Moldex3D

Moldex3D Fibers 2 & Micromechanics

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MOLDING INNOVATION

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Contents

Introduction

Why Fiber

> Fiber Reinforced Plastics (FRP) has widely acted as an major material for lots of plastic parts for their superior mechanical properties

Raw Material Types

> Material types are related to fiber length

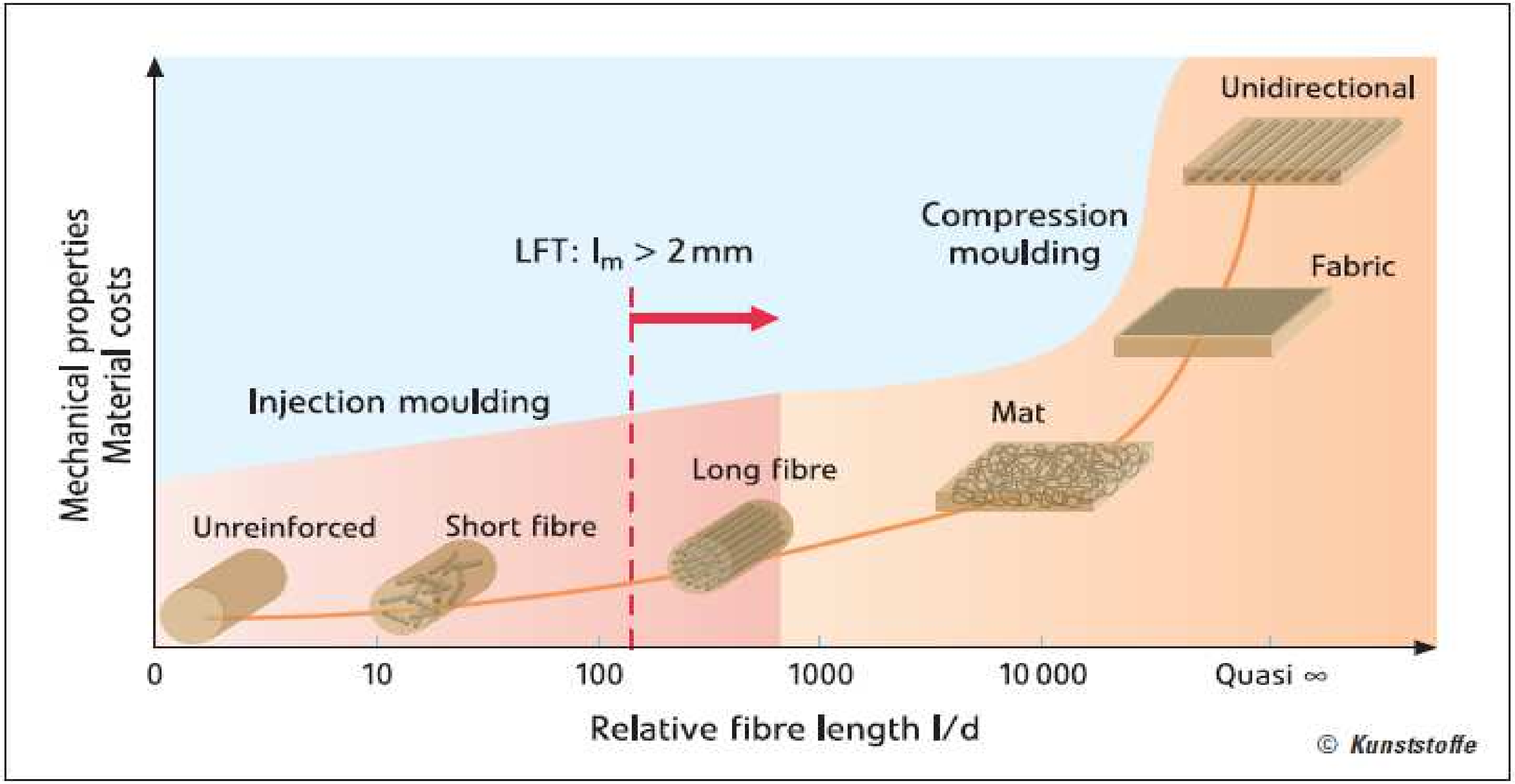


Fig. 9. Classification of long-fibre-reinforced thermoplastics (source: M. Schemme, FH Rosenheim)

Fiber Reinforced Plastics (FRP)

