Instruction to Transfer Molding Using ACM
April 2023

Goal of Presentation

My goal is:

- To present transfer molding while molding ACM material and discuss ways to decrease the chance of molding defects. These molding defects can be weld lines, air trap or scorched material.

I will accomplish this by:

- Focusing on filling pressure
- Filling Temperature
- Curing degree
- Weld lines
- Air trap

Agenda

1. Results by Type of Analysis – ACM Gasket (From GrabCAD)
    - -Review rubber test requirements
    - -Simulation set up
    - -Results and discussion
    - -DoE set up
    - -Results and discussion

Rubber Testing Requirements

Filling and curing analysis

- Thermal conductivity (W/m°K) vs. temperature (°C)
- Specific heat (J/Kg°K) vs. temperature (°C)
- Specific density (g/cc) or pvT (pressure-volume-temperature) data
- Rheology data – viscosity (Pa-s) vs. shear rate (1/s) at least for 3 different temperatures
- Reaction Kinetics – curing degree vs. time (sec) at least for 3 different temperatures
- Reactive Viscosity – Time – Shear rate – Viscosity relationship at least for 3 different temperatures or at three different heating rate*
- Recommended processing conditions

Shrinkage & warpage analysis*

- Young's modulus (MPa) vs. temperature (°C)
- Poisson's ratio vs. temperature (°C)
- Thermal expansion co-efficient (1/°C) vs. temperature (°C)

Optional

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Rubber Testing Requirements

- Volumetric Cure Shrinkage
  - DPL D-020
- Solid Density
  - ASTM D792
  - ISO 1183
- DMA Parallel Plate Dynamic Rheology (3 Temperatures)
  - ASTM D4440
  - ISO 6721-10
- Specific Heat
  - ASTM E1269
  - ISO 11357-4
- Thermal Conductivity Scan
  - ASTM D5930
- Cure Kinetics by DMA-isothermal
  - ASTM D4473

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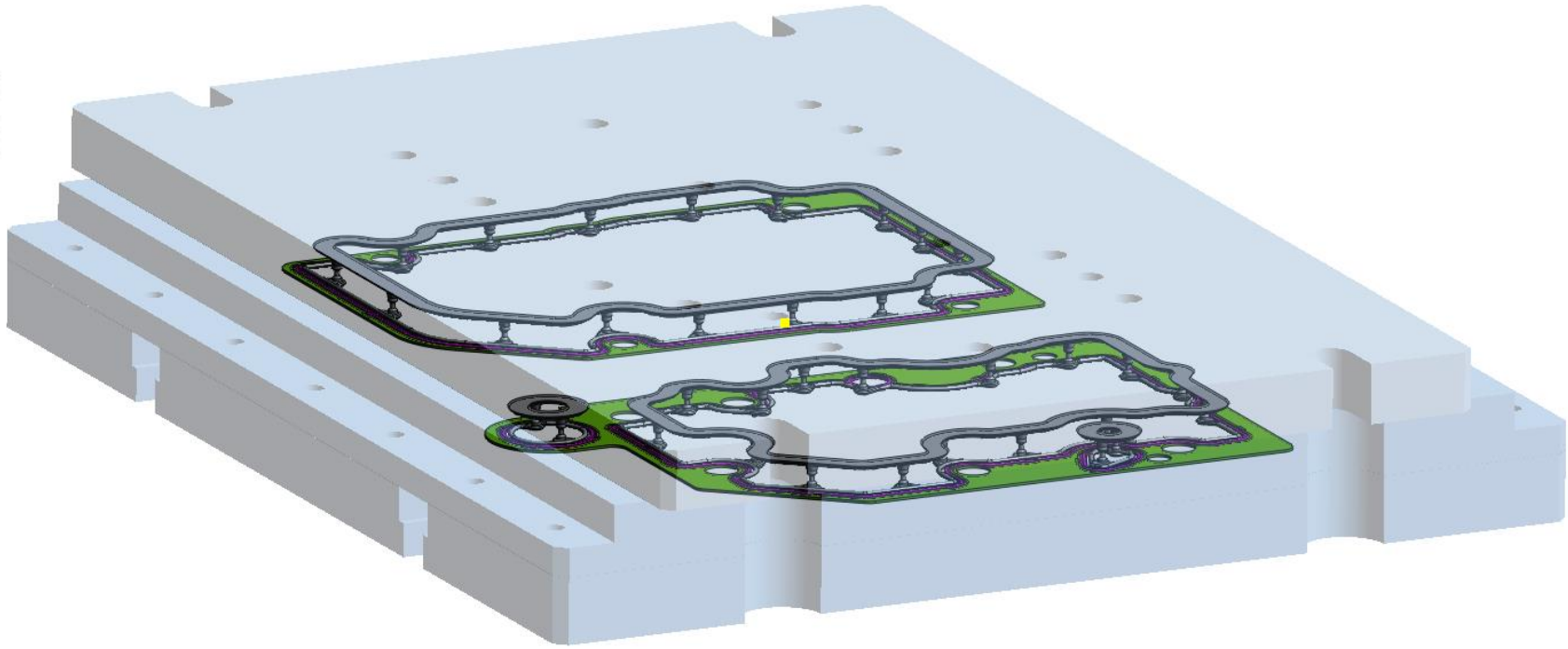
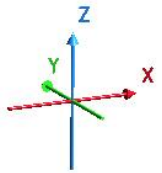
Simulation Setup

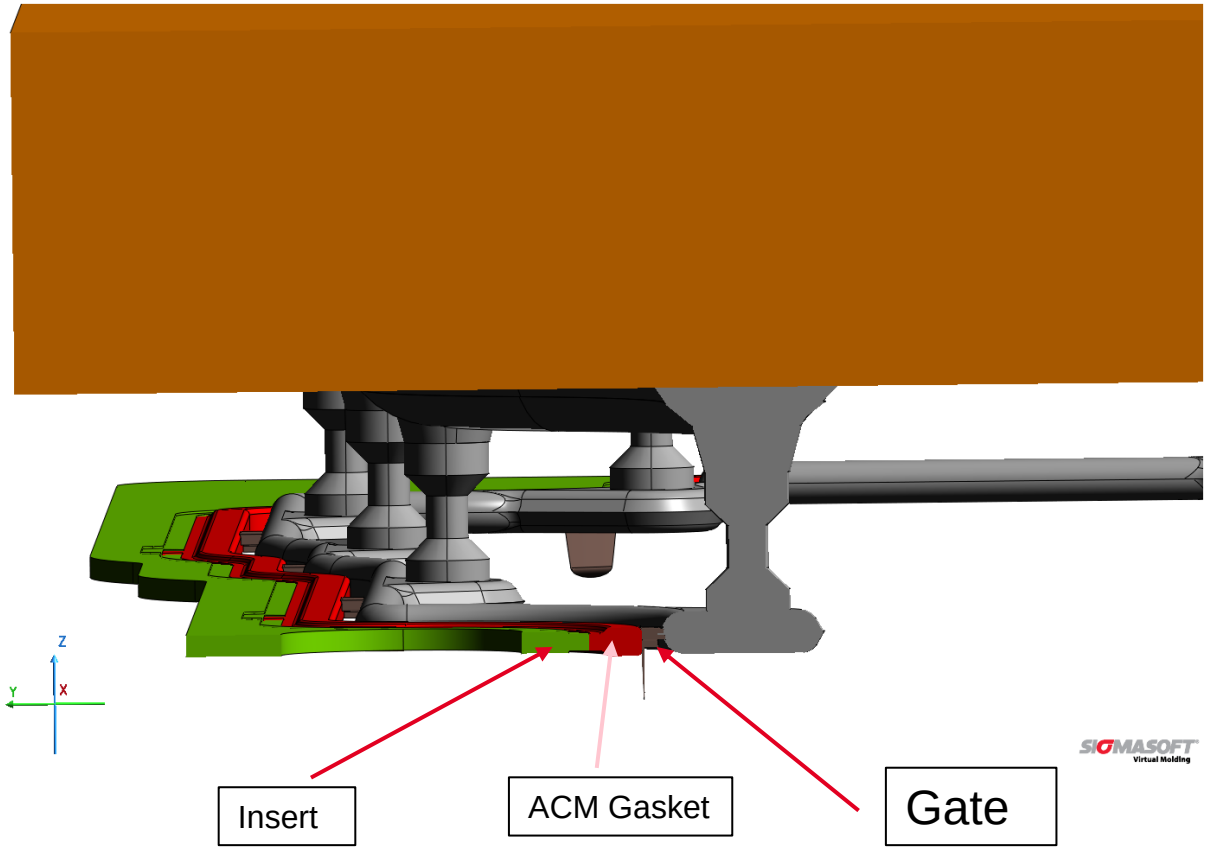
- Local cord system
- Misc Folder
- RM220-ASSLY_ASM
- extrusion2_001 — Preform/ID 1
- extrusion2_002 — Preform/ID 1
- Gate
- New Gates
- Runner
- RM220-COMP-RUBBER

