Digimat USERS' MEETING 2014

The material modeling conference

2014 October 21-23, Rome, Italy

e-Xstream engineering
MSC Software Company

How Moldex3D Tackles Fiber Simulations

Dr. Shih-Po Sun

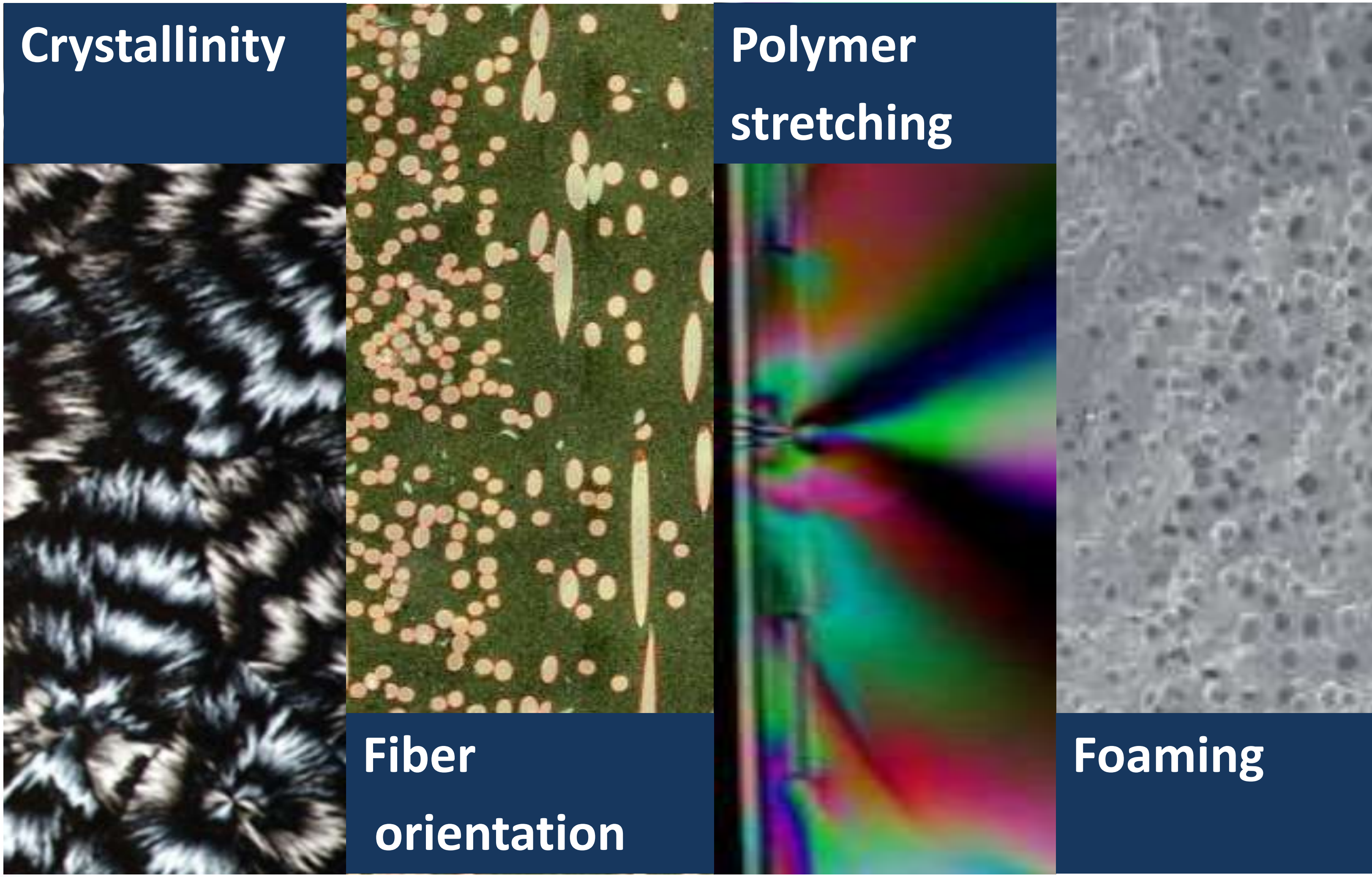
Division Manager, Technical Research Division

tobersun@moldex3d.com

+886-3-5600199

Moldex3D
MOLDING INNOVATION

Flow induced microstructures



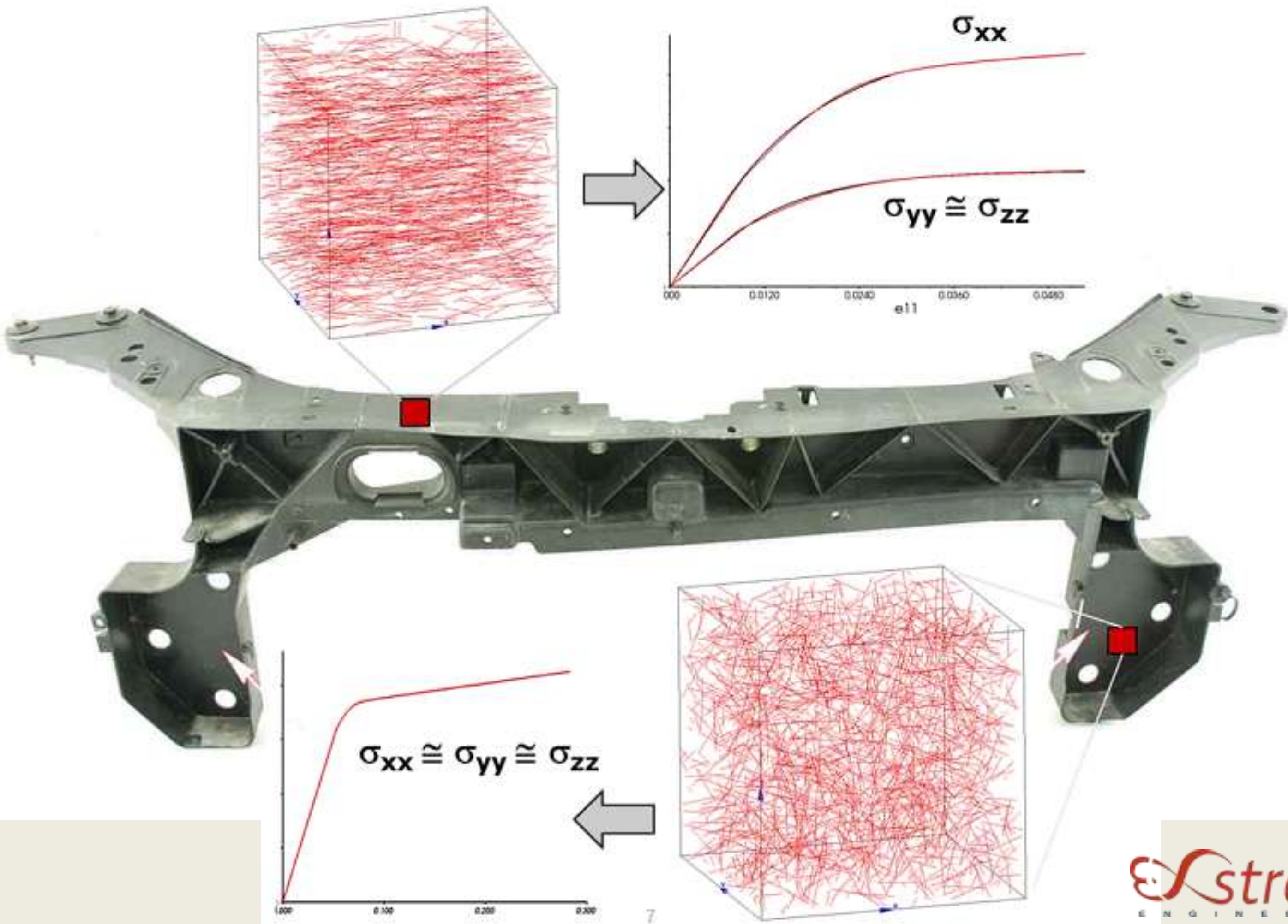
Why isn't broken at center?

(a) (b)

Figure 6. (a) Predicted failure and (b) experimental failure for the flow-direction specimens cut from the 40% glass-PP center-gated plaques

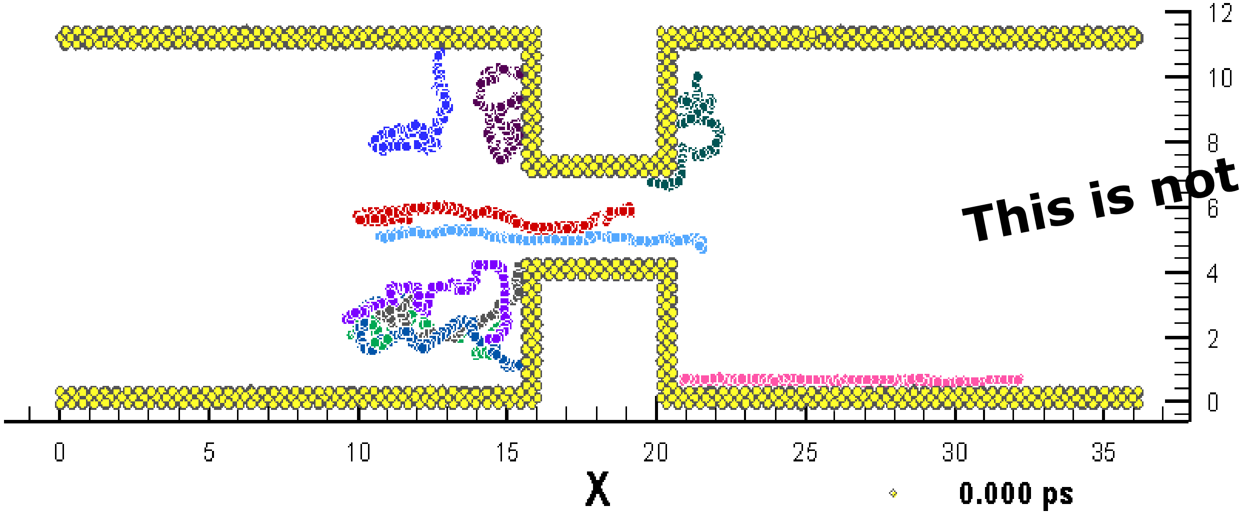
Source: Oak Ridge National Laboratory

Influence of fiber orientation



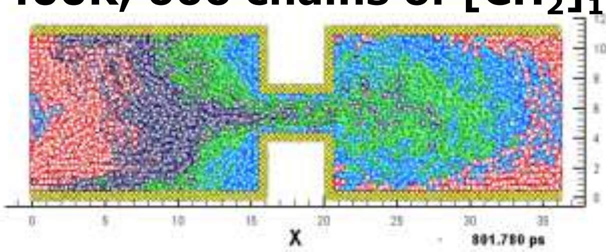
Source: 2014 e-Xstream Engineering

How does a molecule move?

