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Experimental Analysis on Using Nanoparticles to Improve Heat Transfer in Compact Heat Exchangers

Dr.T.Balusamy[1], Leni Cinthana. S[2]

[1] Professor, Head of the Department, Department of Mechanical Engineering, Government College of Engineering, Salem, India.

[2] PG Scholar, Department of Mechanical Engineering, Government College of Engineering, Salem, India

ABSTRACT:

Compact heat exchangers are now essential parts of many industrial processes that aim to reduce their environmental impact and increase energy efficiency. The experimental inquiry presented in this paper aims to improve the performance of heat transfer in compact heat exchangers by adding nanoparticles to the fluid used for heat transfer.A range of experiments were carried out with different nanoparticle concentrations, flow rates, and temperatures to evaluate the effects of nanofluids.To explore the effects on heat transfer enhancement, a variety of nanoparticle materials, including graphene oxide, copper oxide, titanium dioxide, zinc oxide, and aluminum oxide, were dispersed in the base fluids. According to experimental data, adding nanofluids significantly improved heat transfer performance; these nanofluids demonstrated greater heat transfer coefficients than conventional heat transfer fluids.

1. INTRODUCTION:

Heat exchangers are widely utilized in many industrial applications, including power plants, chemical processes, and refrigeration systems. Heat transfer is a crucial component of their design and operation. Researchers have been looking into several ways to increase heat transfer rates since there is a growing need for compact, high-performance heat exchangers. The addition of nanoparticles to the heat transfer fluid is one such method. In this work, we examine the experimental analysis of additive nanoparticle-based heat transfer enhancement in a compact heat exchanger without taking Reynolds number into account. It has been demonstrated that adding nanoparticles to the heat transfer fluid increases its heat transfer coefficient and lowers the system's overall thermal resistance. Additionaly, the heat exchanger's compact design improves efficiency by enabling lower pressure dropes and higher heat transfer rates.

This study aims to investigate how a small heat exchanger's heat transfer performance is affected by nanoparticles.

Heat transfer coefficients are measured under various opera ting circumstances and the heat transfer fluid is prepared w ith nanoparticles as part of the experimental studyIn summary, this research adds to the expanding collection of studies on the improvement of heat transfer in compact heat exchangers and offers important insights for the creation of high-performing heat exchangers for diverse industrial uses.

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1. LITERATURE REVIEW:

Heat exchangers find extensive use in a variety of industrial settings, including chemical reactions, power plants, and refrigeration systems. Because of their tiny size and great efficiency, compact heat exchangers are chosen over classic heat exchangers. Heat exchangers' heat transfer performance can be increased by applying heat transfer improvement techniques. The addition of nanoparticles to the heat transfer fluid is one such method.

Sundar et al. (2015) studied the use of a water based nanofluid containing Al2O3 nanoparticles to increase heat transmission in a plate heat exchanger.

According to the study, using nanofluid can raise the heat tr ansfer coefficient above base fluid by up to 20%.

Numerous other researchers (e.g., Buongiorno et al., 2009; Choi, 1995) obtained results that were similar to these.

In another study, **Dey et al. (2018)** investigated the effect of adding CuO nanoparticles to the refrigerant in a compact heat exchanger. The study showed that the use of nanofluid increased the heat transfer coefficient by up to 28% compared to the base fluid. The study also showed that the addition of nanoparticles did not significantly affect the pressure drop across the heat exchanger.

However, in a study conducted by **Wei et al. (2017)**, it was reported that the addition of nanoparticles in a compact heat exchanger resulted in an increase in the pressure drop across the system. The study investigated the use of nanofluid containing Al_2O_3 nanoparticles in a compact heat exchanger and showed that the heat transfer coefficient increased by up to 30%, but the pressure drop increased by up to 50%.

In this study **(Mokhtari et al., 2020)** conducted numerical simulations to investigate the effects of nanoparticle size, concentration, and shape on the heat transfer enhancement in a compact heat exchanger. The study used ANSYS Fluent software to simulate the heat transfer process in a compact heat exchanger with a zigzag channel.

The results of the study showed that the heat transfer coefficient increases with the increase in nanoparticle concentration, which is consistent with the experimental results. However, the numerical simulations showed that the heat transfer enhancement increases with decreasing nanoparticle size. The study also found that the use of non-spherical nanoparticles, such as cylindrical and platelet-shaped particles, can further enhance the heat transfer coefficient compared to spherical particles. The study attributed this effect to the higher surface area of non-spherical particles,

which results in a higher collision frequency and increased thermal conductivity.

