AUTODESK

Moldflow Summit 2025:

Automated Cavity Balancing through gate location optimization and flow leader generation using Autodesk Moldflow

Felipe Porcher & Paul Borger

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Automated Cavity Balancing through gate location optimization and flow leader generation using Autodesk Moldflow

Presenters: Felipe Porcher[1] and Paul Borger[2]

Contributors: Prof. Dr.-Ing. Georg Gruber[3], Dr.-Ing. Falk Rohnstock[1], Prof. Dr.-Ing. Dietmar Auhl[1]

[1] Technical University of Berlin, Berlin, Germany
[2] BSH Hausgeräte GmbH, Berlin, Germany
[3] HTW Univerisity of Applied Sciences, Berlin, Germany

Overview

Introduction

Berlin University cooperation

Products and Brands of BSH Hausgeräte GmbH

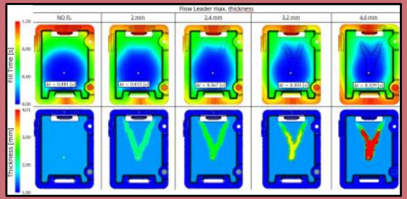
Motivation

Part development process

Cavity Balancing

Gate Location Optimization

Geometry Optimization (Flow Leader)



Summary

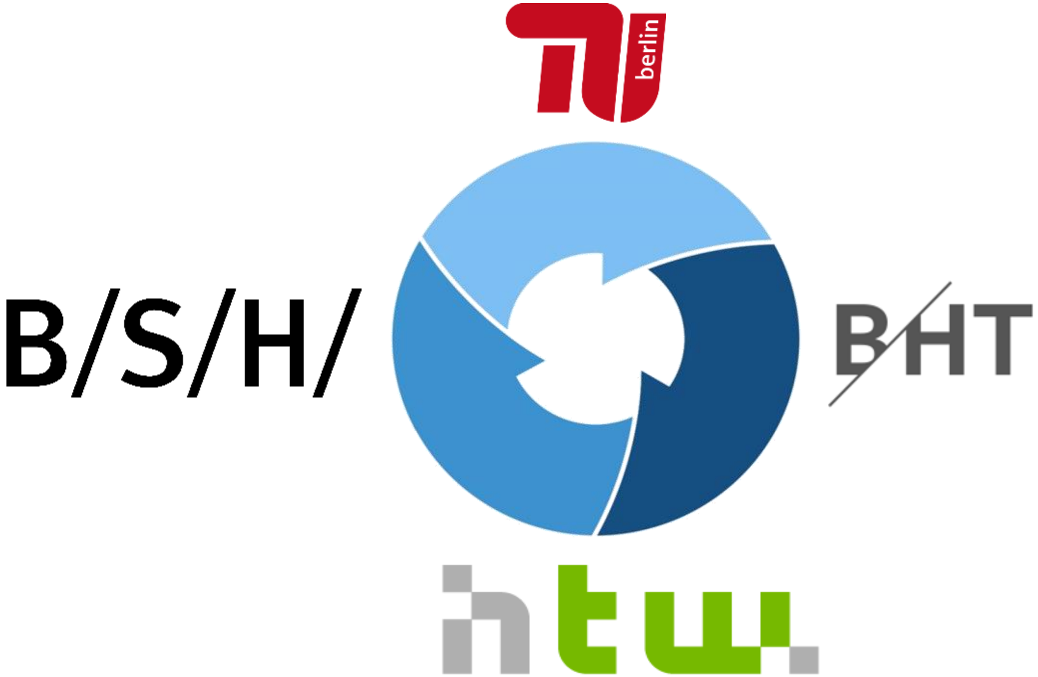
BSH / Berlin University Cooperation

Brief introduction

- Successful cooperation since 2011
- Overall participation of over 200 students
- 8 different institutes involved
- Organized in 8 different topic clusters
- More than 150 finished thesen
- Legal framework for collaborations
- 7 PhD finished 4 running

City of Berlin

- More than 100.000 students
- More than 30 different universities
- Great history of inventions and research



BSH Hausgeräte GmbH

Our numbers

14.8

BILLION EUROS TURNOVER

60,000

EMPLOYEES

No. 1

IN EUROPE*

38

FACTORIES WORLDWIDE**

*per value

**As of August 2024

Source: https://www.bsh-group.com/

BSH Hausgeräte GmbH

Our products

Ovens

Cooktops and Ventilation Hoods

Coffee Machines

Dishwashers

Washers and Dryers

Kitchen Machines

Refrigerators

Vacuum Cleaners

Source: Company presentation 03/2025

BSH Hausgeräte GmbH

Our brands

Appliance Brands
Home Appliances under the brands

Ecosystem Brand

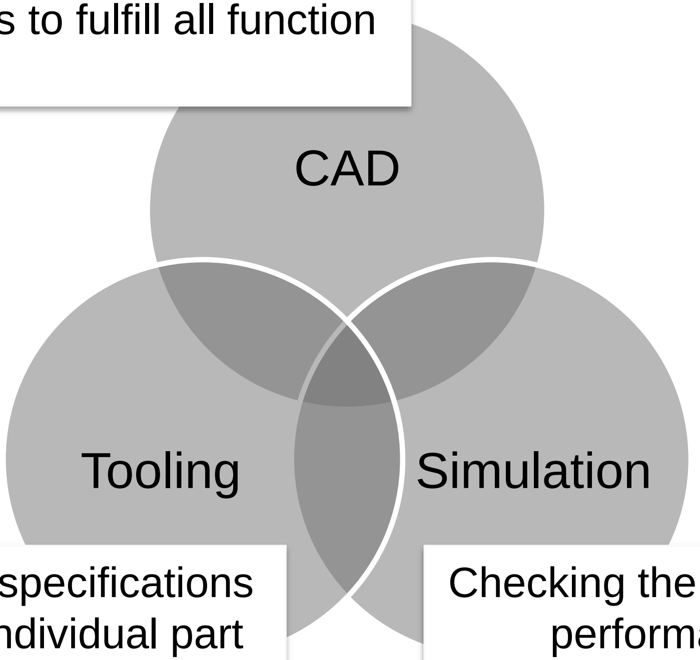
Service Brands

Source: Company presentation 03/2025

Motivation

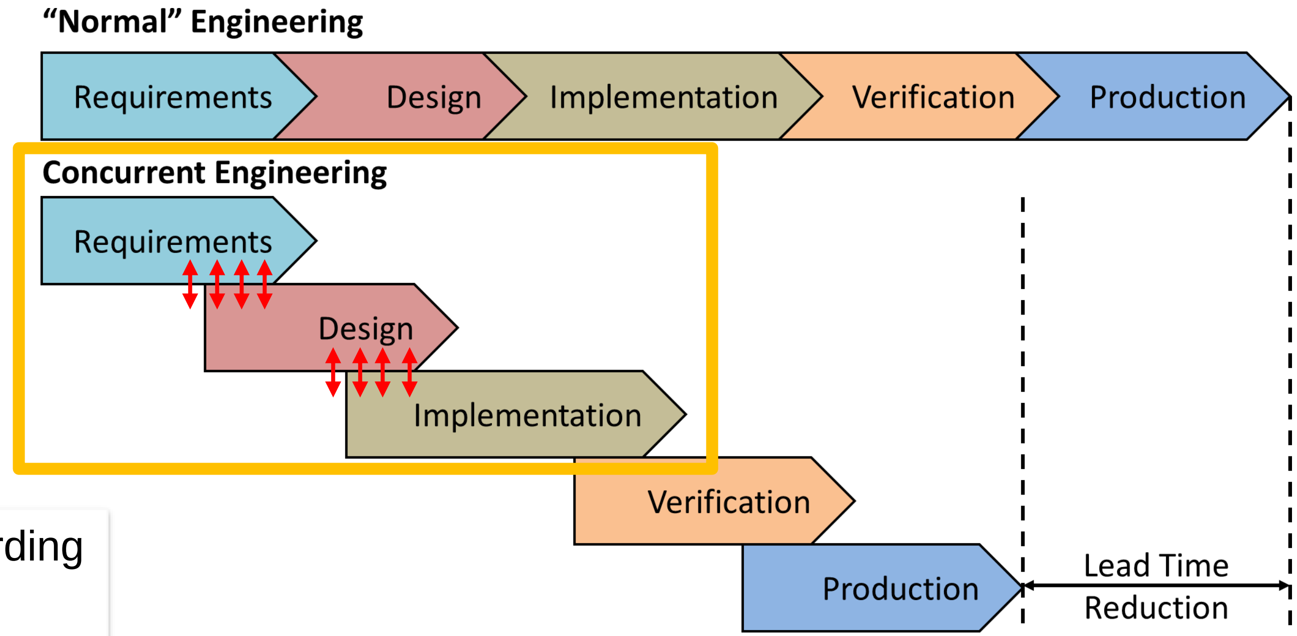
Development process of plastic parts

Designing parts to fulfill all function



Creating tool specifications to meet the individual part requirements

Checking the part regarding performance and manufacturing



Adapted from https://www.allaboutlean.com/wp-content/uploads/2021/01/Concurrent-Engineering.png

→ High number of iterations for one part at an early design phase

Motivation

Challenges

Multiple…

Brands

Parts and Tools

Appliances

Design Iterations

and

Reduced…

Development Time

Labor Force

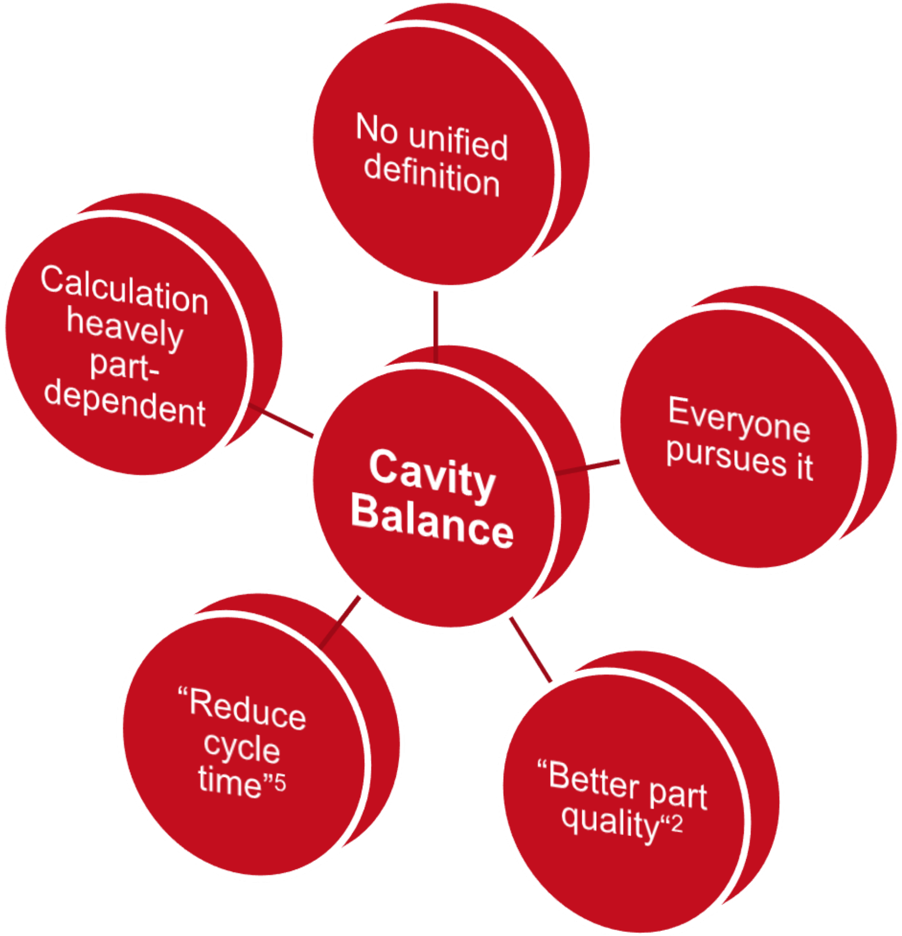
leads to

Automation

AUT PT

Definitions:

- "The process of **altering the flow front within a cavity** through thickness and design changes such that a desired fill pattern is achieved". [1]
- **"The flow paths in the cavity should be the same or similar length everywhere."** [3]
- "Balancing the filling of the cavity in such a way as to **minimize the overall flow resistance**". [1]



Also called:

- Balanced flow [2, p.231]
- Evenly fill of the cavity [3, p. 94]
- Uniform mould filling [4, p. 46 & p.120]

[1] Lam, Y. and Seow L. W. (2000) 'Cavity balance for plastic injection molding', Polymer Engineering and Science, vol. 40, no. 6, pp. 1273-1280.
[2] Zhai, M., Lam, Y., Au, C. K. and Liu, D. S. (2005) 'Automated Selection of Gate Location for Plastic Injection Molding Processing', Polymer-Plastics Technology and Engineering, vol. 44, no. 2, pp. 229-242.
[3] Dangel, R. (2016) Injection moulds for beginners, Munich, Cincinnati, Hanser Publishers; Hanser Publications.
[4] Steinko, W. and Bader, C. (2008) Optimierung von Spritzgiessprozessen, München, Hanser.