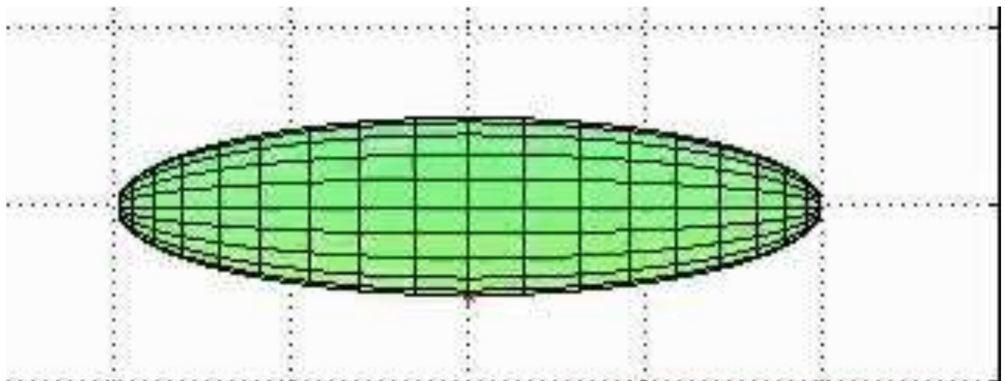


This is not Ebola

400K, 666 chains of $[CH_2]_{100}$

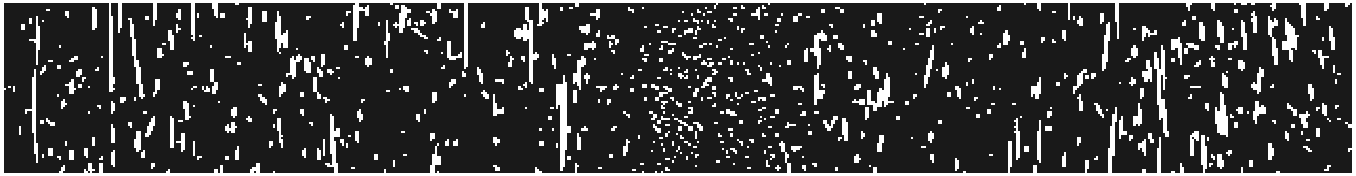


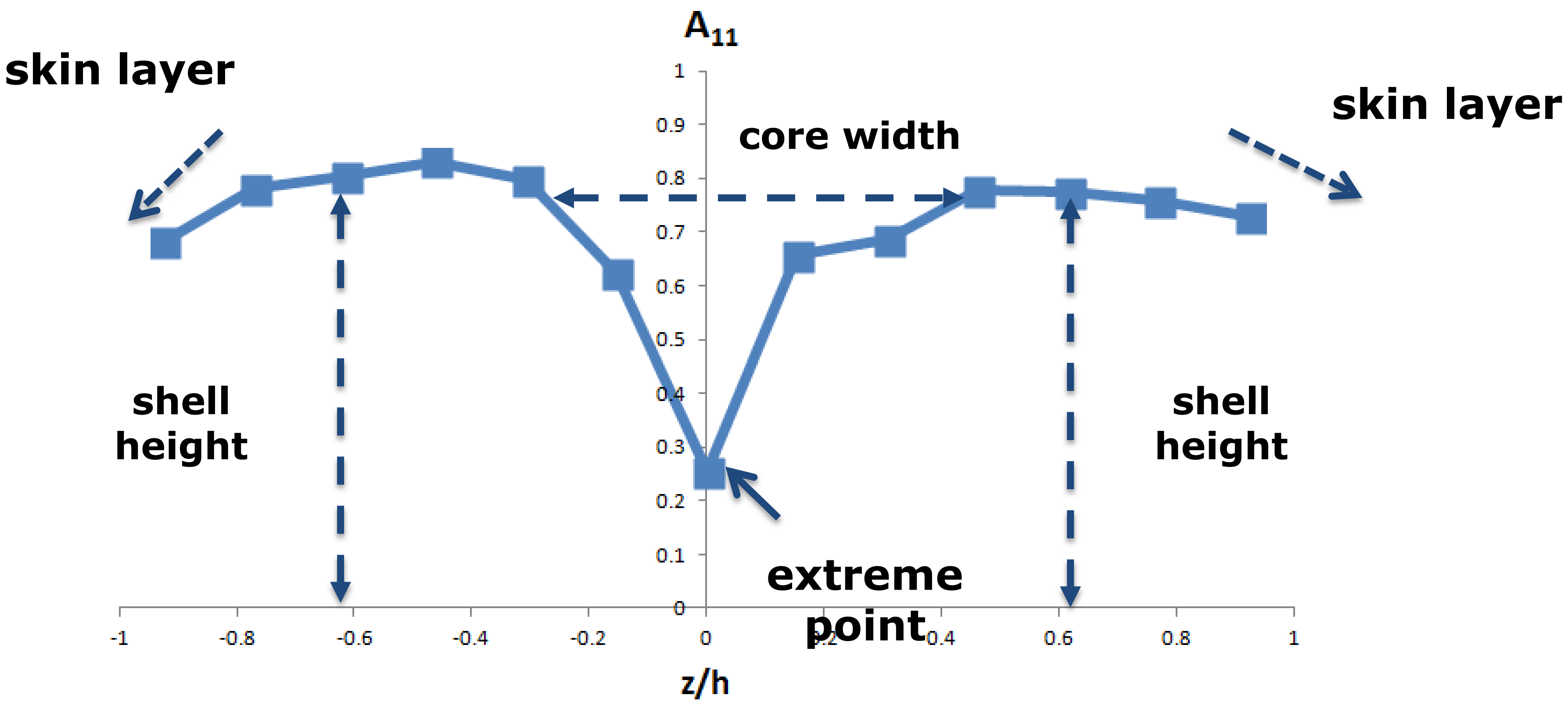
How does a filler do?
Jeffery’s orbit



https://www.youtube.com/watch?v=5mmFs5MkhRI

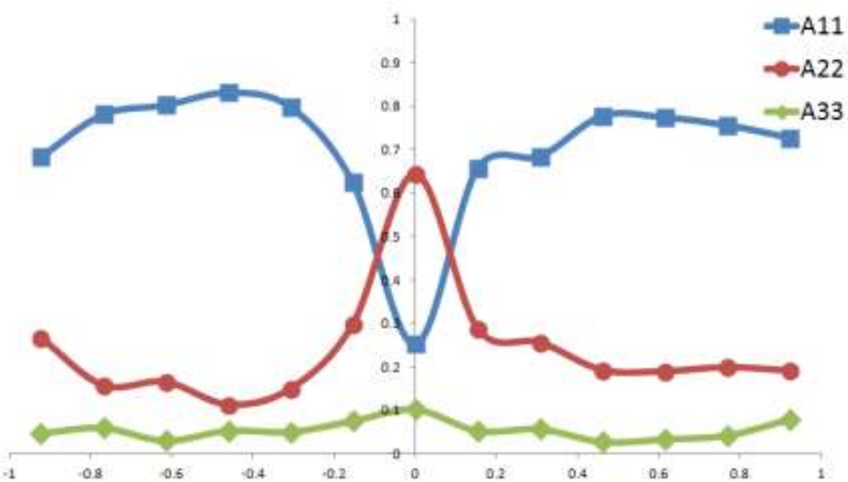
Features of Fiber Orientation Distribution



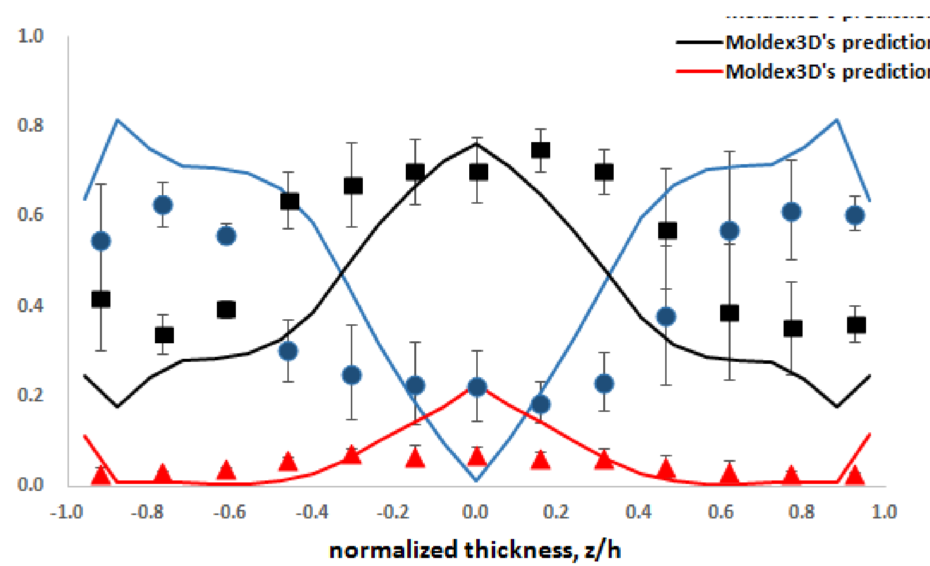


What if I have longer fiber?

