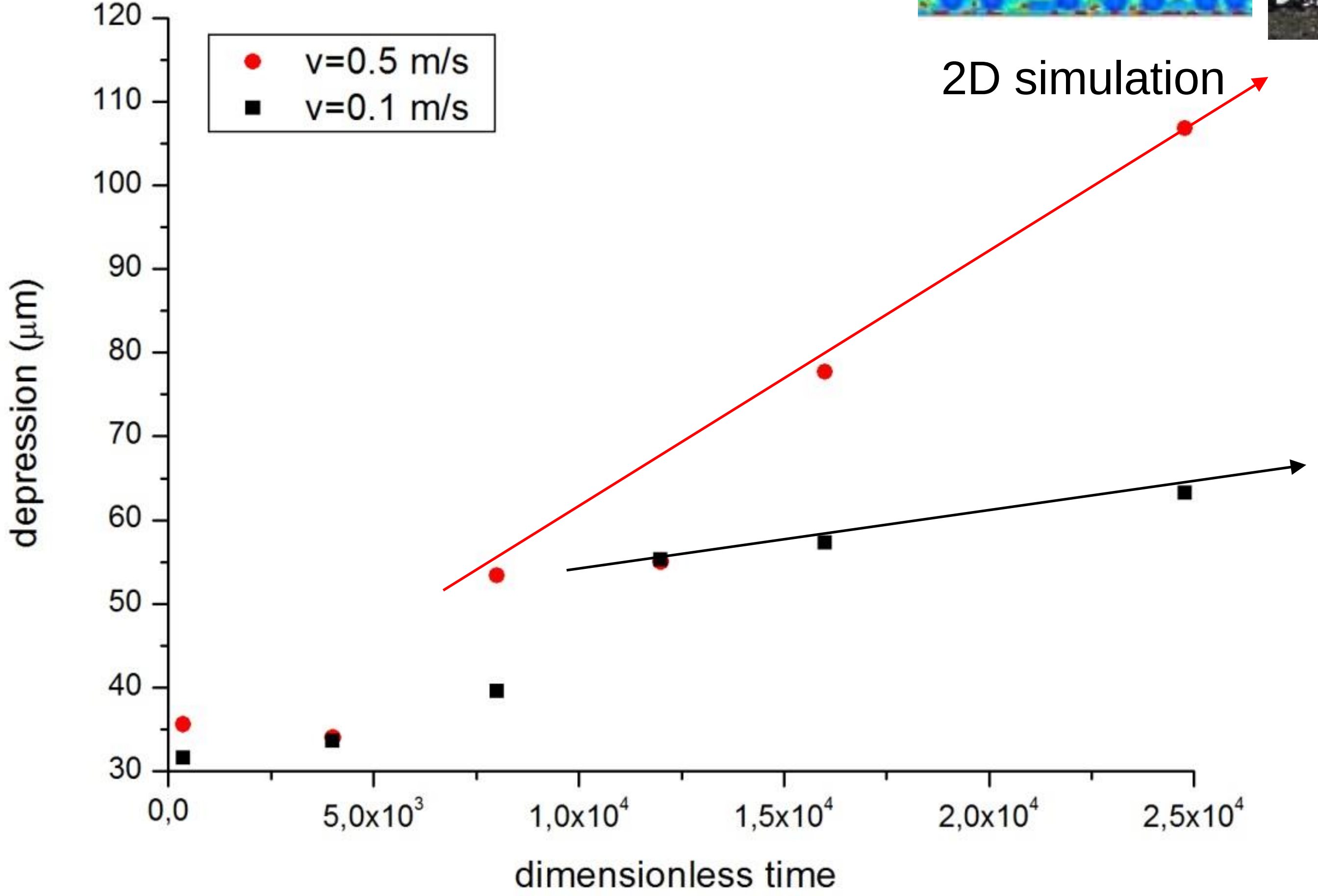
Depression



2D simulation

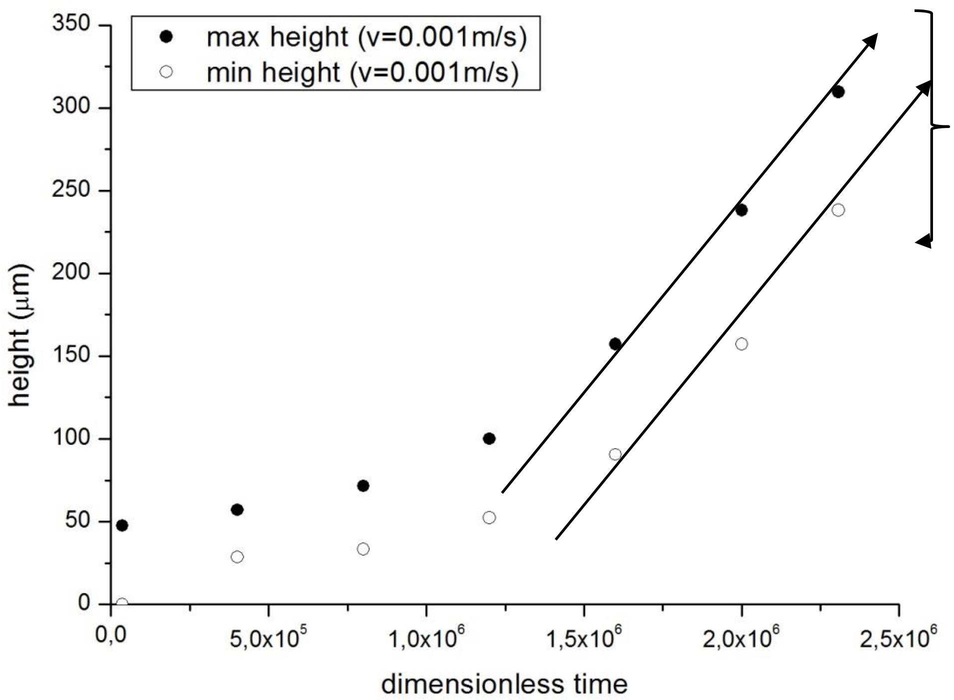


Real sample



Depression height increases ~10 times faster for v=0.5m/s
(compared to v=0.1 m/s)

Case of small flow velocity (1 mm/s)

