Modelling for Heat Transfer Enhancement Using Nano Fluids for Cooling of Electronic Component: A Review

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Abstract
Traditional cooling systems (Air cooling techniques) are not sufficient to remove these heat fluxes, so for many applications, this traditional technique will have to be replaced or increased by some other cooling techniques. The mixture of heat transfer fluid and solid particles together is termed as 'Nano fluid'. Nano fluids are good alternatives for electronic cooling applications. If nanoparticles size is not selected properly then they, settles very fast which causes clogging and damage to pump and flow equipment's. The purpose of this paper is to investigate the literature study, which are been, carried out for potential of using Nano fluids for enhancing heat transfer in the cooling of electronic components. The findings of this study will provide valuable insights for the design and optimization of cooling systems for electronic components, and the use of Nano fluids holds significant promise for achieving better cooling performance and the studies that are linked to these will be considered.
Keywords: Heat transfer, Nano fluids, Cooling, Electronic component, Fluid dynamics, Electronic cooling

1. **Introduction:**

Heat transfer enhancement using Nano fluids is a growing research area in the field of cooling electronic components. The goal of this research is to improve the thermal performance of cooling systems for electronic components, particularly for high power density electronics. In this context, Nano fluids are suspensions of nanoscale particles in a fluid base, and they have shown promising results in increasing heat transfer rates compared to conventional cooling fluids. This introduction provides a brief overview of the current state of the research in heat transfer enhancement using Nano fluids for cooling electronic components, and the potential benefits of this technology.

Peng et.al. (1996) experimentally investigated on the single-phase forced convective heat transfer and the flow characteristics of water in microchannel. Adams et al. (1998) investigated the single-phase turbulent flow of water in circular microchannels. A generalized correlation for the Nusselt number for single-phase turbulent flow in circular microchannels was proposed. Gillot et al. (2000) applied the single-phase and two-phase micro heat sinks for cooling of power components. Qu and Mudawar (2002) experimentally and numerically investigated the pressure drop and heat transfer characteristics of a single-phase micro-channel heat sink. The results obtained from the numerical prediction were reasonable agreement with the measured data. Hetsroni et al. (2002).

Nano fluids

Nano fluids are suspensions of nanoscale particles in a liquid, typically water, with improved thermal conductivity and other physical properties compared to the base fluid. The nanoscale particles can be made of metal oxides, carbon nanotubes, or other materials, and the improved properties of Nano fluids are due to the high surface area of the particles and the way they interact with the fluid. Nano fluids have potential applications in areas such as electronics cooling, solar thermal energy storage, and heat transfer in industrial processes.

Paisarn Naphon et.al. (2013) numerous papers presented the study on heat transfer and pressure drop of nano-fluids in the mini-andmicrochannel with wide variety of nanoparticles. However, only few work reported on the application of nanofluids with suspending TiO_2 nanoparticles for the cooling electronic components.F. Mebarek-Oudina et.al. (2022) Multiple approaches have been adopted3 to develop advanced fluids in order to overcome the constraint of the poor thermo-physical properties of the conventional HTFs and aim for considerable higher thermal conductivities.

modern technology made it possible to avoid such obstacles by providing fluids with small enough-sized particles that can move freely in such passages;14 introducing the term "Nano-fluids" that refers to fluids that have Nano-scale particles dispersed throughout them. They can be produced by suspending nanoparticles sized less than 100 nm of metal components (e.g., Ag, Zn, Cu, and Fe) or oxide components (e.g., CuO, Cu_2O, Al_2O_3, and TiO_2) into conventional heat transfer fluids.

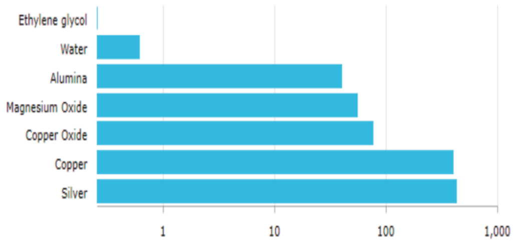

Fig: Thermal conductivity comparison (Source: F. Mebarek-Oudina et.al. (2022))

Importance of cooling electronic components

Electronic components generate heat during operation, which can cause damage and reduce their lifespan. Cooling is important to prevent overheating and maintain the reliability and performance of the components. Effective cooling can also improve energy efficiency and increase the stability of the system, which helps to prevent crashes or shutdowns.

Heat Transfer Enhancement

Heat transfer enhancement refers to the process of increasing the rate of heat transfer from one substance to another, or from a substance to its surroundings. This can be achieved through various methods such as adding a conductive material, increasing the surface area, creating turbulence, using a heat exchanger, or applying a cooling fluid. The goal of heat transfer enhancement is to increase the efficiency of heat transfer and reduce the time required for heating or cooling a substance.

