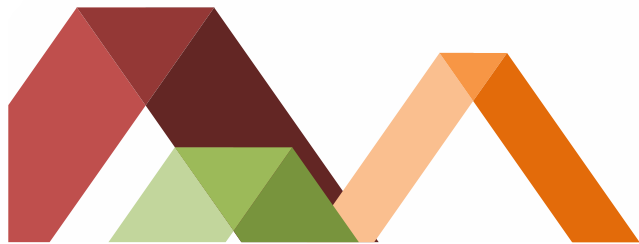




Cast-Designer V7.4 New Functions

May 2019



Cast-Designer V7.4

- Cast-Designer V7.4 is a major release version. It was released on May 2019.
- With more than 20 new functions and 200+ bug fix since Cast-Designer V7.3.

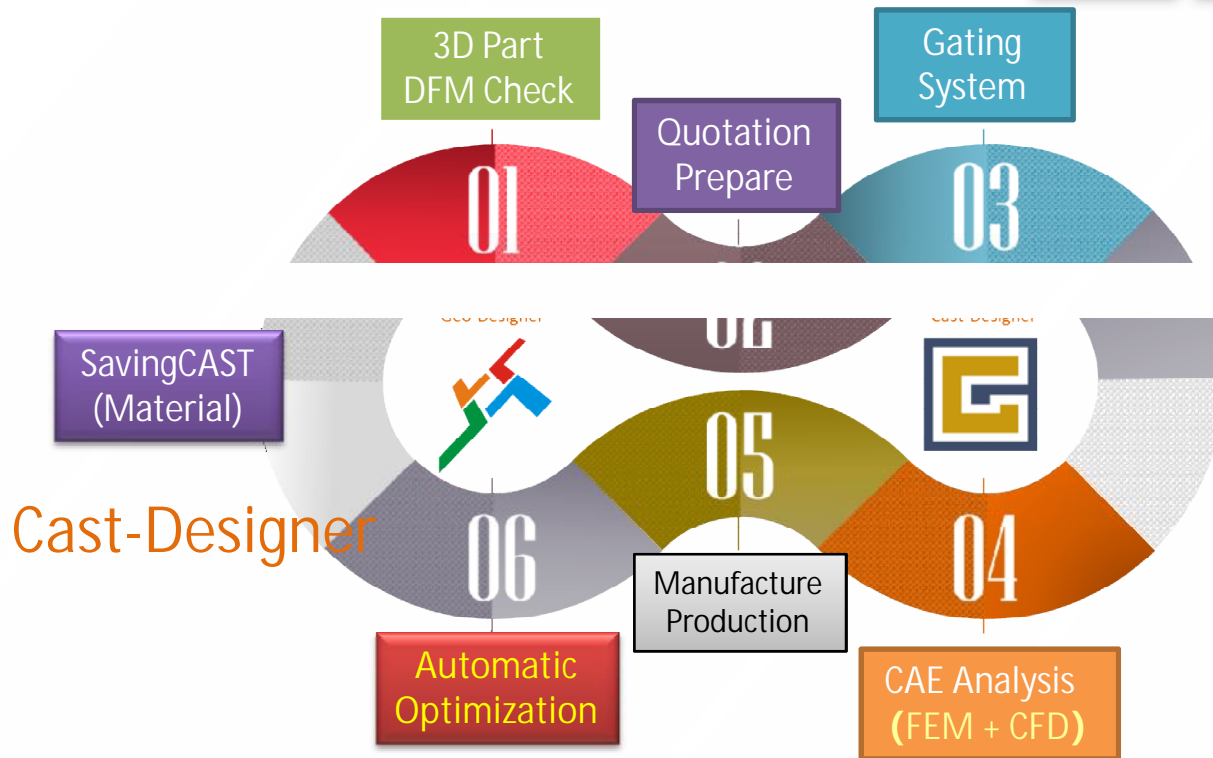
New module à **AI-CAST**, **CDCA**, **CDPE**, **ParaCAD**

Multi-Scale simulation, Global-Local model, Post solver, New gas model

Full CAD driven automatic optimization (Gating system, ParaCAD)

Powerful tools à Mould box, Chill generation, gating system wizard etc.

Cast-Designer Solution



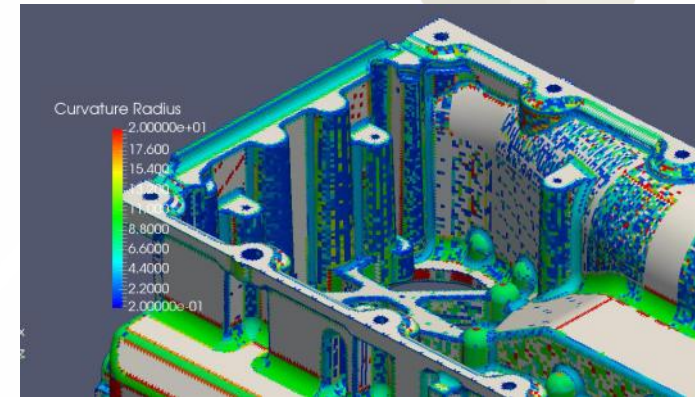
Cast-Designer V7.4

DFM, Geo-Designer



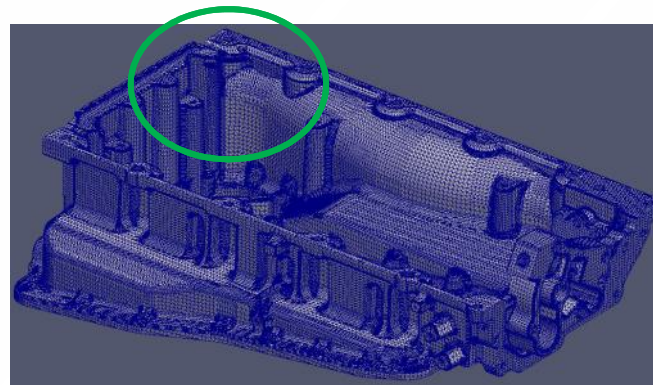
Geo-Designer Supports High Quality Mesh Model

- I A new mesh generator has been used in Geo-Designer to support big model with high quality surface mesh.
- I Flexible mesh parameters to control the mesh size and quality.

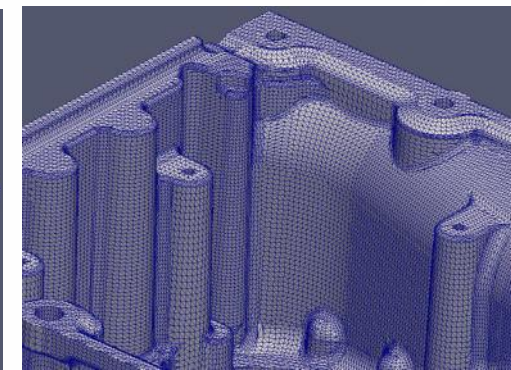


Radius checking

Distance Deflection	0.1
Angular Deflection	15
<input type="radio"/> Surface Mesh	
<input checked="" type="radio"/> Geometry Mesh	
Boundary Box Size	
X range: -197.000 to 147.230 dx: 344.23	
Y range: -210.985 to -19.620 dy: 191.36	
Z range: -508.860 to 22.260 dz: 531.12	
Minimum Edge Size	0.5
Maximum Mesh Size	5.000



2D surface mesh



Region mesh

Cast-Designer V7.4

Gating System Design



HPDC Gating System Design

I The HPDC gating system design wizard has been redesigned with more detail information.

- ü Yield ratio
- ü Projection area
- ü Casting pressure and velocity
- ü Machine selection wizard
- ü Plunger diameter selection
- ü 3rd phase start and stop time and position
- ü Export to Excel report for process design

High Pressure Die Casting Designer Wizard

Gating system for HPDC

Design Information of casting

Casting material type: Al

Total weight: 17.48 kg

Weight of casting (kg): 11.967

Total volume: 7.28333e+06 mm³

Weight of overflow & gas system (kg): 1.703

Part + overflow weight: 13.67 kg

Weight of gating system (kg): 3.81

Percentage yield of casting: 68.46 %

Number of cavities: 1

Projected area: 2313.93 cm²

Average wall thickness: 4.5 mm

Percent solid when the die is filled: 11.6 %

Reference filling time: 88.82 ms

Min. filling time: 62.17 ms

Max. filling time: 115.47 ms

Metal flow: 64.13 L/s

Pressure min: 2.08 MPa

Pressure max: 12.00 MPa

Gate area: 1603.2 mm²

Gate depth: 2.5 mm

Gate width: 641.28 mm

Velocity at gate: 40.00 m/s

Velocity at gate min: 25 m/s

Velocity at gate max: 60 m/s

Information of die casting

Casting machine type: Cold chamber

Select shot machine: MC2

Plunger diameter (mm): 140

Max. casting force (kN): 678.24

Shot sleeve length (mm): 700

Plunger speed (m/s): 8.22

Max. lookup force (tonnes): 2200

Accum. pressure (MPa): 15

Shot cylinder diameter (mm): 240

Intensification ratio: 2.01

Casting pressure (MPa): 88.60

Clamping force margin (%): 5.00

Speed up ratio: 9.60

Filling ratio (%): 67.59

Biscuit height (mm): 10

LS(phase I) (m/s): 0.38

LS time (ms): 782.34

2nd phase start (mm): 297.29

Speed-up time (s): 0.01

Speed-up stroke (mm): 22.70

HS time (ms): 83.94

3rd FL time (s): 0.01

3rd phase start (mm): 669.20

3rd phase stroke (mm): 20.80

Buttons: Generate, Preview, Back

Gating system design sheet

Information of casting

Casting material type	Al	Material density	2400.00 kg/m ³
Weight of casting	11.97 kg	Number of cavities	1.00
Weight of overflow & gas system	1.70 kg	Total weight	17.48 kg
Weight of gating	3.81 kg	Part + overflow weight	13.67 kg
Average wall thickness	4.50 mm	Percentage yield of casting	68.46 %
Percent solid when the die is filled	11.65 %	Total projected area	2313.93 cm ²

Filling time design

Reference filling time	88.97 ms	Gate area	1600.48 mm ²
Min. filling time	62.28 ms	Gate depth	2.50 mm
Max. filling time	115.87 ms	Gate width	640.20 mm
Velocity at gate	40.00 m/s	Metal flow	64.02 L/s
Velocity at gate min	25.00 m/s	Pressure min	2.08 MPa
Velocity at gate max	60.00 m/s	Pressure max	12.00 MPa

Informating of die casting

Casting machine type	Cold chamber	
Shot machine	MC1	
	System	User
Plunger diameter	160.00	160.00
Max. casting force	834.00	834.00
Shot sleeve length	700.00	700.00
Plunger speed	8.22	3.18
Max. lookup force	2800.00	ton
Accum. Pressure	17.00	MPa
Shot cylinder diameter	250.00	mm
Intensification ratio	2.01	

Process design

Casting pressure	83.42	MPa
Clamping force margin	29.72	%
Speed up ratio	12.56	
Filling ratio	51.74	%
Biscuit height	30.00	mm
Low speed (phase I)	0.85	m/s
Low speed time	665.48	ms
2nd phase start	367.56	mm
Speed-up time	0.01	ms
Speed-up stroke	19.15	mm
High speed time	84.08	ms
3rd FL time	0.01	ms
3rd phase start	654.10	mm
3rd phase stroke	15.90	mm

P-Q diagram

Location - Speed

High Pressure Die Casting Designer Wizard

Shot machine

Manufacturer: DEMO

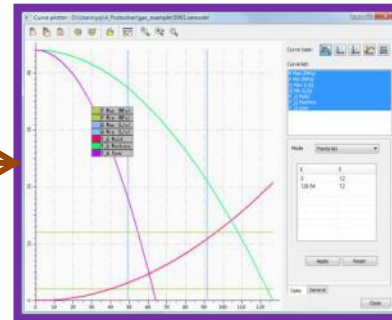
Chamber type: Cold Hot

Description:	MC3	MC1	MC2
Max. lockup force (Tonnes):	2800	2800	2200
Accum. pressure (MPa):	9.8	17	15
Plunger diameter (mm):	160	160	140
Shot cylinder diameter (mm):	250	250	240
Shot sleeve length (mm):	700	700	700
Max. plunger speed (m/sec):	4.26	8.22	8.22
Intensification ratio:	2.42	2.01	2.01
Projected area (cm ²):	2313.93		
Filling ratio (%):	51.749	51.749	67.591
Casting pressure (MPa):	57.900	83.423	88.604
Clamping force margin (%):	51.224	29.724	5.002

P-Q diagram: [P-Q] [P-Q] [P-Q]

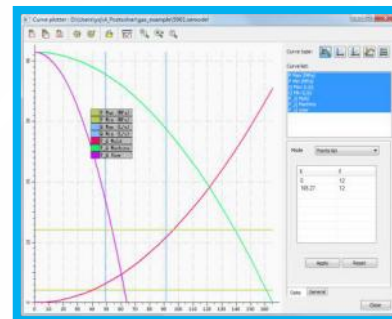
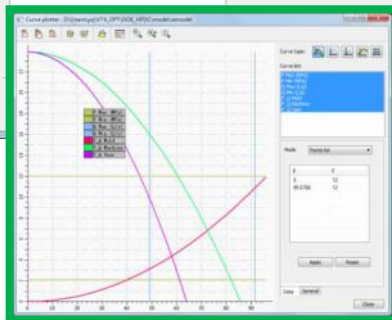
Select Select Select

Close



I Online casting machine comparison and selection.

- ü Filling ratio
- ü Casting pressure
- ü Clamping force margin
- ü P-Q graphics



High Pressure Die Casting Designer Wizard

Sleeve shot calculation

	Weight (kg)	Volume (L)	Ratio (%)	% for phase II
Gating	3.81	1.5875e+06	21.796	0
Casting	11.967	4986249.813	68.461	100
Overflow	1.703	709583	9.743	100
Total	17.48	7283333.067	100	

Sleeve length: 700 mm Effective length: 700 mm Speed-up time: 0.01 s
 Plunger diameter: 140 mm Filling ratio: 67.59 % 3rd FL time: 0.01 s

	Volume (L)	Speed (m/s)	V used (m/s)	Time (ms)	Length (mm)	L (mm)	Position (mm)
3rd phase stroke	0.320	-	-	10	20.8		659.2
Phase II	5.696	4.16	4.16	83.9	349.208		310
2nd speed-up stroke	0.336	-	-	10	21.8		288.2
Phase I-1	4.436	0.38	0.2	1441	288.2	0	0
Phase I-2	0	0	0	0	0		
Phase I-3	0	0	0	0	0		
Phase I-4	0	0	0	0	0		
Phase I-5	0	0	0	0	0		

Parameters for 2nd phase and 3rd phase

With vacuum system and vacuum valve capability

Small (1.5L/s) Middle(3.5L/s) Big(6.5L/s) Very big(9.6L/s) User defined 7.1 L/s

Vacuum	Min time (s)	Length (mm)	Speed (m/s)	Time (s)	Result
Level 1	1.256	288	0.2	1.44	OK
Level 2	0.570	-1393.2	0.1	-13.8	NG

Inlet velocity curve Piston moving curve

Preview curve Export curve Cancel

Shot machine

Manufacturer: YIZUMI

Chamber type: Agrati, Buhler, Chen_Fong, Colosiopresse, DEMO, Frech, Hishinuma, IDRA, Italpresse, Jeng_Fong, Kawaguchi, LK, National, Oleopress, Producer, Shinozuka, TOSHIBA, TOYO, TP Technology, UBE, Urpe, Vihorlat, YIZUMI

Description: DM1250_100

Max. lockup force (Tonnes): 1250

Accum. pressure (MPa): 16

Plunger diameter (mm): 100

Shot cylinder diameter (mm): 240

Shot sleeve length (mm): 910

Max. plunger speed (m/sec): 8

Intensification ratio: 1

Projected area (cm²): 349.5

Filling ratio (%): 10.844

Casting pressure (MPa): 92.16

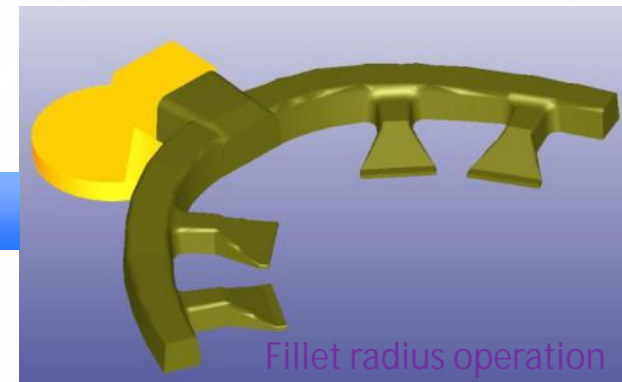
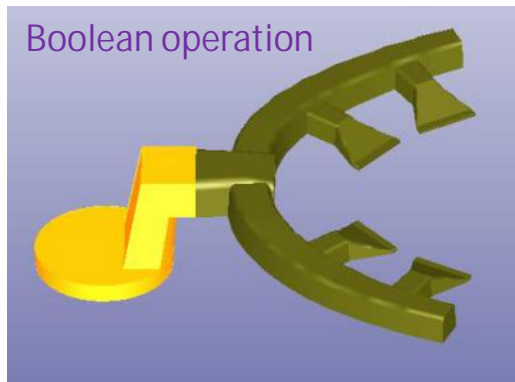
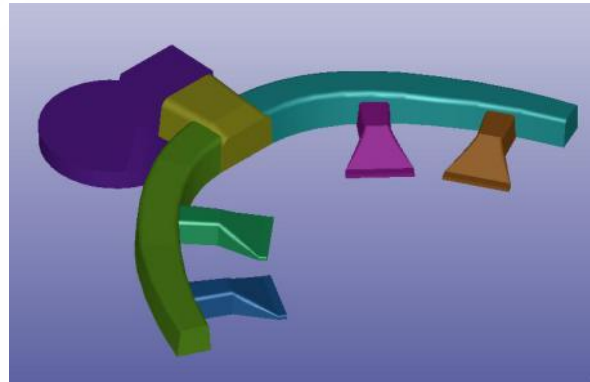
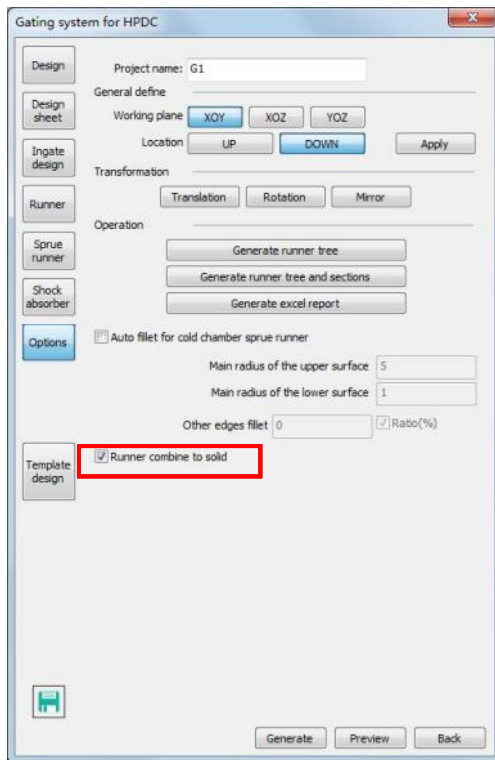
Clamping force margin (%): 73.733

P-Q diagram:

Select Close

Add more casting machine to the database

Gating System Generation



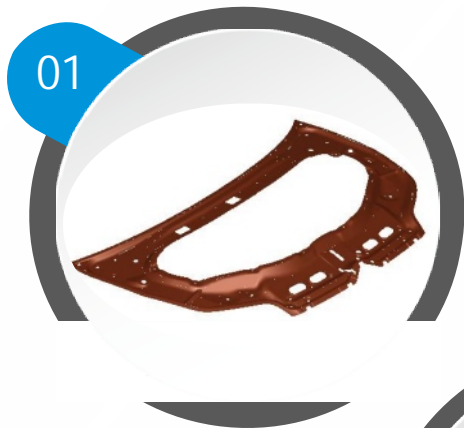
- I A new option for gating system generation method (as default one in V7.4).
- I With this method the gating system is easy to make Boolean operation and fillet radius, this can improve the gating system quality.

Cast-Designer V7.4

ParaCAD



ParaCAD: Die Face Engineering

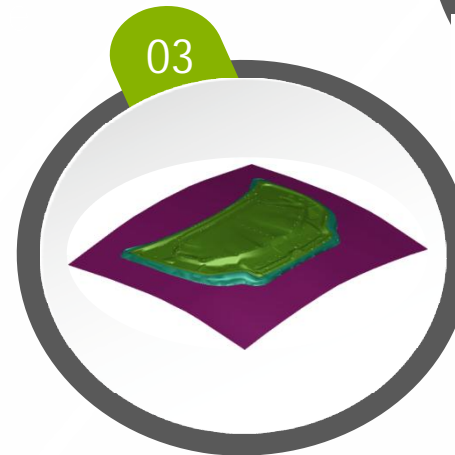
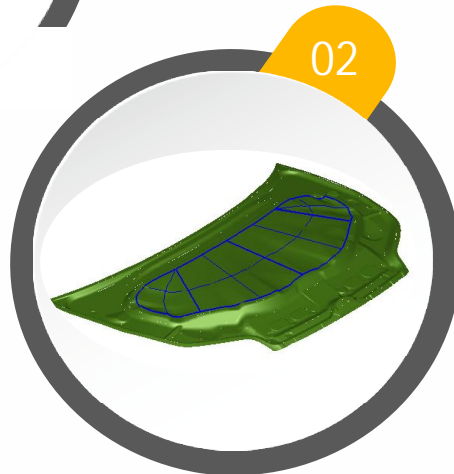


Fill part hole
ØFill holes
ØFill inner patch

Part preparation
ØCAD cleaning
ØSolid to shell
ØTipping
Øflange/ hidden flange



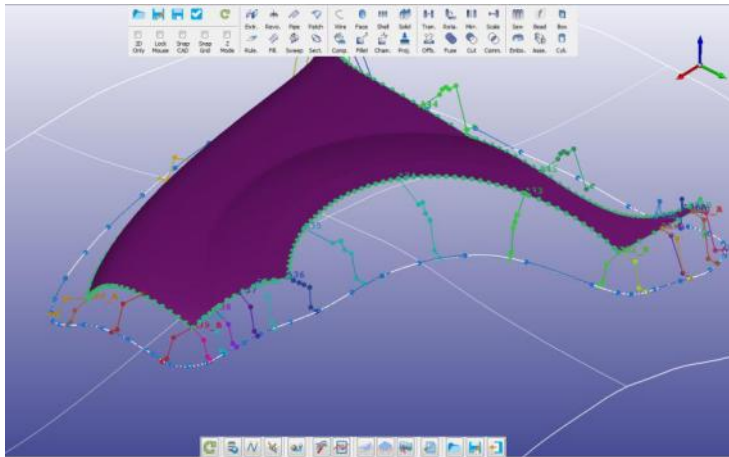
Die face meshing
ØExpress mesh
ØSPW powerful mesh



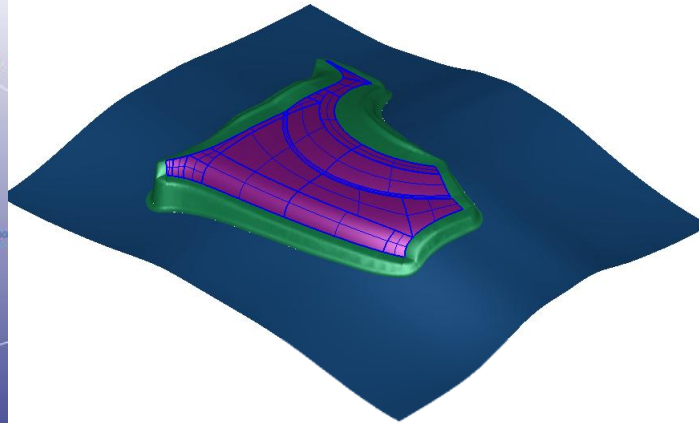
Binder & addendum
ØBinder creation
ØAddendum line and surface generation



