Nanofluids not so super-cool after all

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MIT engineers have shown that nanofluids, which once held promise as a super-coolant, do not have the theoretical cooling capabilities many scientists believed they had.

Nanofluids are suspensions of tiny particles on the nanometer, or billionth of a meter, scale. When nanofluids were first engineered in the early 1990s, experiments showed that their thermal conductivity--a measure of their heat-removing capability--was much higher than expected.

Several new theories were offered in recent years to explain this anomalous behavior. Among them, the "microconvection" theory predicted an astonishing increase of several orders in the thermal conductivity of the fluid just by adding light nanoparticles less than ten nanometers in size.

MIT researchers recently conducted experiments to test the microconvection effect and found that nanofluids in fact do not have the advanced cooling properties ascribed to them. The team reports its findings in the Aug. 31 issue of *Physical Review Letters*.

"We conclude that there is no 'magic' in nanofluids, and the early promise of nanofluids as an 'advanced nanoengineered coolant' remains largely unfulfilled--and will probably remain so in the years to come," said Jacob Eapen, a graduate student in nuclear science and engineering and lead author of the paper.

Liquids are often used for industrial cooling, especially in nuclear reactors and coal-fired power plants. Car engines, air conditioners and refrigerators are also cooled by liquids.

However, solids have a higher thermal conductivity than liquids. Thus, researchers have long experimented with improving the thermal conductivity of liquids by dispersing solid particles in them. In theory, that could improve the efficiency of cooling devices.

In the 1960s, engineers tried this approach with micrometer-scale particles, but the large size of the particles led to pipe erosion and pump damage. It was not until the 1990s that researchers were able to try the same thing with nano-sized particles.

Initial experiments were very promising, showing that the increase in thermal conductivity for nanofluids was several orders of magnitude higher than predicted by the theory of thermal conduction known as Maxwell's theory.

The microconvection theory, which tried to explain this behavior, hypothesized that "the random motion of the diffusing nanoparticles is an efficient source of fluid convection that can increase the heat transfer capability of the surrounding fluid," said Eapen.

The MIT group decided to verify the microconvection theory by testing one of its predictions--that lighter nanoparticles will increase the nanofluid thermal conductivity. The researchers used well-dispersed silica and Teflon particles, both of which are lighter than commonly used alumina and copper oxide nanoparticles. The thermal conductivities they observed were far lower than what the microconvection theory would predict.

"Thus, we could experimentally show that microconvection does not

exist," said Eapen. Their results do match well with the Maxwell theory, he added.

In fact, the nanofluid thermal conductivity is very similar to that of many solid composites and liquid mixtures and falls between the classical bounds for inhomogeneous materials. Describing it as "anomalous" was an unfortunate consequence of focusing on the Maxwell theory which is true only for well-dispersed nanoparticles. In most nanofluids, the dispersed particles form linear chain-like configuration and the classical theory indeed predicts a larger thermal conductivity.

The work was performed at the MIT Center for Nanofluids Technology by Eapen and Wesley Williams, a graduate student in nuclear science and engineering, and Roberto Rusconi, a visiting student from Politecnico di Milan, Italy, with leads provided by Jacopo Buongiorno, assistant professor of nuclear science and engineering; Lin-wen Hu, associate director of the nuclear reactor laboratory; Sidney Yip, professor of nuclear science and engineering; and Roberto Piazza, a professor at Politecnico di Milano.

Source: MIT