



EXPERIMENTAL ANALYSIS OF ENHANCED PERFORMANCE OF PLATED HEAT EXCHANGER USING IN MILK PASTEURATION PROCESS BY USING NANO FLUID

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Abstract— Experimentally to analyzed the enhance performance of Plate heat exchanger in milk pasteurization process using nanofluid at different concentration of 0.1%,0.15%,0.2% 0.25% and 0.3%. in this work the nanoparticles like Al_2O_3 and the base fluid like dematerialized water is used to prepare nanofluid by using two steps method. Exchanger is one of the thermal energy transferring devices, which transfer the heat between different fluids. This is widely used in different application because of its compact in size and higher efficiency compared to other type of heat exchanger. The main focus of using nanofluid is that it has improvement in thermal conductivity. Than the hot fluid as milk and cold fluid as nanofluids are used. The heat transfer rate is increased with increasing the concentration of nanofluid. It conducted by varying operating parameters like mass flow rate of hot milk, mass flow rate of nanofluid , inlet and outlet temperatures of hot milk and inlet outlet temperature of nanofluid . The main objective of this work is to find out mass flow rate and overall all heat transfer coefficient.

Keywords- gasket plate heat exchanger, hot fluid as milk, cold fluid as Al_2O_3 nanofluid, overall heat transfer coefficient.

I. INTRODUCTION

A heat exchanger is a device that is used to transfer enthalpy between two or more fluids between solid surfaces. And a fluid flow between solid particulates at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single- or multi component fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distil, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids can exchanging heat is in direct contact. In most heat exchangers heat transfer between fluids takes place through a separating wall or in and out of a wall in a transient manner.

In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not leak or mix. Such exchangers are referred to as direct transfer type, or simply recuperate. In contrast, exchangers in which there is intermittent heat exchange between hot and cold fluids via thermal energy storage and release through the exchanger surface or matrix are referred to indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure differences and matrix rotation valve switching. Common examples of heat exchangers are shell-and tube exchangers, automobile radiators, condensers, evaporators, air pre-heaters, and cooling towers.

The heat exchanger can classify as.

1. Tubular heat exchanger.
2. Plate heat exchanger.
3. Extended surface heat exchanger.
4. Regenerative heat exchanger.

II. LITERATURE REVIEW

BANI KANANEH et.al. [1] have proposed that Fouling inside gasketed plate heat exchangers used in milk production has been reduced using nano-composites coatings. The coated plates showed reduced deposit build up in comparison with the uncoated stainless steel.

MARZIA GIRIBALDI et.al. [2] have proposed that A new small-scale continuous-flow High-Temperature Short-Time (HTST) pasteurizer has been designed for treating human milk. HELENA F et.al. [3] have proposed that The continuous thermal processing of liquid foods with a three-section plate heat exchanger (PHE), heat integration and a non-isothermal holding tube was modelled in order to derive the temperature history of the product and the lethality distribution. In order to validate and test the model, it was used to simulate the operation of a laboratory-scale plate pasteurizer processing an enzymic time-temperature integrator (TTI) at four temperature conditions (70, 75, 80 and 85 °C). Previous studies of residence time distribution and heat transfer in the equipment provided important parameters for the simulation.

PHAVANEE NARATARUKSA et.al. [3] have proposed that Fouling by coconut milk at different heating temperatures. The results illustrated that the fouling factor increased, when the temperature fell due to a combination of chemical reaction fouling from proteins and precipitation fouling from fat. The fouling factor also increased, when the flow was lowered due to a slow rate of deposit removal introduced by small shear force. Combination of the two effects revealed that the effect of flow was less significant at higher temperatures. All results can be confirmed by an analysis of fouling compositions. At high temperature conditions, more denaturation of proteins resulted in less ability to entrap fat globules onto heating surface.

W. AUGUSTIN et.al [4] have proposed that Heat transfer fouling experiments were carried out in a temperature controlled stirred vessel using aqueous solutions of whey protein concentrate in the concentration range of 3 to 3.5 wt-% at a bulk temperature of 50 °C and pH of 6. Heat transfer data were obtained from thermocouples embedded in an immersed electrical heating rod with various metal plates attached with-and-without surface treatments.