Gate Location Optimization

Gate Location Optimization

Motivation

- Gate locations strongly influence quality and cost of injection molded parts, specially for fiber reinforced thermoplastic
- Engineer’s experience may not lead to the best design
- Manual tryouts of different gate location is a time consuming task
- Currently available commercial solutions are limited in function and individual requirements

Best gate location?

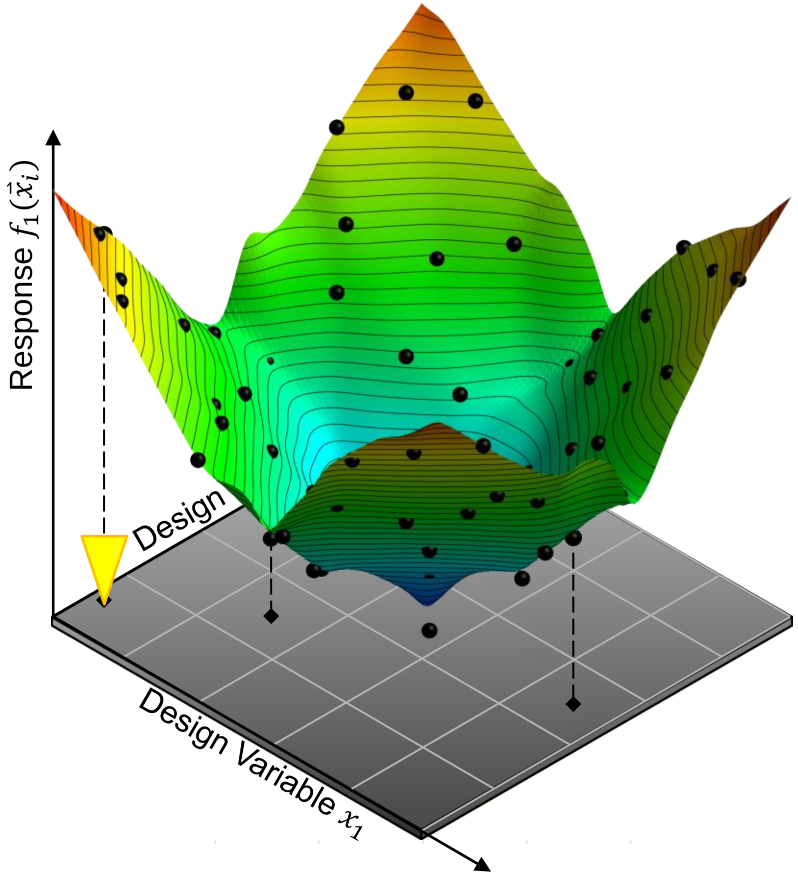
Automated gate location optimization workflow to improve part quality of injection molded plastic parts in the early design phase.

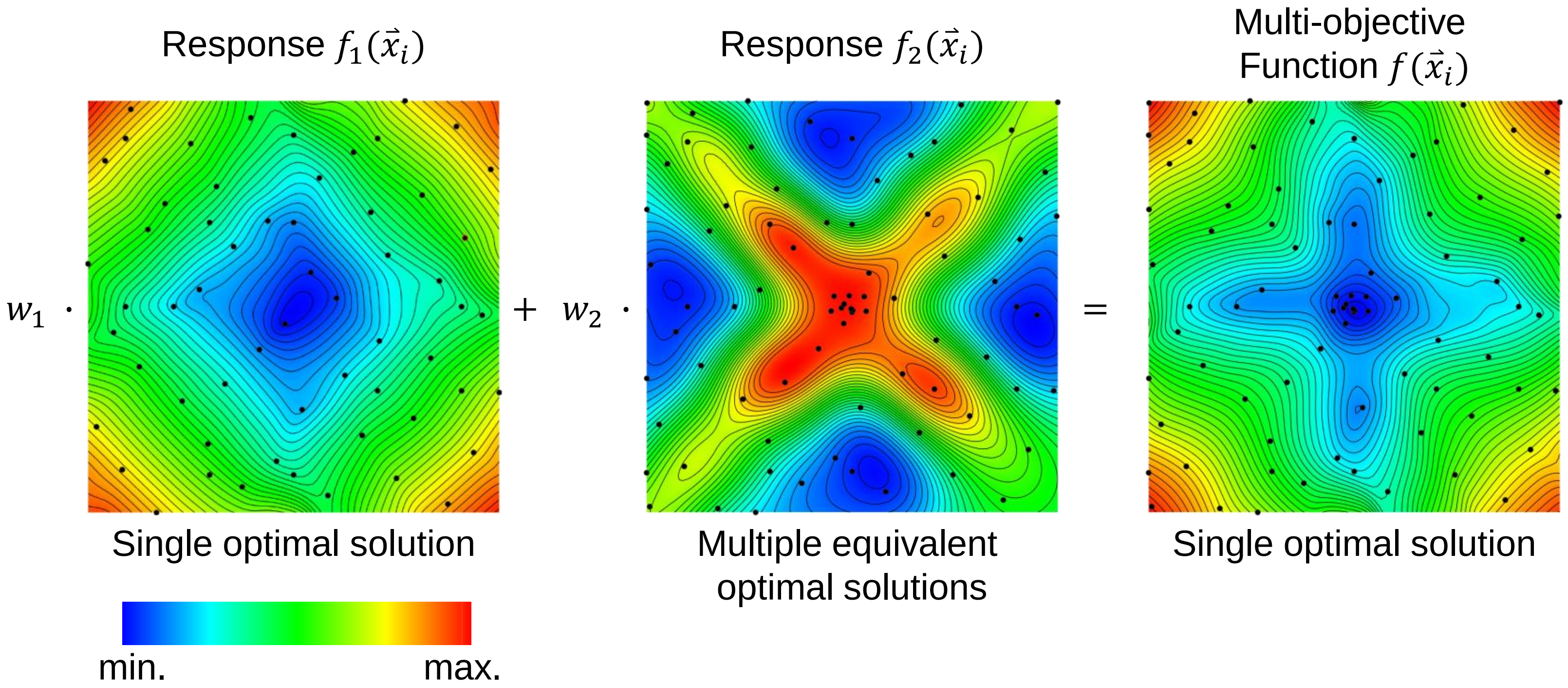
[1] Source: https://imgflip.com/memetemplate/264318081/Please-close-gate

Gate Location Optimization

How does the optimization it work

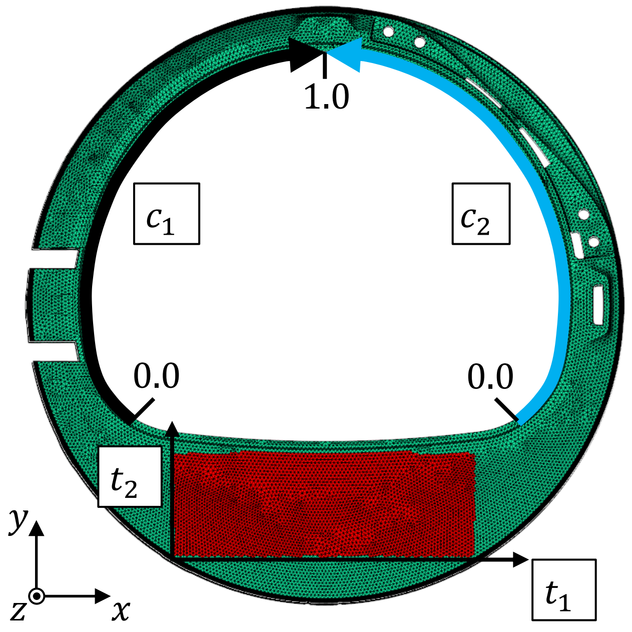
AutoOpt (Automated Optimization) creates gates on user-defined valid gate regions, performs injection molding simulations with Autodesk Moldflow and exports results to create **response surfaces** for the responses and objectives.





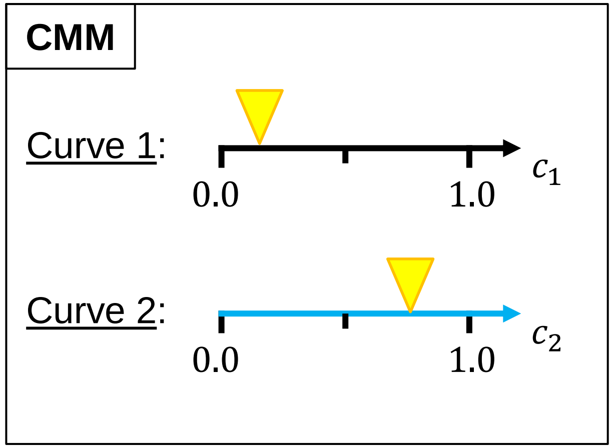
Gate Location Optimization

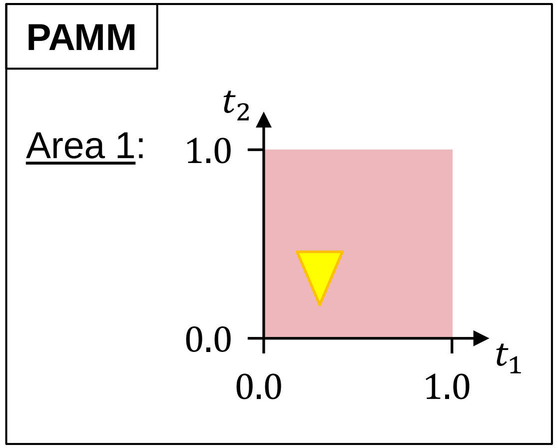
Complete procedure (Workflow)

