



FLOW-3D European Users Conference 2019, Milan 3-5 June

Casting die optimization by mean of IMPROVEit

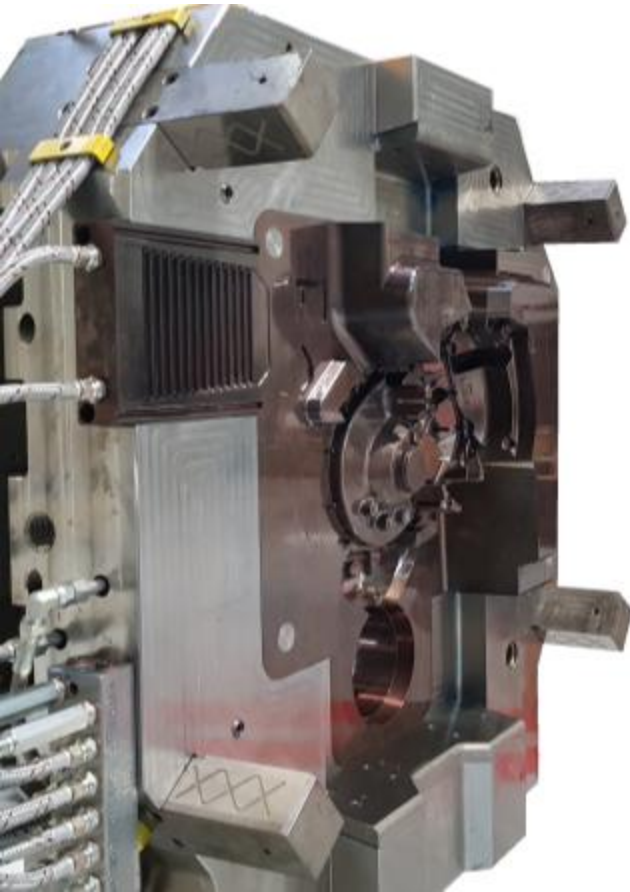
Daniele Grassivaro – daniele.grassivaro@formstampi.it

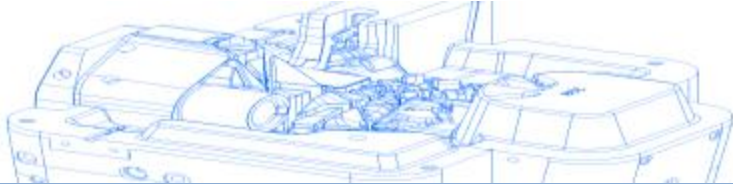
Form Srl – www.formstampi.it



Form Srl in short:

- HPDC dies
- Since 1980
- 35 employees
- 4.4 M€ turnover
 - 3500t max machine size
- Flow3D-CAST user since 2012





Magnesium thin walled-casting

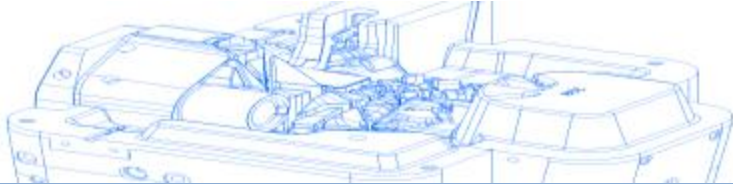
Optimization of gate design

Overall dimensions 120x120x100mm

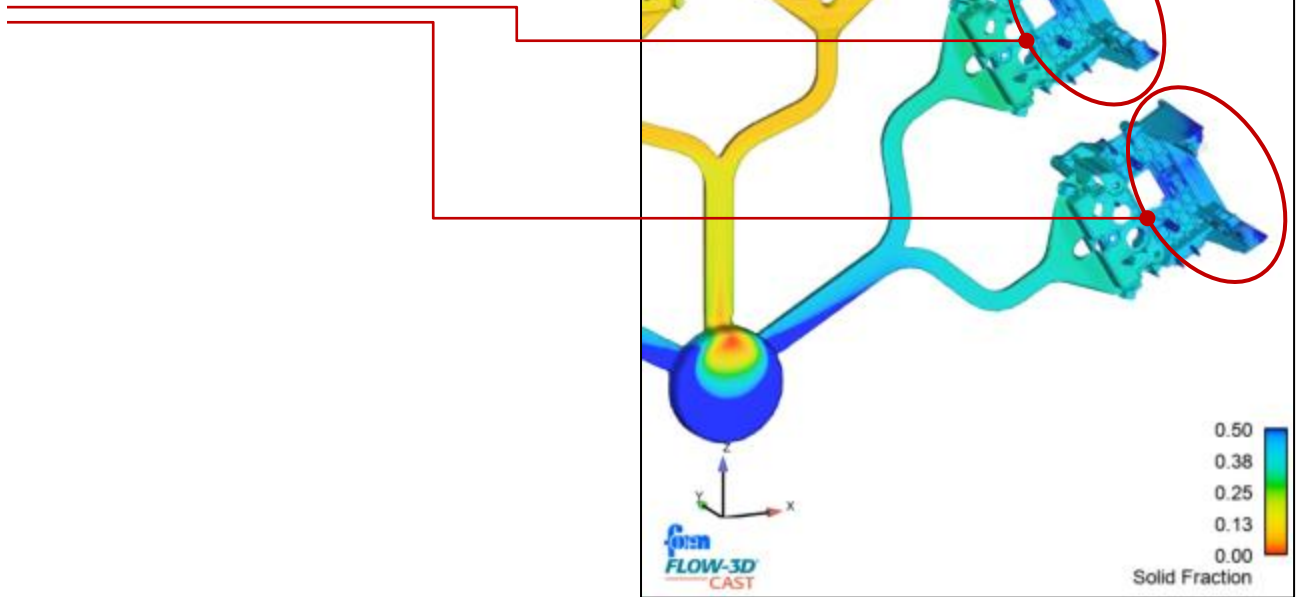
General thickness 1.5mm

6 cavities die



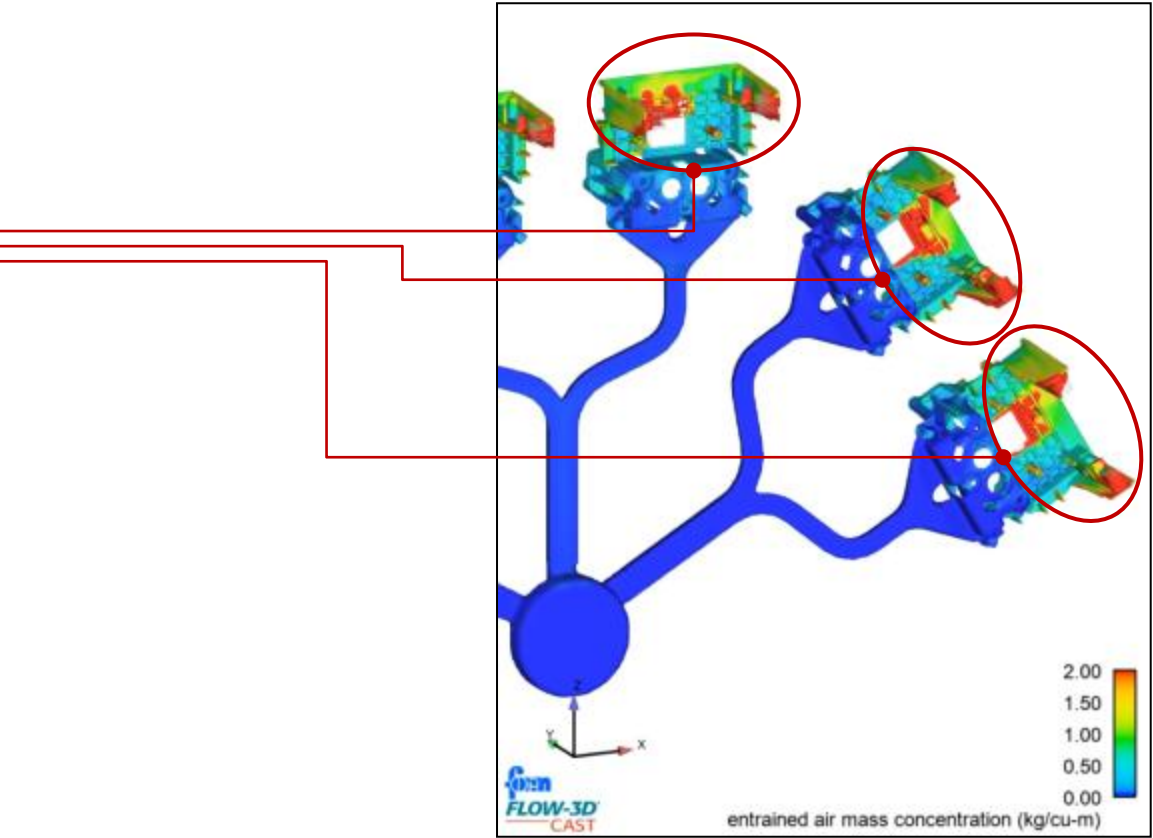


Cold joints here





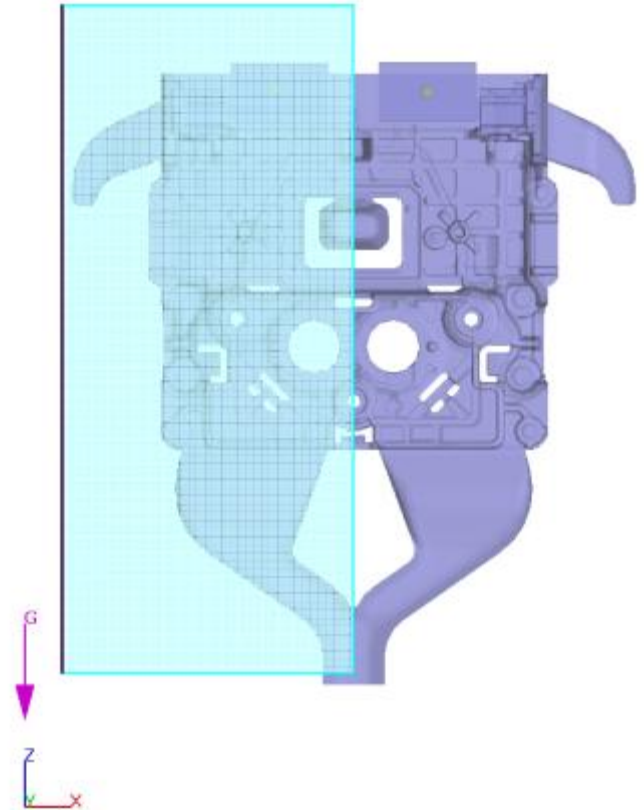
Air entrainment here





Simulation setup:

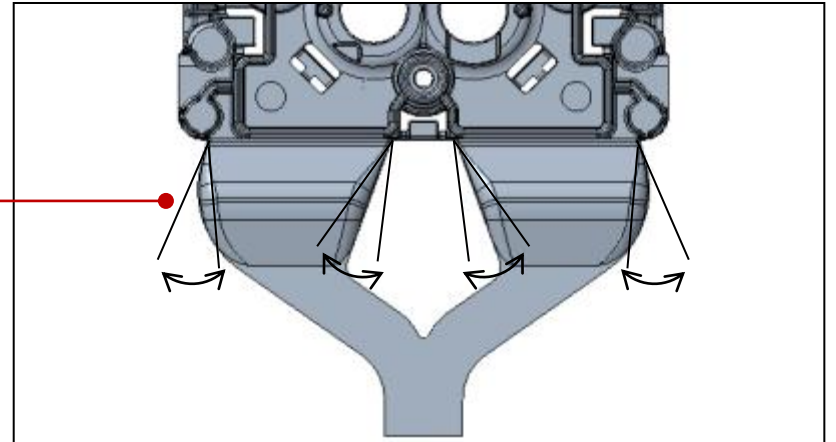
- Symmetry plane $X=0$
- Nr.2 venting valve
- Volume flow rate boundary in Z_{min}
- Size of cells 0.6mm
- Nr. 424k Fluid sub-domain cells
- Duration: 1h 55 min
- Budget: 14 simulations





Optimization Input:

Gate angle

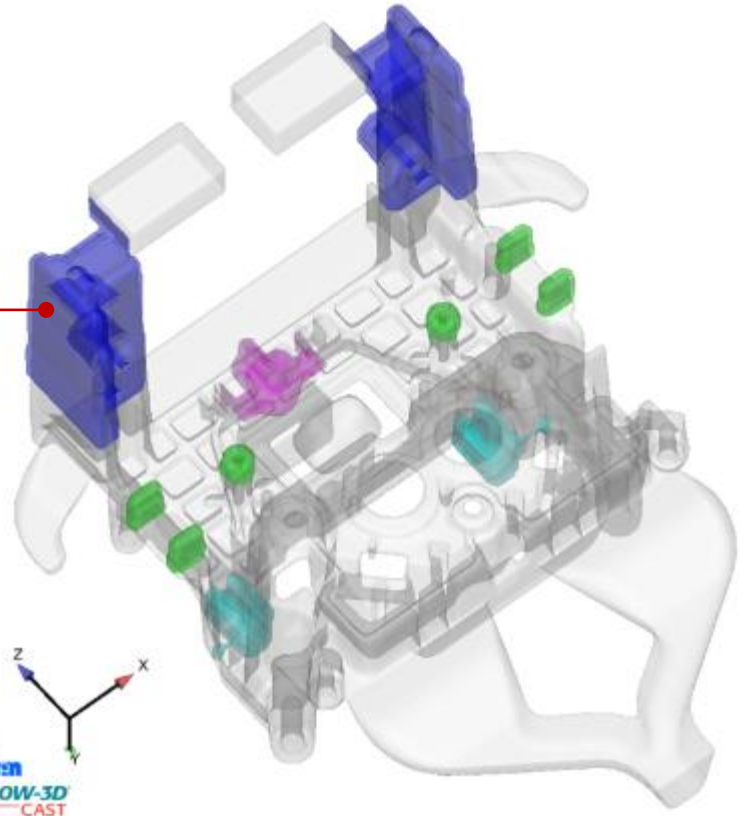




Optimization Output:

Into blue sampling volume:
-Solidified fraction volume

Into all sampling volume:
-Entrained air mass

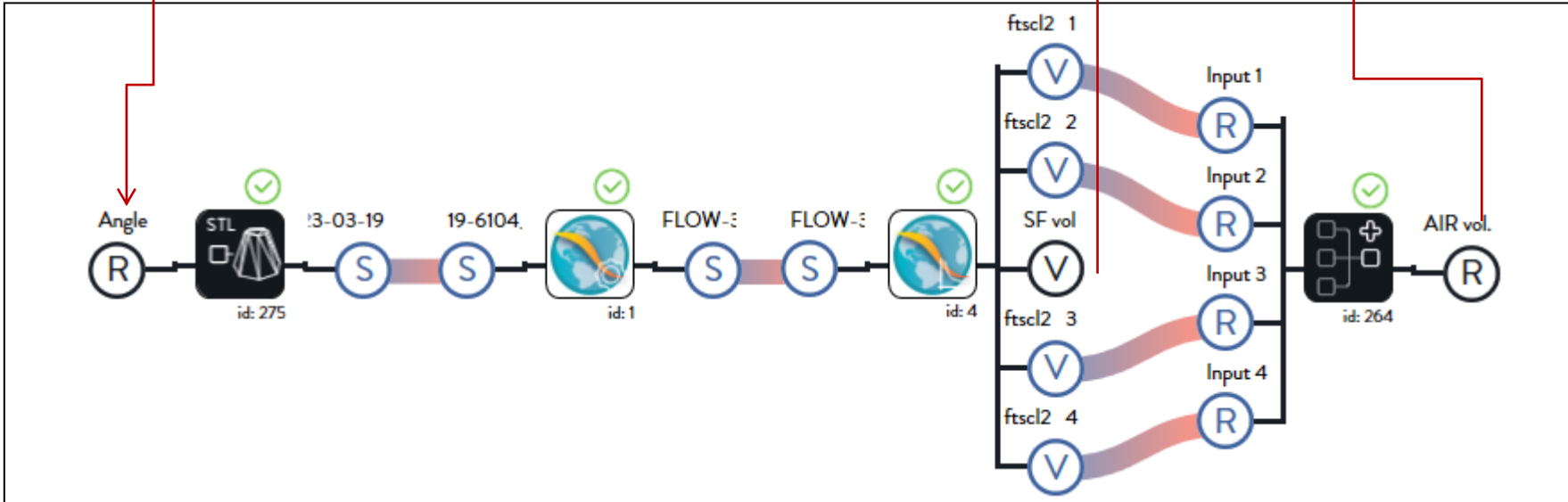




Optimization Workflow:

Input list				
Name	Qualifier	MinimumRange	MaximumRange	InputString
Angle	Variable	-7	10	

Output list	
Name	Objective
SF vol	Minimize
AIR vol	Minimize



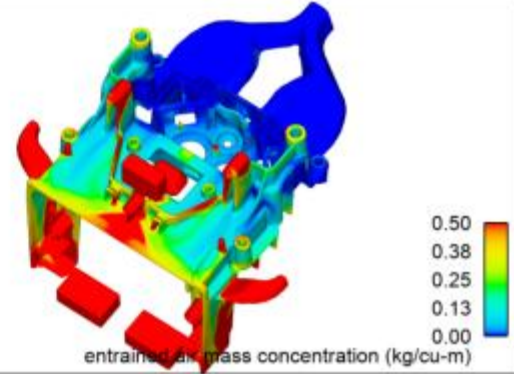
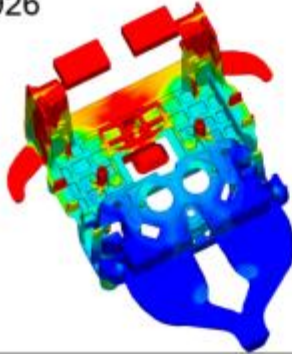


Optimization Results:

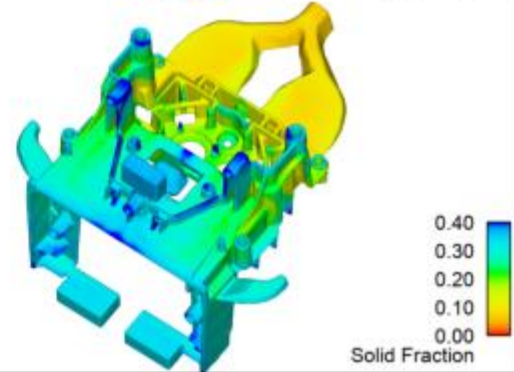
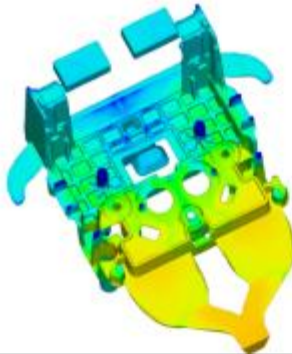


#	Transf 1	SV	AIR	Status
6	1.0000E+01	1.4725E-06	3.9473E-06	Trusted
9	8.9799E+00	1.4746E-06	4.1746E-06	Trusted
5	8.3000E+00	1.4592E-06	4.2245E-06	Trusted
12	6.5906E+00	1.4659E-06	3.9356E-06	Trusted
8	6.3465E+00	1.4668E-06	4.0668E-06	Trusted
7	6.3366E+00	NaN	NaN	Stopped
4	4.9000E+00	1.4668E-06	3.5247E-06	Trusted
14	4.5572E+00	1.4674E-06	3.5462E-06	Trusted
13	4.2214E+00	1.4647E-06	3.5403E-06	Trusted
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3	-5.3000E+00	1.4659E-06	3.8918E-06	Trusted
10	-5.9771E+00	1.4647E-06	3.6713E-06	Trusted
11	-7.0000E+00	1.4662E-06	3.7730E-06	Trusted

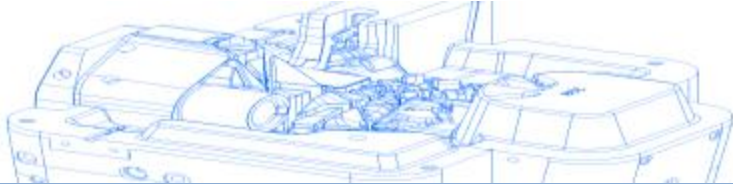
2926



entrained air mass concentration (kg/cu-m)



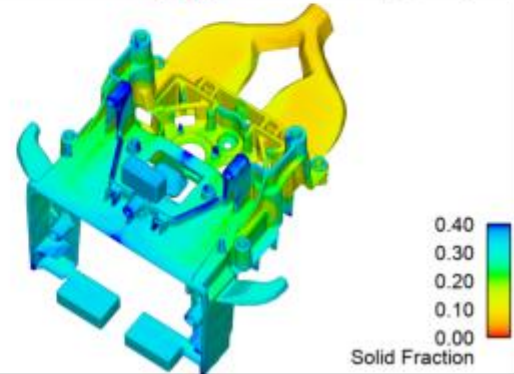
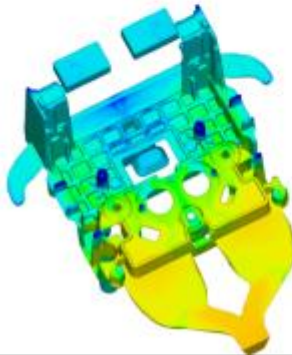
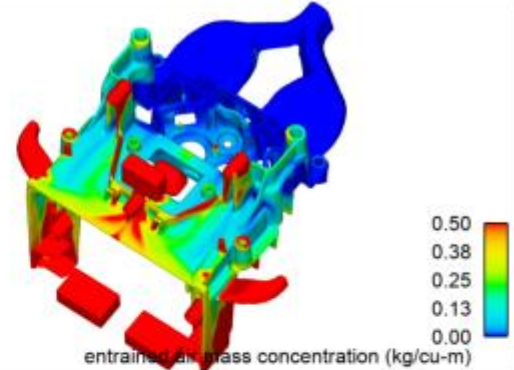
Solid Fraction

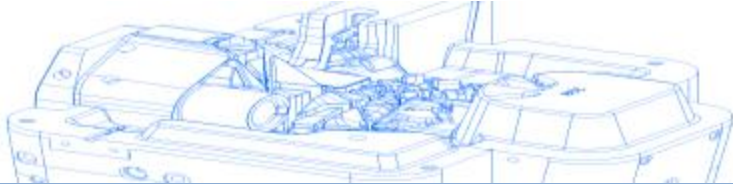


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2929

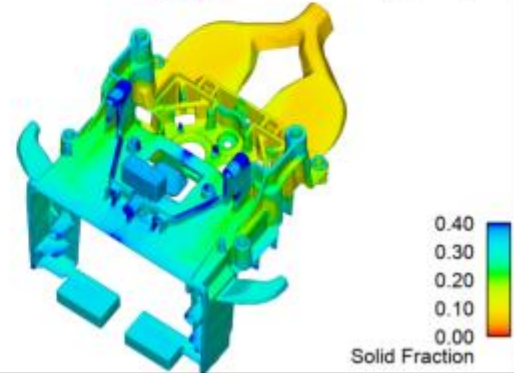
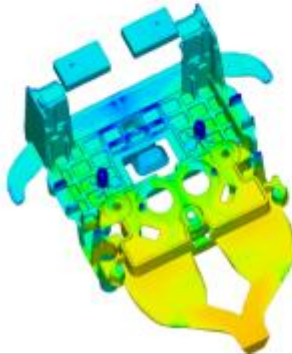
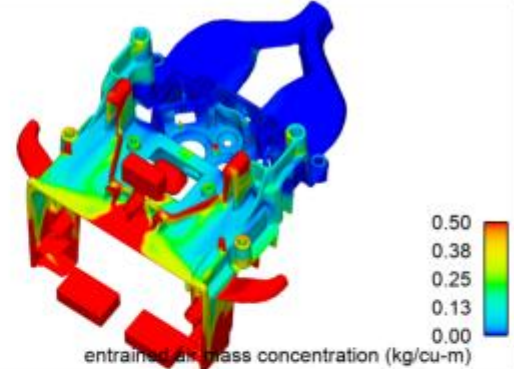
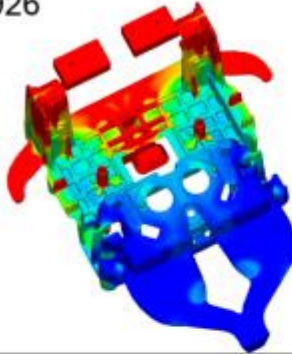




