All models are wrong
but some are useful

George E.P. Box

An Automatic CAE Tool for autonomous feasibility assessment of aluminum gravity die castings – Development & Calibration

Dr.-Ing. Marcus Schopen
AMAP Colloquium
10.11.2022, Aachen

AGENDA

- Introduction
- Development of the Automatic CAE Tool
- Calibration and Validation
- Application
- Conclusion

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Introduction

Motivation

Product development process:

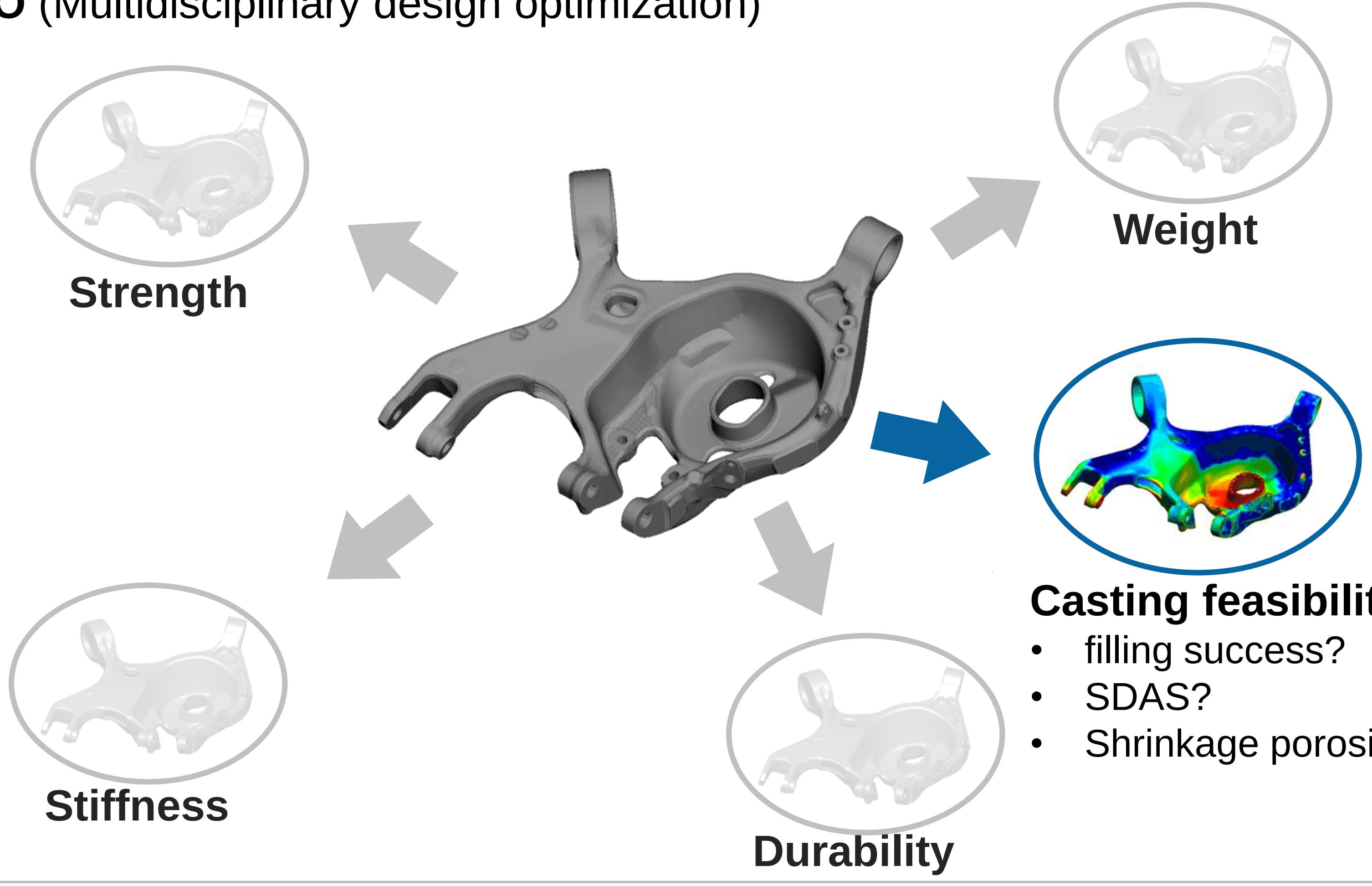
- **Conventional: manual** approach by casting experts, **late ➔limiting** design iterations
- **New: fully automated** for multidisciplinary design optimization (**MDO**), **early ➔ „unlimited“** (**unconventional**) design iterations

Key questions

1. Is it **possible** to develop a fully Automatic CAE Tool?
2. Which level of test data quality is necessary to **calibrate** and **validate** the Automatic CAE Tool?