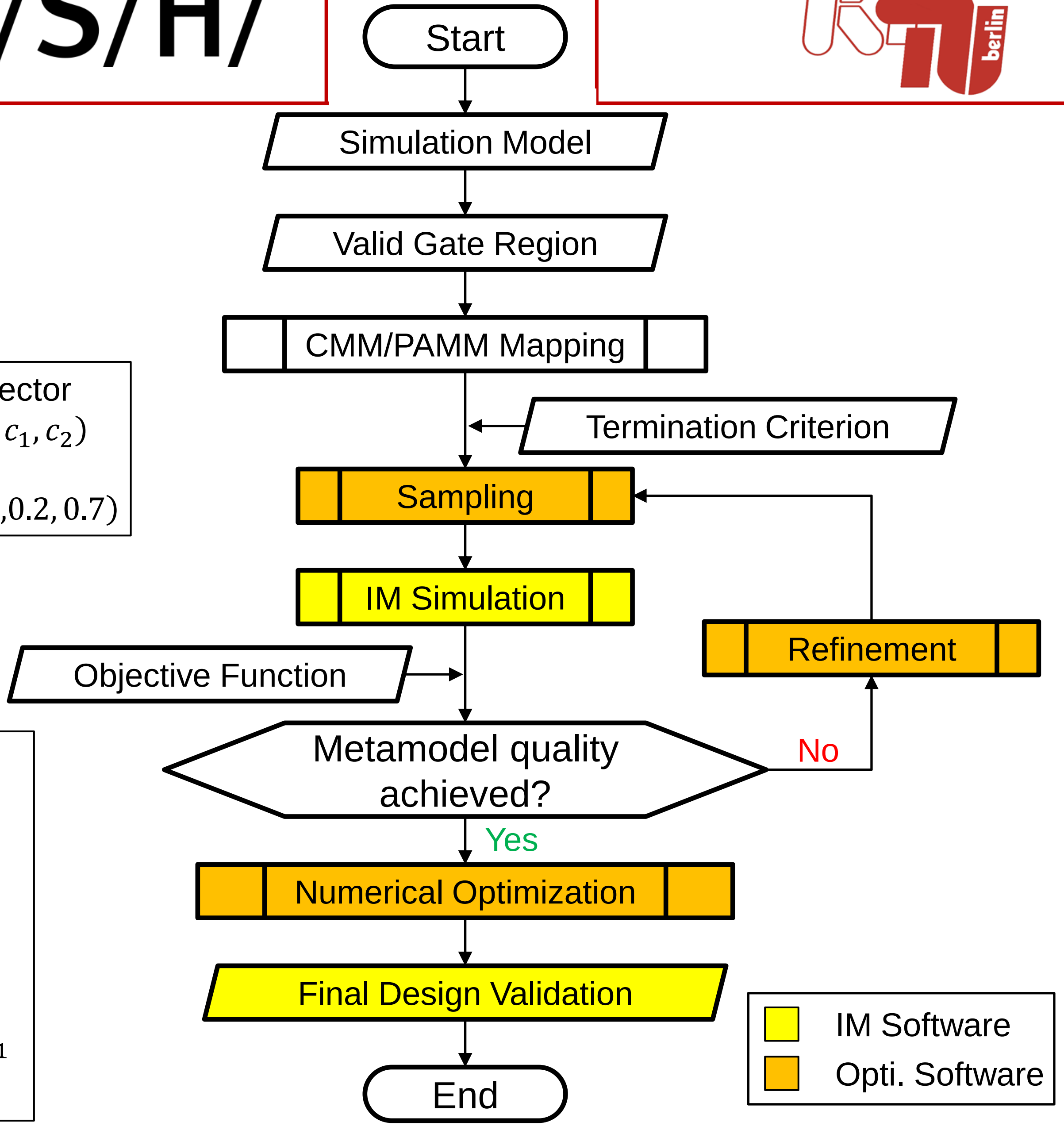


Design Vector
$\vec{x} = (t_1, t_2, c_1, c_2)$

$\vec{x}_1 = (0.3, 0.2, 0.2, 0.7)$

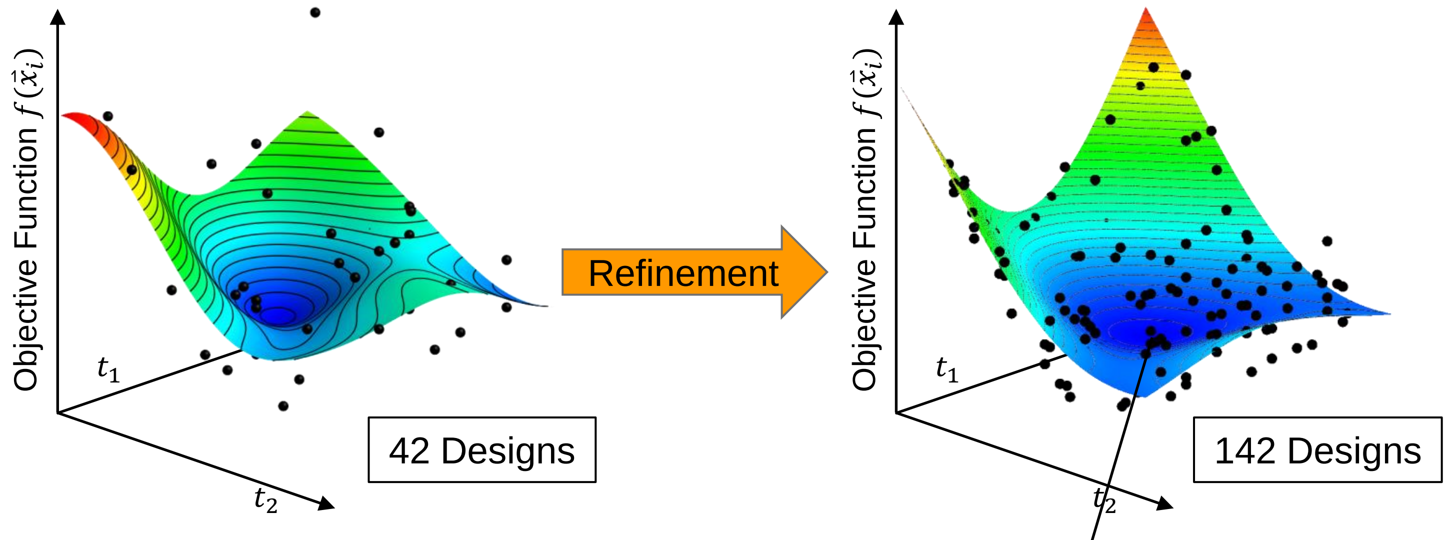


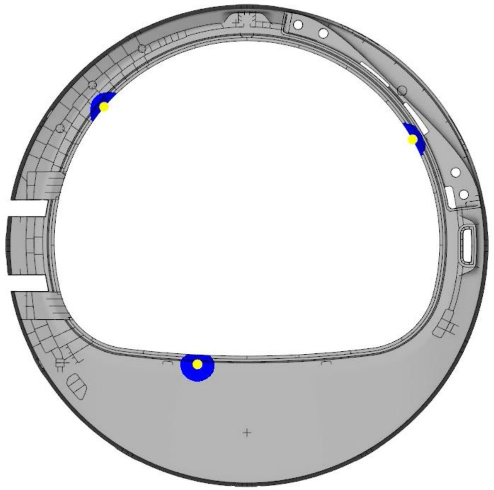




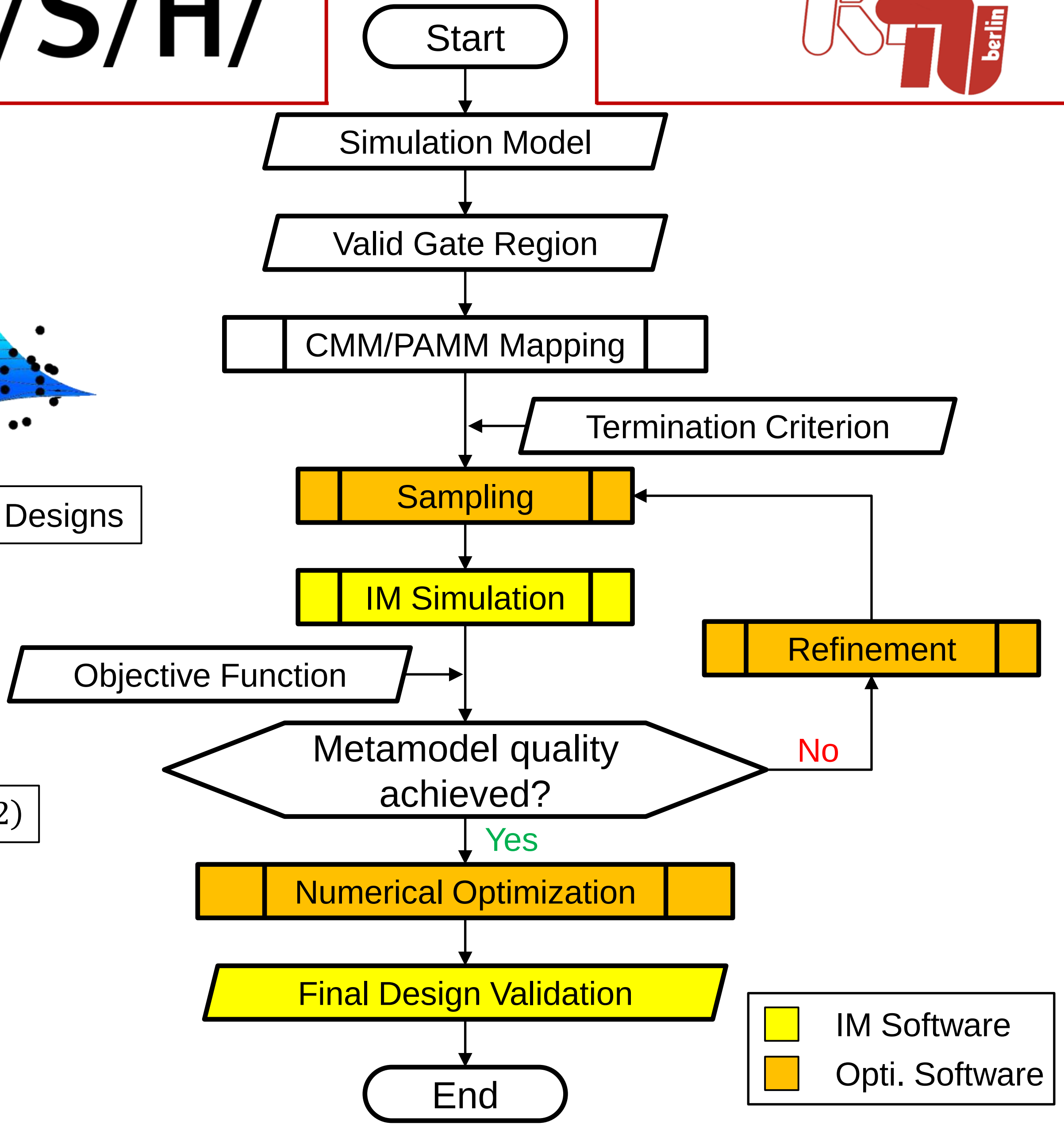
Gate Location Optimization

Complete procedure (Workflow) cont.





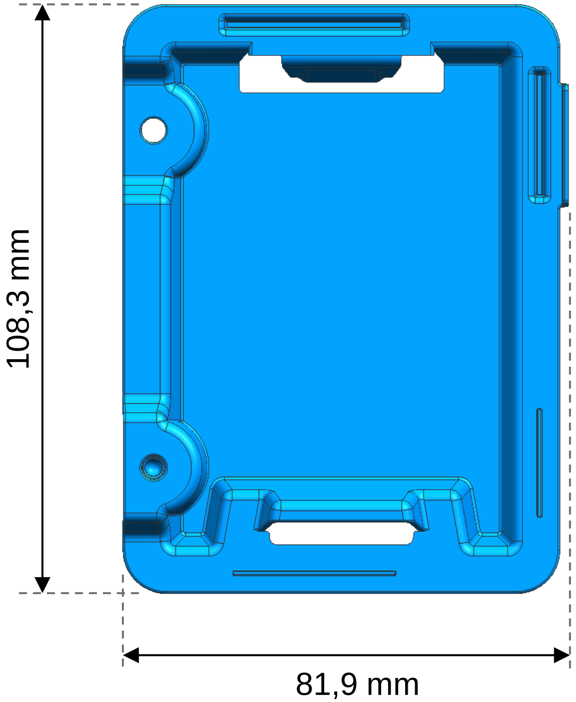
Final Design Validation

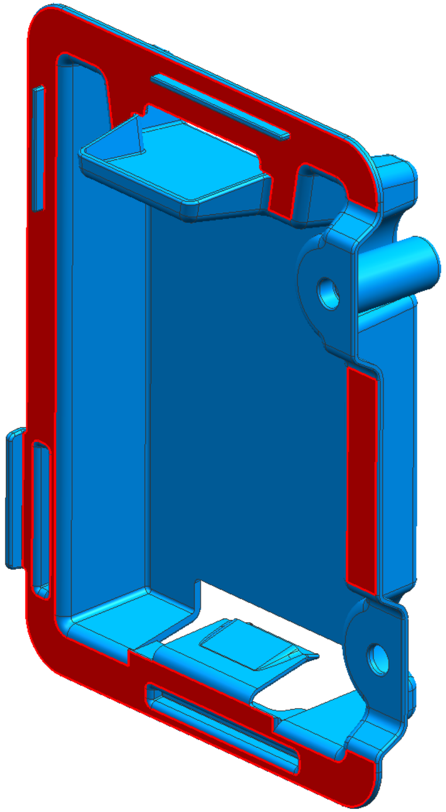


Small demonstrator part created to investigate *AutoOpt* results.

- Every 2 *PromoBox*es, 1 closed box.
- The touching faces should be as flat as possible
- Avoid large gaps when closed

PromoBox





PromoBox Properties

Thickness: 1.00 – 1.60 mm

Shot weight: ~20 g

Material: PP 30wt.% Glass Fiber

Representative of BSH part:

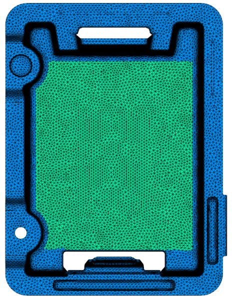
- Snap hook
- Screw dome

Can we reduce the warpage on the touching faces without compromising the cavity balance?