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2926

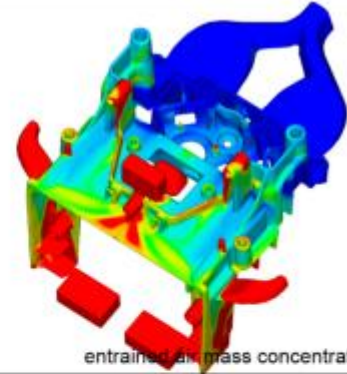
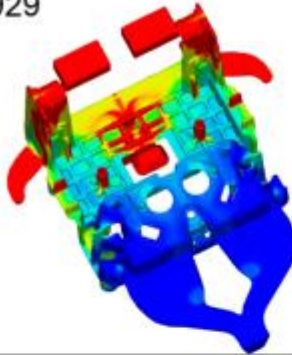




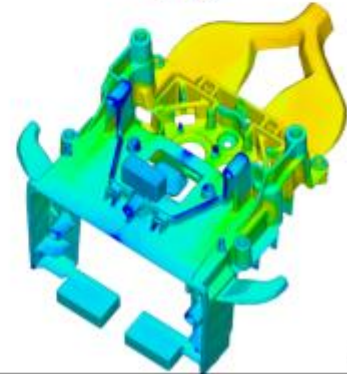
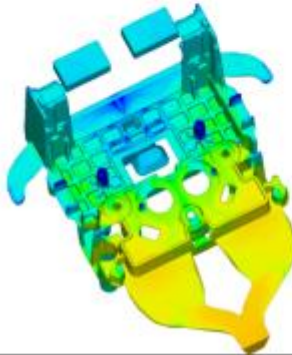
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2929



entrained air mass concentration (kg/cu-m)



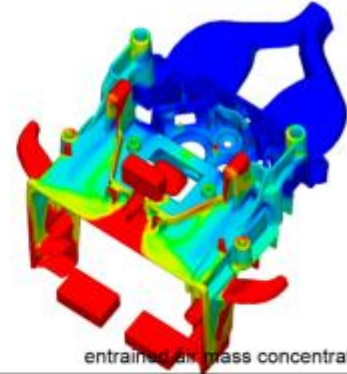
Solid Fraction



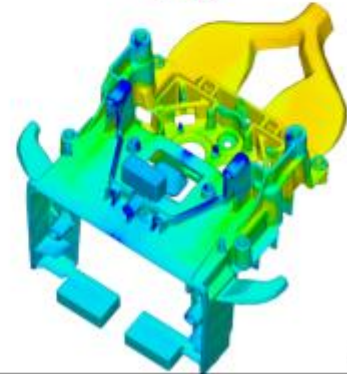
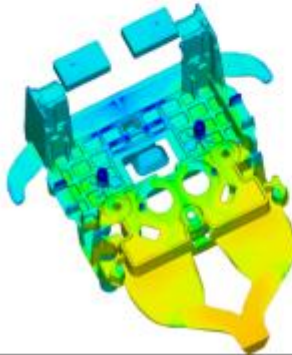
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11	-7.0000E+00	1.4662E-06	3.7730E-06	Trusted

2927



entrained air mass concentration (kg/cu-m)

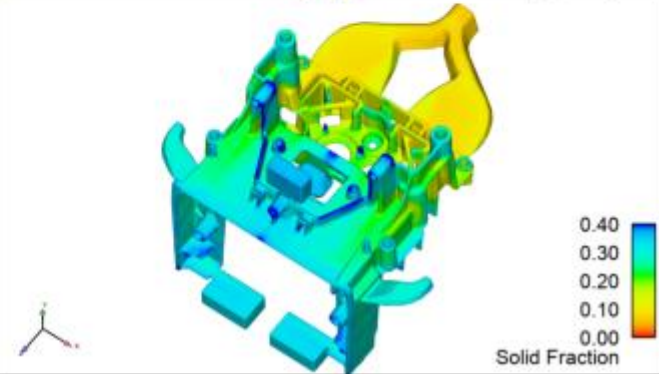
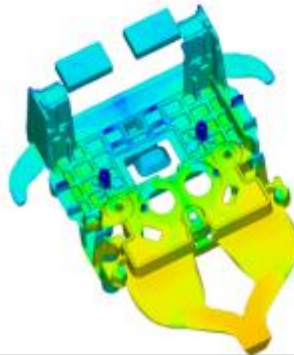
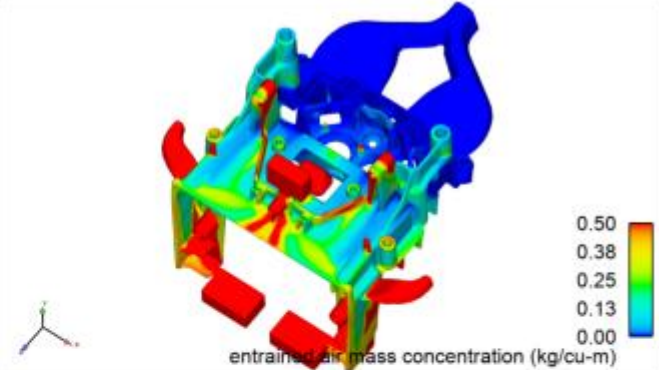
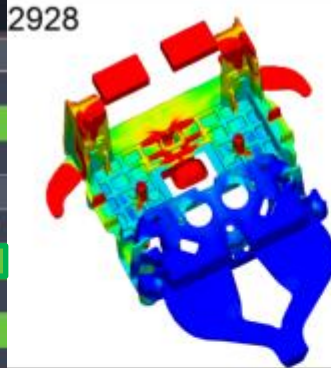


Solid Fraction



Optimization Results:

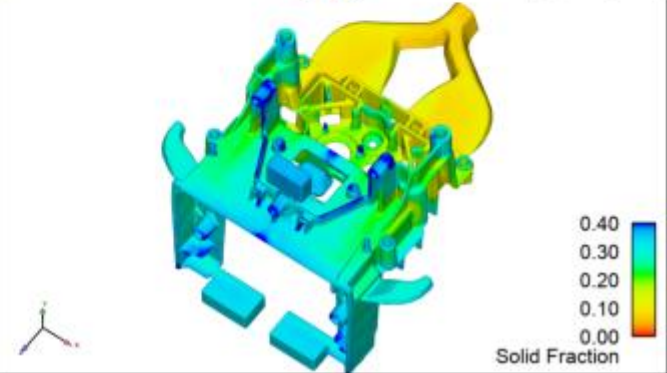
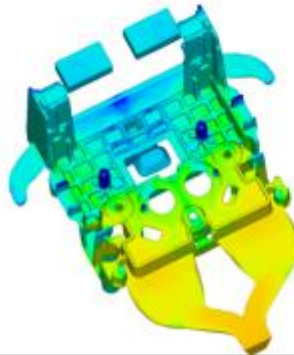
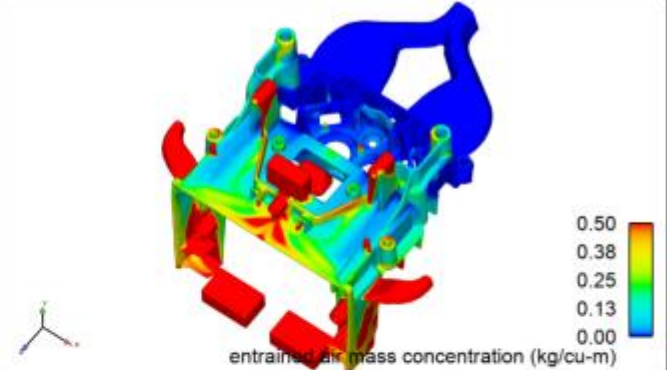
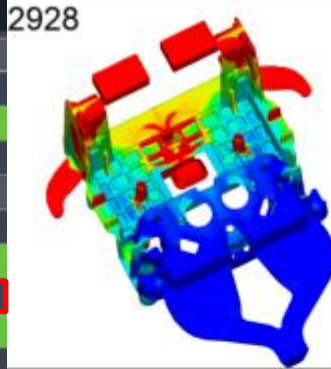
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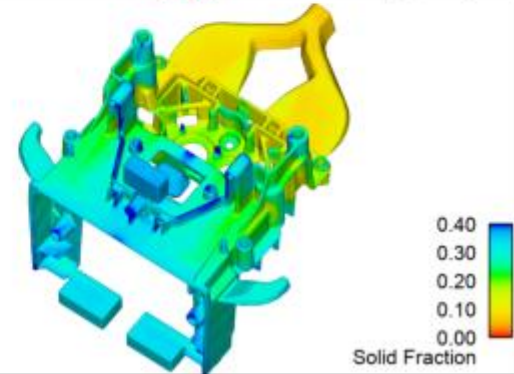
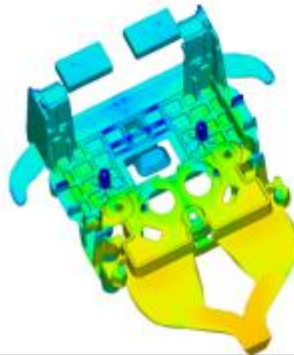
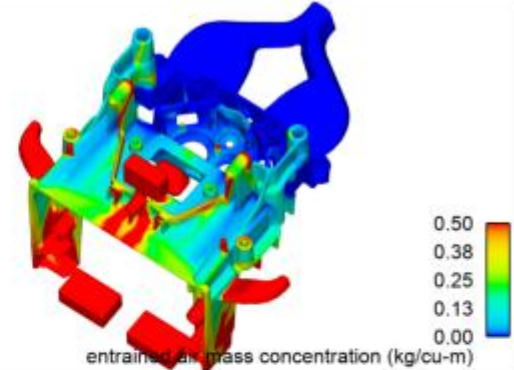
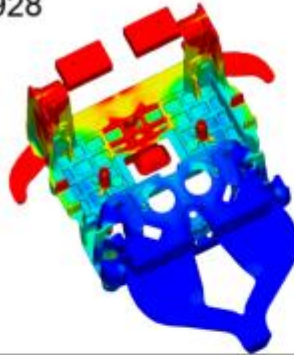




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2928

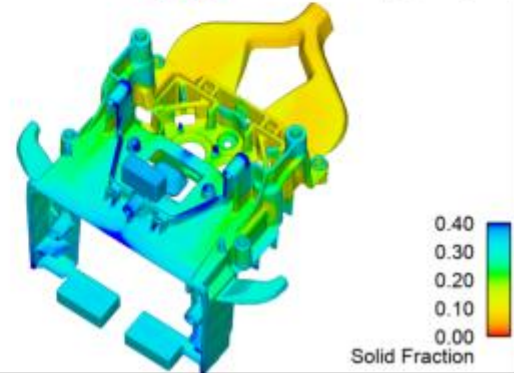
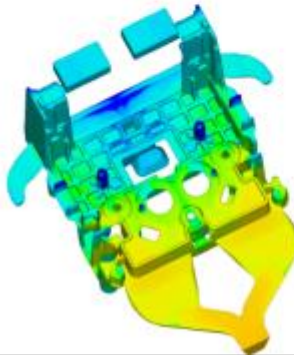
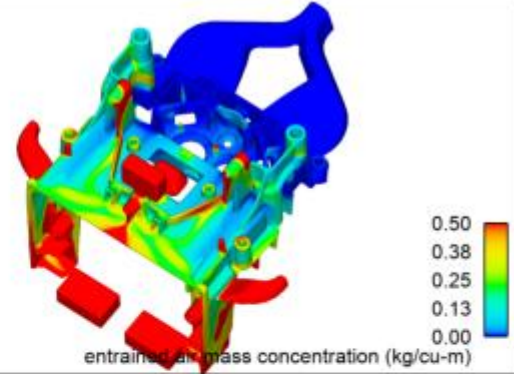
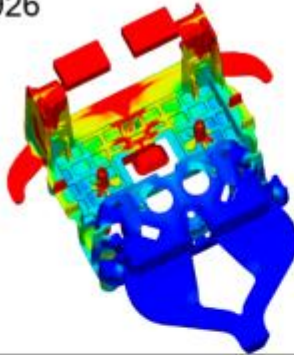


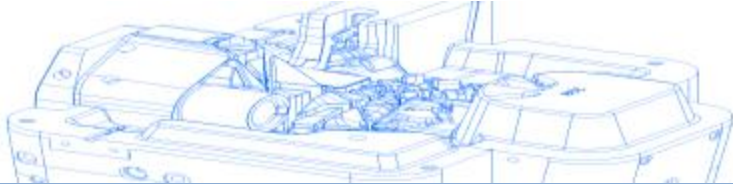


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11	-7.0000E+00	1.4662E-06	3.7730E-06	Trusted

2926

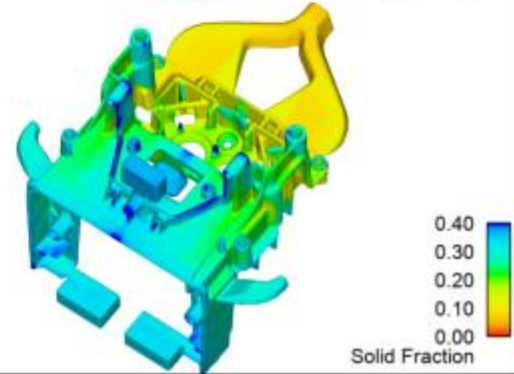
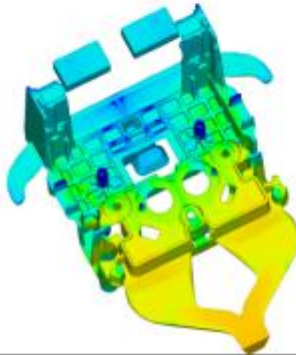
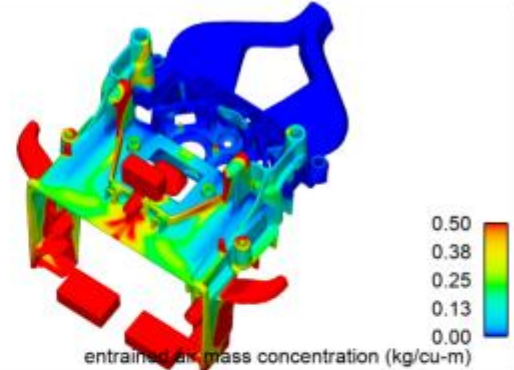
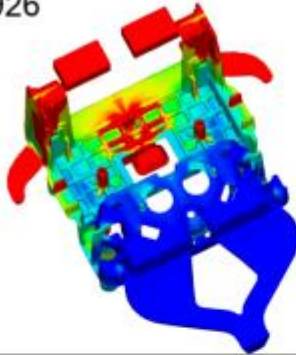


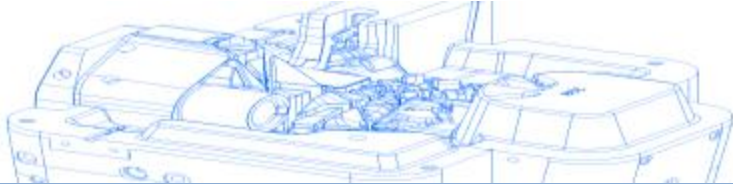


Optimization Results:

#	Transf 1	SV	AIR	Status
6	1.0000E+01	1.4725E-06	3.9473E-06	Trusted
9	8.9799E+00	1.4746E-06	4.1746E-06	Trusted
5	8.3000E+00	1.4592E-06	4.2245E-06	Trusted
12	6.5906E+00	1.4659E-06	3.9356E-06	Trusted
8	6.3465E+00	1.4668E-06	4.0668E-06	Trusted
7	6.3366E+00	NaN	NaN	Stopped
4	4.9000E+00	1.4668E-06	3.5247E-06	Trusted
14	4.5572E+00	1.4674E-06	3.5462E-06	Trusted
13	4.2214E+00	1.4647E-06	3.5403E-06	Trusted
1	1.5000E+00	1.4707E-06	3.6405E-06	Trusted
2	-1.9000E+00	1.4669E-06	4.3971E-06	Trusted
3	-5.3000E+00	1.4659E-06	3.8918E-06	Trusted
10	-5.9771E+00	1.4647E-06	3.6713E-06	Trusted
11	-7.0000E+00	1.4662E-06	3.7730E-06	Trusted

2926

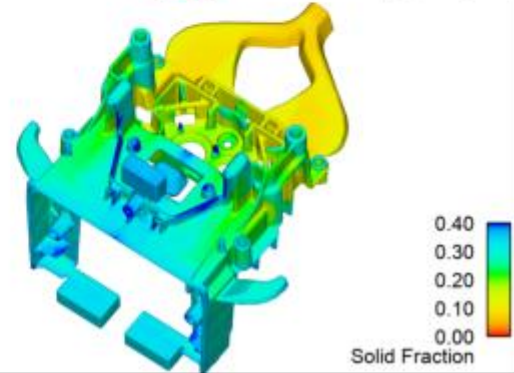
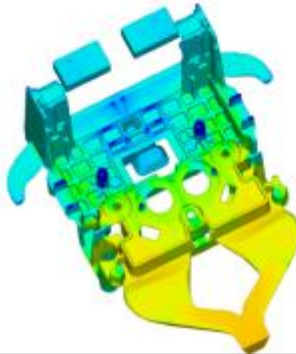
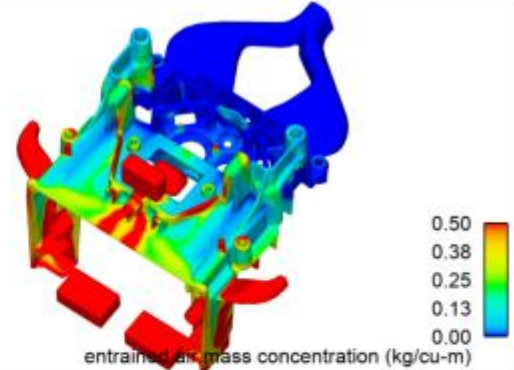
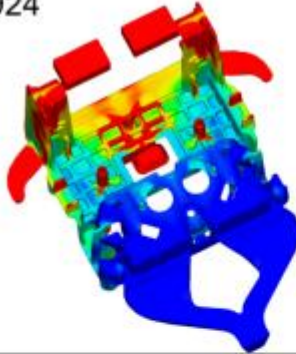




Optimization Results:

#	Transf 1	SV	AIR	Status
6	1.0000E+01	1.4725E-06	3.9473E-06	Trusted
9	8.9799E+00	1.4746E-06	4.1746E-06	Trusted
5	8.3000E+00	1.4592E-06	4.2245E-06	Trusted
12	6.5906E+00	1.4659E-06	3.9356E-06	Trusted
8	6.3465E+00	1.4668E-06	4.0668E-06	Trusted
7	6.3366E+00	NaN	NaN	Stopped
4	4.9000E+00	1.4668E-06	3.5247E-06	Trusted
14	4.5572E+00	1.4674E-06	3.5462E-06	Trusted
13	4.2214E+00	1.4647E-06	3.5403E-06	Trusted
1	1.5000E+00	1.4707E-06	3.6405E-06	Trusted
2	-1.9000E+00	1.4669E-06	4.3971E-06	Trusted
3	-5.3000E+00	1.4659E-06	3.8918E-06	Trusted
10	-5.9771E+00	1.4647E-06	3.6713E-06	Trusted
11	-7.0000E+00	1.4662E-06	3.7730E-06	Trusted

2924

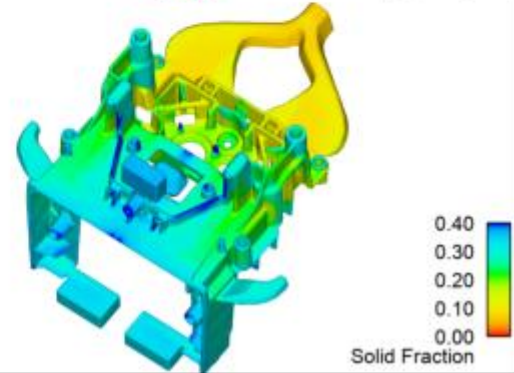
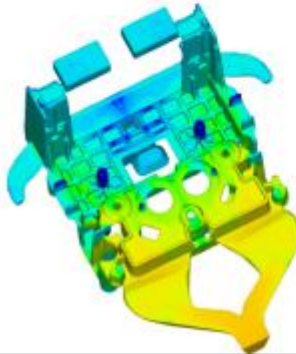
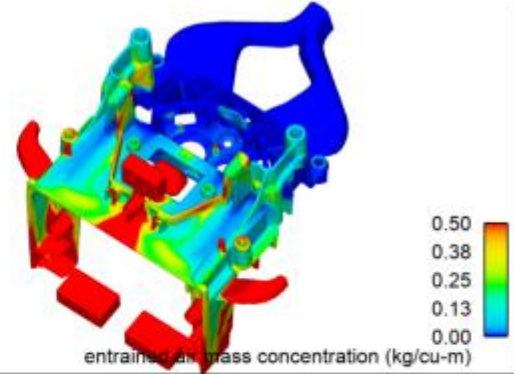
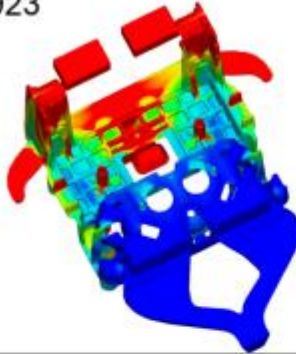




Optimization Results:

#	Transf 1	SV	AIR	Status
6	1.0000E+01	1.4725E-06	3.9473E-06	Trusted
9	8.9799E+00	1.4746E-06	4.1746E-06	Trusted
5	8.3000E+00	1.4592E-06	4.2245E-06	Trusted
12	6.5906E+00	1.4659E-06	3.9356E-06	Trusted
8	6.3465E+00	1.4668E-06	4.0668E-06	Trusted
7	6.3366E+00	NaN	NaN	Stopped
4	4.9000E+00	1.4668E-06	3.5247E-06	Trusted
14	4.5572E+00	1.4674E-06	3.5462E-06	Trusted
13	4.2214E+00	1.4647E-06	3.5403E-06	Trusted
1	1.5000E+00	1.4707E-06	3.6405E-06	Trusted
2	-1.9000E+00	1.4669E-06	4.3971E-06	Trusted
3	-5.3000E+00	1.4659E-06	3.8918E-06	Trusted
10	-5.9771E+00	1.4647E-06	3.6713E-06	Trusted
11	-7.0000E+00	1.4662E-06	3.7730E-06	Trusted

2923

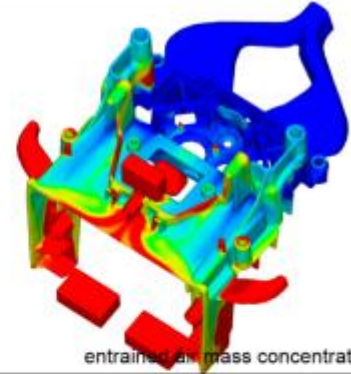
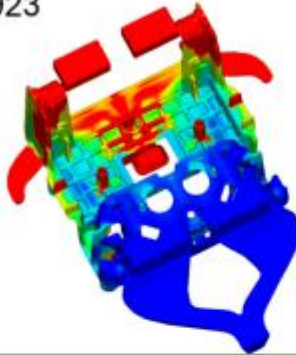




