



Material Testing Report

MAT9532

ISOFIL KCW 4024D

Prepared for:

Sirmax North America, Inc
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Prepared by:

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Prepared on:

17 July, 2019

Report Created By:

A handwritten signature in black ink, appearing to read 'David Schmidt', with a stylized flourish at the end.

David Schmidt

Materials Lab Engineer

17 July, 2019

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Summary

Description

Family name	POLYPROPYLENES (PP)
Trade name	ISOFIL KCW 4024D
Manufacturer	Sirmax SpA
Family abbreviation	PP
Material structure	Crystalline
Data source	Beaumont Advanced Processing : pvT-Measured : mech-Measured
Date last modified	16-JUL-19
Date tested	16-JUL-19
Data status	Non-Confidential
Material ID	60532
Grade code	mat9532
Supplier code	SIRMAX
Fibers/fillers	20% Calcium Carbonate Filled

Recommended Processing

Mold surface temperature	45.00	°C
Melt temperature	215.00	°C

Mold temperature range (recommended)		
Minimum	20.00	°C
Maximum	70.00	°C

Melt temperature range (recommended)		
Minimum	200.00	°C
Maximum	230.00	°C

Absolute maximum melt temperature	250.00	°C
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Ejection temperature	118.00	°C
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Maximum shear stress	0.25	MPa
Maximum shear rate	100000	1/s

Maximum shear stress and maximum shear rate values have been supplemented with generic estimates.

Rheological Properties

Cross WLF Viscosity Model		
n	0.2413	
Tau	50578.8	Pa
D1	1.92443e+011	Pa-s
D2	263.15	K
D3	2.095e-007	K/Pa
A1	24.299	
A2	51.600	K

Juncture loss method coefficients		
C1	1.012e-005	Pa ^(1-c2)
C2	2.121	

Transition temperature		
Ttrans	130.00	°C

Moldflow Viscosity Index	VI(240)65	
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Thermal Properties

Specific heat data		
Temperature (T) °C	Specific heat (Cp) J/kg-°C	Heating/Cooling rate °C/s
217.91	2552.8	-0.33
214.83	2550.4	-0.33
175.65	2427.3	-0.33
136.46	2308.1	-0.33
133.37	2341.5	-0.33
131.33	2726.2	-0.33
129.4	4885.1	-0.33
128.55	7563.2	-0.33
127.06	13220.0	-0.33
126.72	13483.0	-0.33
126.27	13154.0	-0.33
124.28	9328.2	-0.33
121.93	6293.7	-0.33
119.5	4233.2	-0.33
117.16	3148.7	-0.33
113.89	2600.8	-0.33
105.56	2314.4	-0.33
93.152	2217.4	-0.33
80.745	2091.1	-0.33
59.052	1901.1	-0.33
29.136	1708.7	-0.33

Thermal conductivity data		
Temperature (T) °C	Thermal conductivity (k) W/m-°C	Heating/Cooling rate °C/s
230.00	0.223	0.0
220.00	0.229	0.0
200.00	0.225	0.0
180.00	0.229	0.0
160.00	0.231	0.0
140.00	0.328	0.0
120.00	0.350	0.0
100.00	0.351	0.0
80.00	0.347	0.0
65.00	0.340	0.0

PVT Properties

Melt density	0.8939	g/cm ³
Solid density	1.0708	g/cm ³

2-domain Tait PVT model coefficients		
b5	433.15	K
b6	1.105e-007	K/Pa
b1m	0.001078	m ³ /kg
b2m	7.402e-007	m ³ /kg-K
b3m	9.43917e+007	Pa
b4m	0.005444	1/K
b1s	0.000991	m ³ /kg
b2s	4.217e-007	m ³ /kg-K
b3s	1.93297e+008	Pa
b4s	0.003769	1/K
b7	0.000087	m ³ /kg
b8	0.1386	1/K
b9	2.040e-008	1/Pa

Mechanical Properties

Mechanical properties data		
Elastic modulus, 1 st principal direction [E1]	1798.50	MPa
Elastic modulus, 2 nd principal direction [E2]	1820.38	MPa
Poisson's ratio [v12]	0.4430	
Poisson's ratio [v23]	0.4430	
Shear modulus [G12]	624.800	MPa

Transversely isotropic coefficient of thermal expansion [CTE] data		
Alpha1	1.090e-004	1/°C
Alpha2	1.210e-004	1/°C

Nonlinear Mechanical property data		
Sigma Zero	15.7319	MPa
N	5.8997	
Alpha	1	
Beta	1	
Eig	0	
Matrix Modulus	1628.75	MPa
Matrix Poisson's Ratio	0.443	
Fiber Modulus	0	MPa
Fiber Poisson's Ratio	0	
Maximum Von Mises matrix stress at failure	18.7990	MPa
A1	0	1/ MPa ²
A2	0	1/ MPa ²
A4	0	1/ MPa ²
Temperature	23.0	C
Relative Humidity	50.0	%
Strain rate	0.000833	1/s

The nonlinear mechanical data are derived from RO Library Version 2.

Shrinkage Properties

Corrected residual in-mold stress (CRIMS) model coefficients	
A1	0.821895
A2	-0.275259
A3	0.006642
A4	0.996947
A5	-0.5000
A6	0.008242

Residual strain model coefficients		
	Parallel	Perpendicular
A1	0.10043	0.085097
A2	-0.001345	0.001966
A3	-0.000533	-0.00022
A4	1.0643e-007	-1.1207e-007
A5	0.012145	0.013003

The shrinkage models shown above are valid for Autodesk Moldflow Insight 2018 Revision 2 and later. Shrinkage models for previous software versions are included in the 21000.udb file.

Filler Properties

Filler data	
Description	Weight %
Calcium Carbonate	20

Viscosity

Method:

AMPL Test Method

Instrument:

Arburg Allrounder 270S Injection Molding Machine

Test Specifications:

Sample Form:	Pellets
Pre-Processing:	Not required
Moisture Level:	Not measured
Capillary A: Length:	32.3889 mm
L/D:	16.19445
Die Entry Angle:	90 degrees
Capillary B: Length:	8.0249 mm
L/D:	4.01245
Die Entry Angle:	90 degrees
Barrel Diameter:	30 mm
Plastication Time:	20 sec
Dwell Time:	20 sec
Corrections:	Bagley, Rabinowitsch and shear heating
Date Received:	20-JUN-19
Date Tested:	26-JUN-19

Operator's Notes:

Testing was performed per standard testing procedures.

No anomalies were noted during testing.

Apparent Viscosity Data

Temperature (°C)	Apparent Shear Rate (sec ⁻¹)	Apparent Viscosity (Pa-s)	Die Diameter (mm)	Die L/D (-)	Exit Pressure (MPa)
196.8	232	200.12	2.00	16.19	0.000
197.7	25338	10.35	2.00	16.19	0.000
197.8	303	188.79	2.00	16.19	0.000
197.8	766	108.66	2.00	16.19	0.000
197.8	1356	75.50	2.00	16.19	0.000
198.7	2594	49.24	2.00	16.19	0.000
198.7	6462	26.31	2.00	16.19	0.000
198.7	12669	16.49	2.00	16.19	0.000
198.7	63776	5.78	2.00	16.19	0.000
207.8	214	192.41	2.00	16.19	0.000
207.8	63698	5.36	2.00	16.19	0.000
208.8	297	172.84	2.00	16.19	0.000
208.8	778	97.55	2.00	16.19	0.000
208.8	1350	70.02	2.00	16.19	0.000
208.8	2606	45.32	2.00	16.19	0.000
208.8	6387	24.77	2.00	16.19	0.000
208.8	12660	15.46	2.00	16.19	0.000
208.8	25465	9.62	2.00	16.19	0.000
217.7	63739	5.00	2.00	16.19	0.000
217.8	207	177.50	2.00	16.19	0.000
217.8	314	145.79	2.00	16.19	0.000
217.8	782	89.56	2.00	16.19	0.000
217.8	1362	64.14	2.00	16.19	0.000
217.8	2632	42.04	2.00	16.19	0.000
217.8	6408	23.27	2.00	16.19	0.000
217.8	25464	9.04	2.00	16.19	0.000
218.8	12699	14.58	2.00	16.19	0.000
227.6	25490	8.57	2.00	16.19	0.000
227.6	25490	8.57	2.00	16.19	5.840
227.7	749	85.47	2.00	16.19	0.000
227.7	12664	14.26	2.00	16.19	9.533
227.8	211	158.16	2.00	16.19	0.000
227.8	328	127.80	2.00	16.19	0.000
227.8	25453	8.95	2.00	16.19	12.384
227.8	25478	9.26	2.00	16.19	17.935
227.9	25525	9.68	2.00	16.19	24.955
228.7	2619	39.43	2.00	16.19	2.257
228.7	2619	39.43	2.00	16.19	0.000
228.8	1346	60.26	2.00	16.19	1.695
228.8	1346	60.26	2.00	16.19	0.000
228.8	1352	60.92	2.00	16.19	3.670
228.8	1367	61.58	2.00	16.19	6.061
228.8	1374	62.73	2.00	16.19	9.436
228.8	2589	41.82	2.00	16.19	7.947