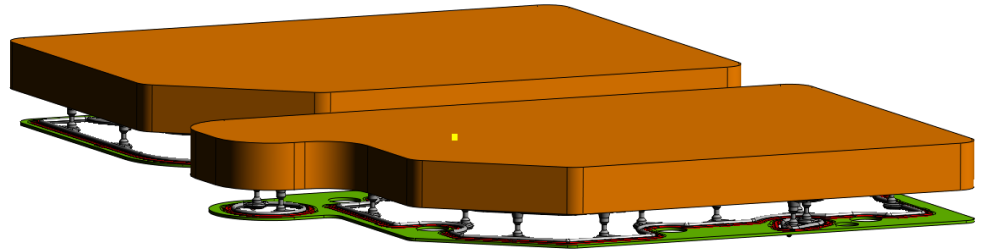




Simulation Setup

Images below shows how preform gets transferred into the gasket.





Transfer Molding Process Inputs

- Mold Material Used – P20
- Insert Material – AISI O1 General Purpose Oil Hardening Steel
- Mold Temperature – 190C
- Rubber Used – AMC 70 Shore A Durometer
- Transfer Molding Moving Time – 4 Seconds

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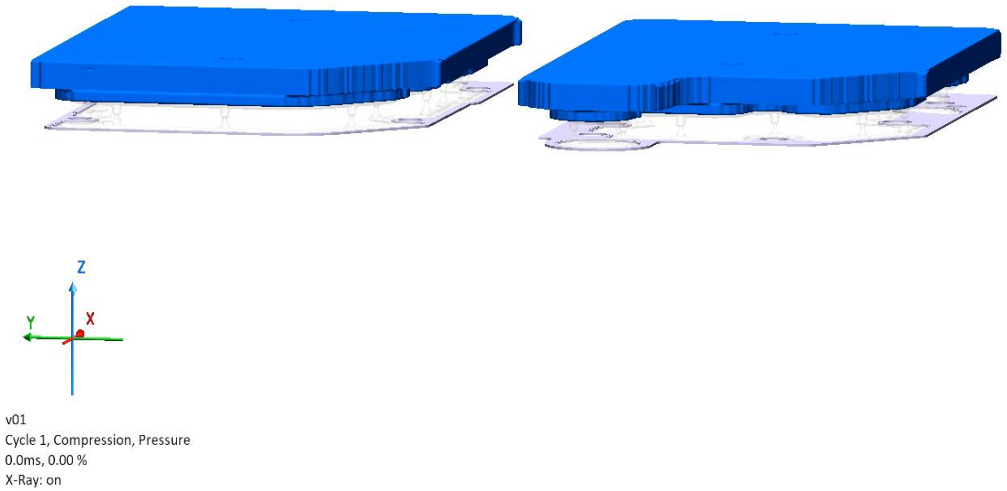
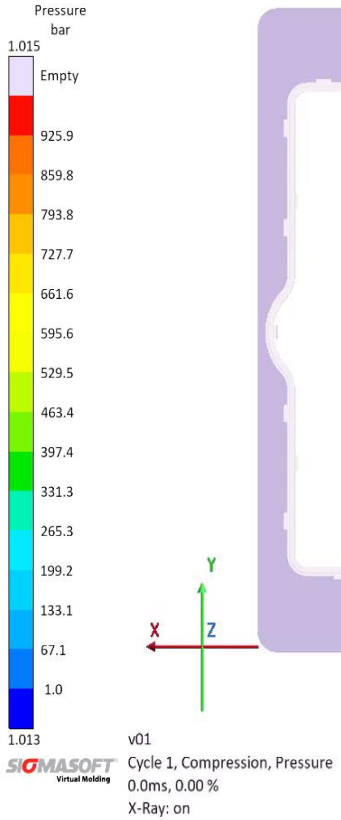
Results and Discussion

- Video shows filling pressure as part fills out. The maximum filling pressure is 925 bar.

Filling Pressure (Bar)





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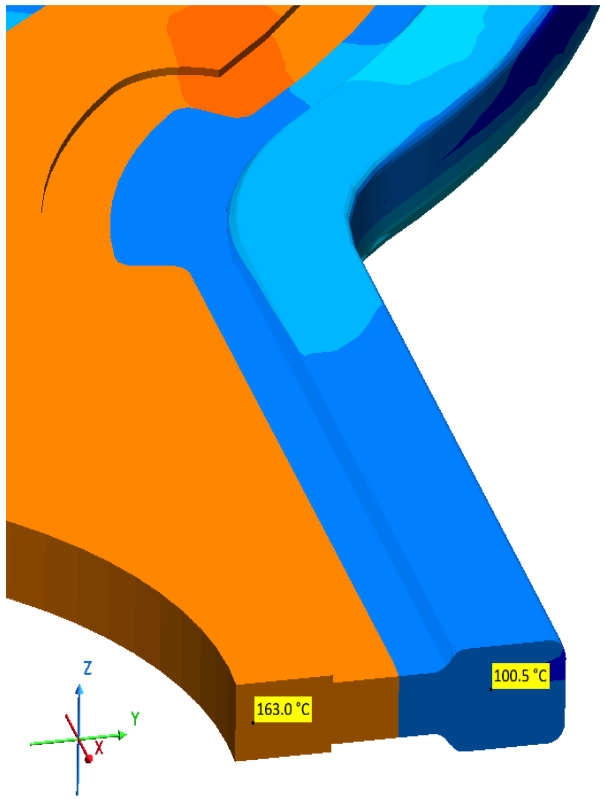
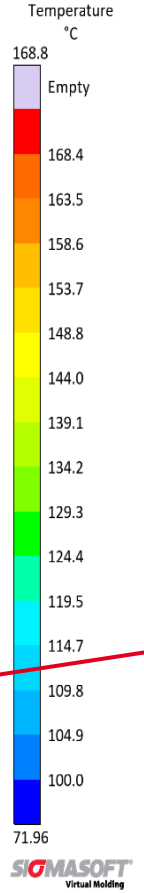
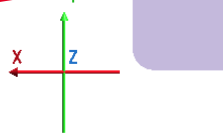
Filling Pressure (Bar)



