Thermal Performance of Nanofluids Applied to the Temperature Control of Electronic Components

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Abstract

The subject of this article is related to the development of a thermal management solution for a surveillance equipment, which needs to dissipate high levels of heat loads using both active and passive thermal control devices. A thermal management system was designed to use both a single-phase forced circulation loop and heat pipes using copper oxide (CuO)-water nanofluid, designed to promote the thermal management of up to 50 kW of heat generated by several arrays of electronic components, being dissipated to the environment by a fan cooling system. The heat pipes collect the heat from electronic components that are far from the main single-phase forced circulation loop, rejecting the heat directly in its cold plates. Results show that with an addition of 20% by mass of CuO nanoparticles to the base fluid in the single-phase system, enhancements of 12% in the heat transfer coefficients were achieved but the increase in the pressure drop was around 32%. The use of nanofluid in the heat pipes resulted in a substantial decrease in the heat source temperature. Upon using nanofluids in heat pipes, the maturity of this technology is considerably high.

Keywords: thermal enhancement, electronics cooling, thermal control, pressure drop, nanofluids.

Introduction

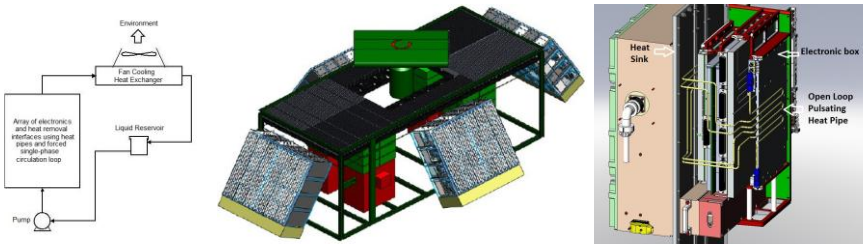
The need for thermal management has increased over the last decade and the prediction is that a steeper increase is yet to come for the next years. Such an increase is related to more powerful electronics used for data processing in high-tech equipments used for satellites and defense/military. Several investigations related to nanofluids applications have been conducted with important contributions to many areas [1,2]. Considering current and future thermal management needs, the use of nanofluids is becoming inevitable. Nanofluids present to be an important approach to enhance the heat transfer capability of heat pipes and loop heat pipes systems, which has already been proven [3]. An important application for today's needs for heat dissipation is related to surveillance systems. As more compact and powerful equipments are necessary, higher heat fluxes need to be properly addressed. Focused on the need for designing a reliable and effective thermal management system that need to operate in hostile environments, with potential use of nanofluid.

Equipment Design and Operation

A specific design for a surveillance system has been conceived to operate in hostile environments where the ambient temperatures can range from +5 to +50 °C and humidity levels up to 95%. In this case, a single-phase thermal control loop has been designed to use a nanofluid, presenting a forced circulation using a pump to move the working fluid throughout the circuit to remove heat from the electronic components, rejecting this heat to the environment by a fan cooling system. For this thermal management system, a hybrid design has been applied where the heat generated by all PCBs are removed by open loop pulsating heat pipes, delivering the heat to the heat sinks allocated thorough the surveillance equipment (cold plates). The heat sinks are then connected to the single-phase thermal control loop that collects all the heat and dissipate it to the environment. The schematics of such arrangement is presented by Fig. 1a and the surveillance equipment where it is installed is shown by Fig. 1b, whilst Fig. 1c presents the hybrid setup where the pulsating heat pipe and the heat sink are connected. As the base fluid, water has been selected. The CuO nanoparticles present an average diameter of 29 nm and purity of 99.8%. The nanoparticles concentration (f) shall vary from 3.5% to 20% (by mass of the base fluid) to verify their effect on the overall thermal performance of the system.

Results and Discussion

Figures 2a and 2b present some results for the pressure drop and heat transfer coefficients, respectively, on a comparison between the use of pure water and the addition of copper nanoparticles at different concentrations (*f*), by mass percentage of the working fluid in the system. The results are related to each individual electronics module (composed of 3 PCBs), which dissipate a maximum of 50 W of heat, thus, based on the module's footprint and heat dissipation, the calculation for the heat transfer coefficient was performed. It is clear that as the nanoparticle concentration increases, the pressure drop also increases up to 32% for *f*=20% as more solid nanoparticles are present in the system



(a) (b) (c)

Figure 1: Schematics of the thermal control system arrangement.

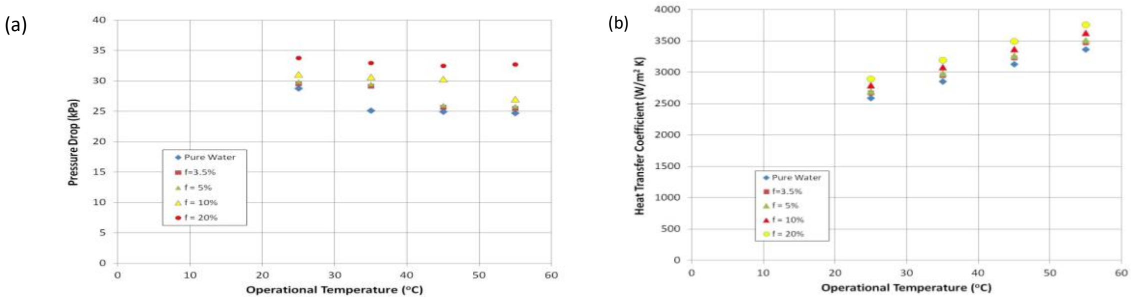


Figure 2: Results for (a) pressure drop and (b) heat transfer coefficient.

Conclusions

In general, the main conclusions that can be derived from this investigation are:

1. Higher heat transfer coefficients can be reached with the increase of the solid nanoparticles concentration, representing an enhancement of up to 12% for *f*=20% at 55 °C when compared with the operation with water;
2. The pressure drop also increases as the concentration of nanoparticles increases, which could compromise the pump operation;
3. The overall analysis indicates that the application of the nanofluid with higher concentrations can be used, as the major parameter for this analysis is the heat transfer coefficient, which is reducing the size of the thermal management system applied to control the temperature of the electronics components.

When considering that the thermal management system is operating at higher capacities, while keeping the working fluid’s temperature differences between the fan cooling inlet and outlet within certain required parameters, the use of a nanofluid presents to be an important innovative approach for this project. This is directly resulting in more gains than loses for the overall thermal system analysis and should remain as the most indicated solution for this application.

References

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