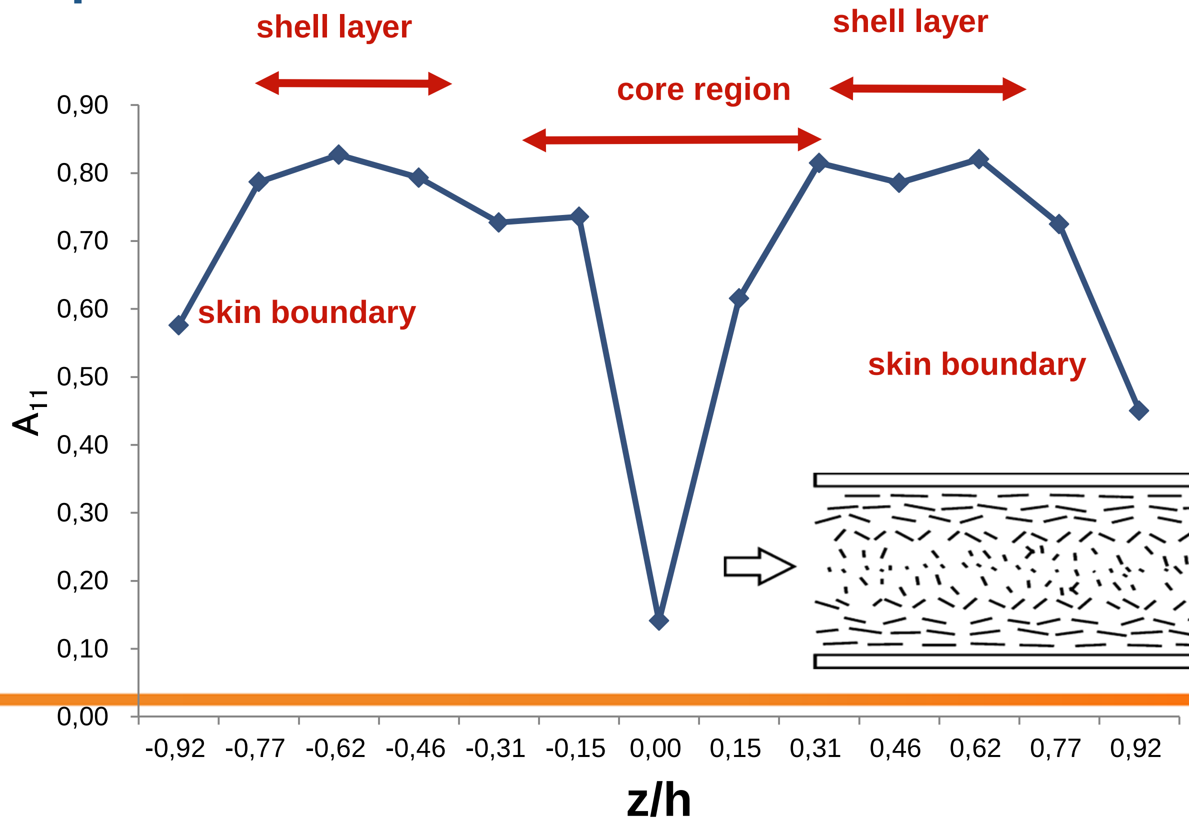
> In fiber-reinforced plastic (FRP) production, there are three most important factors affecting the filling behavior, warpage, and product structural strength

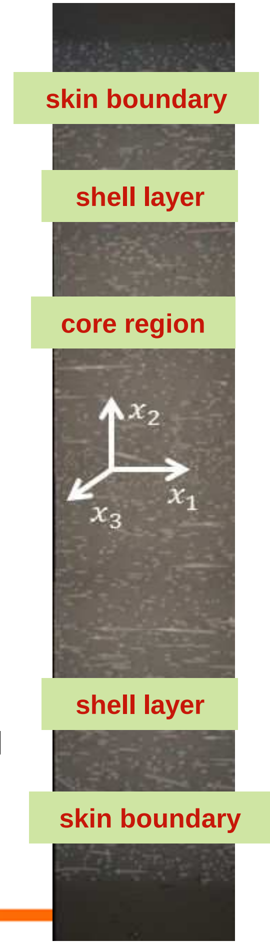
- Fiber orientation
- Fiber length (Breakage Prediction during Screw processing)
- Fiber concentration (The concentration corresponds to the fiber orientation and melt viscosity)

Importance of Orientation - Fiber Orientation Distribution

> Flow orientation distribution consists of core, shell and skin through the thickness of the molding

- Core region contains a more random in plane
- Shell layers are dominantly aligned in the flow direction
- Skip boundaries are due to a fiber-wall interaction





