Erosion of Radiator Materials by Nanofluids

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Project ID
pm008

Vehicle Technologies – Annual Review – June 7–11, 2010

Sponsored by ***Propulsion Systems Materials***

Overview

Timeline

- Project start FY07
- Project end FY12
- 60% complete

Budget

- FY09 = $140 K (DOE)
- FY10 = $252 K (DOE)

Barriers

- Effects of nanofluids for thermal management in heavy vehicles are not established
  - ⇒ erosion of radiator material?
  - ⇒ erosion of pump material?
  - ⇒ power requirements to pump nanofluids?
  - ⇒ clogging of fluid lines?
  - ⇒ physical & thermal changes in the nanofluids over time?

Partners

- Tardec/WFO
- Michelin WFO/cost-share
- Saint Gobain/cost-share
- Valvoline (Ashland Oil)/cost-share

This project complements the overall effort in the area of nanofluids for thermal management

Relevance

- Nanofluids have enhanced thermal properties that have the potential of reducing radiator sizes (SAE-2007-01-2141) resulting in less weight and frontal area and hence less aerodynamic drag resulting in fuel savings. Other applications include energy storage for solar applications (project with DOE Solar), cooling of power electronics (proposal pending), industrial cooling (project with Industrial Technology Program, etc.

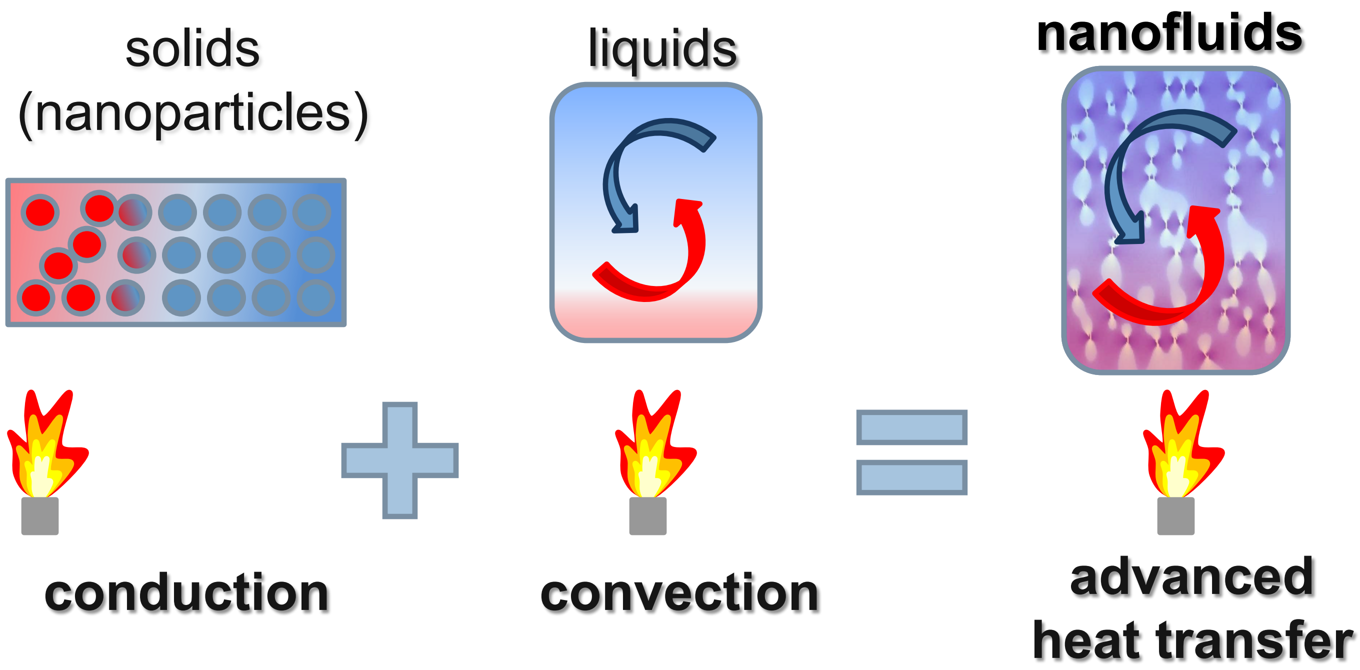
- However, will the nanofluids cause damage to cooling systems?