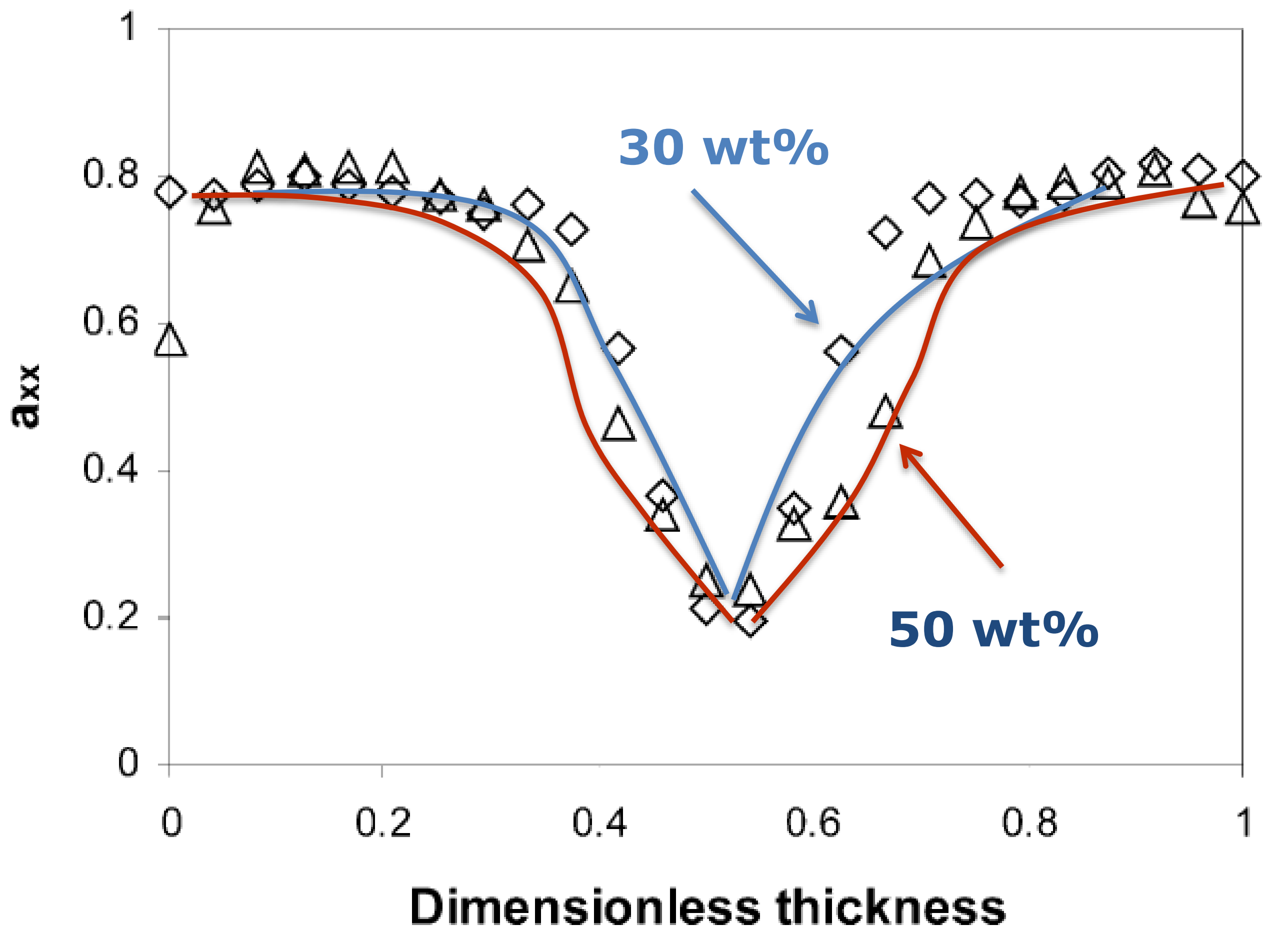
Short



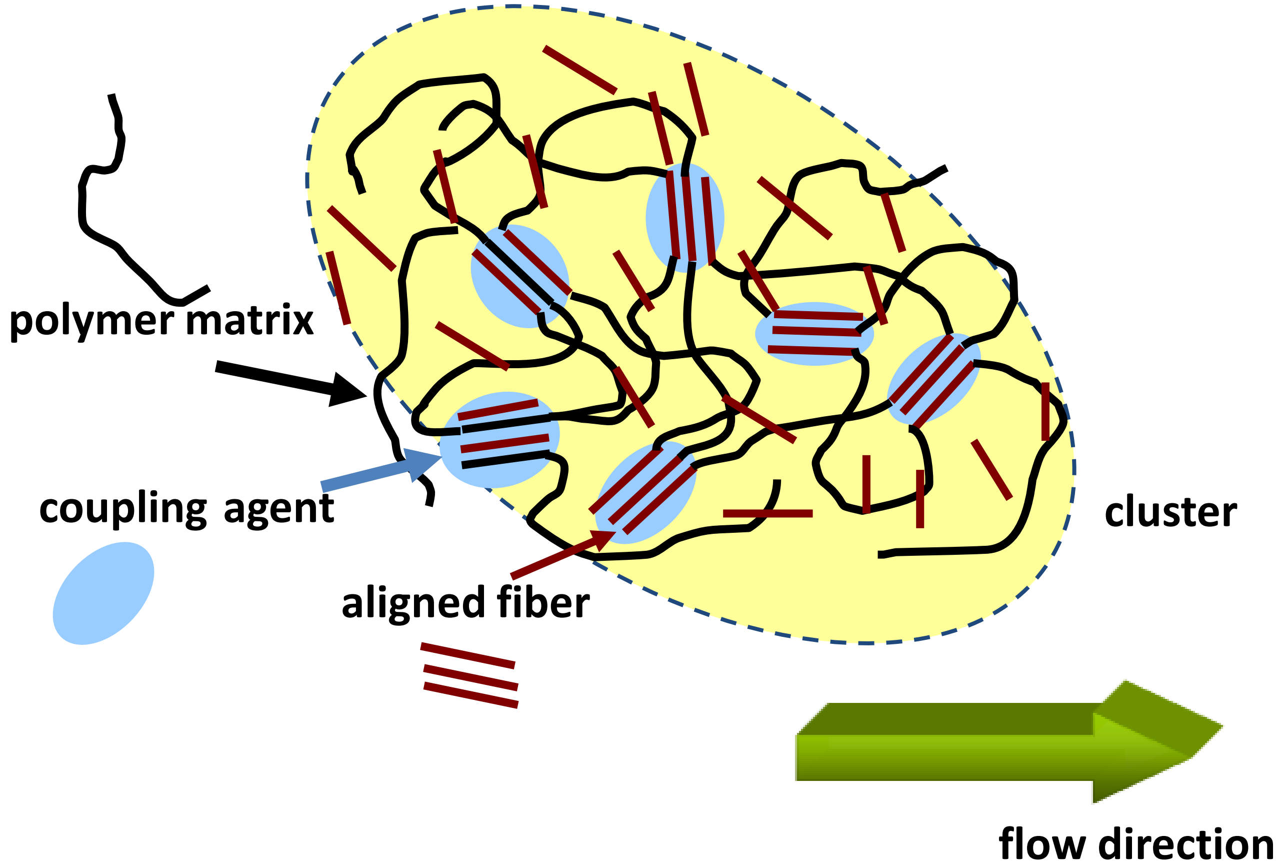
Long



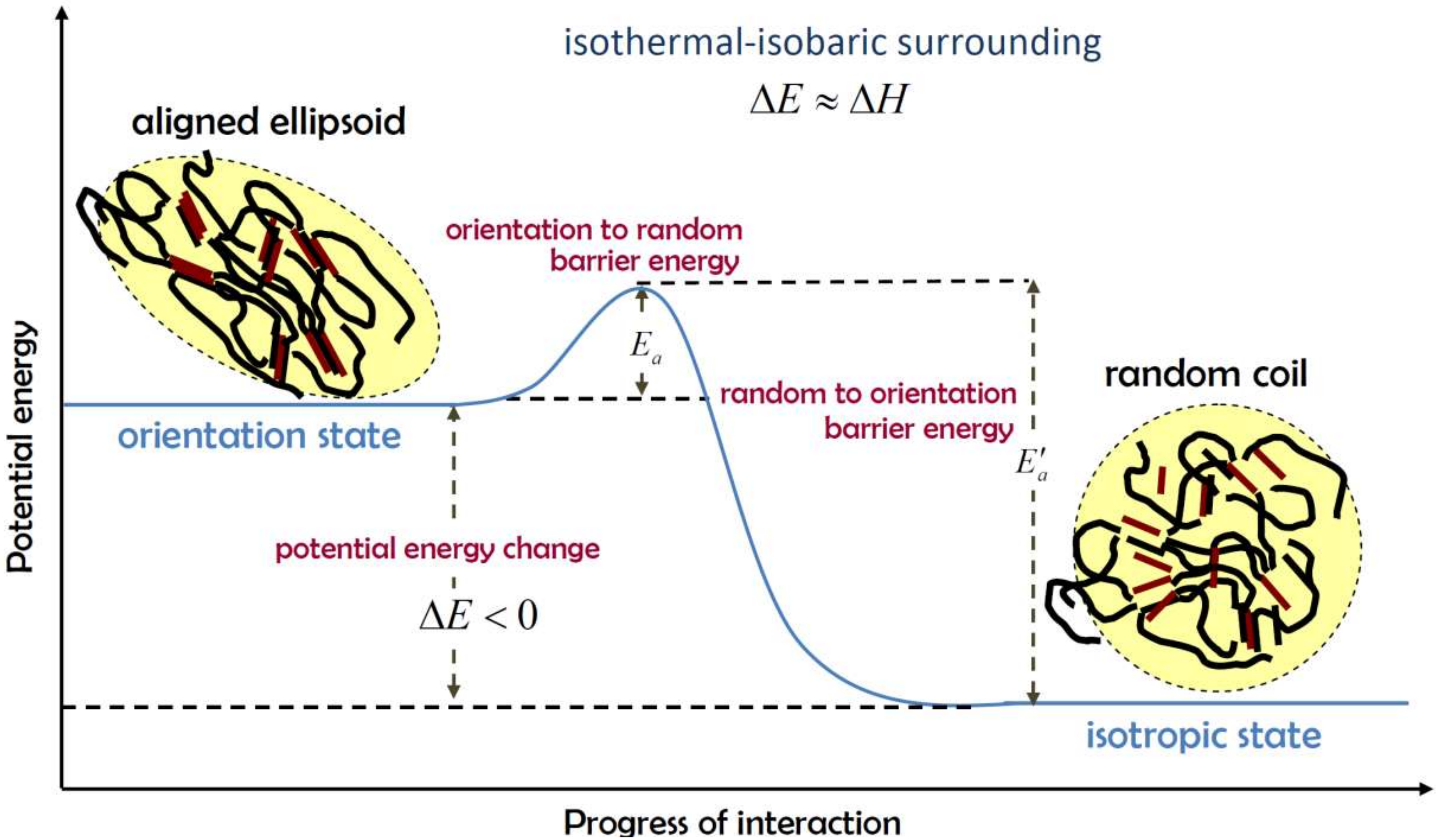
What if I have more fiber?



Considering fiber-fiber and fiber-matrix interaction



Physical approach
Fiber orientation with thermodynamic aspect

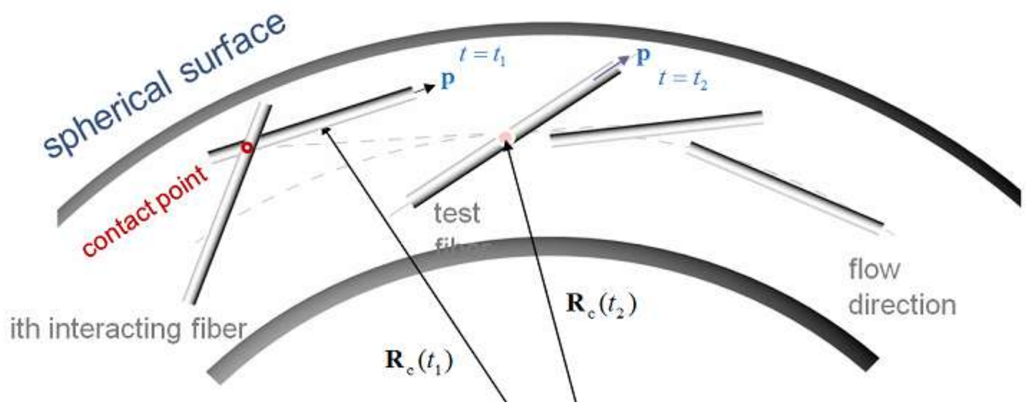


Fiber Model of Moldex3D: iARD-RPR Model

- iARD-RPR (an improved ARD tensor combined with a new Retardant Principal Rate) model involves three parameters, α, C_I, C_M

$$\dot{\mathbf{A}} = \dot{\mathbf{A}}^{\mathrm{HD}} + \dot{\mathbf{A}}^{\mathrm{iARD}}(C_I, C_M) + \dot{\mathbf{A}}^{\mathrm{RPR}}(\alpha)$$

$$\dot{\mathbf{A}}^{\mathrm{HD}} = (\mathbf{W}\cdot\mathbf{A} - \mathbf{A}\cdot\mathbf{W}) + \xi(\mathbf{D}\cdot\mathbf{A} + \mathbf{A}\cdot\mathbf{D} - 2\mathbf{A}_4 : \mathbf{D})$$



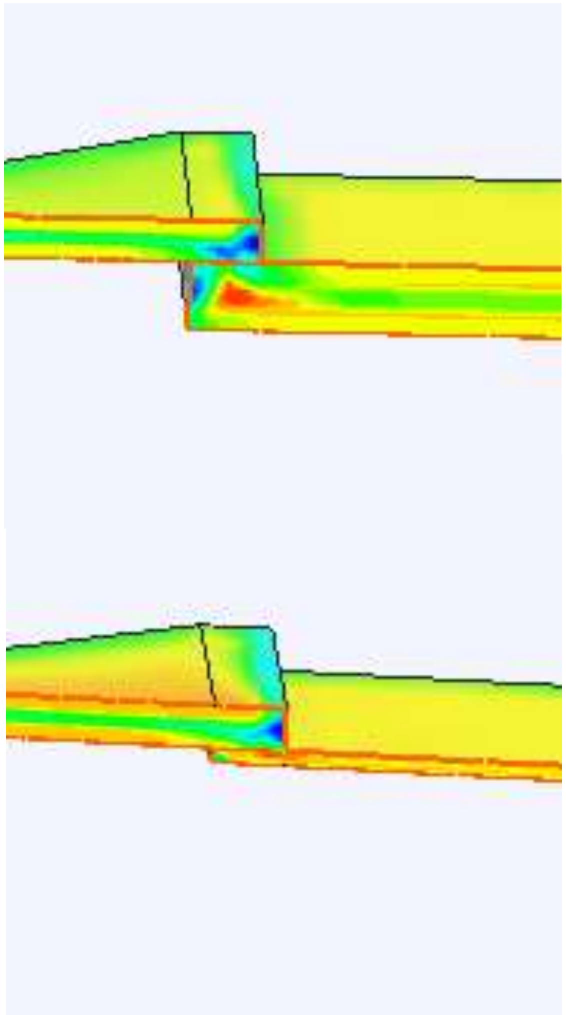
Benefit of iARD-RPR Model

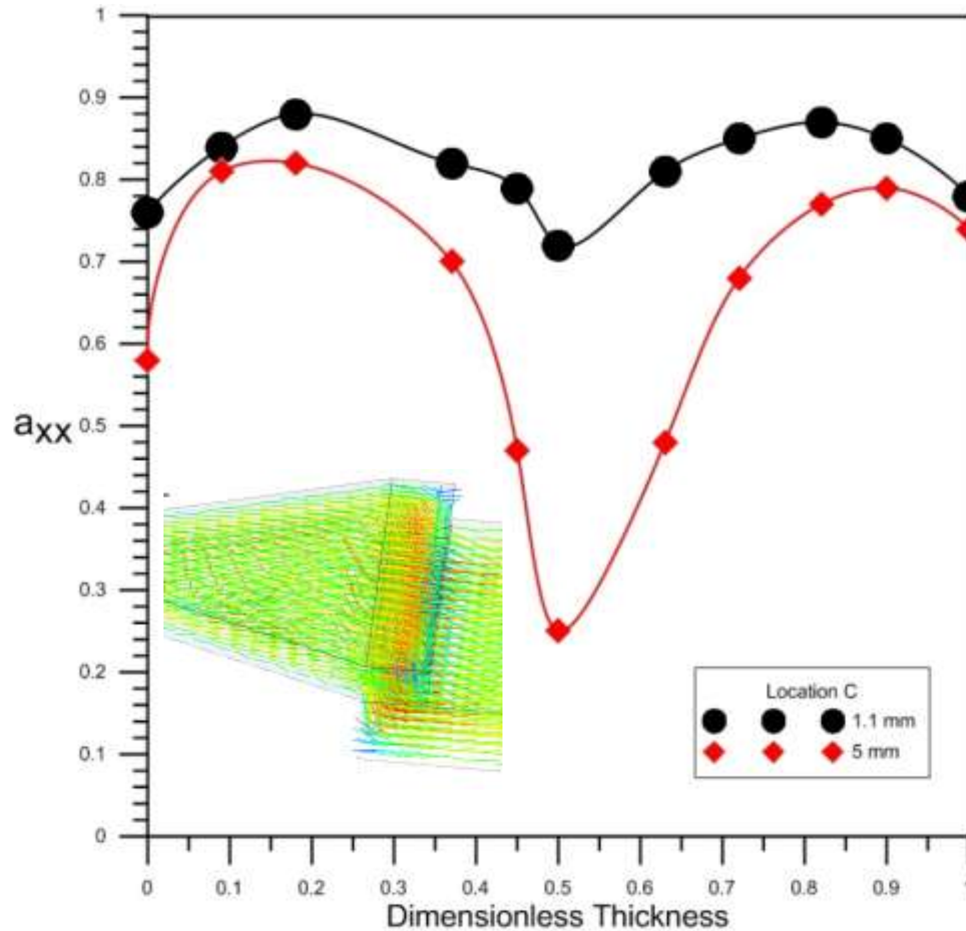
- A simple formula with linear superposition

$$\dot{\mathbf{A}} = \dot{\mathbf{A}}^{\mathrm{HD}} + \dot{\mathbf{A}}^{\mathrm{iARD}}(C_I, C_M) + \dot{\mathbf{A}}^{\mathrm{RPR}}(\alpha)$$

