International Journal of Research and Development in Engineering Science
ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/
Regular Issue, Vol. 5, Issue.5 (September – October), 2023 , Pages: 15 - 19
Received: 18 December 2022 ; *Accepted*: 30 September 2023 ; *Published*: 20 October 2023
https://doi.org/10.63328/IJRDES-V5RI5P3
Brief Review: Policy Research – Editorial Paper

Enhancing Heat Transfer Efficiency with Hybrid Nanofluids: Current Trends and Future Prosopects

Aviradh R N [1*], **Mejo M Francis** [2*], **S Christopher Ezhil Singh** [3], **P Sridharan** [4]

[1-4] Department of Mechanical Engineering, Vimal Jyothi Engineering College, Kannur, Kerala, India – 670632;

** Corresponding Author: Aviradh R N ; aviradh@gmail.com*

Abstract: In this comprehensive overview, numerous papers on the application of hybrid nanofluids across a range of thermal uses are assembled, which also investigates the enhanced heat transmission characteristics of these materials. The study employs multiple approaches and focuses on the development of hybrid nanofluid technology as well as its possible applications to industrial operations. Research highlights how hybrid nanofluids operate better than traditional fluids, with notably higher heat transfer rates and coefficients. Researchers have demonstrated significant improvements in thermal efficiency and conductivity by investigating the application of hybrid nanofluids in different contexts, such as heat exchangers, solar panels, and thermoelectric generator modules. Studies have focused on particular combinations of nanoparticles, like h-BN, CF-MWCNTs, CF-GNPs, Ag-ZnO/Syltherm 800, and Al2O3-TiO2, and they have shown considerable gains in efficiency and heat transmission. The review emphasizes the benefits and drawbacks of hybrid nanofluids, as well as how they affect fluid viscosity and pressure drop. It talks about how they can be used in a variety of fields and how they can solve important problems like stability and economic viability. Research also examines how hybrid nanofluids are made, describing their characteristics and possible uses, highlighting how they can revolutionize heat transfer efficiency in a variety of industrial domains. The thorough examination seeks to bring together the developments, drawbacks, and potential applications of hybrid nanofluids in relation to the world's problems with energy efficiency and heat transmission.

Keywords:

1. Introduction

An in-depth review of hybrid the incredible potential of nanofluids to enhance heat transfer efficiency in a range of industrial applications is provided by this collection of research publications. In terms of heat transfer rates and thermal conductivity, hybrid nanofluids perform better than conventional fluids and mono nanofluids. The research explore the creation, characteristics, and applications of hybrid nanofluids. The investigation covers a wide range of topics, including solar panels, heat exchangers, thermoelectric generating modules, and sophisticated thermal systems. In order to determine how different nanoparticle concentrations and combinations affect thermal efficiency, convective heat transfer, and heat transfer coefficients, researchers experiment. Particularly, when compared to base fluids, some hybrid nanofluid formulations exhibit notable increases in convective heat transfer coefficients and thermal efficiencies, indicating that they have a great deal of potential to improve heat transfer performance. Investigations also highlight the difficulties with hybrid nanofluids, such as their viscosity, penalty for pressure drops, gradual sedimentation of nanoparticles, and requirement for stabilizing chemicals. In spite of these difficulties, the results indicate that hybrid nanofluids have a great deal of potential for use in different heat transfer systems, opening the door for more study to improve their stability, formulations, and economic applications. Having a thorough understanding of the current state of hybrid nanofluids and their potential future possibilities for improving heat transfer efficiency is made possible by this extensive overview.

2. Literature Review

Atul Bhattad et al. [2020] evaluated the effectiveness of an Al2O3-TiO2 hybrid nanofluid in a heat exchanger with plates. The scientists discovered that the hybrid nanofluid performed better at heat transfer than DI water, with a

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ , IJRDES, Vol. 5, Issue 5, 2023 , https://doi.org/10.63328/IJRDES-V5RI5P3

maximum boost of 16.91% for the heat transfer rate, and 4.5 percent for the convective heat transfer coefficient. The authors also developed relationships to predict the Heat transfer coefficient and Nusselt number for the hybrid nanofluid and DI water, respectively.

Yasser M. Abdullatif et al. [2020] talked about how nanofluids are becoming more and more popular because of their improved thermophysical qualities and wide range of uses in heat transfer devices. Additionally, it identifies areas that warrant further investigation and advancement, such as the manufacture of nanofluids, their thermophysical characteristics, the mechanisms that impact their behavior, and their use in a range of heat transfer devices. In order to solve these issues and advance the commercialization of nanofluids, the review emphasizes the necessity for additional research.

