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

QUALITY MANAGEMENT SYSTEM
ISO 17025
ACCREDITED
LABORATORY


TAF
Certificate No. : L3417-171225
財團法人全國認證基金會
Taiwan Accreditation Foundation

Certificate of Accreditation

This is to certify that

CoreTech System Co., Ltd.
Moldex3D Material Research Center
8F-1, No.32, Taiyuan 1st St., Zhubei City, Hsinchu County 302, Taiwan (R.O.C.)

is accredited in respect of laboratory

Accreditation Criteria	: ISO/IEC 17025:2005
Accreditation Number	: 3417
Originally Accredited	: December 25, 2017
Effective Period	: December 25, 2017 to December 24, 2020
Accredited Scope	: Testing Field, see described in the Appendix

Chung-Lin Wang
President, Taiwan Accreditation Foundation
Date : December 25, 2017

P1, total 2 pages

The Appendix forms an integral part of this Certificate, which shall be invalid when use without the Appendix

Material Characterization Center : Instrument Line-up 1

GÖTTFERT

Rheograph RG25
Capillary viscosity and thermal conductivity with counter pressure Equipped

Flow pattern
Filling Pressure

GOTECH

pvT-6000
pvT change at different temperature and pressure

Compressible
Shrinkage

Anton Paar

MCR 502
Rotation and oscillation tests for viscoelastic properties

Low shear
Flow VE
Reactive
GMT/SMC

PerkinElmer

DSC 8500
Transition temperatures and crystallization kinetics

Tg, Tm
Crystallization

TMA 4000
CLTE

Anisotropic
shrinkage

INSTRON

Instron-8966
Mechanical properties

Structural
Shrinkage

Material Characterization Center : Instrument Line-up 2

U-CAN

PVTC for thermoset

PT-6800
Specific volume with curing

Curing shrinkage

NETZSCH

Dynamic Mechanical

DMA 242 E Artemis
Dynamics mechanism analysis for relaxation modulus

Solid VE (Warp, Annealing)

U-CAN

Rheometer for rubber

MDR-A1
Scorch curve

Rubber reaction kinetics, viscosity

Format®
Messtechnik GmbH

Foam Qualification System

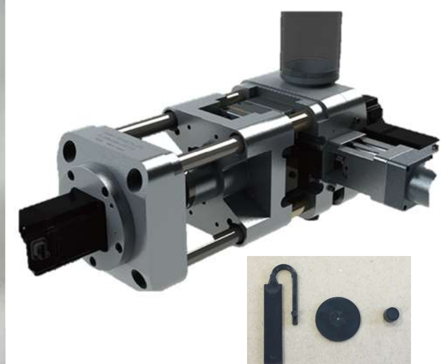
FOAMAT® 285

Foaming and Curing Kinetics

Permeability

EASYPERM

3D permeability of resin in fiber mats



Micromolding machine for DMA, PVT specimen

Plastic Material Digital Twin

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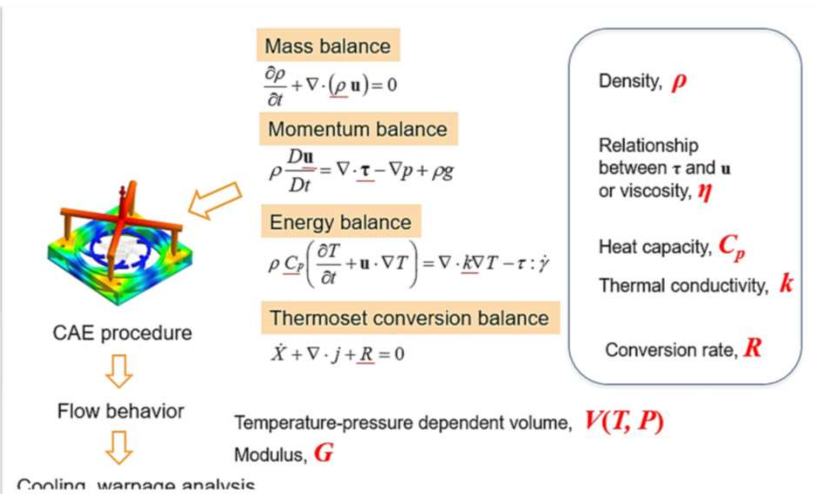
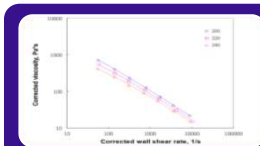
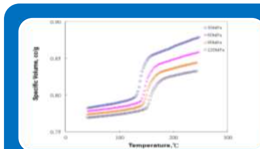
Accuracy of CAE Simulation Depends on Reliability of Plastic Material Data

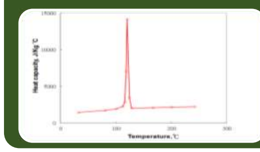




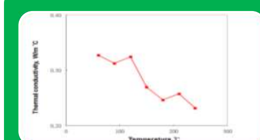
Viscosity: related to filling behavior, short-shot, welding line position, filling/packing pressure and clamping force



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



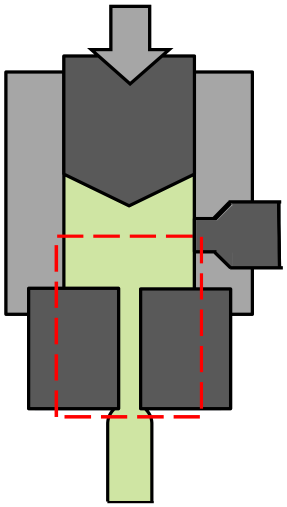
Thermal Conductivity: related to heating/cooling behavior of the part, temperature distribution, and cycle time

Data

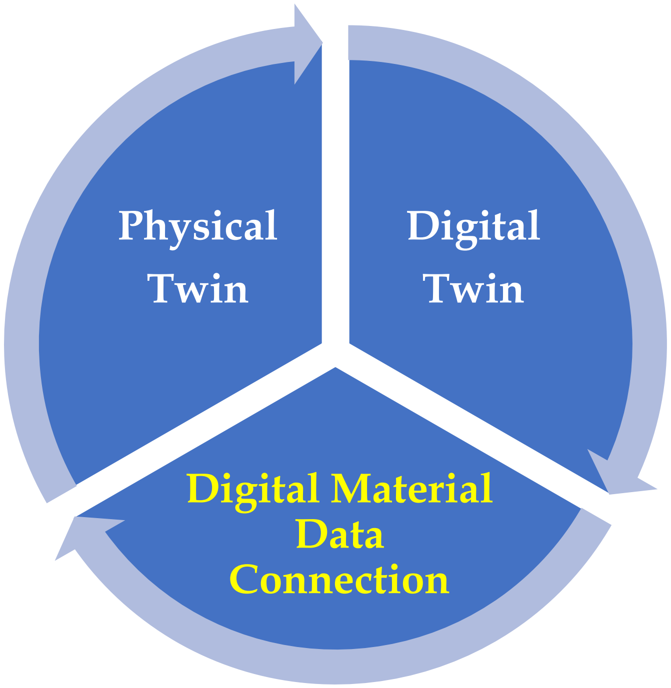
	Modulus E1 (MPa)	Modulus E2 (MPa)	Poisson's Ratio v12	Poisson's Ratio V23
Test 1	6324	2977	0.299	0.370
Test 2	6582	2772	0.310	0.432
Test 3	5878	2767	0.290	0.396
Test 4	6217	3054	0.283	0.402
Test 5	6435	2430	0.285	0.407
average	6287	2800	0.294	0.401
STDEV	266	242	0.011	0.022