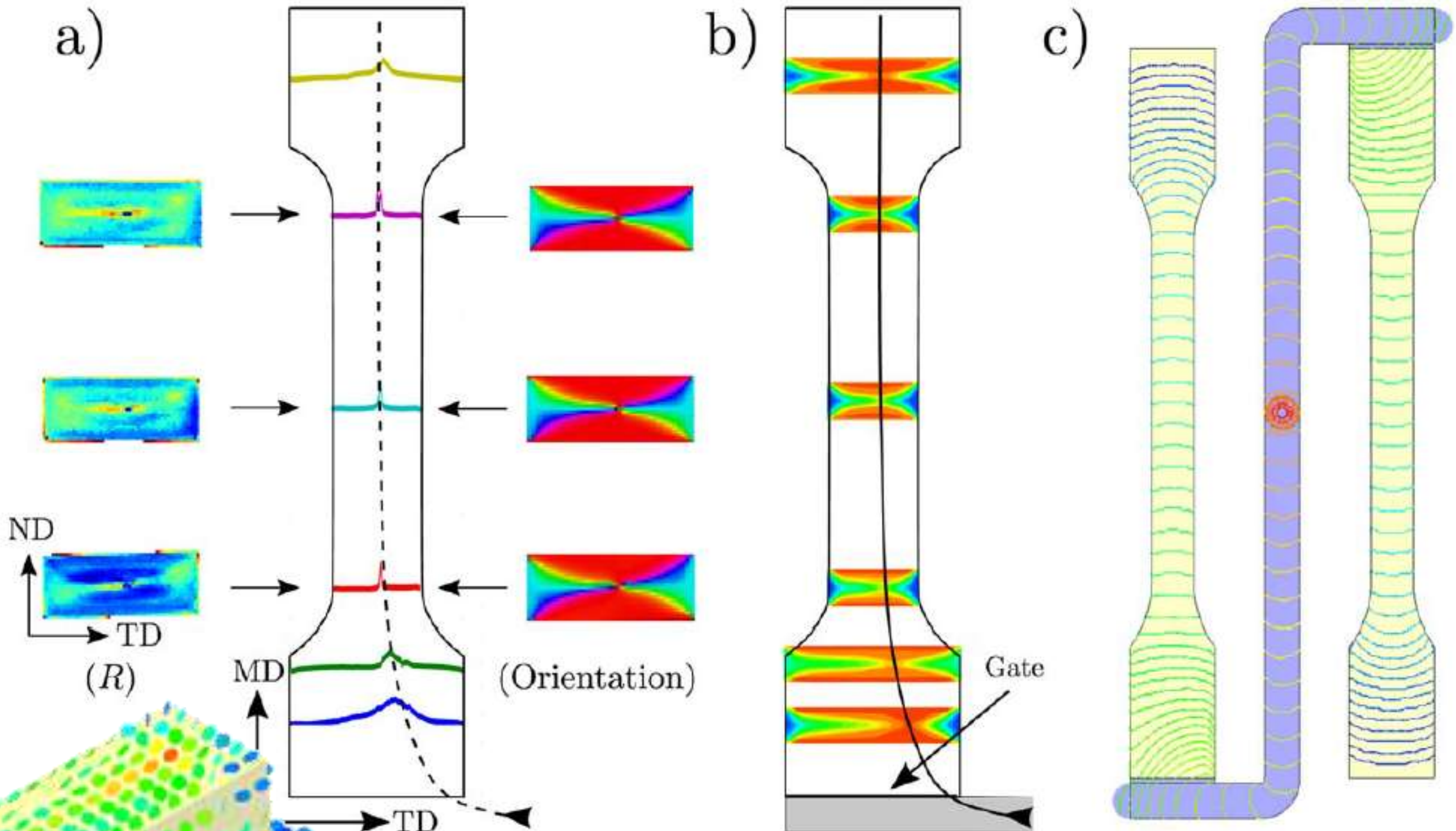
- Only three fitting parameters with physical meaning
- Using inlet condition is NOT necessary.

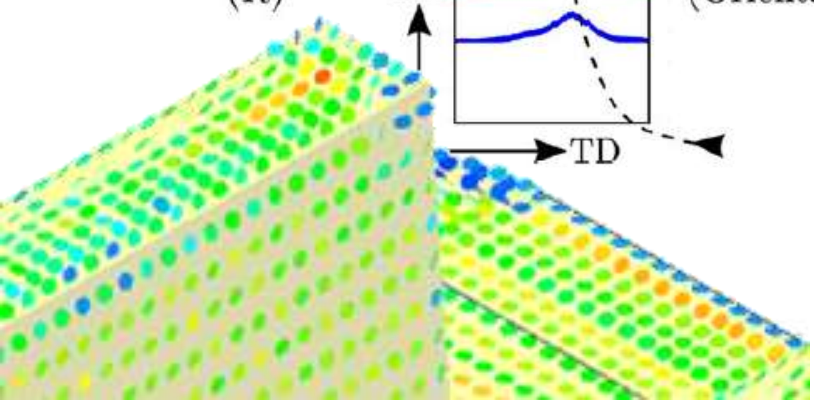
Change of thickness of the part





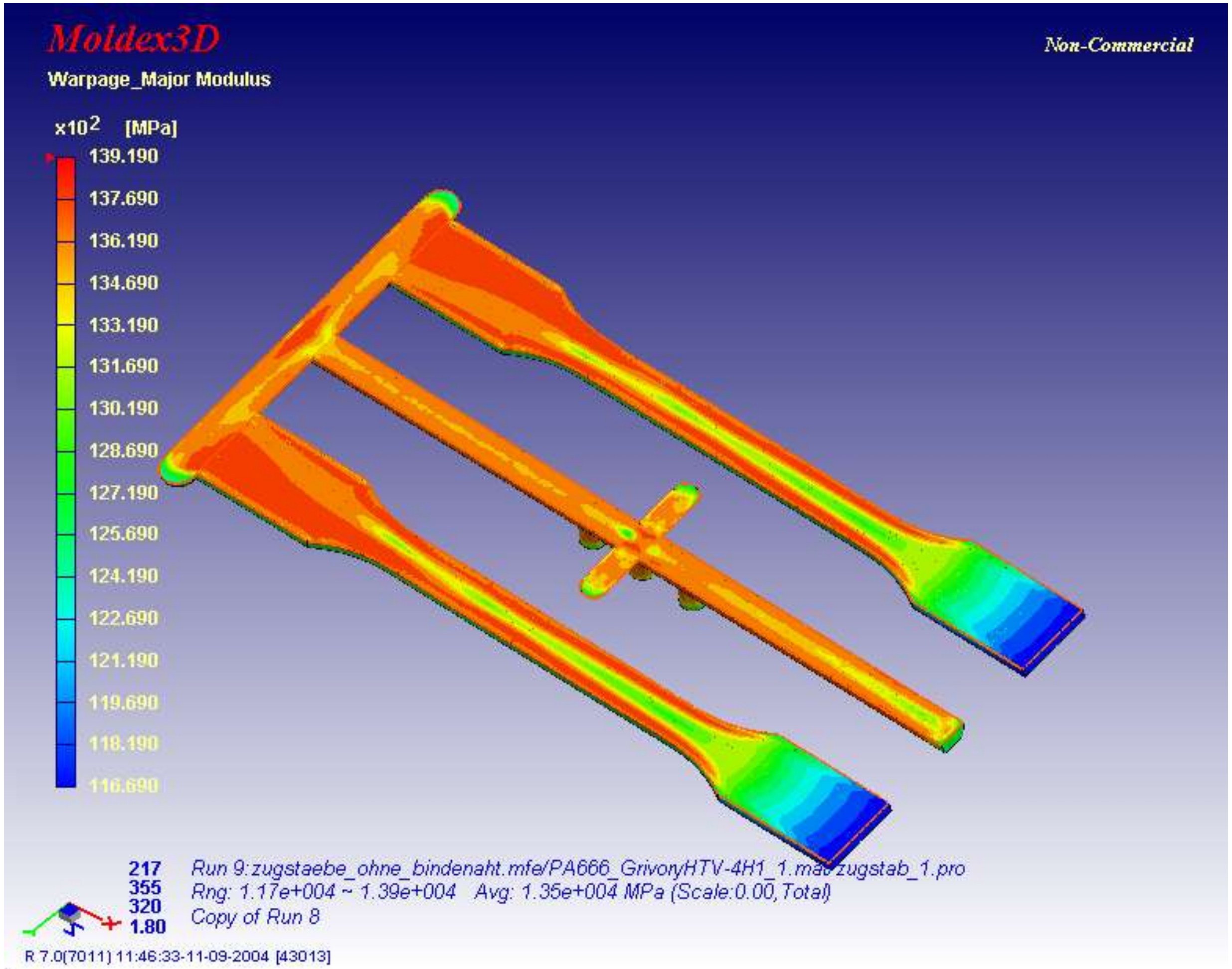
Flat disc instead of a fiber





Source: Granlund, et. al, JOURNAL OF POLYMER SCIENCE, PART B: POLYMER PHYSICS 2014, 52, 1157

Seeing test coupon in a different way



Orientation verified fiber system

Client	Part Shape	Fiber Type	Fiber Length	Fiber Content	Polymer Matrix
Material supplier	2.5 mm Plaque	Short Glass Fiber	5mm	40 wt.%	PA66
	One center point tested accurate with 70%, , *core, shell and skin regions predicted well*.				
Automotive OEM	3.0 mm Plaque and Disk	Short Glass Fiber	5mm	10 & 30 wt.%	PBT
	Three locations tested accurate with 70-80%, core, shell and skin regions predicted well.				
Aerospace	3.4 mm Plaque	Short Carbon Fiber	7mm	30 wt.%	PEEK
	9 out of 9 locations tested accurate with 90%, , core and shell region values predicted				

Orientation verified fiber system

Client	Part Shape	Fiber Type	Fiber Length	Fiber Content	Polymer Matrix
Research Center	3.0 mm Plaque	Long Carbon Fiber	13 mm	40 wt.%	PA66
	8 out of 10 locations tested accurate with 80%, core and shell region values predicted well, especially for more wide core.				
Automotive supplier	3.0 mm Plaque	Long Glass Fiber	13 mm	40 wt.%	PP & PA66
	3 out of 3 locations tested accurate with 60-70%, , core and shell region values predicted well.				
Automotive OEM	Multi Ribbed box-shaped part	Long Glass Fiber	13 mm	20 & 40 wt.%	PP & PA66
	10 out of 17 points are accurate with 70%, , especially for the ribbed areas				

