Convection of Nanofluids in Commercial Electronic Cooling Systems

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Introduction

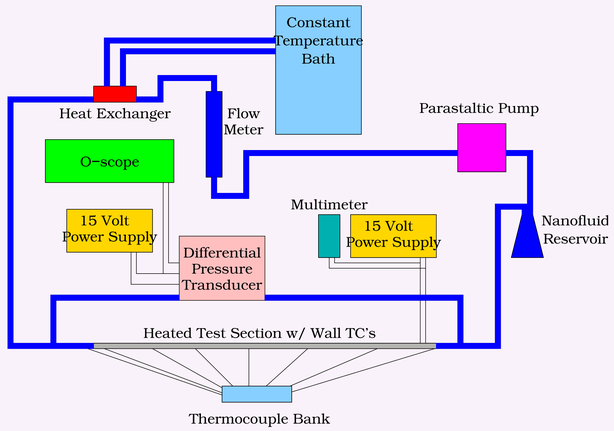
- Nanofluids are colloidal suspensions of nanoparticles in a base fluid
- Typical particles composed of chemically stable metals, oxides or carbon
- Particles range in size between 1 and 100 nm
- Base fluid usually water or organic liquids
- Shown to enhance *thermal conductivity* and possibly convection heat transfer
- Exhibit reduced sedimentation and erosion of containing surfaces compared to larger particles

Why do nanofluids exhibit enhanced properties?

Competing theories

1. Jang and Choi - Brownian motion results in micro or nanoconvection
2. Keblinski - More ordered structure of liquid at the solid interface
3. Domingues - Near field radiation between close particles
4. Keblinski - Agglomeration or chaining of particles

Experimental Setup

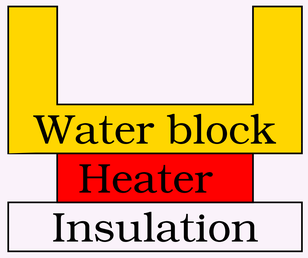


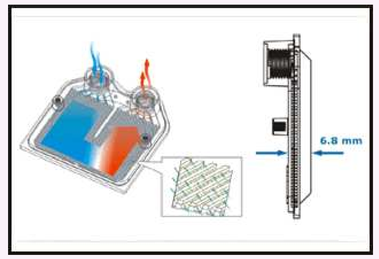
Key measurements

- pressure drop along test section
- temperature profile along outside of test section (12 TC's)
- inlet and outlet temperatures
- dissipation from heater wire
- volumetric flow rate

Funded by: OAK RIDGE National Laboratory

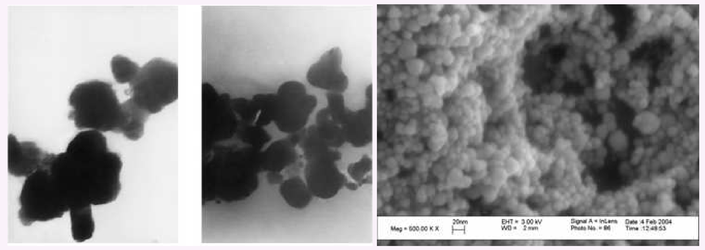
Commercial System





- The water block replaces the straight heated tube from the experimental setup (water block has a redundant micro channel design which we know very little about)
- The measured quantities are inlet and outlet temperature and the temperatures of the top and bottom of the heater
- The heater is a 10 W heater plugged into a wall outlet

Nanoparticles and Preparation



- Nanoparticles (Al_2O_3)
  - γ 10 nm and 20-30 nm
  - α 150 nm
- Preparation
  - Nanoparticles are added to DI-water
  - Particle/Water mixture is sonicated for 1 hour

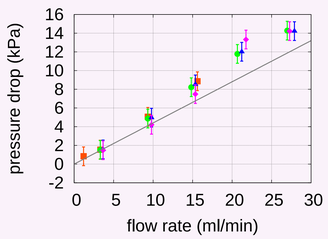
Results from DLS

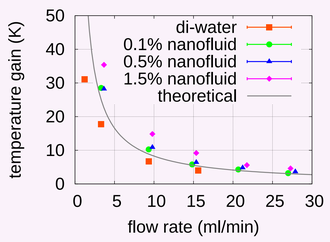
Particle (nm)	10	20-30	150
Ave. Part. Size (nm)	148.7	253.8	333.2
poly disp.	0.783	0.277	0.216

- γ 10 nm unstable in de-ionized water
- γ 20-30 nm and 150 nm stable in de-ionized water

Validation

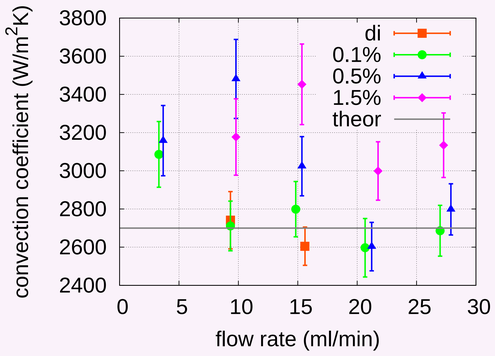
- Nearly equal pressure drop across the tube for all fluids
- Different from theoretical pressure drop for DI-water due to entrance effects and surface roughness





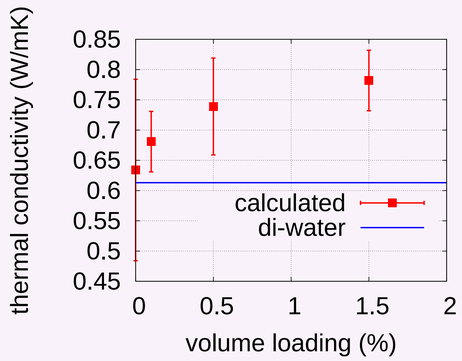
- Nearly equal temperature gain across the heated tube for the DI-water and the 0.5% nanofluid
- Greater temperature gain in the 1.5% nanofluid due to enhanced convective heat transfer

Results: Average Convection Heat Transfer Coefficients

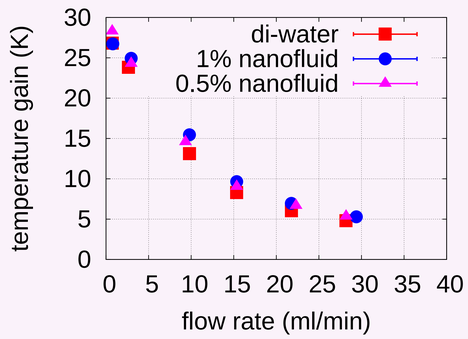


$\mathrm{Re} = [14 : 360]$

Results: Calculated Thermal Conductivity



Results: Commercial System



Conclusions

- Observed enhancement in convection heat transfer coefficient in laminar flow regime
- Enhanced thermal conductivity with increasing volume loading
- No noticeable settling of nanoparticles or development of aggregates within hours
- No noticeable enhancement in the commercial system is likely due to turbulent flow through channels
- If enhancement is reduced because of turbulence then theory #4 is likely