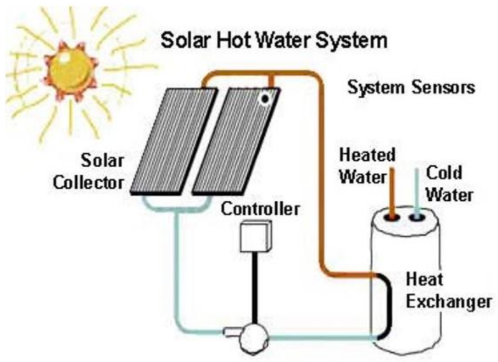

Fig 1: Nanofluids in Electronics Cooling Applications

History of nano fluids for heat transfer

Nanofluids, suspensions of nanoscale particles in a fluid base, were first introduced in 1995 by Prof. Choi at the University of Alabama, as a novel means for enhancing heat transfer. The idea behind nanofluids was to exploit the large surface area to volume ratio of nanoparticles to increase the thermal conductivity of the fluid. Since then, numerous studies have been conducted to investigate the heat transfer characteristics of nanofluids and their potential applications in various fields, including electronics cooling, solar thermal systems, and automotive radiators. Despite initial promising results, the practical implementation of nanofluids in heat transfer applications has been limited by several challenges, such as particle stability, clogging, and toxicity. Nevertheless, the development of new synthesis techniques and the increasing understanding of the mechanisms behind nanofluid heat transfer are expected to open new avenues for their application in the future.

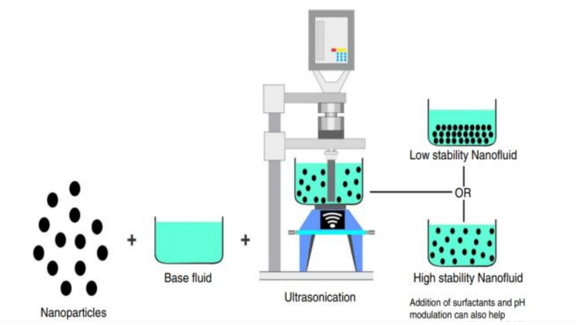

Fig 2: Nanofluids in various heat transfer devices.

Mohsen Izadi (2020) Nano -fluids have a high potential to be used to enhance heat transfer. Many studies have been conducted in the field of heat transfer enhancement using Nano -fluids. Conducted several studies on Nano -fluid heat transfer. In a study, they reported that at low Reynolds numbers, the friction coefficient is a function of particle concentration and this dependency reduces as Reynolds number increases. In another study, they examined 3 -D mixed convection heat transfer and found that secondary flows are reinforced on cross -sections by adding Nano -particles. They also investigated the Buongiorno model for natural convection between two eccentric cylinders and found that as Lewis number reduces, Nano -particle collisions reduce, reducing Nusselt number.
Advantages of using Nano fluids for cooling

Nano-fluids have several advantages for cooling applications, including:

1. Enhanced thermal conductivity: Nanoparticles suspended in a fluid base can increase its thermal conductivity, leading to more efficient heat transfer.
2. Increased heat capacity: The addition of nanoparticles to a fluid also increases its heat capacity, allowing it to absorb more heat before undergoing a temperature change.
3. Improved stability: The small size of the nanoparticles in nanofluids leads to improved stability and reduced sedimentation, making them more effective over a longer period of time.
4. Better cooling efficiency: The increased thermal conductivity and heat capacity of nanofluids can result in improved cooling efficiency in applications such as heat exchangers and cooling systems.
5. Potential for wider temperature range: Different types of nanoparticles can be added to nanofluids to tailor their thermal properties for specific temperature ranges, allowing for wider use in different cooling applications.

Physical Properties of W/A and W/A -C Nano – Fluid's

Physical properties of Nano -fluids, including single Nano -fluid of water/aluminum oxide and hybrid Nano -fluid of water/aluminum oxide -copper, are directly calculated using the existing experimental data, with the physical properties changes in the time being neglected. The thermophysical properties of water, alumina and copper nano - particles, and the solid matrix of the porous environment at 25°C is provided in table below,

Nano-Fluids Applications and Heat Transfer

F. Mebarek-Oudina, et.al (2022) conducted research on "Review on Nano-Fluids Applications and Heat Transfer Enhancement Techniques in Different Enclosures" In this review paper, the use of magnetic fields, porous media, and Nano-fluids in different heat transfer applications is discussed mainly in the solar thermal field. It has been proven that the employment of these techniques provides significant enhancement results for convective flows especially when they are combined, also the mathematical equations used to model this type of flow are summarized. In addition, different studies reported that the geometrical parameters of the enclosures can also effect the flow. In this context, recently scholars maintained many investigations on complex shaped cavities and their impact on heat transfer. These studies showed promising results for the use of this type of geometries especially for the trapezoidal ones. As reviewed in this paper, trapezoidal geometries and their properties strongly effect the convective flow in a great way leading to considerable enhancement.