ParaCAD: Die Face Engineering



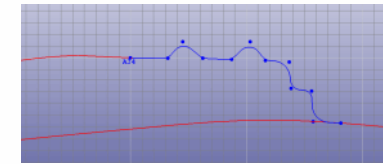
Addendum line design



Die face design



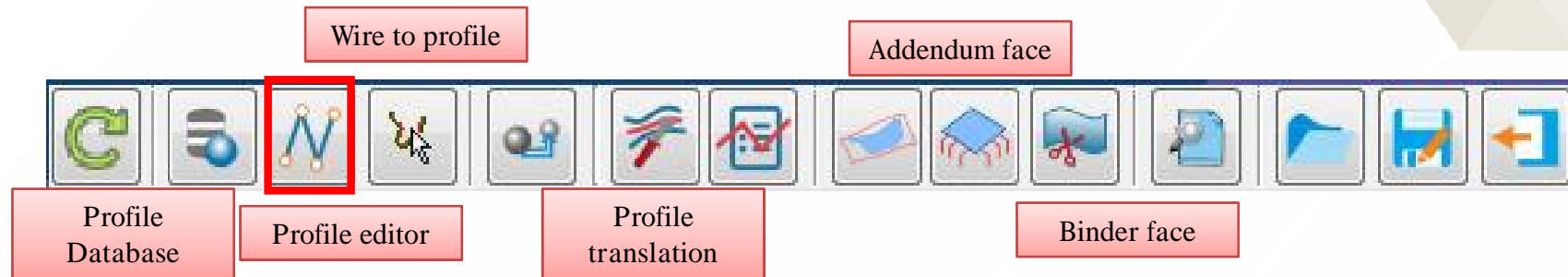
Profile editor



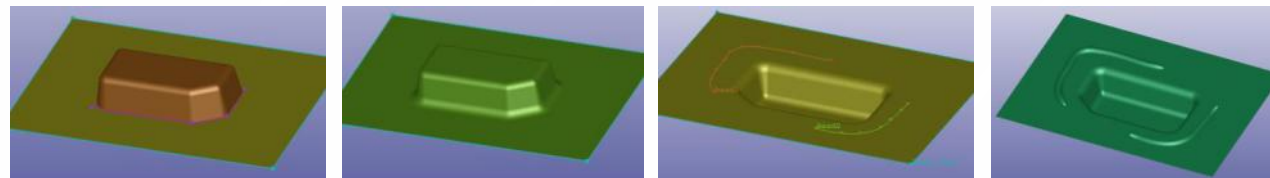
Add more features to profile

- n Easy and rapid creation of high-quality CAD surfaces
- n The customizable standard approach to process design including all operation types
- n A consistent methodology for CAD quality die face design
- n Significantly enhanced productivity

ParaCAD (Toolbar)



Standard CAD functions

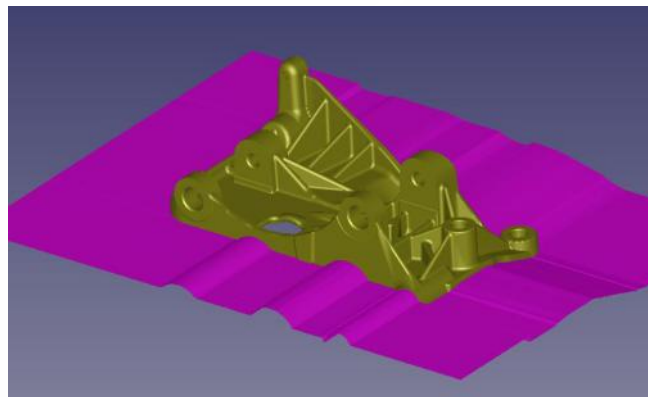
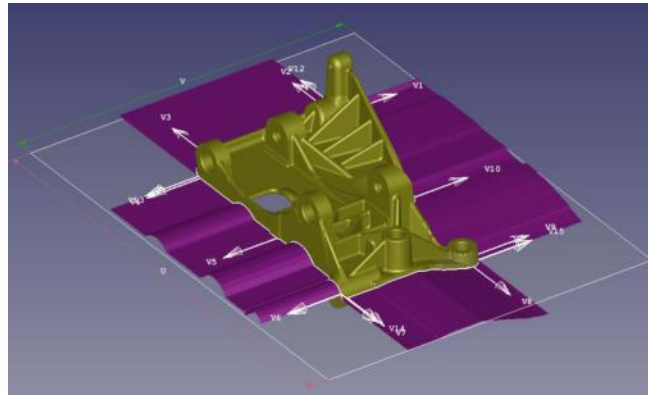
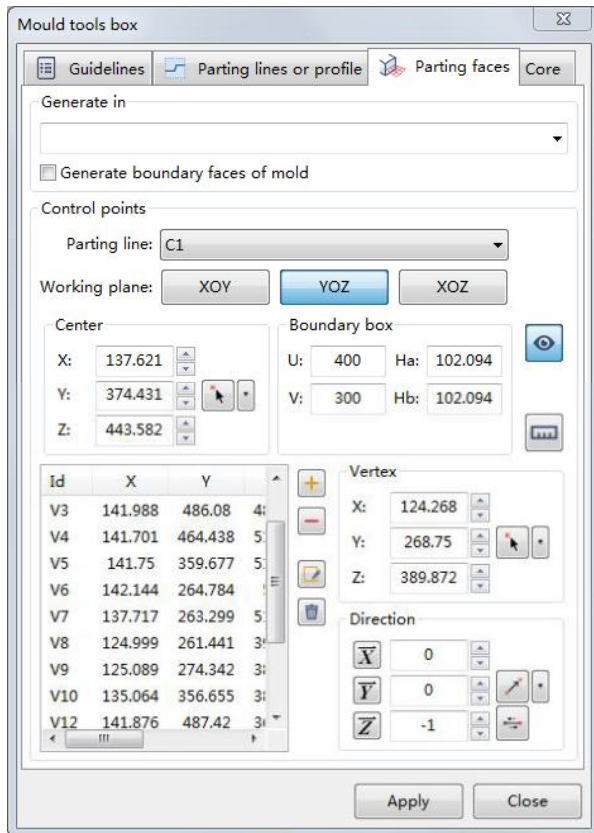


Cast-Designer V7.4

Mould Tools Box



Mold tools box



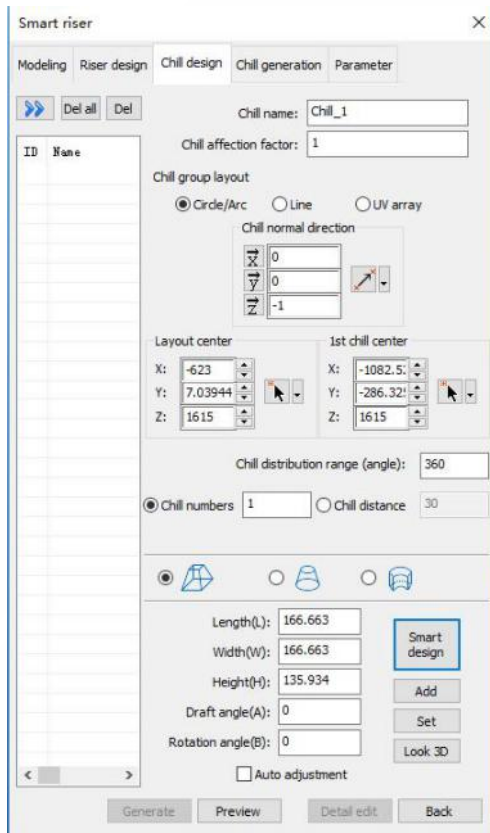
- I A special mould tools box is designed to create the parting line and parting faces.
- I The parting line could extract from the existed CAD geometry.
- I It is also could be used for sand core generation.
- I This function also could be used with 'ParaCAD' together.

Cast-Designer V7.4

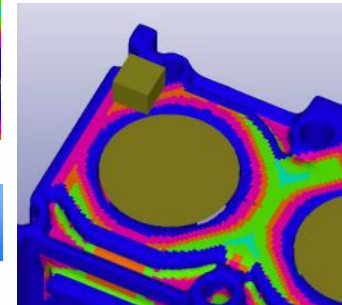
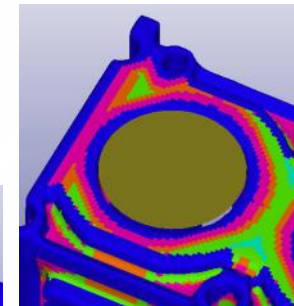
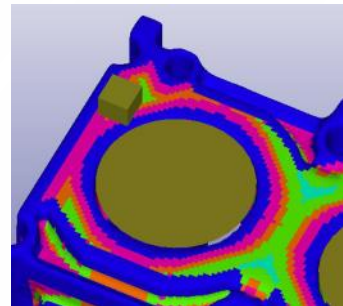
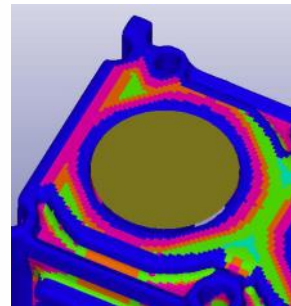
Chill Design



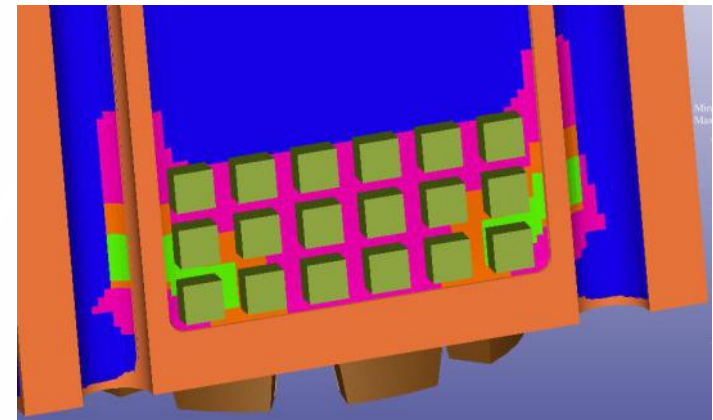
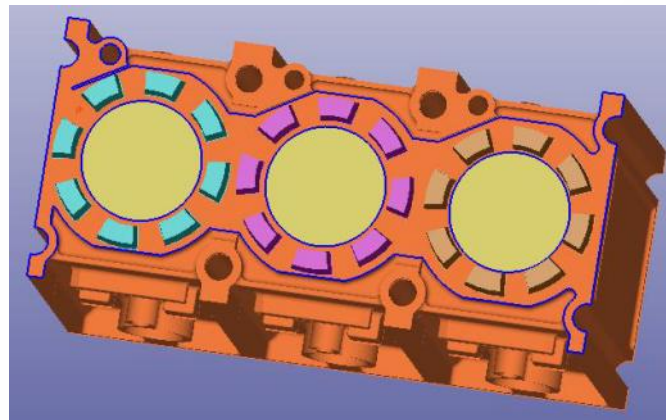
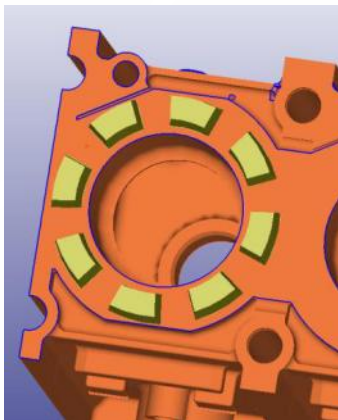
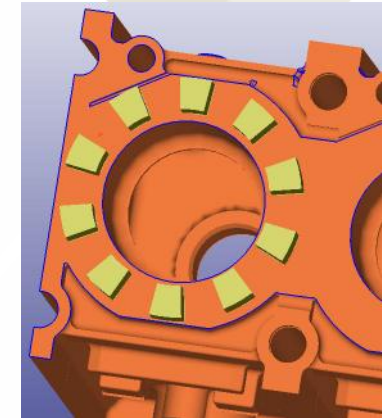
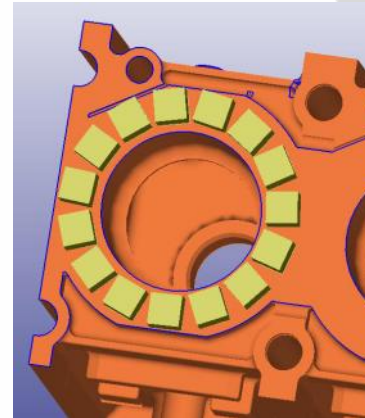
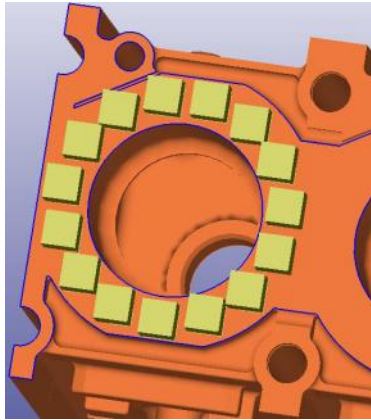
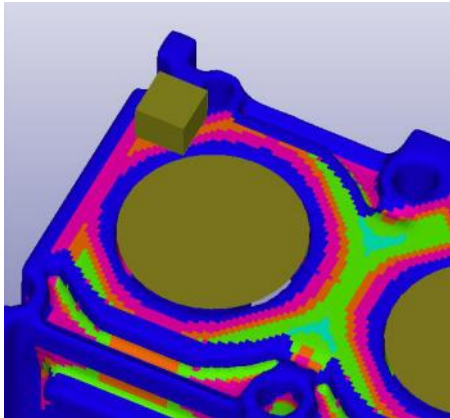
Smart Chill Design



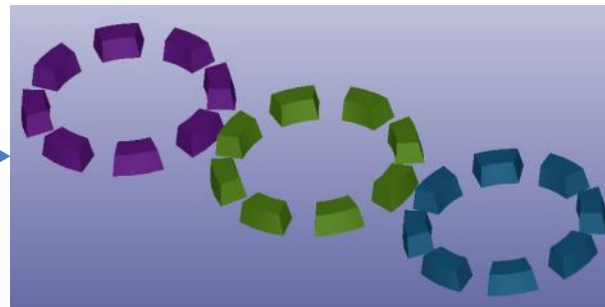
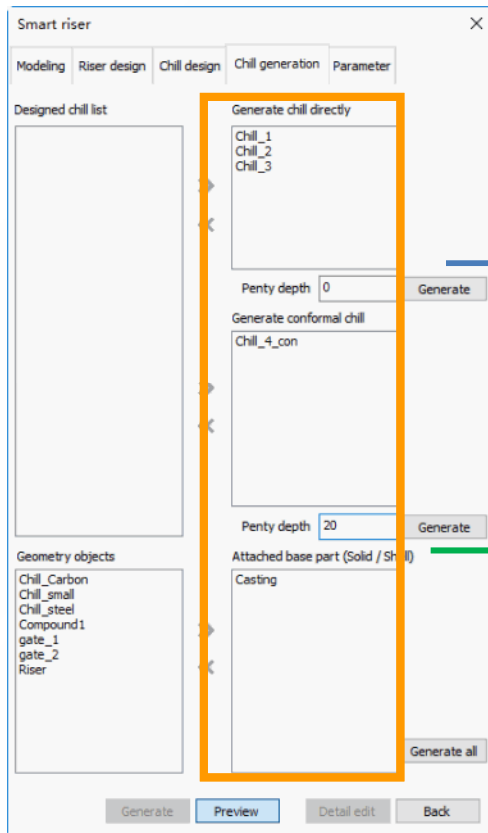
- I Chill smart design is based on the casting alloy, chill material, pouring temperature and the EMDI value.
- I A higher EMDI value also needs a bigger/thicker chill. The chill smart design mainly affects the chill depth/height, the length/width of the chill center could be adjusted by the user as the EMDI distribution.



Batch Chill Design and chill layout

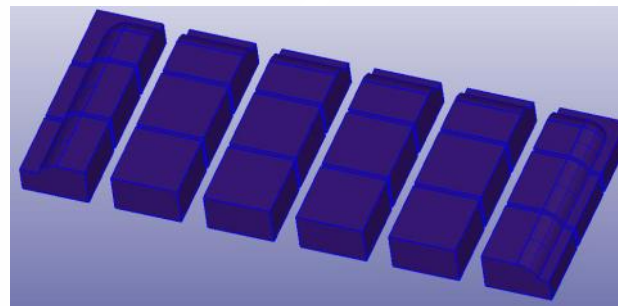


Generate Conformal Chill

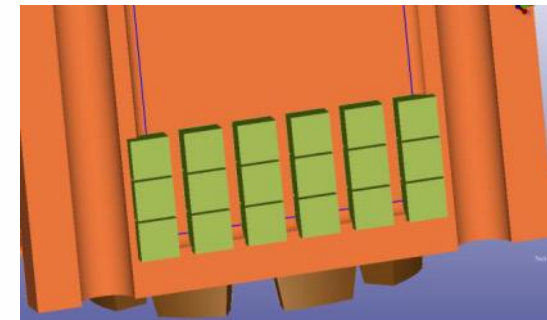


Standard Chill

Conformal Chill

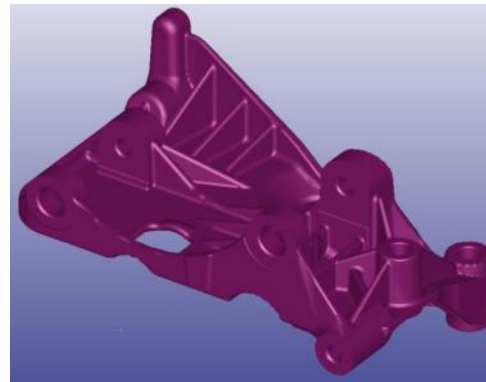
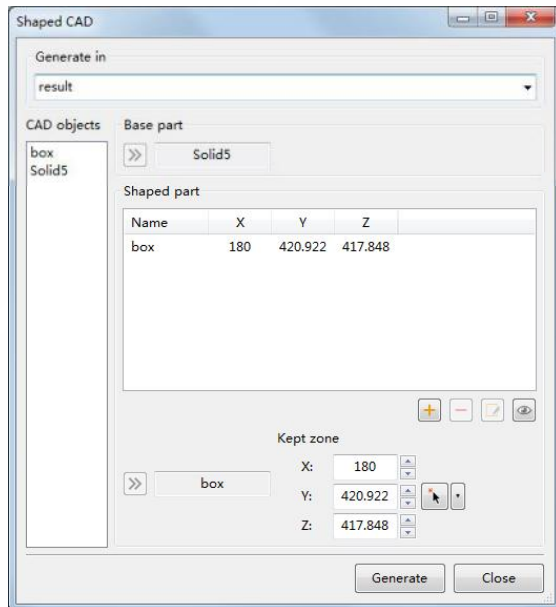


- Both Smart Chill Design and general user environment are supported the conformal chill design. The user only need define the base part and the penalty depth.

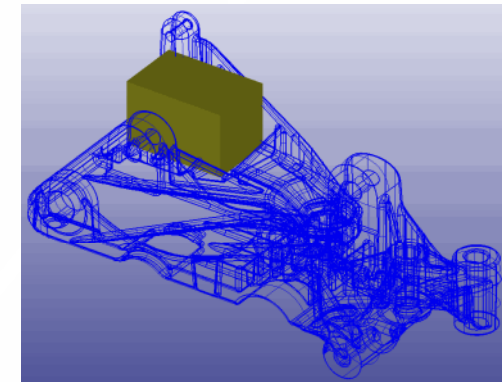


Shape CAD

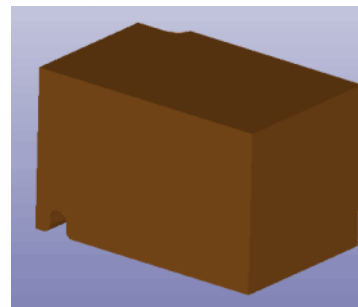
- I A new function called Shape CAD could cut the CAD from given shape while the Boolean operation was failed.



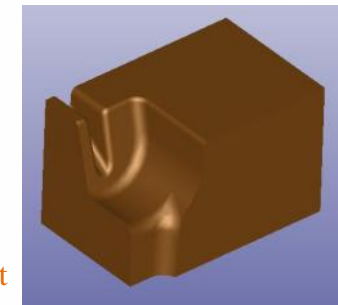
Tools part



Tools part & shaped component



Shaped result

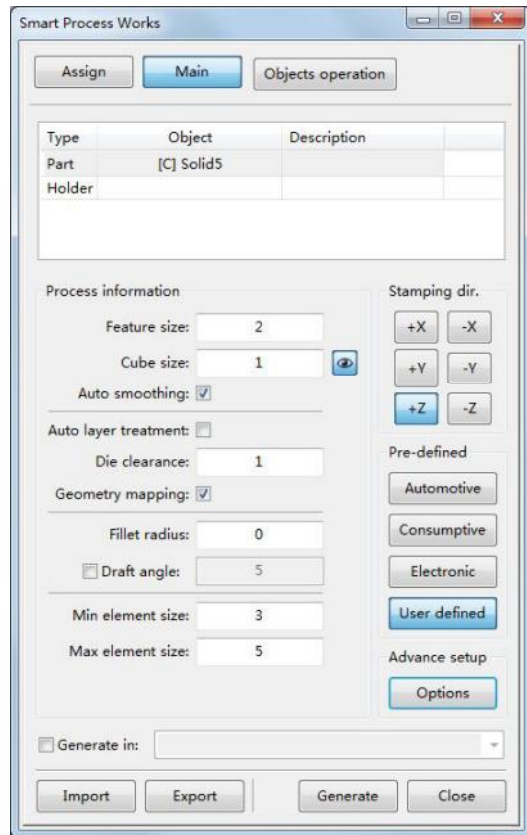


Cast-Designer V7.4

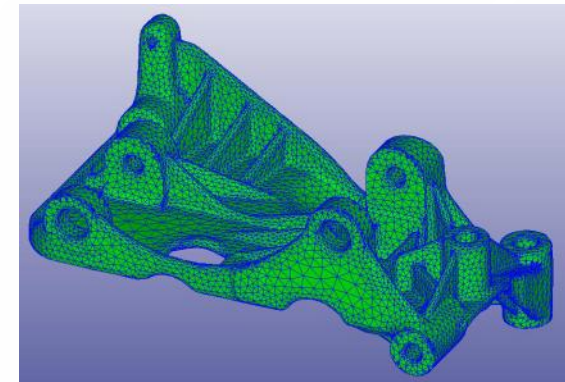
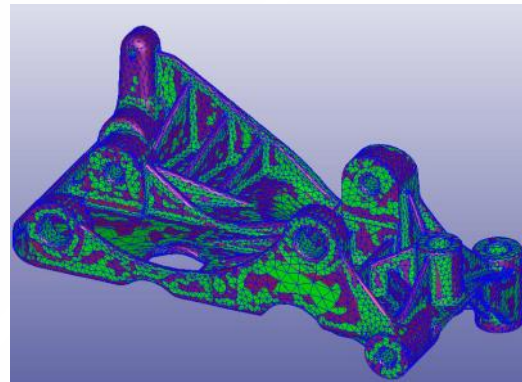
CFD Solver



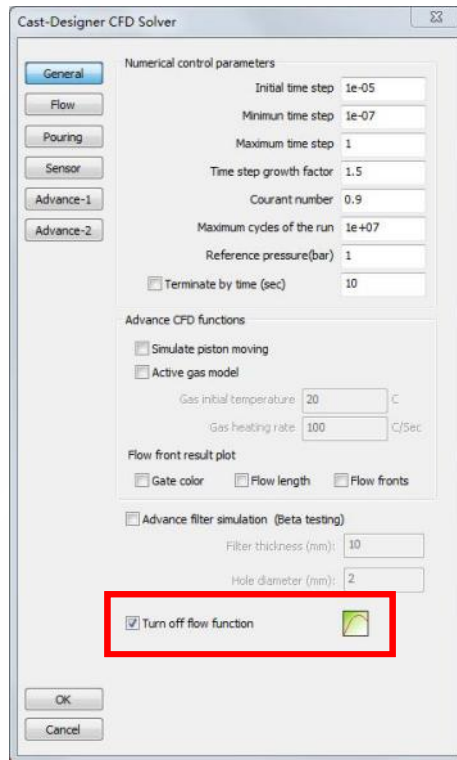
SPW for Meshing



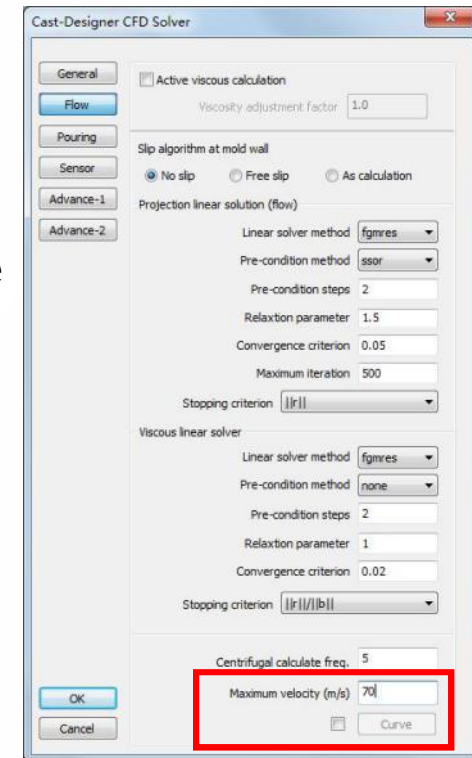
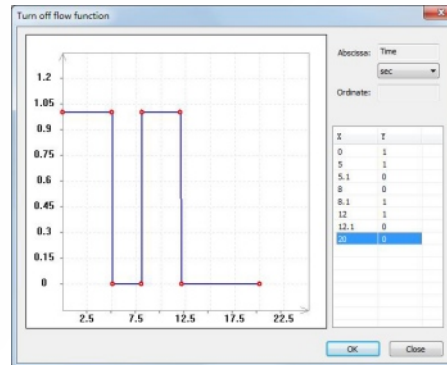
- I SPW could use for 2D surface meshing, the meshing with good geometry description.
- I It is suitable to generate 3D mesh for stress simulation.
- I The small gap and surface overlay also could be treated by SPW automatically.