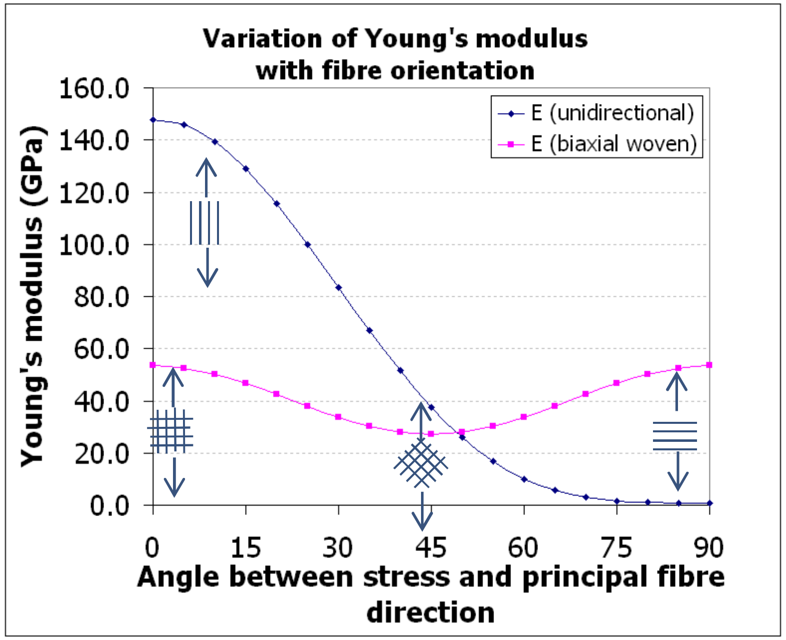
Importance of Orientation - Young's Modulus and Fiber Direction

> **The modulus value for Unidirectional Fiber**

- **The force direction parallel to the fiber direction is maximum, and perpendicular to the fiber direction is minimum**

> **The modulus value for Biaxial Woven Fiber**

- **The force direction are relatively insignificant**

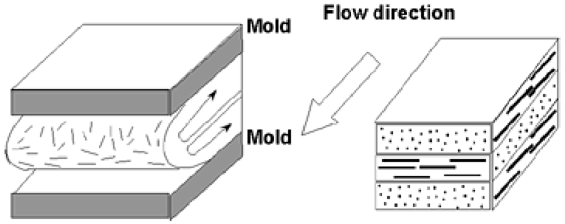


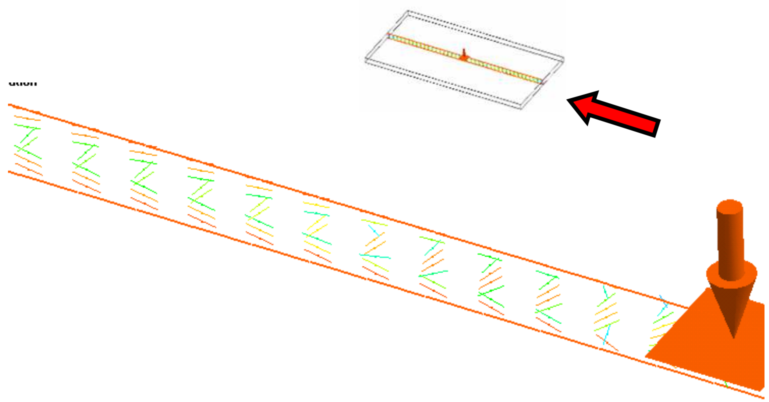
http://www.tech.plym.ac.uk/sme/MATS324/MATS324A2%20E-G-nu.htm

Importance of Orientation - 3D Orientation

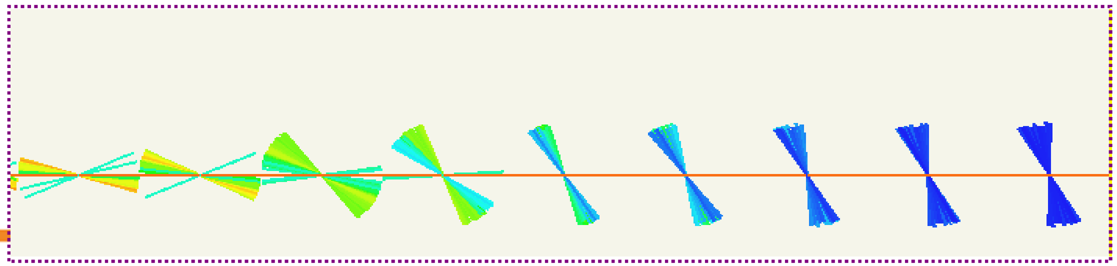
> The fiber orientation shows a full 3D phenomena

- **Traditional 2.5D method**
  - Limited to the thin wall and creeping assumption
  - Only considers in-plane (layer-by-layer) orientation and can not predict out-of-plane phenomenon
- **Fountain effect**



