ISSN (e): 2250 – 3005 || Volume, 08 || Issue, 07|| July – 2018 ||
International Journal of Computational Engineering Research (IJCER)

Use of Nanofluids in Computer Cooling Systems: An Application

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Abstract: *This paper works on the applications of nano fluid for the cooling of computers and other such devices. Various parameters has been considered. Thermal properties and the effect of using nanofluids on cooling performance of liquid cooling systems were investigated in this research.*
Keywords: *cooling, Nanofluid*

I. INTRODUCTION

In electronic industry, improvement of the thermal performance of coolingsystems together with the reduction of their required surface area has always been a great technical challenge. Research carried out on this subject can be classifiedinto three general approaches: finding the best geometry for cooling devices, decreasing the characteristic length and recently increasing the thermalperformance of the coolant. The latest approach is based on the discovery ofnanofluids. Nanofluids are expected to have a better thermal performance than conventional heat transfer fluids due to the high thermal conductivity of suspendednanoparticles. In recent years there have been several investigations showing enhancement of thermal conductivity of nanofluids.The cooling performance of a water cooling kit with the addition of nanofluids is investigated. A real computer setup with a quad-core processor has been used to determine the effect of use of nanofluid on the cooling system in real practical condition.

1.1 LITERATURE SURVEY The basic ideas regarding the topic was taken from the journal paper *Application of nanofluids in computer cooling systems (heat transfer performance ofnanofluids)* by M. RAFATI, A.A HAMIDI, M. SHARIATI NIASER, published in *Applied Thermal Engineering.*The use of enhanced thermal properties of nanofluids for the cooling of computer microchips is the main aim of the researchcarried out in this journal paper. The ideas regarding the performance of nanofluids in a commercially available electronics cooling system was taken fromthe journal paper *Convective Performance of Nanofluids in Commercial Electronics Cooling Systems* by N.A. Roberts, D.G. WALKER, published in*Applied Thermal Engineering*.

1.2 NANOFLUIDS AND ITS APPLICATIONS Nanofluids are liquid-solid suspensions in which particles with the size of 1-100nm are suspended in a heat transfer fluid. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. Nanofluids have been found to possess enhanced thermos physical properties such as thermal conductivity, thermaldiffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil. Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermalmanagement, domestic refrigerator, heat exchanger, nuclear reactor coolant, ingrinding, machining, and in boiler flue gas temperature reduction. The applications of nanofluids are as follows:

HEAT TRANSFER APPLICATIONS Industrial Cooling ApplicationsUsing nanofluids for industrial cooling could result in great energy savings and also result in emissions reductions. Smart Fluids In this new age of energy awareness, our lack of abundant sources of clean energy and the widespread dissemination of battery operated devices, such as cell phones and laptops, have accented the necessity for a smart technological handling of energetic resources. Nanofluids have been demonstrated to be able to handle thisrole in some instances as a smart fluid. Nuclear Reactors Nanofluids can be utilized in nuclear applications for improving the performance of any water-cooled nuclear system that is heat removal limited. Possible applications include pressurized water reactor (PWR) primary coolant, standby safety systems, accelerator targets, plasma divertors and so forth.

AUTOMOTIVE APPLICATIONS Nanofluid Coolant In looking for ways to improve the aerodynamic designs of vehicles, andsubsequently the fuel economy, manufacturers must reduce the amount of energy needed to overcome wind resistance on the road. This is partly due to the large radiator in front of the engine positioned to maximize the cooling effect of oncoming air. The use of nanofluids as coolants would allow for smaller size and better positioning of the radiators. Brake and Other Vehicular Fluid Applications A vehicle's kinetic energy is dispersed through the heat produced during the process of braking and this is transmitted throughout the brake fluid in thehydraulic braking system. If the heat causes the brake fluid to reach its boiling point, a vapor-lock is created that retards the hydraulic system from dispersing theheat caused from braking. Such an occurrence will in turn will cause a brake malfunction and poses a safety hazard in vehicles.Since brake oil is easily affected by the heat generated from braking, nanofluidswith enhanced characteristicsmaximize performance in heat transfer as well as remove any safety concerns.

ELECTRONIC APPLICATIONS

Cooling of Microchips A principal limitation on developing smaller microchips is the rapid heatdissipation. However, nanofluids can be used for liquid cooling of computer processors due to their high thermal conductivity. Microscale Fluidic Applications The manipulation of small volumes of liquid is necessary in fluidic digital display devices, optical devices, and microelectromechanical systems (MEMS) such as lab-on-chip analysis systems. This can be done by electrowetting. It is discovered that nanofluids are effective in engineering the wettability ofthe surface andpossibly of surface tension.

