

Material Testing Report

Material-3940
Bio
CLC_F200

Prepared for: YUDO

Measured by: Material Testing Lab, CoreTech System

Date reported : 23-Dec-22

Authorized by: F. C. Liu

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Parameter Summary

Viscosity

| Model | Parameter | Value | Unit |
|--------------------------|-----------|------------|------|
| Modified Cross Model (3) | n | 1.0000E-01 | - |
| | Taus | 6.6887E+05 | Pa |
| | D1 | 1.1544E+10 | Pa*s |
| | D2 | 3.3315E+02 | K |
| | D3 | 0.0000E+00 | K/Pa |
| | A1 | 2.5100E+01 | - |
| | A2 | 5.1600E+01 | K |

Pressure – Volume – Temperature

| Model | Parameter | Value | Unit |
|-------------------------|-----------|------------|------------------------|
| Modified Tait Model (2) | b1L | 7.4200E-04 | m ³ /Kg |
| | b2L | 3.4296E-07 | m ³ /(Kg.K) |
| | b3L | 3.0519E+08 | Pa |
| | b4L | 3.4999E-03 | 1/K |
| | b1S | 7.4187E-04 | m ³ /Kg |
| | b2S | 1.0240E-07 | m ³ /(Kg.K) |
| | b3S | 3.9092E+08 | Pa |
| | b4S | 4.8230E-03 | 1/K |
| | b5 | 3.3250E+02 | K |
| | b6 | 1.1667E-07 | K/Pa |
| | b7 | 0.0000E+00 | m ³ /Kg |
| | b8 | 0.0000E+00 | 1/K |
| | b9 | 0.0000E+00 | 1/Pa |

Specific Heat

| Model | Temperature, °C | Value, J/kg °C |
|----------------|-----------------|----------------|
| Tabulated Data | 2 | 1052 |
| | 10 | 1078 |
| | 30 | 1159 |
| | 40 | 1213 |
| | 50 | 1319 |
| | 58 | 1498 |
| | 62 | 1548 |
| | 80 | 1601 |
| | 92 | 1636 |
| | 110 | 1669 |
| | 130 | 1709 |
| | 150 | 1746 |
| | 160 | 1767 |
| | 170 | 1790 |
| 182 | 1790 | |

Thermal conductivity

| Model | Temperature, °C | Value, W/m °C |
|----------------|-----------------|---------------|
| Tabulated Data | 60 | 0.311 |
| | 80 | 0.315 |
| | 100 | 0.319 |
| | 120 | 0.295 |
| | 140 | 0.297 |
| | 160 | 0.308 |
| | 180 | 0.304 |

Material description

Family: Bio
Filler: none
Grade Name: CLC_F200
Supplier: AROUNDBLUE
Date received: 5-Dec-22

| Recommended processing condition | |
|----------------------------------|--------------|
| Drying condition | 100°C,4hours |
| Melt temperature | 215-230°C* |
| Mold temperature | 40°C* |
| Ejection temperature | 59°C** |

