Injection moulding simulation of artificial test swarf (Micro-PIM)

Content

Karlsruhe Institute of Technolgy

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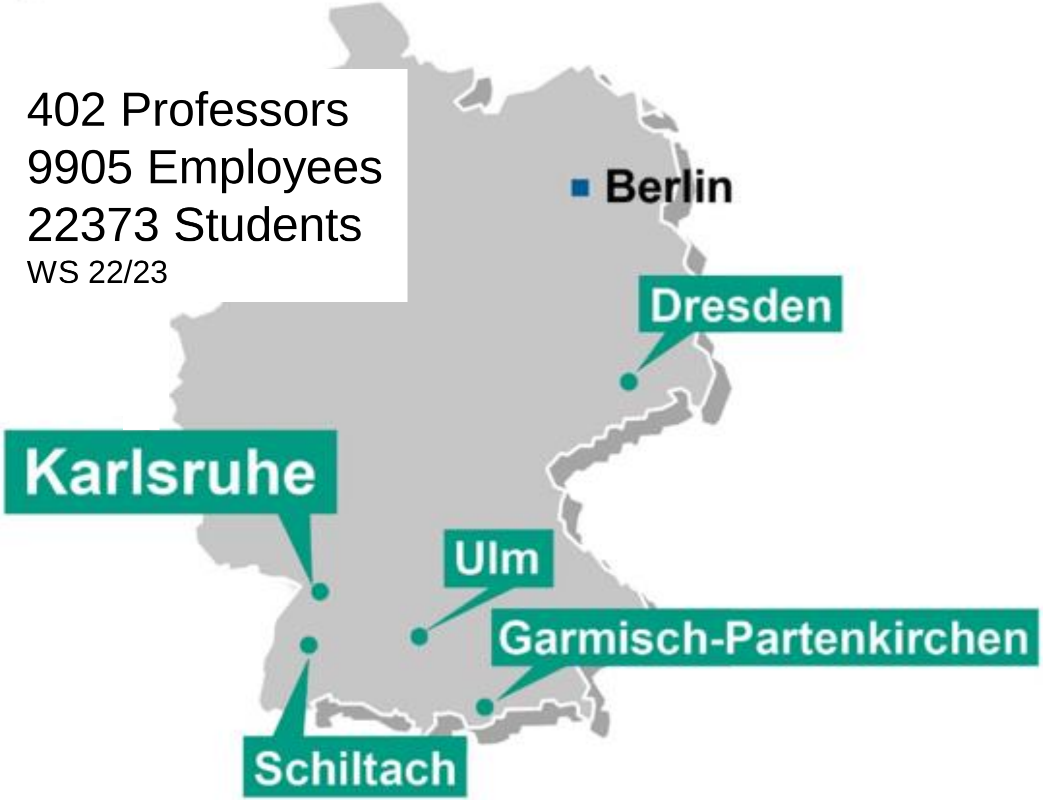

Institute of Applied Materials – Material Process Technology

- Kneader, extruder, rheometer etc. for feedstock development and –measurement etc.
- 5 Injection moulding machines
- Furnaces for debinding and sintering MIM- and CIM-parts

Introduction

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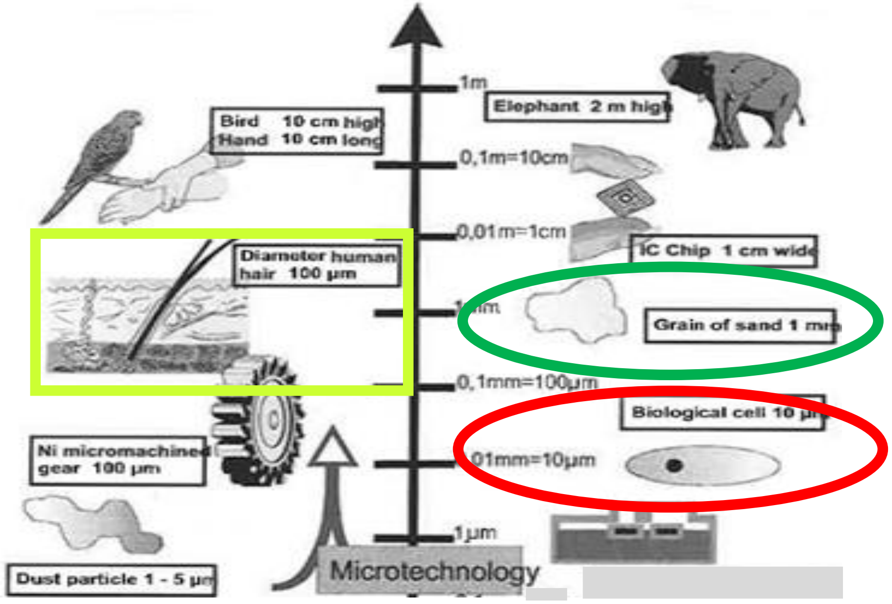
- What is Micro?