In their study, Muhammad Mahmud Jamil et al.[2016] reviewed a wide range of studies on the production, properties, and applications of hybrid nanofluids. They discovered that compared to base fluids, hybrid nanofluids offer superior thermal properties and fluids with individual nanoparticles. Furthermore, up to a certain point, the thermal properties of the volume fraction and temperature of hybrid nanofluids rise. The hybrid nanofluid's performance declines after this point.

In order to improve a thermoelectric generator module's performance surface roughness, as well as hybrid nanofluid are coupled, as stated by Fatih Selimefendigil et al. [2020]. Through numerical simulations, It is shown that the TEG power rises with the Reynolds number (10.95% at 250, 7.50% at 1000), the height of corrugation (9.5% for circular), the quantity of waves in the surface corrugation and the hybrid nanoparticles' solid volume portion (17.3 percent for rectangular, 19.6 percent for circular).
The enhancement of heat transfer from the hybrid nano fluid Al_2O_3-Cu/water was investigated by

S. Anitha et al. [2019]. Compared to water, the heat transfer coefficient increases by 139%, and in contrast to Cu/H_2O nanofluid, it increases by 25%. Comparing the Nusselt number to the Al_2O_3/Water nanofluid, it increases by 90%. There is a 78% increase in the heat transmission rate as theReynolds number raises from 844.4 to 2321.54. The heat exchanger's efficiency riseby 124%.Omar A. Hussein et al. [2020] investigated hybrid nanofluids consisting of hexagonal boron nitride suspended in distilled water, the covalent functionalization of multi-wall nanotubes made of carbon and covalent functionalization-graphene nanoplatelets as working fluids for flat plate solar collectors . Compared to foundational fluids, the hybrid nanofluids showed improved thermal efficiency and increased thermal conductivity. The hybrid nanofluid showed an 85% thermal efficiency, a 21.9% increase in the heat removal factor (FR), and a 78.3% increase in the FR utilization factor (FRUL) at a weight concentration of no more than ten percent.

Examined under turbulent flow circumstances were three different hybrid nanofluids (Ag– ZnO/Syltherm 800, Ag–TiO_2/Syltherm 800, and Ag–MgO/Syltherm 800) in a parabolic trough solar collector (PTC) receiver by Recep Ekiciler et al. [2020]. The findings demonstrated that, in comparison to the base fluid, Syltherm 800, all three hybrid nanofluids improved heat transfer. The most effective working fluid was discovered to be the hybrid nanofluid Ag–MgO/Syltherm 800 with a volume fraction of 4.0 percent nanoparticles. This fluid demonstrated a 31% improvement in convective heat transfer and a 13% increase in thermal efficiency.

Heat transfer enhancement using (BFS) and microscale or (FFS) was studied by S. Salman et al. [2019]. Simulations and experiments consistently demonstrated that FFS and BFS improve heat transfer; however, studies utilizing hybrid nanofluids were scarce and experiments were limited to local measurements. In comparison to base fluids, hybrid nanofluids functioned better, and their efficacy rose with temperature and volume fraction.

According to S. Manjunatha et al. [2019], due to their higher thermal conductivity, nanofluids that are hybrids perform better in heat transfer than standard nanofluids. Temperature and flow are influenced by magnetic field, convection, and variable viscosity. Temperature and fluid flow are increased by volume fraction. Heat transfer nanofluids that are hybrids are more efficient.

Improved heat transfer in solar panels, HVAC systems, heat sinks, heat pipes, heat exchangers, boiling, jet impingement cooling, and latent heat thermal energy storage systems is a topic covered by M. Muneeshwaran et al. [2021]. Although hybrid nanofluids perform noticeably better in terms of heat transfer, their higher viscosity results in a pressure drop penalty.

In a study conducted by Adnan Mohammed Hussein [2017], it was found that hybrid nano fluids, when compared to regular nanofluids with a 4% nanoparticle concentration and a 2% nanoparticle concentration, enhanced heat transfer by 16%–27%. Because of its superior thermal properties, the hybrid nanofluid containing 2% CuO nanoparticles has a higher heat transfer rate than one containing 1% Al_2O_3 and 1% CuO nanoparticles. Since the heat transfer coefficient hybrid nano fluid is so similar to that of the 2% CuO nanofluid, it is still a good choice when CuO usage is restricted.