* from datasheet provided by supplier,

** from thermal properties of DSC measurement

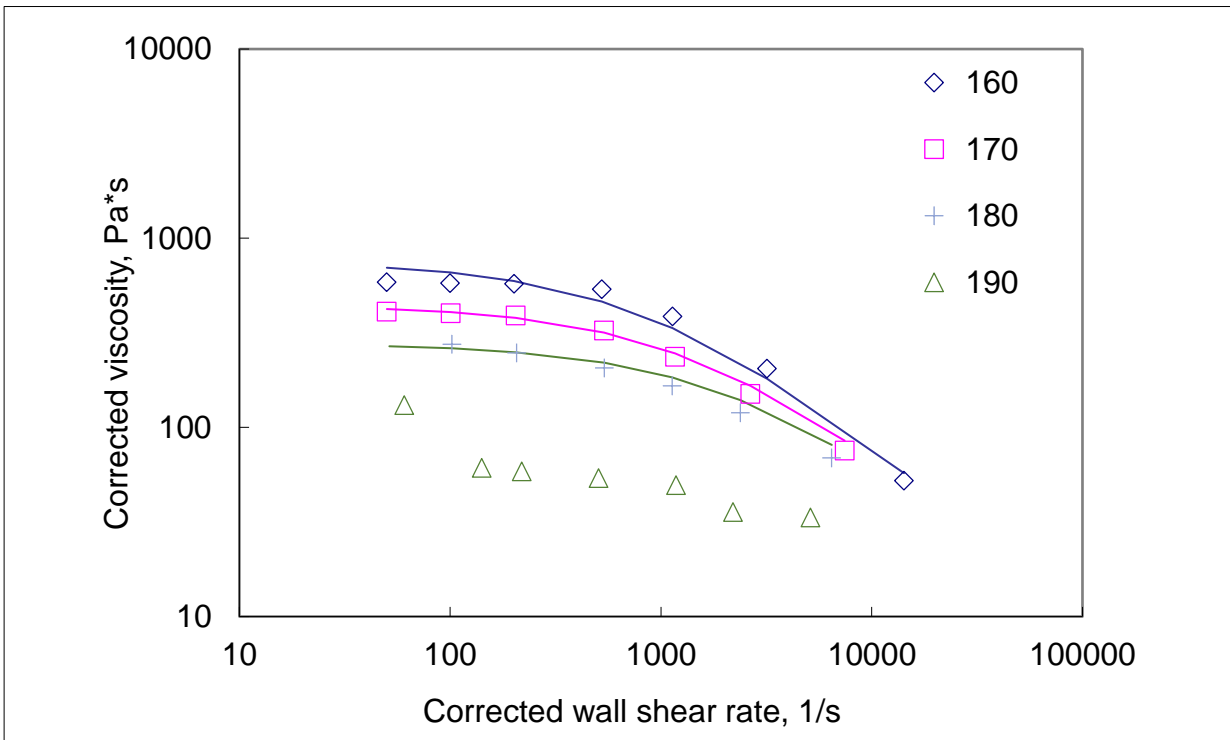
Viscosity

| | |
|------------------------------------|---|
| Purpose | Capillary rheometer measures viscosity-shear rate relationship of material at specific temperature. |
| Instrument | Capillary rheometer, GOTTFERT RG25 |
| Procedure | ASTM D3835 <i>Pressure drop across the die is measured for each flow rate, and viscosity-shear rate data are calculated.</i> |
| Sample drying condition | 100°C,4hours |
| Moisture level after drying | 0.86% |
| Sample shape | Pellet |

| | |
|---|--------------|
| Capillary rheometer specifications | |
| Die length | 30 mm |
| Die diameter | 1 mm |
| Die entry angle | 90 degrees |
| Barrel diameter | 15 mm |
| Corrections | Rabinowitsch |

Raw Data

| Temperature, °C | Apparent shear rate, s-1 | Apparent viscosity, Pa*s | Corrected shear rate, s-1 | Corrected viscosity, Pa*s |
|-----------------|--------------------------|--------------------------|---------------------------|---------------------------|
| 160 | 5.00E+01 | 5.89E+02 | 5.01E+01 | 5.88E+02 |
| | 1.00E+02 | 5.81E+02 | 1.00E+02 | 5.81E+02 |
| | 2.00E+02 | 5.79E+02 | 2.01E+02 | 5.76E+02 |
| | 5.00E+02 | 5.65E+02 | 5.24E+02 | 5.39E+02 |
| | 1.00E+03 | 4.40E+02 | 1.14E+03 | 3.87E+02 |
| | 2.00E+03 | 3.27E+02 | 3.19E+03 | 2.05E+02 |
| | 5.00E+03 | 1.49E+02 | 1.42E+04 | 5.25E+01 |
| 170 | 5.00E+01 | 4.11E+02 | 5.01E+01 | 4.10E+02 |
| | 1.00E+02 | 4.05E+02 | 1.00E+02 | 4.03E+02 |
| | 2.00E+02 | 3.99E+02 | 2.04E+02 | 3.91E+02 |
| | 5.00E+02 | 3.49E+02 | 5.37E+02 | 3.25E+02 |
| | 1.00E+03 | 2.77E+02 | 1.17E+03 | 2.37E+02 |
| | 2.00E+03 | 2.00E+02 | 2.65E+03 | 1.51E+02 |
| | 5.00E+03 | 1.12E+02 | 7.44E+03 | 7.56E+01 |
| 180 | 5.00E+01 | 3.20E+02 | 5.15E+01 | 3.11E+02 |
| | 1.00E+02 | 2.81E+02 | 1.02E+02 | 2.76E+02 |
| | 2.00E+02 | 2.57E+02 | 2.06E+02 | 2.49E+02 |
| | 5.00E+02 | 2.23E+02 | 5.40E+02 | 2.07E+02 |
| | 1.00E+03 | 1.88E+02 | 1.13E+03 | 1.66E+02 |
| | 2.00E+03 | 1.42E+02 | 2.38E+03 | 1.20E+02 |
| | 5.00E+03 | 8.93E+01 | 6.47E+03 | 6.90E+01 |
| 190 | 5.00E+01 | 5.00E+01 | 5.00E+01 | 5.00E+01 |
| | 1.00E+02 | 1.00E+02 | 1.00E+02 | 1.00E+02 |
| | 2.00E+02 | 2.00E+02 | 2.00E+02 | 2.00E+02 |
| | 5.00E+02 | 5.00E+02 | 5.00E+02 | 5.00E+02 |
| | 1.00E+03 | 1.00E+03 | 1.00E+03 | 1.00E+03 |
| | 2.00E+03 | 2.00E+03 | 2.00E+03 | 2.00E+03 |
| | 5.00E+03 | 5.00E+03 | 5.00E+03 | 5.00E+03 |

