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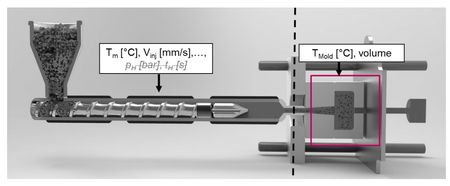
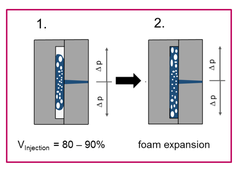
Controlling cellular structure and surface quality in foam injection molding – innovative core-back mold for research

M. Tromm, H.-P. Heim

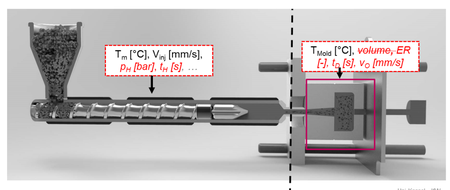
Introduction – FIM procedures

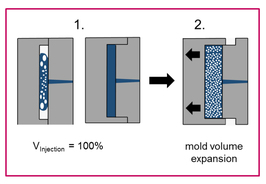
Conventional / low-pressure procedure



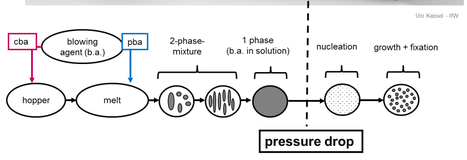


Core-back (high pressure foam injection molding)

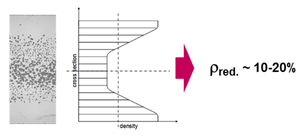


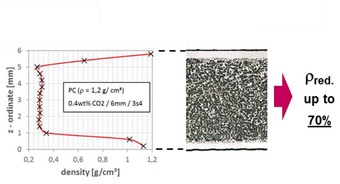


Actively initiated 2nd pressure drop
➔ Influence on nucleation rate

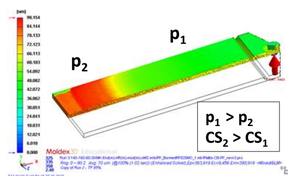


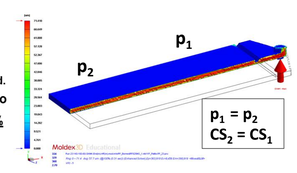
Density distribution





Cellsize (CS) [t = End of Cooling]

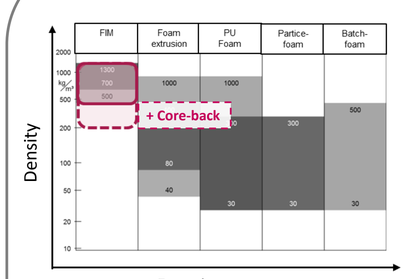


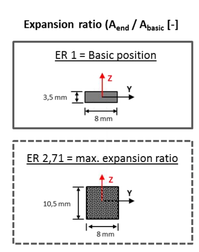


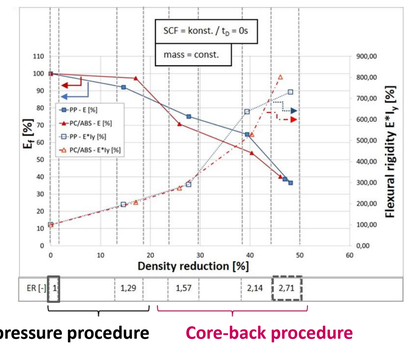
Advances of Core-back

- More uniform, flow path independent cell structure
  → cell formation induced by active pressure drop – every position at same time
- Much higher density reduction possible
- Active influence on structure by additional process parameters

Potential of core-back technology







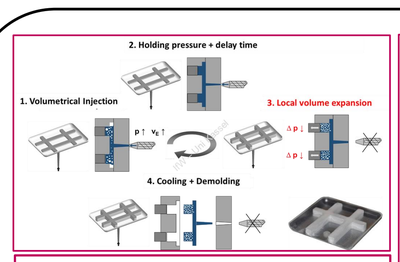
Conventional / low-pressure procedure | Core-back procedure

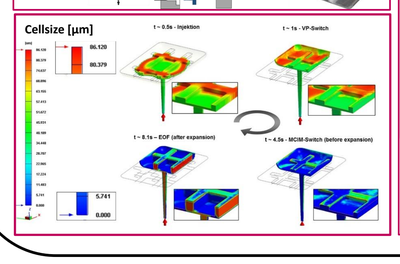
- Potential 1: Density reduction / material / weight savings - same part design
- Potential 2: „Sandwich effect“ – geometry variation at same part weight
  → E-Modulus decreases by increasing density reduction
  → Area moment of inertia increases ➔ Flexural rigidity increases

