CEEES 2012

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Simulating different phases in the printing process

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Reden B.V.

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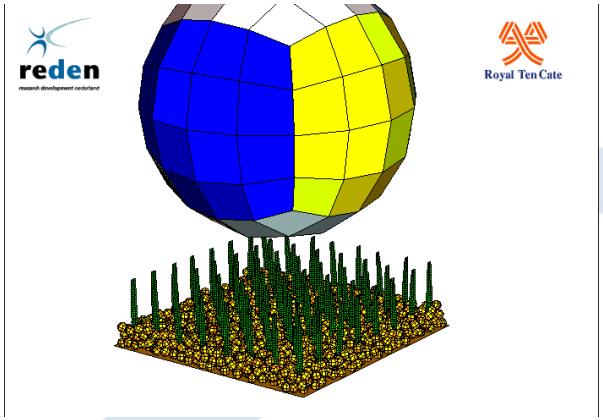
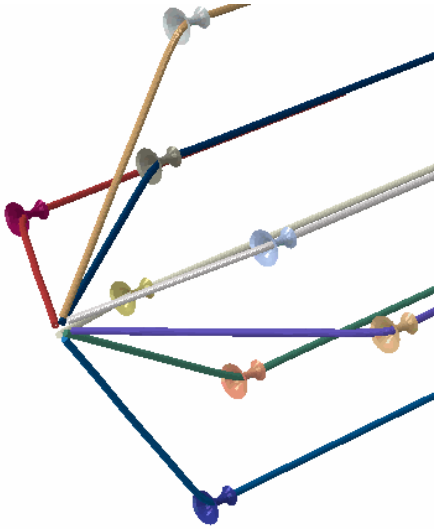
Introducing Reden

Reden is an abbreviation for: **Re**search & **De**velopment **N**ederland



Mission:

Initiate a *break-through in product development* for our customers. By bringing state of the art scientific knowledge to commercial clients.



Method:

Providing profound insights for the product developers using *validated simulation models of the product and/or the production process*.

Introducing Reden

What is the benefit of modelling and simulation?

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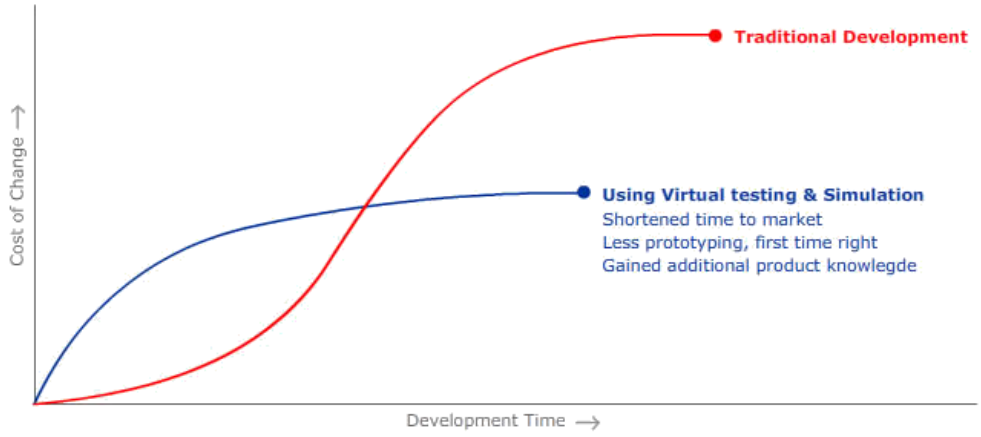
1. The aims in product development are achieved more often
2. Break-through in results, through-put and predictability of the designs
3. Newly developed knowledge is secured in models and design rules
4. Early-stage developments by means of virtual testing result in cost reduction on long term base *(fewer experiments, less prototyping, first-time-right products)*



Introducing Reden

In which domain?

We excel in the domain of physical products and systems, in which is found:

- Large complexity
- High demands on performance
- Multi physics*, with the focus on Applied Mechanics

  (*multiple subject simultaneously: construction science, mechanics, thermodynamics, acoustics, material science, vibrations, electromagnetism, etc.)

We maintain the high level of expertise by:

- Participating as an SME in national and European funded innovation projects
- Maintain close contacts with Universities (e.g. University of Twente)

Knowledge build-up with simulations

Introduction

Printing is the assembly of building blocks (droplets) into a new product.

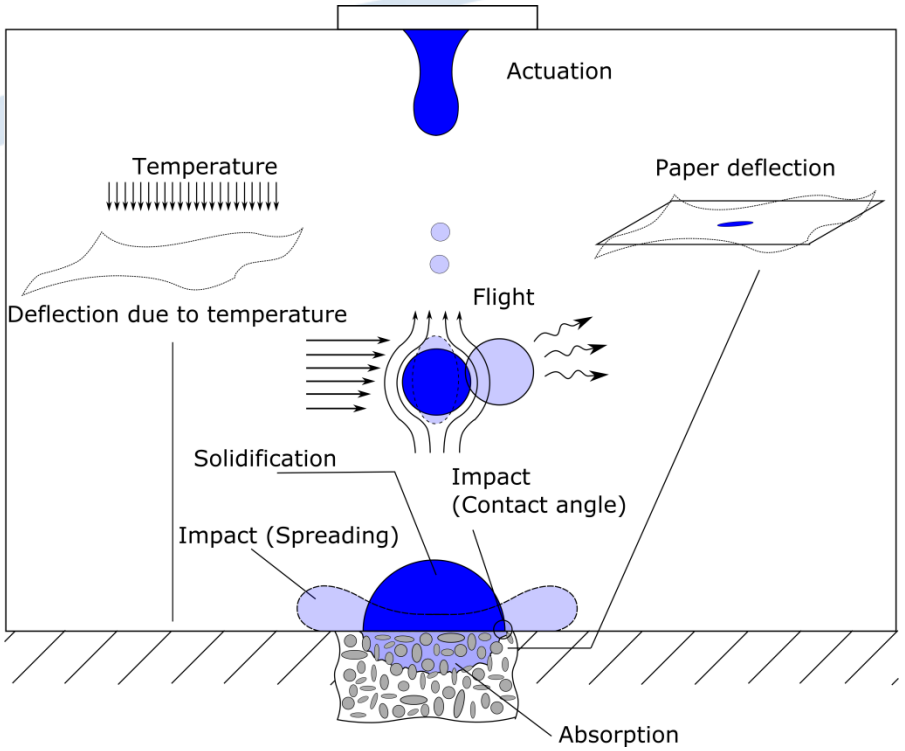
The quality of the product is largely dependent on the level of control on the different stages of the assembly/printing process.