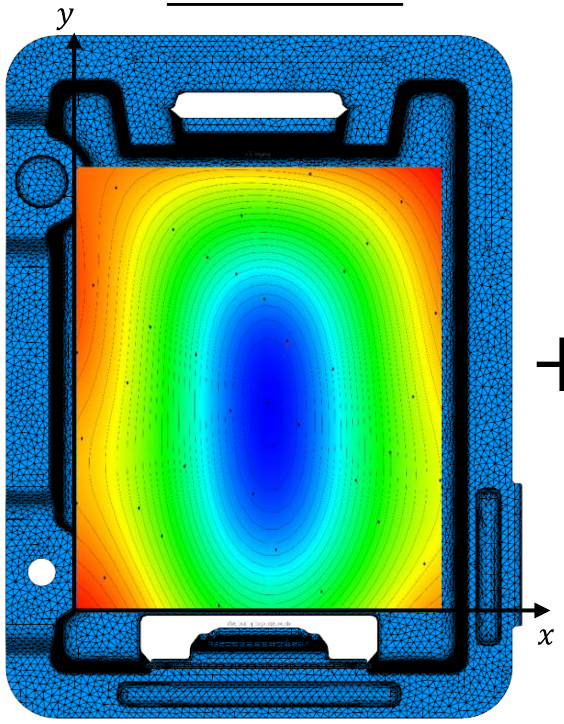
Gate Location Optimization

PromoBox - Simulation Results and Gate Selection

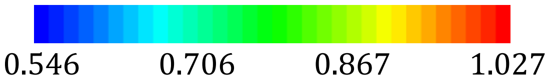
Response surface for each objective reveals the best gate regions for *fill time range*, *flatness* and *multi-objective*



Fill Time Delta

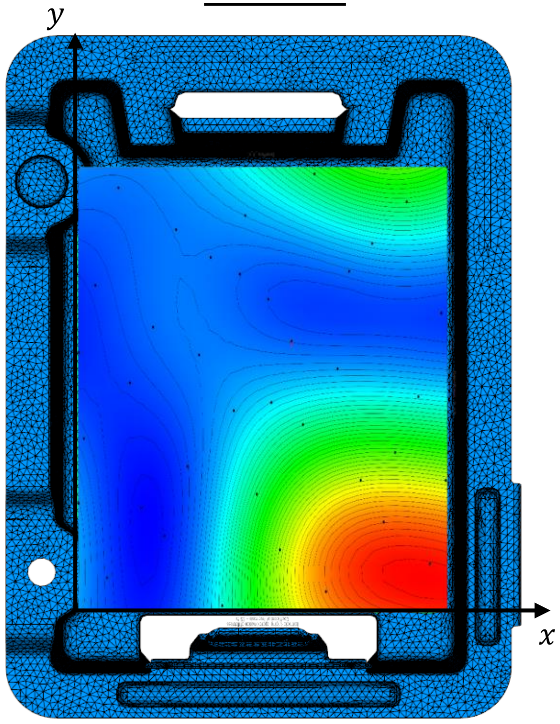


Fill time [s]

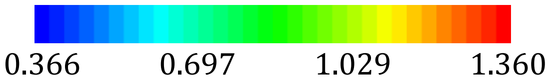


+

Flatness

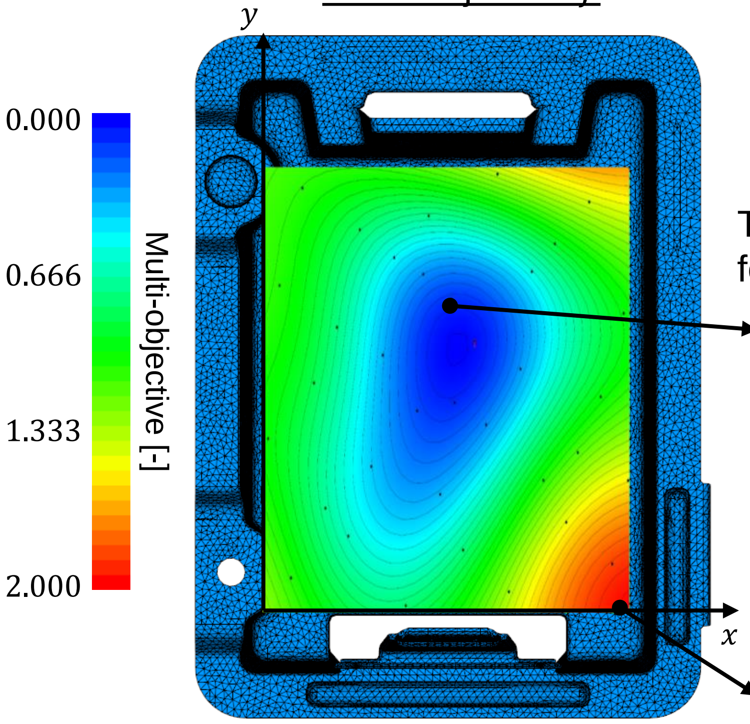


Flatness [mm]



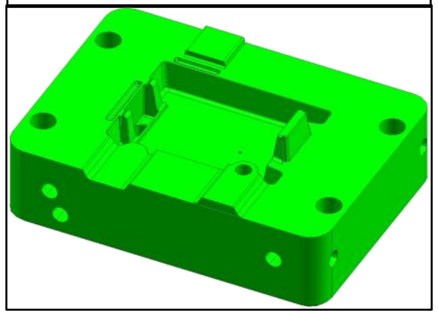
=

Multi-Objective f

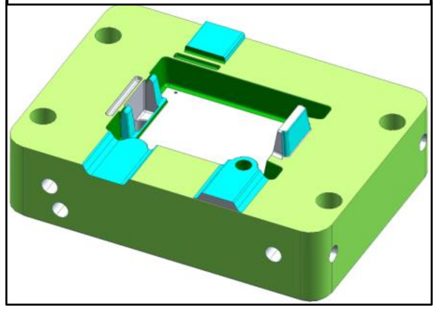


Two gate locations selected for experimental validation:

MIDDLE Gate - Insert



CORNER Gate - Insert



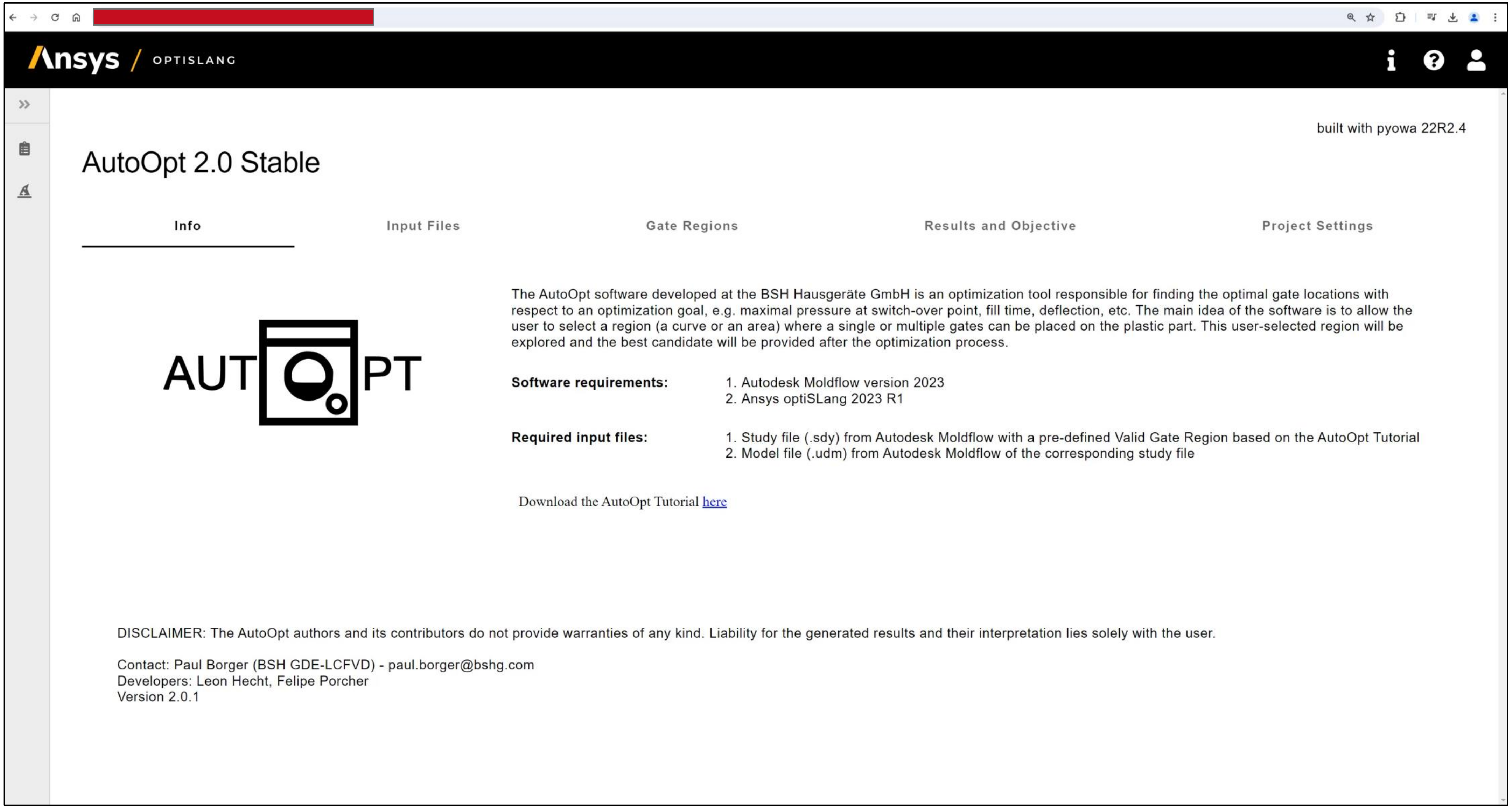
Objective function f:
Normalized sum of fill time range and flatness

Goal: $\min(f)$

$$f = \frac{fill\_time\_delta - 0.546}{1.027 - 0.546} + \frac{flatness - 0.366}{1.360 - 0.366}$$