Introduction

MDO (Multidisciplinary design optimization)



Casting feasibility
- filling success?
- SDAS?
- Shrinkage porosity?

Requirements
- batch mode capability
- fast & efficient → directional
- no 3D modeling

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Automatic CAE Tool Overview

User/MDO

- Geometry
- Alloy
- Engineering Spec.

Output: feasibility assessment (text file)

Automatic CAE Tool

Pre-Processing

Solidification I

Assessment I & casting system (1D)

$t_{calc} \downarrow 30\%$

Solidification II + analytical tool

$t_{calc} \downarrow 90\%$

T_m

Assessment II
- Filling success (analytical)
- SDAS (liquidus time)
- Shrinkage porosity (ASTM)

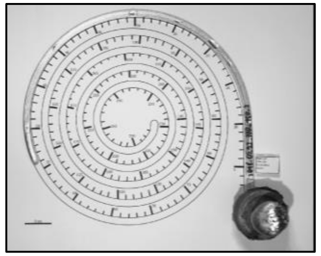
Validation

CAE mesh size study

best-practice rules

new

Fluidity Spiral



Multi-Tool

- pouring temperature T_p, mold temperature T_m DoE

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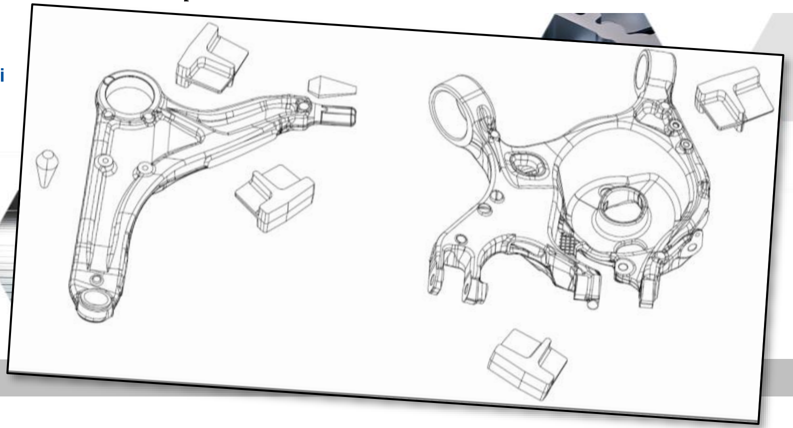

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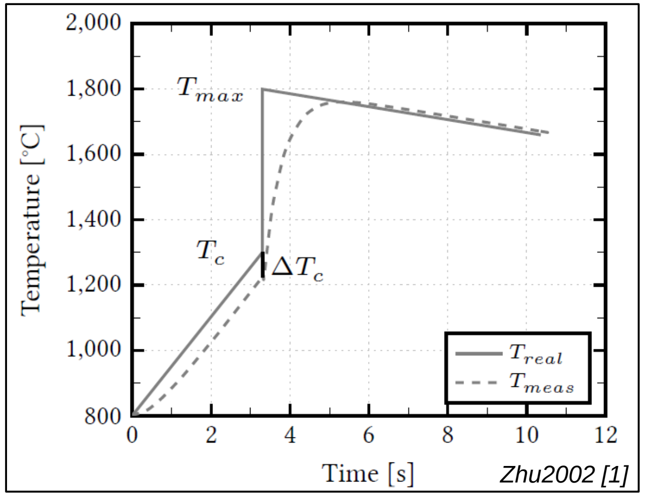
Calibration Method

I. Reliable Data extraction from the experiments

1. Analysis of real process conditions and results as required input for calibration ➔ extrapolation method
2. Confirmation of best initial casting conditions/implemented rules