K. S. HONG et.al [5] have proposed that Nanofluids have been attractive for the last few years with the enormous potential to improve the efficiency of heat transfer fluids. This work focuses on the effect of the clustering of nanoparticles on the thermal conductivity of nanofluids. Large enhancement of the thermal conductivity is observed in Fe nanofluids sonicated with high powered pulses.

III. PLATE HEAT EXCHANGER

The plate heat exchanger normally consists of corrugated plates assembled into a frame. The hot fluid flows in one direction in alternating chambers while the cold fluid flows in true counter-current flow in the other alternating chambers. The fluids are directed into their proper chambers either by a suitable gasket or a weld depending on the type of exchanger chosen. Traditionally, plate and frame exchangers have been used almost exclusively for liquid to liquid heat transfer. The best example is in the dairy industry.

The corrugated pattern on the thermal plate induces a highly turbulent fluid flow. The high turbulence in the PHE leads to an enhanced heat transfer, to a low fouling rate, and to a reduced heat transfer area. Therefore, PHEs can be used as alternatives to shell-and-tube heat exchangers. R410A approximates an azeotropic behavior since it can be regarded as a pure substance because of the negligible temperature gliding.

The resulting flow passages are narrow, highly interrupted, and tortuous, and enhance the heat transfer rate and decrease fouling resistance by increasing the shear stress, producing secondary flow, and increasing the level of turbulence. The corrugations also improve the rigidity of the plates and form the desired plate spacing. Plates are designated as hard or soft, depending on whether they generate a high or low intensity of turbulence.

Sealing between the two fluids is accomplished by elastomeric molded gaskets [typically, 5 mm (0.2 inch) thick] that are fitted in peripheral grooves. Gaskets are designed such that they compress about 25% of thickness in a bolted plate exchanger to provide a leak tight joint without distorting the thin plates. In the past, the gaskets were cemented in the grooves, but now, Snap-On gaskets, which do not require cementing, are common.

3.1 Specification of PHE

Plate Type	: VT04 PH K
Heat Transfer Area (Total/per unit)	: 0.14 m ²
Number of Plates (Total/per unit)	: 7
Plate Thickness	: 0.60 mm
LMTD	: 35.99 K
Plate Material	: AISI316
Gasket Material/ Gasket Type	: NBR / Glued
Internal flow (passes × channels)	: 2×4
No. of Frames	: 1
Frame Material	: CS-IS 2062 Gr B
Surface	: Painted RAL50

IV. NANOFLUID

Nanofluid is a fluid containing nanometer sized particles called nanoparticles. These fluids are colloidal suspensions of nanoparticles with sizes typically of the order 1-100 nm in base fluid. Modern nanotechnology provides great opportunities to process and produce materials with average crystallite size below 50 nm. Recognizing an opportunity to apply this emerging nanotechnology to established thermal energy engineering, it was proposed by Choi in 1993 that nanometer sized metallic particles could be suspended in industrial heat transfer fluids such as water, ethylene glycol or engine oil to produce a new class of engineered fluids with thermal conductivity. The average size of particles used in nanofluids is below 50 nm.

V. PREPARATION OF NANO FLUIDS

In this study, PHE = water nanofluid was prepared by a two-step method consisting of dispersion of nanoparticles purchased from Neutrino Co. in distilled water as the base fluid. In this, nanoparticles with 5–15 nm in diameter and 20 nm in length were smoothly added to distilled water for about 3 minutes, which was on the magnet stirrer, and was continuously stirred for 45 minutes. Then, the suspension was subjected to an ultrasonic bath for about 60 minutes, it was maintained at 90°C and a mechanical high-speed agitator was used in it to have a more stable nanofluid. The amount of surfactant was 2.5 times of weight of the nanoparticles. The volume of the nanofluids, for having an economic consumption of nanoparticles, investigations were chosen in weight fraction concentrations instead of the volume fractions. So, the nanofluids with 0.1%, 0.15%, 0.20%, 0.25% and 0.30% weight fractions were obtained by the method illustrated above. No sedimentation was observed after 2 days and even at low flow rates in the experiments. Also, to prevent from possible sedimentation, a new nanofluid was prepared and immediately used for each test.

