Moldex3D

Procomp project: thermoplastic composites technology
Società: Proplast
Speaker: Andrea Romeo - Head of Engineering Dept

MOLDING INNOVATION

2016 Users' Meeting Italia

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Procomp: Thermoplastic composite technology

One-step processing

Highly structural components

Design freedom of injection moulded features

Termoplastic/ continuous fiber composite

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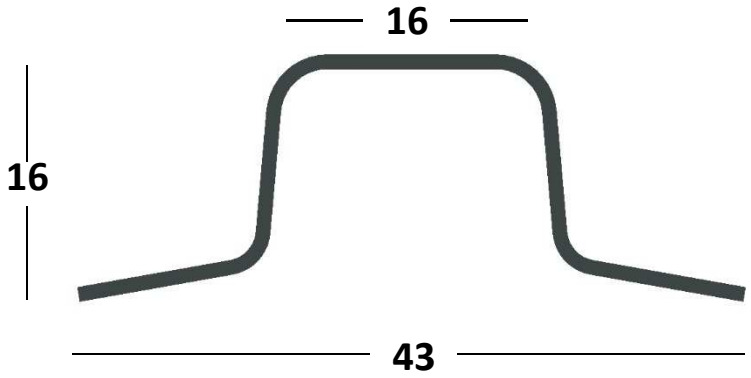
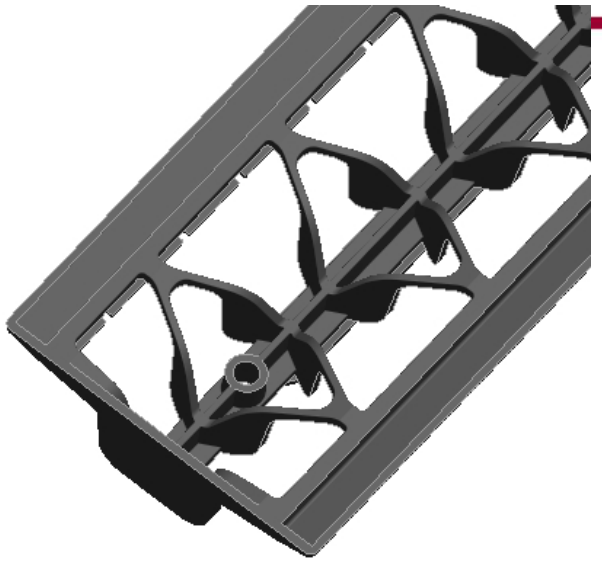
Procomp: Thermoplastic composite technology





Omega-shaped composite bone by in-mould thermoforming

Ribs / bosses / snaps

Thermoplastic laminate (PP/continuous glass fibers)

Overmoulding of thermoplastic PP+30% gf

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Equipment

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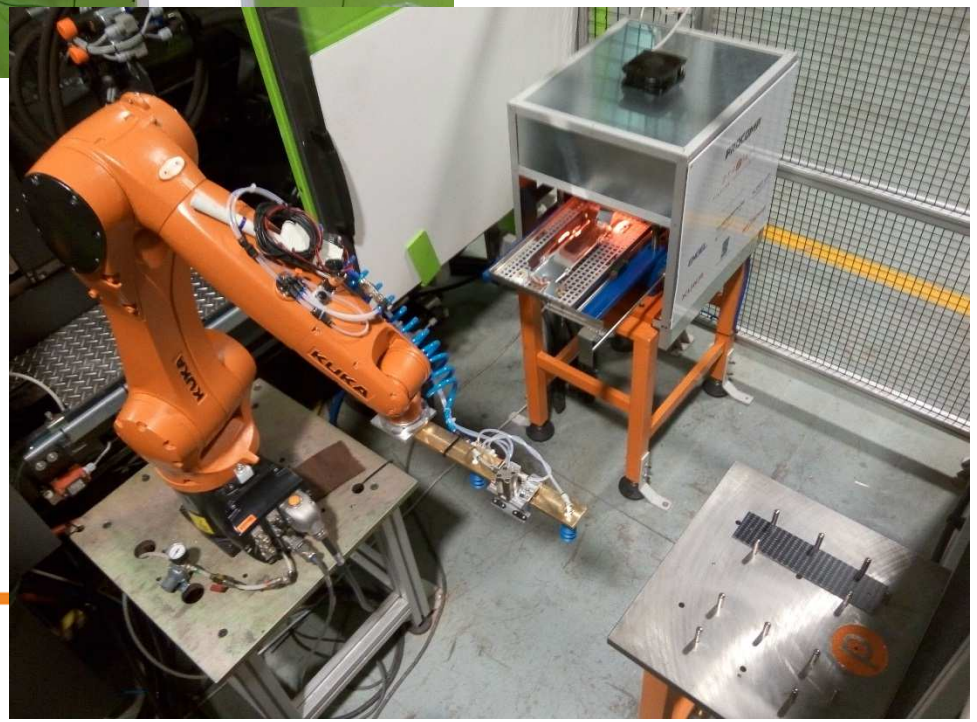
ENGEL

KUKA



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Process steps

Laminate heating
By IR-lamp oven
Glass fiber Twill 50/50 fabric
PP matrix
Thickness = 1 mm

$T_{laminate}$ after heating = 170-180°C

Laminate transfer
Pick-up from oven
Fast movement
Extraction of previous part from mould
Placing pre-heated laminate

Process steps

Mould closing/laminate thermoforming
One-step forming
By mould clamping (cavity/core)

Thermoplastic injection overmoulding
PP+30% gf (Borealis GD301FE black)

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Mold features

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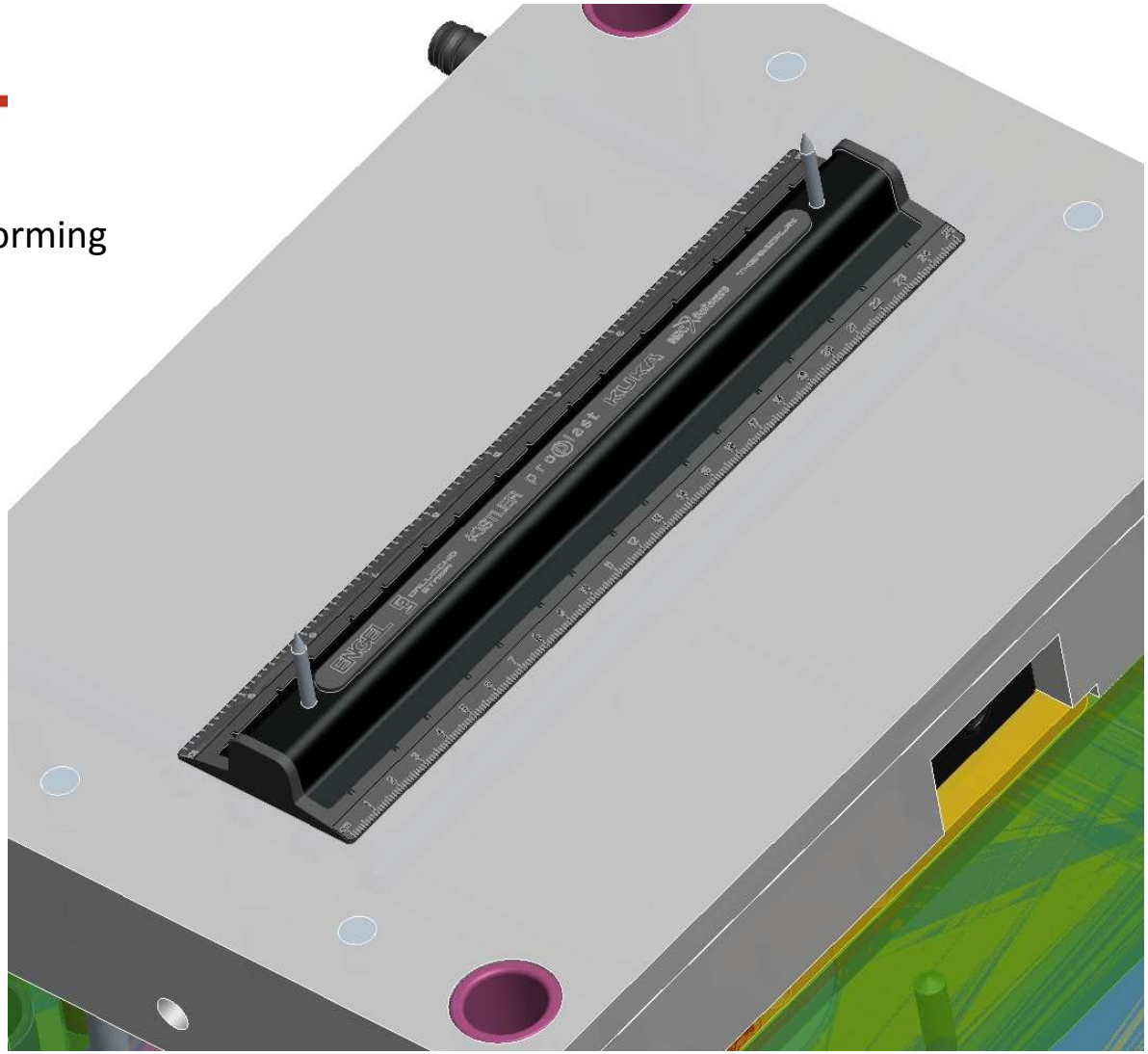
Laminate retaining system
To hold the laminate for thermoforming
By means of pins



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Mold features

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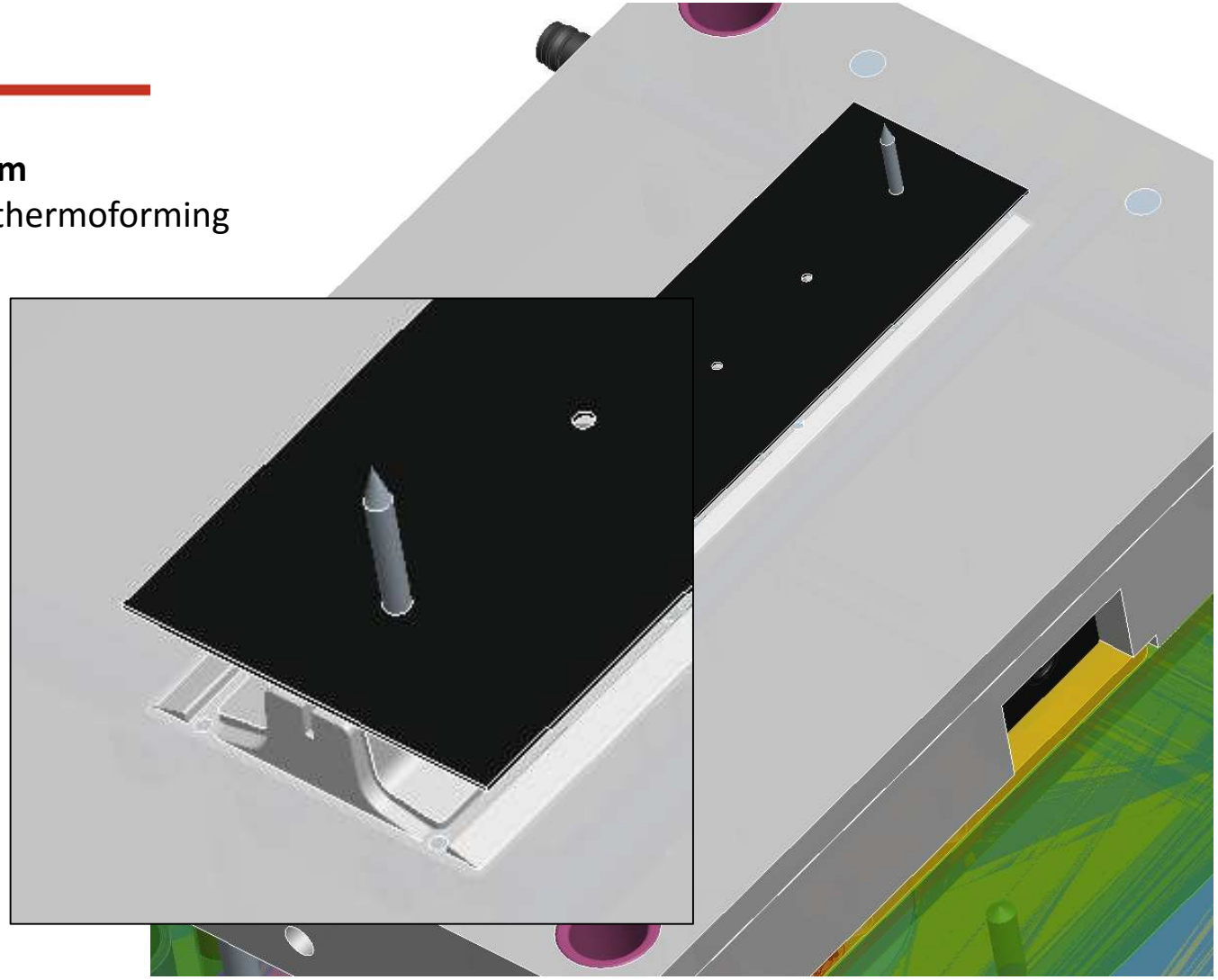
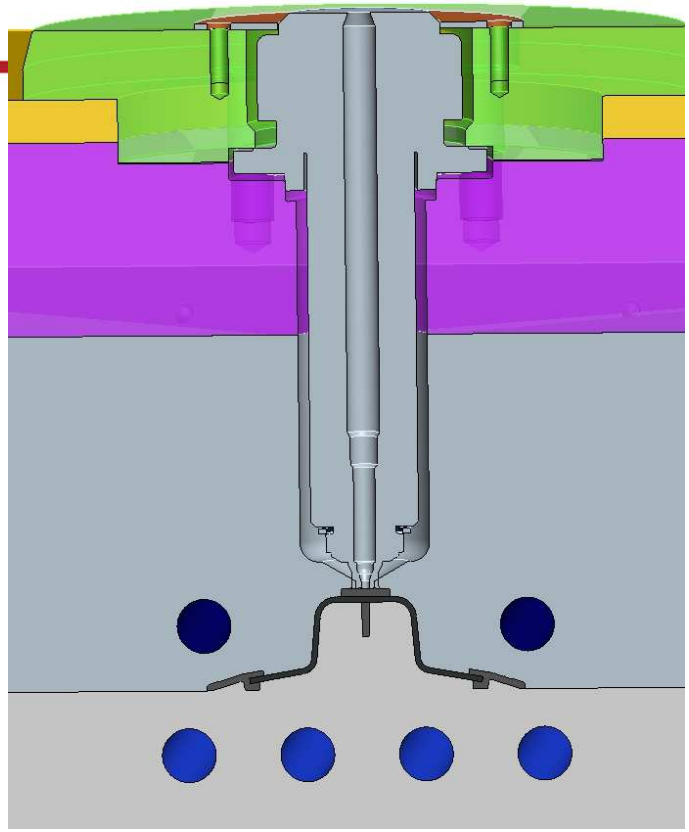
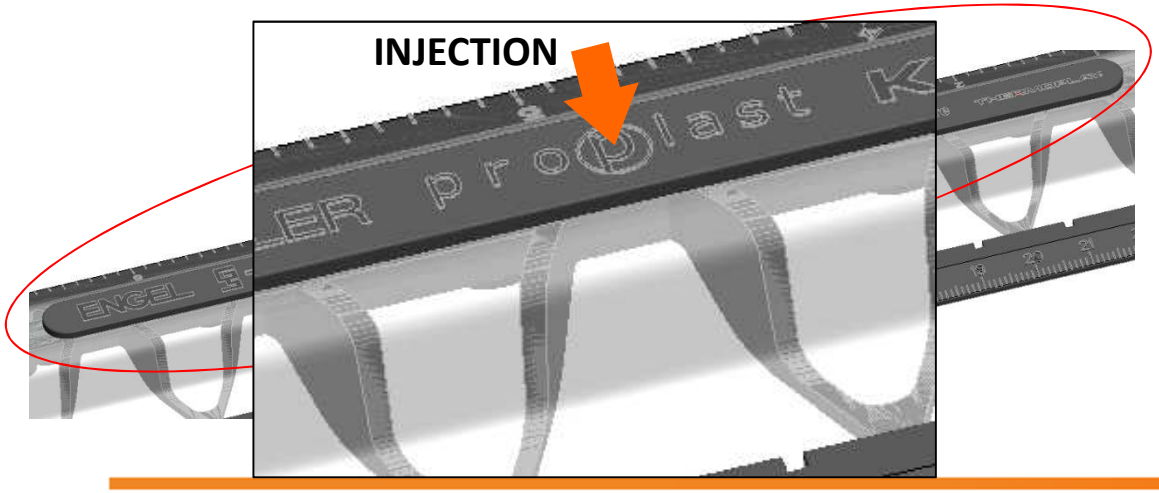


