Moldex3D

Simulation and new processes

Moldex3D
John LIN

MOLDING INNOVATION

Outline

> Hot Runner Steady

> RTM

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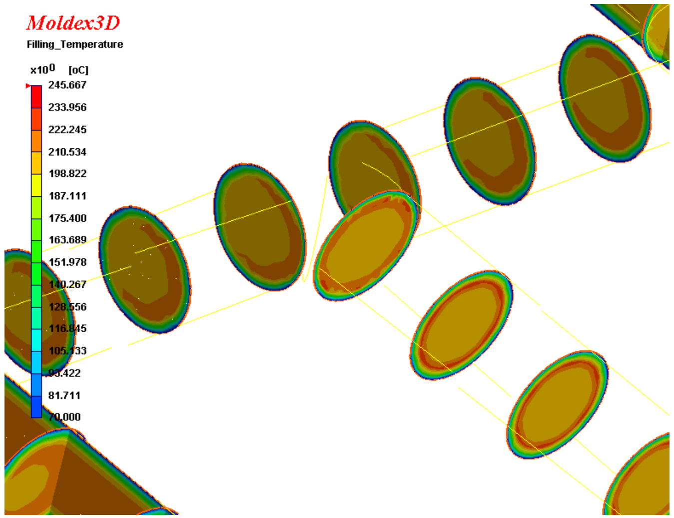
Hot Runner Steady

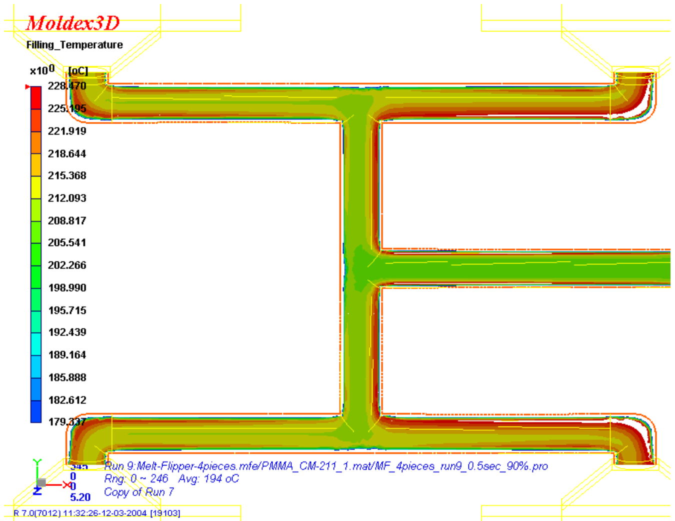
Situation and Challenge

> ## Situation

- **High-Cavitation (16 ~ 128) HRS applications are getting popular**

- **The average report delivery time of flow analysis is taking too long since the element count is higher for high-cavitation HRS applications**



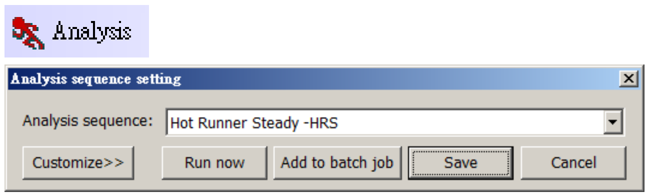


Concept

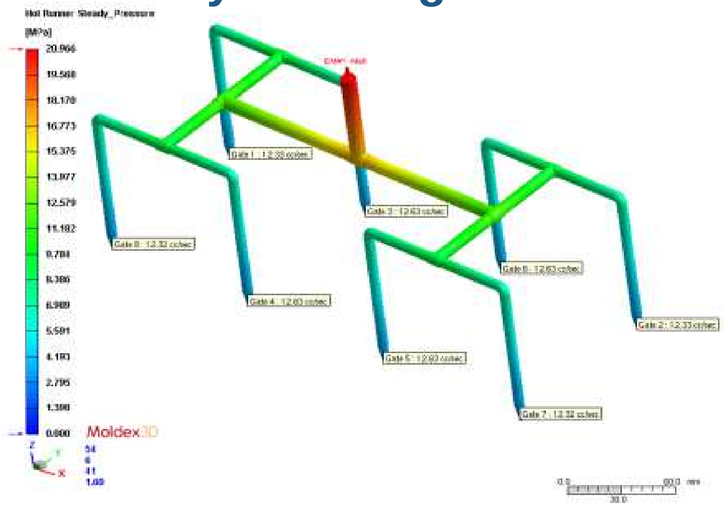
> **3D Hot Runner Steady Analysis**
  - **Supports the quick steady analysis of complex hot runner layout design, including the support for advanced hot runner module from cooling analysis**

> **Benefit**
  - **Balance ratio study for the design of hot runner layout**
  - **Enhanced cycle to cycle prediction for viscous heating**
  - **Save the analysis time for hot runner layout designer**

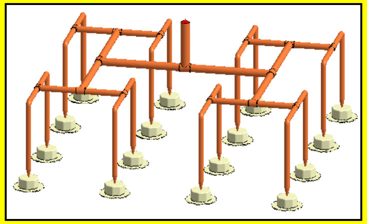
New Analysis Item in R14.0



- AHR license is required
- Support MFE mesh type



Application Sample

Hot Runner Design	• 16-drop system • 2,601,248 elements 	
	Filling Analysis	**HRS Analysis**
CPU Time (by 8 CPUs)	62.2 min	4.2 min
Pressure Drop in Hot Runner	16.925 MPa (23.983 – 7.058 MPa)	17.346 MPa (24.404 – 7.058 MPa)

15 times faster

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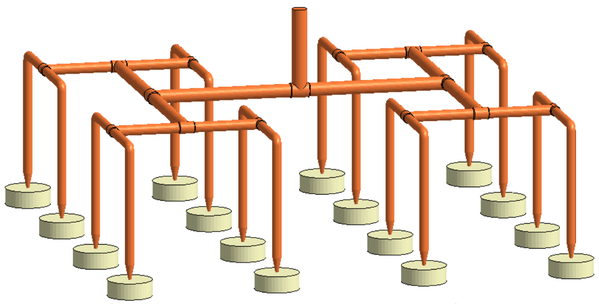
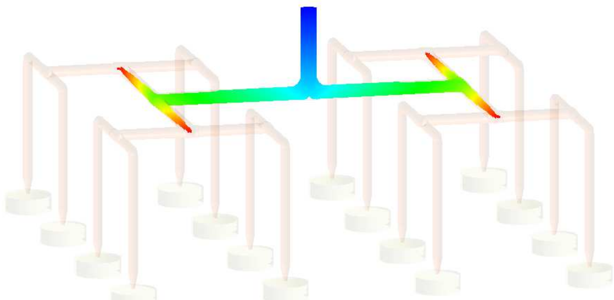
High Cavitation Hot Runner System

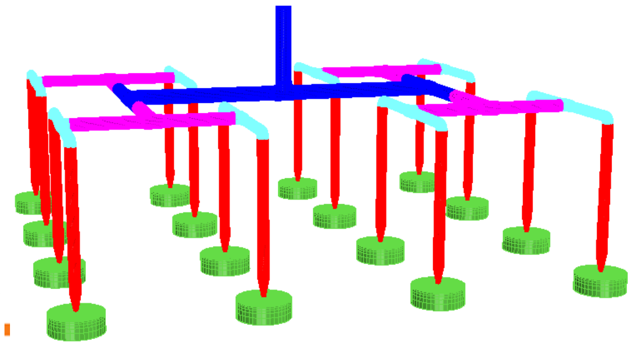
> **Inherit Hot Runner Temperature from Previous Cycles**
- **HRS volume >> Cavity volume**
  - **For high cavitation (16+) hot runner case, usually the volume ratio between cavity and HRS is huge.**
- **Steady Melt Temperature in HRS**
  - **Upstream (inlet) has higher shear rate than downstream (drop) due to flow front area difference**
  - **It usually takes several cycles to accumulate the shear heating effect, and then induce non-symmetry temperature distribution between different drops.**