v01
Cycle 1, Compression, Temperature
2.096s, 52.27 %
X-Ray: on





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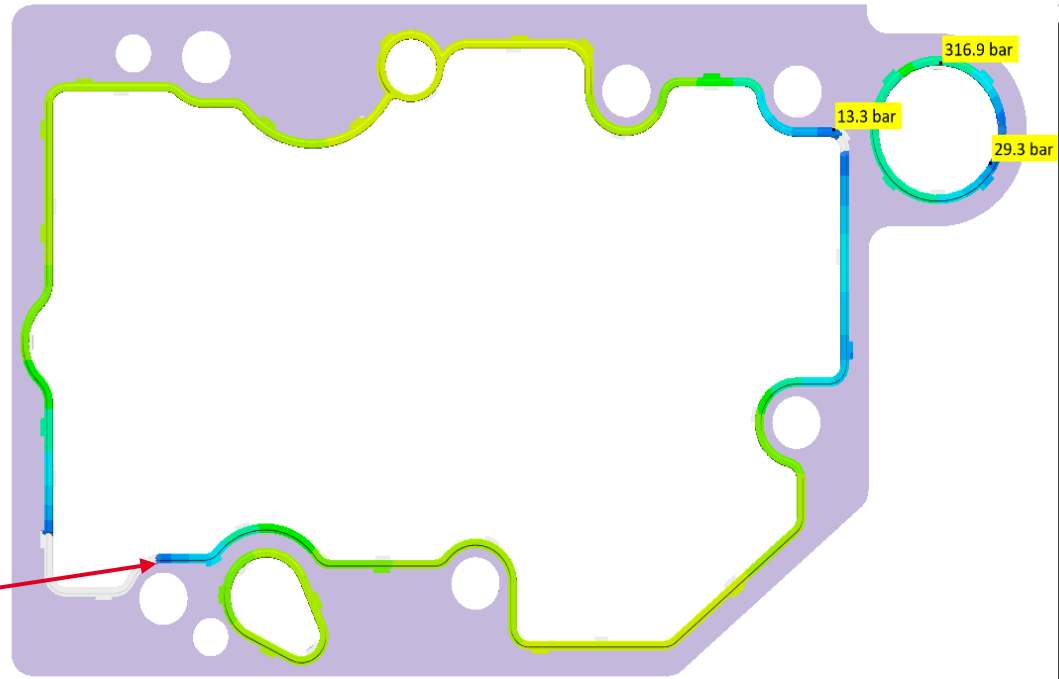
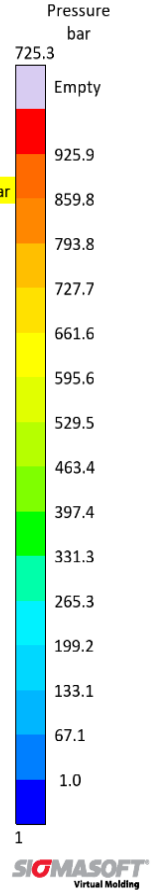
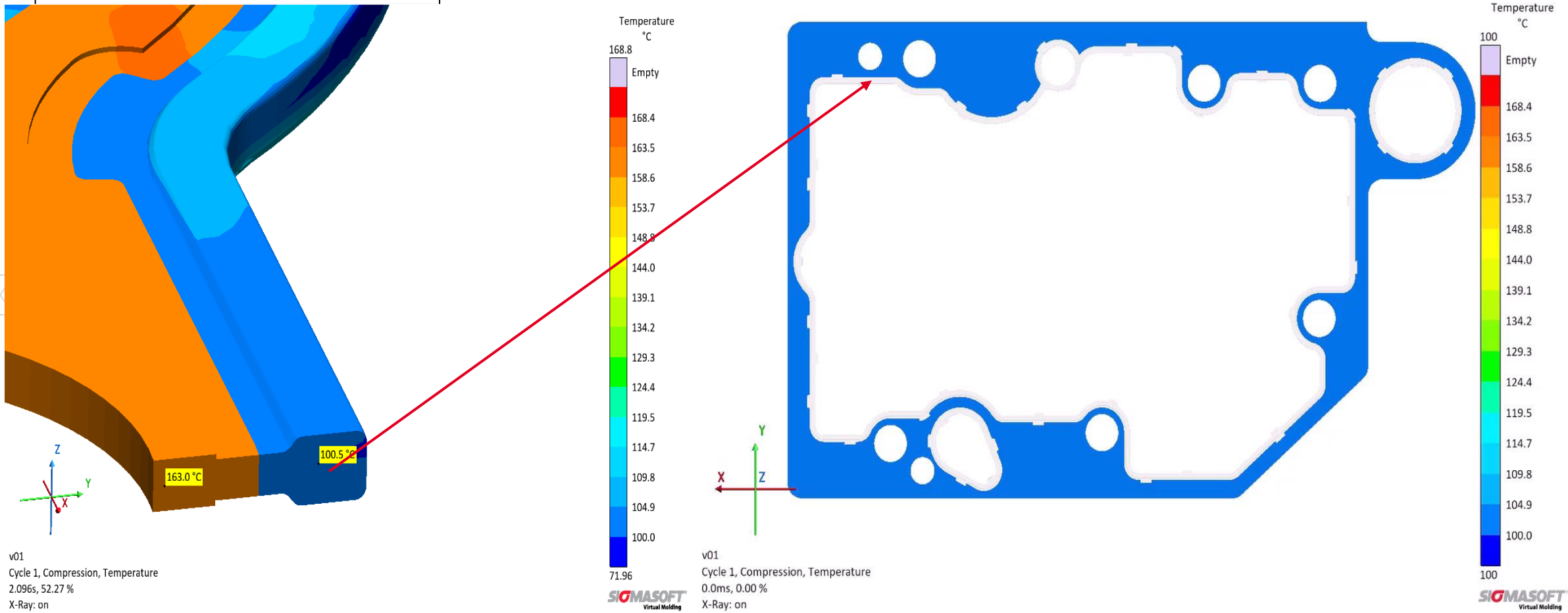




- Pictures show filling pressure as part is almost filled out. Maybe this would be of interest to you for bonding purposes.

Filling Temperature C

- Video shows filling temperature as part fills out. The maximum filling temperature is 128C (Material temp. only)



