Understanding the Origin of Uncertainty in Thermometer Calibration

Researchers are using simulation to improve calibration of temperature sensors.

BY JENNIFER HAND

Thermometers have widespread application ranging from their role in measuring temperature in common consumer goods to integration in sophisticated medical and industrial technology or processes. Like any measurement device, they must be calibrated with the International Temperature Scale of 1990 (ITS-90).

The Calibration Process

ITS-90 is based on fixed points at which a pure metal changes its phase by melting or freezing. During the phase change process heat is either absorbed or released by the metal without changing its temperature. At a fixed-point, a thermometer immersed in it observes a temperature plateau that can be used as a practical reference.

Jonathan Pearce, who leads contact thermometry at the UK's National Physical Laboratory, explains: "The ITS-90 is disseminated to users with the standard platinum resistance thermometer. This is a very sensitive device capable of measuring temperatures with a precision of the order of a microkelvin."

The platinum resistance thermometer calibrates using a fixed-point cell. This is typically a graphite crucible, which is a container with a well running through its center for insertion of the thermometer (see Figure 1). In the container is a material of very high purity, typically 99.9999%. The central well allows a thermometer to be inserted so that the sensing element at its bottom is completely immersed in the fixed-point metal. The container is then placed in a furnace to allow controlled melting and freezing of the metal.

FIGURE 1: Cross-section of a typical fixed-point cell showing the graphite container, the metal ingot, and the central well for insertion of the thermometer.

Despite the high performance device, the uncertainty of temperature during calibration can still be in the order of 1 millikelvin. To better understand the microscopic behaviour, Pearce, working with Surrey University student Matthew Large, turned to COMSOL Multiphysics.

Simulating Morphological Instability

Freezing or solidification is much less well-behaved than melting. For example, some areas will solidify before others thus influencing the freezing temperature.

The simulation utilizing the phase-field method implemented in COMSOL Multiphysics provided the researches with fascinating insights: under certain conditions the liquid-solid interface is not planar at all; as freezing progresses, ripples become apparent at the interface. These become cells that begin to protrude outwards (see Figure 2) with their tips being at a significantly lower temperature than their roots. "This positive feedback loop is very interesting," says Pearce. "Although such an effect was predicted by Mullins and Sekerka in the 1960s, this is the first time we have observed its manifestation in this context. Our main objective was to simulate freezing behavior by investigating the effect of furnace settings on the process and identifying what the actual sensor used was measuring. The working model we ended up with is a very powerful means of understanding the influence of heat and mass flow on the evolution of the liquid-solid interface."

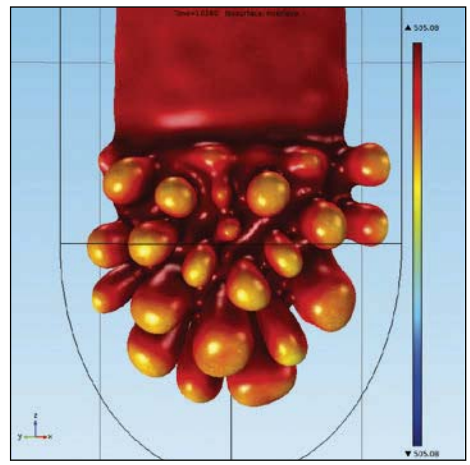

FIGURE 2: Morphological instability at the liquid-solid interface.

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Through simulation, it is possible to identify specific behavior in a system that is difficult to observe experimentally and yet contributes to the overall uncertainty in a measurement. The information gained through simulation can be applied to a thoughtful re-design of the device ultimately improving measurement precision. ■

More Information

http://www.npl.co.uk/temperature-humidity/