<u>Definitions</u>

Micro part
overall size, e.g. 3mm with relevant details in micrometre range

Micro structured part
Macro part with micro structured surface, e.g. DVD's

Source: KIT / IMT: Skript: *Grundlagen der Mikrosystemtechnik II,* 2009

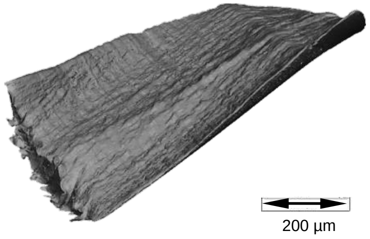
Introduction

- Issue: Wear and damage in moving components like bearings, pistons e.g. in engines and gearboxes caused by tiny flakes and swarf
- Idea: robustness tests to evaluate the risk of failure
- Aim: standardized test particles producible via powder injection molding

→ artificial swarf

Swarf reference model

source: photo



source: CT

Artificial Swarf

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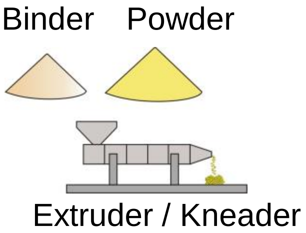
- Which kind of design for artificial swarf?
- Requirement:
  Wall thickness approximately 10 times greater than average grain size (d_{50} = 5µm)
- Which geometry of artificial swarf show significant wear and damage?
  - Size?
  - Edges?

Artificial Swarf

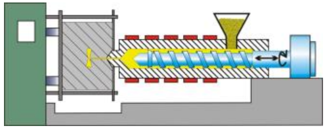
- Material: 42CrMo4 (high strength, high toughness, good hardenability, temper brittleness, high fatigue limit)
- Fabrication method: Powder injection molding