Stages:

- Droplet generation
- Flight
- Impact on substrate
- Absorption/solidification

Boundary conditions:

- Substrate deformation



Knowledge build-up with simulations

Introduction

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Goal:

- Gain insight in the mechanisms that play a role in the different stages
- Develop design rules that relate the design parameters of the printing process with the performance.

Advantages of a solution path involving simulations**:**

- The combination of practical experiments and simulations will provide knowledge before the first prototype has been made.
- The knowledge is directly captured and available within the model.
- Virtual experiments (simulations) can be conducted which are hard or impossible in real live.
- Insight is gained in fields which are hard to measure in practice. Like velocity field or stresses and strains.

Knowledge build-up with simulations

Droplet generation

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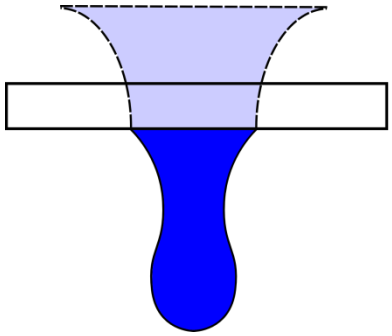
Goal:

Determine the relations between the design parameters of the actuation process and the performance

Design parameters	Performance parameters
Pressure pulse	Speed
Nozzle geometry	Droplet shape
Fluid properties	Satellites
Contact angle	Robustness



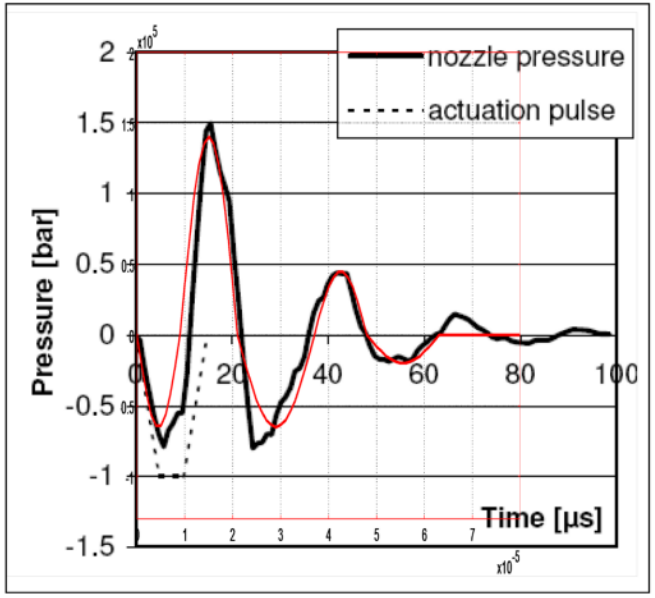
Steps:

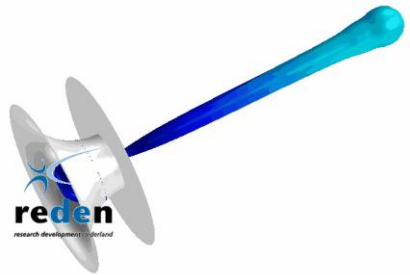
1. Model construction
2. Validation of the simulation model
3. Perform a parameter variation study (case specific, not in this presentation)

Knowledge build-up with simulations

Droplet generation

- An axisymmetric model in COMSOL has been made
- The droplet is generated by a pressure pulse (see figure)





Knowledge build-up with simulations

Droplet generation

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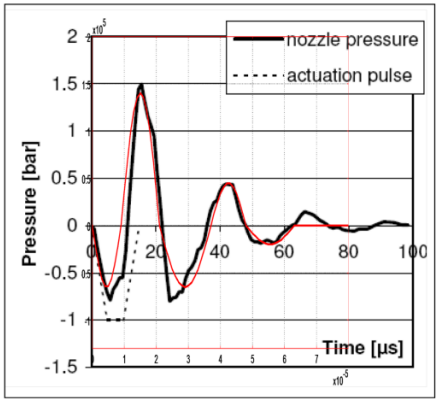
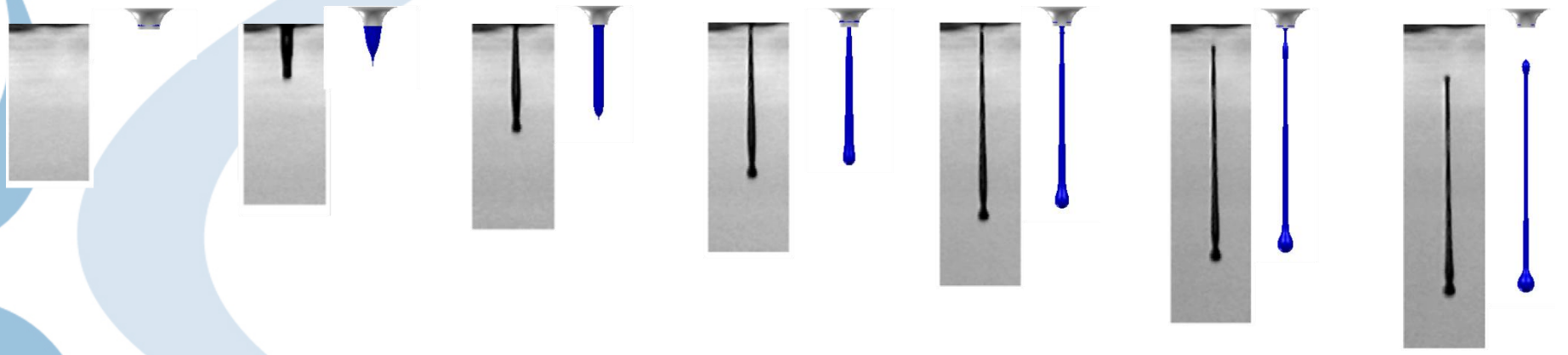
Validation

