EXPERIMENTAL STUDY OF DYNAMIC THERMAL CONDUCTIVITY OF FLUIDS FOR HEATING AND COOLING CYCLE

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ABSTRACT

This paper reports the measurement of dynamic thermal conductivity of fluids for different Reynolds numbers in the laminar flow region. The fluids that have been traditionally used for heat transfer applications are water, ethylene glycol and engine oil. There are a number of possible ways of improving the thermal conductivity, each suitable for a limited range of materials, depending on the thermal properties and the medium temperature. We propose to use nano particles with base fluids to improve the heat transfer coefficient and thermal conductivity. But before that we needed the values of dynamic thermal conductivity of base fluids without nanoparticles. This paper discusses the results obtained in this regard. Generally, the values of thermal conductivity given in literature are for static fluid and not for the flowing fluid. Here, we have measured the values of thermal conductivity for a flowing fluid by varying the flow rates and temperature differences.

. **Keywords:** *Thermal conductivity, heat transfer coefficient, Reynolds number, laminar flow.*

1. INTRODUCTION

Thermal conductivity is the most important thermo physical material parameter for describing the heat transport properties of material of component. The measurement of thermal transport properties for a liquid is a key issue to attain optimum performance for a particular application. There is a growing need to improve the performance of thermal systems by enhancing the heat transfer coefficient and thermal conductivity. The conventional ways of improving heat transfer coefficient such as increasing surface area, etc. have reached the saturation. There is a need to use unconventional fluids such as nano fluids in thermal systems such as engines, refrigerators and air conditioners. We have initiated the research work in this regard. The first step was to measure the heat transfer coefficient and thermal conductivity of flowing base fluids using the experimental set up simulating the actual working conditions of thermal systems. The next step is to add nano particles to the base fluids and measure these parameters again. The earlier researchers who have worked in this field have tested nan ofluids with very less volume of the order of 100-200 milli litres. We have devised a set up that will test nano fluids in the actual working conditions found in thermal systems and handling a much larger volume of the order of 2-4 liters. The goal is to achieve the results using nano fluids in the environment matching the actual working conditions. The first task was to measure the thermal conductivity of base fluids in the dynamic condition that is of the flowing fluids. The experimental set up and the results are discussed here.

2. EXPERIMENTAL SETUP AND PROCEDURE

A schematic diagram of the experiment apparatus is shown in figure 1. It consists of a storage tank, glass tube rotameter, magnetic flow pump, bypass valve, cold bath and hot bath with U-tube heat exchanger, necessary piping. The storage tank made up of stainless steel is of 25 liters capacity. Pump is ¼ HP with bypass arrangement. Rotameter has 3 to 30 LPH range. Heat exchanger in hot bath and cold bath has U-shape heat exchanger with 50 cm length and tube of 6” inner diameter. Heat exchanger is made up of stainless steel. Hot bath and cold bath tank has dimensions 30 X 30 X 10 cm3. (approx 9litres) with electric heater in hot bath. Temperature controller with thermostat is attached to the set-up. It has 4 channel indicators with 4 PT 100 sensors. The U shape heat exchanger is placed in hot and cold bath. The fluid from storage tank first passes through the rotameter. The rotameter is provided to measure the flow of liquid. The volume flow rate of the fluid can be varied with changing the position of by- pass valve. The fluid then enters the heat exchanger first, placed in hot bath. Temperature sensor 1 fitted at the inlet of heat exchanger passing through hot bath measures the temperature T1. Temperature sensor 2 fitted at the outlet of heat exchanger coming out from hot bath measures the exit temperature T2 of fluid. Then fluid with increased temperature flows into the heat exchanger passing through cold bath. Temperature sensor 2 is common to the outlet of hot bath and inlet of cold bath. The exit temperature of fluid is measured by temperature sensor 3 which is fitted at the outlet of heat exchanger coming out from cold bath as temp T3. Temperature sensor 4 is kept in storage tank to measure fluid temperature in storage. The effective thermal conductivity is calculated by taking the difference in temperature. All the temperature sensors are connected to the digital temperature indicators.