- Will the increased viscosity of the nanofluid result in much higher pumping power required?

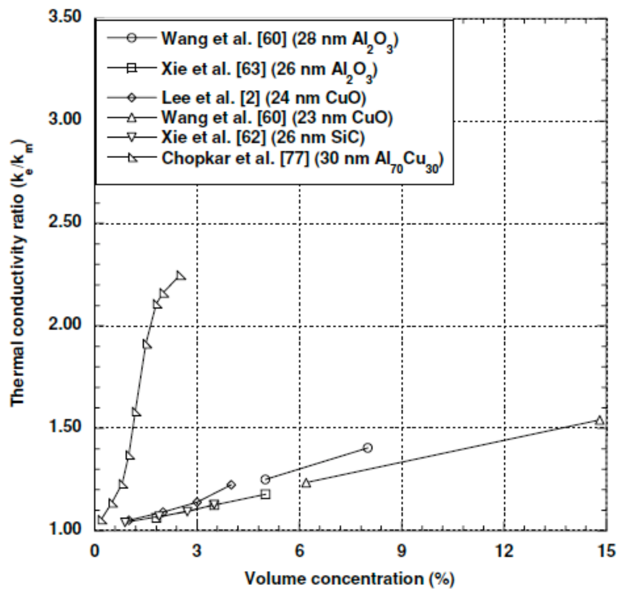
- Will nanofluids stay in suspension over long periods and not clough the cooling system?

Objectives of this project is to answer these questions

Potential of Nanofluids for Cooling Applications

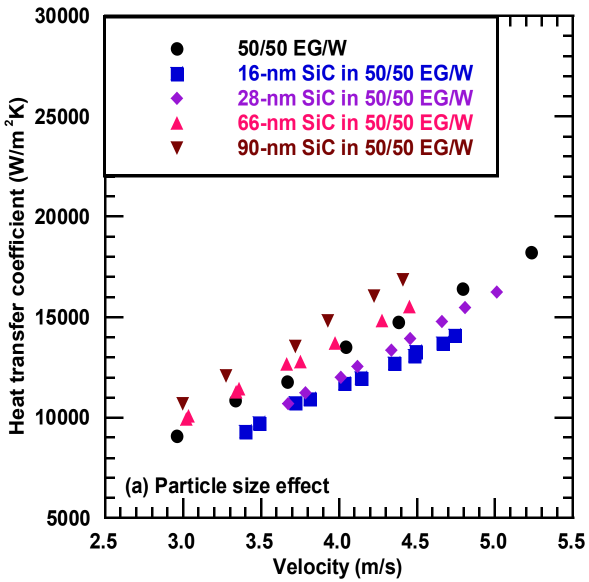


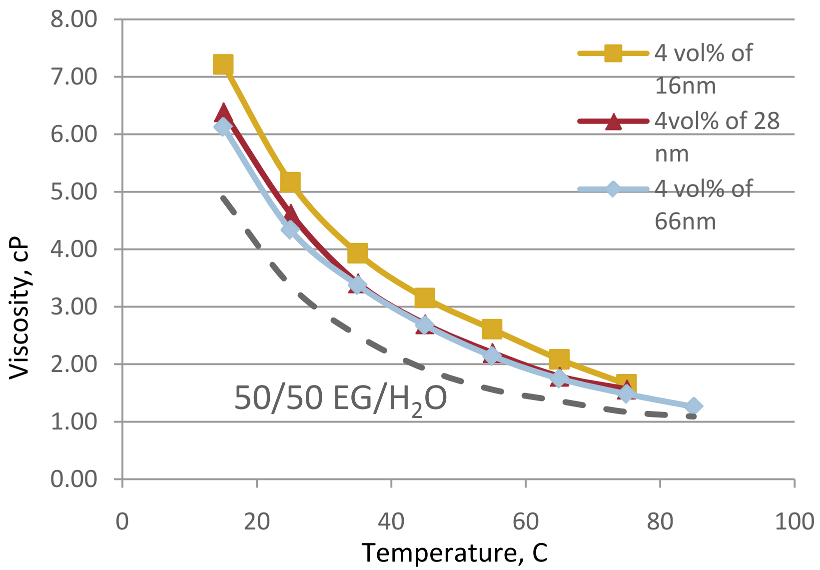
Why Nanofluids??