Process chain

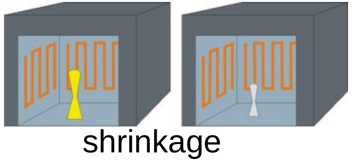
Creating feedstock



Injection molding

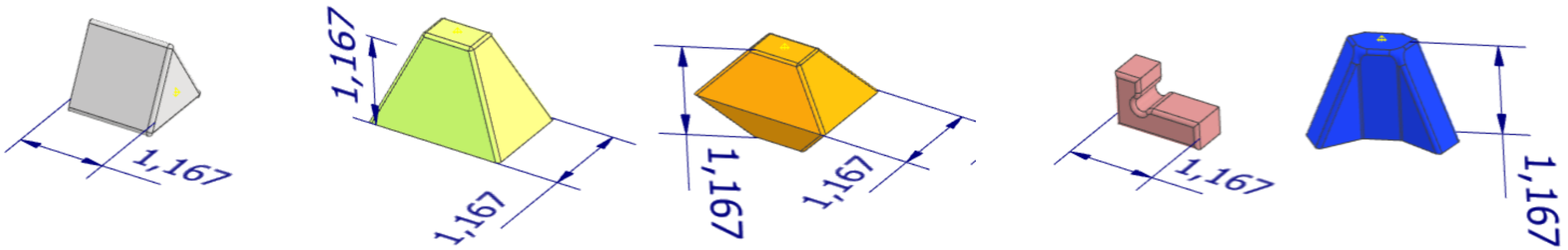


Debinding sintering



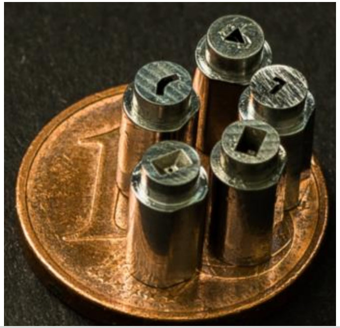
Artificial Swarf

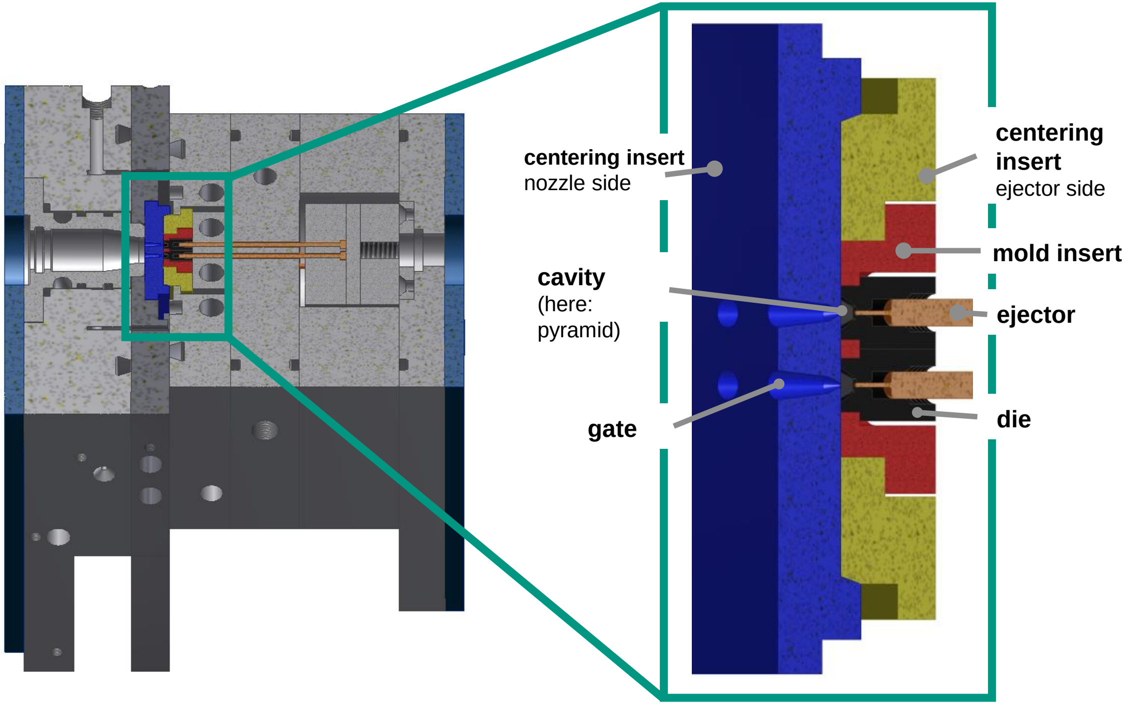
- max. lenght: 1mm (as sintered)
- Producible with an existing injection molding tool
- Varieties in size and number of edges



Injection molding tool

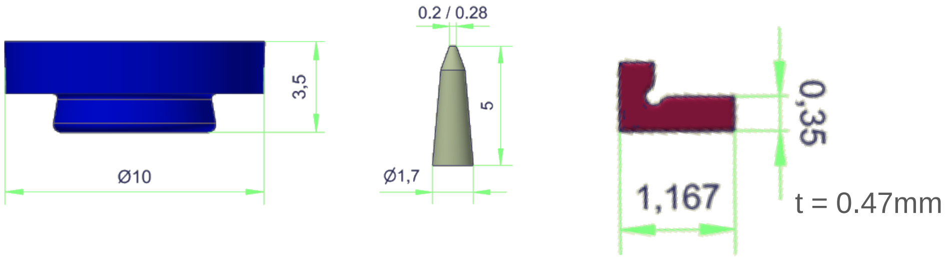
- One gate size for all parts. Smallest part defines gate size.
- 4 dies. Each die with one cavity.
- Dies exchangeable