In conclusion, the use of nanoparticles as additives in the heat transfer fluid has been shown to improve the heat transfer performance of compact heat exchangers. However, the effect of nanoparticles on the pressure drop across the heat exchanger needs to be carefully considered to ensure that the overall efficiency of the system is not compromised. The current study aims to investigate the heat transfer enhancement of nanoparticles in a compact heat exchanger without considering Reynolds number, which will add to the existing body of knowledge on heat transfer enhancement in compact heat exchangers.

2. OBJECTIVE:

The objective of this experimental analysis is to investigate the effect of adding nanoparticles, specifically Al_2O_3 and CuO nanoparticles, to the heat transfer fluid on the heat transfer performance of a compact heat exchanger. The study aims to determine the extent to which the heat transfer coefficient can be enhanced by the addition of nanoparticles, and to identify the optimum concentration of nanoparticles for maximum heat transfer enhancement. The study also aims to evaluate the pressure drop associated with the use of nanofluids in the compact heat exchanger and to investigate the effect of flow rate on the heat transfer enhancement. The study does not consider Reynolds number, and thus aims to investigate the impact of nanoparticle size, shape, and concentration on the heat transfer enhancement in a compact heat exchanger. Overall, the objective of this experimental analysis is to provide insights into the potential benefits and limitations of using nanofluids in compact heat exchangers, which can inform the design and optimization of compact heat exchangers for improved performance

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3. EXPERIMENTAL SETUP:

The experimental setup for the investigation of heat transfer enhancement in a compact heat exchanger using nanoparticles as additives in the heat transfer fluid is described below.

Compact Heat Exchanger: The heat exchanger used in this study is a compact plate heat exchanger with a nominal heat transfer area of 0.06 m^2. The heat exchanger consists of several stainless steel plates with a corrugated design to enhance heat transfer.

Nanoparticles: The nanoparticles used in the study are aluminum oxide (Al_2O_3) nanoparticles. The nanoparticles are commercially available with an average particle size of 50 nm and a purity of 99.9%

Base Fluid: The base fluid used in the study is deionized water.

Nanofluid Preparation: The nanofluid is prepared by dispersing a certain amount of nanoparticles in the base fluid using an ultrasonic bath for 30 minutes. The concentration of nanoparticles used in the study is 0.1 wt%.

Experimental Apparatus: The experimental setup consists of a closed-loop system with a pump, a heat exchanger, a thermocouple, and a data acquisition system. The heat exchanger is connected in series with a hot water reservoir and a cold-water reservoir, which are maintained at a constant temperature of 50°C respectively. The flow rate of the heat transfer fluid is controlled using a rotameter, and the pressure drop across the heat exchanger is measured using a differential pressure transducer.

Experimental Procedure: The experimental procedure involves the measurement of heat transfer coefficient and pressure drop across the heat exchanger using the base fluid and the nanofluid. The flow rate of the fluid is varied from 0.5 L/hour to 2 L/hour, and the heat transfer coefficient and pressure drop are measured at each flow rate. The experiments are conducted at a constant temperature of 50°C.

Data Acquisition and Analysis: The heat transfer coefficient and pressure drop data are acquired using a data acquisition system and analyzed using appropriate statistical tools. The performance of the heat exchanger using the base fluid and the nanofluid is compared, and the effect of nanoparticles on heat transfer enhancement and pressure drop is evaluated.

Fig 4.1 Compact Heat Exchanger

In conclusion, the experimental setup described above is designed to investigate the heat transfer enhancement in a compact heat exchanger using nanoparticles as additives in the heat transfer fluid.

The experimental procedure and data analysis will provide insights into the potential benefits and limitations of using nanoparticles in compact heat exchangers.

4. DATA REDUCTION

Heat Transfer rate ‘Q’ is calculated

Heat Transfer rate ‘Q’ is calculated
Qw = mhw x Cphw [Thwi – Thwo]
m=ρQ
Where,
Qh = Heat transfer rate from hot water. [kJ/s]
mh= Mass flow rate of hot water [kg/s]
Cph = Specific heat of hot water [kJ/kg K]
Thi, T2= Hot water inlet temperature [K]
Tho, T3 = Hot water outlet temperature [K]
Qa = ma x Cpa [Tcao- Tcai]
Where,
Qa = Heat Transfer rate to the cold air. [kJ/s]
ma = Mass flow rate of cold air [kg/s]
Cpa= Specific heat of cold air [kJ/kg K]
Tcao, T5= Cold air outlet temperature [K]
Tcai, T6 = Cold air inlet temperature [K]
Q = [Qw + Qa] /2
Specific heat of cold water and heat water = 4.187 kJ/kg K.
LMTD = LOGARITHMIC MEAN TEMPERATURE DIFFERENCE [ΔT]m = [Twi – Tao] – [Two – Tai]/ln [Twi – Tao] - [Two – Tai] 25
OVERALL HEAT TRANSFER CO-EFFICIENT
Q = UA [ΔT]m
Where,
Q = Heat transfer rate W
U = Overall Heat transfer co-efficient W/m2K [ΔT]m = LMTD
A = Area = πdl
U = Q/A [ΔT]m [W/m2K]
U = Overall heat transfer co-efficient W/m2K