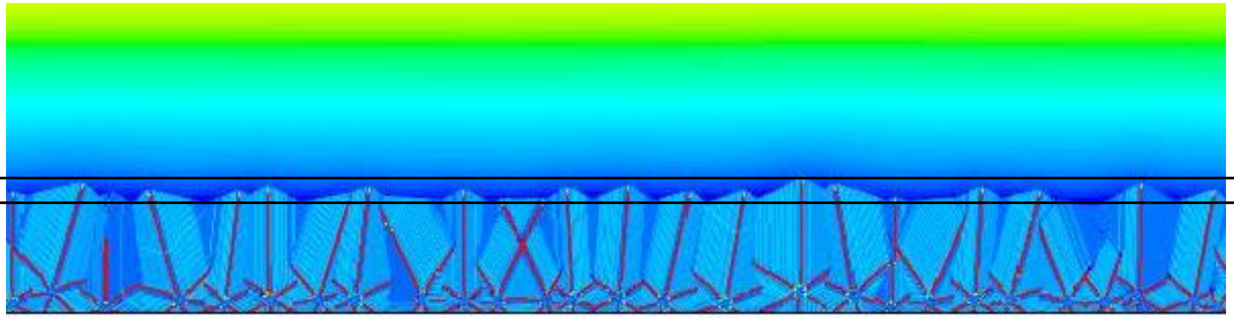


Maximum and minimum evolve with the same velocity

=>

Constant depressions

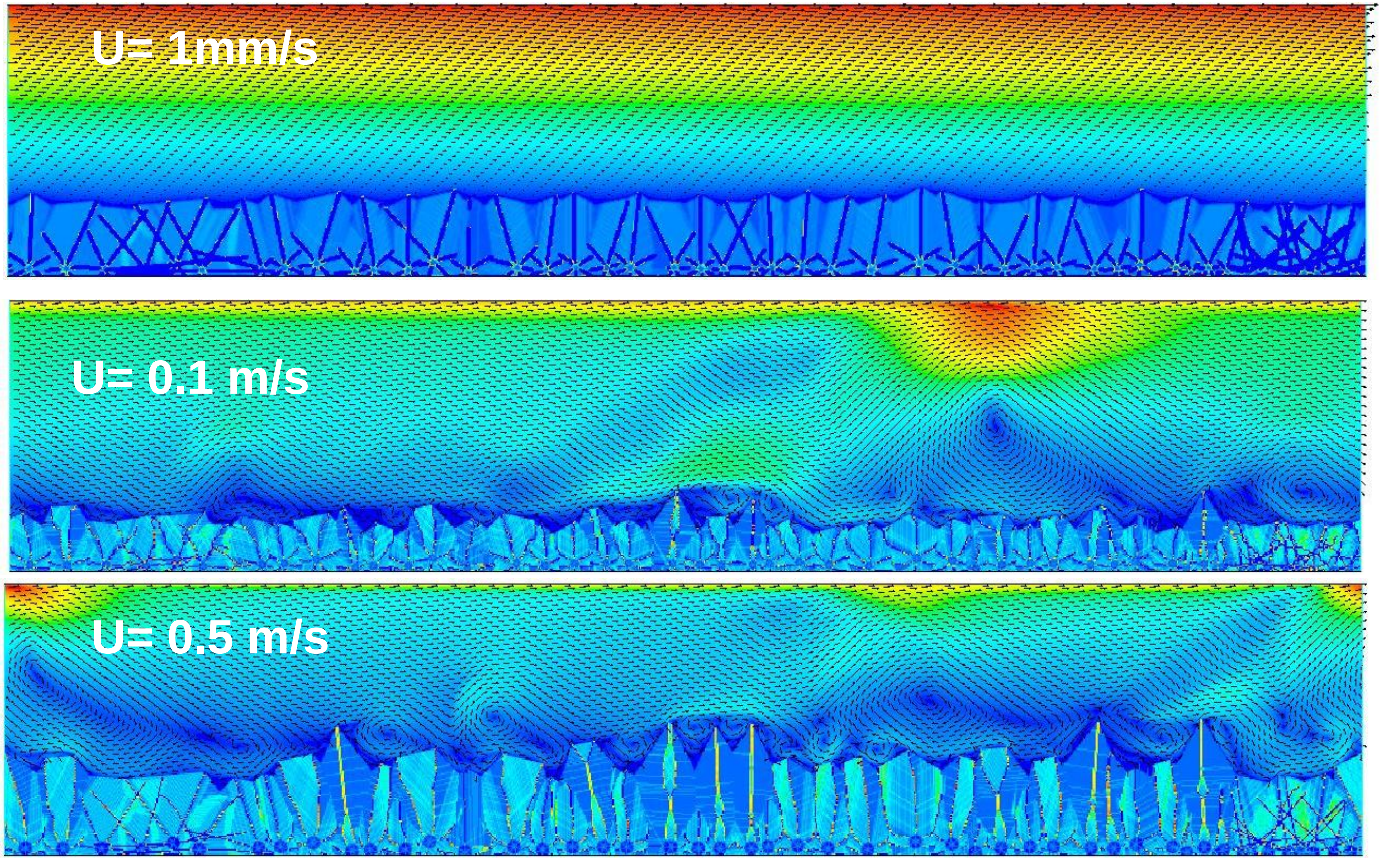
Growth is about 20 times smaller than for U = 0.5m/s



