APPLICATION OF OPENFOAM FOR THE SET UP OF THE INJECTION MOLDING PROCESS

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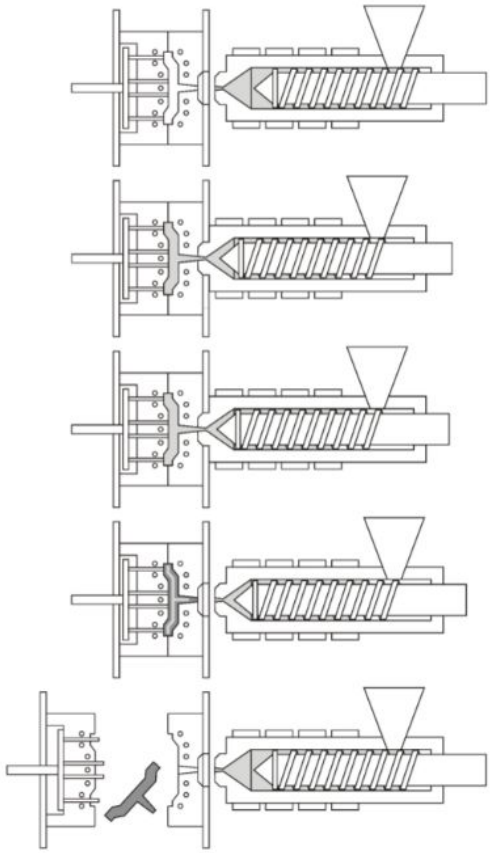
Introduction

- Polymer injection molding
  - communication, medicine, automotive, packaging
  - high pressure, high viscosity, high clamping forces
  - difficult experiments, location of measurement point
- Simulation
  - J. Nagy et al.: *Polymer injection molding simulations in OpenFOAM®*, PFAU 9, Linz, Austria, 03.11.2014
  - J. Nagy et al.: *Fluid dynamic and thermal modeling of the injection molding process in OpenFOAM®*, OFW11, Guimaraes, Portugal, 29.06.2016
  - J. Nagy et al.: *Modeling and optimization of the injection molding process with OpenFOAM®*, 4th Annual OF User Conference, Cologne, Germany, 11.10.2016
  - J.Nagy et al.: *Runtime optimization in injection molding simulations with adaptive and selective grid refinement*, OF12, Exeter, GB, 25.07.2017
  - J. Nagy et al.: Selective, adaptive & manual (SAM) mesh ref. in injection molding simulation in OpenFOAM, 5th OF User Conference, Wiesbaden, Germany, 17.10.2017
- Application of simulations

Process



1. Plastification
2. **Filling**
3. **Packing**
4. **Cooling**
5. Part ejection

Modeling

- Compressible flow
  - Continuity equation
  - Navier Stokes equations
  - Tait model for specific volume
- Energy equation
  - shear heating
  - heat transfer from melt into the mold
- Non-Newtonian material
  - Cross-WLF
  - shear rate
  - temperature
  - pressure
- Multiphase flow

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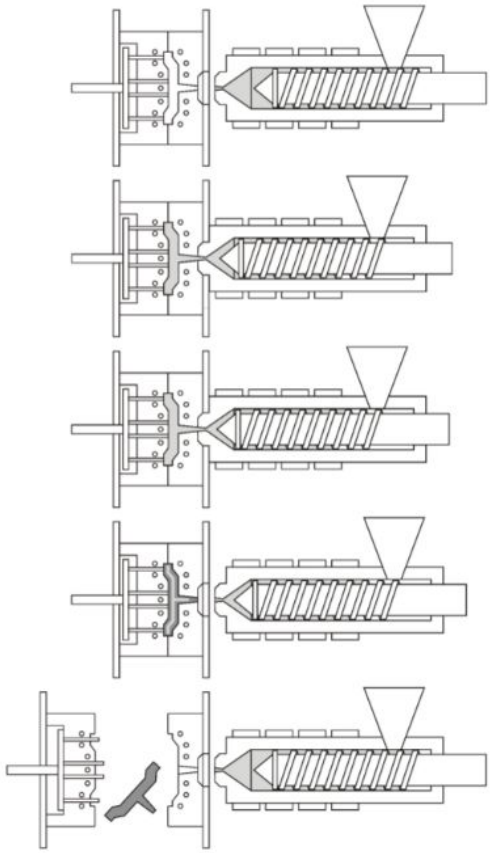
Phases



phase	velocity	pressure
filling	time dep. profile	zeroGradient
packing	zeroGradient	time dep. profile
cooling	zeroGradient	1 bar

