

mid Moulding
Innovation
Day 2023

Moldex3D Material Digital Twin & MHC

Ethan Chiu | 2023,06,20

Moldex3D

Content

- Material Characterization Center
- Plastic Material Digital Twin
 - Shear heating Correction
 - Warpage Validation
 - Injection Pressure Based Viscosity Correction
- MHC
- Summary



Material Characterization Center

ISO 17025 Certified Material Characterization Center



Rheograph RG25
Capillary viscosity and thermal conductivity with counter pressure equipped



CR-6000
Capillary viscosity at different temperature and shear rates

pvT-6000
pvT change at different temperature and pressure



MCR 502
Rotation and oscillation tests for viscoelastic properties



TMA 4000
Coefficient of thermal expansion

DSC 8500
Transition temperatures and crystallization kinetics



Instron 5966
Mechanical properties

Material Characterization Center : Instrument Line-up 1



Rheograph RG25

Capillary
viscosity and
thermal
conductivity
with counter
pressure
Equipped

Flow pattern
Filling Pressure



pvT-6000

pvT change
at different
temperature
and
pressure

Compressible
Shrinkage



MCR 502

Rotation and
oscillation
tests for
viscoelastic
properties

Low shear
Flow VE
Reactive
GMT/SMC



DSC 8500

Transition
temperatures
and
crystallization
kinetics

T_g, T_m
Crystallization



Instron- 8966

Mechanical
properties

Structural
Shrinkage

Material Characterization Center : Instrument Line-up 2



PVTC for
thermoset

PT-6800
Specific volume
with curing

Curing shrinkage



Dynamic
Mechanical

**DMA 242 E
Artemis**
Dynamics
mechanism
analysis for
relaxation
modulus

**Solid VE
(Warp, Annealing)**



Rheometer for
rubber

MDR-A1
Scorch curve

**Rubber reaction
kinetics,
viscosity**



Foam Qualification
System

FOAMAT® 285

**Foaming and
Curing Kinetics**



Permeability

EASYPERM

**3D permeability
of resin in fiber
mats**

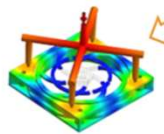


**Micromolding machine
for DMA, PVT
specimen**



Plastic Material Digital Twin

Accuracy of CAE Simulation Depends on Reliability of Plastic Material Data



CAE procedure

Flow behavior

Cooling/warpage analysis

Mass balance

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0$$

Momentum balance

$$\rho \frac{D\mathbf{u}}{Dt} = \nabla \cdot \underline{\boldsymbol{\tau}} - \nabla p + \rho \mathbf{g}$$

Energy balance

$$\rho C_p \left(\frac{\partial T}{\partial t} + \mathbf{u} \cdot \nabla T \right) = \nabla \cdot \underline{\mathbf{k}} \nabla T - \boldsymbol{\tau} : \dot{\boldsymbol{\gamma}}$$

Thermoset conversion balance

$$\dot{X} + \nabla \cdot \mathbf{j} + \underline{R} = 0$$

Density, ρ

Relationship between $\boldsymbol{\tau}$ and \mathbf{u} or viscosity, η

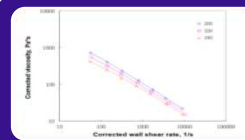
Heat capacity, C_p

Thermal conductivity, k

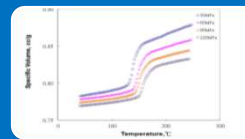
Conversion rate, R

Temperature-pressure dependent volume, $V(T, P)$

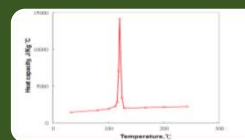
Modulus, G



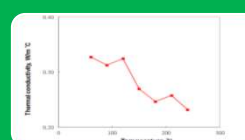
Viscosity: related to filling behavior, short-shot, welding line position, filling/packing pressure and clamping force



PVT: related to packing behavior, part shrinkage and sink mark issue



Heat Capacity: related to heating/cooling behavior of the part, temperature distribution, and cycle time

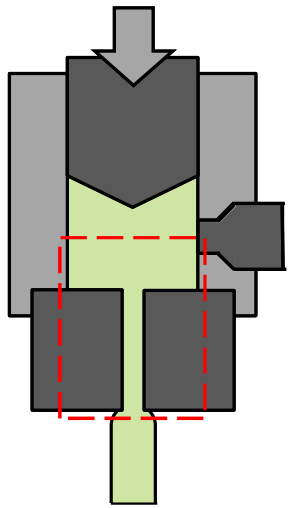


Thermal Conductivity: related to heating/cooling behavior of the part, temperature distribution, and cycle time

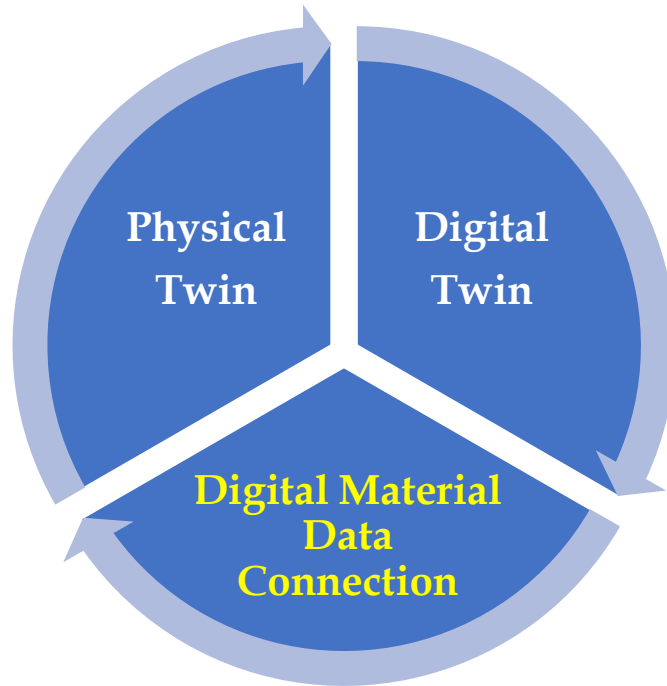
Data	Modulus E1 (MPa)	Modulus E2 (MPa)	Poisson's Ratio ν12	Poisson's Ratio ν23
Test 1	4324	2977	0.296	0.310
Test 2	4562	2772	0.310	0.422
Test 3	5878	2767	0.290	0.366
Test 4	6217	3054	0.293	0.402
Test 5	4436	2420	0.286	0.467
Average	4287	2900	0.294	0.401
STDEV	286	242	0.011	0.022

Mechanical Properties: related to part strength and mechanical behavior, shrinkage and warpage