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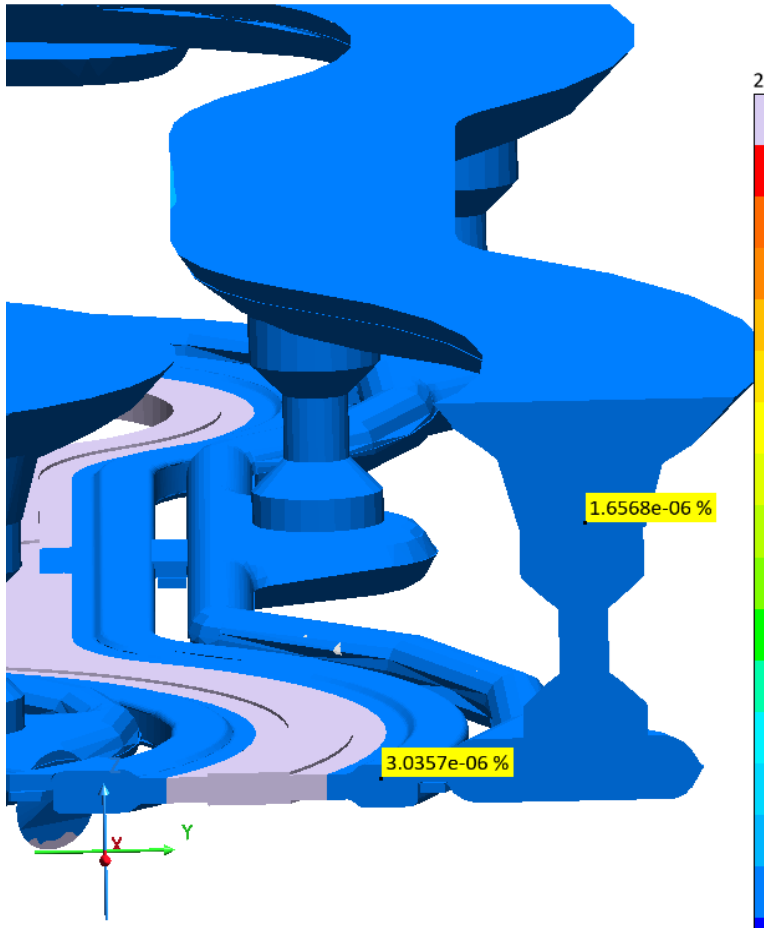
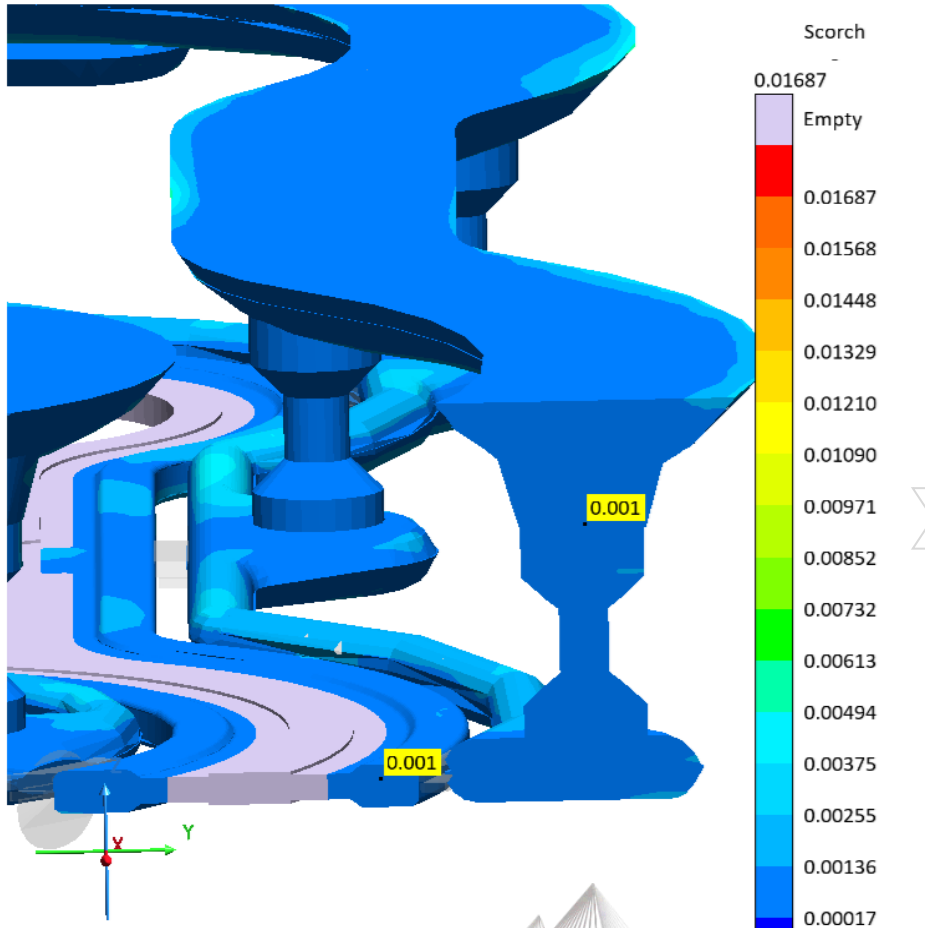
Curing Degree & Scorch While Filling (2 seconds in)

- End of fill using ACM shows minimum curing degree and scorch



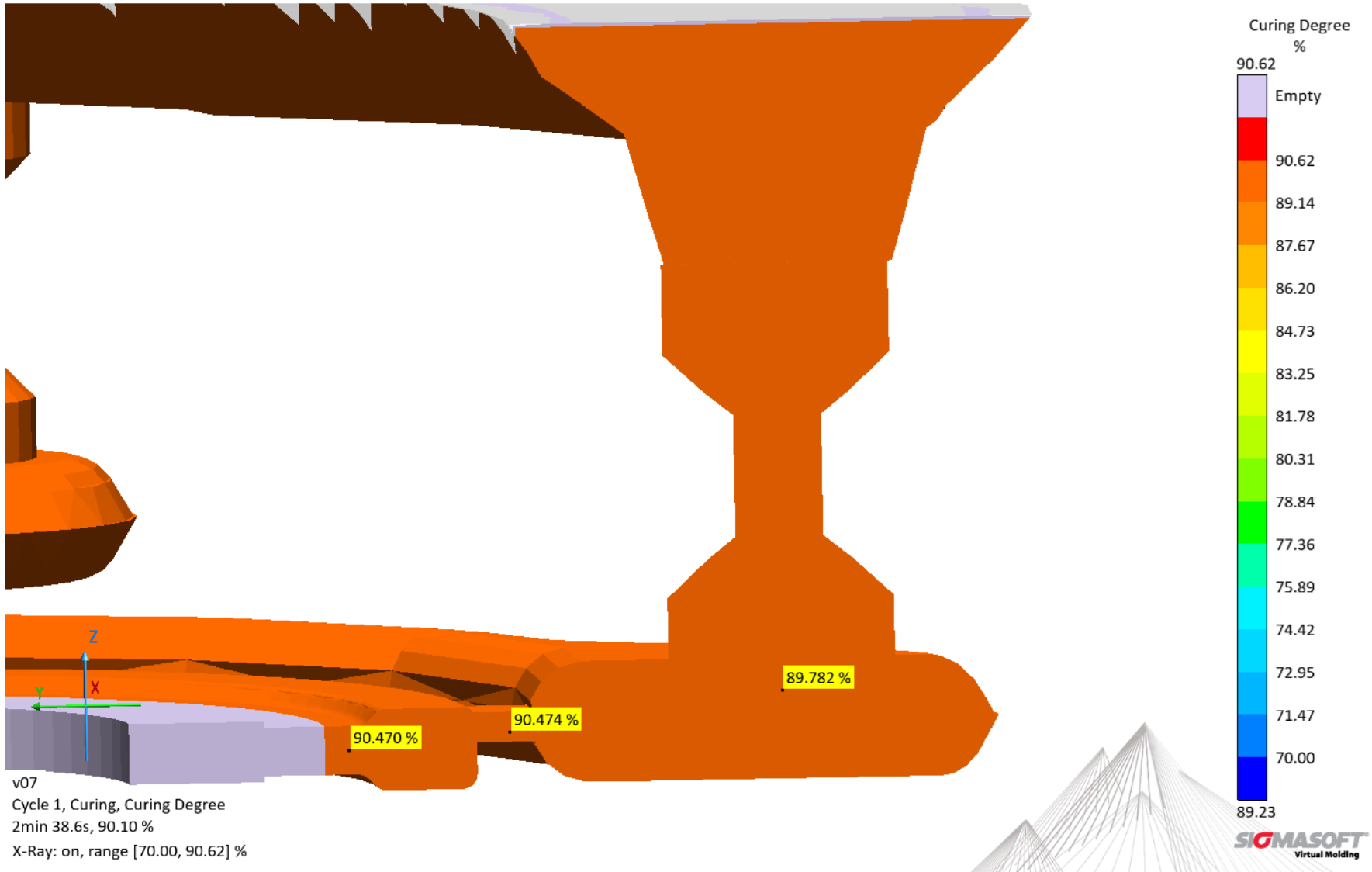
Curing Degree



Scorch

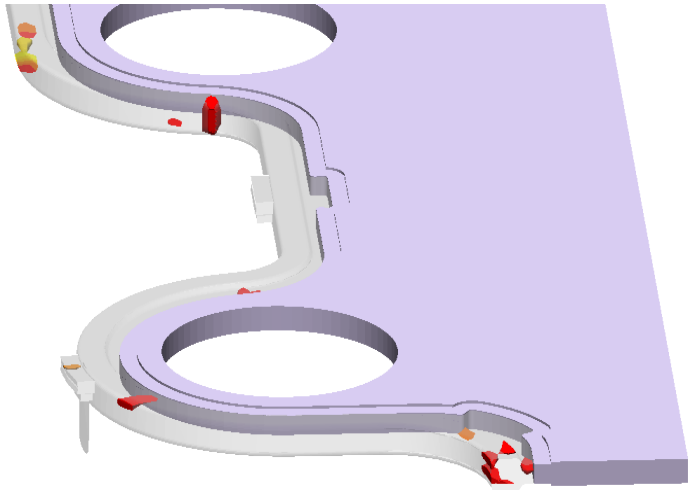
Curing Degree End of Cure (Tc90)