Temperature (°C)	Apparent Shear Rate (sec ⁻¹)	Apparent Viscosity (Pa·s)	Die Diameter (mm)	Die L/D (-)	Exit Pressure (MPa)
228.8	2592	42.97	2.00	16.19	11.973
228.8	2600	40.55	2.00	16.19	4.999
228.8	6427	21.88	2.00	16.19	3.293
228.8	6427	21.88	2.00	16.19	0.000
228.8	6432	22.43	2.00	16.19	7.333
228.8	12719	13.77	2.00	16.19	4.362
228.8	12719	13.77	2.00	16.19	0.000
228.8	63622	4.73	2.00	16.19	0.000
229.7	12696	14.67	2.00	16.19	14.027
229.8	6440	23.08	2.00	16.19	11.125
229.8	6441	23.77	2.00	16.19	16.796
230.9	12693	15.32	2.00	16.19	21.601
198.0	232	247.32	2.00	4.01	0.000
198.0	303	235.01	2.00	4.01	0.000
198.0	12669	24.84	2.00	4.01	0.000
198.9	2594	66.91	2.00	4.01	0.000
198.9	63776	10.20	2.00	4.01	0.000
199.0	766	138.89	2.00	4.01	0.000
199.0	1356	98.69	2.00	4.01	0.000
199.0	25338	16.49	2.00	4.01	0.000
199.9	6462	37.65	2.00	4.01	0.000
209.0	297	206.60	2.00	4.01	0.000
209.0	778	120.49	2.00	4.01	0.000
209.6	12660	22.77	2.00	4.01	0.000
209.9	2606	59.80	2.00	4.01	0.000
209.9	63698	9.35	2.00	4.01	0.000
210.0	214	228.08	2.00	4.01	0.000
210.0	1350	88.26	2.00	4.01	0.000
210.0	25465	15.08	2.00	4.01	0.000
211.0	6387	34.72	2.00	4.01	0.000
218.9	1362	80.37	2.00	4.01	0.000
218.9	63739	8.61	2.00	4.01	0.000
219.0	207	207.98	2.00	4.01	0.000
219.0	314	175.02	2.00	4.01	0.000
219.0	782	108.06	2.00	4.01	0.000
219.0	25464	14.03	2.00	4.01	0.000
219.9	12699	21.19	2.00	4.01	0.000
220.0	2632	54.30	2.00	4.01	0.000
221.0	6408	32.10	2.00	4.01	0.000
228.0	1367	80.18	2.00	4.01	4.302
228.9	12696	21.49	2.00	4.01	9.649
228.9	25478	14.82	2.00	4.01	11.875
229.0	1352	78.83	2.00	4.01	1.960
229.0	2589	56.40	2.00	4.01	5.604
229.9	2619	50.67	2.00	4.01	0.127
229.9	2619	50.67	2.00	4.01	0.000
229.9	25453	14.05	2.00	4.01	6.644

229.9	25525	15.97	2.00	4.01	18.414
230.0	1346	74.19	2.00	4.01	0.000
230.0	1346	74.19	2.00	4.01	0.093
230.0	1374	82.83	2.00	4.01	7.609
Temperature (°C)	Apparent Shear Rate (sec ⁻¹)	Apparent Viscosity (Pa-s)	Die Diameter (mm)	Die L/D (-)	Exit Pressure (MPa)
230.0	2592	58.09	2.00	4.01	9.556
230.0	2600	54.24	2.00	4.01	2.736
230.0	6440	32.55	2.00	4.01	7.760
230.0	12664	20.91	2.00	4.01	5.283
230.0	12719	19.67	2.00	4.01	0.346
230.0	12719	19.67	2.00	4.01	0.000
230.0	25490	12.99	2.00	4.01	0.526
230.0	25490	12.99	2.00	4.01	0.000
231.0	328	149.00	2.00	4.01	0.000
231.0	749	102.05	2.00	4.01	0.000
231.0	6427	29.73	2.00	4.01	0.226
231.0	6427	29.73	2.00	4.01	0.000
231.0	6432	31.38	2.00	4.01	4.094
231.0	6441	34.41	2.00	4.01	13.239
231.0	63622	7.92	2.00	4.01	0.000
231.4	12693	23.39	2.00	4.01	16.834
232.0	211	181.30	2.00	4.01	0.000

Calculated Viscosity

Temperature (°C)	Shear Rate (sec ⁻¹)	Calculated Viscosity (Pa-s)	Exit Pressure (MPa)
196.8	232	203.28	0.000
197.7	25338	8.05	0.000
197.8	1356	67.60	0.000
197.8	303	173.88	0.000
197.8	766	98.85	0.000
198.0	232	201.19	0.000
198.0	303	173.61	0.000
198.0	12669	13.49	0.000
198.7	12669	13.44	0.000
198.7	63776	4.00	0.000
198.7	2594	42.76	0.000
198.7	6462	22.11	0.000
198.9	2594	42.72	0.000
198.9	63776	4.00	0.000
199.0	1356	67.12	0.000
199.0	25338	8.00	0.000
199.0	766	98.08	0.000
199.9	6462	21.98	0.000
207.8	214	192.60	0.000
207.8	63698	3.85	0.000
208.8	2606	40.45	0.000
208.8	297	160.98	0.000
208.8	778	91.24	0.000
208.8	12660	12.84	0.000
208.8	25465	7.63	0.000
208.8	1350	63.64	0.000
208.8	6387	21.25	0.000
209.0	297	160.74	0.000
209.0	778	91.13	0.000
209.6	12660	12.80	0.000
209.9	63698	3.81	0.000
209.9	2606	40.21	0.000
210.0	214	188.99	0.000
210.0	25465	7.59	0.000
210.0	1350	63.21	0.000
211.0	6387	21.03	0.000
217.7	63739	3.69	0.000
217.8	2632	38.42	0.000
217.8	6408	20.36	0.000
217.8	314	145.68	0.000
217.8	1362	60.18	0.000
217.8	207	179.47	0.000

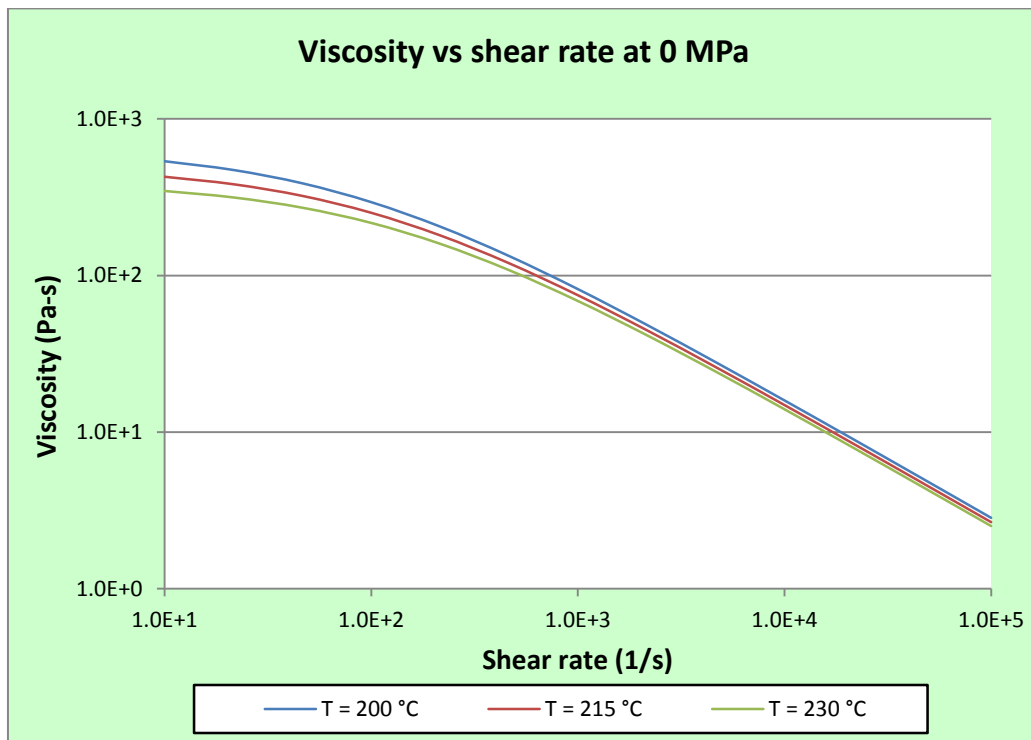
Temperature (°C)	Shear Rate (sec ⁻¹)	Calculated Viscosity (Pa-s)	Exit Pressure (MPa)
217.8	25464	7.35	0.000
217.8	782	86.00	0.000
218.8	12699	12.27	0.000
218.9	63739	3.68	0.000
218.9	1362	59.80	0.000
219.0	207	177.71	0.000
219.0	782	85.39	0.000
219.0	314	144.35	0.000
219.0	25464	7.31	0.000
219.9	12699	12.22	0.000
220.0	2632	38.00	0.000
221.0	6408	20.08	0.000
227.6	25490	7.06	0.000
227.6	25490	7.06	5.840
227.7	749	83.21	0.000
227.7	12664	11.86	9.533
227.8	328	132.34	0.000
227.8	211	163.98	0.000
227.8	25453	7.07	12.384
227.8	25478	7.06	17.935
227.9	25525	7.05	24.955
228.0	1367	56.88	4.302
228.7	2619	36.60	2.257
228.7	2619	36.60	0.000
228.8	1346	57.25	1.695
228.8	1346	57.25	0.000
228.8	1352	57.07	3.670
228.8	2600	36.78	4.999
228.8	12719	11.78	4.362
228.8	12719	11.78	0.000
228.8	1374	56.45	9.436
228.8	6427	19.38	3.293
228.8	6427	19.38	0.000
228.8	2592	36.85	11.973
228.8	1367	56.64	6.061
228.8	2589	36.88	7.947
228.8	6432	19.37	7.333
228.8	63622	3.54	0.000
228.9	12696	11.79	9.649
228.9	25478	7.03	11.875
229.0	1352	57.01	1.960
229.0	2589	36.85	5.604
229.7	12696	11.75	14.027
229.8	6440	19.28	11.125
229.8	6441	19.27	16.796