High cavitation sample case

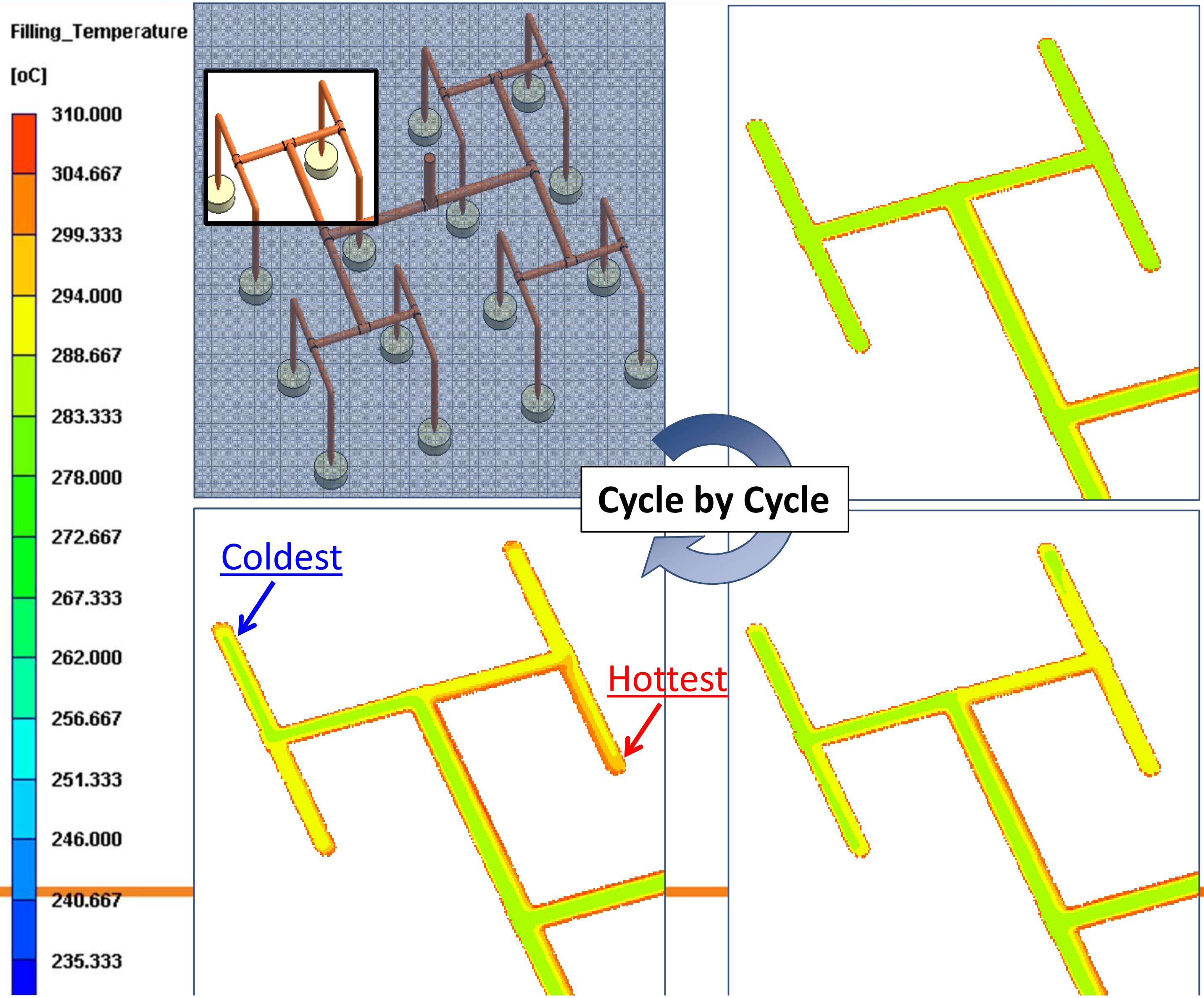


Particle tracer
(flow length for single shot)



Volume ratio: 4 times

Hot Runner Temperature between Cycles



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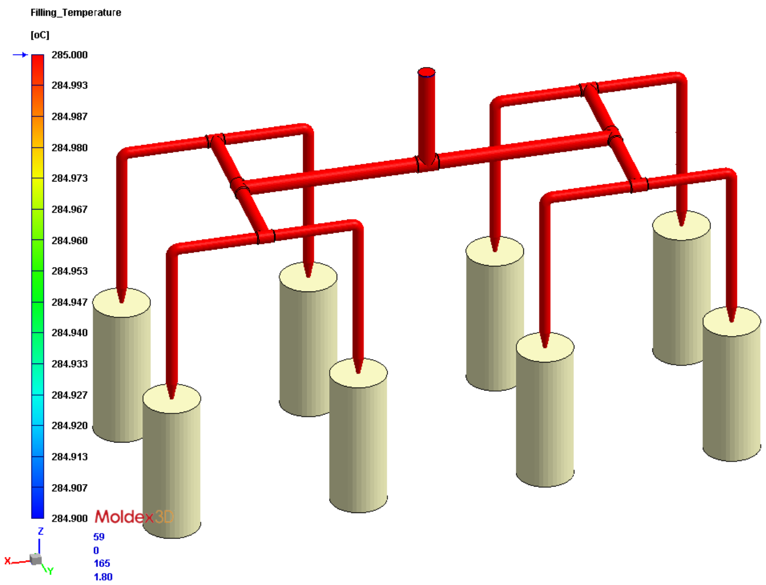
Conventional Multi-Cavity Flow Analysis

> Initial Melt Temperature in HRS

- **Ideal situation: Uniform melt temperature distribution**
- **The initial melt temperature is considered as uniform distribution and is equivalent to the setting in process condition**

Uniform Temperature in HRS



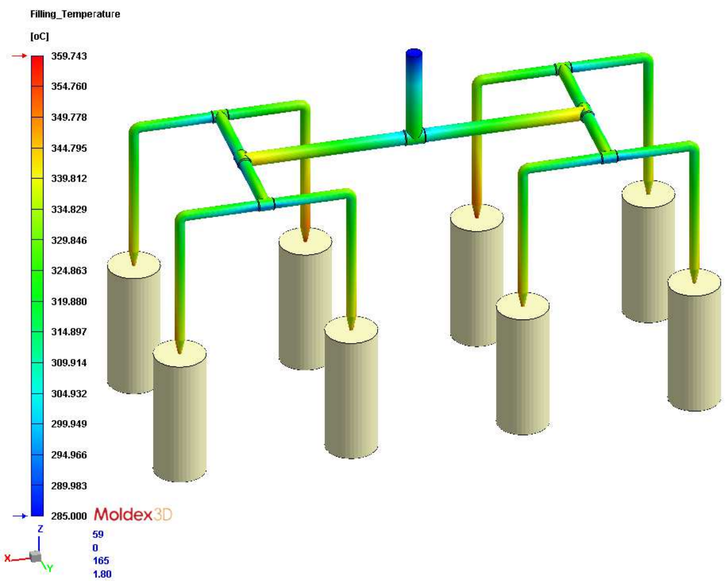
Uniform initial melt temperature distribution at beginning of filling analysis (filling process at 0 sec)

Multi-Cavity Flow Analysis New Approach

> **Initial Melt Temperature in HRS**

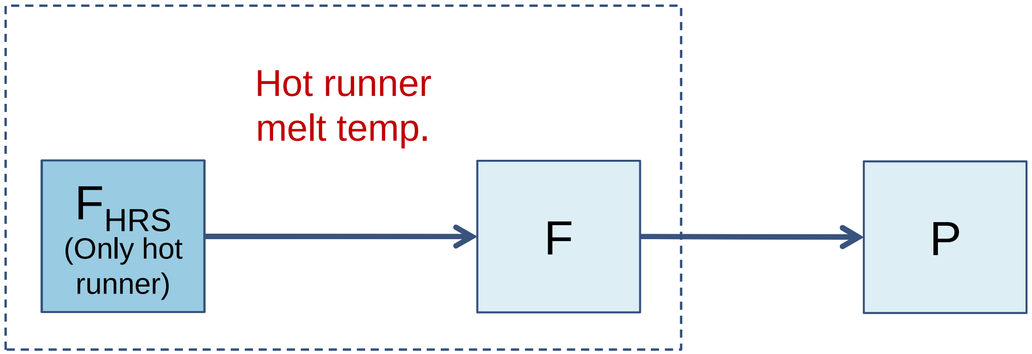
- **Actual situation: Non-uniform & Non-symmetry distribution due shear heating effect**

Non-uniform Temperature in HRS



Residual shear heated melt from previous cycles
(influence factor comes from inside of hot runner channel)