Mold features

Injection system
Hot runner injection system
Thermoplay FNH624076



Injection directly on part
On longitudinal flow leader (supporting partners' LOGOS)
4 holes for flow transfer to inner side



Mold features

Injection system
Hot runner injection system
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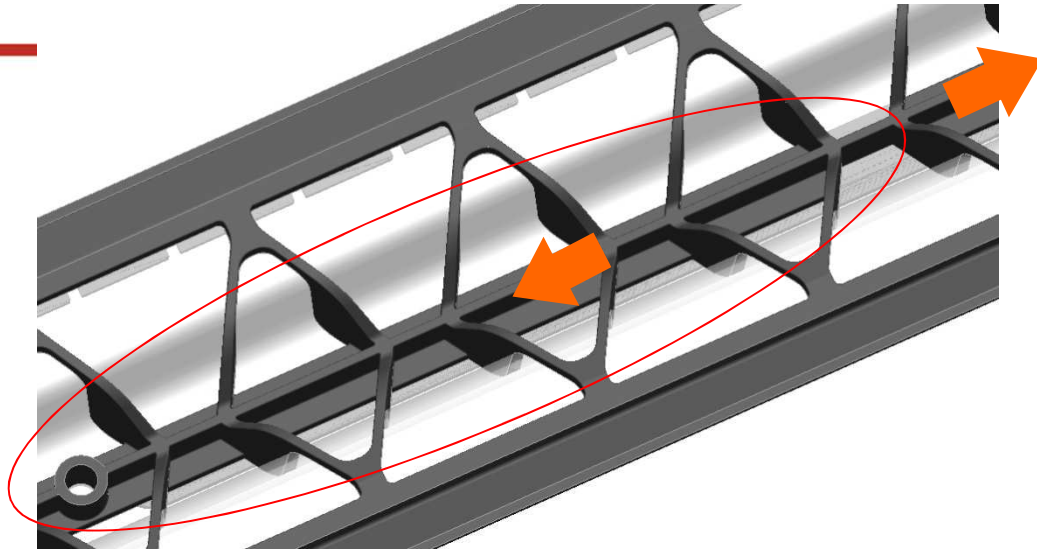
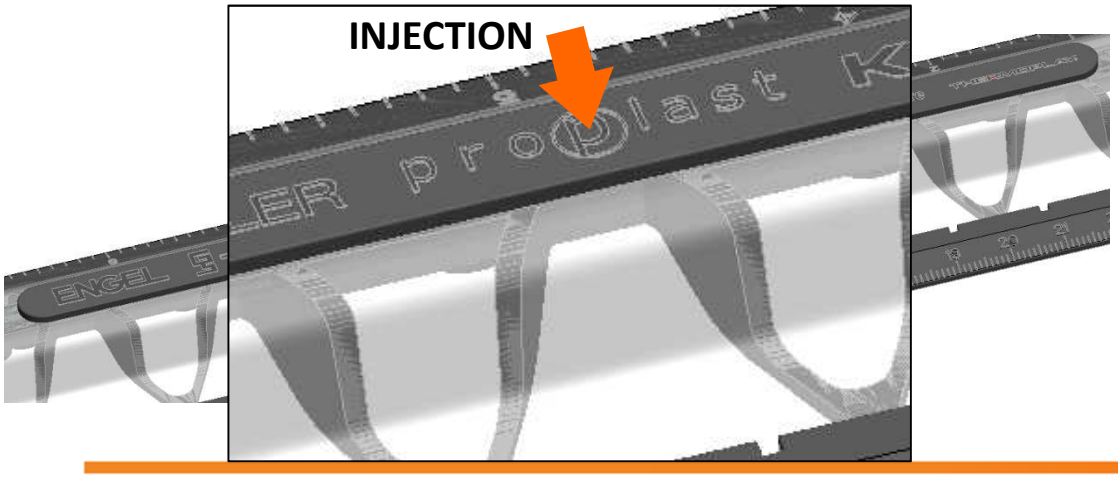


Internal flow leader to distribute material to periphery and fill ribs



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Mold features

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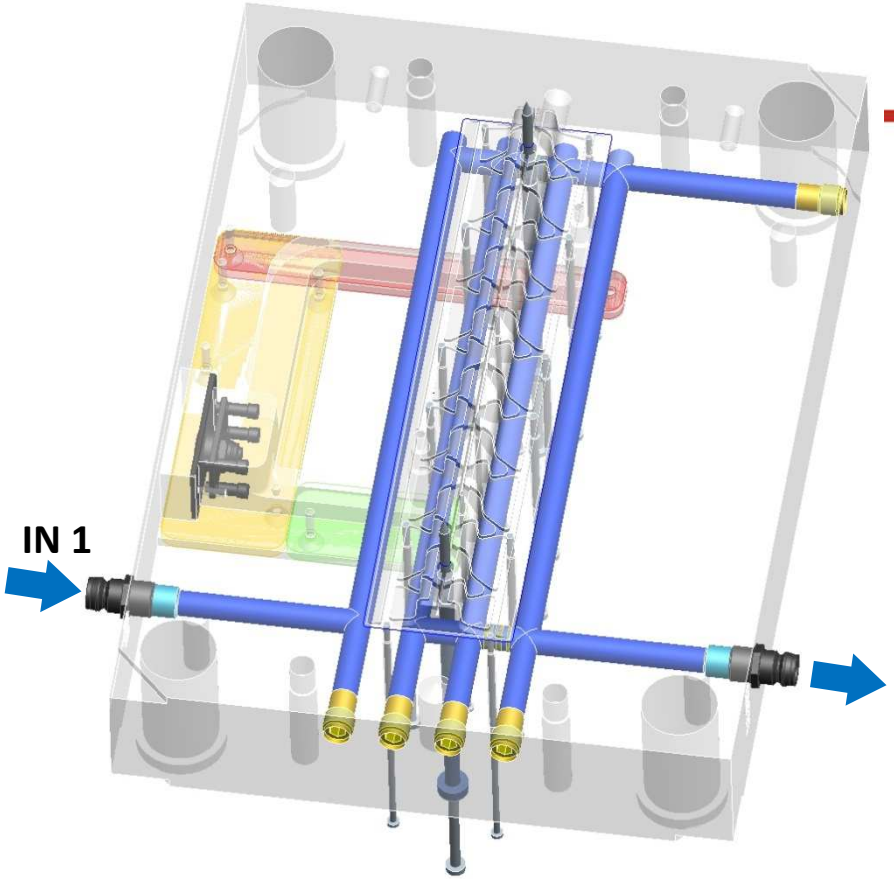
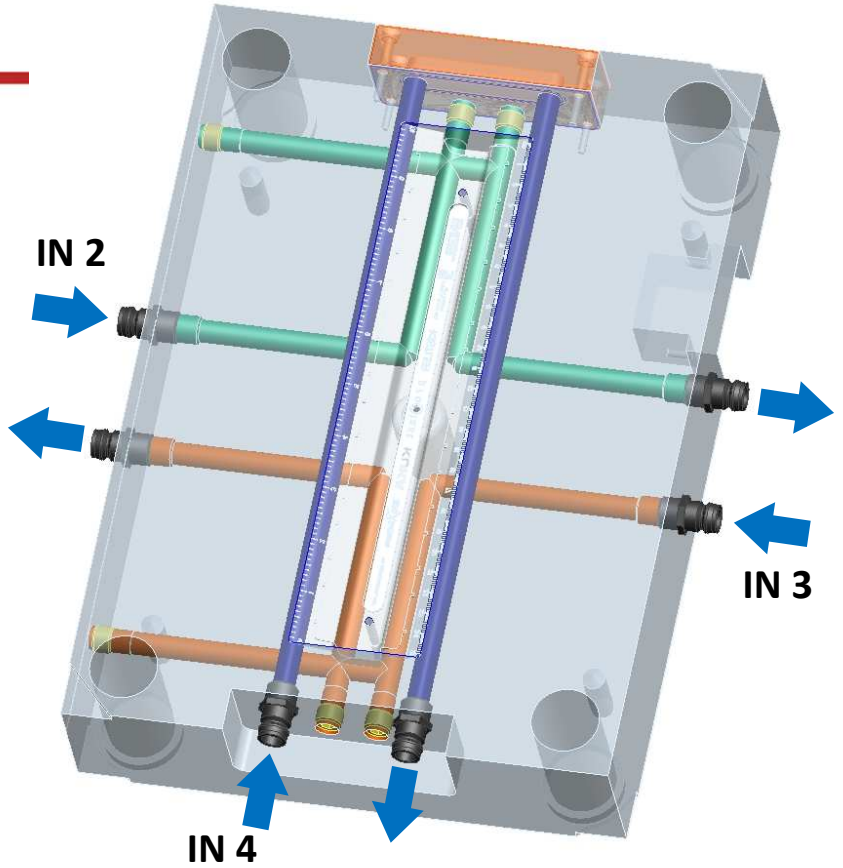
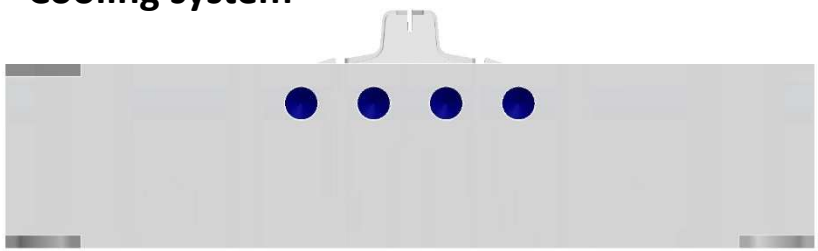
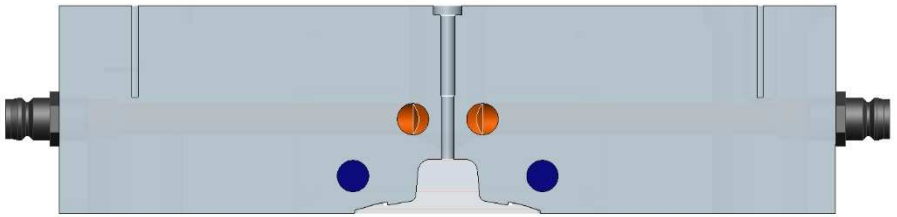




Cooling system





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Material choices

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Materials

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ORGANOSHEETS

- PP+GF 50/50 (Twill fabric)

  TEPEX® dynalite 104-RG600(2)/47%

  Thickness = 1 mm

BOND LAMINATES

- PP+FV 80/20 (Almost unidirectional)

  TEPEX® dynalite 104-RGUD600(2)/47%

  Thickness = 1 mm

BOND LAMINATES

OVEROULDING THERMOPLASTIC

- PP+30%FV

  Xmod™ GD301FE

BOREALIS

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Testing

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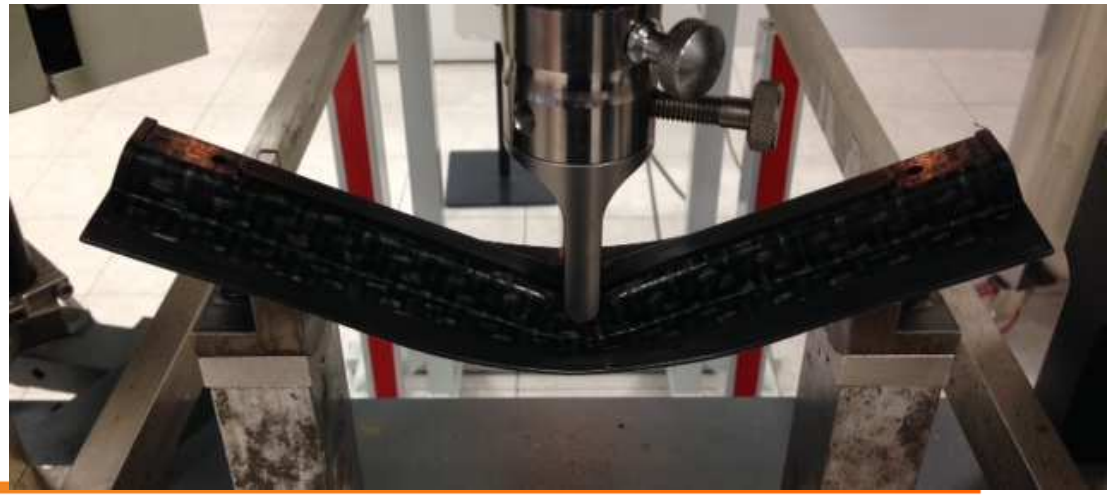

