

#### Moldex3D Application in Microcellular Injection Molding Development

SimpaTec Sarl

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## SimpaTec

- founded 1/2004
- Reseller Moldex3D
  - since 2004 in Germany
  - since 2005 in BeNeLux
  - since 2006 in France, Swiss et Austria
  - Office at Guebwiller, Grenoble, Aachen, Stuttgart, Bangkok.
- Since 10/2007 Beaumont Technologies Inc. reseller







## SimpaTec - Focus

#### 1. Services

- Plastic injection simulation services;
- Moldex3D distribution
- Moldex3D support and training
- BIMS seminar with Dr Vito LEO

#### 2. Commitment

- Research
- Software development
- Workshop, seminar
- Partnership...

## Moldex3D



# Microcellular Foam Injection Molding

- The Microcellular Foam Injection Molding is based on the control of supercritical fluid (PBA) during the injection molding cycle to create millions of micron-sized voids in thermoplastics.
- MuCell® is most well known commercial microcellular foaming injection process registered and marketed by Trexel, Inc.







MuCell is a registered trademark of Trexel, Inc.



# **Microcellular Foaming Process**

#### Three major steps: (1) formation of a uniform polymer-gas solution; (2) cell nucleation;







#### Three major steps:

Near surface

(1) formation of a uniform polymer-gas solution;(2) cell nucleation;(3) cell growth and shaping







# Foaming Fundamentals

- Cell Nucleation
  - Formation of cell site driven by the pressure drop
  - Related to the "cell number density"
- Cell Growth
  - Cell growth on cell site driven by the gas diffusion
  - Related to the "cell size"





# **Motivation and Objectives**

True 3D approach to provide more accurate micro-structure fluid flow information.

Predict cell number density and cell size by considering the cell nucleation and cell growth simultaneously.

Consider the interaction between cell development and melt flow during molding.

Consider the effect of cell structure to the part warpage.



# Fundamental Theory and CAE Method



# Theory of Cell Growth and Bubble Pressure

#### Radius over time

$$\frac{\mathrm{d}R}{\mathrm{d}t} = \frac{R}{4\eta} \left( P_D - P_C - \frac{2\gamma}{R} \right)$$

where *R* is the bubble radius,  $\eta$  the viscosity, *P*<sub>D</sub> the bubble pressure, *P*<sub>C</sub> the ambient pressure, and  $\gamma$  the surface tension. Bubble pressure and cell concentration



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(2)

Polymer

Han and Yoo (1981) stated that

$$\frac{\mathrm{d}}{\mathrm{d}t}(P_D R^3) = \frac{6D(\Re_g T)(c_\infty - c_R)R}{-1 + \left\{1 + \frac{2/R^3}{\Re_g T} \left(\frac{P_D R^3 - P_{D0} R_0^3}{c_\infty - c_R}\right)\right\}^{1/2}}$$

where the assumed concentration profile:

$$\frac{c_{\infty} - c}{c_{\infty} - c_R} = \left(1 - \frac{r - R}{\delta}\right)^2$$

and  $\delta$  is the concentration boundary thickness.

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# Theory of Cell Nucleation

Nucleation model

$$J(t) = f_0 \left(\frac{2\gamma}{\pi M_W/N_A}\right)^{1/2} \exp\left(-\frac{16\pi\gamma^3 F}{3k_B T(\overline{c}(t)/k_H - P_C(t))^2}\right) N_A \overline{c}(t)$$

- f0 and F are fitting parameters of bubble nucleation rate equation
- nucleation commences when the bubble nucleation rate  $J(t) > J_{threshold}$

$$\overline{c}(t)V_{L0} = c_0 V_{L0} - \int_0^t \frac{4\pi}{3} R^3(t - t', t') \frac{P_D(t - t', t')}{\Re g T} J(t') V_{L0} dt'$$





# Output of Molex3D MuCell® Simulation

Cell radius distribution (typically 5-100 microns)