- Compared with experimental data out of the thesis of Wijshoff.

- Conclusion;
  The simulation model is capable of describing the phenomena.





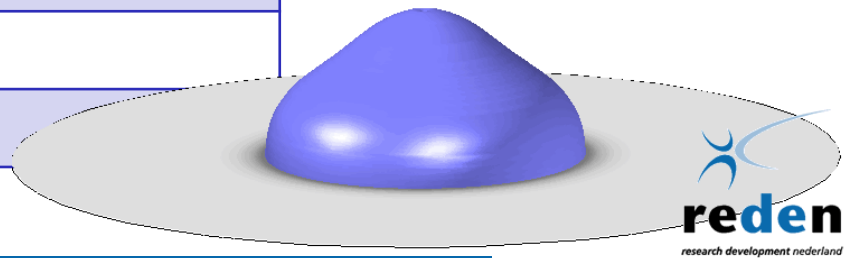
Knowledge build-up with simulations

Droplet Impact

Goal:

Determine the relations between the design parameters of the actuation process and the performance

Design parameters	Performance parameters
Impact speed	Wetting area
Droplet diameter	Splashing
Density	Debris
Viscosity	Dynamic response
Surface tension	Velocity field
Contact angle with substrate	
Angle of impact	

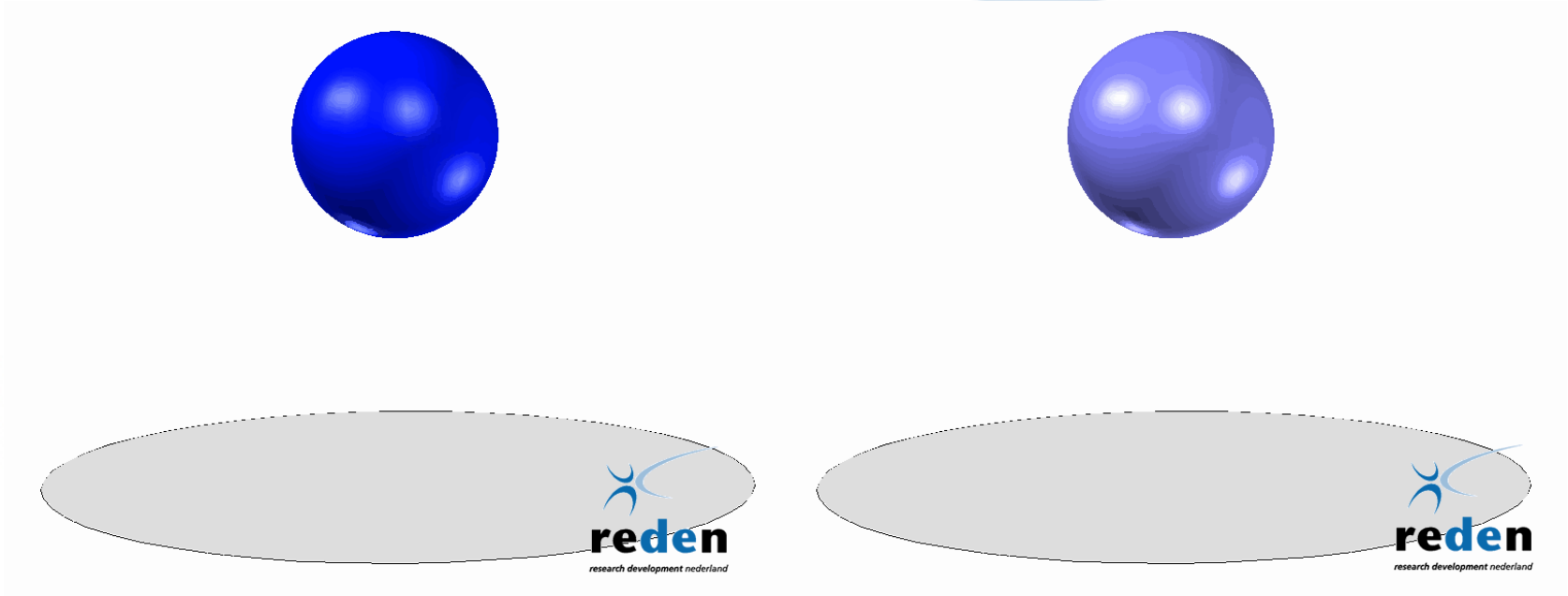


Knowledge build-up with simulations

Droplet Impact

Axisymmetric droplet impact at low Weber number

Package used: Comsol



contact angle: 50 [deg]

contact angle: 90 [deg]