VI. EXPERIMENTAL INVESTIGATION

A scheme of the experimental setup shown in fig.1 mainly included two flow loops for hot and cold fluids. It shows the hot flow loop consisted of an isothermal water bath (for milk as hot fluid) with a heater by 1500 W power and 5 Lit capacity, a centrifugal pump, a dampener (to minimize the vibration), and PHE as the test section of this process. The counter current heat exchange was established between hot and cold streams. The inlet and outlet temperatures of the nanofluid and milk were measured by four PT-100 thermocouples, which had a precision of 0.1°C and were calibrated using a mercury thermometer at high and low temperatures of fluid. The water bath was set at the required temperature. After the temperature of the nanofluid went up and exceeded the temperature, the pump was

turned on, and the nanofluid was circulated. Since the hot fluid came back to the bath after passing through the PHE, its temperature suddenly fell down and then went up again to reach the set temperature. Before returning to the reservoir, flow rate of the nanofluid was measured from the time required capacity and a valve on the bottom. In the second loop, milk was pumped from the milk reservoir and, after warming in PHE, the pasteurized milk with higher temperature entered a cooler to keep constant temperature at the inlet of PHE by tap nanofluid as coolant. Thermocouples and flow rate measurements were the same at the nanofluid loop as described. In order to minimize the heat loss around the PHE, it was isolated by a glass wool. Bypass lines for both of the milk reservoir and water bath were used to control flow rates of the fluids. The system needed 10 minutes to reach the steady-state condition, and then the temperatures were recorded. In this PHE, critical Reynolds number was 100, and the experiments were carried out in both ranges of laminar and turbulent flow regimes for the nanofluid and just in the laminar flow for milk stream.