- Skin (as small as better)
- Core

Cell number density distribution (typically, 107 - 109 [cells/cm3]

- Skin (as less as better)
- Core



Microstructure Near Surface



Microstructure Near Core

http://www.forestprod.org/composites09pilla.pdf /

# Output of Moldex3D MuCell® Simulation





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# Output of Moldex3D MuCell® Simulation





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## Moldex3D MuCell®:

Step by Step Tutorial



# **Create a New Project**

#### Choose type as "Microcellular injection molding" when creating a new project

New Project	<b>X</b>	
Project name:	R11Demo	
Project location:	D:\Parallel_Folder	🕼 Step 3 of 5 : Application Type Setting [R11Demo]
Solver type:	3D Solid Model Solver 🔹	Application Type Setting
Application:	Microcellular injection molding	Please select the application you want to simulate by the project:
Application	General 👻	<ul> <li>Traditional injection molding (for thermoplastics)</li> </ul>
Purpose:	Case Study 🗸	Gas-assisted injection molding
Security level:	Public 🗸	<u>Water-assisted injection molding</u>
Study for:		Reactive injection molding     Encapsulation
Study by:	Moldex3D Liser	Injection-compression molding
Study by:	Melderop	© Co-injection molding
Engineer:	Moldex3D	Microcellular injection molding
Project		Application Field :
Summary of th	e project	General
Set <u>P</u> assword	OK Cancel	◆ Back ♦ Next K Cancel Einis

#### Simple Mode

#### **Classic Mode**



# Process Settings (1)

In filling/packing setting, users can shut off nozzle by checking the box "Nozzle is shut off". This action can skip packing process and avoid reverse flow of melt during foaming.

	Eilling softing	Construction of the local sectors of the			sphirischet.
	Filling time : 0.1	16			
	rining time : 0.1	SI	30		
	Elow rate pro	file (1)	2		
	Injection pressure	profile (1)			
a	VP switch-over				
Rout	By volume(%) filled		as 98		96
1100	Packing setting				
2/10	V Nozzle is Shut off	1			
1 Ann	Packing time : 0		Sec		_
	Packing pressure re	fers to end of	filling pre	ssure	*
	Packing pressure	profile (1)			
	Melt Temperature	221		σC	
	Mold Temperature	25		oC	
				Adva	nced Setting



# Process Settings (2)

#### Microcellular settings

 three settings shown below: Foaming duration time, Start foaming setting, and Initial Gas concentration.

Moldex3D Process Wizard	king Settings Microcellular Settings Coo	ling Settings   S	Summary
	Foaming Setting Foaming duration time : 10 Start foaming by	sec	
	Volume filled     •     ds       Initial Gas Concentration     Gas dosage amount     •     0.	90 5 wt	%
Capture Option	Help < Back	<u>N</u> ext >	Cancel

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# Process Settings (3)

#### Foaming duration time

 specify the holding time (sec) after filling to simulate the foaming process, which includes cell growth and solidification.

#### Start foaming by (Control shot size)

 If "Nozzle is shut off" is selected, nozzle is shut off at this starting time. Users can define the starting time in terms of *Volume filled* (%) or *Pre-injected volume* (cm^3) as below.

#### Initial Gas Concentration

5	Start foaming by			
	Volume filled	🚽 as	95	%
	Volume filled	13 <sup>3</sup>		
	Pre-Injected volume			

 define the initial gas concentration in terms of Gas dosage amount (wt %) or Gas saturation pressure (MPa) as below.