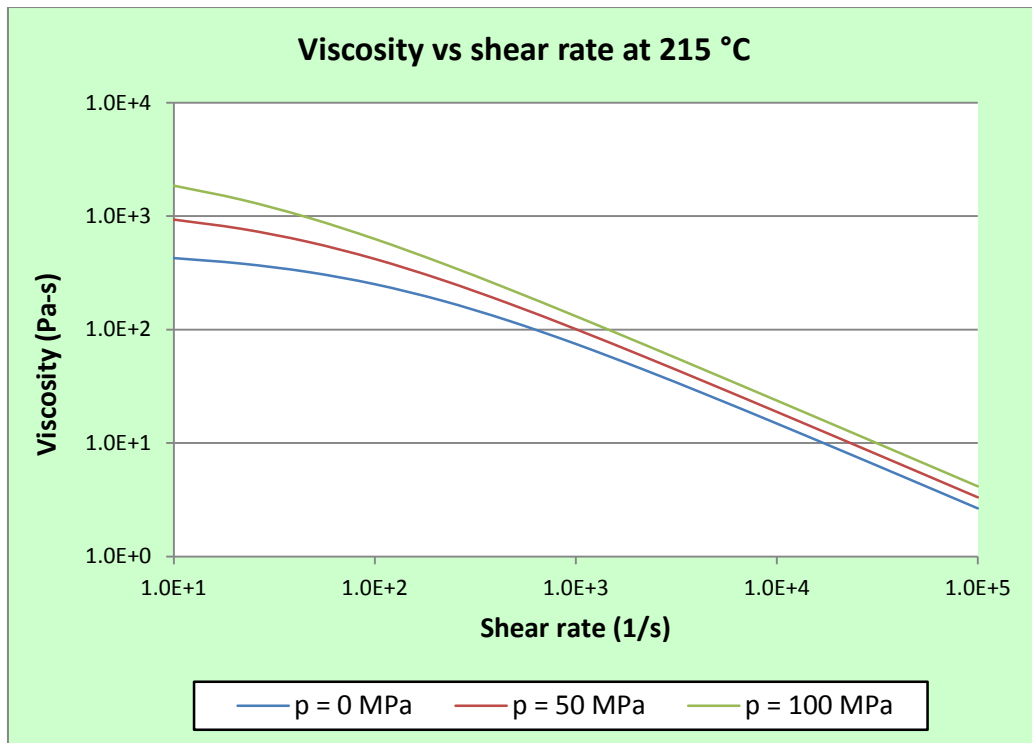
229.9	25453	7.01	6.644
229.9	2619	36.39	0.127
229.9	2619	36.39	0.000
Temperature (°C)	Shear Rate (sec ⁻¹)	Calculated Viscosity (Pa-s)	Exit Pressure (MPa)
229.9	25525	7.00	18.414
230.0	1346	56.89	0.000
230.0	1346	56.89	0.093
230.0	2592	36.65	9.556
230.0	25490	7.00	0.526
230.0	25490	7.00	0.000
230.0	1374	56.11	7.609
230.0	2600	36.57	2.736
230.0	12664	11.76	5.283
230.0	12719	11.72	0.346
230.0	12719	11.72	0.000
230.0	6440	19.26	7.760
230.9	12693	11.70	21.601
231.0	6441	19.18	13.239
231.0	749	81.65	0.000
231.0	6432	19.20	4.094
231.0	328	129.29	0.000
231.0	6427	19.21	0.226
231.0	6427	19.21	0.000
231.0	63622	3.52	0.000
231.4	12693	11.68	16.834
232.0	211	158.51	0.000

Rheological Data

Cross WLF Viscosity Model		
n	0.2413	
Tau	50578.8	Pa
D1	1.92443e+011	Pa-s
D2	263.15	K
D3	2.095e-007	K/Pa
A1	24.299	
A2	51.600	K

Juncture loss method coefficients		
C1	1.012e-005	Pa ^(1-c2)
C2	2.121	





Thermal conductivity

Method:

ISO 22007-2, Plastics - Determination of thermal conductivity and thermal diffusivity - Part 2: Transient plane heat source (hot disc) method

Instrument:

Hot Disk TPS 2500 S Thermal Constants Analyser

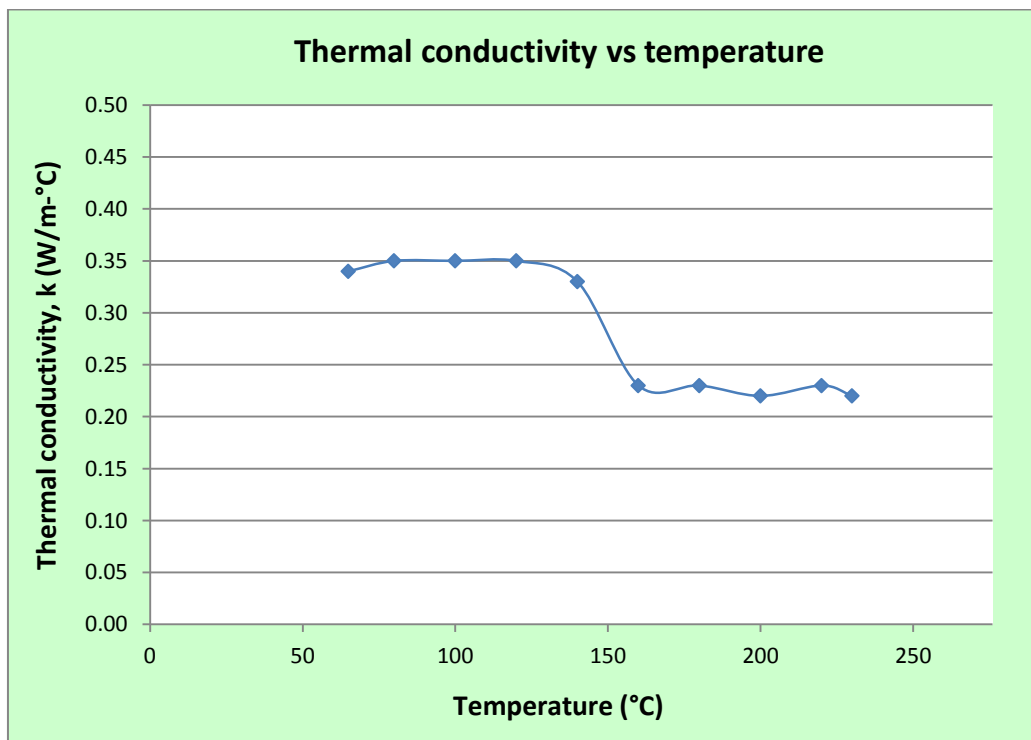
Test Specifications:

Sample Form:	19 mm disks (2) machined from molded plaque
Pre-Processing:	N/A
Moisture Level:	DAM (Dry As Molded)
Sensor Specification	Hot Disk 5465 3.189mm Kapton sensor
Measurement Time	10 sec
Heating Power	20 mW
Date Received:	20-JUN-19
Date Tested:	28-JUN-19

Operator's Notes:

Testing was performed per standard testing procedures.
No anomalies were noted during testing.