Digimat is the gateway

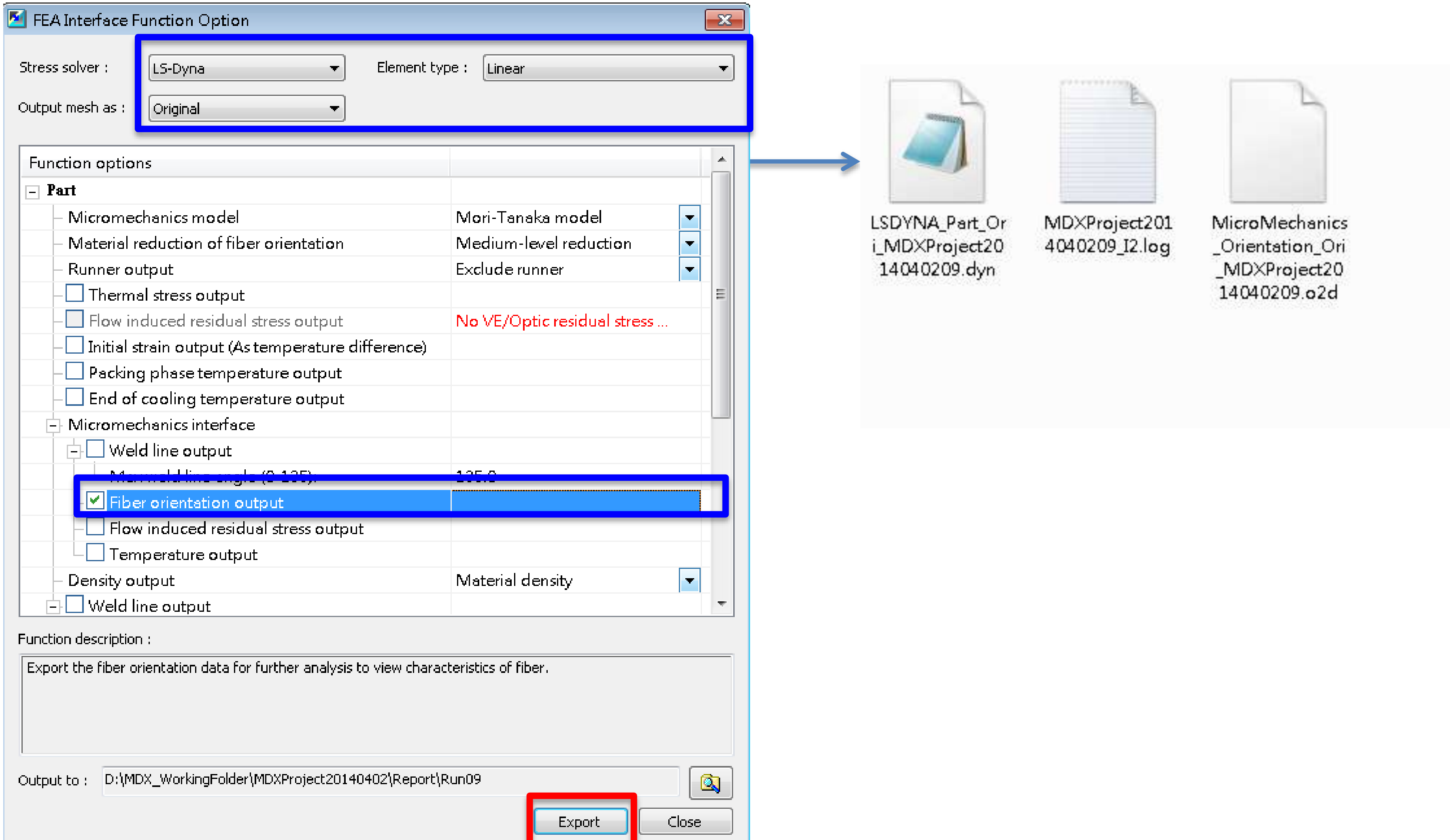
Moldex3D

digimat

Altair ANSYS esi get it right™

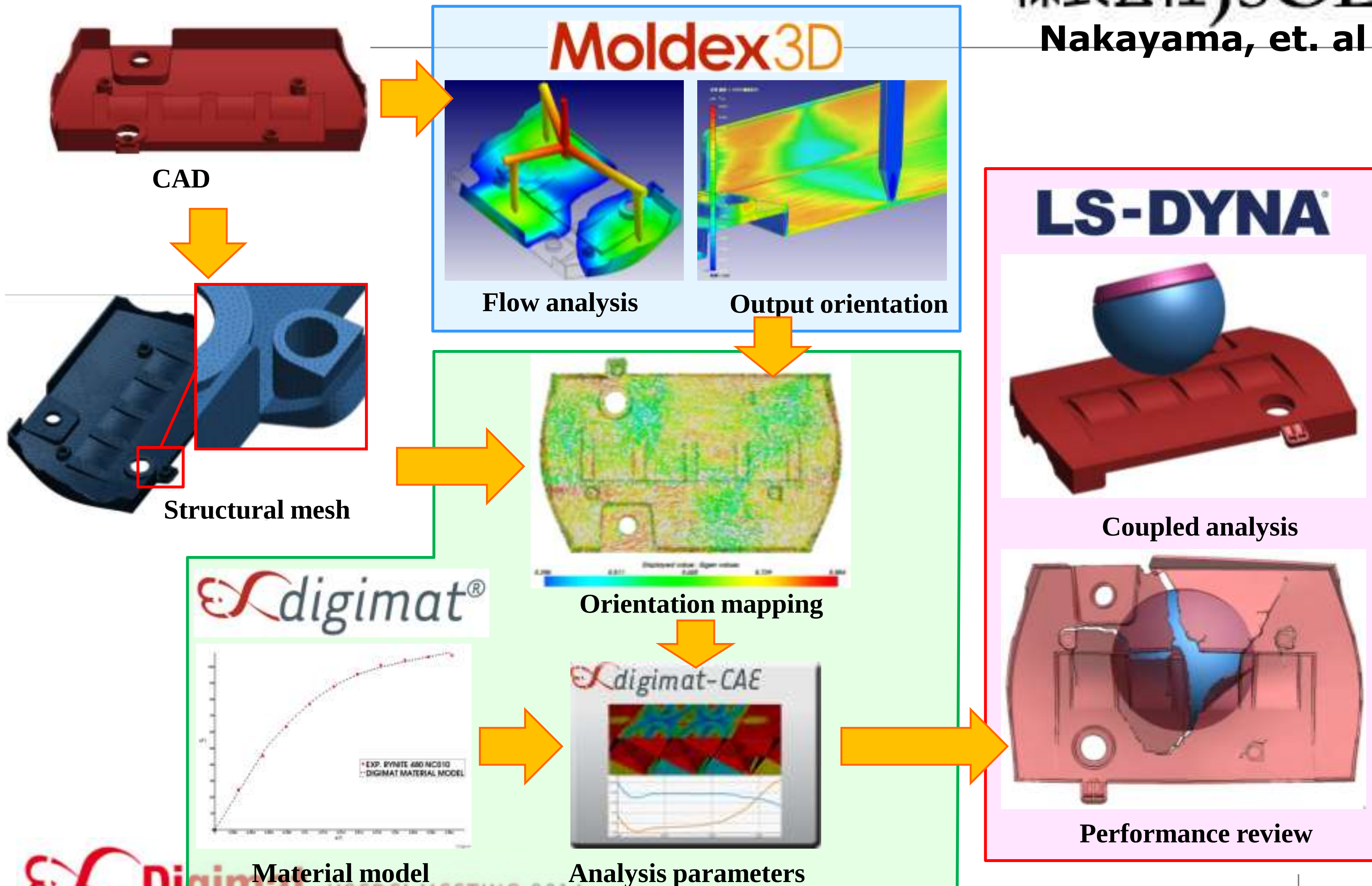
MSC Software SAMTECH Abaqus Solution Partner 3DS SIMULIA

Exporting fiber information to Digimat

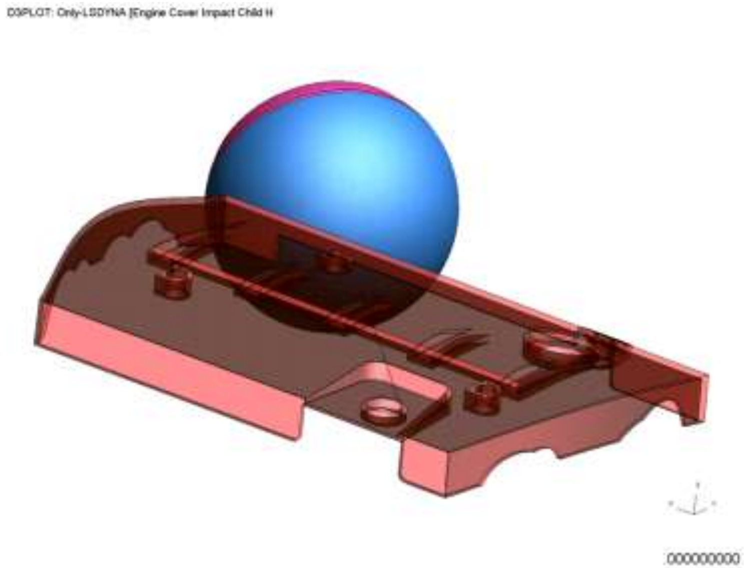


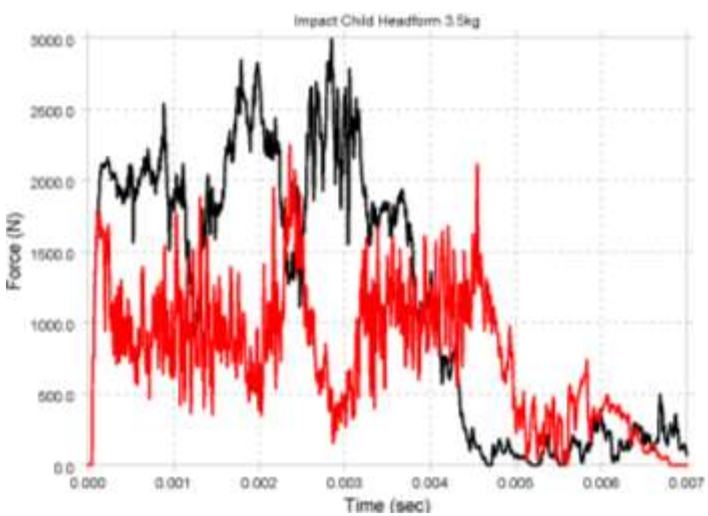
Moldex3D-Digimat-LS DYNA simulation

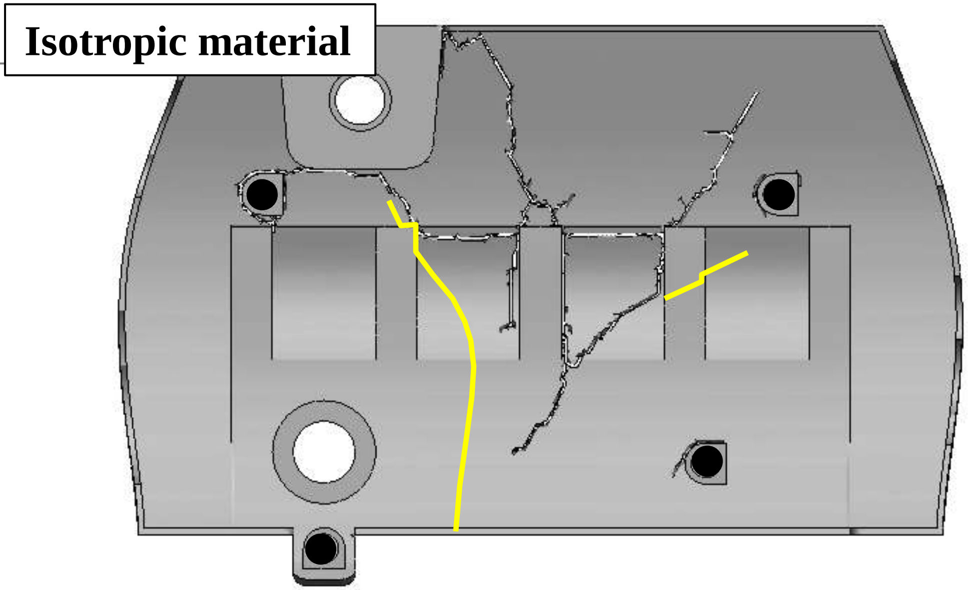
Courtesy:
株式会社JSOL
Nakayama, et. al

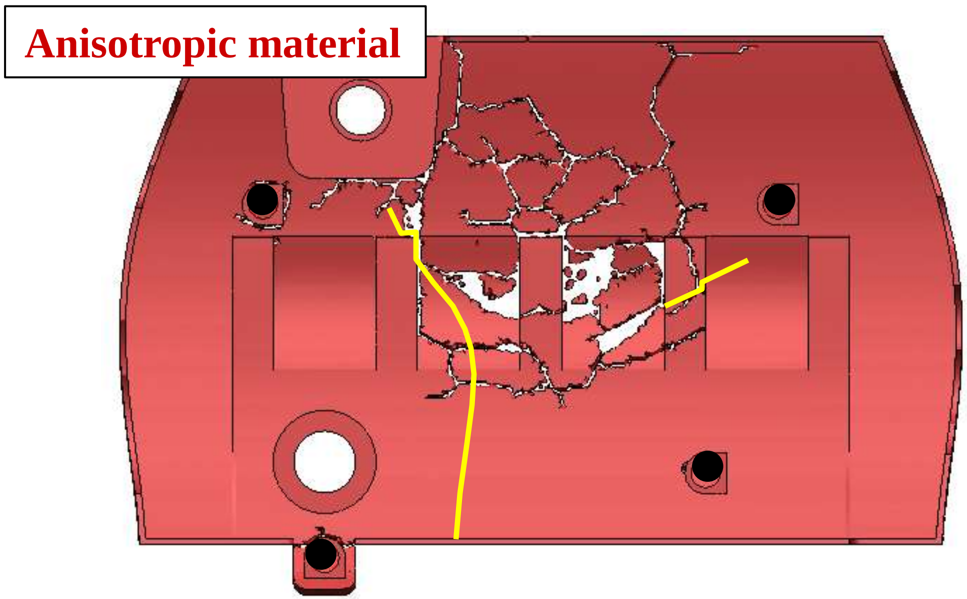


Impact result comparison

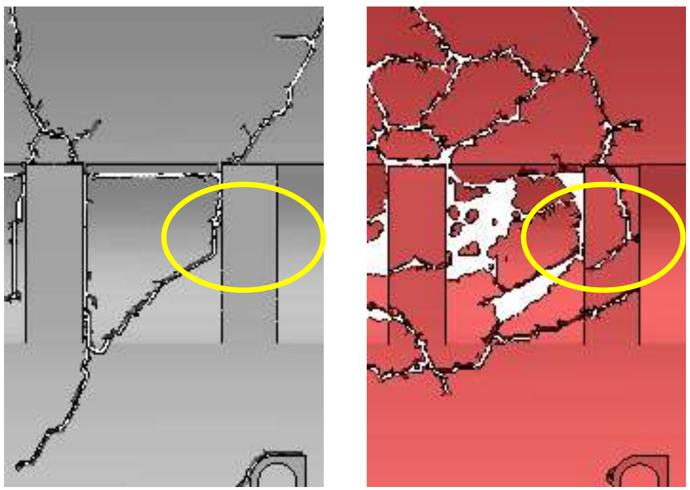


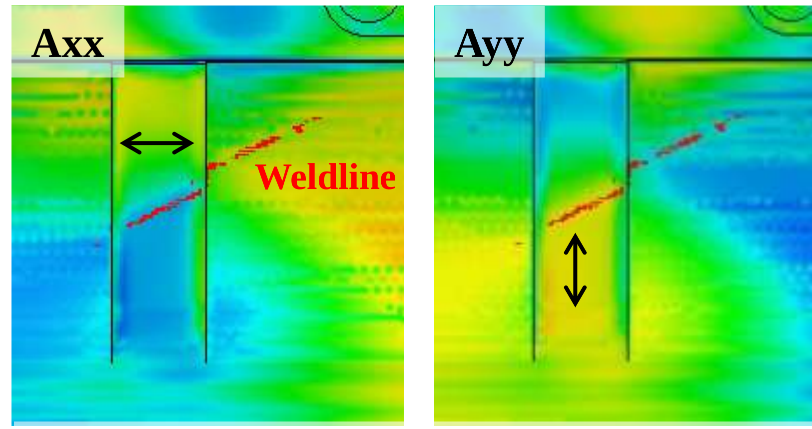




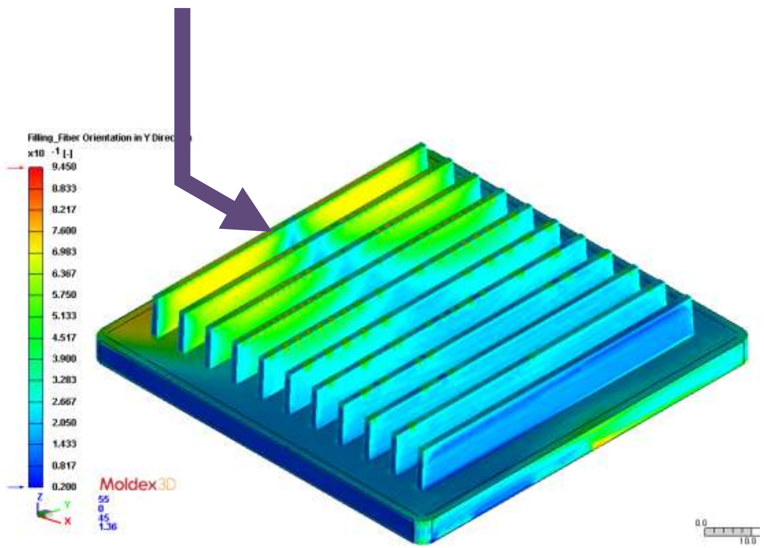


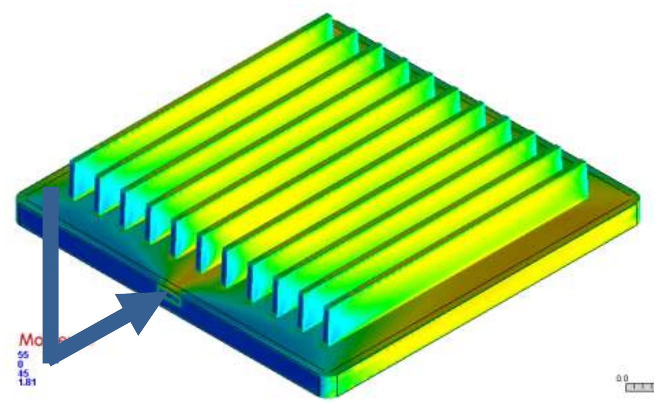
Orientation across the weldline results in different breakage pattern