II. Simulation Calibration

1. Melt temperature
2. Filling success
3. Shrinkage porosity
4. (SDAS) ➔ correlation t_{liq} from literature



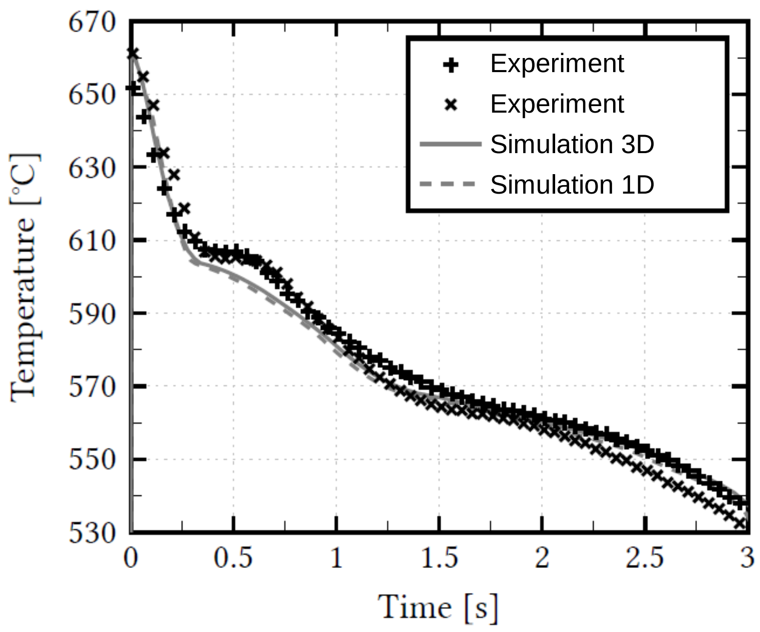
[1] Zhu, P.; Li, J. C. M.; Liu, C. T.: “Reaction mechanism of combustion synthesis of NiAl.”In: Materials Science and Engineering: A 329-331 (2002), pp. 57–68.

1. Melt Temperature

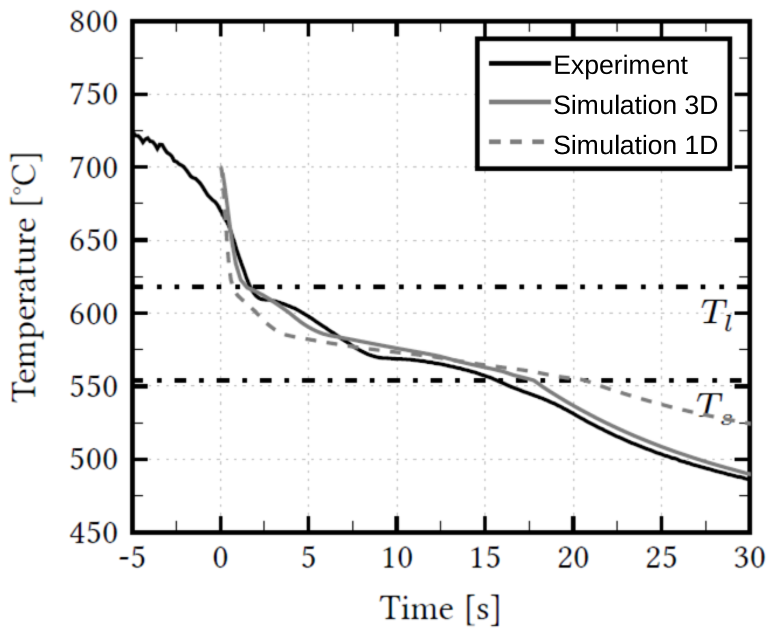
HTC adjustments, correction factors of 1D-components