Mohsen Izadi, et.al (2020) study founded on "Effects of Porous Material on transient natural convection Heat Transfer of Nano -Fluid s inside a Triangular Chamber" This study numerically investigates the impact of porous materials, Nano particle types, and their concentrations on transient natural convection heat transfer of Nano fluid inside a porous chamber with a triangular section. The governing equations of the two - phase mixture model are separated on the computational domain and solved using the Finite Volume Method, taking into account the Darcy - Brinkman model for porous medium. It was observed that convection heat transfer inside the triangular chamber consists of three stages named initial, transient, semi -steady. The features of each step are provided in detail.

Nano fluids and Al2O3

In Cheol Bang et.al (2005) conducted research on "Boiling heat transfer performance and phenomena of Al2O3–water Nano-fluids from a plain surface in a pool" This study is related to a change of surface characteristics by the deposition of nano-particles. In addition, comparisons between the heat transfer data and the Rhosenow correlation show that the correlation can potentially predict the performance with an appropriate modified liquid-surface combination factor and changed physical properties of the base liquid. Boiling heat transfer characteristics of nano-fluids with nano-particles suspended in water are studied using different volume concentrations of alumina nano-particles. Pool boiling heat transfer coefficients and phenomena of nano-fluids are compared with those of pure water, which are acquired on a smooth horizontal flat surface (roughness of a few tens nano-meters).

O. Pourmehran, et.al (2018) study focused on "Rheological behaviour of various metal-based nano-fluids between rotating discs: a new insight" In this study, nanofluid flow and heat transfer between two contracting and rotating disks are investigated. Brownian motion is considered to simulate viscosity of nanofluid and Patel model is used to predict the behavior of thermal conductivity of nanofluid. The governing equations are solved via the fourthorder Range–Kutta method. Different kinds of nanoparticles are examined. Effects of active parameters such as nanoparticle volume fraction, rotational Reynolds number, injection Reynolds number, and expansion ratio are considered. Results indicate that Nusselt number is a decreasing function of expansion ratio while it is increasing function of other parameters such as nanoparticle volume fraction, rotational Reynolds number, and injection Reynolds number.

Shilpi, et.al (2020) conducted study on " Heat transfer model to study nano fluids & its application" In this review article we will discussed various method to synthesis Nano fluids and its thermo physical properties and applications. With enormous improvisations in nanotechnology field, a heat transfer in Nano fluid become gorgeous phenomena and their thermal conductivity measurement are more attractive concept then conventional heat transfer mechanism in fluids. Tactlessly the enhancement of thermal conductivity in Nano fluids unable to explain by conventional model. When nanoparticles are suspended in a fluid, at very low concentration it can enhanced thermophysical properties and heat transfer performance.

Nandy Putra, et.al (2003) conducted research on "Natural convection of nano-fluids" The present study deals with one such aspect of natural convection of nano fluids inside horizontal cylinder heated from one end and cooled from the other. An apparently paradoxical behaviour of heat transfer deterioration was observed in the experimental study. Nature of this deterioration and its dependence on parameters such as particle concentration, material of the particles and geometry of the containing cavity have been investigated. The fluid shows characters distinct from that of common slurries. Fluids with nano size solid particles suspended in them have been given the name nano-fluid which in recent studies have shown tremendous promise as heat transfer fluids. However, before suggesting such fluids for applications a thorough knowledge of physical mechanism of heat transfer in such fluids is wanted

Sarit K. Das, et.al (2003) conducted research on "Pool boiling characteristics of nano-fluids" This study indicates that the role of transient conduction in pool boiling is overshadowed by some other effect. Since the particles under consideration are one to two orders of magnitude smaller than the surface roughness it was concluded that the change of surface characteristics during boiling due to trapped particles on the surface is the cause for the shift of the boiling characteristics in the negative direction. The results serve as a guidance for the design of cooling systems with nanofluids where an overheating may occur if saturation temperature is attained. It also indicates the possibility of such engineered fluids to be used in material processing or heat treatment applications where a higher pre-assigned surface temperature is required to be maintained without changing the fluid temperature. Common fluids with particles of the order of nanometers in size are termed as nano-fluids which have created considerable interest in recent times for their improved heat transfer capabilities.