II. COMPUTER COOLING SYSTEM

Computer cooling is required to remove the waste heat produced by computercomponents, to keep components within permissible operating temperature limits. Components that are susceptible to temporary malfunction or permanent failure ifoverheated include integrated circuits such as CPUs, chipset, graphics cards, andhard disk drives. Components are often designed to generate as little heat as possible, and computers and operating systems may be designed to reduce power consumption and consequent heating according to workload, but more heat may still be produced than can be removed without attention to cooling. Integratedcircuits like CPU and GPU are the prime generators of heat in modern computers. Heat generation can be reduced by efficient design and selection of operating parameters such as voltage and frequency, but ultimately acceptable performance can often only be achieved by accepting significant heat generation. Use of heatsinks cooled by airflow reduces the temperature rise produced by a given amount of heat. Computer fans are very widely used to reduce temperature by actively exhausting hot air. There are also more exotic and extreme techniques, such as liquid cooling. Fans are most commonly used for air cooling when natural convection is insufficient. Computer fans may be fitted to the computer case, andattached to CPUs, GPUs, chipset, PSU, hard drives and PCI cards. Common fansizes include 40, 60, 80, 92, 120, and 140 mm square.Desktop computers typically use one or more fans for cooling. Almost all desktop power supplies have at leastone fan to exhaust air from the case.

NEED OF LIQUID COOLING SYSTEM

Most computers dispel heat with heat sinks and fans. The chip warms theheatsink, the heat sink warms the air, and the fan moves the warm air out of the PC case.This system works most of the time, but sometimes, electronic componentsproduce more heat than simple air circulation can dispel. High-end chips with lots of transistors can overwhelm an air-cooling system. Liquid cooling is a highly effective method of removing excess heat, with themost common heat transfer fluid in desktop PCs being water. The advantages of liquid cooling system over air cooling system include the high specific heatcapacity and thermal conductivity of water. The principle used in liquid cooling computers is identical to that used in an automobile's internal combustion engine,with the water being circulated by a water pump through a block mounted on the CPU and out to a heat exchanger, typically a radiator. Liquids allow the transfer of more heat from the parts being cooled than air, making liquid cooling suitable for overclocking and high performance computer applications. Compared to aircooling, liquid cooling is also influenced less by the ambient temperature. Liquidcooling system is comparatively less noisy than air cooling system. It is projectedthat the next generation of computer chips will produce localized heat flux over 100MW/m2,with the total power exceeding 300 W. No existing low-cost coolingdevice can effectively manage the heatproduced at this level. Therefore, it iswidely assumed that cooling systemsthat incorporate nanofluids will be usedfor future cooling of computer chips.

PARTS OF A LIQUID COOLING SYSTEM

The important parts of a liquid cooling system are: Liquid Cooling Pump The pump is one of the most important parts of the system. Its flowrate determines how quickly the coolant moves through the tubes and blocks.The pump is usually a centrifugal pump. Some liquid-cooling pumps are submergible and they can be placed directly inside the coolant reservoir. 2.2.2 RadiatorA radiator is present to dispel heat into the air. A liquid cooling radiator is necessary for transferring heat fromthe water to the air. 2.2.3 Coolant Reservoir Coolant reservoir holds extra fluid and allows easy addition of coolant. It is also one of the most important parts of a liquid cooling system.2.2.5 Water Blocks **Fan,[5]** Many electronic components do not tolerate direct contact with liquid. So insteadof using channels to pump liquid directly through microchips, a liquid-cooled PC uses water blocks. A water block is a piece of heat-conductive metal, like copper or aluminum, that's filled with hollow tubes and channels. The bottom of the water block is a flat piece of metal that sits directly on top of the chip being cooled. Thermal paste between the chip and the block improves the heat transferbetween the two surfaces. The chip heats the block, and the water absorbs the heatas it flows through all the channels.