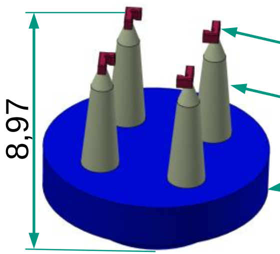


Geometry swarf „L“

- Size



- Volume ratio

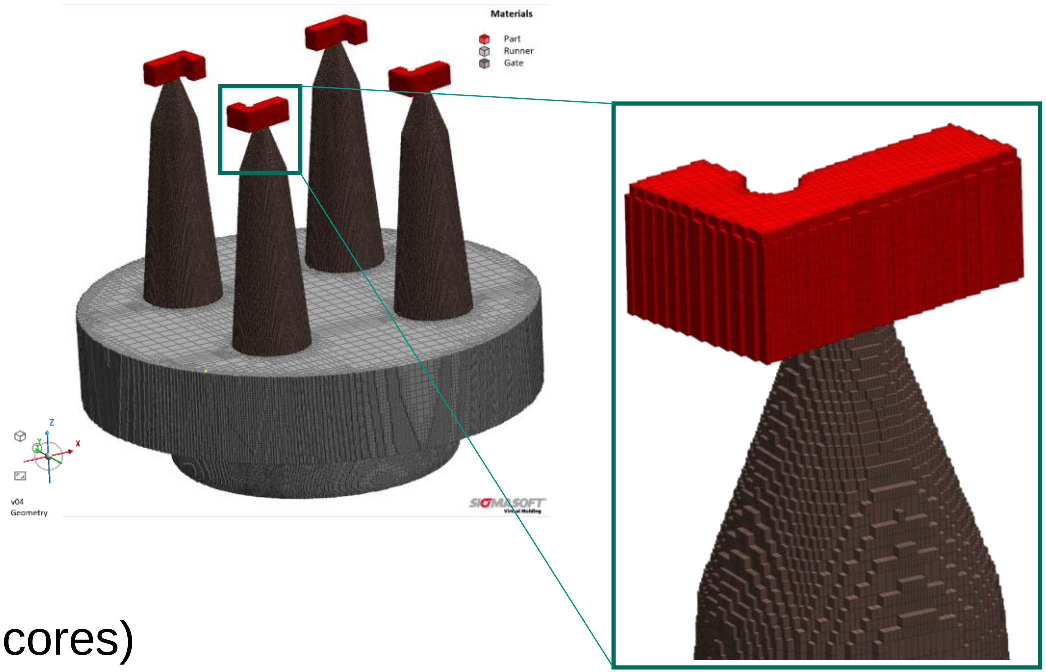


	Volume [mm³]	Volume [%]
part	0.95	0.4
gate	25.1	11
runner	202.4	88.6
Σ	228.5	100

Mesh

Parameter sets		Min. wall thickness		
		x [mm]	y [mm]	z [mm]
Rough	Runner	3	3	3
Fine	Gate	0.6	0.6	0.6
Very Fine	Part	0.03	0.03	0.1

Cavity cells	
Composed mesh	758,871
Cartesian mesh	9,759,695

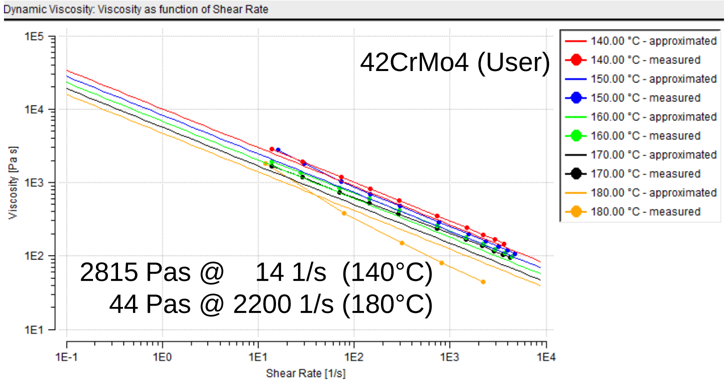


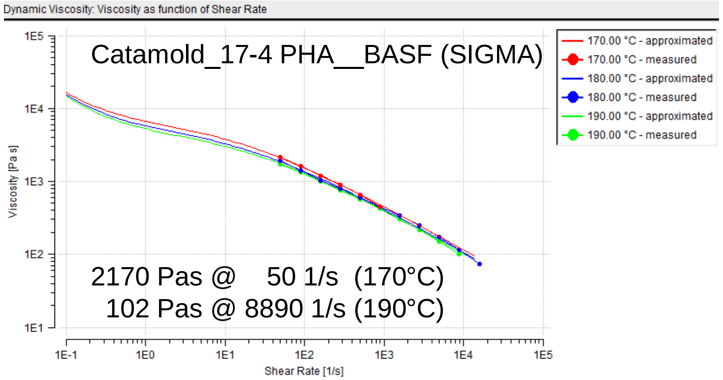
→ Calculation time: 7h 25m (2 cores)

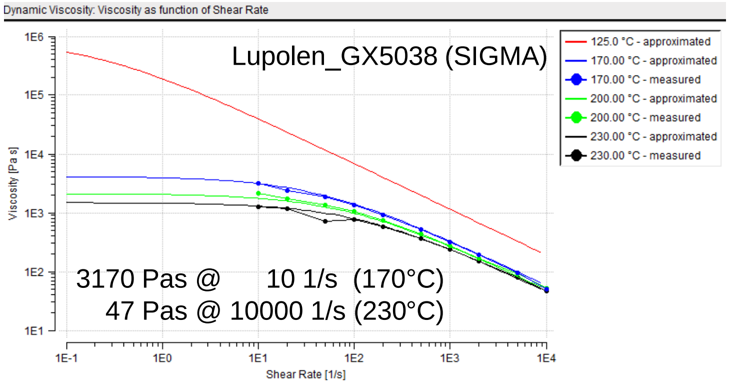
Part material

- Designed by KIT
- Metal Powder: 42CrMo4 (1.7225)
  - $D10 = 2.9\mu m$
  - $D90 = 5.7\mu m$
- Binder: Paraffin wax / PE / stearic acid – 50 / 45 / 5 vol%
- Powder – binder ratio: 63vol%
  - Magnification 1.167 (compensation shrinkage during sintering)
- Compounding: Measurement kneader
  - Constant mixing torque = homogeneous feedstock preparation