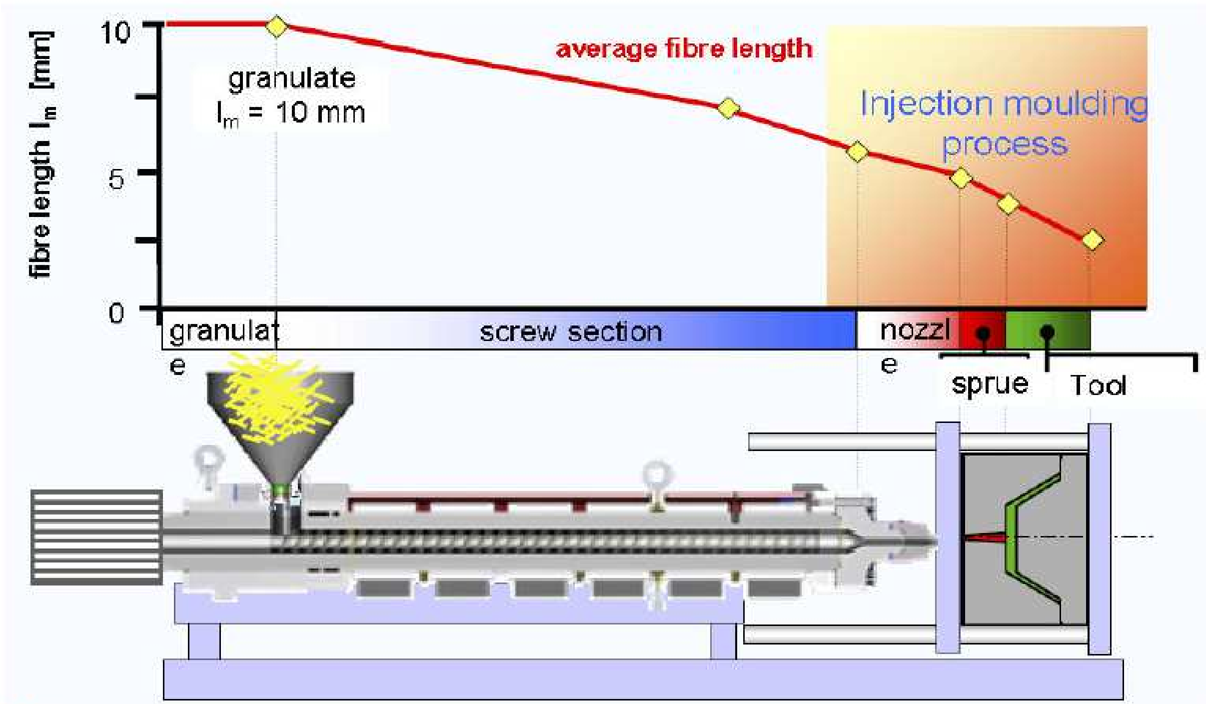


- **Tumbling of fibers**



Importance of Fiber Length

- The melt went through the screw melting and injecting process, high shear forces can easily snap the fibers
- Apparent fiber length degradation, less than 1/5 the original length can be easily found in the finished part



EATC EUROPEAN ALLIANCE FOR THERMOPLASTIC COMPOSITES

Importance of Fiber Length - Strength and Stiffness

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- > Long fiber can all reinforce the part in its strength and stiffness better than the short
- > Adding long fibers also get a better impact strength value

	Reinforcement Ratio [Property of reinforced grade/Property of virgin grade]		
	Short Fibers Thermoplastics	Long Fiber Thermoplastics	Continuous fibers
Tensile strength	1.5	1.5-4	Upto 50
Tensile modulus	3.2	4-10	Upto 80
Notched impact strength	0.3	2-5	
HDT A	2.0	2-3	
Thermal conductivity	1.4	1.5-2	
Coefficient of thermal expansion	0.5	0.2-0.5	

Importance of Fiber Concentration

- **In 1956, Maron and Pierce describe the phenomenon in Suspension Balance Model**
- **Later in 1980, Kitano et al. conducted an experiment**
  - **The higher fiber concentration will be the greater the viscosity and make the polymer melt difficult to flow forward**
- **Moldex3D based on these research studies and experiments to verify the simulation accuracy**

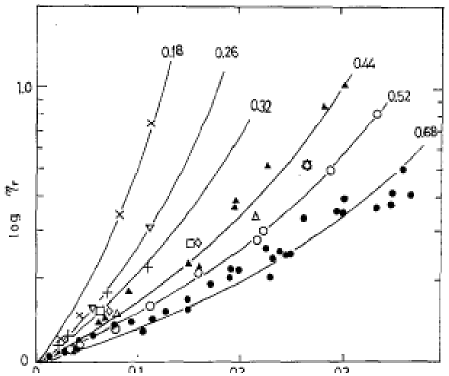
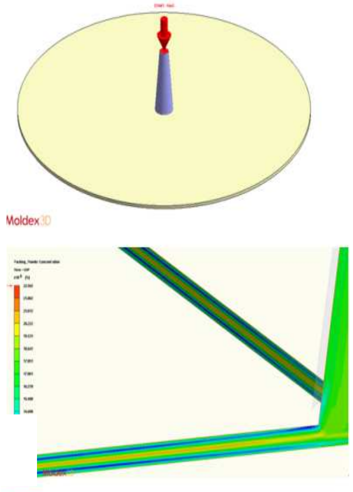
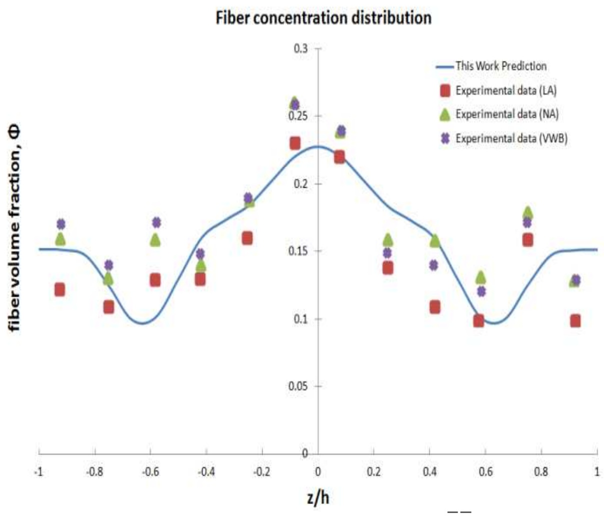


