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Role of Nano Coolant in Optimizing Heat Transfer

G. Sudha[1], V. Ganesh[2], B. Chitra[3], S. V. Vanisuvathsala[4], K. Vidhyavarshini[5]*

[1,4,5]Department of Chemical Engineering, Sri Venkateswara College of Engineering, Pennalur, India.

[2]Department of Chemical Engineering, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India.

[3]Department of Chemical Engineering, Sri Sivasubramaniya Nadar College of Engineering, Chennai, Tamil Nadu, India.

Emails: *chitrab@ssn.edu.in[3]*

Abstract

Nanofluids are colloidal mixtures of base fluids such as oil, ethylene glycol, water, or a combination of these base fluids and metal, metal oxide, or ceramic nanoparticles. The concept of Nano coolants is used in jacketed vessel to increase the thermal conductivity of water. The Nano sized powder will then be distributed into a fluid with the aid of strong magnetic force agitation, ultrasonic agitation, etc. Due to the high surface area and surface activity nanoparticles has the tendency to aggregate. Lower concentration of nanocoolant will increase the heat transfer rate without increase in the pumping power and pressure drop. The Concentrations of nanofluid prepared are 0.001%. Cupric oxide Nanoparticle mixture was prepared by blending the respective nanoparticles in water using a bath-type sonicator. The heat transfer rate of cupric oxide nanofluids in a jacketed vessel was calculated and compared with base fluid. The increase of heat transfer coefficient using 0.001% Cupric oxide Nanoparticle was found to be 160.56 % when compared with basefluid.

Keywords: *Jacketed Vessel; Nanocoolant; Sonication; Heat Transfer Rate*

1. Introduction

The field of nanotechnology includes different scientific fields like physical, chemical, biological and engineering sciences where novel techniques are being developed to control single atoms and molecules [1,2].A nanoparticle is defined as a small object of the order of 10^{-9} m that behaves as a whole unit in terms of its transport properties and potential application. Nanoparticles of either simple or composite nature are important materials in the development of novel nano devices that can be used in numerous physical, biological, biomedical, and pharmaceutical applications. The colloidal mixture of metal, metal oxide, or ceramic nanoparticles with base fluids like water, ethylene glycol, oil or a combination of these base fluids are termed as nanofluids. These suspensions intensify the heat transfer rate compared to the original base fluid since the metal, metal oxide, and ceramic particle have higher thermal conductivity [3,4].The benefits of using nanofluids are as follows: (i) increased fluid surface area and heat capacity; (ii) enhanced thermal conductivity effectively; (iii) increased collision between nanoparticles and the flow passage surface, and (iv) reduced activity of particle agglomeration. Heat transfer applications include industrial equipment cooling, IC engine cooling, electronics equipment cooling, etc. Cooling is a major challenge for applications like car engines, power electronics, and computers which are caused by higher power ratings and smaller sizes. A significant increase in fuel consumption occurs when larger-size radiators are used to achieve high engine power. Metal or metal oxide nanoparticles are used for the preparation of nano-liquids [5,6]. Operating the reactor within the operational and safety limits based on thermal performance is one of the primary tasks in industries. In order to keep the reactor's temperature range within the safety limit, the reactor's temperature can be managed by adding coolant to the jacketed vessel [7]. Low thermal conductivity heat transfer fluids do

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not function as quickly in this situation; as a result, nanoliquids can be employed [8]. A vessel with a jacket aids in the consistent flow of heat between the vessel wall and the fluid inside it. Agitation is one method for enhancing the uniformity of the fluid characteristics. The petrochemical, pharmaceutical, food processing, adhesives, composites, and other sectors use jacketed vessels [9-11]. The performance of heat transfer for copper nanofluid in a jacketed vessel was studied. In this paper, the overall heat transfer coefficient of the jacketed vessel is studied using Cupric Oxide (CuO) water nanofluid for 0.001% particle volume concentrations. Cupric oxide nanoparticle were chosen based on its thermal properties, availability and cost. The experimental test rig has been configured to compare the thermal enhancement of hybrid CuO/water nanofluid with that of base fluid, water.

2. Preparation of Nanofluids

First, a specific volume of cupric oxide is added to the water (base fluid). After a thorough 30minutes of stirring with a magnetic stirrer, the mixture was placed on a bath sonicator for one hour to get mono nanofluids. The amount of nanoparticles required for the preparation of nanofluid can be found from the Eq. (1), the thermal properties of cupric oxide used for synthesis is shown in table (1).

$$Vol\,\% = \frac{\text{Weight of nanoparticle} / \text{Density of Nanoparticle}}{\text{Weight of nanoparticle} / \text{Density of nanoparticle} + \text{Volume of base fluid}} \quad ...(1)$$

3. Estimation of Heat Transfer Rate Using Jacketed Vessel

Centrifugal pump, external tank, thermocouples, temperature indicator, mixer and heater are among the apparatus employed. The external tank was connected to the centrifugal pump, jacketed vessel, and external sink in that order. The vessel with the jacket is filled with water. In a vessel with a jacket, coolant is transmitted as the circulating fluid. The heater's thermocouples are used to link the jacketed vessel to the device [1,2]. The jacketed vessel was filled with water with 2/3 of vessel capacity and it was heated until it reaches 80°C. The coolant and jacketed vessel fluid temperatures were recorded. Next, use the centrifugal pump to transfer 4 liters of coolant from the external tank to the jacketed vessel. After ten minutes of running with the stirrer ON, the temperatures of the sink fluid and the jacketed vessel fluid were taken.From the observed measurements, heat transfer rate was calculated using the difference in temperature of the coolant. Further the overall heat transfer coefficient was compared for cupric oxide nanofluid as coolant and water as coolant. The suggested experimental configuration uses nanocoolants to dissipate heat from the water inside the vessel by passing them along the jacket side. The most illustrative parameter has been determined to be the heat transfer coefficient of the coolant, or nanofluid, to water. It is assumed that the wall and hot water temperatures are the same. Since the temperature of the nanofluids increases as they pass through the jacket side, Equation (2) gives the heat absorbed by the coolant as