Data Exchange to Filling Analysis



Information in filling log file

```
>>> G1002: No existing cooling result.
        The default mold temperature will now be used for calculation.

>>> Update Hot Runner Temperature Distribution from Hot Runner Steady Solver.

<Solver_Options_Information>
    Flow  Solver Accuracy/Performance Options = 5
    Fiber Computation                         = OFF
    Non-Isothermal                            = ON
    Viscous Heating                           = ON
    Consider crystallization effect           = OFF
    Non-Newtonian Fluid Effect                = ON
    Estimate Cooling Time                     = OFF
    Flow-induced Residual Stress Computation  = OFF
    Compressible Flow                         = OFF
    Mesh Type                                 = Solid mesh file
    Criterion of Stopping Calculation Type    = Filling percentage(99.9654%)
    Initial Hot runner condition              = From Hot runner Steady
    Stabilized Calculation                    = ON
    Gradient Operator Type                    = 0
    Projection Area On Mold-Opening Direction = 28.7509 cm^2
    Number of Computation Processes           = 4
    Fixed HTC Mode                            = ON
    Particle Tracer Analysis                  = OFF
    Weld line Particle Tracer Analysis        = OFF
    Melt front enhancement                    = ON
```

Flow solver uses HRS analysis result as initial hot runner melt temperature

Data Exchange Between Different Analyses

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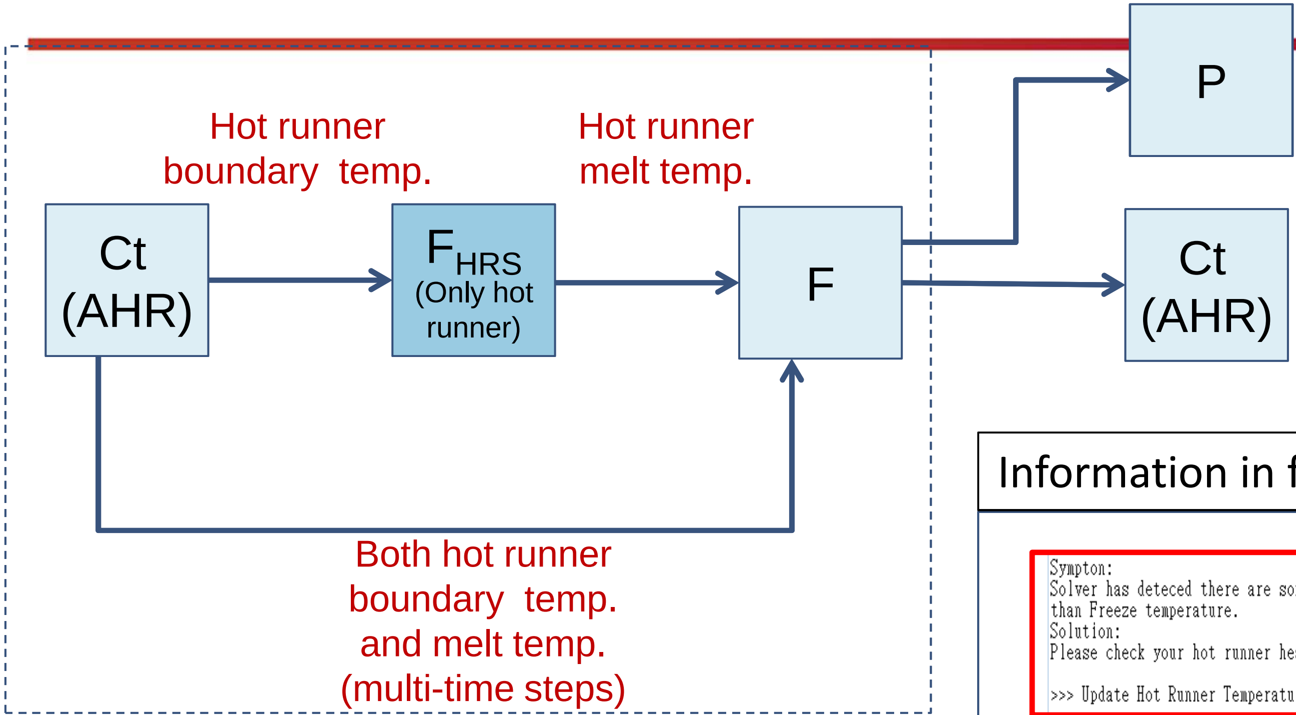


Remark: Hot runner steady and filling analyses will take the hot runner result from cooling analysis when only it is **AHR Cooling**, but not cycle-average and general transient cool.

Information in filling log file

```
Sympton:
Solver has deteced there are some hot runner elements with temperature lower than Freeze temperature.
Solution:
Please check your hot runner heater setting to get a resaonable result.

>>> Update Hot Runner Temperature Distribution from Cool Solver.
```

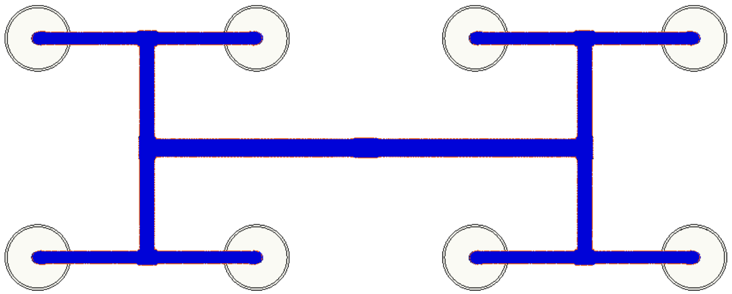
Update hot runner melt temperature by flow solver in case the melt temperature is improperly

```
Hot runner result                = Advanced Hot Runner Module
```

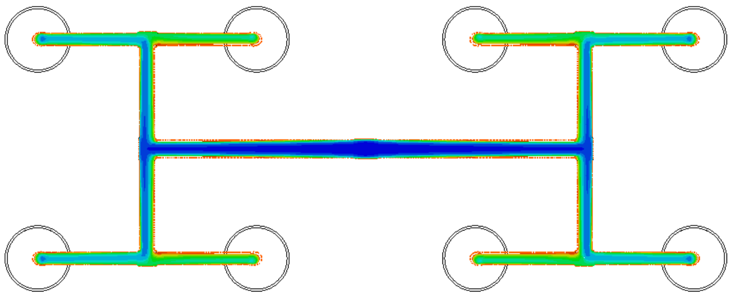
Flow solver uses AHR Ct analysis result as initial hot runner melt temperature

Hot Runner Temperature Comparison

Conventional Flow Analysis



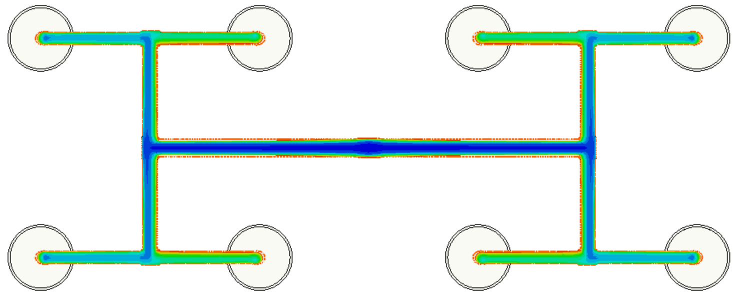
Temperature at 0% of filling



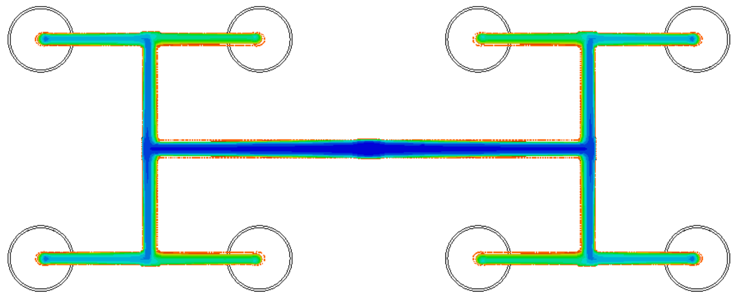
Temperature at end of filling

New Approach Flow Analysis

New approach provides more realistic initial hot runner melt temperature for better prediction