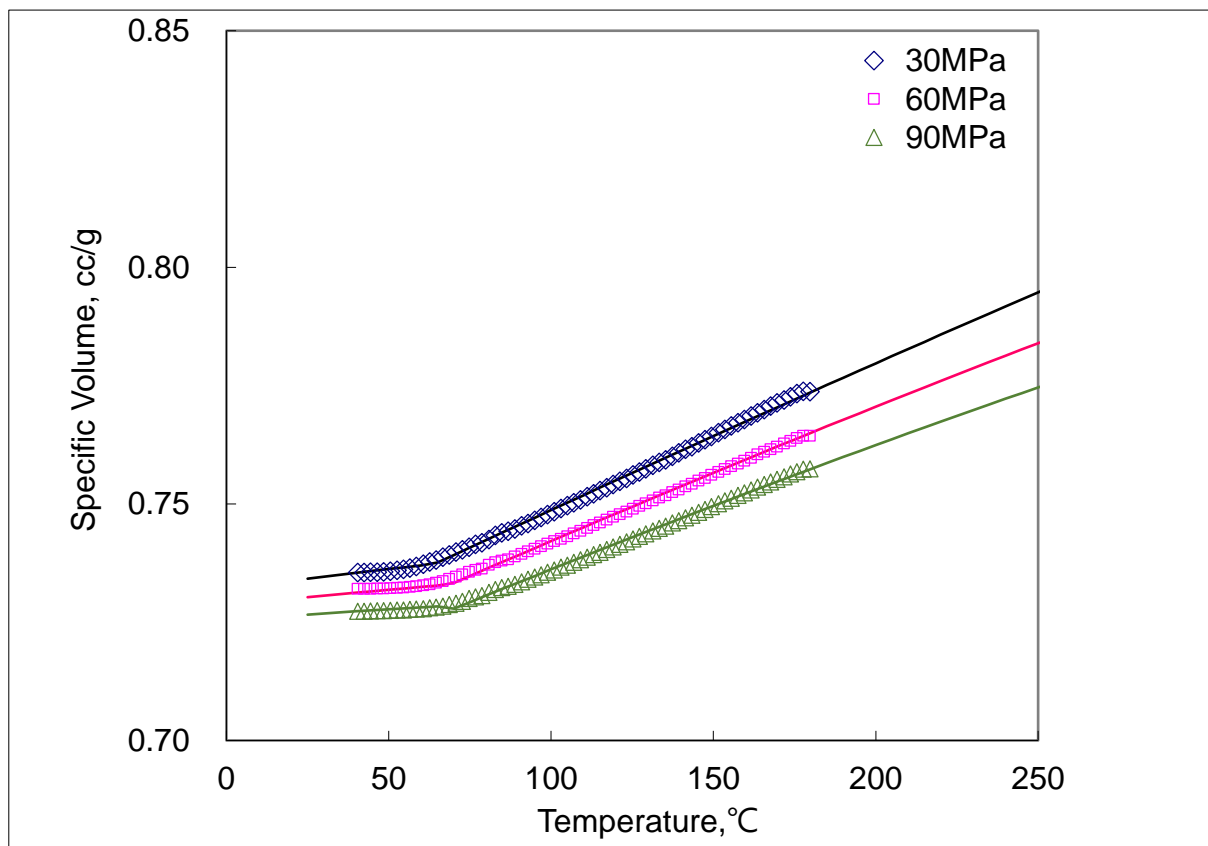


Dot: measurement data

Line: model predictions using parameters provided

Pressure-Volume-Temperature

| | |
|------------------------------------|--|
| Purpose | PVT describe volume change at different pressure and temperature of cooling process. |
| Instrument | GOTECH PVT6000 (piston type) |
| Procedure | ISO 17744, isobaric cooling 5°C/min <i>The machine is heated to the processing temperature, keeping in fixed pressure, then cooling to 40oC at constant rate of 5 oC/min. Measure the volume change at least 3 different pressures.</i> |
| Sample drying condition | 100°C,4hours |
| Moisture level after drying | 0.86% |
| Sample shape | Pellet |



Dot: measurement data

Line: model predictions using parameters provided

Raw Data

| Temperature, °C | Specific volume, cc/g | | |
|-----------------|-----------------------|--------|--------|
| | 30 MPa | 60 MPa | 90 Mpa |
| 180 | 0.7738 | 0.7644 | 0.7575 |
| 178 | 0.7738 | 0.7644 | 0.7573 |
| 176 | 0.7733 | 0.7639 | 0.7568 |
| 174 | 0.7727 | 0.7633 | 0.7563 |
| 172 | 0.7720 | 0.7628 | 0.7558 |
| 170 | 0.7713 | 0.7621 | 0.7552 |
| 168 | 0.7707 | 0.7616 | 0.7546 |
| 166 | 0.7700 | 0.7610 | 0.7541 |
| 164 | 0.7693 | 0.7604 | 0.7535 |
| 162 | 0.7686 | 0.7598 | 0.7530 |
| 160 | 0.7678 | 0.7591 | 0.7524 |
| 158 | 0.7671 | 0.7585 | 0.7518 |
| 156 | 0.7665 | 0.7580 | 0.7512 |
| 154 | 0.7658 | 0.7573 | 0.7507 |
| 152 | 0.7650 | 0.7567 | 0.7500 |
| 149 | 0.7643 | 0.7561 | 0.7494 |
| 147 | 0.7636 | 0.7555 | 0.7488 |
| 145 | 0.7629 | 0.7549 | 0.7482 |
| 143 | 0.7621 | 0.7542 | 0.7476 |
| 141 | 0.7616 | 0.7537 | 0.7471 |
| 139 | 0.7608 | 0.7530 | 0.7465 |
| 137 | 0.7601 | 0.7525 | 0.7460 |
| 135 | 0.7594 | 0.7518 | 0.7453 |
| 133 | 0.7588 | 0.7513 | 0.7448 |
| 131 | 0.7581 | 0.7508 | 0.7443 |
| 129 | 0.7574 | 0.7501 | 0.7437 |
| 127 | 0.7567 | 0.7496 | 0.7432 |
| 125 | 0.7561 | 0.7490 | 0.7426 |
| 123 | 0.7554 | 0.7484 | 0.7420 |
| 121 | 0.7548 | 0.7478 | 0.7415 |
| 119 | 0.7541 | 0.7473 | 0.7409 |
| 117 | 0.7535 | 0.7466 | 0.7404 |
| 115 | 0.7528 | 0.7461 | 0.7398 |
| 113 | 0.7522 | 0.7455 | 0.7393 |
| 111 | 0.7515 | 0.7449 | 0.7387 |
| 109 | 0.7509 | 0.7443 | 0.7382 |
| 107 | 0.7502 | 0.7438 | 0.7377 |
| 105 | 0.7497 | 0.7432 | 0.7371 |
| 103 | 0.7490 | 0.7426 | 0.7366 |
| 101 | 0.7484 | 0.7421 | 0.7361 |
| 99 | 0.7477 | 0.7416 | 0.7356 |
| 97 | 0.7471 | 0.7410 | 0.7351 |
| 95 | 0.7465 | 0.7405 | 0.7345 |
| 93 | 0.7459 | 0.7400 | 0.7341 |