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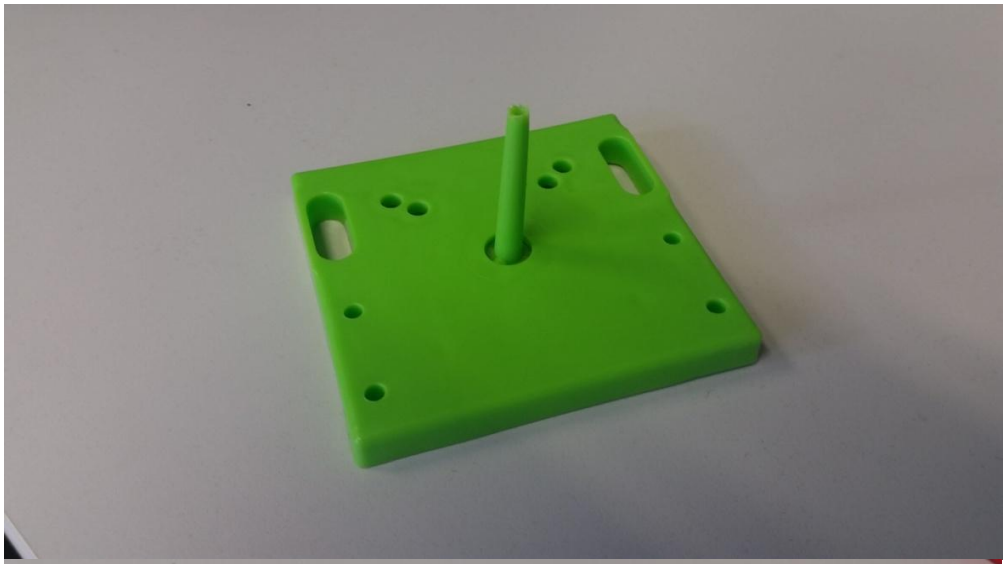
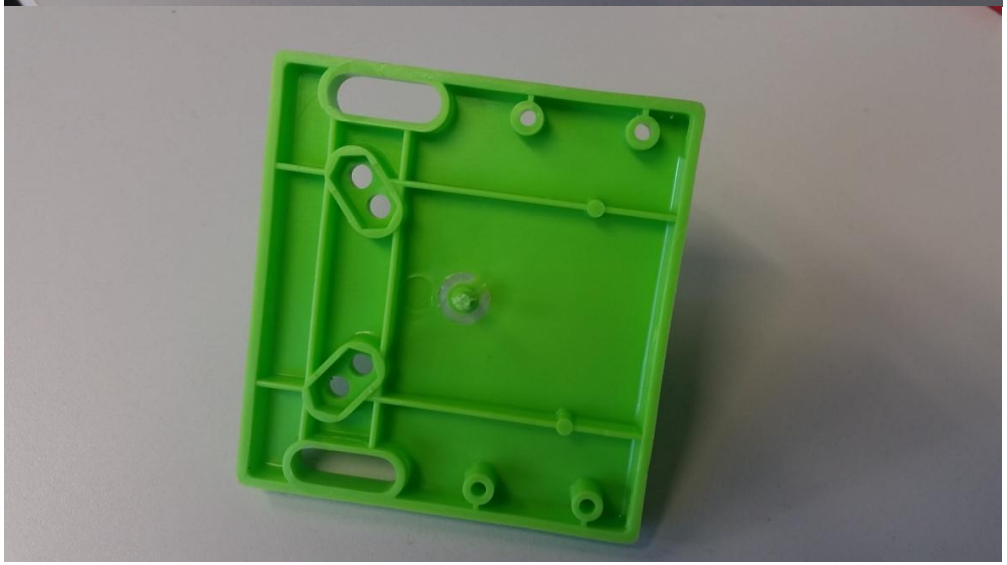
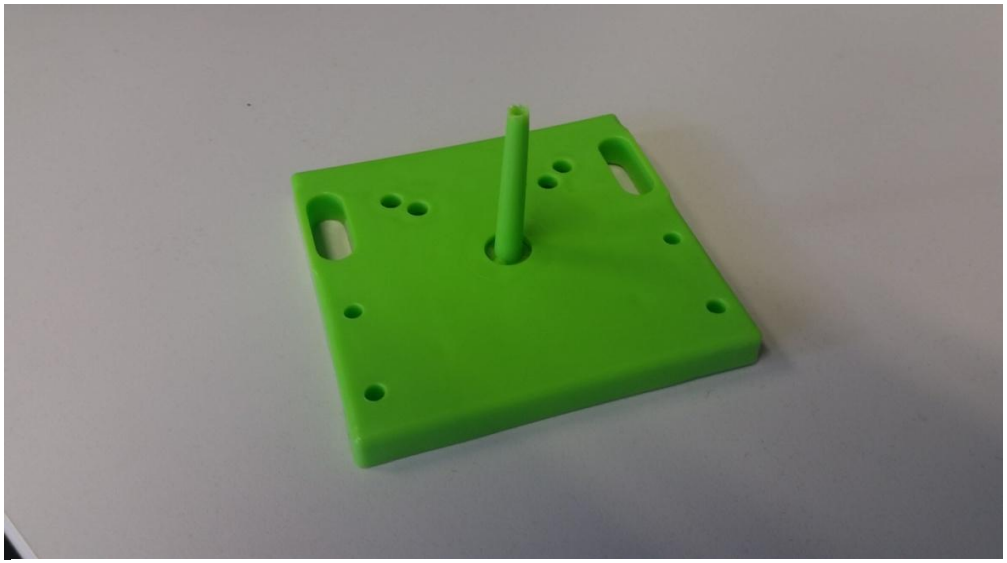
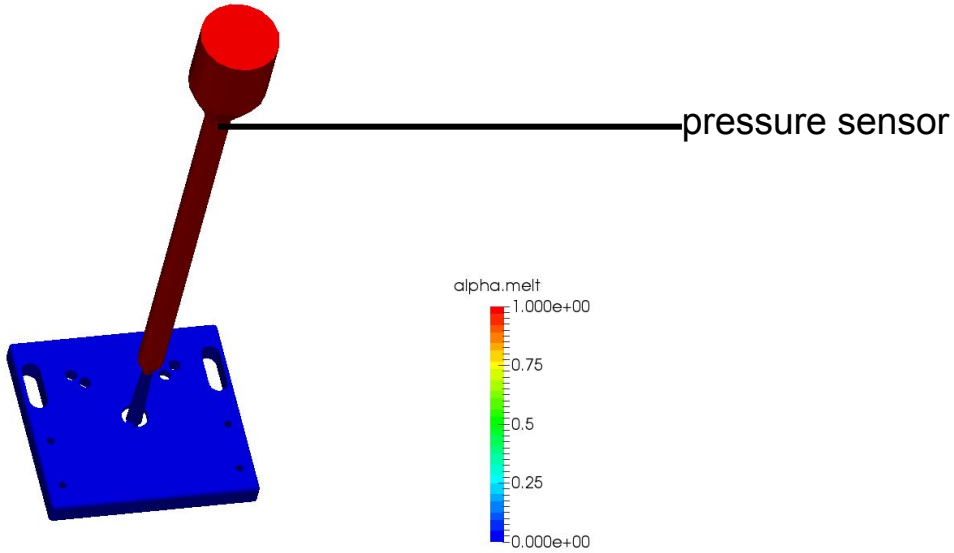
Filling - Endplate