III. RESULTS AND CONCLUSIONS

Nanofluid preparation and characterization Preparation of stable and suitable nanofluid with low or no agglomeration of nanoparticles is the first step in any nanofluid experiments. In this investigation,nanofluids have been prepared using the two-step method. First nanoparticles are prepared as dry powder and are then dispersed into the base fluid. In order to maintain the stability of the suspension and to minimize the agglomeration and settling of the nanoparticles, some techniques such as the use of ultrasonic mixer,addition of surfactants and pH level control of the fluid are usually used. In this investigation,an ultrasonic mixer (BandelinSonoPlus HD 3200) is used to obtain stable and uniform distribution of nanoparticles in the suspension.Three types of nanoparticles, alumina, silica and titania have been used in the research. In preparation of the nanofluids, no additive or stabilizer was used. Each sample was stored for at least 24 h to ensure of the stability of the suspension. The results of samples in which any visible sign of settlingof nanoparticles was observed in lessthan 24 h, were not considered in the analysis. Titania and silica nanofluids showed great stability even after one week. The base fluidwas a mixture of deionized water (75% vol.) and ethylene glycol (25% vol.). For the experimental setup, commercial liquid cooling kit of 3D Galaxy II from Gigabyte was used. The system consisted of a quad core processor, AMD PhenomII X4. The operating parameters of theprocessor such as voltage and frequency have been raised from nominal conditions to produce more heat under operation. For better contact between water block and processor’s integrated heat spreader, a high conductive thermal paste was used. Covering of Integrated Heat Spreader(IHS) and water block contact interface with this thermal paste, ensures maximum possible heat transfer between coolant and the processor.

The cooling kit is customized in such away to measure flow rate and fluid temperature before and after the block. In order to control the flow rate of the coolant, a valve was installed after the pump just before the flow meter. The flow rate of the coolantwas one of the parameters which has been investigated. Three values of 0.5, 0.75and 1.0 L per minute were used for the flow rate of the coolant in the system. The cooling process is started by pumping the coolant into the system. The coolantenters the water block and absorbs the heat produced by the processor. Leaving the processor, it bcools down by passing through the radiator and the process is repeated. The temperature of the coolant was measured at the inlet and outlet of the water block by two PT-100 thermocouples. These temperatures were used to calculate the convective heat transfer coefficient at the water block. The pump used on 3D Galaxy II cooling kit is able to provide flow rates up to 8 L/minwithmaximum power consumption of 6.5 W. The experiments were carried out for maximum flowrate of 1 L/min resulting in very low pump power consumption, which is considerably lower than the nominalpower consumption mentioned. Therefore, although using nanofluid in comparison to base fluid results in higher viscosity and density resulting in higher pressure drop, the increase does not affect the power consumption of the cooling kit. As a result, the effect of increased viscosity of nanofluid on pressure drop hasnot been considered.

RESULT

The best parameter for evaluating the thermal performance of a flowing fluid is the convective heat transfer coefficient. In this experiment, heat transfer coefficient of the coolant to the water block has been calculated as the most indicative parameter. According to the Newton’s cooling law, the rate of heattransfer between the wall of water block and the coolant is given as follows. $q = hA\Delta T_m$Where, q is the rate of heat generation in the processor, h is convective heattransfer coefficient, A is heat transfer area, and ΔTm is the Log mean temperature difference between the wall and the fluid in contact with the wall. The temperature of wall and processor are assumed to be equal. Using thermal paste between wall and processor IHS and also design of IHS is rightly assumed to satisfy thisassumption. Therefore,

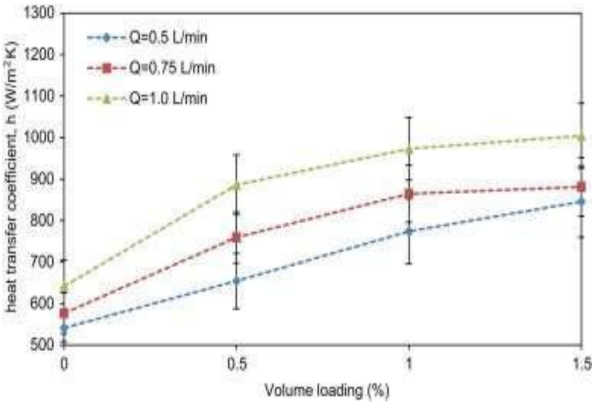
$$T_w = T_{core} \quad 1$$

CONVECTIVE HEAT TRANSFER COEFFICIENTS The calculated heat transfer coefficients as the function of volume concentrations for the three types of nanofluids at three different flow rates are as follows: As expected, the heat transfer coefficient of base fluid increases with addition of nanoparticles. For 0.5% volumetric concentration of alumina nanofluid, at flow rate of 1.0 L per minute, a two fold increase in the convection coefficient was observed.

