IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 11, May 2023

Investigation of Rate of Heat Transfer ofWater for various Concentrations of Nanoparticles for Plate Heat Exchanger

[1]Saniya N. Chavan, [2]Pranita S. Jadhav, [3]Alisha N. Mujawar, [4]Hitesh B. Markad, [5]Prof. Mahesh C. Shinde

Students, Department of Mechanical Engineering[1,2,3,4]

Guide and Professor, Department of Mechanical Engineering[5]

Jaywantrao Sawant College of Engineering, Pune, India

Abstract: *The statement describes a study conducted to enhance the heat transfer efficiency of water in a compact heat exchanger, specifically a corrugated plate heat exchanger. The objective is to overcome the limitation of conventional plate heat exchangers, which become bulky when the heat transfer area is increased. To achieve this, the researchers propose two approaches: adding nanoparticles to the base fluid (creating a Nano fluid) and incorporating corrugations on the plates. The addition of nanoparticles is expected to increase the heat transfer coefficient of the base fluid, while the corrugations enhance the effectiveness of the heat exchanger. The study examines both parallel flow and counter flow arrangements for different mass flow rates of the hot fluid. The results indicate that the effectiveness of the heat exchanger varies depending on the heat capacity ratio. The effectiveness values range from 0.66 to 0.80 for water as the working fluid and from 0.70 to 0.82 for Nano fluids. The slight drop in effectiveness with an increase in heat capacity ratio suggests that the performance of the heat exchanger is affected by the characteristics of the working fluid.*

Keywords: Corrugated PHE, Counter flow, Effectiveness, Nano Fluids, Sizing etc. Corrugated PHE, counter flow, Effectiveness, Sizing etc.

I. INTRODUCTION

Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperature while keeping them without mixing with each other. These exchangers are classified according to construction, flow arrangement; number of fluids, compactness, etc. The use of heat exchanger gives higher thermal efficiency to the system. In many applications like power plants, petrochemical industries, air conditioning etc. heat exchangers are used. Plate heat exchanger is generally used in dairy industry due to its ease of cleaning and thermal control. The plate heat exchangers are built of thin metal heat transfer plates and pipe work is used to carry streams of fluid. Plate heat exchangers are widely used in liquid to liquid heat transfer and not suitable for gas to gas heat transfer due to high pressure drop. Maximizing the heat transfer area (A) leading to increase in the size of heat exchanger which ultimately leads to unwanted increase in weight and cost. So in order to overcome above problems, addition of Nano-particles in the base fluid is recommended for the purpose of improving heat transfer. Heat exchangers are devices designed to transfer heat between two fluids at different temperatures while keeping them separate. They are classified based on construction, flow arrangement, the number of fluids involved, compactness, and other factors. Heat exchangers offer higher thermal efficiency to systems and find applications in power plants, petrochemical industries, air conditioning, and more. They are constructed using thin metal heat transfer plates, and the fluid streams are directed through pipe work. Plate heat exchangers are widely used for liquid-to-liquid heat transfer but are not suitable for gas-to-gas heat transfer due to high pressure drop. By, introducing nanoparticles into the fluid, the heat transfer properties can be improved. The nanoparticles can enhance heat transfer by increasing the thermal conductivity of the fluid, promoting better mixing, and providing a larger surface area for heat exchange. This approach allows for improved heat transfer

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 11, May 2023

without significantly increasing the size or weight of the heat exchanger. In summary, plate heat exchangers are widely used in various industries for their efficiency and hygienic properties

II. LITERATURE SURVEY

In research paper by R. K. Shah and S. G. Kandilkar (1989), the authors present a classification of plate heat exchangers (PHE) based on the number of passes, flow arrangement, and considering the end plate effect. The configurations studied in this research include 1-1, 2-1, 2-2, 3-3, 4-1, 4-2, and 4-4 arrangements, as well as six configurations for the 3-1 arrangement.The paper provides results for temperature effectiveness and log-mean temperature difference correction factor as functions of the number of transfer units, heat capacity ratio, and totalnumber of thermal plates. The authors also offer guidelines for selecting an appropriate plate heat exchanger configuration based on their findings.These research papers contribute to the understanding and selection of plate heat exchanger configurations.

The paper titled "Thermal-physical Properties of Nanoparticles Suspended in Refrigerant and Lubricating Oil Refrigerating Systems" by R. Saidur, S.N. Kazi, and M.S. Hossain (2011).The paper discusses the use of nano refrigerants in refrigeration systems and their impact on heat transfer performance and energy consumption. Theauthors specifically focus on studying the heat transfer performance of various nano refrigerants with different concentrations.Based on their findings, the authors conclude that, TiO2 nanoparticles provides improved performance.