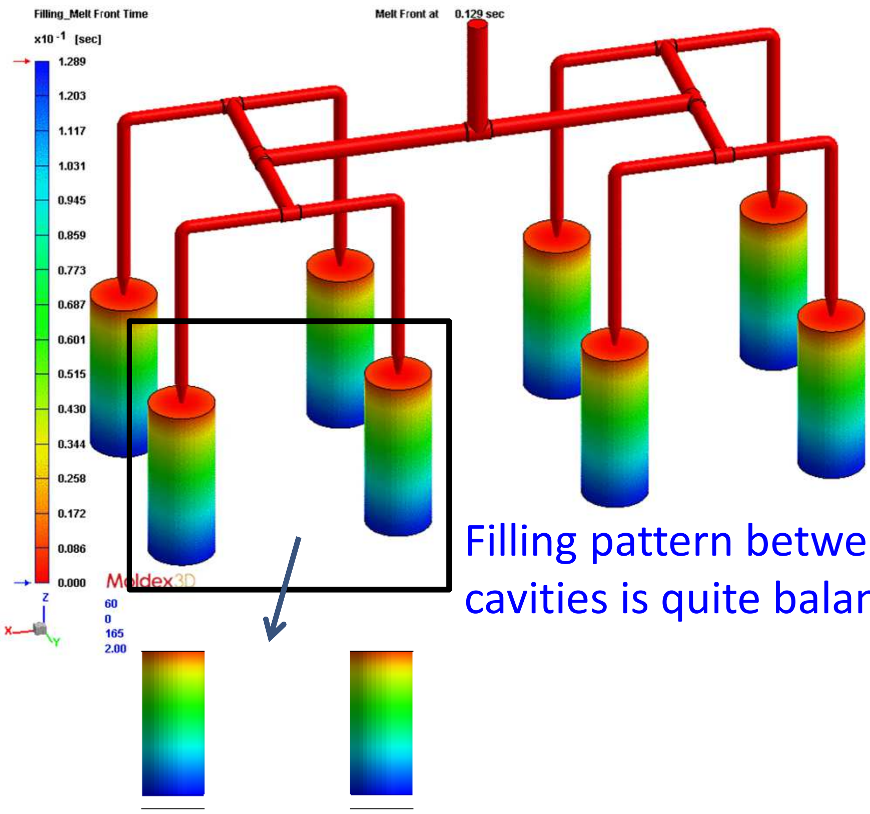
Temperature at 0% of filling



Temperature at end of filling

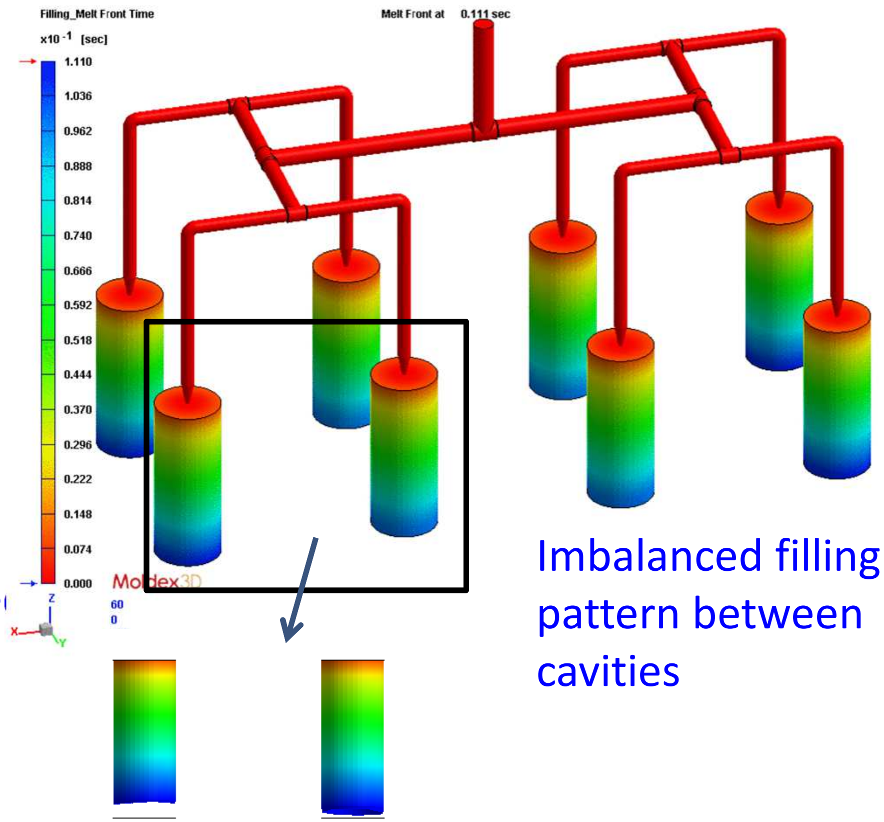
Melt Front Time Animation

Conventional Flow Analysis



Filling pattern between cavities is quite balance

New Approach Flow Analysis



Imbalanced filling pattern between cavities

Proper initial hot runner temperature is a key factor for predicting accurate filling pattern

Summary

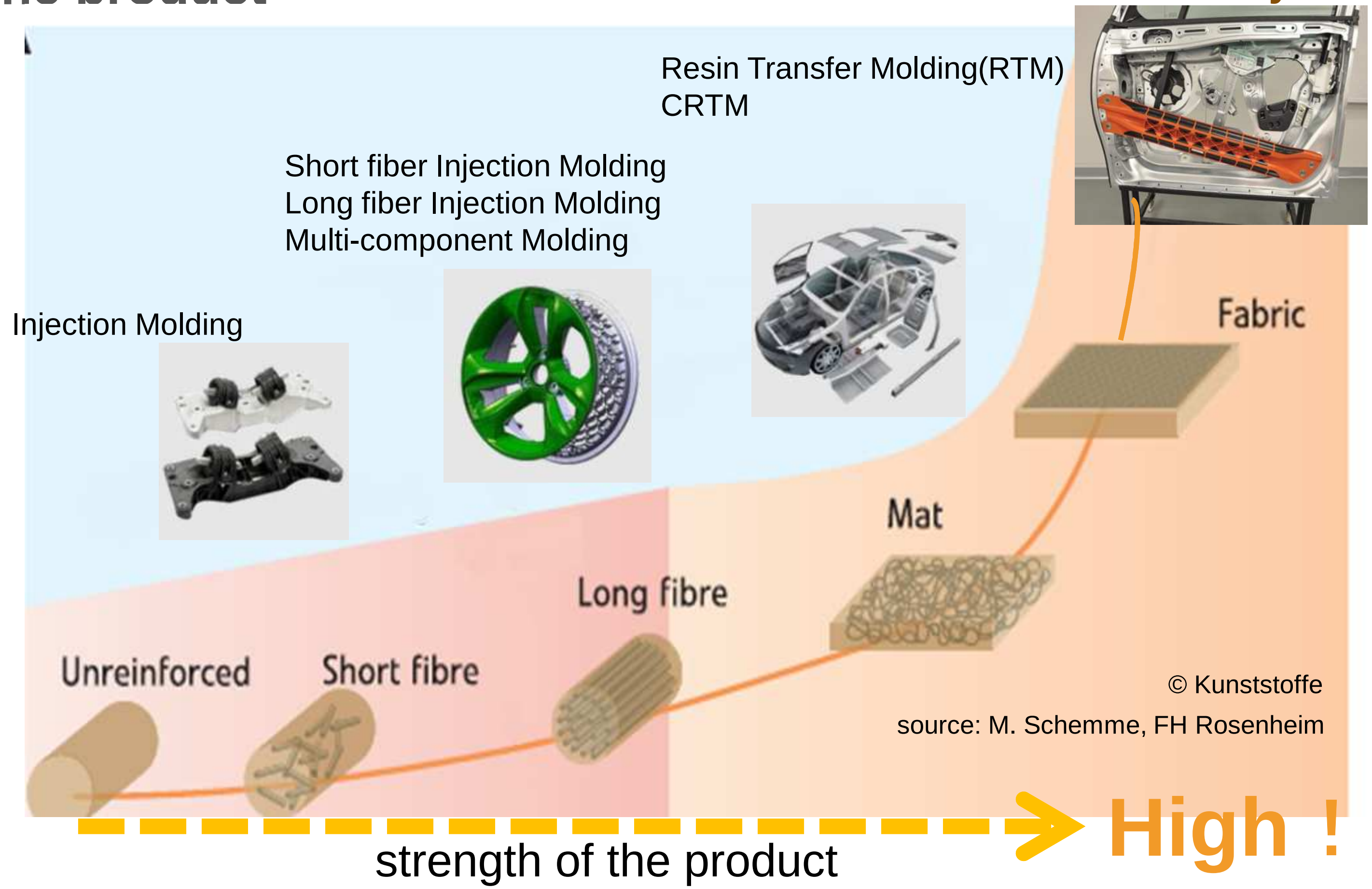
> Hot runner steady analysis can

- support symmetry boundary condition setting as usual
- cut down element count in high-cavitation cases for hot runner pressure drop predilection by using dummy cavities
- save the analysis time significantly to predict pressure drop and help to optimize hot runner layout design efficiently
- accurately detect potential flow balance issues to help making appropriate design changes, resulting in better hot runner design