Gate Location Optimization

AutoOpt WebApp Presentation Video

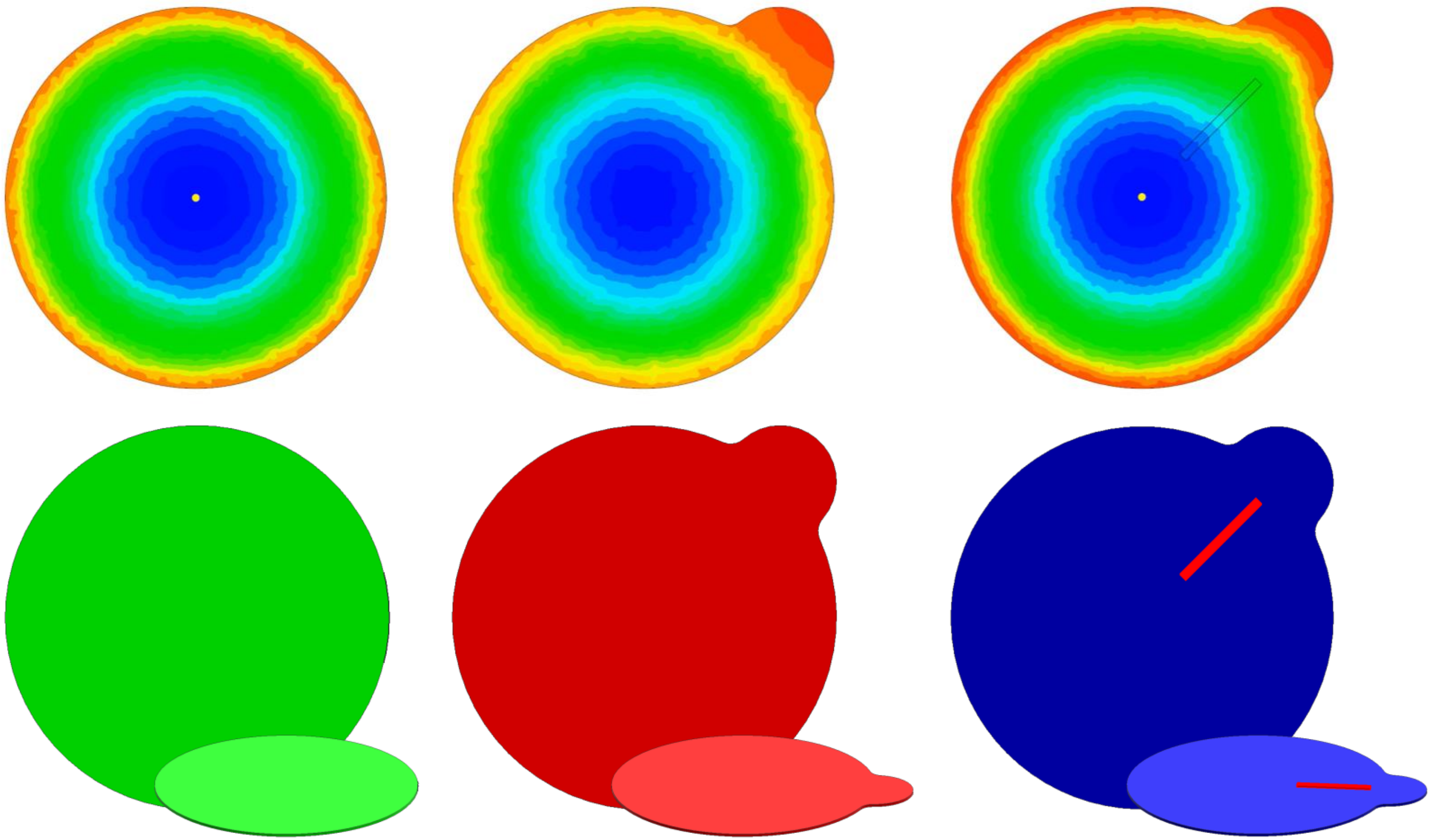


Automated Flow Leader Generation

Automated Flow Leader Generation

Motivation

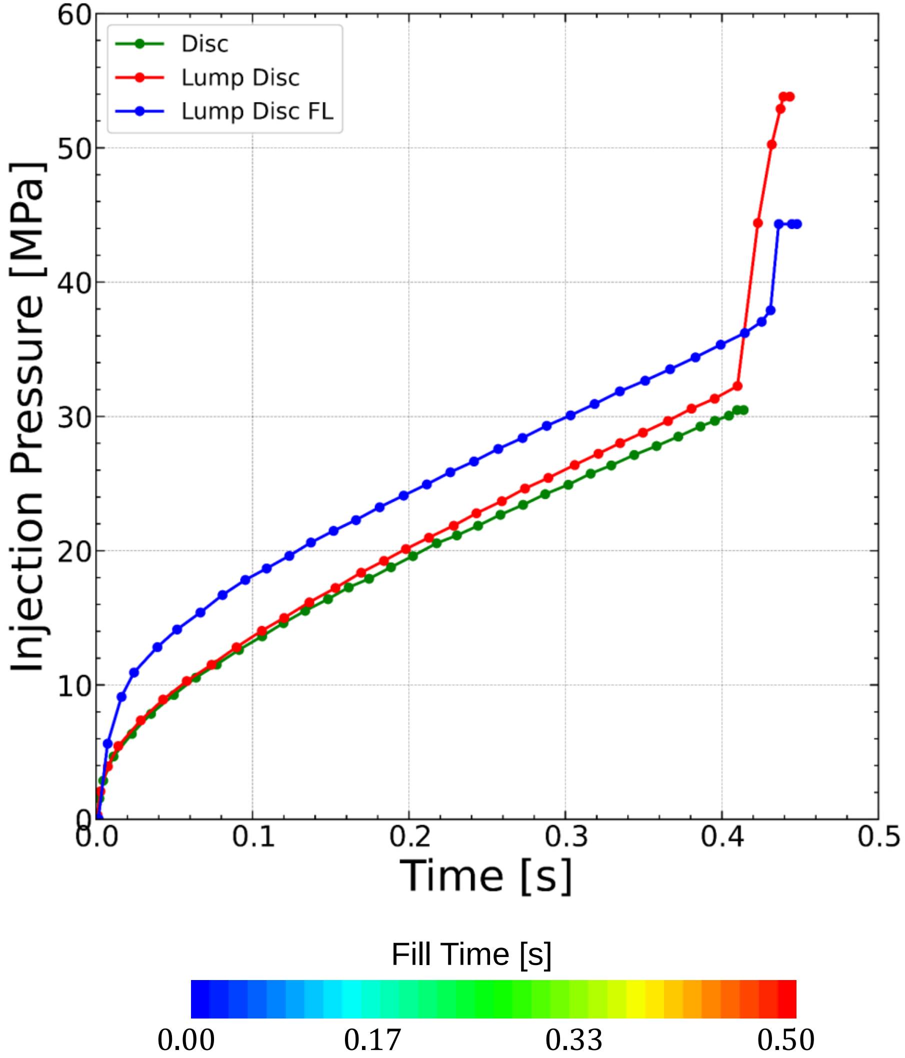
“Cavity balance is reached when **the polymer melt reaches the extremities of the cavity at the same time**”. [Lam, Y. and Seow L. W. (2000)]



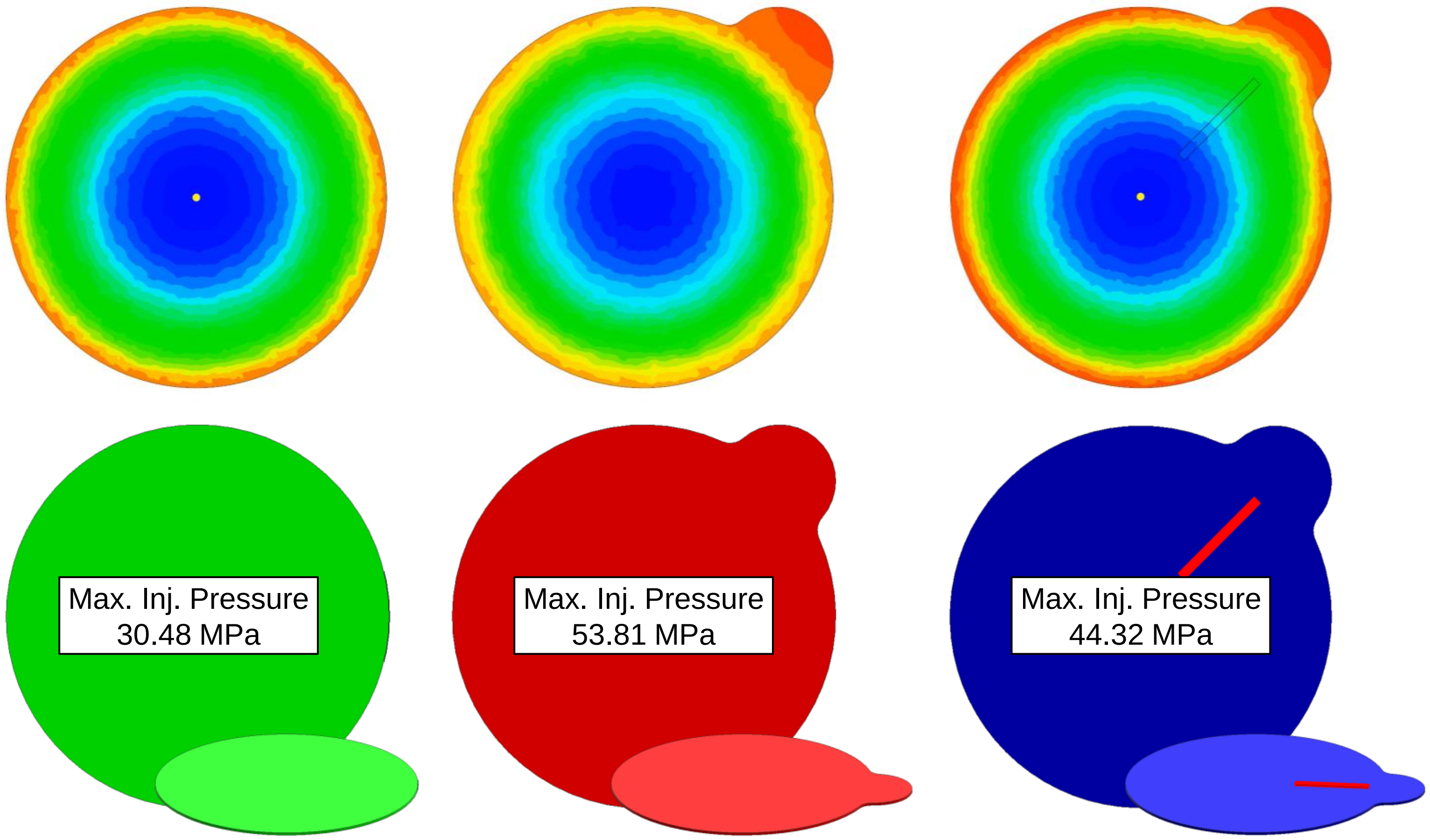
(a) Disc

(b) Lump Disc

(c) Lump Disc – Flow Leader



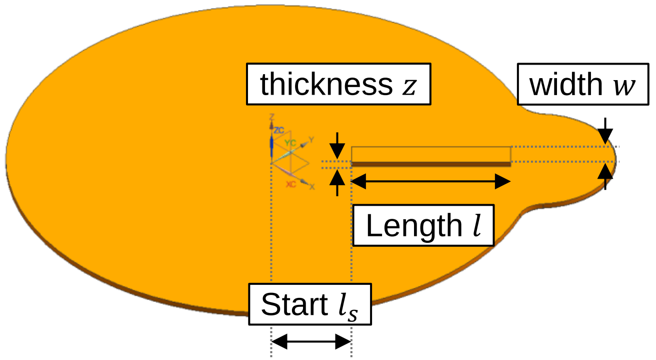
Effect of an unlabanced cavity



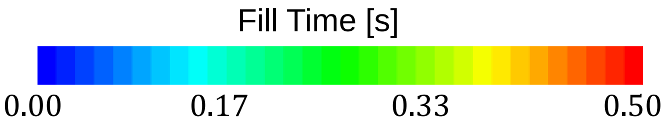
(a) Disc (b) Lump Disc (c) Lump Disc – Flow Leader

Q: How to determine the Flow Leader's path and geometry?