Thermal conductivity data		
Temperature (T) °C	Thermal conductivity (k) W/m-°C	Heating/Cooling rate °C/s
230.00	0.223	0.0
220.00	0.229	0.0
200.00	0.225	0.0
180.00	0.229	0.0
160.00	0.231	0.0
140.00	0.328	0.0
120.00	0.350	0.0
100.00	0.351	0.0
80.00	0.347	0.0
65.00	0.340	0.0



Specific heat

Method:

ASTM E 1269, Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry

ASTM D 3418, Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry

Instrument:

TA Instruments Discovery Differential Scanning Calorimeter

Test Specifications:

Sample Form:	Pellets
Pre-Processing:	Not required
Moisture Level:	Not measured
Initial Temperature:	230°C
Final Temperature:	20°C
Cooling Rate:	-20°C/min
Equilibrium Time:	3 min
Sample holder material:	Aluminum
Sample holder volume:	40 µl
Sample holder mass:	53 mg (pan+lid)
Purge gas:	99.99% pure nitrogen
Purge gas flow rate:	50 ml/min
Date Received:	20-JUN-19
Date Tested:	26-JUN-19

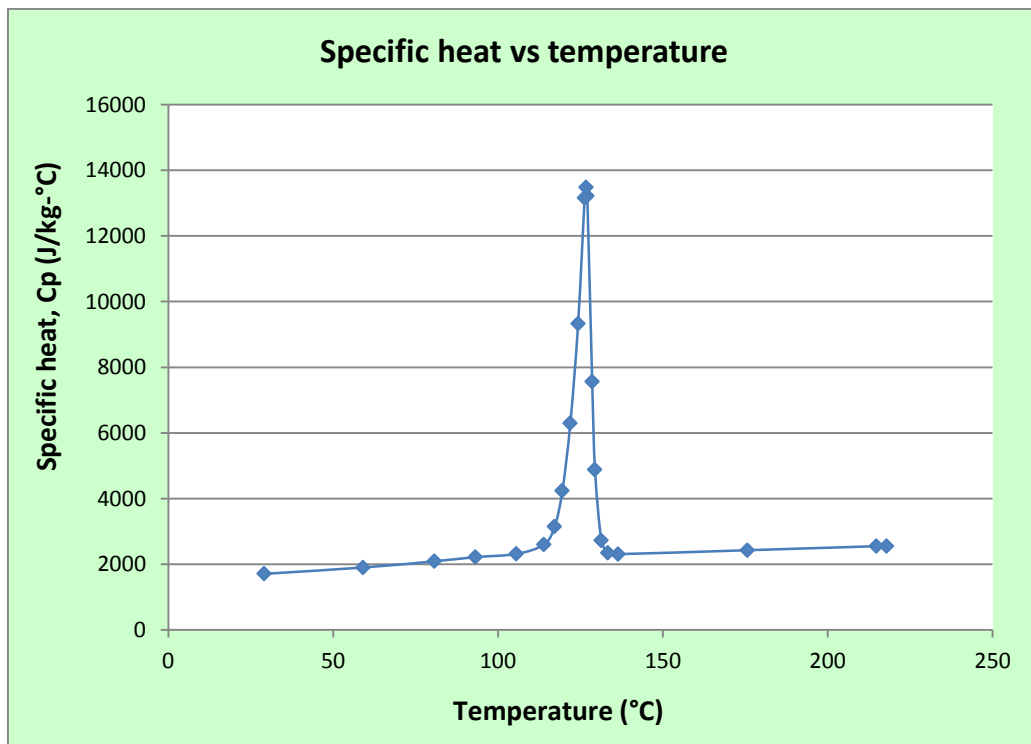
Operator's Notes:

Testing was performed per standard testing procedures.

No anomalies were noted during testing.

Specific heat data		
Temperature (T) °C	Specific heat (Cp) J/kg-°C	Heating/Cooling rate °C/s
217.91	2552.8	-0.33
214.83	2550.4	-0.33
175.65	2427.3	-0.33
136.46	2308.1	-0.33
133.37	2341.5	-0.33
131.33	2726.2	-0.33
129.4	4885.1	-0.33
128.55	7563.2	-0.33
127.06	13220.0	-0.33
126.72	13483.0	-0.33
126.27	13154.0	-0.33
124.28	9328.2	-0.33
121.93	6293.7	-0.33
119.5	4233.2	-0.33
117.16	3148.7	-0.33
113.89	2600.8	-0.33
105.56	2314.4	-0.33
93.152	2217.4	-0.33
80.745	2091.1	-0.33
59.052	1901.1	-0.33
29.136	1708.7	-0.33

Ttrans	130.00	°C
Ejection temperature	118.00	°C



Pressure-Volume-Temperature

Method:

High Pressure Indirect Dilatometry

Instrument:

Gnomix pvT Apparatus

Test Specifications:

Sample Form:	Molded Plaque
Pre-Processing:	Not required
Scan type:	Isothermal Cooling
Date Received:	20-JUN-19
Date Tested:	29-JUN-19

Operator's Notes:

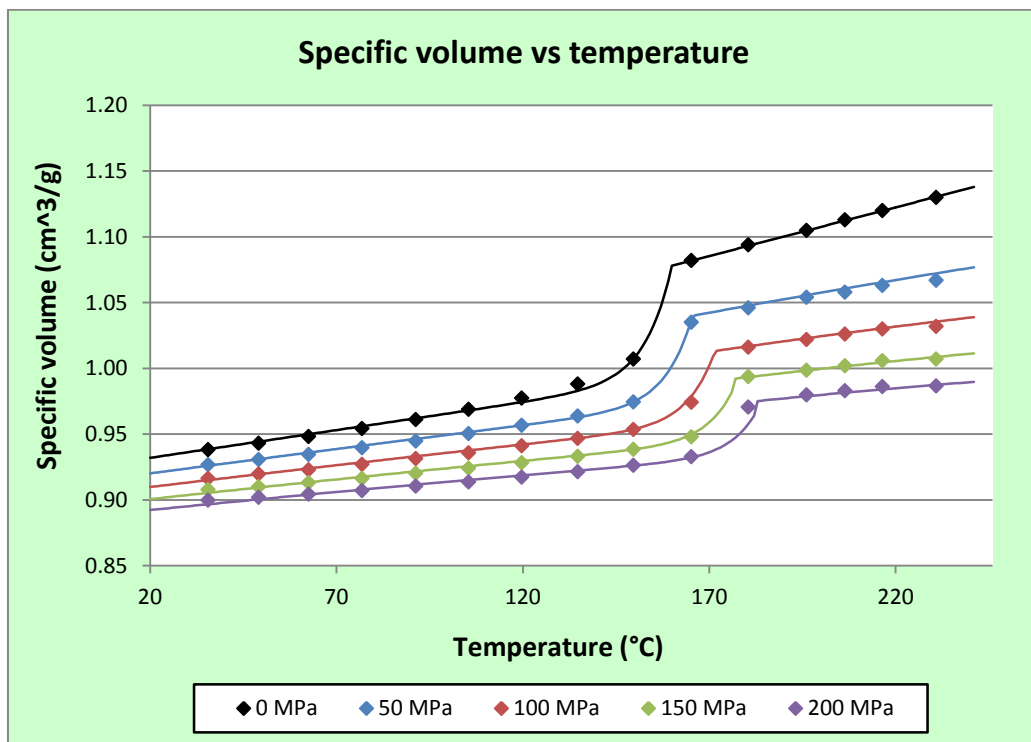
Testing was performed per standard testing procedures.
No anomalies were noted during testing.

pVT Experimental Data

Temperature (°C)	Pressure (MPa)				
	0MPa	50MPa	100MPa	150MPa	200MPa
35.61	0.9382	0.9268	0.9164	0.9077	0.8998
49.17	0.9430	0.9307	0.9197	0.9101	0.9019
62.60	0.9482	0.9346	0.9230	0.9131	0.9044
76.89	0.9543	0.9396	0.9271	0.9164	0.9072
91.30	0.9611	0.9447	0.9313	0.9202	0.9104
105.50	0.9688	0.9505	0.9358	0.9241	0.9137
119.70	0.9775	0.9568	0.9411	0.9283	0.9172
134.80	0.9881	0.9639	0.9468	0.9332	0.9214
149.70	1.0070	0.9746	0.9536	0.9386	0.9262
165.20	1.0820	1.0350	0.9742	0.9479	0.9328
180.50	1.0940	1.0460	1.0160	0.9938	0.9707
196.10	1.1050	1.0540	1.0220	0.9987	0.9799
206.40	1.1130	1.0580	1.0260	1.0020	0.9830
216.50	1.1200	1.0630	1.0300	1.0060	0.9863
230.90	1.1300	1.0670	1.0320	1.0070	0.9866

Melt density	0.8939	g/cm^3
Solid density	1.0708	g/cm^3

2-domain Tait PVT model coefficients		
b5	433.15	K
b6	1.105e-007	K/Pa
b1m	0.001078	m^3/kg
b2m	7.402e-007	$\text{m}^3/\text{kg-K}$
b3m	9.43917e+007	Pa
b4m	0.005444	1/K
b1s	0.000991	m^3/kg
b2s	4.217e-007	$\text{m}^3/\text{kg-K}$
b3s	1.93297e+008	Pa
b4s	0.003769	1/K
b7	0.000087	m^3/kg
b8	0.1386	1/K
b9	2.040e-008	1/Pa



Shrinkage

Method:

AMPL Shrinkage Test Method (QOP-17-M)

Instrument:

Krauss Maffei KM160-750CX Injection molding machine
 Test mold inscribed with a fine grid pattern
 Temperature and Humidity Controlled Room
 OGP Smartscope Flash 400 metrology system

Test Specifications:

Sample Form:	Pellets
Pre-Processing:	Not required
Moisture Level:	Not measured
Date Molded:	26-JUN-19
Post-Processing:	Conditioned at 23°C / 50% relative humidity for 7 days
Date Measured:	03-JUL-19
Shrinkage Data Correlated With:	Moldflow Insight 2018 Revision 2
Default Shrinkage Model:	Residual Stress (CRIMS)
Date Received:	20-JUN-19

Operator's Notes:

Testing was performed per standard testing procedures.