Fig. 1. Relations between η_r and ϕ for polymer melts filled with various filler. The numerical values represent the values of A in eq. [2]. (●): glassy spheres, (○): natural calcium carbonate (NC), (△): talc (TC), (▲): precipitated calcium carbonate (PC), (□): GF/PE with $\bar{p}$ = 6, (◇): GF/PE with $\bar{p}$ = 8, (+): CF/PE with $\bar{p}$ = 18, (▽): GF/PP with $\bar{p}$ = 23, and (×): CF/PE with $\bar{p}$ = 27, respectively. Data of GF/PE with $\bar{p}$ = 6 and 8, TC and PC are roughly represented by the same curve with A = 0.44

(Ref: An empirical equation of the relative viscosity of polymer melts filled with various inorganic fillers, T. Kitano, T. Kataoka, and T. Shirota, 1980)





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Features and Benefits

Benefits of Moldex3D Fiber

> More reliable model

- **Objective improvement to complete Moldex3D's iARD-RPR orientation model**
  - Especially for enhancing the core region
  - Not to set an additional inlet condition around gate

> More accurate default

- **Friendly suggestion of optimal default parameters for short/long fibers**
  - High Accuracy within experiment verification
  - Material Parameter without largely fine-tuning parameter

> More anisotropic warp

- **Accurate fiber orientation to better anisotropic warp**

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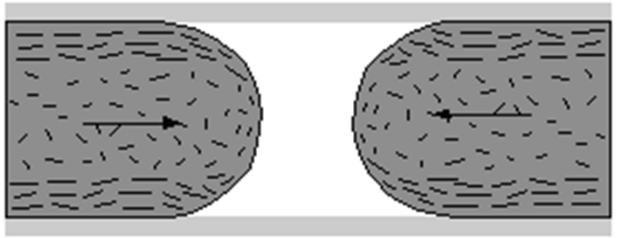
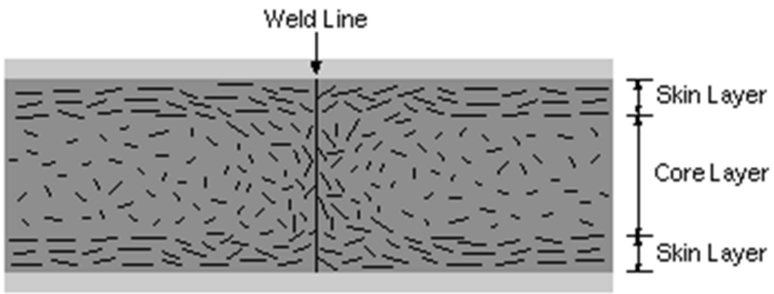
Fiber Analysis in Flow

> Orientation at weld line region

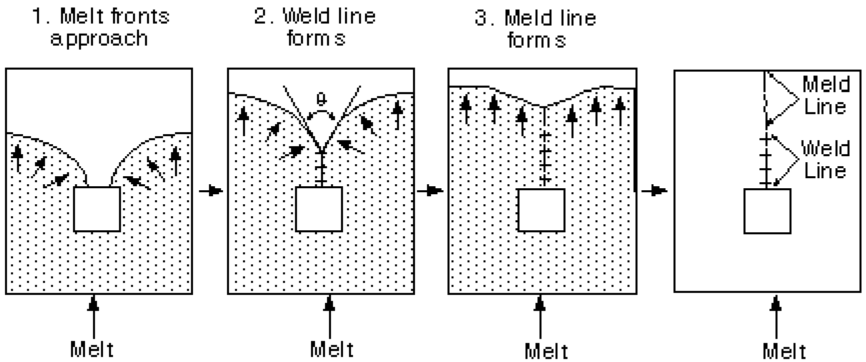


(a)
Fiber reinforced material; melt fronts approach.

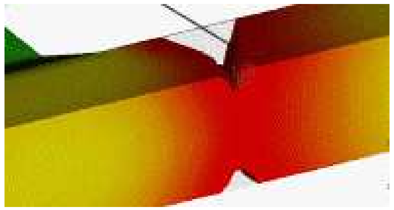


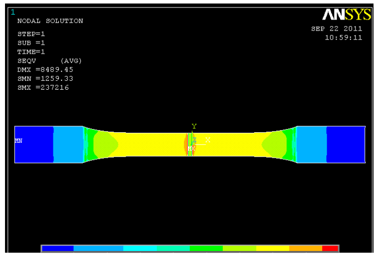
(b)
Weld line formation in fiber-reinforced material.