Flexural testing 3 (points bending)
Supports span: 150 mm
Testing speed: 2 mm/min

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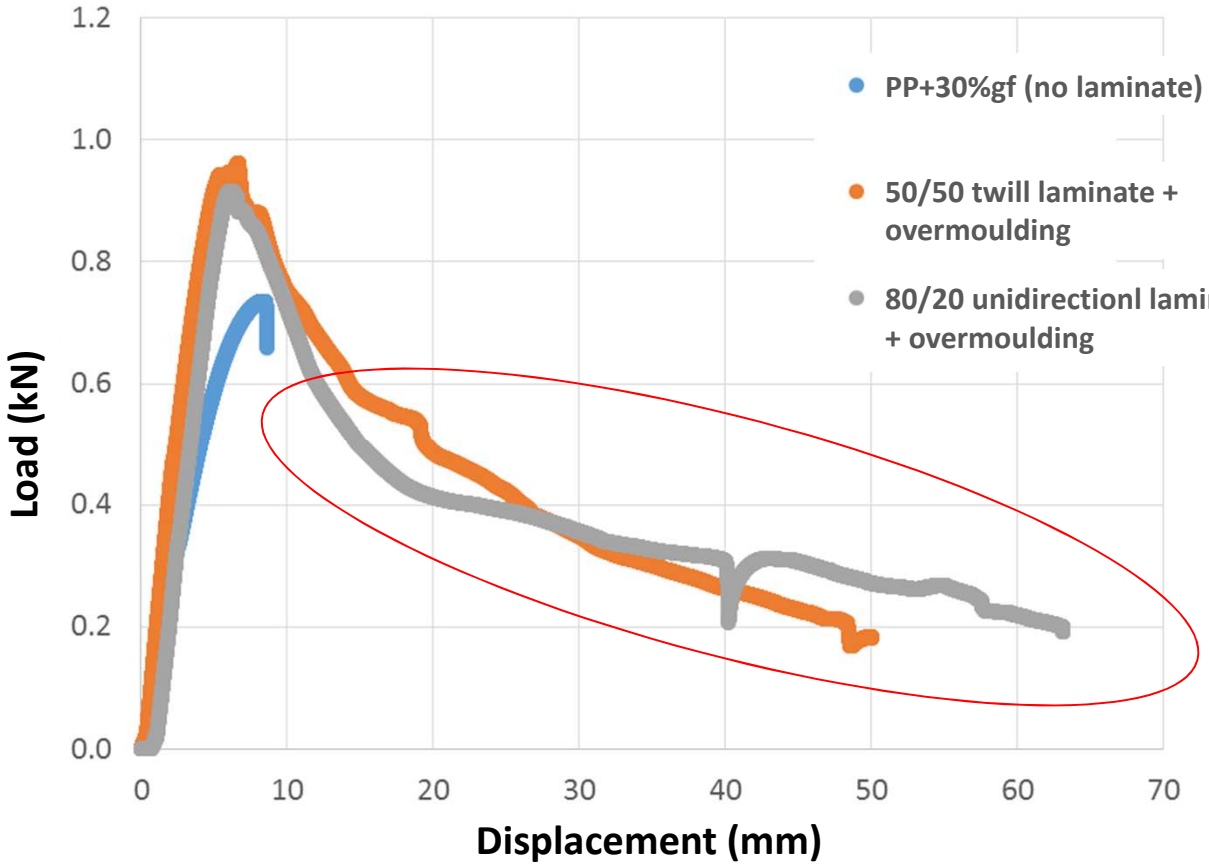
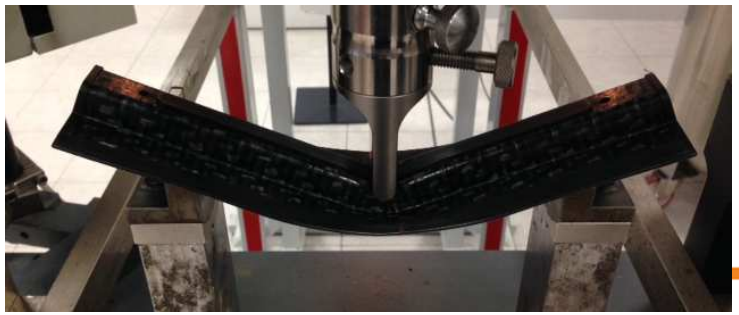
Response





Material	σ_{fM} kN	ε_{fM} mm
PP+30%gf (no laminate)	0.74	8.35
50/50 twill laminate + overmoulding	0.96	6.66
80/20 unidir laminate + overmoulding	0.92	6.06

Overmoulding simulations

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TP composite overmoulding simulation

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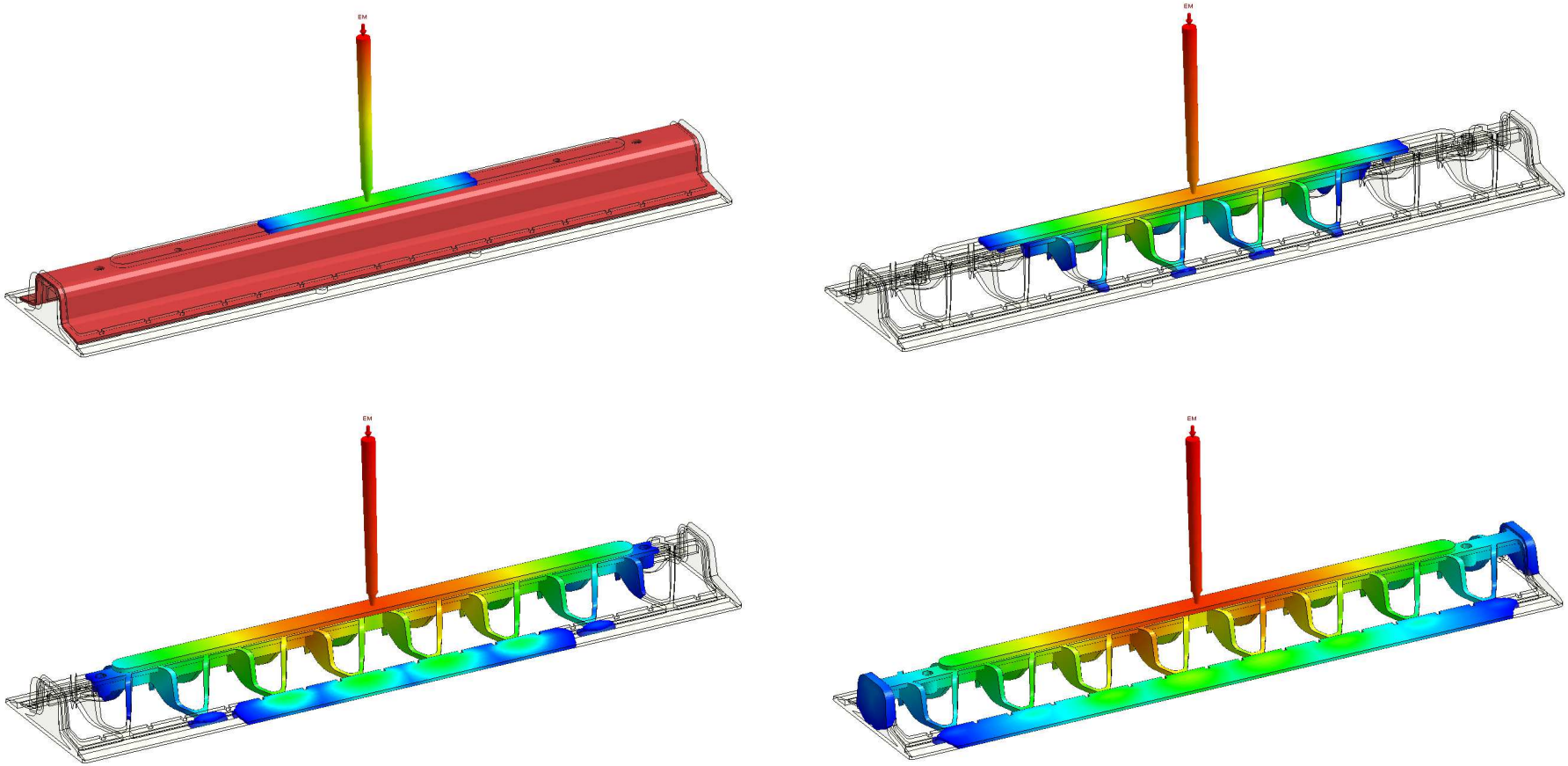
Filling pattern



Balanced filling

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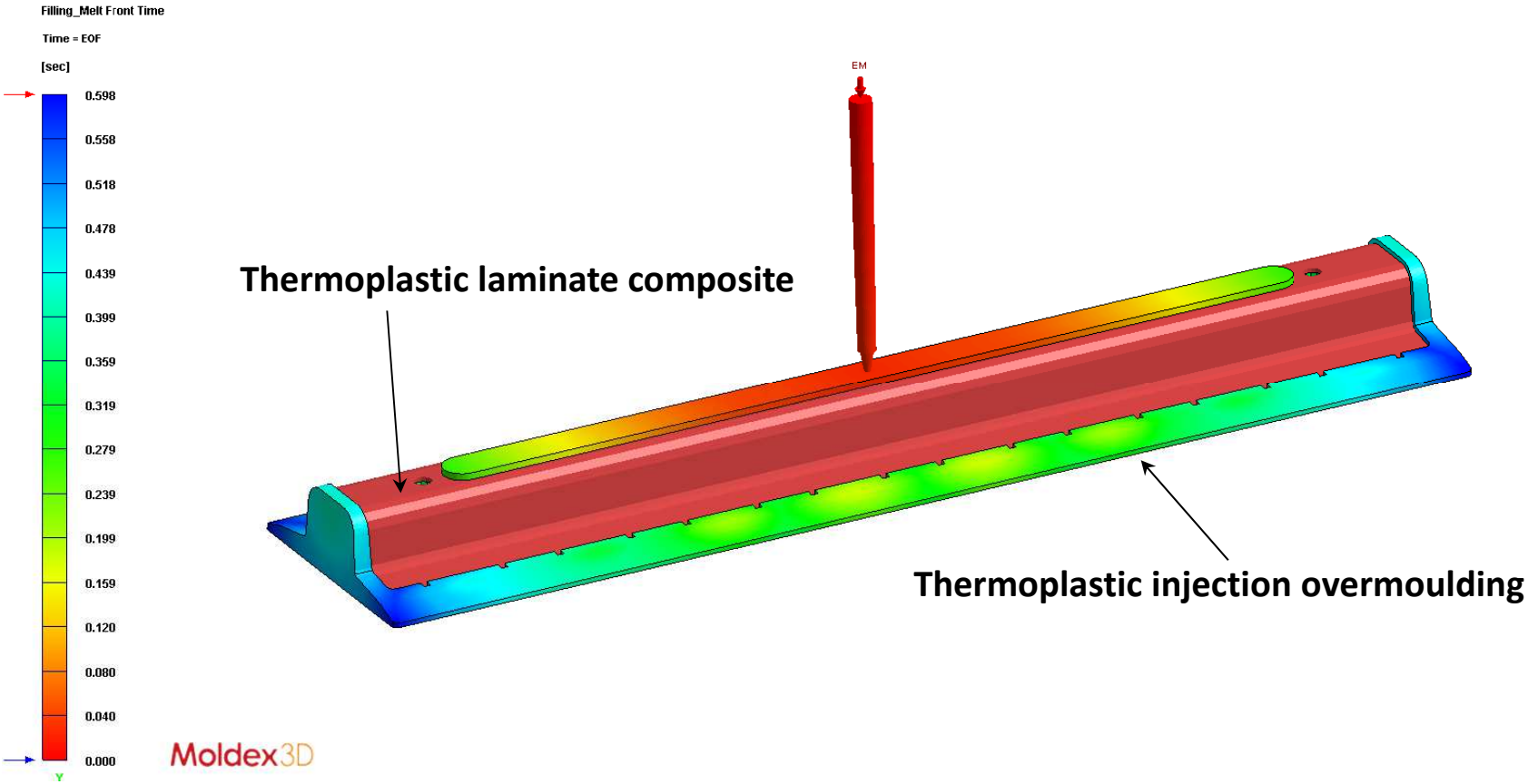
Complete filling



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TP composite overmoulding simulation

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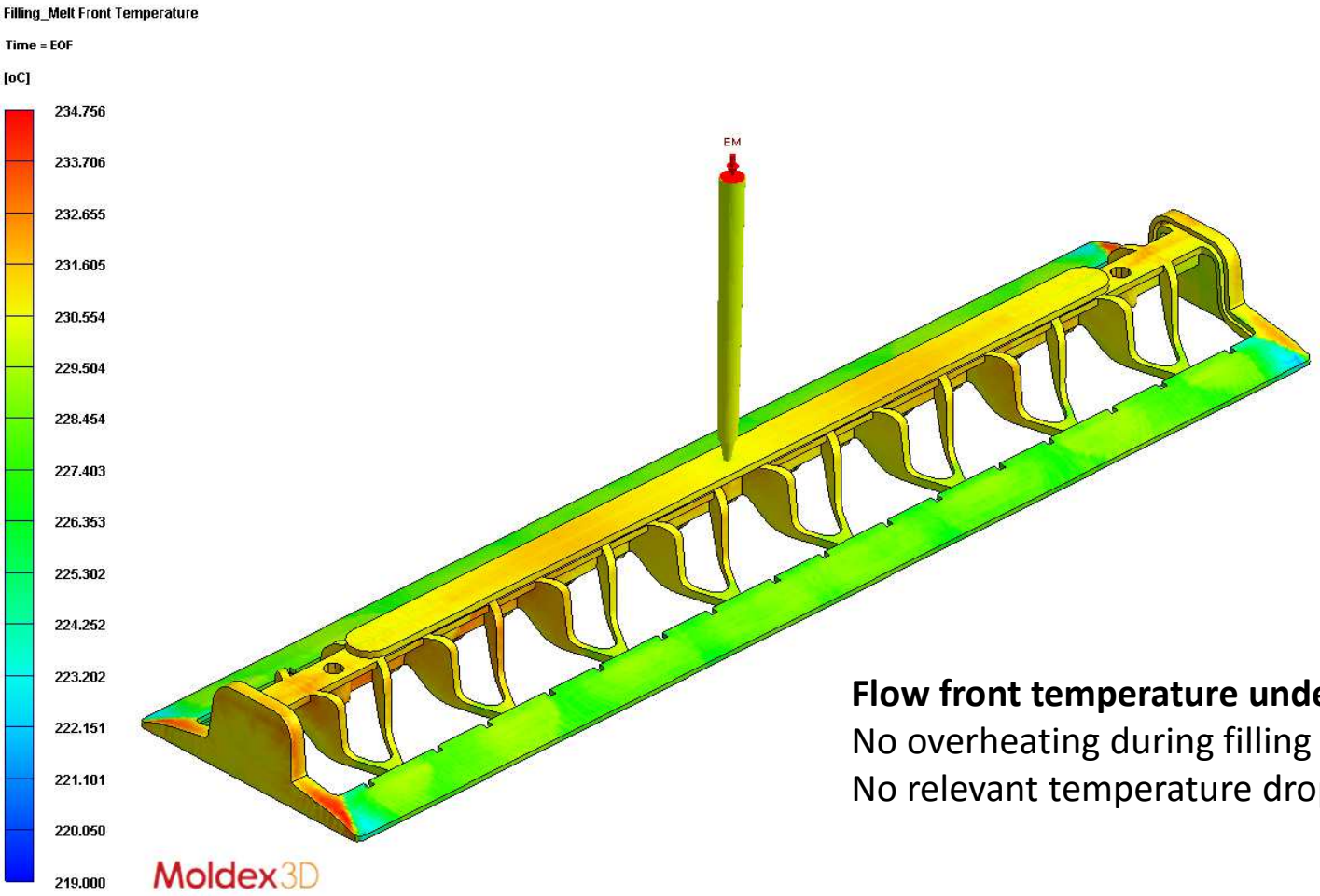
Temperature at flow front