Eric C. Okonkwo, et.al (2021) study focused on "An updated review of nanofuids in various heat transfer devices" This review aims to update readers on recent progress while also highlighting the challenges and future of nanofuids as the next-generation heat transfer fuids. Finally, a conclusion on the merits and demerits of nanofuids is presented along with recommendations for future studies that would mobilise the rapid commercialisation of nanofuids. The feld of nanofuids has received interesting attention since the concept of dispersing nanoscaled particles into a fuid was frst introduced in the later part of the twentieth century. This is evident from the increased number of studies related to nanofuids published annually. The increasing attention on nanofuids is primarily due to their enhanced thermophysical properties and their ability to be incorporated into a wide range of thermal applications ranging from enhancing the efectiveness of heat exchangers used in industries to solar energy harvesting for renewable energy production.

3. Scope of The Research

Heat dissipation from microprocessors is increasing constantly. Demand for microprocessors having high computing ability has increased due to growth in information technology. Heat dissipation from high end CPU is 110-140 W. To remove this much heat, conventional air cooling techniques are not sufficient. So for various applications this technique will have to be replace by some advanced thermal management techniques. Advancement in nanofabrication and processes allowed to create solid particles of nanoparticle size. These particles are mixed with base fluids such as water. The mixture so formed is termed as nanofluids. Various experimental investigation have been done using various nanofluids for heat transfer enhancement. These various methods were detected through the literatures and the best suited proper research method can be implemented.

4. Conclusion

The review paper provides a comprehensive review of the intriguing scientific advancement in the heat transfer enhancement domain. According to the work of many scholars in literature, investigating Nano-fluids flow in porous enclosures under magnetic fields in various solar, thermal and medical applications can be advantageous when it comes to environmental sustainability. It was reported by these studies that Nano-fluids and porous media properties have a proportional relationship with the flow enhancement, particularly regarding hybrid Nano-fluids that can offer remarkable heat transfer boosting effects. The various models that were studied are further compared and the cooling of Electronic components with the help of nano fluids is explained.

References

[1] Izadi, M. (2020). Effects of porous material on transient natural convection heat transfer of nano-fluids inside a triangular chamber. Chinese Journal of Chemical Engineering, 28(5), 1203–1213. https://doi.org/10.1016/j.cjche.2020.01.021

[2] Mebarek-Oudina, F., & Chabani, I. (2022).

[3] Review on Nano-Fluids Applications and Heat Transfer Enhancement Techniques in Different Enclosures. Journal of Nanofluids, 11(2), 155–168. https://doi.org/10.1166/jon.2022.1834

[4] Okonkwo, E. C., Wole-Osho, I., Almanassra, I. W., Abdullatif, Y. M., & Al-Ansari, T. (2021). An updated review of nanofluids in various heat transfer devices. In Journal of Thermal Analysis and Calorimetry (Vol. 145, Issue 6). Springer International Publishing. https://doi.org/10.1007/s10973-020-09760-2

[5] Das, S. K., Putra, N., & Roetzel, W. (2003). Pool boiling of nano-fluids on horizontal narrow tubes. International Journal of Multiphase Flow, 29(8), 1237–1247. https://doi.org/10.1016/S0301-9322(03)00105-8

[6] Krishna, K. H., Ganapathy, H., Sateesh, G., & Das, S. K. (2011). Pool boiling characteristics of metallic nanofluids. Journal of Heat Transfer, 133(11), 1–8. https://doi.org/10.1115/1.4002597

[7] Putra, N., Roetzel, W., & Das, S. K. (2003). Natural convection of nano-fluids. Heat and Mass Transfer/Waerme- Und Stoffuebertragung, 39(8–9), 775–784. https://doi.org/10.1007/s00231-002-0382-z

[8] Shilpi, Vasishth, A., & Aggarwal, N. (2020). Heat transfer model to study nano fluids & its application. Materials Today: Proceedings, 37(Part 2), 3074–3076. https://doi.org/10.1016/j.matpr.2020.09.014

[9] Pourmehran, O., Sarafraz, M. M., Rahimi-Gorji, M., & Ganji, D. D. (2018). Rheological behaviour of various metal-based nano-fluids between rotating discs: a new insight. Journal of the Taiwan Institute of Chemical Engineers, 88, 37–48. https://doi.org/10.1016/j.jtice.2018.04.004

[10] Bang, I. C., & Heung Chang, S. (2005). Boiling heat transfer performance and phenomena of Al2O 3-water nano-fluids from a plain surface in a pool. International Journal of Heat and Mass Transfer, 48(12), 2407–2419. https://doi.org/10.1016/j.ijheatmasstransfer.2004.12.047