More Factors to Be Considered

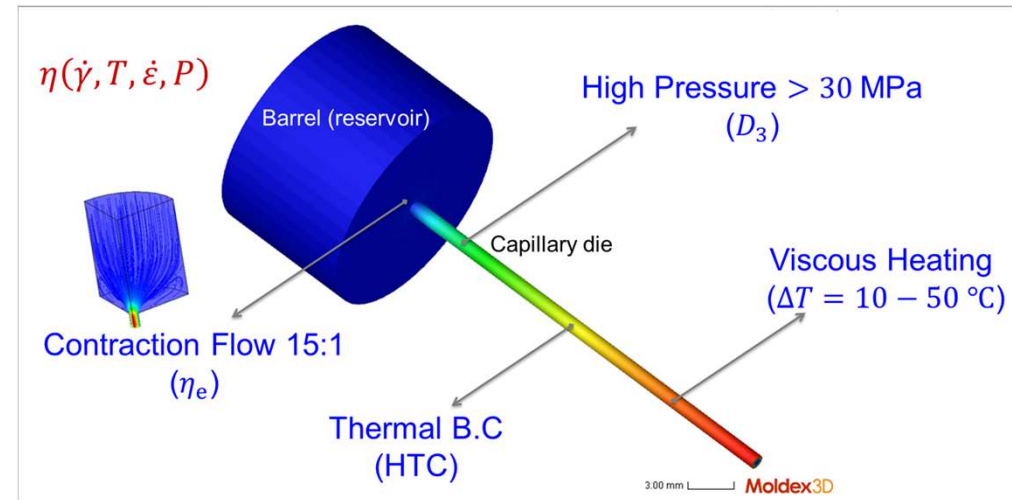


Capillary rheometer



Model parameters

- η_S, η_E, D_3

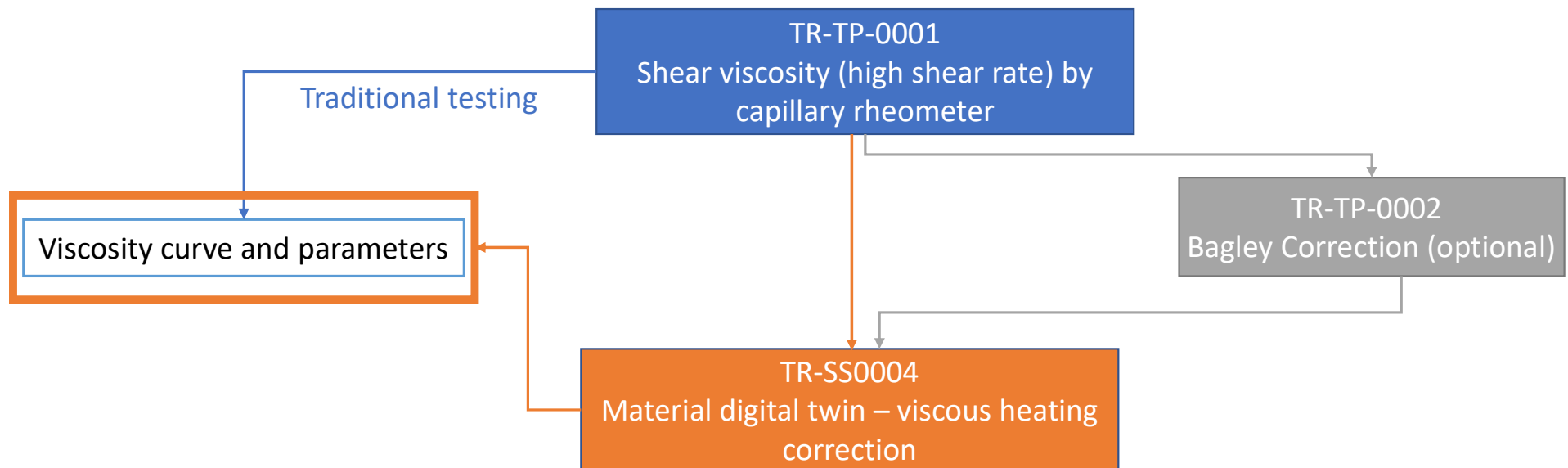




Shear Heating Correction

Correction Process of viscous heating

- › Main focuses on retrieving the viscosity curve from viscous heating interference



DT correction : Data regression precise correction

Shear viscosity measurement method

TR-TP-0001
shear viscosity (high shear rate) by
capillary rheometer



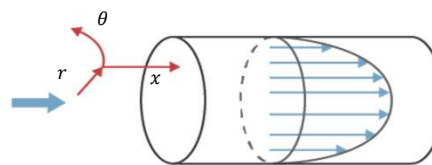
Rheograph RG25

Capillary viscosity and thermal conductivity with counter pressure equipped

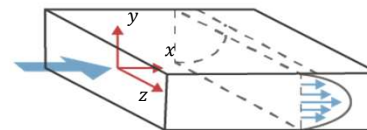
TR-TP-0001 Shear viscosity (medium to high shear rates)-TP
• Capillary die by 1mm/30mm @ MDX

Pressure Flow Die on Rheograph RG25

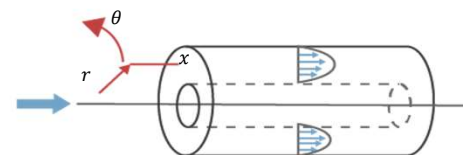
Capillary
(Poiseuille flow)



Slit flow



Axial annulus flow



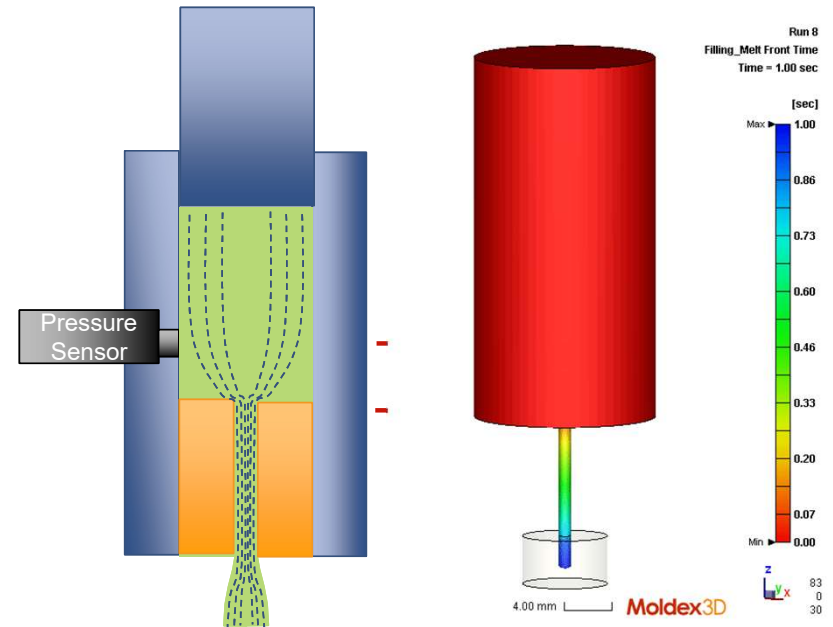
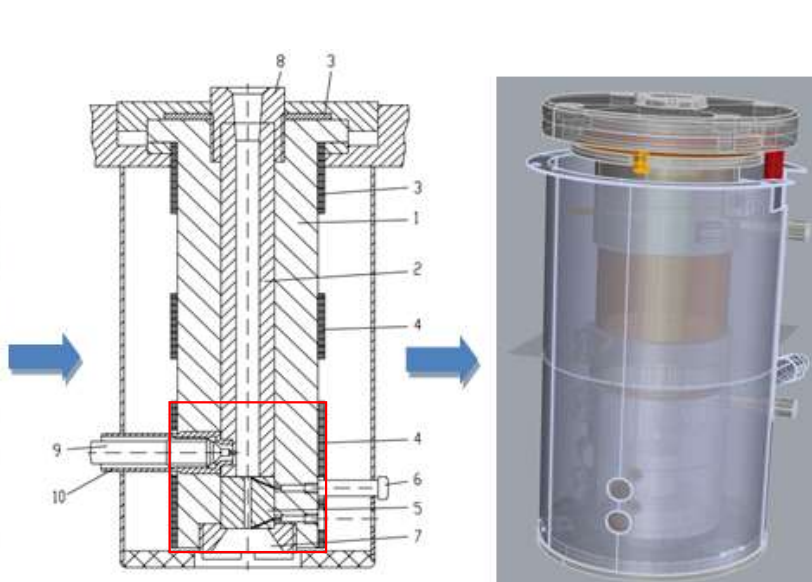
Digital Twin Correction