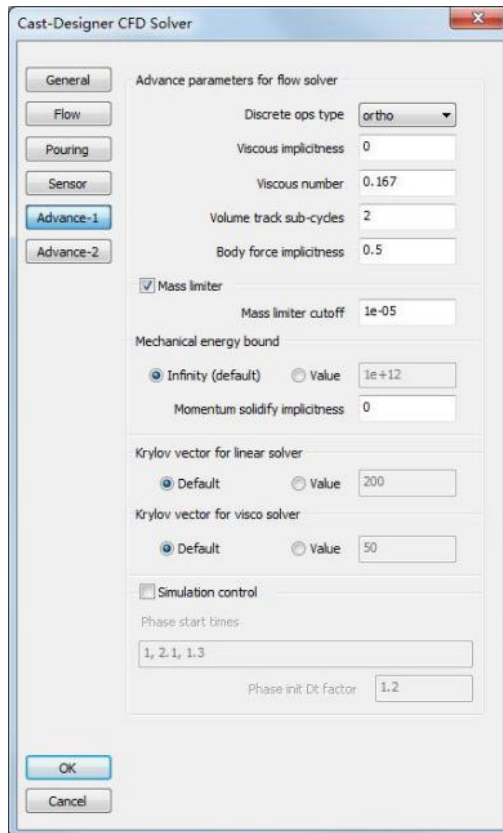
CFD Solver



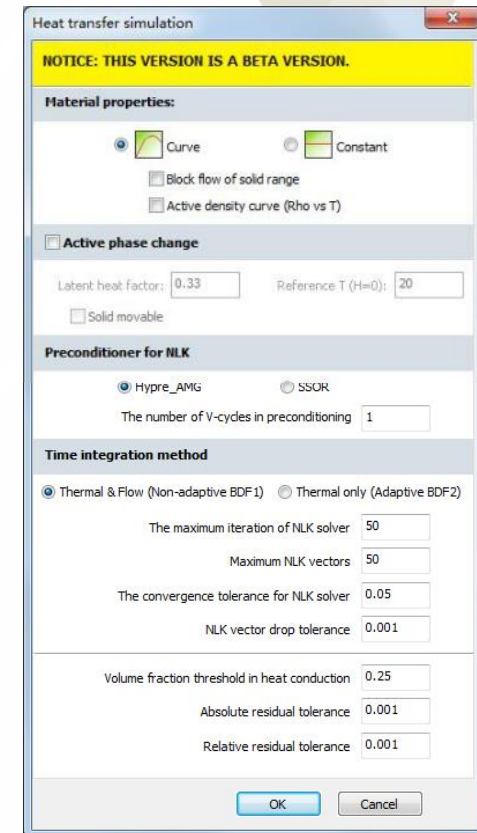
- I More options have been enhanced to the CFD solver.
- I When to turn on and turn off the CFD solver, it could be controlled by a time depended curve.
- I The maximum velocity also could be controlled by a curve or a value.



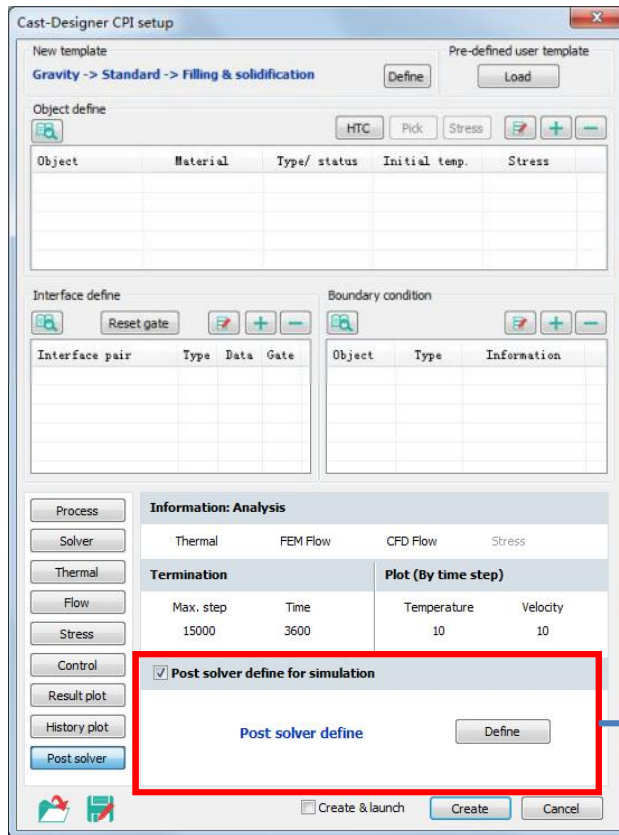
CFD Solver (Advance Parameters)



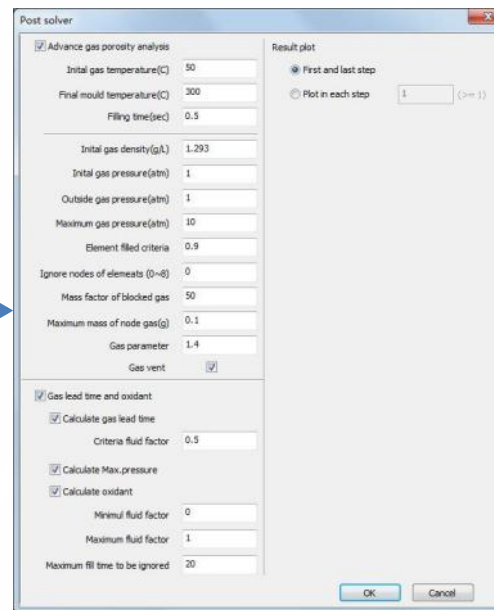
- | More advance parameters have been added to the CFD solver for flow and thermal simulation.
- | The thermal and flow simulation could be full coupled.
- | The robust of CFD solver has been improved special for the final stage simulation.
- | A special technology has been enhance to the CFD solver for the last percentage filling.



Post Solver in CPI Setup



- I The Post Solver has built in CPI setup also. It could be carried out automatically in a single run.
- I The parameters were exactly same the standalone program.

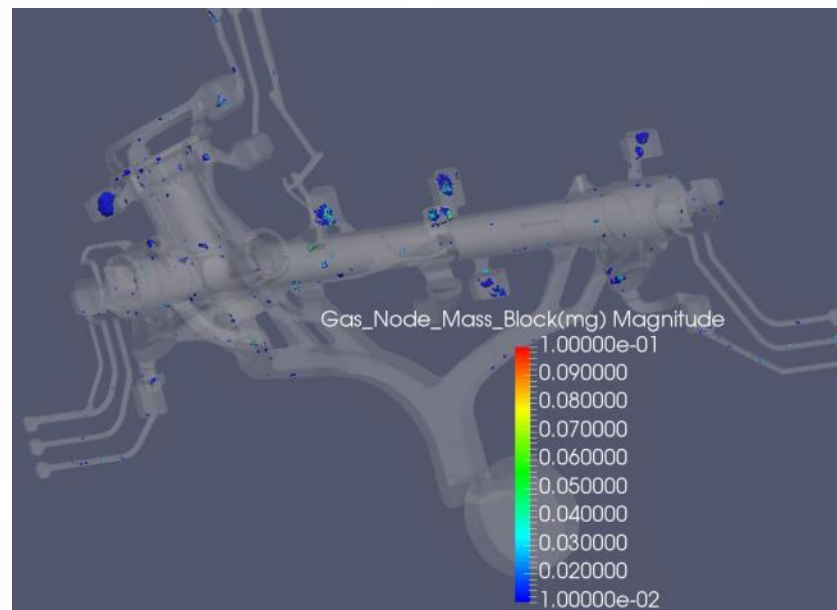


- I This option could be used for AI-CAST directly.
- I The history plot is supported also.
- I The result filename will be named in XXX-post.EXOII

New Gas tools in ParaVIEW



- I The 'Gas' button has been redesigned in ParaVIEW to check the node blocked gas mass. The inner node, outside node and link node could be checked alone.



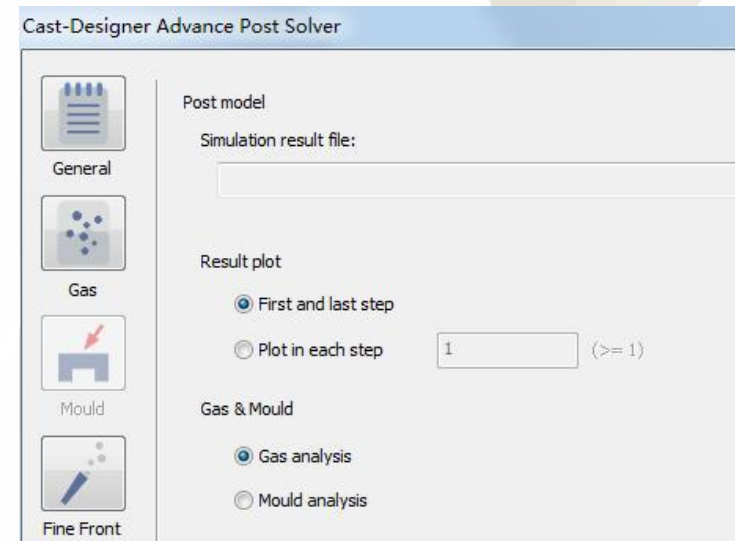
Cast-Designer V7.4

Post Solver



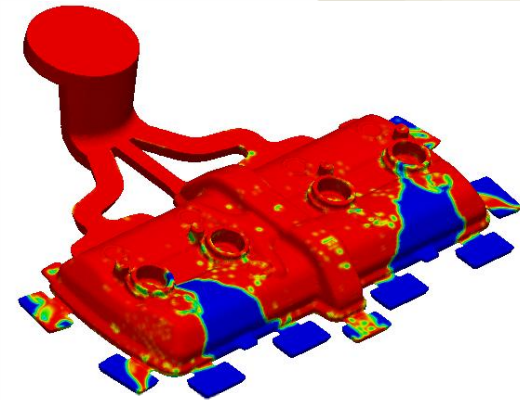
Cast-Designer Post Solver

- I The Post Solver is a new approach to analyze the Cast-Designer result.
- I Treat the analysis result after the simulation to generate new results
 - I CPU time and memory limitation during the simulation
 - I Data search and big data analysis: study the simulation results of several steps together, only consider the result of one step is not enough.
- I Functions today
 - I 1) Gas and bubble movement;
 - I 2) Mold erosion
 - I 3) fine front of the flow result



Tracking of gas bubbles during casting filling process

- I If the gas bubble size is smaller than one element size, the gas bubble will disappear in the general method, the software could not track the bubble anymore.
- I After that, it does not provide any information about the size of the defect itself, because it does not keep in account the evolution of the bubble volume and pressure.
- I Cast-Designer develop a new gas solver to track such smaller bubble. With this method, each bubble, and even the smallest one, should be tracked during the filling, varying their size and internal pressure. Moreover, they should influence the movement of the fluid itself and eventually rejoin with other bubbles.



Tracking of gas bubbles during casting filling process

Cast-Designer Advance Post Solver

General

Advance gas porosity analysis

Initial gas temperature(C) 50

Final mould temperature(C) 250

Filling time(sec) 0.5

Initial gas density(g/L) 1.293

Initial gas pressure(atm) 1

Outside gas pressure(atm) 1

Maximum gas pressure(atm) 10

Element filled criteria 0.9

Ignore nodes of elements (0-8) 0

Mass factor of blocked gas 50

Maximum mass of node gas(g) 0.1

Gas parameter 1.4

Gas vent Preview Delete all Edit + -

X	Y	Z	D
62.5811	186.2	-5.38396	3
-174.737	-27.7738	-0.045247	3
-174.654	98.508	0.836529	3
-175.536	234.596	0.253195	3
-141.812	278.161	-5.41462	3
-141.095	69.4375	-4.68196	3
-139.413	23.0071	-3.00207	3
-138.689	-61.1414	-3.88918	3
-138.842	151.253	-5.56546	3
-138.685	198.252	-3.76586	3
-102.604	165.906	-7.3122	3
-101	38.266	-4.03074	3
-99.3962	296.305	-5.44064	3
102.568	175.186	-6.31145	3
104.974	-83.4877	-6.31145	3
104.974	45.4764	-5.50403	3
134.964	-71.8285	-4.69661	3
137.05	15.3603	-3.08175	3

Gas lead time and oxidant

Calculate gas lead time

Criteria fluid factor 0.5

Calculate Max.pressure

Calculate oxidant

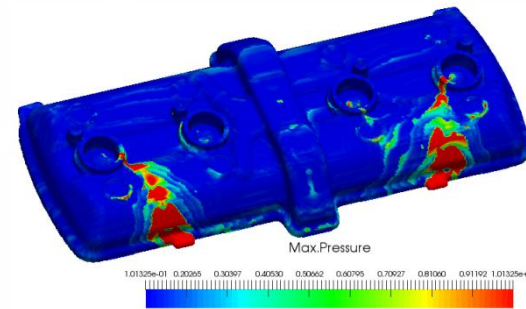
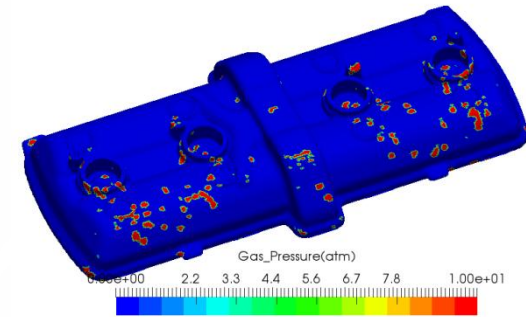
Minimum fluid factor 0

Maximum fluid factor 1

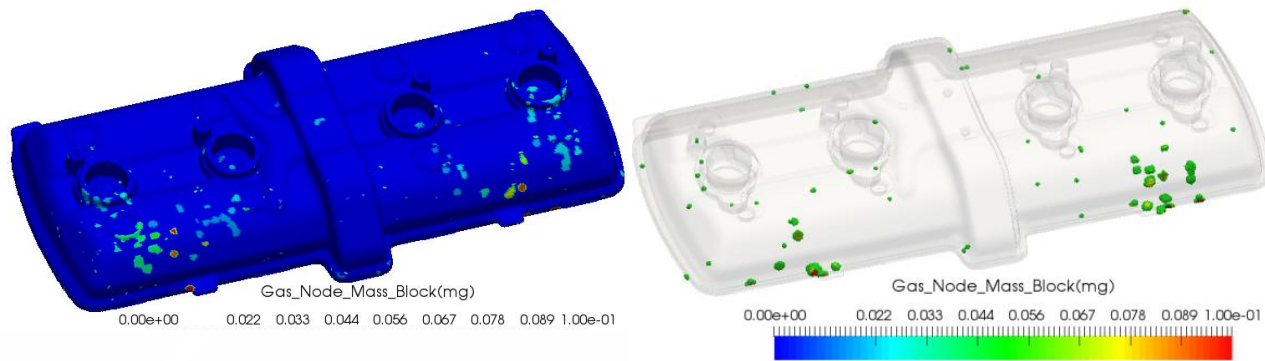
Maximum fill time to be ignored 20

Load Save Generate Run Cancel

Advance gas porosity analysis interface

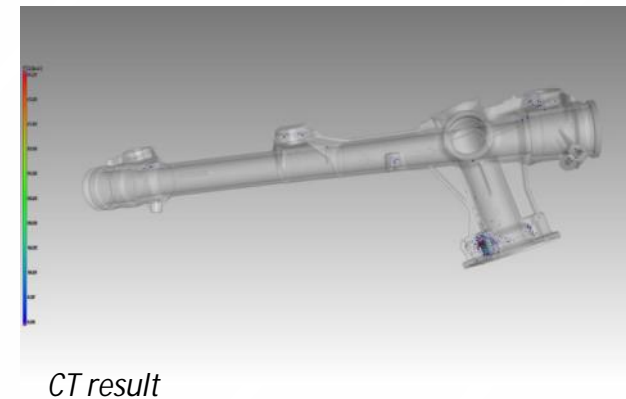
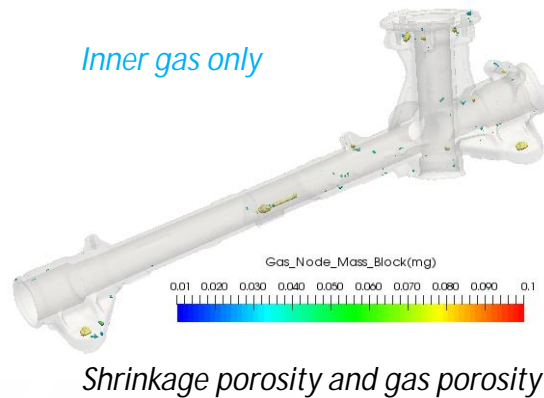
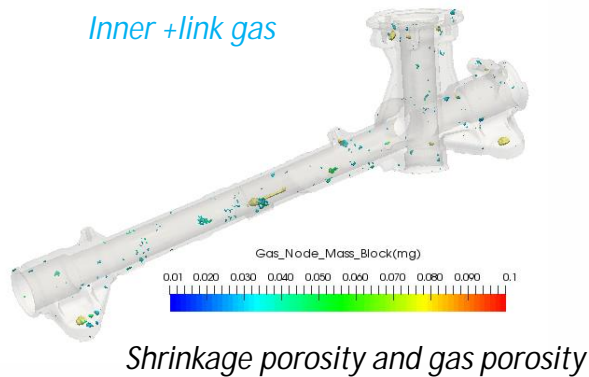
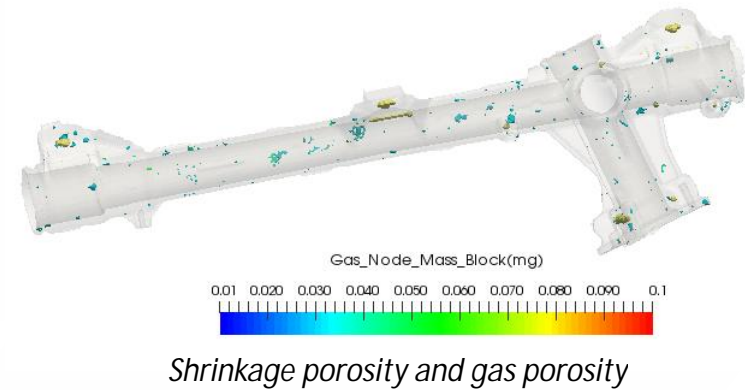
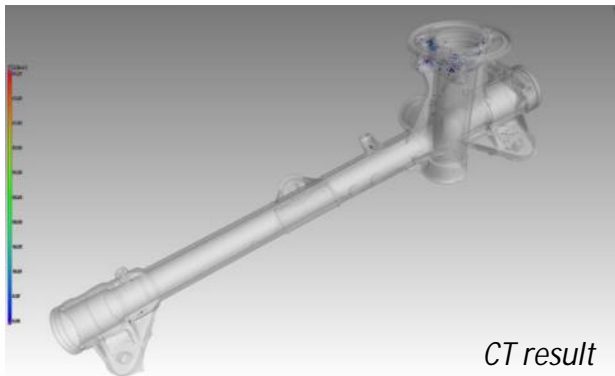


Tracking of gas bubbles during casting filling process

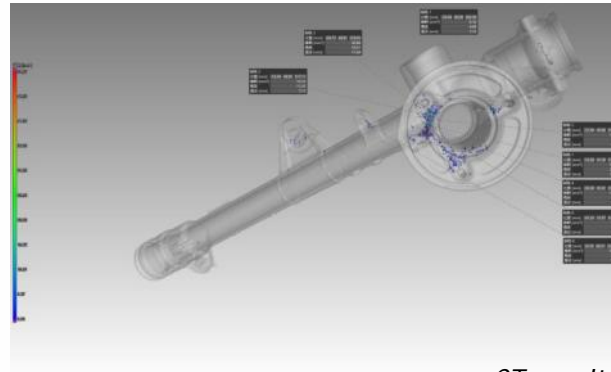


- | No experience is required from the user
- | No need to check the filling process step by step to get a reliable result
- | Helping avoid the mistake during result analysis
- | This method is very useful for the automatic optimization as a criteria output.

Tracking of gas bubbles during casting filling process



Tracking of gas bubbles during casting filling process



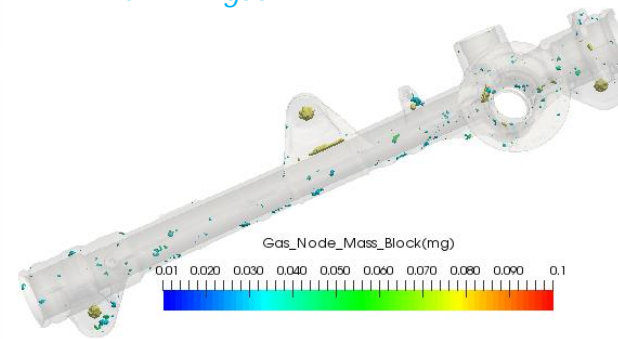
CT result

Inner gas only



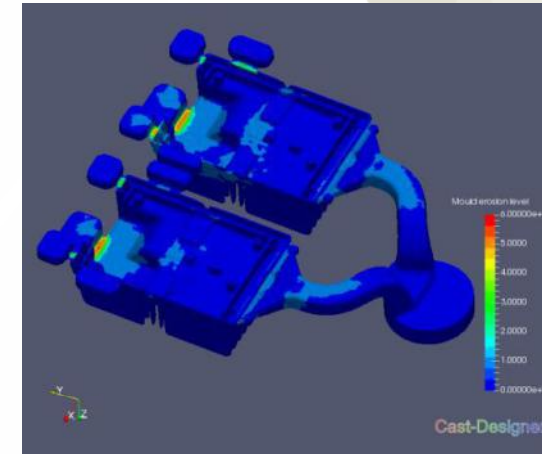
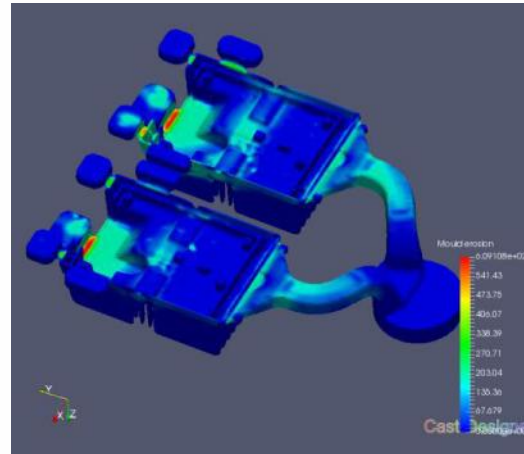
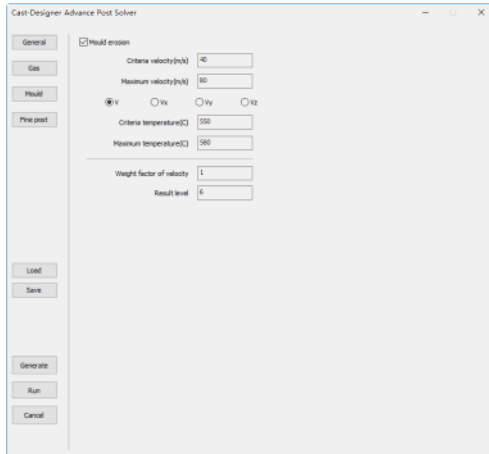
Shrinkage porosity and gas porosity

Inner +link gas



Shrinkage porosity and gas porosity

Mold Erosion

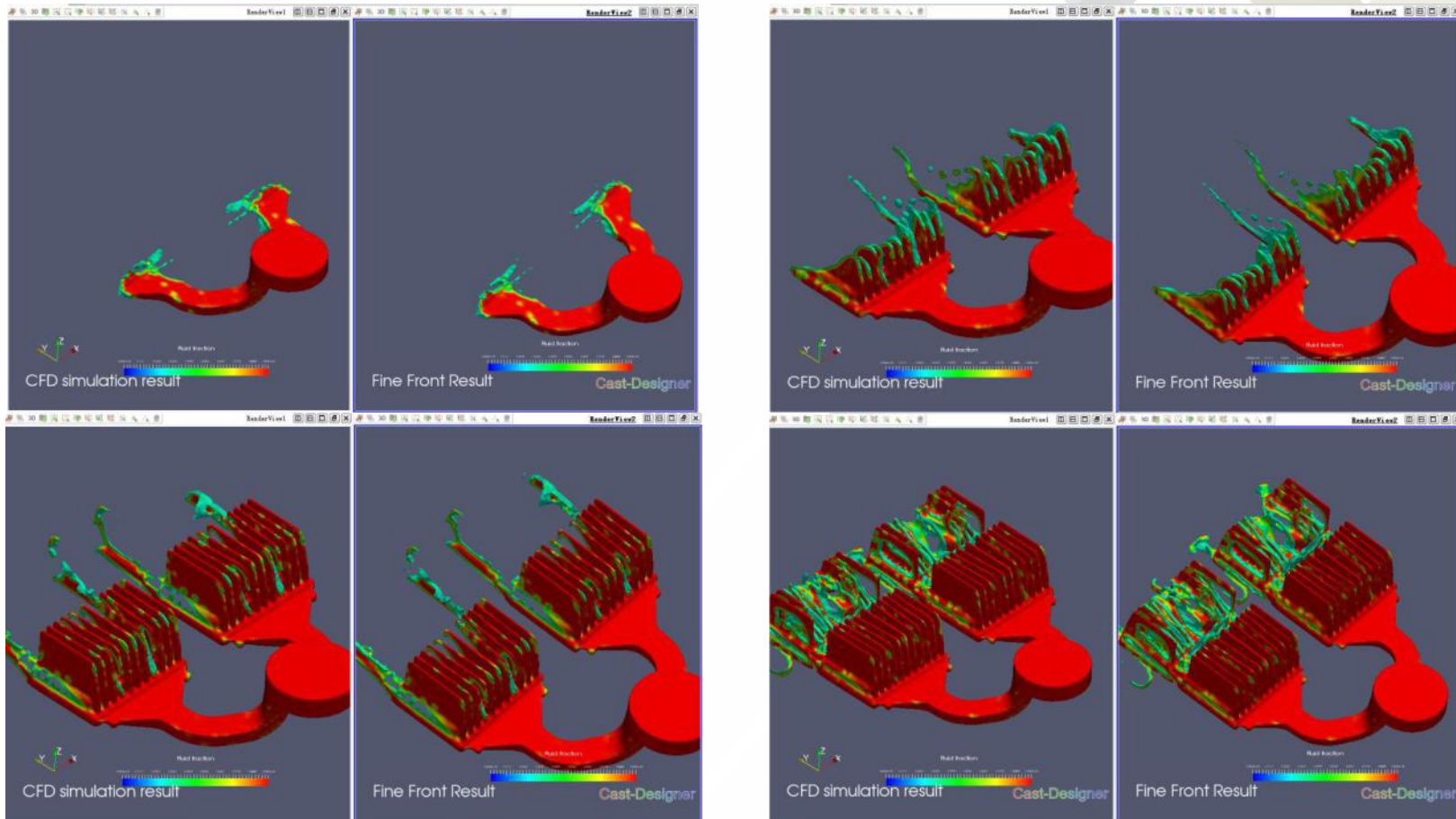


Mold erosion is considered as the high velocity/high pressure and a high temperature of the casting/mold interface, also the lead time will be considered.