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

More Factors to Be Considered

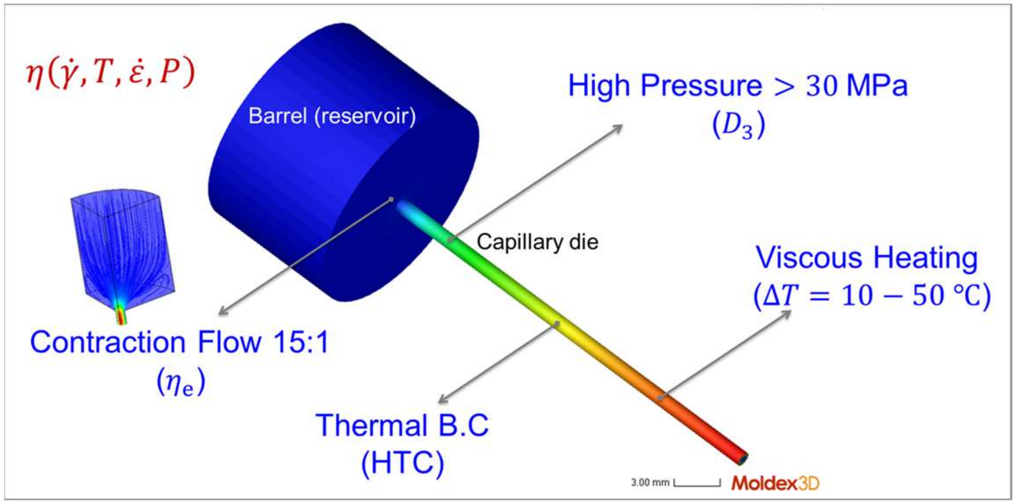


Capillary rheometer



Model parameters

- η_S, η_E, D_3



Shear Heating Correction

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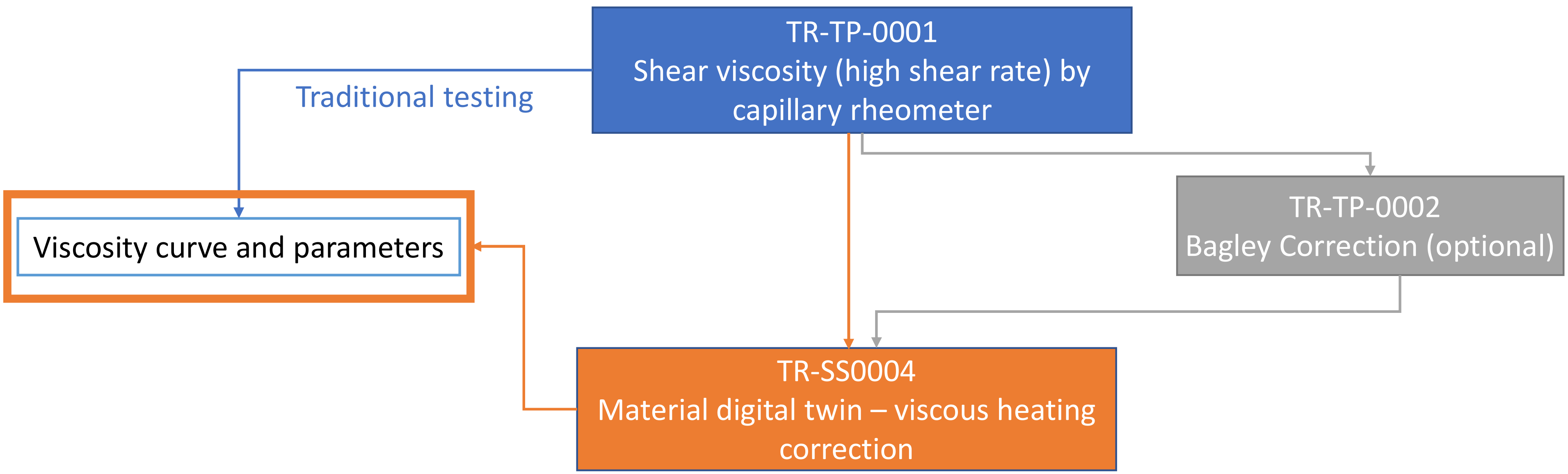
Correction Process of viscous heating

- **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

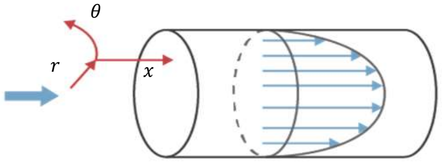
Rheograph RG25
Capillary viscosity and thermal conductivity with counter pressure equipped

TR-TP-0001 Shear viscosity(medium to high shear rates)-TP

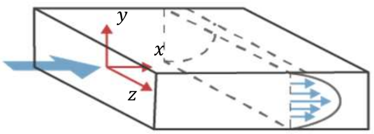
- Capillary die by 1mm/30mm @ MDX

Pressure Flow Die on Rheograph RG25

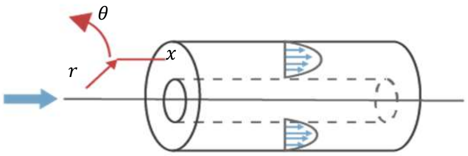
Capillary
(Poiseuille flow)



Slit flow



Axial annulus flow



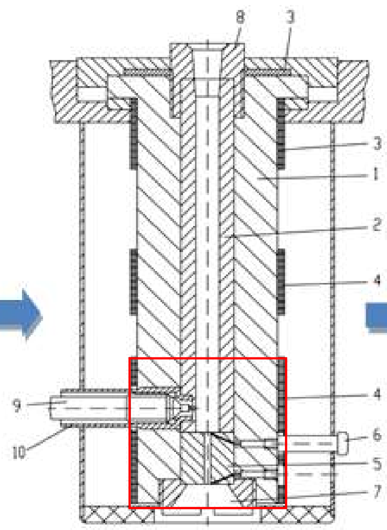
Digital Twin Correction

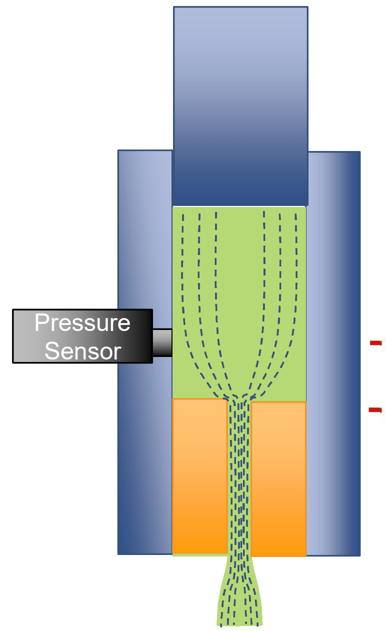
TR-SS0004
Material digital twin – viscous heating correction

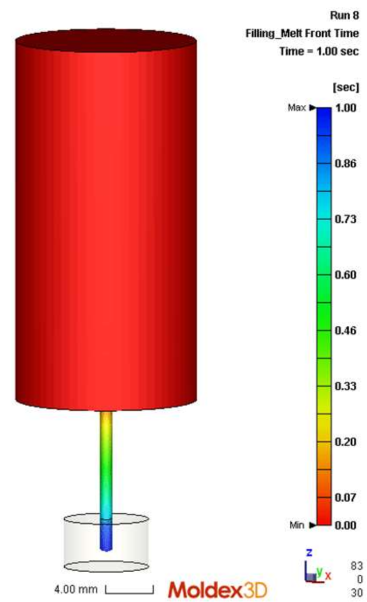
- **Target :**

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

  - **non-isothermal, Entrance effect, non-Newtonian, pressure effect, …**



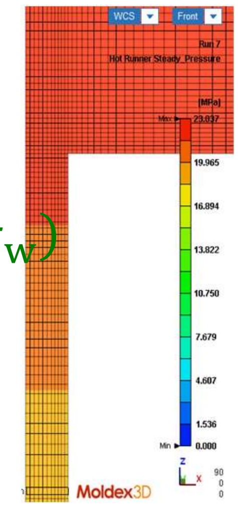




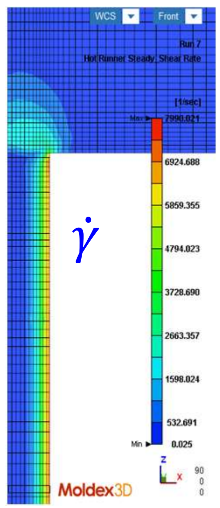
Distribution in the Flow Field Simulation