The research paper authored by R. Saidur, K.Y. Leong, and H.A. Mohammad in 2011, discusses the potential of nanofluids as heat transfer fluids. Nanofluids are a type of fluid in which nanoparticles are dispersed in a base fluid, resulting in enhanced heat transfer performance. This characteristic makes them suitable for various applications aimed at improving energy efficiency, heat transfer, and overall performance.

Advantage of nanofluids is their significantly higher thermal conductivity compared to conventional fluids, especially at low particle concentrations. Additionally, the thermal conductivity of nanofluids is strongly dependent on temperature. These properties contribute to their potential for enhanced heat transfer in various systems and devices.

In their review, Jogi Nikhil G. and Lawankar Shailendra M. (2012) examined the impact of plate geometry onthe heat transfer characteristics of corrugated Plate Heat Exchangers (PHE). They likely analyzed different configurations of plate geometry, such as corrugation patterns, angles, and dimensions, and investigated how these factors influenced the heat transfer efficiency of the PHE.

Nanoparticles Information

Aluminum Oxide (Al2O3) Nanoparticles

The nanoparticles of α-Al2O3 were prepared using the sol-gel method. 10 g of Al(NO3)3•9H2O was completely dissolved in 150 ml of distilled water yields a concentration of 0.18 M. Drying, annealing, and calcination processes were used to obtain α-Al2O3 nanoparticles**.**

Aluminum oxide has a chemical formula Al2O3. Its chemical name Aluminium oxide. It is also called as Alpha-Alumina, alumina, alundum or aloxide. It is amphoteric in nature, and is used in various chemical, industrial and commercial applications. It is considered an indirect additive used in food contact substances by the FDA.

Alpha, High Purity: 99.95%, Size: 180 nm, Hydrophilic

Technical Properties:

Purity (%)	99.95
Color	white
Average Particle Size (nm)	180
Specific Surface Area (m^2/g)	>10
Density (g/cm3)	4
Melting Point (°C)	2050
Boiling Point (°C)	2990
Crystallographic Structure	rhombohedral
Elemental Analysis (wt%)	B2O3 CaO Fe2O3

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 11, May 2023

Fig. Preparation of nano fluid

Setup -

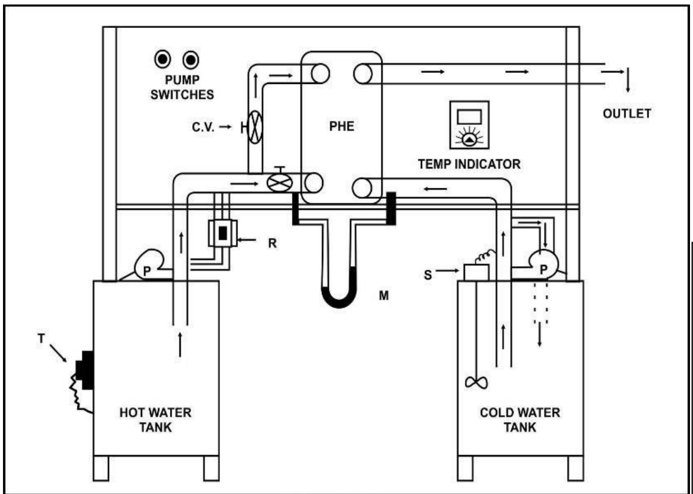


Fig. Test Rig

Nomenclature:
M –Manometer
C.V –Control valve
P – Pumps
PHE –Plate heat exchanger
Temperature Indicator
R- Rotameter

Experimental setup consists of tanks, pumps, Rotameter, U tube manometer, temperature indicators, corrugated plate heat exchanger. test the performance of heat exchanger for parallel and counter flow arrangement with wateras a working fluid. The heat exchanger has total 13 plates and it is constructed using Stainless Steel AISI 316. Each plate is flat and has thickness of 0.5 mm. The total heat transfer area is 0.2548 m2. Thermometers are placedto measure inlet and outlet temperatures of hot and cold water. Following, trials are taken

- Test on corrugated plate heat exchanger with parallel flow arrangement (with water)
- Test on corrugated plate heat exchanger with counter flow arrangement (with water)
- Test on corrugated plate heat exchanger with parallel flow arrangement (with water and Nano- fluids)
- Test on corrugated plate heat exchanger with counter flow arrangement (with water and Nano-fluids).