RTM

Composite Products

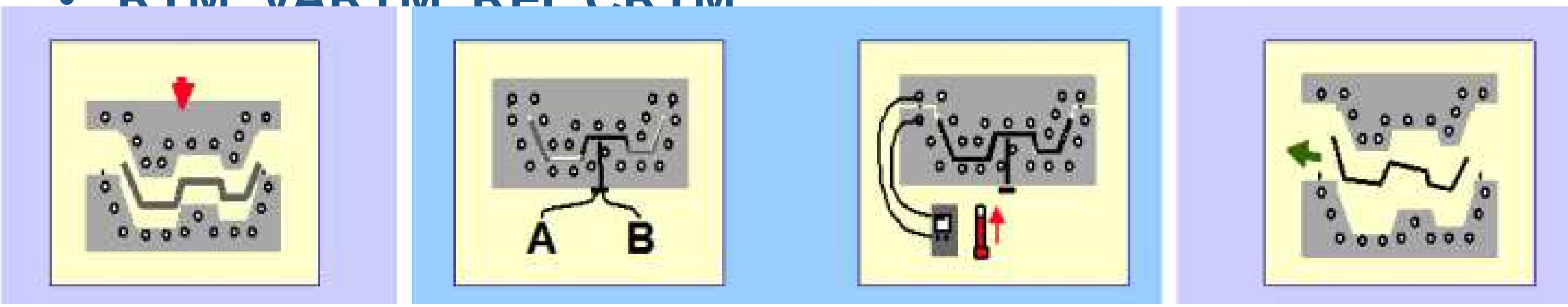
> **Goal: Reduce vehicle weight, Improve mechanical strength of the product**



Liquid Composite Molding (LCM) Processes

> For manufacturing of composite parts with a high content of oriented reinforcement
- **The impregnation of a dry preform with a liquid matrix by liquid composite molding processes**
- **Very high potential for economical manufacturing of high performance composite components**

> Types of processes covered
- **Hand layup, spray up**
- **RTM, VARTM, RFI, CRTM**



BMW i3

4m

http://www.bmw.com.cn/cn/zh/newvehicles/i/i3/2013/showroom/

Yacht

http://horizonyacht.com/tw/News.aspx?Cond=7bf10f7c-4f4c-4a94-b285-e6dc4f13bdb8&Pindex=14&Year=All&Month=All

Wind Turbine Blades

http://www.moneydj.com/KMDJ/News/

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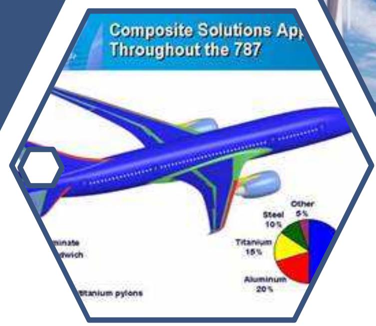
Fiber Reinforced Plastic Application

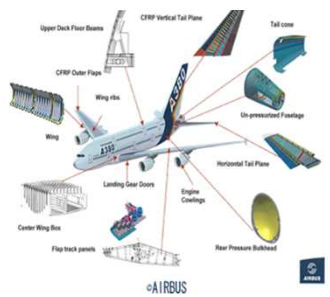
Yacht

Wind turbine

Aircraft



Automobile



Source
787: http://goo.gl/1aZ2qM
Airbus380: http://goo.gl/bbD98x
Luggage: http://goo.gl/HbrVKo
Car parts: http://goo.gl/QVoK5d
Car: http://goo.gl/hh6D3c
MBT: http://goo.gl/cgbJMK
Yacht: http://goo.gl/EVb6P4
Wind turbine (up): http://goo.gl/WUYMts
Wind turbine (down): http://goo.gl/0WNFfC

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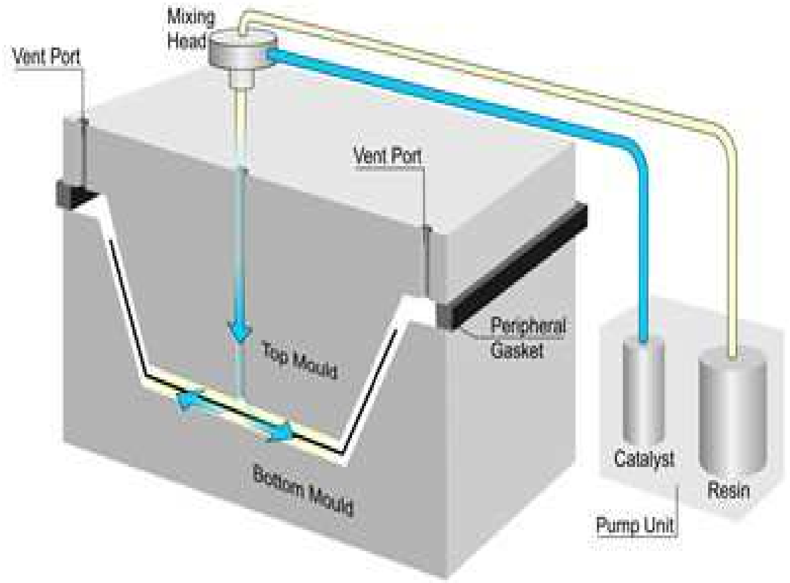
Benefit of RTM

> **Resin transfer molding (RTM)**
- **Mass production**
- **Same quality**
- **Parts can be manufactured with an A-class finish on both sides**



