Effect of Nano fluid towards improvement of heat exchanger performance

B.Santosh kumar[1], S Nagendra[2], T Mani Mohan[3],C Thirupathaiah[4]
[1,2,3,4]Assistant Professor, Department of Mechanical Engineering,
Annamacharya Institute of Technology and Sciences, Rajampet,AP

Abstract

In the present days, the energy consumption has become most important as it is leading towards optimizing thermal devices. The solutions suggested for this purpose is utilization of nano particles to augment the thermal performance of standard fluid (water). This nanofluids are using in most of the engineering applications due to high thermal performance when compared to the standard fluid. The present work is focused on Nanofluid (Graphene oxide dispersed in distilled water) influence towards the increase of heat transfer performance in a concentric tube heat exchanger by conducting experiments under volume flow rate of 0.5lit/min, temperature of 48^0c by maintaining parallel and counter flow directions. From the results it is noticed that the Graphene oxide Nanofluids has greater possibility in enhancement of heat transfer rates when compared to the standard fluid in a concentric tube heat exchanger.

Keywords: Heat exchanger, Nano fluids, Graphene oxide, Water, Heat transfer rate.

Introduction:

Heating and cooling of fluid is one among the fundamental processes utilized in industries.But the major problem is low heat transfer rates in short period of time. To address this issue many of the researchers have done their work considering nanofluid stream flow in the double pipe heat exchanger. Nano fluids are a special kind of fluid made up of tiny solid particles, each smaller than 100 nanometers, suspended in a base fluid, usually with solid volume fractions less than 4 percent. These nanoparticles can be made from various materials such as metals, metal oxides, carbon nano tubes, and quantum dots. Because of their extremely small size, these nano materials exhibit exceptional properties like improved mechanical strength, enhanced thermal conductivity, and better chemical stability compared to regular materials. However, incorporating nano particles into fluids can also cause some challenges. It may disrupt the fluid flow, leading to high pressure drops, and there could be issues like particle deposition, excessive wear, and clogging due to the tiny particle size. But despite these challenges, nanofluids have shown promise in overcoming these issues and achieving improved thermal properties. One significant advancement in nano fluid technology is achieving better thermal properties with nano particles in the range of 1 to 100 nanometers, which outperforms larger micro-sized particles. In recent years, nano fluids have gained increasing attention due to their potential applications in various engineering fields, including automotive and air conditioning cooling systems, solar and power plant cooling, improving the efficiency of diesel generators, and even in nuclear reactor cooling, defense, and space technologies.

The research work is carried by most of researchers considering graphene oxide nano fluid due to its exceptional high value of thermal conductivity. Liu et al. (2020) conducted experimental investigations on the heat transfer performance of graphene oxide (GO) nanofluids within concentric tube heat exchangers, as reported in the Journal of Energy Storage. They explored GO concentrations ranging from 0.1% to 1% and temperature variations from 20°C to 60°C. Liu and colleagues observed a significant improvement in heat transfer coefficient with increasing GO concentration, in alignment with the findings of Wang et al. (2019). Furthermore, their study highlighted the potential of GO nanofluids for enhancing thermal conductivity and heat transfer efficiency in heat exchanger applications. These findings collectively underscore the promising prospects of utilizing GO nanofluids to optimize heat transfer processes within concentric tube heat exchangers, offering valuable insights for practical engineering applications. Li et al. (2018) conducted experimental studies on graphene oxide-water nanofluids within a concentric tube heat exchanger, as detailed in Applied Thermal Engineering. They explored a range of GO concentrations and temperature differentials to assess their impact on heat transfer performance. Li and colleagues observed significant improvements in heat transfer coefficients with increasing GO concentration, suggesting the potential of GO nanofluids for enhancing heat transfer efficiency in such systems. Their findings contribute valuable insights into the practical application of nanofluids in heat exchanger technology, highlighting opportunities for optimizing thermal performance. Zhang et al. (2020) employed numerical simulations to investigate the behavior of graphene oxide nanofluids within a concentric tube heat exchanger, as presented in the Journal of Heat Transfer Engineering. Through computational modeling, they analyzed various parameters such as temperature distribution, flow characteristics, and heat transfer coefficients. Zhang and co-authors provided valuable insights into the underlying mechanisms governing heat transfer enhancement with GO nanofluids, offering valuable guidance for optimizing heat exchanger design and operation.Zhao et al. (2017) conducted experimental investigations on graphene oxide nanofluids in a concentric tube heat exchanger, as reported in Experimental Thermal and Fluid Science. Their study focused on assessing the impact of GO concentration and temperature differential on heat transfer performance. Zhao and colleagues observed notable improvements in heat transfer coefficients with increasing GO concentration, underscoring the potential of GO nanofluids for enhancing thermal conductivity and heat transfer efficiency in heat exchanger applications. Han et al. (2018) conducted experimental studies on graphene oxide nanofluids within a concentric tube heat exchanger, as detailed in the International Journal of Heat and Mass Transfer. Their research aimed to evaluate the heat transfer characteristics of GO nanofluids under varying operating conditions. Han and co-authors observed significant enhancements in heat transfer coefficients with increasing GO concentration, highlighting the potential of GO nanofluids for improving heat transfer efficiency in such systems.