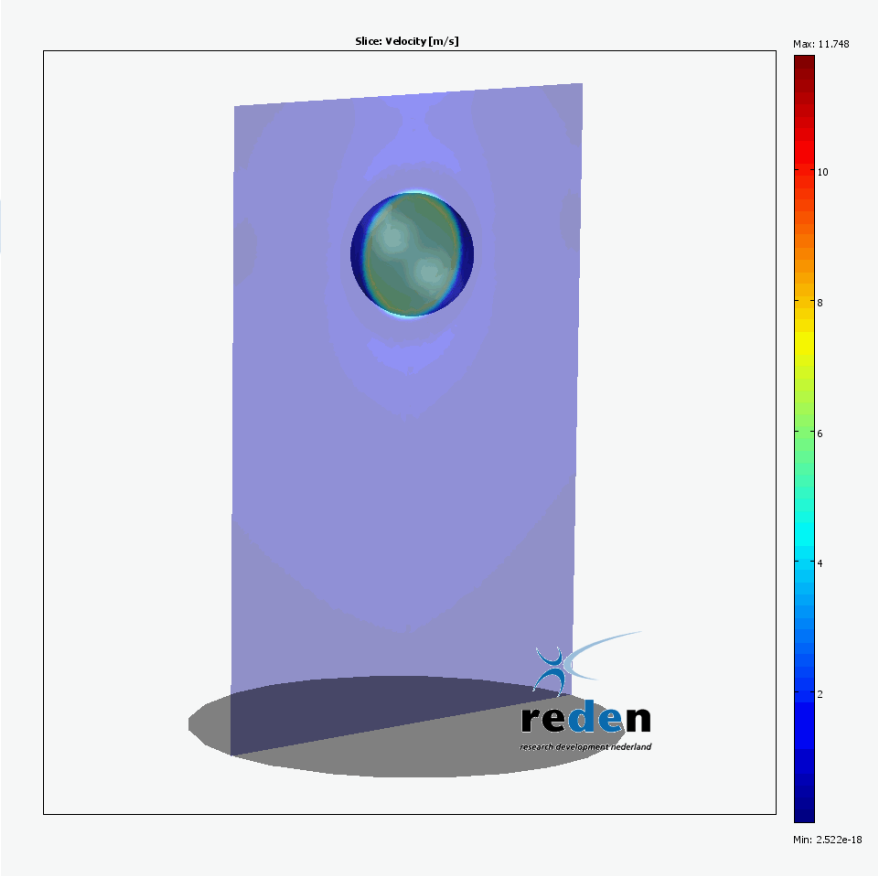
Knowledge build-up with simulations

Droplet Impact

Axisymmetric droplet flight

Package used: Comsol

Visualization of the velocity field of the air surrounding the droplet



Knowledge build-up with simulations

Droplet Impact

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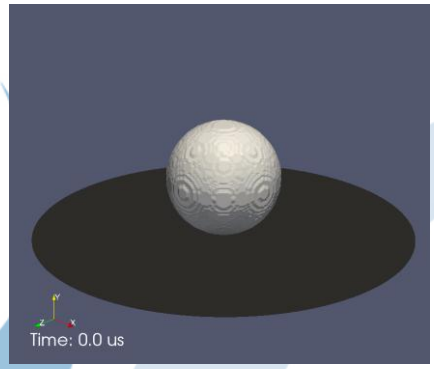
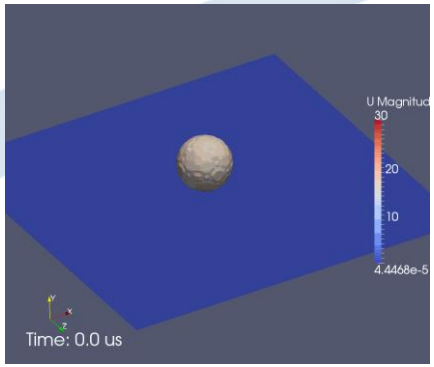
3D droplet impact at high Weber number

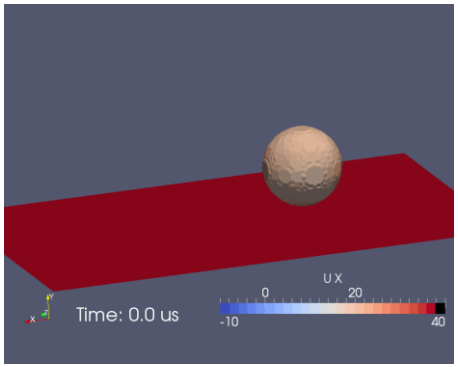
Package used: OpenFoam (open source)