TR-SS0004
Material digital twin – viscous heating
correction

- **Target :**

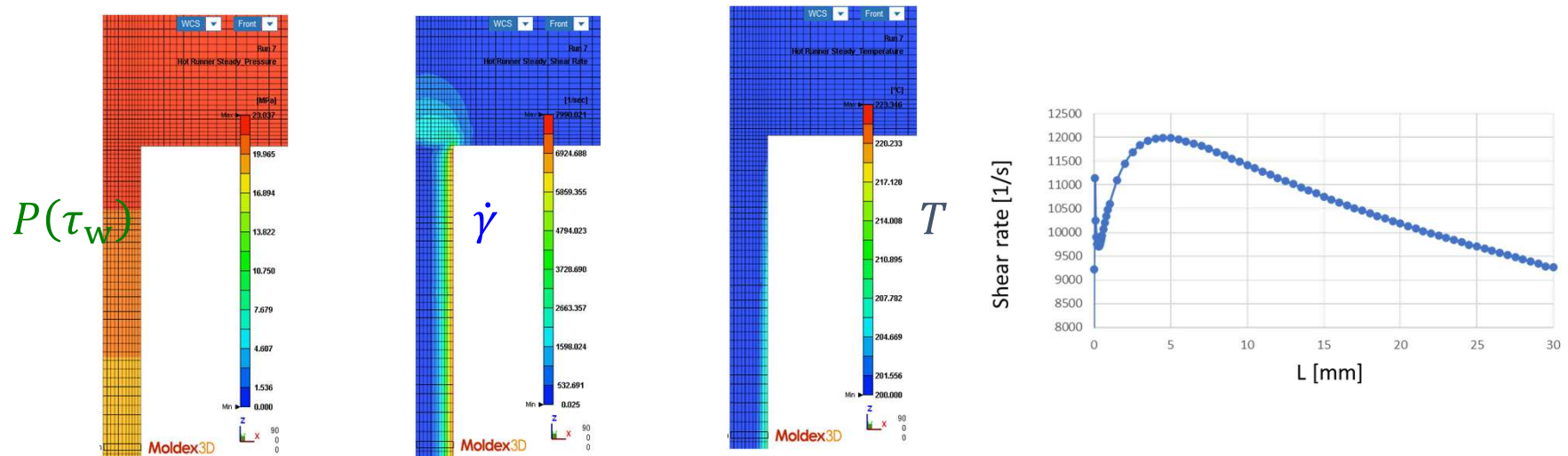
Curve data correction of non-ideal conditions that exist in the testing process

- non-isothermal, Entrance effect, non-Newtonian, pressure effect, ...



Distribution in the Flow Field Simulation

- Non-homogenous physical properties in the axial directions could be different, which are assume constant in the traditional rheometric evaluation

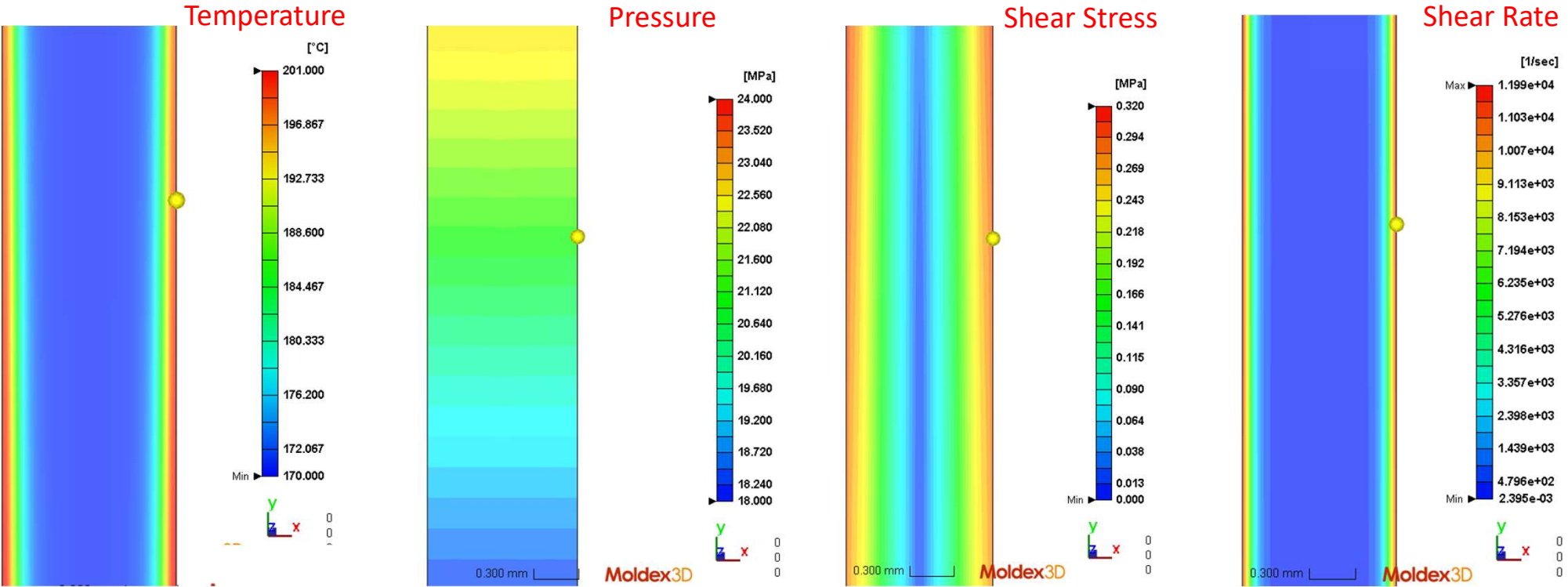


- In a general capillary rheometer, the temperature rising, and uneven distribution will lead to data deviation, so that the ideal working equation cannot be 100% valid.

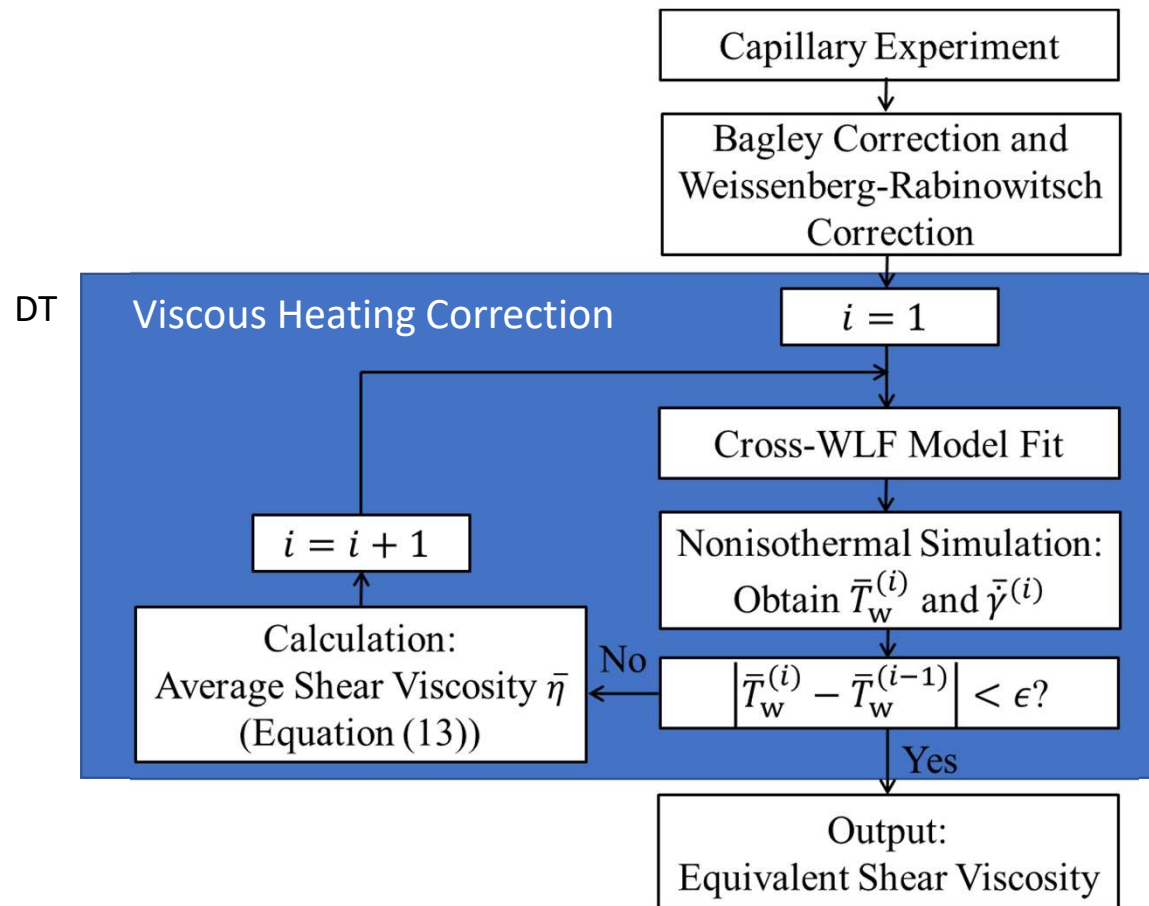
➔ These deviation from ideal assumption will be corrected by Digital Twin Calibration !