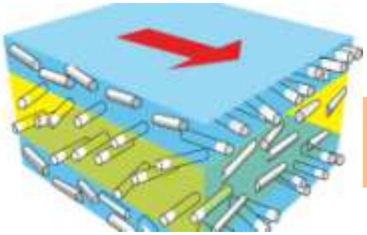


Design considerations for performance



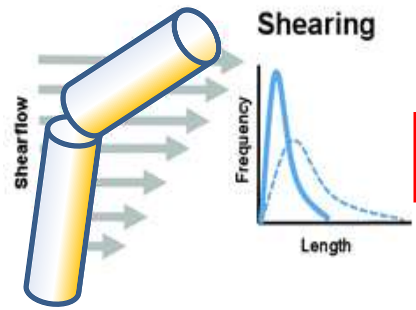


Adding more fiber aspects for realistic simulation

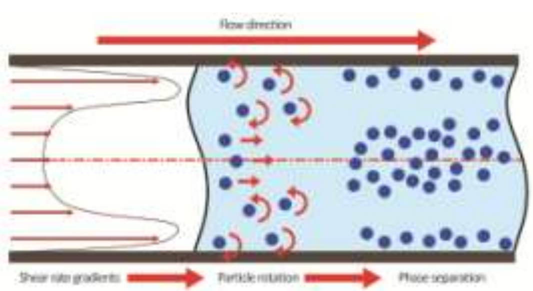


http://www.en.emi.fraunhofer.de

Orientation



Length



Concentration

Fiber breakage prediction model

Fiber Breakage Rate Model

$$P_i = C_B \dot{\gamma} \max\left\{0, \left[1 - \exp\left(1 - \frac{\overline{F}_i}{F_{\text{crit}}}\right)\right]\right\}$$

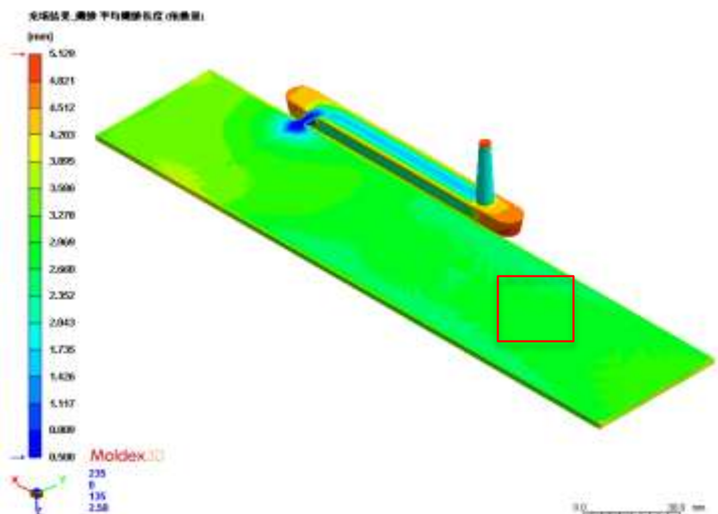
Dimensionless critical fiber breakage force

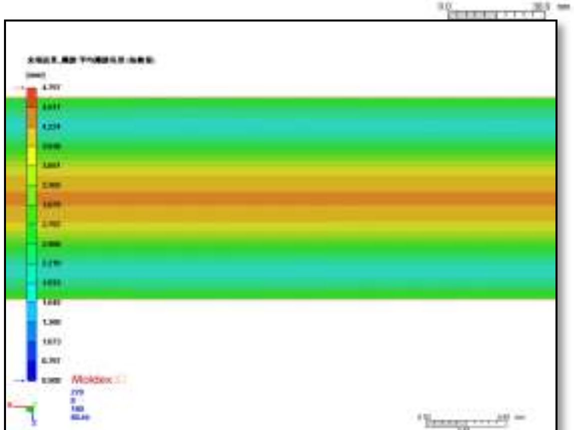
$$\frac{\overline{F}_i}{F_{\text{crit}}} = \frac{8}{\pi^3} \overbrace{\eta_m}^{\text{matrix viscosity}} \overbrace{C_D}^{} \underbrace{\frac{l_i^4}{E_f d_f^4}}_{\text{fiber information}} \left(- \overbrace{\mathbf{D}}^{\text{folw field}} : \overbrace{\mathbf{A}}^{\text{fiber orientation}} \right) > 1$$

C_D: dimensionless drag coefficient

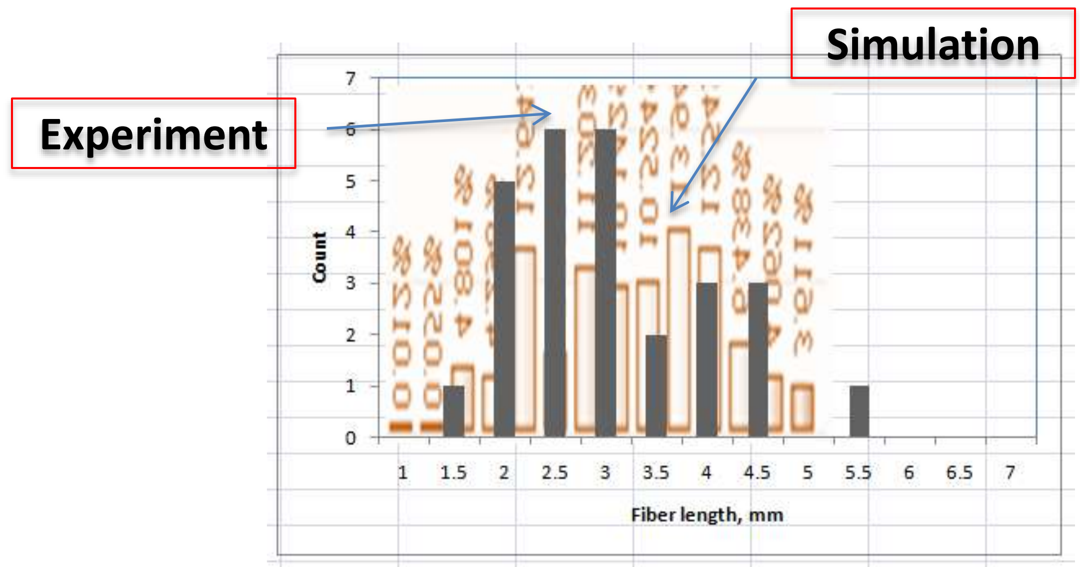
Reference: J. H. Phelps, Processing-microstructure Models for Short- and Long-fiber Thermoplastic Composites, *Ph.D. Thesis, University of Illinois at Urbana-Champaign, (2009)*

Exemplary length result





Center 4.3 mm
Skin 1.5 mm
Average 3.2 mm



Major length reduction is due to plastication

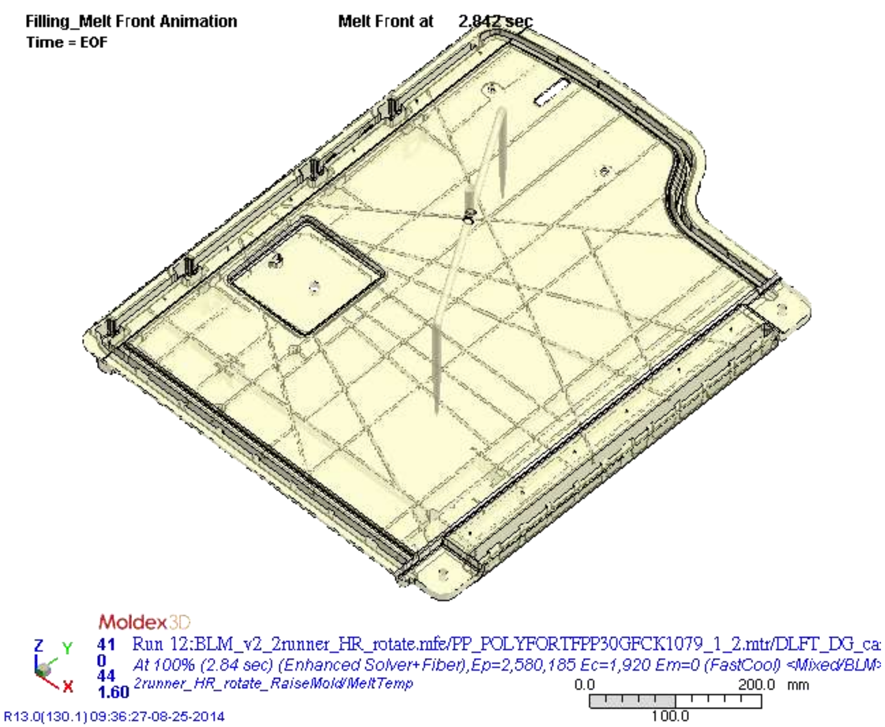
Item	Feed section	Transition se	Metering sec	Unit
Pitch Size	85			mm
Screw Speed	25			rpm
Screw Diameter	66	85	77	mm
Channel Depth	9.5	Slope(9.5/4	4	mm
Section Length	855	430	425	mm
Number of Pitch	10	5	5	-
Nozzle Diameter	2			mm
Nozzle Length	10			mm

Temperature Control Zones		
Time Const of Injection Speed	0.0075	-
Time Const of Injection Pressure	0.1	-
Nozzle volume	80	cm^3
Max Pressure Slope	2500	MPa/sec

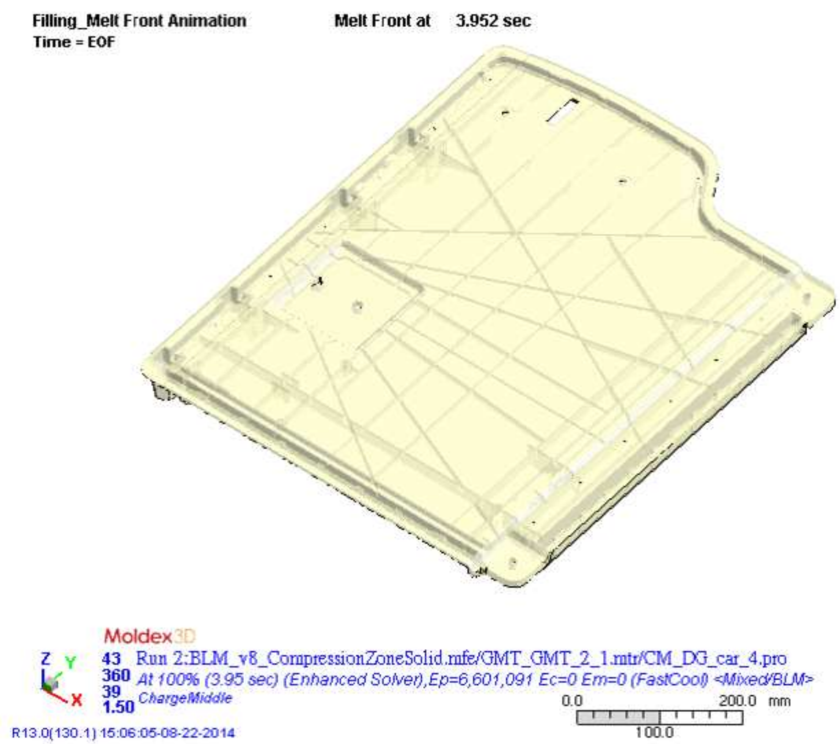
Processing condition	Length after plstication
Plastication 25RPM	1.93
Plastication 60RPM	1.10
Fiber mixed during compression zone (D-LFT 1)	2.28
Fiber mixed during mertering zone，enlarged nozzle (D-LFT 2)	5.74