Part material

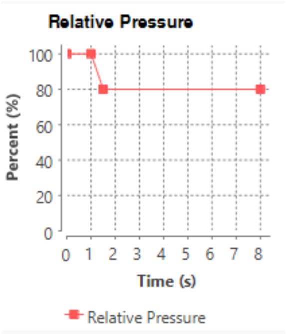






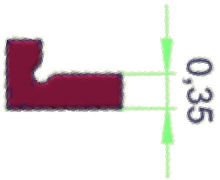
Simulation swarf „L“

- Fill time: 0.5s
- Packing
  - Switch over: 99,5% fill state
  - Inlet control: 5s
- Result package
  - Filling & cooling
    - from 0.0% to 90% every 5.0%
    - from 90% to 98% every 2.0%
    - from 98% to 99.5% every 0.25%
    - from 99.5% to 100% every 0.02%

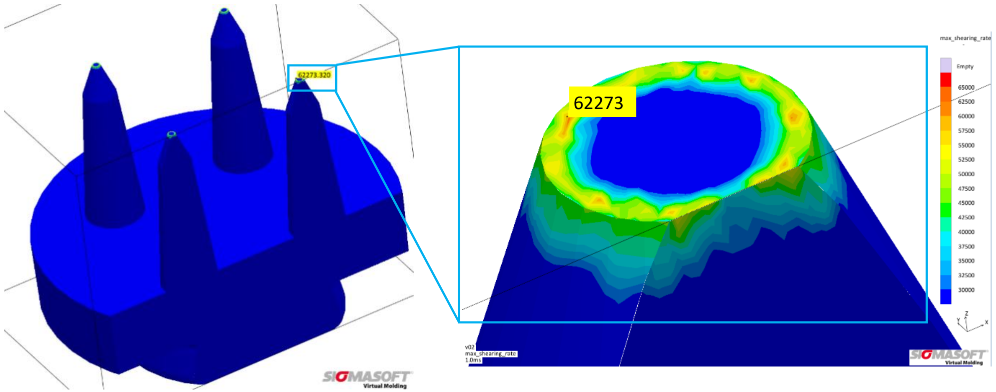


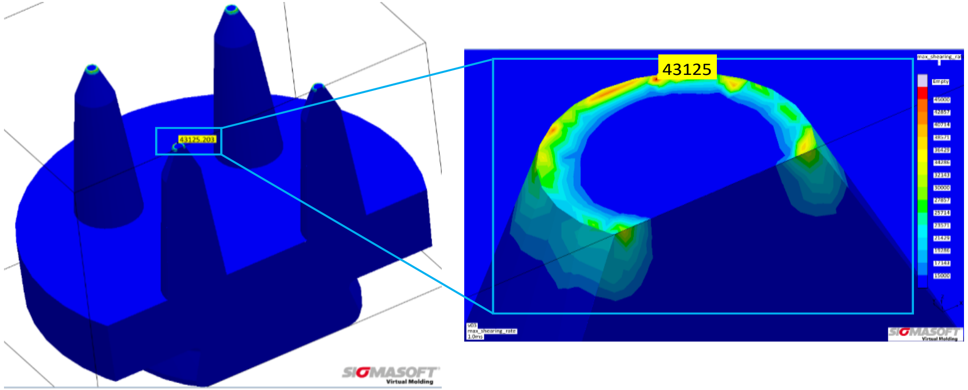
Simulation swarf „L“

- Diameter gate: 0.2mm
  - Max. shear rate: 62,000 1/s



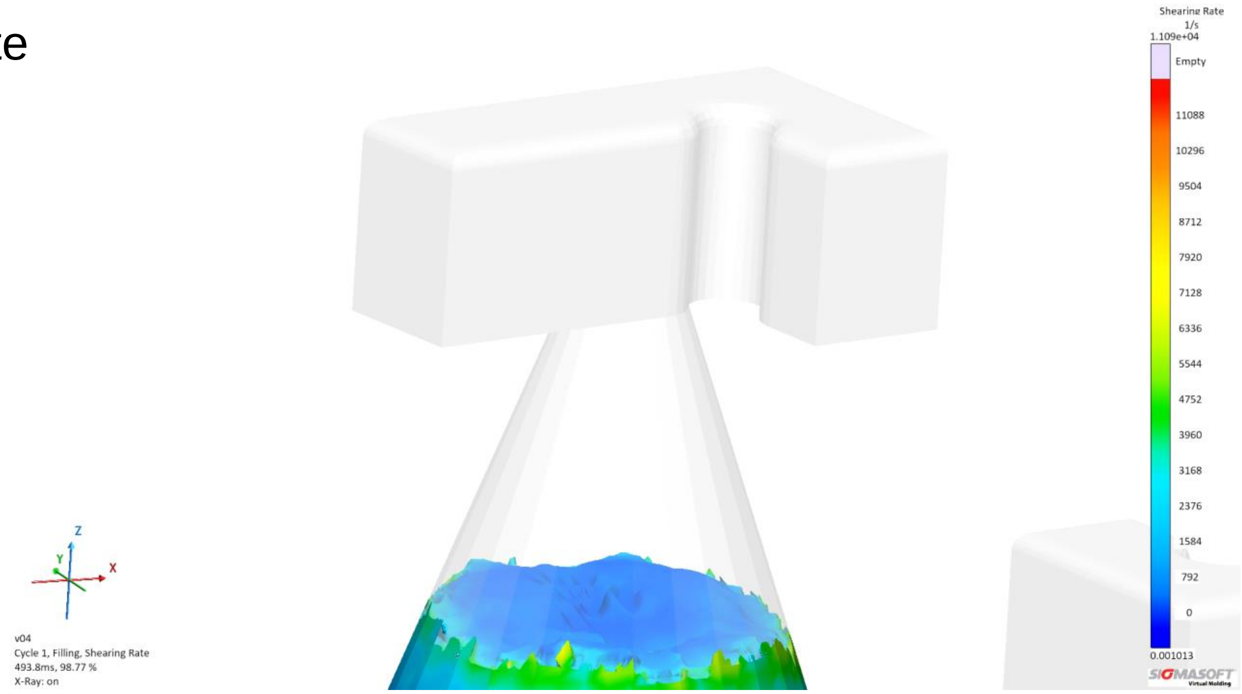
- Diameter gate: 0.28mm
  - Max. shear rate: 43,000 1/s
- Critical shear rate value: ≈40,000 1/s valid for KIT-Feedstock