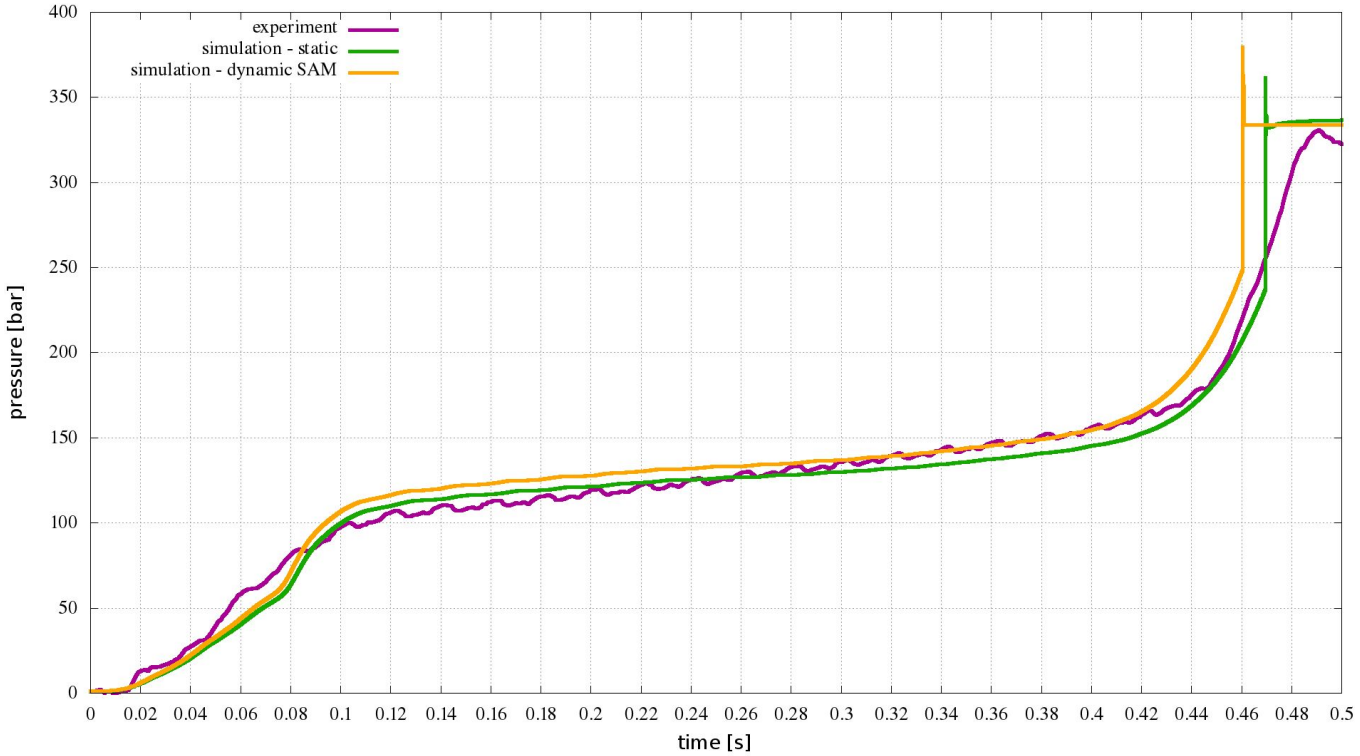


Filling phase - injection pressure



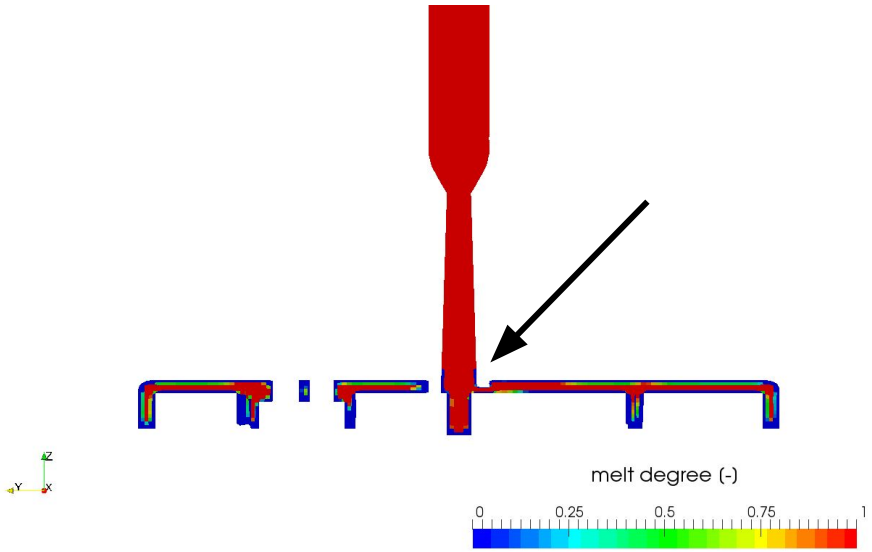


Filling phase - injection pressure

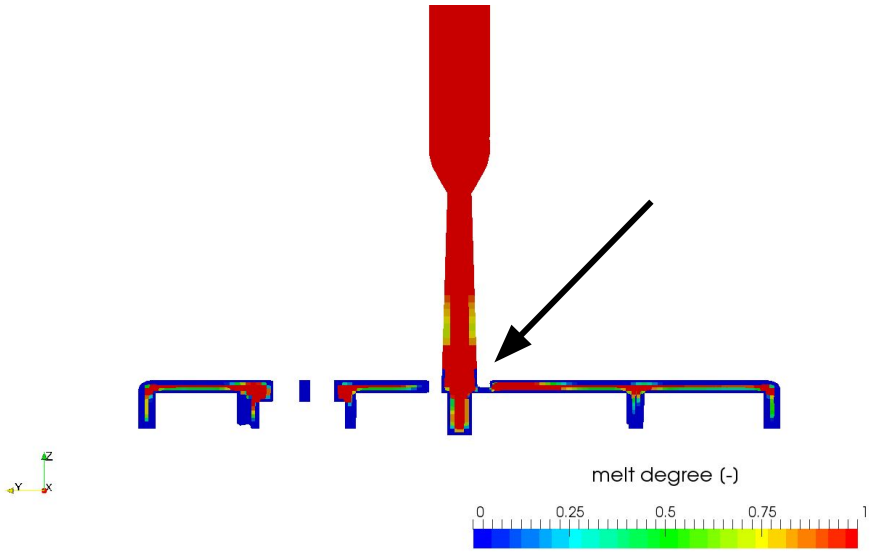


	p_{switch} [bar]	$\triangle p_{switch}$ [%]	t_{switch} [s]	$\triangle t_{switch}$ [%]
experiment	238	-	0.465	-
fine sim.	233	-2.1	0.468	0.6
dyn. sim.	248	4.2	0.461	-0.8