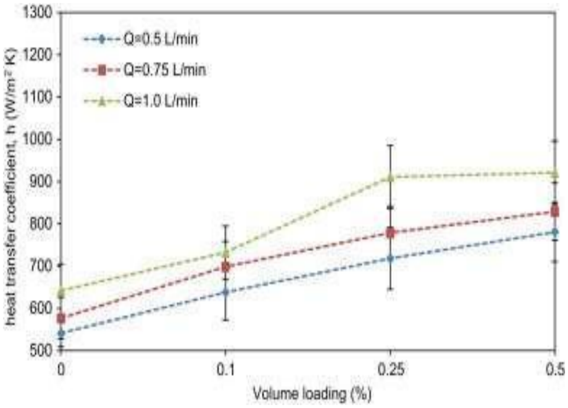
For SiO_2nanofluid, a more significant increase in the convective heattransfer is observed, which can be attributed to the higher particle concentrationsused. Longer stabilityof thisnanofluid, even without addition of the stabilizer, makes the use of higher concentrations possible.

These nanofluids were stable even after one month after preparation which is an important issue for the use of coolants in this type of cooling systems.

Comparison of convective heat transfer coefficients as a function of the Reynolds number is illustrated below: The Reynolds number was calculated using the following equation: $\rho_{eff} u d H$Re= μ_{eff}(6) Where u, ρ, and μ are respectively the velocity, the density and the viscosity of nanofluid, and is the hydraulic diameter of the water block. For all the experiments, the heat transfer coefficient is enhanced with increase inReynolds number. In addition to flow velocity, density and viscosity of thecoolant also changes with the change of nanoparticle concentration. In fact, for any given flow rate, increase in concentration of nanoparticles will result in reduction of Reynolds number.



PROCESSOR OPERATING TEMPERATURE Decreasing the processor operating temperature is the main purpose of using nanofluids in liquid cooling systems. This temperature is measured while applying a constant processing load on the processor, resulting in the highest operating temperature. The internal temperature sensor of the processor is used to measure the temperature. As expected, adding any of the nanofluids to the cooling system reduced theprocessor operating temperature in comparison to when pure base fluid is used.Temperatures relating to pure base fluid are shown by 0% of particle loading.Again, alumina nanofluid showed the greatest decrease on the measured temperature. Although adding a small amount of nanoparticles to the base fluidresulted in a significant decrease in processor operating temperature, increasingthe concentration of the nanoparticles resulted in a lower reduction in thisparameter. This fact has been observed for all three nanoparticles used in this study. As it can be seen in from the figures, increasing both concentrations of nanoparticles and flow rate of coolant in the system, resulted in lower operatingtemperature of the processor.However increasing these parameters would effect on operating costs. Increasing the flow rate will result in higher powerconsumption and also more noise generation by the cooling system which is notdesirable. Adding more nanoparticles to the base fluid will increase the cost of the coolant and possible instability of nanofluid which should be avoided. Therefore,an optimum value for flow rate and particle concentration should be determined to satisfy the economy of system for real practical operating conditions.



IV. CONCLUSIONS

For the selection of suitable nanofluid for computer cooling systems, thefollowing parameters should be considered:

1. Better thermal performance in comparison to common thermal fluids suchas water and ethylene glycol
2. No chemical and corrosion impact on cooling system
3. Stability of suspension
4. Economical aspects over its cooling performance
5. Availability and price

Thermal properties and the effect of using nanofluids on cooling performance of liquid cooling systems were investigated in this research. Three nanoparticles of alumina, silica and titania were used with a mixture of water/ethylene glycol as the base fluid. Using thesenanofluids resulted in the considerable reduction of processor operating temperature as compared to the pure base fluid. However, the diversity of nanoparticles suggests that there may be other nanoparticles withbetter thermal performance, which could have more favorable effect on the cooling system. But the cost of nanoparticles and in general the economy of thecooling system should not be neglected. Therefore, exploiting nanofluids can only be performed if the final cost of the cooling system with nanofluid is in a reasonable range. Stability of nanofluid is the other challenging aspect of their useas coolants. It seems that nanofluids have a good prospective for new computercooling systems, especially for data centers, computer servers and any electronic systems in which heat generation is a major problem. Decreasing operationtemperatures, reducing the volume of cooling system and reduction of requiredpower for pumping the coolant through the system are main advantages of using nanofluids in the liquid cooling system compared to common water cooling kits. In fact, more research is needed to determine the stability of nanofluid in cooling systems and their influence on different parts of the system.

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