Flow front temperature under control
No overheating during filling
No relevant temperature drop

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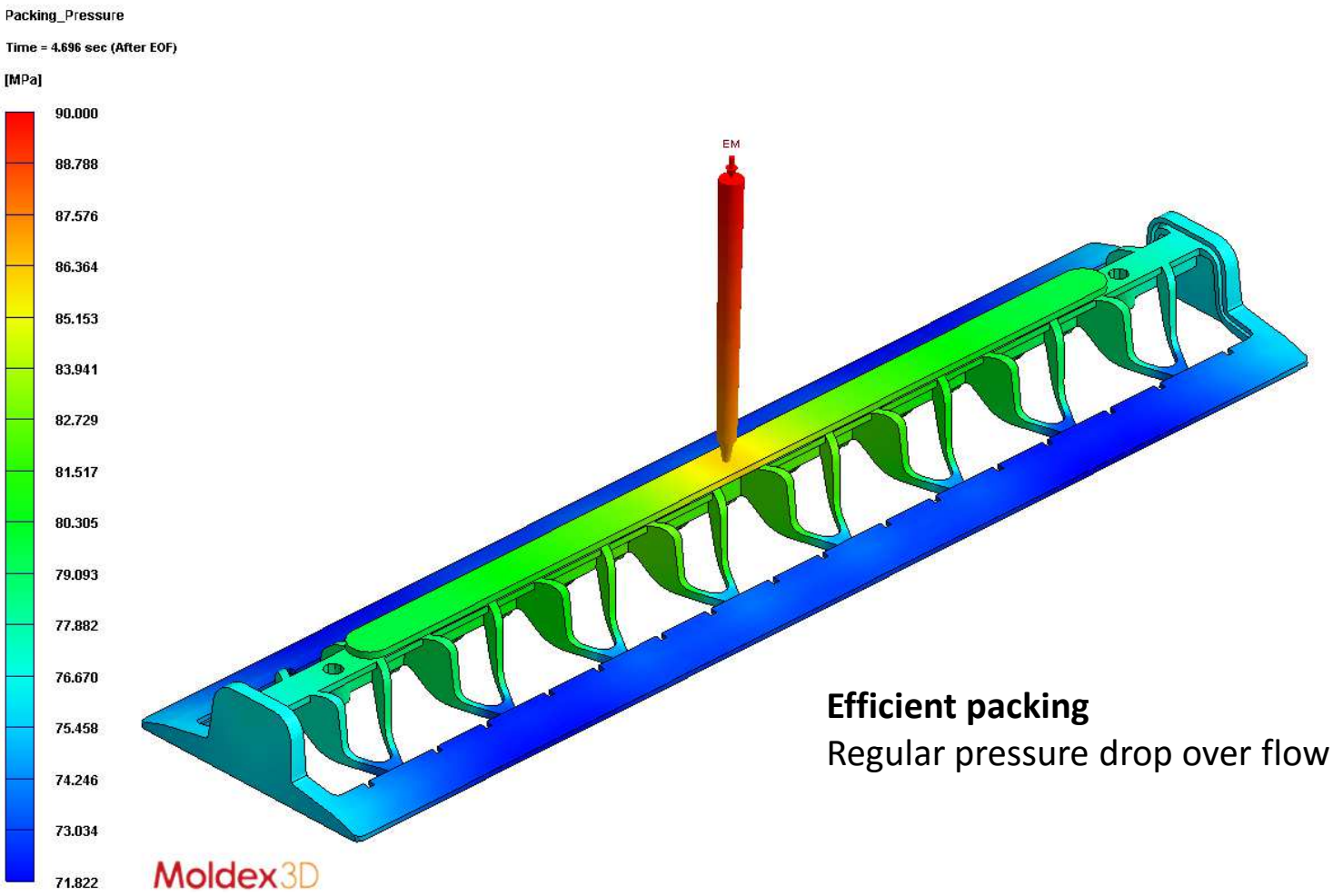
Packing phase



Efficient packing
Regular pressure drop over flow lenght

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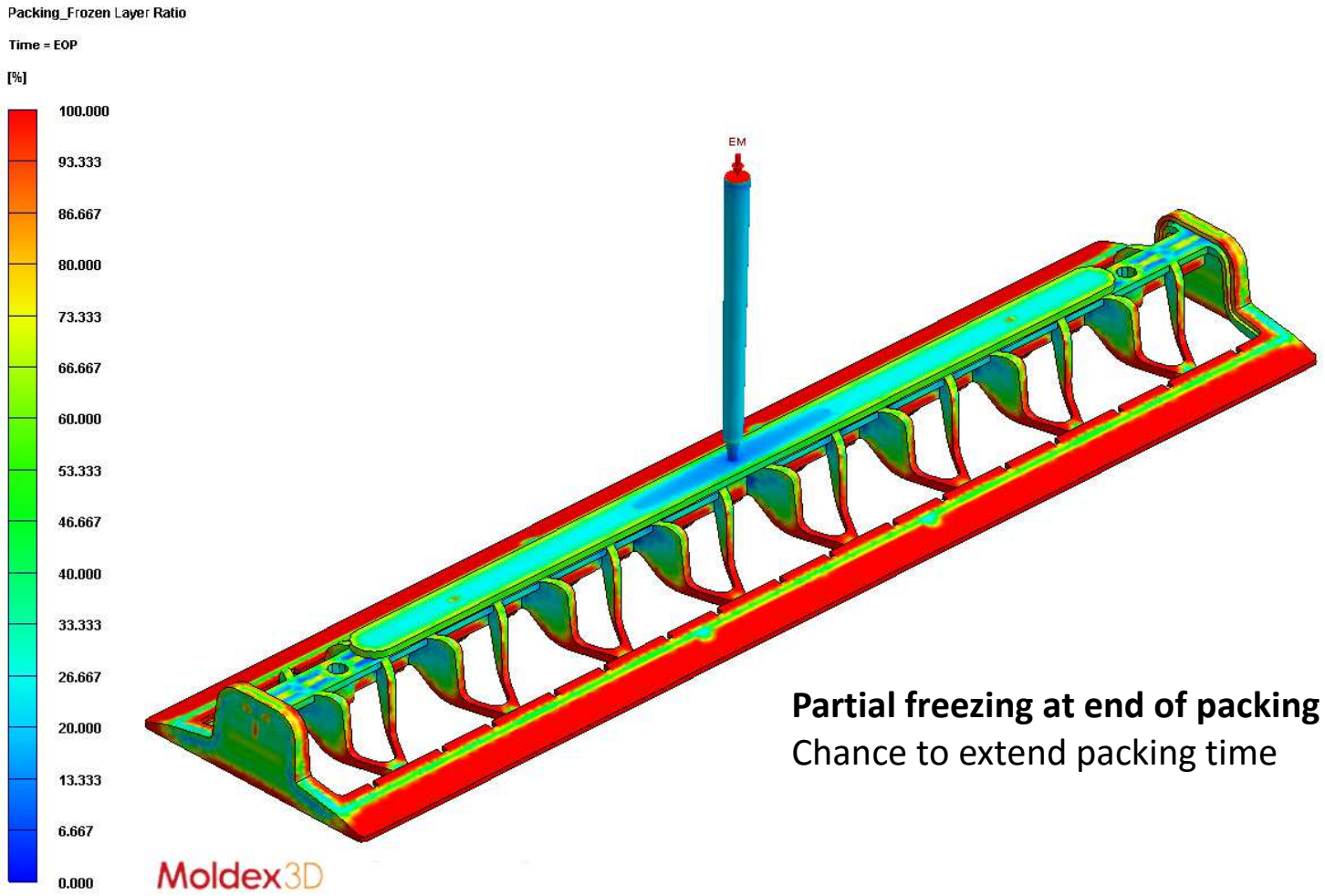
Frozen layer at end of packing



Partial freezing at end of packing
Chance to extend packing time

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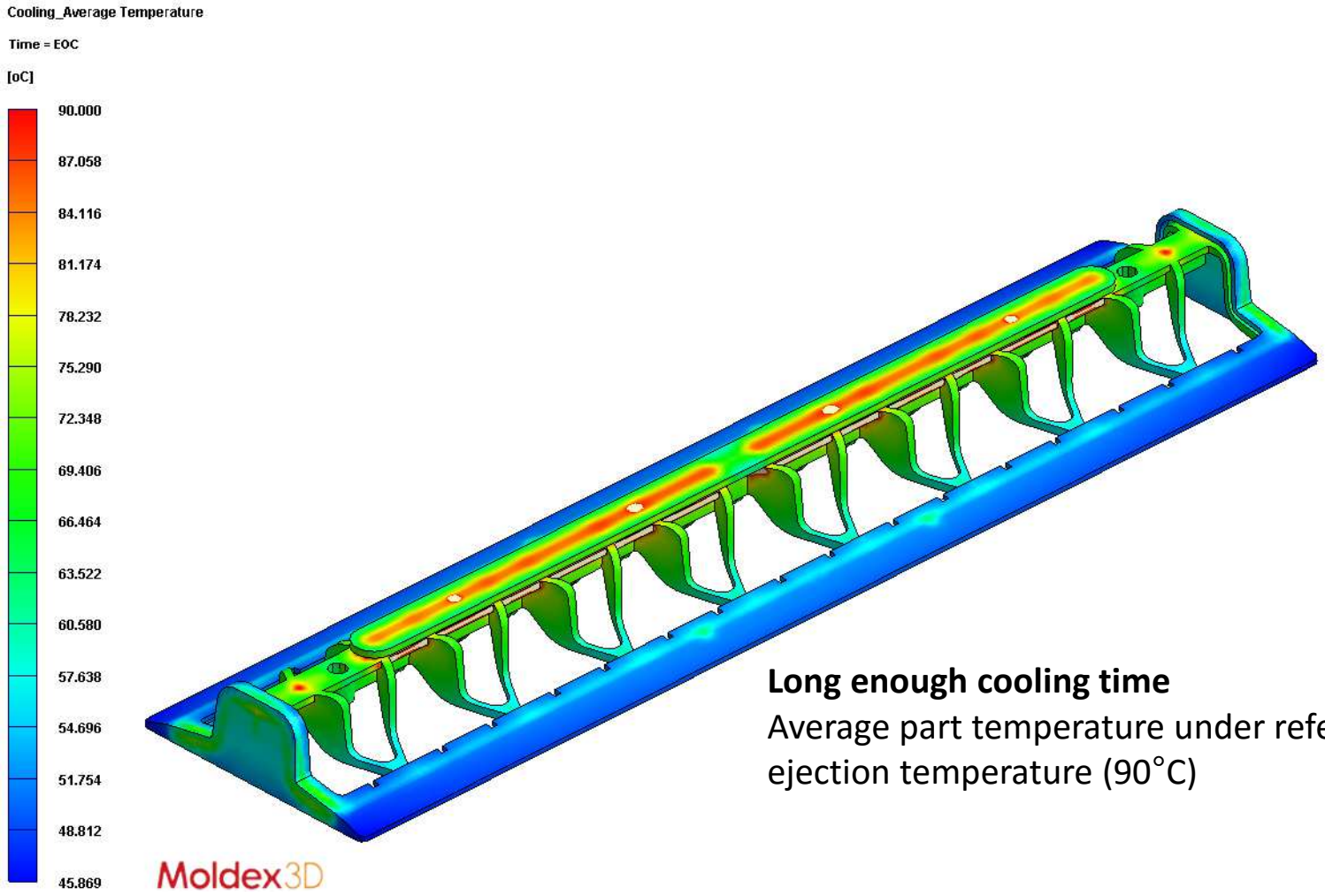
Temperature at end of cooling



Long enough cooling time
Average part temperature under reference ejection temperature (90°C)