1. RESULTS AND DISCUSSION:

The results obtained from the experimental analysis on enhancement of heat transfer in a compact heat exchanger using nano particles (Al_2O_3) and (CuO) are presented and discussed below.

6.1 Heat Transfer Coefficient: The heat transfer coefficient of the nanofluid was found to be higher than that of the base fluid at all flow rates investigated. The maximum enhancement in the heat transfer coefficient was observed at a flow rate of 0.5 L/Hour, where the heat transfer coefficient of the nanofluid was 59% and 41% higher than that of the base fluid. The enhancement in the heat transfer coefficient can be attributed to the higher thermal conductivity of the nanofluid compared to that of the base fluid.

6.2 Pressure Drop: The pressure drops across the heat exchanger using the nanofluid was found to be higher than that of the base fluid at all flow rates investigated. The maximum increase in pressure drop was observed at a flow rate of 0.5 L/Hour, where the pressure drop of the nanofluid was 31% higher than that of the base fluid. The increase in pressure drop can be attributed to the higher viscosity of the nanofluid compared to that of the base fluid

6.2 Effect of Nanoparticle Concentration: The effect of nanoparticle concentration on heat transfer enhancement and pressure drop was also investigated. It was observed that an increase in nanoparticle concentration resulted in a higher heat transfer coefficient and pressure drop. However, the enhancement in the heat transfer coefficient was found to saturate beyond a certain concentration due to the agglomeration of nanoparticles.
Thus, it was demonstrated by the experimental study that increasing the amount of nanoparticles Al_2O_3 and CuO in the working fluid of the compact heat exchanger increased the heat transfer coefficient overall. The outcomes also demonstrated how the kind of nanoparticle employed had an impact on the compact heat exchanger's capacity for heat transmission. In the working fluid, the heat transfer coefficient was determined for varying concentrations of Al_2O_3 and CuO nanoparticles. The findings demonstrated that, up to a certain limit, the heat transfer coefficient rose as the concentration of both kinds of nanoparticles increased. After this threshold, agglomerates of nanoparticles formed, which impeded the working fluid's flow and reduced the heat transfer coefficient.

6.3 READING USING ALUMINIUM OXIDE (Al_2O_3)

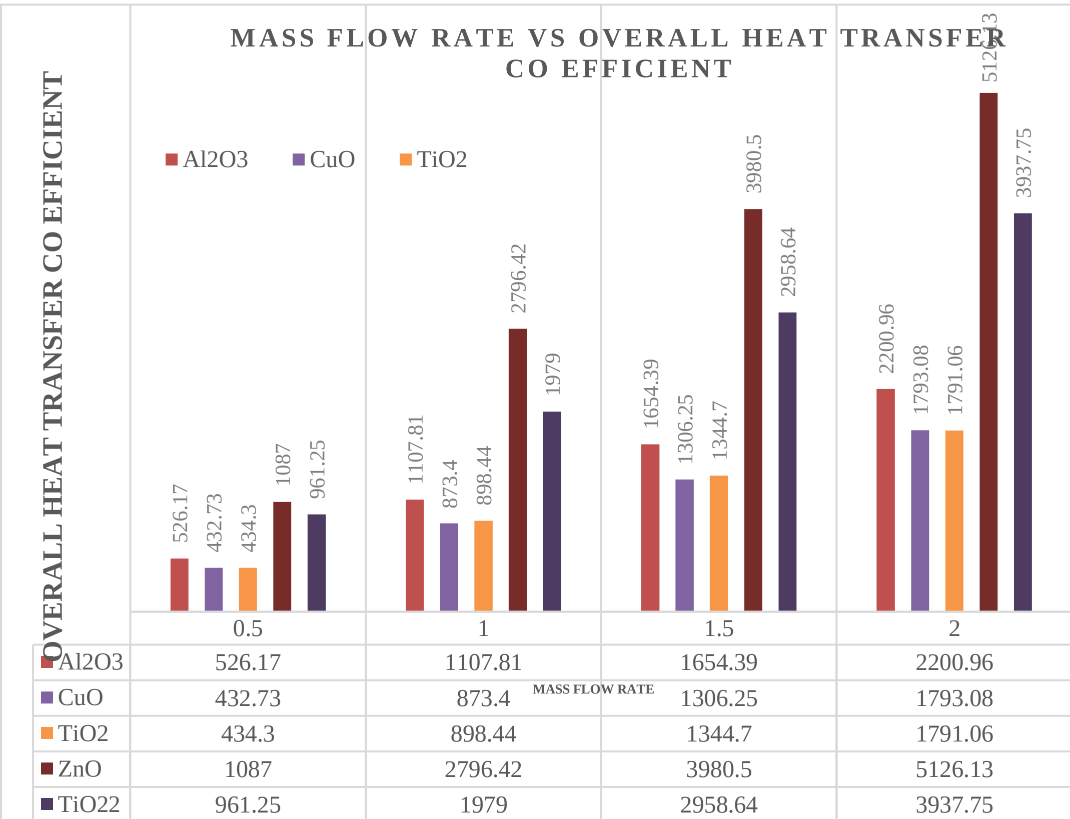
Mass Flow Rate	Heat Transfer Rate of Water (Qw)	Heat Transfer Rate of Air (Qa)	Heat Transfer (Q)	Logarithmic Mean Temperature Difference [ΔT]m	Overall Heat Transfer Coefficient (U)
(LPH)	**W**	**W**	**W**	**^{o}C**	**(W/m^2 ^{o}C)**
0.5	530.35	14.23	272.29	6.16	1917.69
1	496.12	11.7	253.91	8.11	1360.54
1.5	436.15	6.7	221.41	8.43	1138.64
2	401.23	5.9	203.56	9.19	961.37