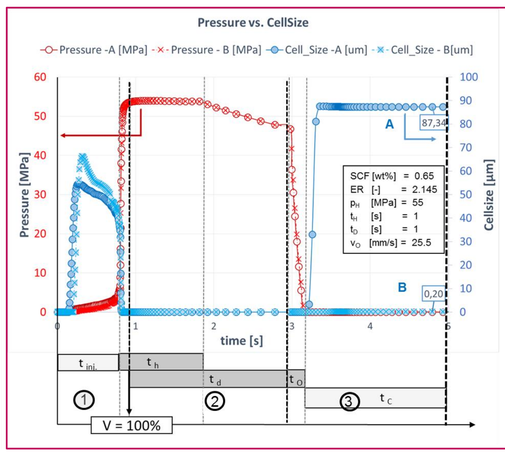
Objectives – new mold

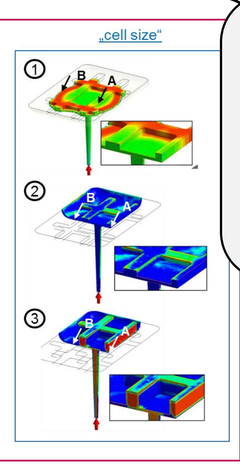
- Several core-back molds at institute → different restrictions
- New mold should…
  → enable precise control of core-back speed
  → enable precise control and adjustment of core-position
  → allow definition of movement-profiles (compression + core-back)
  → allow moving core by time or pressure
  → allow sufficient variation of packing pressure
  → allow variotherm mold temperature control
  → be independent of machine control options

Process variant – Local core-back







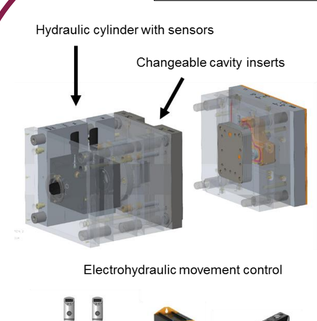


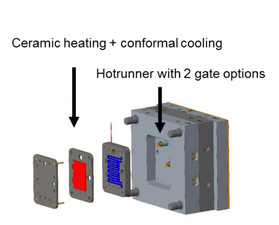
Local Core-back procedure

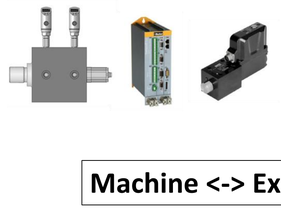
- Create locally different foam structures → Tailoring mechanical properties
- Possibility to create foamed structures while adjacent areas remain compact