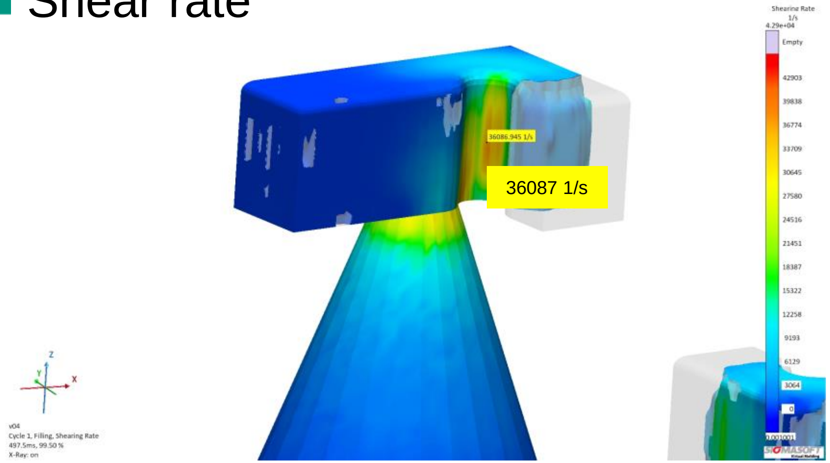
Simulation swarf „L“

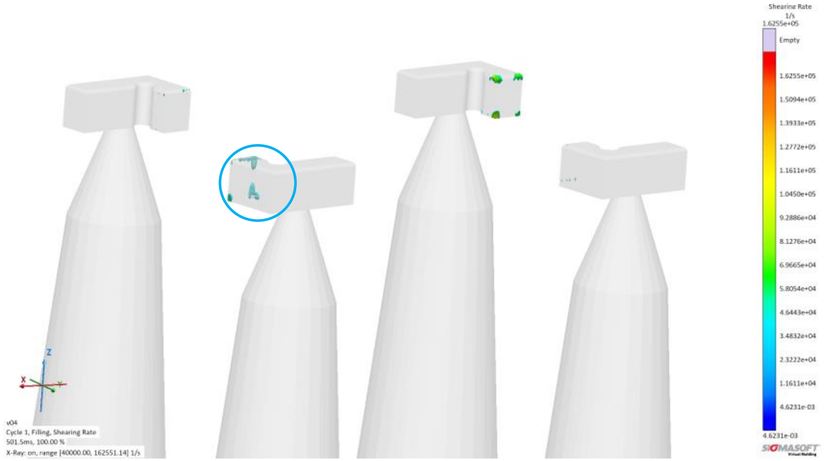
- Shear rate

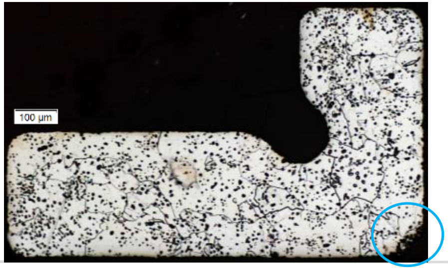


Simulation swarf „L“

- Shear rate





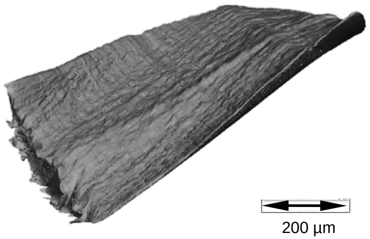


Potential effect of high shear rate

Effect of increasing shear rate

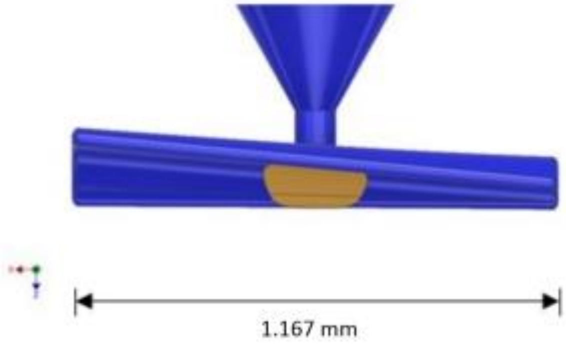
- Artificial swarf near to reference model