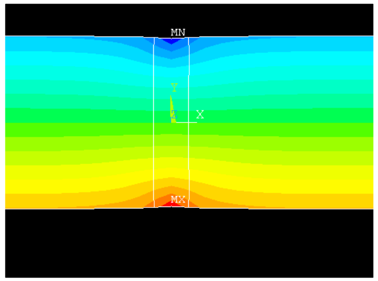
Fibers have trouble penetrating the weld line



If the joining angle is too large, the polymer will not penetrate past the weld line weakening the interfacial adhesion



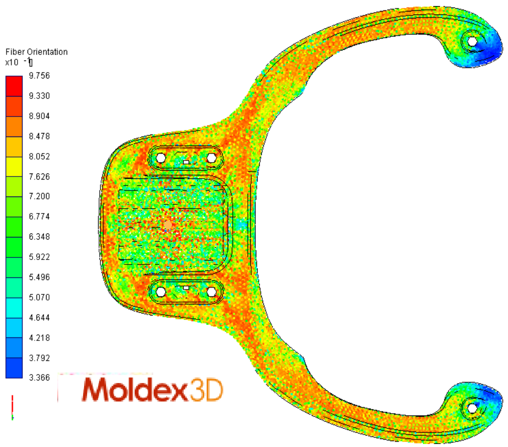




http://www.dc.engr.scu.edu/cmdoc/dg_doc/develop/trouble/weldmeld/f6000001.htm

Fiber Analysis in Warp

> Capable of simulating the fiber orientation and the anisotropic warpage behaviour
  - **Anisotropic mechanical properties**



Fiber: New Moldex3D R14.0 Fiber Kernel (con’t)

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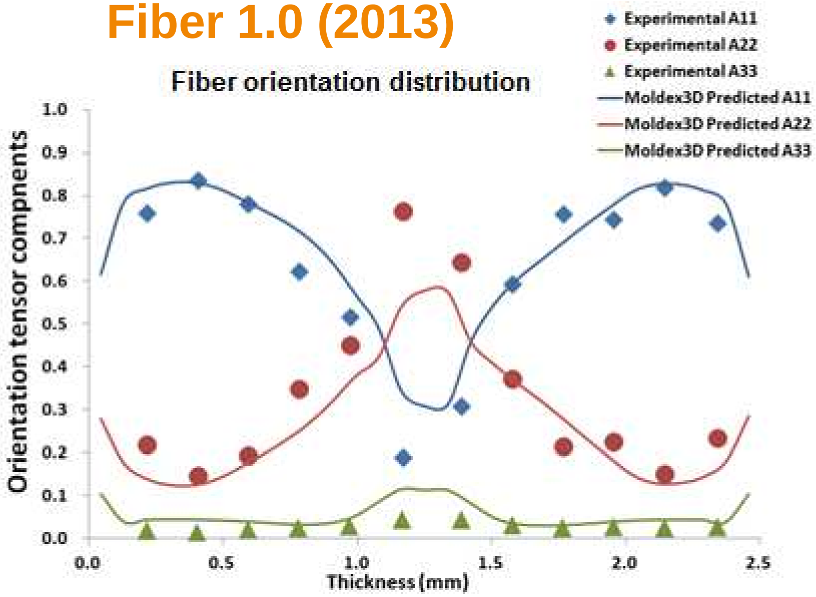
- > **Moldex3D R13.0 provides 70-80% accuracy on of fiber orientation prediction**
- > **Moldex3D R14.0 further enhances the core region with an accuracy increment of at least 20%**

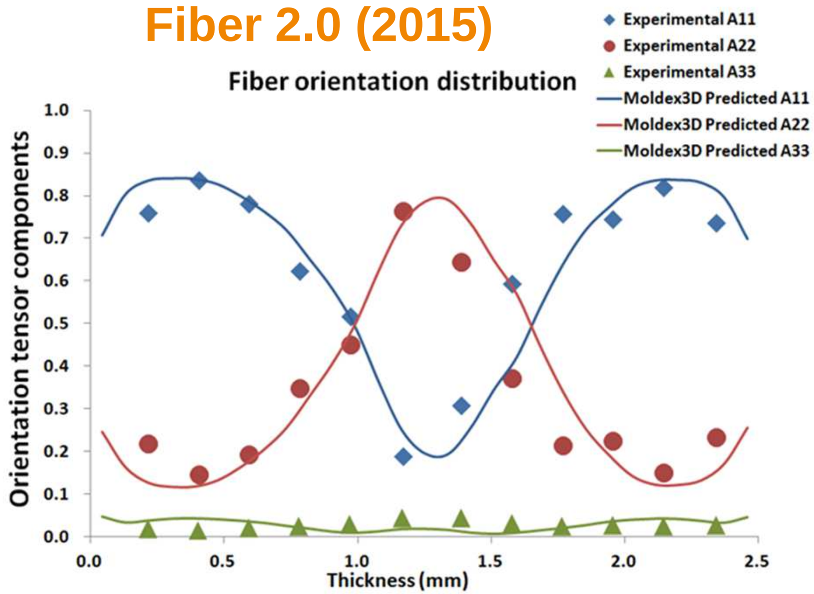
Moldex3D R13.0

Fiber 1.0 (2013)