User input parameters:

- I Criteria velocity (m/s)
- I Velocity vector
- I Criteria temperature
- I Weight factor of velocity
- I Result level

Fine Post



Cast-Designer V7.4

Local-Global Model



■ The Concept of Global-Local Model

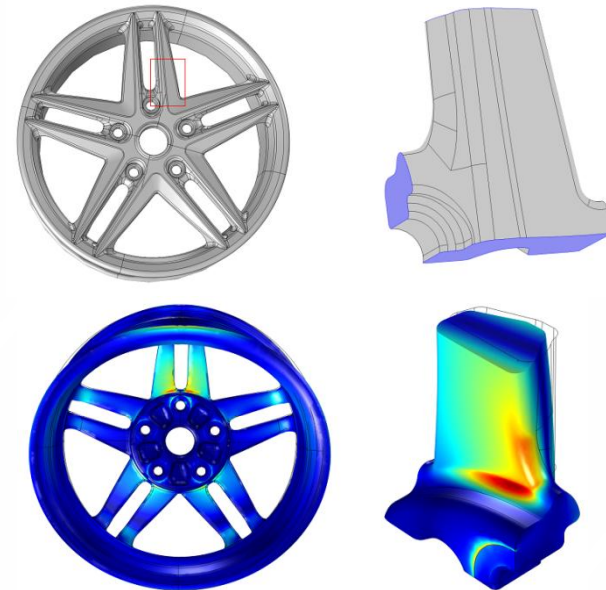
The Challenge of Simulation Large Casting Model

- n In order to properly reflect the reality, we continuously **increase the modeling complexity** when we simulate, validate, or optimize our applications. A simple technique to improve a model is to **increase the number of elements** that in turn create more evaluation points.
- n Even at **today's state of computation and processing power**, for some very complex casting model, i.e more than 10 parts in one casting tree or gate, creating a complete full casting model, detailed CAE model to compute thermal, flow and stress is extremely difficult, if **not practically impossible**.
- n A new simulation technology called **Global-Local model** was introduced to Cast-Designer.



■ The Concept of Global-Local Model

- I Many times, we need to model a large structure in order to properly prescribe the **boundary conditions**. However, **the critical part may be local and occupy only a small region of the model**.
- I In **global-local model** (sometimes also called **submodeling**), **you first analyze the behavior of the entire model**. The mesh is chosen so that the boundary conditions and loads are properly transferred to the entire model. In other words, **the field variables, displacements, and temperature should give proper results globally**, but the derivatives, such as **detail flow, may not be accurate locally**.



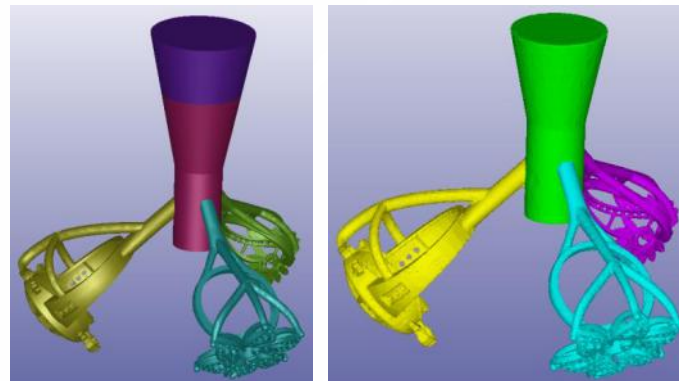
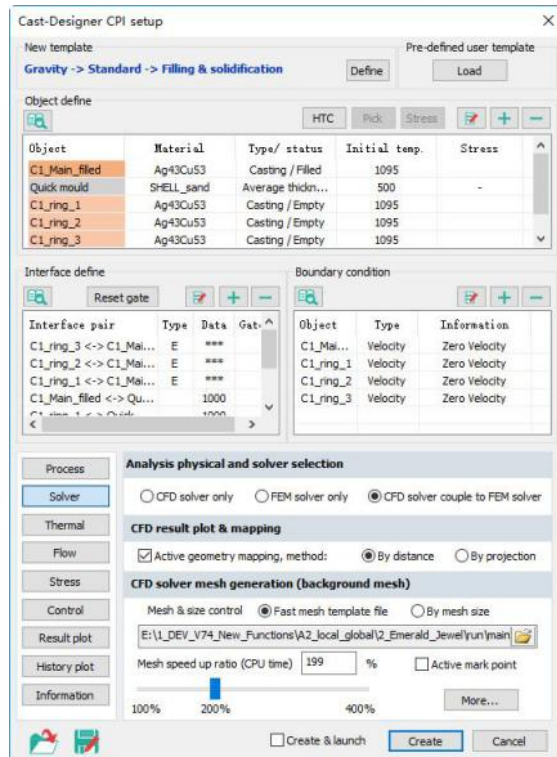
- I Then, **cut the critical part out from the global model**. The cut should be sufficiently **far from the critical point** so that the results of the global model give a good representation.

Global-Local Model Operation -1



STEP -1

- I Generate the **Global** CAE model as usual, using it for thermal and general flow simulation.
- I The mesh of detail feature need not too fine.
- I The flux-time curve will be used as boundary condition of the local model.

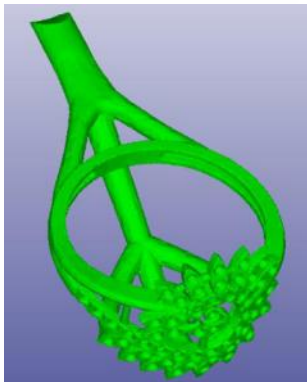


	Elements	%
Main runner	169,988	45.8%
Ring-1	33,224	9.0%
Ring-2	88,120	23.8%
Ring-3	79,556	21.5%
Total	370,888	

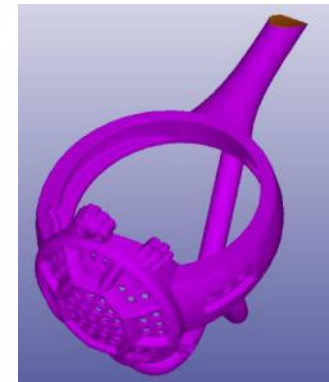
Global-Local Model Operation -2



STEP -2



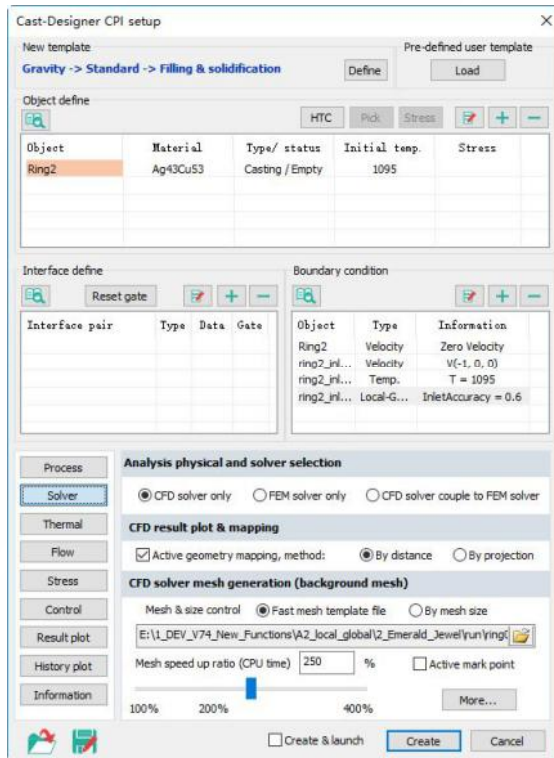
- | Generate the fine mesh for the local model.
- | The mapped inlet should be far away from the detail feature to maintenance the accuracy.
- | The local model will be used for the detail flow simulation, special for gas porosity and filling defects track.



	Elements
Ring-1 (Global model)	33,224
Ring-1 (Local model)	263,436

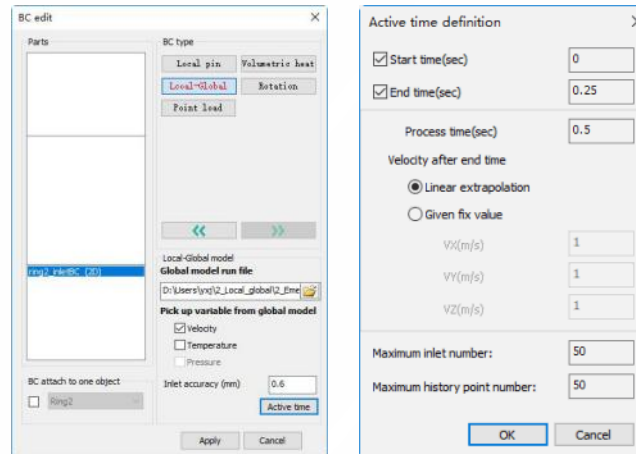
	Elements
Ring-2 (Global model)	88,120
Ring-2 (Local model)	593,373

Global-Local Model Operation -3



STEP -3

- I CPI setup for local model. For each detail feature, one local model is required.
- I Only the flow calculation is performed in the local model, the temperature result must refer the global model.



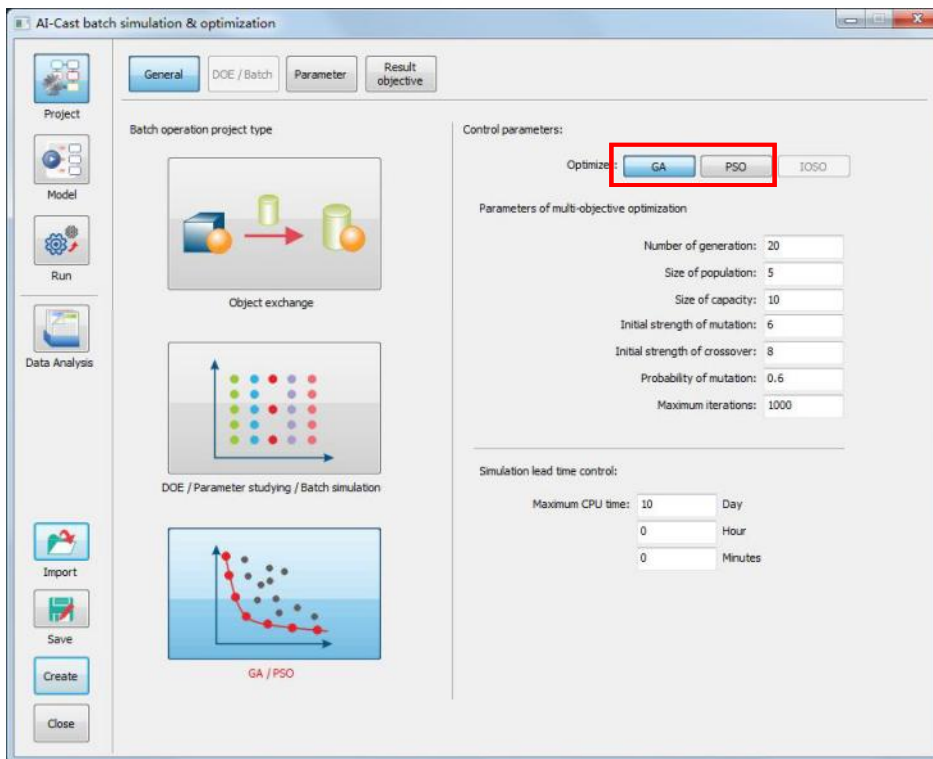
- I Pick up the result of global model set to boundary to local model
- I The node velocity and temperature could be used to local model.

Cast-Designer V7.4

AI-CAST



AI-CAST



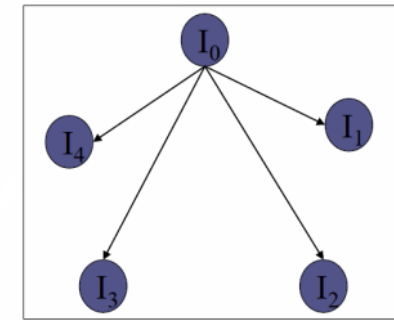
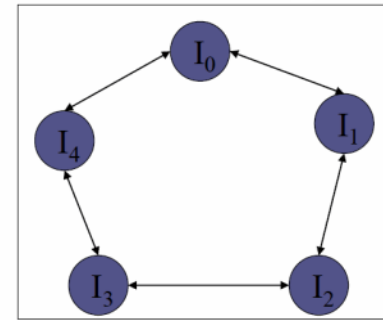
- I To highlight the automatic optimization capability of Cast-Designer, we rename the 'Optimization' to 'AI-CAST'.
- I A new optimization method PSO has been added to AI-CAST.

I DOE/GA/PSO



AI-CAST PSO: Particle Swarm Optimization

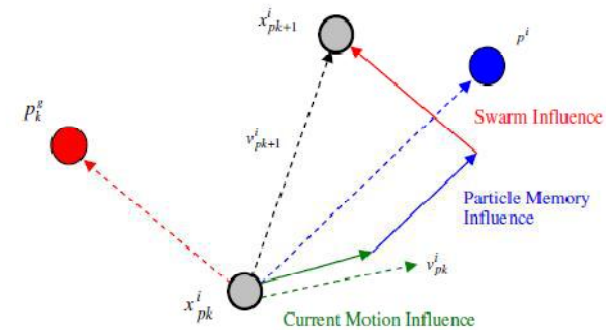
- | Particle Swarm Optimization (PSO) applies the concept of social interaction to problem solving.
- | It was developed in 1995 by James Kennedy and Russ Eberhart.
- | It has been applied successfully to a wide variety of search and optimization problems.
- | In PSO, a swarm of n individuals communicate either directly or indirectly with one another search directions (gradients).
- | PSO is a simple but powerful search technique.



- | In PSO, there have been two basic topologies used in the literature
 - | –Ring Topology (neighborhood of 3)
 - | –Star Topology (global neighborhood)

AI-CAST PSO: Particle Swarm Optimization

- I Each particle adjusts its travelling speed dynamically corresponding to the flying experiences of itself and its colleagues.
- I Each particle modifies its position according to:
 - I its current position
 - I its current velocity
 - I the distance between its current position and pbest
 - I the distance between its current position and gbest





The image displays two screenshots of the 'Analysis result' dialog box in AI-CAST software, illustrating the redesigned interface for optimization results.

Left Screenshot: Shows the 'Sub-class' section with 'Flow' selected. The 'Result list' includes 'Gas_Node_Mass_Block_In' highlighted in blue. The 'Extract result from object' section shows 'Point1_A_R20' selected.

Name	Extract result from object	Result type	Time
Porosity_part	Part	Shrinkage_porosity_g	45
Porosity_point	Point3_A_R20	Shrinkage_porosity_g	45
Gas_por01_IN	Point1_A_R20	Gas_Node_Mass_Block_In_g	45
Gas_por01_link	Point1_A_R20	Gas_Node_Mass_Block_Link_g	45
Gas_por02_IN	Point2_A_R20	Gas_Node_Mass_Block_In_g	45
Gas_por02_link	Point2_A_R20	Gas_Node_Mass_Block_Link_g	45
gas_leadtime	Point3_A_R20	Gas_Lead_Time_Out_g	45

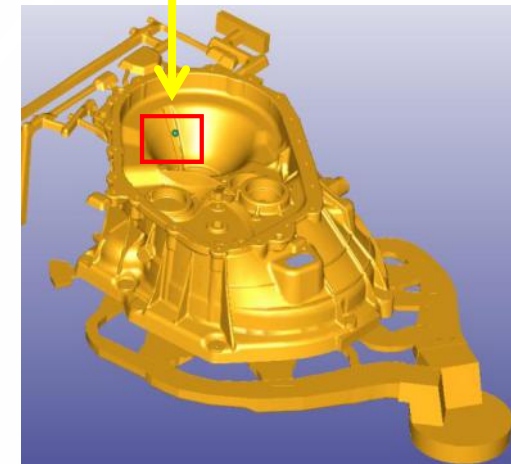
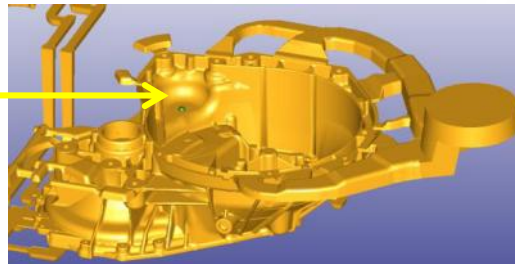
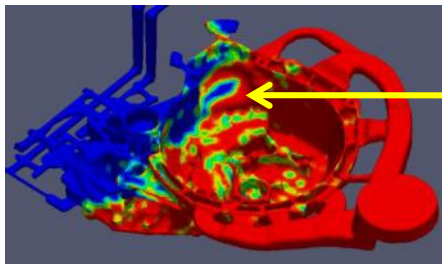
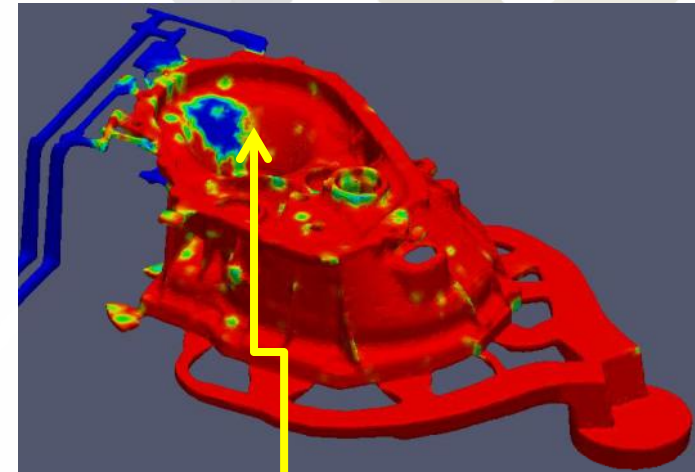
Right Screenshot: Shows the 'Result list' with 'Gas_Node_Mass_Block_In' highlighted in blue. The 'Extract result from object' section shows 'Point1_A_R20' selected.

Name	Extract result from object	Result type	Time
Porosity_part	Part	Shrinkage_porosity_g	45
Porosity_point	Point3_A_R20	Shrinkage_porosity_g	45
Gas_por01_IN	Point1_A_R20	Gas_Node_Mass_Block_In_g	45
Gas_por01_link	Point1_A_R20	Gas_Node_Mass_Block_Link_g	45
Gas_por02_IN	Point2_A_R20	Gas_Node_Mass_Block_In_g	45
Gas_por02_link	Point2_A_R20	Gas_Node_Mass_Block_Link_g	45
gas_leadtime	Point3_A_R20	Gas_Lead_Time_Out_g	45

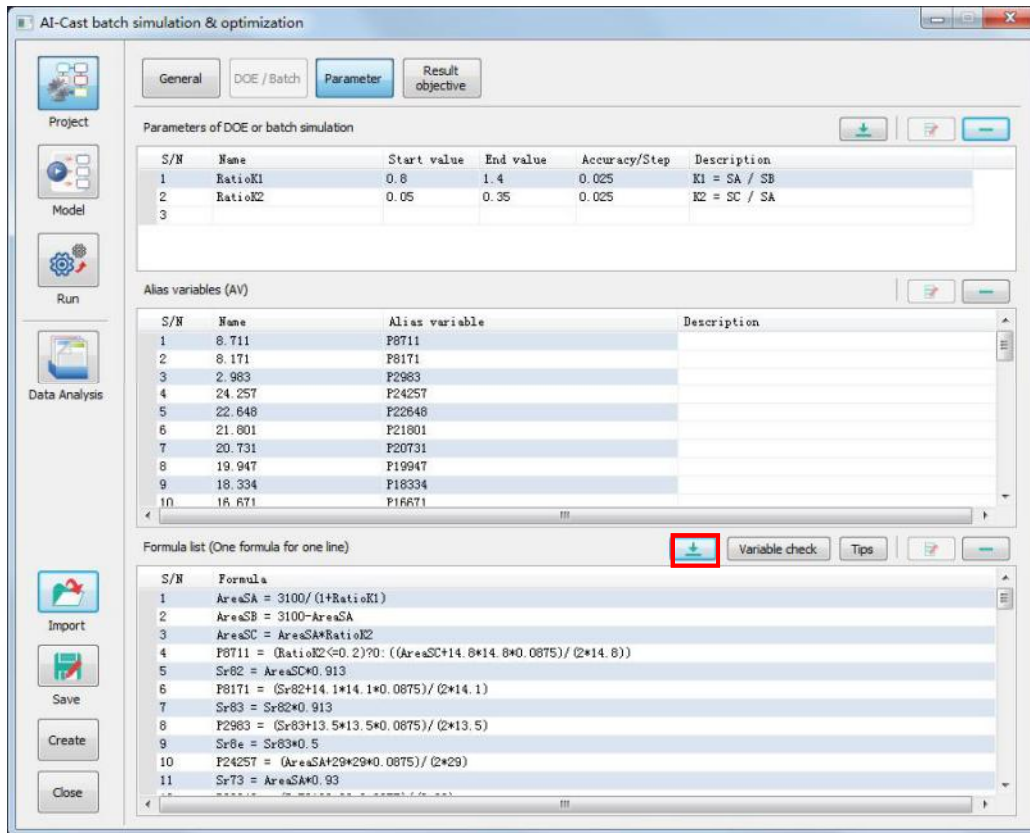
- n The 'Analysis result' page of optimization has been redesigned.
- n The result of post-solver has been enhanced to the optimization solver.
- n The 'Gas_Node_Mass_Block' could be used to the optimization for the flow process.
- n Both node result and group result could be supported.