- Designer's Experience
- Injection Molding Simulation
- Parametric Geometry

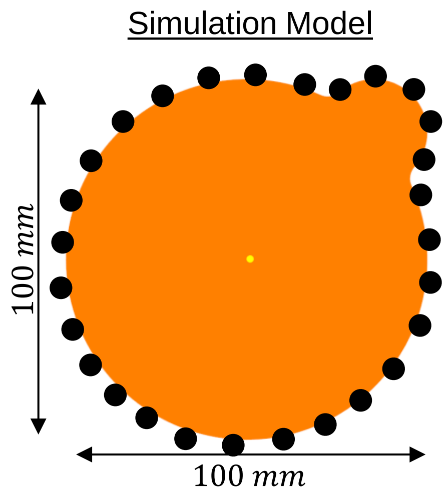


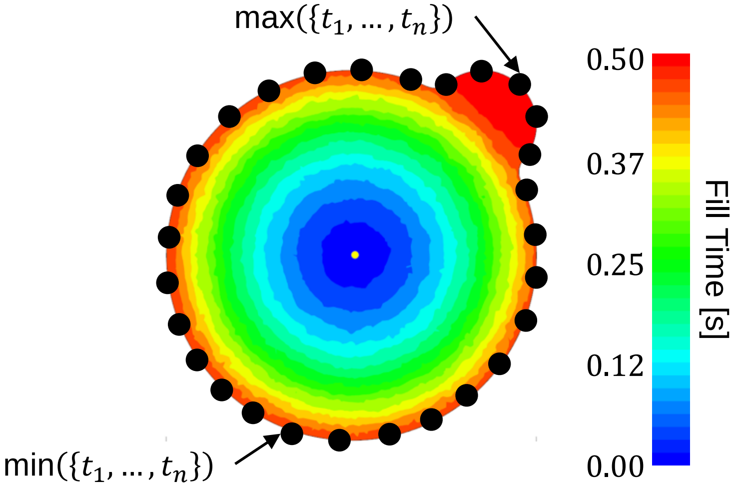
Automated Flow Leader Generation

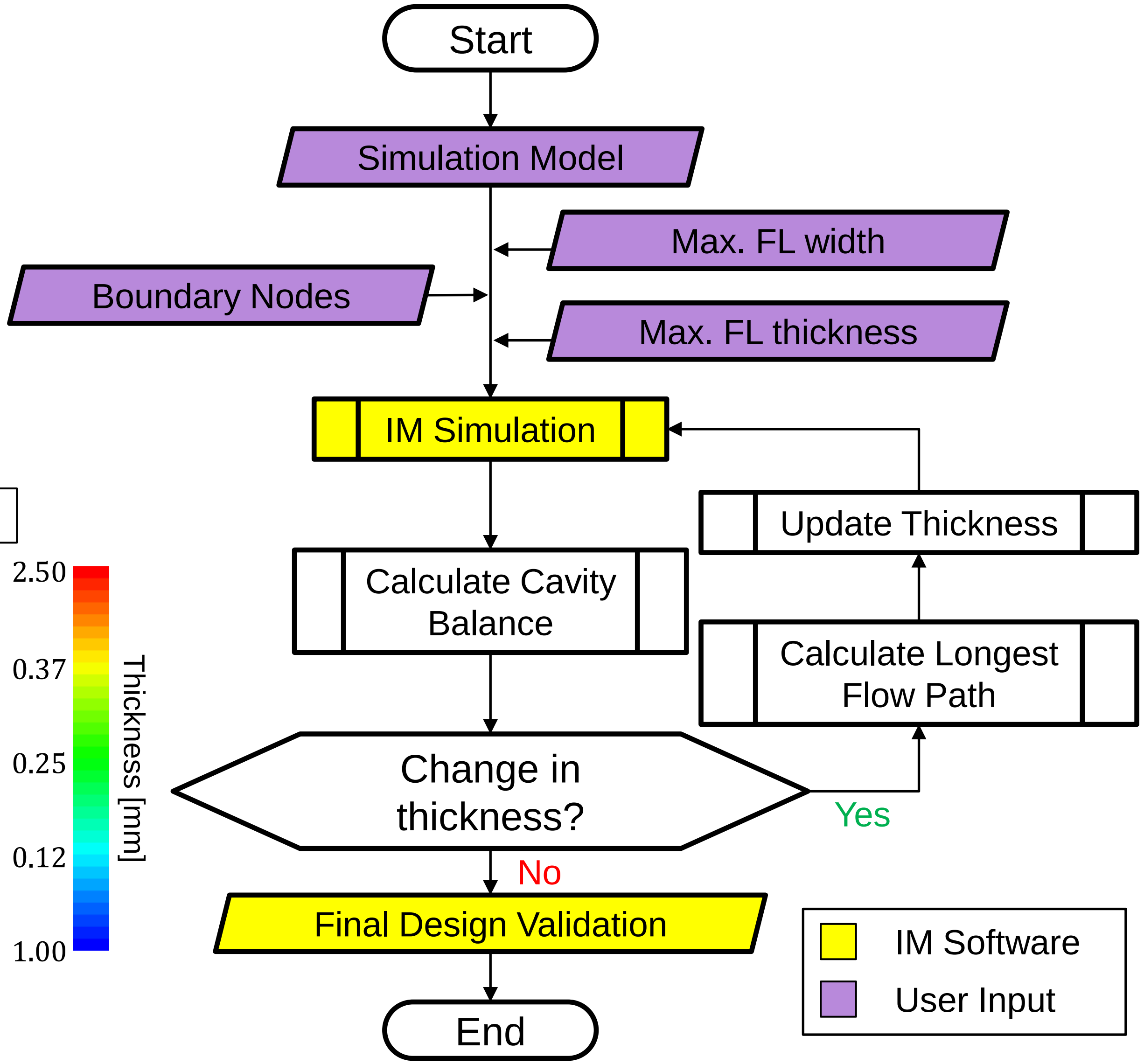


Automated Flow Leader Generation

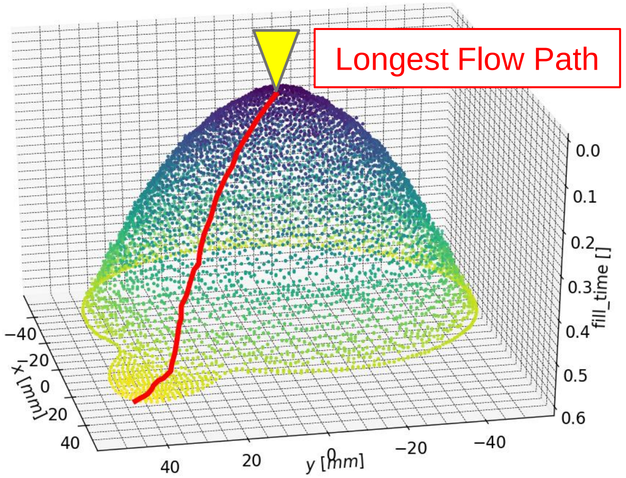
Workflow

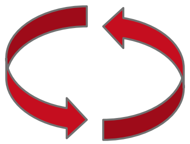


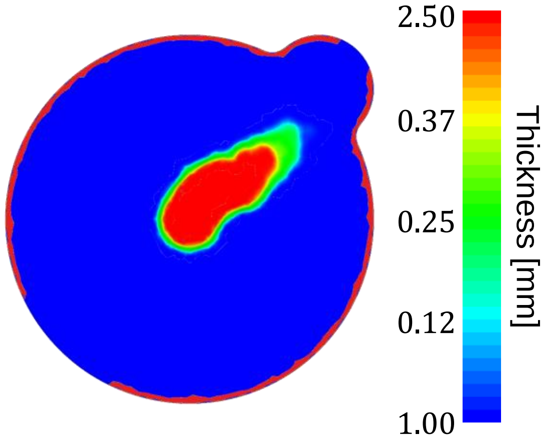




Calculate Cavity Balance: Fill time delta: $\Delta t = \max(\{t_1, \dots, t_n\}) - \min(\{t_1, \dots, t_n\})$



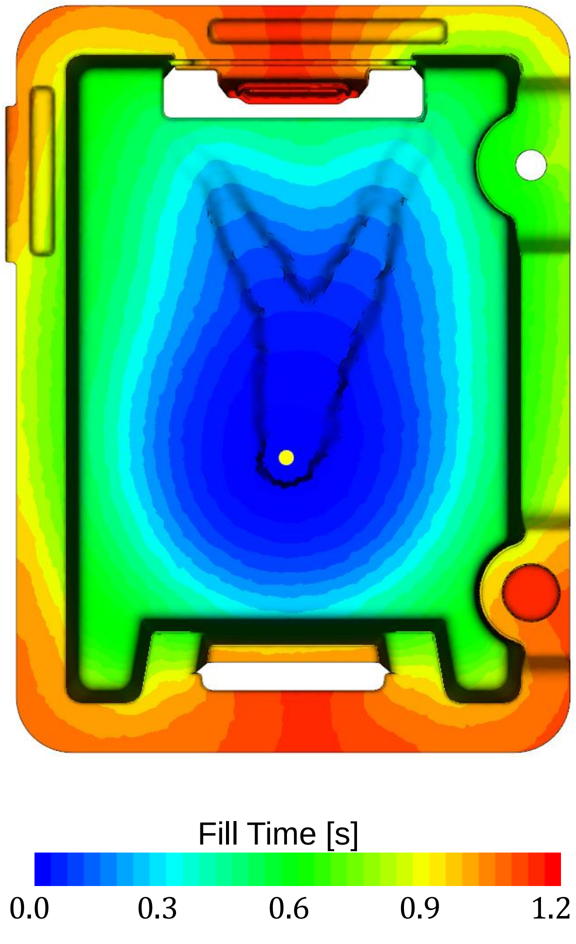


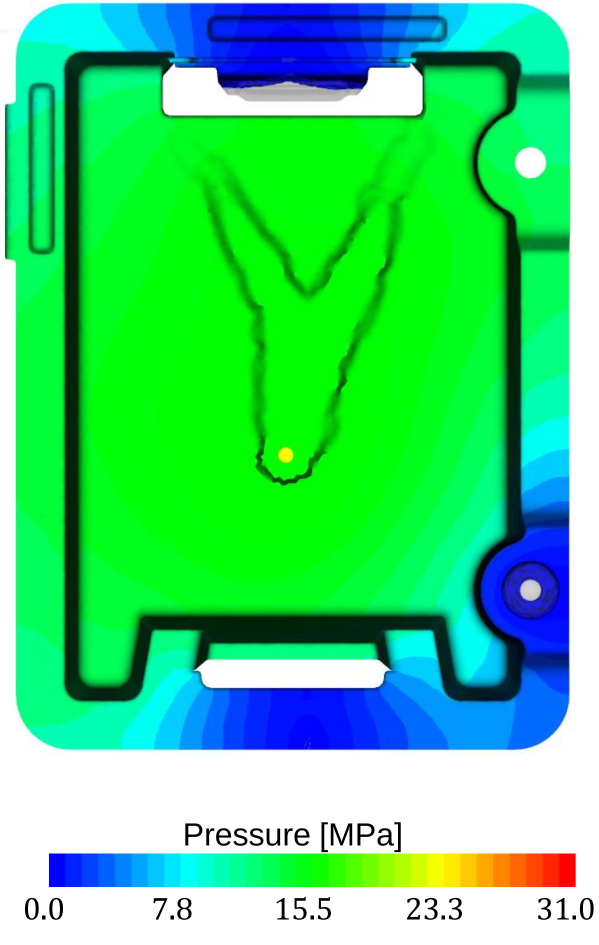


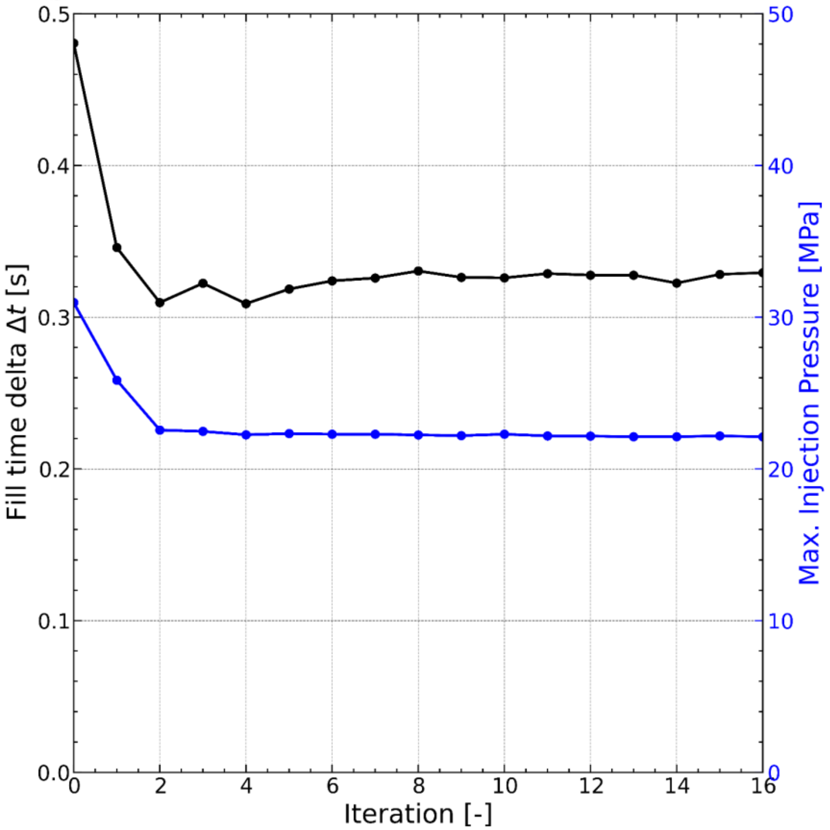
[Lam, Y. and Seow L. W. (2000), Polymer Engineering and Science, vol. 40, no. 6, pp. 1273-1280]
[Porcher F. et al. (2023), PPS-38, St. Gallen, Switzerland, Poster Presentation]