- 3D components ➔ 1D components

Fluidity Spiral



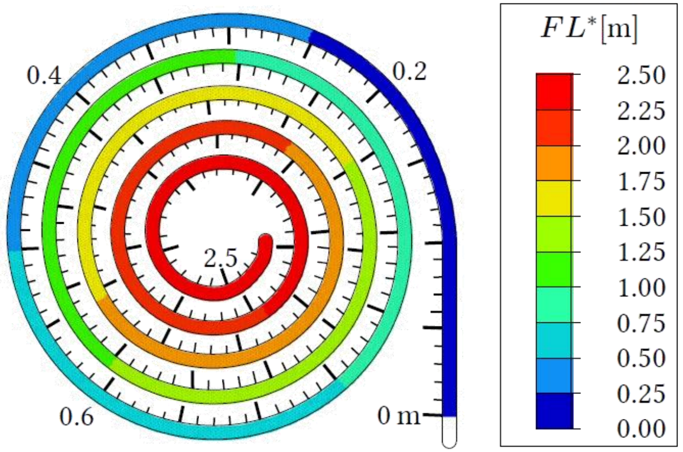
Multi-Tool



Different HTC values
➔ different shapes
➔ component classes

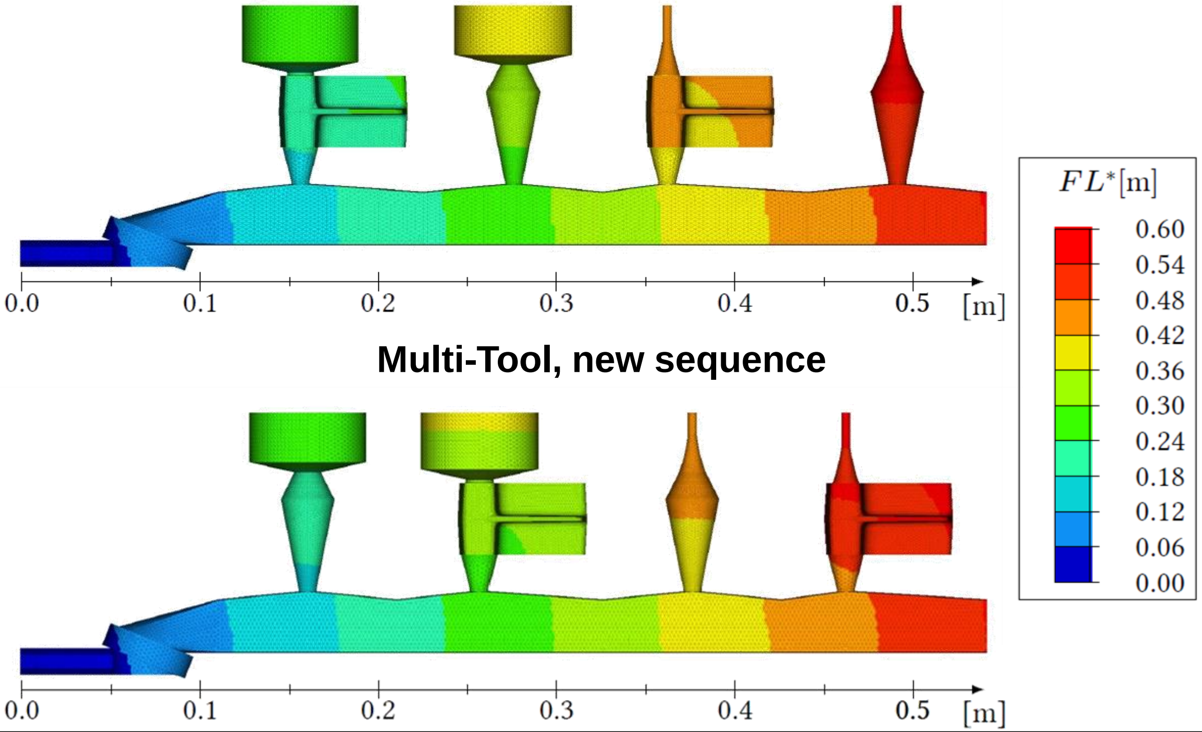
2. Filling Success – Geometrical Flow Length FL^*, qualitative