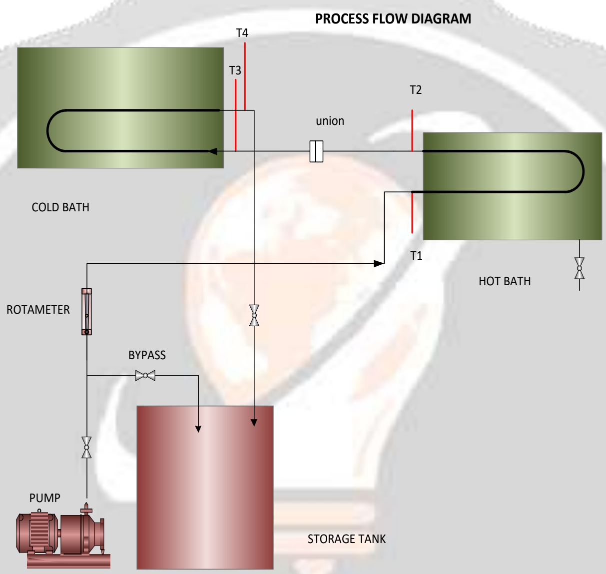

Fig 1: The experimental set up flow diagram

The experimental procedure is as follows:

The system is warmed up by start the pump and heater. It takes 5-10 minutes to increase the pump temperature to the operating range and remove interior bubbles. The fluid to be tested is filled in the storage tank up to a certain required level. The hot and cold bath tanks are filled with normal tap water. The system is started by switching on the pump and the heater. The heater is set to a definite temperature, say 45oC. It takes 5-10 min to increase the temperature to the operating range and remove interior bubbles. After the heater reaching the set temperature of 45 oC, readings are taken for 5, 10, 15, 20 and 25 LPH of volume flow rate. Then again the heater temperature is set for 55 oC and same procedure is repeated for taking readings. The system usually attains thermal steady state within 30 min. Each measurement is repeated at least once.

3. RESULTS AND DISCUSSION

Physical properties of base fluids and nano fluids are illustrated in Table 1. Thermal conductivities of the base fluids are 0.6 for distilled water and 0.3 for ethylene glycol based coolant found in literature.

Table-1: Fluid Properties

Fluid	Density (kg/m^3)	Molar mass (g/mol)	Viscosity (Pa s)
Ethylene Glycol	1056	62.07	0.0161
Distilled water	999.9720	18.01528 (33)	0.001

Calculate temperature difference for heating and cooling cycle. The heat transfer rate into the process fluid is given by:

$Q= m\, c_P\, (T_2-T_1)$

T_1 = hot bath inlet temperature

T_2 = hot bath outlet temperature

We can calculate the heat transfer coefficient of test fluid (h) using the following equation:

$Q= h\, A\, (T_h-T_m)$

Where,

$A= \Pi\, D\, L$

T_h = hot bath temperature

$$T_m = \frac{T_1 + T_2}{2}$$

Q= Rate of heat transfer (W),

A= Area exposed to heat transfer (m^2),

h= co-efficient of convective heat transfer (W/m^2K),

For cooling cycle, the heat transfer coefficient is calculated in the similar way as heating cycle.

$Q=m\, cp\, (T_2-T_3)$

Then,

$Q= h\, A\, (T_c-T_m)$

Where,

T_2 = cold bath inlet temperature

T_3 = cold bath outlet temperature

$A= \Pi\, D\, L$

T_c- cold bath temperature

$$T_m = \frac{T_2 + T_3}{2}$$

To calculate thermal conductivity, Nusselt number is taken as 4.36 for convection process with uniform surface heat flux for circular tubes. Further the value of k is obtained by Nusselt number equation for flow through internal tubes:

$$N_u = \frac{hL}{k}$$

Thus the value of k can be obtained from above equation.

3.1 REYNOLDS NUMBER EFFECT

The experiment was conducted in laminar flow region ($Re < 2000$). The base fluid showed the increasing trend in heat transfer coefficient as the value of average velocity and Reynolds number increased.

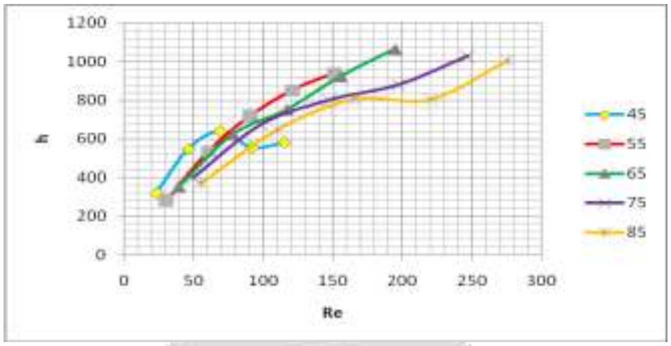

Fig 2(a): Plot of heat transfer coefficient versus Reynolds number for commercial coolant, (a) Heating cycle (b) Cooling cycle