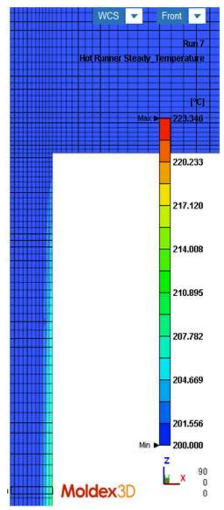
- **Non-homogenous physical properties in the axial directions could be different, which are assume constant in the traditional rheometric evaluation**

$P(\tau_w)$



$\dot{\gamma}$





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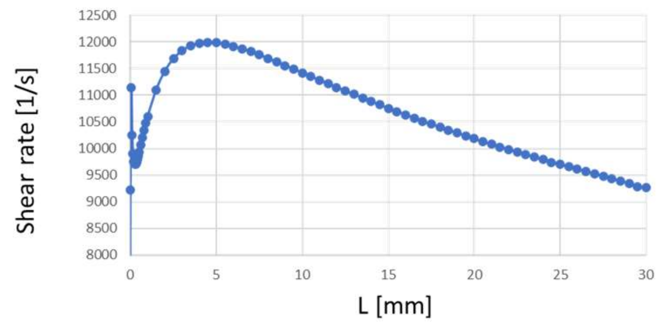


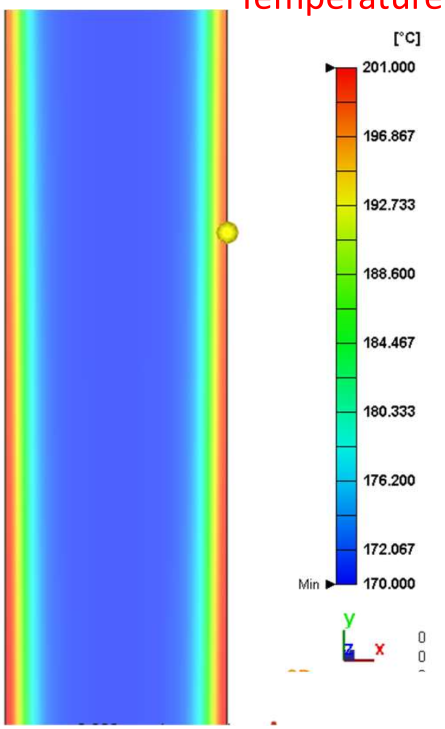
- **In a general capillary rheometer, the temperature rising, and uneven distribution will lead to data deviation, so that the ideal working equation cannot be 100% valid.**