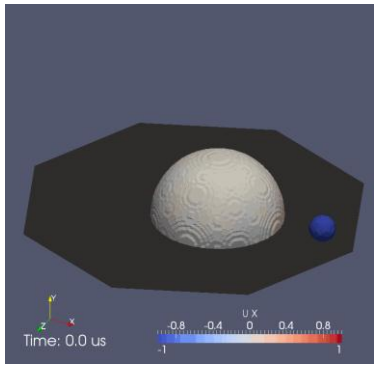
Dry impact



Wetted impact



Oblique wet impact



Droplet impact

A practical experiment never hurts

Knowledge build-up with simulations

Droplet Impact

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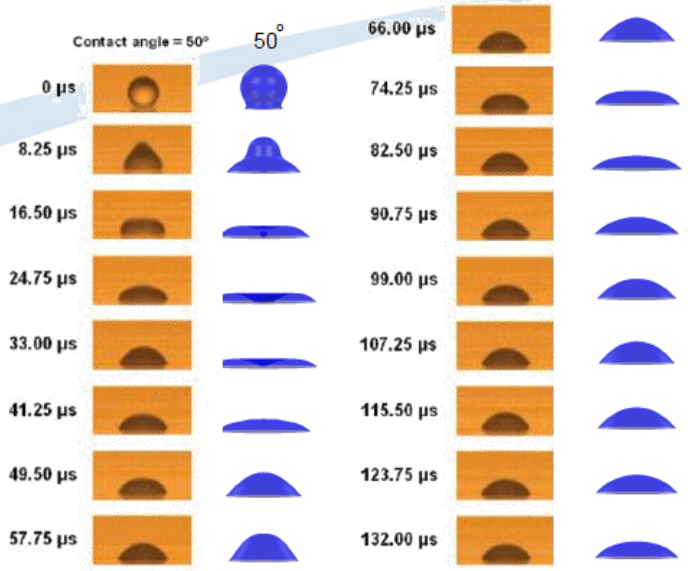
Validation

- For axisymmetric droplet impact the simulation results are compared with practical experiments.
- For 3D droplet impact with splashing the simulation results are validated by comparison with the results M. Bussmann has presented in his paper "Modeling the splash of a droplet on a solid surface"

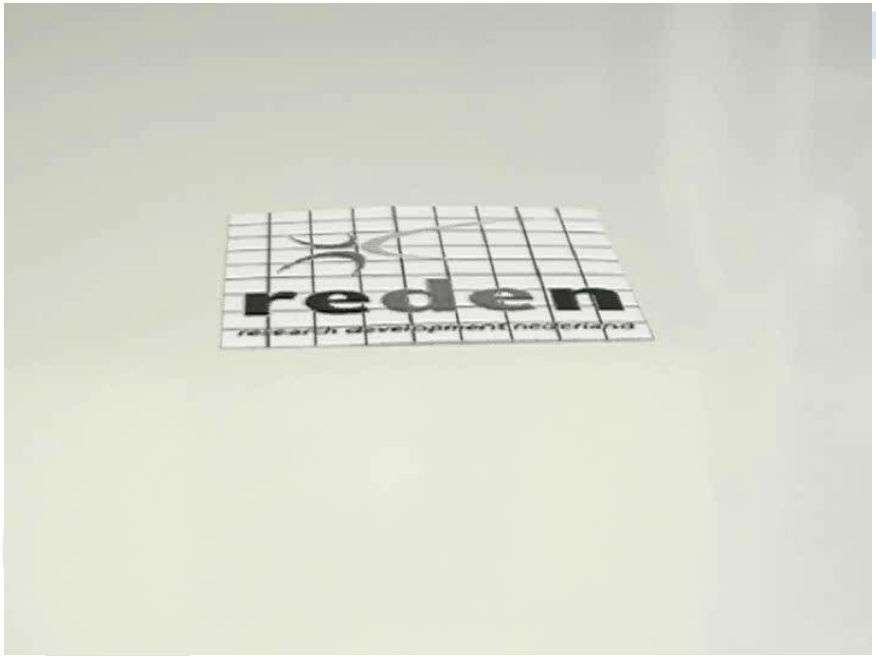


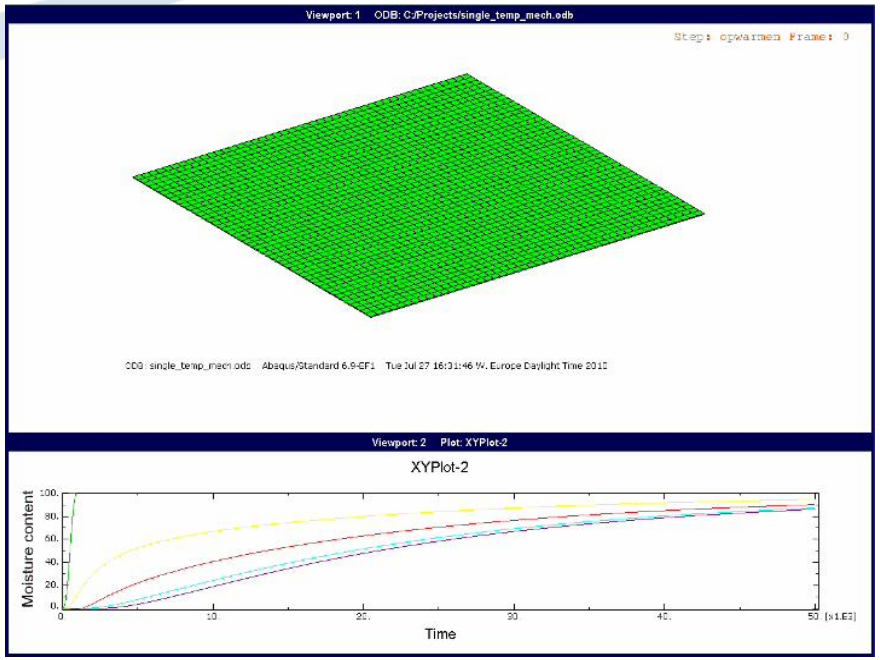
Knowledge build-up with simulations

Substrate deformation

Introduction

- Substrate deformation can lead to inaccuracy of the printing process
- The substrate can deform due to a change in temperature or moisture level.