$$Q = m \times CP \times (T4 - T3) \quad .....(2)$$

where,Q is the rate of heat on the jacket side (W), 'm' is the mass flow rate of fluid passed into the jacket (g/s), Cp is the specific heat capacity of the coolant (J/g K) T4 is the outlet temperature of the coolant from the jacket (ºC) and T3 is the inlet temperature of the coolant of the jacket (ºC). Overall heat transfer coefficient on the jacketed vessel was calculated from the temperature data and flow rates using the following Equation (3):

$$U = Q/(A * \text{LMTD}) \quad ....(3)$$

where, U is the overall heat transfer coefficient on the jacketed vessel (W/ m2 K), 'A' is the heat transfer area (m2) Q is the heat transfer rate (W) and LMTD is the log mean temperature difference based on the initial and final temperatures of the coolant and the fluid inside the vessel (ºC).The logarithmic mean temperature difference can be calculated from the initial and final temperature Of fluid inside the vessel and the coolant inlet and

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outlet temperature of fluid inside the vessel and the coolant inlet and outlet temperature.

Table 1 Thermo-Physical Properties of Nano Coolants At 303K

Composite Coolant	Density (kg/m^3)	Specific heat capacity (J/(kg.K))
0.001% Cupric oxide Nanoparticle	1284.46	2.94
Composite Coolant	Thermal conductivity (W/(mK))	Viscosity (cP)
0.001% Cupric oxide Nanoparticle	1.09	5.002

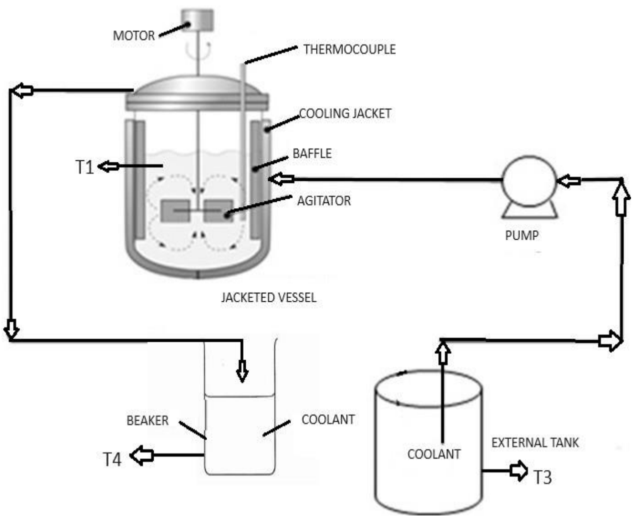

Figure 1 Experimental Setup of Jacketed Vessel

The overall heat transfer coefficients for water, and cupric oxide (0.001%) nanofluids were determined. It was observed that nanofluids heat transfer is higher than water as coolant. Appendix provided the overall heat transfer coefficient calculation for water as coolant and cupric oxide nanofluid as coolant. When compared to cupric oxide nano coolants, water's heat transfer performance in a jacketed vessel under the identical experimental conditions appeared to be less. Since thermal conductivity rises with volume concentration, a further, steady increase in concentration accelerates heat transmission, shown in Figure 1.

Appendix

Heat transfer Area of jacketed vessel=0.24 m2

ΔT (LMTD) = (T1-T3)-(T2-T4)/ln((T1-T3)/(T2-T4))

Case1:

- Coolant = Cupric oxide nanocoolant
- Density of nanocoolant = 1002 kg/m3
- Volumetric flow rate of nanocoolant = 1litre/min = 1.66*(10-5) m3/s Mass flow rate of nanocoolant = 0.01667 kg/s
- Initial Coolant Temperature = 30.1℃ (T3) Inside liquid temperature = 80℃ (T1)

After10 minutes

- Final coolant temperature = 50℃ (T4)
- Final inside liquid Temperature = 60.3℃ (T2) ΔT=19.9℃

Q = m*Cp*ΔT

= 0.0167kg/s*4182(J/(kg.℃) *19.9℃
= 1389.8W

Q = U*A*ΔT(LMTD) U=Q/(A*ΔT(LMTD))

=1389.8/(0.24*25.126)
=230.47W/(m2.℃)

Case2:

- Coolant = water
- Inside Liquid Temperature = 80℃ (T1)
- Final inside liquid temperature =64℃ (T2)
- Initial coolant liquid Temperature=29℃ (T3)
- Final Coolant Liquid Temperature=39℃ (T4)

ΔT=10 ℃
Q = m*Cp*ΔT

= 0.0166kg/s*4182(J/(kg.℃) *10℃
= 694.212 W

U=Q/(A*ΔT(LMTD))

=694.212/(0.24m2*36.46℃)
=79.33W/(m2.℃)

Conclusion

The 0.001% cupric oxide/water nanocoolant was initially prepared using volume percentage formula. Using a jacketed vessel setup, the cupric oxide nanocoolant were finally examined for their potential uses in real time. According to experimental findings, cupric oxide nanocoolant have a higher total heat transfer coefficient than their base fluid, water. In addition, heat transfer rate rise for nanocoolant compared to water. The aim of this experiment is also to reduce the heat transfer equipment size using the cupric oxide nanocoolant. Such an innovation will definitely find its importance in the commercial grounds.

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