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Application Note

How Cool are Nanofluids

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Nanofluids are the next big thing in cooling everything from engines to supercomputers. Before they can be commercially interesting, however, they need to be better understood. So far, research results have been anything but consistent.

Searching for "Experimental Reality"

Some studies have reported astonishing thermal conductivities for nanofluids; others have found much more modest numbers. The high end numbers fall way outside values that current "effective medium theory" would predict. Some people have speculated that a whole new theory is needed to understand these super fluids.

Dr. Samuel Sprunt, a physicist at Kent State University, was asked to look into the "experimental reality" of these surprisingly high thermal conductivities and, if he could replicate them, to propose a theory that explained them.

Measuring Liquids: A Challenge

Measuring the thermal conductivity of any liquid can be tricky. The technique is simple, but thanks to the effects of convection it's hard to do properly. Many investigators use the hot-wire technique, in which a super thin heating wire approximates the "infinite line heat source" required by the theory behind a popular thermal properties measurement method. Dr. Sprunt was concerned about transient effects, however, so he initially planned to use the parallel plate method, in which you heat one plate and measure temperature changes at the other.

A Quick and Accurate Way

According to Dr. Sprunt, this method has a lot of theoretical advantages, but in practice, it proved difficult. "While we were able to find a vendor and try some samples, the results we got were not satisfactory," he says. "We tried just ordinary pure fluids whose thermal conductivities are well tabulated, and those numbers were not consistent or accurate." Dr. Sprunt speculates that readings were distorted by fluid convection or invalidated by an air pocket between the plates.

Needing to come up with a "quick and hopefully accurate way" to measure thermal conductivity in fluids, Dr. Sprunt and his colleagues found Decagon's KD2 Pro on the internet. "The price was surprisingly good," says Dr. Sprunt, "so we figured if this didn't work, it wasn't that much of an outlay." He was surprised and pleased to see that measurements on the pure fluids correlated well with known values.

"Pretty Phenomenal Results"

"We discovered that there are some limitations to the probe...it doesn't work terribly well above about 60 or 70 °C. But at lower temperatures, we were getting some pretty phenomenal results," says Dr. Sprunt, "And Doug [Cobos, Decagon Research Scientist] has been giving us some ideas about how to lower the heat pulse in the unit further."

When Dr. Sprunt and his colleagues tested the nanofluids, they found no extraordinary thermal conductivities. In fact, says Dr. Sprunt, it was just "what you would expect if you substituted volume for volume a higher conducting substance for a lower conducting substance. That's the basic conclusion of our paper*."

Of course, these results don't constitute a definitive answer. They have to be checked, double checked, and rechecked. Nanofluids researchers are setting up a consortium to exchange samples and correlate results, and Kent State University plans to participate in that consortium.

New Challenges

Even while participating in the consortium, however, the Kent State researchers are ready to move on to new challenges. Dr. Sprunt expects that real advances in the thermal properties of these liquids will come not through discovering a nanofluid with extraordinary properties, but through "using existing, well understood, simple, boring, dull effective medium theory" to create better thermal enhancements.

"We're probably not going to continue the search for this mysterious 'enhanced conductivity.' [Instead,] we're going to look at deliberately making structures that within the effective medium theory will give large enhancements, not anomalous or mysterious, but enhancements that can be understood and exploited. One way to do that is to make anisotropic particles. If you get those lined up along the temperature gradient, you can get quite a boost in conductivity, but within well understood principles, and not from speculative mechanisms that nobody's been able to demonstrate consistently."

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