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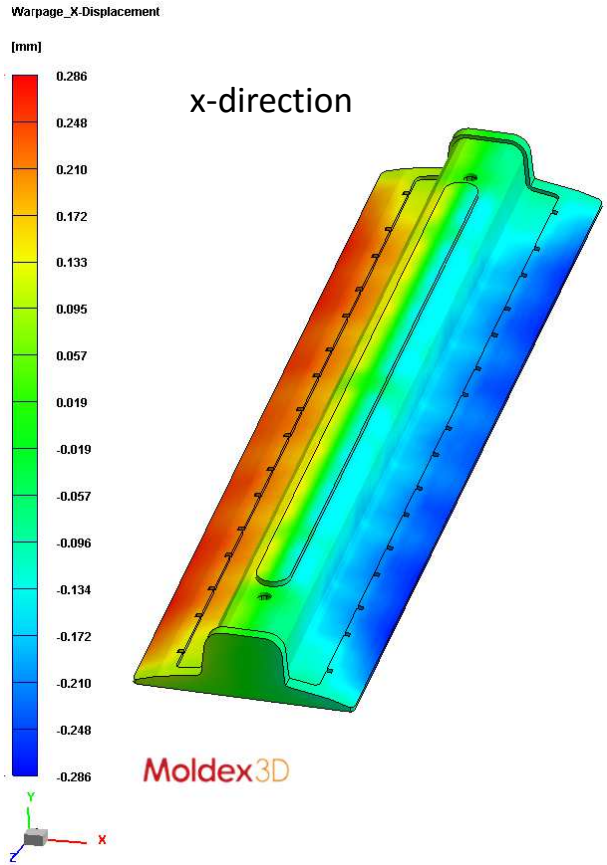
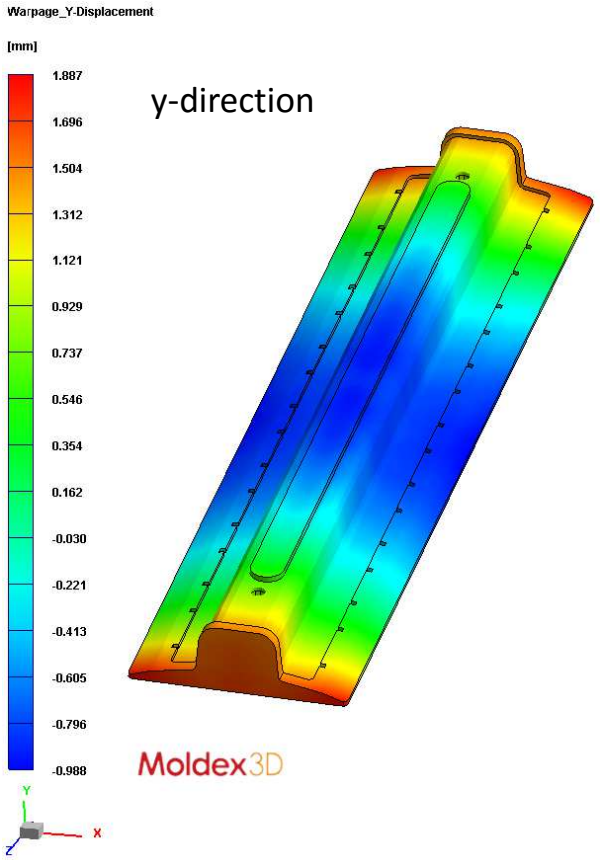
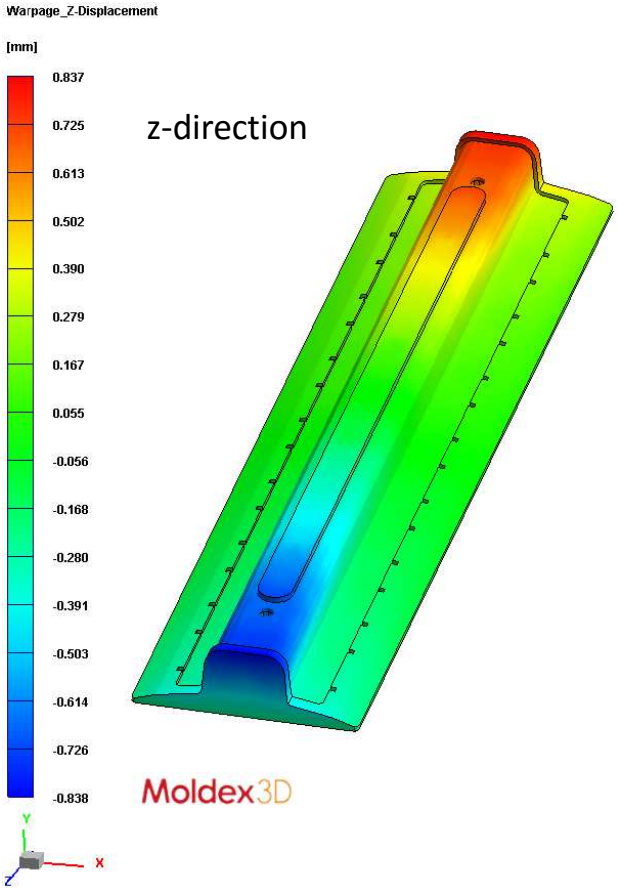
Warpage







Limited warpage in x directions.
Symmetrical deformation.
Relevant warpage in y and z direction

Mucell foaming injection moulding
(to reduce warpage)

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Mucell foaming injection moulding

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Key points

1. Reduced viscosity of molten thermoplastics

2. Microcellular structure of thermoplastic moulded parts

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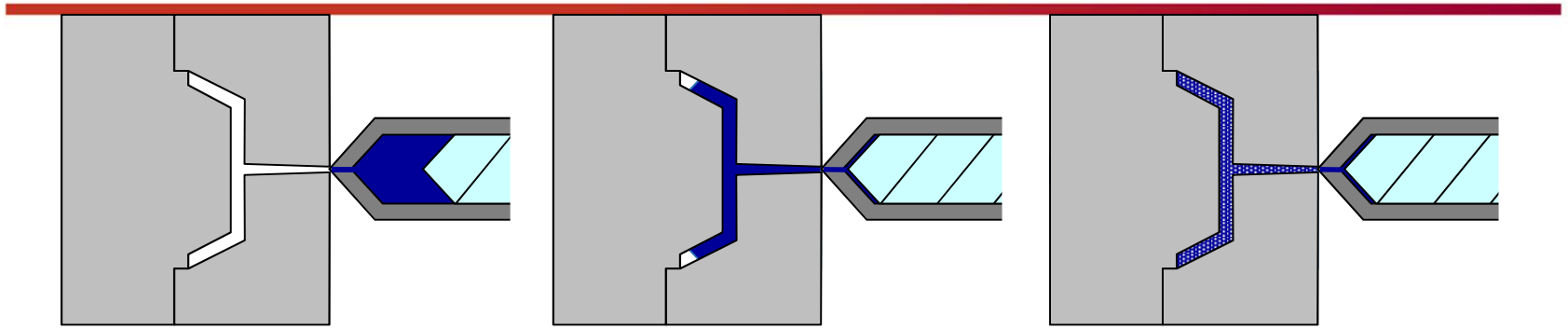
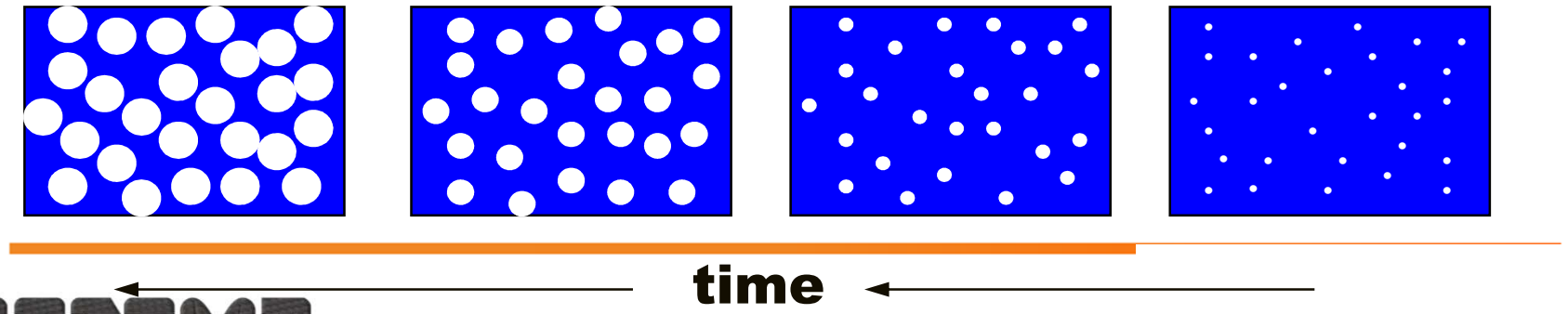
Mucell foaming injection moulding



Injection starts | Partial volumetric filling | In cavity gas expansion

3. Nucleation and growth of cells depends on pressure during injection

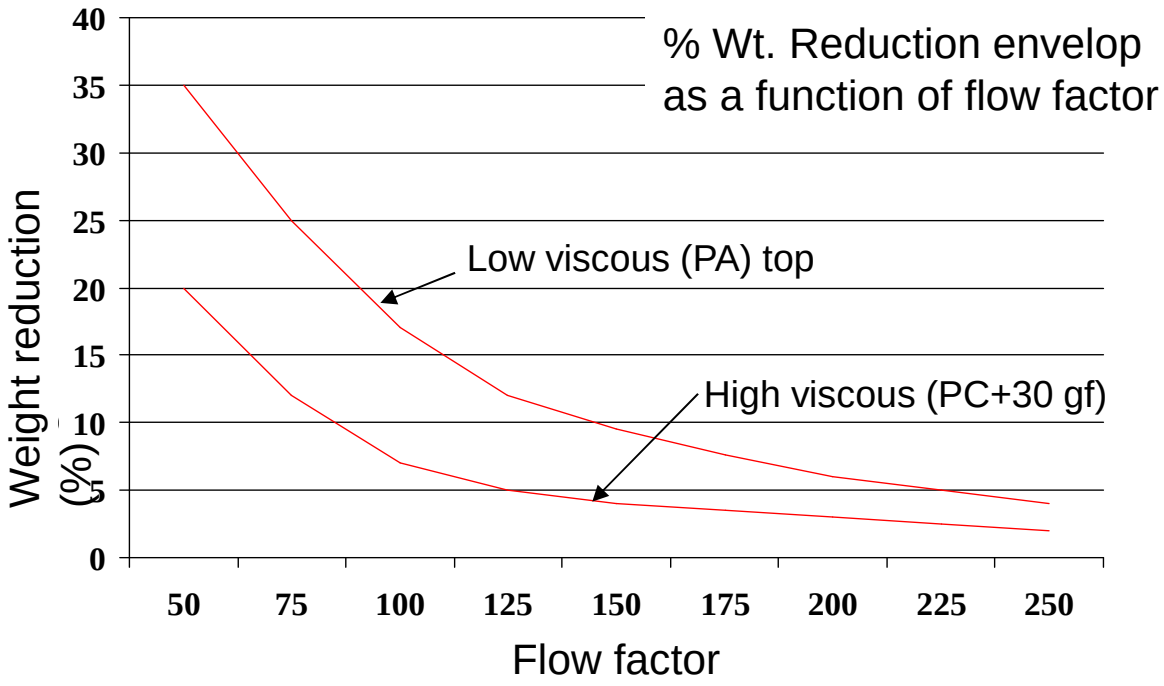
4. Growth goes on until material freezes



Mucell foaming injection moulding

5. Expansion capability of gas is affected by part thickness

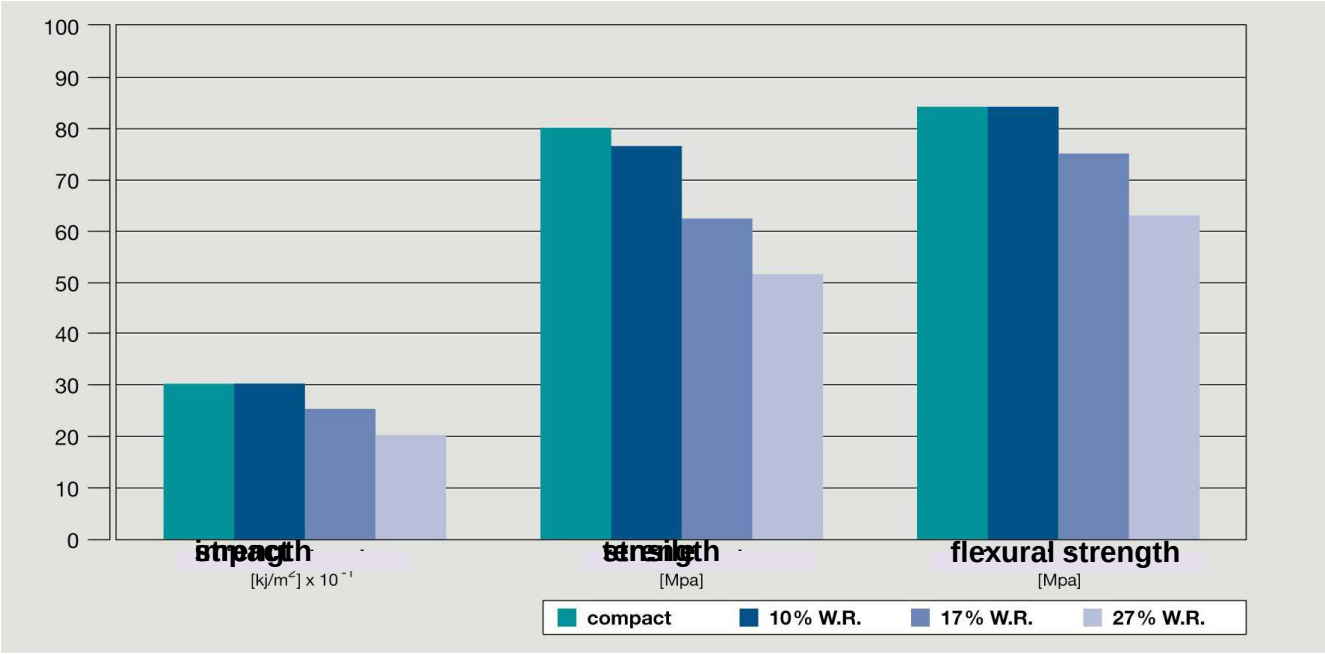
6. Foaming level depends on flow length (see chart)



Mucell foaming injection moulding

7. Foaming is controlled and repeatable

8. Mechanical properties are preserved up to expansion about 10%



Celanex® 2300 GV 1/30 (PBT with 30 % glass)