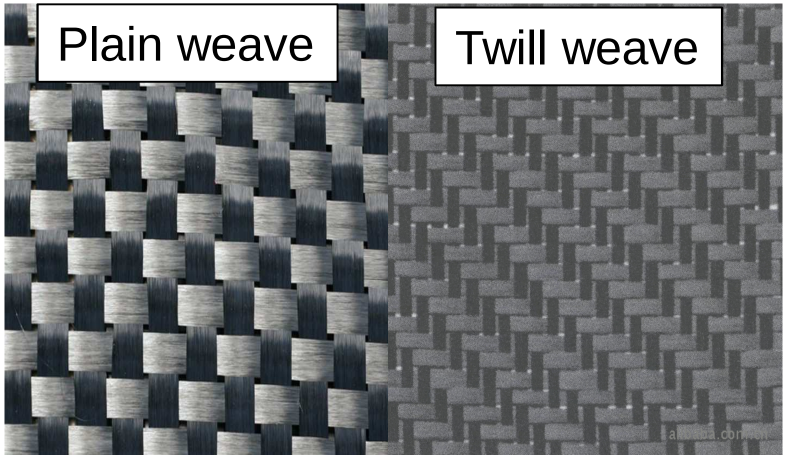
Source: http://goo.gl/p1gD3w

Source: http://goo.gl/pz65E2

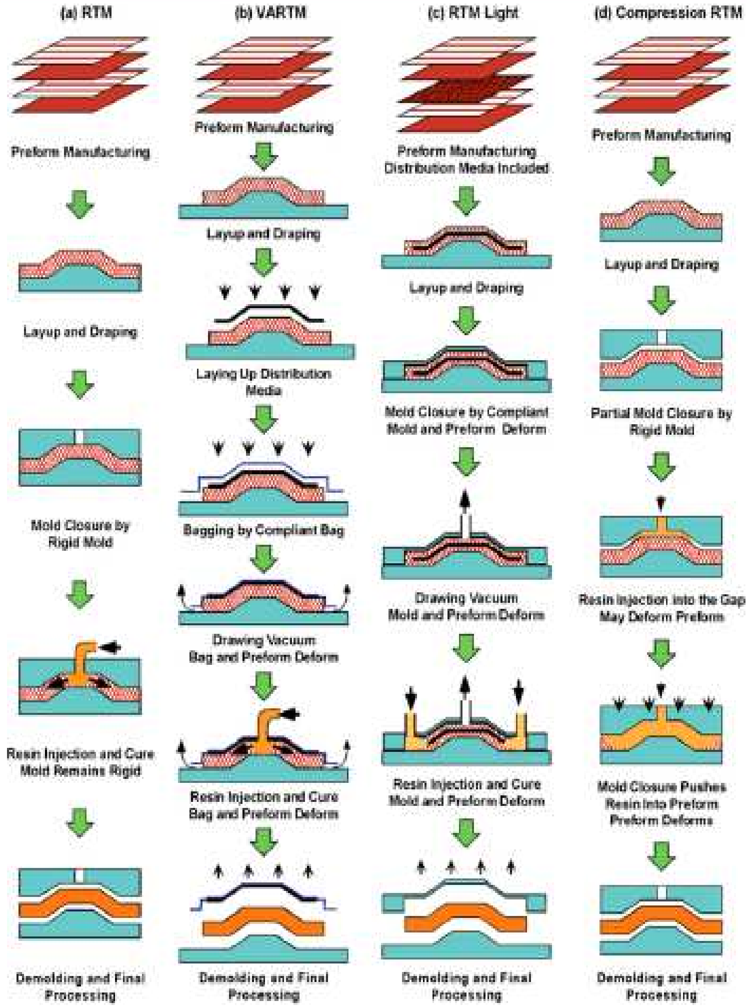
Manufacturing Process

> **FRP manufacturing process**

- **RTM**
- **VARTM (Vacuum Assisted)**
- **RTM Light (LRTM)**
- **CRTM**



http://goo.gl/S4A9wz Source: http://goo.gl/i35Z8c



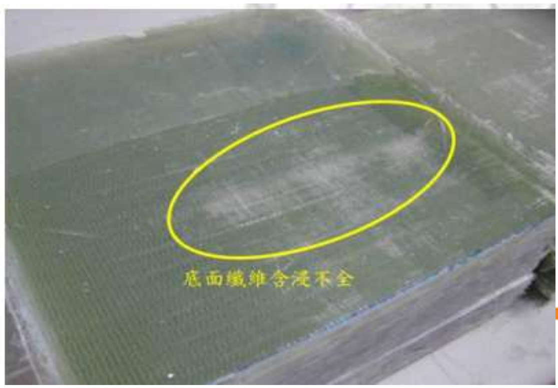
Pavel Simacek, SureshG. Advani, "Modeling resin flow and fiber tow saturation induced by distribution media collapse in VARTM", Composites Science and Technology, Volume 67, Issue 13, October 2007, Pages 2757–2769

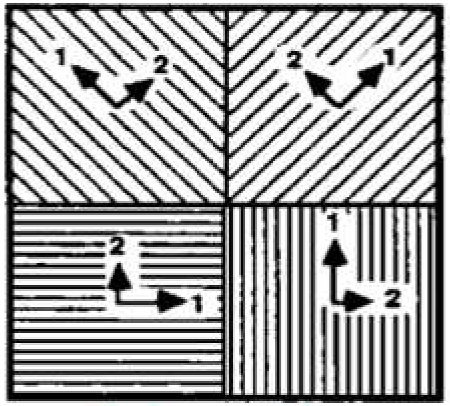
Problems and Challenges

> Defects
- **Incomplete filling**
- **Air-trap**

> Process
- **Very difficult to make the successful process effectively**

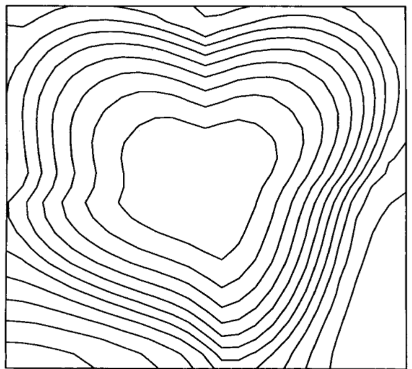
> Behind the molding
- **How to catch material property with the complex fiber-mat structure**





Fiber Mat Orientation

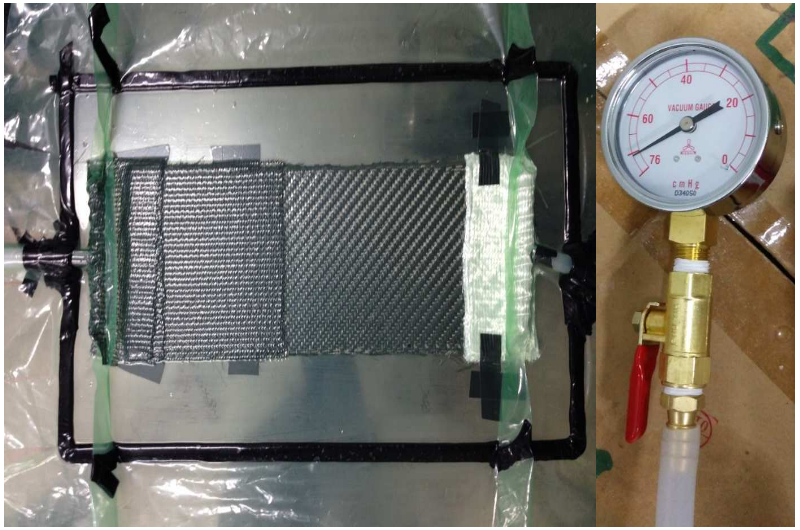
Why?



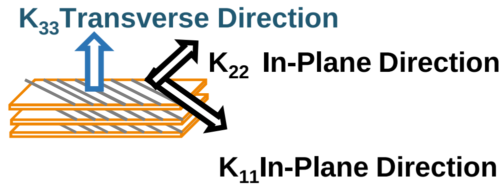
Filling - Darcy's law

$$\vec{\mathbf{v}} = -\frac{1}{\mu}[K]\nabla P$$

- Permeability K (m^2 or cm^2) is used to describe the easiness of filling in different direction. The larger the K is, the faster the filling under the same pressure difference.



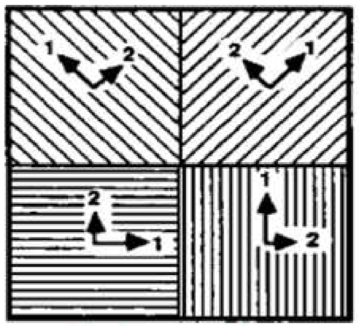
$$\mathbf{K} = \begin{bmatrix} K_{xx} & K_{xy} & K_{xz} \\ K_{yx} & K_{yy} & K_{yz} \\ K_{zx} & K_{zy} & K_{zz} \end{bmatrix}$$



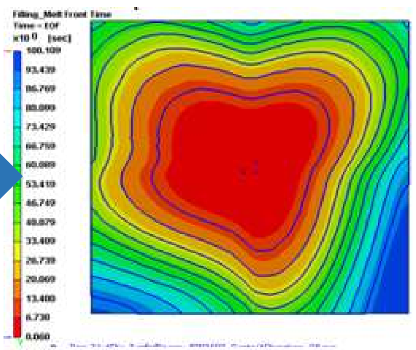
Overcome the Challenges

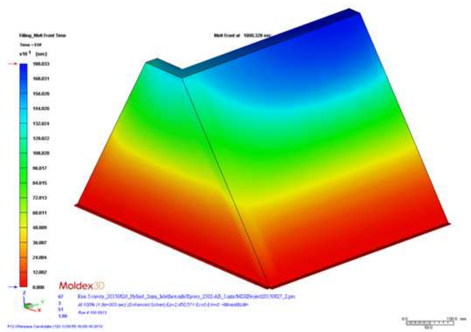
> **Developed Moldex3D Resin Transfer Molding (RTM) module**

- **Through dynamic features to understand process inside mechanism**
- **Help integrate for design, process, and material**
- **For quality retain and defects solving**
  - **Using virtual system to make validation**
  - **Allow us to make qualitative and quantitative prediction**