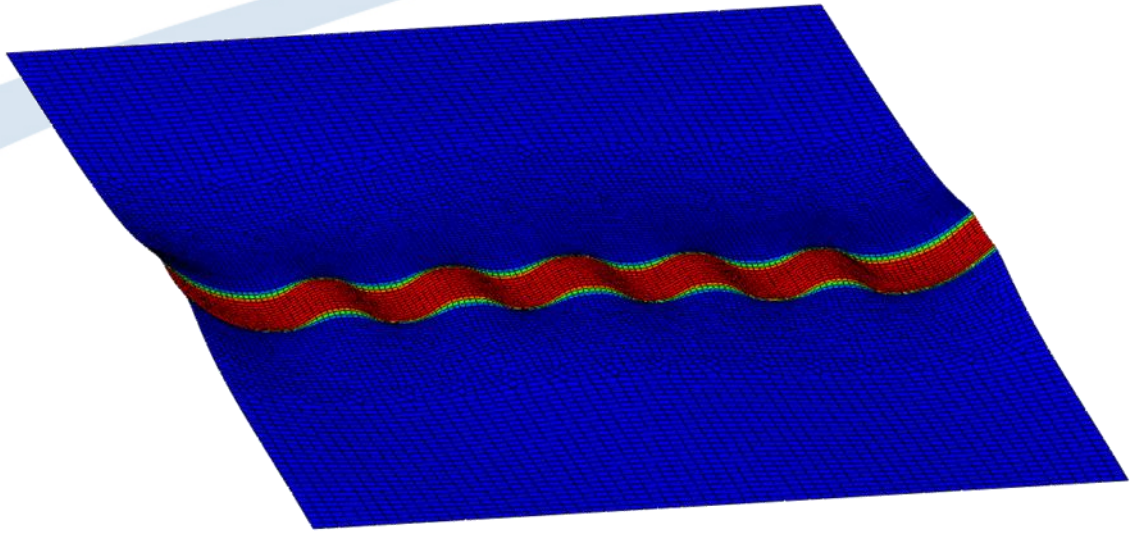


Example of a piece of paper sprayed by some water

Knowledge build-up with simulations

Substrate deformation

- Wrinkling due to wetting (Blue is dry, red is wetted paper).
- The deformations are scaled with a factor 5.
- Static analysis



Knowledge build-up with simulations

Substrate deformation

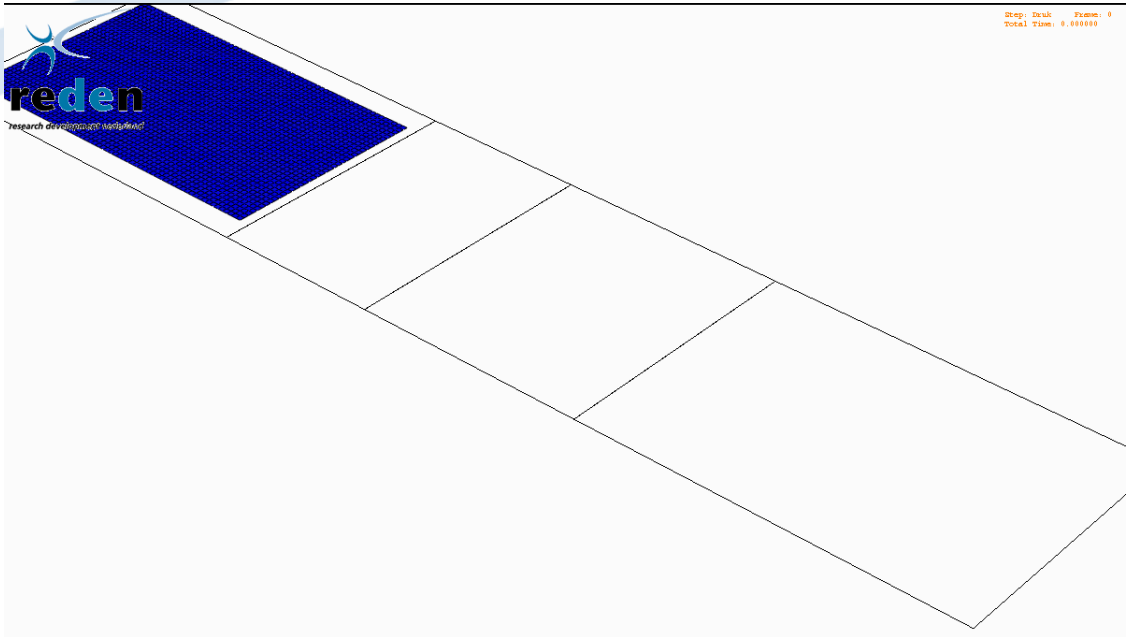
Example process

Step 1:
Paper is transported with a relative high moisture content

Step 2:
Paper is dried

Step 3:
Ink is applied (increase in moisture level)

Step 4:
Final transport



Mr Reves knows (almost) all!

Introduction

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Design rules can be:

- Complex (many parameters, difficult relations)
- Multiple
- Implicit, f(x)=g(y)
- Fuzzy logic

Question:

- How can we efficiently apply these design rules for our design?
- How can we guarantee that the same set of rules is used by everyone within the company?
- What are the possible solutions for a wanted performance?

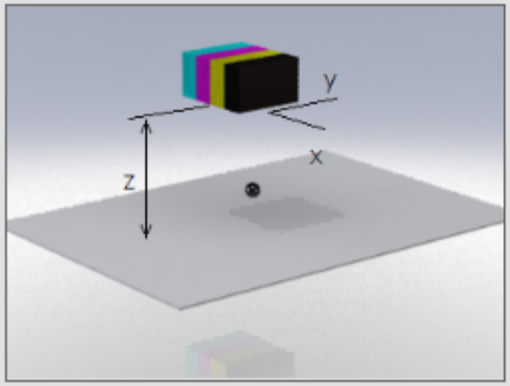
Answer:

Mr Reves stores and applies the design rules to generate solutions.

Mr Reves knows (almost) all!