Source: Ticona GmbH

Mucell foaming injection moulding

9. Mechanical properties variation depends on the plastic material itself

10. Mechanical properties variation depends on fillers/reinforcement

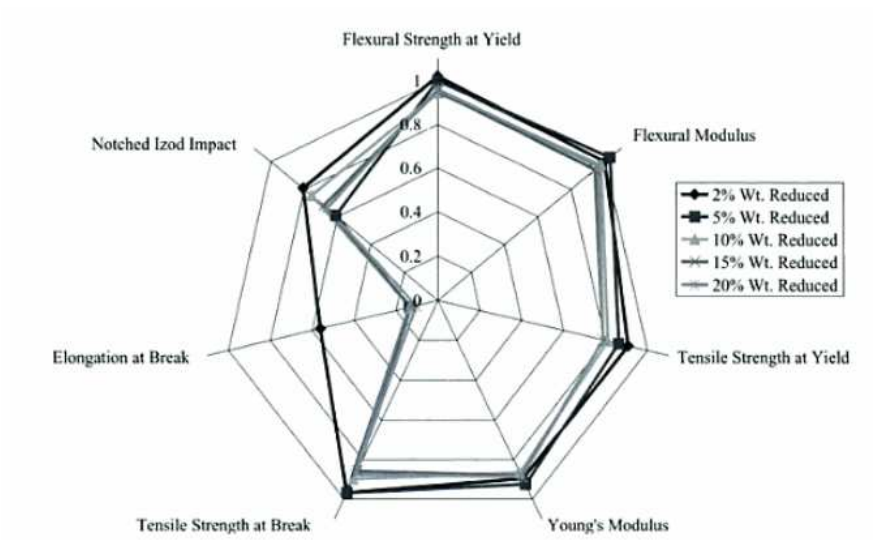


Figure 6.10 Property comparison GE Noryl 731 SEI PPO/PS

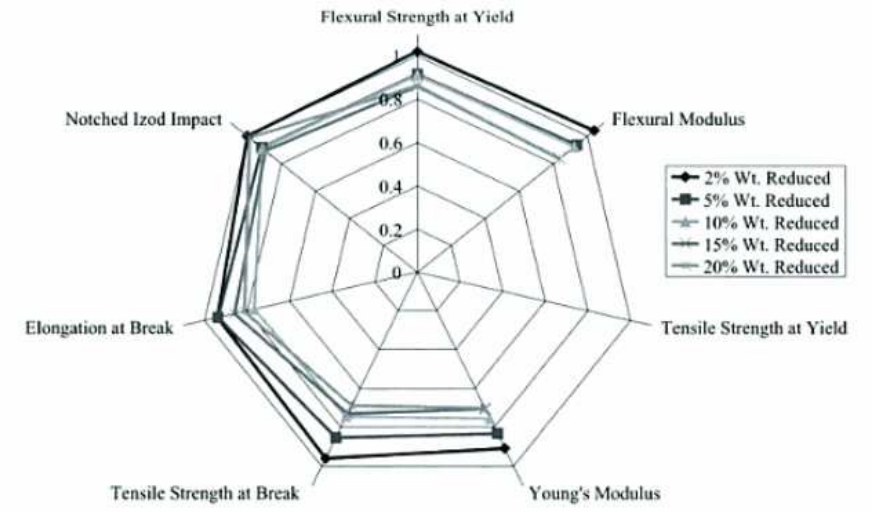


Figure 6.13 Property comparison GE Noryl GFN2 20% GF PPO/PS

Unfilled

Filled

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Mucell foaming injection moulding

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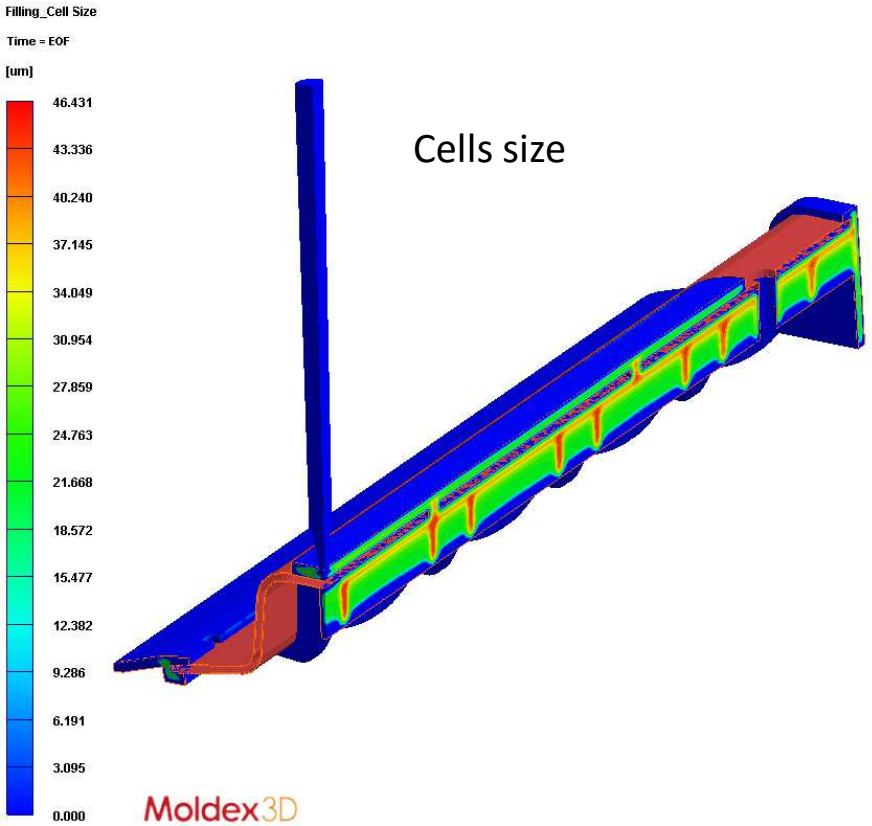
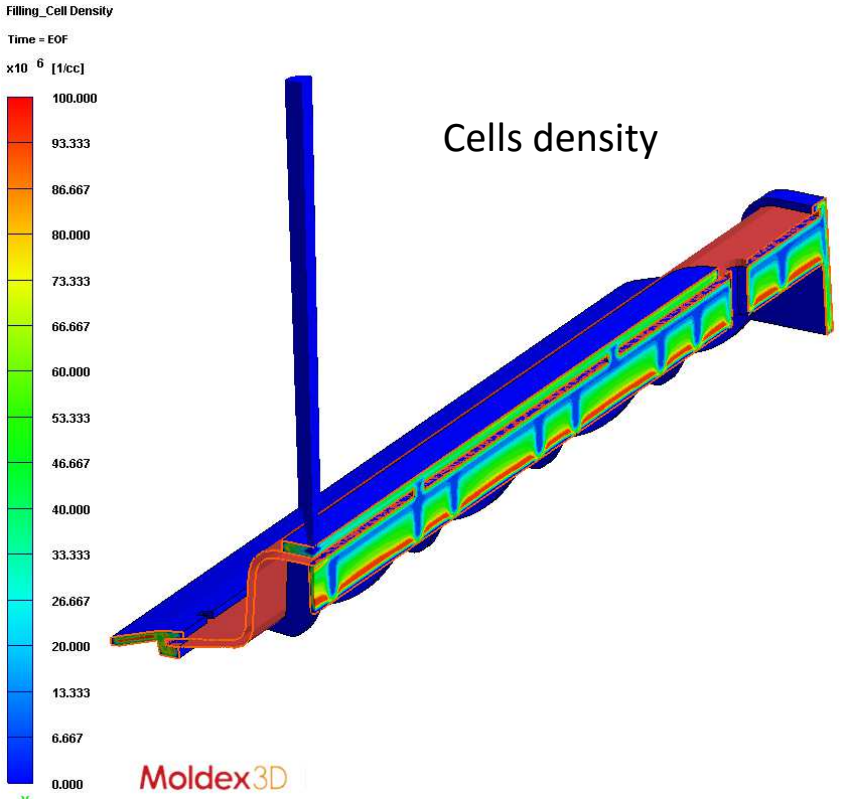
Expansion prediction



Cells size



Cells density

Good foaming properties
Cells size under 50µm
Cells density well distributed

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Mucell foaming injection moulding

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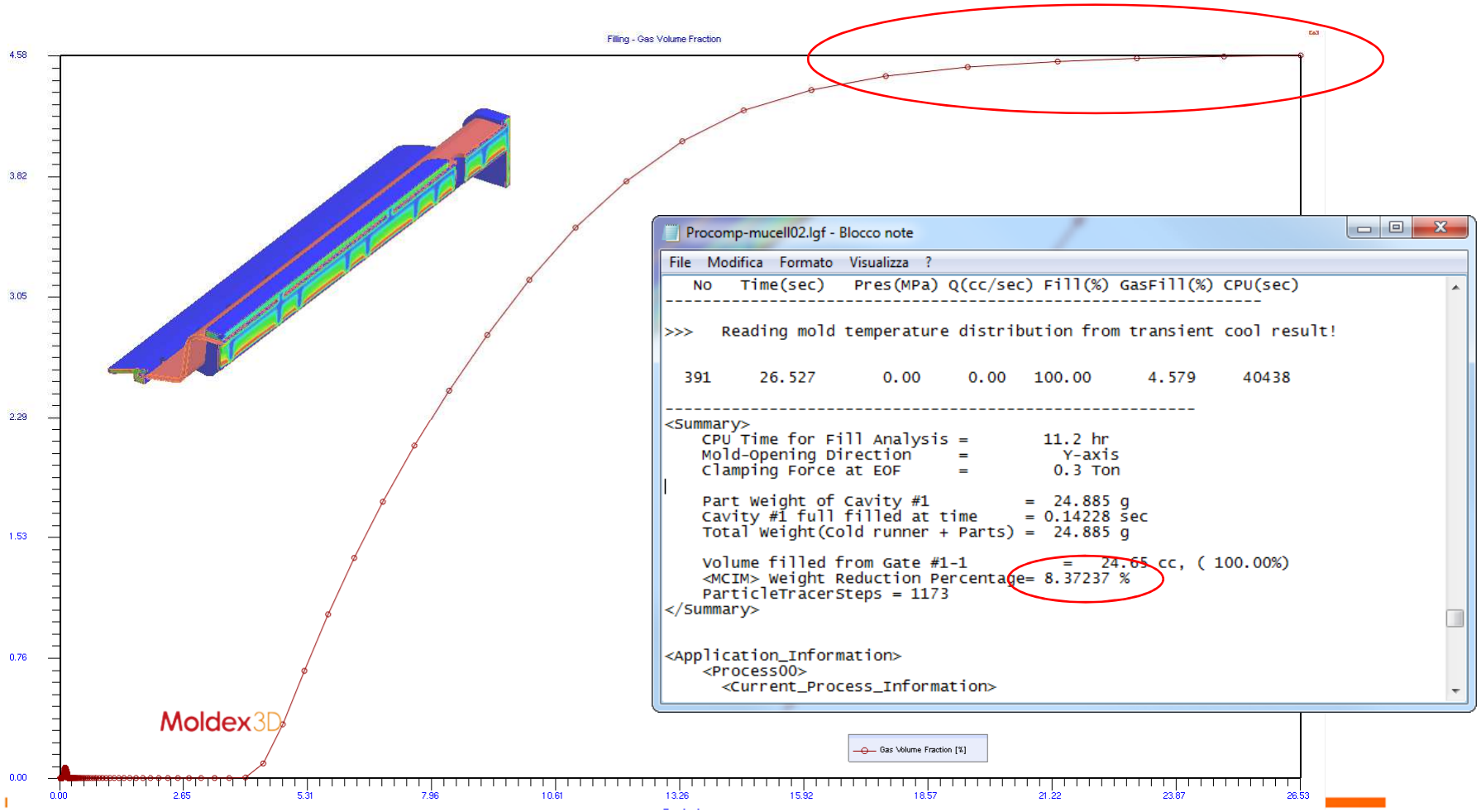
Expansion prediction

Good foaming properties

Completed gas foaming (cells growth finished)