Distribution across tube

- e.x. Temperature raise up to 30°C (PS: T=170°C, app Shear rate =5000)



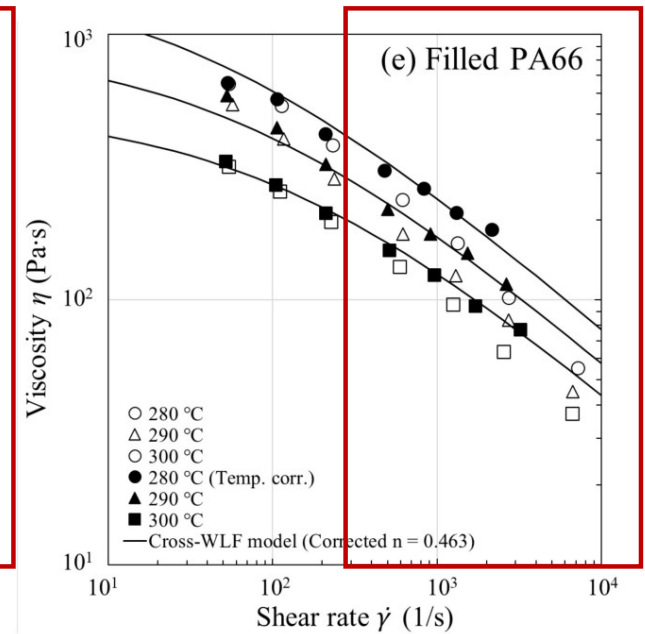
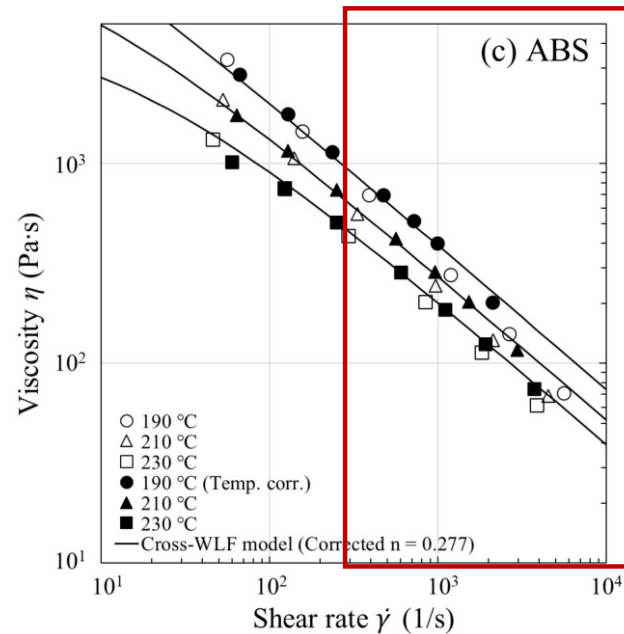
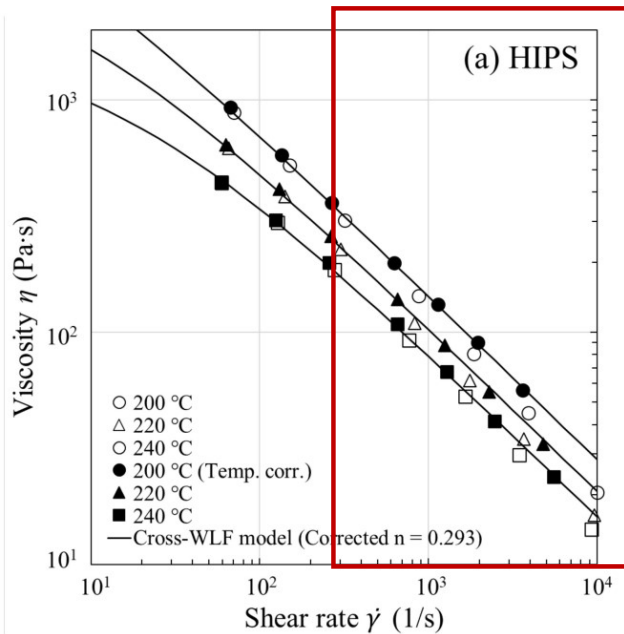
Theoretical Justification & Methodology



Usually, number of iteration is 4~7

Viscosity Curve Before and After VH Correction

- Empty points: without correction
- Solid points: after correction



Moldex3D Publication about Viscous Heating Correction



ANTEC[®] 2021




Viscous Heating Correction for Polymer Melts in Capillary Viscometry

Yu-Ho Wen, Chen-Chieh Wang, Chia-Hsiang Hsu, and Rong-Yeu Chang

CoreTech System Co., Ltd (Moldex3D), Hsinchu 30265, Taiwan


Moldex3D #ANTEC21


US20220063166A1
United States

 Download PDF  Find Prior Art  Similar

Inventor: Chen-Chieh WANG, Yu-Ho Wen, Guo-Sian Cyue, Chih-Chung Hsu, Chia-Hsiang Hsu, Rong-Yeu Chang

Current Assignee : CoreTech System Co Ltd



Polymers 2021, 13, 4094 

Article

Retrieving Equivalent Shear Viscosity for Molten Polymers from 3-D Nonisothermal Capillary Flow Simulation

Yu-Ho Wen, Chen-Chieh Wang *, Guo-Sian Cyue, Rong-Hao Kuo, Chia-Hsiang Hsu and Rong-Yeu Chang
CoreTech System (Moldex3D) Co., Ltd., Chupei, Hsinchu 302082, Taiwan

Testing Items

› After correction iteration, the test report shown on the right will be provided.

TR-SS0004 Viscosity Curve verification-TP

Material digital twin – viscous heating correction

Viscosity

Model	Parameter	Value	Unit
Modified Cross Model (3)	n	2.0179E-01	-
	Taus	1.9605E+04	Pa
	D1	3.0384E+14	Pa*s
	D2	2.4815E+02	K
	D3	0.0000E+00	K/Pa
	A1	3.2019E+01	-
A2	5.1600E+01	K	

Viscosity curve verification

Procedure	7 speeds are applied in sequence within a run isothermally. Recording the history of pressure.
------------------	--

Rheometer specifications (GÖTTFERT RG25)

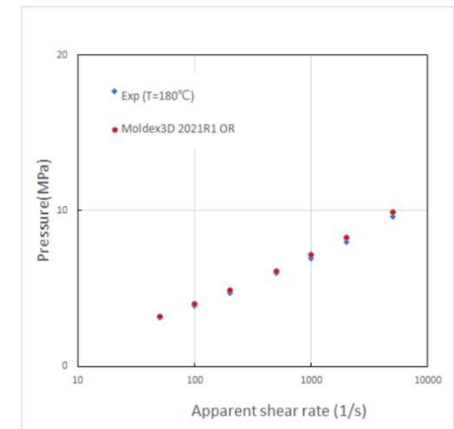
Die length	30 mm
Die diameter	1 mm
Die entry angle	90 degrees
Barrel diameter	15 mm