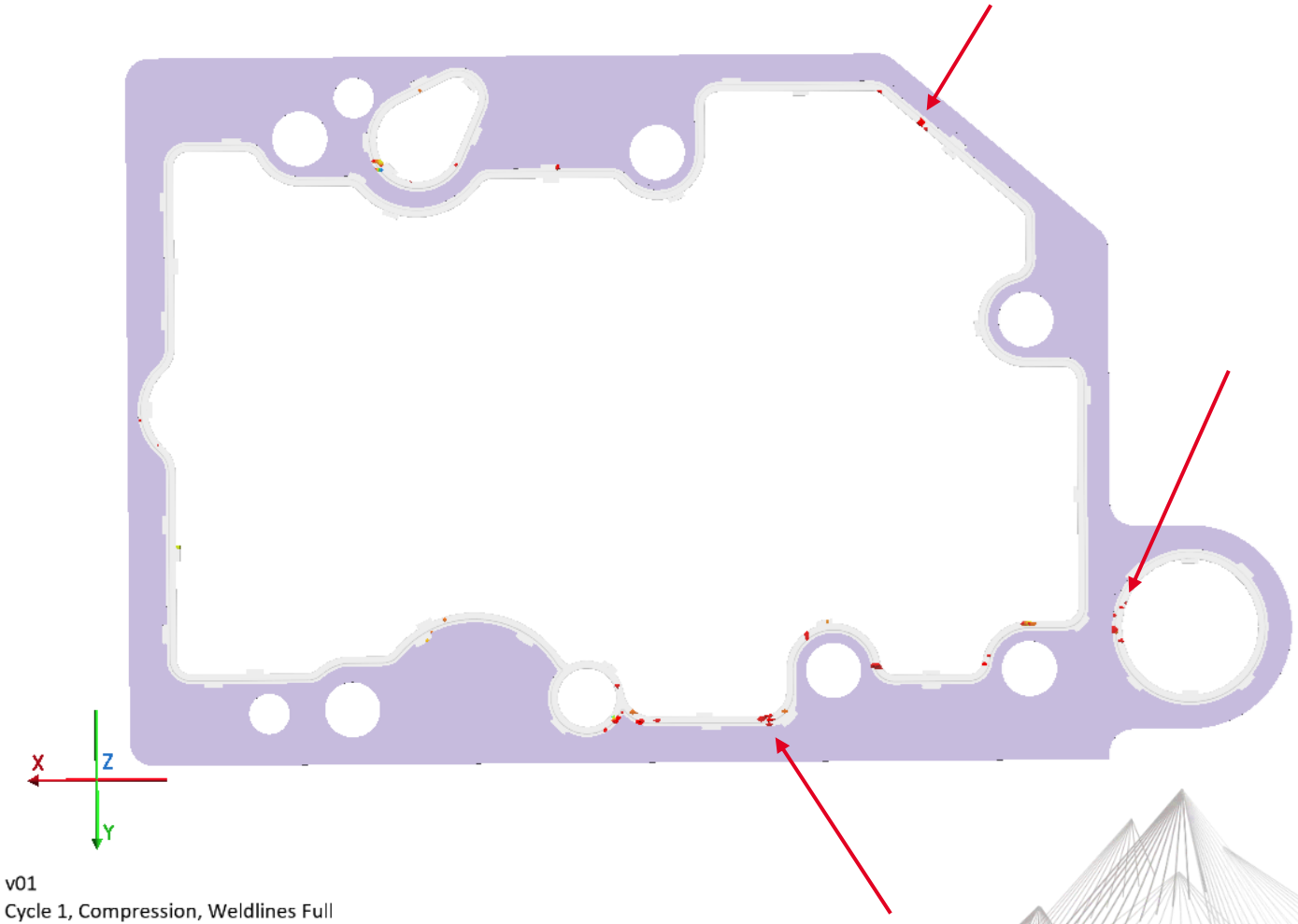
- Here is the curing degree at the end of the cycle at 2 minutes and 37 seconds.



Location of Weld Lines

- Colored areas on the part represent weld lines





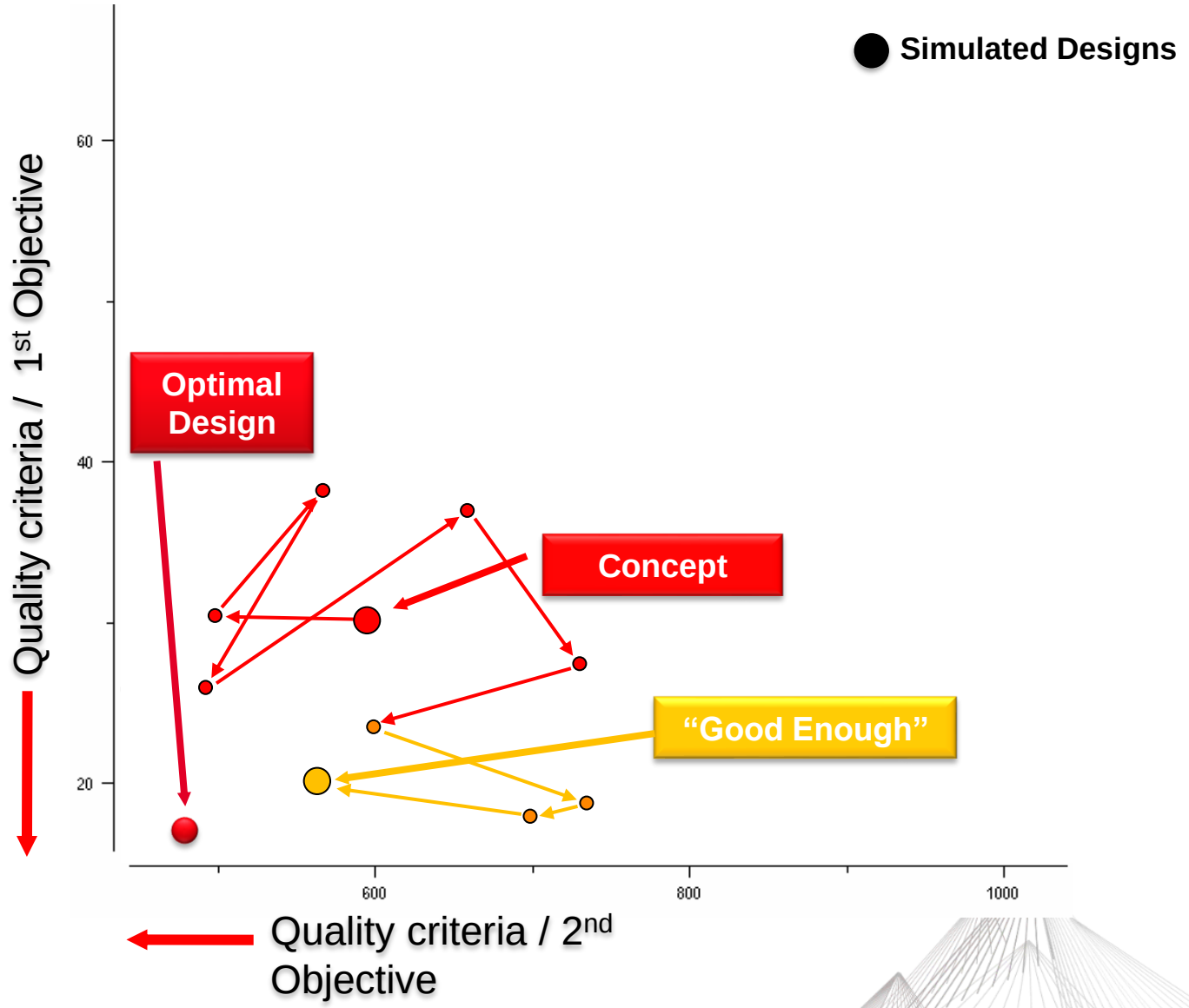
Design of Experiments and Autonomous Optimization