Automated Flow Leader Generation

Flow Leader Thickness Comparison



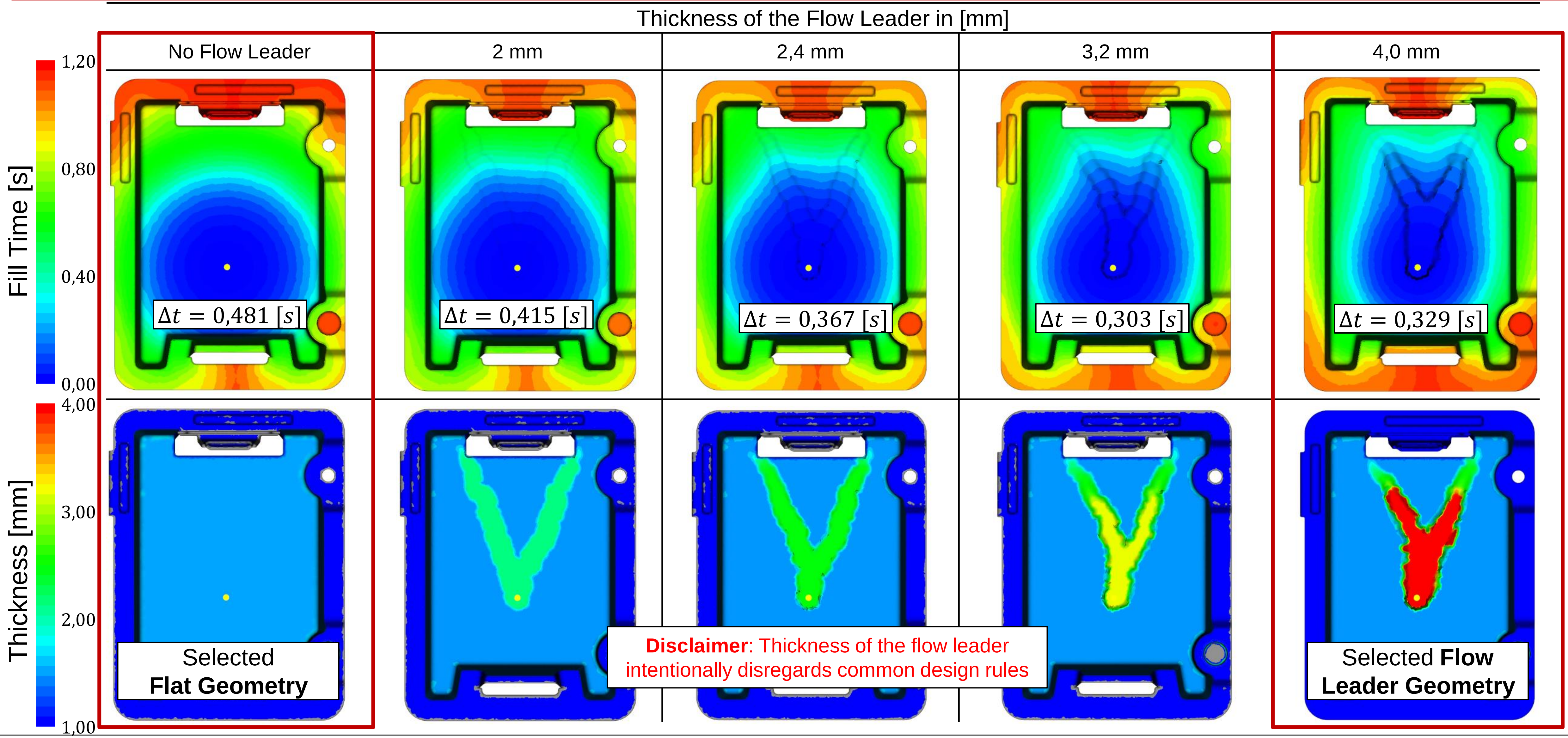




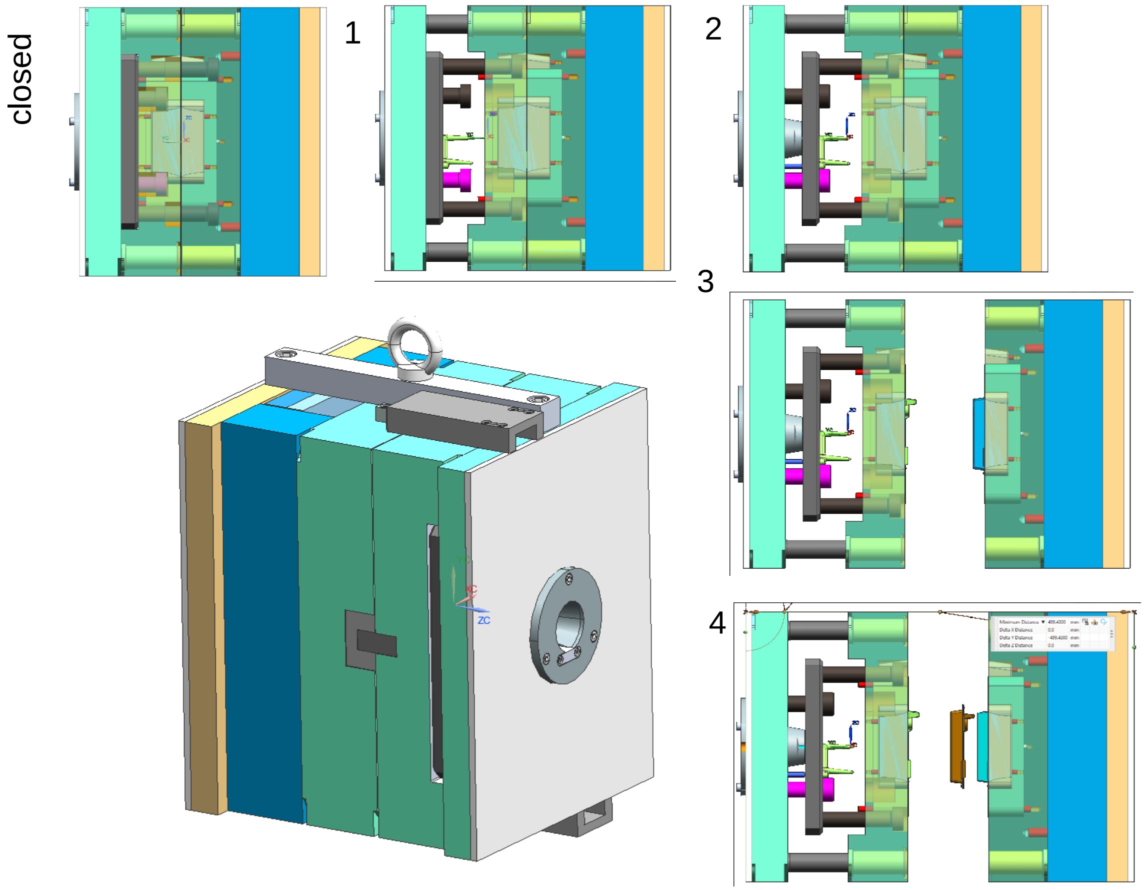
- ~ 32% Δt reduction → 0,16 s
- ~ 28% p_{max} reduction → 16,2 MPa

Automated Flow Leader Generation

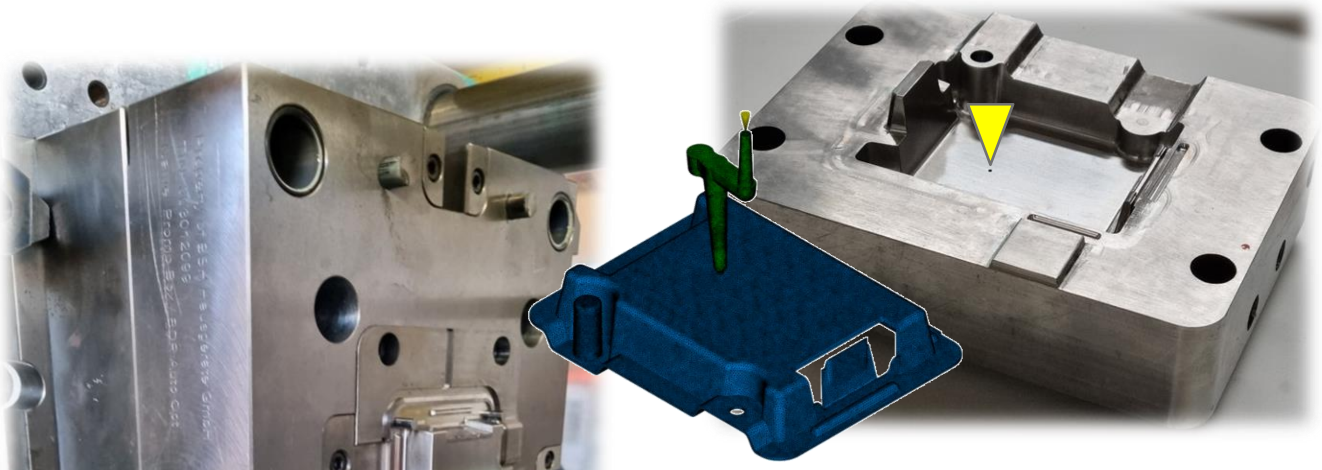
Flow Leader Thickness Comparison



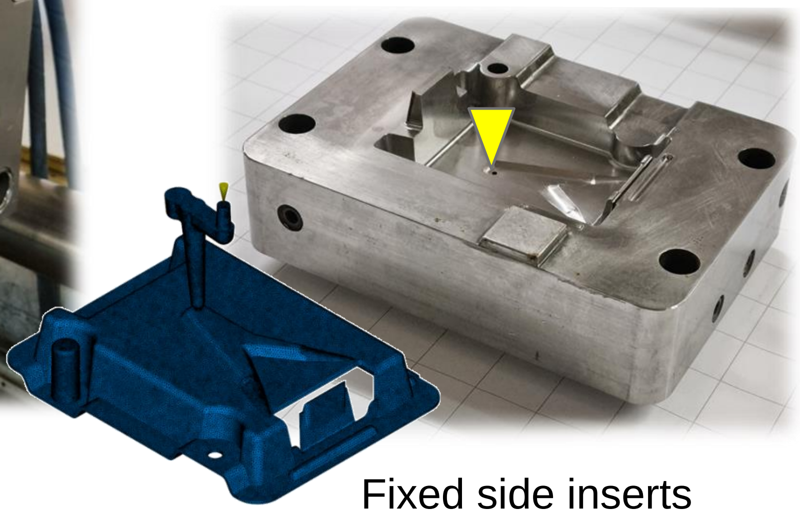
Injection molding tool with different cavity inserts



FLAT (MID) GEOMETRY MOLD



FLOW LEADER GEOMETRY MOLD



Moving side

Fixed side inserts

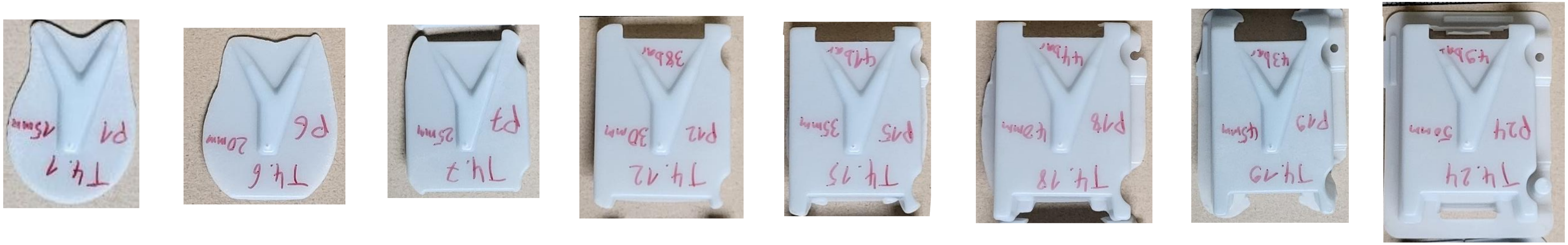
Acknowledgement: Gino Wybranietz & Konstantin Jakob

Experiments

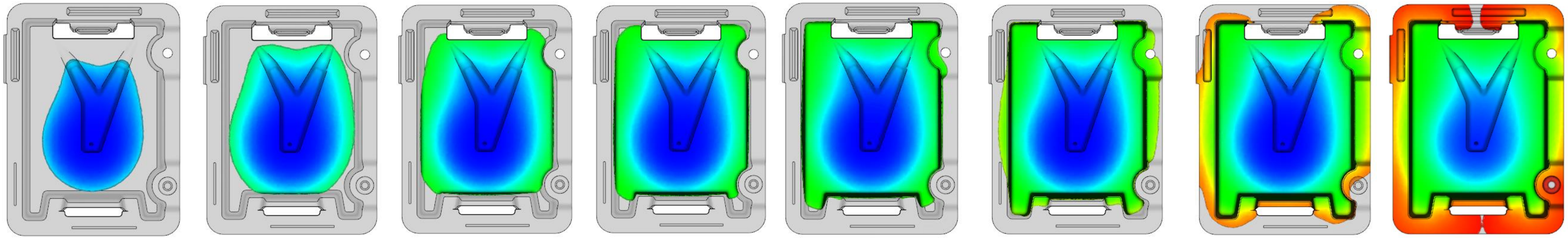
Fill Study Comparison between Simulation and Reality

Fill Time [s]

0.0 0.3 0.6 0.9 1.2



(a) 6,79 ccm³ (b) 9,05 ccm³ (c) 11,31 ccm³ (d) 13,57 ccm³ (e) 15,83 ccm³ (f) 18,10 ccm³ (g) 20,36 ccm³ (h) 22,62 ccm³