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

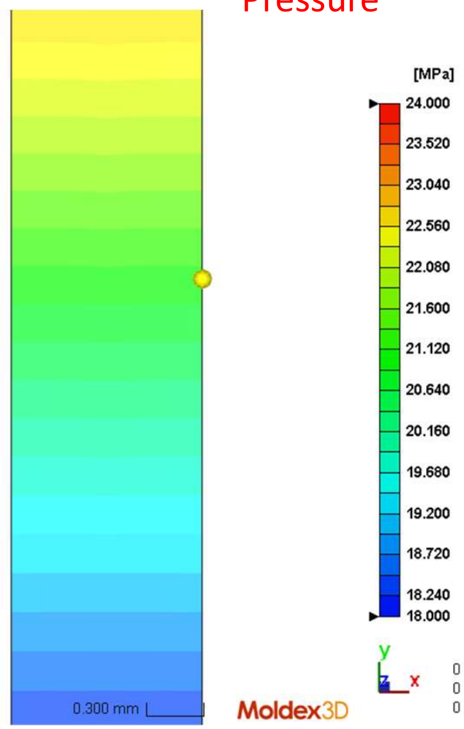
Distribution across tube

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

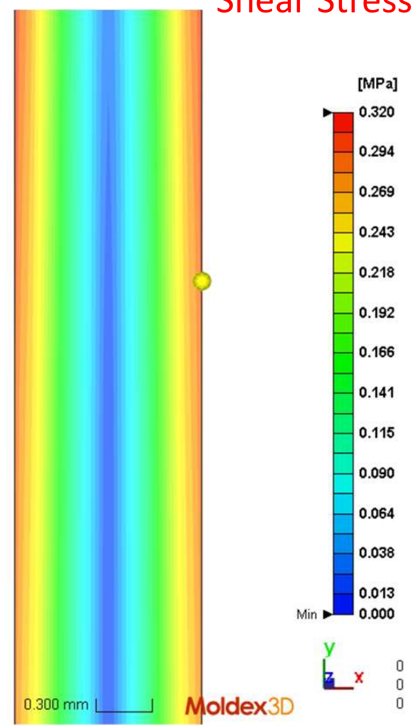
Temperature



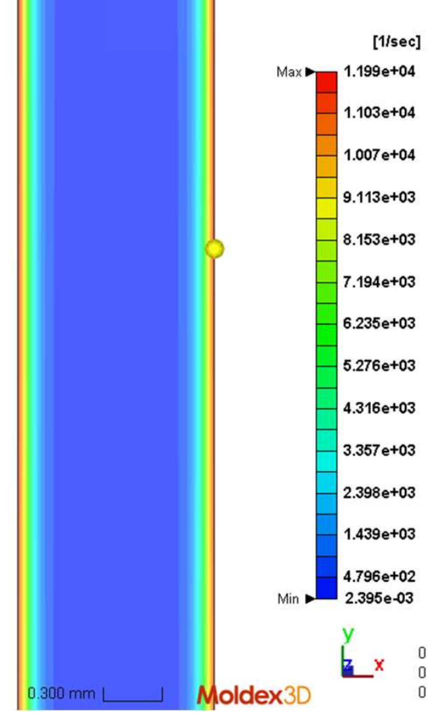
Pressure



Shear Stress

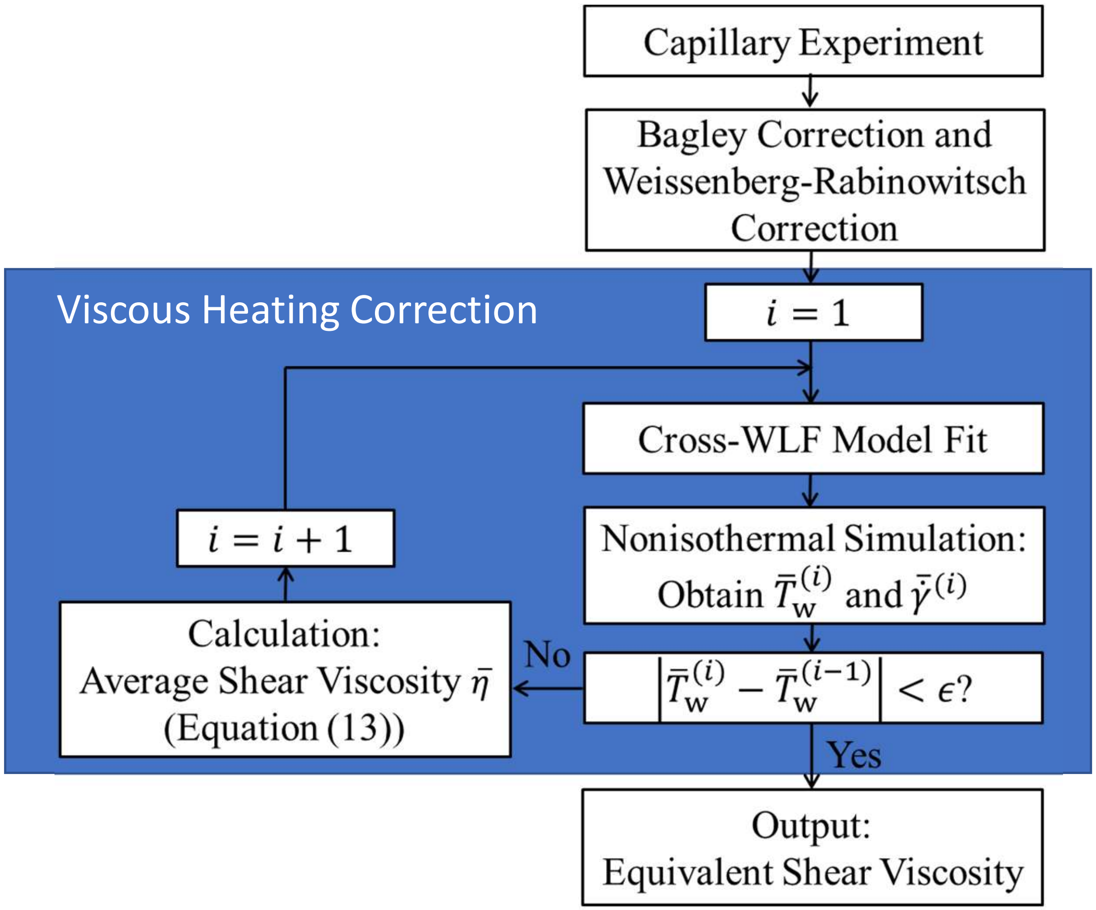


Shear Rate



Theoretical Justification & Methodology

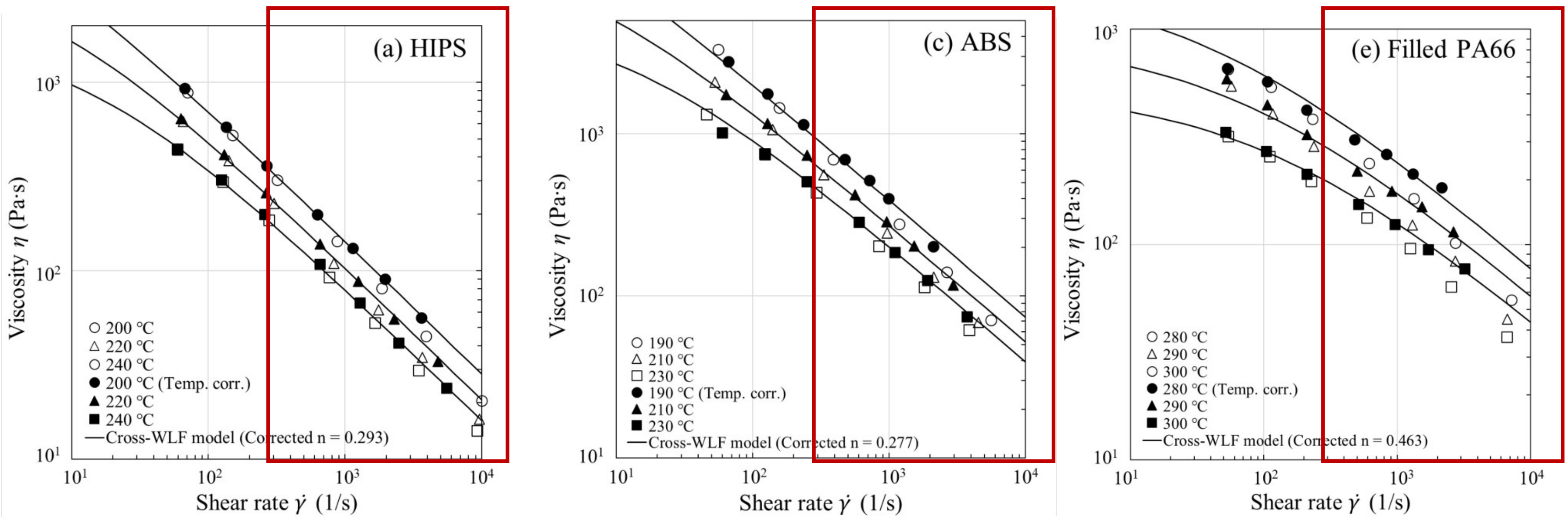
DT



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

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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 *Polymers* **2021**, *13*, 4094 MDPI

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.

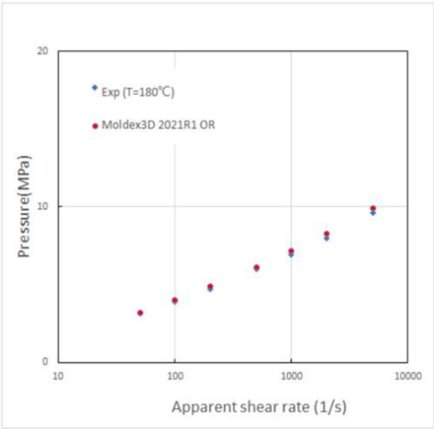
Rheometer specifications (GÖTTFERT RG25)	
Die length	30 mm
Die diameter	1 mm
Die entry angle	90 degrees
Barrel diameter	15 mm

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

Testing report

180℃

Piston Speed [mm/s]	App. Shear rate [1/s]	Pressure Experiment [MPa]	Pressure Simulation (MPa)	Rel. Error (%)
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

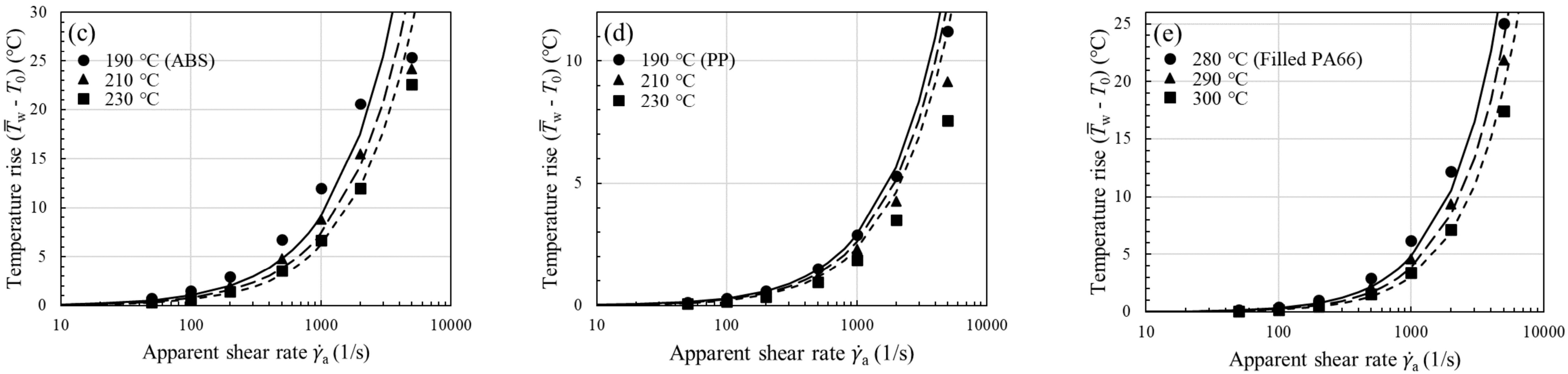


Summary

› 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

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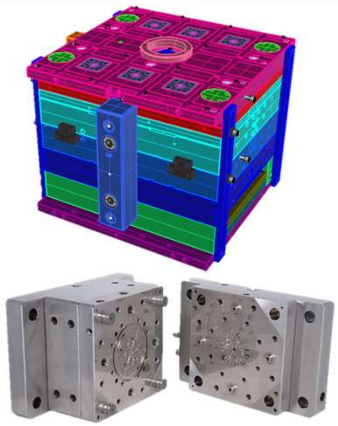
Moldex3D Molding Research Center : Material Molding Validation



