
International MAGMA User Meeting 2024
October 9-11, 2024
RADISSON BLU – Frankfurt
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MAGMA

LPDC / Wheel in MAGMASOFT® 6.1

New Developments / Improvements

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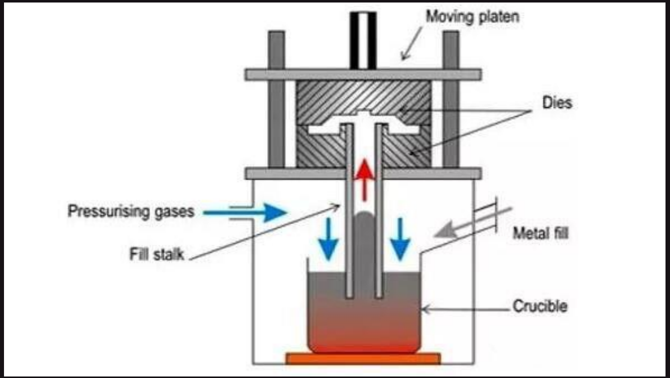
Workshop Non-Ferrous Applications

International MAGMA User Meeting 2024 Frankfurt

10th October 2024

Agenda

1. Introduction
2. New Features in Enmeshment
3. New Features in Temperature Control
4. New ‘Air’ Result
5. New Features in Filling Simulation
6. Pressure Dependent Feeding
7. Counter Pressure Casting
8. Pressure Drop
9. Modified Boundary Conditions
10. Cold Run
11. Recommendations

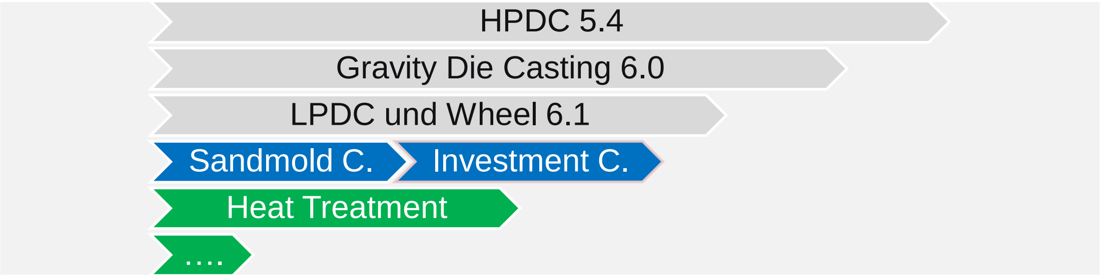


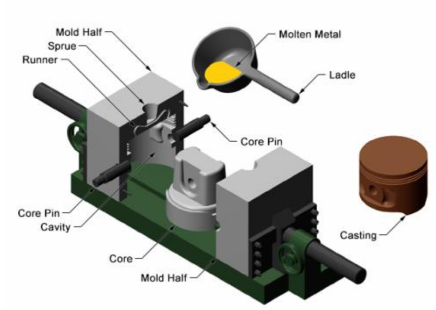
Introduction

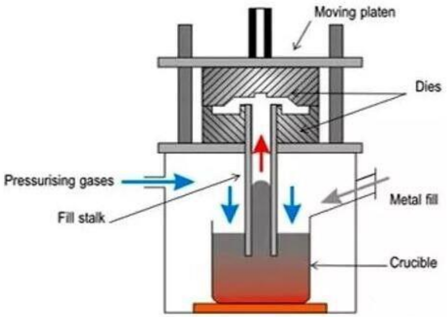
Solver Implementation

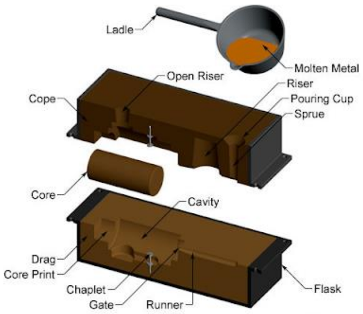
Roadmap

- Step-by-step implementation of process modes
- Parallel addition of new functions
- Future-proof platform for new developments
- State-of-the-art algorithms and networks
- Increase in software development speed









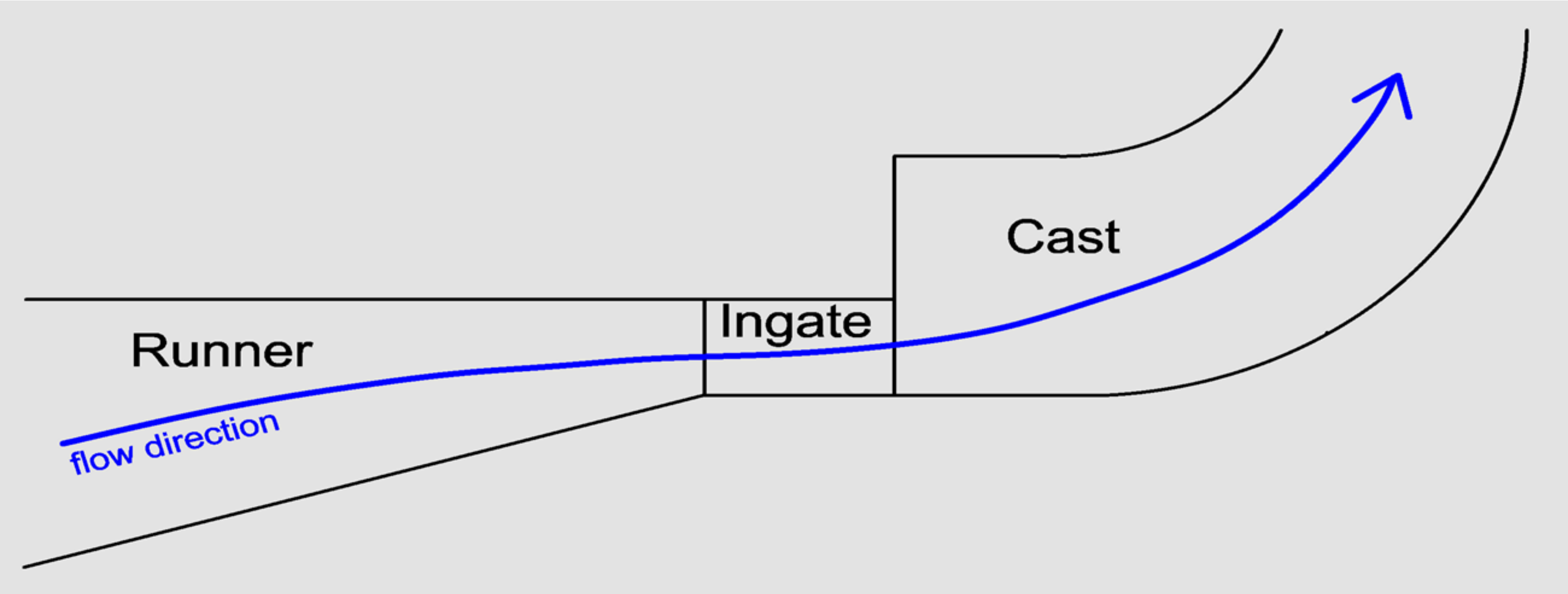
New Flow and Solidification Solver

- New algorithms for fluid flow, free surface, viscosity and air inclusions
- Different physical models can be used simultaneously (e.g. flow through cooling channels during mold filling, solidification and cooling)
- All mesh types can be used

What's different?

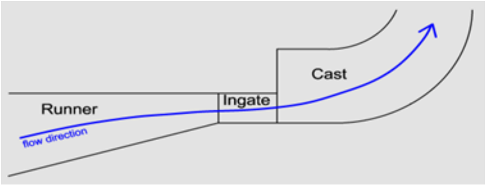
“cell-centered” approach

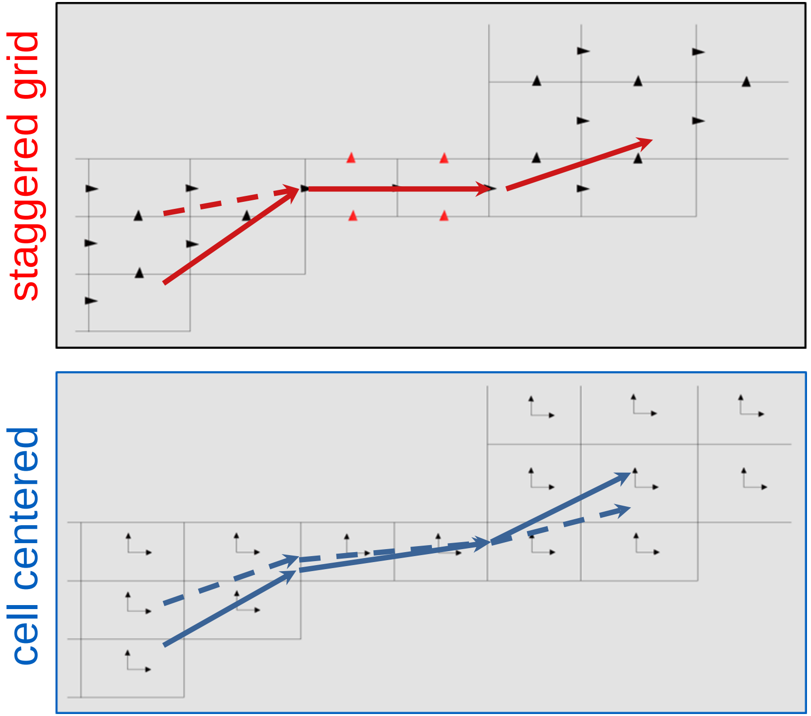
Runner → Gate → Cast Geometry

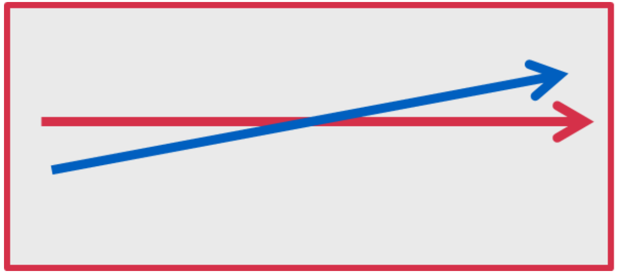


What's different?

“cell-centered” approach







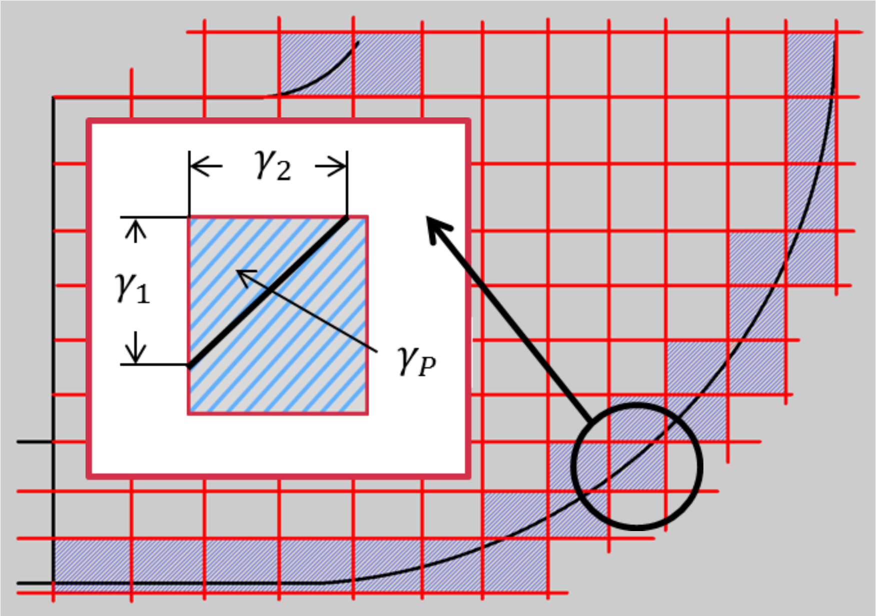
LPDC / Wheel 6.1

- **New Solver** (already in HPDC / GDC)
  - Solver for the future
  - TAG mesh and coarsening in the mold material
- **Tempering**
  - Heat up cycle
  - Flow in cooling channels
  - Electric heating cartridges
  - Variotherm
- **Filling**
  - Improved algorithm for the free surface
  - Improved surface tension
- **Thermal Solver**
  - External boundary conditions adjusted (!)
  - Pressure-dependent porosity
  - New algorithm for hotspot
- **Further Highlights**
  - Counter Pressure Casting - CPC
  - Venting model and air results as in HPDC / GDC
  - Binder degradation and core gas also for cooling after eject
  - Ejection simulation