Packing phase - freezing time

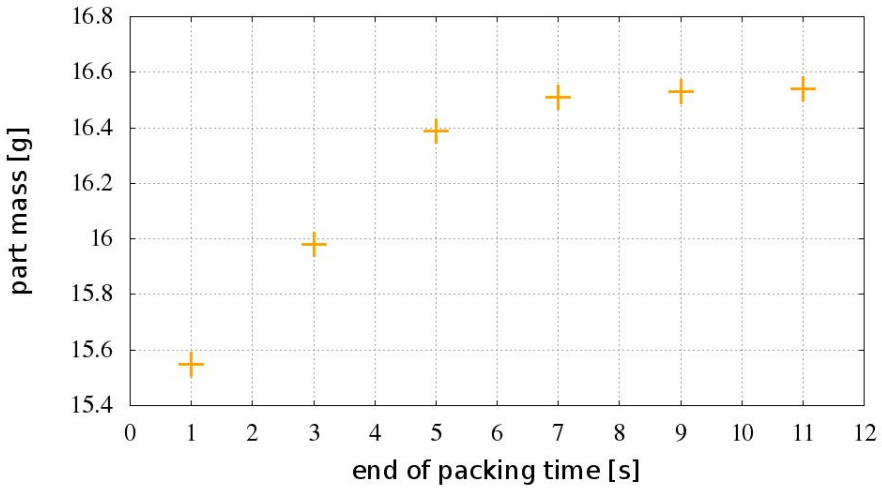


t = 6.5s



t = 7.5s

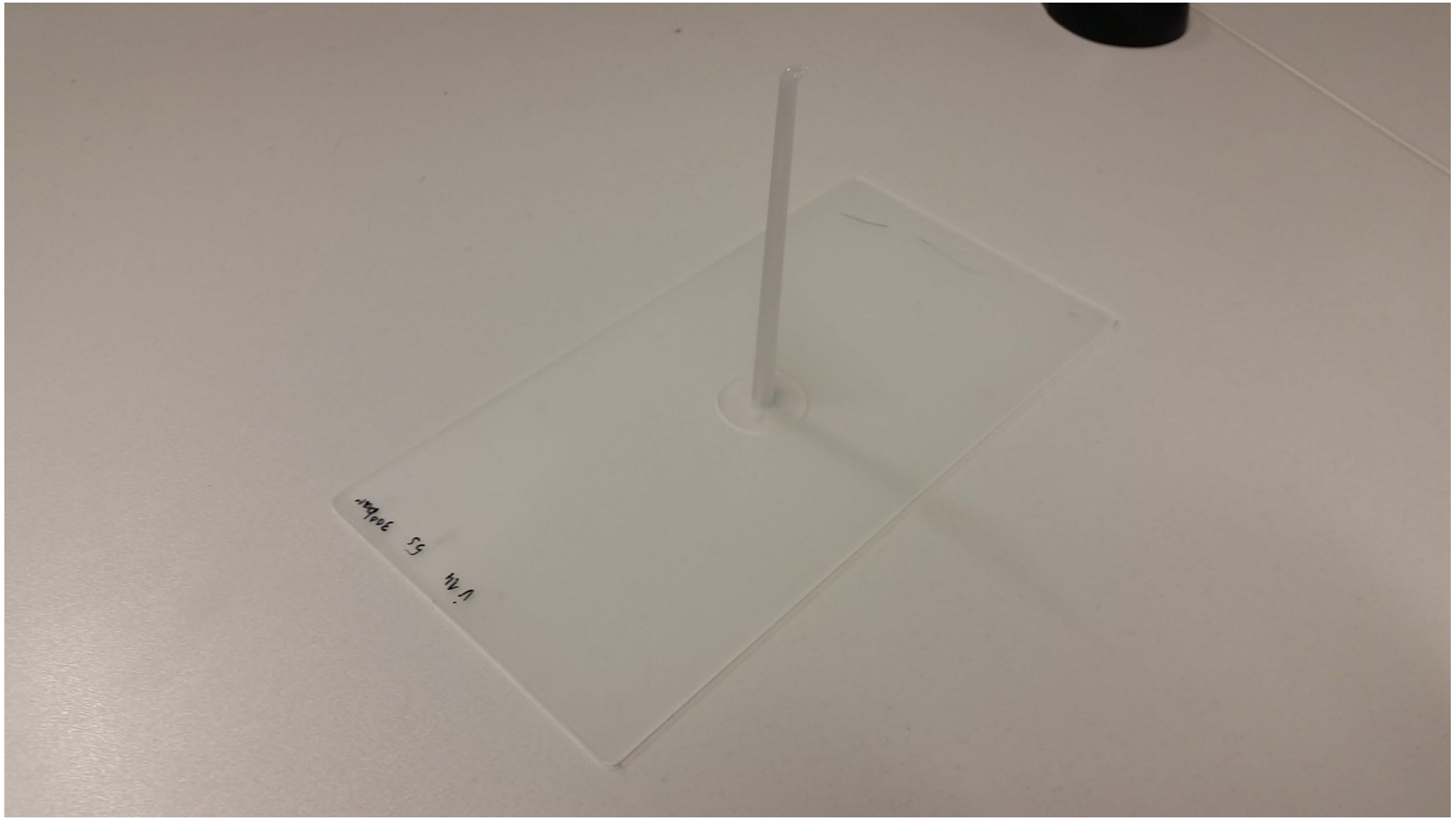
	t_{freeze} [s]
experiment	~7
fine sim.	7.05
dyn. sim.	6.98



Process set up

- Definition of important parameters
- Filling time - safety (switch over from velocity to pressure)
- Pressure - safety
  - maximum
  - cavity
- Packing time - energy consumption
- New development mold
  - installation of 14 pressure sensors
  - perfect opportunity to apply the simulation