AI-CAST for Flow Optimization

- n Thanks to the new gas entrapment technology and post solver, the setup of flow optimization model become very easy.
- n Simple select a point to put a sensor on the target region to monitor the blocked gas mass.
- n Both the single node result and nodes group result are supported.
- n This is unique in the market today, and much better than other criteria like total oxidant or contact surface area etc.

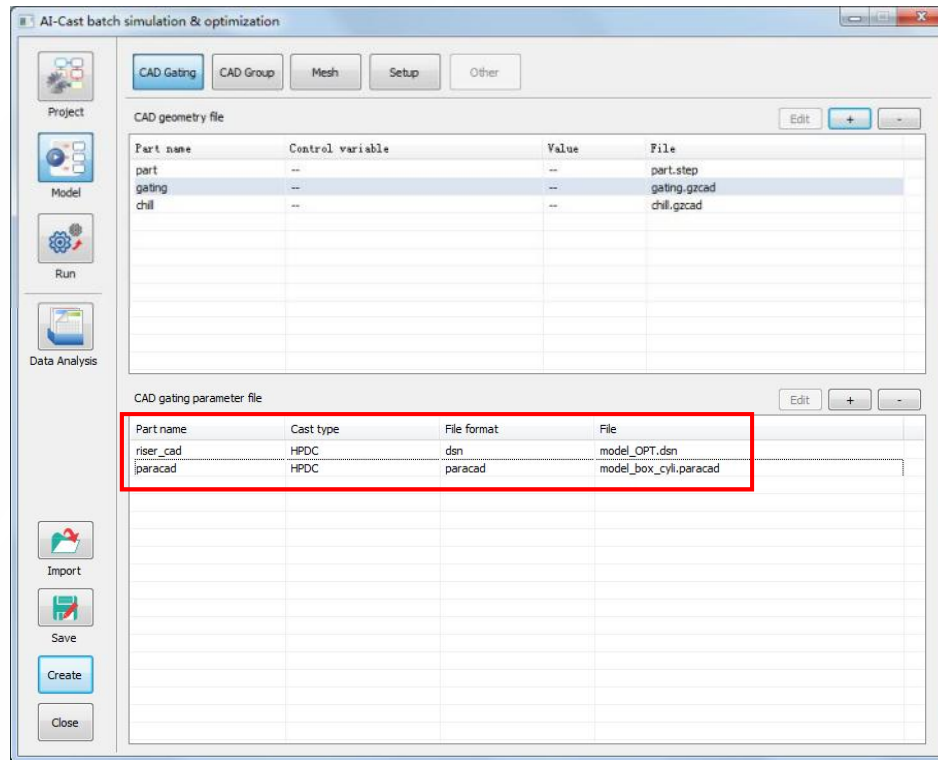


AI-CAST Parameter



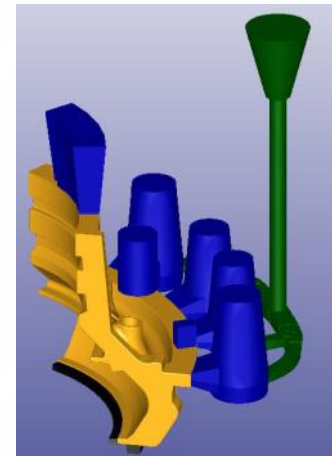
- I Import text file from any 3rd ASCII editor. This is useful for complex model with many line formula.
- I The space line, space and table chart are support in the ASCII file.
- I 'Variable check' to check the variables definition.

AI-CAST driven ParaCAD



I AI-Cast support both the gating system design file and ParaCAD file. The automatic optimization engine can drive the CAD modification directly.

I ParaCAD could be used for any CAD geometry design. i.e. the casting part, gating, riser, standard components, chills etc.



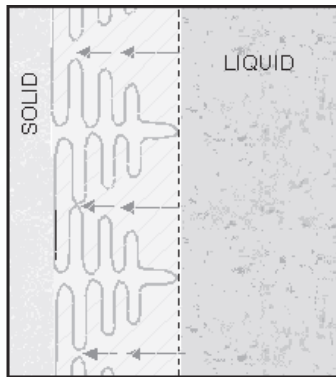
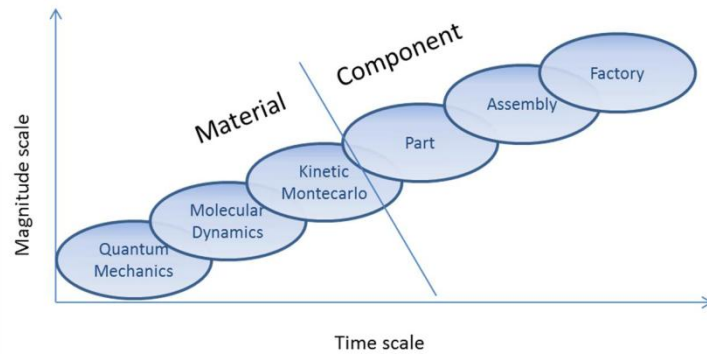
I Several ParaCAD files could be used in one optimization.

Cast-Designer V7.4

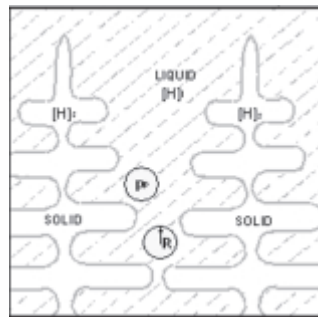
CDCA



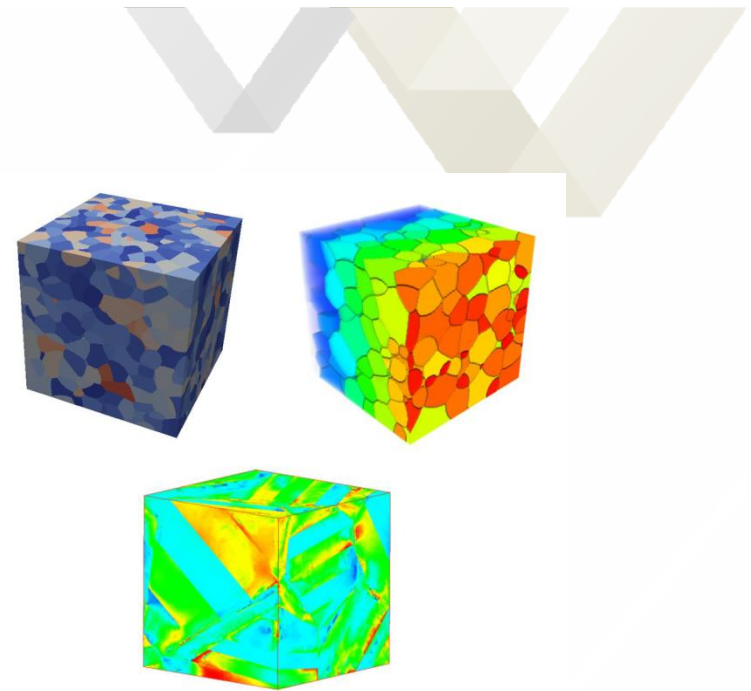
Multi-Scale Model



Liquid metal flow in the mushy zone, during solidification



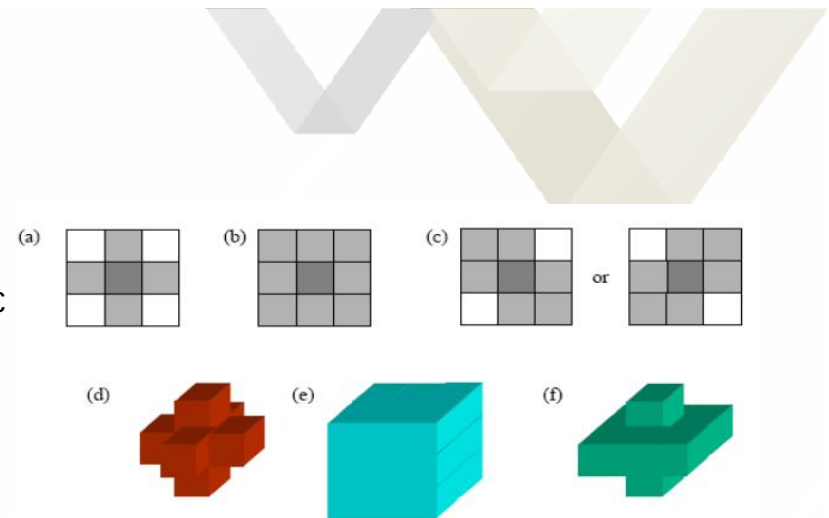
Schematic of micro-porosity formation by numerical simulation



Grain growth simulation

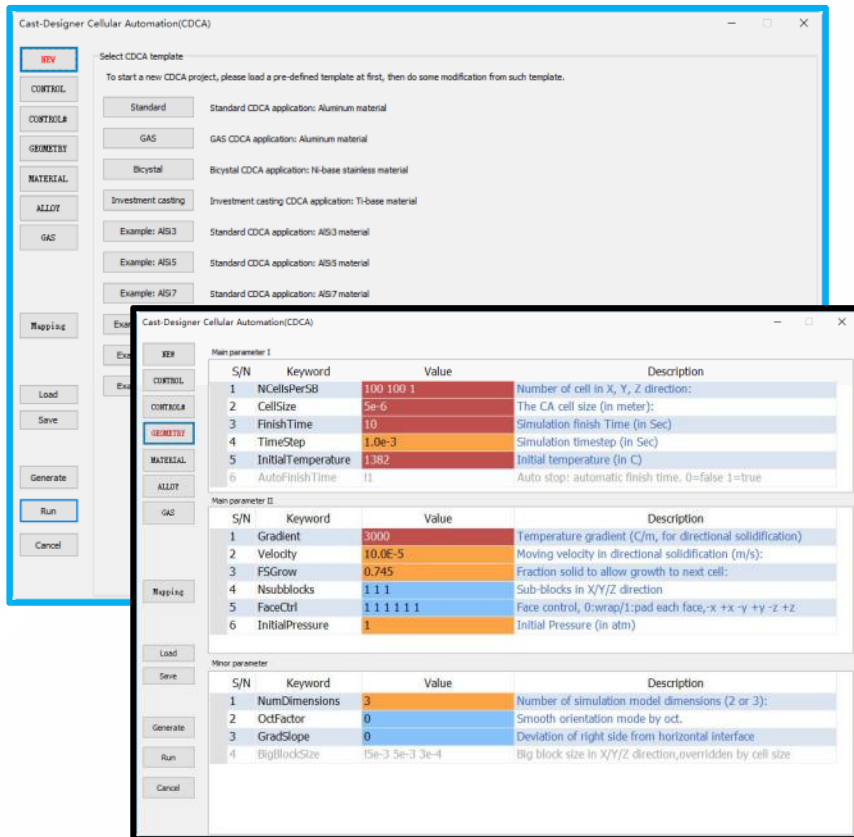
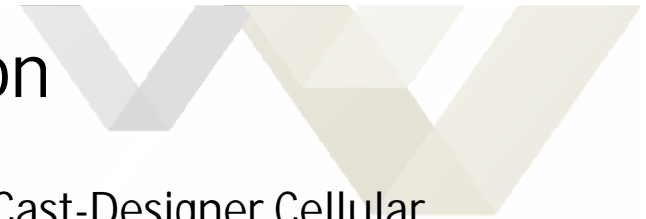
Cellular Automaton (CA) Model

- n Cellular Automaton (CA) is an algorithm that describes the dynamic systems where space, time, and variables are discrete on all sites of a lattice and local, global deterministic or stochastic rules can be applied to each site.
- n A universe consisting of a homogeneous array of “cells” is assigned at the beginning of calculation. Each cell is endowed with a finite number of states and evolves in discrete time according to a uniform local transition rule. The rule can be seen as a function whose arguments are the state at time t of neighboring cells and whose value is the state of the considered cell at time $t+1$.
- n At each time step, all the cells “compute” their new state and update the values according to the pre-defined transition rules.
- n By iterating this operation, the evolution of the variables associated with the cells is obtained and thus some physical events such as nucleation and growth of solid are simulated.



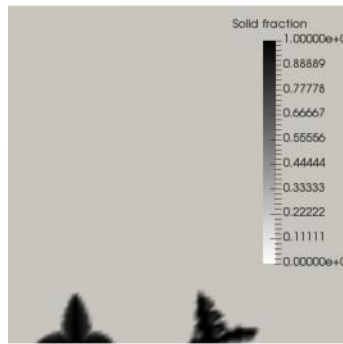
Some cellular automata neighborhoods: (a) The 4-cell or von Neumann neighborhood; (b) The 8-cell or Moore neighbourhood; (c) the left- and right-handed hexagonal neighbourhoods; (d) the 3D 6-cell von Neumann neighbourhood; (e) the 3D 26-cell Moore neighbourhood; (f) the 3D hybrid 10-cell neighbourhood.

CDCA: Software Interface and Operation

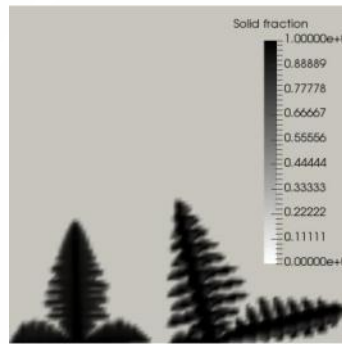


- n The theory of Cast-Designer Cellular Automation (CDCA) was very complex and with lots of parameters.
- n To simple the operation and user understanding, it was designed as template style. The user is recommended to select the most close template to start the work.
- n Material data is the key of the simulation with very limited reference. Before a simulation, the user must do carefully studying of the CDCA material.
- n All functions of CDCA were integrated to the unique interface, including the model coupling.

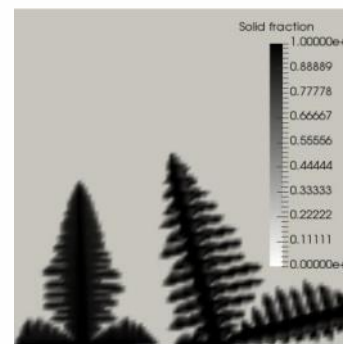
CDCA Application: Bicrystal Growth



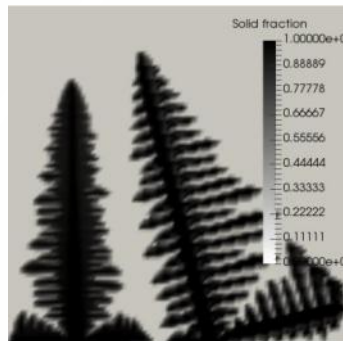
Time: 1.001000



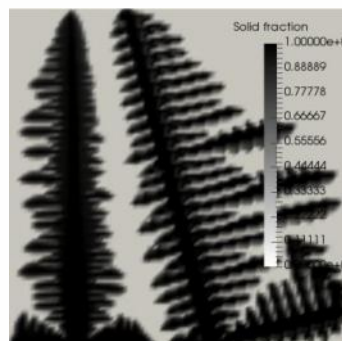
Time: 3.001000



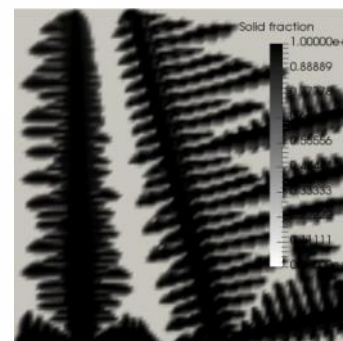
Time: 4.001000



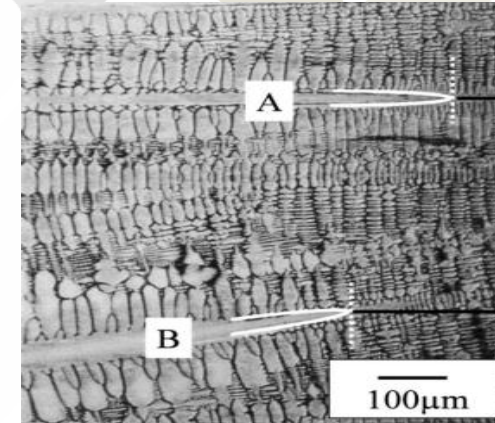
Time: 6.001000



Time: 8.001000



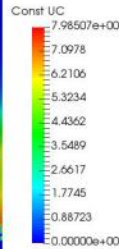
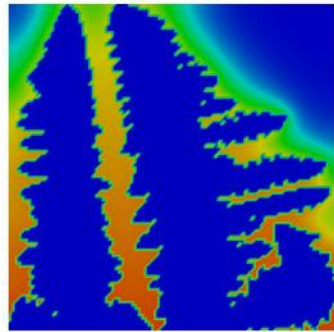
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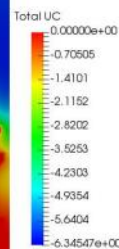
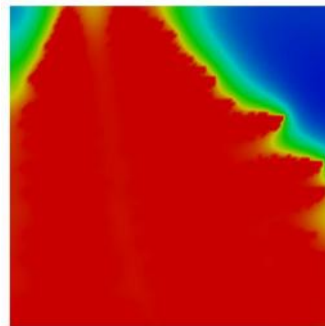
A wide range of axial orientations can be produced during the directional solidification of highly alloyed Ni-base superalloys depending on the efficiency of the competitive growth mechanism.

In a second generation Ni-base superalloy such as CMSX-4, misaligned grains may deviate by up to 15° from the <001> orientation as illustrated in the right.

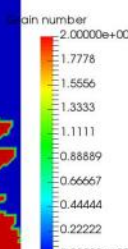
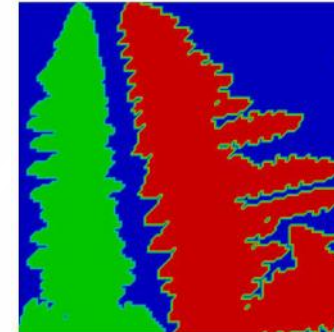
CDCA Application: Bicrystal Growth



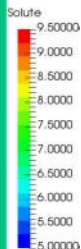
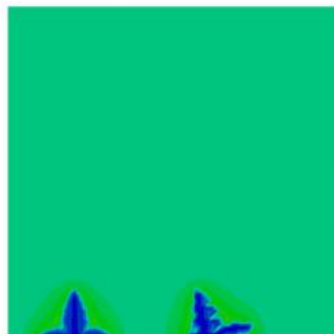
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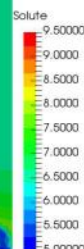
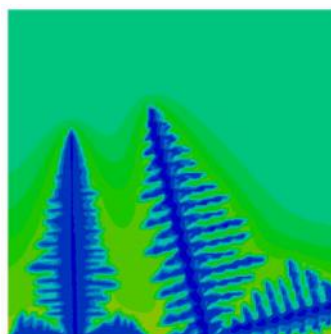
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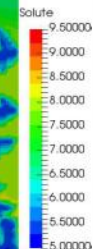
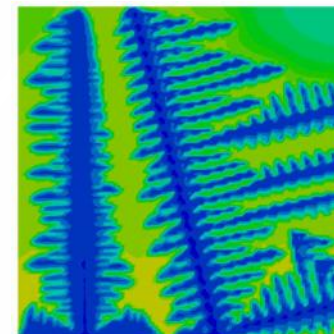
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Time: 1.001000



Time: 5.001000



Time: 10.001000

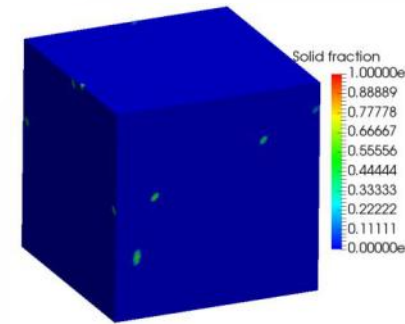
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Cinit

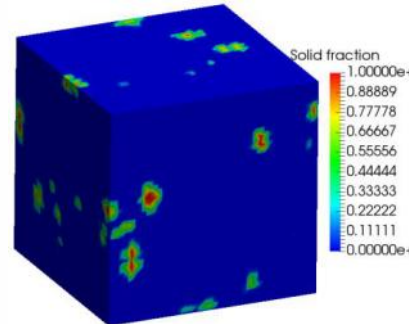
6.5

Initial concentration:

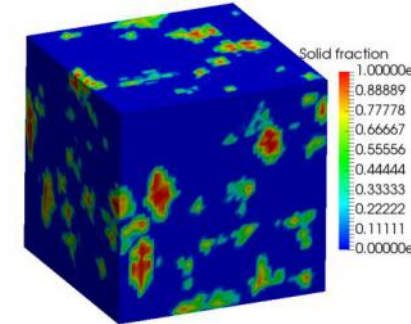
CDCA Application: 3D Cube – Solid Fraction



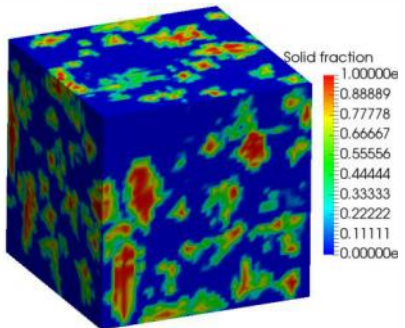
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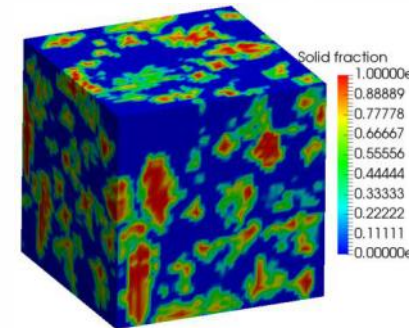
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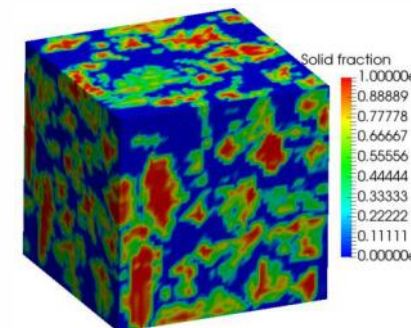
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Time: 9.001000

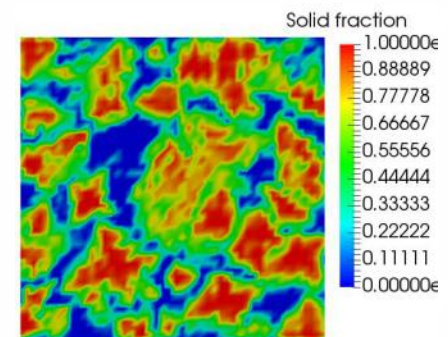
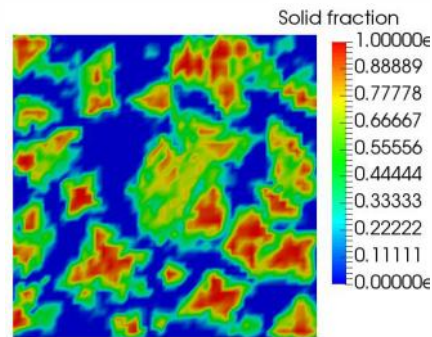
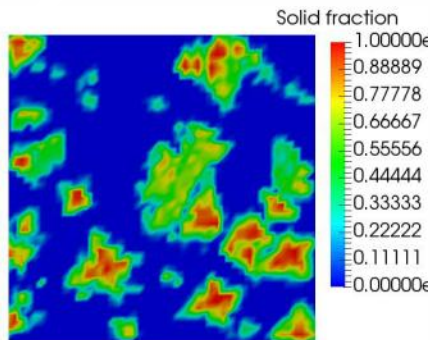
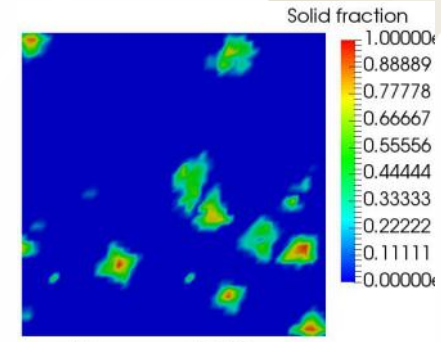
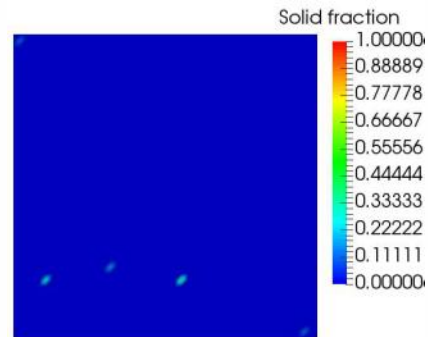
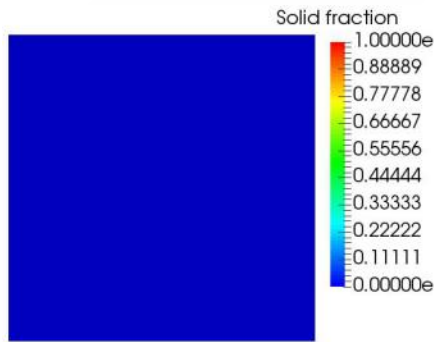