Moldex3D R14.0

Fiber 2.0 (2015)



Fiber Analysis for Structural Simulation (1) - FEA Interface Workflow

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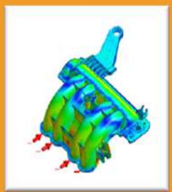

Flow analysis

Orientation information

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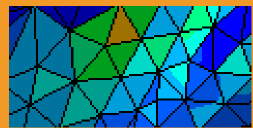


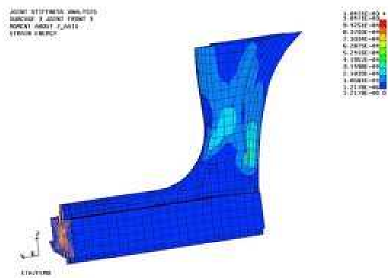
Polymer | Grade Name | Producer	PA6 | Ultramid B3WG7 | BASF
Mechanical Properties	Fiber-filled polymer - Experimental properties
Poisson's ratio v12	0.37 (-)
Poisson's ratio v23	0.54 (-)
Modulus E1 (fiber direction)	1.28e+011 (dyne/cm^2)
Modulus E2 (transverse direction)	4.49e+010 (dyne/cm^2)
Shear Modulus G	1.53e+010 (dyne/cm^2)
CLTE a1 (fiber direction)	2e-005 (1/K)
CLTE a2 (transverse direction)	5.65e-005 (1/K)
Fiber Length/Diameter (L/D)	20 (-)
Interaction coefficient	0.01 (-)
Fiber weight percentage	35 (%)

+

Material parameters

Element properties

Structural simulation software



Fiber Analysis for Structural Simulation (2) - Digimat Workflow

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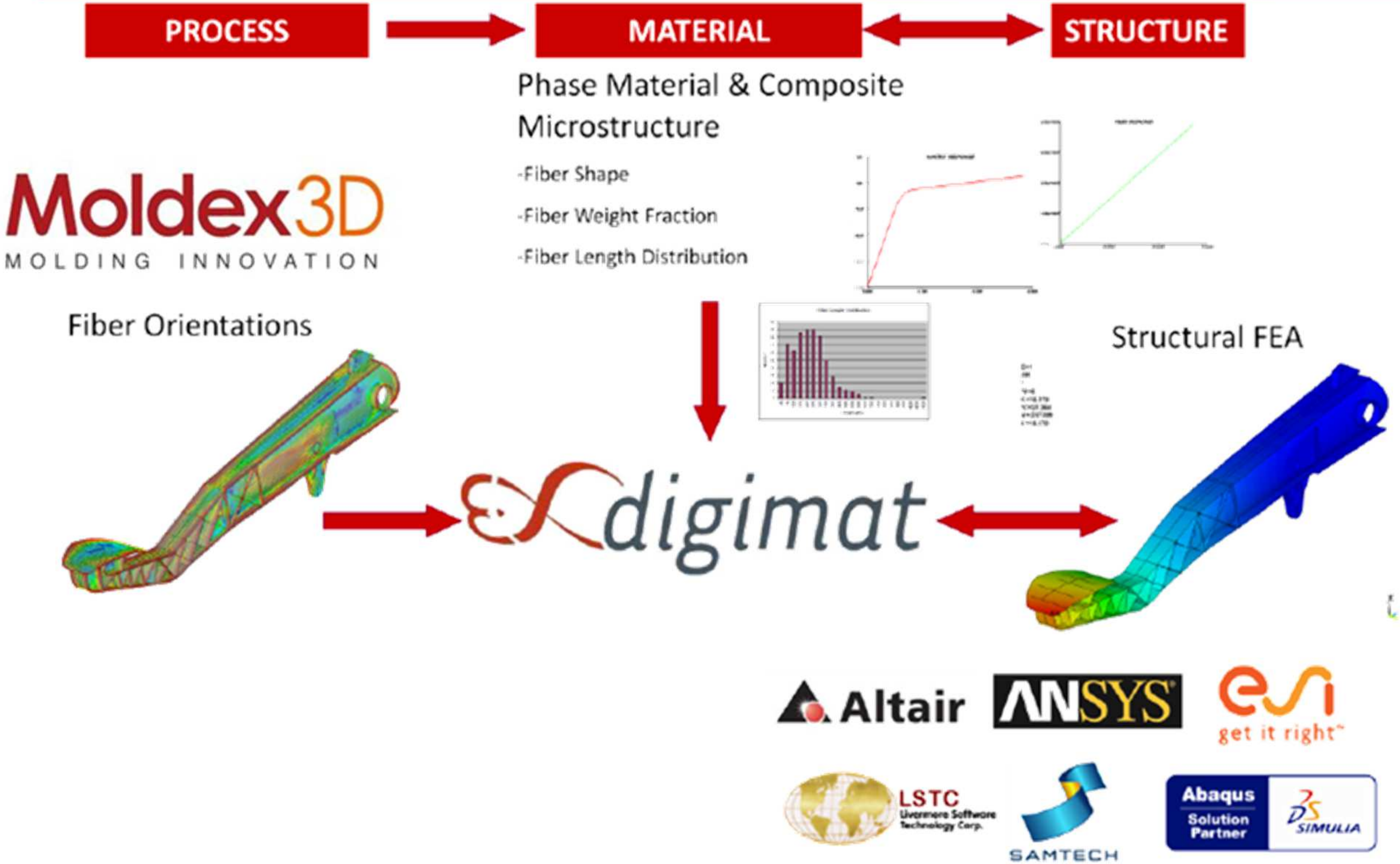