Simulation information

Module	Moldex3D HRS Solver
Version	2021 R1OR
Number of elements	39,696
Injection speed	According to piston speed

Testing report

180°C				
Piston Speed	App. Shear rate	Pressure Experiment	Pressure Simulation	Rel. Error
[mm/s]	[1/s]	[MPa]	[MPa]	(%)
0.0278	50.0	3.15	3.17	0.2
0.0556	100.0	3.88	4.01	1.3
0.1111	200.0	4.72	4.87	1.6
0.2778	500.0	5.97	6.12	1.5
0.5556	1000.0	6.94	7.14	2.1
1.1111	2000.0	7.98	8.26	2.9
2.7778	5000.0	9.61	9.92	3.2

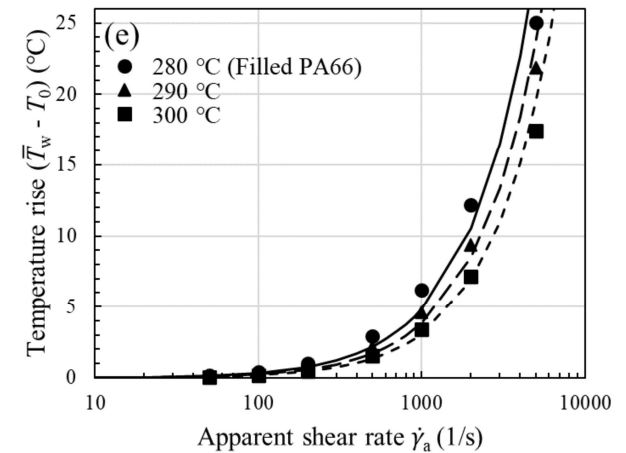
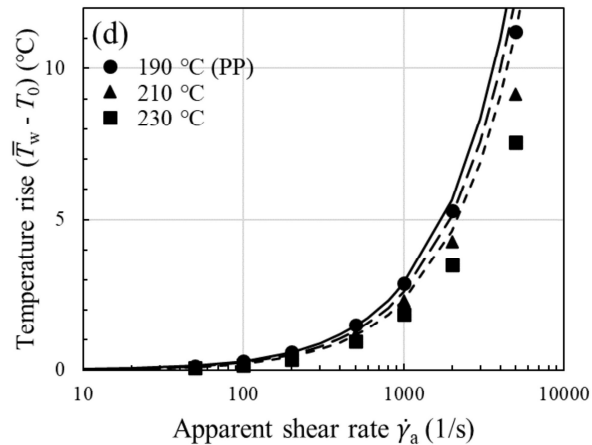
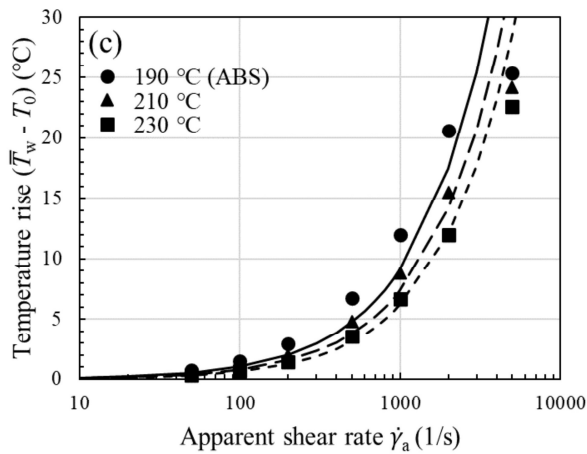


Summary

➤ The Viscous Heating will be proportional to the viscosity and the square of shear rate. Therefore, the Test correction will be an important for high viscosity material under high shear rate conditions.

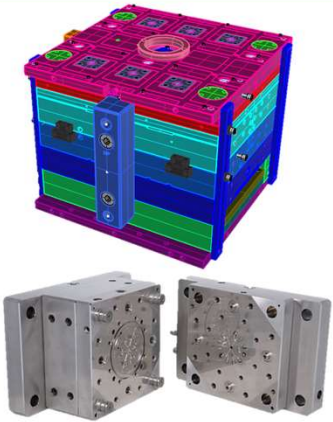
- Significant material : PC, POM, ABS, HDPE, PEI, PA12, Fiber reinforcement material
- Minor material : PP, LDPE, PA66, TPV
- Insignificant material : LCP

$$\Delta H \sim \eta \dot{\gamma}^2$$



Warpage Validation

Moldex3D Molding Research Center : Material Molding Validation



Mold System

Core side:
9 Pressure
Sensors

Cavity Side
9 Temperature
Sensors

Mold Plate
Temp Sensing

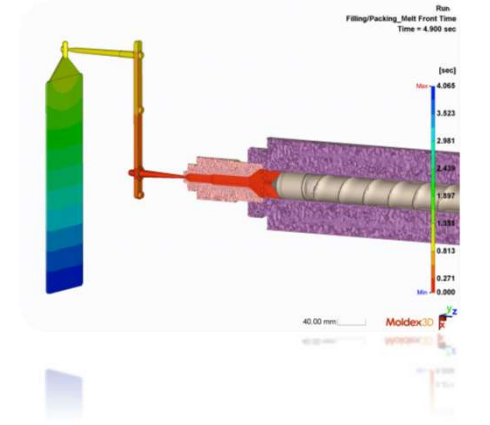
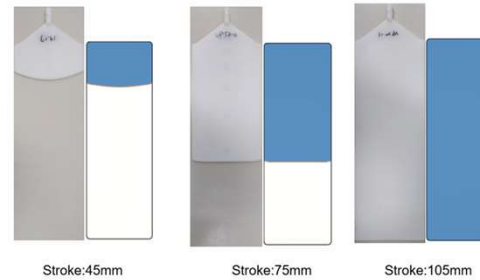
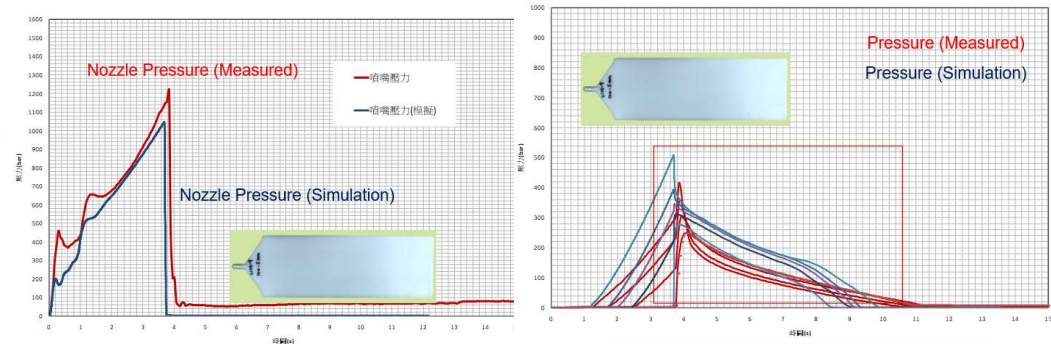
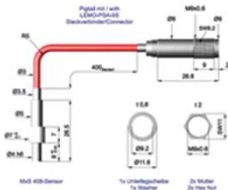
Data
Collection