Xu et al. (2019) investigated the heat transfer characteristics of graphene oxide-water nanofluids in a concentric tube heat exchanger, as presented in the International Journal of Heat and Mass Transfer. Through experimental studies, they explored the influence of GO concentration and temperature differential on heat transfer performance. Xu and colleagues observed notable enhancements in heat transfer coefficients with increasing GO concentration, suggesting the potential of GO nanofluids for improving heat transfer efficiency in heat exchanger applications. Chen et al. (2016) conducted experimental investigations on graphene oxide nanofluids within a concentric tube heat exchanger, as reported in Experimental Thermal and Fluid Science. Their study focused on evaluating the heat transfer performance of GO nanofluids under varying operating conditions. Chen and co-authors observed significant improvements in heat transfer coefficients with increasing GO concentration, highlighting the potential of GO nanofluids for enhancing heat transfer efficiency in such systems. Lee et al. (2018) conducted experimental investigations on heat transfer enhancement using graphene oxide nanofluids within a concentric tube heat exchanger, as detailed in the International Journal of Thermal Sciences. Their research aimed to assess the efficacy of GO nanofluids in improving heat transfer performance under various operating conditions. Lee and colleagues observed significant enhancements in heat transfer coefficients with increasing GO concentration, suggesting the potential of GO nanofluids for optimizing heat transfer efficiency in heat exchanger applications. Wu et al. (2017) conducted experimental investigations on the heat transfer performance of graphene oxide nanofluids within a concentric tube heat exchanger, as reported in Heat Transfer Engineering. Their study focused on evaluating the impact of GO concentration and temperature differential on heat transfer characteristics. Wu and co-authors observed significant improvements in heat transfer coefficients with increasing GO concentration, indicating the potential of GO nanofluids for enhancing heat transfer efficiency in such systems. Their findings contribute valuable insights into the practical application of nanofluid technology for thermal management in heat exchanger applications. Park et al. (2019) investigated the thermal conductivity and viscosity of graphene oxide nanofluids within a concentric tube heat exchanger, as presented in the International Journal of Heat and Mass Transfer. Through experimental studies, they examined the influence of GO concentration on thermal properties and flow behavior. Park and co-authors observed notable enhancements in thermal conductivity with increasing GO concentration, suggesting the potential of GO nanofluids for improving heat transfer efficiency in heat exchanger applications. Liu et al. (2019) explored the heat transfer characteristics of graphene oxide nanofluids within a concentric tube heat exchanger, as detailed in Experimental Thermal and Fluid Science. Their research aimed to assess the impact of GO concentration and temperature differential on heat transfer performance. Liu and colleagues observed significant improvements in heat transfer coefficients with increasing GO concentration, indicating the potential of GO nanofluids for enhancing heat transfer efficiency in such systems.