| | | | |
|----|--------|--------|--------|
| 91 | 0.7454 | 0.7394 | 0.7335 |
| 89 | 0.7447 | 0.7389 | 0.7330 |
| 87 | 0.7442 | 0.7383 | 0.7326 |
| 85 | 0.7439 | 0.7380 | 0.7324 |
| 83 | 0.7433 | 0.7377 | 0.7320 |
| 81 | 0.7425 | 0.7371 | 0.7313 |
| 79 | 0.7418 | 0.7363 | 0.7306 |
| 77 | 0.7415 | 0.7360 | 0.7303 |
| 75 | 0.7409 | 0.7356 | 0.7300 |
| 73 | 0.7403 | 0.7351 | 0.7294 |
| 71 | 0.7398 | 0.7346 | 0.7290 |
| 69 | 0.7392 | 0.7342 | 0.7287 |
| 67 | 0.7387 | 0.7337 | 0.7284 |
| 65 | 0.7382 | 0.7334 | 0.7282 |
| 63 | 0.7377 | 0.7330 | 0.7280 |
| 61 | 0.7373 | 0.7328 | 0.7279 |
| 59 | 0.7368 | 0.7326 | 0.7278 |
| 57 | 0.7364 | 0.7324 | 0.7277 |
| 55 | 0.7362 | 0.7323 | 0.7276 |
| 53 | 0.7360 | 0.7322 | 0.7276 |
| 51 | 0.7358 | 0.7322 | 0.7275 |
| 48 | 0.7357 | 0.7321 | 0.7275 |
| 46 | 0.7356 | 0.7321 | 0.7274 |
| 44 | 0.7355 | 0.7321 | 0.7274 |
| 42 | 0.7355 | 0.7320 | 0.7273 |
| 40 | 0.7355 | 0.7320 | 0.7273 |