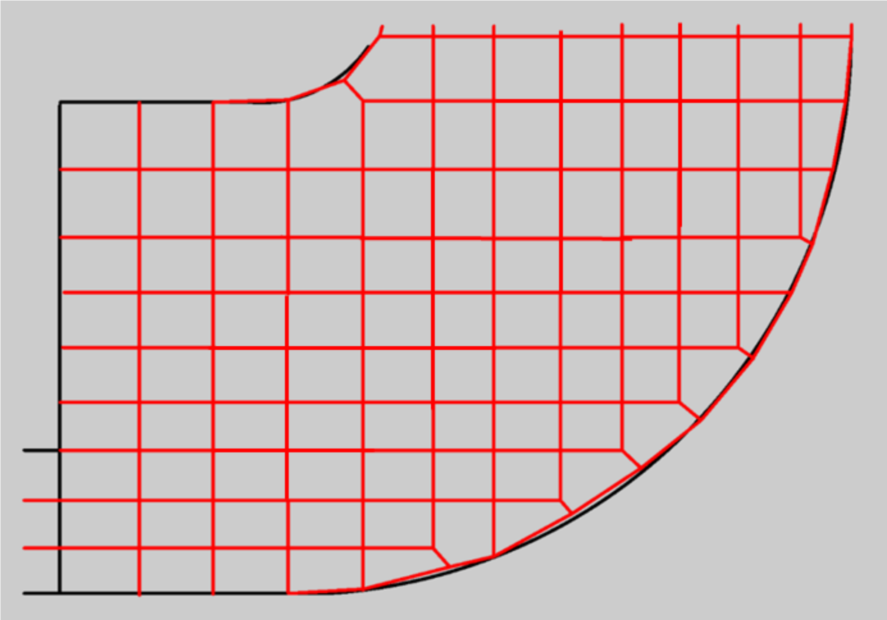
New Features in Enmeshment

TAG Mesh

“Solver5” Mesh

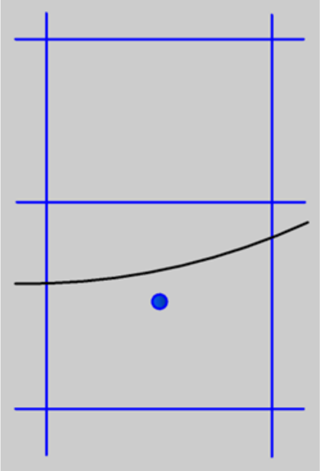


New Solver

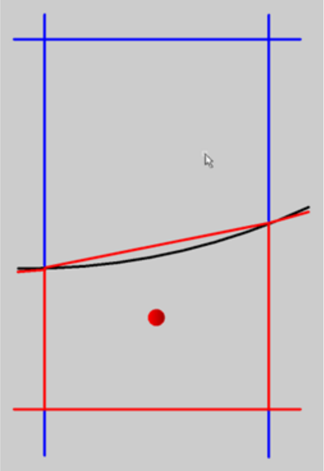


TAG Mesh

Merging

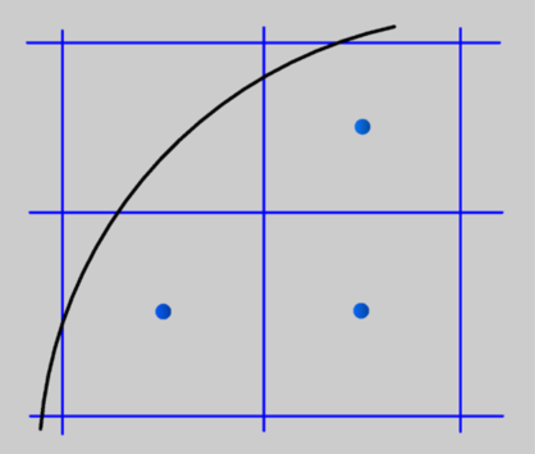


Before

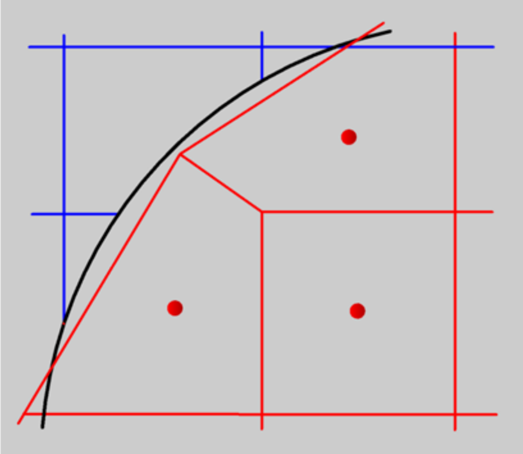


After

Linking

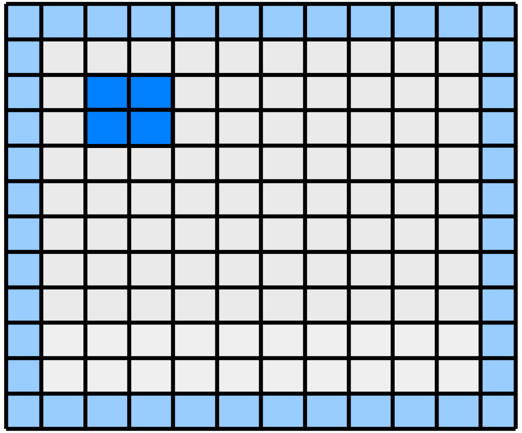


Before

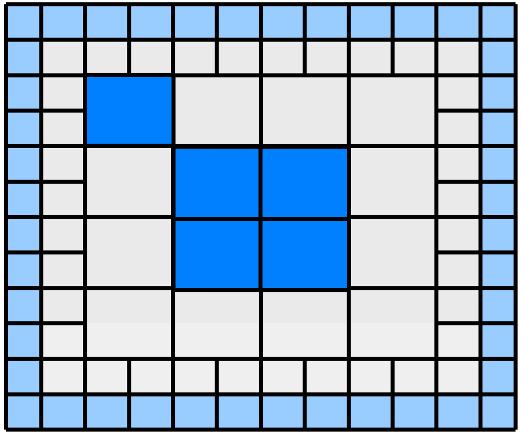


After

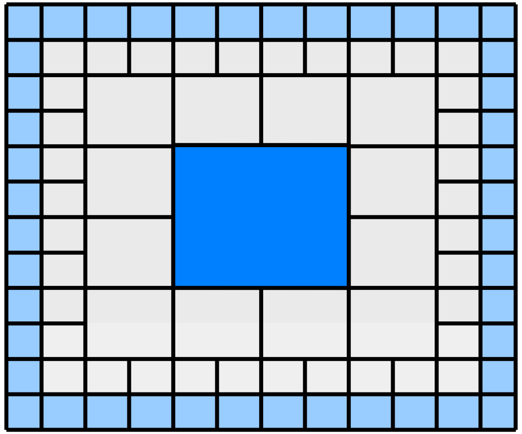
Composed Meshes and Coarsening



Original



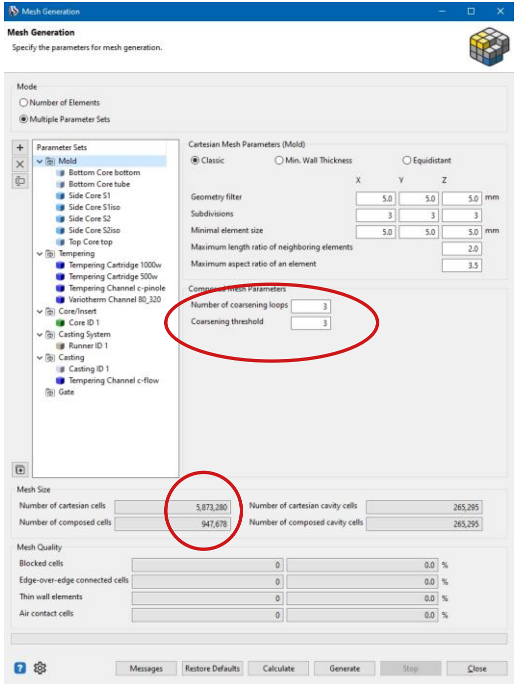
Coarsening Loop 1



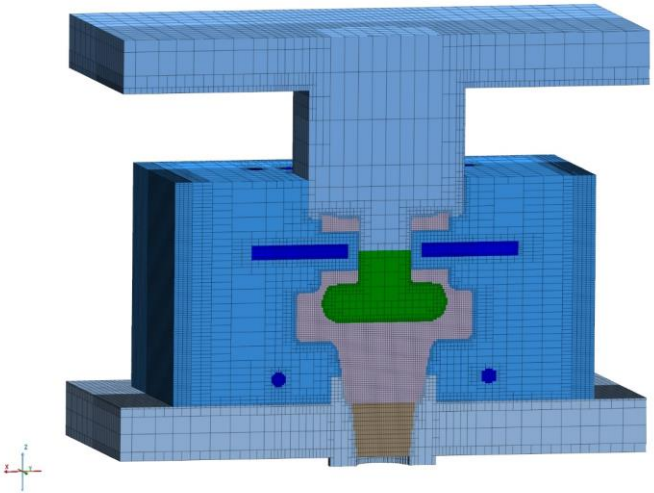
Coarsening Loop 2

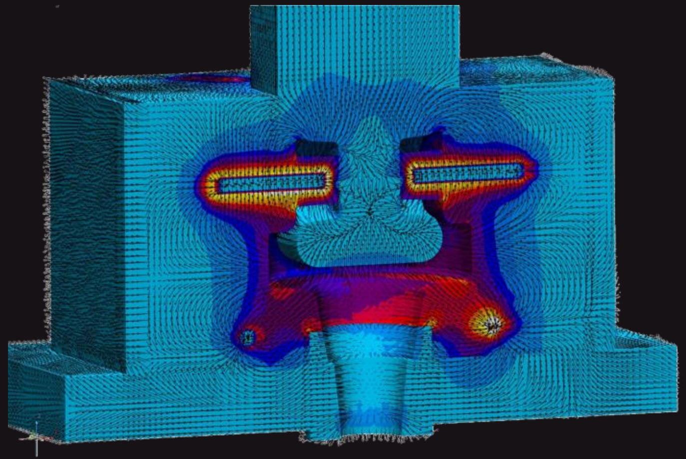
Enmeshment

Coarsening in the die material – known from HPDC / GDC



LPDC demo part

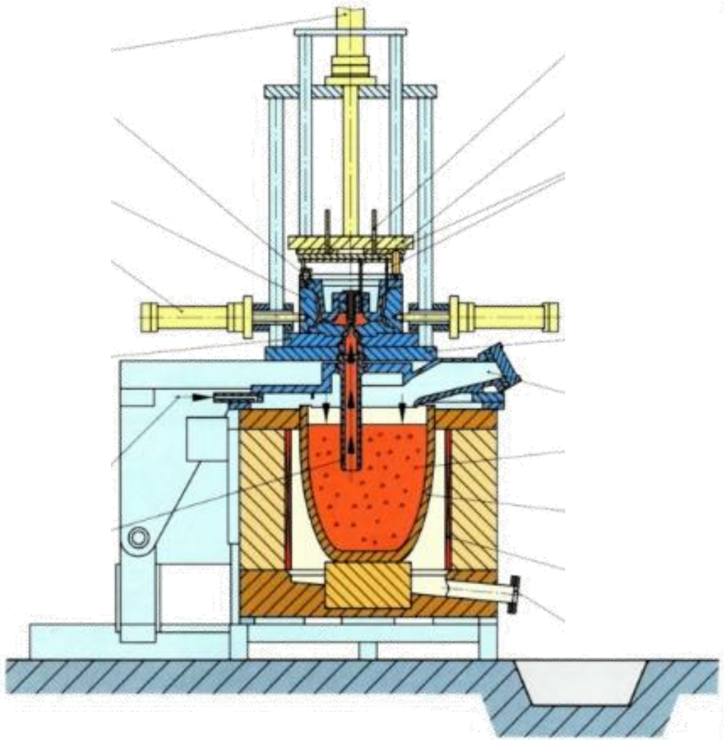




New Features in Temperature Control

LPDC / Wheel

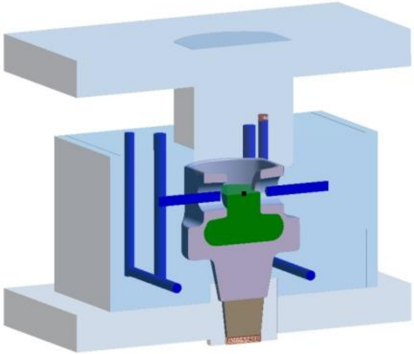
Process control

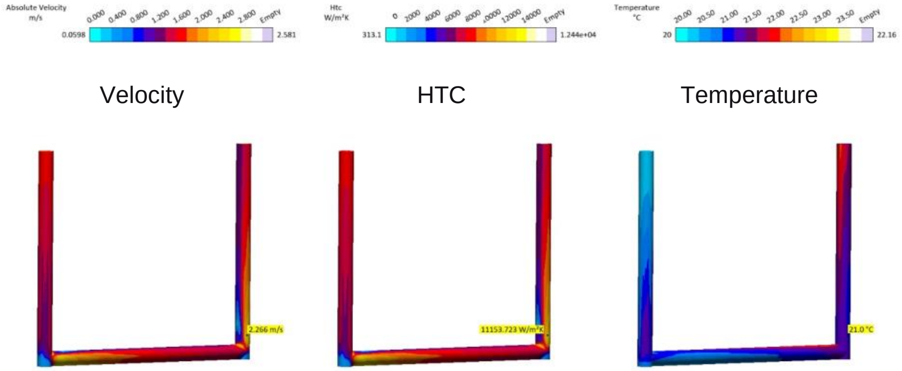


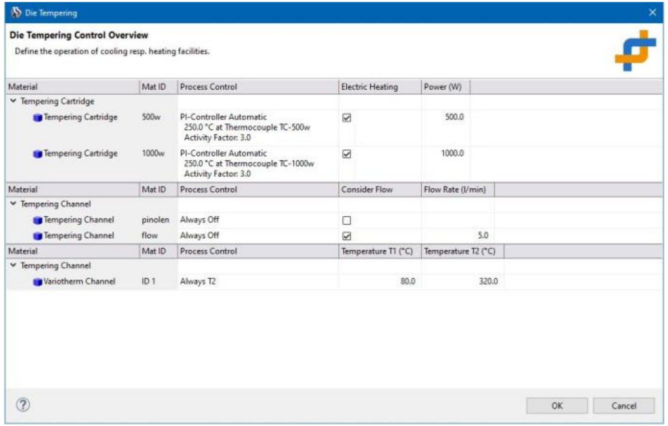
Die Tempering

Different options

- Heat up cycle
- Electric heating cartridges (incl. PI Controller)
- Variotherm (to different temperatures in the same channel)
- Flow in tempering channel – HTC-calculation from local flow

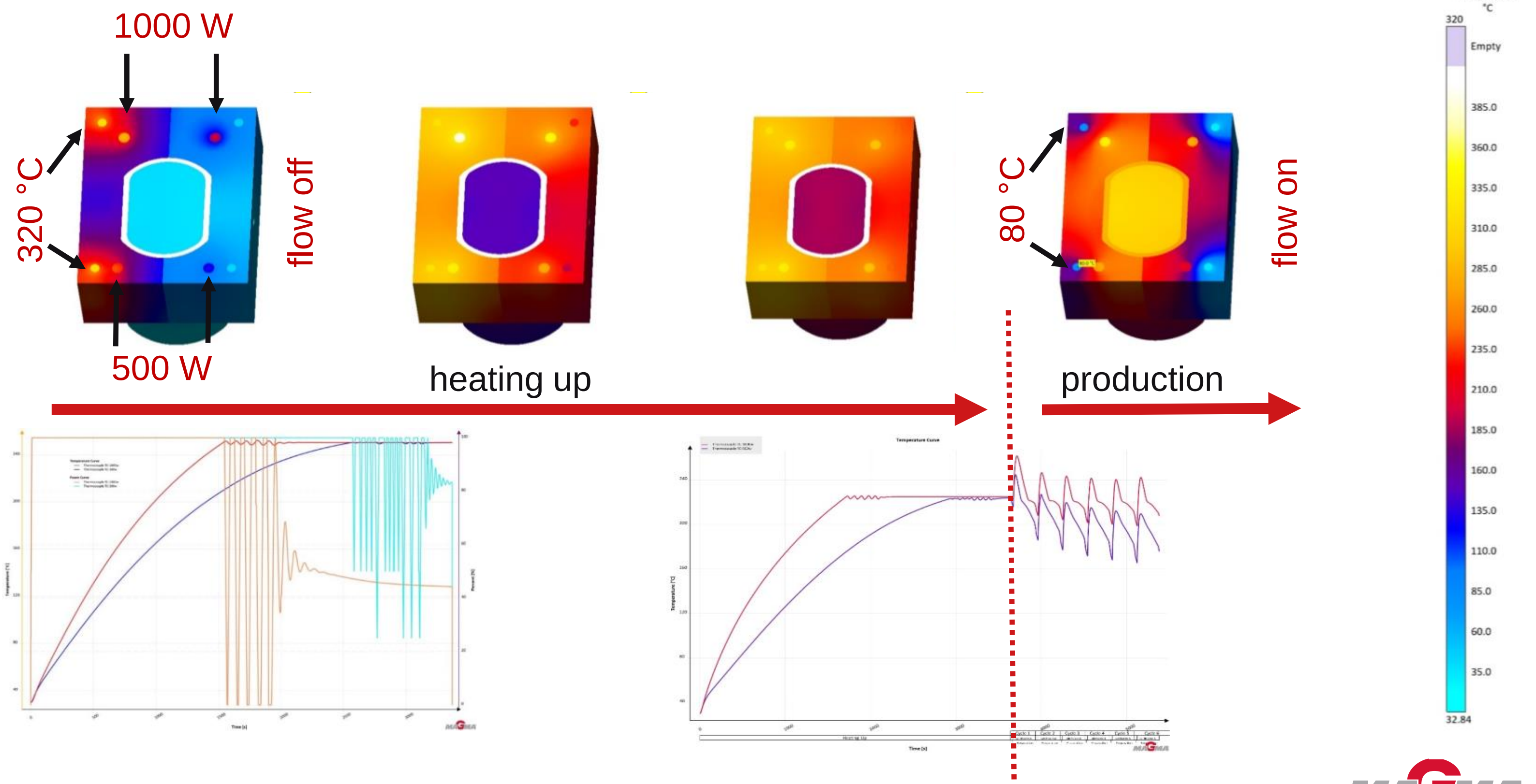




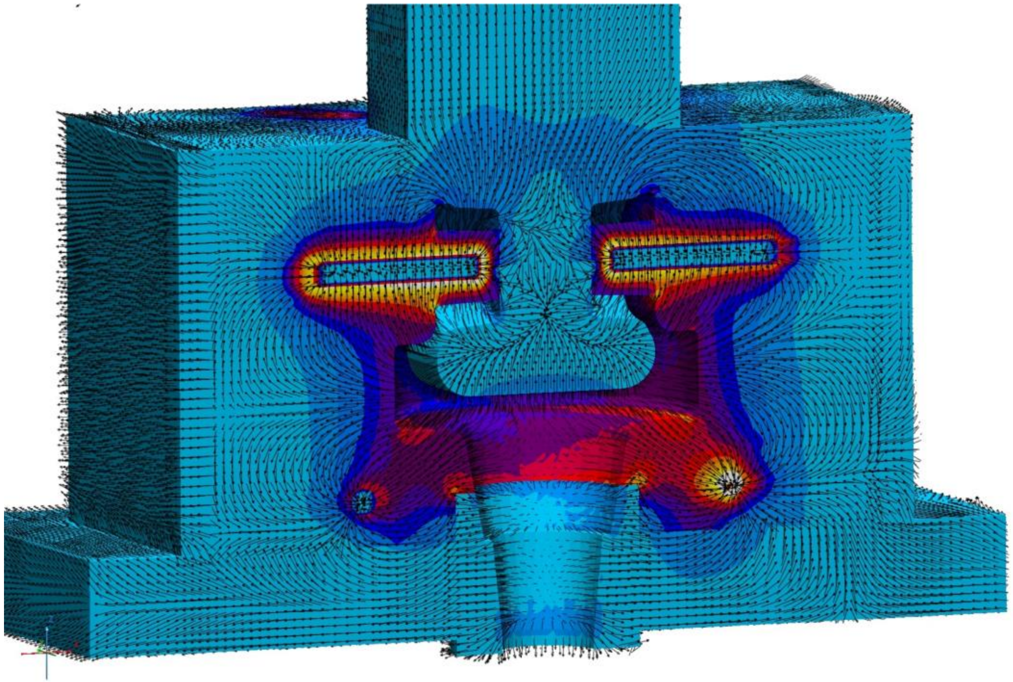


Tempering

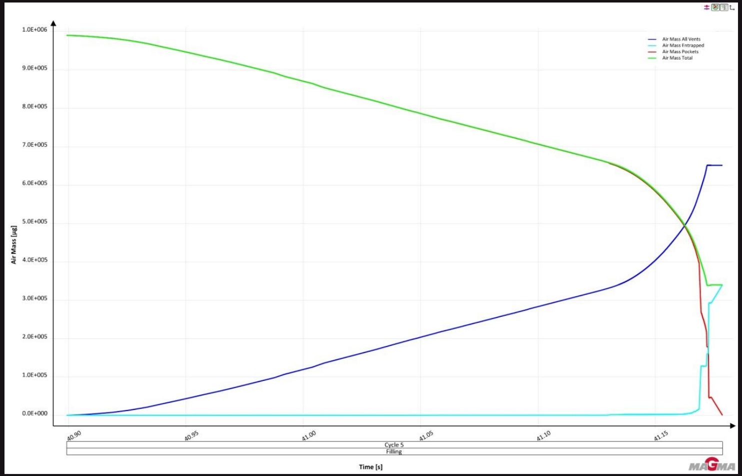
Heating Cartridge, Variotherm, Channel Flow



Heat Flux Density



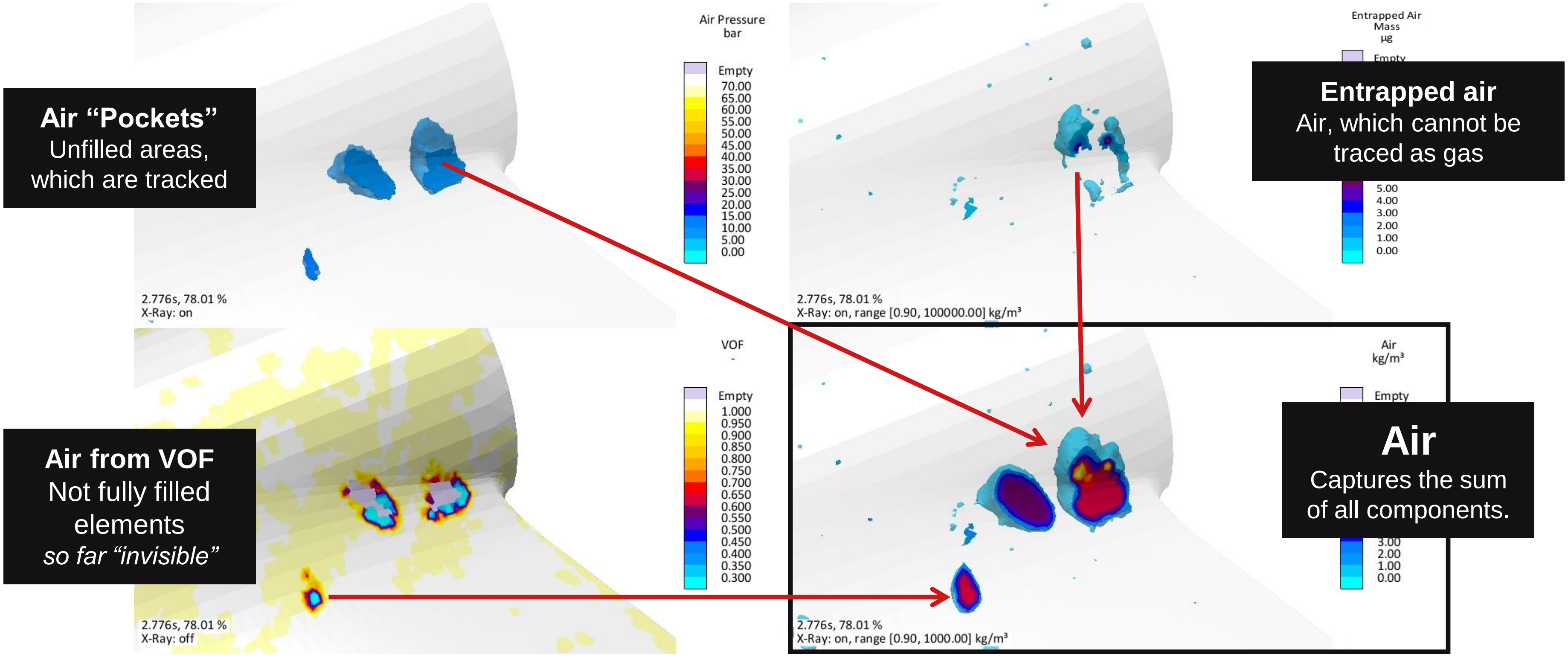
„Heat Flux Density“ shows the (resulting) heat flow in magnitude and direction (vectors) for each process phase.