Fiber Mat Orientation





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Melt Front in RTM Module

> Distribution medium effect in thickness direction for 3D simulation

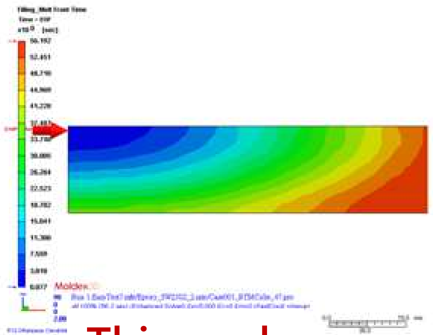
Resin Inlet

Cavity

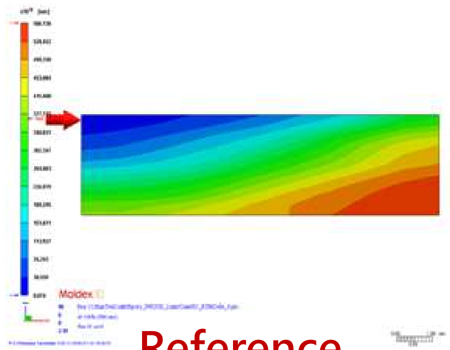
Geometry

Distribution medium

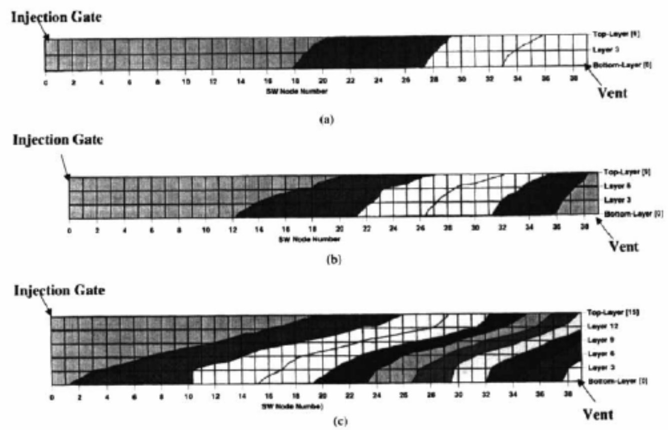
Cavity



This work



Reference

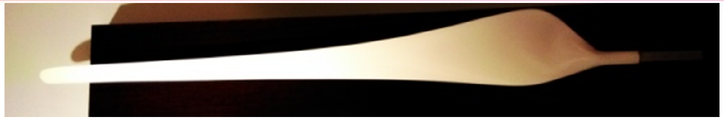


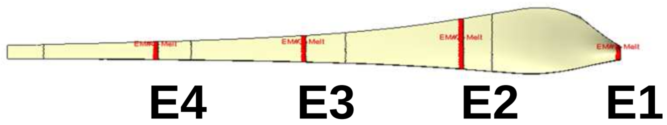
R. Mathur, D. Heider, C. Hoffmann, J.W. Gillespie JR., S. G. Advani, and B. K. Fink. "Flow Front Measurement and Model Validation in the Vacuum Assisted Resin Transfer Molding Process" Polymer Composite, August 2001, Vol. 22,

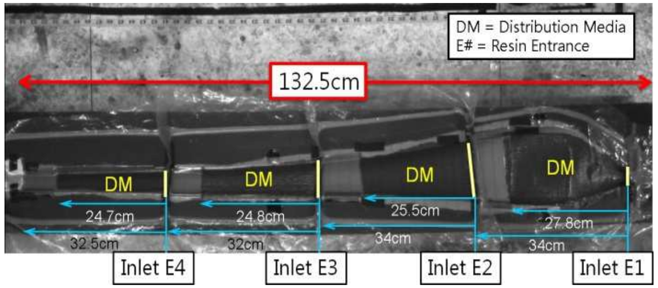
Case verification for 1kw wind blade

> Resin:
  - SWANCOR 2502 A/B

> Pressure Control
  - 1 atm





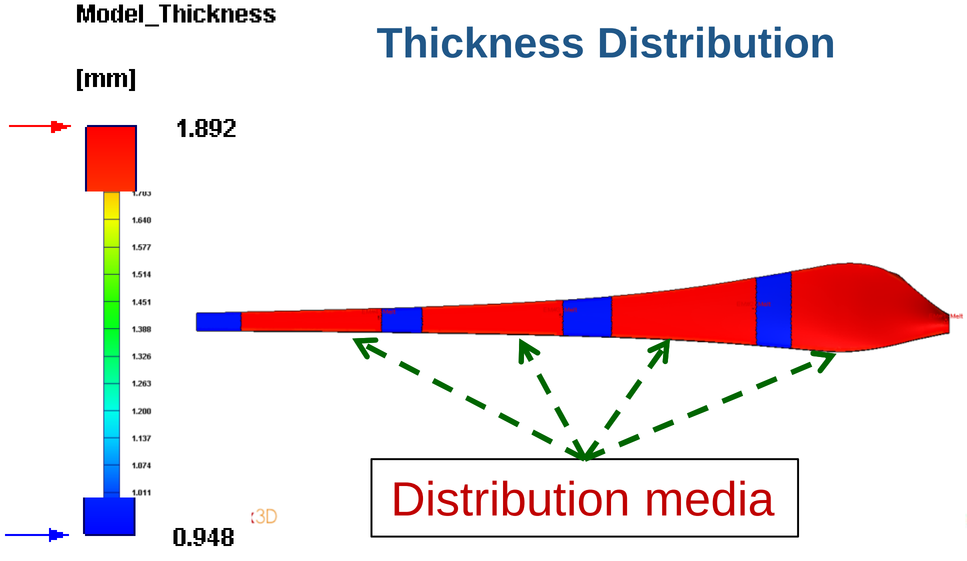


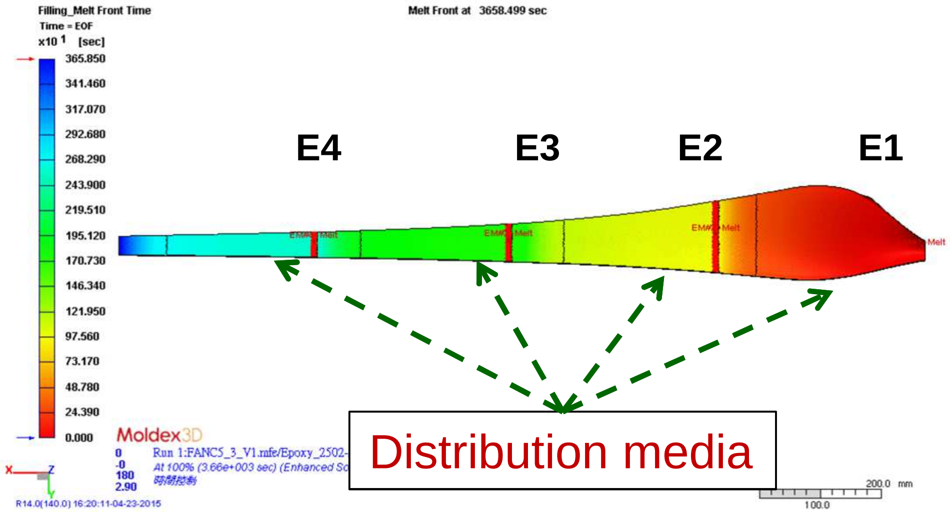
> Permeability

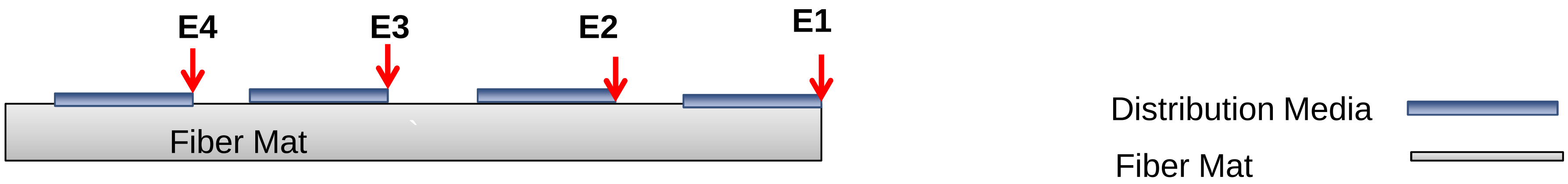
	Carbon fabric	Distribution Media
Thickness[mm]	0.9653	0.9263
$K_{11}[m^2]$	8.387E-12	1.071E-9
$K_{22}[m^2]$	8.387E-12	1.071E-9
$K_{33}[m^2]$	8.400E-13	1.071E-9
	0.399	0.491