Review and Comparison of Nanofluid Thermal Conductivity and Heat Transfer Enhancements,
W. Yu, D. France, J. Routbort, and S. Choi,
Heat Transfer Engineering, 29, 432-460 (2008)

ANL results





Milestones

- FY09 (complete)
  - Measure erosion of radiator materials using SiC EG/H_2O based nanofluids
    - Velocity & impact angle
    - Particle size & loading
  - Modify erosion rig to:
    - Incorporate an automotive pump
    - Measure pumping power of various nanofluids
  - Develop collaborations with industry

- FY10
  - Continue to measure erosion of materials using various nanofluids
    - Finish SiC EG/$H_2$0 nanofluids (from Saint Gobain)
    - Start graphite based nanofluids (from Valvoline)
  - Correlate increased pumping power of candidate nanofluids measured from new computerized data collection system with theory

Approach

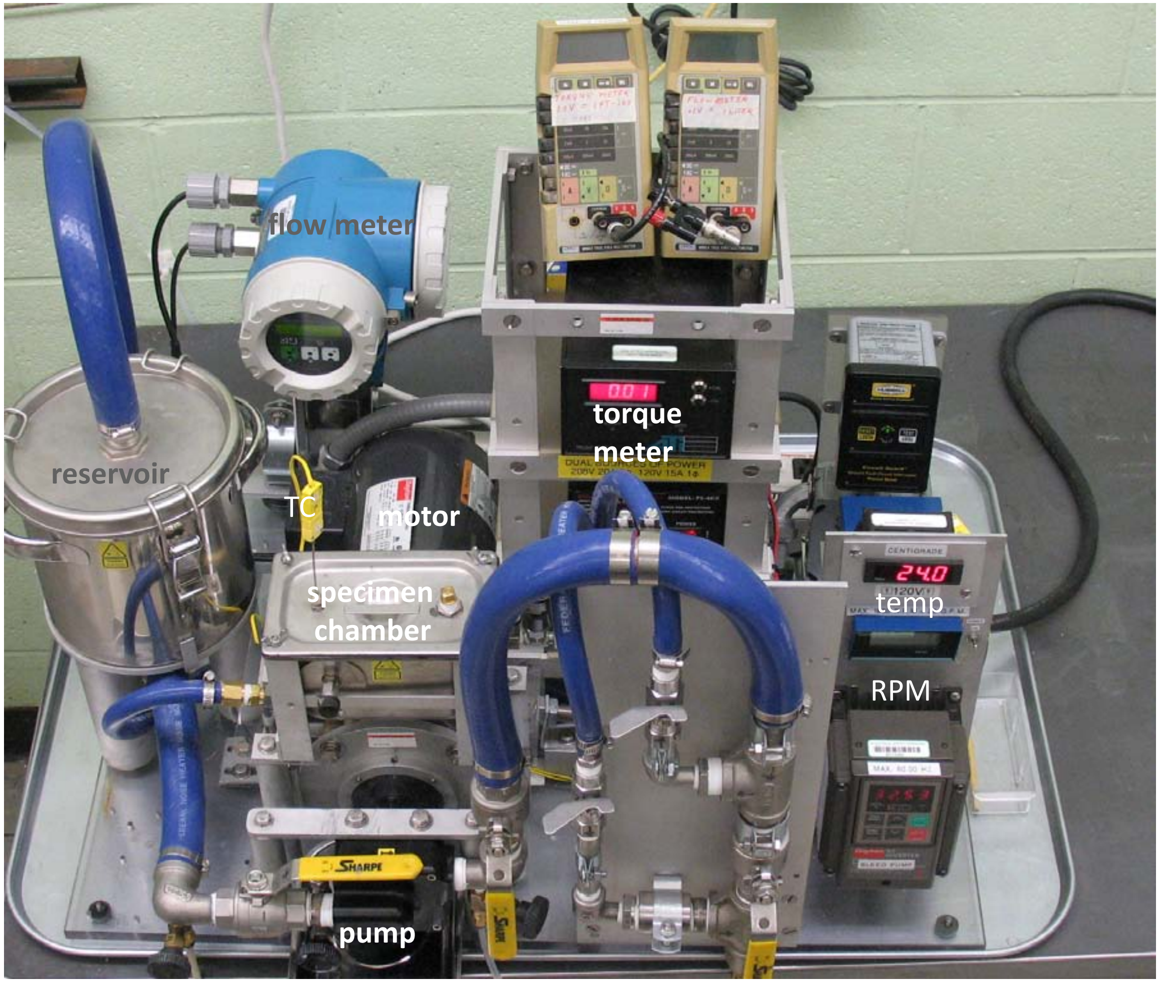
- Characterize nanofluids for performance (ITP project)
  - particle size & distributions using laser and x-ray techniques
  - viscosity and thermal conductivity