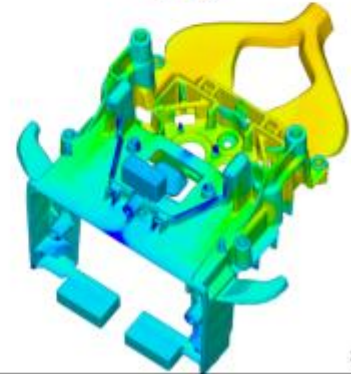
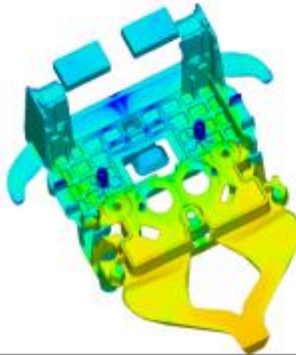
Optimization Results:

#	Transf 1	SV	AIR	Status
6	1.0000E+01	1.4725E-06	3.9473E-06	Trusted
9	8.9799E+00	1.4746E-06	4.1746E-06	Trusted
5	8.3000E+00	1.4592E-06	4.2245E-06	Trusted
12	6.5906E+00	1.4659E-06	3.9356E-06	Trusted
8	6.3465E+00	1.4668E-06	4.0668E-06	Trusted
7	6.3366E+00	NaN	NaN	Stopped
4	4.9000E+00	1.4668E-06	3.5247E-06	Trusted
14	4.5572E+00	1.4674E-06	3.5462E-06	Trusted
13	4.2214E+00	1.4647E-06	3.5403E-06	Trusted
1	1.5000E+00	1.4707E-06	3.6405E-06	Trusted
2	-1.9000E+00	1.4669E-06	4.3971E-06	Trusted
3	-5.3000E+00	1.4659E-06	3.8918E-06	Trusted
10	-5.9771E+00	1.4647E-06	3.6713E-06	Trusted
11	-7.0000E+00	1.4662E-06	3.7730E-06	Trusted

2923



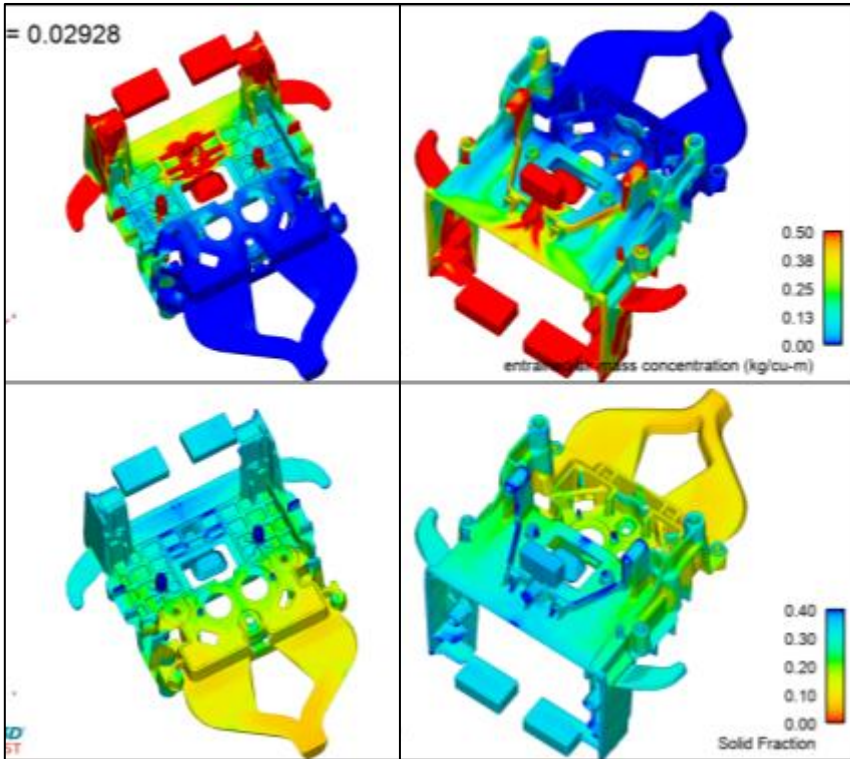
entrained air mass concentration (kg/cu-m)



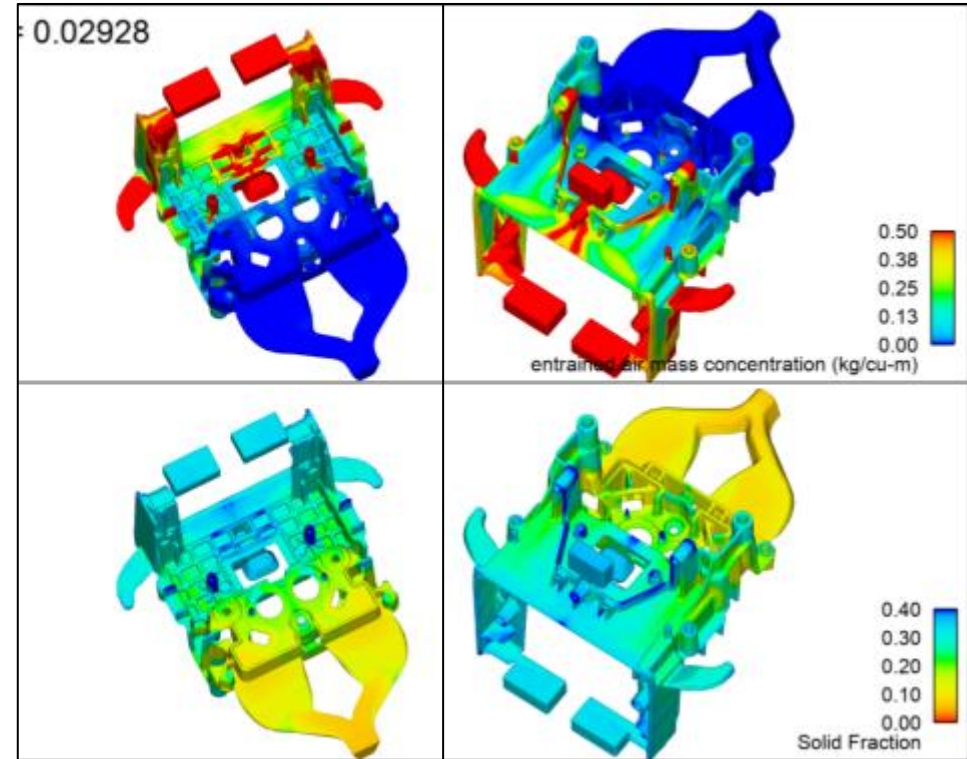
Solid Fraction



Initial Result:



Optimized Result:





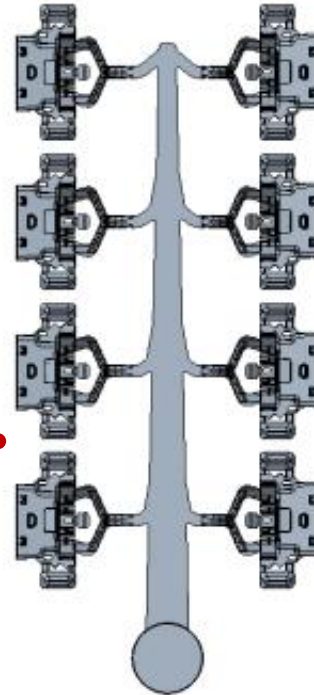
Magnesium thin walled-casting

Optimization of runner design

Overall dimensions 80x60x40mm

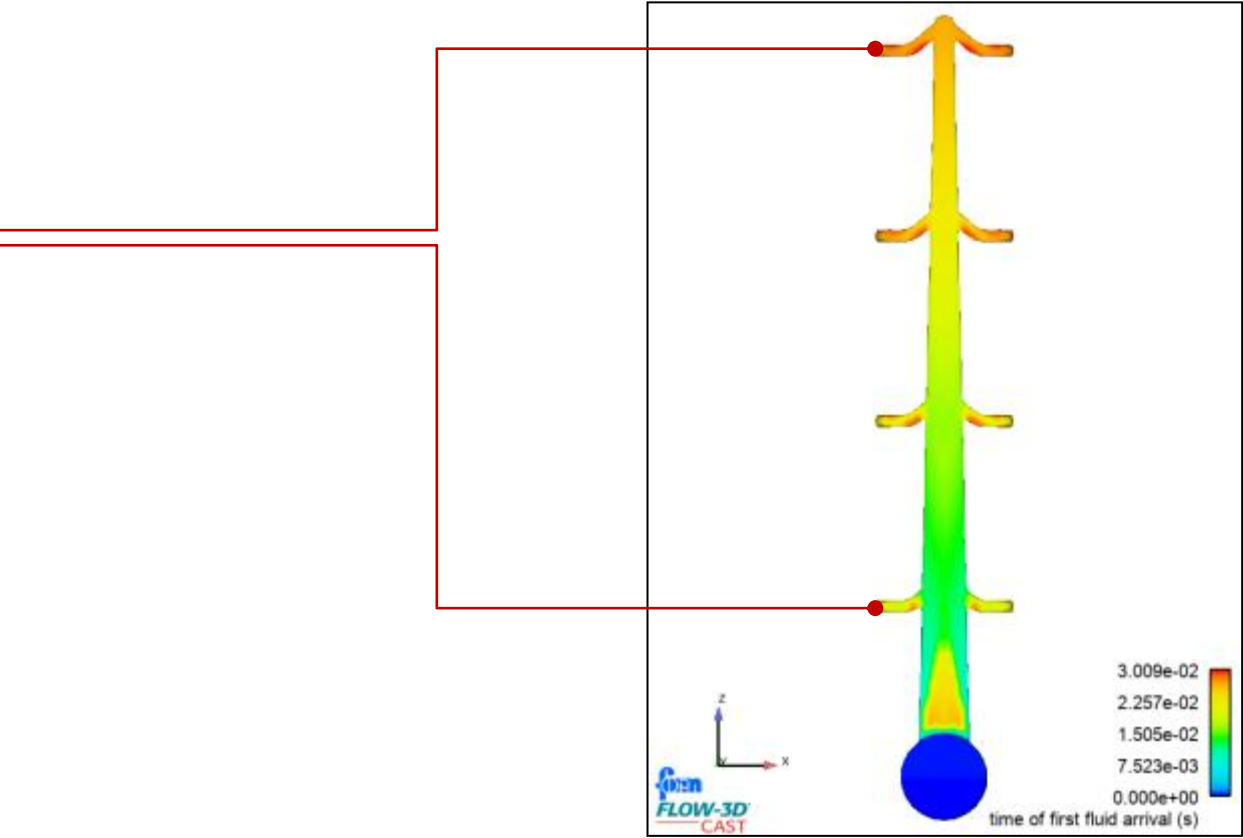
General thickness 1.9mm

8 cavities die





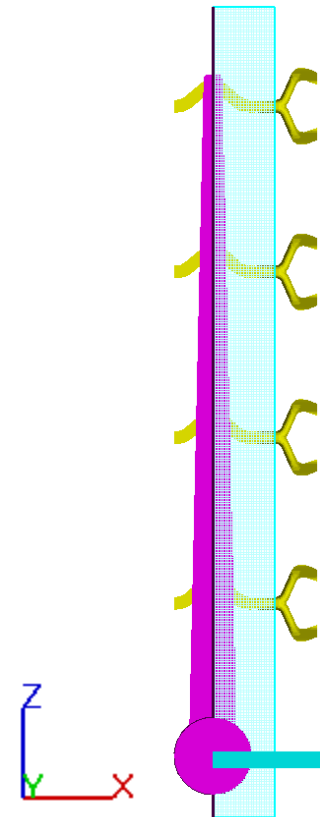
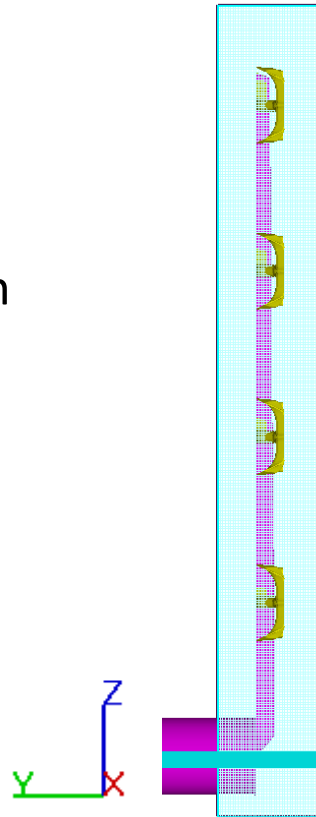
Different filling time





Simulation setup:

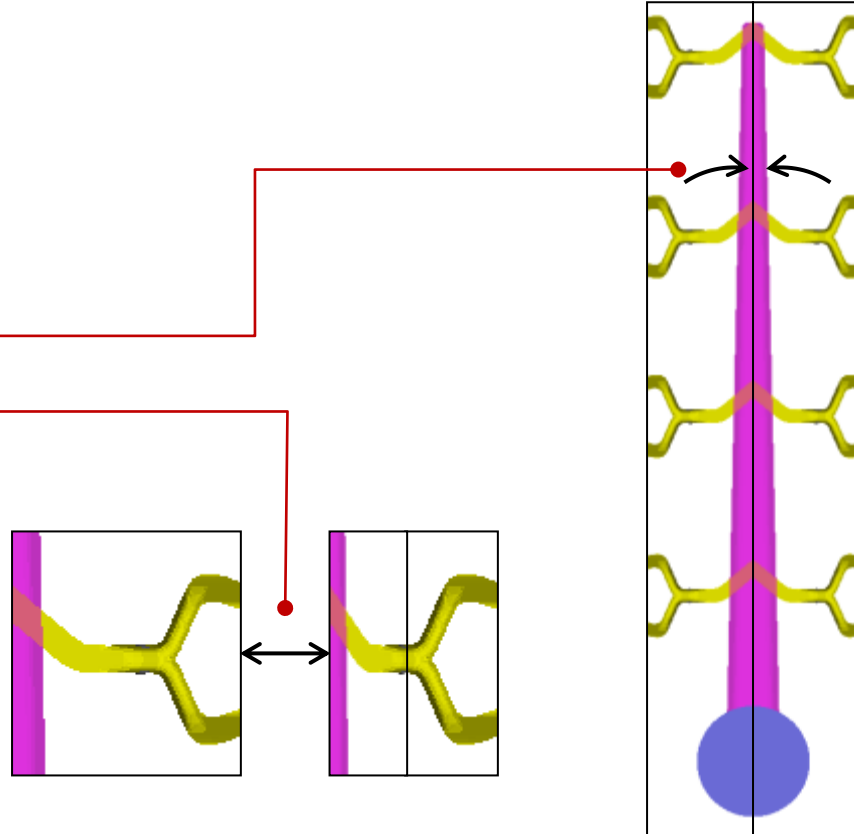
- Symmetry plane $X=0$
- Outflow boundary in X_{max}
- Metal velocity boundary in Y_{min}
- Size of cells 2mm
- Nr. 34k Fluid sub-domain cells
- Duration: 3 min
- Budget: 50 simulations

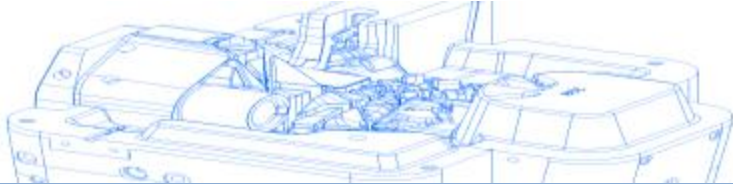




Optimization Input:

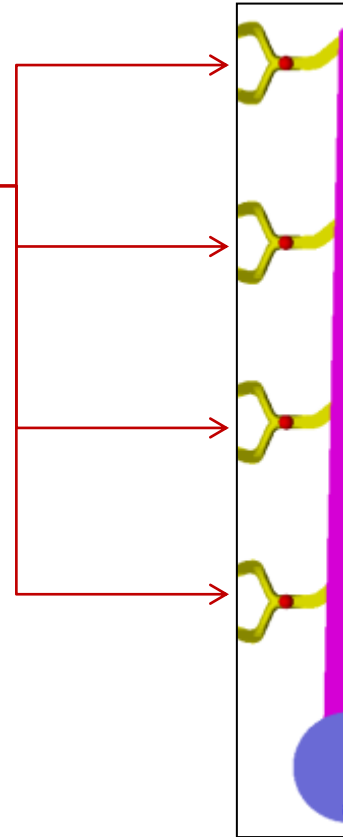
- Main runner angle
- Secondary runner stretch





Optimization Output:

- time of first fluid arrival on 4 probes

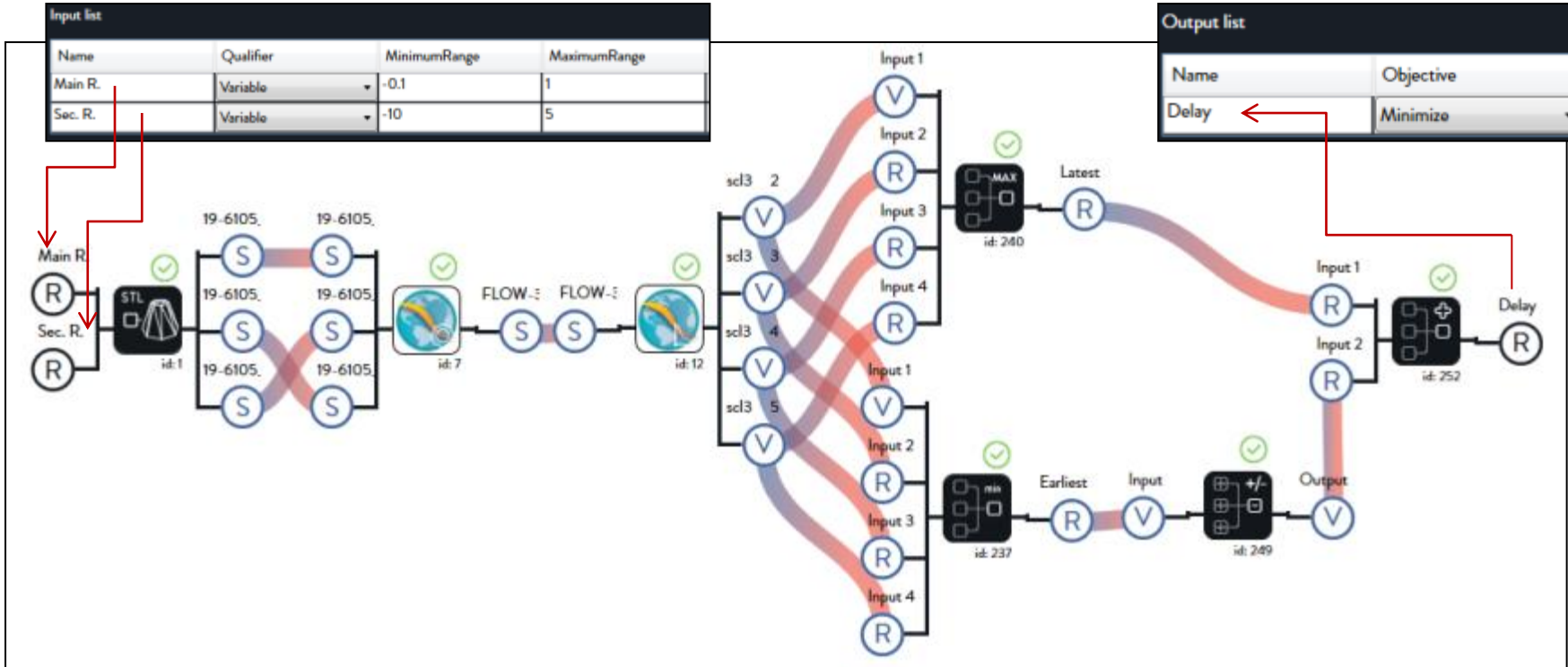




Optimization Workflow:

Input list			
Name	Qualifier	MinimumRange	MaximumRange
Main R.	Variable	-0.1	1
Sec. R.	Variable	-10	5

Output list	
Name	Objective
Delay	Minimize

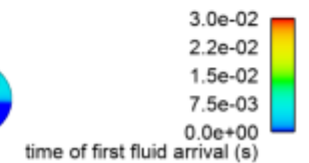
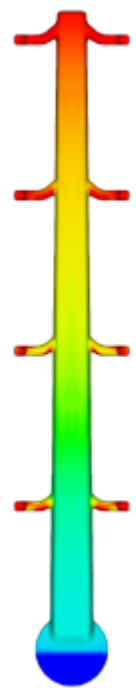
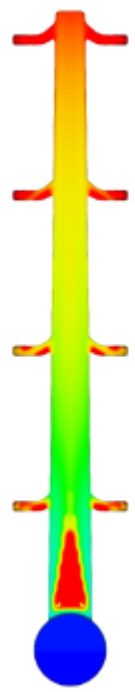




Optimization Results:

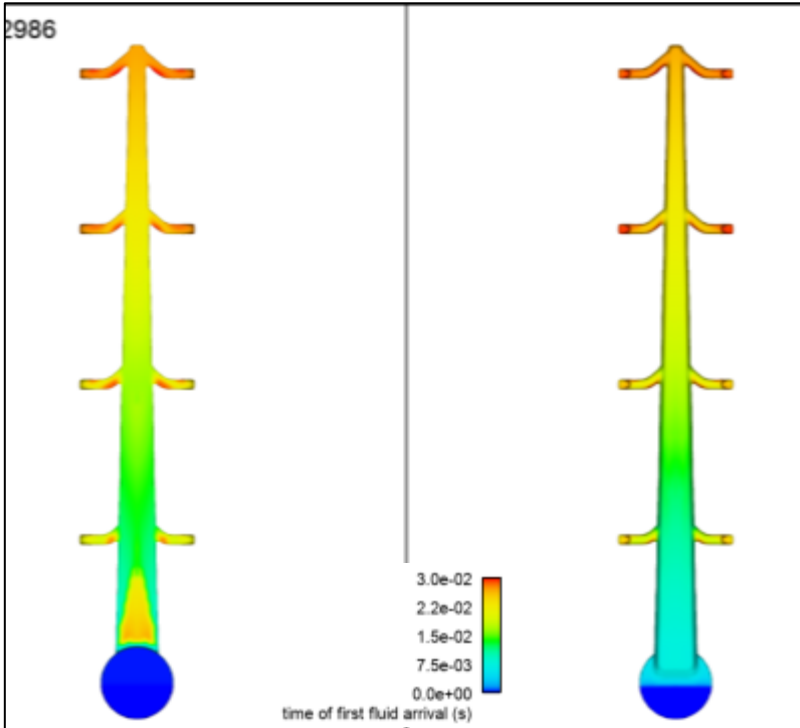
25	9.7800E-01	4.7000E+00	3.4119E-03	Treated
26	7.2742E-01	-7.7212E+00	2.2306E-03	Treated
27	8.1748E-01	-1.0000E+01	3.5569E-03	Treated
28	7.4990E-01	-4.1812E+00	2.1855E-03	Treated
29	7.5090E-01	-5.2845E+00	2.0956E-03	Treated
30	6.7028E-01	-5.5225E-01	3.1555E-03	Treated
31	7.7185E-01	-4.7973E+00	2.7571E-03	Treated
32	5.7586E-01	7.6396E-02	2.6218E-03	Treated
33	6.0592E-01	-7.9982E-01	2.7076E-03	Treated
34	6.2689E-01	-4.3183E-01	5.8500E-04	Treated
35	6.3018E-01	-7.2346E-02	2.0844E-03	Treated
36	6.9450E-01	-4.7799E+00	2.0869E-03	Treated
37	6.2257E-01	-3.9622E-01	1.9314E-03	Treated
38	5.1208E-01	8.3141E-01	1.3328E-03	Treated
39	6.4072E-01	-4.1376E-01	2.4386E-03	Treated
40	6.0018E-01	1.2013E+00	2.0374E-03	Treated
41	6.2886E-01	-4.7408E-01	1.5089E-03	Treated
42	6.2558E-01	-1.0000E+00	1.5792E-03	Treated
43	6.2928E-01	-3.8571E-01	8.2570E-04	Treated
44	5.5321E-01	5.6047E-01	3.7840E-03	Treated
45	6.2729E-01	-4.2196E-01	7.4382E-04	Treated
46	6.5218E-01	1.5448E-02	1.9347E-03	Treated
47	6.2802E-01	-4.4281E-01	1.5510E-03	Treated
48	6.2804E-01	-4.3580E-01	1.2892E-03	Treated
49	6.2727E-01	-3.1071E-01	3.0049E-03	Treated
50	6.3109E-01	2.8929E-01	1.5728E-03	Treated