No anomalies were noted during testing.

Shrinkage measurements have been corrected to account for mold thermal expansion.

Data for some process conditions may have been removed in the determination of the favored model.

Shrinkage Experimental Data

Process Condition	Melt Temperature (°C)	Mold Temperature (°C)	Flow Rate (cc/sec)	Part Thickness (mm)	Packing Pressure (MPa)	Packing Time (sec)	Cooling Time (sec)
1	200.5	45.2	36.3	2	57.4	12	10
2	200.5	46.5	36.3	2	67.1	12	10
3	200.7	47.6	35.3	2	76.9	12	10
4	200.8	46.5	18.4	2	66.8	12	10
5	200.9	45.4	57.7	2	67.2	12	10
6	215.3	46.2	36.3	2	47.6	12	10
7	216.4	46.7	35.3	2	57.4	12	10
8	216.0	44.5	35.3	2	47.6	12	10
9	215.7	44.8	37.4	2	67.2	12	10
10	215.7	45.6	18.7	2	57.1	12	10
11	232.7	45.6	36.3	2	37.8	12	10
12	232.3	44.7	36.3	2	47.5	12	10
13	231.3	45.5	35.3	2	57.4	12	10
14	231.1	46.4	19.0	2	47.4	12	10
15	231.1	46.2	57.7	2	47.6	12	10
16	215.8	45.6	18.6	1	77.2	6	10
17	216.1	46.4	19.1	1	86.9	6	10
18	215.8	47.1	19.1	1	96.7	6	10
19	215.6	45.6	9.3	1	86.8	6	10
20	215.3	44.9	34.2	1	87.1	6	10
21	215.3	45.8	40.0	3	28.2	20	10
22	215.7	45.1	40.0	3	37.8	20	10
23	215.1	44.3	42.7	3	47.6	20	10
24	215.0	45.3	22.9	3	37.7	20	10
25	214.8	46.2	62.0	3	37.9	20	10

Part Shrinkage

Process	Condition	Average Measured Parallel	Average Measured Perpendicular	Average Predicted Volumetric
1		1.132%	1.366%	3.330%
2		1.042%	1.268%	2.942%
3		0.944%	1.161%	2.533%
4		1.077%	1.275%	2.950%
5		1.015%	1.214%	2.871%
6		1.205%	1.470%	3.691%
7		1.121%	1.384%	3.271%
8		1.023%	1.258%	3.700%
9		1.148%	1.377%	2.863%
10		1.101%	1.365%	3.277%
11		1.274%	1.589%	4.148%
12		1.203%	1.459%	3.634%
13		1.103%	1.368%	3.202%
14		1.222%	1.478%	3.617%
15		1.188%	1.465%	3.640%
16		1.148%	1.234%	4.842%
17		1.053%	1.091%	4.706%
18		0.968%	1.039%	4.316%
19		1.277%	1.197%	3.835%
20		0.957%	1.093%	4.815%
21		1.326%	1.716%	3.784%
22		1.242%	1.560%	3.337%
23		1.151%	1.406%	2.914%
24		1.260%	1.534%	3.418%
25		1.240%	1.570%	3.294%

Residual Stress Coefficients

Corrected residual in-mold stress (CRIMS) model coefficients	
A1	0.821895
A2	-0.275259
A3	0.006642
A4	0.996947
A5	-0.5000
A6	0.008242

Residual Strain Coefficients

Parallel				
	Coefficient	Lower Limit	Upper Limit	Centroid
1	0.10043	0.019946	0.066435	0.035457
2	-0.001345	0.014807	0.76018	0.40704
3	-0.000533	4.5871	23.895	12.064
4	1.0643e-007	5466.40	61570.00	24228.00
5	0.012145	0	0	0

Perpendicular				
	Coefficient	Lower Limit	Upper Limit	Centroid
1	0.085097	0.019946	0.066435	0.035573
2	0.001966	0.014807	0.76018	0.39196
3	-0.00022	4.5871	25.959	12.582
4	-1.1207e-007	2049.80	7494.50	4032.30
5	0.013003	0	0	0

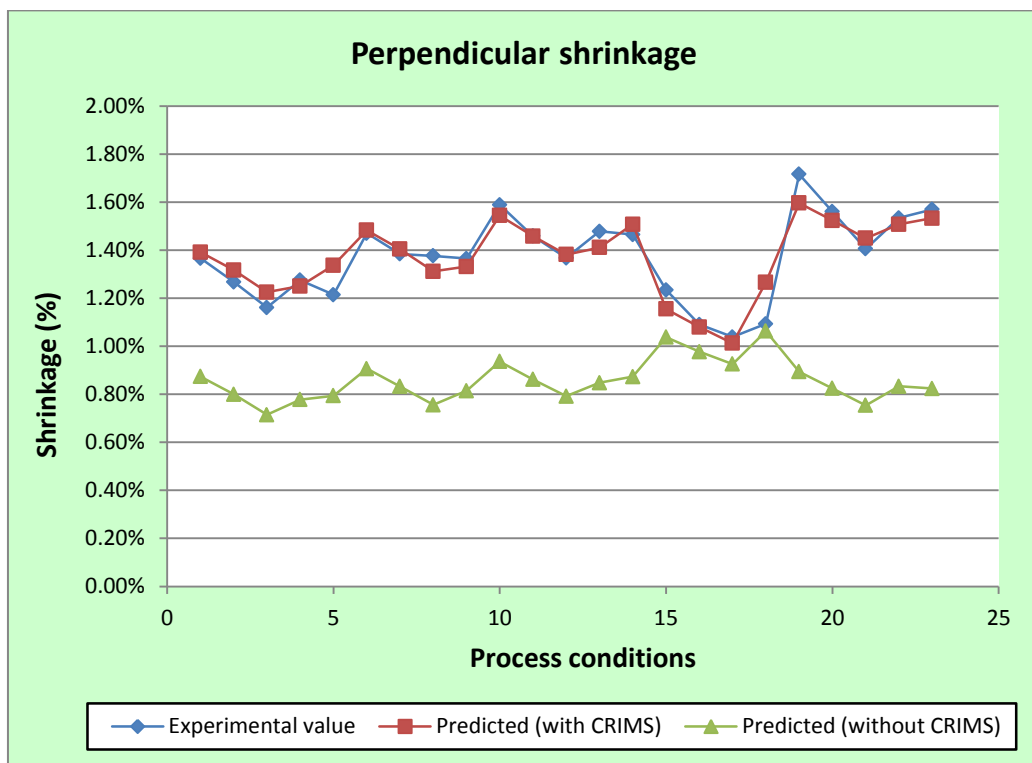
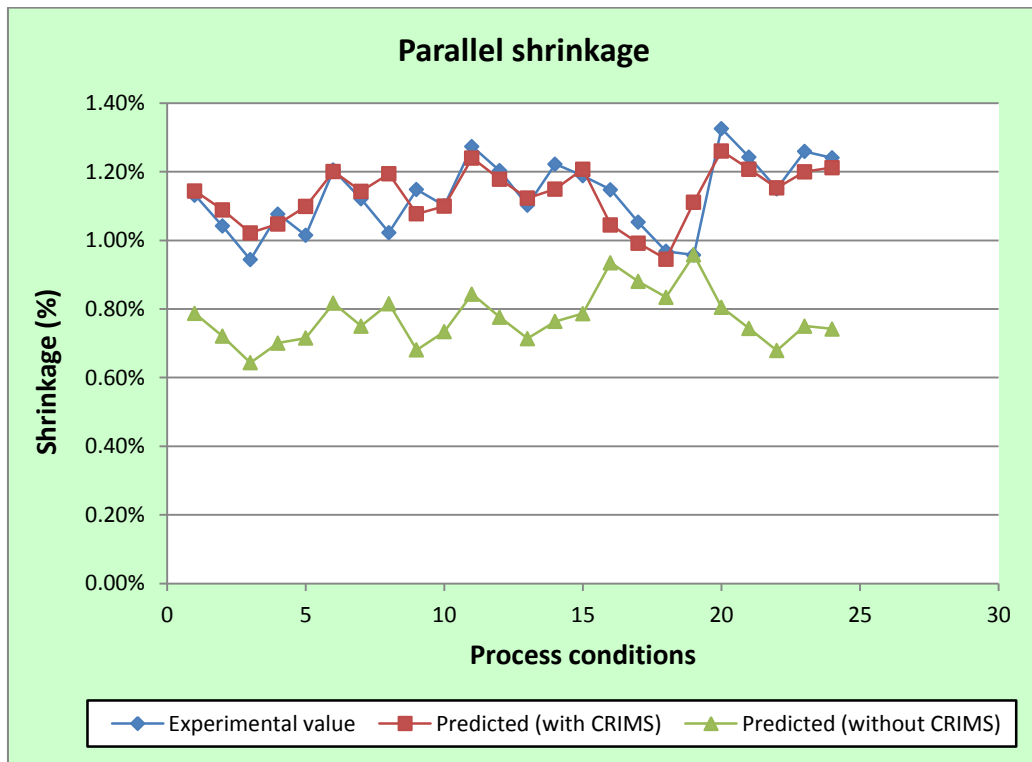
The shrinkage models shown above are valid for Autodesk Moldflow Insight 2018 Revision 2 and later. Shrinkage models for previous software versions are included in the 21000.udb file.

