

Thermoplastic Material Testing for Use in SIGMASOFT and the Effect of Moisture on PA 6/6









Our Brands

DatapointLabs

technical center for materials



Material testing for new product development



Material parameters for CAE, material model validation



testing for simulation

Store, analyze, compare any material data, create CAE material cards, master material files



Record & analyze any experimental and simulation data



atapointLabs

Knowledge resource for CAE users related to materials in simulation







Know Your Materials

knowmats	strengthening the materials core of manufacturing enterprises					
Home About Test Types Material Types	Sigmasoft	Profile Posts Links				
Industries	Inermal 1 Plastics 2 Rubbers 2 CAE Vendor/Supplier 0 Injection Molding 3 SIGMASOFT 3	Mold Tempering: Conformal Cooling - yes or no? August 24, 2015 by Sigmasoft views 27				
Fechnical Interests Automotive 3 Bromedical 3 Newsletters 3 Visco-elastic 1		The tempering layout for injection molds is often designed departing from previous experiences. The manufacturing feasibility is the main driver when deciding where to place cooling lines. However, often the relevance of the tempering in the process profitability or in the part quality is underestimated, and due to the lack of better information sometimes the resulting tempering performs far from the optimum. As a consequence, the molding efficiency is reduced, the part quality is compromised and, once the mold is already built, sometimes expensive trial-and-error is required to bring the mold to an optimum configuration.				
		read full post				
		Rheology Thermal Plastics Automotive Biomedical Injection Molding SIGMASOFT Newsletters				
		Ejection system design: Optimization with SIGMASOFT Virtual Molding August 24, 2015 by Sigmasoft views 28				
		As the demand for functional integration and the need of design differentiation in manufactured products increase, the complexity of plastic parts increases as well; thus some previous knowledge on effective ejection				

Knowmats is a knowledge resource for CAE users related to materials in simulation.

A curated collection of:

- Blog-style posts
- Links to technical papers
- Articles or newsletters

Help simulation professionals perform best-in-class simulation with a better understanding of how materials are represented in FEA and simulation.





Material Testing Expertise

Plastic Rubber

Film

Metal

Foam

Composite Cement Ceramic Paper Wire

atapointLabs

Fiber

- Product development / R&D support
 - CAE-centric
 - Commitment to simulation accuracy
- All kinds of materials
 - Over 1,800 materials tested each year
- All kinds of material behavior
 - Over 200 physical properties:
 - Mechanical properties
 - Thermal properties
 - Flow properties

strengthening the materials core of manufacturing enterprises

Tensile Compressive Flexural Stress-strain Poisson's ratio High strain rate Bulk modulus Fatigue Viscoelasticity Stress relaxation Creep Friction **Hyperelasticity Thermal expansion** Thermal conductivity Specific heat PV/T Rheology



Customer Base

• 1200+ companies

atapointLabs

- 11 manufacturing verticals
- Product development / R&D
- Globally available at www.datapointlabs.com visit | browse | buy | download

Aerospace Automotive Appliance Biomedical Consumer products Electronics Industrial goods Materials Petroleum Packaging





Required Testing







Rheometer Measurement of Viscosity

- Capillary rheometer is used
- Material is extruded through a restriction of known geometry (extremely high tolerance dies)
- Temperature and flow rate are controlled
- Pressure drop across the restriction is used to determine viscosity as a function of shear rate and temperature









Viscosity Properties

• As shear rate increases, viscosity decreases







Viscosity Properties

As temperature increases, viscosity decreases







Viscosity Measurements

- Apparent Viscosity
- Shear rate:

atapointLabs

- Shear stress:
- Shear viscosity:
- $\dot{\gamma}_a = \frac{32Q}{\pi d^3}$ $\tau_{w} = \frac{\Delta pd}{4L}$ $\eta_a = \frac{ au_w}{\dot{\gamma}}$
 - $\Delta p = Pressure drop$ d = Capillary diameter L = Capillary length

Where: Q = Volume flow rate

- Corrections to viscosity
 - Reservoir and friction losses (transducer located at die)
 - End pressure drop (Bagley)
 - Non-parabolic velocity (Rabinowitsch correction)



Bagley Correction Testing

- Bagley Correction
 - Perform viscosity measure on two different die ratios at equal shear rates
 - Evaluate pressure differences between die geometries (capillary diameter remains the same)
 - $\Box \tau = R/2(dP/dL)$

atapointLabs





Viscosity Modeling

- Very strong rheological models
 - Cross WLF, Cross Arrhenius
 - Combines a model of shear rate dependency with temperature dependency $\eta(T, \dot{\gamma}) = -\frac{\eta_0(T)}{\eta_0(T)}$
 - Allows us to predict beyond testing range $\eta(T,\dot{\gamma}) = \frac{\eta_0(T)}{1 + \left(\frac{\eta_0\dot{\gamma}}{\tau^*}\right)^{1-n}}$, where



n	0.28400
τ*	32096.1
D1	3.86E+13
D2	263.15
A1	30.87
A2	51.6



 $\eta_0(T) = D_1 \exp \left[-\frac{A_1(T-D_2)}{A_1 + (T-D_2)} \right]$



Considerations for Testing

- Limited in shear rates
 - Typically test 10-10000 /s
- Residence times are longer in testing
 - Testing takes several minutes (approx. 6-10 min.)
 - Need to worry about thermal stability
- Processing temperatures are typically higher than test temperatures
- Typically testing is performed at two temperatures within the processing range and one below