Max height

Min height

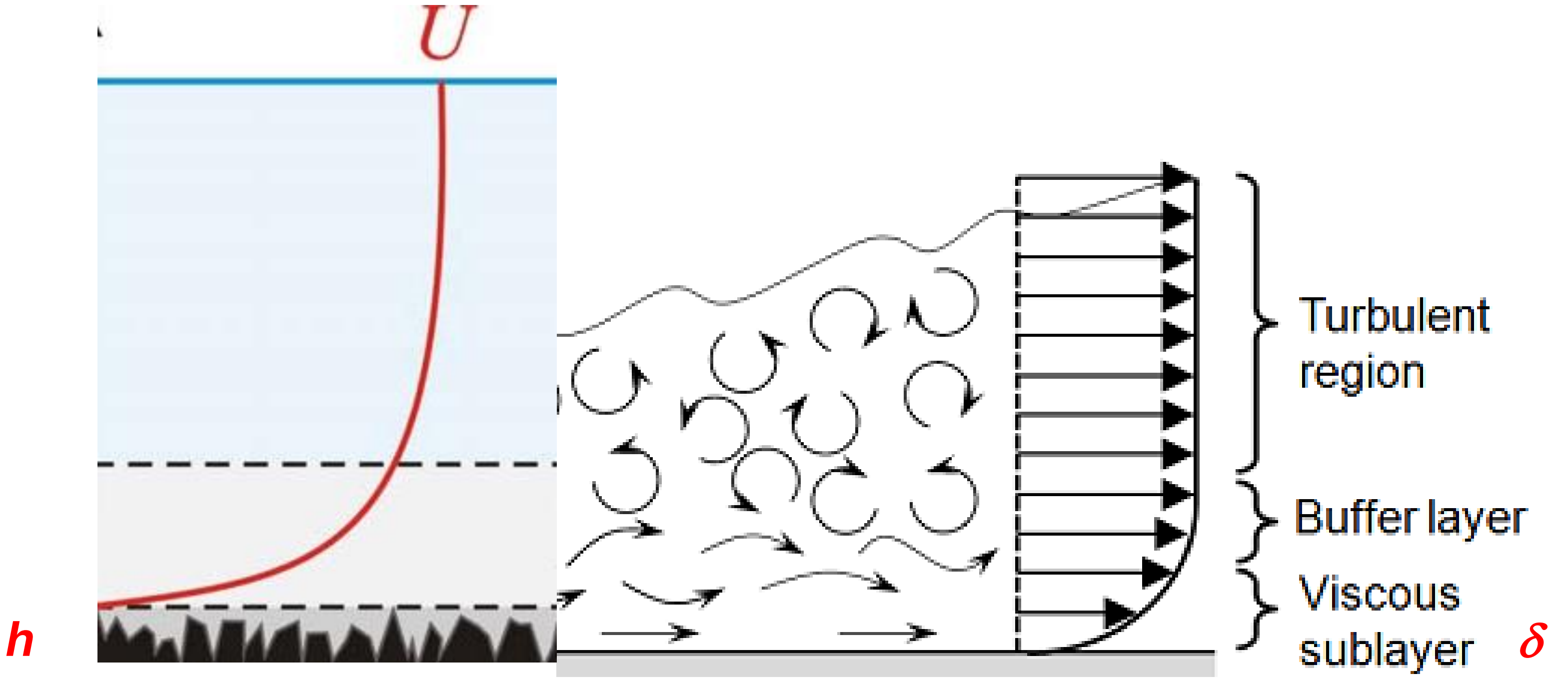
Velocity field



Steady,
Flow parallel to
the build-up

Presence of
eddies
(unsteady
& turbulent)