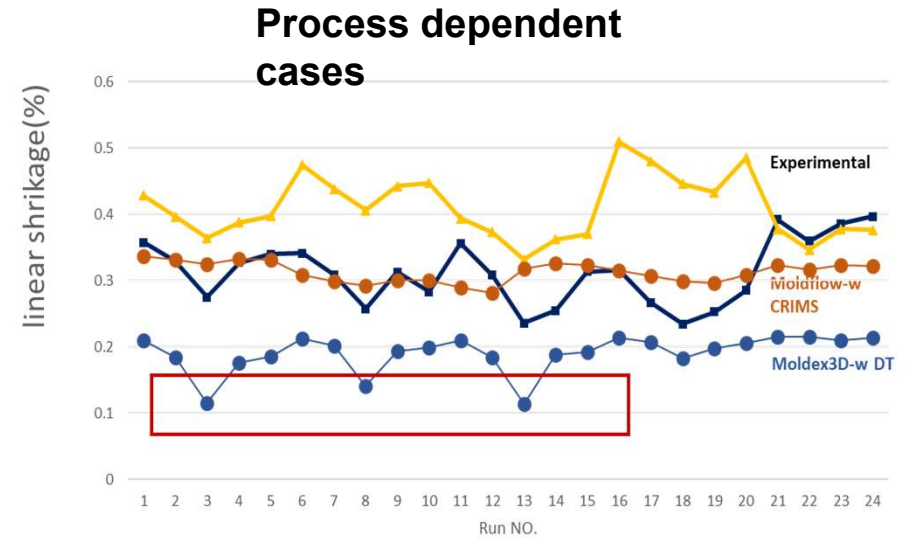
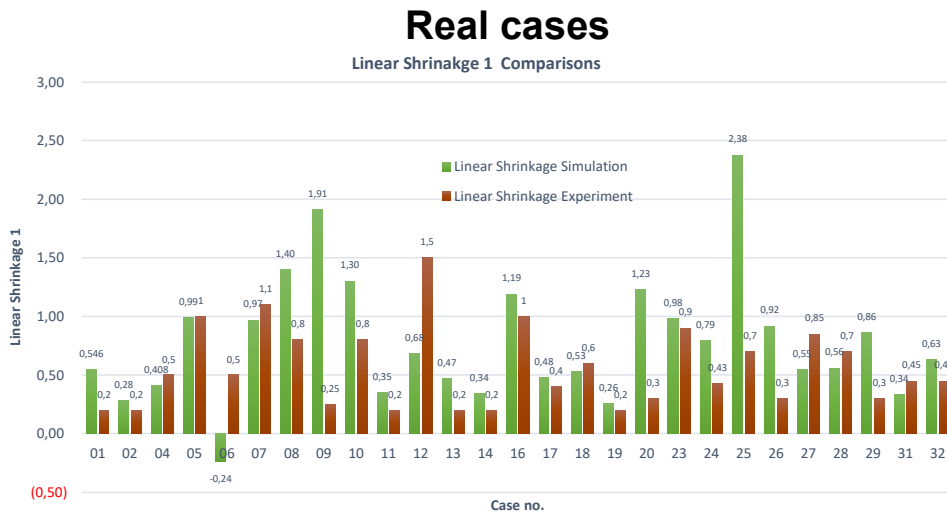
MISUMI



Sensor
Data



Build & Improve Shrinkage testcase database by DT



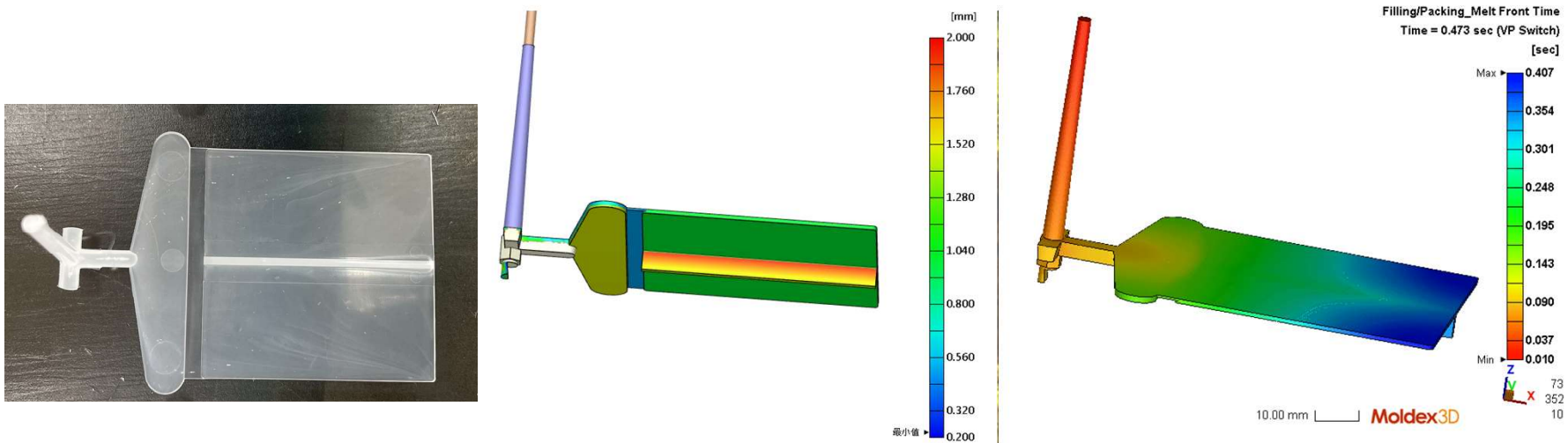
1. Improve integrated API for shrinkage rate report and comparisons
2. Integrated API into the RD auto test
3. Solver accuracy report for release version



Injection Pressure Based Viscosity Correction

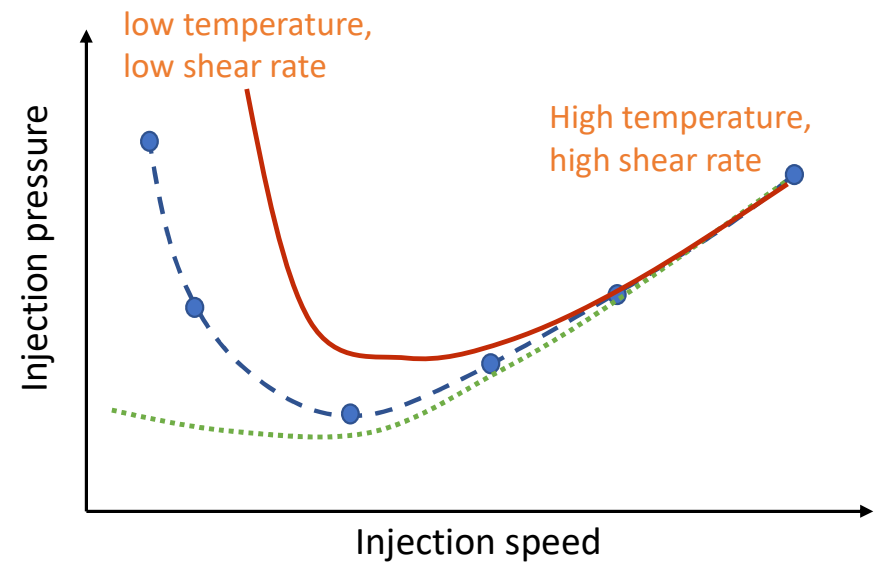
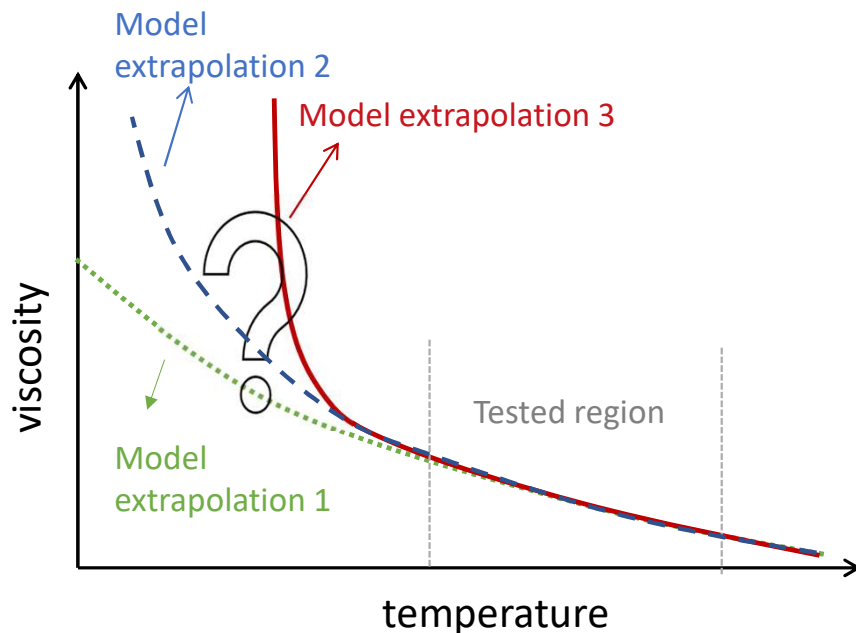
Objective

- › Traditionally the **viscosity curves are measured under high temperature, and the low temperature viscosity are extrapolated from high temperature data.**
- › The verification of injection molding pressure from very low to high injection speed is used to check the artificial solver modification near freeze temperature and calibrated the extrapolated part of viscosity curve. That is crucial for thin wall parts, low speed injection, and packing stage.