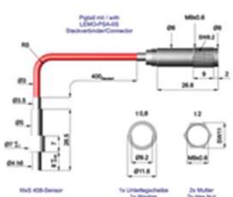
Mold System

Core side:
9 Pressure
Sensors

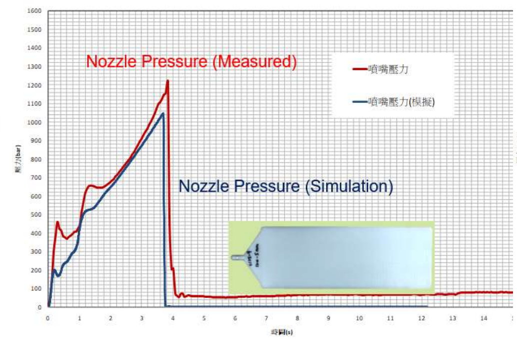
Cavity Side
9 Temperature
Sensors

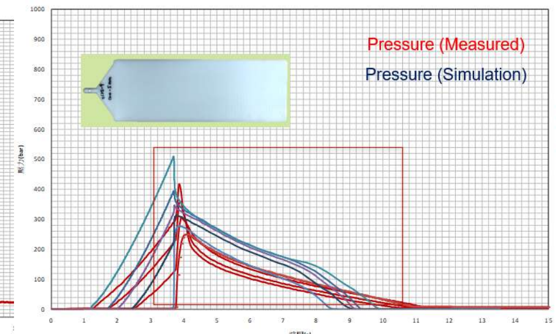
Mold Plate
Temp Sensing

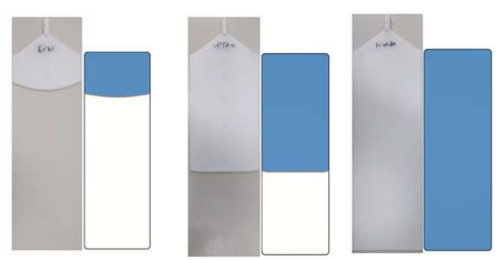
Data Collection



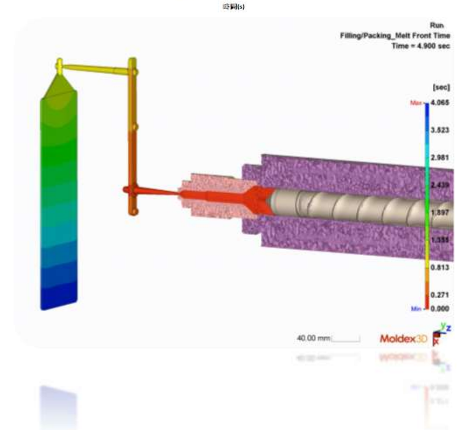
Sensor
Data





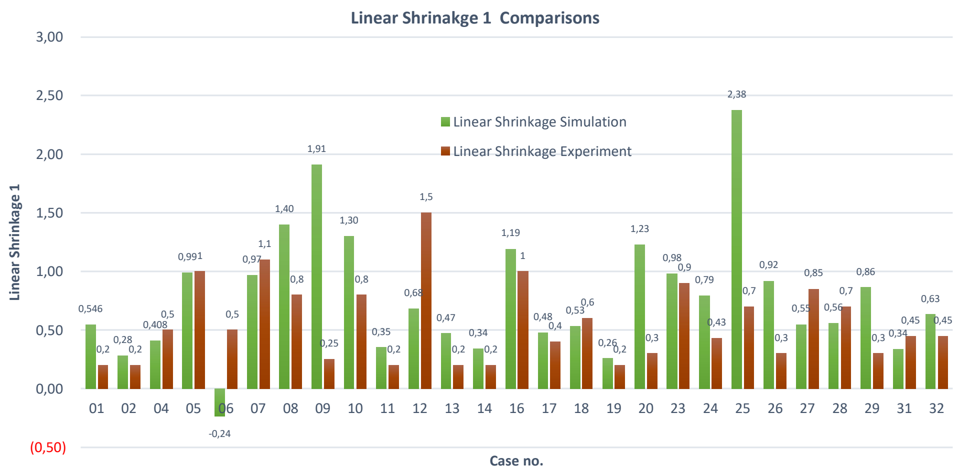


Stroke:45mm Stroke:75mm Stroke:105mm

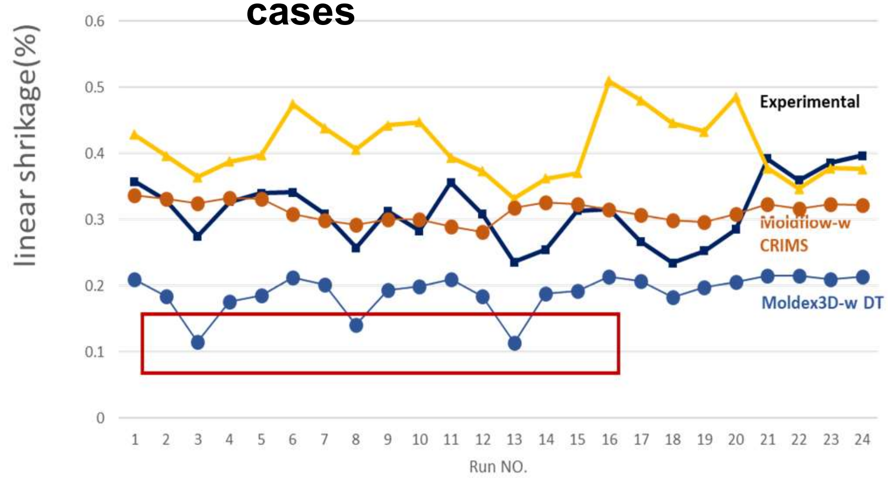


Build & Improve Shrinkage testcase database by DT

Real cases



Process dependent cases



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

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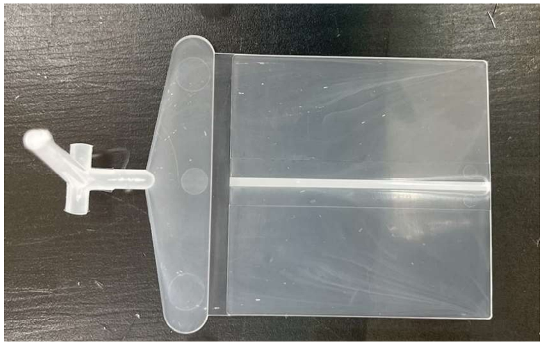