Fluidity Spiral



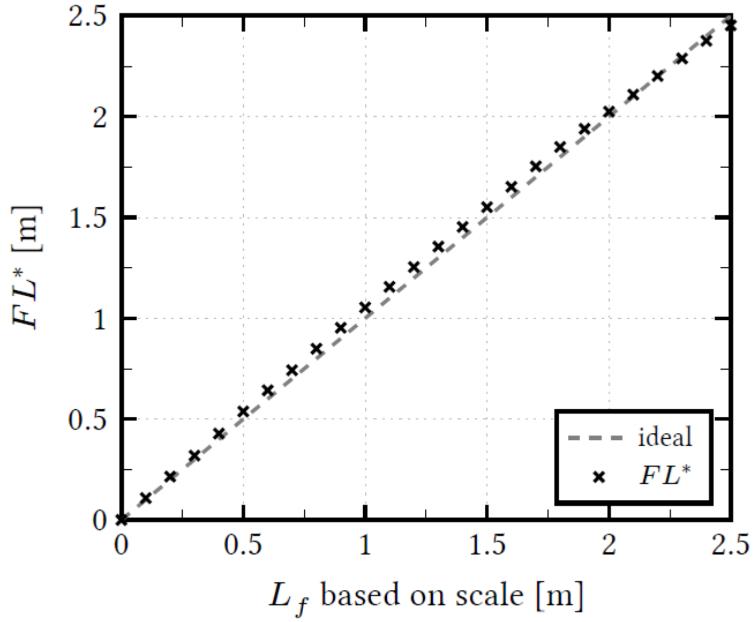
Multi-Tool, full factorial DoE sequence

Multi-Tool, new sequence

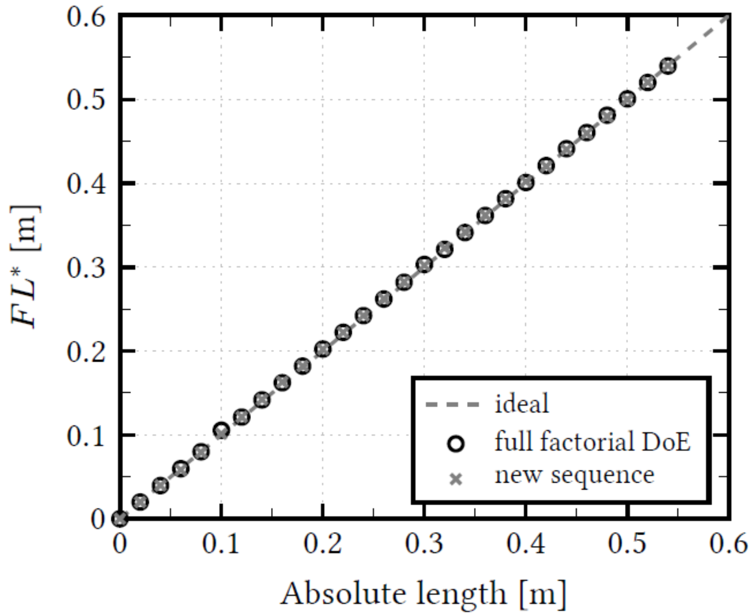


2. Filling Success – Geometrical Flow Length FL^*, quantitative

Fluidity Spiral



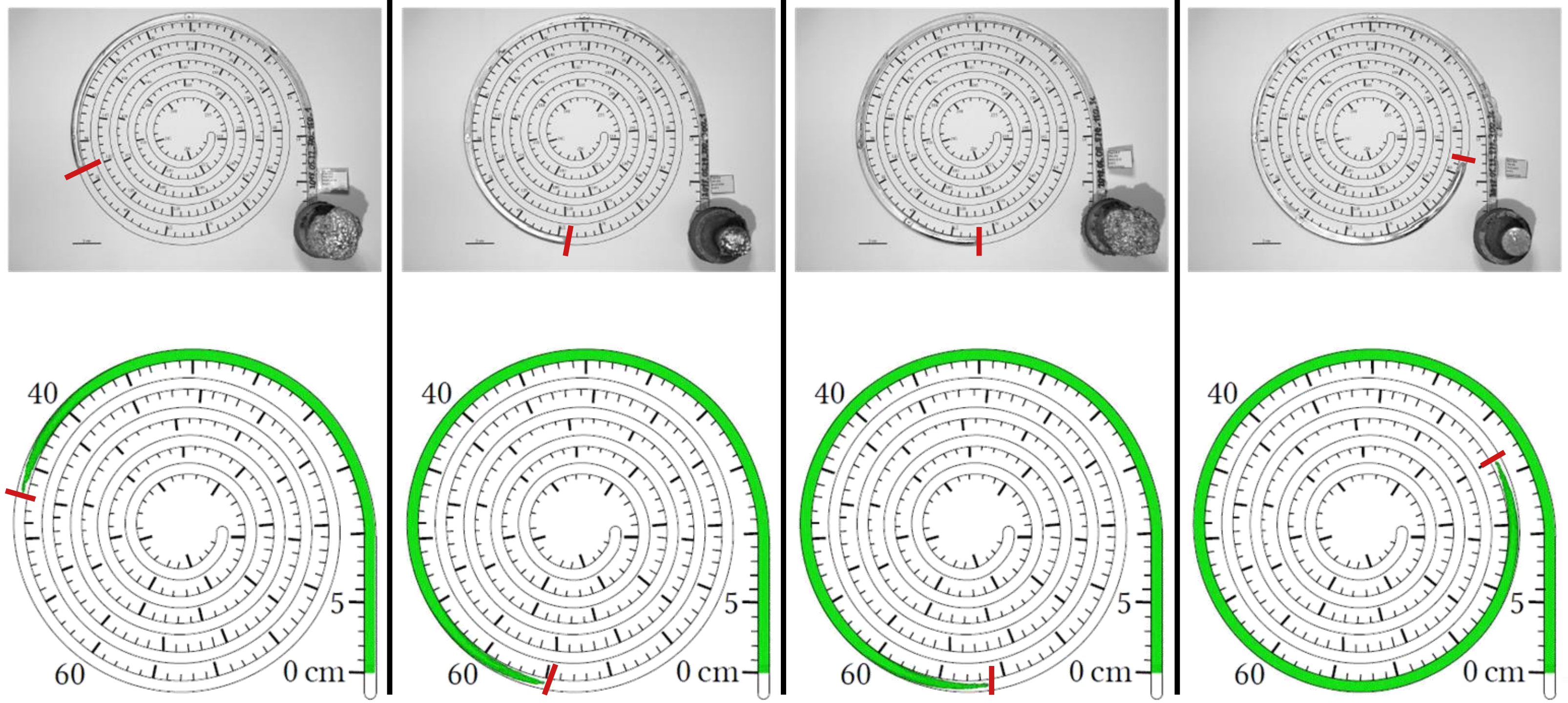
Multi-Tool



Almost perfect match!