- Determine if nanofluids degrade/erode radiator system materials
  - develop apparatus/pumping system
  - weight-loss measurements (or erosion rate) as a function of fluid velocity, impact angle, temperature, and type of nanofluid on target and on pump impellor
  - monitor fluid pressure/flow rate/torque to identify changes in fluid and/or pump system
  - model fluid/target impact and correlate with experiments

- Develop predictive model if any erosive wear

- Quantitatively assess power consumption using torque meter and compare base fluid and nanofluids power requirements

Approach – Apparatus



Torque measurement behind
Data logger behind

Specimen chamber

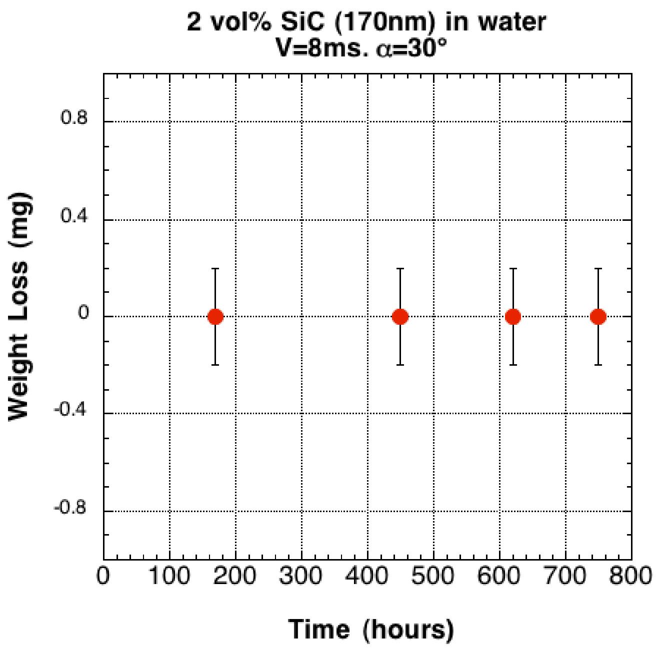
SiC/water nanofluid

Approach - Parameters

- Target material – 3003 aluminum
  - Impeller – cast aluminum (unknown spec)
- Erosion measurements
  - Weight loss at 2-10 m/s for 30 and 90° impact angles (RT so far)
- Nanofluids Investigated
  - 0.1 – 0.8 CuO in ethylene glycol (FY09)
  - 0.5 – 4.0 vol.% SiC in water and in ethylene glycol/water (50-50)
  - Various particle sizes (55 nm to 500 nm)
- Torque Measurements
  - SiC nanofluids
  - Al_2O_3 nanofluids
  - Graphite nanoparticles in EG/H_2O
  - Compare to calculated pressure drops