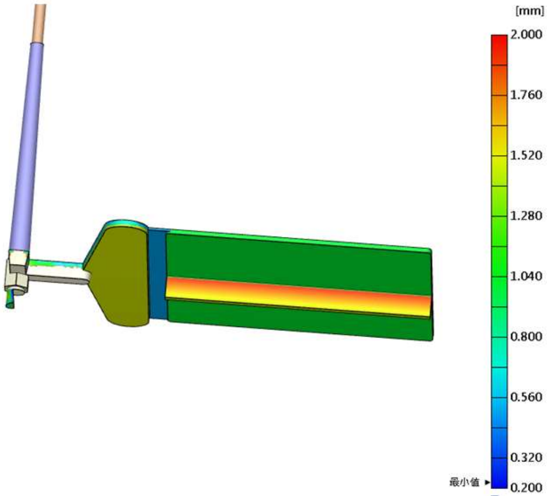
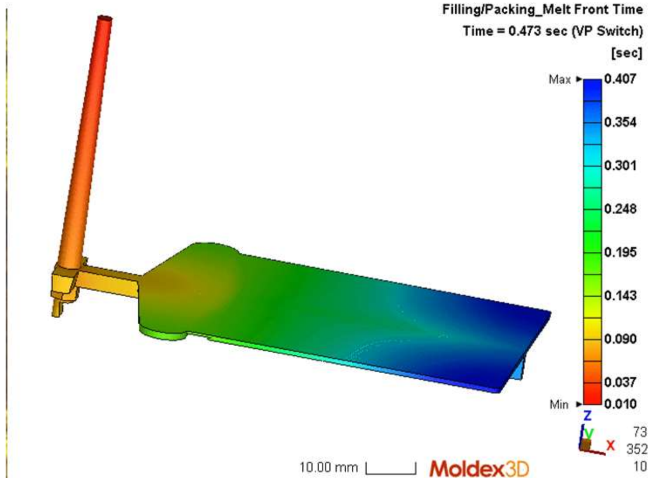
Objective

- 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.

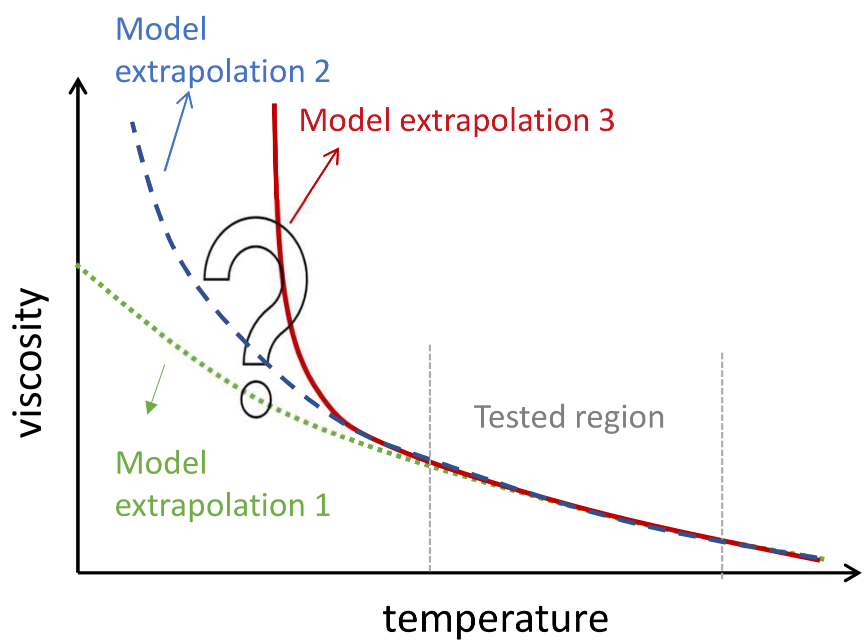


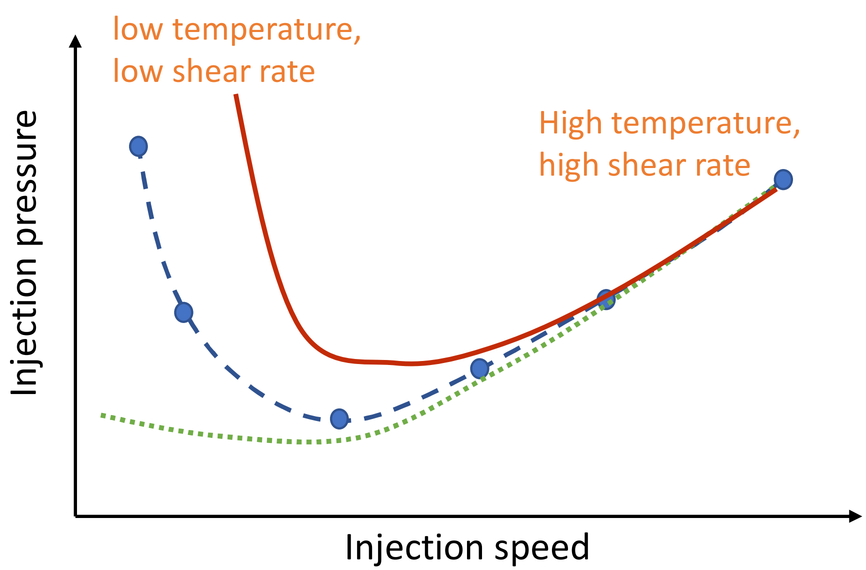




Our proposal : Injection Pressure Based Viscosity Calibration (IPBVC)

- **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.**

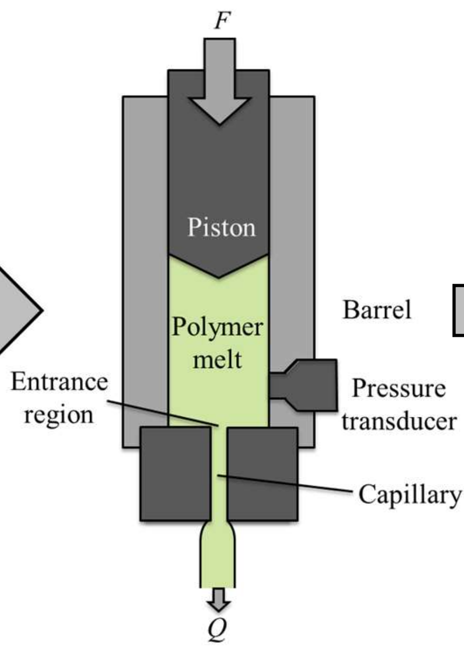




Use Material Digital Twin to Improve Material Model Parameters

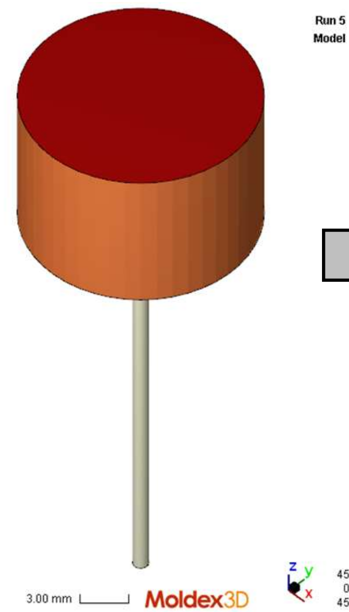
(1) Capillary Rheometer (physical twin)

(2) Measurement



(3) Material File (original)

(4) Simulation & Correction (digital twin)



(5) Material File (*corrected*)

Reliable Simulation

Material Hub Cloud (MHC)

