Industrial Materials For The Future
Project Fact Sheet

INVERSE PROCESS ANALYSIS FOR THE ACQUISITION OF ACCURATE THERMOPHYSICAL PROPERTY DATA

BENEFITS

Significant benefits will be made as a result of improved materials design and materials processing by the use of more accurate thermophysical properties.

- Benefits will lead to improved materials design and optimization, reduced scrap, reduced downtime, increased productivity by enabling rapid process changes, a decrease in hot-tearing defects, improved strength, reduced porosity defects, and improved fracture resistance.

APPLICATIONS

Several Industries of the Future and supporting industries will derive benefits from this project:

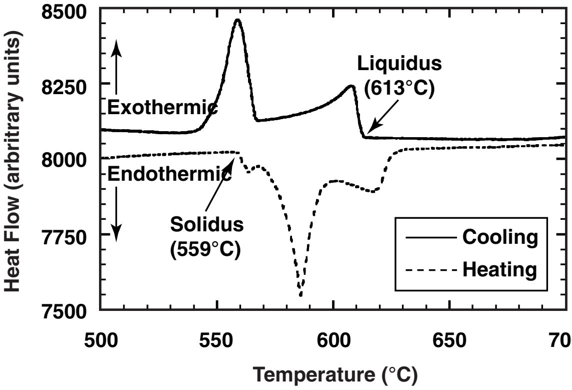
- **Aluminum,**
- **Glass,**
- **Metalcasting,**
- **Steel,** and
- **Welding.**

INCREASED ACCURACY OF THERMOPHYSICAL MATERIALS PROPERTIES DATA AND MORE ACCURATE SIMULATIONS WILL LEAD TO IMPROVEMENTS IN MATERIALS PROCESSING

One of the main barriers in the analysis and design of materials processing and industrial applications is the lack of accurate experimental data on thermophysical properties. For example, in the aluminum, steel, and metalcasting industries, the prediction of defect formation (including shrinkage voids, microporosity, and macrosegregation) is limited by the data available on fraction solid and density evolution during solidification.

By performing a computational analysis of the measurement process, the time lags, which are inherent to the measurement arrangement, can be estimated, and their effect can be taken into account in determining accurate thermophysical properties data. The project will focus on the analysis of two high-temperature techniques, including differential scanning calorimetry (DSC) and dilatometer measurements. New computational methodologies and measurement procedures will be developed to obtain the required high-accuracy data. Heat transfer models based on inverse-type computational analyses of the measurement process will be developed. The inverse-type analysis is required in order to identify the various model parameters for each of the two instrumental techniques. By identifying model parameters, the analysis will make possible the use of higher cooling/heating rates during the data acquisition phase. The results from this project will lead to improvements and benefits in various IOF and supporting industries, including the aluminum, glass, metalcasting, steel, and welding industries.

Cell mounting for typical heat-flux-type DSC system used for high-temperature applications.



Sample of current DSC data: the liquidus and solidus temperatures can be determined from the DSC measurements performed during cooling and heating, respectively. The DSC latent heat data obtained upon heating is significantly different from that obtained during cooling.

Project Description

Goal: The goal of this project is to improve the acquisition of data on thermophysical properties (including solid fraction and density during solidification) by developing realistic thermal models and concurrently using inverse-type computational analyses of the measurement process.

Issues: To date, the measurement of most high-temperature thermophysical properties is often plagued by time lags and poor thermal modeling that does not properly take into account thermal resistance in the physical network. This occurs especially at high temperature because radiative heat transfer represents a significant mode of heat transfer process. Currently, significant errors often exist in the interpreted measurements. In the current state of the art, time lags are inherent to the measurement arrangement because (a) the sample temperature cannot usually be measured directly and the temperature data are recorded by using a thermocouple that is normally placed at a different location from the sample's location and (b) there is a nonhomogeneous temperature distribution within the instruments themselves.

Technical hurdles to be overcome by this project include the development of (a) a proper thermal model of the physical phenomena that is then coupled with an inverse analysis and (b) controlled/benchmark experiments for developing the necessary input to the inverse codes.

Approach: In this project, new computational methodologies and measurement procedures will be developed to obtain accurate data on thermophysical properties. Methodologies include high-heat-flux DSC and dual-push-rod dilatometer analyses. By performing a computational analysis of the measurement process, the time lag and thermal resistances can be estimated and their effect can be taken into account in determining more accurate data on thermophysical properties.

The tasks include
– Develop analytical models for DSC,
– Develop analytical models for dilatometry,
– Conduct DSC and dilatometry measurements,
– Experimentally validate the proposed methodologies, and
– Evaluate and summarize experimental and computational procedures.

Potential payoff: As a result of this R&D, the data acquisition by DSC and dilatometry instruments will be improved and benefits will result in the aluminum, glass, metalcasting, steel, and welding industries. The increased accuracy of thermophysical material properties data will lead to more accurate designs of materials processes.

Progress and Milestones

- Develop heat-transfer models for DSC and dilatometer.
- Develop inverse models for dilatometer.
- Experimentally validate inverse and heat transfer models for DSC and dilatometer.
- Demonstrate the new data acquisition procedures for nonstandard materials.

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