Observed Shrinkage

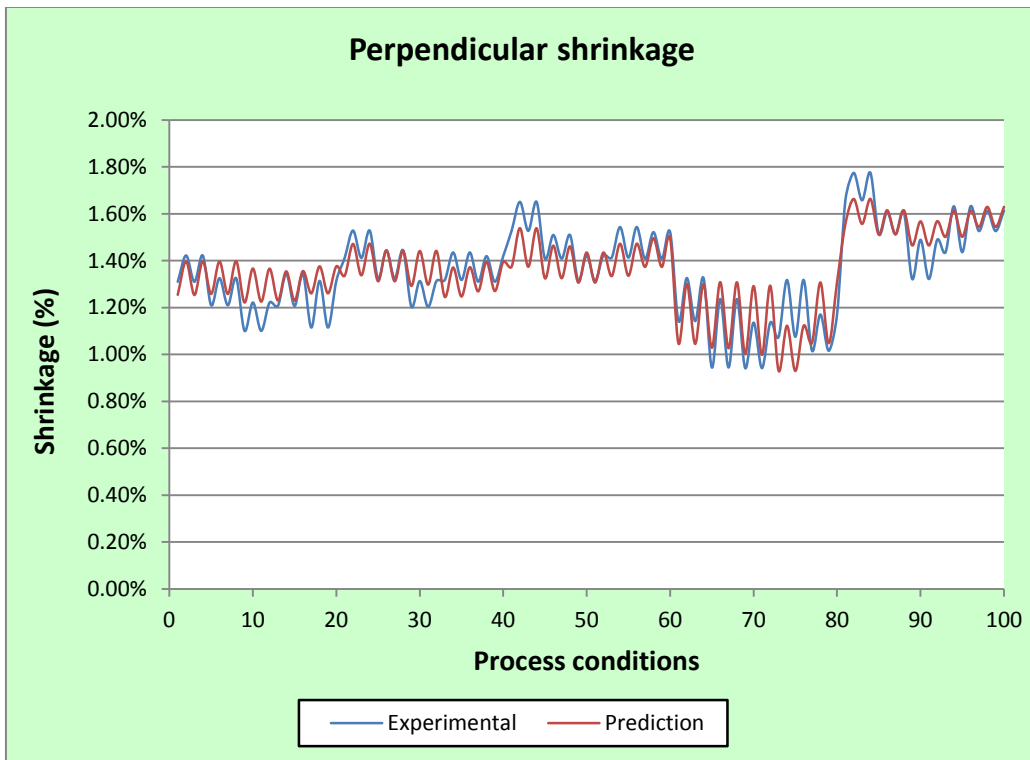
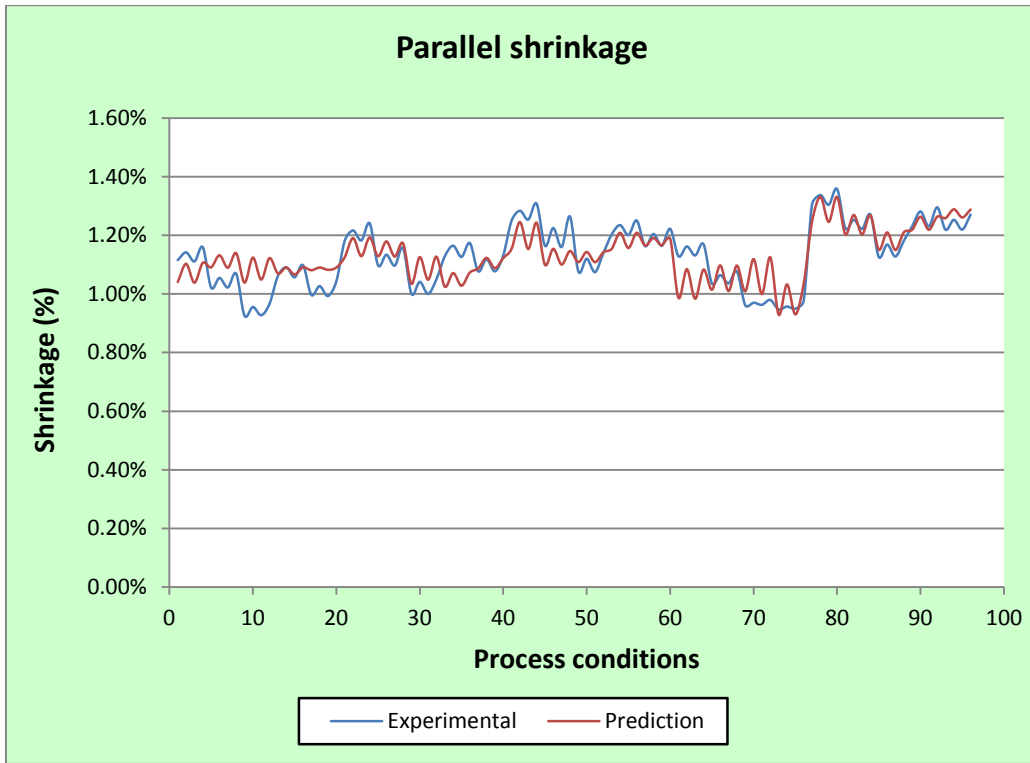
Observed nominal shrinkage	
Parallel	1.137%
Perpendicular	1.358%

Observed shrinkage	
Minimum Parallel	0.944%
Maximum Parallel	1.326%
Minimum Perpendicular	1.039%
Maximum Perpendicular	1.716%

Residual Stress Plots



Residual Strain Plots



Mechanical

Elastic modulus and Poisson's ratio

Method:

ASTM D 638, Standard Test Method for Tensile Properties of Plastics
 ASTM E 132, Standard Test Method for Poisson's Ratio at Room Temperature

Instrument:

MTS Sintech 5/G Universal Testing Machine

Test Specifications:

Specimens Tested:	8 (per direction)
Pre-Processing:	23°C +/-2°C at 50% +/-5% relative humidity for a minimum of 40 hours
Sample Form:	Machined from molded plaques
Test Speed:	5 mm/min
Date Received:	20-JUN-19
Date Tested:	15-JUL-19

Operator's Notes:

Testing was performed per standard testing procedures.

Inconsistent results seen for V23. V23 made equal to V12 for isotropic behavior.

Elastic modulus		
Elastic modulus, 1 st principal direction [E1]	1798.50	MPa
Elastic modulus, 2 nd principal direction [E2]	1820.38	MPa

Poisson's ratio		
Poisson's ratio [v12]	0.4430	
Poisson's ratio [v23]	0.4430	

Shear modulus

Method:

ASTM D 638, Standard Test Method for Tensile Properties of Plastics

Instrument:

MTS Sintech 5/G Universal Testing Machine

Test Specifications:

Specimens Tested:	8
Pre-Processing:	23°C +/-2°C at 50% +/-5% relative humidity for a minimum of 40 hours
Sample Form:	Machined from molded plaques
Test Speed:	5 mm/min
Date Received:	20-JUN-19
Date Tested:	15-JUL-19

Operator's Notes:

Shear modulus is calculated using orthotropic elasticity from the tensile modulus measured on a sample cut at an angle of 45° with the flow direction.

Testing was performed per standard testing procedures.

No anomalies were noted during testing.