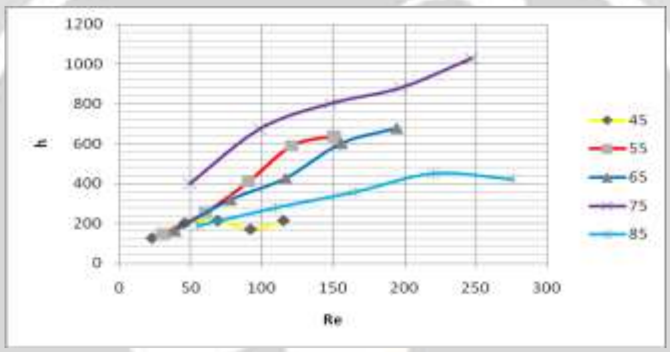

Fig 2(b): Plot of heat transfer coefficient versus Reynolds number for commercial coolant, (a) Heating cycle (b) Cooling cycle

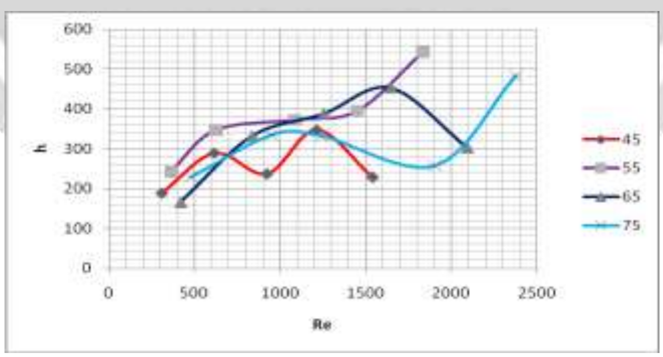

Fig 3: Plot of heat transfer coefficient verses Reynolds number for distilled water (a) Heating cycle (b) Cooling cycle

Figures 2 (a) and (b) and figures 3 (a) and (b) show that, there is increase in heat transfer coefficient with increasing Reynolds number. We conducted trials with distilled water, commercial engine coolant (name: Puroguard, 80% ethylene glycol) and mixture of coolant and distilled water in different percentages. The results obtained in the calculation of thermal conductivity showed tremendous increase in the parameter.

4. CONCLUSION

An apparatus to measure the dynamic thermal conductivity measurement of flowing fluids has been designed, developed, and fabricated with main objective to measure thermal conductivity of fluids, polymer solution, nano fluids and polynano fluids. The goal was to match the working conditions experienced by the heat transfer fluids as much as possible. Experimental results show that the heat transfer coefficient of the fluid system in laminar flow increases with increasing Reynolds number. The tests on base fluids were conducted to see the effect of various parameters such as temperature difference and flow rates. The fluids tested in these experiments were distilled water and ethylene glycol based commercial engine coolant. The next stage of our study is to test nano fluids in this set up and see the increase in heat transfer coefficient and thermal conductivity. The volume handled here is sufficiently large compared to the work done by earlier researchers.

5.REFERENCES

[1] Kostic, M, Critical Issues and Applications Potentials in Nanofluids Research, *ASME-MN2006 Multifunctional Nanocomposites International Conference, Honolulu, Hawaii,* ASME Proceedings, MN2006-17036, 2006.

[2] ISO 8301, "Thermal insulation – Determination of steady-state thermal resistance and related properties – Heatflow meter apparatus"

[3] Thermal conductivity and thermal diffusivity of timothy hay" A. Opoku, L.G. Tabil*, B. Crerar and M.D. Shaw*Department of Agricultural and Engineering, University of Saskatchewan, 57 Campus Drive, Saskatoon, Saskatchewan S7N 5A9, Canada. *Email: lope.tabil@usask.ca.*

[4] Heat transfer properties of nanoparticle-in-fluiddispersions (nanofluids) in laminar flowYing Yang a, Z. George Zhang b,*, Eric A. Grulke a,*, William B. Anderson b, Gefei Wu ba Department of Chemical and Materials Engineering, University of Kentucky, Lexington, KY 40506, USAb New Product Development Laboratory, The Valvoline Company, P.O. Box 14000, Lexington, KY 40509
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[5] S.U.S. Choi, Enhancing thermal conductivity of fluid withnanoparticles, in: D.A. Siginer, H.P. Wang (Eds.), Developmentand Application of Non-Newronian Flows, The American Society of Mechanical Engineers, New York, NY, FED-vol. 231/MD-vol. 66, 1995, pp. 99–105.

[6] S.U.S. Choi, Enhancing thermal conductivity of fluid withnanoparticles, in: D.A. Siginer, H.P. Wang (Eds.), Development and Application of Non-Newronian Flows, The American Society of Mechanical Engineers, New York, NY, FED-vol. 231/MD-vol. 66, 1995, pp. 99–105.

[7] J.A. Eastman, U.S. Choi, S. Li, L.J. Thompson, S. Lee, Enhanced thermal conductivity through the developmentof nanofluids, Materials Research Society SymposiumProceedings, vol. 457, Pittsburgh, PA, 1997, pp. 3–11.