Turbulent boundary layer, a key to understand build-up growth

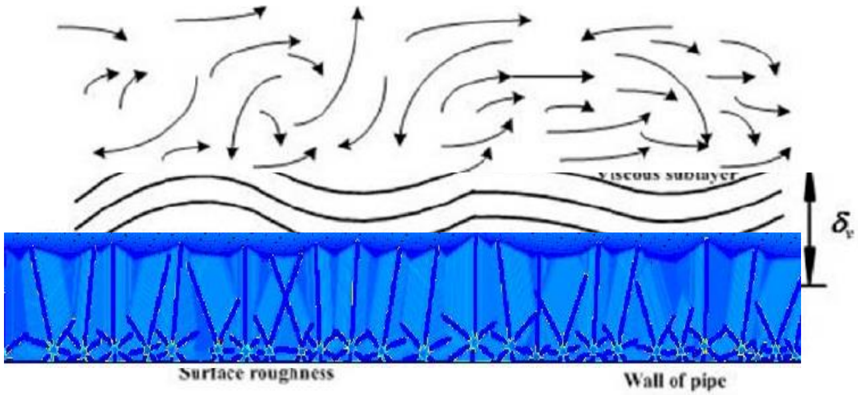


Crystal height *h interacts with the flow :*

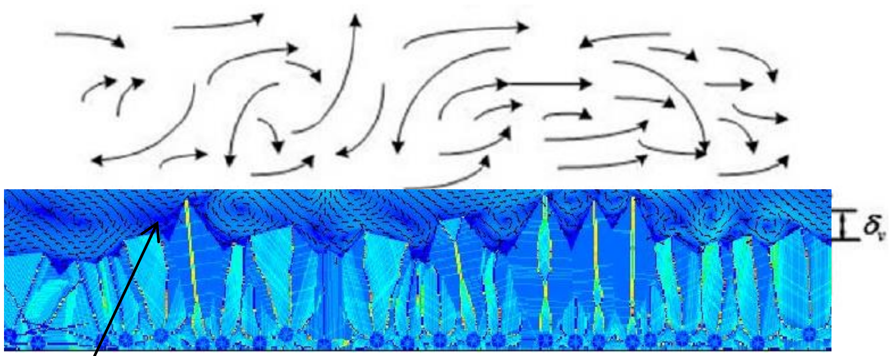
1) *Flow changes dross growth rate*
2) *Size and shape of the dross defines the wall roughness*
3) *Wall roughness controls the flow&turbulence arround the roll*

But situation with ***h/δ<<1*** *must be very different from situations where crystals are very large compared to viscous sublayer* ***h/δ>>1***

What we understood (1)



When crystals are small,
a laminar layer protect the crystals
$\Rightarrow$ Growth is moderate