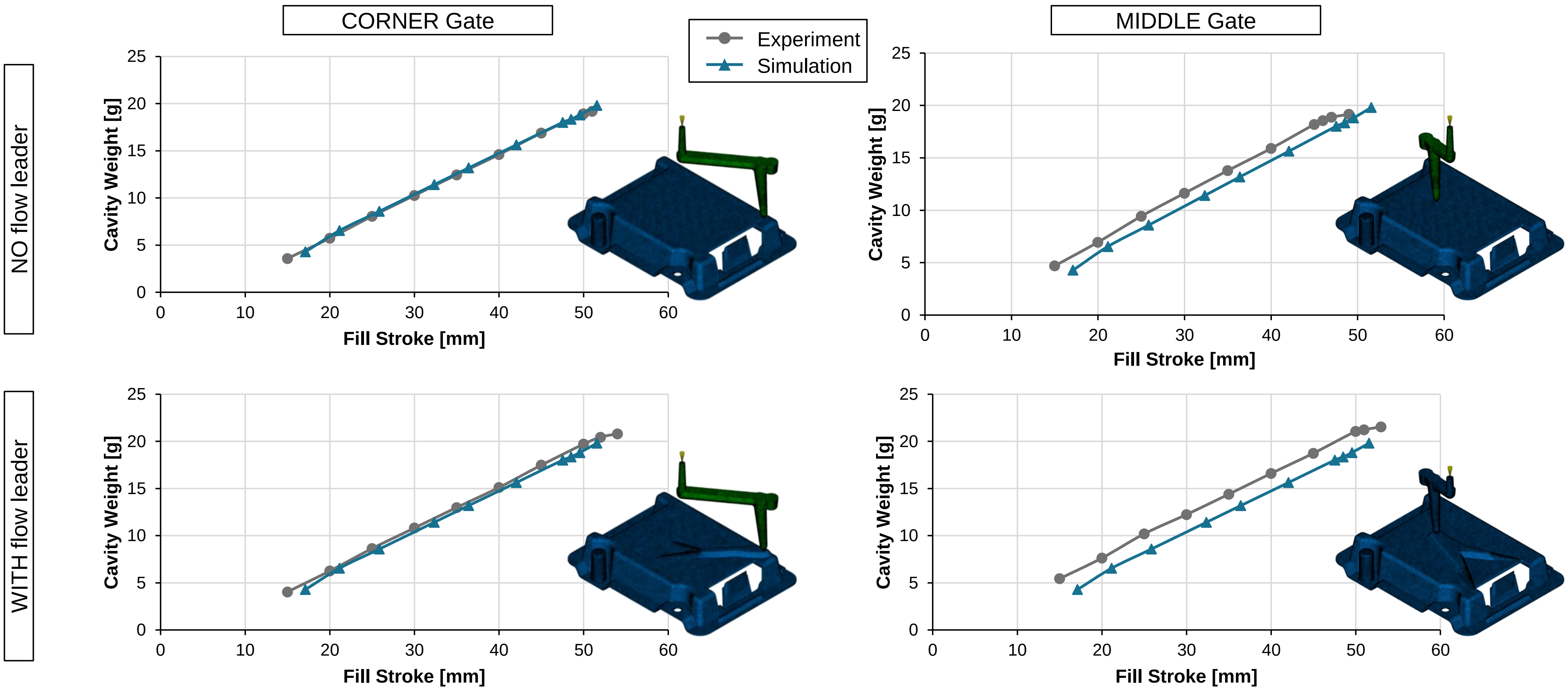
0,215 [s]	0,264 [s]	0,324 [s]	0,405 [s]	0,442 [s]	0,527 [s]	0,593 [s]	0,606 [s]
30,90 [%]	41,20 [%]	51,50 [%]	61,80 [%]	72,11 [%]	82,41 [%]	92,71 [%]	94,77 [%]
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)

Acknowledgement: Alessandro Capriotti

Cavity Balance

Filling Study Comparison

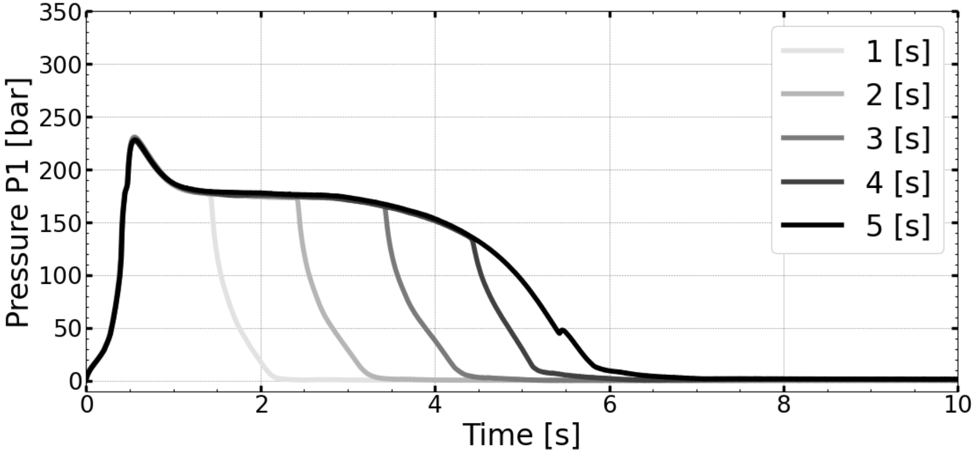
Shot (cavity) weight for all 4 cavities were compared with simulation prediction.



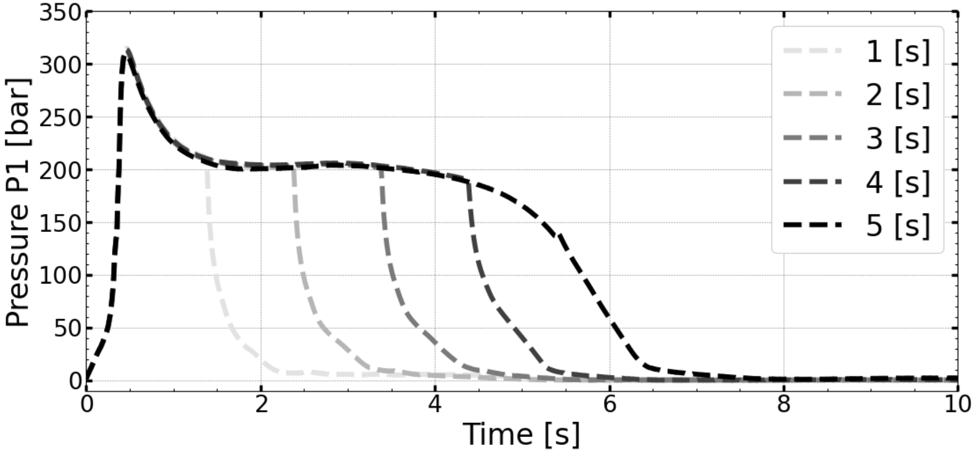
Experiments

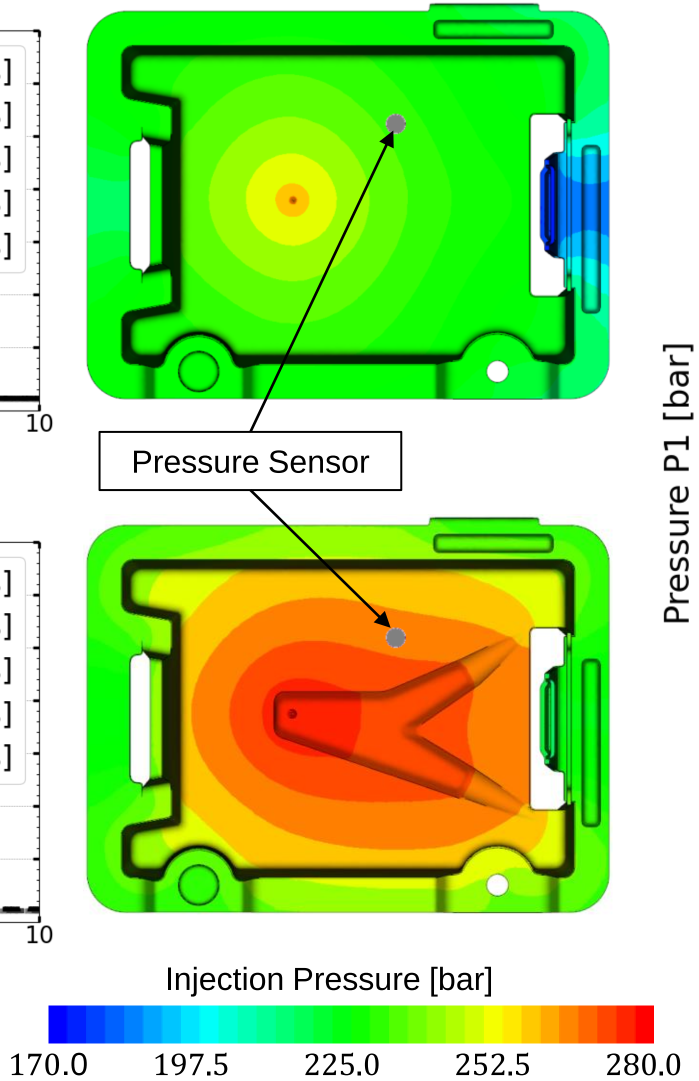
Packing Pressure Comparison between Flat and Flow Leader Geometries

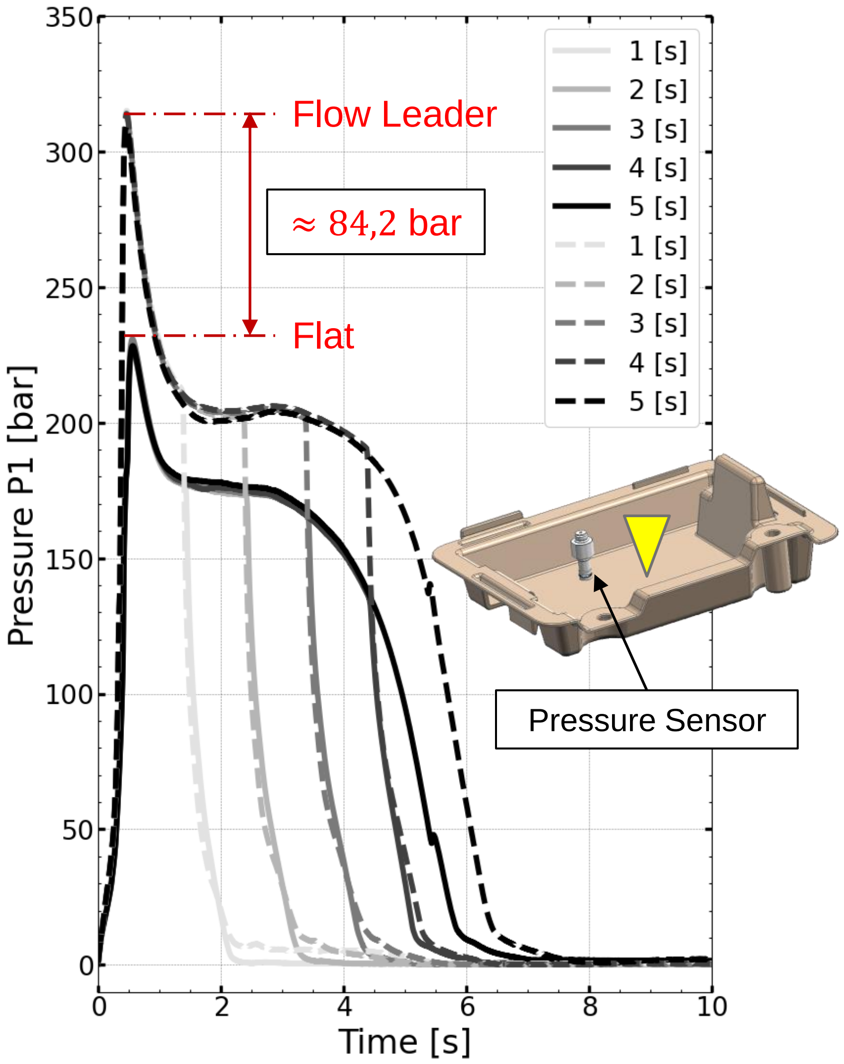
Flat Geometry



Flow Leader Geometry







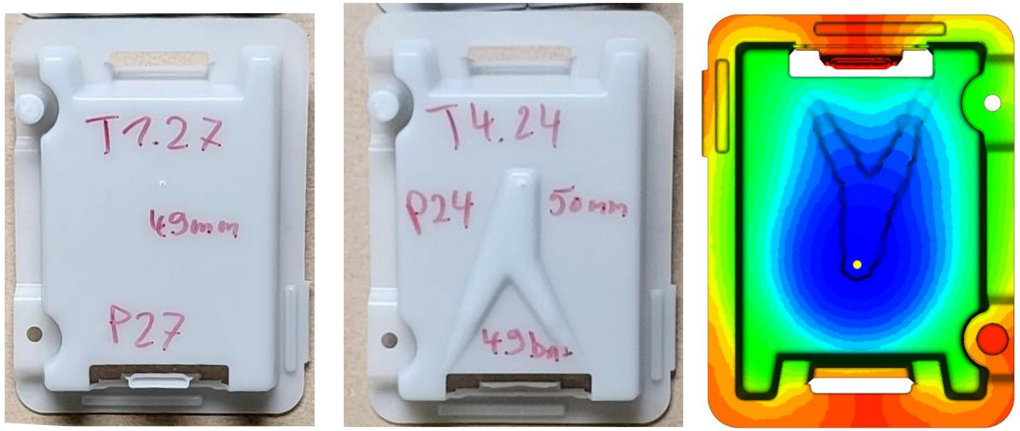
Summary & Open Questions

Summary

- The *AutoOpt* tool effectively identified both promising and problematic gating regions for the *PromoBox* demonstrator part

- Our automated solution
  - shortens development time
  - promotes the discovery of innovative solutions
  - Explores the influence on part quality for many gate locations

- Successfully improved **Cavity Balance** for the *PromoBox* through **gate location** and **flow leader** optimization.



Open Questions

- Is cavity balancing always the most important criterion for injection molding tools?
- How to convince experienced decision makers to trust simulation (tools)?
- How to maintain the tool chain with changing software versions and API?
- Can we optimize total mass usage or CO_2eq for the parts?

We are happy to answer your questions.

Paul Borger
paul.borger@bshg.com

Felipe Porcher
f.porcher@tu-berlin.de

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Make Anything

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