Accomplishments - Erosion

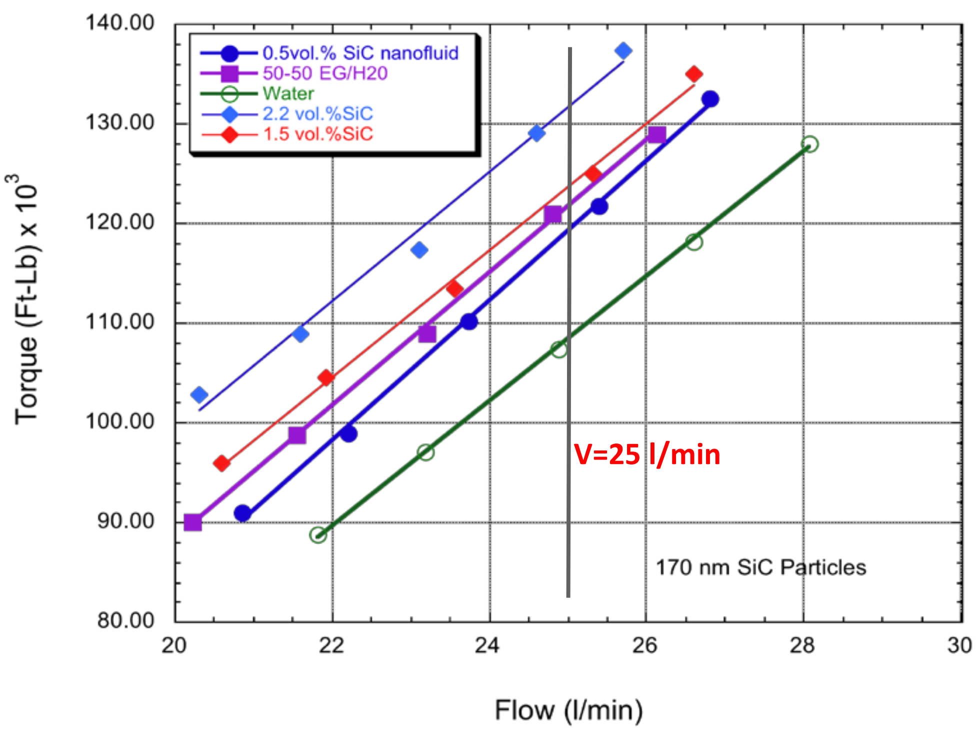
- **NO** weight loss measured on 3003 Al after testing 2 vol. % 170 nm SiC/water for ≥700 hours at 8 m/s (equivalent to ≈ 10 years of HV operation)
  - Impact angle – 30°
  - Impact angle – 90°



- Thus far, no damage to cast aluminum of impellor of commercial automotive water pump