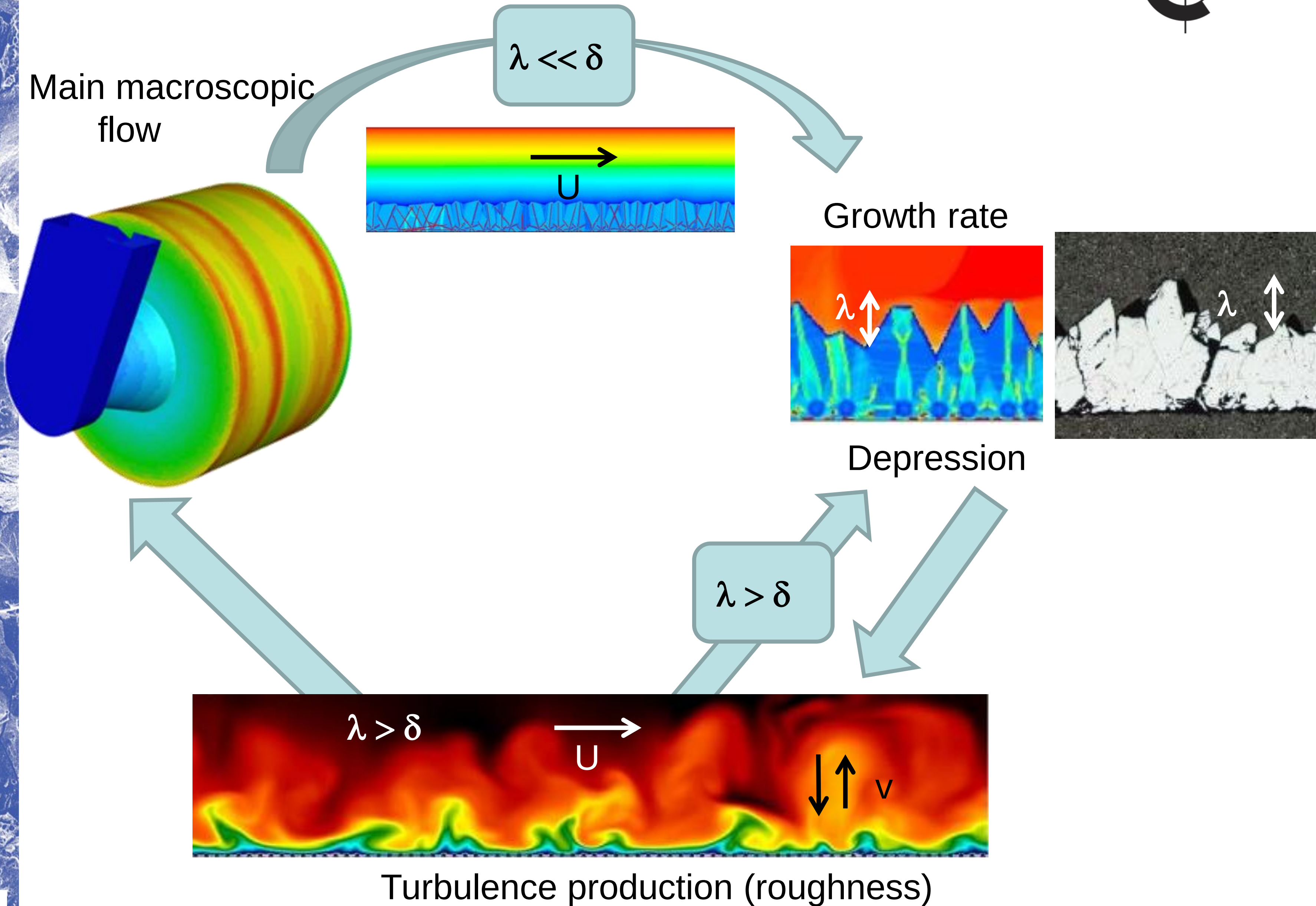


When crystals are larger than δ,
=> Growth is enhanced

Surface roughness

Sultan T, Cho J-S (2016) Methodology considering surface roughness in UV water disinfection reactors. Chem Pap 70(6):777–792

What we understood (2)



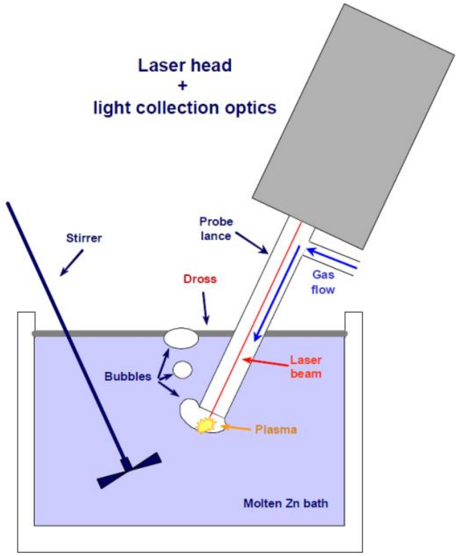
Summary and Outlook

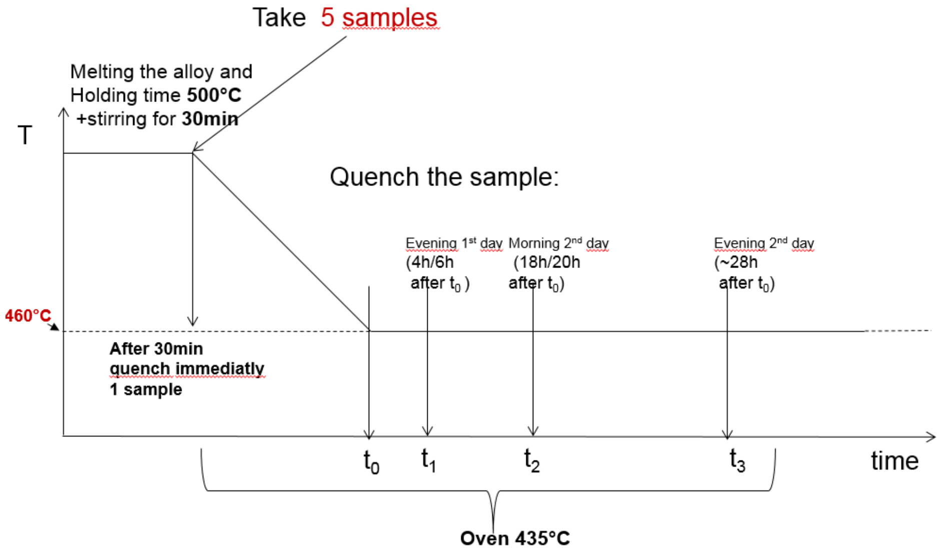
- Computation of conditions near the bath hardware (both stationary and rotating) for selected conditions.
- Different operating conditions can have an influence of the dross build-up formation tendency.
- Strong interaction between Build-up and turbulence has been put in evidence.
- When the build-up is small, the growth is weakly influenced by the hydrodynamics. The growth is relatively “slow”.
- Larger build-up (roughness) generate more turbulence which in turn strongly increase the crystals growth velocity.
- The control parameter of this interaction is not the height of the crystals but the depressions.