Geometry



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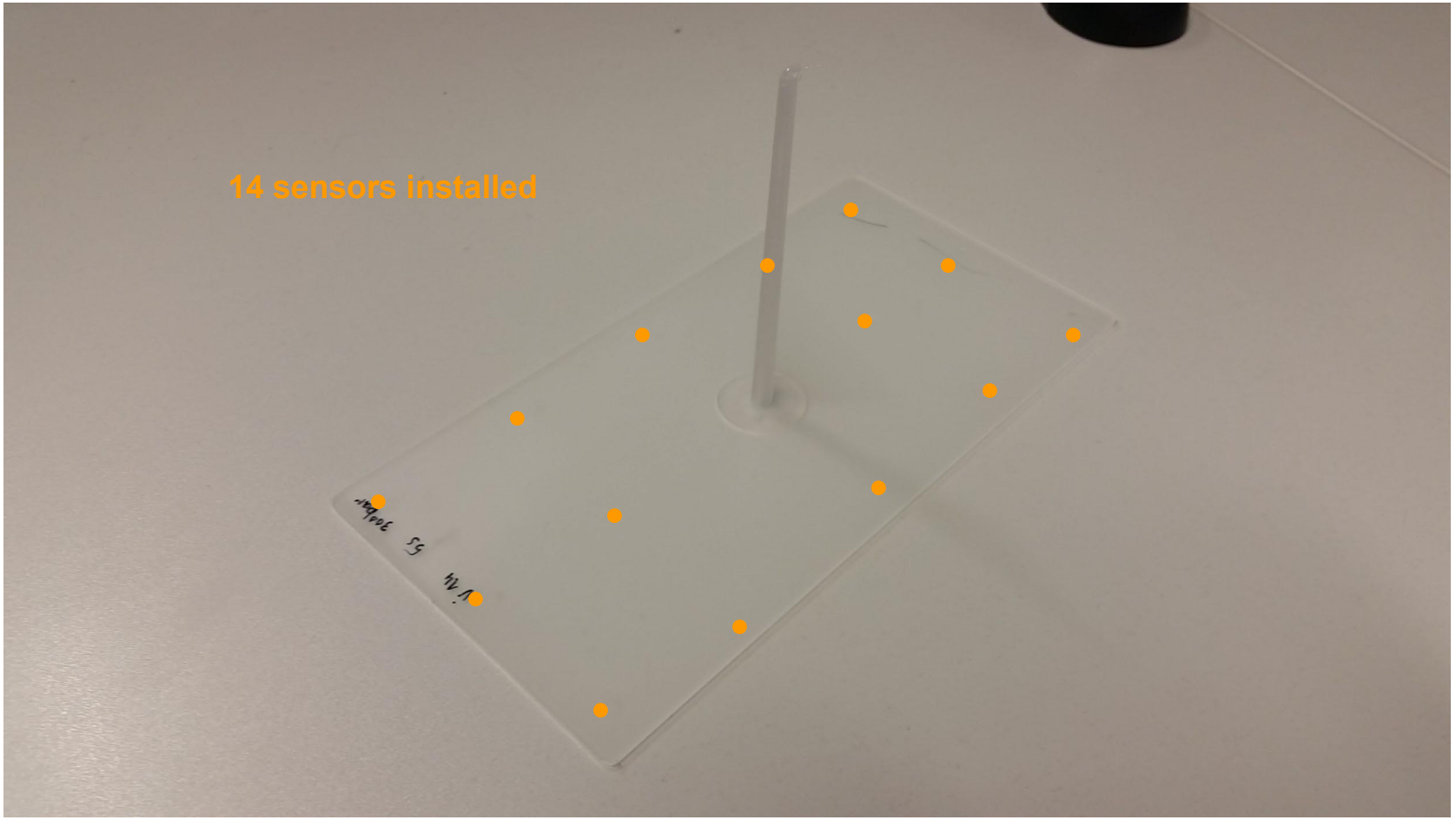
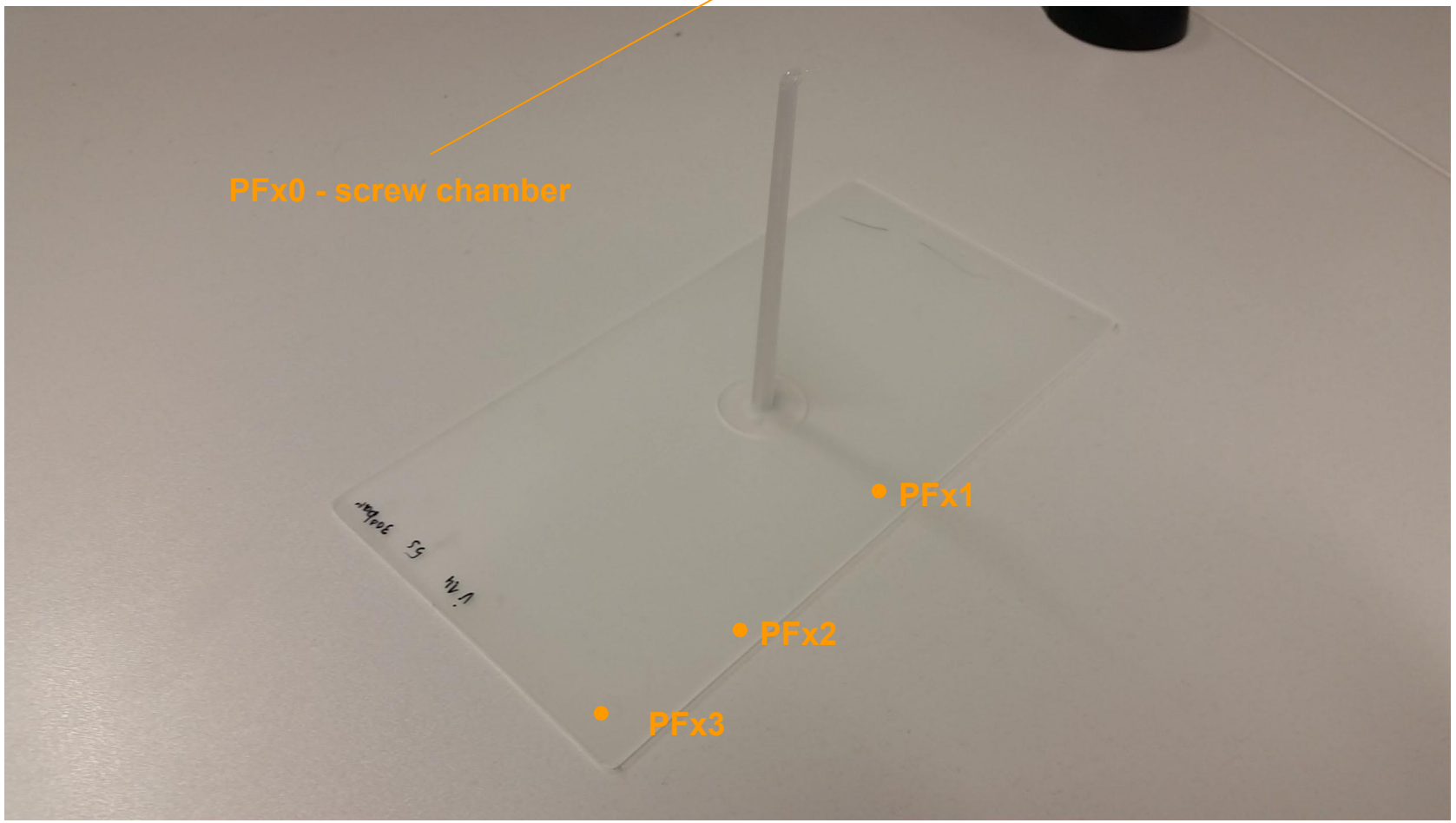
Pressure sensors



