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Heat Transfer in Polymers

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Heat Transfer in Polymers - Summary

- Introduction
- Heat Transfer Coefficients
- Standards for Thermal Properties Measurement
- Future Work

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Why is a better understanding of heat transfer in polymers important?

- polymer processing times are dominated by the cooling phase, particularly in injection moulding
- heat transfer processes are still inadequately understood / measured
- improved heat transfer measurements would lead to more accurate modelling of polymer processing
- could lead to significant improvements in product properties, e.g. reductions in warpage, shrinkage, inadequate melting and thermal degradation, and reduced cycle times

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Aims of the work

- To help companies measure and model heat transfer in polymer processing
- To enable measurement of more accurate data and encourage the use of improved models for numerical simulation software
- Leading to:
  - Faster processing due to reduced cycle times
  - Less scrap due to reduced warpage, shrinkage, fewer ‘hot spots’ and energy savings
  - Right first time design and fewer failures in service

COST REDUCTIONS AND IMPROVED QUALITY

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Heat transfer project H1 2005-08

H1: Measurement methods for heat transfer properties data for application to polymers

Objectives:

- Development of the method for the **measurement of heat transfer properties** across surfaces (particular interest has been expressed in the effect of the solid/air interface)
- Industrial **case study** to demonstrate the value of reliable heat transfer data
- Support development of **standards** for measurement of thermal properties of plastics, including an intercomparison of thermal conductivity methods that are being proposed for standardisation
- Assessment of **uncertainties in heat transfer data** and effect on modelling predictions
- Development of a new user-friendly **web-enabled modelling** facility, to facilitate industrial adoption of the above

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Measurement of Heat Transfer Coefficients

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Standards for Thermal Properties Measurement of Plastics

Plastics thermal conductivity standards

ISO TC61 SC5 WG8 Thermal Properties

ISO 22007 Plastics –
Determination of thermal conductivity and thermal diffusivity

ISO/CD 22007-1 Part 1: General principles

ISO/DIS 22007-2 Part 2: Transient plane source hot-disc method (Gustafsson method)

ISO/DIS 22007-3 Part 3: Temperature wave analysis method

ISO/DIS 22007-4 Part 4: Laser flash method

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Plastics thermal conductivity standards

Possible proposal to develop
Line Source Method for Thermal Conductivity
as part of ISO 22007 series

Method currently standardized as:

- ASTM D 5930-01, Test Method for Thermal Conductivity of Plastics by Means of a Transient Line-Source Technique

However this does not make provision for:

- effect of applying pressure to minimize measurement scatter, and
- effect of pressure on thermal conductivity
- inadequate calibration procedure
- over-simple analysis of data

Your support, or otherwise?

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Plastics thermal conductivity standards - intercomparison

Intercomparison of thermal conductivity methods

- Being carried out in support of standardisation activity
- Repeatability / reproducibility of methods is suspect
- To cover transient methods
  - but not excluding steady state methods
- Results to help prepare precision statement for ISO 22007 series

Led by NPL/Japan

Initial restricted intercomparison has commenced,
to be followed by larger participation intercomparison

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Plastics thermal conductivity standards - intercomparison

Intercomparison of thermal conductivity methods

Methods to include at least:

- Transient plane source hot-disc method (Hot Disk AB)
- Temperature wave analysis method (Tokyo Inst. Tech.)
- Laser flash method (NMIJ, DataPoint Labs, NPL, LNE, OMTRI)
- Line source probe (DataPoint Labs, NPL, Moldflow, CEAST)
- Guarded Hot plate / heat flow meter (OMTRI, DataPoint Labs,)
- Other (DSC?)

Your participation in the intercomparison is welcomed

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Differential scanning calorimetry standards

ISO TC61 SC5 WG8 Thermal Properties

ISO 11357 Plastics - Differential scanning calorimetry (DSC)

- ISO 11357-1: 1997 Part 1: General principles (being revised)
- ISO 11357-2: 1999 Part 2: Determination of glass transition temperature
- ISO 11357-3: 1999 Part 3: Determination of temperature and enthalpy of melting and crystallization
- ISO 11357-4: 2005 Part 4: Determination of specific heat capacity
- ISO 11357-5: 1999 Part 5: Determination of characteristic reaction-curve temperatures and times, enthalpy of reaction and degree of conversion
- ISO 11357-6: 2002 Part 6: Determination of oxidation induction time
- ISO 11357-7: 2002 Part 7: Determination of crystallization kinetics