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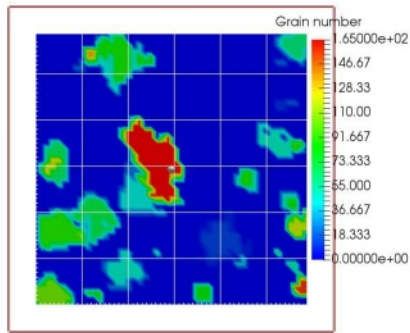


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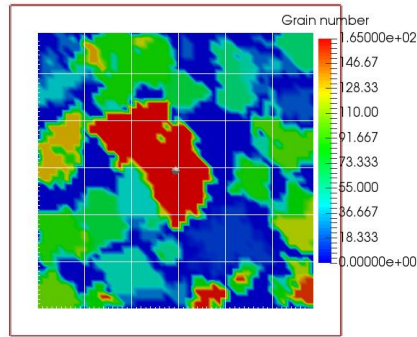
CDCA Application: Solid Fraction (section)



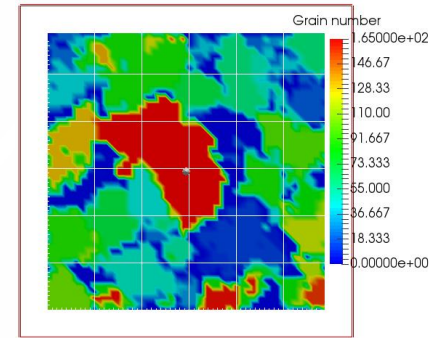
CDCA Application: Grain number & Solute (cube section)



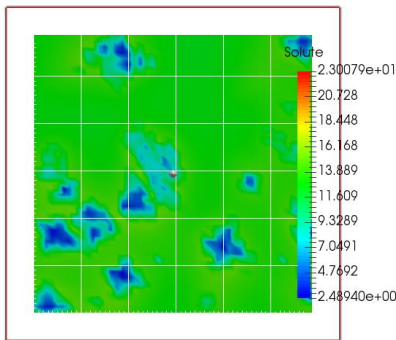
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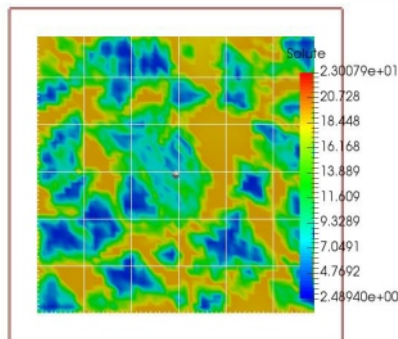
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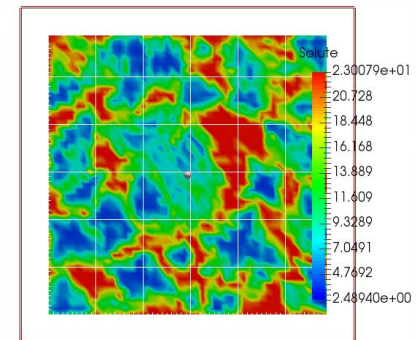
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Time: 5.00

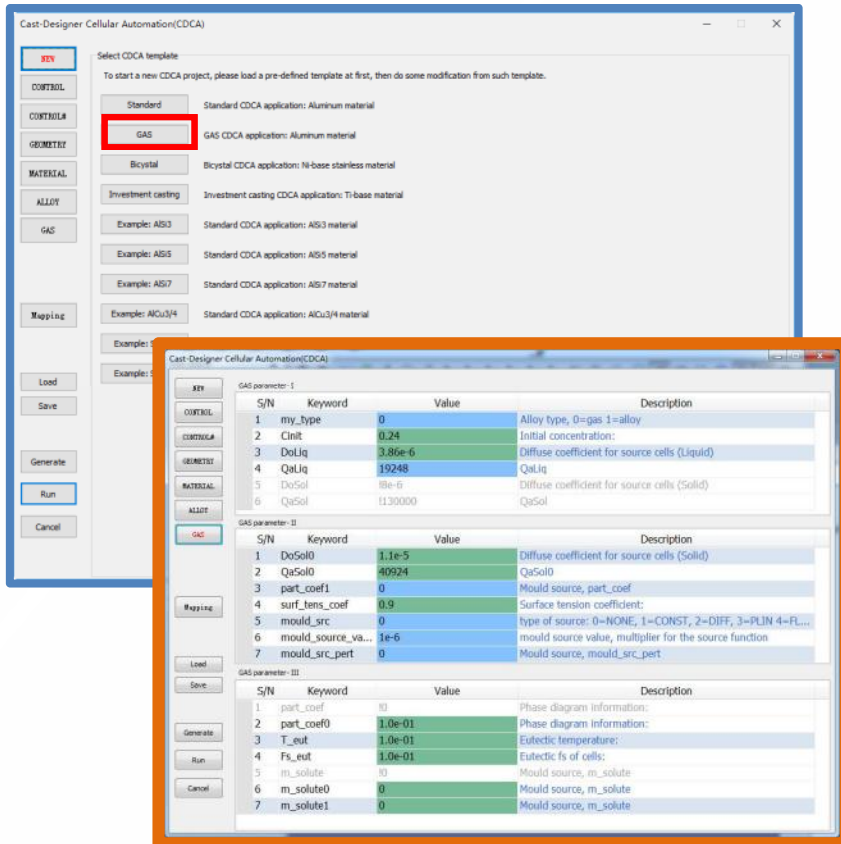


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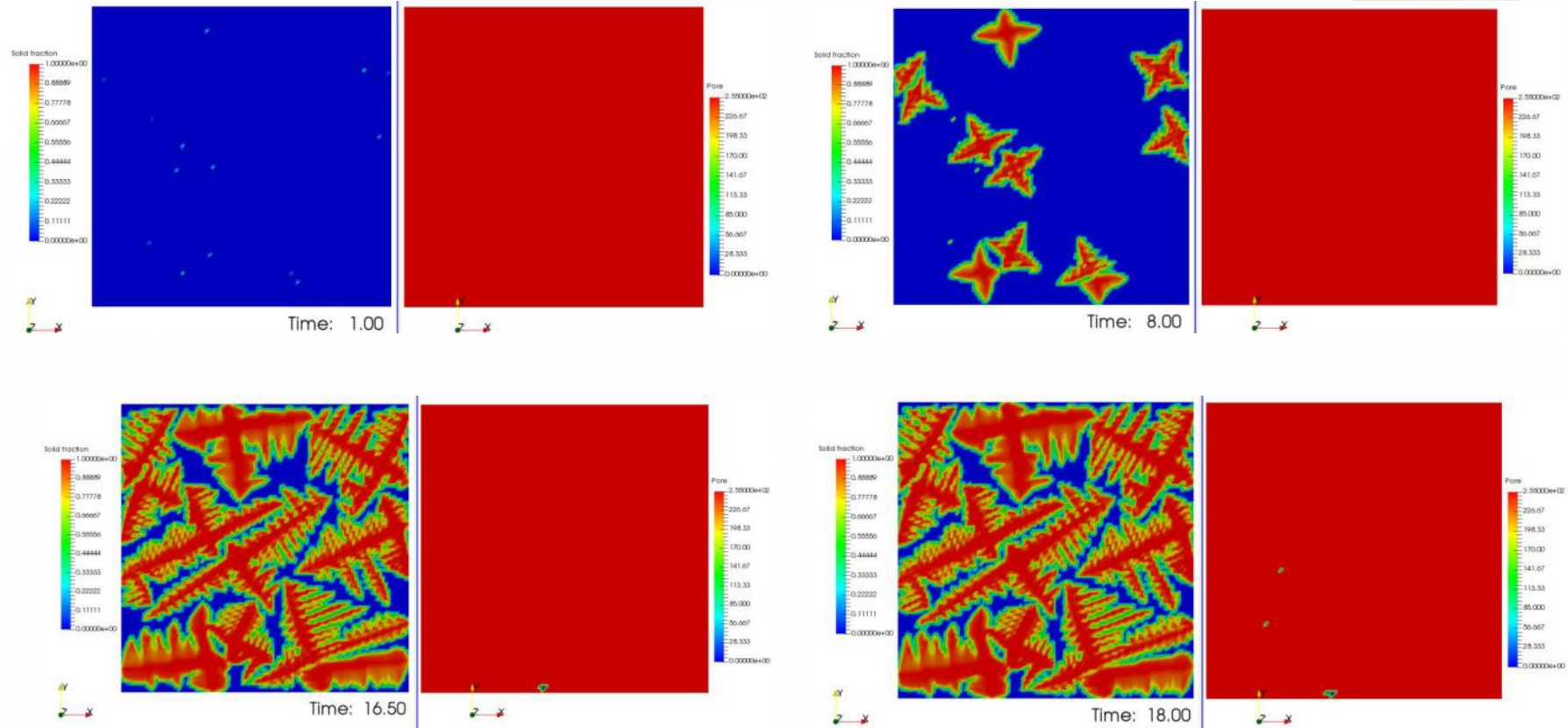
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Gas pore and growth

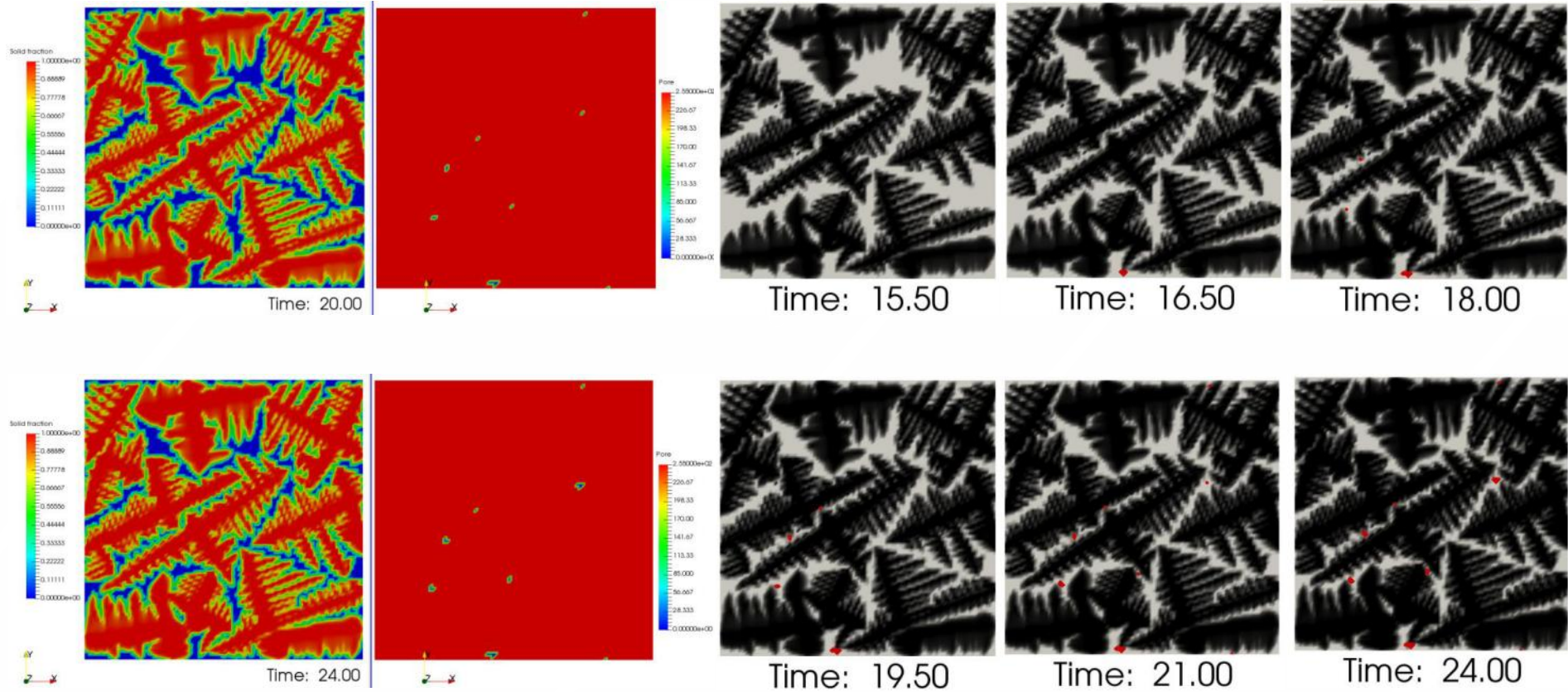


- n The CDCA model is a cellular automaton growth model combined with finite-difference solution of diffusion equations.
- n Porosity formation is classically divided in two stages: nucleation and growth. Both of them can be simulated with CDCA code.
- n Many physical phenomena occurring during solidification have been included in the CDCA model, among these, the following functions might be useful when simulating porosity:
 - | Pre-fixed nucleation of pores;
 - | Stochastic nucleation;
 - | Diffusion controlled growth.

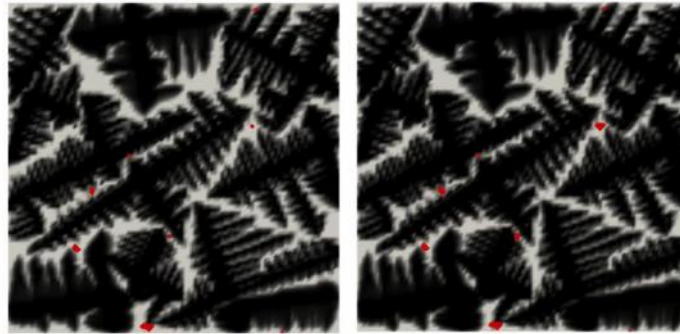
CDPE Application: Solid Fraction & Pore



CDPE Application: Solid Fraction & Pore

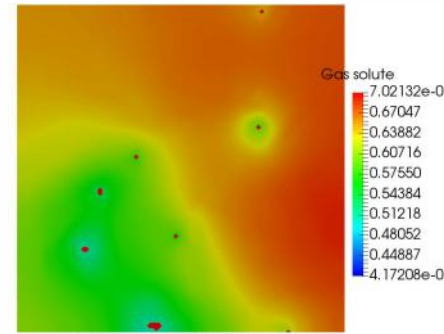


CDPE Application: Solid Fraction & Pore

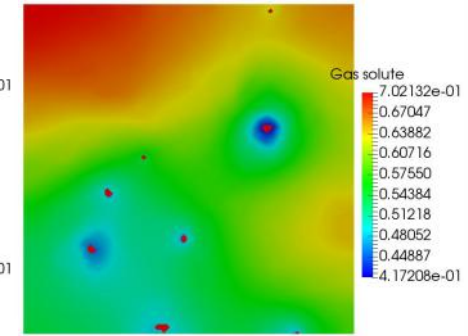


Time: 21.00

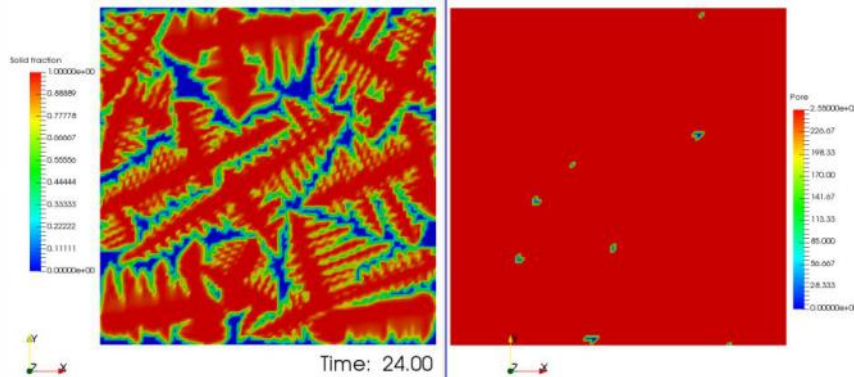
Time: 24.00



Time: 20.00

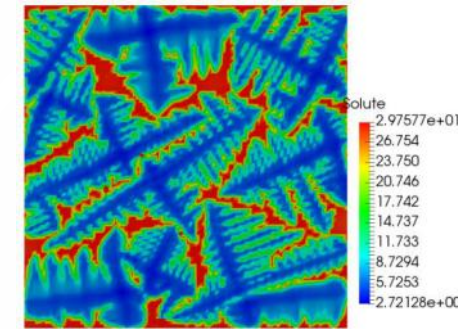


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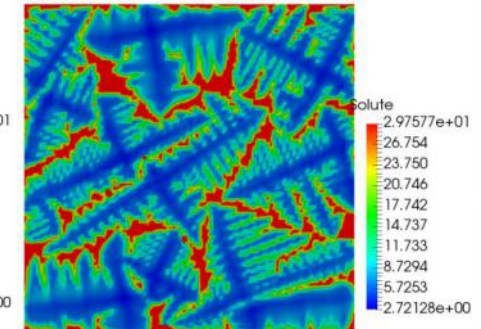


Time: 24.00

Time: 24.00

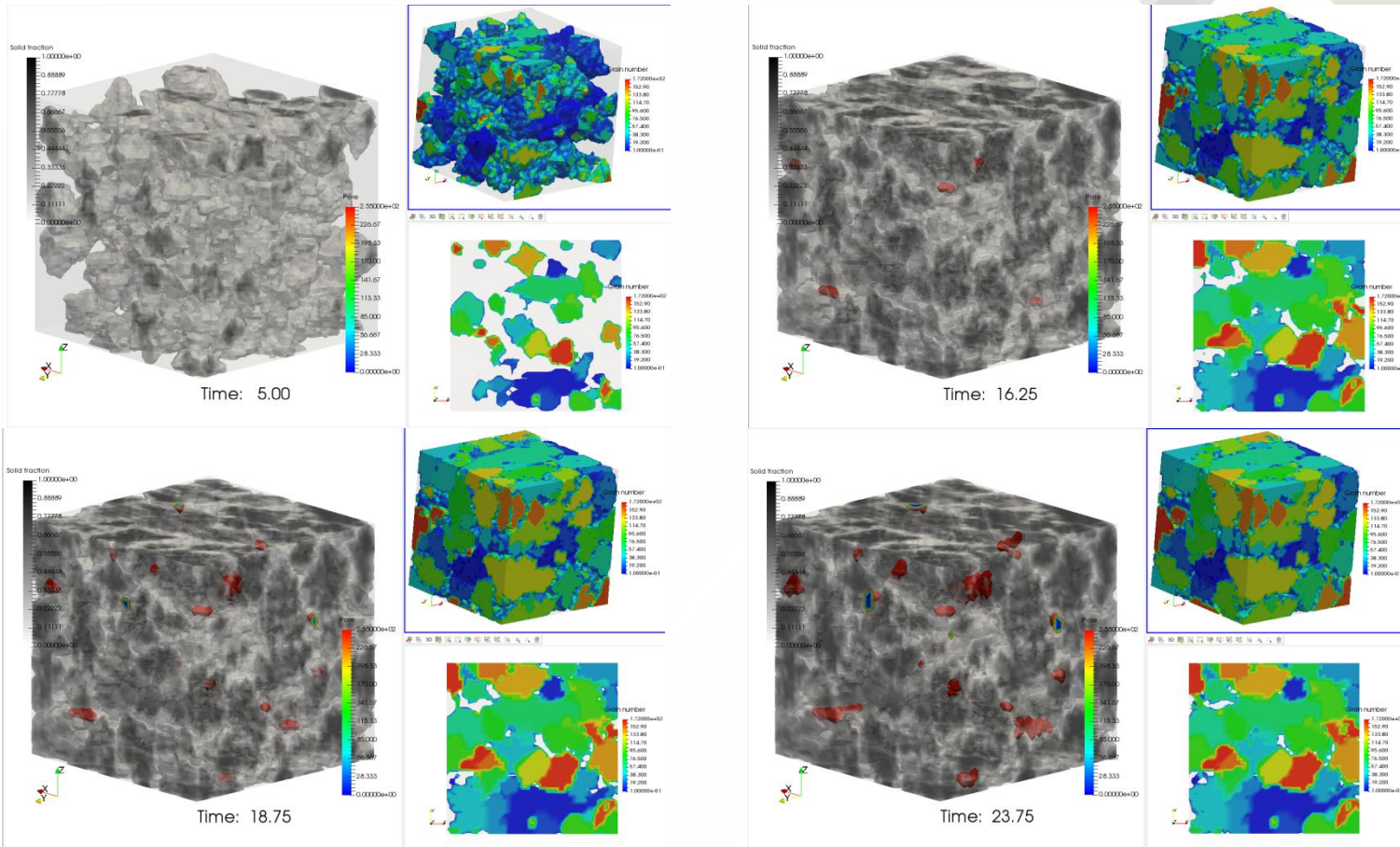


Time: 20.00



Time: 24.00

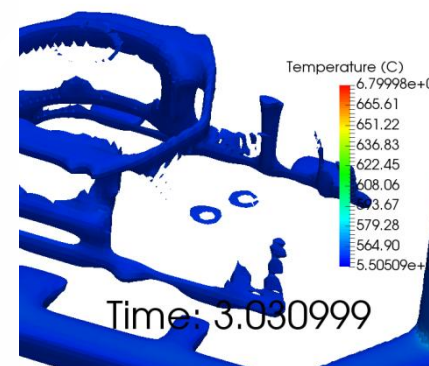
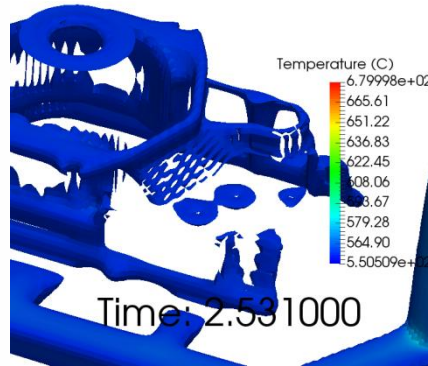
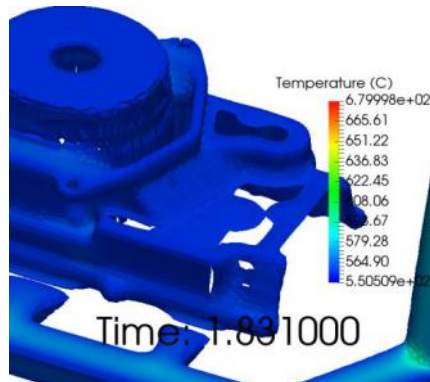
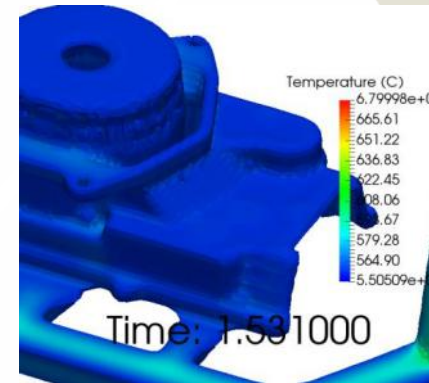
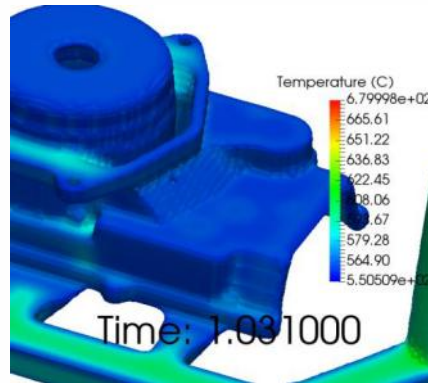
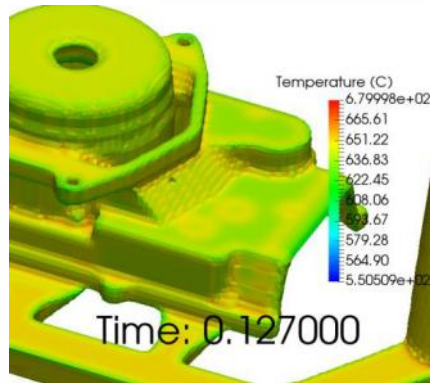
CDPE Application: Solid Fraction & Pore