Autonomous Optimization - Optimal Design and Process Window

Manual Iteration

DoE

Autonomous Optimization



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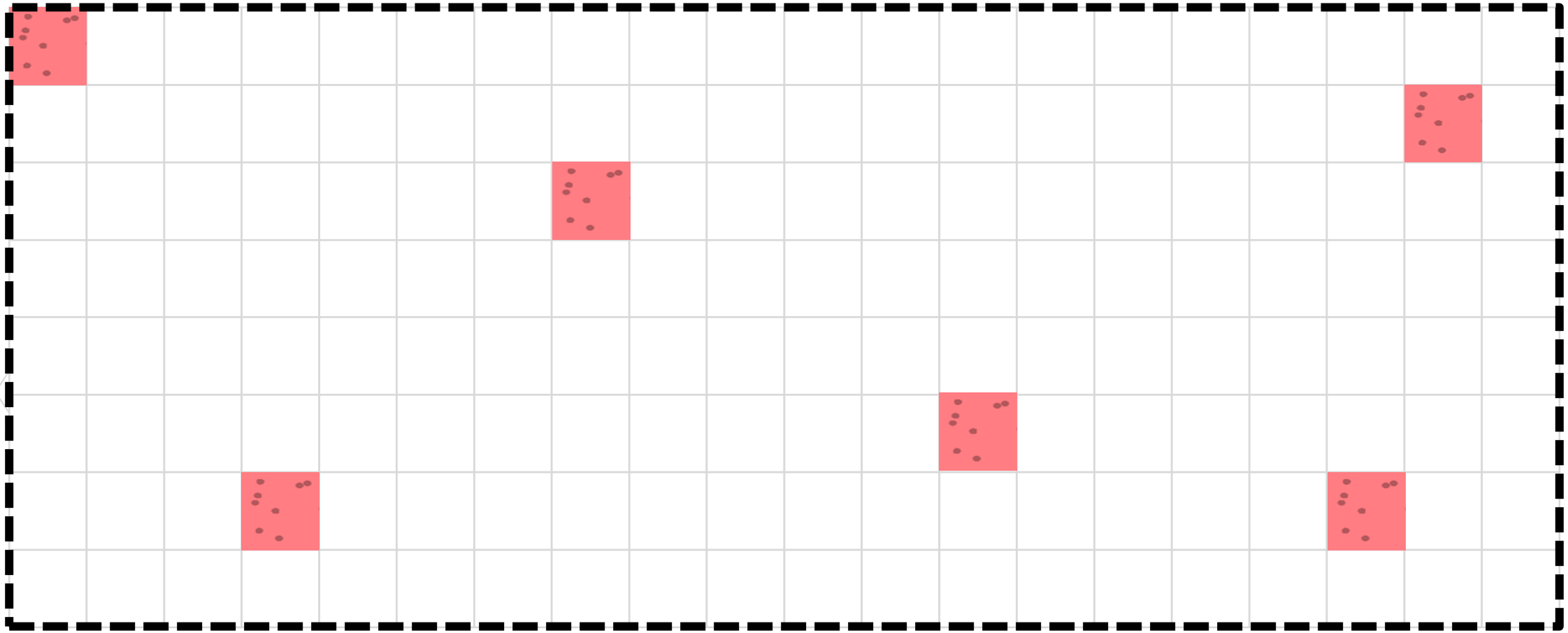
Autonomous Optimization: Generation 1



1st Generation

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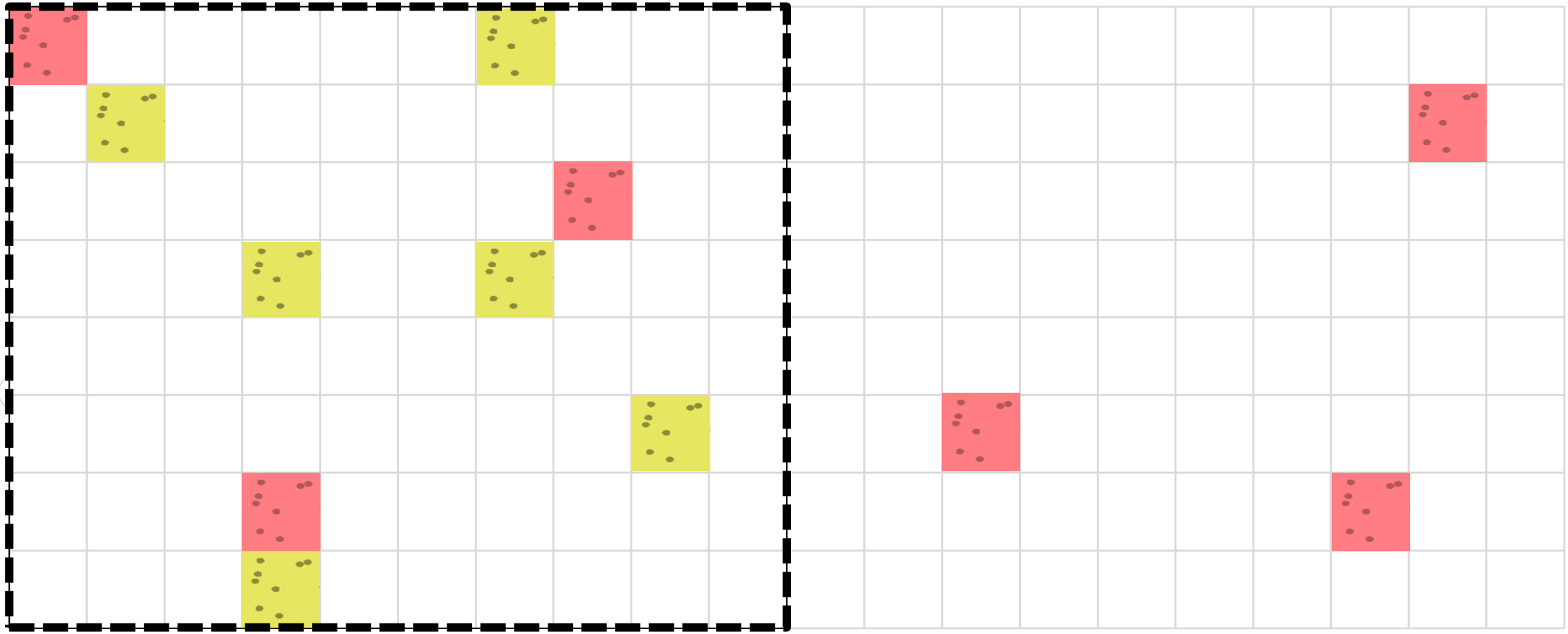
Autonomous Optimization: Generation 2