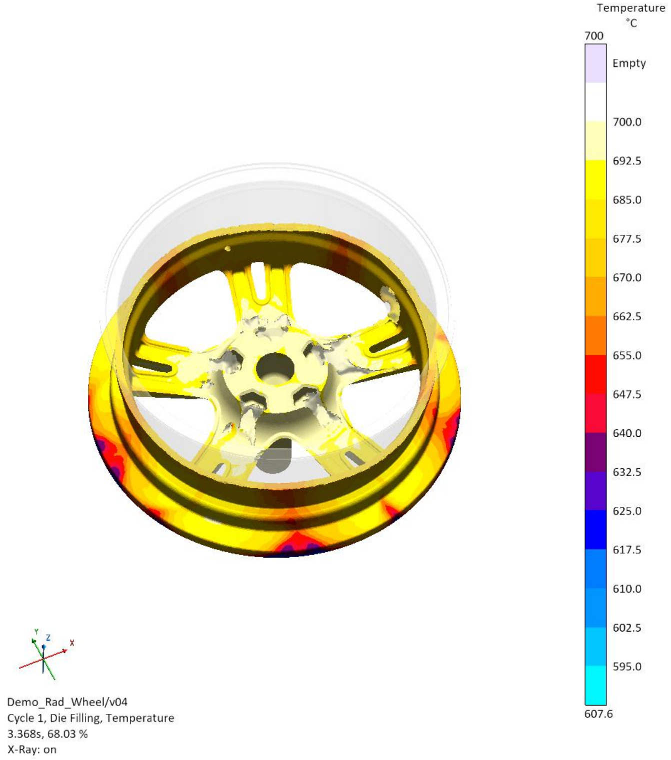
New ‘Air’ Result

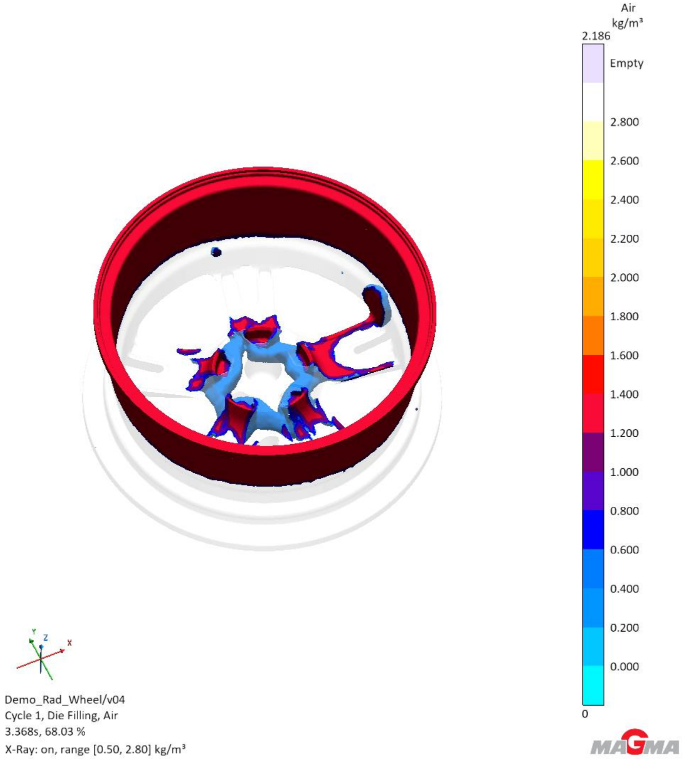
New “Air”– Result (known from HPDC / GDC)

“Air“ – Sum of all calculated air components



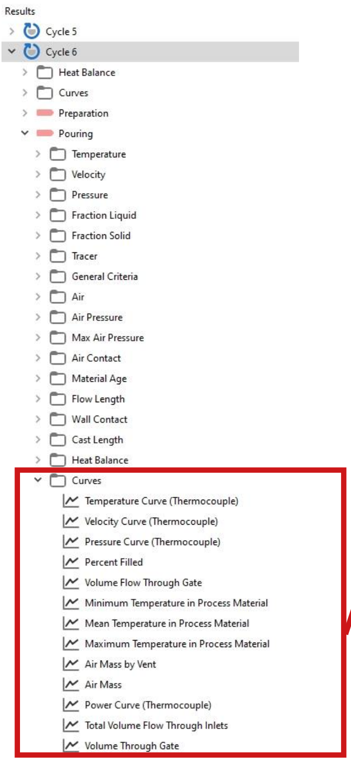
New “Air”– Result (known from HPDC / GDC)

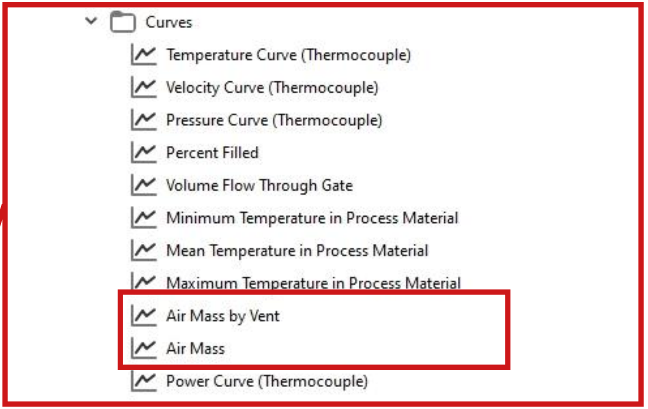




Air Curves

New curves for evaluating the die venting



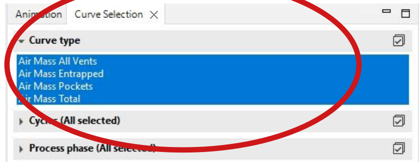


Air Mass – shows the progress of the individual air components during the filling phase
Air Mass by Vent – one curve is shown per vent

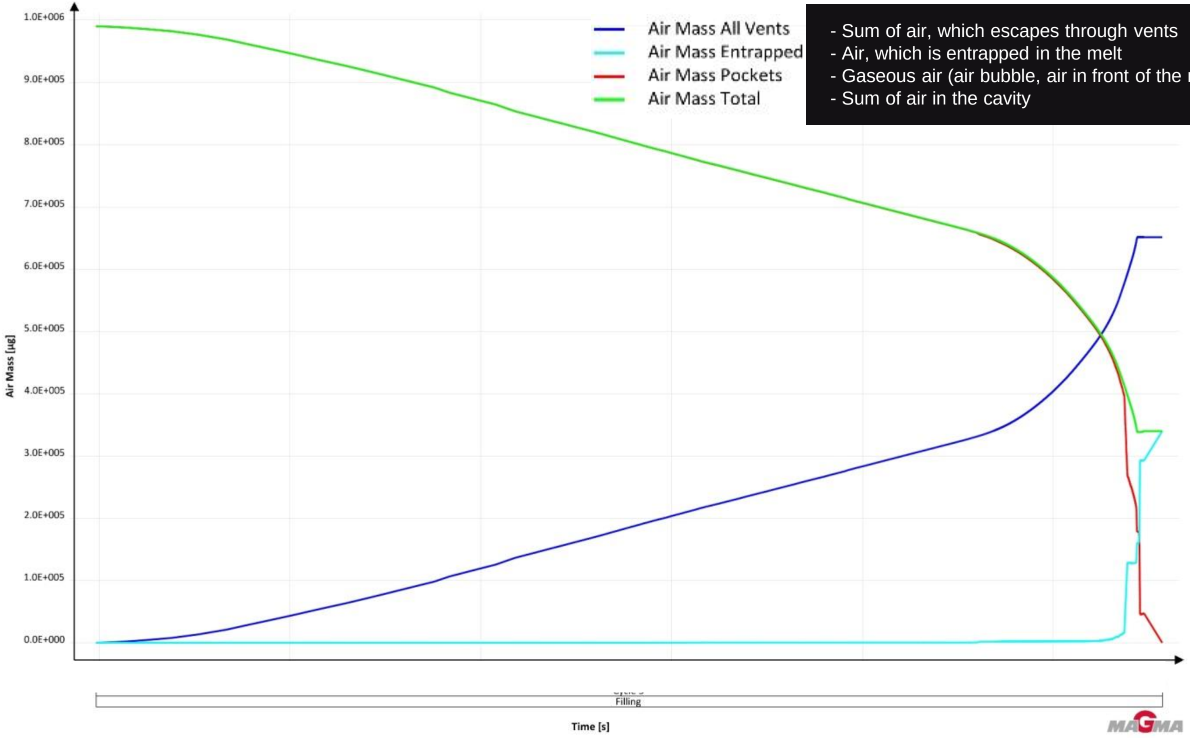
Air Curves

Air Mass

When “Air Mass" is selected, 4 curves are always shown



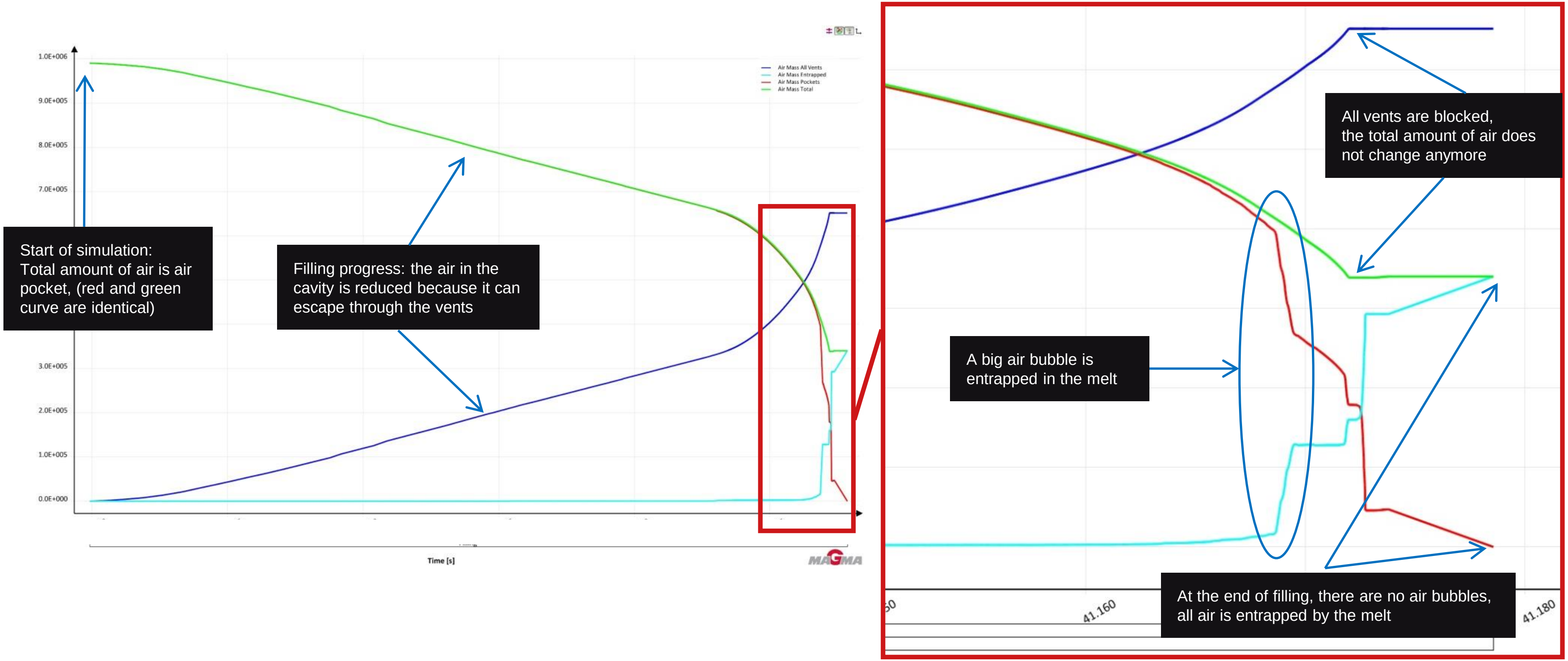
The individual components can be shown/hidden separately



- Sum of air, which escapes through vents
- Air, which is entrapped in the melt
- Gaseous air (air bubble, air in front of the melt front)
- Sum of air in the cavity

Air Curves

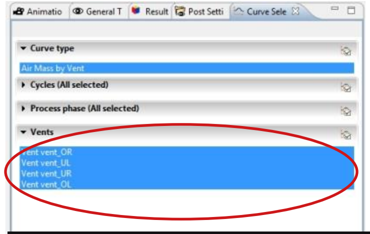
Air Mass – Interpretation



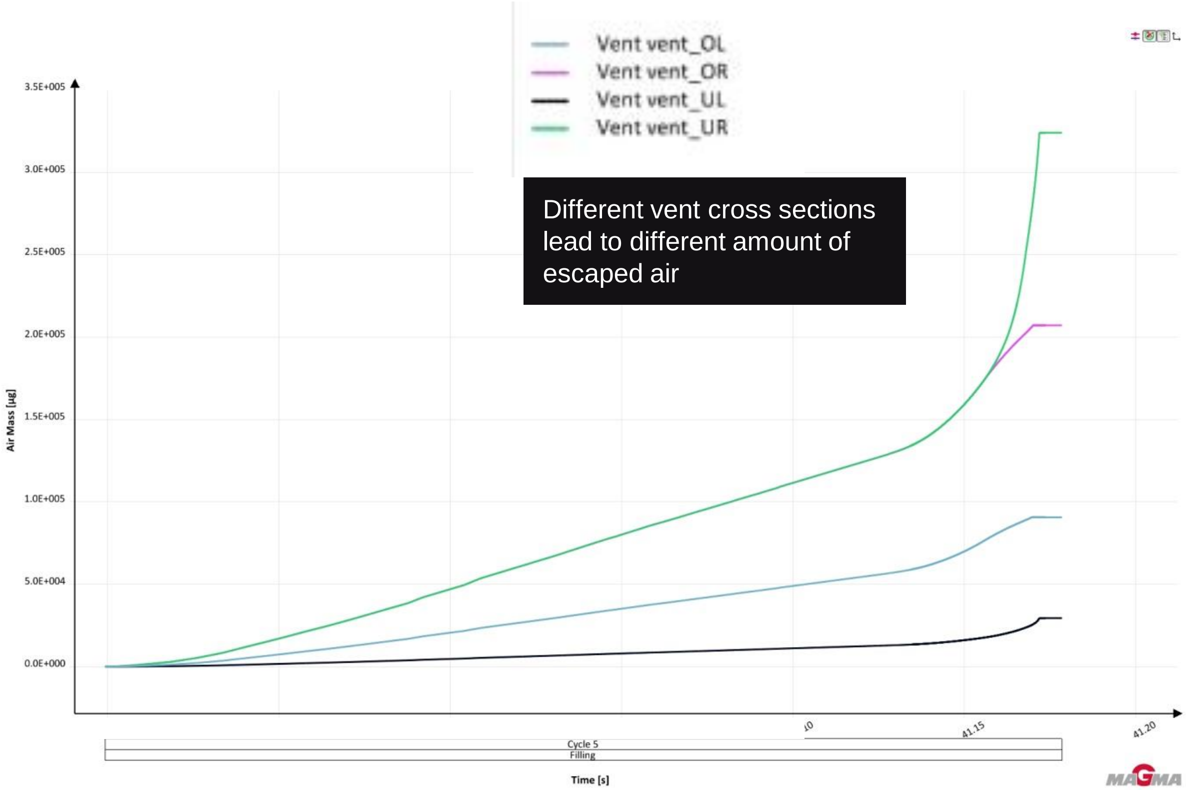
Air Curves

Air Mass by Vent

One curve is shown per vent, the result definition is automatic, the labels are taken from the geometry