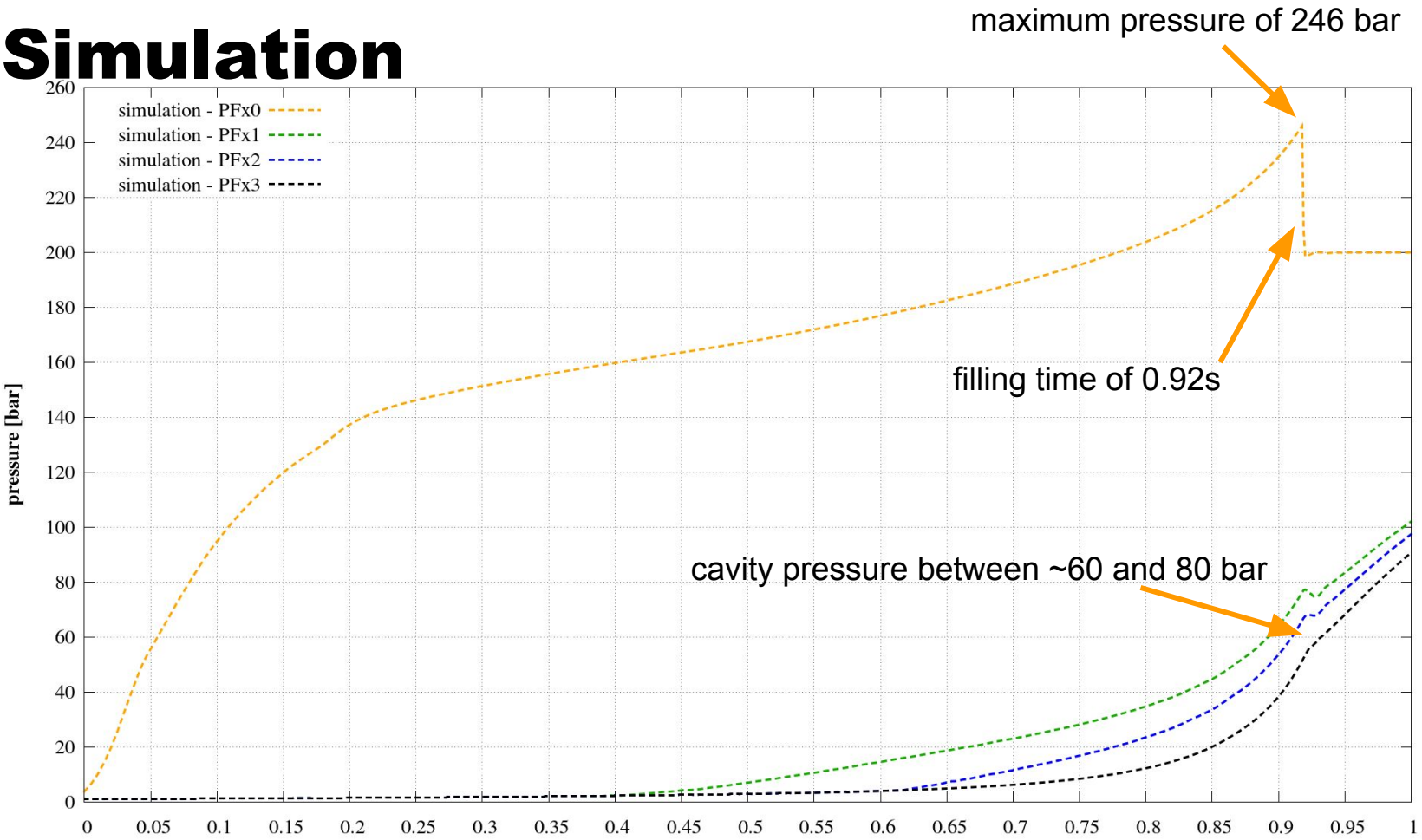
Pressure sensors



Process set up

- Definition of important parameters
- Filling time - safety (switch over from velocity to pressure)
- Pressure - safety
  - maximum
  - cavity
- Packing time - energy consumption
- New development tool
  - installation of 14 pressure sensors
  - perfect opportunity to apply the simulation

Simulation



	p_{switch} [bar]	$\triangle p_{switch}$ [%]	p_{cav} [bar]	$\triangle p_{cav}$ [%]	t_{switch} [s]	$\triangle t_{switch}$ [%]
exp.		-		-		
sim.	246		60-80		0.92	