Initial Gas Concentration		
Gas dosage amount	0.5	wt %
Gas dosage amount	~~~	
Gas saturation pressure		



# **Computation Parameters (1)**

Click the "Advanced Options for filling/packing solver" button in Fill/Pack tab to input the parameters

C Computation Parameter	×	
🎒 Fill/Pack 👩 Cooling 🤰 Crystallinity 冯 Warpage 🛸 St	• •	
Solver : Enhanced-P 🔻		
Standard analysis		
🔘 East analysis		
© <u>C</u> ustomize		
Viscous heating     Non-isothermal       Stabilized calculation     Non-Newtonian flow       Compressible flow     Non-Newtonian flow		
Gravitational force : cm/sec^2 Example : (0, 0, -980) for z-gravity X: 0 Y: 0 Z: 0		
- Multiple time steps output setting :		
+ Filling/Packing : 3		
Estimate required cooling time		
Run fiber orientation analysis		
Solver acceleration		
+ Particle Tracer		
Advanced Default		
OK Cancel		

Gas type :	2	•
Bubble growth model :	lan and Yoo	•
Material Properties		
Polymer molecular weight	410000	g/mol
Gas diffusion coefficient :	8.07e-005	cm^2/s
Gas solubility parameter :	4e-011	mol/(cm^3Pa)
Surface tension :	0.000178	N/cm
Nucleation Parameters		
Correction factor f0	9e-023	
Correction factor F	0.001	
Threshold of bubble(Jt)	0.1	1/cm^3s
		Default



# **Computation Parameters (2)**

# Four settings: Gas type, Bubble growth model, Material properties and Nucleation parameters.

Advanced Options for Filling/Packing Solver	
Fiber Parameter   Venting Microcellular   Gas type : N2 Bubble growth model : Han and Yoo Material Properties Polymer molecular weight : 410000 g/mol	Gas type : N2 Bubble growth model : CO2 Others
Gas diffusion coefficient :       8.07e-005       cm^2/s         Gas solubility parameter :       4e-011       mol/(cm^3Pa)         Surface tension :       0.000178       N/cm	Bubble growth model : Han and Yoo Han and Yoo Material Properties Payvar Delymer melacular weight
Nucleation Parameters Correction factor f0 : 9e-023 Correction factor F : 0.001 Threshold of bubble(Jt) : 0.1 1/cm^3s Default OK Cancel	Note: Parameters of $N_2$ /PP (Gas/polymer) are set as $N_2$ 's default value and $CO_2$ /PP as $CO_2$ 's default value. If a different Gas or polymer is chosen, user may modify the material properties and nucleation parameters to get an accurate result.



# **Gating Location Effect**

#### Melt front animation



Gating from thick area

Gating from thin area



## **Case Study**



R152(110.2) 10 12 29 09 01 20 12

# **Comparisons of Simulation and Experiment of Position A**

#### 0.2 wt% $N_2$ SCF dissolved in PP









# **Comparisons of Simulation and Experiment of Position B**

#### 0.2 wt% $\rm N_2$ SCF dissolved in PP









# Solid Shot Warpage

#### Production – solid shot

#### Moldex3D – Solid shot



傳統 第2模 (84.04mm)



#### Solid Shot - mm



# Mucell Warpage - 0.5 wt%

#### **Production - Mucell**

#### Moldex3D - Mucell



#### (濃度 0.5%) 發泡 第 20 模 (88.02mm)



# DIGIMAT 5.0 – Moldex3D Mucell



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# Comparison (X10)

#### Solid

#### MuCell



# Application example: Warpage improvement

## N2/PS (Gas:0.5wt%))





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# Melt Front Animation of Microcellular Molded Part



# Foam Properties of Microcellular Molded Part

#### Cell Density of Microcellular (~1.3 x10<sup>7</sup> [cells/cm<sup>3</sup>])



# Size Distribution (<45 µm)

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0.611

0.305

0.006

0

1.90

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# <figure>

°ann 10° m



Moldex3D





# **Dimensional Stability - X Displacement**



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# Conclusion

This study presents the 3D simulation capability of predicting dynamic behavior for microcellular injection molding process.

Good quantitative agreement between simulation and experimental results are found.

In the industrial application, simulation results meet the criteria of prediction capability for application on microcellular injection molding product.

R12 Support eDesign

R13 Support MuCell + "Injection Expansion" (Core-Back)

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## Interested? Talk to us:

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