III. METHODOLOGY

1. Testing of counter flow arrangement for varying mass flow rate with water as a working fluid.
2. Testing of parallel flow arrangement for varying mass flow rate with water as a working fluid.
3. Testing of counter flow arrangement for varying mass flow rate with the addition of Nano fluids
4. Testing of parallel flow arrangement for varying mass flow rate with the addition of Nano fluids
5. Performance analysis of varying mass flow rate of hot fluid.
6. Comparison of results and discussion.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 11, May 2023

Observation table :

For Counter Flow With Water

Sr. No	Mass flow rate (Kg/sec)	
	m_h	m_c
1	0.11	0.25
2	0.125	0.25
3	0.1527	0.25
4	0.194	0.25
5	0.20	0.25
6	0.25	0.25

Table 1: For Counter Flow with water and Nano-fluids

Sr. No	Mass flow rate (Kg/sec)	
	m_h	m_c
1	0.11	0.25
2	.12	0.25
3	0.15	0.25
4	.19	0.25
5	0.25	0.25

Table 2: Calculations-

In the given equation:

Heat Duty (Q) :

Heat rejected by hot water, $Q = mh * Cph * \Delta Th$

By substituting the given values into the equation: $Q = 0.25 * 4194 * (85 - 65)$

$Q = 0.25 * 4194 * 20$

Q = 20970 Watts (or Joules per second)

We have a mass flow rate of 2 kg/s and a flow area of 0.5 m^2. The density of water is approximately 1000 kg/m^3.

Velocity of Water :

Substituting the values into the equation: $V = m / (A * \rho)$

$V = 2$ kg/s / (0.5 m^2 * 1000 kg/m^3) $V = 2 / (0.5 * 1000)$

$V = 2 / 500$

V = 0.004 m/s

Therefore, the velocity of the hot water is approximately 0.004 m/s.For hot water:

$Vh = (mh * Ah * \rho h) / \rho h$

= (0.25 kg/s) * (0.0012 m^2) * (974.851 kg/m^3) / 974.851 kg/m^3

≈ 0.02137 m/s

Therefore, the velocity of hot water is approximately 0.02137 m/s.

For cold water:

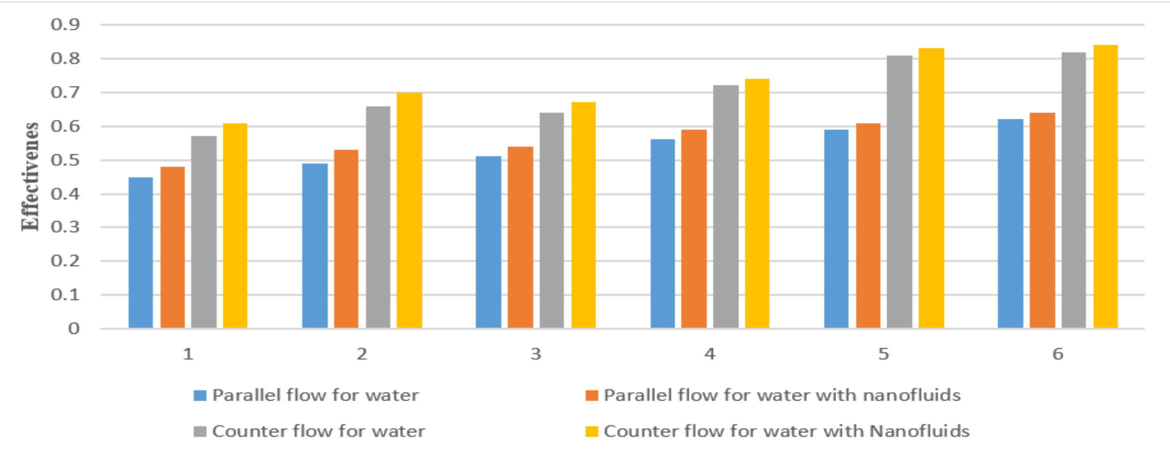
mc = 0.25 kg/s (mass flow rate)