However, higher concentrations and/or larger particle sizes not yet tested

Technical Accomplishments - Pumping Power

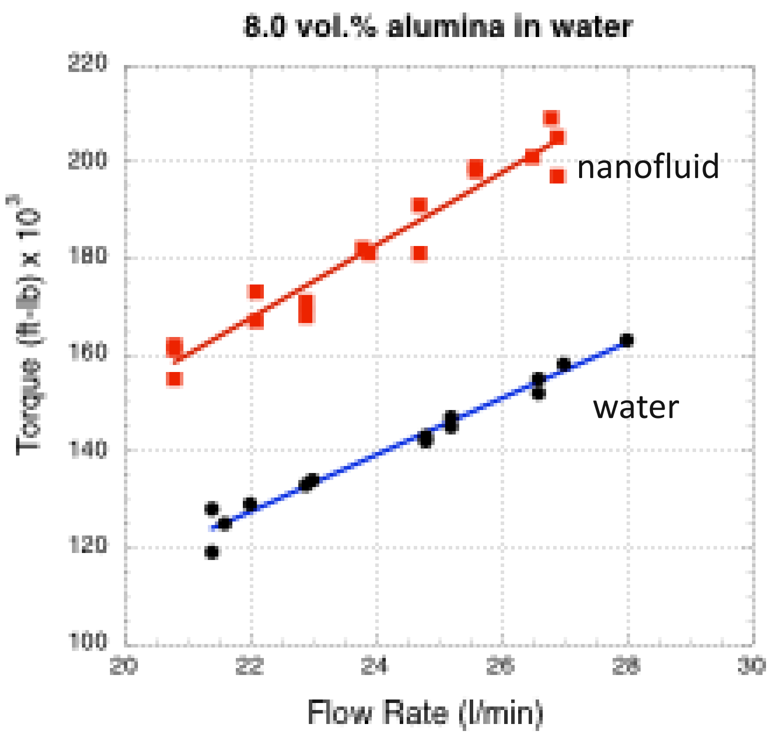


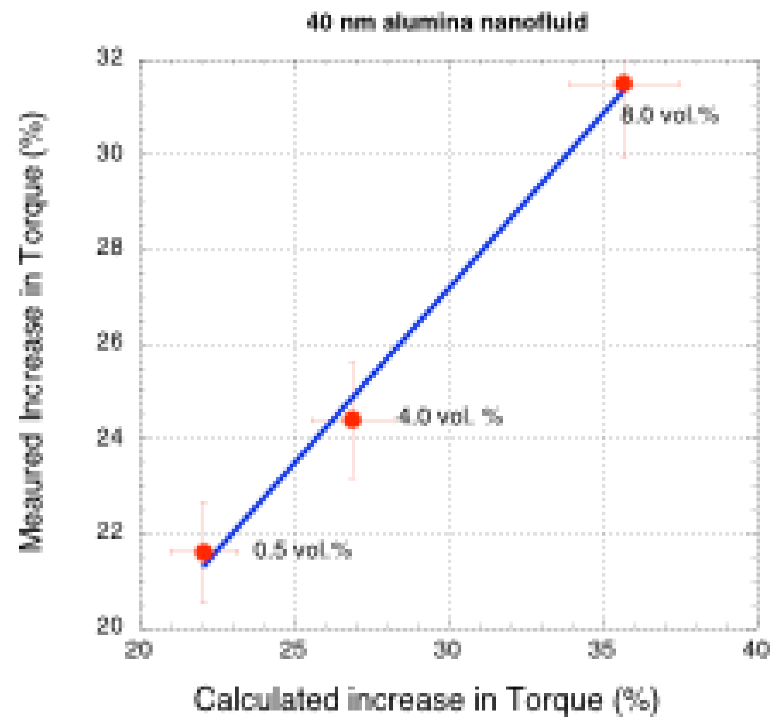
Turbulent flow (R_e≈7000–8000)

V = velocity
μ = viscosity
f = Fanning friction factor
L = length
d = diameter
ρ = density
η = pump efficiency

% theoretical increase of NF/base fluid	8.4
% measured increase of NF/base fluid	8.0

Technical Accomplishments - Pumping Power
40 nm Al_2O_3 in H_2O





Collaborations

- TARDEC (Work for others, $200K) – completed
- Michelin (Work for others, $300K) – completed
- DOE Office of Industrial Technologies – on going
- DOE Office of Solar – on going
- Saint Gobain – partner in OIT project to develop manufacturing capacity for nanofluids ($75K)
- Nanoscale (Kansas City, supplied nanofluids)
- Ashland Oil (Valvoline), new partner in OIT project, graphitic based nanofluids

Path Forward

- Continue erosion tests with new nanofluids being developed
- Conduct CFD modeling of fluid/target interactions, including the effects of nanoparticles
- Conduct tests with the modified erosion apparatus using larger sizes and higher volume % SiC nanofluids as well as the graphitic nanofluids
  - measure erosion rate on the automotive pump impallor
  - measure pumping power of nanofluids and base fluids
  - determine efficiency of the best nanofluids in compact heat exchanger
- Determine long-term performance of selected nanofluids
  - compare thermo-physical properties before and after erosion tests
- As part of the overall nanofluid effort, provide guidance to the industrial partner(s) on the heavy vehicle cooling applications
- Test in full–scale radiator facility, depending on funding

Conclusions

- Identified critical barriers for the use of nanofluids for cooling applications
- Completed characterizations of selected nanofluids
- Erosion tests with SiC (170 nm)–water based nanofluids does not show any erosion on the target (3003 aluminum), or on cast aluminum impellor.
- Measurements and calculations of pumping power for a 2 vol.% SiC/water nanofluid agree.