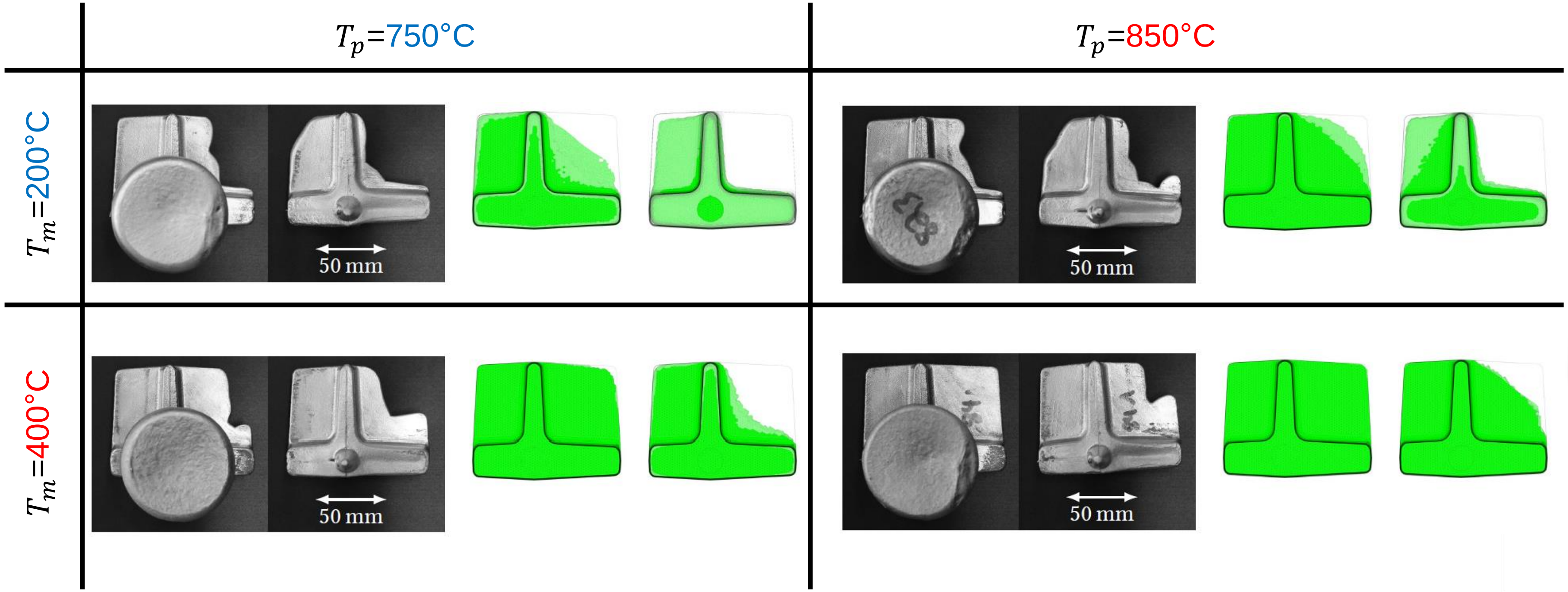
2. Filling Success – Fluidity Spiral (SFcrit=0.7)

T_p=700°C, T_m=150°C	T_p=700°C, T_m=300°C	T_p=780°C, T_m=150°C	T_p=780°C, T_m=300°C