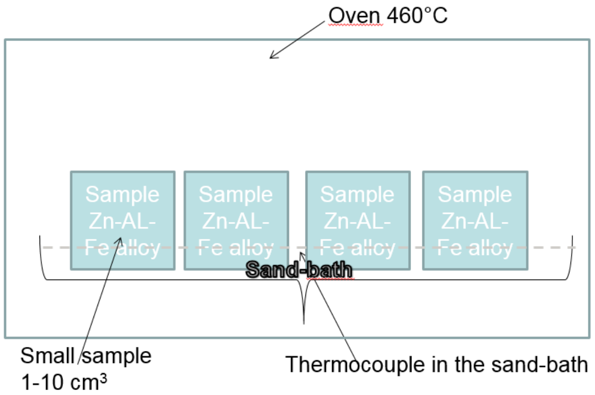
- Project Overview
- WP4: Numerical build-up analysis of selected conditions and reducing strategy
  - Analysis of the build-up on hardware of selected conditions.
- WP3: Interaction of Growth with Hydrodynamic strategy
  - Growth on the surface influenced by hydrodynamics and roughness
- Update on kinetic measurements

Kinetic measurements

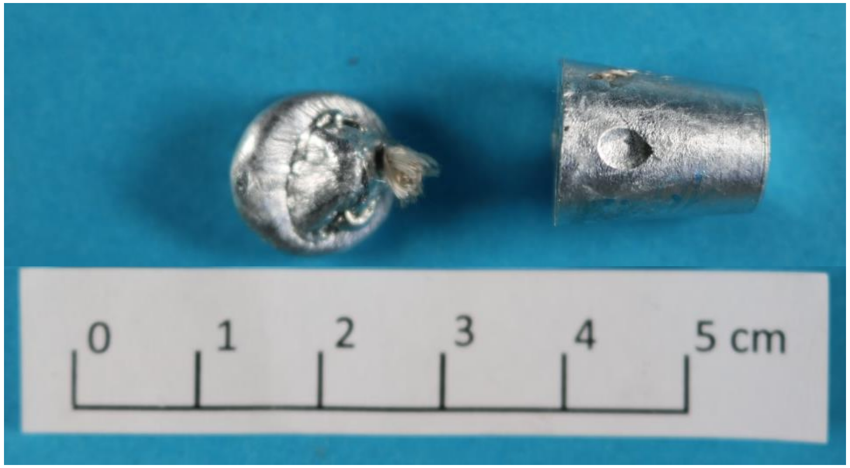
Proposed growth kinetic measurement: Take 5 samples from well stirred laboratory pot. Hold them at specified temperature for different times in oven and quench the samples. Analyse the mass and size distribution of dross particles.