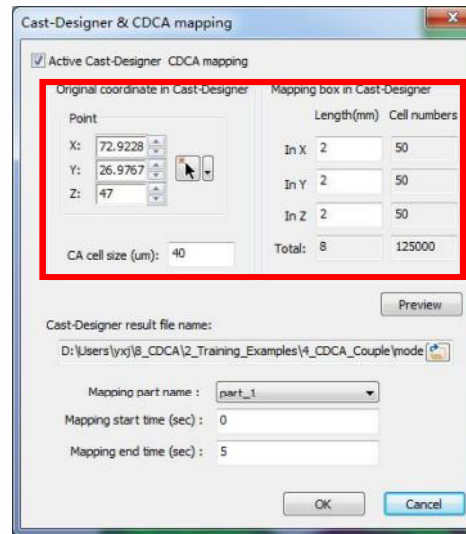
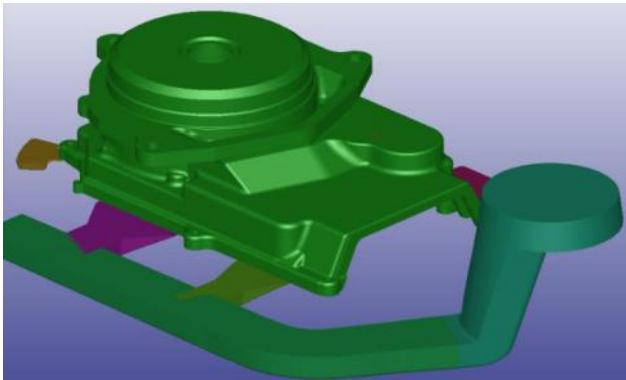
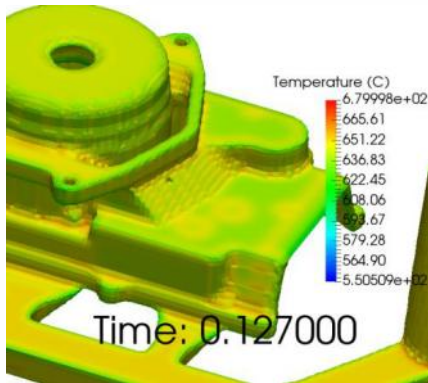
CDPE Application: Couple to Marco Model

- n When combined with a macro-model, the behavior of a large system may be simulated for averaged properties, while simulation of the microstructure is performed only on a small segment.
 - n This allows some insight into a system for which micro-structural simulation of the whole would not be feasible.
- ü Run a standard Cast-Designer simulation for the Marco-model
 - ü Usually solidification only simulation
 - ü Consider complex temperature distribution
 - ü Check the Marco-model simulation result
 - ü Temperature distribution
 - ü Where is the key region need run CDCA
 - ü Result output in the key frame should be fine enough
 - ü Define the process start time and end-time
 - | Start time: when to start CDCA couple (all liquid)
 - | End time: when to stop CDCA couple (all solid)

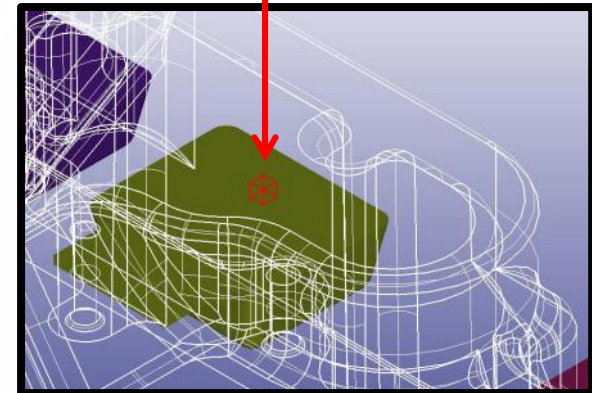
CDPE Application: Couple to Marco Model



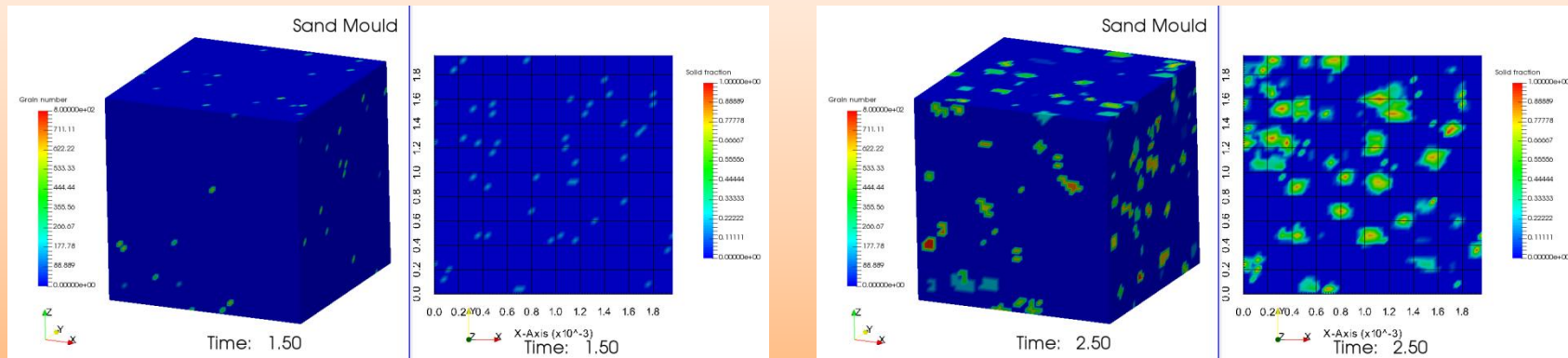
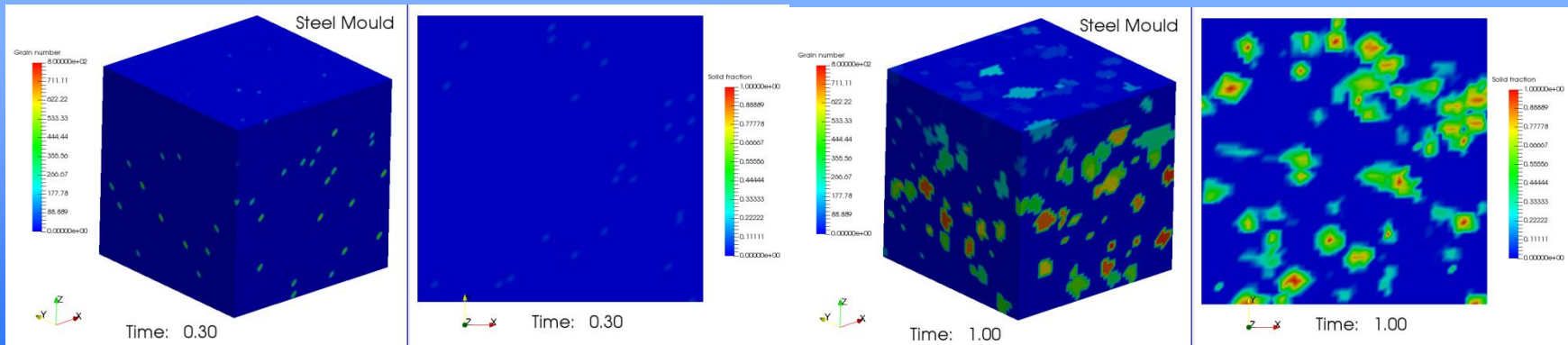
CDCA Application: Couple to Marco Model



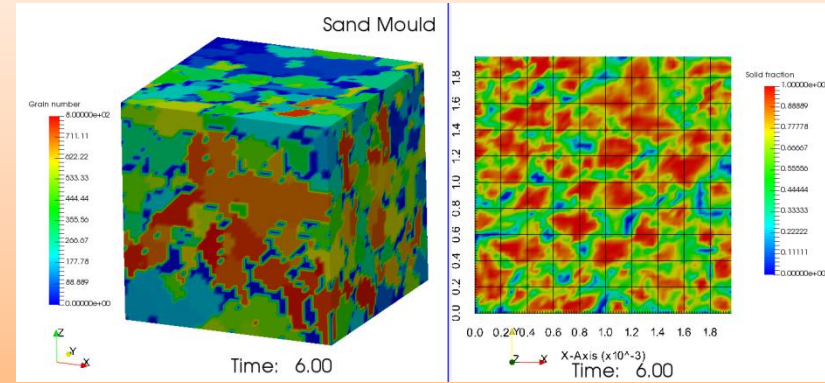
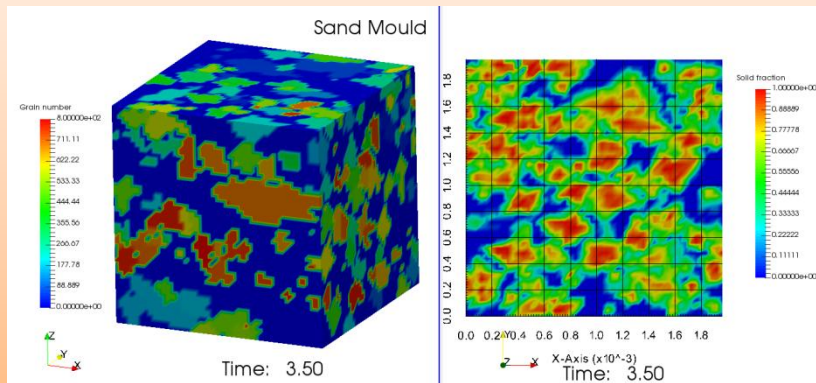
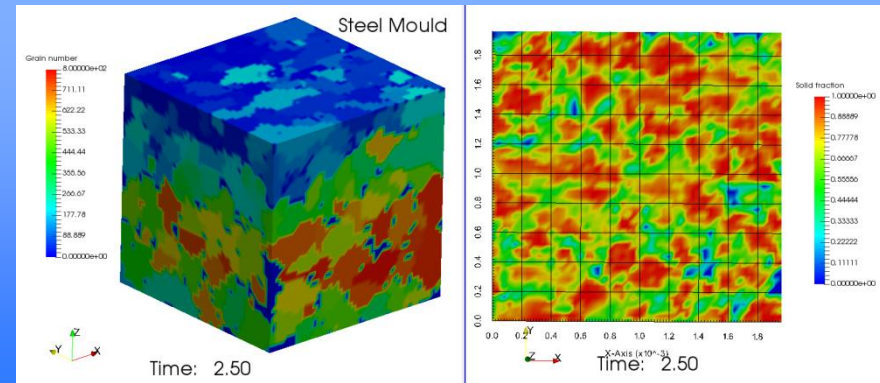
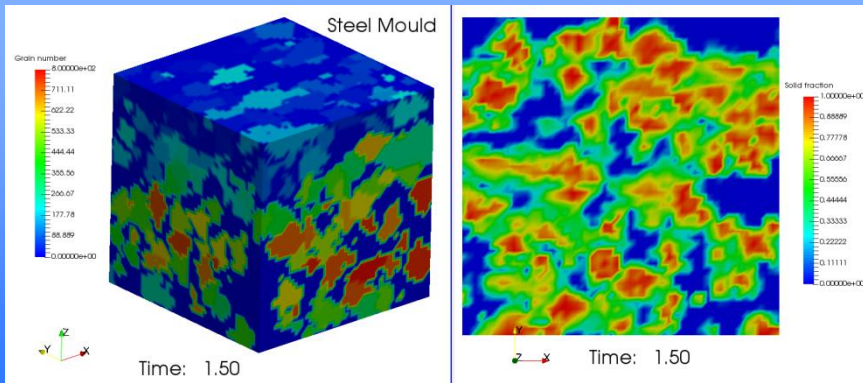
Define the CDCA coupling model
Pick up the temperature –time data
from the marco model and assign to the
CDCA simulation.
The cooling rate also could be
considered in the CDCA model.



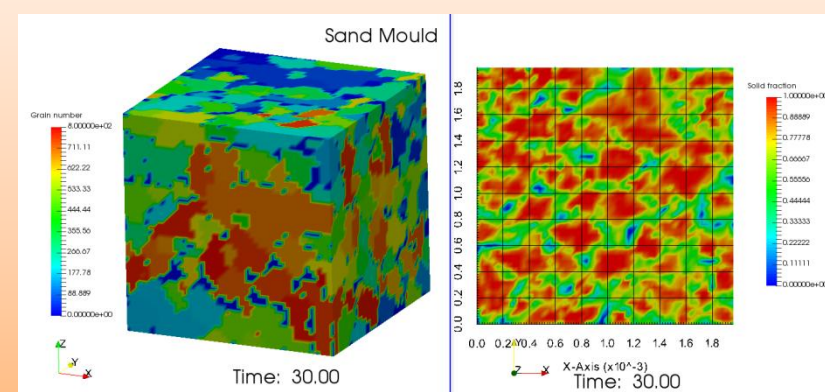
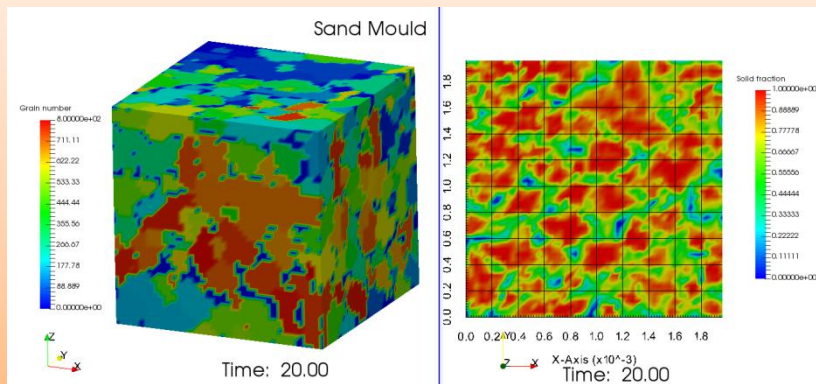
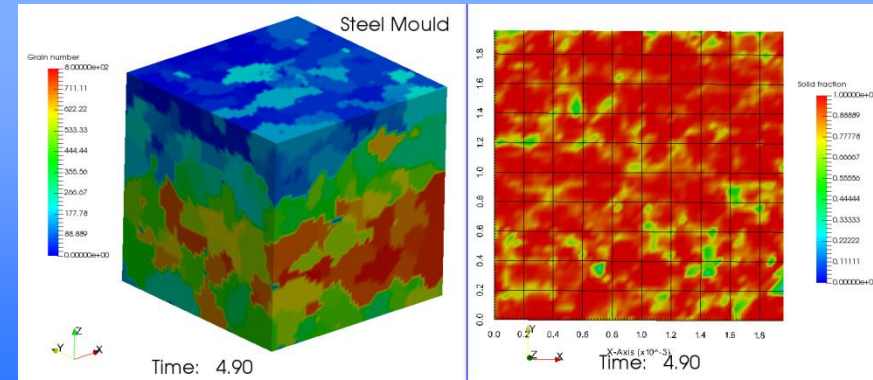
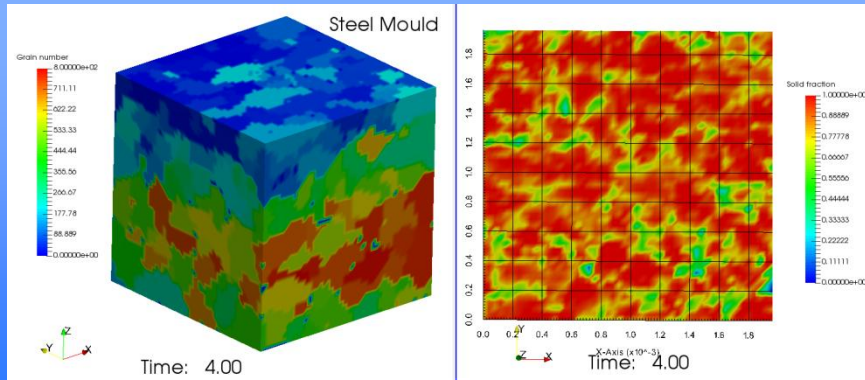
Couple to Marco Model: Steel mould vs Sand mould



Couple to Marco Model: Steel mould vs Sand mould



Couple to Marco Model: Steel mould vs Sand mould



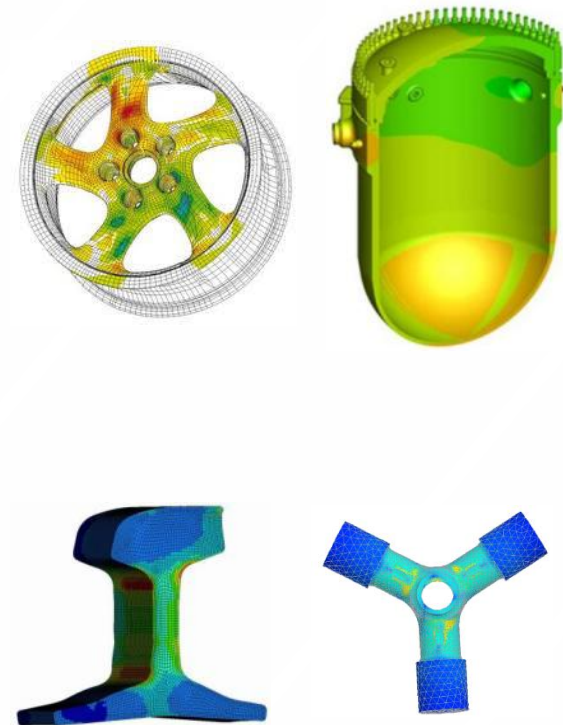
Cast-Designer V7.4

CDPE



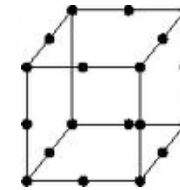
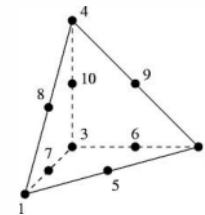
What is Cast-Designer Performance (CDPE)?

- n CDPE is a 3D nonlinear FEA code for solid mechanics
- n **Function:**
 - n Solids subjected to static, dynamic, thermal loadings
- n **Parallel computing:**
 - n Extensive parallel execution via threads and threads+ MPI
- n **Big analysis model:**
 - n It is used to solve nonlinear solids models with 1M nodes/elements on desktops; much larger models (2-5 M) nodes on supercomputers/clusters
- n Highly targeted feature set (e.g. Crystal plasticity, FGMs, crack extension, Gurson models, cohesive models...) supporting.



Key Features of CDPE

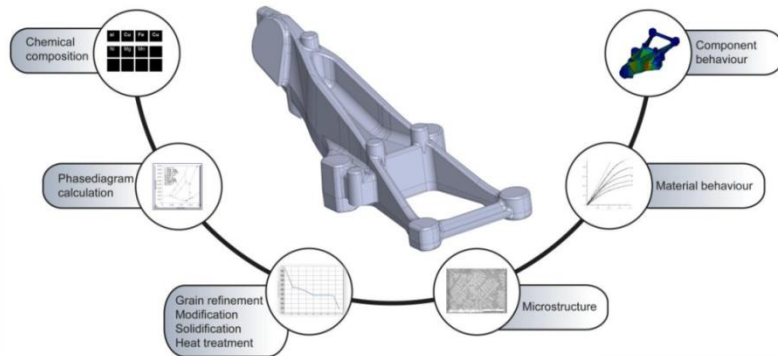
- n Support elements: Solids 8, 9, 12, 15, 20 node (hex) isoparametrics; 4, 10 node tets; all with face, temperature, body loadings
- n Static, impact/dynamic (time-history integration)
- n Finite-strain plasticity (mises, crystal plasticity, deformation plasticity, hydrogen effects, Gurson-Tvergaard, strain-rate dependent, Frederick-Armstrong & Generalized cyclic, temperature dependent, etc.)
- n Fully automatic crack growth modelling (element death, CTOA and user controlled node release, interface cohesive, adaptive solution strategies)



- | **Solvers:** *Pardiso (direct, iterative) in Intel Math Kernel Library for threaded parallel execution*
- | **Material:** *incremental Mises with segmental definition of uniaxial true stress-log strain curve. Isotropic hardening. Finite strains.*



◆ The closed chain of simulations of cast components

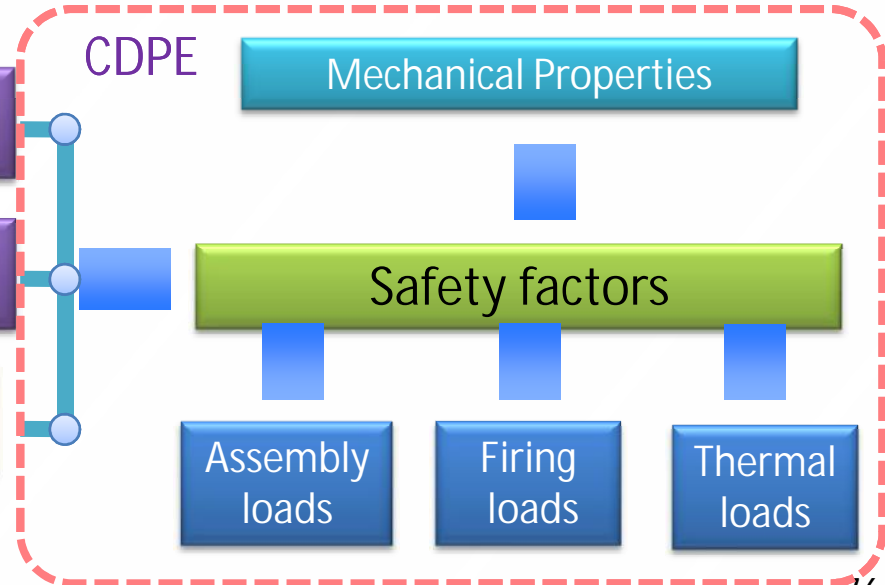


CDPE: couple the casting simulation result to the performance simulation.

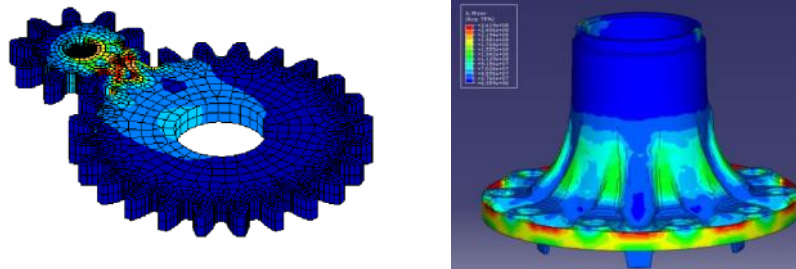
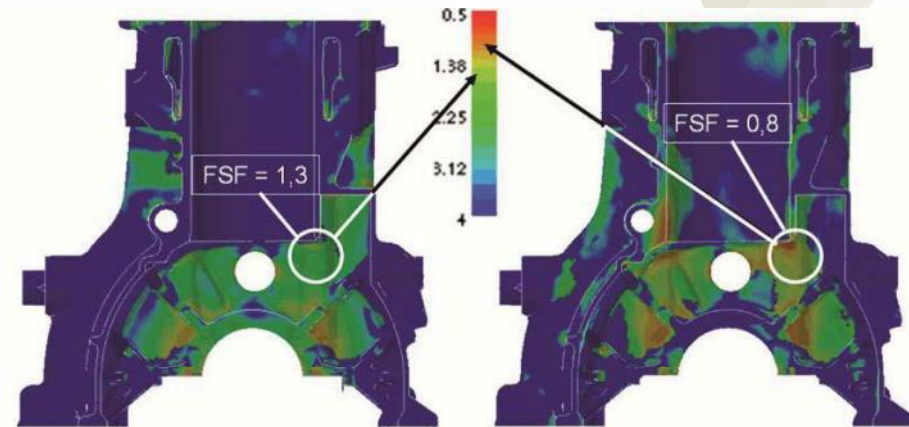
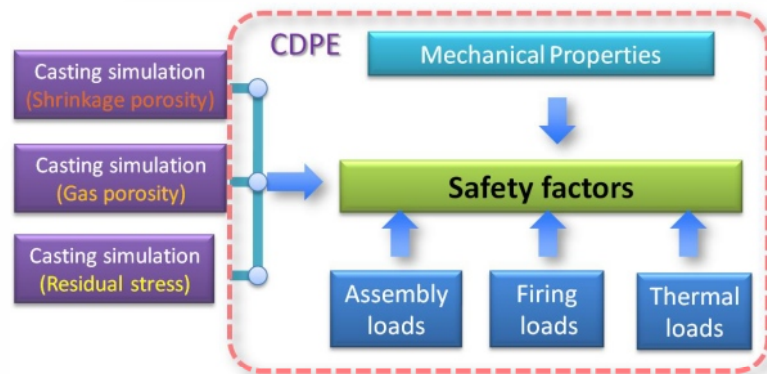
- | Same user environment
- | Same mesh system
- | Automatic result coupling, no data lose.