Arun Kumar Tiwari et al. [2021] investigated the behavior of hybrid nanofluids in a spiral plate heat

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ , IJRDES, Vol. 5, Issue 5, 2023 , https://doi.org/10.63328/IJRDES-V5RI5P3

exchanger (SPHE) in turbulent flow conditions. The results showed that, at nanoparticle volume concentrations of 4% and 2%, hybrid nanofluids comprising Al2O3 and CuO nanoparticles could raise the heat transfer coefficient by 16–27 percent and 10–16 percent, respectively, in comparison to pure water. The hybrid nanofluid containing Al2O3 and CuO nanoparticles likewise showed a higher heat transfer coefficient than the one including Al2O3 and TiO2 nanoparticles. The authors concluded that hybrid nanofluids present a viable alternative to conventional heat transfer fluids for SPHE applications.

The making of hybrid nanofluids, their thermophysical characteristics as well as the use of hybrid nanofluids to transfer heat enhancement were covered by Ahmed A. Hussien et al. [2021]. It is also discussed how the combination of various nanoparticle properties leads to superior heat conductivity and a 148% increase in relation to the base fluid's heat transfer coefficient.

Abderrahmane Aissa et al. [2022] discussed the usage of Advanced thermal systems employ ceramics and ceramic matrix composites in their heat exchangers. They also went over the most current advancements in these materials, their applications, and how heat exchanger performance is impacted by them. It was also discussed how these materials might improve the thermal systems' dependability and efficiency.

Hybrid nanofluids, or base fluids containing two or more distinct nanoparticles, have been shown to improve heat exchanger performance by up to 20 percent, according to research by Javier P. Vallejo et al. [2021]. The effectiveness of heat transfer is greatly influenced by the type and concentration of nanoparticles. Hybrid nanofluids have the potential to be used in a wide range of heat exchanger applications; however, further study is needed to maximise their potential and overcome the challenges associated with commercialization.

According to J.A. Ranga Babu et al. [2017], hybrid nanofluids are a novel class of heat transfer fluids that have the ability to get around some of the drawbacks of mono nanofluids. Their thermal conductivity is much higher, and they can increase heat transfer efficiency by up to 13.56%. They also have a greater pressure drop and viscosity, though. Although hybrid nanofluids are still in the research and development phase, many heat exchanger applications may find use for them.

According to Humaira Yasmin et al. [2022], nanofluids (NFs) are suspensions of nanoparticles in regular thermal fluids. They outperform conventional thermal fluids in terms of heat transfer performance, photothermal conversion, optical, tribological, and convective characteristics. NF preparation, characteristics, performance, and application, however, depend on stability. Additionally, it covered the methods for characterization, stability, and preparation used in NF studies as well as the effects of various preparations features regarding the transport of heat, photothermal conversion, and thermal properties of mono and hybrid NFs.

3. Result and Discussion

The results of several studies highlight how important hybrid nanofluids are for improving heat transfer efficiency in a range of applications. Atul Bhattad et al. [2020] demonstrated that Al2O3- TiO2 hybrid nanofluids outperform DI water in plate heat exchangers, with a 16.91 percent increase at most in the convective coefficient of heat transmission. Similar to this, S. Anitha et al. [2019] found that Al2O3-Cu/water hybrid nanofluids significantly increased their heat transfer coefficients, surpassing those of both water and Cu/water nanofluids.
In addition, studies conducted by Omar A. Hussein in 2020, et al. and Recep Ekiciler in addition to others [2020] highlighted the potential of various hybrid nanofluids, including CF-MWCNTs, CF-GNPs, h-BN, Ag–ZnO, in notably enhancing thermal efficiency and convective heat transfer in solar power accumulators, separately.

Nonetheless, as some academics have pointed out, difficulties still exist. Although J.A. Ranga Babu et al. [2017] warned about increased pressure drop and viscosity associated with hybrid nanofluids, despite their improved heat transfer efficiency, Javier P. Vallejo et al. [2021] emphasized the necessity for further optimization of hybrid nanofluids in specific applications. Abdul Kaggwa et al. [2019] brought out stability concerns, highlighting the need for stabilizing chemicals to stop nanoparticle sedimentation over time.

Notwithstanding these difficulties, a comprehensive analysis of the research indicates that hybrid nanofluids have great potential to transform heat transfer systems. Numerous studies in the reviewed literature emphasize the need for additional research to address stability, enhance formulations, and close the gap between commercial use and lab-scale advancements.

4. Conclusion

Although Hybrid nanofluids have been the subject of much research on how to increase heat transfer in a variety of applications, which shows that they could be a viable option for better thermal performance. Research findings continuously demonstrate the substantial benefits of hybrid nanofluids over single nanoparticles and base fluids, exhibiting noteworthy improvements in thermal

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ , IJRDES, Vol. 5, Issue 5, 2023 , https://doi.org/10.63328/IJRDES-V5RI5P3

efficiency, convective heat transfer coefficients, as well as heat transmission rates.