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Differential scanning calorimetry standards

ISO 11357 Plastics - Differential scanning calorimetry (DSC)

- ISO 11357-1: 1997 Part 1: General principles (being revised)

Significant dispute over direction of exotherm / endotherm in plots

Currently:

exothermic direction is up

Proposed revision:

The endothermic and /or exothermic direction shall be indicated on the DSC curve. According to the requirements of thermodynamics energy absorbed by a system is counted positive while energy released has a negative sign. Thus the endothermic direction shall preferably point upwards the ordinate and the exothermic direction downwards.

Your views?

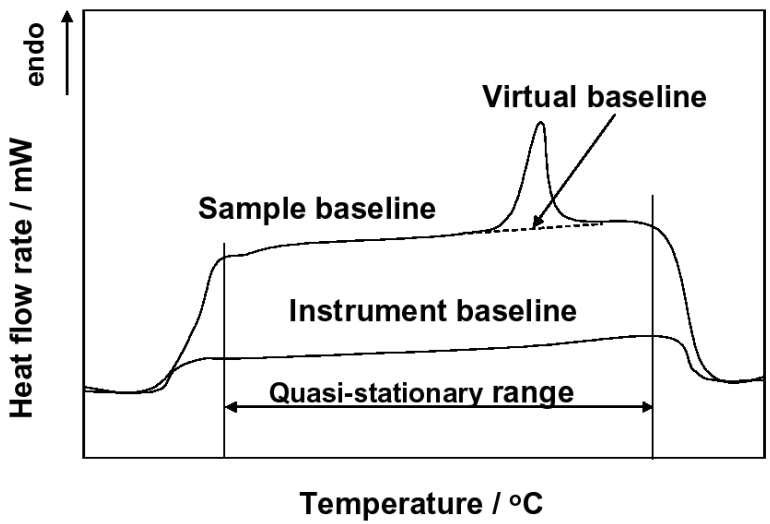

Figure 1 — Schematic drawing of baselines

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Standards report

Further details on standards for measurement of thermal properties of plastics in:

Report on the annual working group meeting ISO TC 61 Plastics / SC5 Physical-chemical properties / WG8 Thermal Analysis Yokohama, Tuesday 19 - Wednesday 20 September 2006

http://www.npl.co.uk/materials/polyproc/iag/october2006/thermal_properties_polymers_isomeeting2006.pdf

Next meeting: September 2008

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Heat transfer project H1 2005-08

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The next 12 months

- Initiate thermal conductivity intercomparison
- Carry out industrial case study/studies on heat transfer
- Consider initiation of NWIP for standard for line source method (based on outcome of intercomparison)
- Continued contributions to development of standards (DSC and thermal conductivity)
- Disseminate thermal conductivity and heat transfer coefficient measurement work

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Heat Transfer in Polymer Processing

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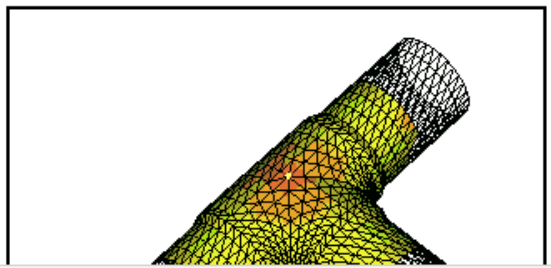
MPP7.1 Heat Transfer in Polymer Processing - Project Overview

Contents:

- Introduction
- Aims and Objectives
- Importance of Thermal Conductivity In Process Simulation
- Effect of processing conditions on thermal conductivity of polymer melts
- Heat Transfer Coefficient Measurement
- Differential Scanning Calorimetry Method
- Concluding Remarks
- Outputs
- Acknowledgements and Support
- Industrial Advisory Group
- Further Information

Introduction

Polymer processing is fundamentally a heat transfer - mass transfer process, with heat being initially added to and finally removed from the polymer. Heat transfer is a key to increasing throughput particularly as, due to the low thermal conductivity of polymers, the cooling phase often dominates the cycle time.



Furthermore, a better understanding of heat transfer, resulting in improved predictive capability, can lead to reductions in scrap rates due to the elimination of hot spots and excessive temperature gradients that

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Acknowledgements

DTI

Chris Brown