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Moldex3D Fiber 2.0

> Provide the three major factors: fiber orientation, fiber length, and fiber concentration that directly affect the material properties of FRP products

> Validate resultant anisotropic mechanical properties of fiber-reinforced materials

> Moldex3D FEA Interface outputs fiber orientation information and combines with DIGIMAT to provide material information to structural analysis software

> Moldex3D users can benefit from getting a comprehensive fiber analysis in the injection molding process

Micromechanics Interface

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Micromechanics Interface

- More considerations for nonlinear multi-scale material modeling simulation with integration of Digimat and Converse before FEA software
- Provide more efficient and accurate structural analysis of composite materials
- Give users an opportunity to solve complex nonlinear multi-scale finite element problems

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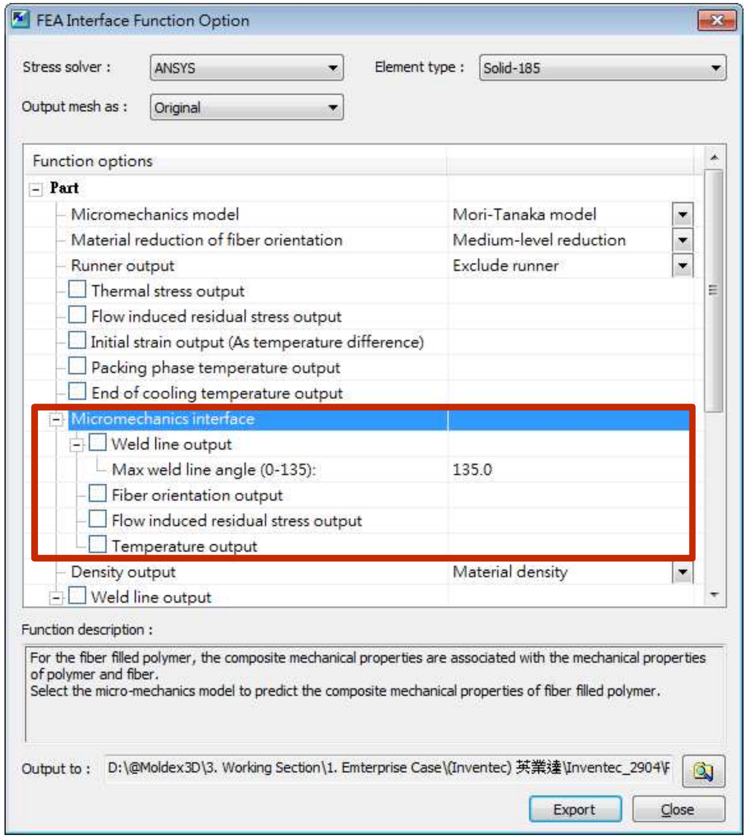
Supported Output Files

digimat Converse



Function Items	Description	File name
Weld line	Weld line definitions are imported in Digimat-MAP in the form of node sets. This allow to export these sets to CAE codes, using proper element set definition, in order to assign them particular material properties.	*.nwd
Fiber orientation	Export the fiber orientation data for further analysis to view characteristics of fiber.	*.o2d
Flow-induced residual stress	When the mold opens to extract the part, those residual stress induce part deformations. Digimat-MAP is there to map such data input and allow to account for it as inputs of mechanical simulations.	*.s2d
Temperature	Temperatures before this cooling step could then be exported from the injection simulation results in order to perform a warpage analysis using DIGIMAT, Digimat-MAP allowing to map those temperatures from the injection mesh onto the structural mesh.	*.t2d
MuCell®	Export the cell size and cell density data for analysis to observe the mechanical properties of Mucell® structure. Digimat-MF and Digimat-CAE can transform the element modulus.	*.m2d

Note: Converse supports *.o2d (Fiber orientation output) ONLY

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Thank You

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