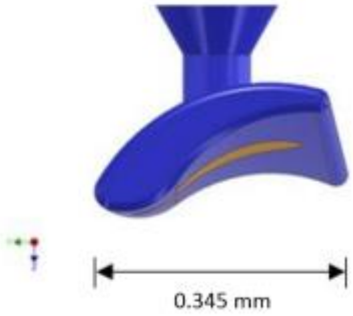
Swarf reference model



source: CT

t = 5µm……70µm



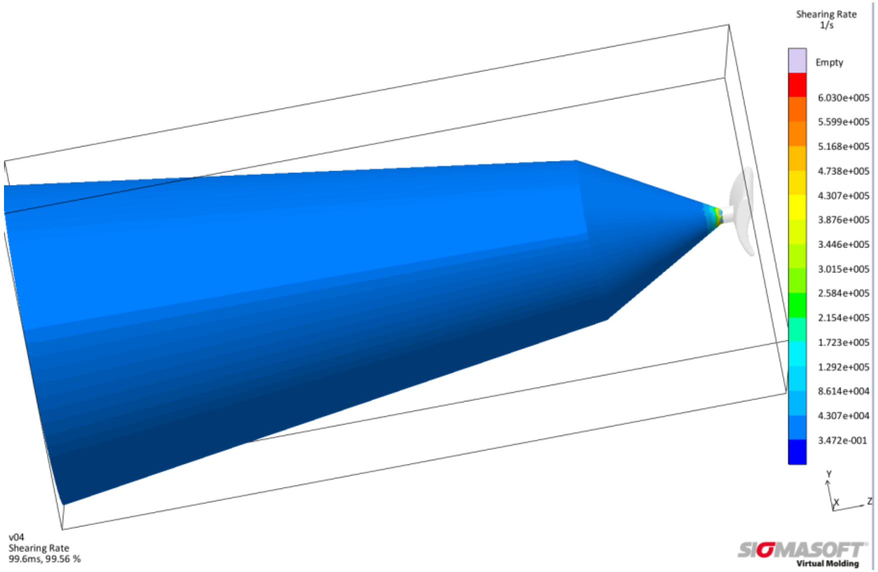


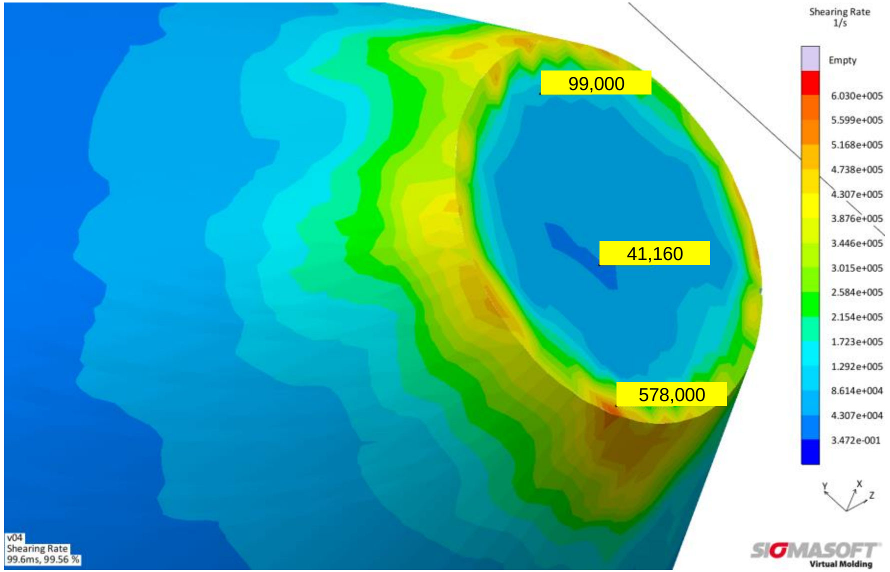
t = 10µm……80µm

Gate: Ø 0,1

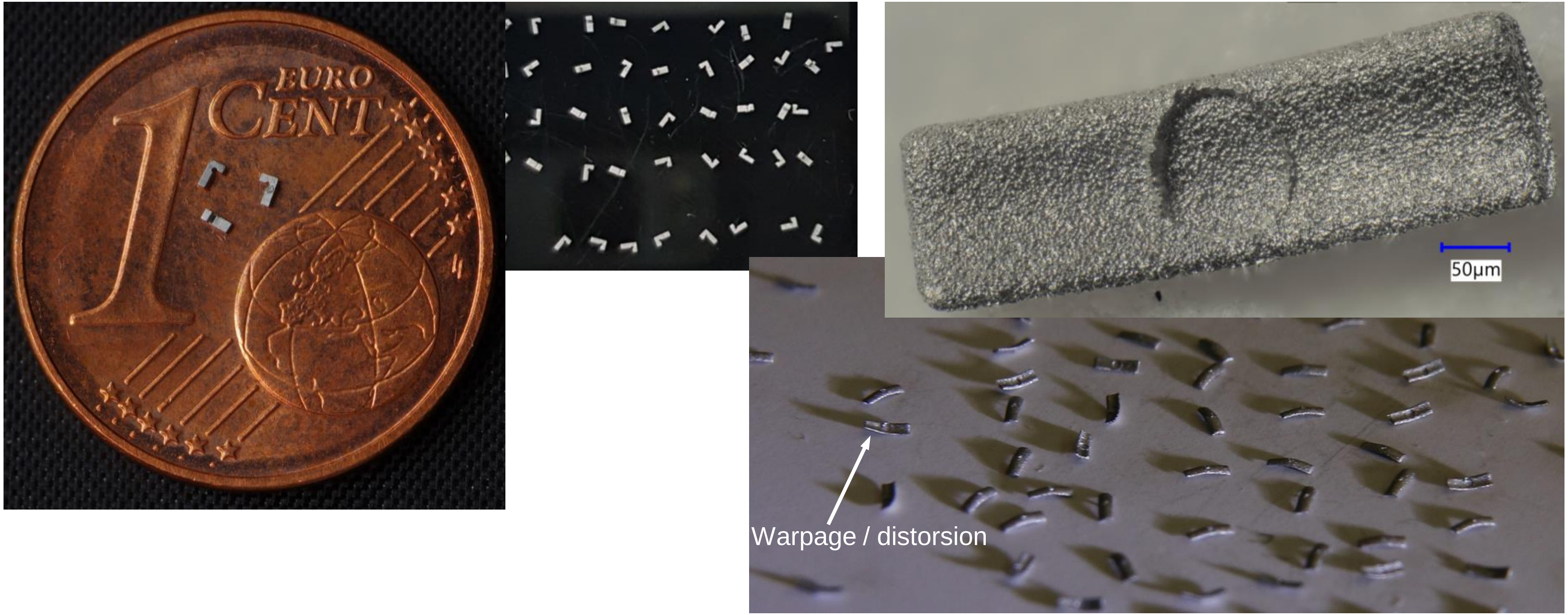
Effect of increasing shear rate

- Increasing shear rate due to decreasing gate diameter + part geometry





Effect of increasing shear rate



Conclusion

- High number of mesh elements for micro parts simulation.
- Small parts, long calculation time.
- Simulation can help avoid high shear rates in PIM-parts. This improves part quality.
- For the PIM process, internal material characterisation is important and useful.

Thank you !