In contrast to mono- and conventional-fluids, hybrid nanofluids—which contain several different nanoparticles—offer better thermal properties. Their enhanced thermal conductivity leads to improved heat transfer efficiency in a number of systems, including solar collectors, thermoelectric generator modules, plate heat exchangers. Hybrid nanofluids' improved heat conductivity, significant gains in convective heat transfer, and increased thermal efficiency are all caused by the combination of several nanoparticle characteristics.

On the other hand, difficulties still exist, such as problems with stability, viscosity, and particle sedimentation over time. To enhance formulations, handle stability issues, and close the gap between laboratory-scale breakthroughs and the real-world commercial application of hybrid nanofluids, more research is required. The requirement for uniform formulas and thorough knowledge regarding the manufacture, stability, and characterisation of these nanofluids is further highlighted by the variation in reported heat transfer increases.

Despite these challenges, the combined research shows how The potential for hybrid nanofluids to revolutionize mechanisms for transferring heat across a range of industries and pave the way for more advanced and efficient thermal management approaches.

References

[1]. Atul Bhattad & Jahar Sarkar & Pradyumna Ghosh, (2020) Heat transfer characteristics of plate heat exchanger using hybrid nanofluids: effect of nanoparticle mixture ratio, Volume 56, DOI: https://doi.org/10.1007/s00231-020-02877-y

[2]. Eric C. Okonkwo, Ifeoluwa Wole-Osho, Ismail W. Almanassra, Yasser M. Abdullatif, Tareq Al-Ansari, (2020) An updated review of nanofluids in various heat transfer devices

[3]. ,volume 145, DOI: https://doi.org/10.1007/s10973-020-09760-2

[4]. Nor Azwadi Che Sidik, Isa Muhammad Adamu, Muhammad Mahmud Jamil, G.H.R. Kefayati ,Rizalman Mamat , G. Najafi, (2016) Recent progress on hybrid nanofluids in heat transfer applications: A comprehensive review ,volume 78, DOI : https://doi.org/10.1016/j.icheatmasstransfer.2016.08.019

[5]. Fatih Selimefendigil, Hakan F. Oztop, (2020) The potential benefits of surface corrugation and hybrid nanofluids in channel flow on the performance enhancement of a thermo-electric module in energy systems ,volume 213, DOI: https://doi.org/10.1016/j.energy.2020.118520

[6]. S. Anitha, Tiju Thomas, V. Parthiban, M. Pichumani, (2019) What dominates heat transfer performance of hybrid nanofluid in single pass shell and tube heat exchanger? ,volume 30, DOI: https://doi.org/10.1016/j.apt.2019.09.018

[7]. Omar A. Hussein, Khairul Habib, Ali S. Muhsan, R. Saidur, Omer A. Alawi, (2020) Thermal performance enhancement of a flat plate solar collector using hybrid nanofluid, volume 204, DOI: https://doi.org/10.1016/j.solener.2020.04.034

[8]. Recep Ekiciler, Kamil Arslan, Oğuz Turgut, Burak Kurşun, (2020) Effect of hybrid nanofluid on heat transfer performance of parabolic through solar collector receiver, volume 143, DOI: https://doi.org/10.1007/s10973-020-09717-5

[9]. S. Salman, A.R. Abu Talib, S. Saadon, M.T. Hameed Sultan, (2020) Hybrid nanofluid flow and heat transfer over backward and forward steps: A review, volume 363, DOI: https://doi.org/10.1016/j.powtec.2019.12.038

[10]. Babak Sadeghi, B. Ammani Kuttan, S. Jayanthi, Ali Chamkha, B. J. Gireesha, (2019) Heat transfer enhancement in the boundary layer flow of hybrid nanofluids due to variable viscosity and natural convection, volume

[11]. M. Muneeshwaran, G. Srinivasan, P. Muthukumar, Chi-Chuan Wang, (2021) Role of hybrid-nanofluid in heat transfer enhancement – A review ,volume 125, DOI: https://doi.org/10.1016/j.icheatmasstransfer.2021.105341

[12]. Adnan Mohammed Hussein, (2017) Thermal performance and thermal properties of hybrid nanofluid laminar flow in a double pipe heat exchanger, volume 88, DOI: https://doi.org/10.1016/j.expthermflusci.2017.05.015

[13]. Arun Kumar Tiwari, Vijay Kumar, Zafar Said, H.K. Paliwal, (2021) A review on the application of hybrid nanofluids for parabolic trough collector: Recent progress and outlook ,volume 292, DOI: https://doi.org/10.1016/j.jclepro.2021.126031