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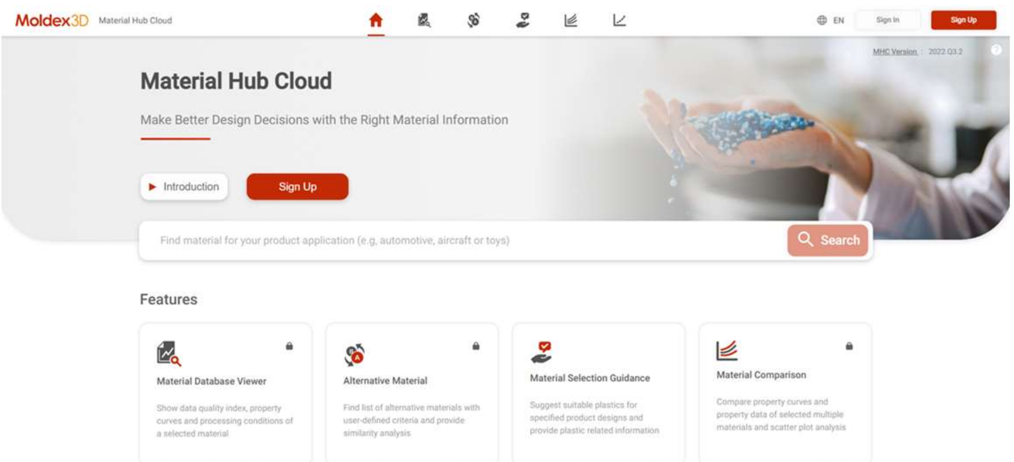
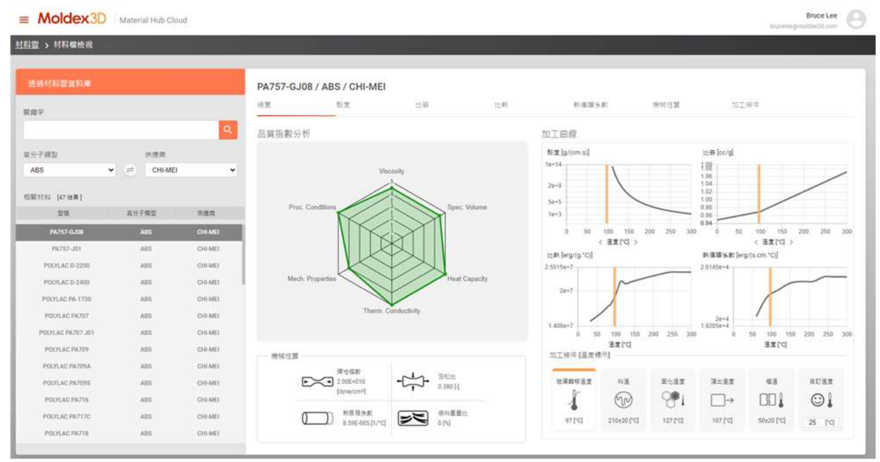
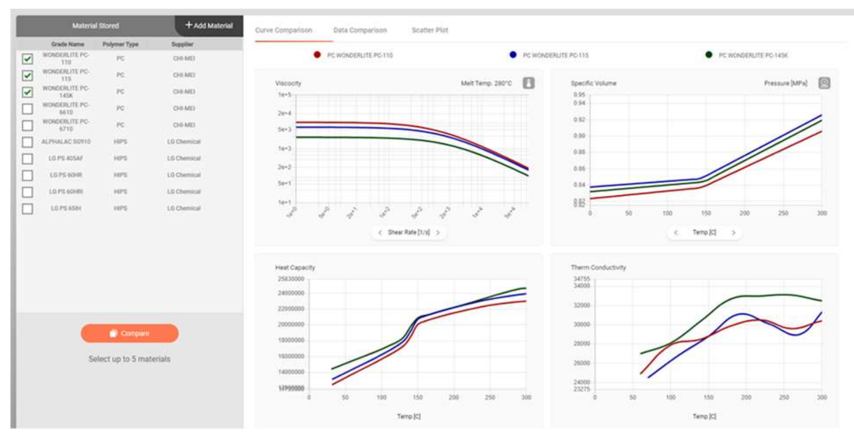
Outlook in Material Hub Cloud (MHC) Web Service