Shear modulus		
Shear modulus [G12]	624.800	MPa

Nonlinear Mechanical Model

Method:

ASTM D 638, Standard Test Method for Tensile Properties of Plastics

Instrument:

MTS Sintech 5/G Universal Testing Machine

Test Specifications:

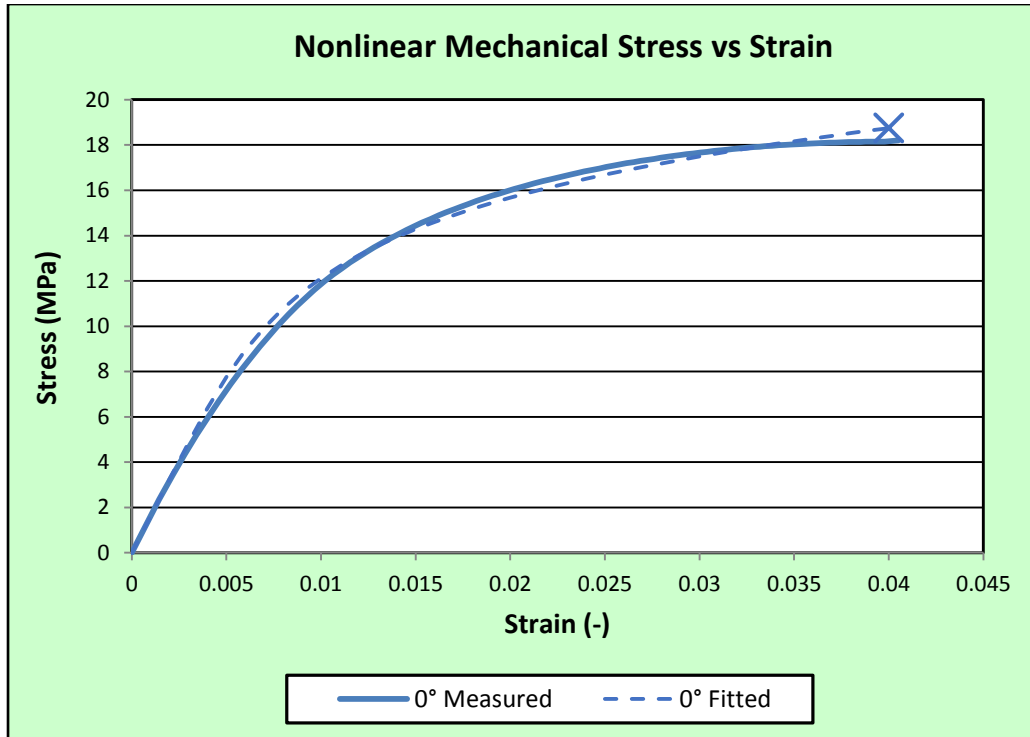
Specimens Tested:	8 (per direction)
Pre-Processing:	23°C +/-2°C at 50% +/-5% relative humidity for a minimum of 40 hours
Sample Form:	Machined from molded plaques
Test Speed:	5 mm/min
Date Received:	20-JUN-19
Date Tested:	15-JUL-19

Operator's Notes:

Testing was performed per standard testing procedures.
No anomalies were noted during testing.

Ramberg Osgood Parameter (Tension)		
Sigma Zero	15.7319	MPa
n	5.8997	
Alpha	1	
Beta	1	
Eig	0	
Matrix Modulus	1628.75	MPa
Matrix Poisson's Ratio	0.443	
Fiber Modulus	0	MPa
Fiber Poisson's Ratio	0	
Maximum Von Mises matrix Stress at failure	18.7990	MPa
A1	0	1/MPa ²
A2	0	1/MPa ²
A4	0	1/MPa ²
Temperature	23.0	C
Relative Humidity	50.0	%
Strain Rate	0.000833	1/s

The nonlinear mechanical data are derived from RO Library Version 2.



Coefficient of linear thermal expansion

Method:

QOP-11, Coefficient of Linear Thermal Expansion of Plastics

Instrument:

Quartz tube dilatometer per ASTM

Test Specifications:

Specimens Tested:	2 (per direction): test repeated 2 times per specimen
Pre-Processing:	23°C +/-2°C at 50% +/-5% relative humidity for a minimum of 40 hours
Sample Form:	Machined from molded plaques
Specimen Geometry:	Rectangular, 8mm x 50mm, full thickness
Temperature Range:	0°C to 60°C
Date Received:	20-JUN-19
Date Tested:	03-JUL-19

Operator's Notes:

Testing was performed per standard testing procedures.
No anomalies were noted during testing.

Transversely isotropic coefficient of thermal expansion [CTE] data		
Alpha 1	1.090e-004	1/°C
Alpha 2	1.210e-004	1/°C

Mold verification

Method:

AMPL Mold Verification Test Method (QOP-16-M)

Instrument:

Krauss Maffei KM160-750CX Injection molding machine

Test Specifications:

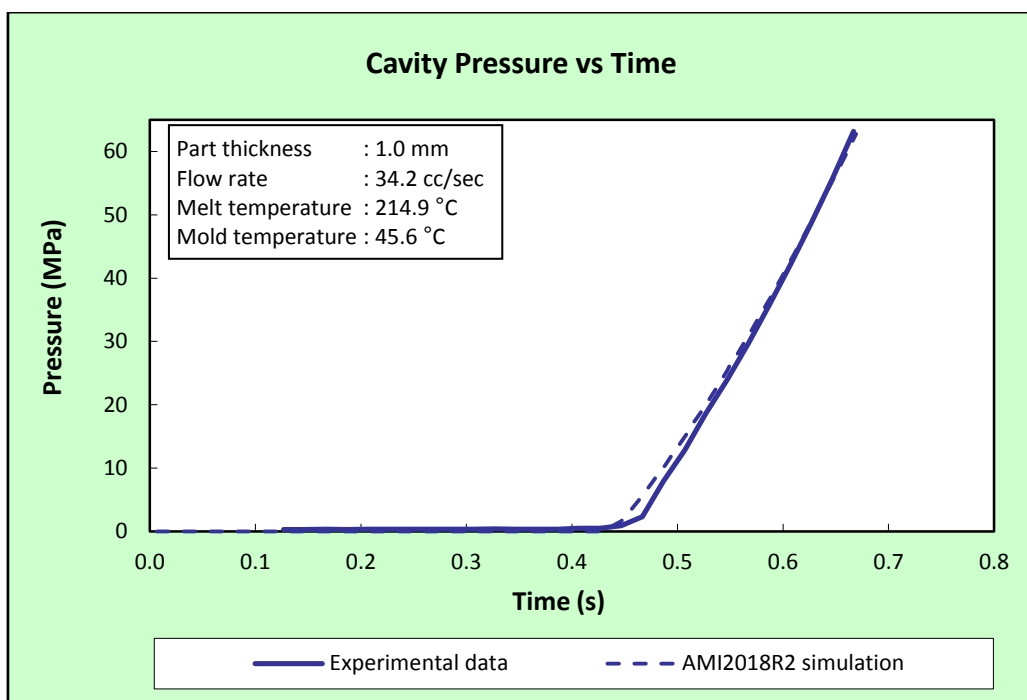
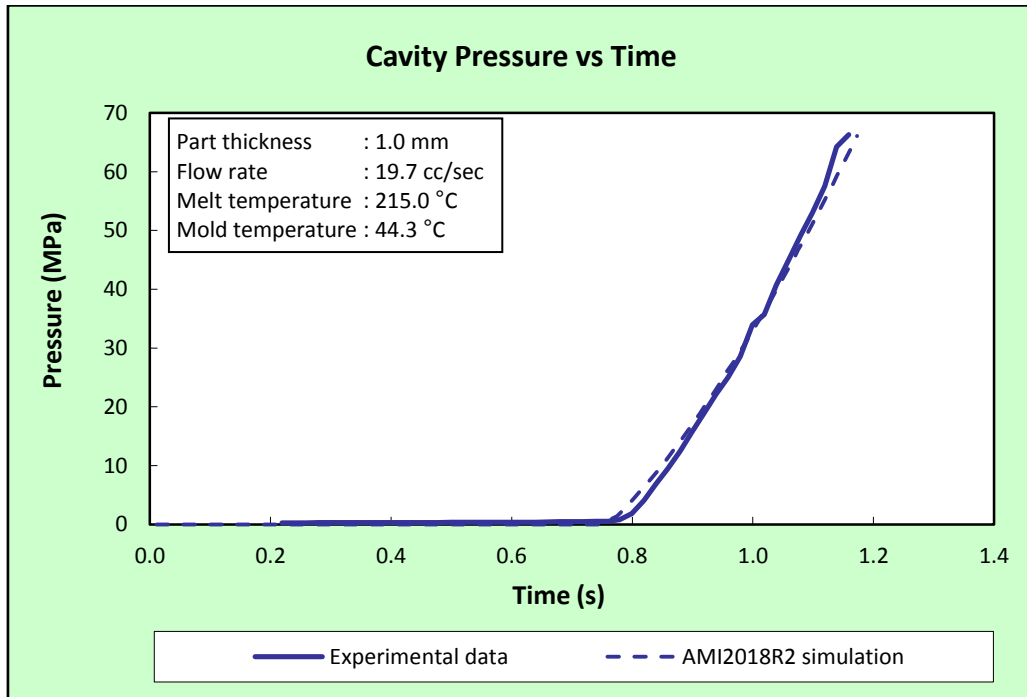
Sample Form:	Pellets
Pre-Processing:	Not required
Moisture Level:	Not measured
Date Received:	20-JUN-19
Date Tested:	26-JUN-19

Operator's Notes:

Testing was performed per standard testing procedures.
No anomalies were noted during testing.