Our proposal : Injection Pressure Based Viscosity Calibration (IPBVC)

- › Validate injection pressure under various injection speeds and calibrate the low temperature viscosity.
 - Determine the optimal extrapolated viscosity curve that yields the closest match between the simulated injection pressure and the real injection pressure.

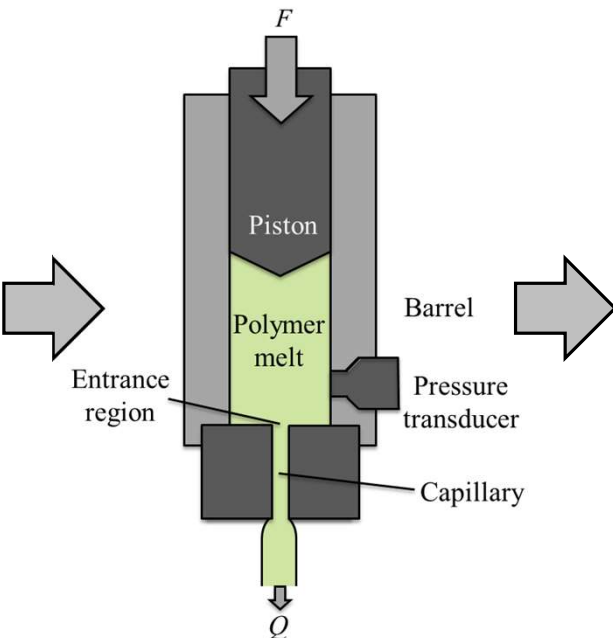


Use Material Digital Twin to Improve Material Model Parameters

(1)
Capillary Rheometer
(physical twin)



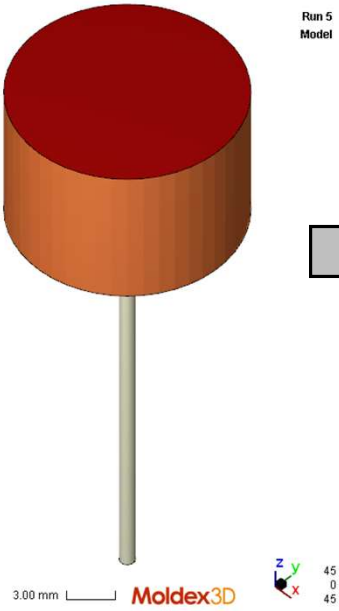
(2)
Measurement



(3)
Material File
(original)



(4)
Simulation & Correction
(digital twin)



(5)
Material File
(corrected)



*Reliable
Simulation*



Material Hub Cloud (MHC)

Outlook in Material Hub Cloud (MHC) Web Service

> 8000+ Thermoplastics Materials

Moldex3D Material Hub Cloud

Material Hub Cloud

Make Better Design Decisions with the Right Material Information

Introduction Sign Up

Find material for your product application (e.g. automotive, aircraft or toys)

Search

Features

- Material Database Viewer**
 Show data quality index, property curves and processing conditions of a selected material
- Alternative Material**
 Find list of alternative materials with user-defined criteria and provide similarity analysis
- Material Selection Guidance**
 Suggest suitable plastics for specified product designs and provide plastic related information
- Material Comparison**
 Compare property curves and property data of selected multiple materials and scatter plot analysis



Moldex3D Material Hub Cloud

PA757-GJ08 / ABS / CHI-MEI

品質指數分析

加工曲線

黏度 [Pa·s]

比熱容 [J/kg·K]

熱傳導係數 [W/m·K]

熱膨脹係數 [1/K]

熱穩定性 [h]

熱變形溫度 [°C]

熔點 [°C]

玻璃化溫度 [°C]

收縮率 [%]

熱穩定性 [h]

熱變形溫度 [°C]

熔點 [°C]

玻璃化溫度 [°C]

收縮率 [%]

熱穩定性 [h]

熱變形溫度 [°C]

熔點 [°C]

玻璃化溫度 [°C]

收縮率 [%]

Material Stored + Add Material

Grade Name	Polymer Type	Supplier
<input checked="" type="checkbox"/> WUNDERLITE PC-110	PC	CHI-MEI
<input checked="" type="checkbox"/> WUNDERLITE PC-115	PC	CHI-MEI
<input checked="" type="checkbox"/> WUNDERLITE PC-116	PC	CHI-MEI
<input checked="" type="checkbox"/> WUNDERLITE PC-118	PC	CHI-MEI
<input checked="" type="checkbox"/> WUNDERLITE PC-119	PC	CHI-MEI
<input checked="" type="checkbox"/> WUNDERLITE PC-120	PC	CHI-MEI
<input checked="" type="checkbox"/> WUNDERLITE PC-121	PC	CHI-MEI
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<input checked="" type="checkbox"/> WUNDERLITE PC-124	PC	CHI-MEI
<input checked="" type="checkbox"/> WUNDERLITE PC-125	PC	CHI-MEI
<input type="checkbox"/> ALPHALAC 50910	HIPS	LG Chemical
<input type="checkbox"/> LG PS 603AF	HIPS	LG Chemical
<input type="checkbox"/> LG PS 603R	HIPS	LG Chemical
<input type="checkbox"/> LG PS 603H	HIPS	LG Chemical
<input type="checkbox"/> LG PS 604	HIPS	LG Chemical

Compare

Select up to 5 materials

Curve Comparison Data Comparison Scatter Plot

Velocity

Melt Temp: 280°C

Specific Volume

Pressure [MPa]

Heat Capacity

Temp [°C]

Therm Conductivity

Temp [°C]

Thermoplastic Material Fitting Functions

PVT

Material Data Fitting

PVT_Ex2_data.mrd

Uploaded

Reupload

Raw Data Template

Click template to download for modification :

PVT template 1 (.csv) PVT template 2 (.mrd)

Viscosity template 1 (.csv) Viscosity template 2 (.mrd)

Crystallinity template 1 (.csv) Crystallinity template 2 (.csv)