- Good match!
- T_p impact is more dominant than T_m

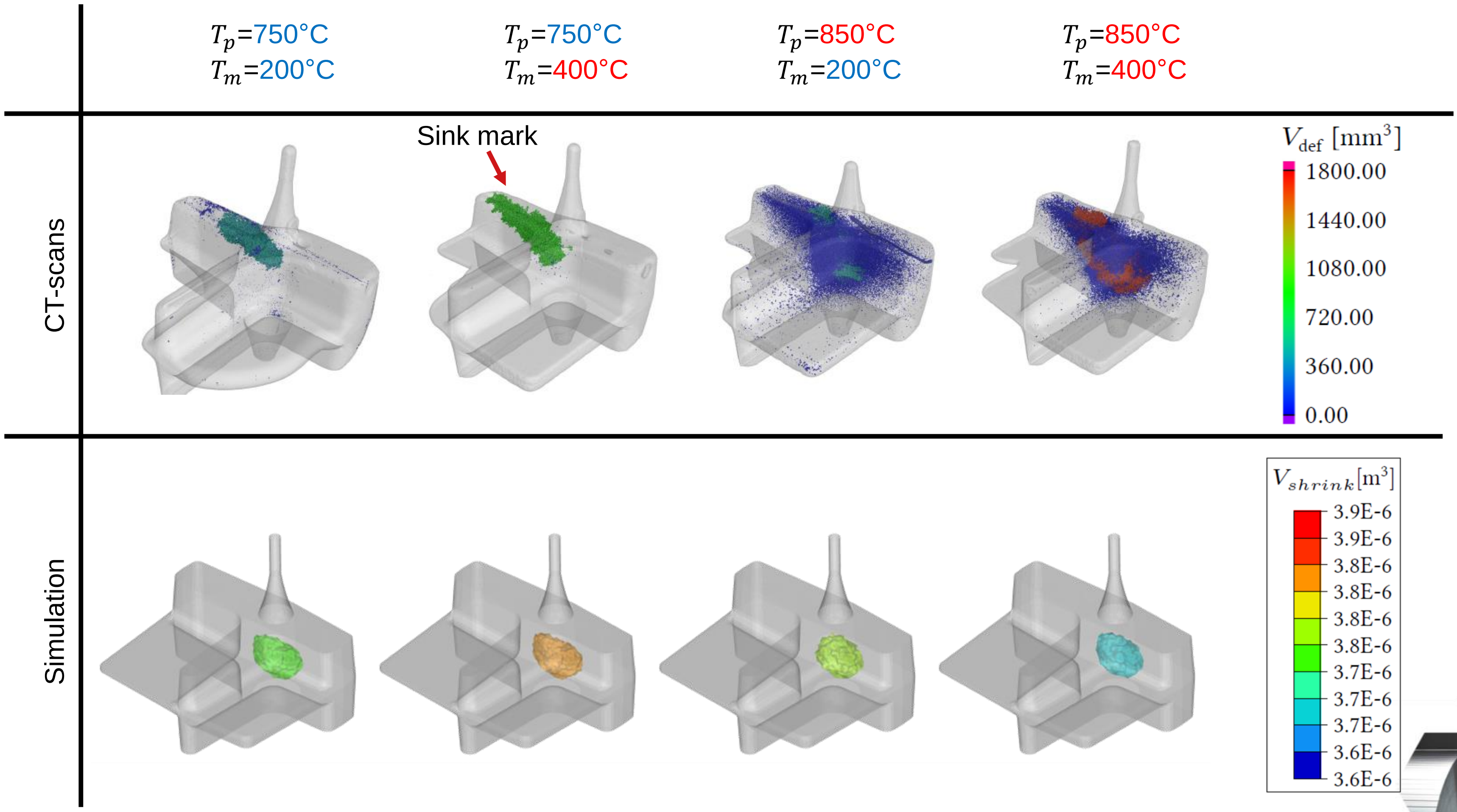
2. Filling Success – Multi-Tool (SFcrit=0.3)



- Good match!
- T_m impact is more dominant than T_p

SFcrit variation between Fluidity Spiral and Multi-Tool
➔ Part specific calibration database

3. Shrinkage Porosity – Multi-Tool



- No correlation with temperatures
- Increased Hydrogen-Porosity at elevated T_p
- Different location ➔ sink mark formation

Automatic CAE Tool
- Development ☑
- Fast & efficient ☑
- Calibration & validation ☑
- …

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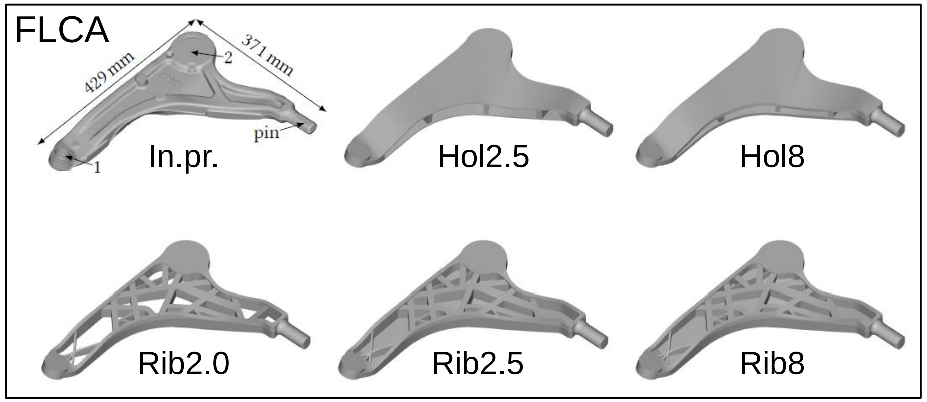
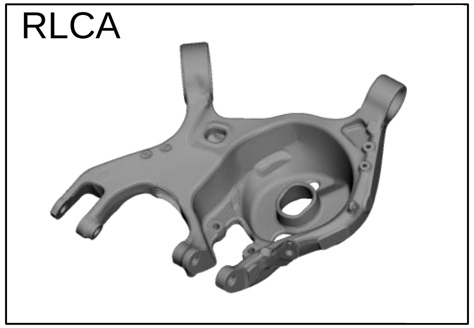
Application