Geometry and Layup

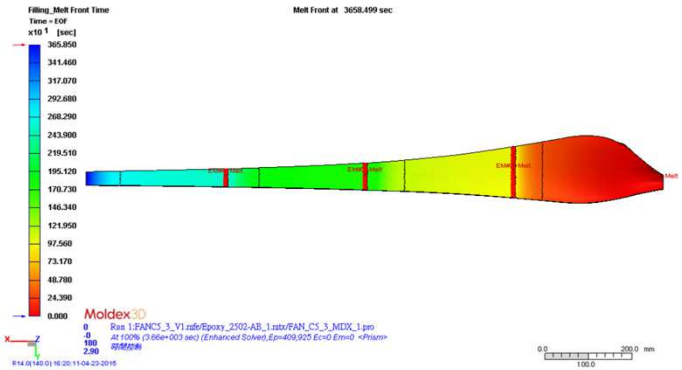
Thickness Distribution

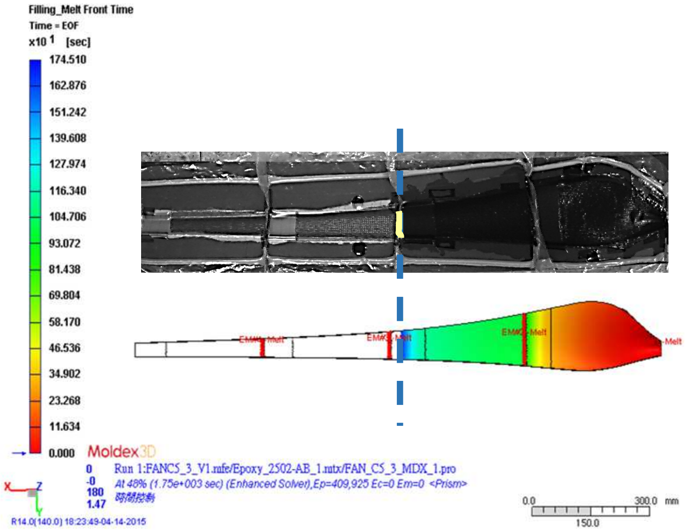




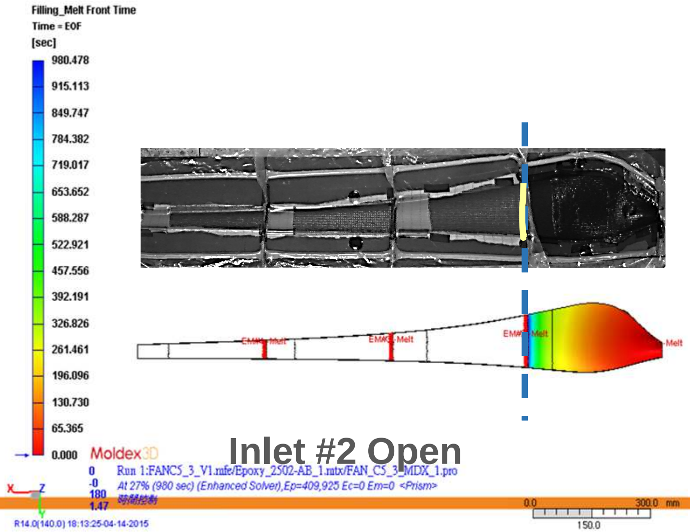


Flow Front Result

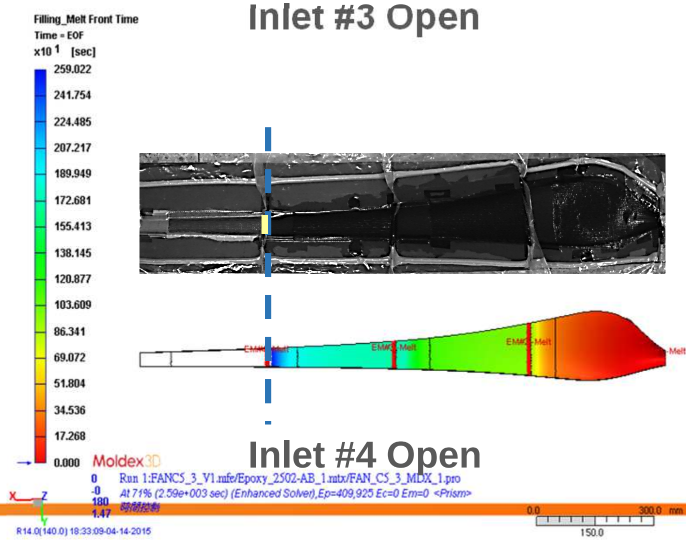




Inlet #3 Open



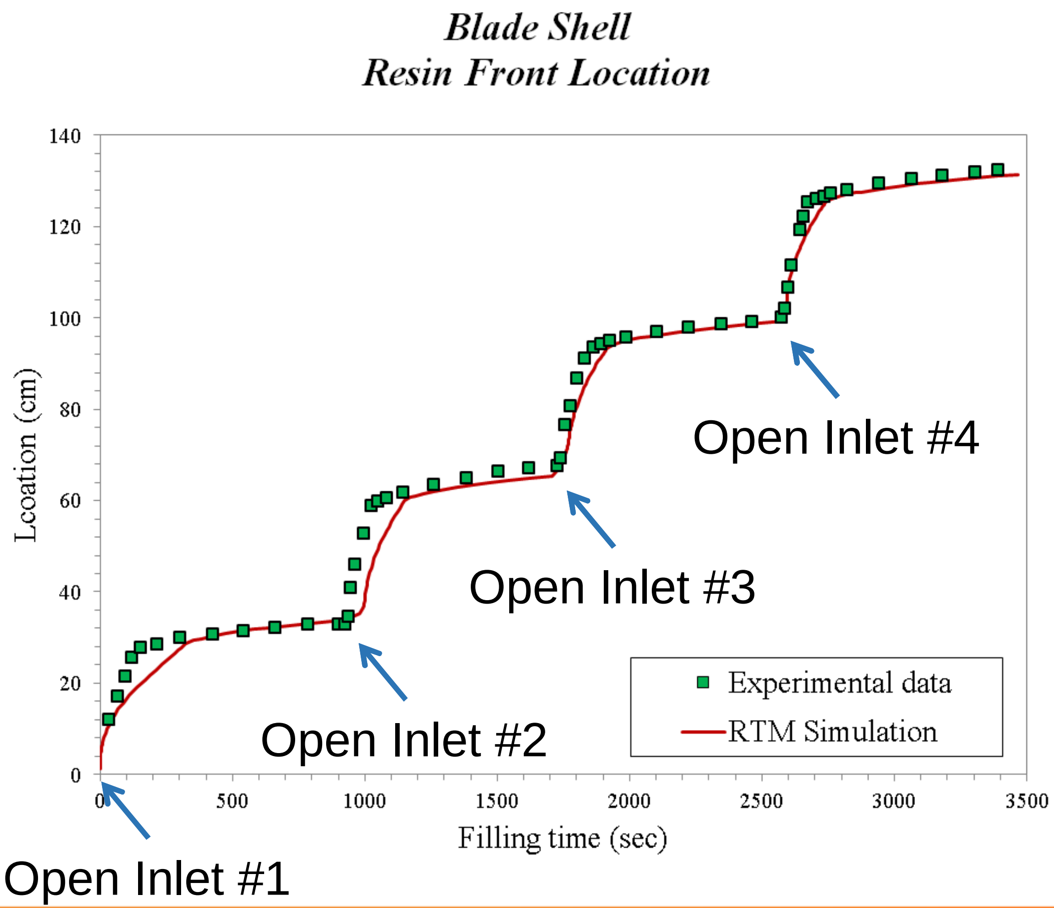
Inlet #2 Open



Inlet #4 Open

Evolution of Flow Front Location Experiment - Simulation

> **Detailed comparison between the simulation and experiment results**



Moldex3D RTM

> Supports pressure/flow rate control, multi-inlet open/close control. The simulation result can reflect the influence of changing fiber mat type and orientation

> With true 3D simulation solver, Moldex3D can predict the filling behavior in thickness direction and the venting region effect of the RTM process

Thank You