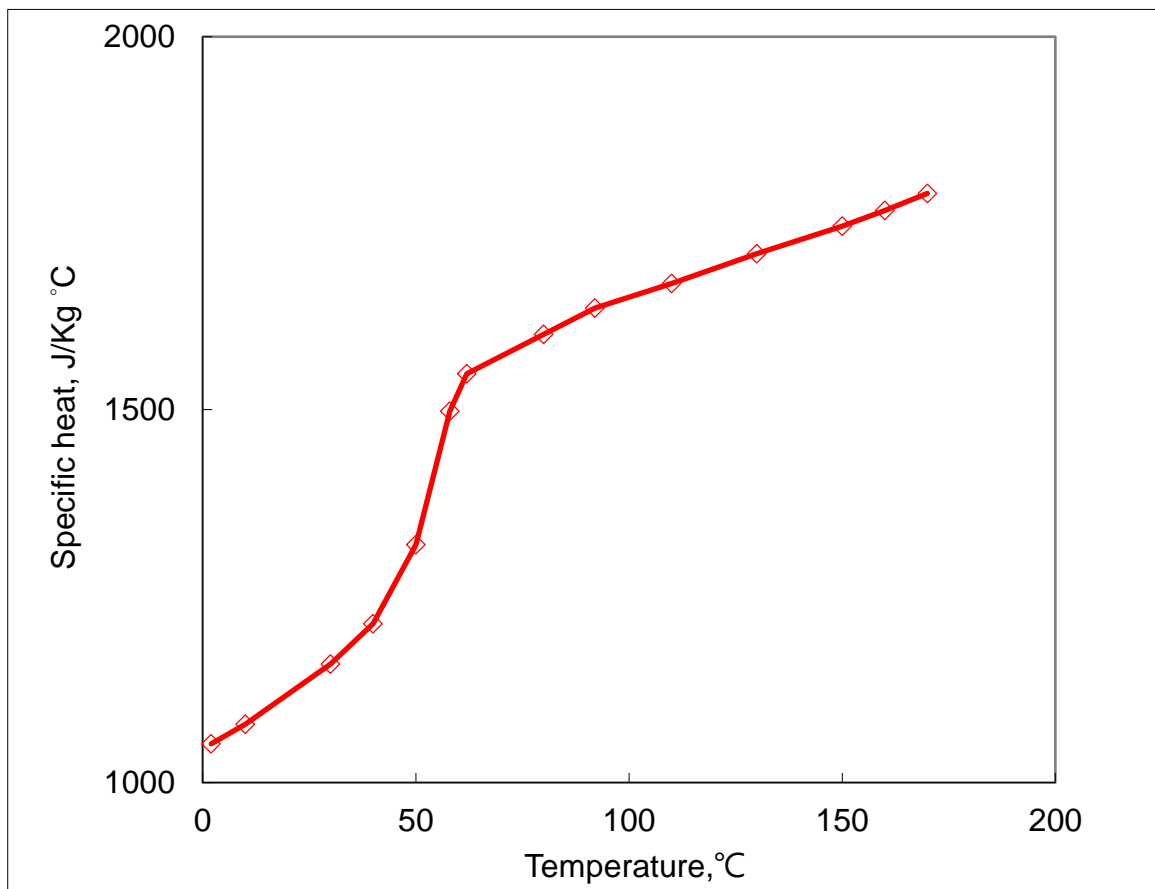
Specific Heat

| | |
|------------------------------------|--|
| Purpose | Specific Heat is amount of heat retained by the material. |
| Instrument | Perkin Elmer 8500 |
| Procedure | ASTM E1269 <i>The material is heated to its molten state and then cooled down to 30 oC at a constant rate of 20 oC/min.</i> |
| Sample drying condition | 100°C,4hours |
| Moisture level after drying | 0.86% |
| Sample shape | Pellet |
| Sample weight | 6.63mg |

| | |
|------------------------------|----------|
| Test specifications | |
| Temperature range(°C) | 200 to 0 |
| Cooling rate(°C/min) | 20 |
| Purge gas | Nitrogen |

Raw Data

| Temperature, °C | Specific Heat, J/kg °C |
|-----------------|------------------------|
| 2 | 1052 |
| 10 | 1078 |
| 30 | 1159 |
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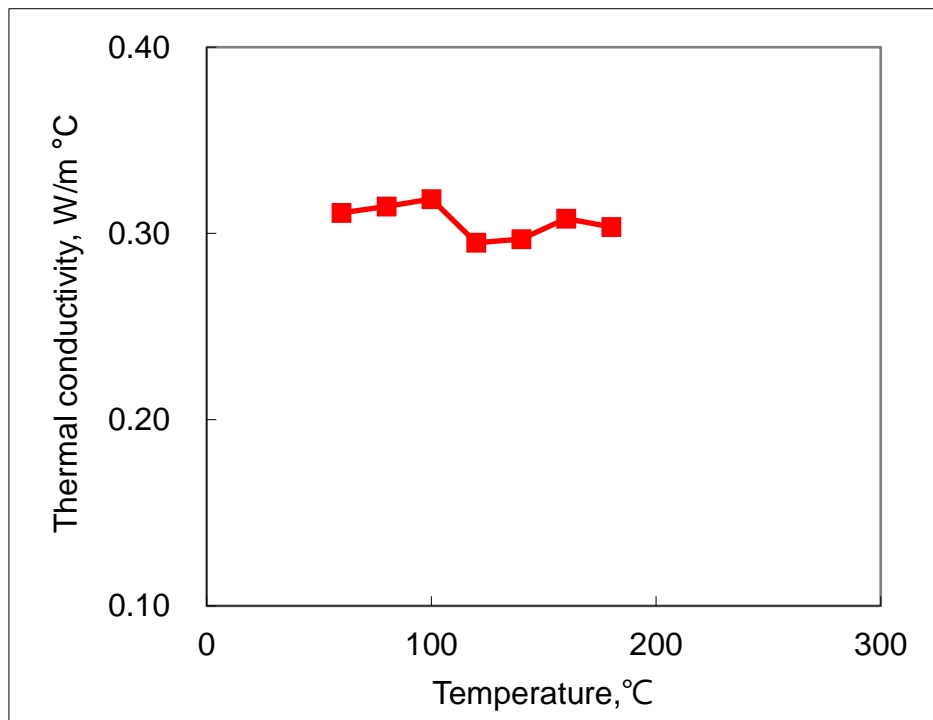
Line: model predictions using parameters provided

Thermal conductivity

| | |
|------------------------------------|---|
| Purpose | Thermal conductivity refers to the ability of a given material to conduct/transfer heat. relating with heat, distance and temperature. |
| Instrument | GOTTFERT RG25 |
| Procedure | ASTM D 5930 <i>A line source probe is inserted into the molten polymer, and then the temperature gradient is measured after an applied voltage to the probe at each acquisition temperature.</i> |
| Sample drying condition | 100°C,4hours |
| Moisture level after drying | 0.86% |
| Sample shape | Pellet |

Raw Data

| Temperature, °C | Thermal conductivity, W/m °C |
|-----------------|------------------------------|
| 60 | 0.311 |
| 80 | 0.315 |
| 100 | 0.319 |
| 120 | 0.295 |
| 140 | 0.297 |
| 160 | 0.308 |
| 180 | 0.304 |



Dot: measurement data

Line: model predictions using parameters provided



Contact details

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