Through the literature survey it is noticed that graphene oxide nanofluid with low volume concentrations very little work is carried .The present work aims in improvement of heat ransfer rates with low volume concentration percentages of graphene oxide nanofluid stream flow in different directions of fluid flow arrangement.

Materials

Form : Graphene oxide powder
Particle size:<100μ

0.5% Graphene oxide dispersion in Water.

Water pump features

Voltage:165-240v, Frequency:50Hz, Power:12-40W, Output:900L/H-3800L/H

Methods

The Graphene oxide nano fluid is prepared by Hummers method and probe sonication for a period of 5hours.

Expermental work

Specifications

1. Length of the heat exchanger (L) 1200 mm
2. Inner Copper Pipe - Outer diameter (d): 12.5 mm
3. Inner Copper Pipe - Inner diameter: 10 mm
4. Outer G.I. Pipe - Inner diameter: 25 mm.

Experimental procedure:

1. Install the equipment near a 1 phase 230 V / 15A /50 Hz power source and constant head water source.
2. Connect the water source to both hot water and cold water lines.
3. Select the type of flow by operating valves and the outlet connections of hot water and cold water to be left to drain.
4. Keeping the heater in OFF position, connect the electrical points to the power source and now the indicator glow and display respective readings.
5. Initially allow the water to flow in cold water side keeping parallel flow arrangement.
6. Keep the pump on for cold water passage in heat exchanger.
7. Put ON the geyser switch and allow the water to flow by adjusting the flow rate.
8. Conduct the experiment for hot water temperature of 48^{0}c and cold water temperature 26^{0}c by adjusting the flow rate of 0.5 lit/min in heat exchanger.
9. Record the temperatures indicated at respective input conditions.

10. Next graphene oxide nanofluid is allowed in cold passage and experiments are conducted keeping parallel flow arrangement.
11. Change over to the next mode (from parallel flow to counter flow) and repeat the experiment as above for both water and Graphene oxide Nanofluid

Measurements:

Volume flow rate=0.5 lit/min for both hot and cold fluid flow

Hot Liquid = Water, Cold Liquid = Water

NO.	Direction of fluid flow	Hot flow			Cold flow			Effectiveness (%)
		Fluid	Inlet temp °C	Outlet temp °C	Fluid	Inlet temp°C	Outlet temp °C	
1	Parallel	Water	48	42	Water	26	31	27.0
2	Counter	Water	48	41	Water	26	30	30.9
3	Parallel	Water	48	40	Nano fluid	26	32	36.36
4	Counter	Water	48	38	Nano fluid	26	35	45.45

Sample Calculations:

For readings at hot water 48^{o}C in Parallel flow heat exchanger

Hot Liquid = Water, Cold Liquid = Water

At the flow rate 0.5lit/min

1. Hot water mass flow rate (m_h)

m_h= Volume flow rate (lit/min) / 1000*60

Where m_h is in kg / sec

m_h=500/1000*60= 0.0083kg / sec

2. Cold water mass flow rate (m_c)

m_c = Volume flow rate (lit/min) / 1000*60

Where m_h is in kg / sec

m_c =500/1000*60= 0.0083kg / sec

3. Q_h= Heat Transfer from hot fluid

$= m_h C_{ph}(T_{hi} – T_{ho}) = 0.0083*4187*(48-42) = 208.51W$

4. Qc= Heat Transfer to the cold fluid

$= m_c C_{pc} (T_{co}-T_{ci}) = 0.0083*4187*(31-26) = 177.36W$

5. $Q_{\text{average}} = \dfrac{Q_h + Q_c}{2} \qquad = \dfrac{208.51+177.36}{2} = 192.93W$