[14]. Ahmed A. Hussien, Wael Al- Kouz, Nadiahnor Md Yusop, Mohd Z. Abdullah, Ayub Ahmed Janvekar, (2023) A Brief Survey of Preparation and Heat Transfer Enhancement of Hybrid Nanofluids, volume 220, DOI: https://doi.org/10.5545/sv-jme.2019.6077

[15]. Abderrahmane Aissa, Naef A.A. Qasem, Abed Mourad, Houssem Laidoudi, Obai Younis, Kamel Guedri, Anas Alazzam, (2017) A review of the enhancement of solar thermal collectors using nanofluids and turbulators ,volume 19, DOI: https://doi.org/10.1016/j.applthermaleng.2022.119663

[16]. Javier P. Vallejo, Jose I. Prado, Luis Lugo, (2022) Hybrid or mono nanofluids for convective heat transfer applications. A critical review of experimental research, Volume, 203, DOI: https://doi.org/10.1016/j.applthermaleng.2021.117926

[17]. J.A. Ranga Babu, K. Kiran Kumar, S. Srinivasa Rao, (2017) State-of-art review on hybrid nanofluids, volume 77, DOI: https://doi.org/10.1016/j.rser.2017.04.040

[18]. Humaira Yasmin , Solomon O. Giwa, Saima Noor ,Hikmet ¸S. Aybar, (2022) Influence of Preparation Characteristics on Stability, Properties and Performance of Mono- and Hybrid Nanofluids: Current and Future Perspective , volume 28, DOI: https://doi.org/10.3390/machines11010112

[19]. Humaira Yasmin, Solomon O Giwa, Saima Noot, Hikmet, S. Aybar, (2022) Influence of Preparation and Performance of Mono and Hybrid Nanofluids: Current and Future Perspective, Volume 28, DOI: https://doi.org/10.3390/machines11010112

[20]. Sujata Kalsi, Sunil Kumar, Anil Kumar, Tabish Alam, Dan Dobrota, (2023) Thermophysical Properties of nanofluids and their potential applications in heat transfer enhancement: A review, volume 16. DOI: https://doi.org/10.1016/j.arabjc.2023.105272

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ , IJRDES, Vol. 5, Issue 5, 2023 , https://doi.org/10.63328/IJRDES-V5RI5P3

[21]. S. Suneetha, K. Subbarayudu, P. Bala Anki Reddy, (2020) Hybrid nanofluids development and benefits: A comprehensive review , volume 42, DOI : https://doi.org/10.18186/thermal.1117455

[22]. Abdul Kaggwa, James K. Carson, (2019) Developments and future insights of using nanofluids for heat transfer enhancements in thermal systems: a review of recent literature, volume 124, DOI : https://doi.org/10.1007/s40089-019-00281-x

[23]. Temiloluwa O Scott, Daniel R E Ewim, Andrew C Eloka-Eboka, (2022) Hybrid nanofluids flow and heat transfer in cavities: a technological review, volume 17, DOI: https://doi.org/10.1093/ijlct/ctac093

[24]. Xiaoke Li, Hao Wang, Boqiu Luo, (2021) The thermophysical properties and enhanced heat transfer performance of SiC-MWCNTs hybrid nanofluids for car radiator system , volume 612, DOI: https://doi.org/10.1016/j.colsurfa.2020.125968

[25]. Zafar Said, Prabhakar Sharma, L. Syam Sundar, Changhe Li, Duy Cuong Tran, Nguyen Dang Khoa Pham, Xuan Phuong Nguyen, (2022) Improving the thermal efficiency of a solar flat plate collector using MWCNT-Fe3O4/water hybrid nanofluids and ensemble machine learning , volume 40, DOI: https://doi.org/10.1016/j.csite.2022.102448

[26]. A.G. Olabi, Tabbi Wilberforce, Enas Taha Sayed, Khaled Elsaid, S.M. Atiqure Rahman, Mohammad Ali Abdelkareem, (2021) Geometrical effect coupled with nanofluid on heat transfer enhancement in heat exchangers , Volume 10, DOI: https://doi.org/10.1016/j.ijft.2021.100072

[27]. Qingang Xiong, Sam Altnji, Tahar Tayebi, Mohsen Izadi, Ahmad Hajjar, Bengt Sundén, Larry K.B. Li, (2021) A comprehensive review on the application of hybrid nanofluids in solar energy collectors, volume 47, DOI: https://doi.org/10.1016/j.seta.2021.101341