Better length preservation through compression process

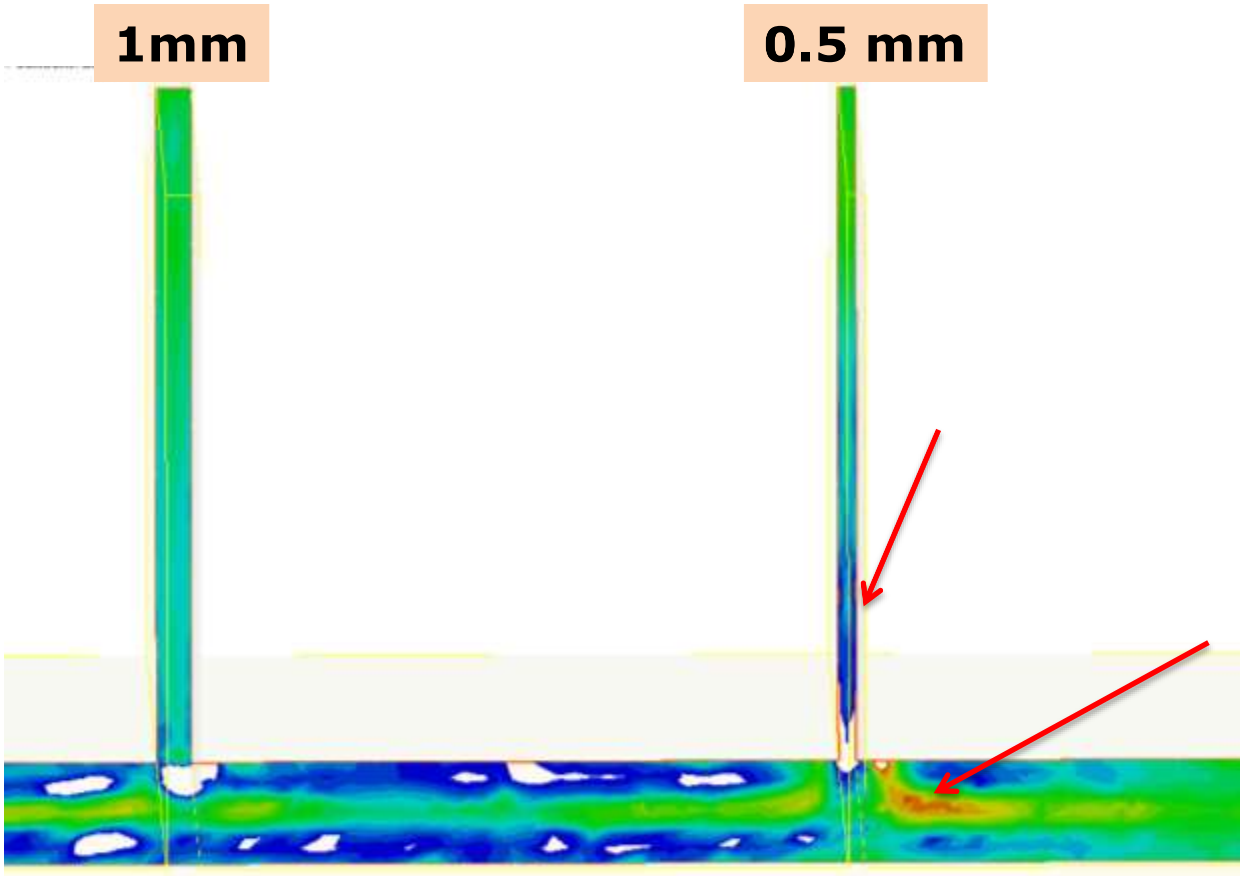
Injection molding



Compression



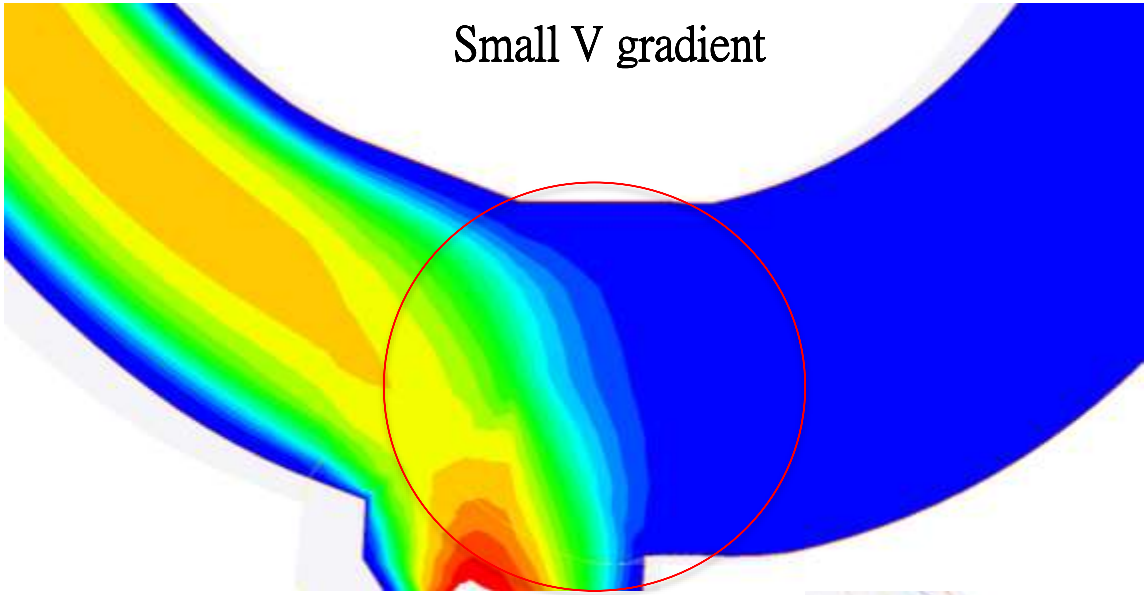
Fiber concentration benefits part design

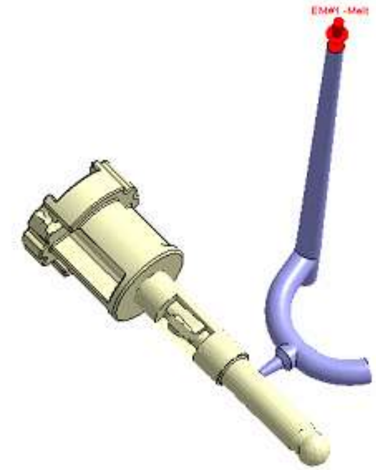


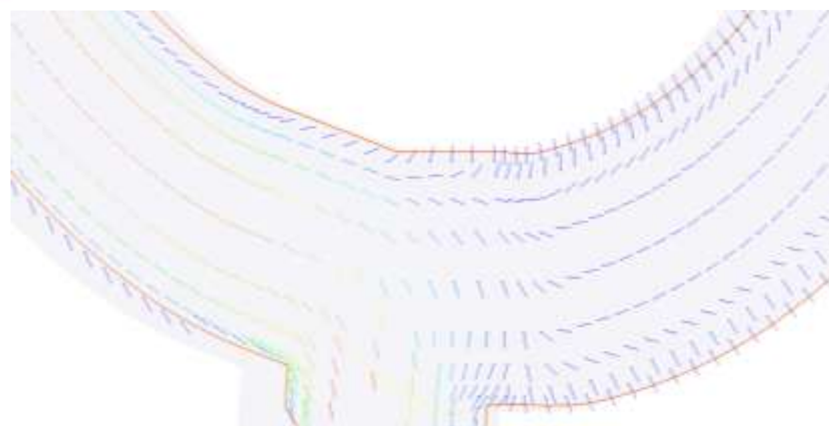
Sewing machine puller study

Item	Production date	GF%	Fiber length(mm)
Pellets(mt'l)	-	31.86	0.239
Old pusher	2012/July	19.89	0.088
New Pusher	2012/Sept	23.15	0.133

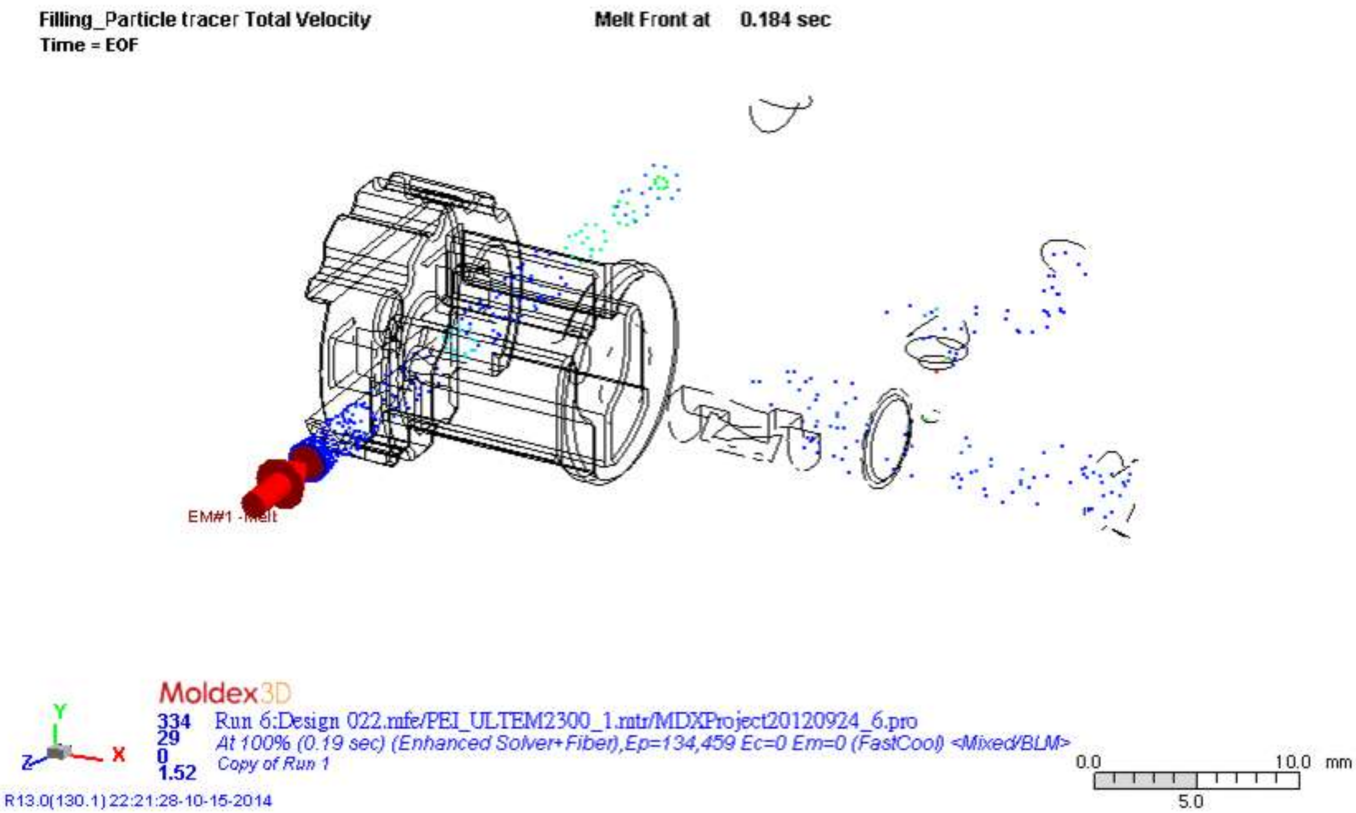
Runner design causing fiber accumulation