2nd Generation

1st Generation

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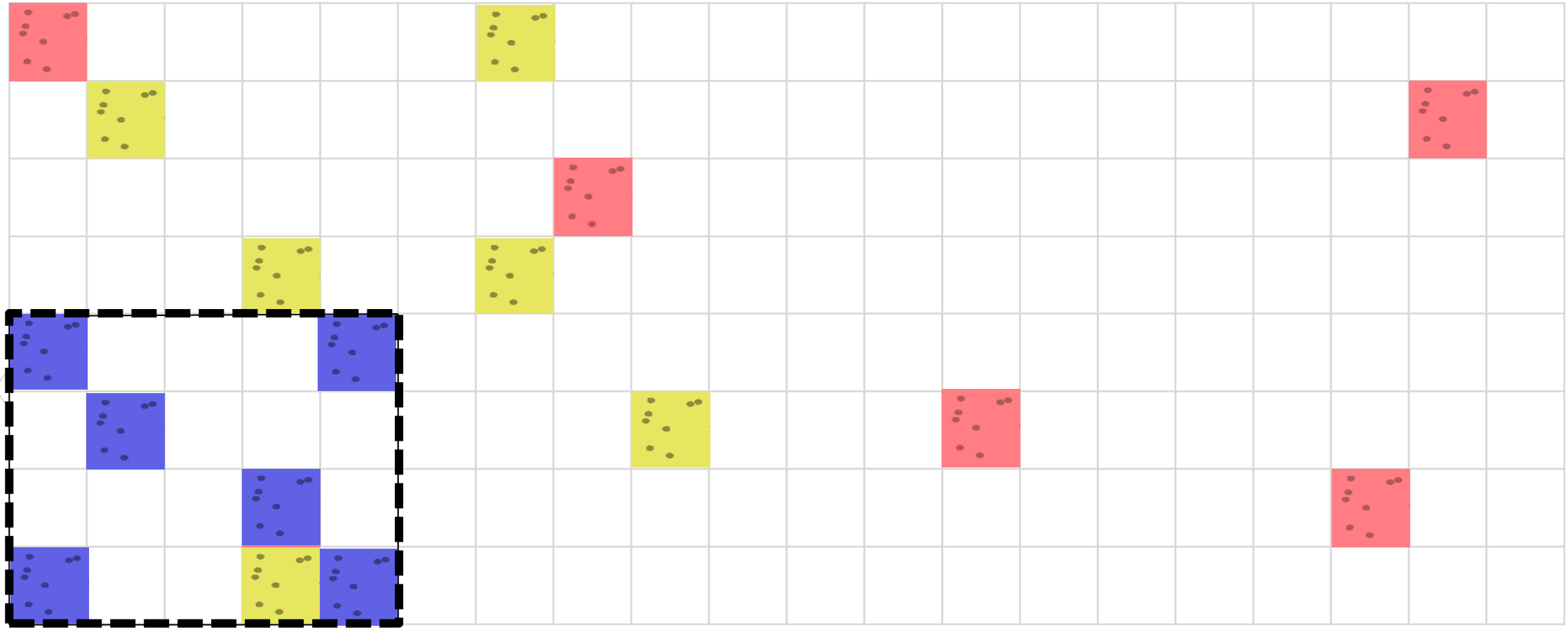
Autonomous Optimization: Generation 3



3rd Generation

2nd Generation

1st Generation

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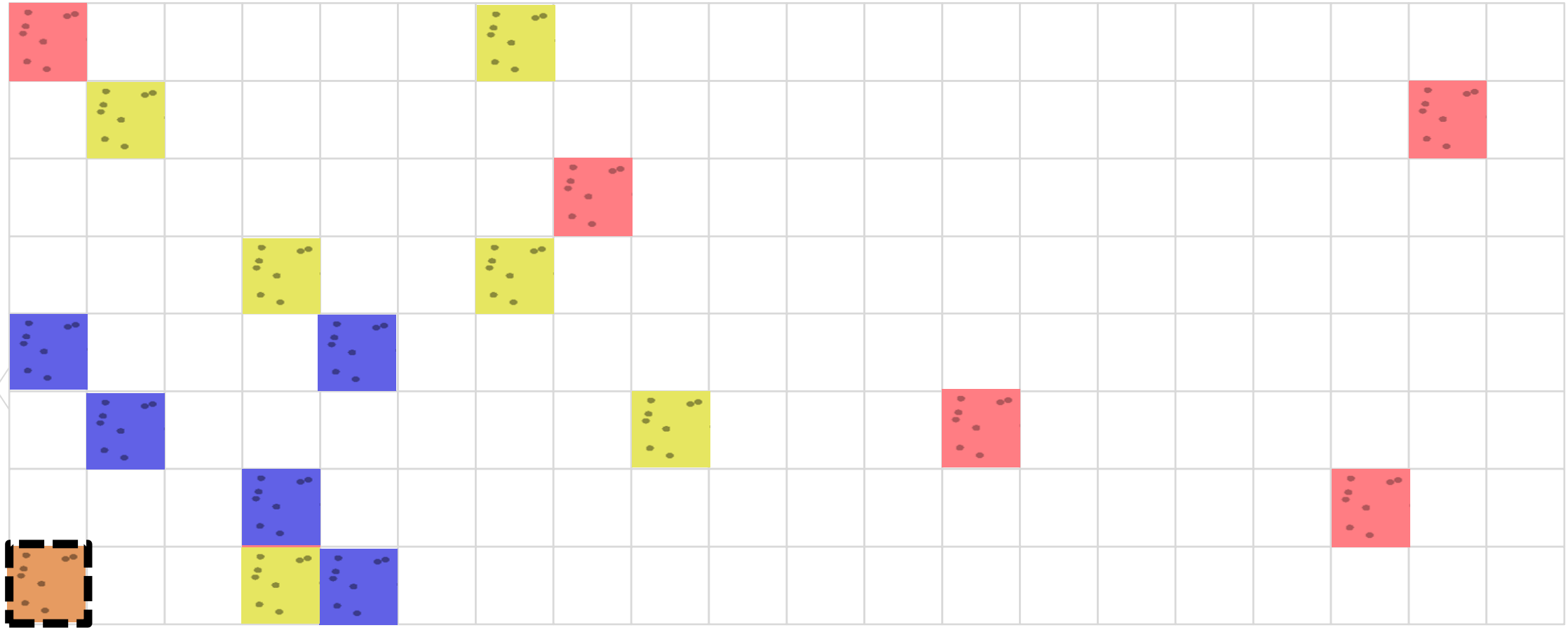
Autonomous Optimization: Solution



Optimal Design

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Design of Experiment #1

- Goal – Determine best curing degree while decreasing and increasing cure time.

Design of Experiment Set-Up

Original cure time to reach Tc90 is 157 seconds or 2.62 minutes

Design Variables

	Design Variable	Lower Limit (s)	Upper Limit (s)	Step (s)
☑	Mold Open Step - Fixed Mold ID 1 - Time	137.0	177.0	5.0

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DoE Results

Best design

	Rank	Design	Curing Degree (-)
■	Rank 1	Design 1	87.89
	Rank 2	Design 2	89.28
	Rank 3	Design 3	90.45
	Rank 4	Design 4	91.44