03452

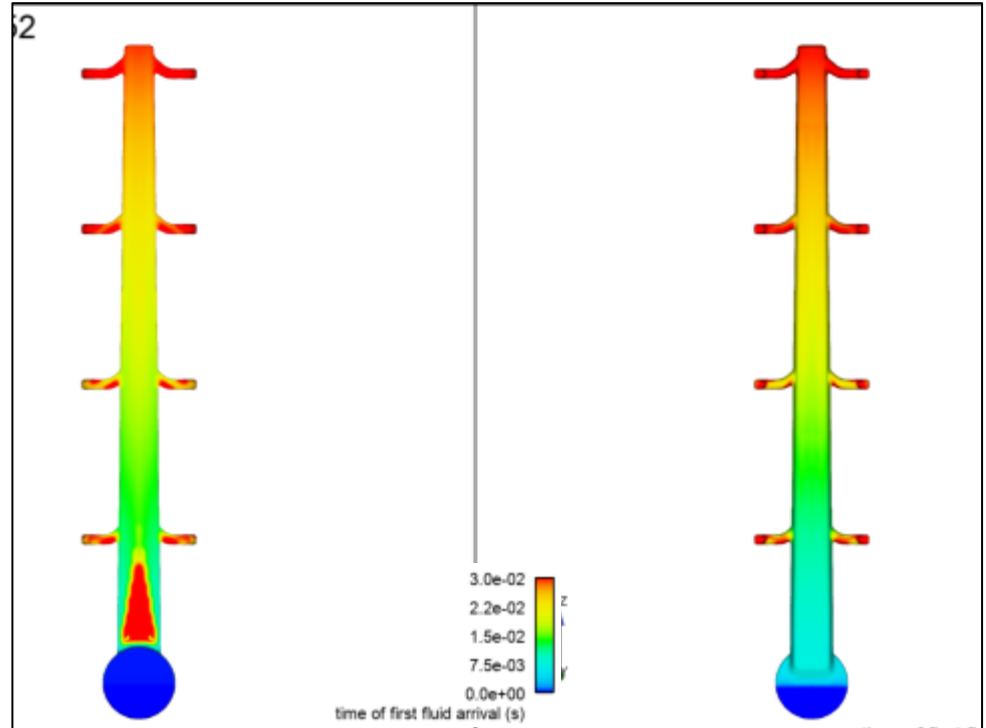


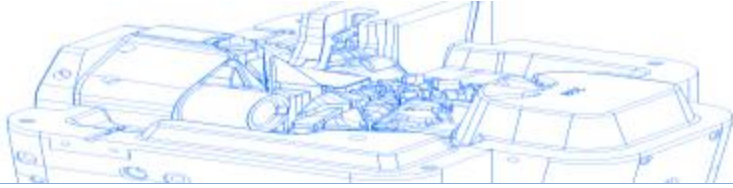


Initial Result:



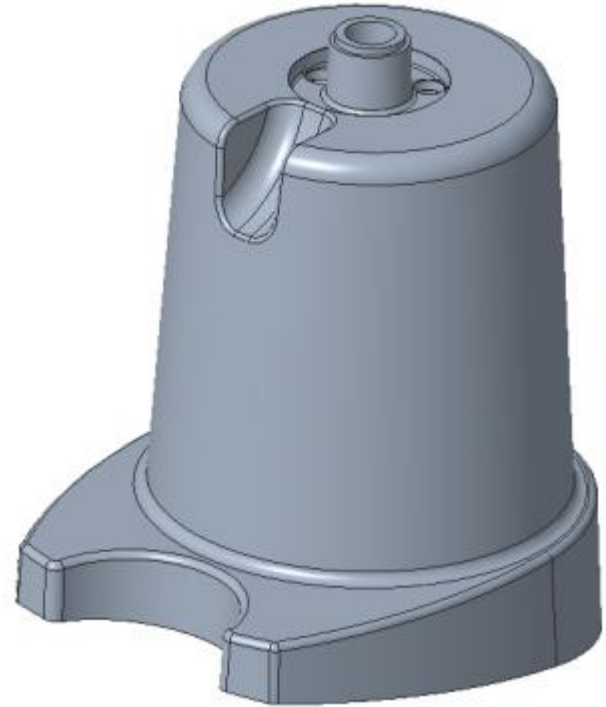
Optimized Result:





Aluminum casting Optimization of gate design

Application:
professional squeezer base





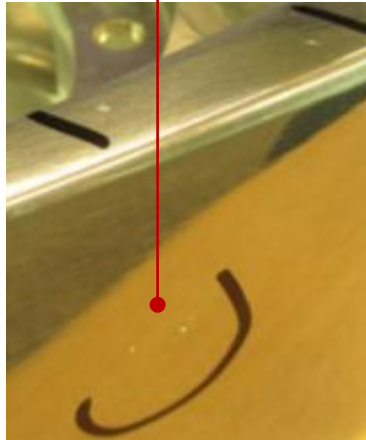
Mirror-Polished

Risk of:

Cold drops

Air porosity

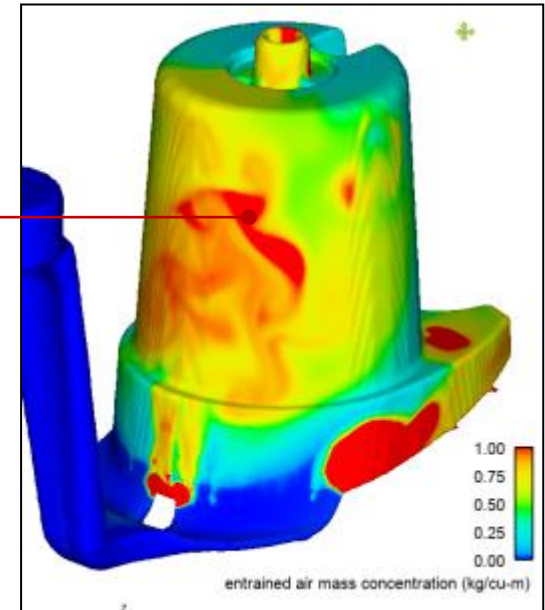
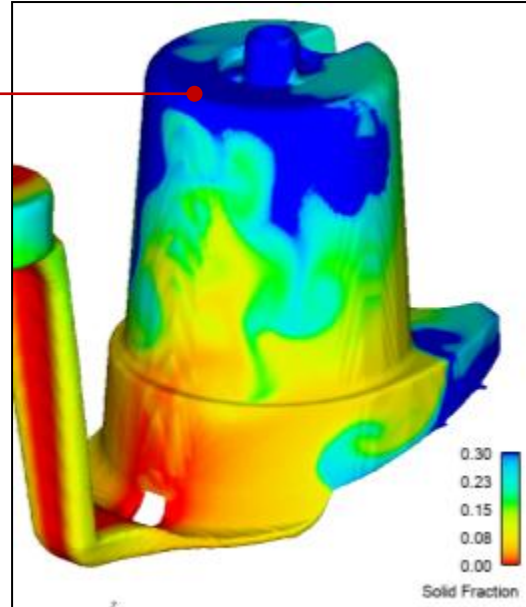
Cold joints





Air entrainment

Solidified fraction

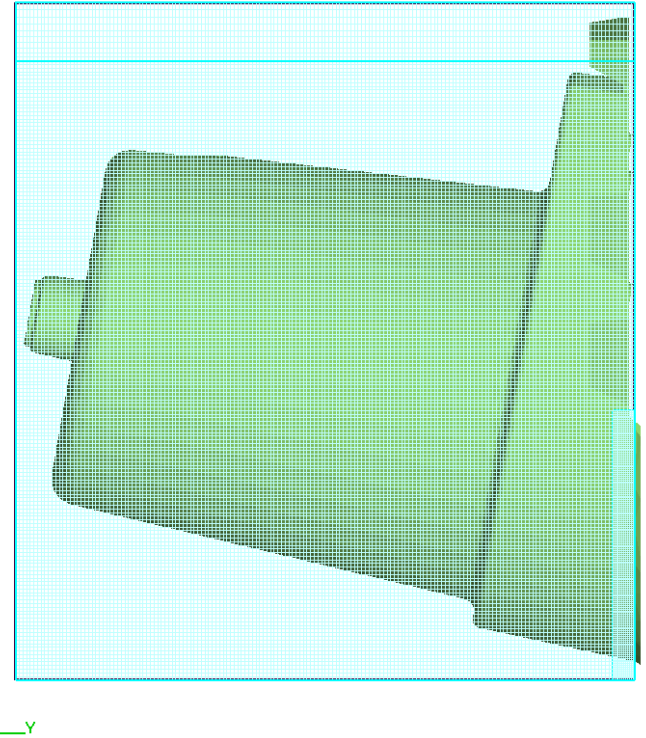
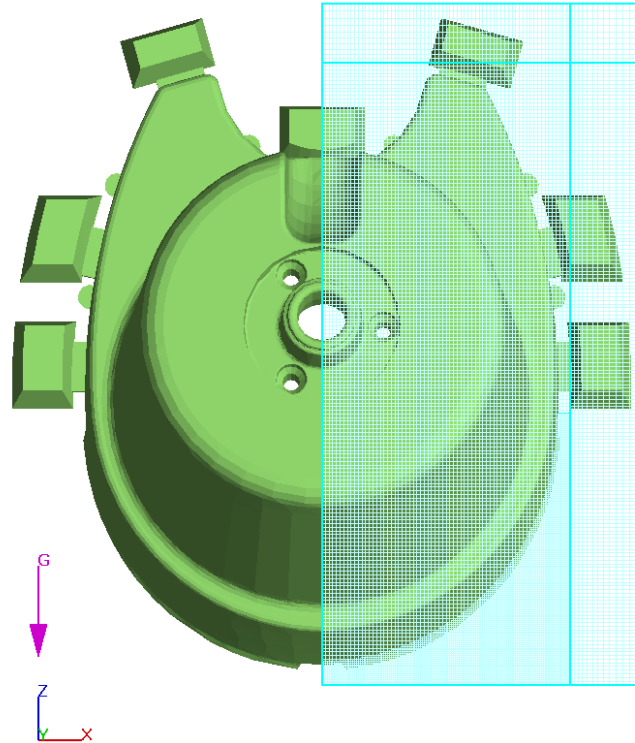


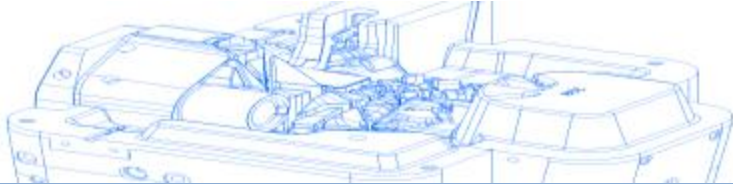


Simulation

setup:

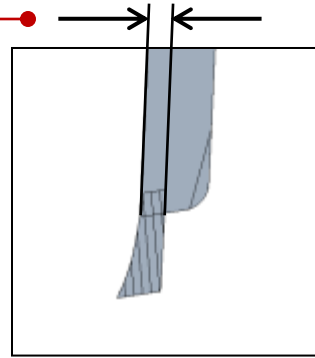
- Symmetry plane $X=0$
- Metal velocity boundary in Y_{min}
- Size of cells
 - Main block 1.5mm
 - Block at gates 0.75mm
- Nr. 238 k Fluid sub-domain cells
- Duration: 1h 15 min
- Budget: 7 simulations





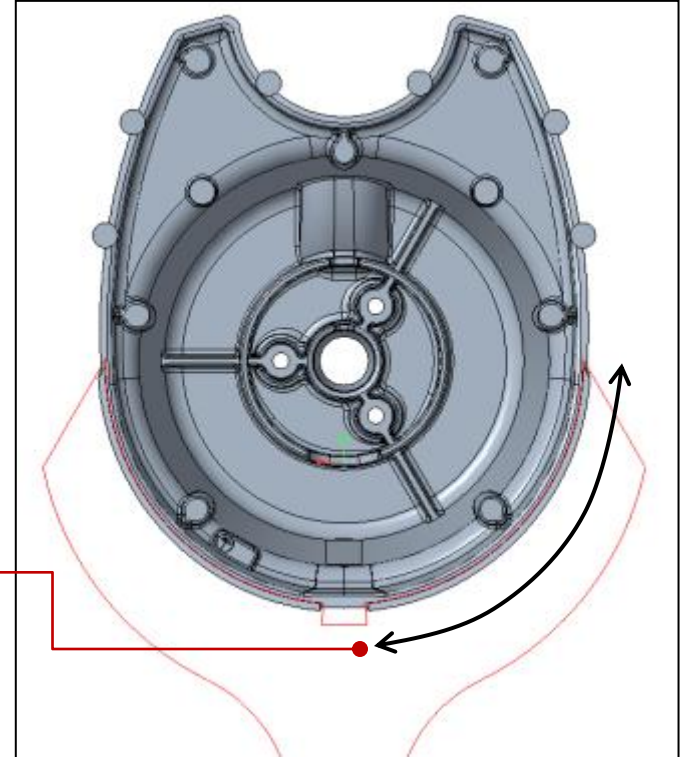
Optimization Input:

- Gate thickness (1.6 ÷ 4mm)



Constraint:

- constant gate section = 450mm²
→ change of gate length from 40° to 90°

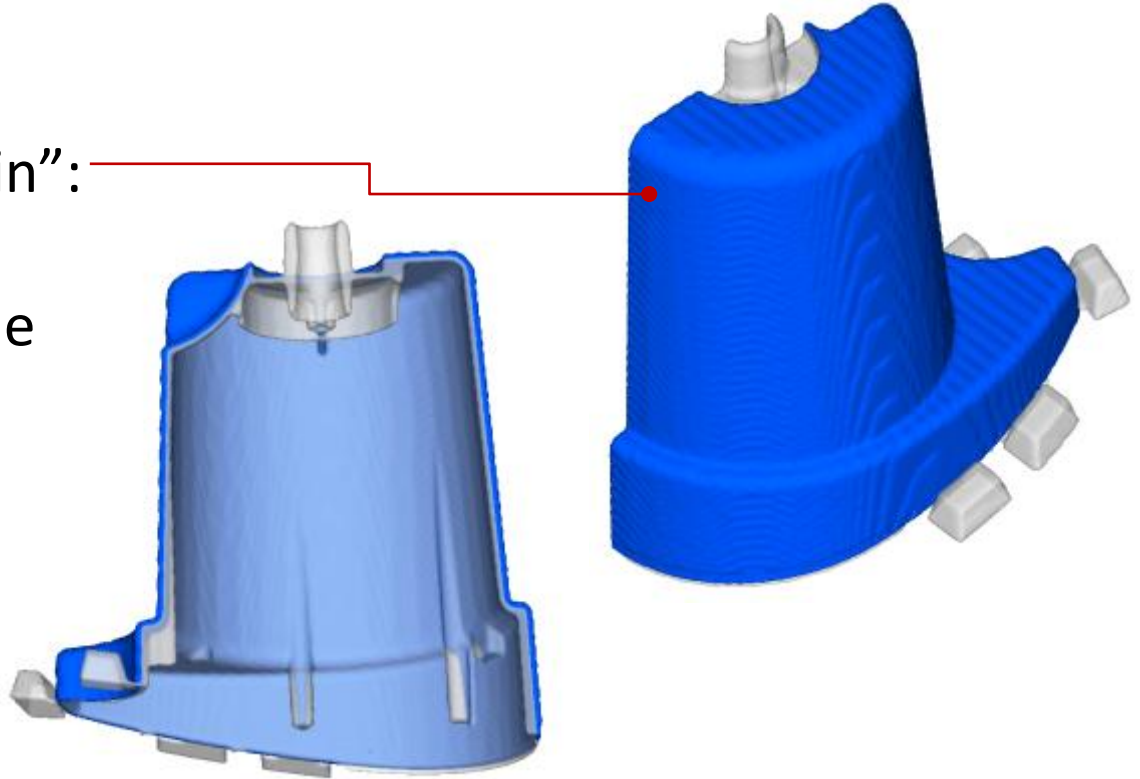


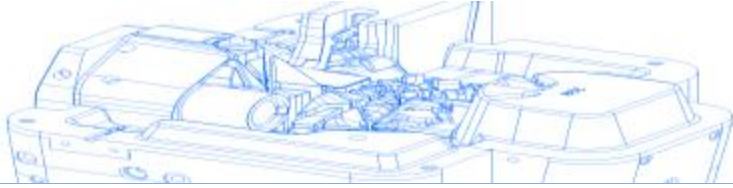


Optimization Output:

Into sampling volume “skin”:

- Entrained air mass
- Solidified fraction volume

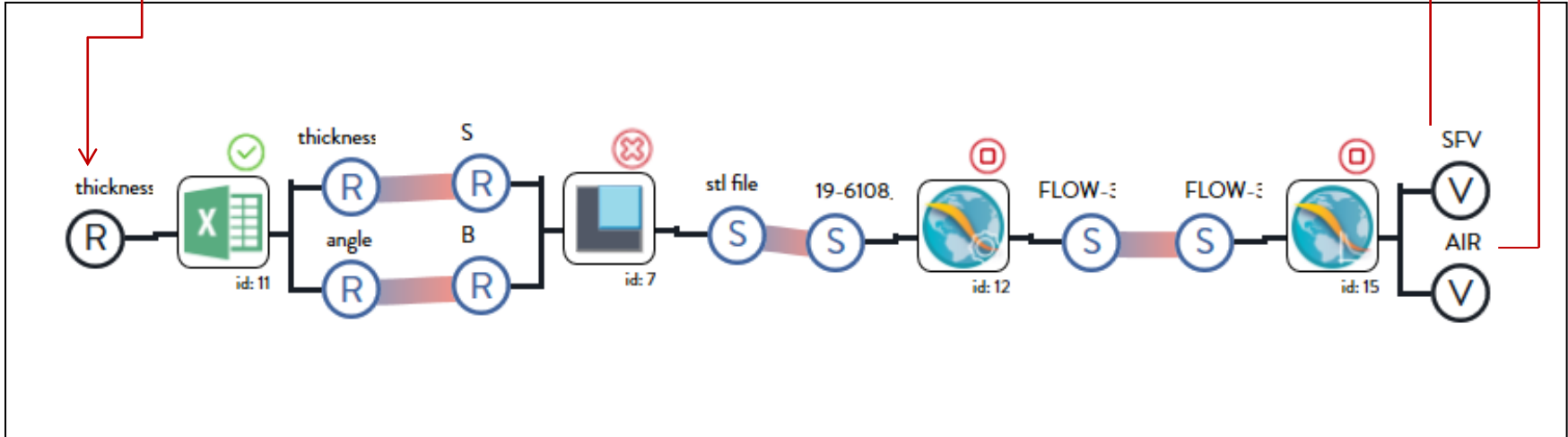




Optimization Workflow:

Input list			
Name	Qualifier	MinimumRange	MaximumRange
thickness	Variable	1.6	4

Output list	
Name	Objective
SFV	Minimize
AIR	Minimize

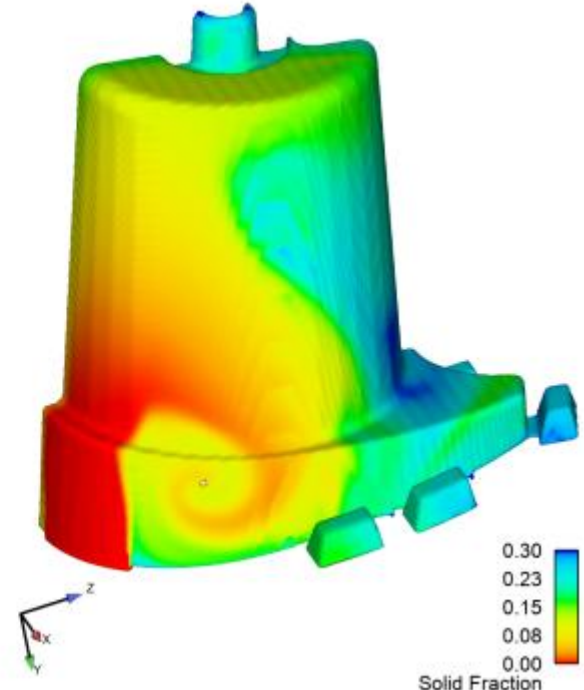
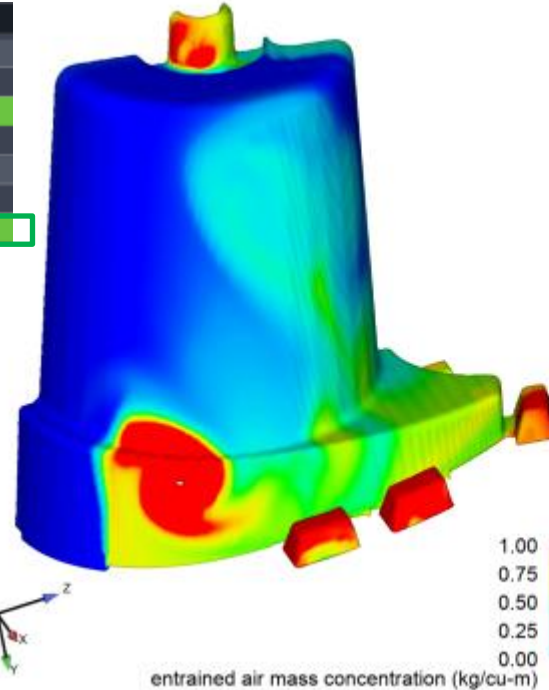




Optimization Results:

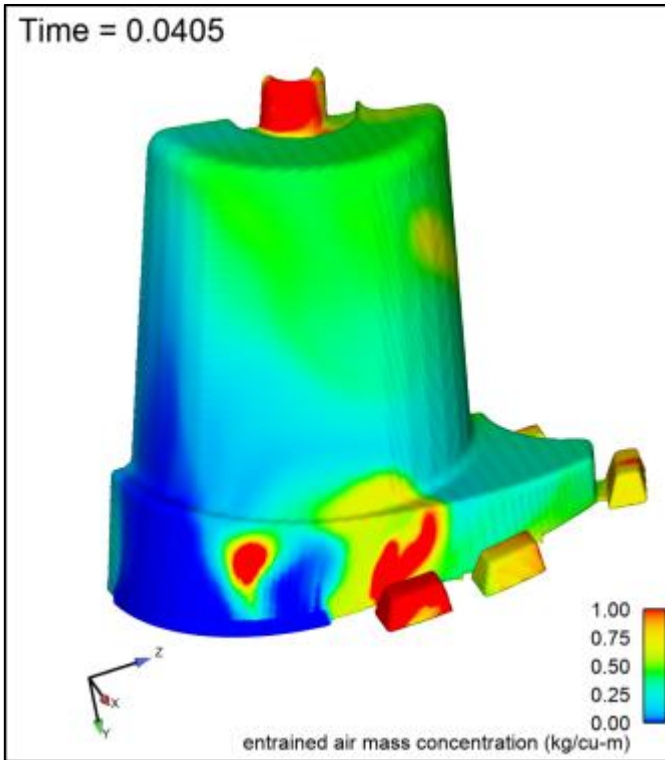
Time = 0.0404

#	thickness	SFV	AIR	Status
1	1.7500E+00	2.6832E-05	6.8160E-05	Treated
2	2.0500E+00	2.6699E-05	6.8434E-05	Treated
3	2.3500E+00	2.6212E-05	6.5992E-05	Treated
4	2.6500E+00	2.6589E-05	7.2730E-05	Treated
5	2.9500E+00	2.6686E-05	7.0932E-05	Treated
6	3.2500E+00	2.6923E-05	6.9584E-05	Treated
7	3.5500E+00	2.7297E-05	6.1931E-05	Treated