Overall weight reduction ≈ 8.4%



Procomp-mucell02.lgf - Blocco note

File Modifica Formato Visualizza ?

```
   No    Time(sec)    Pres(MPa) Q(cc/sec) Fill(%) GasFill(%) CPU(sec)
-------------------------------------------------------------------

>>>   Reading mold temperature distribution from transient cool result!


  391      26.527        0.00      0.00   100.00       4.579      40438

-------------------------------------------------------------------
<Summary>
    CPU Time for Fill Analysis =        11.2 hr
    Mold-Opening Direction     =          Y-axis
    Clamping Force at EOF      =         0.3 Ton

    Part Weight of Cavity #1          =  24.885 g
    Cavity #1 full filled at time     = 0.14228 sec
    Total Weight(Cold runner + Parts) =  24.885 g

    Volume filled from Gate #1-1            =   24.65 cc, ( 100.00%)
    <MCIM> Weight Reduction Percentage= 8.37237 %
    ParticleTracerSteps = 1173
</Summary>


<Application_Information>
    <Process00>
      <Current_Process_Information>
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Mucell foaming injection moulding

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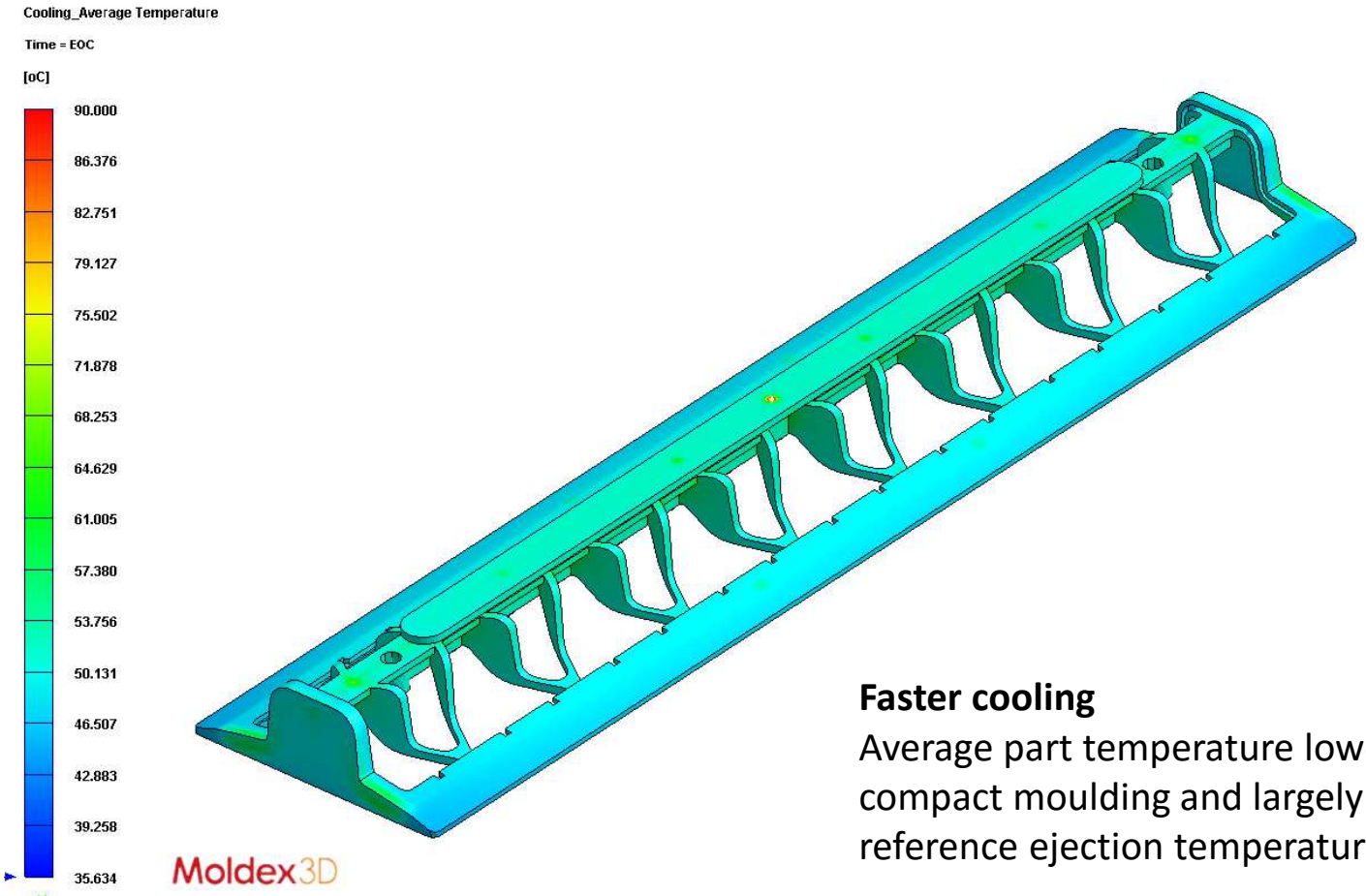
Temperature at end of cooling



Faster cooling

Average part temperature lower than compact moulding and largely below reference ejection temperature (90°C)

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Mucell foaming injection moulding

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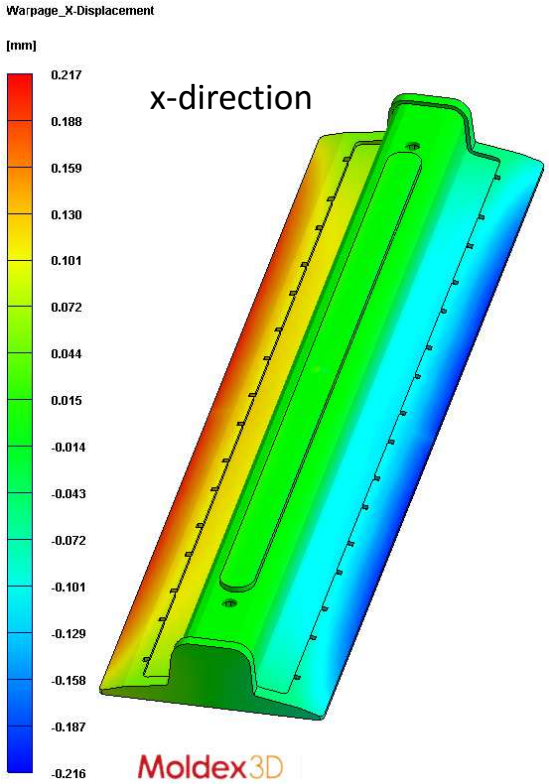
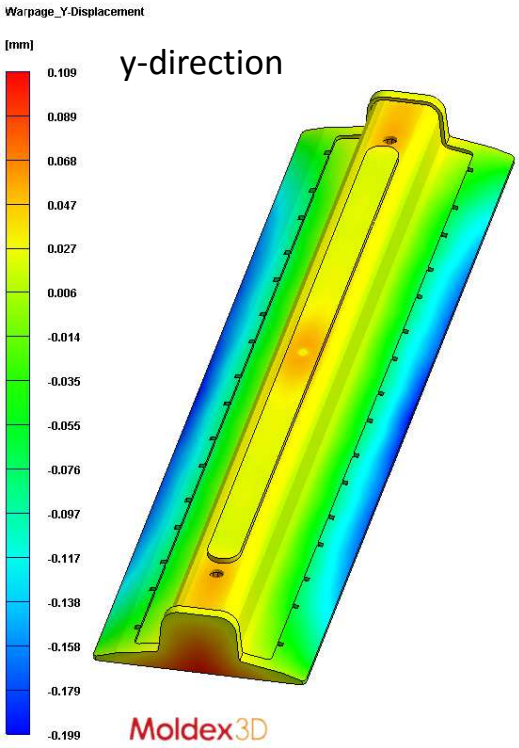
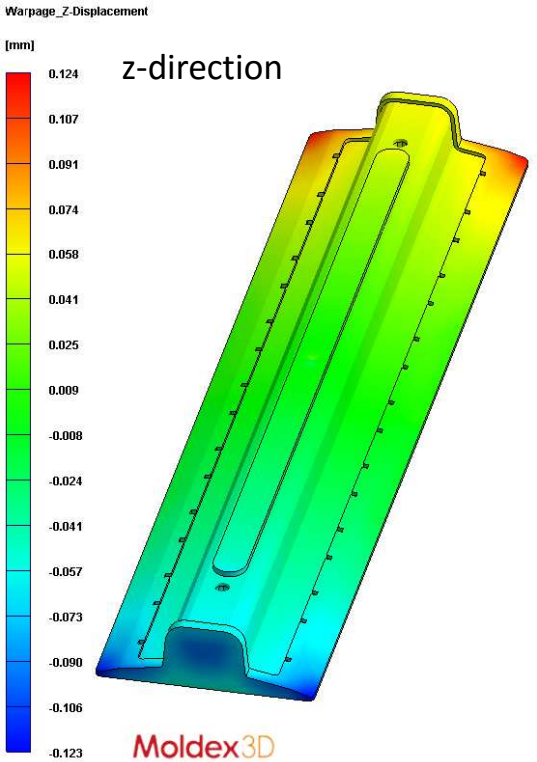
Warpage



x-direction



y-direction



z-direction

By Mucell process:

Strong reduction of warpage in all directions.
Symmetrical deformation.
Planarity largely recovered

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TP composite overmoulding simulation

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Mucell
virtual cycle

	Mucell	Compact	
t_{inj} (s)	0.15	0.53	
T_{melt} (°C)	245	245	
T_{mould} (°C)	40	40	
Gas dosage (%)	1	--	
Switchover (%)	97	98	
$t_{holding}$ (s)	1	9	
$P_{holding}$ (bar)	700	900	
$t_{cooling}$ (s)	33	28	**Variation (%)**
t_{cycle} (s)	**39.1**	**42.5**	**-8**
Shot weight (g)	**24.9**	**27.2**	**-8.4**
x-warpage (mm)	**-0.216/+0.217**	**-0.286/+0.286**	**-24 / -24**
y-warpage (mm)	**-0.199/+0.109**	**-0.988/+1.887**	**-79 / -94**
z-warpage (mm)	**-0.123/+0.124**	**-0838/+0.837**	**-85 / -85**

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FEM simulations

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Virtual run

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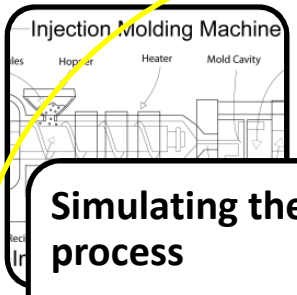
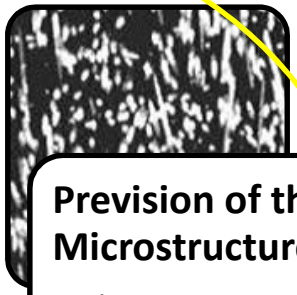
Process ↔ Material ↔ Structure



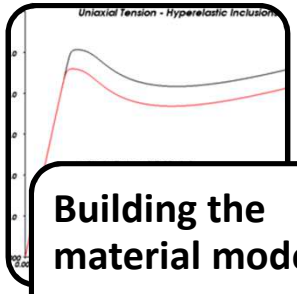
Simulating the process

- Conventional moulding
- Mucell injection moulding
- Heat and cool injection moulding



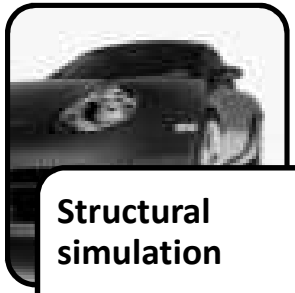
Prevision of the Microstructure

- Fiber orientation
- Cell dimensions
- Cell density and distribution



Building the material model

- Accurate Mechanical model sensitive to morphology