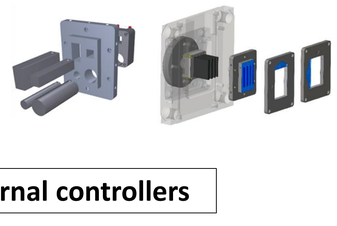
New local core-back mold

Concept / Key features

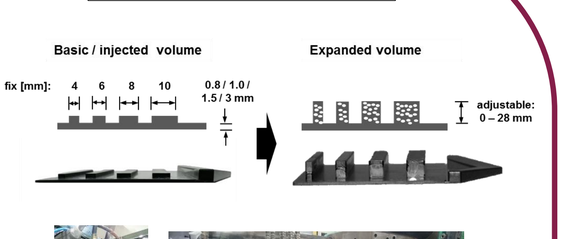


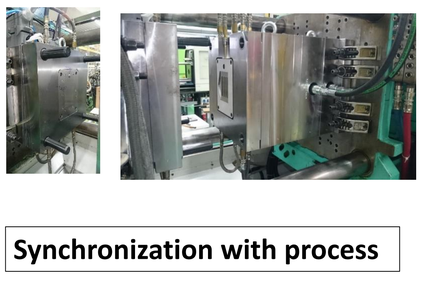




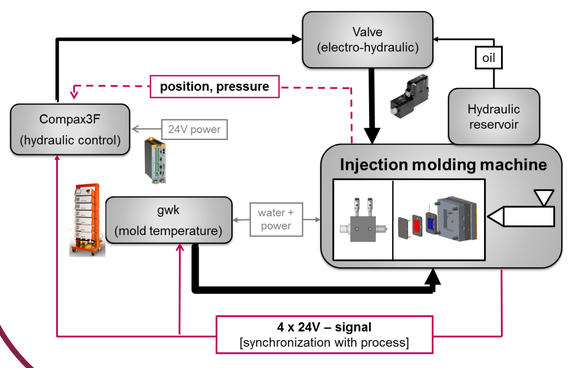


First geometry / insert

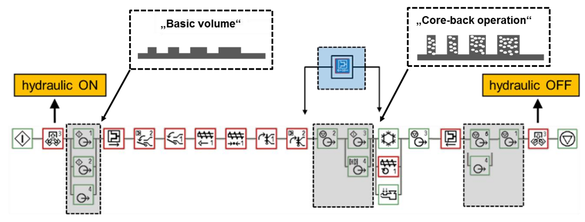




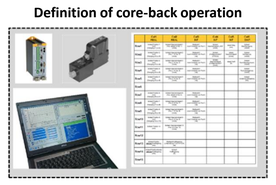
Machine <-> External controllers



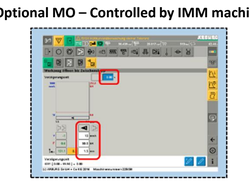
Synchronization with process



Definition of core-back operation

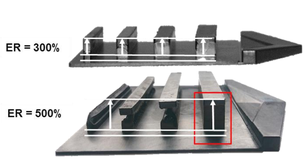


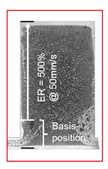
Optional MO – Controlled by IMM machine

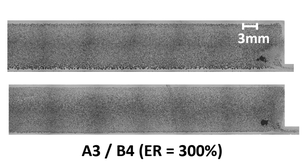


Results

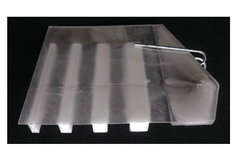
Expansion ratio (ER)



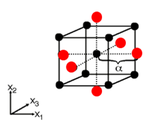




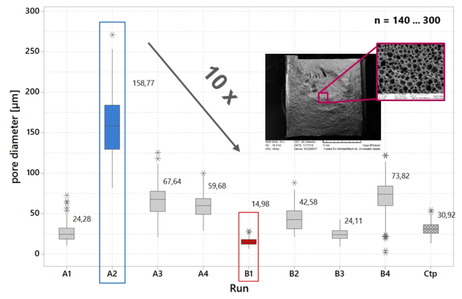
A3 / B4 (ER = 300%)

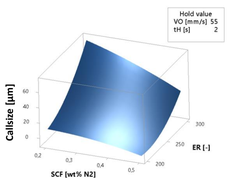


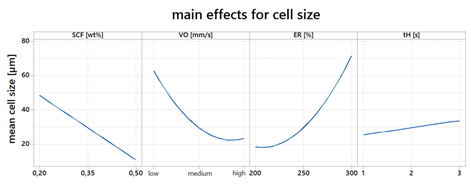
DOE - Cellular structure



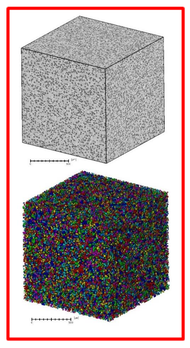
	min	max
SCF [wt%]	0,2	0,5
v_O [mm/s]	10	100
ER [%]	200	300
t_H [s]	1	3



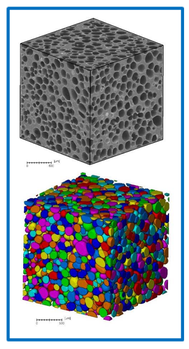




B1



A2

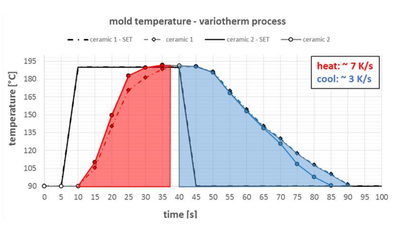


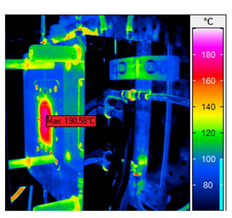
	B1	A2
Cellsize [µm]	21,20	159,80
Celldensity [1/cm³]	54.450.211	555.556

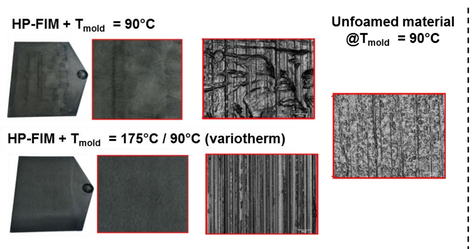
10 x

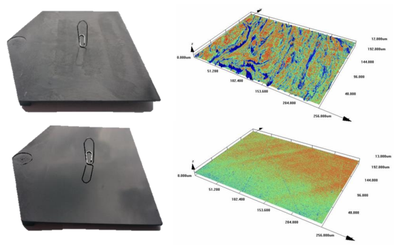
Regression model: „Cellsize“ = 'SCF [wt% N2]' 'VO [mm/s]' 'ER [-]' 'tH [s]' 'SCF [wt% N2]'*'SCF [wt% N2]' 'VO [mm/s]'*'VO [mm/s]' 'ER [-]'*'ER [-]' 'tH [s]'*'tH [s]' 'SCF [wt% N2]'*'VO [mm/s]' 'SCF [wt% N2]'*'ER [-]' 'SCF [wt% N2]'*'tH [s]'

Surface quality









Precision-grind cavity surface | Mirror-finished cavity surface

Simulation of boundary conditions

Core-back speed

Δp
→ Cellsize
→ Celldensity

Conclusion / Outlook

Procedure
→ Extends lightweight potential of foam injection molding
→ Foam injection molding accessible for complex geometries
→ Controlled foaming process: homogeneous cell structures
→ Possibility to restrict foam formation locally

Mold
→ Powerful mold for investigations – many possibilities
→ Precise variation of core-back parameter
→ High surface quality (promoted by packing pressure)
→ For application: simple core movement via machine

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