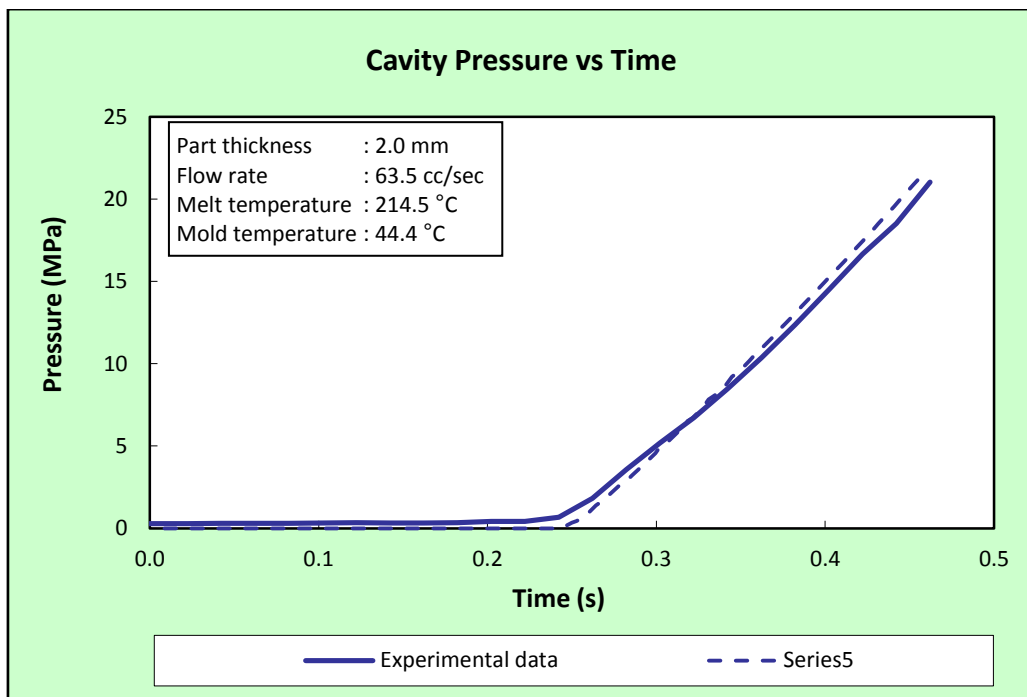
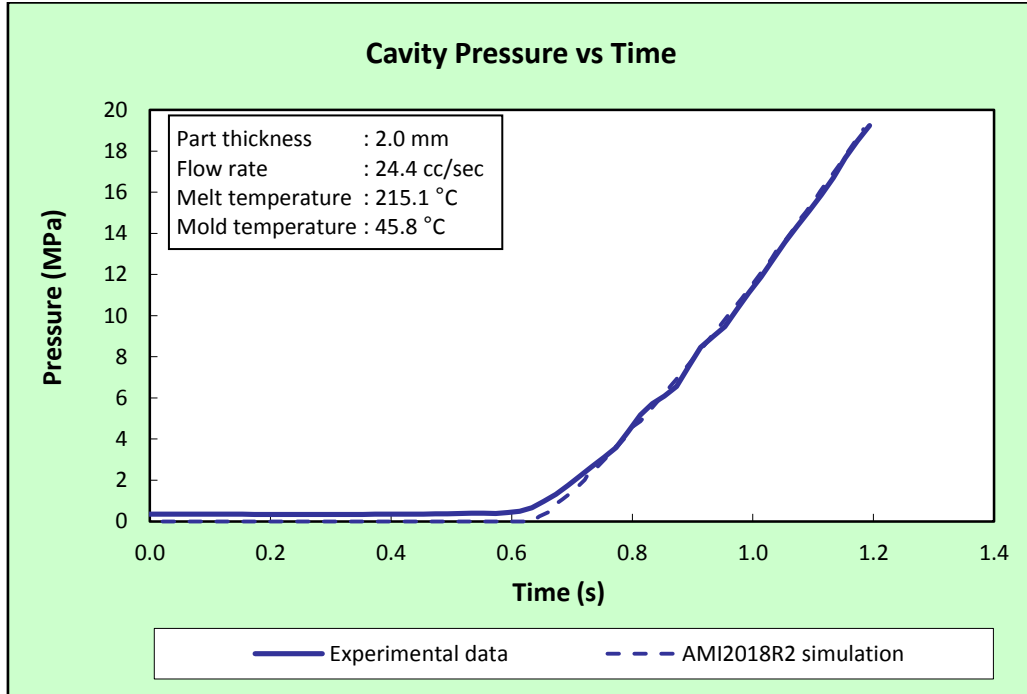
1mm tag die

Experiment Number	Flow Rate (cc/sec)	Melt Temperature	Mold Temperature
Cyc0149	19.7	215	44.3
Cyc0155	34.2	214.9	45.6



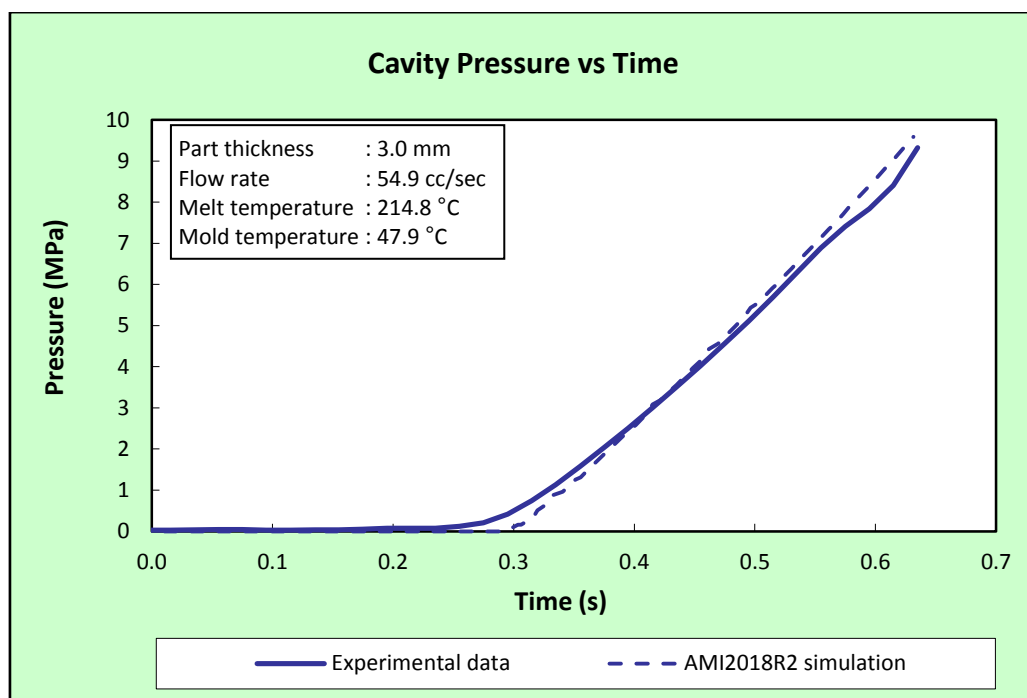
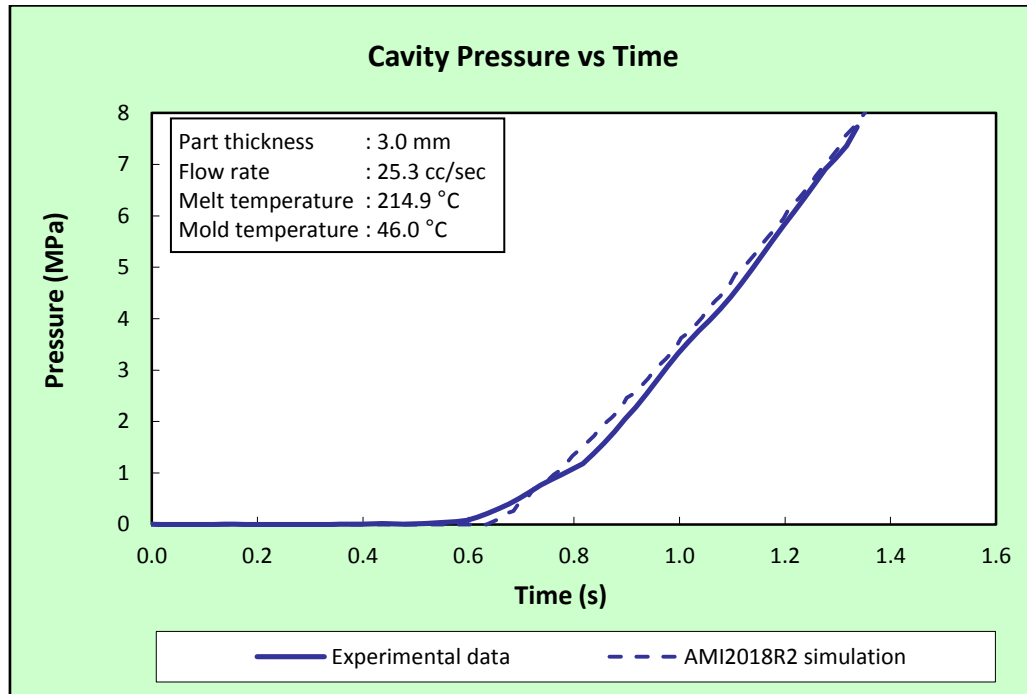
2mm tag die

Experiment Number	Flow Rate (cc/sec)	Melt Temperature	Mold Temperature
Cyc0049	24.4	215.1	45.8
Cyc0061	63.5	214.5	44.4



3mm tag die

Experiment Number	Flow Rate (cc/sec)	Melt Temperature	Mold Temperature
Cyc0195	25.3	214.9	46
Cyc0201	54.9	214.8	47.9



Contact details

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