Problematic Materials

- Moisture sensitive materials
 - Improperly dried materials cause reduction in viscosity
 - Over-dried materials cause a rise in viscosity
 - PET, PA, PC, PBT etc.
- Highly filled materials
 - Can "log jam" the die entrance
 - Special dies must be used
 - Higher scatter in test data requires engineering judgment on behavior
- Thermally unstable materials
 - Requires very careful attention to residence times
 - PVC





Moisture Study of PA 6/6

- Drying Method Used (Dry)
 - Fluid bed dryer, 10 hrs 110°C
 - KFC titration
 - 0.109% moisture
- Humidification (Wet)
 - Tenny humidification chamber
 - 10 hrs 70% RH, 60°C
 - 0.351% moisture







Viscosity of Dry PA 6/6







Viscosity of Wet PA 6/6





DatapointLabs

Wet/Dry Viscosity Comparison







DatapointLabs

Implementation Into SIGMASOFT

- General parameters
 - Material type \rightarrow Plastic (Semi-crystalline or Amorphous)
 - Initial temperature → minimum temperature
 - Material models → PVT (Tait), Viscosity (Cross WLF), Stress (Viscoelastic), Fiber Model (Deactivated when viscoelastic is used), Crystallization (Weibull, when semicrystalline material is selected)

7 Edit Material of database User				76 Edit Material of database User		
Data Edit Memo		Help	MALT	Data Edit Memo		Help
	Material: test				Material: test	
General Parameters				General Parameters		
Material type:	Plastic			Material type:	Plastic	
Initial temperature				Initial temperature	180.00	°C
No-Flow Properties:	<unset></unset>			No-Flow Properties:	Based on pvT	
				pvT material type:	Semi-Cristalline	
pvi matenal type.	Amorphous			pvT model:	Tait	
pvT model:	<unset></unset>			Crystallization model:	Deactivated	
Rheology model:	<unset></unset>			Rheology model:	Cross-WLF	
extensional Rheology model:	<unset></unset>		,	autonoional Bhaalagu madal	0.4	
Viscosity relaxation model:	<unset></unset>			extensional Kneology model.	UII	
- Fibra Madala		P		Viscosity relaxation model:	Deactivated	
, Fibre Model	<unset></unset>			Fibre Model:	Deactivated	
Stress Model:	<unset></unset>		; core of manufact	Stress Model:	Viscoelastic	

Implementation Into Sigmasoft

	7% Edit Material of database User	
	Data Edit Memo	Help
 Thermal conductivity 	✓ Global Information 183	
Specific heat	Globall Cambda	
Viscosity	Cp fs fs	<u> </u>
• PVT	Rho*Cp (view only)	
• CTE	Extensional Rheology	
Mechanicals	Viscosity relaxation	
• Order of input counts	Fibre General Properties Vitrification	
- PVT, Cp, Lambda, Visc,	Young's Modulus	
CTE, mechanicals	Poisson Ratio Poisson Ratio Thermal Expansion Coefficient StressStrain Relevation time	×
	Protection: Unpro	otected



DatapointLabs

Implementation Into Sigmasoft

- X-Y pairs in text files
 - Viscosity (3)
 - Specific heat (1)
 - Thermal conductivity (1)
 - PVT (4-6)
 - CTE (1)
 - Mechanicals (5)
 - At least 17 input files

pvt150.t	xt - No 💻	
<u>F</u> ile <u>E</u> dit	Earmat Via	
25.1	VISCOSTO.	.txt
44.3	<u>F</u> ile <u>E</u> dit	F <u>o</u> rmat <u>V</u> iew <u>H</u> elp
54	48 1	151.99
73.7	207 📃 ten	ns75.txt - Notepad
83.5	535 <u>File</u>	Edit Format View Help
103.1	234 8.909	Cp.txt - Notepad 💶 💷 💌 🔭
112.7	620 0.099	File Edit Format View Help
132.2	0.304	4 D87 1864
141.8	0.400	277 1876
151.5 161.1	0.602	
170.8	0.696	247 1860
180.6	0.78 0.891	237 1845
199.8	0.78 0.990	- 22/ 1831 9 217 1814
209.4	0.79 1.089	207 1795
228.4	0.79 1.287	
238.4	0.79 1.381	
248	0.80 1.4/8	167 1716
267.4	0.80 1.684	4 147 1657
277.1	0.80	146 1652 L
296.4	0.8147150	
		144 1655
		142 1606
		141 1589
		139 1559
		138 1550 137 1535
		136 1523 -



Molding Conditions

• Flow rate 66 cc/s

DatapointLabs

- Flow Temperature 300°C
- Mold Temperature 87°C





Mold Filling Pressure

- Look at approx. 75% fill
- Dry→566 bar inlet pressure
- Wet→120 bar inlet pressure



atapointLabs





Pressure Profile Near Gate and Away

- Dramatic difference in pressure in mold
- Almost 5 times pressure for only 0.25 % moisture



atapointLabs



Consequences of Design Based on Wet Material Data

- Mold design underestimates clamping force
- Flow patterns are wrong
- Fiber orientation is wrong
- Fill time is off







Consequences of Molding an Actual Part With Wet Material

- Inferior strength
- Voids from entrapped moisture
- Splay/streaking
- Blisters







Conclusion

- Materials that are subject to moisture
 PET, PA, PC, PBT Filled Materials
- Always have a target moisture declared
 - Simple dry times and temperatures may not be enough
 - Record actual moisture content
- Be aware that you can over-dry a material as well... to be continued