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 11, May 2023

Ac = 0.001411 m^2 (cross-sectional area)ρc = 994.034 kg/m^3 (density)
Using equation (2.8):
Vc = (mc * Ac * ρc) / ρc
= (0.25 kg/s) * (0.001411 m^2) * (994.034 kg/m^3) / 994.034 kg/m^3
≈ 0.1783 m/s
Therefore, the velocity of cold water is approximately 0.1783 m/s.
Nusselt Number :
Based on the given values, let's calculate the Nusselt numbers for hot water and cold water using the provided formulas.
For hot water:
Reh = 2127.34
Prh = 2.3732
Nu_hot = 0.662 * (Reh0.5) * (Prh0.33)
= 0.662 * (2127.340.5) * (2.37320.33)
≈ 54.45
For cold water:
Rec = 950.18
Prc = 4.7627
Nu_cold = 0.662 * (Rec0.5) * (Prc0.33)
= 0.662 * (950.180.5) * (4.76270.33)
≈ 39.77
Therefore, the Nusselt number for hot water is approximately 54.45, and the Nusselt number for cold water is approximately 39.77.
Overall heat transfer coefficient :
Based on the provided values, the overall heat transfer coefficient (U) is calculated as follows:
1/U = 1/hh + t/kp + 1/hc Substituting the given values:
1/U = 1/7027.90 + 0.0005/17.5 + 1/5588.90
Simplifying the equation:
1/U = 0.0001422 + 0.00002857 + 0.000179
1/U = 0.0003497
Taking the reciprocal of both sides:
U = 1/0.0003497
U ≈ 2858.81 W/(m²·K)
Therefore, the overall heat transfer coefficient is approximately 2858.81 W/(m²·K).
Logarithmic Mean Temperature Difference (LMTD):
Regarding the Logarithmic Mean Temperature Difference (LMTD):
LMTD is calculated using the formula:
ΔTm = [(Th1 - Tc2) - (Th2 - Tc1)] / ln[(Th1 - Tc2) / (Th2 - Tc1)]
Substituting the given values:
ΔTm = [(85 - 45.07) - (65 - 45.07)] / ln[(85 - 45.07) / (65 - 45.07)]
Simplifying the equation:
ΔTm = [39.93 - 19.93] / ln[39.93 / 19.93]
ΔTm = 20 / ln(2)ΔTm ≈ 28.78 °C
Therefore, the Logarithmic Mean Temperature Difference (LMTD) is approximately 28.78 °C.

IV. RESULTS

Comparison of effectiveness for water and Nano fluids with parallel and counter flow arrangement



V. CONCLUSION

The addition of nanoparticles to the working medium enhances its thermal conductivity, leading to improved heat transfer efficiency and higher temperature differentials across the heat exchanger plates.

Pressure drop across the heat exchanger increases with an increase in mass flow rate and Reynolds number. This is because the addition of nanoparticles increases the viscosity of the working medium, resulting in higher flow resistance. The plate geometry, including the corrugations, also contributes to the pressure drop.

The thermal efficiency of the heat exchanger is enhanced due to the improved heat transfer characteristics. The higher temperature drop achieved across the heat exchanger allows for more effective heat exchange between the hot and cold fluids, resulting in better energy transfer

Overall, the experimental investigation indicates that the addition of nanoparticles to the working medium of a plate heat exchanger improves its heat transfer performance by increasing the convective heat transfer coefficient, enhancing thermal conductivity, and achieving higher temperature differentials.

ACKNOWLEDGEMENT

We would like to extend our heartfelt gratitude to our guide and our faculty members who have played a significant role in supporting and assisting us throughout our work. Their invaluable contributions and unwavering dedication have made a remarkable impact, and we are truly grateful for their involvement.

REFERENCES

[1]. R. K. Shah and S. G. Kandilkar MAY (1989) “Multipass Plate Heat Exchangers- Effectiveness-NTU Results and Guidelines for Selecting Pass Arrangements”, Transactions of ASME, Vol.111,

[2]. R Saidur, S.N. Kazi, M.S. Hossain (2011) “A review on the performance of nanoparticles suspended with refrigerants and lubricating oils in refrigeration system”

[3]. R Saidur, K.Y. Leong, H.A. Mohammad (2011) “A review on applications and challenges of nanofluids”,

[4]. Renewable and Sustainable Energy Reviews, 1646–1668

[5]. Jogi Nikhil G., Lawankar Shailendra M. Oct (2012) “Heat Transfer Analysis of Corrugated Plate Heat Exchanger of Different Plate Geometry”, International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2,

[6]. Murugesan M.P. and Balasubramani R. February (2013), “The Experimental Study on Enhanced Heat Transfer Performance in Plate Type Heat Exchanger” Research Journal of Engineering Sciences, Vol.2(2),16-22, ISSN 2278-9472.

[7]. Vishal R. Naik, V.K. Matawala (April 2013) "Experimental Investigation of single phase Chevron Type Gasket Plate Heat Exchanger", International Journal of Engineering and Advanced Technology(IJEAT), ISSN: 2249-8958, Volume-2, Issue-4,

[8]. T K S Sai Krishna, S G Rajasekhar, C Pravarakhya July-August (2013) "Design and Analysis of Plate Heat Exchanger with CO2 and R134a as working fluids", International Journal of Mechanical Engineering and Technology (IJMET), ISSN 0976- 6359 Volume 4. Issue 4

[9]. Masoud Asadi, Ramin Haghighi Khoshkhoo (February 2014) "Effects of Chevron Angle on Thermal Performance of Corrugated Plate Heat Exchanger", International Journal of Engineering Practical Research (IJEPR) Volume 3 Issue 1,

[10]. Raman Chouda (September 2014) "Analysis of Heat Exchanger with Nano fluids", International Journal of Core Engineering & Management (IJCEM) Volume 1, Issue 6,