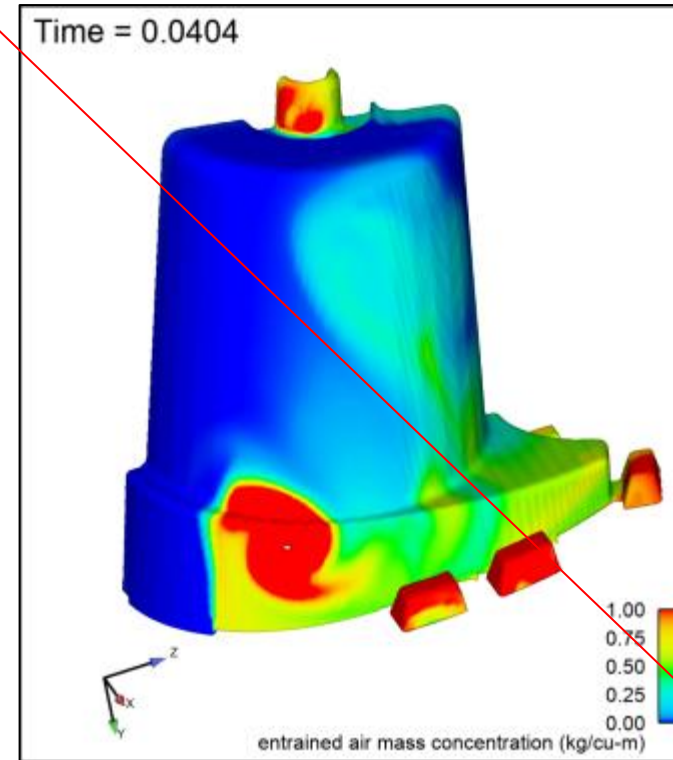




Our choice:

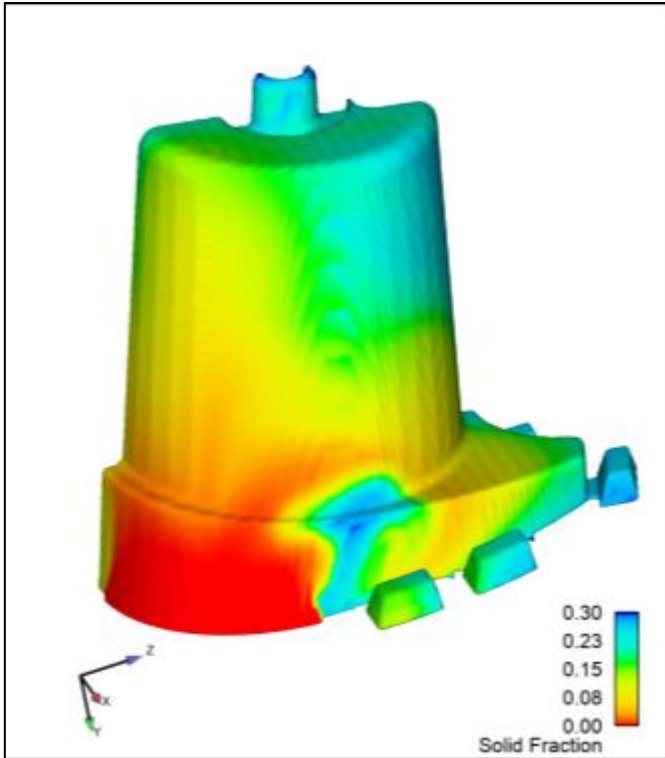


Optimized Result:

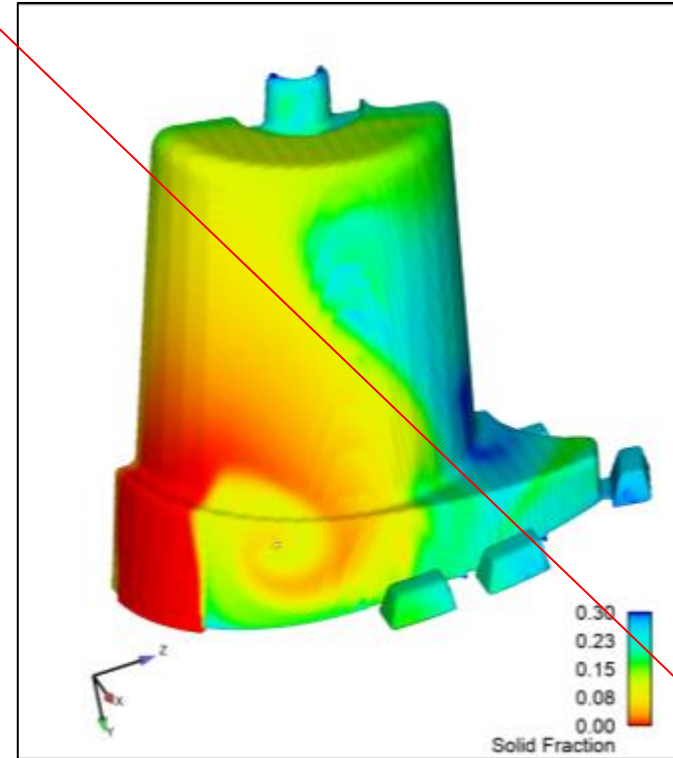




Our choice:



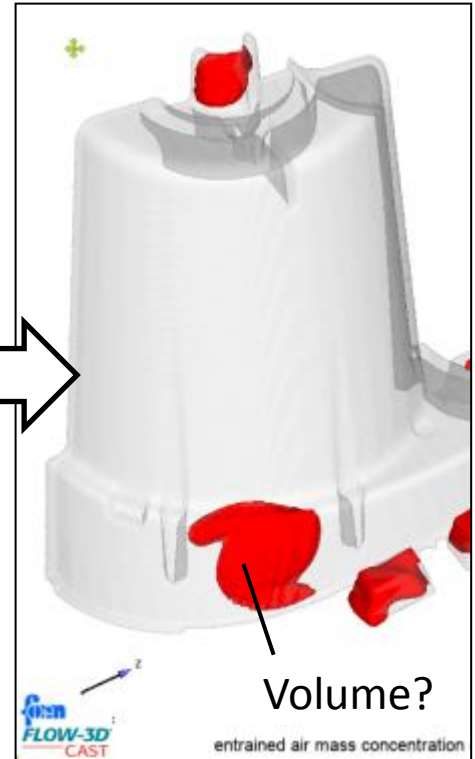
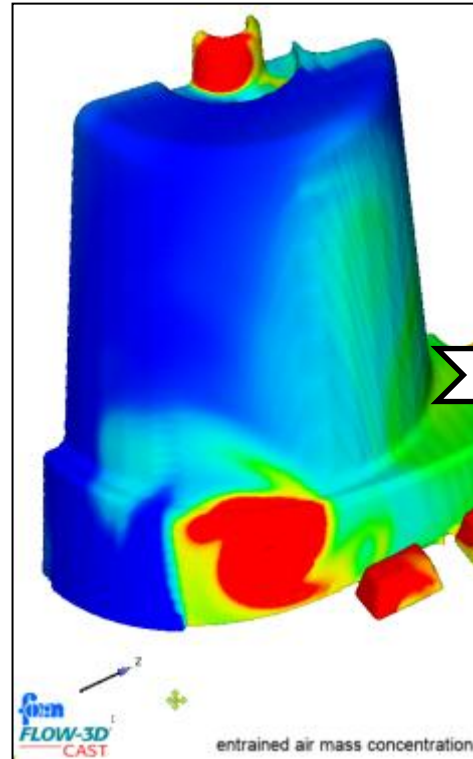
Optimized Result:

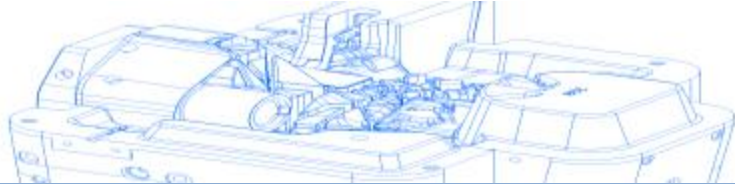




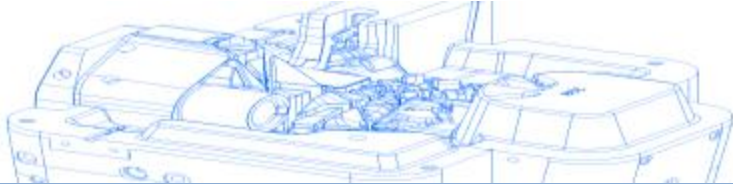
Idea to improve Optimization:

To implement into IMPROVEit a new node using Flowsight post processing to calculate the volume of the isosurface with
Entrained air mass conc. > 1

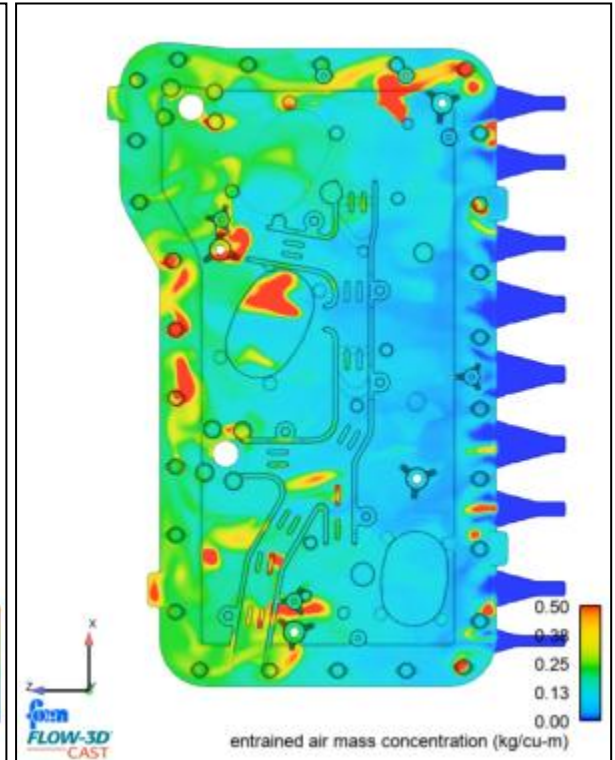
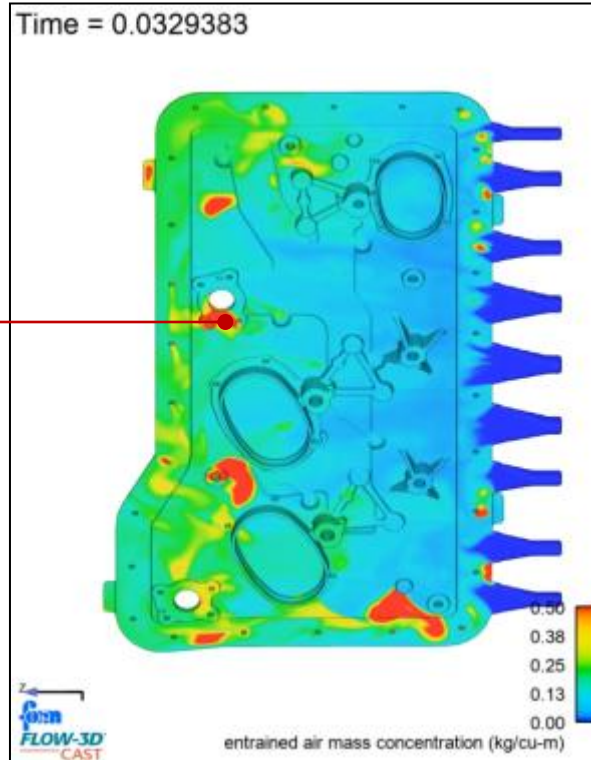




Aluminum vacuum casting Optimization of die design



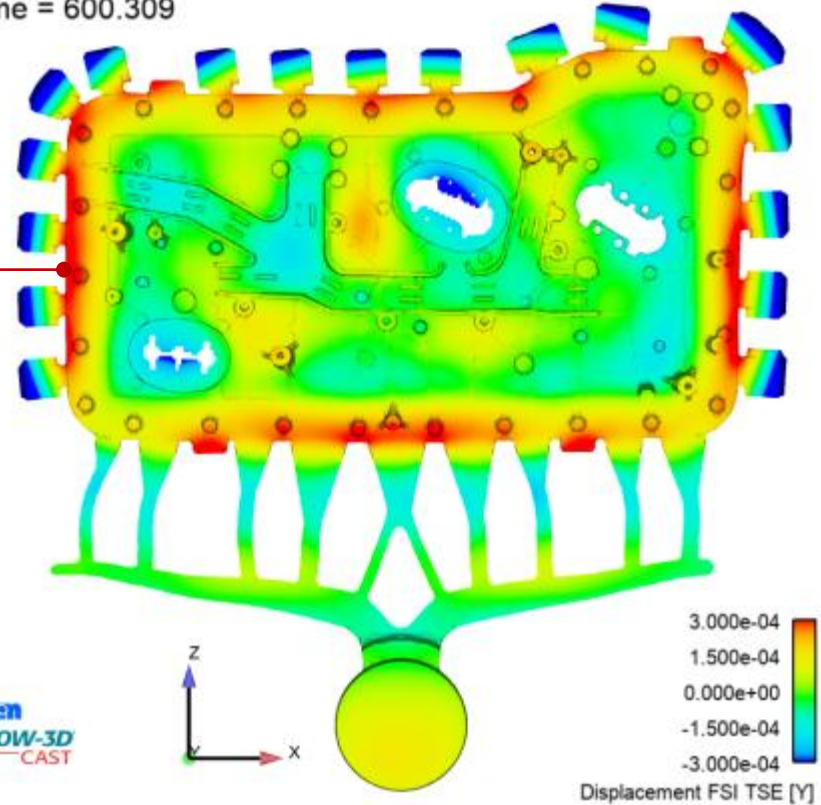
Air entrainment





Deformation

Time = 600.309

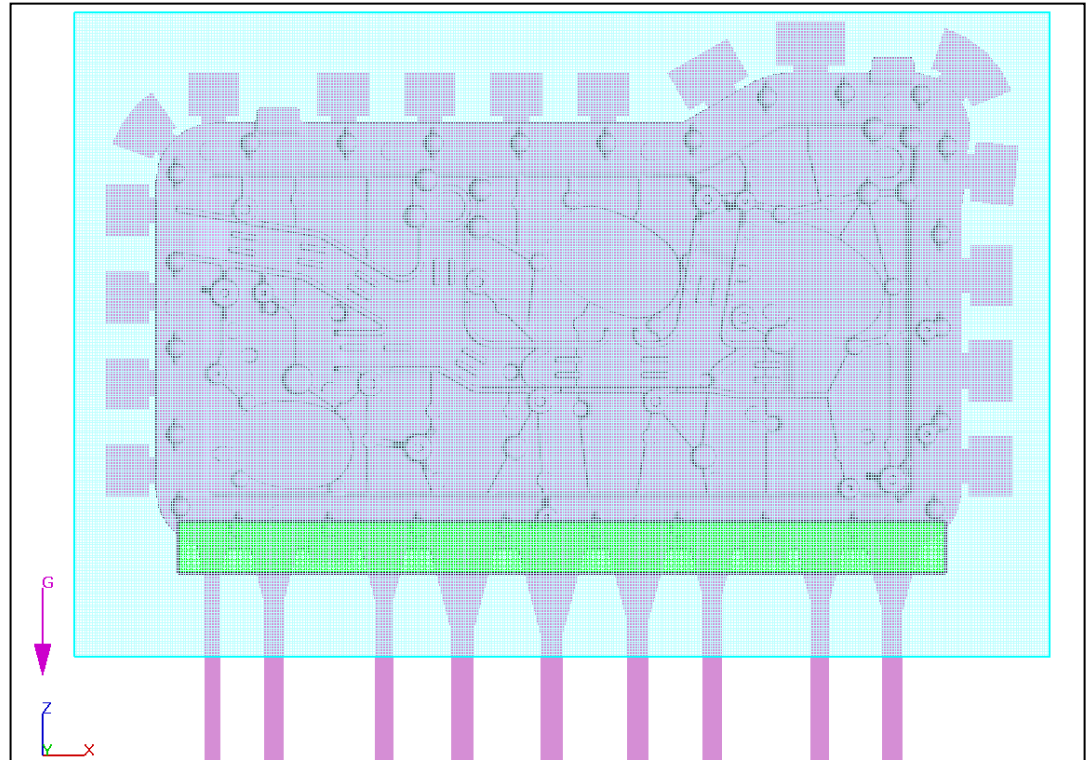




Gate optimization

Simulation setup:

- Metal velocity boundary in Zmin
- Size of cells
 - Main block 1.5mm
 - Block at gates 1mm
- Nr. 632 k Fluid sub-domain cells
- Duration: 1h 40 min
- Budget: 20 simulations

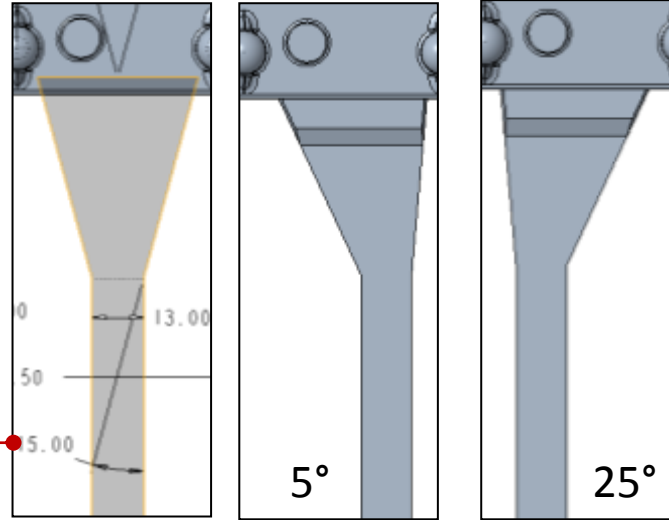




Gate optimization

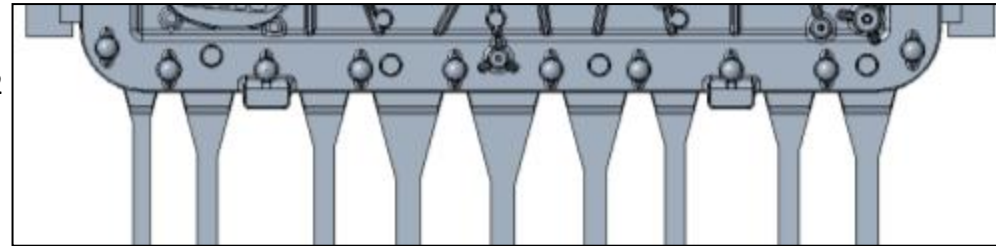
Input (PTC Creo 5):

- 9 gates angle ($5^\circ \div 25^\circ$)



Constraint:

- Gates position
- constant gates total section = 680mm^2



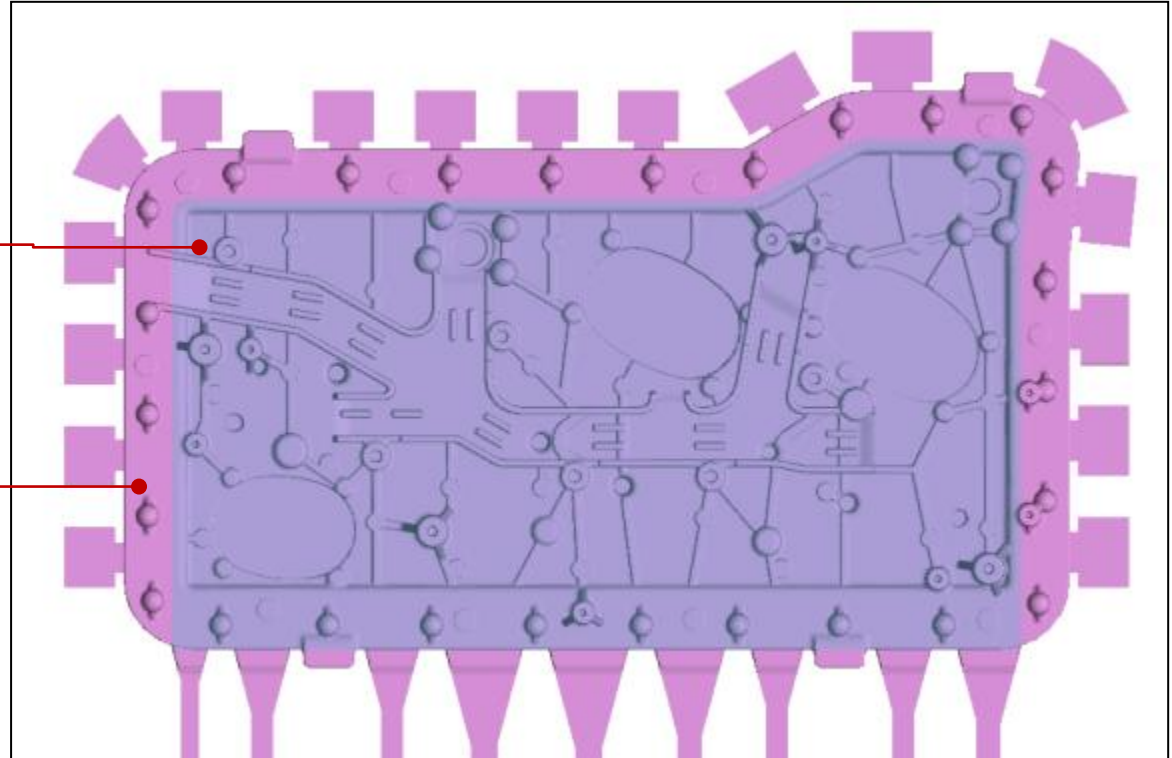


Gate optimization

Output:

Into sampling volume:
-Entrained air mass

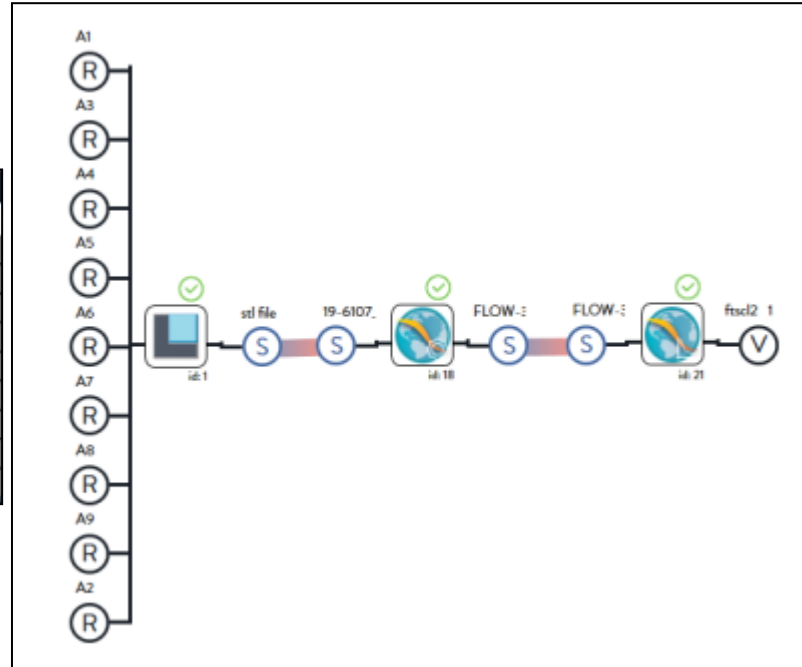
The external flange is out
of the sampling volume
because here we can
easily remove air using
overflows