The individual vents can be shown/hidden separately

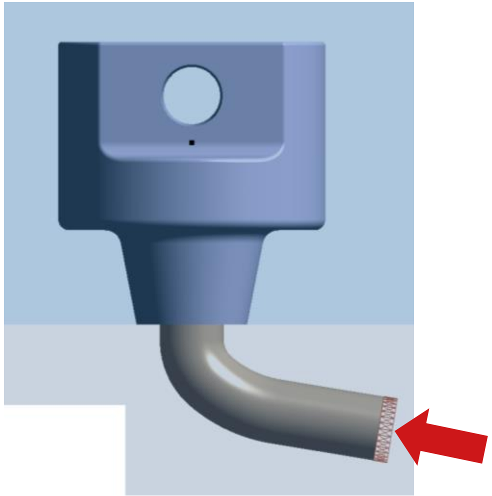


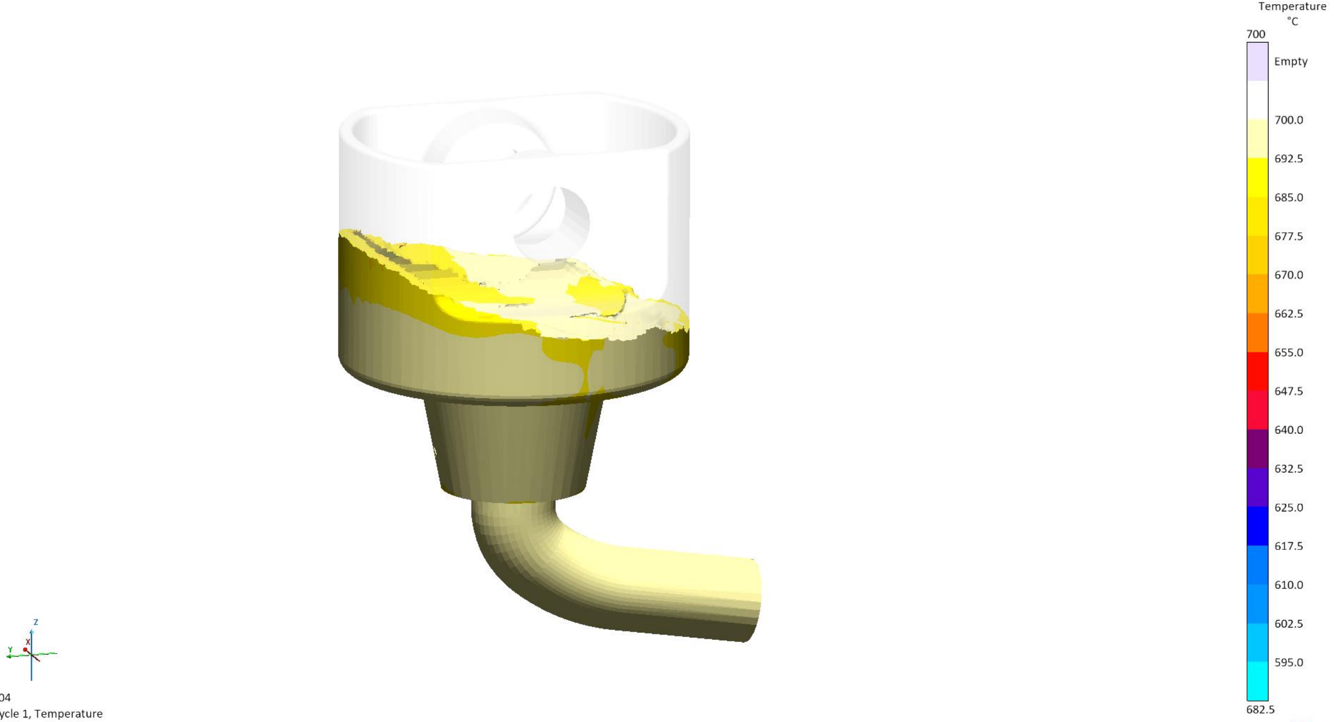
Different vent cross sections lead to different amount of escaped air

New Features in Filling Simulation

Filling from any Direction

It is no longer necessary to align the inlet to the main coordinates

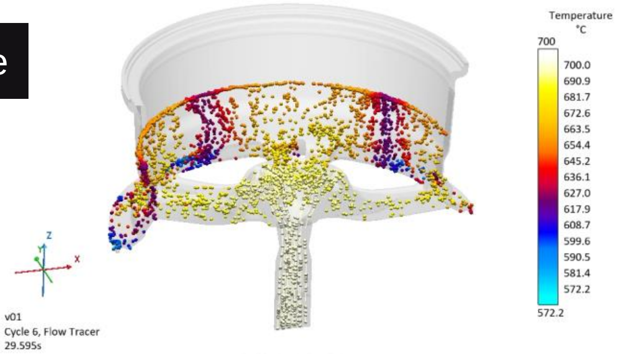




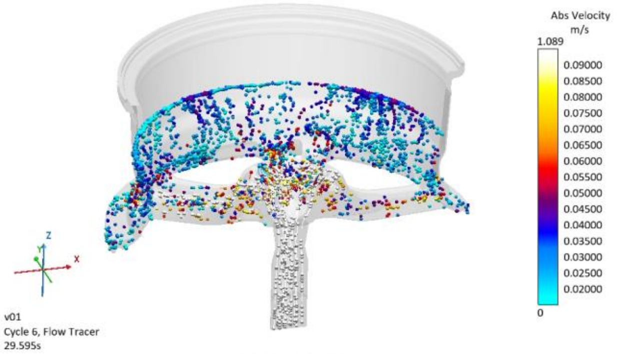
v04
Cycle 1, Temperature
400.3ms, 68.02 %
X-Ray: on

New Tracer Results

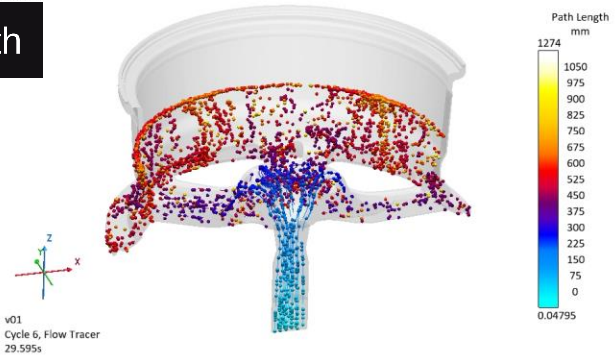
Temperature



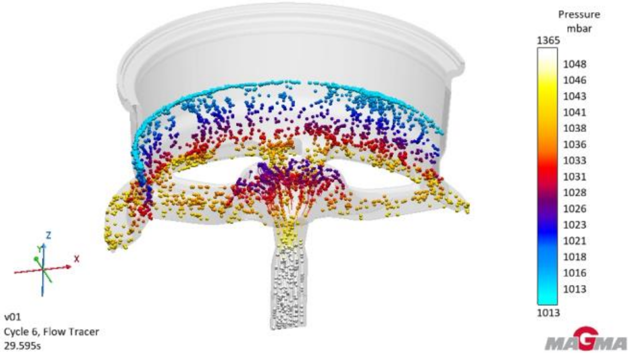
Velocity



Path Length



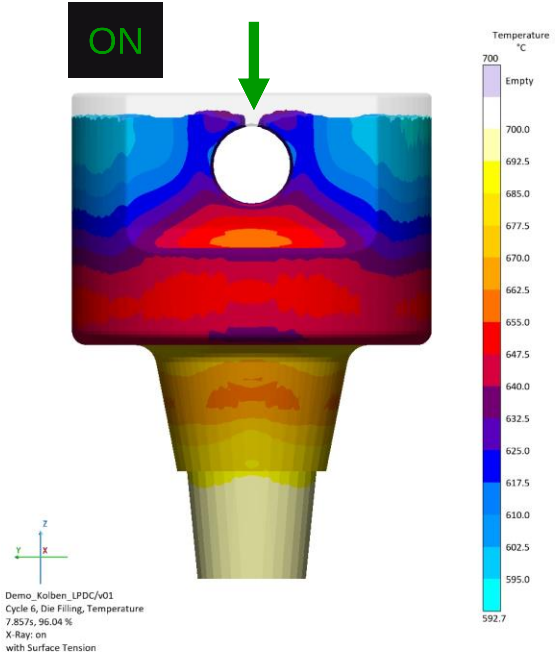
Pressure

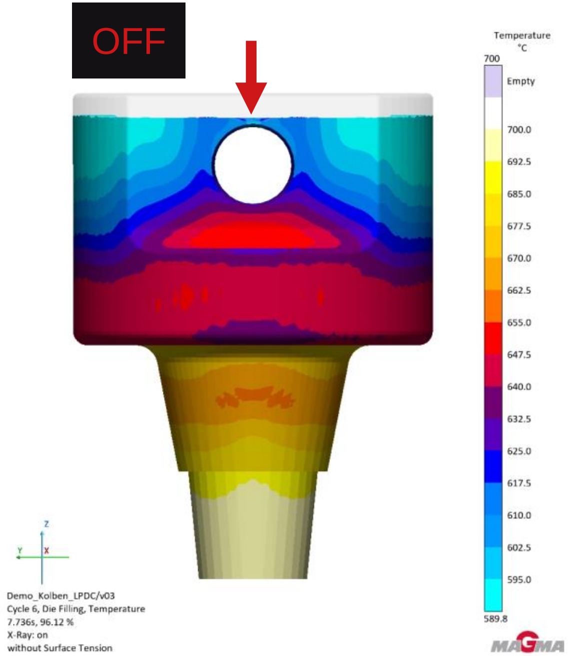


Surface Tension

Impact on the melt front

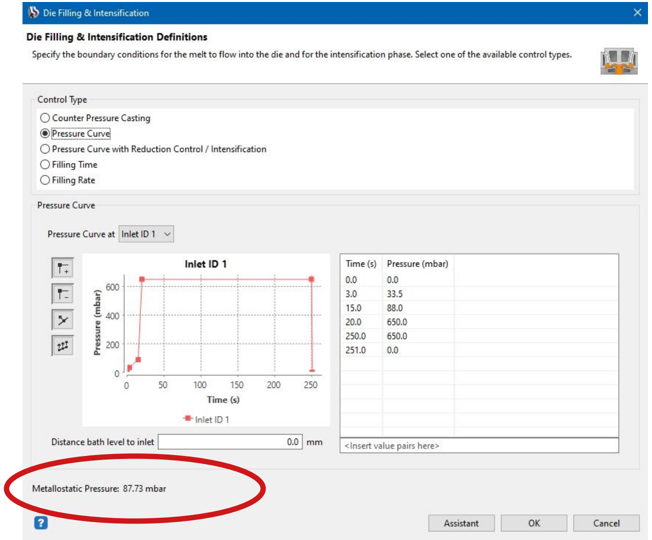
Surface Tension



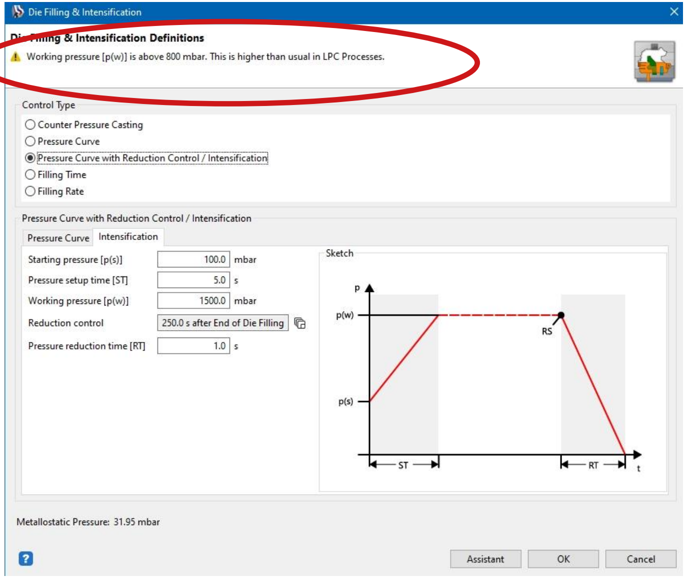


LPDC / Wheel / CPC 6.1

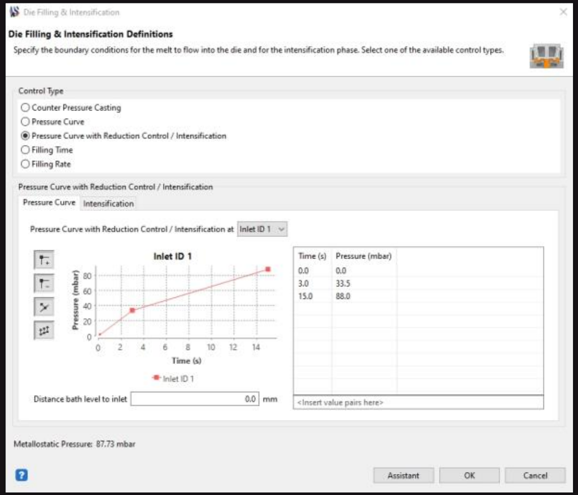
Helpful changes in the definition



The required metallostatic pressure is permanently displayed



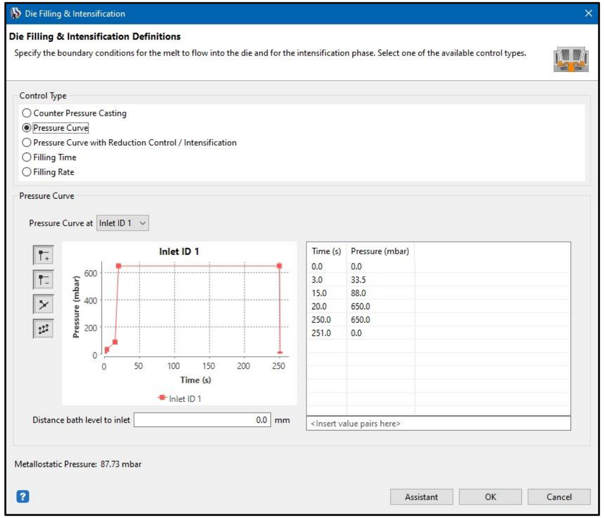
If you define **pressures** that are **too high**, you **lose** your **porosity** that's why there is a warning for high pressures

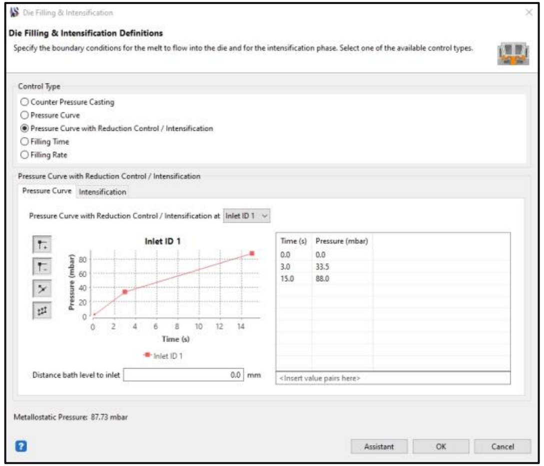


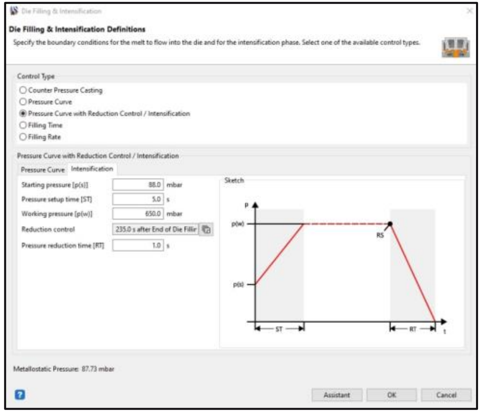
Pressure Dependent Feeding

Pressure Dependent Feeding

- From MAGMASOFT® 6.1 onwards, the feeding is also calculated in LPDC/Wheel depending on the intensification pressure
- Regardless of the selected pressure option, the defined working pressure will result in an improved feeding







Pressure Dependent Feeding

Calculation δf_s

Starting from the momentum equation, taking into account an interdendritic term, a non-linear equation can be derived.

$$\frac{\partial}{\partial t}\rho\bar{v} + \nabla\cdot\left(\rho\bar{v}\,\bar{v}\right) = -\nabla p + \nabla\cdot\left(\mu\nabla\bar{v}\right) + \rho\bar{g} - \frac{\mu}{\kappa}\bar{v}$$

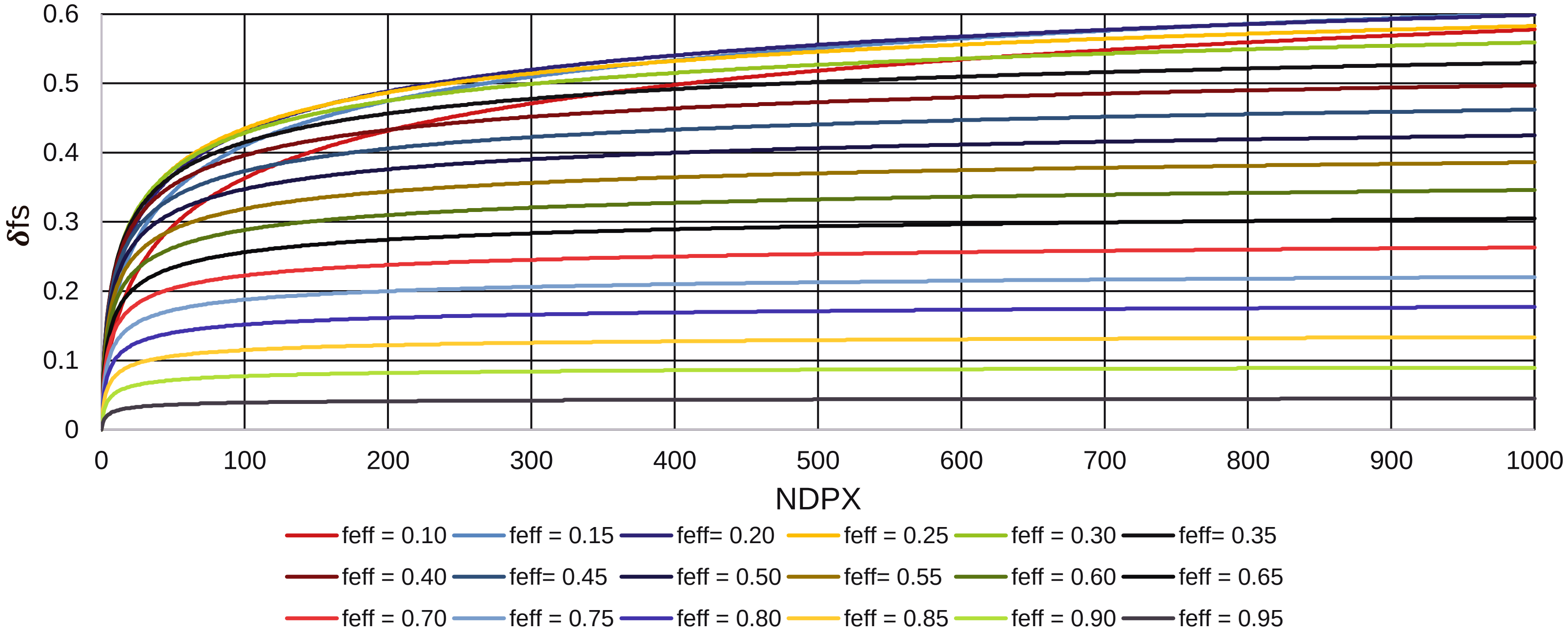
$$(1 - f_s)^3(f_s + \delta f_s)^2 = f_s^2[1 - f_s - \delta f_s]^3(1 + NDPX)$$

$$NDPX = \frac{\delta p}{\rho g x}$$

If the applied pressure $\boldsymbol{\delta p}$ is known, and the height x, NDPX can be calculated. For $f_s = f_{eff}$, the calculation is derived by solving the nonlinear δf_s equation.