Droplet flight example

Set Performance	Set parameters	Free parameters
Print temperature	Fluid properties	Droplet volume
	Head temperature	Nozzle height
	Air temperature	Drop speed
	Horizontal speed	
	DPI	



Printer parameters

Nozzle height	0.5:3	mm
Nozzle speed (x)	200	mm/s

Ink parameters

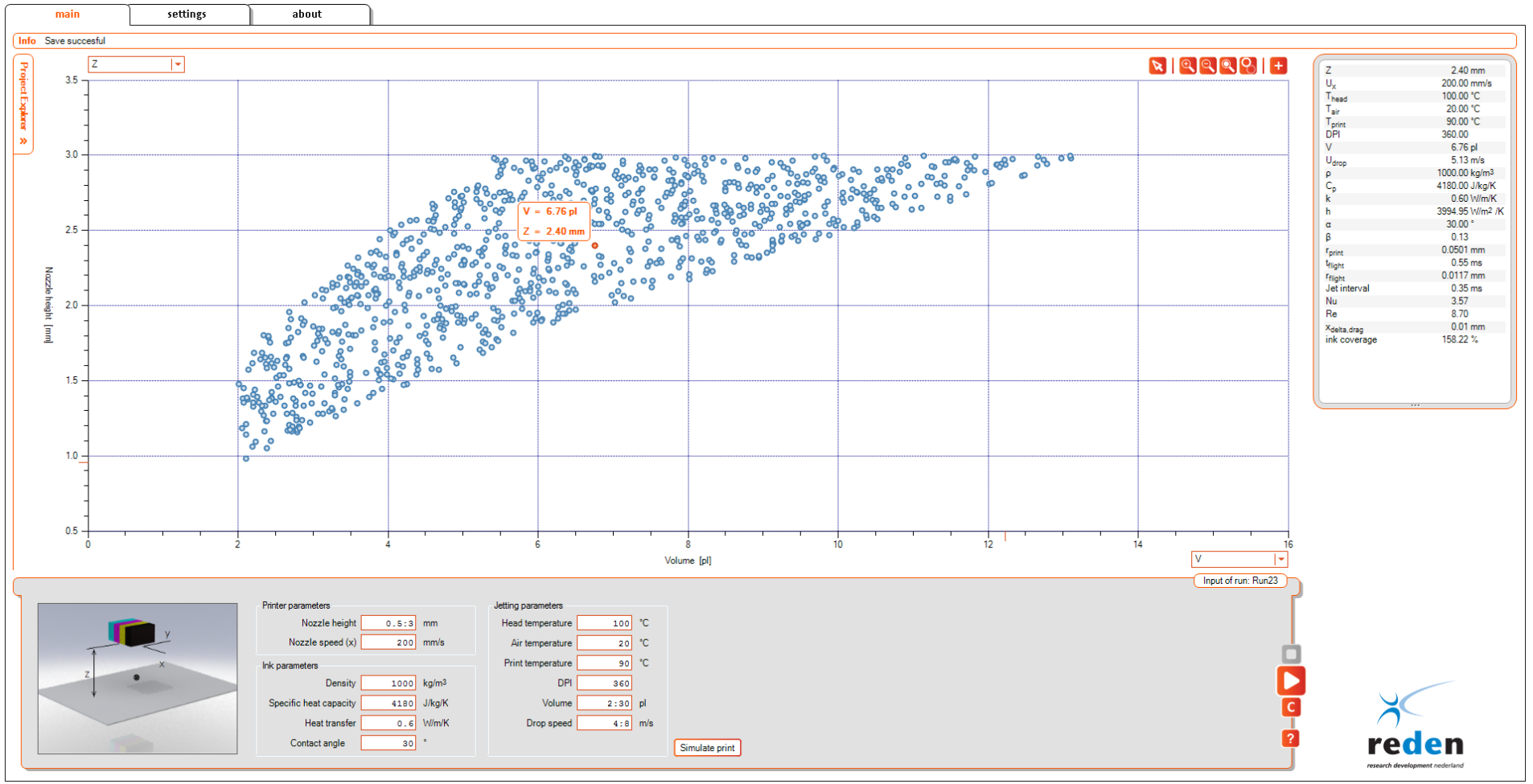
Density	1000	kg/m3
Specific heat capacity	4180	J/kg/K
Heat transfer	0.6	W/m/K
Contact angle	30	°

Jetting parameters

Head temperature	100	°C
Air temperature	20	°C
Print temperature	90	°C
DPI	360	
Volume	2:30	pl
Drop speed	4:8	m/s

Mr Reves knows (almost) all!

Droplet flight example



Mr Reves knows (almost) all!