Gate optimization Workflow:

Input list			
Name	Qualifier	Minimum Range	Maximum Range
A1	Variable	5	25
A3	Variable	5	25
A4	Variable	5	25
A5	Variable	5	25
A6	Variable	5	25
A7	Variable	5	25
A8	Variable	5	25
A9	Variable	5	25
A2	Variable	5	25



Output list	
Name	Objective
ftscl2_1	Minimize



Gate optimization Results:

Best Result



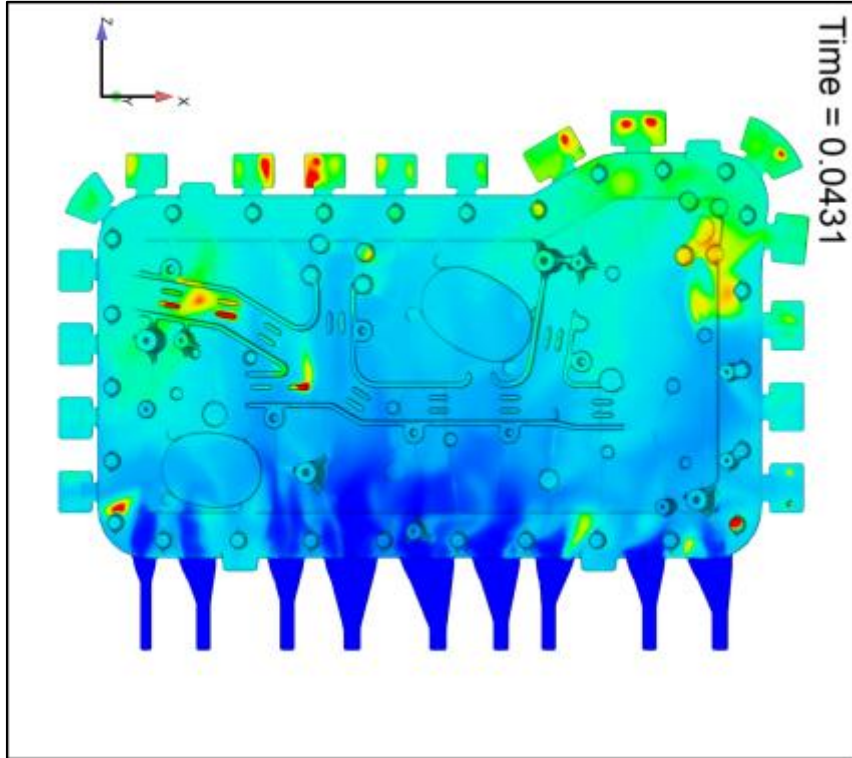
Worst Result



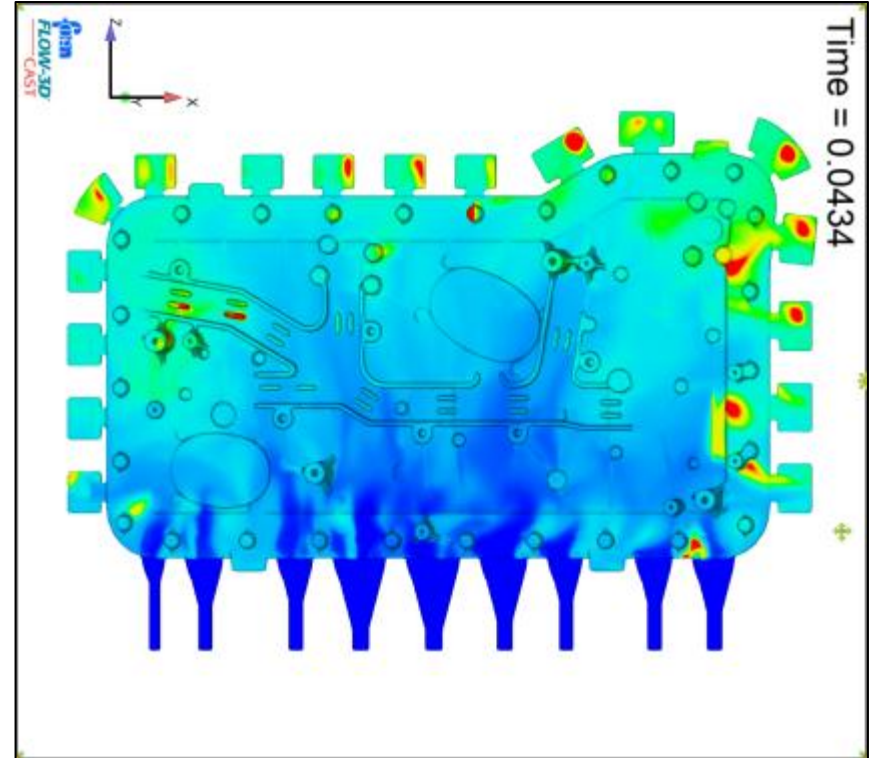
#	A1	A3	A4	A5	A6	A7	A8	A9	A2	ftscl2_1	Status
1	1.5000E+01	1.5000E+01	1.5000E+01	1.5000E+01	1.5000E+01	1.5000E+01	1.5000E+01	1.5000E+01	1.5000E+01	4.2414E-05	None
2	1.3462E+01	1.1923E+01	1.9615E+01	1.8077E+01	5.7692E+00	7.3077E+00	1.1923E+01	1.1923E+01	2.2692E+01	4.7079E-05	Trusted
3	1.6538E+01	1.3462E+01	1.0385E+01	2.1154E+01	2.2692E+01	8.8462E+00	7.3077E+00	8.8462E+00	7.3077E+00	4.7452E-05	Trusted
4	3.8462E+00	8.8462E+00	2.1154E+01	8.8462E+00	1.1923E+01	2.4231E+01	1.6538E+01	1.0385E+01	1.0385E+01	4.5549E-05	Trusted
5	1.5000E+01	1.5000E+01	1.5000E+01	7.3077E+00	1.8077E+01	5.7692E+00	1.8077E+01	2.4231E+01	8.8462E+00	4.8779E-05	Trusted
6	1.0385E+01	7.3077E+00	7.3077E+00	1.1923E+01	1.6538E+01	1.0385E+01	1.9615E+01	7.3077E+00	2.1154E+01	4.7436E-05	Trusted
7	2.4231E+01	1.0385E+01	2.4231E+01	2.2692E+01	1.3462E+01	1.3462E+01	1.3462E+01	1.9615E+01	1.8077E+01	4.6547E-05	Trusted
8	1.9615E+01	1.9615E+01	1.1923E+01	5.7692E+00	7.3077E+00	1.5000E+01	5.7692E+00	1.3462E+01	1.5000E+01	4.8554E-05	Trusted
9	7.3077E+00	2.4231E+01	5.7692E+00	1.9615E+01	1.0385E+01	1.1923E+01	1.5000E+01	1.8077E+01	1.1923E+01	4.5968E-05	Trusted
10	5.7692E+00	2.2692E+01	2.2692E+01	1.3462E+01	2.1154E+01	1.8077E+01	8.8462E+00	1.6538E+01	1.9615E+01	4.5548E-05	Trusted
11	1.8077E+01	5.7692E+00	8.8462E+00	1.6538E+01	1.9615E+01	2.2692E+01	1.0385E+01	2.2692E+01	1.3462E+01	4.7013E-05	Trusted
12	2.2692E+01	2.1154E+01	1.8077E+01	1.5000E+01	1.5000E+01	1.6538E+01	2.1154E+01	5.7692E+00	5.7692E+00	4.4601E-05	Trusted
13	1.1923E+01	1.8077E+01	1.3462E+01	2.4231E+01	8.8462E+00	2.1154E+01	2.4231E+01	2.1154E+01	1.6538E+01	4.4635E-05	Trusted
14	2.1154E+01	1.6538E+01	1.6538E+01	1.0385E+01	2.4231E+01	1.9615E+01	2.2692E+01	1.5000E+01	2.4231E+01	4.5342E-05	Trusted
15	5.0000E+00	2.5000E+01	2.5000E+01	2.5000E+01	2.5000E+01	2.5000E+01	2.5000E+01	5.0000E+00	5.0000E+00	4.8366E-05	Trusted
16	2.5000E+01	2.5000E+01	1.5784E+01	2.5000E+01	5.0000E+00	2.5000E+01	2.5000E+01	5.0000E+00	2.0858E+01	4.4133E-05	Trusted
17	2.5000E+01	2.3703E+01	1.7823E+01	1.7317E+01	9.4442E+00	2.5000E+01	2.5000E+01	6.4449E+00	1.1399E+01	4.6230E-05	Trusted
18	1.8715E+01	2.5000E+01	1.1300E+01	2.5000E+01	6.0536E+00	1.8008E+01	2.5000E+01	5.0000E+00	2.5000E+01	4.6218E-05	Trusted
19	2.5000E+01	1.8192E+01	2.5000E+01	2.5000E+01	5.0000E+00	2.5000E+01	1.7630E+01	5.0000E+00	2.5000E+01	4.4449E-05	Trusted
20	5.0000E+00	1.9619E+01	1.5856E+01	2.5000E+01	5.0000E+00	2.5000E+01	1.6428E+01	2.5000E+01	2.4916E+01	4.7862E-05	Trusted

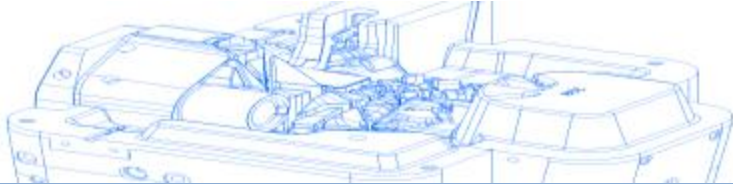


Worst Result:

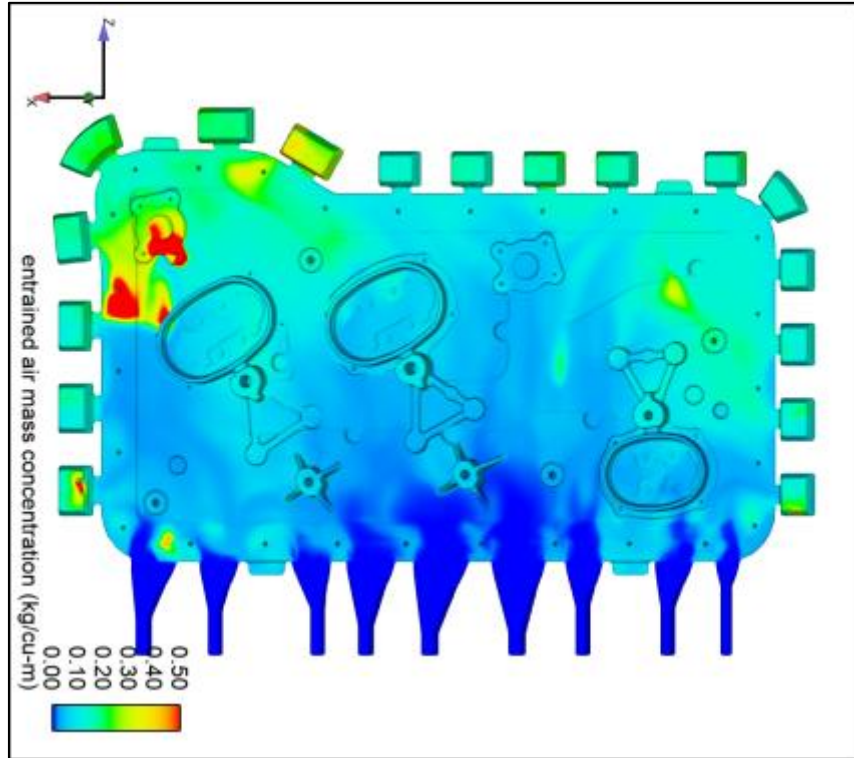


Best Result:

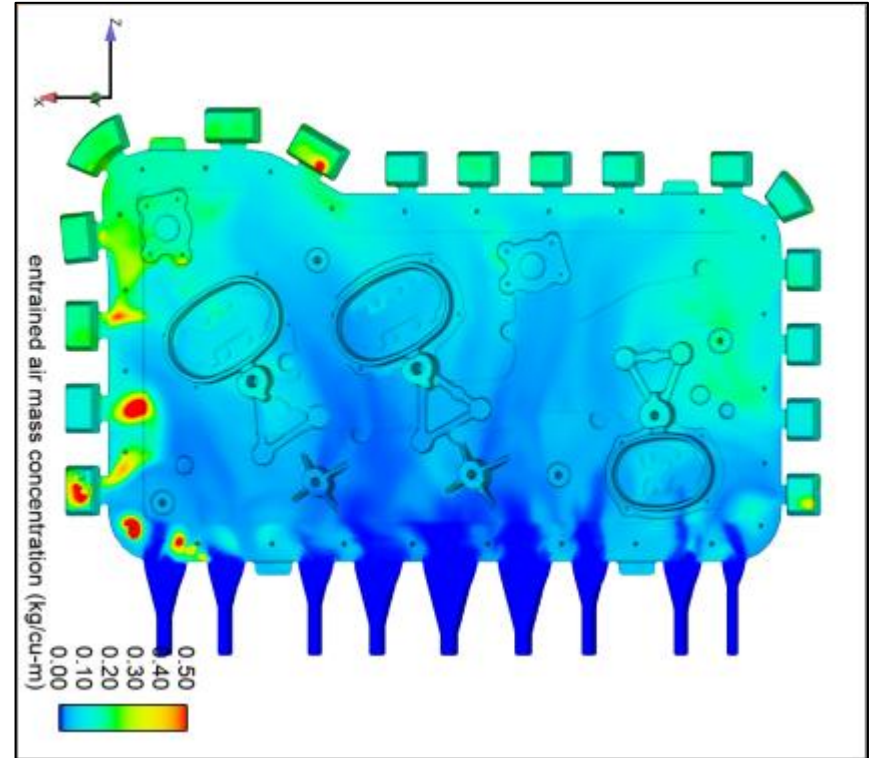




Worst Result:



Best Result:

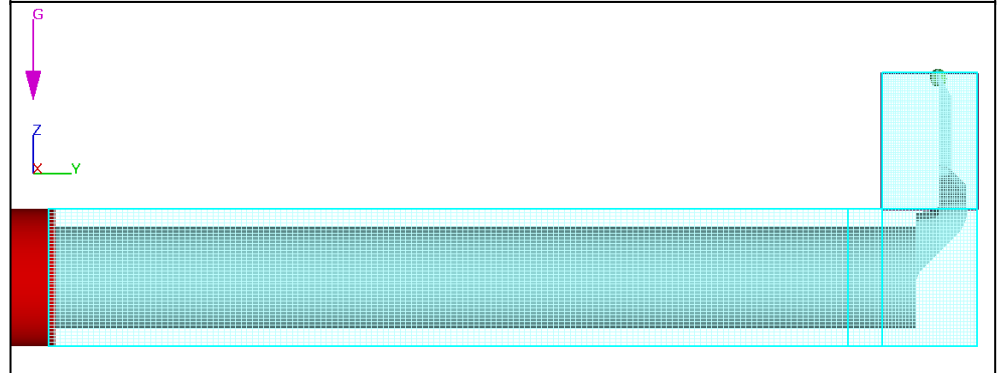
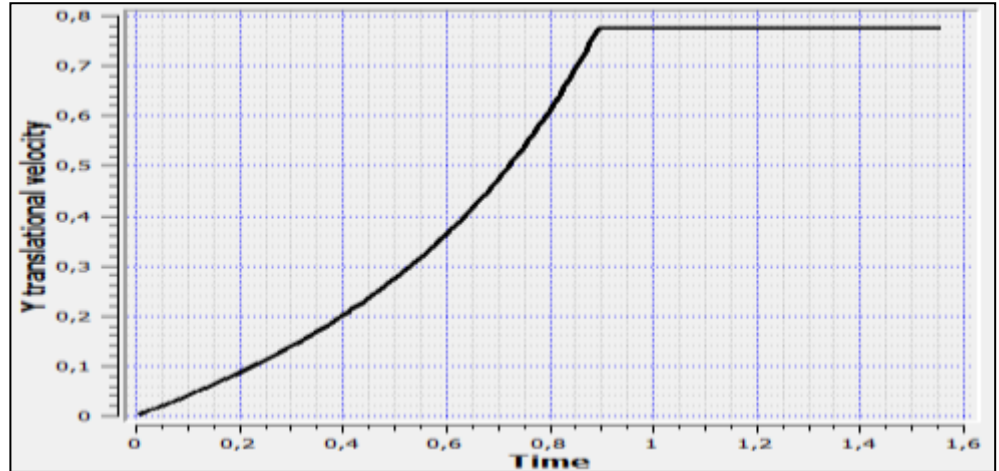




Runners optimization

1st phase simulation setup:

- Filling simulation of the chamber up to active simulation control probe
- Optimized slow shot plunger speed
- Size of cells
 - Shot sleeve 3x3x5mm
 - Runner/gates 2mm
- Nr. 190 k Fluid sub-domain cells
- Duration: 14 min

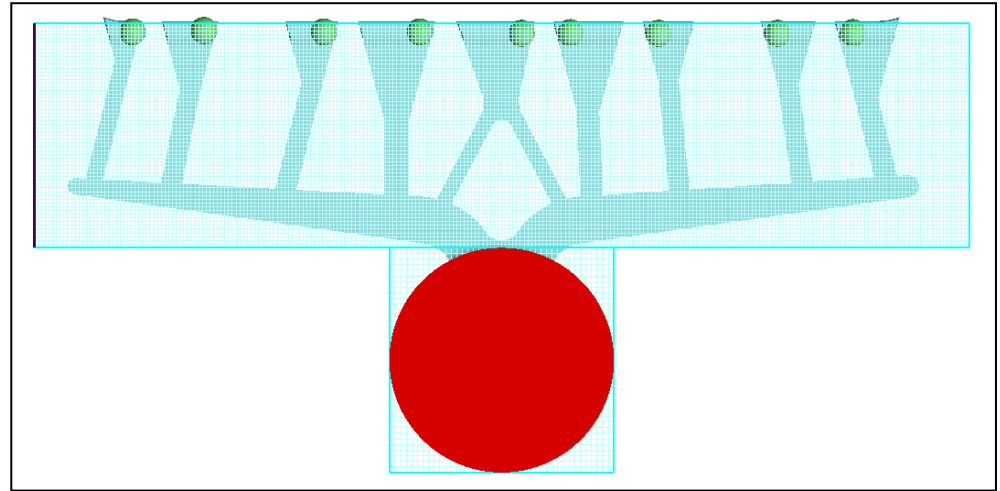




Runners optimization

2nd phase simulation setup:

- Restart from 1st simulation
- Acceleration of plunger speed to 3.5m/s in 0.02s
- Size of cells
 - Shot sleeve 3x3x5mm
 - Runner/gates 2mm
- Nr. 190 k Fluid sub-domain cells
- Duration: 6 min
- Budget: 20 simulations

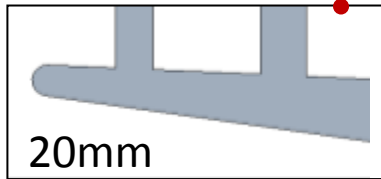
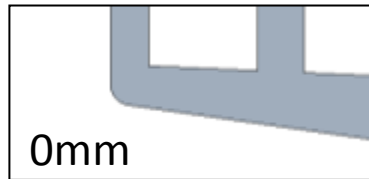
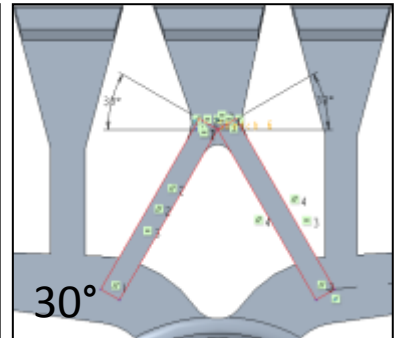
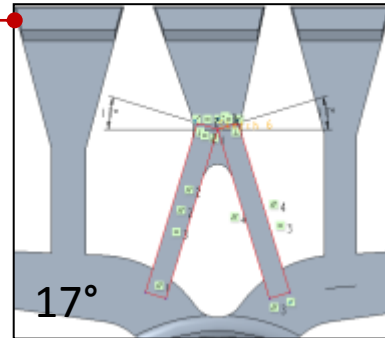
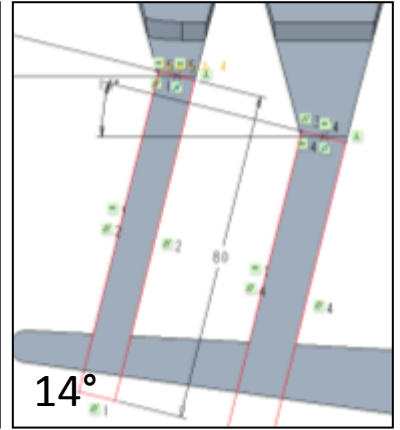
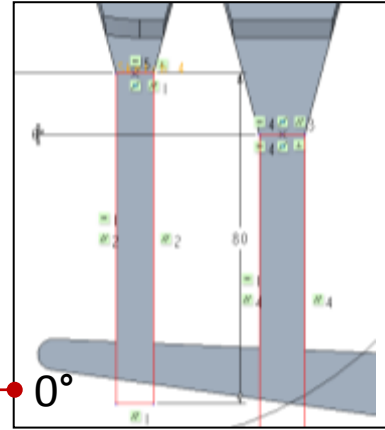


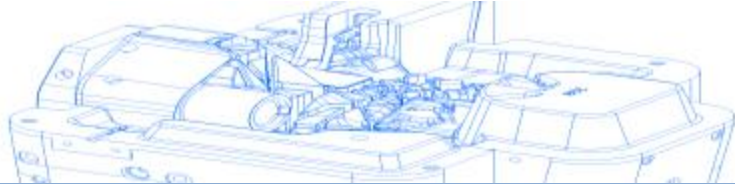


Runners optimization

Input (PTC Creo 5):

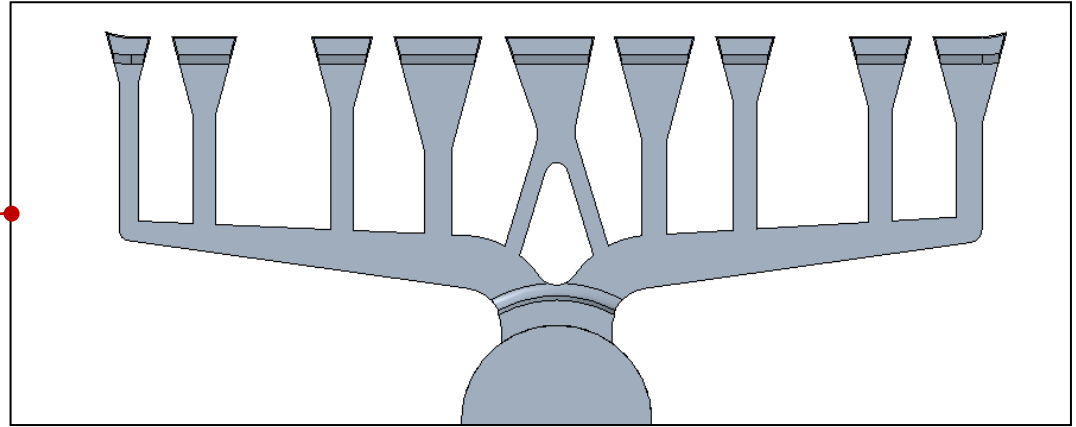
- 8 side runners angle ($0^\circ \div 14^\circ$)
- 2 central runners angle ($17^\circ \div 30^\circ$)
- 2 terminals length (0-20mm)