Structural simulation

- Stiffness
- Strength
- Performance

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digimat®

MSC Software

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FEM simulation of thermoplastic composites

Moldex3D

Procomp

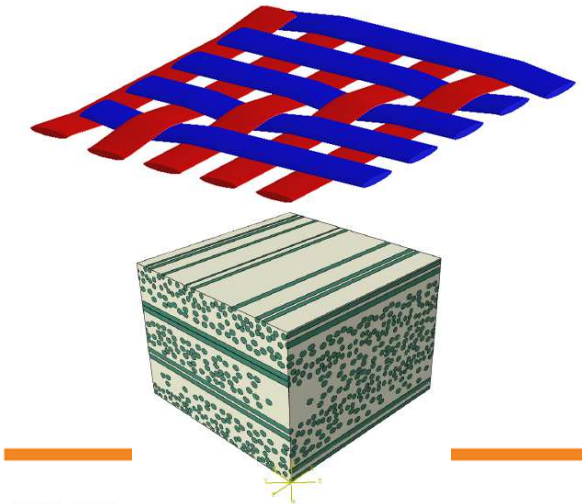
Laminate modeling (exahedral mesh)

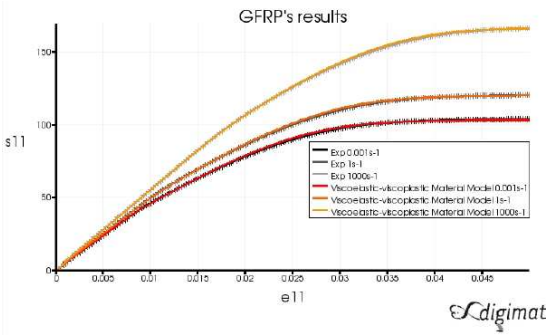
Overmoulding modeling (tetrahedral mesh)

Laminate: **Twill 50/50 glass, PP matrix**

Overmoulding: **PP+30%gf (Borealis GD 301FE)**

Mirostructure description + Microstructure overall response





Material model sensitive to microstructure

FEM

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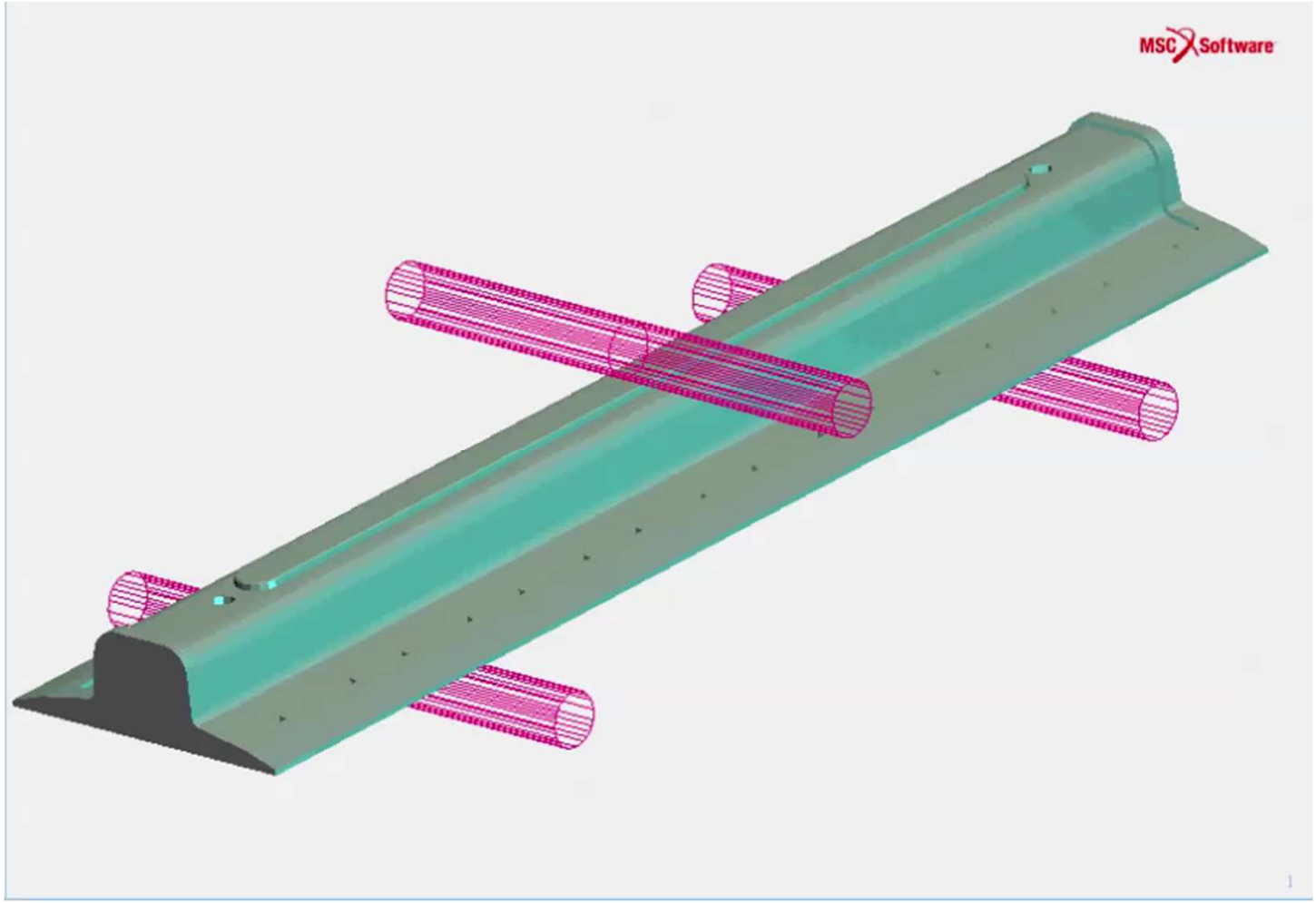

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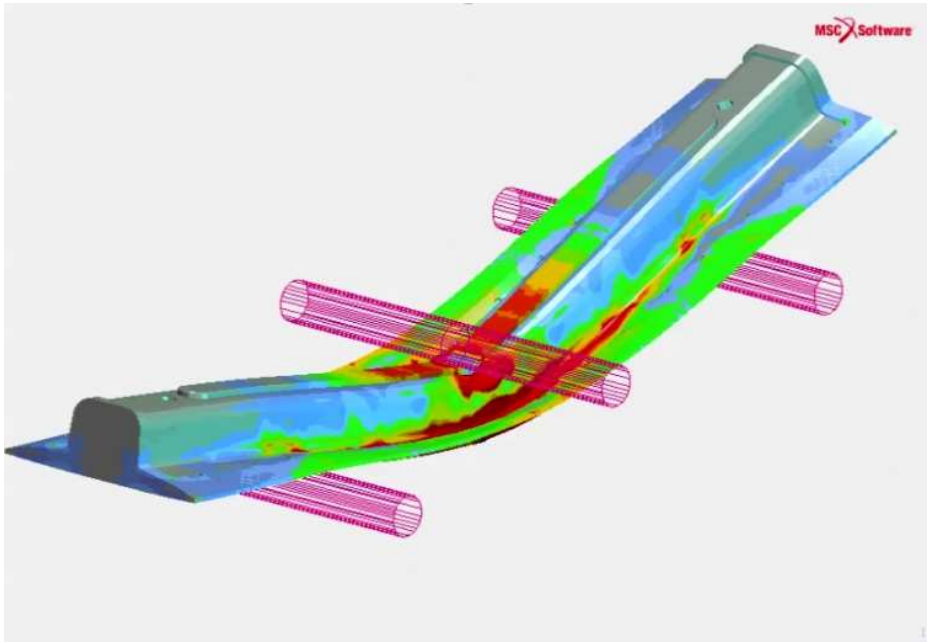

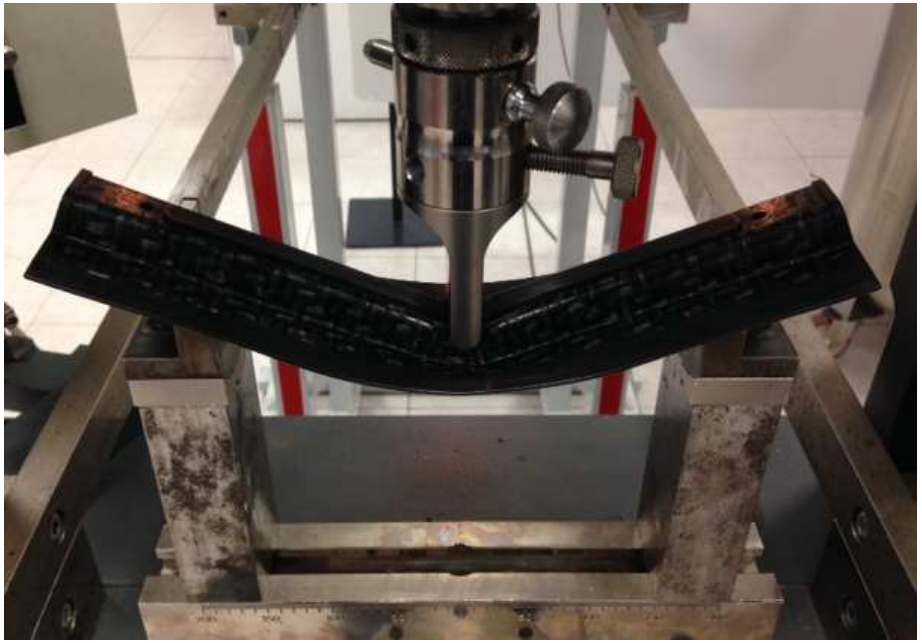

Simulation vs experimental

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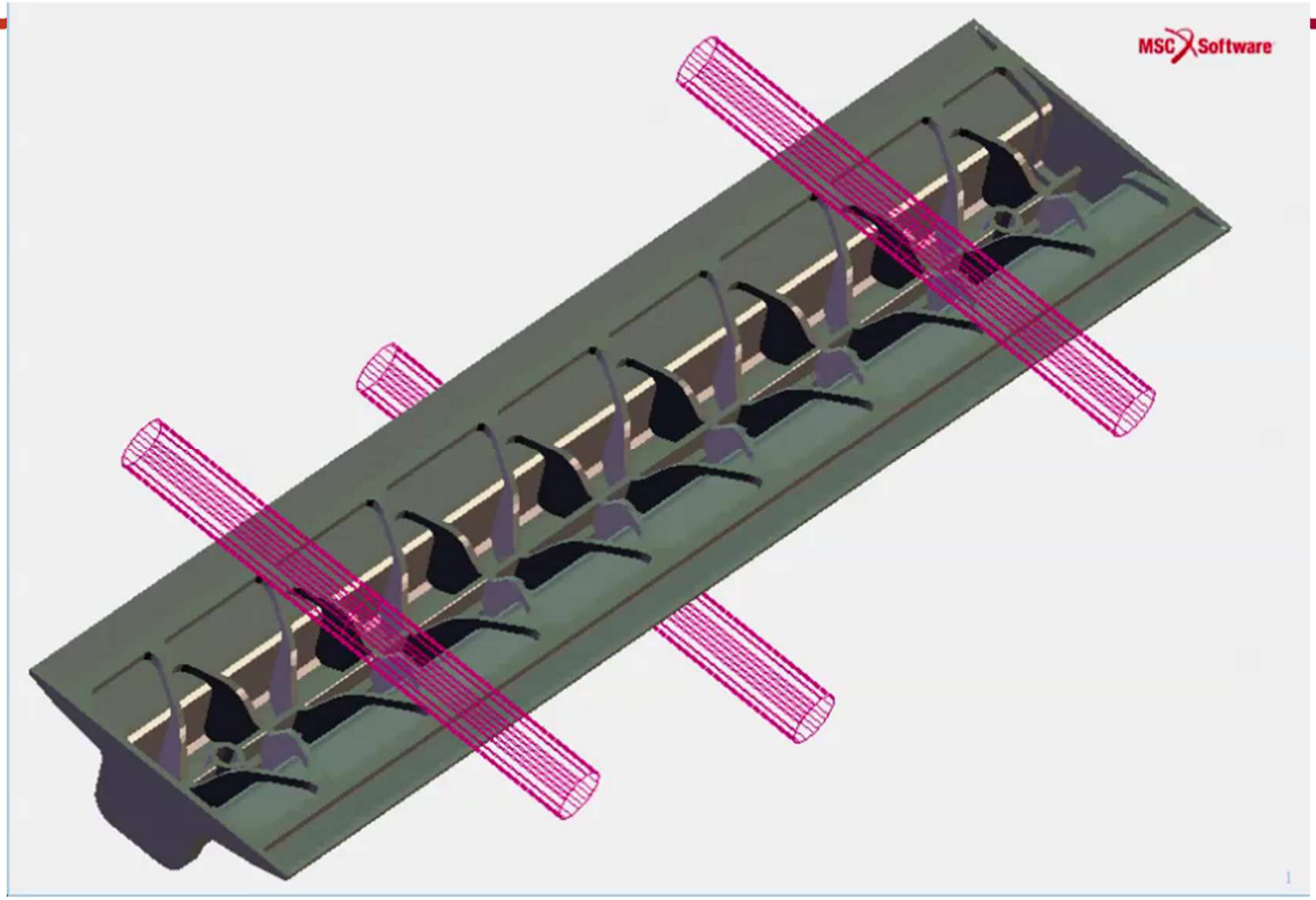

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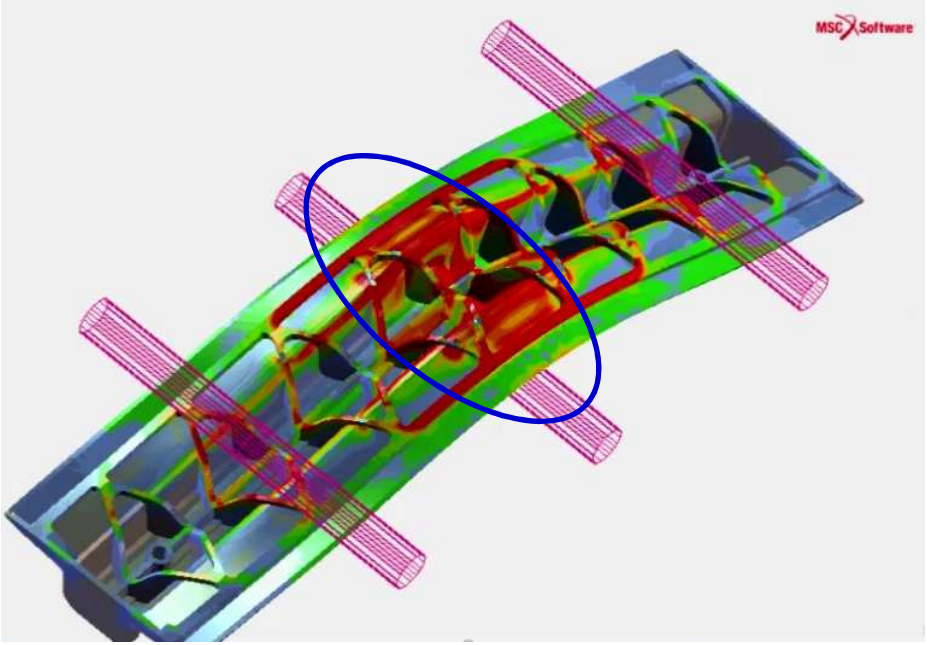

Crack initiation

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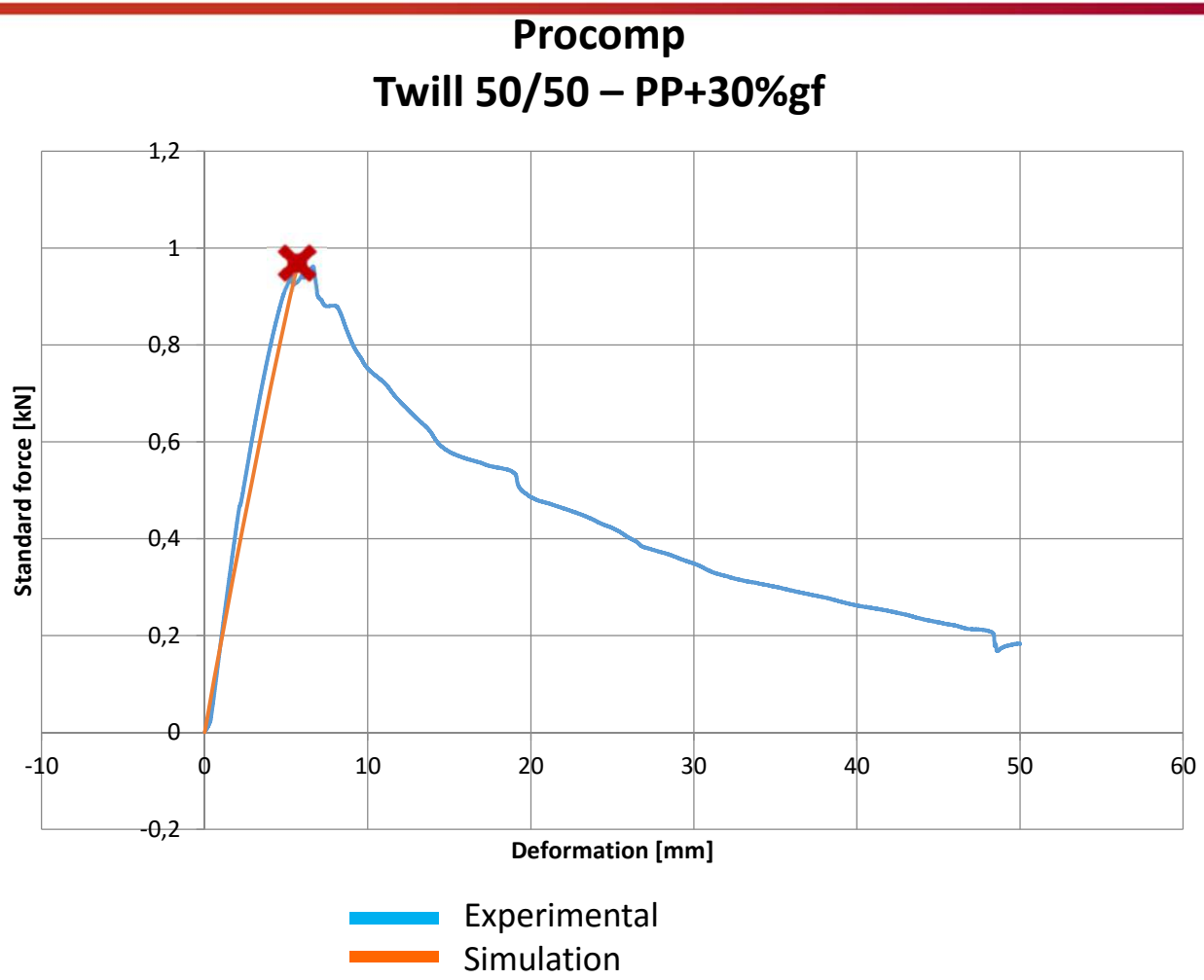

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Sum up

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Thermoplastic composites

Favourable combination of reinforce by continuous fibers (fabric) characteristic of traditional thermoset composites and chance to integrate on parts features typical of injection moulding

- High stiffness
- High mechanical strength
- Excellent impact resistance
- Lightweight
- Chemical resistance
- Processability

Production process of high productivity

- Production cycle similar to injection moulded thermoplastics
- Unlike Thermosets, no long curing times are required
- NO need of autoclave neither specific process devices
- Completely automated process

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Design freedom / integration of functions

- Chance to integrate functional details by overmoulding (ribs, bosses, pins, anchor points, snap-fits etc.)
- Unlike hi-filled thermoplastics, exhibit progressive damage and progressive failure
- No sudden failure

Simulations of thermoplastic composites

Simulation on injection overmoulding

- Compact/Mucell simulation
- Prediction of process and part quality
- Local prediction of overmoulded component's morphology (fiber orientation, cells size and density)
- Exploitation of flow simulation results into FEM structural simulations

Integration of process-dependent morphology into FEM structural simulations

- Material model sensitive to microstructure of both laminate and overmoulding
- Advanced structural simulations
- Highest correlation between virtual modeling and reality

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Thank you for your attention

Andrea Romeo
Consorzio Proplast
Head of Engineering Dept
andrea.romeo@proplast.it
+39 01311859743
www.proplast.it

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Sezione

Il problema

La soluzione

I Vantaggi

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Thank You

MOLDING INNOVATION