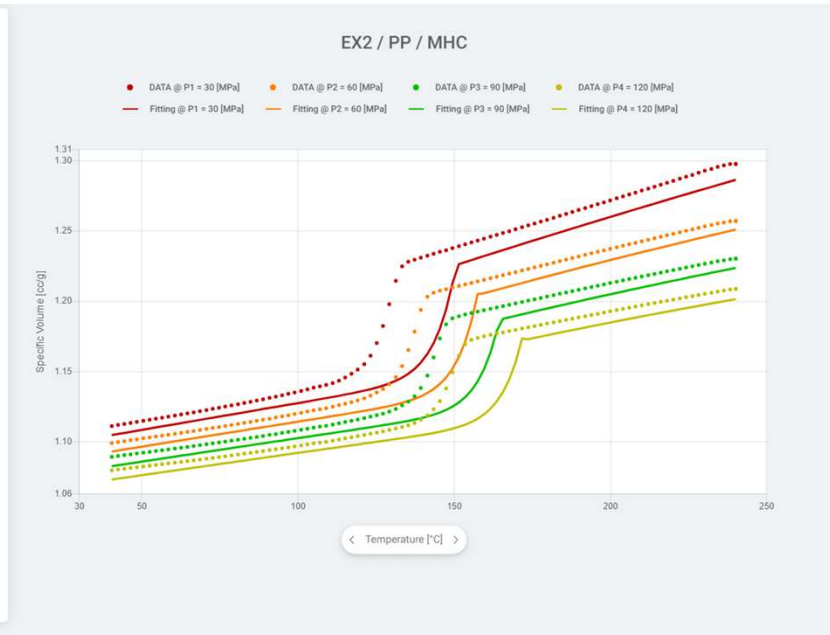
Fitting

PVT Model Parameters *fix*

b1L	1.253	cc/g
b2L	0.0008704	cc/(g.K)
b3L	909700000	dyne/cm ²
b4L	0.004826	1/K
b1S	1.161	cc/g
b2S	0.0004134	cc/(g.K)
b3S	1714000000	dyne/cm ²
b4S	0.00206	1/K
b5	417	K
b6	2.356e-8	cm ³ .K/dyne
b7	0.09194	cc/g
b8	0.1543	1/K
b9	3.949e-9	cm ³ /dyne

Error Sum 1.644e-1

Export Result



Viscosity

Model Parameters *fix*

n	0.4
SP	0.000000000
SP1	1.6420000000000000
SP2	0.0000000000000000
SP3	0
SP4	0.0000000000000000
SP5	0.0000000000000000
SP6	0.0000000000000000
SP7	0.0000000000000000
SP8	0.0000000000000000
SP9	0.0000000000000000
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Digital Material Generator Function

- Digital Material Generator: Allows users to **create material file (MTR)** for new materials or to **check basic properties** (e.g., viscosity, PVT, heat capacity, etc.) of possible materials.

Material File Generator

New Material

Polymer Type*

Supplier

Grade Name

Comment

Unit* Metric (cgs) SI (mks) English

[Create a Template](#)

[Export Material File](#)

Personal / ABS / MHC

Viscosity PVT Heat Capacity Thermal Conductivity Mechanical Properties Process Conditions

Model Parameters

W	0.2756	-
Y	32868	dynamic
O1	9742	g/cm.s
O2	471.2	K
O3	8	cm ³ /K.s
A1	2.528	-
A20	0.16	K

[Upload by Material Data Fitting Result](#)

[Modify](#)

Material File Generator

New Material **Supplier Material**

Supplier Polymer Type

Related Material [47 Result(s)]

Grade Name	Polymer Type	Supplier
POLYLAC PA757	ABS	CHI-MEI
POLYLAC PA747H	ABS	CHI-MEI
POLYLAC PA747S	ABS	CHI-MEI
PA757-GJ08	ABS	CHI-MEI
POLYLAC PA727	ABS	CHI-MEI
POLYLAC PA746	ABS	CHI-MEI
POLYLAC PA757H	ABS	CHI-MEI
POLYLAC PA763	ABS	CHI-MEI
POLYLAC PA765	ABS	CHI-MEI
PA757-J01	ABS	CHI-MEI
POLYLAC D-2200	ABS	CHI-MEI

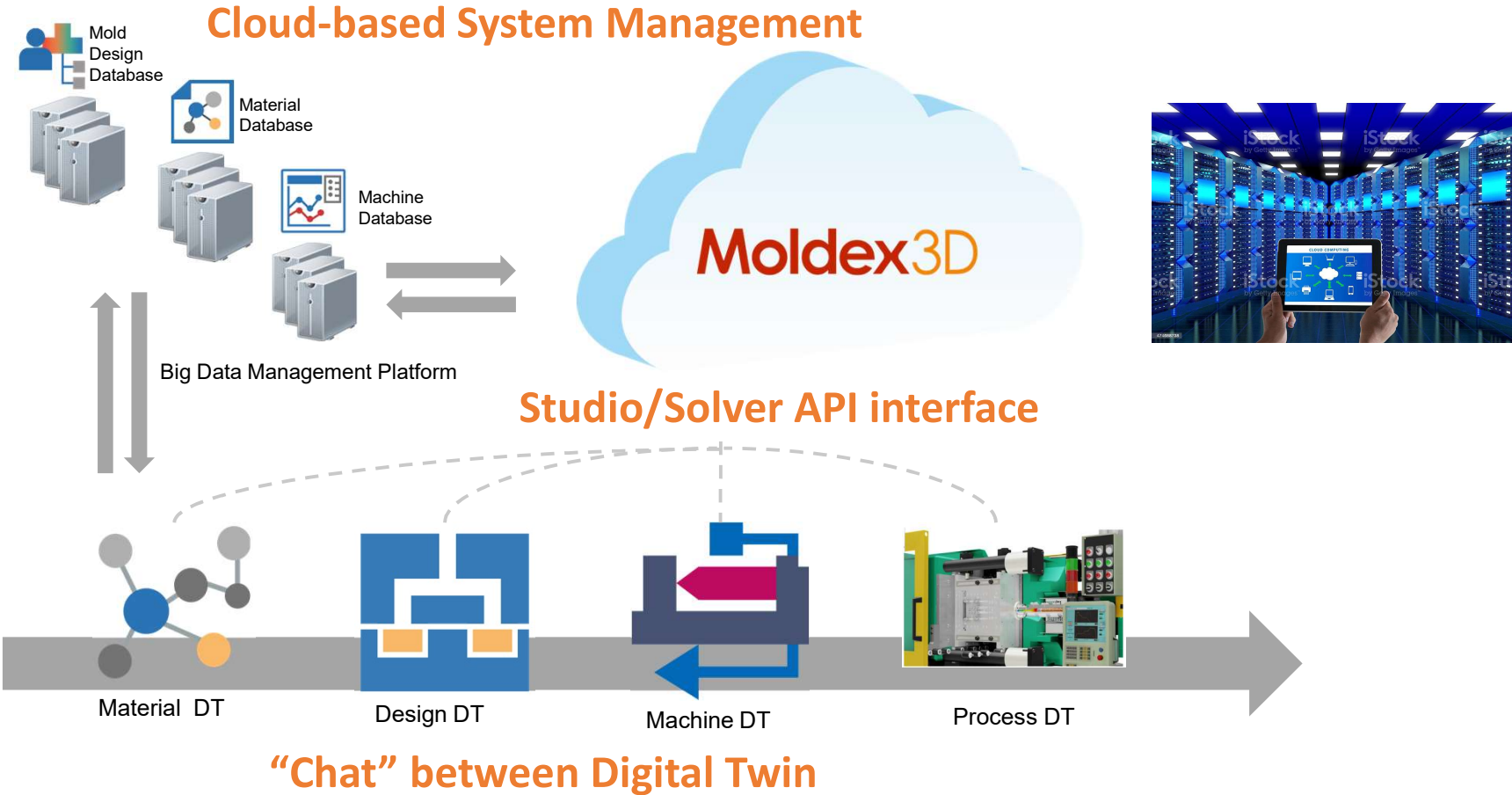
[Export Material File](#)

POLYLAC PA757 / ABS / CHI-MEI

Cross Check Viscosity PVT Heat Capacity Thermal Conductivity Mechanical Properties Process Conditions

	Viscosity	PVT	Heat Capacity	Thermal Conductivity	Mechanical Properties	Process Conditions
Viscosity	-	5	-	-	-	-
PVT	-	-	4	-	4	2
Heat Capacity	-	-	-	-	-	3
Thermal Conductivity	-	-	-	-	-	-
Mechanical Properties	-	-	-	-	-	-
Process Conditions	-	-	-	-	-	-

Moldex3D Digital Twin-Driven Simulations



The background is a complex, abstract composition of overlapping, angular shapes. The color palette is dominated by deep, dark purples and blues, with some lighter teal and cyan accents. The shapes are layered, creating a sense of depth and movement. The overall effect is a modern, digital aesthetic.

Thank you