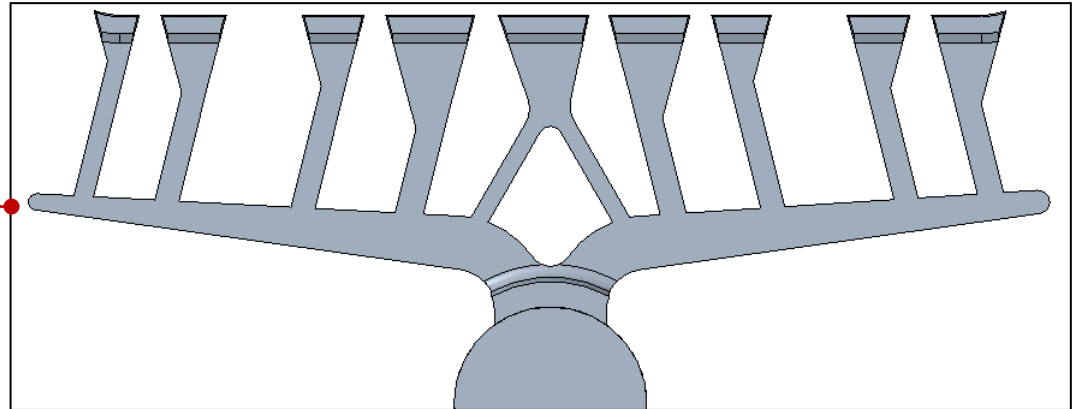
Minimum Range:

- 8 side runners angle 0°
- 2 central runners angle 17°
- 2 terminals length 20mm



Maximum Range:

- 8 side runners angle 14°
- 2 central runners angle 30°
- 2 terminals length 20mm

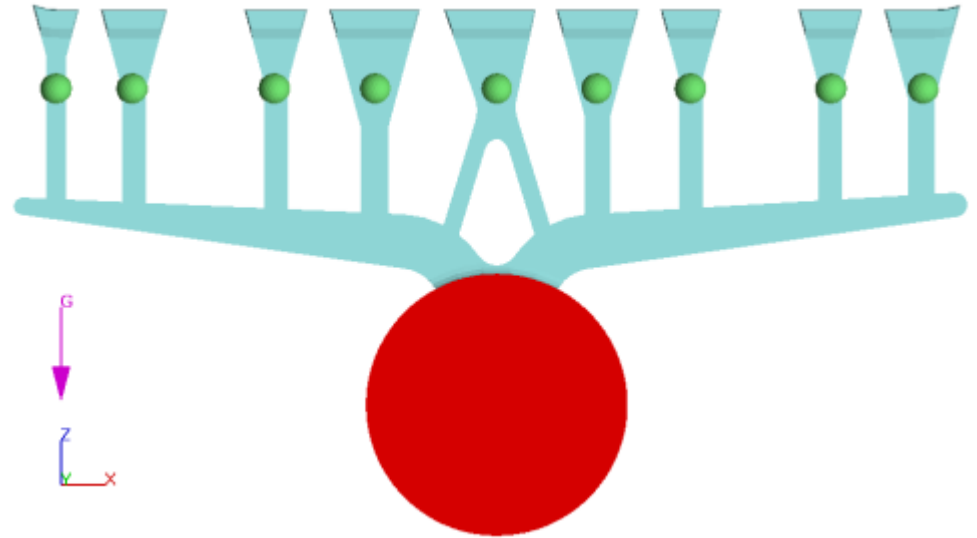




Runners optimization

Output:

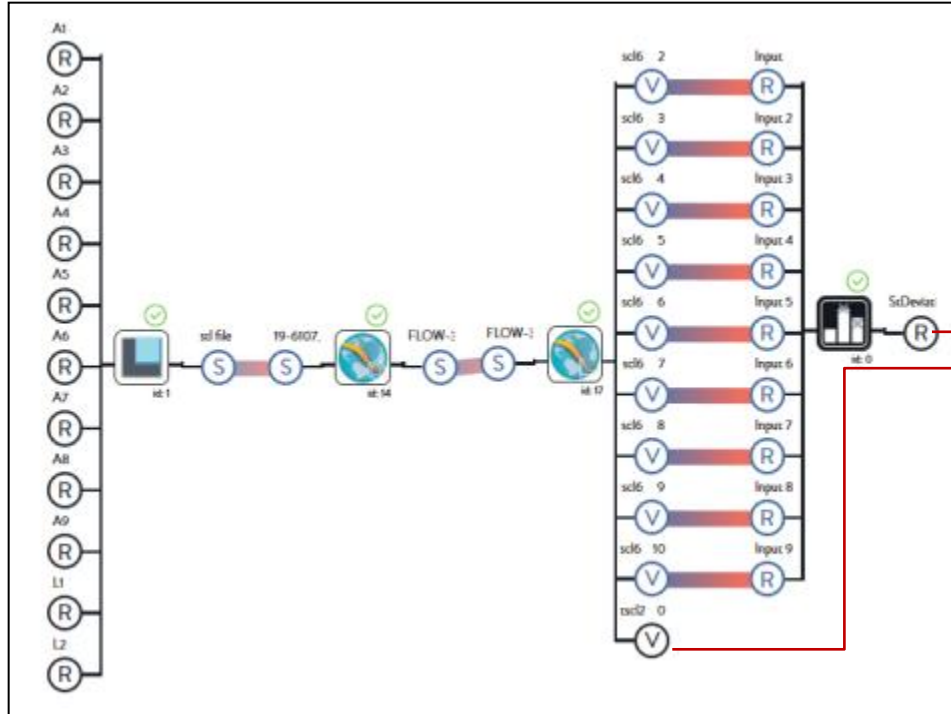
- time of first fluid arrival on 9 probes
- entrained air mass conc.



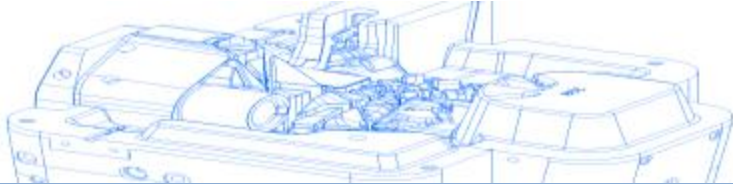


Runners optimization Workflow:

Input list		
Name	MinimumRange	MaximumRange
A1	0	14
A2	0	14
A3	0	14
A4	0	14
A5	17	30
A6	0	14
A7	0	14
A8	0	14
A9	0	14
L1	0	20
L2	0	20



Output list	
Name	Objective
tscf2 0	Minimize
StDeviation	Minimize

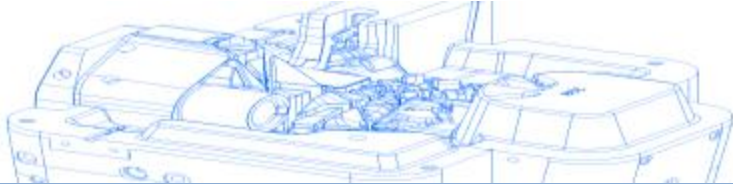


Runners optimization Results:

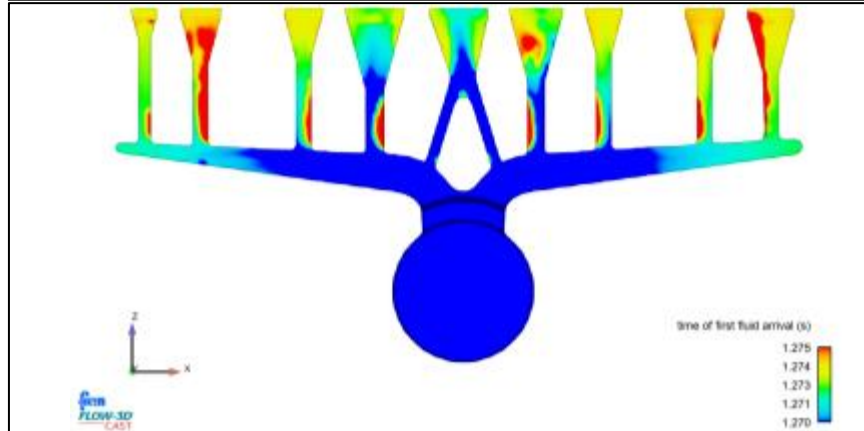
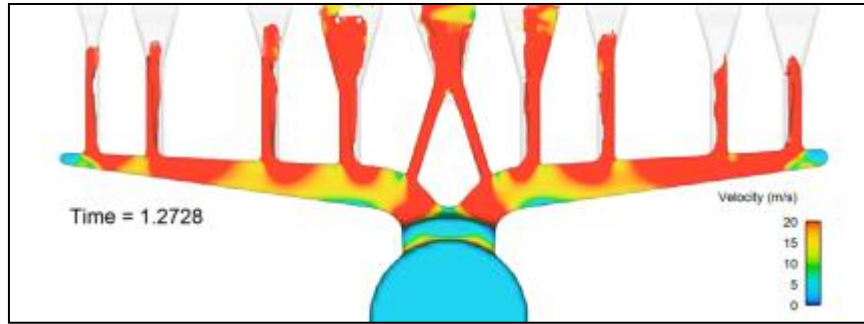
#		A1	A2	A3	A4	A5	A6	A7	A8	A9	L1	L2	tscI2_0	StDeviatio	Status
1		1.0500E+01	3.5000E+00	9.1000E+00	7.0000E-01	1.7650E+01	9.1000E+00	6.3000E+00	7.0000E-01	9.1000E+00	1.3000E+01	5.0000E+00	5.3294E-06	9.9662E-04	Trusted
					9.1000E+00	1.8950E+01	2.1000E+00	1.0500E+01	4.9000E+00	3.5000E+00	1.5000E+01	1.7000E+01	5.0305E-06	1.1003E-03	Trusted
					6.3000E+00	2.1550E+01	4.9000E+00	3.5000E+00	7.7000E+00	1.1900E+01	1.0000E+00	1.0000E+00	4.9971E-06	8.5706E-04	Trusted
					7.7000E+00	2.4150E+01	7.0000E-01	2.1000E+00	1.3300E+01	4.9000E+00	1.7000E+01	7.0000E+00	4.7318E-06	9.9932E-04	Trusted
					1.1900E+01	2.2850E+01	1.0500E+01	9.1000E+00	6.3000E+00	1.3300E+01	1.9000E+01	1.1000E+01	4.8940E-06	1.1906E-03	Trusted
					4.9000E+00	2.6750E+01	1.3300E+01	7.0000E-01	3.5000E+00	7.0000E-01	1.1000E+01	9.0000E+00	5.0786E-06	1.0575E-03	Trusted
					2.1000E+00	2.0250E+01	7.7000E+00	1.3300E+01	1.1900E+01	2.1000E+00	5.0000E+00	1.3000E+01	4.6391E-06	1.0645E-03	Trusted
					1.0500E+01	2.9350E+01	3.5000E+00	7.7000E+00	2.1000E+00	1.0500E+01	3.0000E+00	1.5000E+01	5.2704E-06	1.2032E-03	Trusted
					3.5000E+00	2.8050E+01	6.3000E+00	4.9000E+00	1.0500E+01	7.7000E+00	9.0000E+00	1.9000E+01	5.1372E-06	1.2750E-03	Trusted
					1.3300E+01	2.5450E+01	1.1900E+01	1.1900E+01	9.1000E+00	6.3000E+00	7.0000E+00	3.0000E+00	4.3502E-06	8.2687E-04	Trusted
					1.4000E+01	3.0000E+01	1.4000E+01	1.4000E+01	1.4000E+01	1.4000E+01	2.0000E+01	0.0000E+00	4.2129E-06	1.2187E-03	Trusted
					1.4000E+01	1.7000E+01	0.0000E+00	1.4000E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9749E-06	1.4007E-03	Trusted
					1.4000E+01	1.7000E+01	1.4000E+01	0.0000E+00	1.4000E+01	1.4000E+01	0.0000E+00	2.0000E+01	4.0851E-06	1.3674E-03	Trusted
					1.4000E+01	1.7000E+01	1.4000E+01	1.4000E+01	1.4000E+01	0.0000E+00	0.0000E+00	0.0000E+00	4.0200E-06	2.0712E-03	Trusted
					1.2227E+01	2.9399E+01	9.8613E+00	6.2738E+00	3.5625E+00	7.9618E+00	1.1419E+01	2.5496E-01	4.4678E-06	1.3012E-03	Trusted
					6.4059E+00	2.2082E+01	8.2905E+00	9.9897E+00	1.1399E+01	1.1648E+01	3.2668E+00	3.8893E+00	4.3642E-06	1.3936E-03	Trusted
17		5.4529E-01	3.9883E-01	1.3733E+01	1.3869E+01	1.7495E+01	1.3956E+01	1.3479E+01	1.3581E+01	3.7641E-01	7.4447E-01	6.5139E-01	4.2100E-06	1.3434E-03	Trusted
18		3.8003E-02	7.6017E-01	1.3924E+01	1.3624E+01	1.7598E+01	1.3417E+01	1.3885E+01	1.3780E+01	7.4436E-01	4.5038E-01	9.0445E-03	4.0754E-06	1.4299E-03	Trusted
19		9.2031E-02	1.1118E+00	1.3196E+01	1.3444E+01	1.8042E+01	1.3050E+01	1.3399E+01	1.3873E+01	1.2561E+00	1.1847E-01	1.0460E+00	4.0886E-06	1.8639E-03	Trusted
20		5.7400E+00	4.5873E+00	1.3695E+01	1.3351E+01	2.4979E+01	1.1971E+01	1.1862E+01	8.7092E+00	6.6660E+00	7.7886E+00	2.4221E+00	4.1137E-06	7.5330E-04	Trusted

Best Result

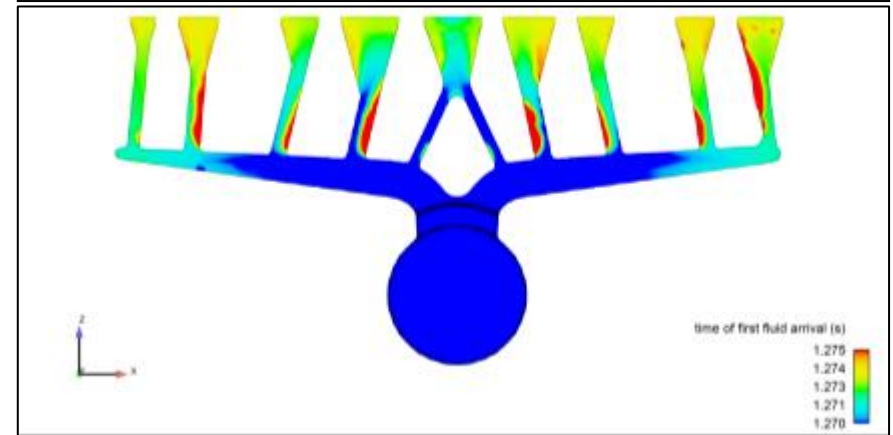
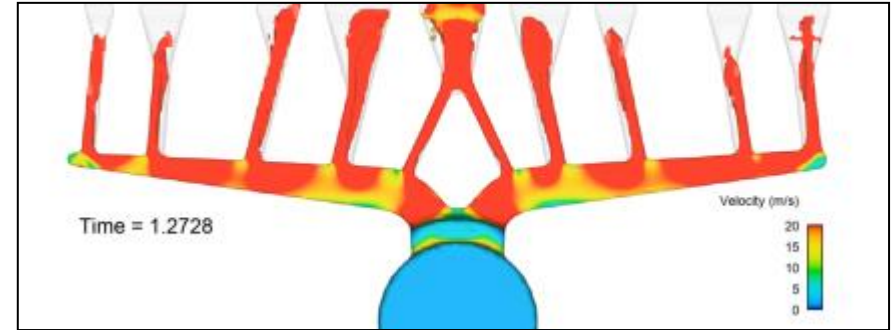




Initial Result:

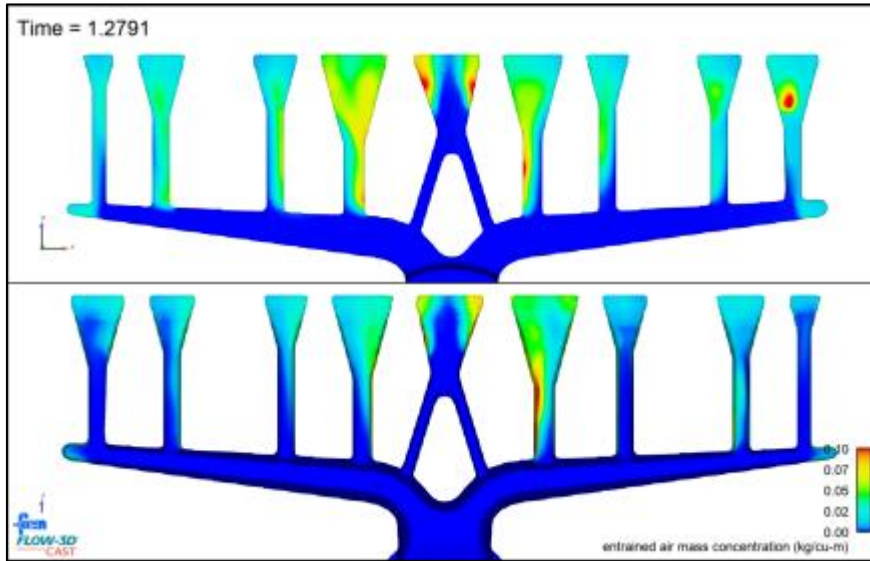


Best Result:

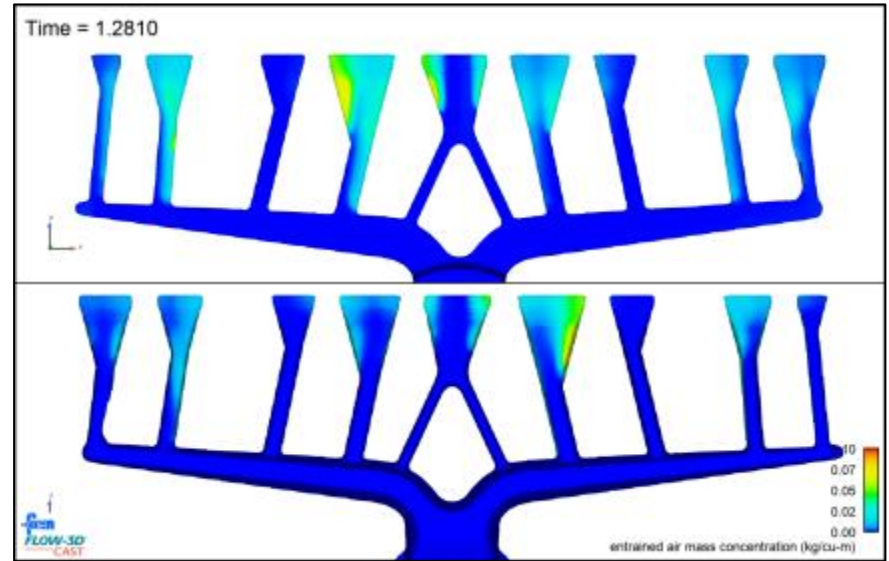




Initial Result:



Best Result:

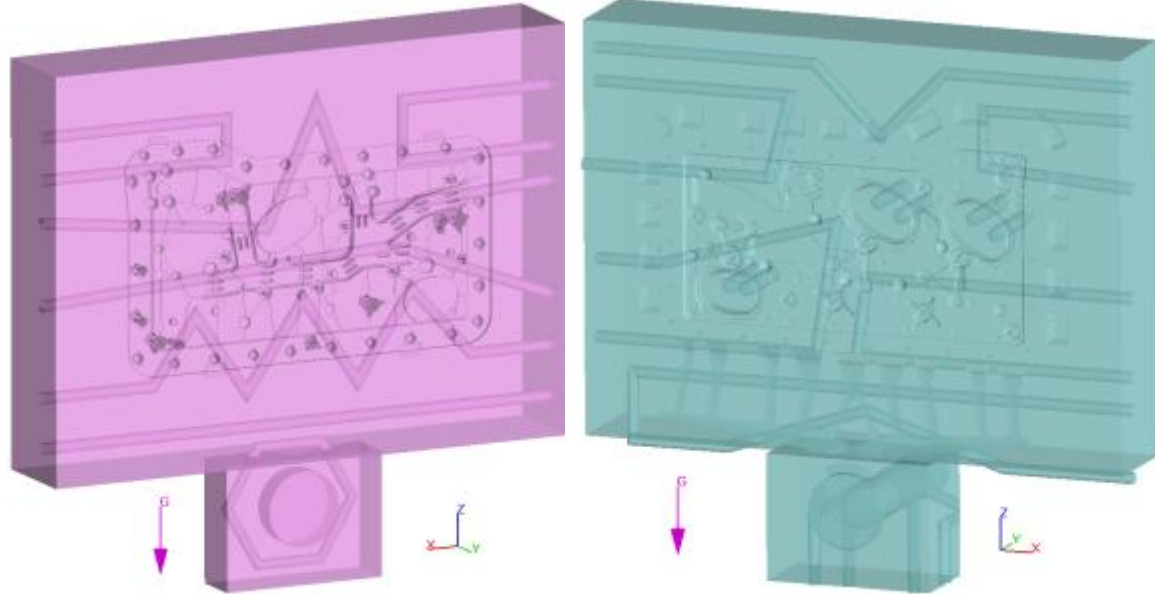




Cooling optimization

TDC simulation setup:

- All circuit in the cavity with the same temperature $T=80^{\circ}\text{C}$ but different flow (HTC)
- Nr.6 cycles starting from die at 200°C
- Restart from previous filling
- Size of cells 2mm
- Nr. 6.7M Solid sub-domain cells
- Duration: 55 min
- Budget: 24 simulations

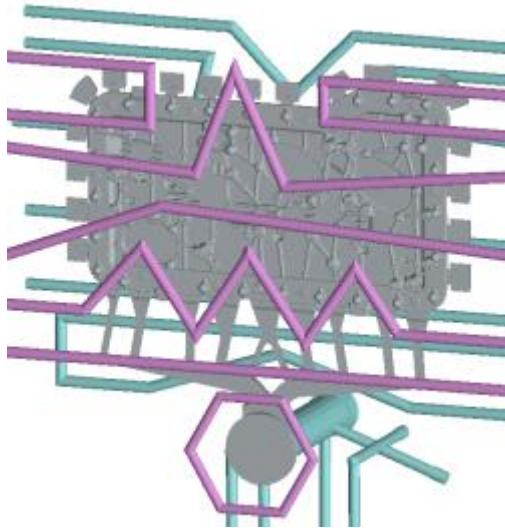




Circuits HTC optimization

Input:

-15 HTC (0 ÷ 5600 W/m² K)