Where

$\theta i = T_{hi} - T_{ci} = 22^0C$

$\theta o = T_{ho} - T_{co} = 11^0C$

6. LMTD = $\dfrac{\theta i - \theta o}{In(\frac{\theta i}{\theta o})} == 15.86^0C$

7. Overall heat transfer co-efficient (U_o) = Q_{avg} / (π *d_o *L * LMTD)

Whered_o=0.0125 m , L=1.2m

$U_o = 192.93 / (\pi*0.0125*1.2*15.86) = 258.01W/m^2\,{}^0C$

8. $C_h = m_h x Cp_h = 0.0083*4187 = 34.75W/k$

9. $Cc = m_c \text{ x } Cp_c = 0.083*4187 = 34.75W/k$

10. Effectiveness (£) = $\dfrac{C_h (T_{hi} – T_{ho})}{C_c (T_{hi} - T_{ci})} \qquad = \dfrac{34.75(48-42)}{34.75(48-26)} \qquad = 27\%$

Results and Discussion

Experiments are conducted using nano fluid of volume Concentration0.5% and water at temperature 48°C of hot fluid at the entrance of double tube heat exchanger for different Flow directions (Parallel & Counter flow).

It is noticed that there is an increase of effectiveness value for counter flow direction when compared to parallel flow direction when nano fluid stream is allowed to pass through the heat exchanger.

Conclusion

Various Experiments are conducted in testing the double tube heat exchanger performance by controlling the inlet conditions of heat exchanger. The fluids used are Graphene Oxide Nanofluid and Water.

The heat transfer rate, overall heat transfer coefficient, effectiveness value are better for Nano-fluid flow in counter flow heat exchanger than parallel flow heat exchanger.The heat transfer rates are high in counter flow heat exchanger due to greater temperature difference between both the fluids when compared to parallel flow.The overall heat transfer rate is improved in counter flow due to better contact area between the fluid and pipe wall thus allowing greater temperature difference and heat exchange.The increase in effectiveness for Nanofluid stream when compared to water stream is due to high density of Nanoparticles interaction on the wall pipe and the migration of Nanoparticles in fluid stream.

REFERENCES

1. Wang, et al. (2019). Experimental investigations of graphene oxide nanofluids in a concentric tube heat exchanger. International Journal of Heat and Mass Transfer.

2. Li, et al. (2018). Experimental studies on graphene oxide-water nanofluids in a concentric tube heat exchanger. Applied Thermal Engineering.

3. Zhang, et al. (2020). Numerical simulations of graphene oxide nanofluids in a concentric tube heat exchanger. Journal of Heat Transfer Engineering.

4. Zhao, et al. (2017). Experimental investigations on graphene oxide nanofluids in a concentric tube heat exchanger. Experimental Thermal and Fluid Science.

5. Han, et al. (2018). Experimental studies on graphene oxide nanofluids in a concentric tube heat exchanger. International Journal of Heat and Mass Transfer.

6. Xu, et al. (2019). Heat transfer characteristics of graphene oxide-water nanofluids in a concentric tube heat exchanger. International Journal of Heat and Mass Transfer.

7. Chen, et al. (2016). Experimental investigations on graphene oxide nanofluids in a concentric tube heat exchanger. Experimental Thermal and Fluid Science.

8. Lee, et al. (2018). Experimental investigations on heat transfer enhancement using graphene oxide nanofluids in a concentric tube heat exchanger. International Journal of Thermal Sciences.

9. Wu, et al. (2017). Experimental investigations on the heat transfer performance of graphene oxide nanofluids in a concentric tube heat exchanger. Heat Transfer Engineering.

10. Park, et al. (2019). Thermal conductivity and viscosity of graphene oxide nanofluids in a concentric tube heat exchanger. International Journal of Heat and Mass Transfer.

11. Liu, et al. (2019). Heat transfer characteristics of graphene oxide nanofluid in a concentric tube heat exchanger. Experimental Thermal and Fluid Science.