LPDC Porosity Calculation

Lpdctable ($NDPX$)

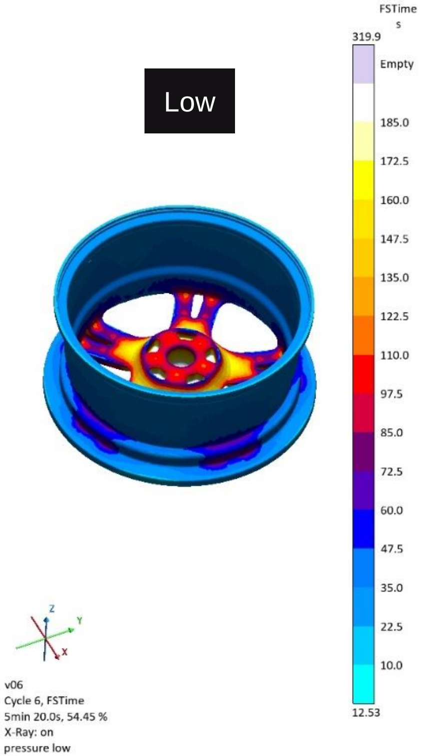


Pressure Dependent Feeding

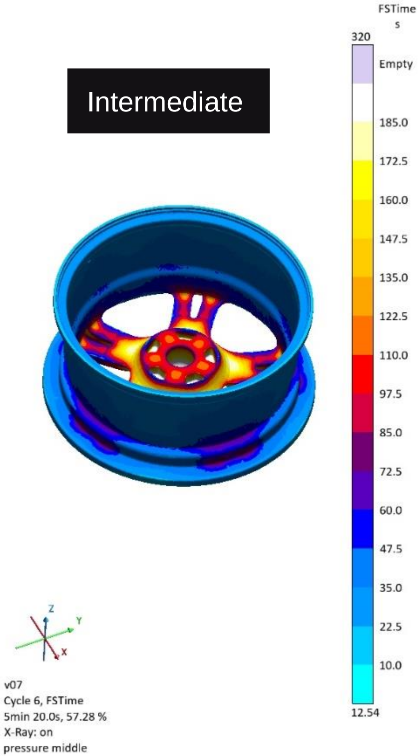
FSTime

Pressure

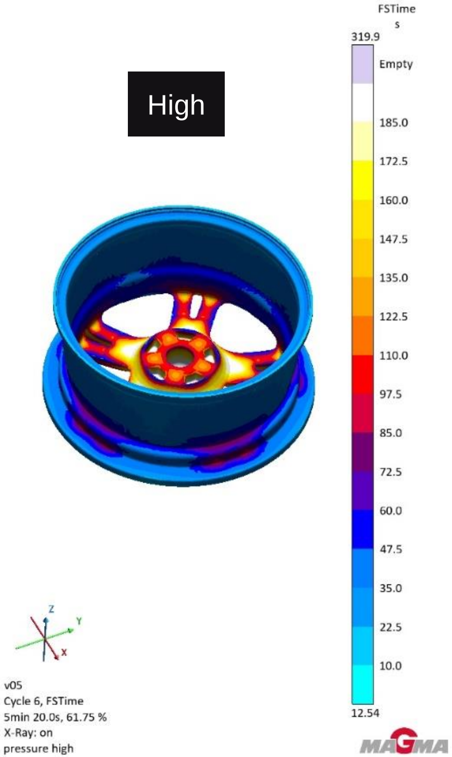
Low



Intermediate



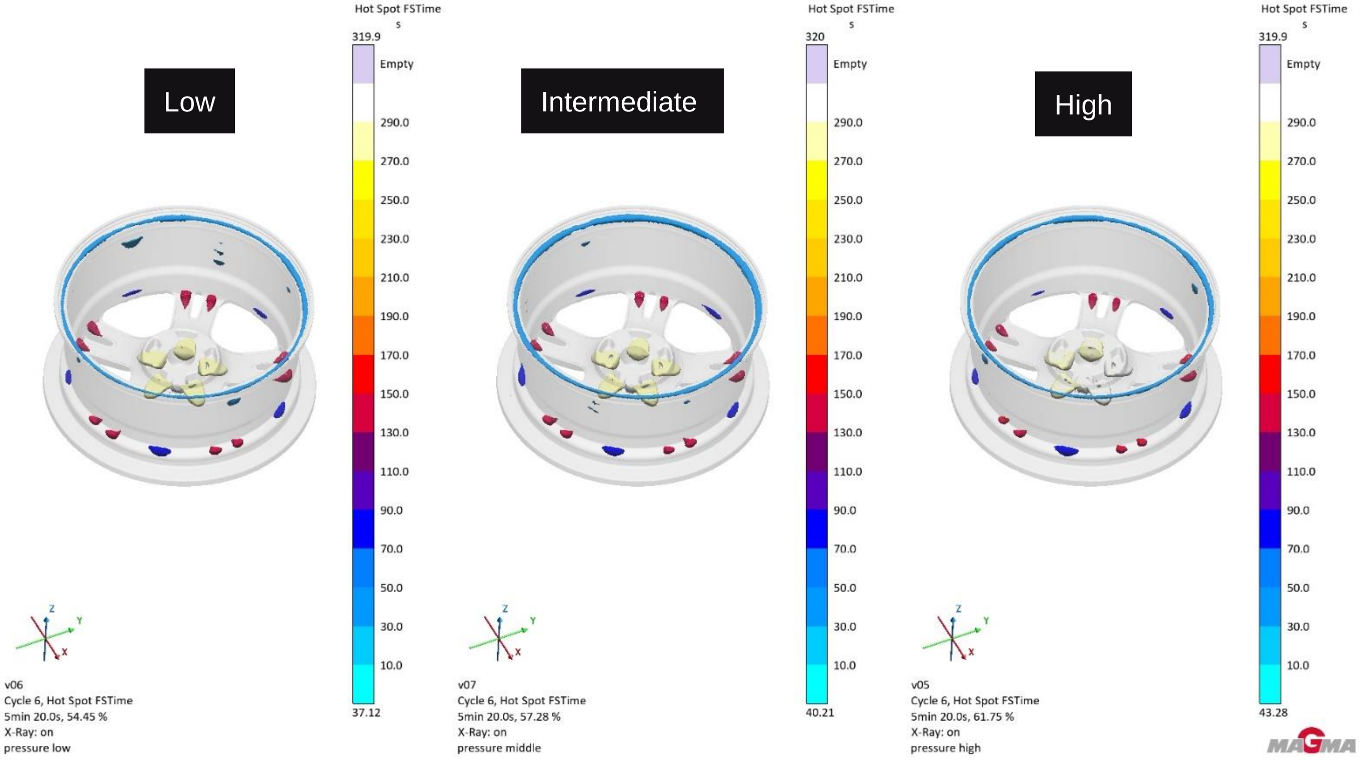
High



Pressure Dependent Feeding

Hot Spot FSTime

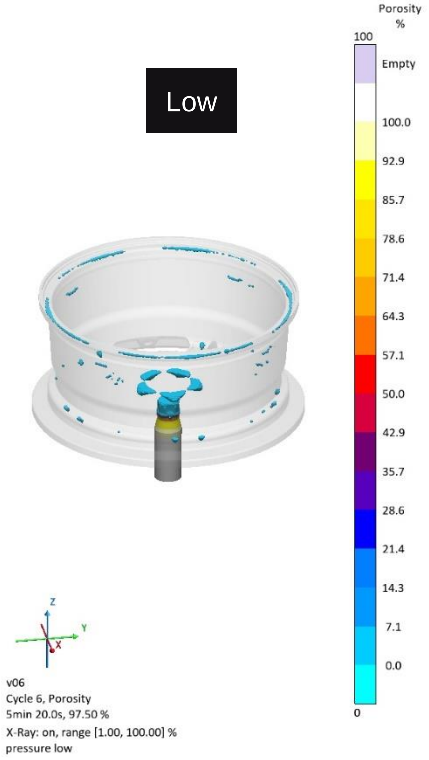
Pressure → Low | Intermediate | High

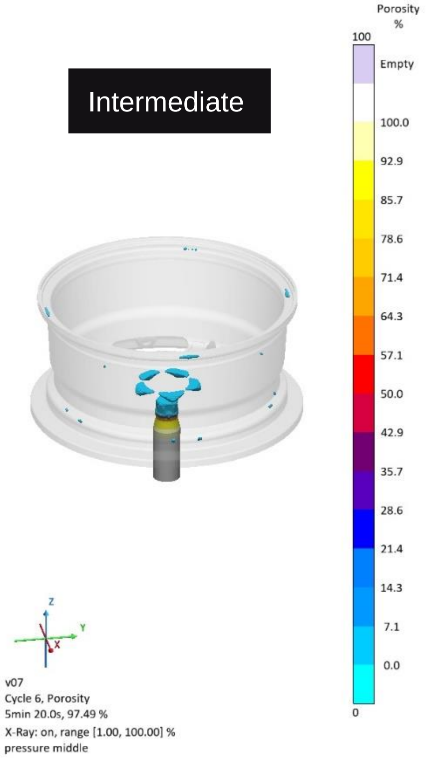


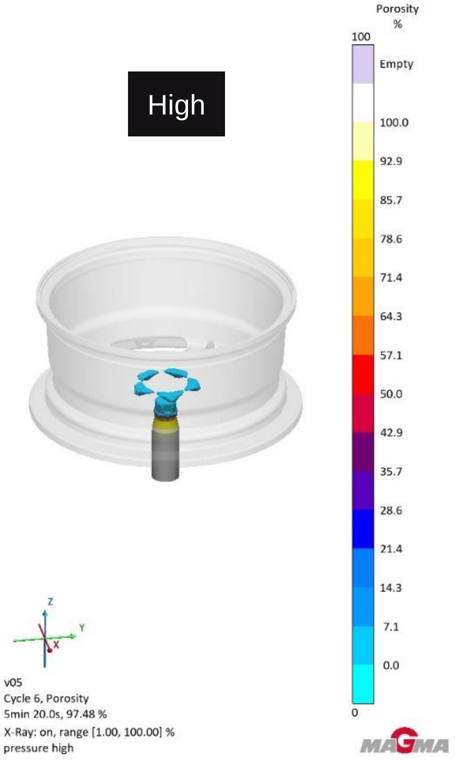
Pressure Dependent Feeding

Porosity

Pressure → Low | Intermediate | High



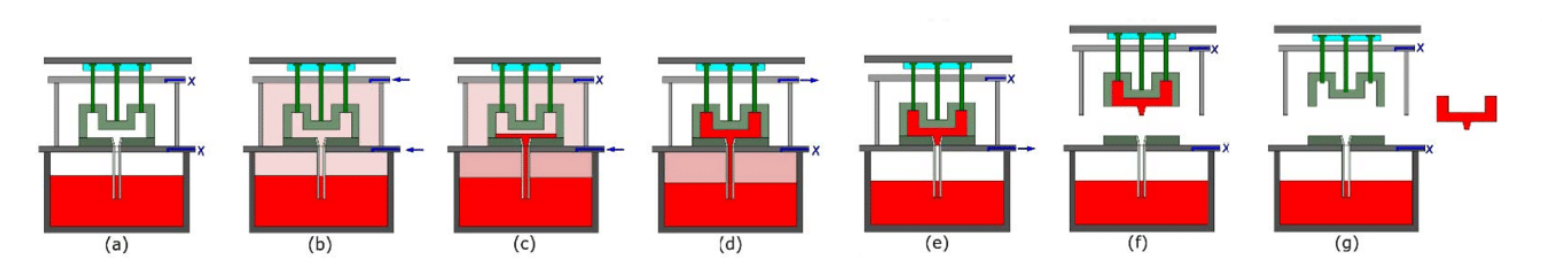




Pressure Dependent Feeding

What to consider?

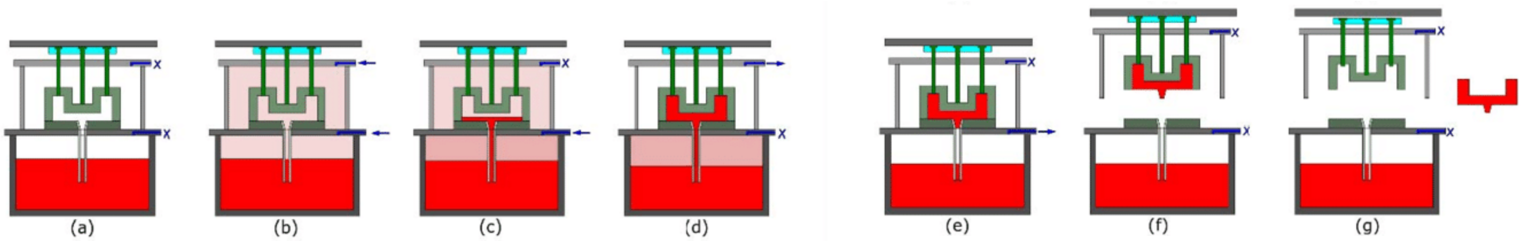
- The pressure dependent feeding model is based on the feeding effectivity (FE) of the database (30% - 40%),
- Many users have adapted the FE in the past to achieve a better match with reality,
- If your processes work with working pressures of 200 to 600 mbar, **reset the FE to the original database** values in 6.1



Counter Pressure Casting (CPC)

CPC in MAGMASOFT ® 6.1

Schematic process

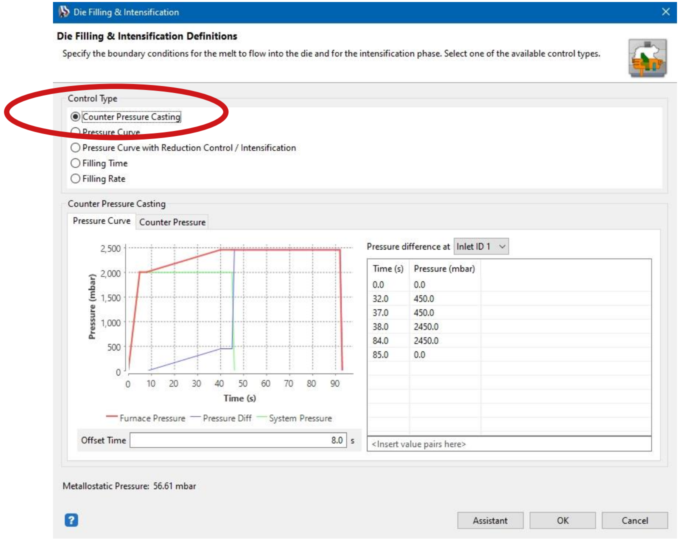


a. Die close
b. Build-up counter pressure
c. Die filling
d. Releasing counter pressure
e. Releasing furnace pressure
f. Die open
g. Eject casting

CPC in MAGMASOFT ® 6.1

Modeling in MAGMASOFT ®

- Counter Pressure Casting is created as a normal LPDC project,
- The differences between CPC and classic low-pressure casting are taken into account in the filling definition,

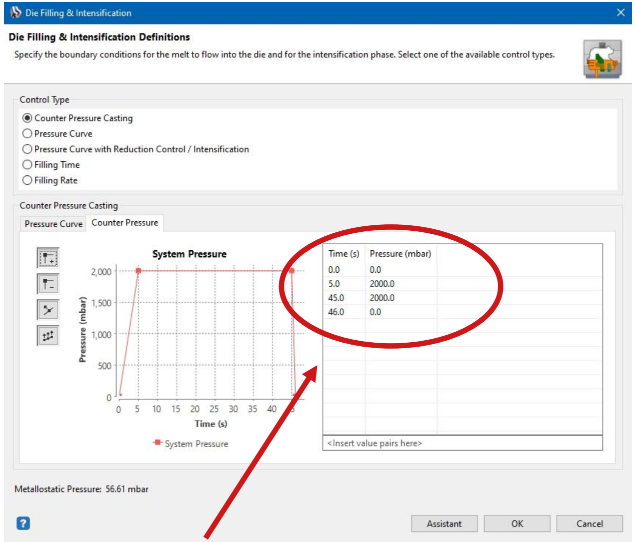


For CPC there is a new control type in the fill definition

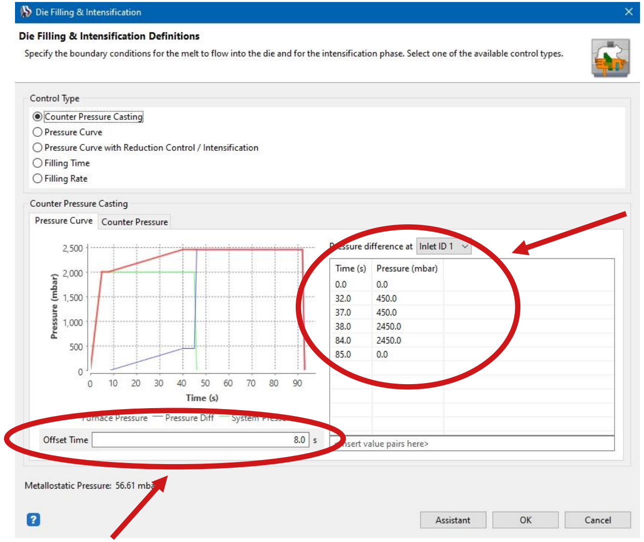
CPC in MAGMASOFT ® 6.1

Modeling in MAGMASOFT ®

- A CPC filling definition is done by two pressure curves



Input of counter pressure (b)