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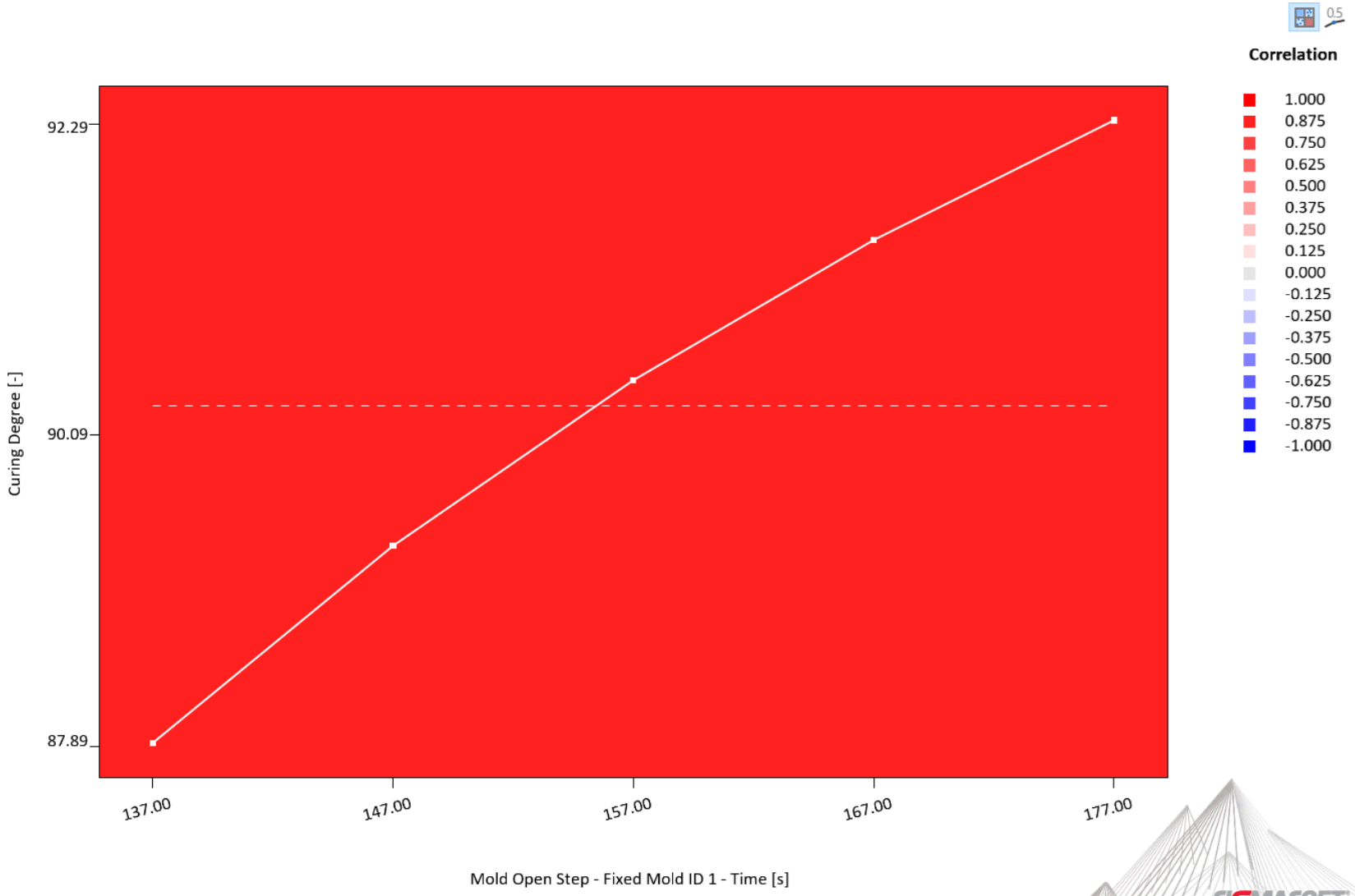
Curing Degree vs. Mold Open Time

Original cure time to reach Tc90 is 157 seconds or 2.62 minutes. If you're ejecting parts at 137 seconds (2.28 min) and post curing ACM you're covered. This took 20 seconds off the original cure time.



Design of Experiment #2

- Goal – Determine highest cavity pressure while increasing and decreasing compression time.

Design of Experiment Set-Up

Design Variables

	Design Variable	Lower Limit (s)	Upper Limit (s)	Step (s)
☑	Move Compression Mold - Moving Time	2.0	6.0	2.0
	Design Variable	**Lower Limit (°C)**	**Upper Limit (°C)**	**Step (°C)**
☑	Compression Mold All - Initial Temperature	170.0	190.0	5.0
☑	Fixed Mold All - Initial Temperature			

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DoE Results

Rank	Design	Compression Mold All - I...	Fixed Mold All - Initial Te...	Move Compression Mold...	Pressure (-)	Pressure1 (-)
Rank 1	Design 9	180.0	180.0	6.0	115.5	1051.05
Rank 2	Design 6	175.0	175.0	6.0	120.31	1083.43
Rank 3	Design 3	170.0	170.0	6.0	128.78	1192.89
Rank 4	Design 8	180.0	180.0	4.0	160.32	1615.27
Rank 5	Design 5	175.0	175.0	4.0	173.25	1584.27
Rank 6	Design 2	170.0	170.0	4.0	172.62	1712.52
Rank 7	Design 4	175.0	175.0	2.0	289.68	2335.01
Rank 8	Design 7	180.0	180.0	2.0	278.18	2431.17
Rank 9	Design 1	170.0	170.0	2.0	288.25	2433.49

Best design (Highest cavity pressure which will help with rubber to metal bonding)

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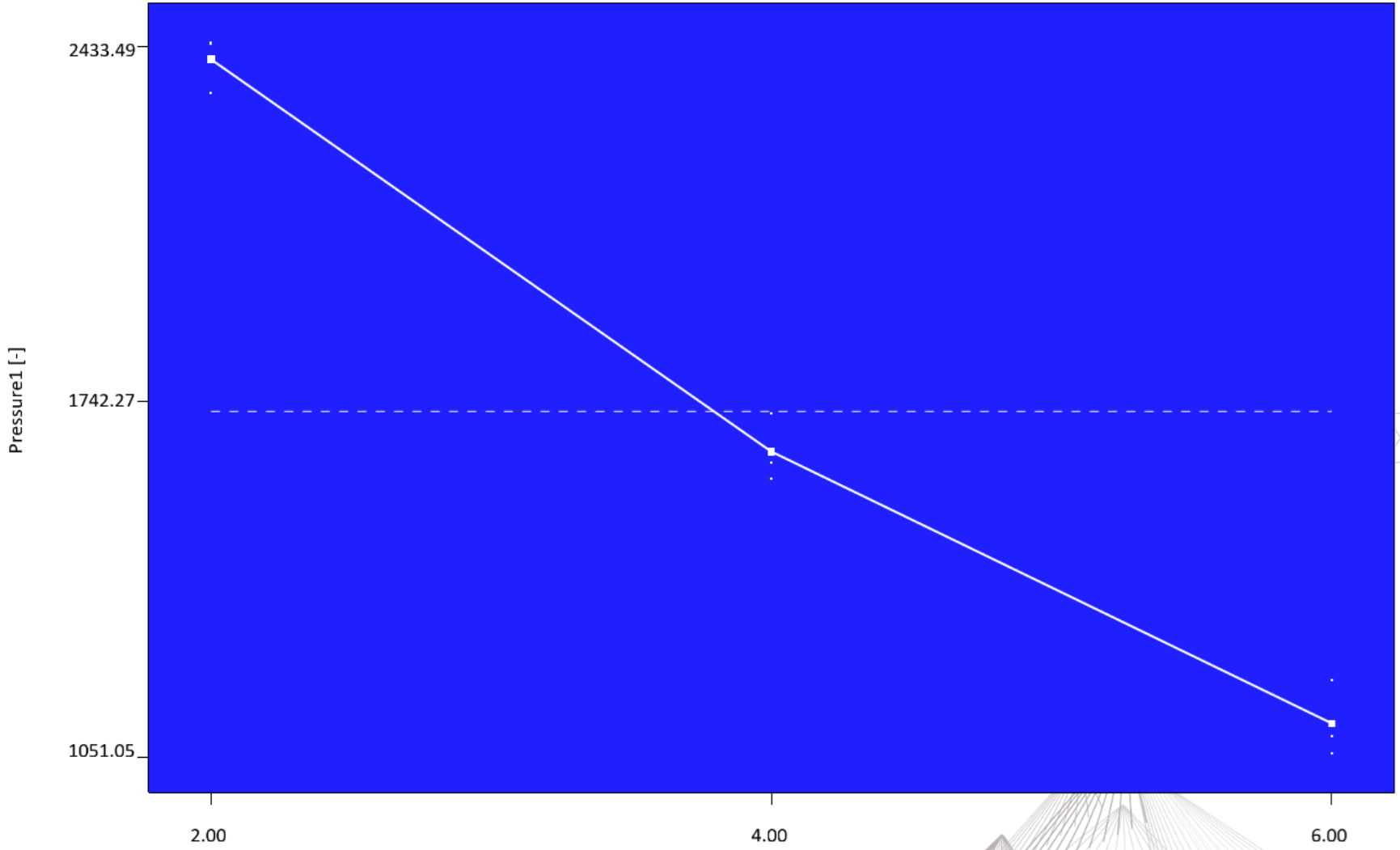
Compression Time vs. Cavity Pressure

With the compression time being 2 seconds this was able to get us high cavity pressure. This will help with rubber to metal bonding.



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Remarks

- Data suggests that lowering your cure time for 2.3 minutes will still get you around Tc90.
- If you want to accomplish high cavity pressure a 2 second compression time will give you a higher result. This should help with rubber to metal bonding.