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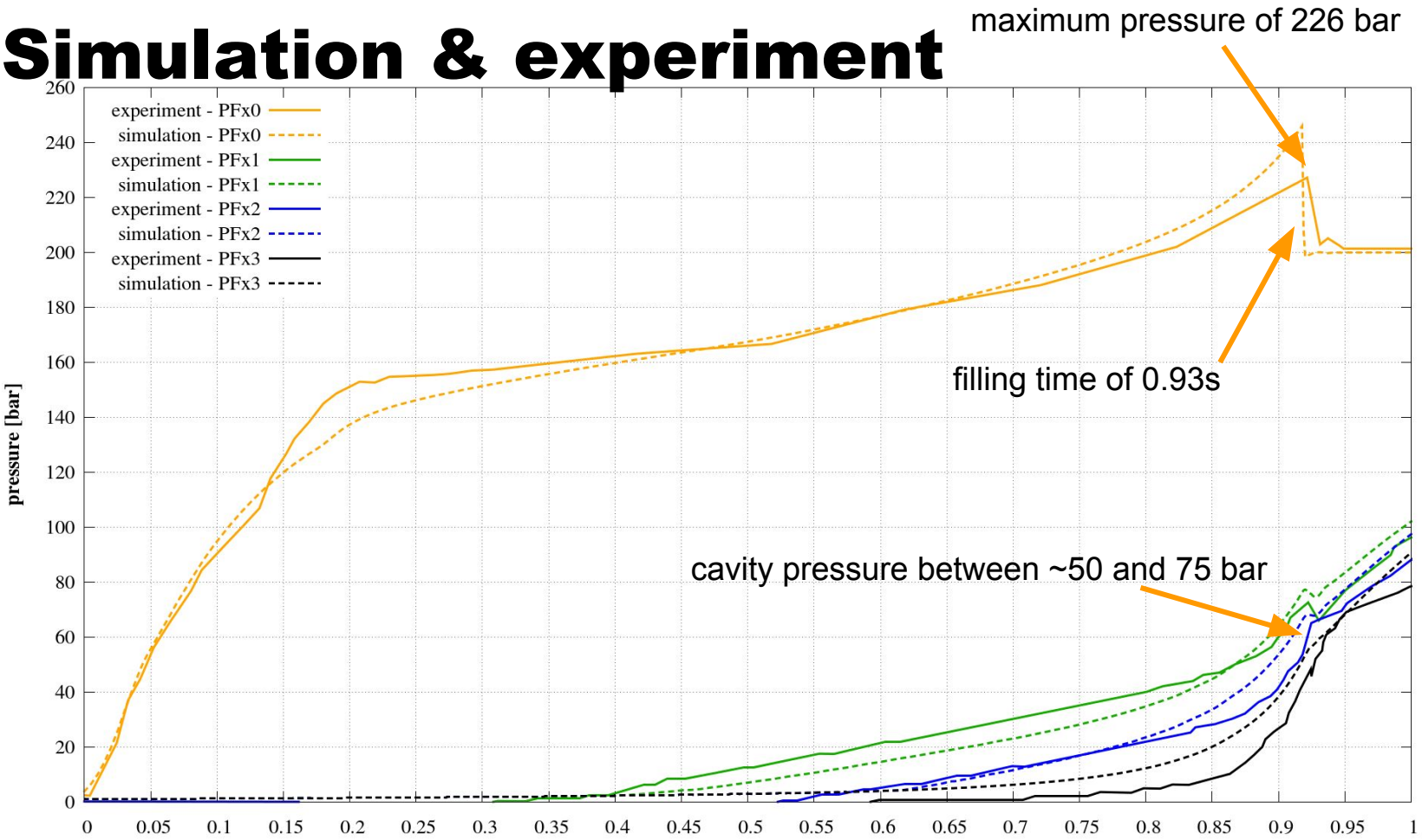
Simulation & experiment



	p_{switch} [bar]	$\triangle p_{switch}$ [%]	p_{cav} [bar]	$\triangle p_{cav}$ [%]	t_{switch} [s]	$\triangle t_{switch}$ [%]
exp.	226	-	50-75	-	0.93	-
sim.	246	< 9	60-80	< 5	0.92	-1.1

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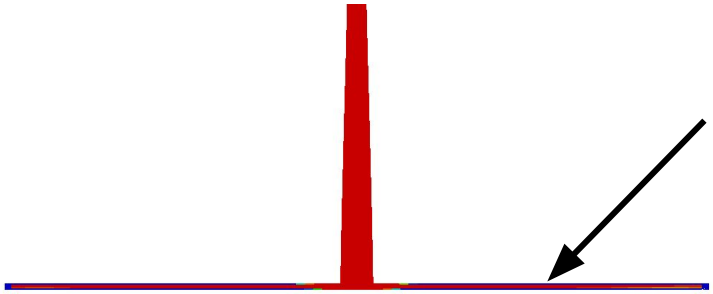
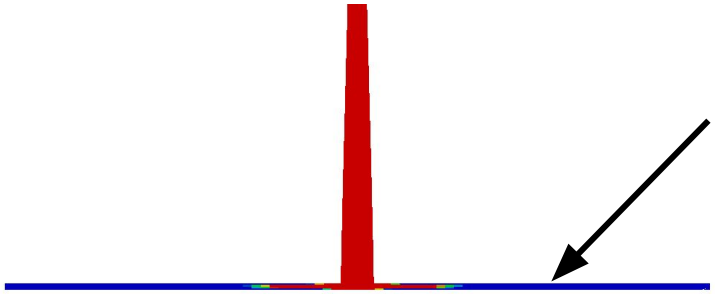
Packing phase - freezing time



t = 7s



t = 8s

	t_{freeze} [s]
experiment	~7-8
simulation	7.35

Conclusion

- Simulation of injection molding process
- Good agreement (<5-10%)
- Set up of process possible
- Run time between 30s and 6h
- Runtime here ~2.5 min
- Experimental process set up ~0.5-1h
- Simulation in OpenFOAM is a good alternative
- Next steps:
  - Further analysis of different (curved) geometries
  - Further analysis of different materials (PE, PA, PC etc.)
  - Shrinkage

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