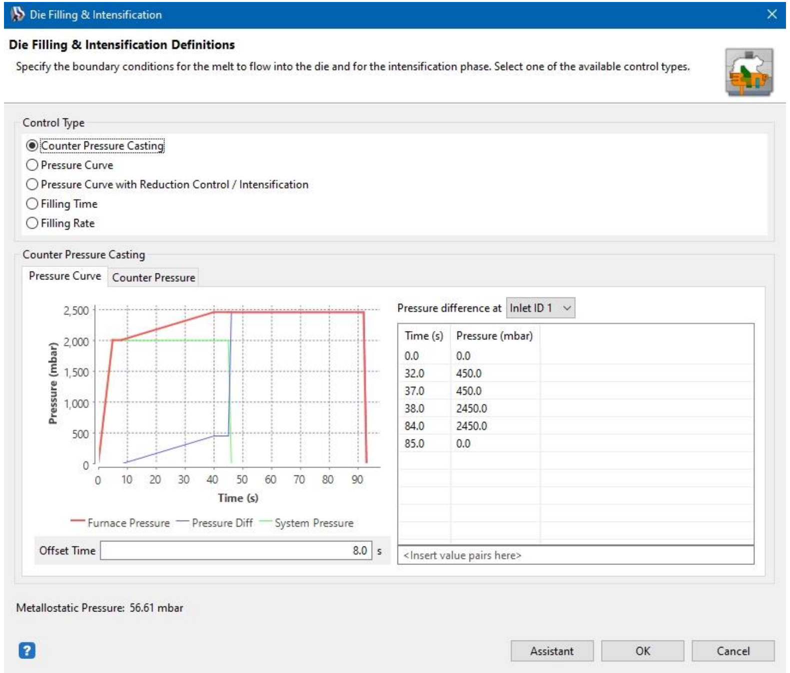
Input of difference pressure (blue line)

For the required level of differential pressure you can also use the "Assistant"

After the "offset time" has elapsed, the die filling starts

CPC in MAGMASOFT ® 6.1

Modeling in MAGMASOFT ®



It is assumed that all CPC machines carry out an automatic correction of the metal height in the riser tube
Therefore it is not possible to define a height difference between the melt level and the inlet

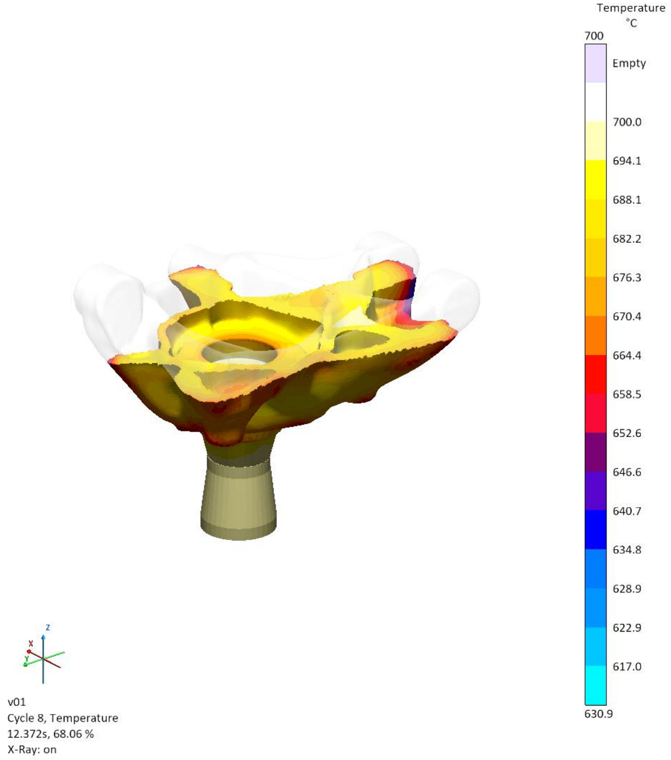
For CPC the inlet must be modeled and meshed at the height of the melt level

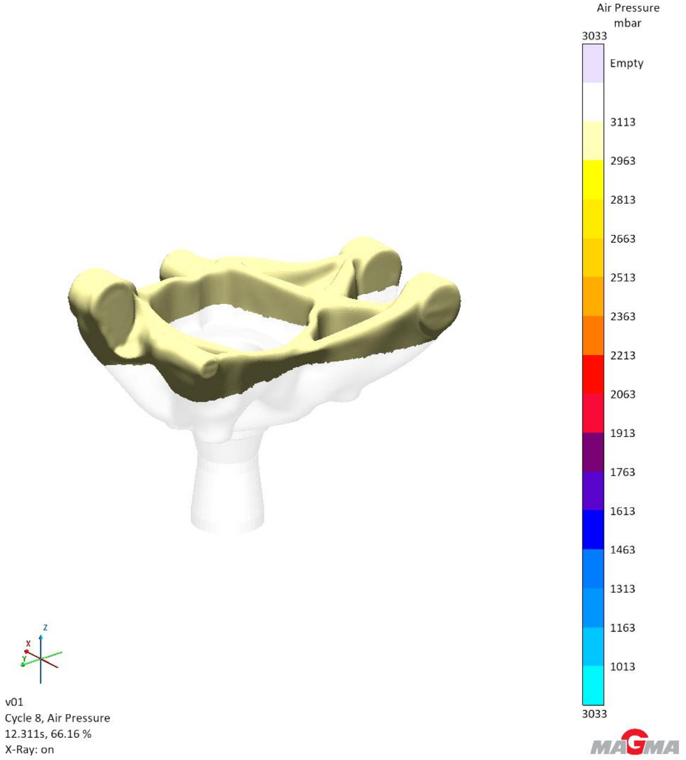
The difference pressure (blue line) and the counter pressure (green line) are added together to give the furnace pressure (red line)

CPC in MAGMASOFT ® 6.1

Temperature

Air Pressure





Pressure Drop

LPDC / Wheel / CPC 6.1

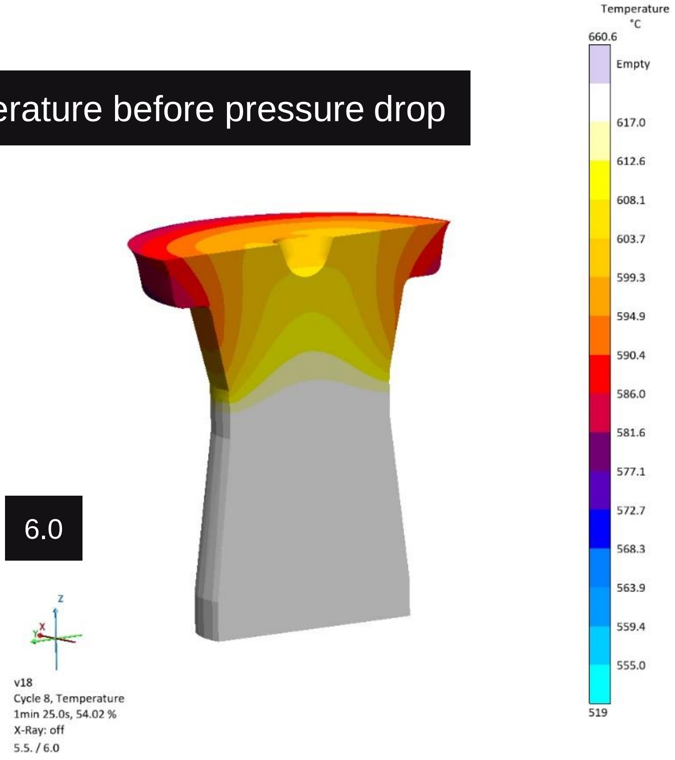
Behavior in case of pressure drop

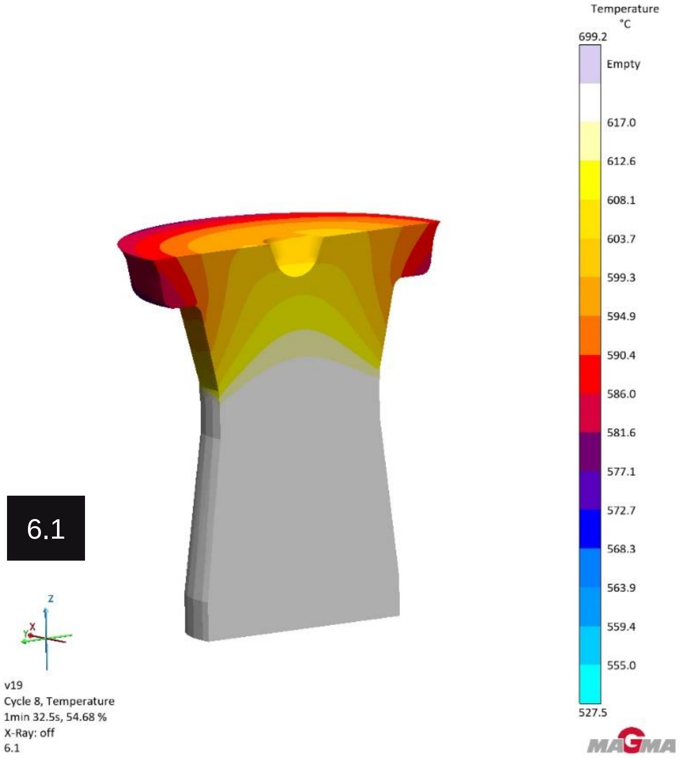
- There is an important difference in the behavior of the melt in case of pressure reduction.
- In 6.0 (and earlier) all the material, that had not yet reached the critical feeding effectivity, was removed from the model.
- From 6.1 onwards not all the material but only the liquid part will flow back into the furnace.

LPDC / Wheel / CPC 6.1

Behavior in case of pressure drop

Temperature before pressure drop

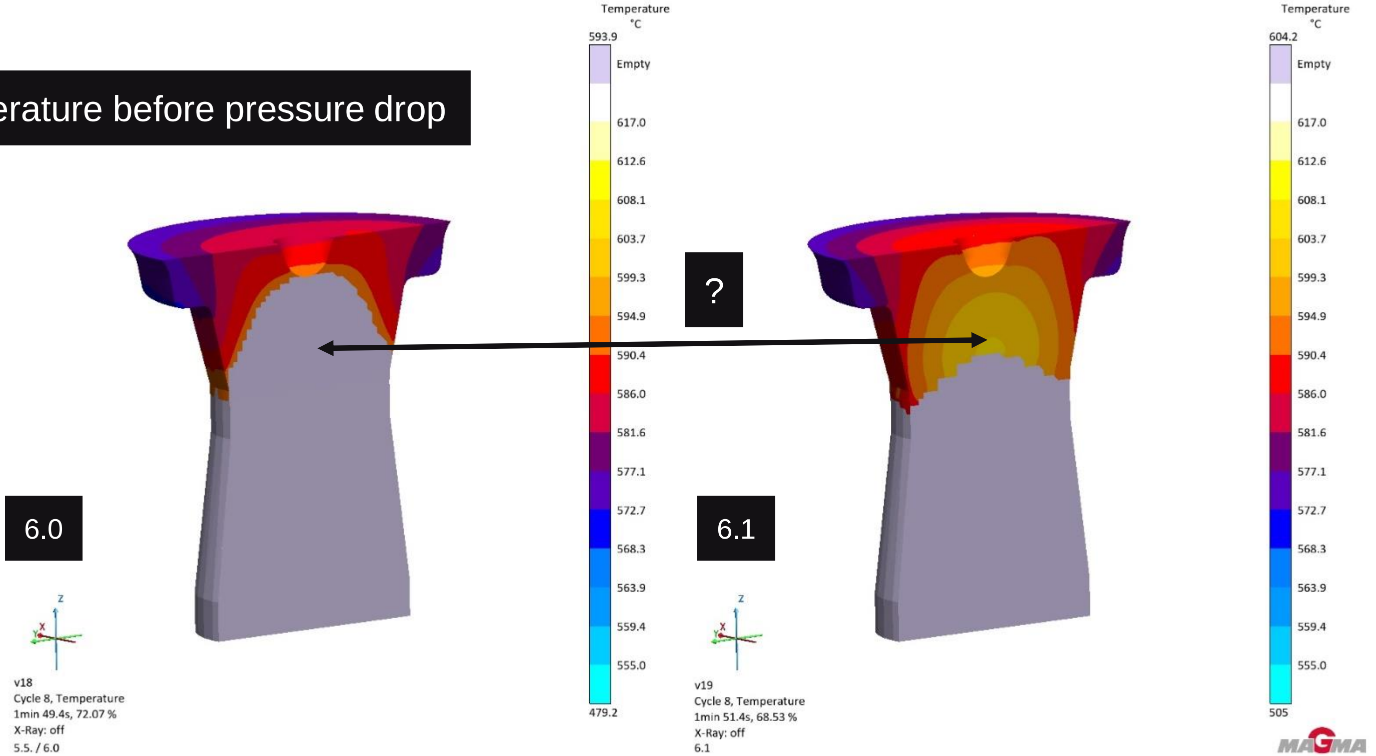




LPDC / Wheel / CPC 6.1

Behavior in case of pressure drop

Temperature before pressure drop

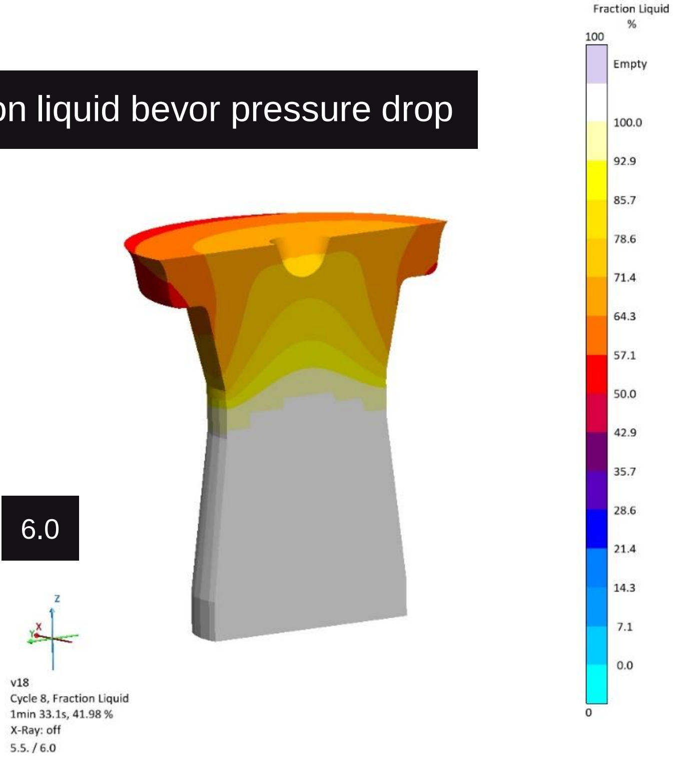


LPDC / Wheel / CPC 6.1

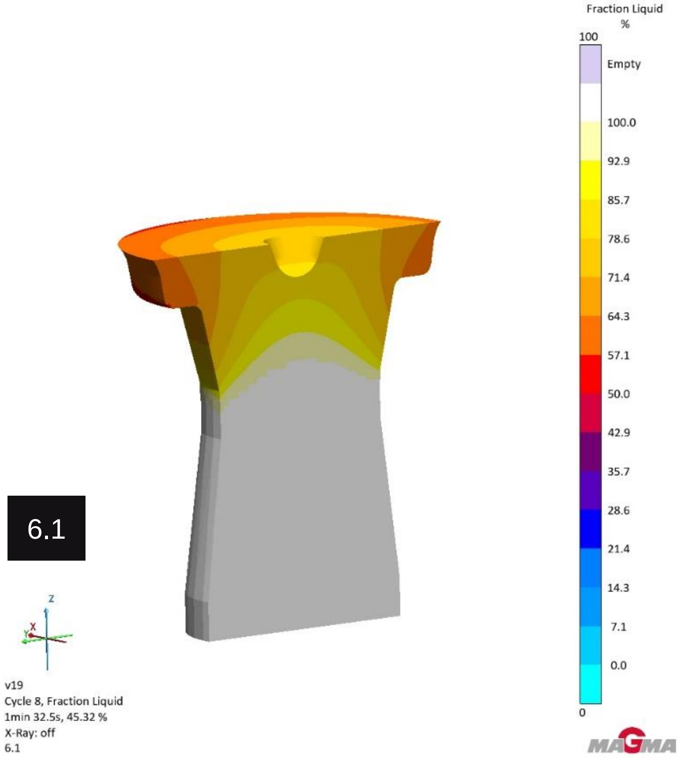
Behavior in case of pressure drop

Fraction liquid bevor pressure drop

6.0



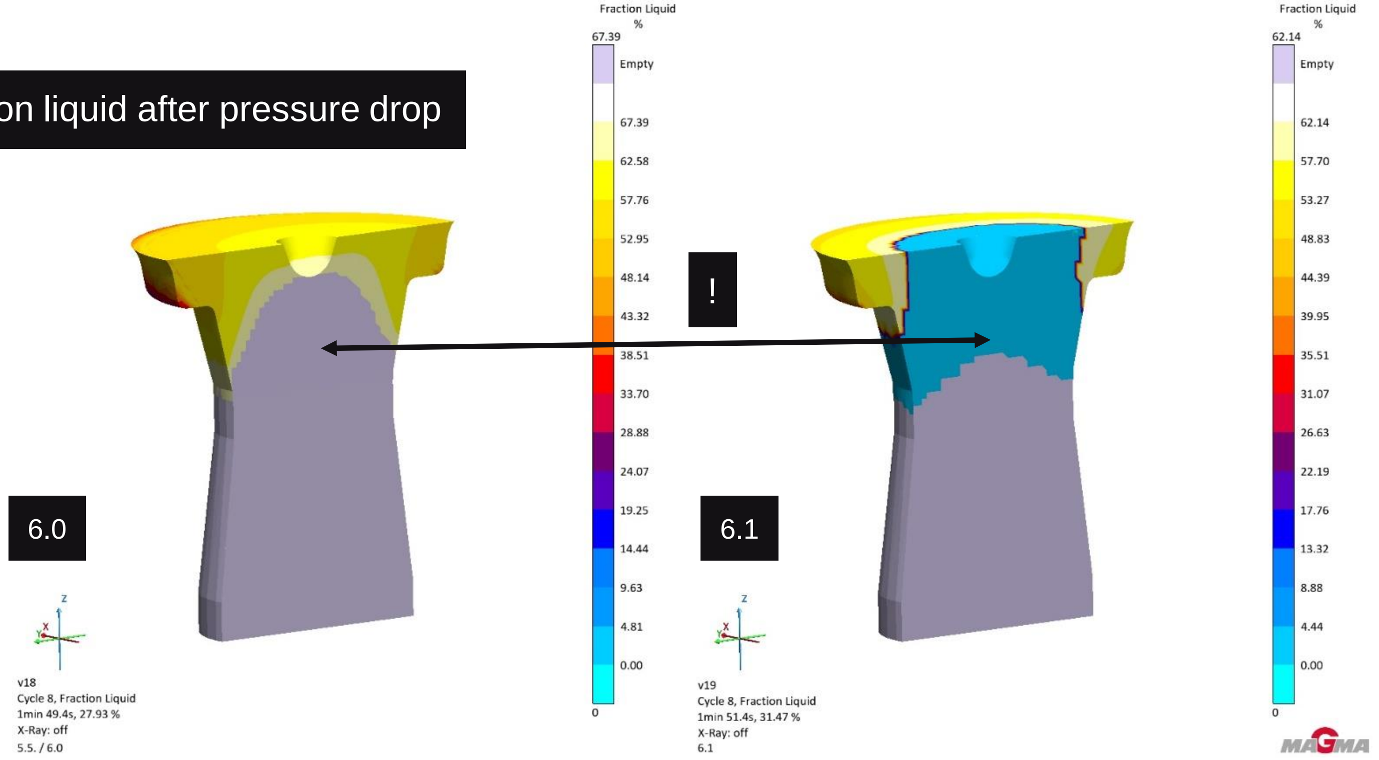
6.1



LPDC / Wheel / CPC 6.1

Behavior in case of pressure drop

Fraction liquid after pressure drop



External Boundaries

Specify the datasets used for external boundary conditions.