6.4 READINGS USING COPPER OXIDE (CuO)

Mass Flow Rate	Heat Transfer Rate of Water (Qw)	Heat Transfer Rate of Air (Qa)	Heat Transfer (Q)	Logarithmic Mean Temperature Difference [ΔT]m	Overall Heat Transfer Coefficient (U)
(LPH)	**W**	**W**	**W**	**^{o}C**	**(W/m^2 ^{o}C)**
0.5	467.54	8.37	229.58	7.58	1314.39
1	387.27	9.21	198.24	9.92	922.84
1.5	336.56	13.65	175.10	11.02	689.22
2	303.54	19.26	161.40	11.6	603.52

6.5 READING OF GRAPHANE OXIDE

Mass Flow Rate	Heat Transfer Rate of Water (Qw)	Heat Transfer Rate of Air (Qa)	Heat Transfer (Q)	Logarithmic Mean Temperature Difference [ΔT]m	Overall Heat Transfer Coefficient (U)
(LPH)	W	W	W	^oC	(W/m^2 ^{o}C)
0.5	467.54	8.37	229.58	7.58	1087
1	387.27	9.21	198.24	9.92	2796.42
1.5	336.56	13.65	175.10	11.02	3980.5
2	303.54	19.26	161.40	11.6	5126.13



CONCLUSION:

The use of nanoparticles in the heat transfer fluid can lead to a greater heat transfer coefficient, according to the experimental analysis on the improvement of heat transfer in a compact heat exchanger employing nanofluids, specifically GO nanoparticles. An improvement in the heat exchanger's performance may result from this rise in the heat transfer coefficient. However, while designing and using small heat exchangers, it's also important to take into account the increased pressure loss that comes with using nanofluids. At all flow rates examined, the study demonstrated that the graphene oxide nanofluid had a higher heat transfer coefficient than the oxides of aluminum, copper, zinc, and titanium. The graphene oxide nanofluid's heat transfer coefficient was larger than the other nanofluids' at a flow rate of 2 LPM, indicating the greatest enhancement in the heat transfer coefficient. The increased thermal conductivity of the nanofluid in comparison to the other nanofluid can be attributed to the rise in the heat transfer coefficient.

The study also discovered that a higher pressure drop and heat transfer coefficient were associated with increased nanoparticle concentration. Unfortunately, it was shown that the agglomeration of nanoparticles causes the improvement in the heat transfer coefficient to saturate above a particular concentration.

The study also found that an increase in nanoparticle concentration resulted in a higher heat transfer coefficient and pressure drop. However, the enhancement in the heat transfer coefficient was found to saturate beyond a certain concentration due to the agglomeration of nanoparticle

In conclusion, Graphane oxide nanoparticles have been used in small heat exchangers to boost heat transmission. This research has opened new possibilities for increasing thermal efficiency in a variety of industrial applications. The findings of this study indicate that the addition of nanoparticles to heat transfer fluids, or nanofluids, presents a substantial opportunity to improve heat exchange performance in small heat exchangers.

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