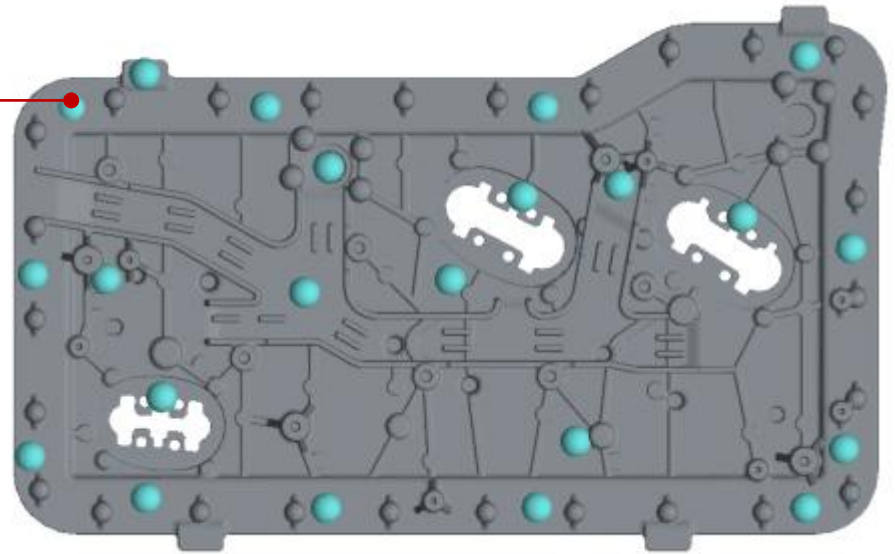
Cooling Channel					
19-6107_circuiti_fissa_6	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_fissa_5	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_fissa_4	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_fissa_3	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_fissa_2	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_fissa_1	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuito_contenitore	<input type="checkbox"/> /Time	35	C	<input type="checkbox"/> /Time	5000 W/m ²
19-1020_circuito_controcolata	<input type="checkbox"/> /Time	35	C	<input type="checkbox"/> /Time	5000 W/m ²
19-6107_circuiti_tass_3	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_tass_2	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_tass_1	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_mobile_6	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_mobile_5	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_mobile_4	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_mobile_3	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_mobile_2	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²
19-6107_circuiti_mobile_1	<input type="checkbox"/> /Time	80	C	<input type="checkbox"/> /Time	5600 W/m ²



Circuits HTC optimization

Output:

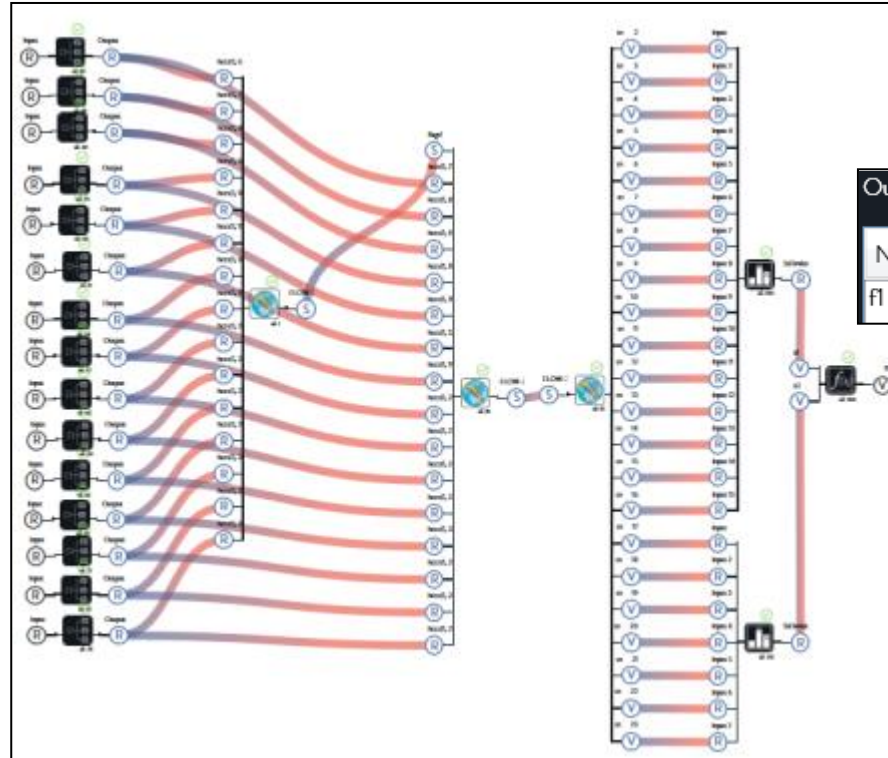
-22 probes to measure wall temperature





Circuits HTC optimization Workflow

Input list		
Name	MinimumRange	MaximumRange
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600
Input	0	5600



Output list	
Name	Objective
f1	Minimize

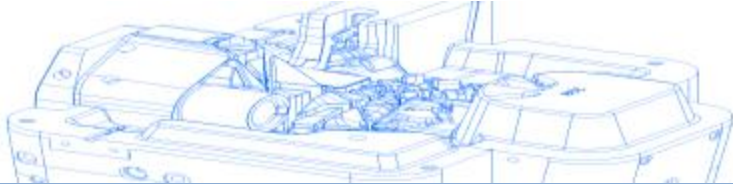


Circuits HTC optimization results:

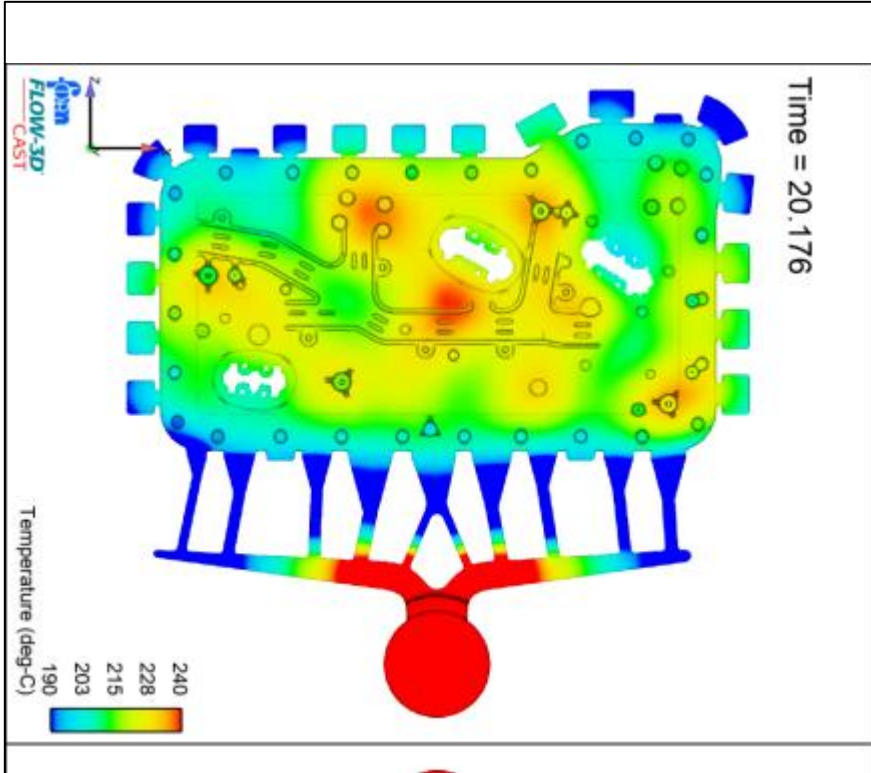
#	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	f1	Status
1	4.5920E+03	3.2480E+03	7.8400E+02	1.1200E+02	4.5920E+03	1.2320E+03	1.0080E+03	1.9040E+03	4.1440E+03	1.4560E+03	1.1200E+02	2.5760E+03	2.1280E+03	2.1280E+03	4.1440E+03	2.0576E+01	Trusted
2	2.8000E+03	3.9200E+03	1.9040E+03	1.0080E+03	5.6000E+02	4.5920E+03	1.1200E+02	2.1280E+03	3.6960E+03	3.4720E+03	3.6960E+03	1.1200E+02	4.3680E+03	1.0080E+03	1.2320E+03	1.5210E+01	Trusted
3	1.6284E+03	1.7465E+03	4.6711E+03	1.6623E+03	1.6623E+03	1.3426E+03	5.4203E+03	5.2454E+03	5.2454E+03	2.0813E+03	3.5612E+03	3.5612E+03	2.0226E+03	1.9723E+03	1.8194E+03	1.2894E+01	Trusted
4	5.4699E+03	1.9633E+03	2.8572E+03	1.4223E+03	1.4223E+03	5.1473E+03	6.1313E+02	3.0170E+03	3.0170E+03	1.6467E+03	1.0875E+03	1.0875E+03	4.0849E+03	5.7520E+02	3.6676E+03	1.4275E+01	Trusted
5	2.3901E+03	1.1526E+02	2.9692E+03	3.7671E+03	3.7671E+03	1.9514E+03	2.8427E+03	3.2378E+03	3.2378E+03	1.8304E+03	4.6362E+03	4.6362E+03	4.8846E+03	2.5288E+03	7.8901E+02	1.1267E+01	Trusted
6	3.0016E+03	6.6040E+02	4.1577E+03	3.0216E+03	3.0216E+03	5.1893E+03	5.4582E+02	5.5787E+03	5.5787E+03	3.2943E+03	3.3388E+03	3.3388E+03	4.4160E+03	5.4299E+03	2.1910E+03	1.1236E+01	Trusted
7	1.5136E+03	3.8181E+03	3.5087E+03	1.4919E+03	1.4919E+03	2.1347E+03	5.3412E+03	1.6120E+03	1.6120E+03	3.1699E+02	2.1570E+03	2.1570E+03	4.2595E+03	4.3779E+03	5.2157E+03	1.1919E+01	Trusted
8	4.1806E+02	2.0491E+03	2.5447E+03	1.3929E+03	1.3929E+03	3.0896E+02	1.6141E+02	2.0268E+03	2.0268E+03	8.4955E+02	1.5384E+03	1.5384E+03	1.1251E+03	4.5751E+03	5.2033E+03	1.3949E+01	Trusted
9	5.3513E+03	4.2064E+03	1.3212E+02	1.9066E+03	1.9066E+03	4.4560E+03	4.2529E+03	1.8727E+02	1.8727E+02	1.2972E+03	2.7466E+03	2.7466E+03	4.5855E+03	1.0729E+03	4.0157E+03	1.5392E+01	Trusted
10	5.5401E+03	2.0708E+03	2.9712E+03	1.3128E+03	1.3128E+03	6.0212E+02	4.2359E+03	2.1386E+03	2.1386E+03	2.6483E+03	2.4789E+03	2.4789E+03	3.6721E+03	2.8753E+03	4.0458E+03	1.6149E+01	Trusted
11	2.9408E+03	5.4146E+01	5.0478E+03	4.2249E+03	4.2249E+03	8.5454E+02	5.5809E+03	6.9040E+02	6.9040E+02	2.1418E+03	2.6612E+01	2.6612E+01	9.4703E+02	4.0830E+03	2.8618E+03	1.6828E+01	Trusted
12	4.4352E+03	1.8337E+03	4.9586E+03	2.4653E+02	2.4653E+02	1.9077E+03	3.2356E+03	2.4579E+03	2.4579E+03	1.1430E+03	3.7115E+02	3.7115E+02	2.6739E+03	5.2022E+03	2.4715E+00	1.6941E+01	Trusted
13	3.9202E+03	1.9919E+02	1.0748E+03	5.4229E+03	5.4229E+03	5.1979E+03	4.8023E+03	8.5405E+02	8.5405E+02	3.2100E+03	4.0306E+03	4.0306E+03	1.2495E+03	3.8668E+03	3.0836E+03	1.0607E+01	Trusted
14	3.9280E+03	2.0831E+03	5.4833E+03	1.7674E+03	1.7674E+03	4.4278E+03	3.3396E+03	4.4551E+03	4.4551E+03	4.3272E+02	4.9330E+03	4.9330E+03	2.8837E+01	2.7801E+03	2.7546E+02	1.2334E+01	Trusted
15	2.8524E+03	2.6966E+02	8.0565E+01	6.2883E+02	6.2883E+02	4.0055E+03	5.1423E+03	4.1927E+03	4.1927E+03	2.6323E+03	3.1375E+02	3.1375E+02	5.3197E+03	3.4117E+03	3.7487E+03	2.1376E+01	Trusted
16	1.6565E+03	3.6893E+03	4.4934E+03	5.0699E+03	5.0699E+03	3.4909E+03	2.5650E+03	5.4587E+03	5.4587E+03	3.1882E+03	2.9918E+03	2.9918E+03	1.5428E+03	4.8753E+03	4.3882E+03	1.1412E+01	Trusted
17	3.7134E+03	1.4325E+03	1.1360E+03	2.0489E+03	2.0489E+03	7.4956E+02	2.5988E+03	4.9396E+03	4.9396E+03	2.7772E+03	4.0664E+03	4.0664E+03	1.9681E+03	4.7303E+03	2.0698E+03	1.2519E+01	Trusted
18	0.0000E+00	5.6000E+03	5.6000E+03	5.6000E+03	0.0000E+00	5.6000E+03	0.0000E+00	1.5620E+03	8.0297E+02	3.4034E+03	2.2823E+03	5.3337E+03	2.2906E+03	3.1521E+03	3.6381E+03	1.1913E+01	Trusted
19	0.0000E+00	5.6000E+03	5.6000E+03	0.0000E+00	5.6000E+03	5.6000E+03	0.0000E+00	5.6000E+03	0.0000E+00	4.9660E+02	4.7082E+03	2.0444E+03	5.4958E+03	5.2084E+03	2.2667E+03	1.2096E+01	Trusted
20	4.2637E+03	7.4433E+02	3.7845E+03	5.1766E+03	1.4422E+03	1.7477E+03	1.6020E+03	3.1490E+03	5.5645E+03	2.6066E+01	5.3175E+03	4.9466E+03	4.0502E+03	5.3681E+03	5.3566E+03	1.1456E+01	Trusted
21	0.0000E+00	1.1391E+03	4.2192E+03	4.3944E+03	1.2890E+03	8.2761E+02	5.2429E+03	5.3858E+03	1.0399E+03	3.6200E+02	5.5740E+03	3.8739E+03	4.3523E+03	5.3952E+03	4.6269E+03	1.3221E+01	Trusted
22	4.9683E+02	1.9493E+02	4.2015E+03	4.3015E+03	3.6488E+03	5.5695E+03	2.6355E+03	1.6130E+03	2.3253E+03	3.1137E+03	5.4944E+03	3.5361E+03	1.1340E+03	3.5613E+03	3.0992E+03	1.1264E+01	Trusted
23	4.1152E+03	2.2154E+03	1.8754E+03	5.4268E+03	3.3724E+03	5.1700E+03	1.4986E+03	5.1262E+03	8.8915E+02	1.7154E+03	4.2128E+03	4.8479E+03	3.3188E+03	4.2995E+03	8.3776E+02	9.9243E+00	Trusted
24	2.3669E+02	4.6320E+03	2.7834E+03	5.0834E+03	5.0080E+03	5.4309E+03	2.1502E+03	3.2833E+00	2.4715E+02	2.1734E+02	4.8086E+03	4.4932E+03	4.5782E+03	4.8170E+03	4.4418E+03	1.1267E+01	Trusted

Best Result

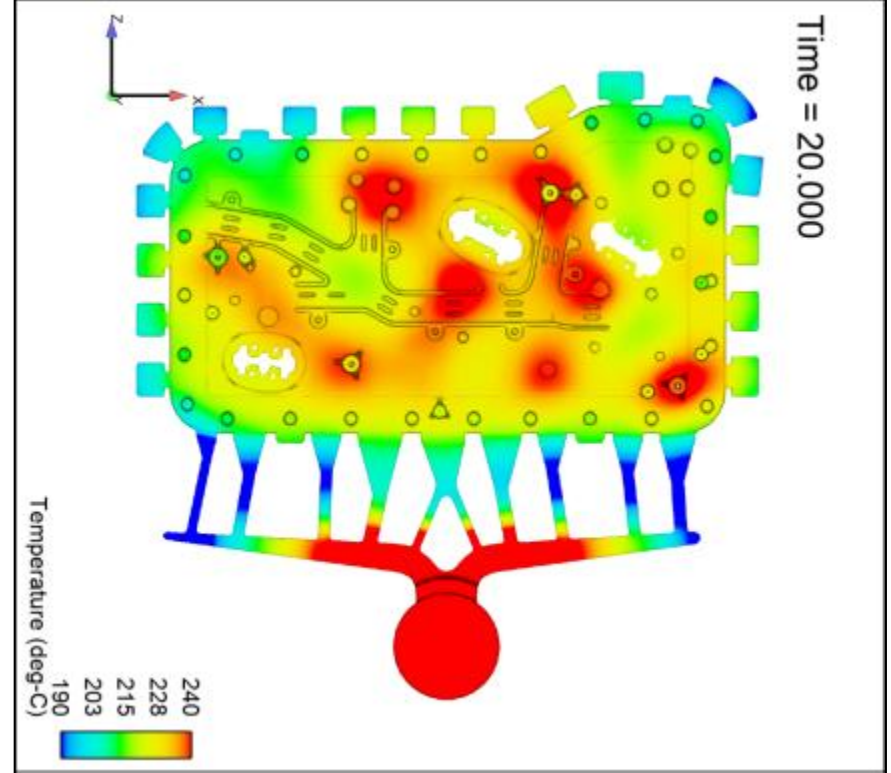


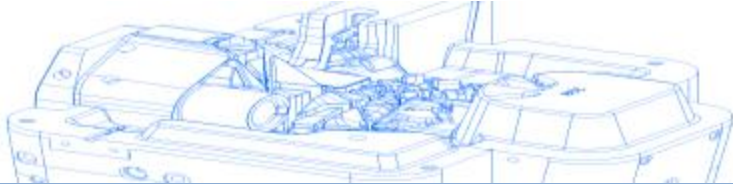


Initial Result: output 12.3 °C



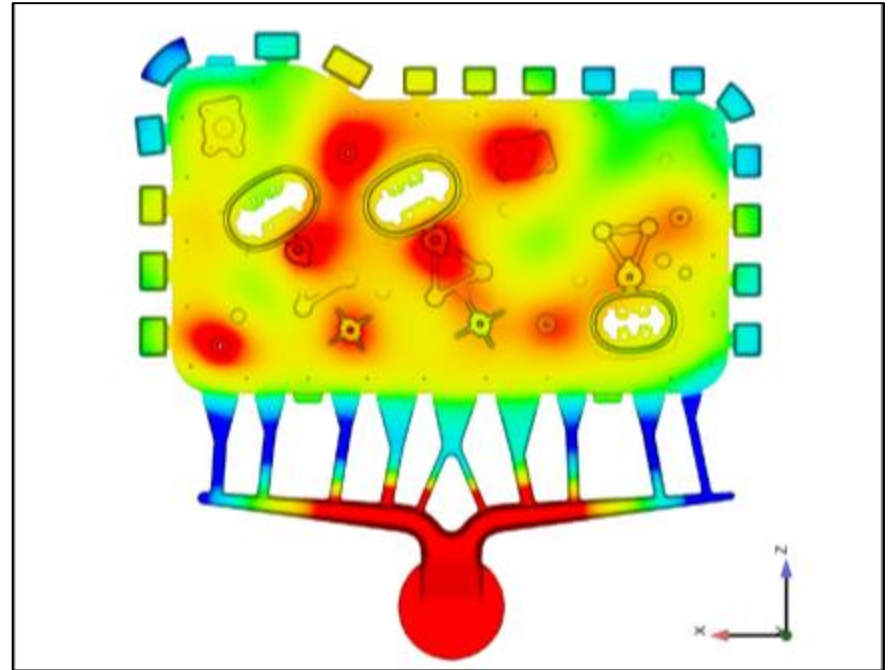
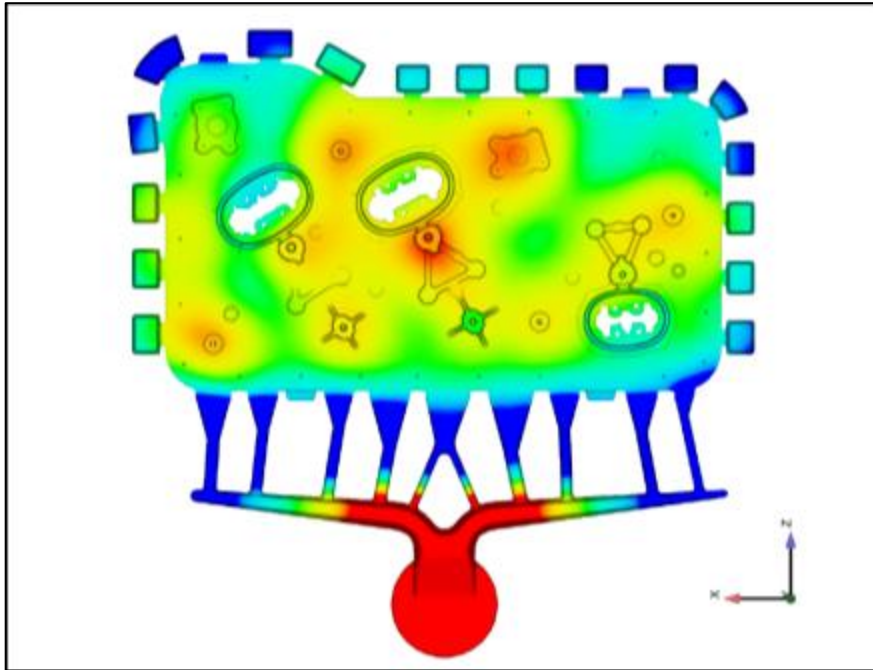
Best Result: output 10 °C





Initial Result: output 12.3 °C

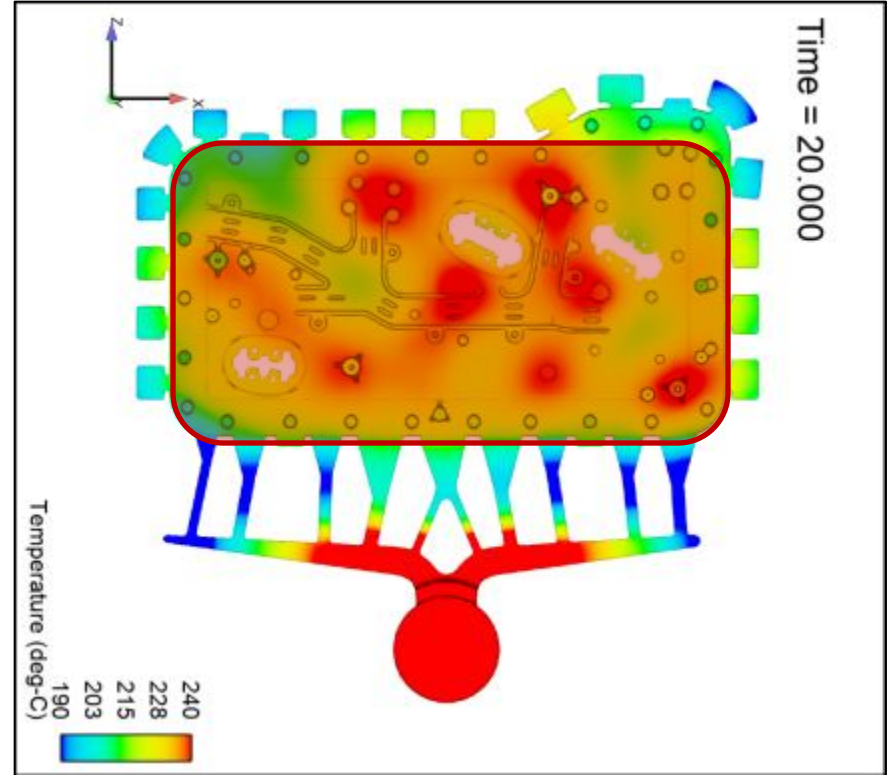
Best Result:





Idea to improve Optimization:

To have as new statistics output from Flow3d / Flowsight computed into all sampling volume (like average temperature, standard deviation etc..) instead of punctual control gived by probes





Conclusions

- Automation of design-simulation-interpretation-correction loop
→ saving of design time
- The choose of correct outputs is crucial
→ more output from Flow3d / Flowsight could help
- Greater is the number of simulation, best will be the result
→computation time
- More complete is the model, more reliable will be the result
→computation time



Thanks to XC Engineering and their



THANK YOU

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