External Boundary	Description	Database/Filename
All External Boundaries (LPDC)	Boundary condition for all materials (except feeder) in contact with environment for LPDC process	MAGMA/default.enviro100
Blowing	Boundary condition for all mold materials considered in blowing process	MAGMA/default.blow
Coating	Boundary condition for all mold materials considered in coating process	MAGMA/default.coat
Die Closed	Boundary condition for mold - cavity neighborhoods after die has been closed and before cavity is filled	MAGMA/default.enviro100
Die Insert	Boundary condition for insert materials in contact with environment	MAGMA/default.enviro100
Die Opened (LPDC)	Boundary condition for all materials in contact with environment after die has been opened for LPDC process	MAGMA/default.enviro100
Dipping	Boundary condition for all mold materials considered in dipping process	MAGMA/default.dip
External Cooling/Shake Out/Removing Casting System	Boundary condition for all materials in contact with environment during treatment after casting	MAGMA/default.enviro20
Feeder Surface	Boundary condition for feeder materials in contact with environment	MAGMA/default.enviro100
Spraying	Boundary condition for all mold materials considered in spraying process	MAGMA/default.spray
Tempering	Boundary condition for tempering channel in contact with tempering inflow or tempering outflow	MAGMA/default.enviro100
Tempering Channel Off	Boundary condition for inactive tempering channels	MAGMA/default.cool

OK Cancel

Modified Boundary Conditions

LPDC / Wheel 6.1

Modified Boundary Conditions

External Boundaries

External Boundaries

Specify the datasets used for external boundary conditions.

6.0

External Boundary	Description	Database/Filename
All External Boundaries (LPDC)	Boundary condition for all materials (except feeder) in contact with environment for LPDC process	MAGMA/default.lpdc
Blowing	Boundary condition for all mold materials considered in blowing process	MAGMA/default.blow
Coating	Boundary condition for all mold materials considered in coating process	MAGMA/default.coat
Die Closed	Boundary condition for mold - cavity neighborhoods after die has been closed and before cavity is filled	MAGMA/default.dc
Die Insert	Boundary condition for insert materials in contact with environment	MAGMA/default.insert
Die Opened (LPDC)	Boundary condition for all materials in contact with environment after die has been opened for LPDC process	MAGMA/default.lpdcdo
Dipping	Boundary condition for all mold materials considered in dipping process	MAGMA/default.dip
External Cooling/Shake Out/Removing Casting System	Boundary condition for all materials in contact with environment during treatment after casting	MAGMA/default.shaout
External Cooling/Shake Out/Removing Casting System	Boundary condition for all materials in contact with environment during treatment after casting	MAGMA/default.shaout
Feeder Surface	Boundary condition for feeder materials in contact with environment	MAGMA/default.12
Spraying	Boundary condition for all mold materials considered in spraying process	MAGMA/default.spray
Tempering	Boundary condition for tempering channel in contact with tempering inflow or tempering outflow	MAGMA/default
Tempering Channel Off	Boundary condition for inactive tempering channels	MAGMA/default.cool

External Boundaries

External Boundaries

Specify the datasets used for external boundary conditions.

6.1

External Boundary	Description	Database/Filename
All External Boundaries (LPDC)	Boundary condition for all materials (except feeder) in contact with environment for LPDC process	MAGMA/default.enviro100
Blowing	Boundary condition for all mold materials considered in blowing process	MAGMA/default.blow
Coating	Boundary condition for all mold materials considered in coating process	MAGMA/default.coat
Die Closed	Boundary condition for mold - cavity neighborhoods after die has been closed and before cavity is filled	MAGMA/default.enviro100
Die Insert	Boundary condition for insert materials in contact with environment	MAGMA/default.enviro100
Die Opened (LPDC)	Boundary condition for all materials in contact with environment after die has been opened for LPDC process	MAGMA/default.enviro100
Dipping	Boundary condition for all mold materials considered in dipping process	MAGMA/default.dip
External Cooling/Shake Out/Removing Casting System	Boundary condition for all materials in contact with environment during treatment after casting	MAGMA/default.enviro20
Feeder Surface	Boundary condition for feeder materials in contact with environment	MAGMA/default.enviro100
Spraying	Boundary condition for all mold materials considered in spraying process	MAGMA/default.spray
Tempering	Boundary condition for tempering channel in contact with tempering inflow or tempering outflow	MAGMA/default.enviro100
Tempering Channel Off	Boundary condition for inactive tempering channels	MAGMA/default.cool

? OK Cancel

When the boundary for gravity die casting was changed from 5.5 to 6.0, only the names were changed, so there was no influence on the results.

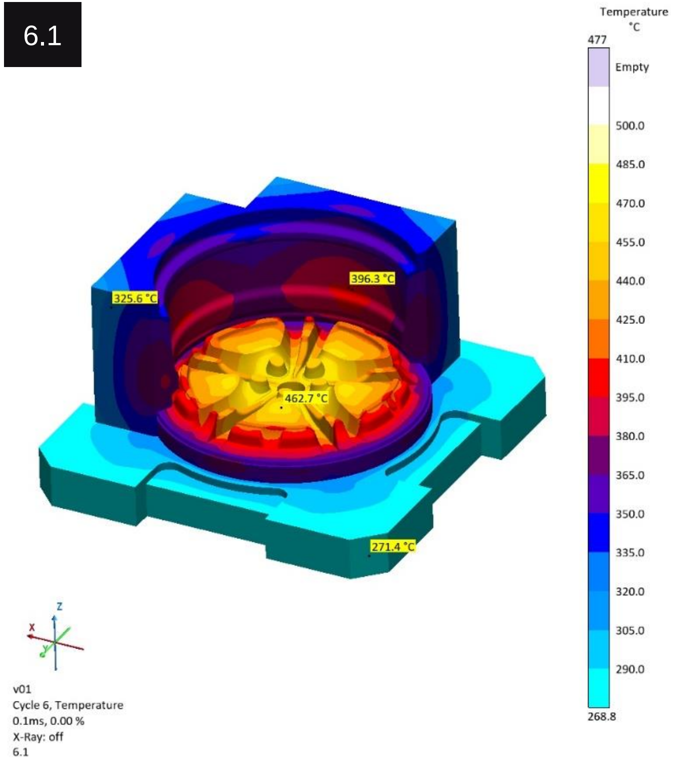
The changes to LPDC do not only affect the names. The **radiation coefficient** was changed from 0.3 to 0.8.

This means that in 6.1 more radiation energy is released into the environment. Lower die temperatures are calculated.

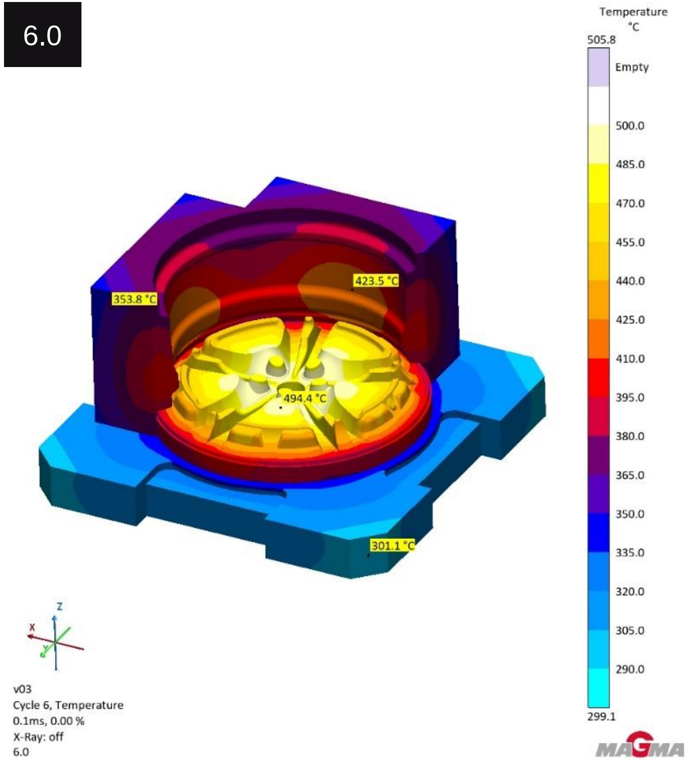
LPDC / Wheel 6.1

Die Temperature @ Start Filling

6.1

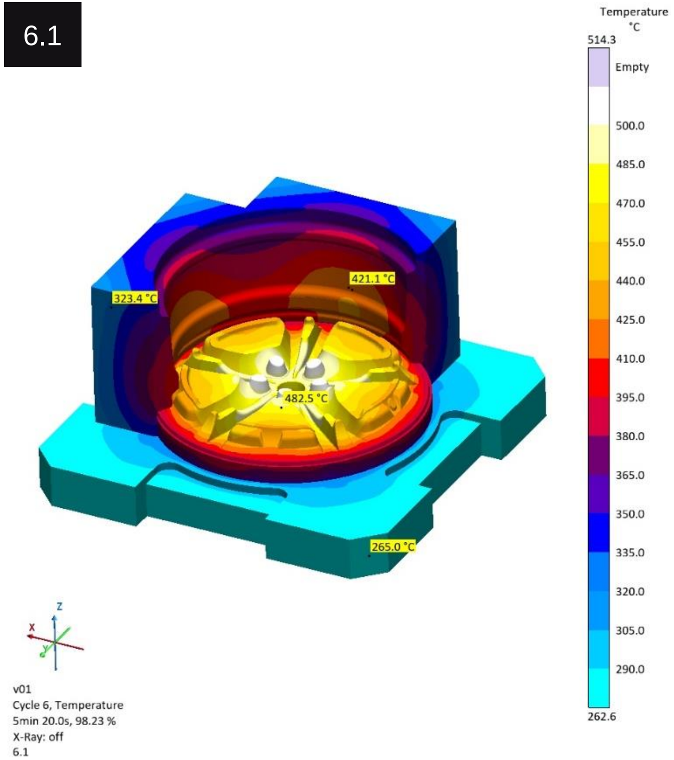


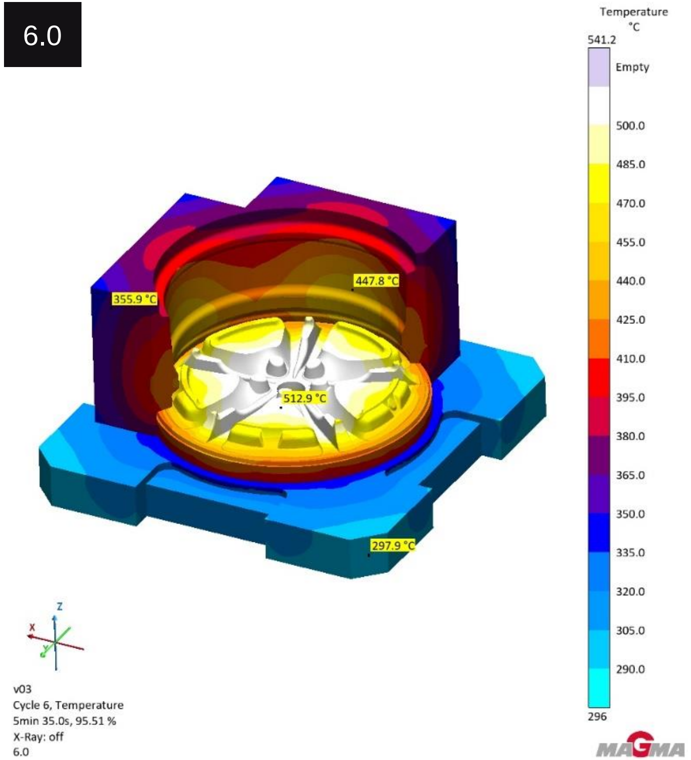
6.0



LPDC / Wheel 6.1

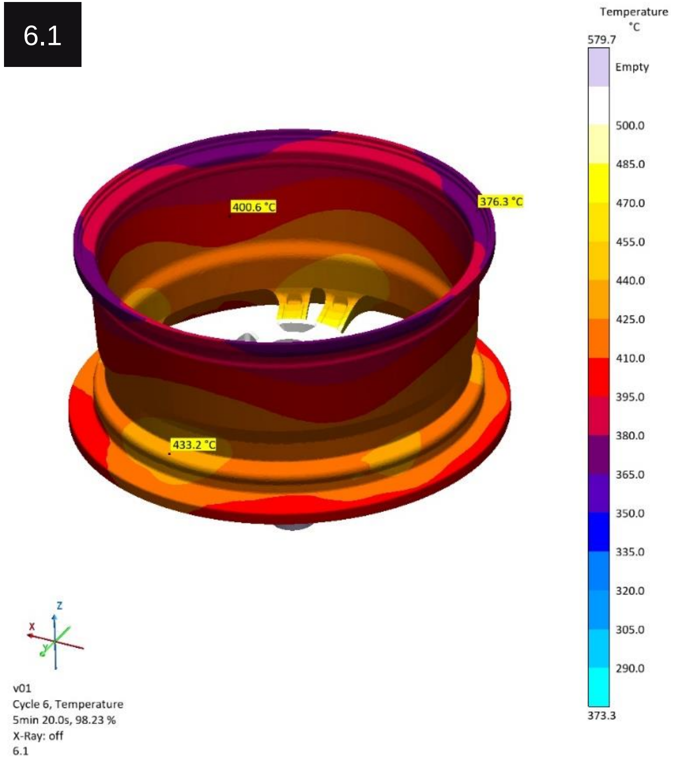
Die Temperature @ End of Cycle

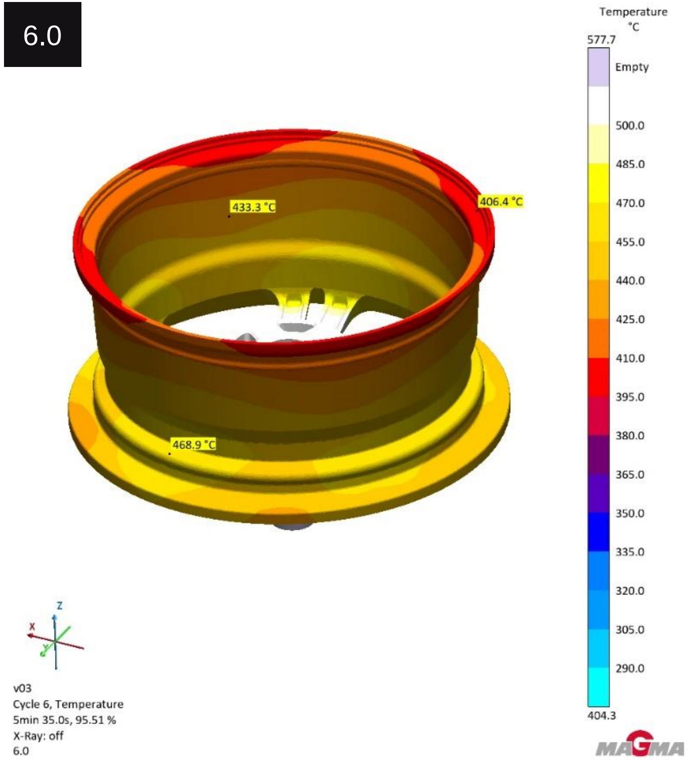




LPDC / Wheel 6.1

Casting Temperature @ End of Cycle





LPDC / Wheel 6.1

Modified Boundary Conditions - What to consider?

- Many customers have reported that despite using exact real parameters, the calculated temperatures in the mold are too high.
- A demo project shows a reduction in temperature of around 30 °C under identical conditions due to changed boundary conditions.
- This difference can be higher or lower in the specific case, depending on the materials used and the process parameters set.