Droplet flight example

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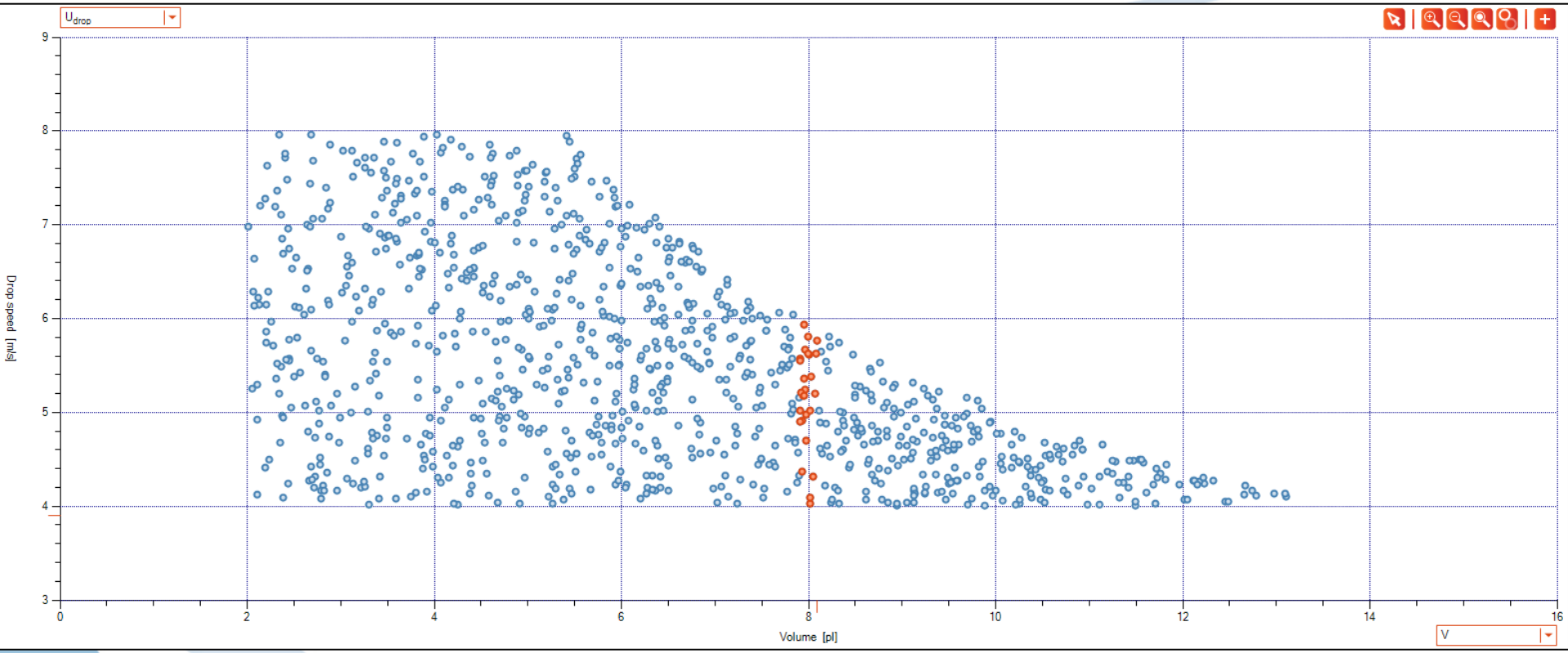

Mr Reves knows (almost) all!

Droplet flight example

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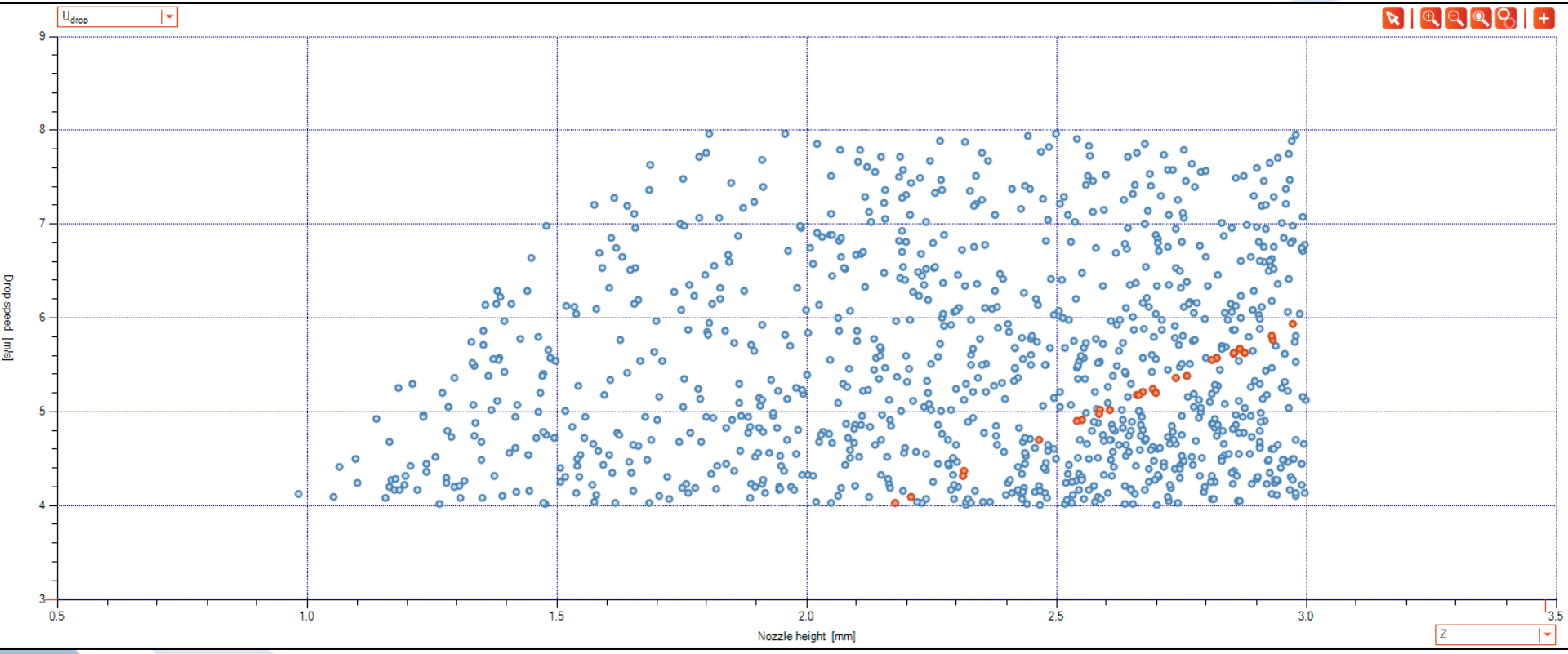

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Questions?

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