- design variation
- 3 different SFcrit (0.3, 0.5, 0.7)
- process temperatures

…on…

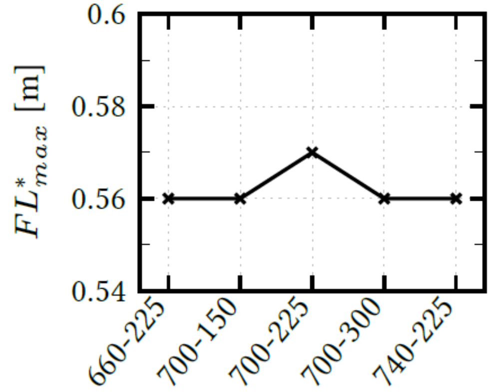
- Filling success & Flow Length
  - CR_{fill}: critical ratio number of non-fill-able nodes divided by total nodes
- SDAS
- Shrinkage porosity





Application

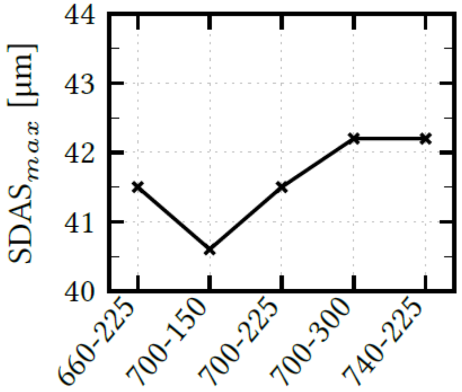
- Process Temperatures: T_p-T_m, e.g., T_p=660°C, T_m=225°C➔ 660-225



FL_{max}

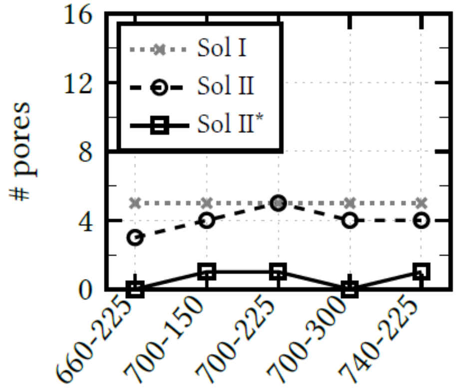
- No significant impact

➔ same mesh



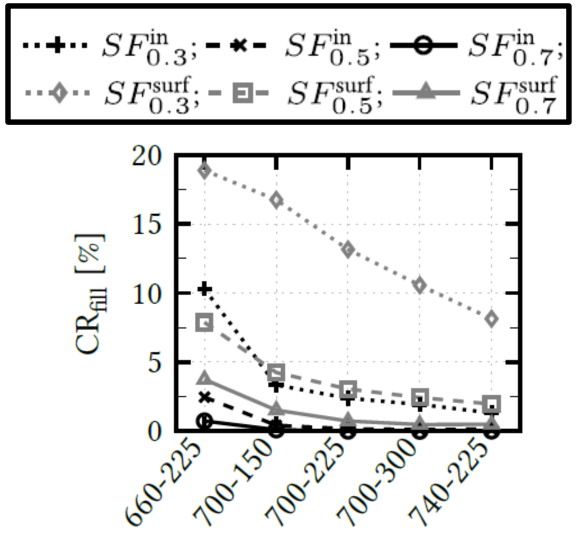
$SDAS_{max}$

- No significant impact ➔ Feeder patch and wall thickness impact is more dominant than temperature



pores, multi-inlet

- No significant impact



Filling success

- Increasing process temper-atures decreased CRfill

Automatic CAE Tool
- Development ☑
- Fast & efficient ☑
- Calibration & validation ☑
- Sensitivity & plausibility ☑

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Key Question I – Possible? ✓

- batch mode capability ✓
- fast & efficient ✓
- no 3D modeling ✓

Key Question II – Calibration & Validation? (✓)

- not direct applicable data

Accuracy increase ➔ unsolved issues of casting CAE (gap dependent HTC, gas porosity) solved

plausible & identifying relevant differences (sensitivity)

- specific validation database

manual, experience based ➔ **fully automatic, analysis driven**

Full text available:

https://publications.rwth-aachen.de/record/850402

Thank you!