- Casting simulation (Shrinkage porosity)
- Casting simulation (Gas porosity)
- Casting simulation (Residual stress)



◆ The closed chain of simulations of cast components

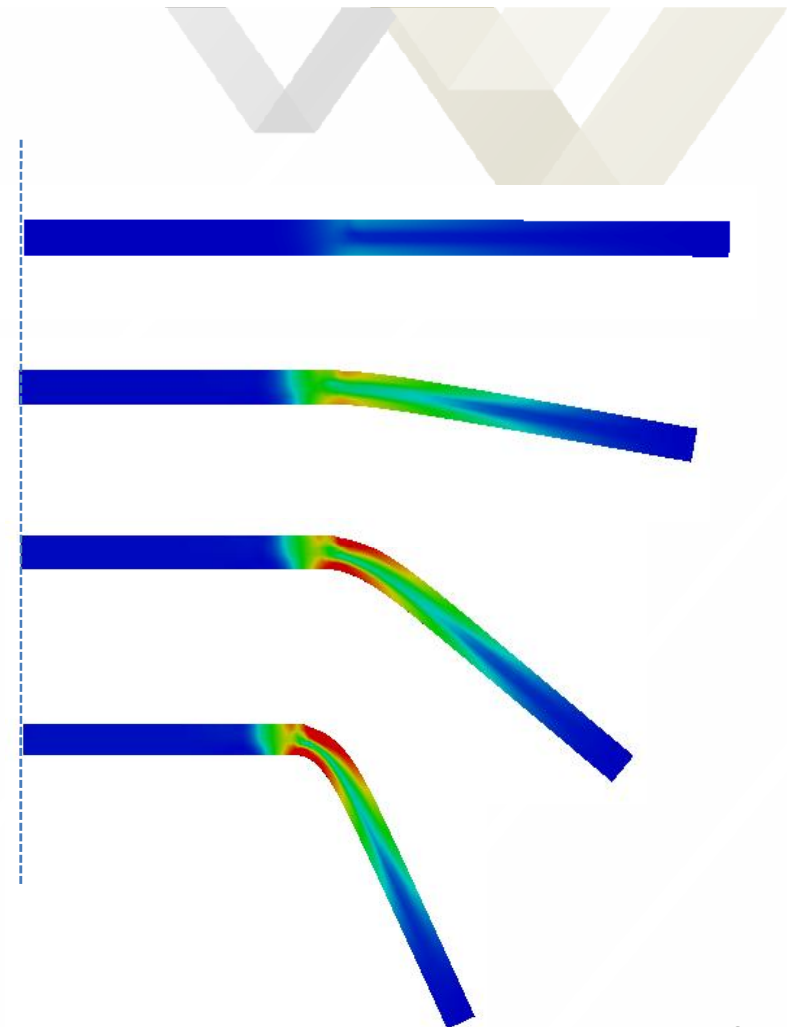
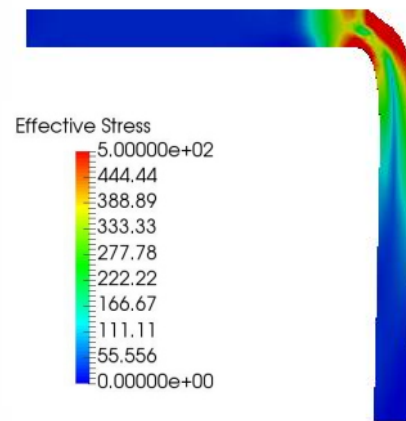
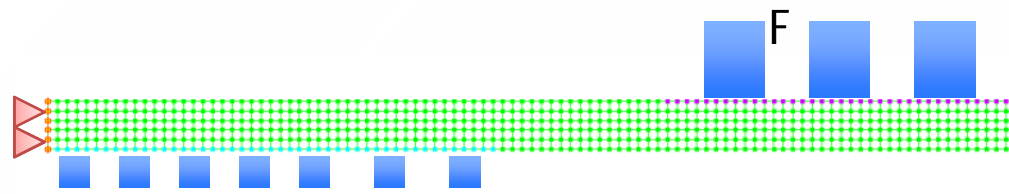


Impact of as-cast residual stresses on durability of a cast iron engine block.

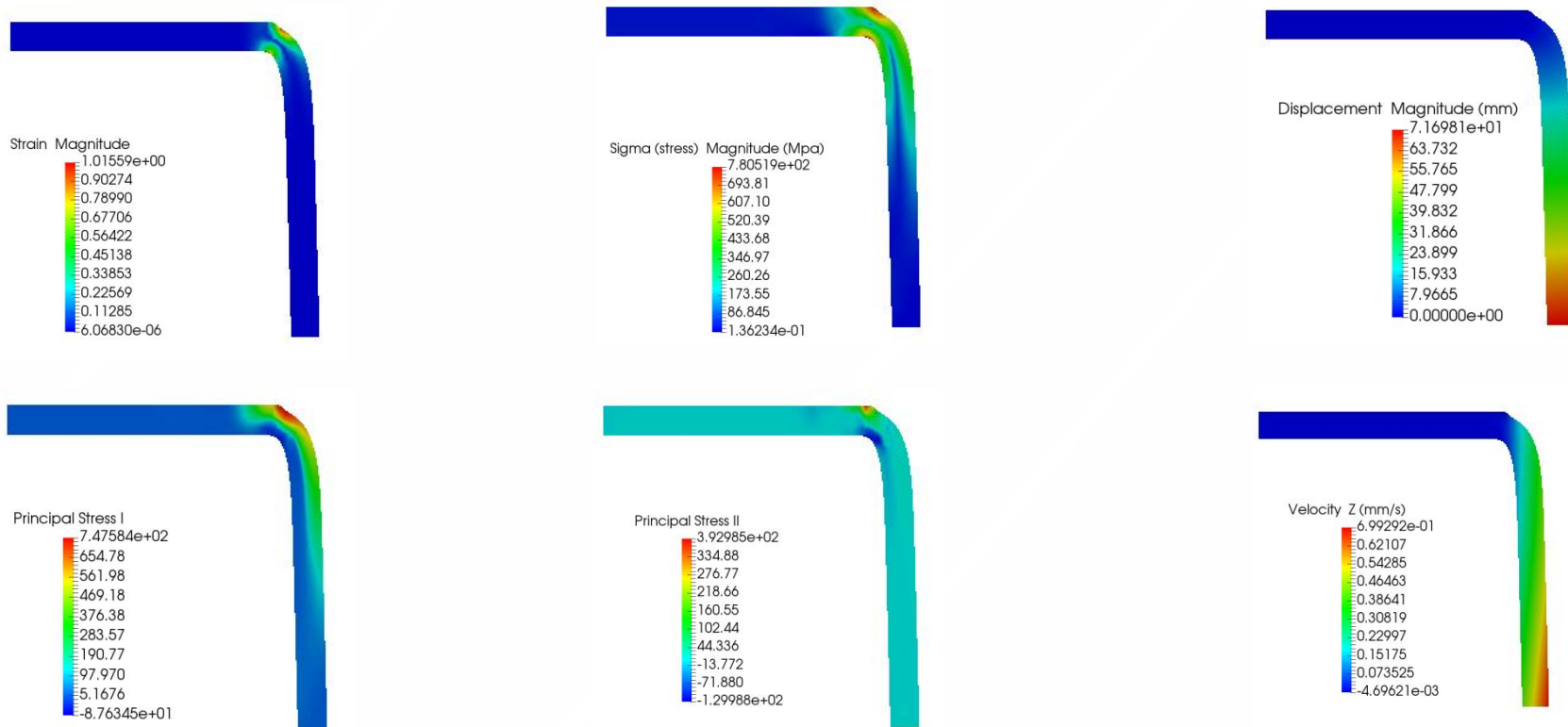
The classical life time prediction does not consider stresses resulting from manufacturing. The stress free casting shows a safety margin of 30% in a critical area (left).

If residual stresses from the casting process are considered as an additional load, the safety margin in the critical area drops down to 80% (right).

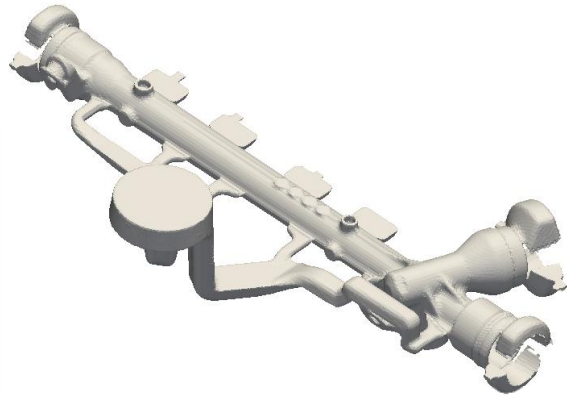
CDPE Example: Bending Process



CDPE Example: Bending Process

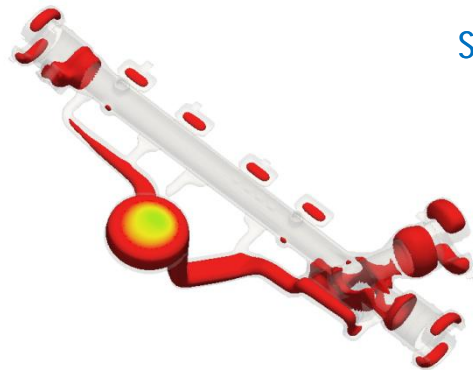


CDPE Example: Housing



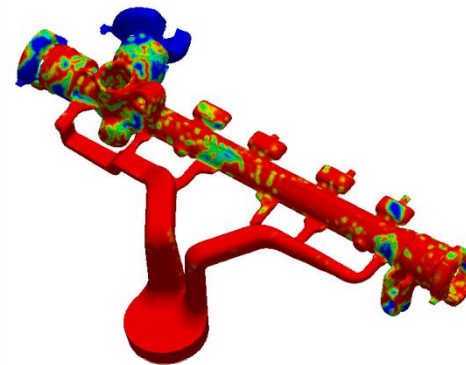
The casting part **failed** to pass the **mechanical testing** of the housing. Other vendor can pass the testing without problem, so the **casting defects** is the key of the part performance.

CDPE Example: Housing



Solidification result

Hot spots

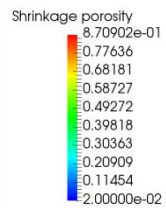


Filling result

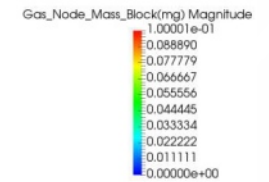
Gas entrapment during flow



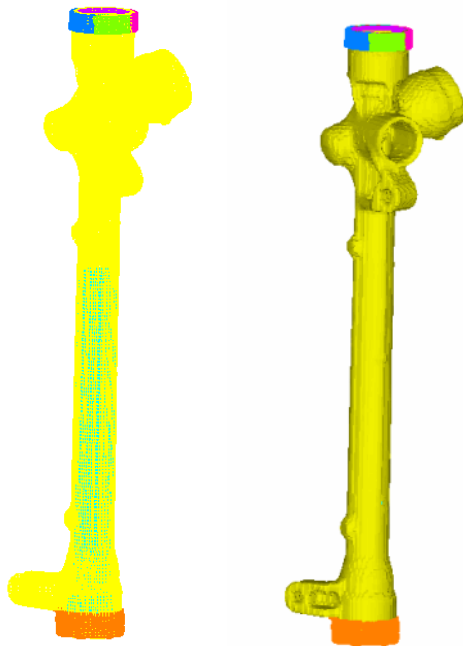
Shrinkage porosity



Gas blocked in the casting



CDPE Example: Housing, CDPE model setup



- n Fix half of the inner surface
- n For the nodes of the bottom of the casting part
- n Fix the Z coordinator of the top surface
- n Add a torque of the top head
- n Compare 2 result, one is the theory part without casting defects and another one with the shrinkage porosity and gas porosity, add the same force in the same location.



Map Cast - Designer stress / porosity result to performance analysis

Couple gas porosity and shrinkage porosity result

Shrinkage porosity result file name: D:\Users\jyx\3_Performance\2_Zinal\2_housing_couple\model\1_model_TPF

gate_3D
Inlet_3D
Overflow_3D

casting_3D

Extract result in step: 165

Shrinkage porosity range: Minimum(%) Maximum(%)
0.5 5

Gas porosity result file name: D:\Users\jyx\3_Performance\2_Zinal\2_housing_couple\model\1_model_TPF

gate_3D
Inlet_3D
Overflow_3D

casting_3D

Extract result in step: 165

Gas porosity: Minimum(mg) Porosity(%) Maximum(mg) Porosity(%)
0.001 0.5 0.02 5

Material properties

Material Name	E(Mpa)	Nu	Nu Yield stress (Mpa)
AL	70000	0.33	150

n Tan-E

Density(Ton/mm ³)	Alpha
2.7e-9	1.0e-6

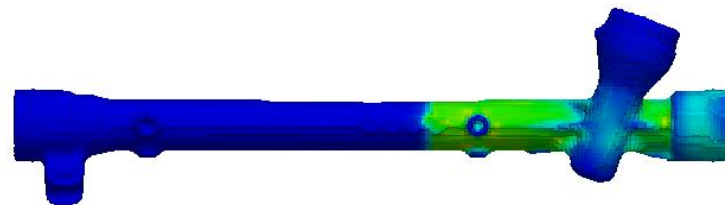
Mapped material numbers: 20 E(ph)Min 5000

Porosity to mechanical properties $E(ph) = E0 * (1 - Ph0/Ph0)^n$

Parameters: Ph0 n
0.5 2.5

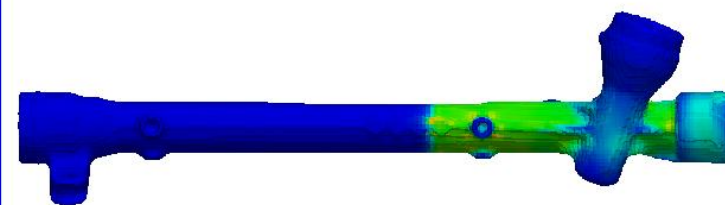
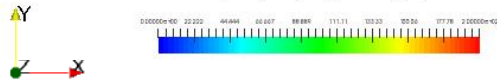
Steel Aluminum

CDPE Example: Housing, Result Analysis



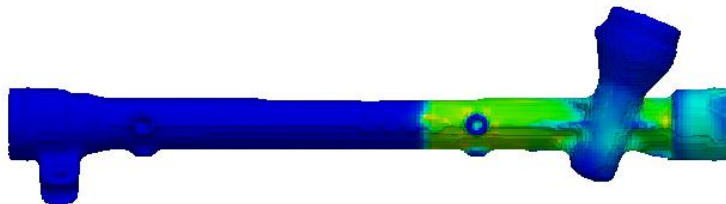
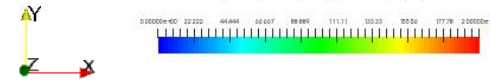
No couple

Sigma (stress) Magnitude (Mpa)



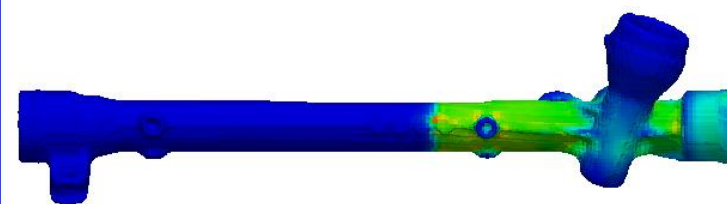
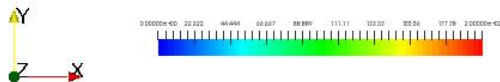
Couple: shrinkage + gas porosity

Sigma (stress) Magnitude (Mpa)



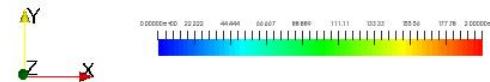
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Sigma (stress) Magnitude (Mpa)

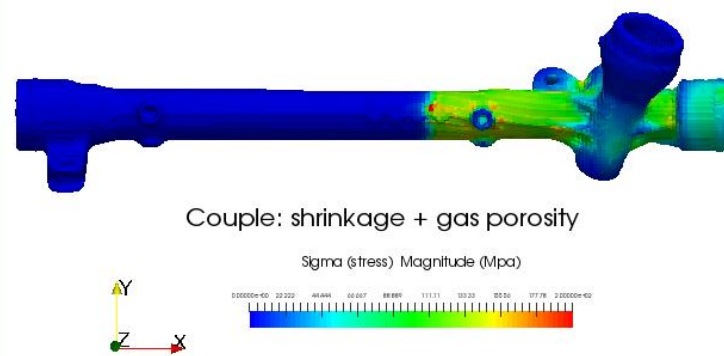
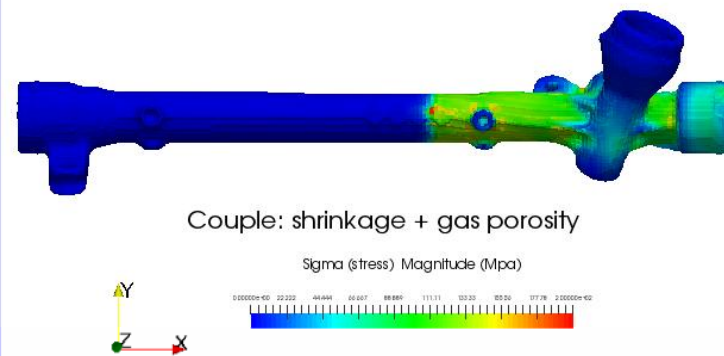


Couple: shrinkage + gas porosity

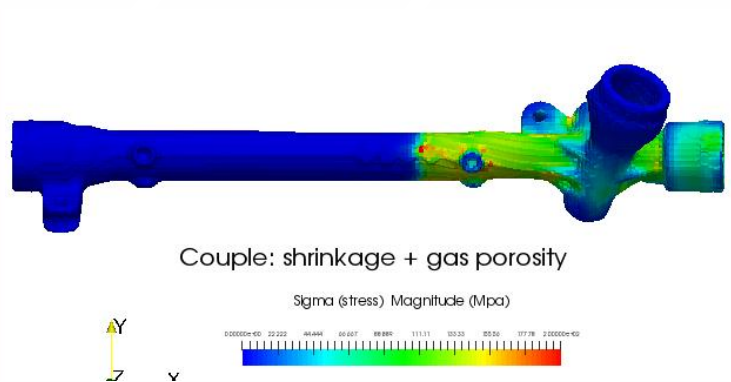
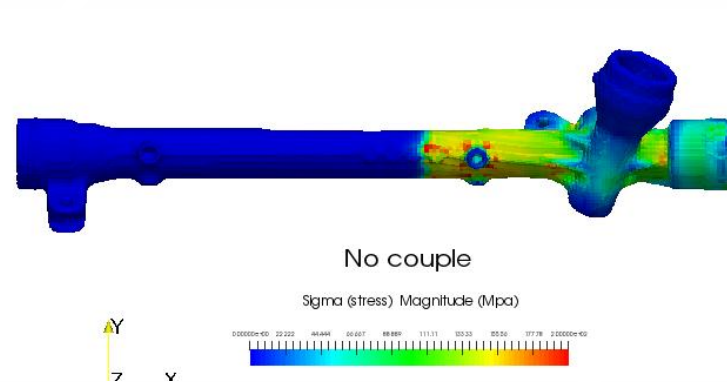
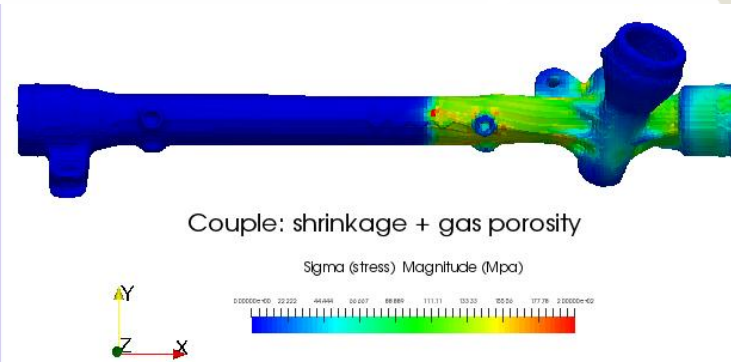
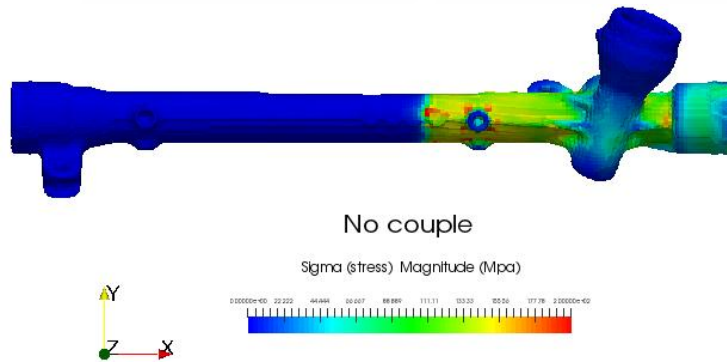
Sigma (stress) Magnitude (Mpa)



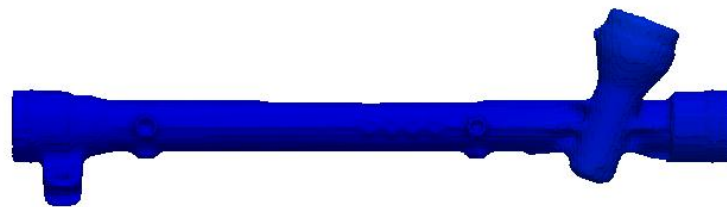
CDPE Example: Housing, Result Analysis



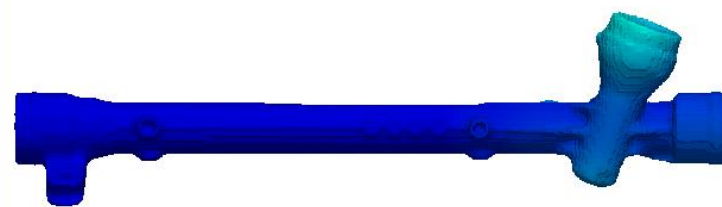
CDPE Example: Housing, Result Analysis



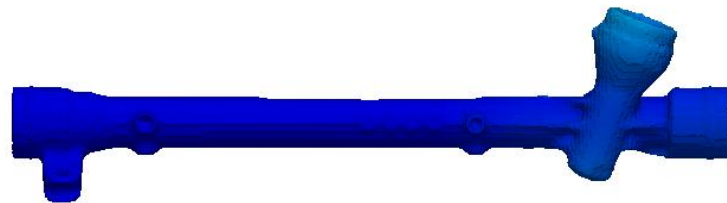
CDPE Example: Housing, Result Analysis



No couple



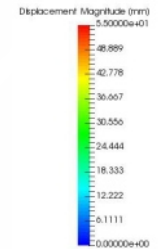
Couple: shrinkage + gas porosity



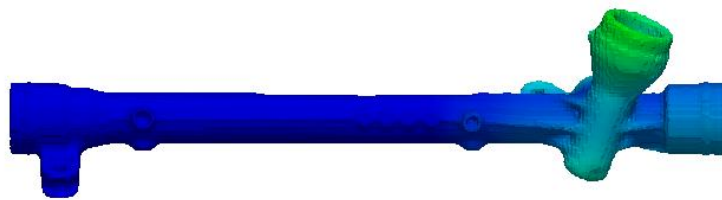
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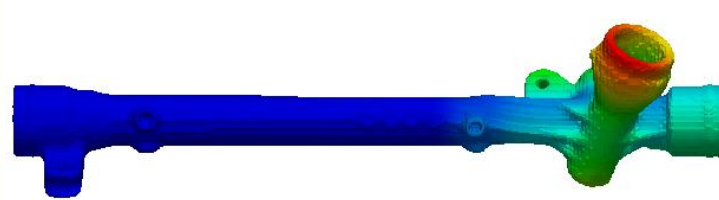
Couple: shrinkage + gas porosity



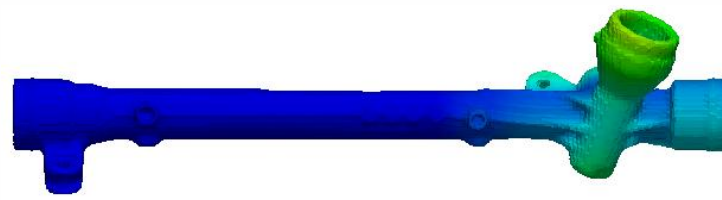
CDPE Example: Housing, Result Analysis



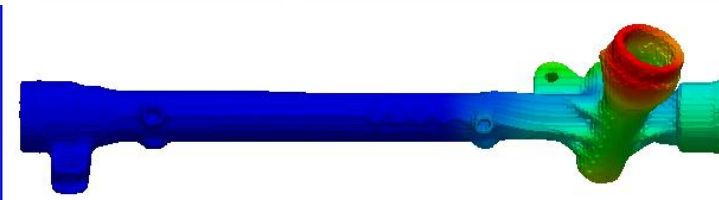
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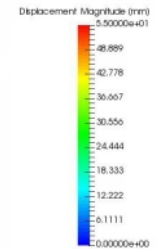
Couple: shrinkage + gas porosity



No couple



Couple: shrinkage + gas porosity





Thank you!

C3P Engineering Software International Co., LTD

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