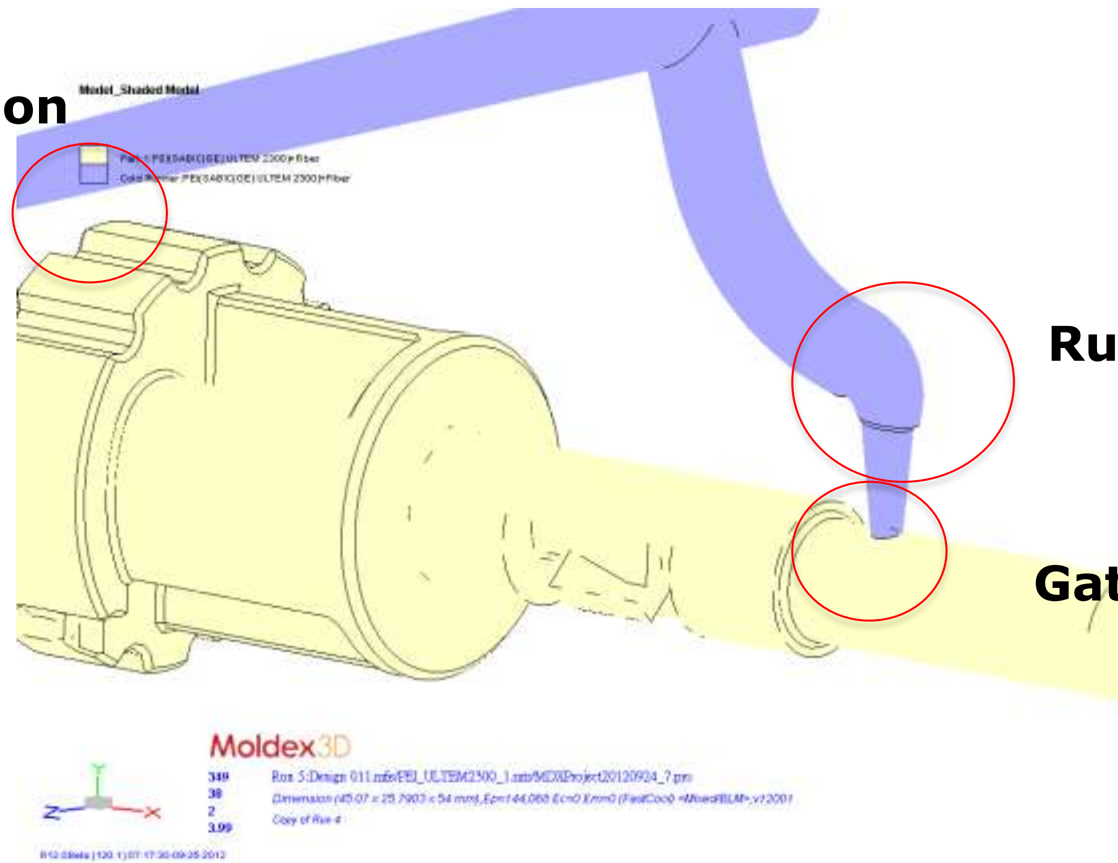




Particle tracer visualization



Design suggestions



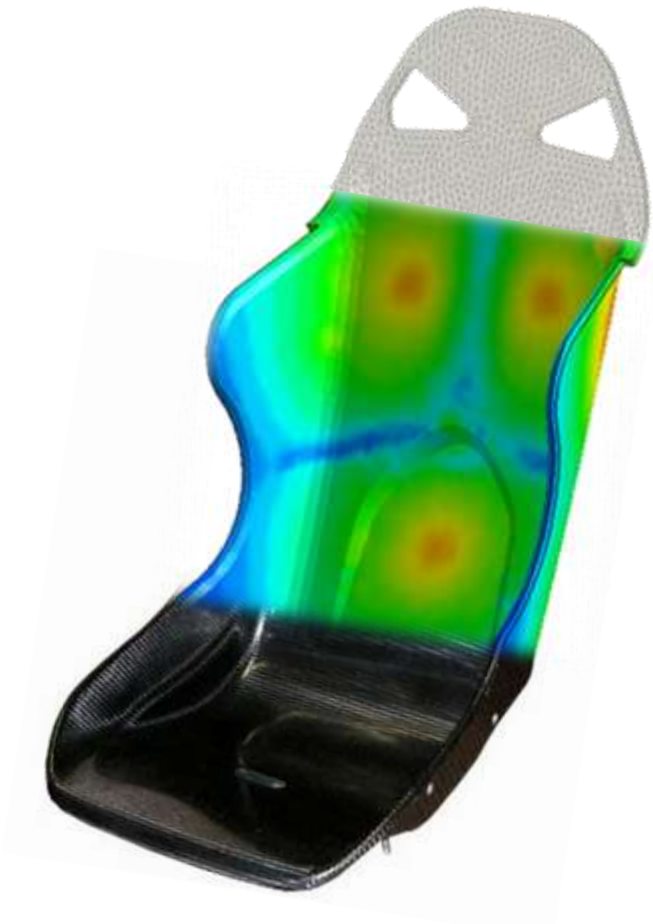
Gate location

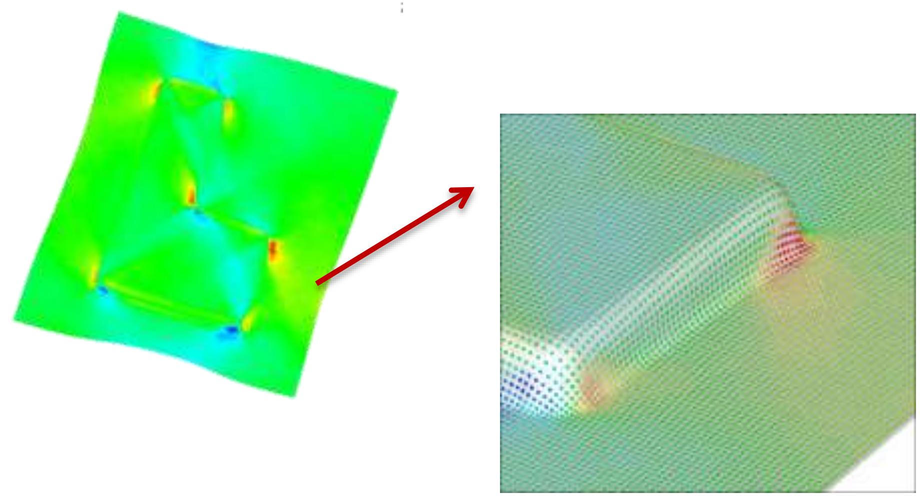
Runner design

Gate size

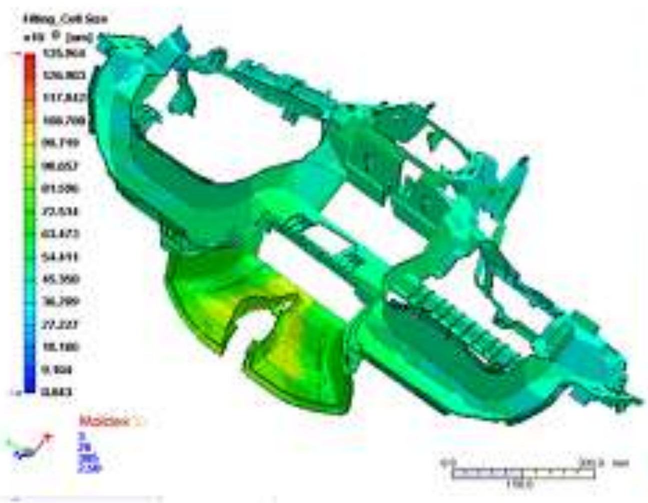
New function – resin transfer molding

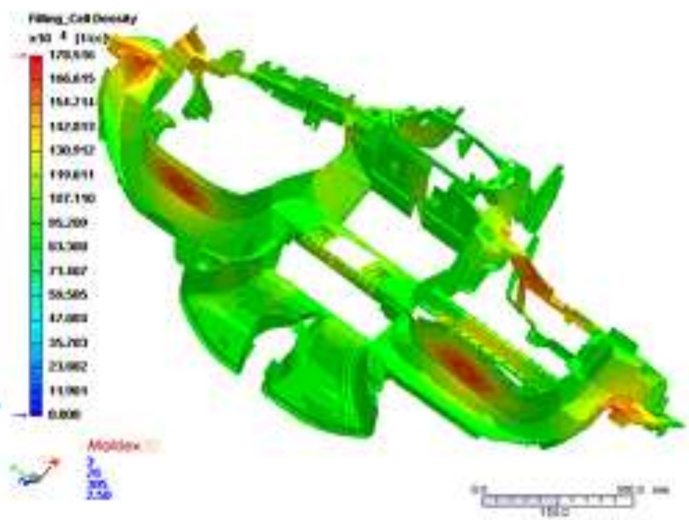
- Flow analysis Including draping analysis

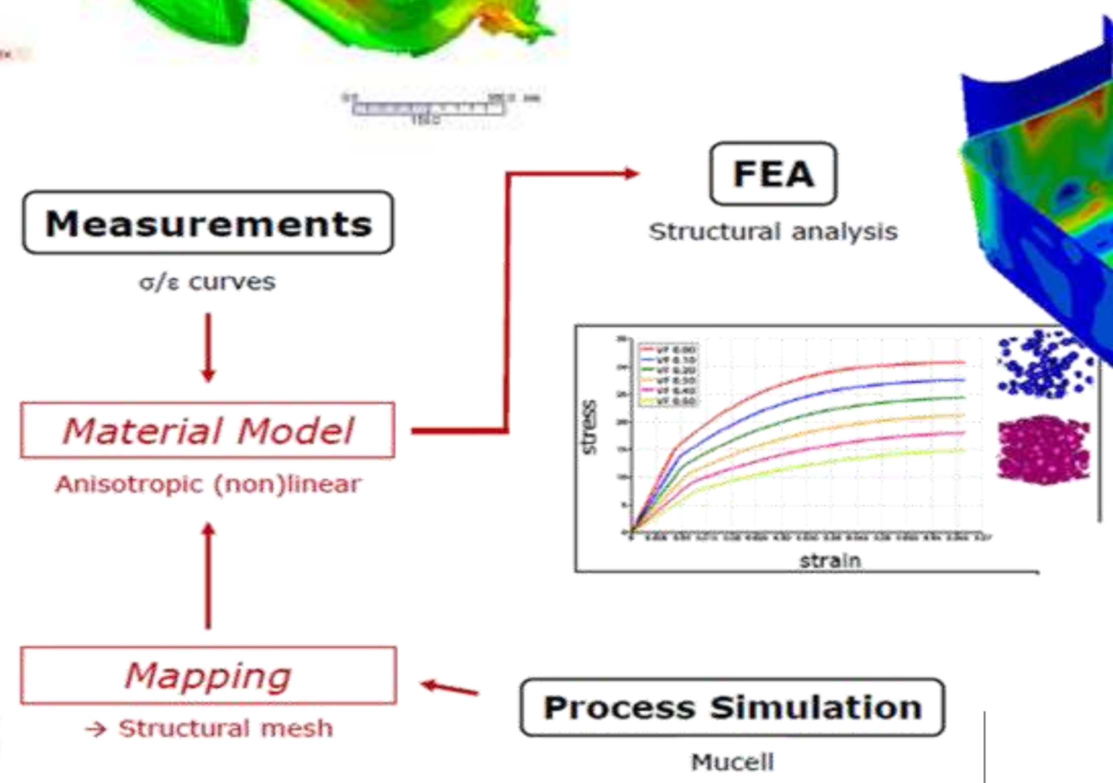




New Function – exporting cell microstructures
Foaming makes product lighter

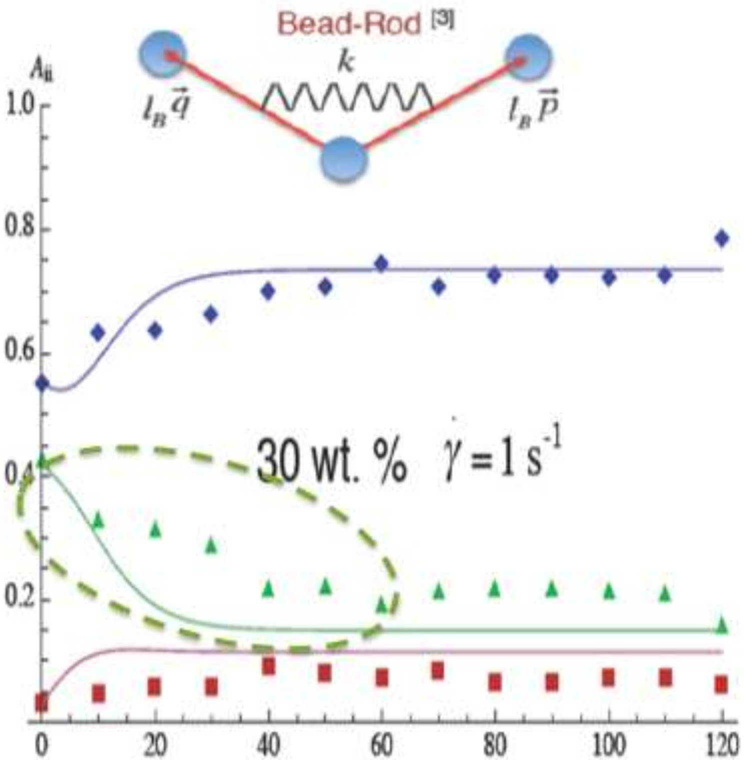




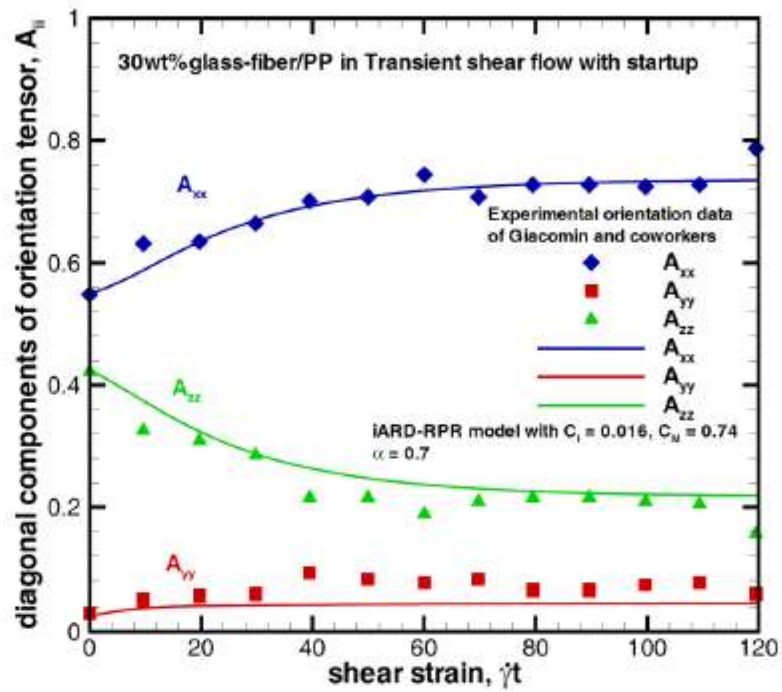


Upcoming: Bending of fiber

Published Result



Moldex3D's work



Company History (1983-2014)

> Many years of development and experience in perfecting CAD-CAM-CAE workflow from design to simulation and manufacturing process

> Current customers have confidence in our leading technology

> Distinctive business image and value system

2014 — Non stop molding innovation

Moldex3D MOLDING INNOVATION — New Logo Image

2011 — Digimat as solution partner (digimat)

2009 — Product Alliance Integration (SIEMENS, PTC, Cimatron, DASSAULT SYSTEMES, MSC SOFTWARE, LSTC, Altair Engineering, ANSYS)

2008 — A Global Leading Provider of CAE Simulation Solution

2001 — Global Market Service

Serves markets with a global network of direct offices and collaborative channel partners

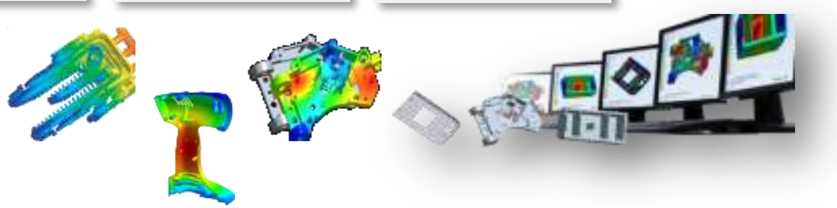
Moldex3D — Own Brand Marketing

1995 — Founded in 1995, more than 80% of employees are experienced engineering professionals for CAE simulation-driven development

1989 — Industry Cooperation

1983 — Theory Foundation

- Software
- Solution
- Service



See you in 2015!

www.e-Xstream.com