› 8000+ Thermoplastics Materials

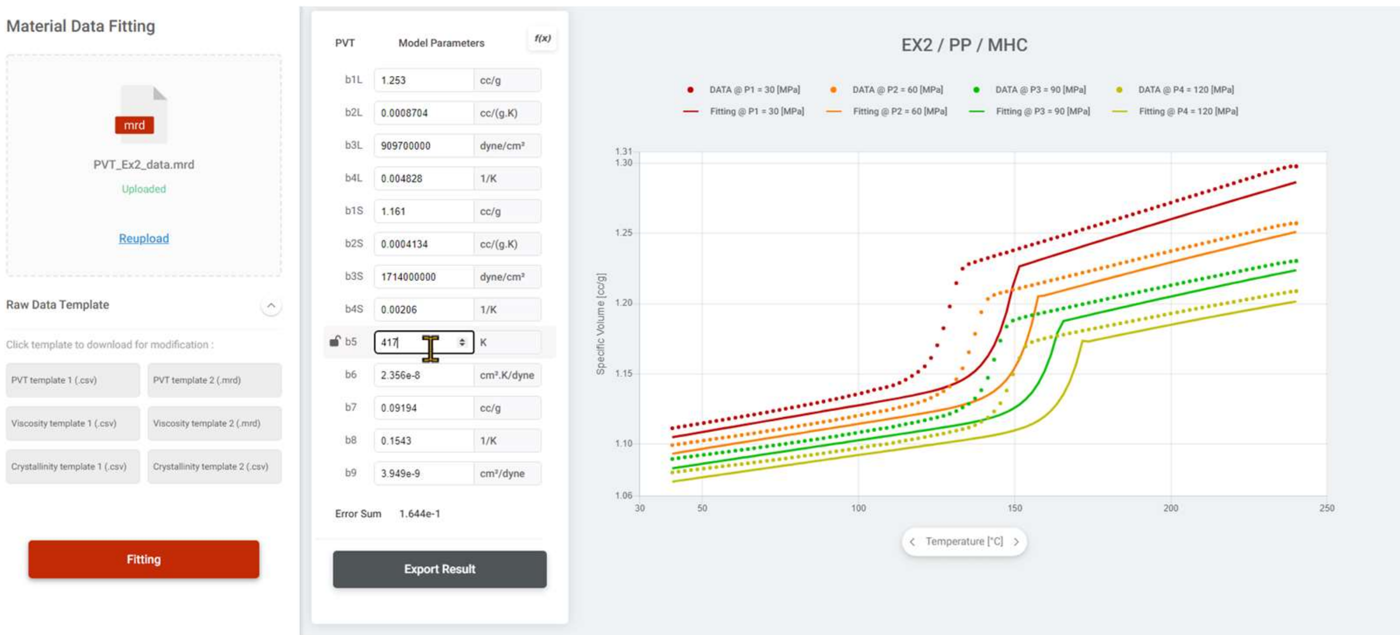




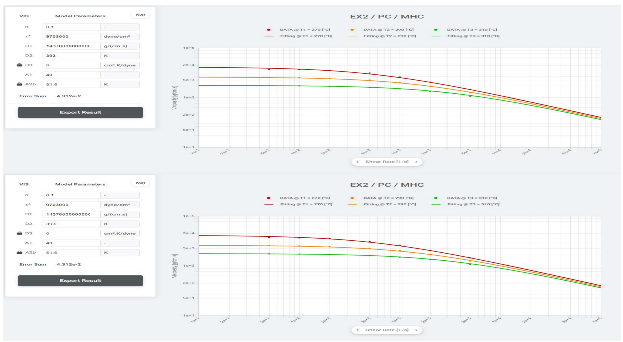


Thermoplastic Material Fitting Functions

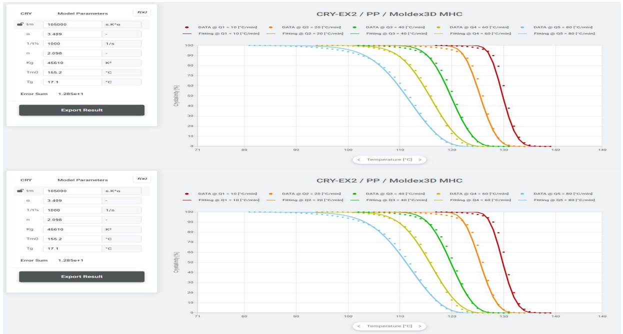
PVT



Viscosity



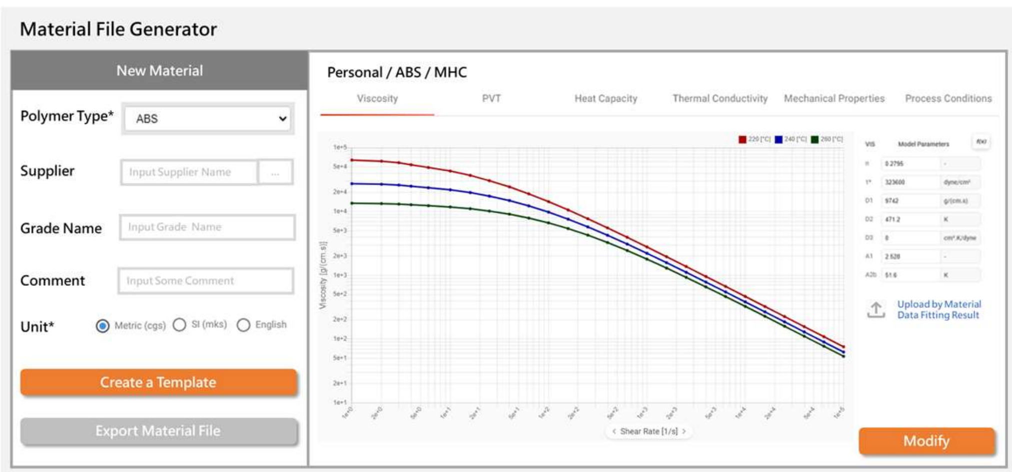
Crystallinity

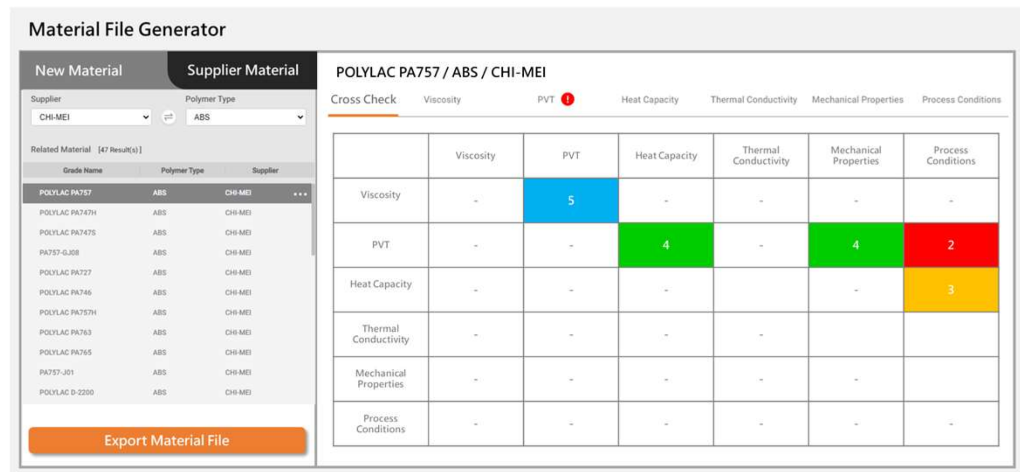


Support CSV or MRD file format, and provide template to download for editing

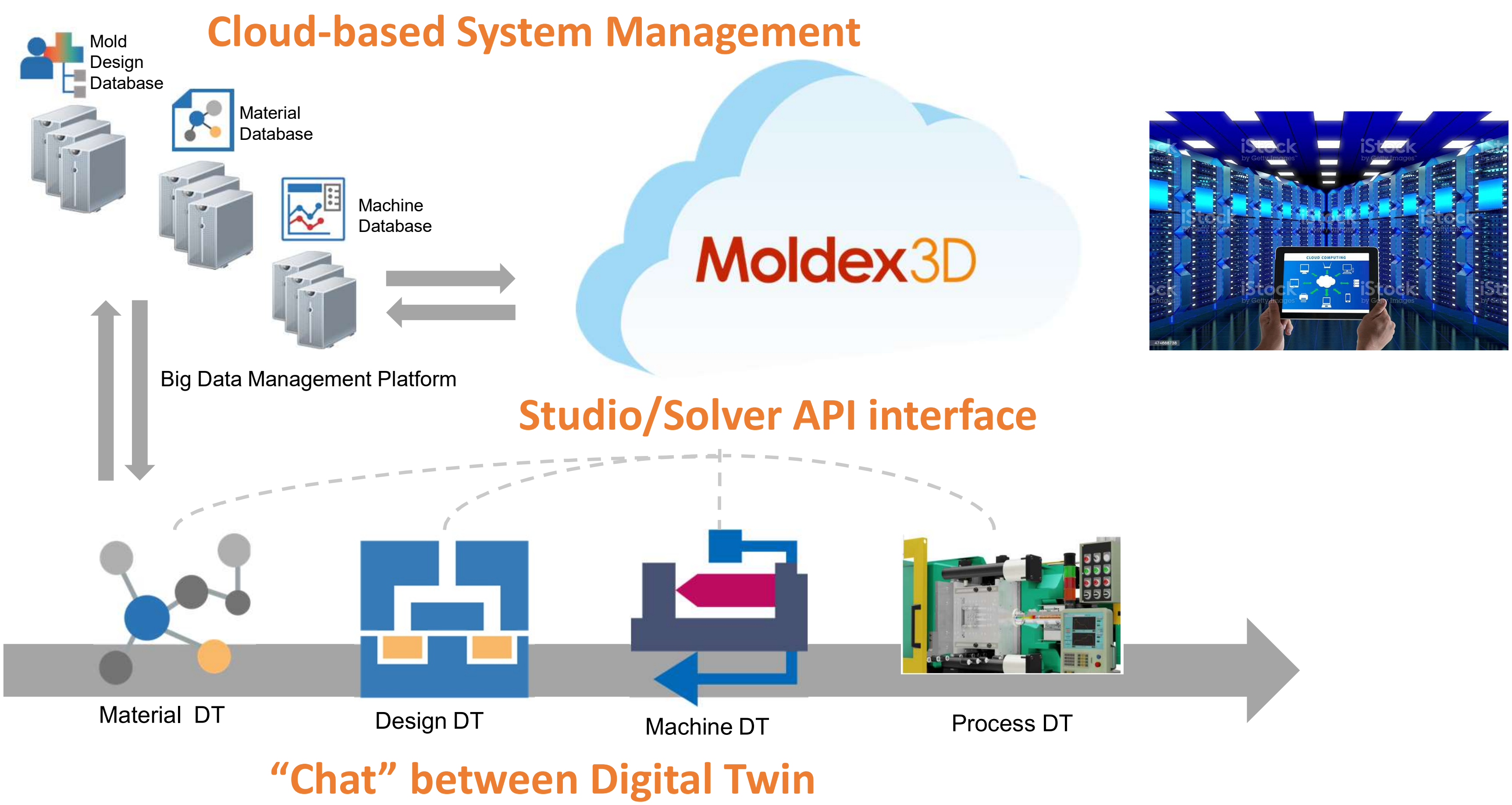
Digital Material Generator Function

- 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.





Moldex3D Digital Twin-Driven Simulations



Thank you