- *There is no obligation to use the suggested boundary conditions. We believe that the new values reflect reality better and have therefore made them to default. Each user can of course use their own values, if this makes the results more realistic.*

LPDC / Wheel 6.1

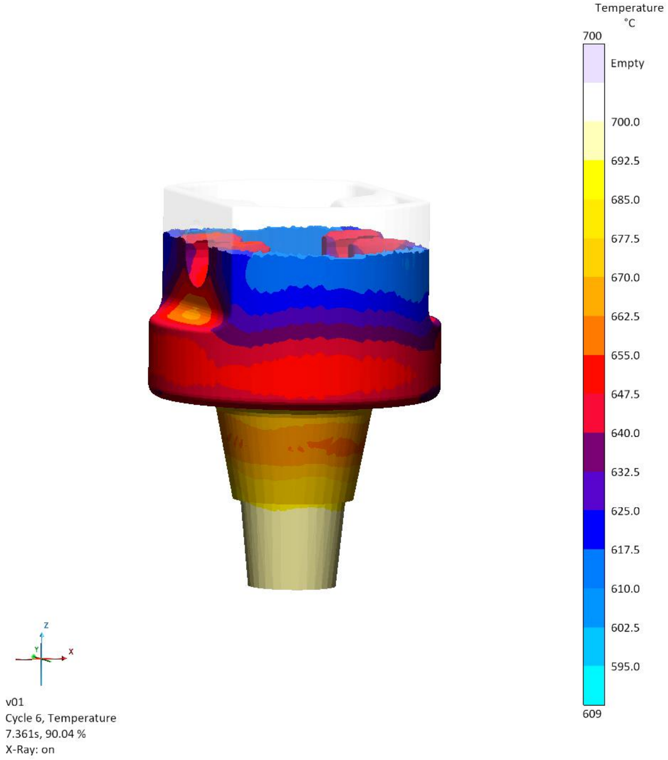
Modified Boundary Conditions - What to consider?

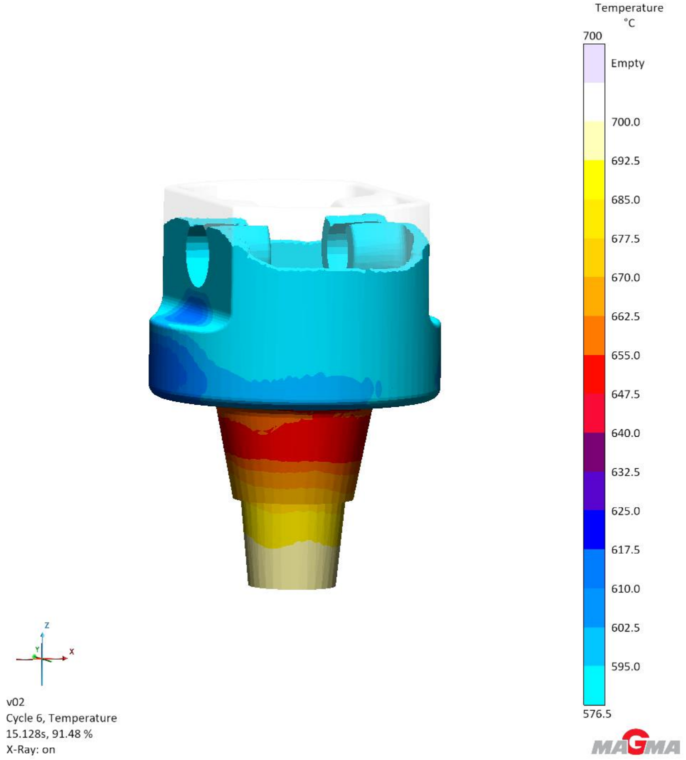
- The **new boundary** conditions are only active when a **new** LPDC/Wheel/CPC **project** is created in 6.1.
- Projects **converted** from 6.0 (or earlier) retain the **old** boundary conditions.
- “***New Project from Version/Design***..” are not new 6.1 projects, but copies of the old versions, so in terms of status they correspond to converted projects.
- If you want to change the boundary conditions for converted projects, you can do this manually in the “Heat Transfer Definition” - right-click “External Boundaries..”

Cold Run

New Solver and Cold Run

Examples



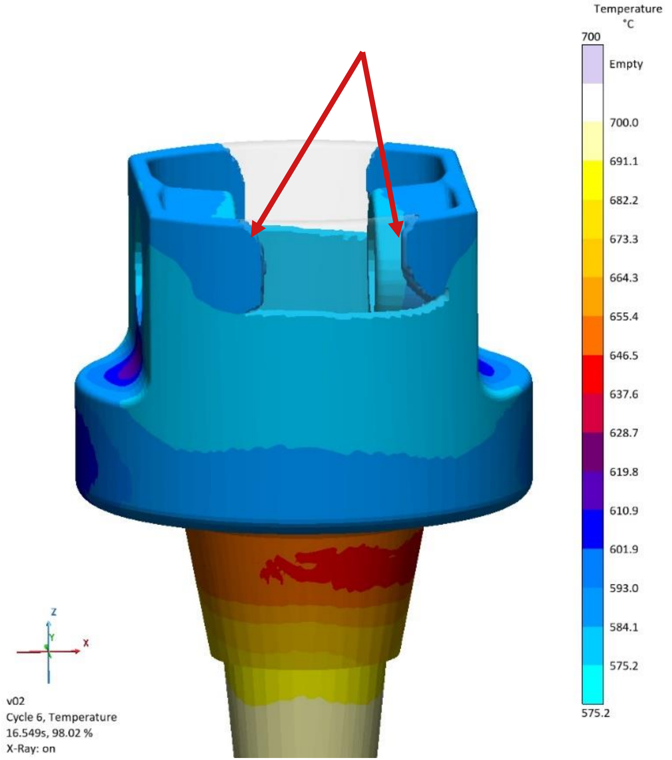


Slower pressure increase

→ Longer filling time,
→ More temperature loss
→ High risk of cold run

New Solver and Cold Run

Examples



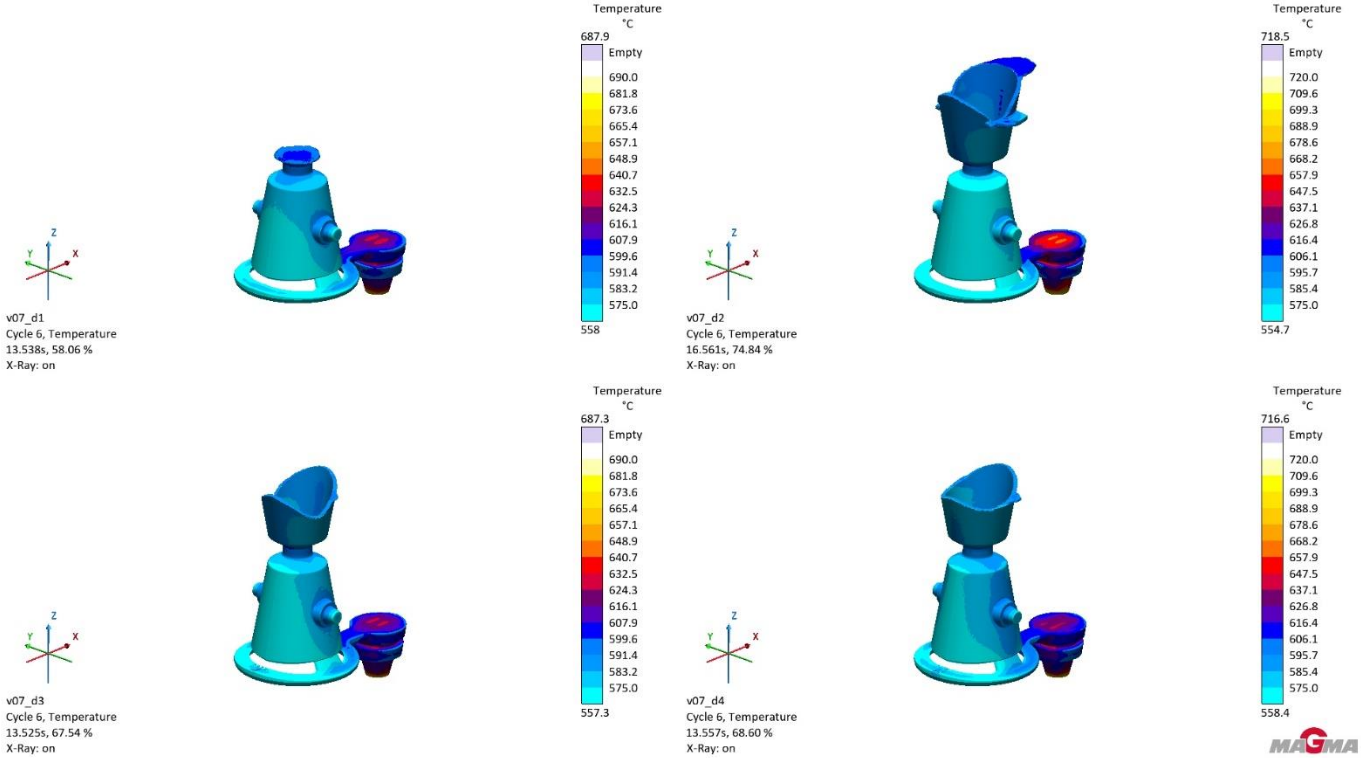
Why is the flow front different on the left and the right?

New Solver and Cold Run

Real experiments with different temperatures and filling pressures

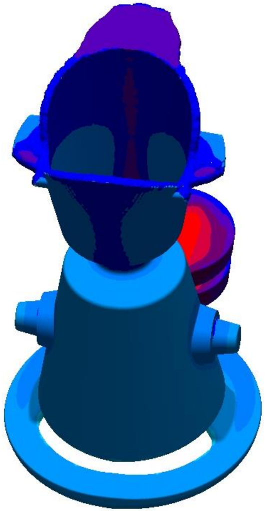
New Solver and Cold Run

Virtual experiments with different temperatures and filling pressures



New Solver and Cold Run

Examples – real vs. virtual



The tool halfs have the same temperatures

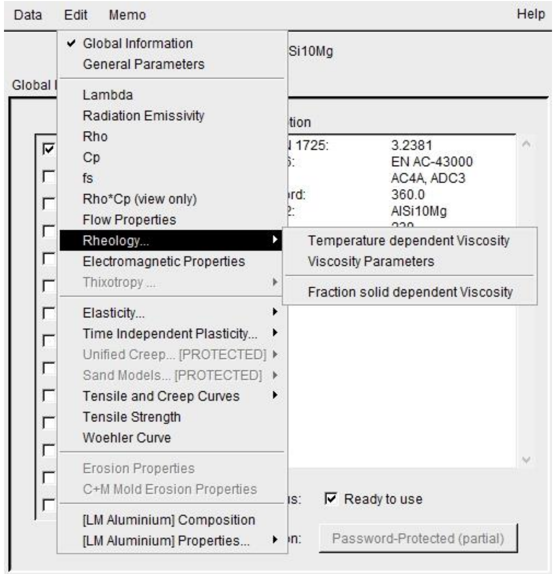
Left tool half has a lower temperature

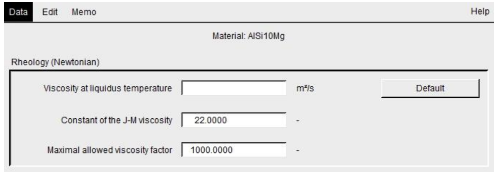
New Solver and Cold Run

- Viscosity is an important factor in flow behavior.
- The flow solver takes into account a fraction-solid-dependent viscosity

$$\nu = \nu_l \cdot e^{JM \cdot fs}$$

- ν – viscosity
- ν_l - liquid viscosity
- JM – const.
- fs – fraction solid





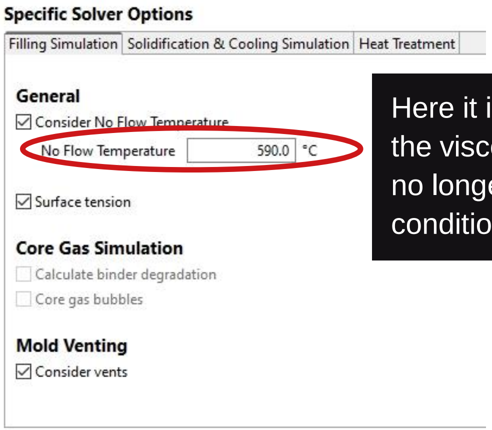
New Solver and Cold Run

- The current material data only cause a significant increase in viscosity at very low temperatures.
- This means that cold running problems are hardly visible, especially since many users also apply very “optimistic” parameters.
- With the help of some (customer) examples from practice, we have found material values that enable a better prediction.
- Our current recommendation:
  - Define the liquid viscosity at 10^{-5}
  - Use 46 as the J-M constant

New Solver and Cold Run

- With simplified models it is not always possible to “match" the true temperatures.
- In addition, the fluidity of a melt also depends on other, sometimes unknown factors (e.g. exact alloy composition, surface quality of the mold, melt treatment, etc.).

- Therefore, in the future there will be a simple input option for users with which the viscosity can be adjusted by MAGMASOFT.



Here it is defined, that at 590 °C the viscosity is so high that flow no longer occurs under normal conditions.

New Solver and Cold Run

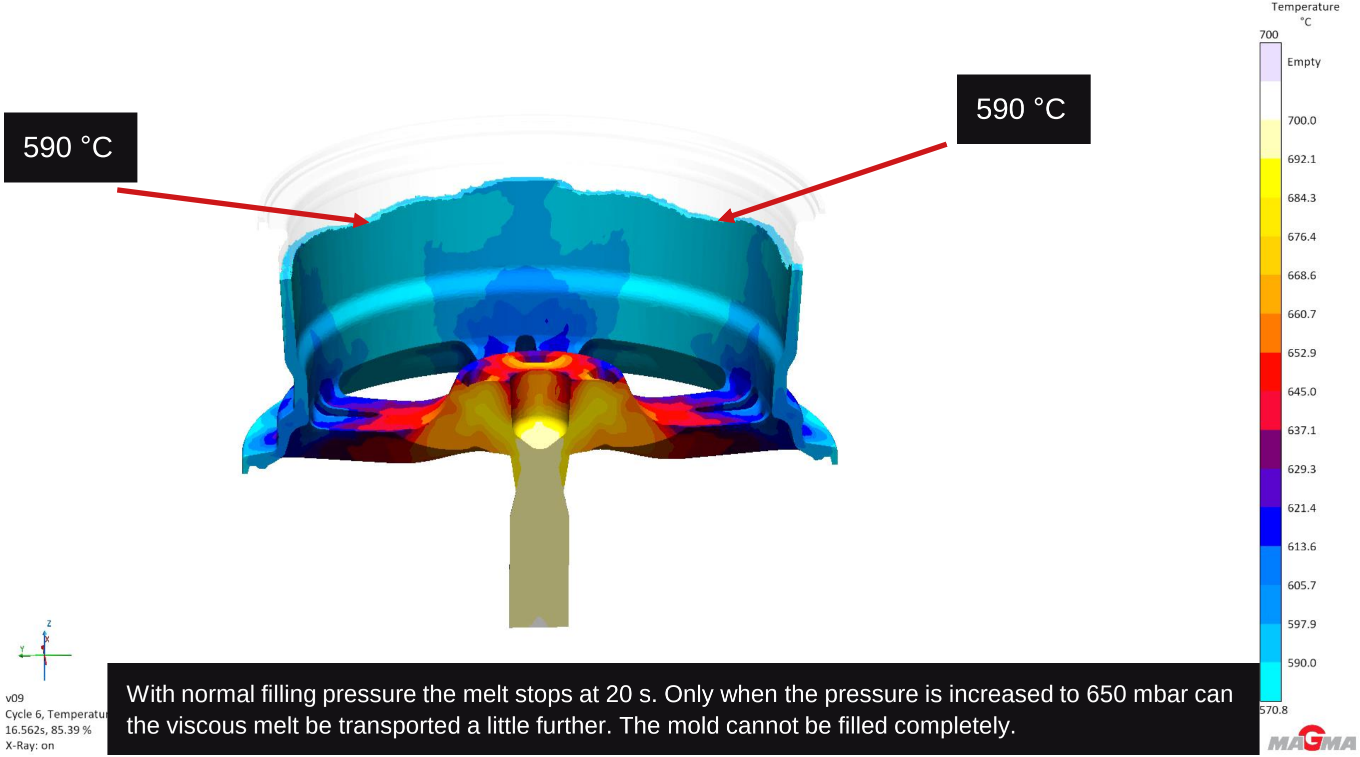
Velocity in an example part

New Solver and Cold Run

Temperature in an example part

Time (s)	Pressure (mbar)
0.0	0.0
3.0	33.5
20.0	88.0
25.0	650.0
250.0	650.0
251.0	0.0

<Insert value pairs here>



With normal filling pressure the melt stops at 20 s. Only when the pressure is increased to 650 mbar can the viscous melt be transported a little further. The mold cannot be filled completely.

Recommendations

Switching from 6.0 (or earlier) to 6.1

Some Recommendations

- The simulation **results** in 6.1 **will change** in all permanent mold processes (e.g. due to improved free surface calculation, improved venting model, bug fixing, ...).
- There are **small differences** in **permanent mold casting** and HPDC, in **LPDC/Wheel** the differences will be **larger**.
- You will **not** achieve **identical results**, but the casting statement will be identical.
- However, it should be noted that in gravity casting and LPDC the **solidification defects depend** considerably on the **temperature** field of the **filling** and that the most significant changes will occur in LPDC.

Switching from 6.0 (or earlier) to 6.1

Some Recommendations

- We generally recommend creating “**New Projects**” in the new software - this is the safest way but also the more complex.
- If you have created **new projects for GDC** in 6.0 and in **HPDC** after 5.4, converting to 6.1 is quite easy. In GeometryP it may be necessary to **update** the new **assembly groups**, otherwise you can continue working directly.

*If your **simulation project** will be completed in the foreseeable future (? 1/2 year..?), **stay** with **6.0**. Start **new projects** with the **latest software**.*

Switching from 6.0 (or earlier) to 6.1

Some Recommendations

- For **LPDC/Wheel**, we strongly recommend creating “**New Projects**” in order to use the new settings for the **boundary conditions**.
- Import the geometry from previous projects, meshing according to the new guidelines and define the process.

! ”New Project from Version..” is a copy of the old definition !

- Do not use old "master projects“
- If possible, use data from the current MAGMA database, if you use data from your userdb, compare it with the MAGMA data if necessary

Switching from 6.0 (or earlier) to 6.1

Some Recommendations

- It is not forbidden to **convert** old projects to 6.1
- **Remeshing** is mandatory,
- Use the preset default and initially only adjust the mesh parameters for the cast material so that approximately the same number of metal cells is generated.
- **Do not** try to mesh with the **old parameters without coarsening** - you will burn money.
- If you're coming from **before 6.0**, note the **change** in **cooling times**
- Use **current material data** if possible, necessary information for the new solver is not always available in "ancient" data

Thank you for your attention!

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