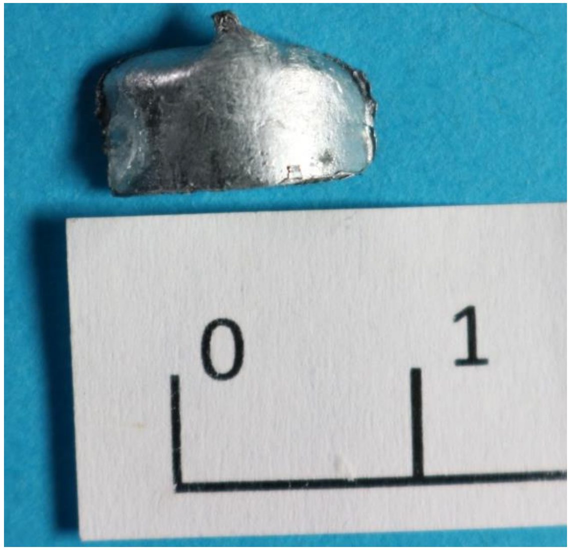






Kinetic measurements





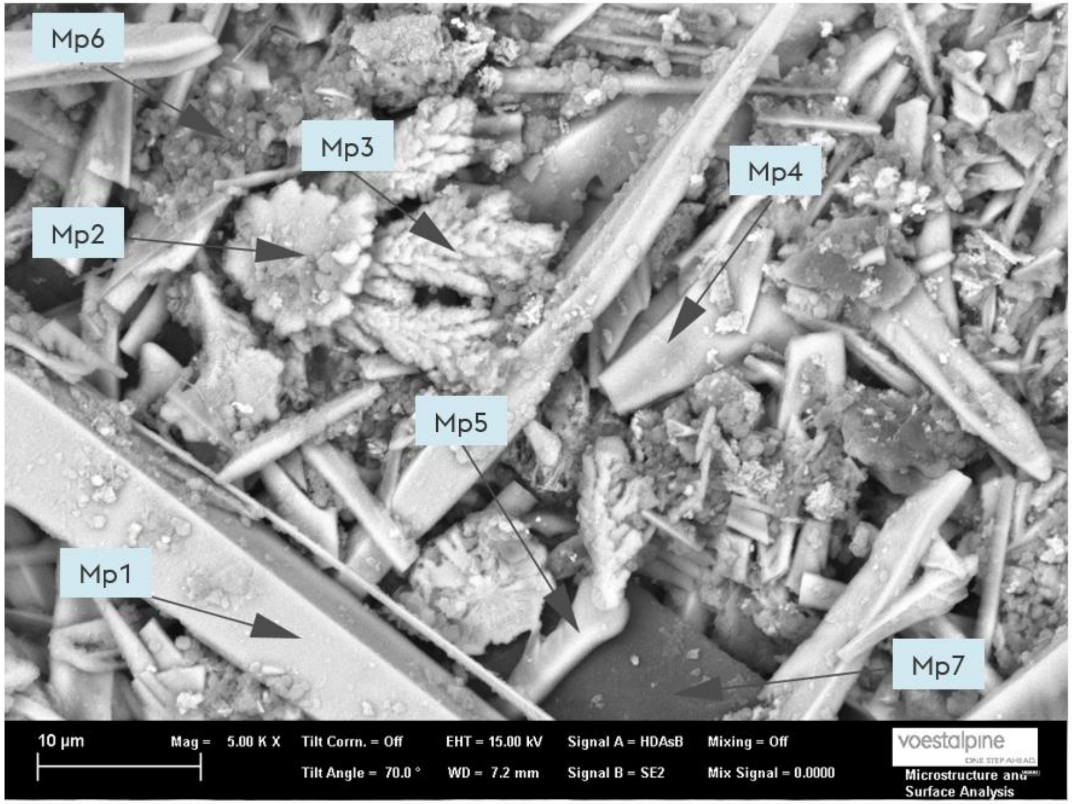
Kinetic measurements

The zinc matrix of the sample was dissolved in HNO_3 and the remaining particles are filtrated.

In a subsequent measurement the particle mass and particle size distribution was evaluated.

However, much more particles than expected were found and also the shape was quite surprisingly.

Kinetic measurements



	Al	Fe	Zn	O	C
	Gew.%	Gew.%	Gew.%	Gew.%	Gew.%
Mp1	**34,1**	**32,1**	**11,8**	4,1	15,9
Mp2	**32,2**	**21,9**	**11,8**	7,9	23,9
Mp3	**34,6**	**22,2**	**13,5**	7,1	19,1
Mp4	**22,4**	**32,3**	**9,8**	7,4	24,9
Mp5	**14,1**	**11,6**	**6,2**	18,4	**47,6**
Mp6	7,4	5,2	13,5	18,1	**50,6**
Mp7	1,1	1,4	4,8	**25,8**	**64,8**

voestalpine
ONE STEP AHEAD.

Various shapes like needles or dendritic structures, apart from the expected faceted crystals, were identified. Most of them contain Al and Fe.

The same structures were found in CT-measurement in an additional sample.

Thank you for your attention!

Financial support by the International Zinc Association and the Austrian Federal Government (in particular from Bundesministerium für Verkehr, Innovation und Technologie and Bundesministerium für Wirtschaft, Familie und Jugend) represented by Österreichische Forschungsförderungsgesellschaft mbH and the Styrian and the Tyrolean Provincial Government, represented by Steirische Wirtschaftsförderungsgesellschaft mbH and Standortagentur Tirol, within the framework of the COMET Funding Programme is gratefully acknowledged.

Competence Centers for
Excellent Technologies