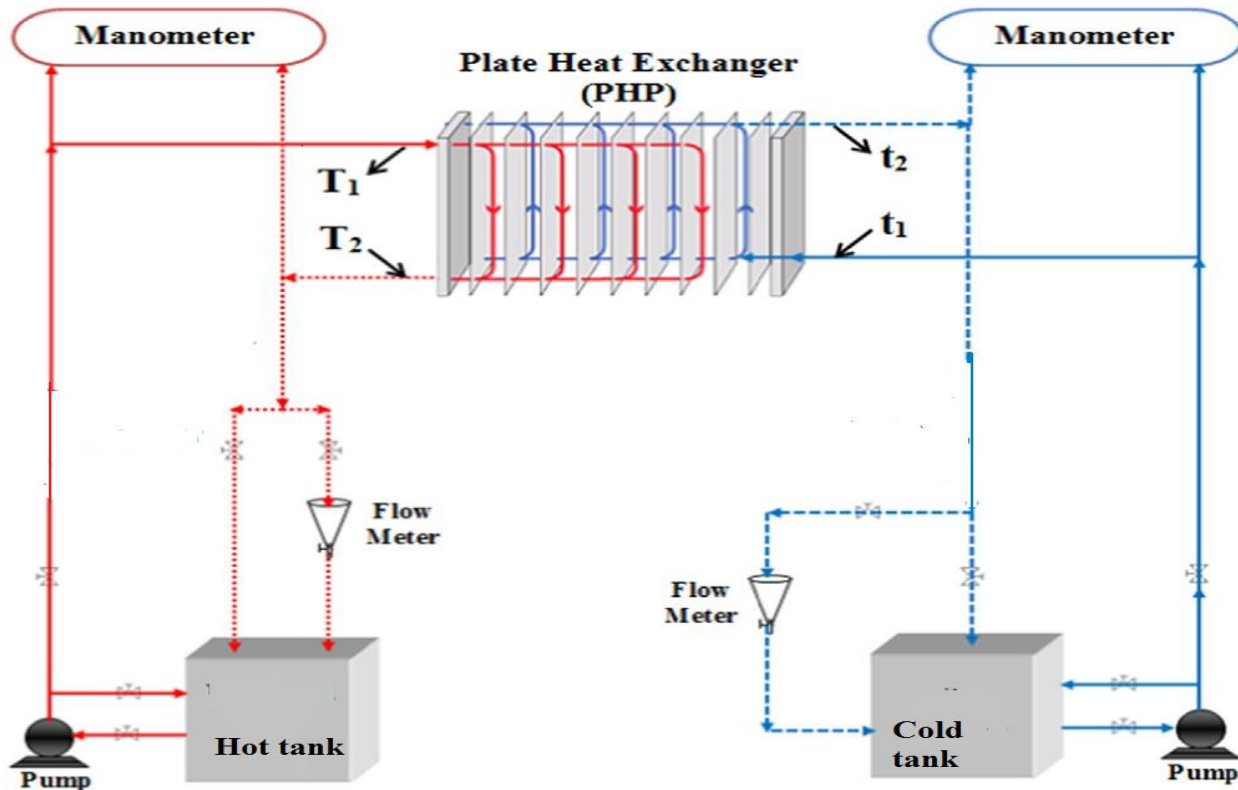


Fig 1. Experimental Setup of Plate Heat Exchanger

VII. DATA ANALYSIS

Experimental data have been used to calculate the heat transfer rate and over all heat transfer coefficient characteristics, each of the involved fluids.

7.1. Specific Heat

$$C_{pnf} = \Phi C_{pp} + (1 - \Phi) C_{pf}$$

7.2. Over All Heat Transfer Co-Efficient

$$U = [1/h_i + 1/h_o]^{-1}$$

7.3. Heat Transfer Rate

$$Q = UA \Delta T_m$$

VIII. RESULTS AND DISCUSSION

In nanofluid-milk heat transfer various results are plotted based on different parameters such as heat transfer rate, specific heat, thermal conductivity, heat transfer coefficient.

Chart 1. shows the differens of concentration with respect specific heat. It is observes that concentration will increases with decrease the specific heat.

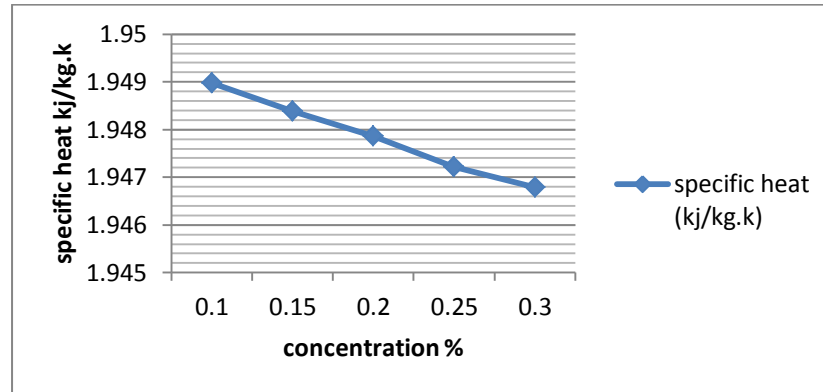


Chart 1. Concentration Vs specific heat

Chart 2. shows the differens of concentration with respect thermal conductivity. Increase in concentration results into increase in thermal conductivity of fluid.

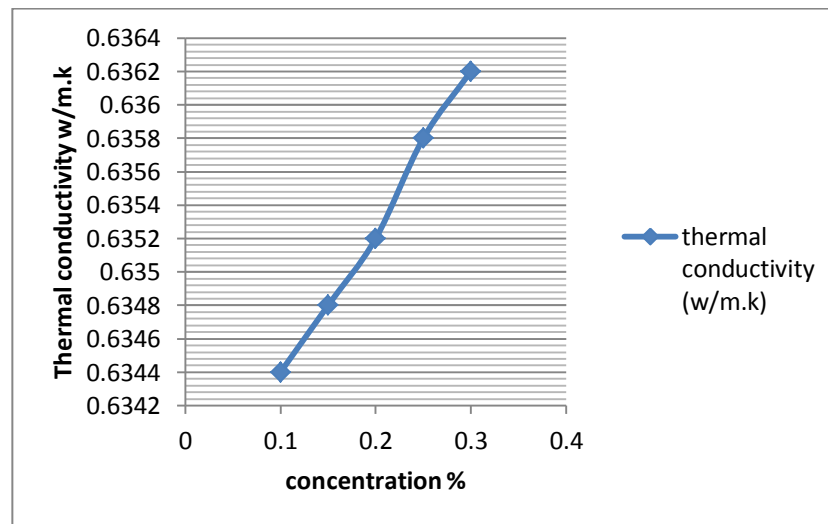


Chart 2. Concentration Vs thermal conductivity

Chart 3. shows the differens of concentration with respect heat transfer rate. Increase in concentration results into increase in heat transfer rate of fluid.

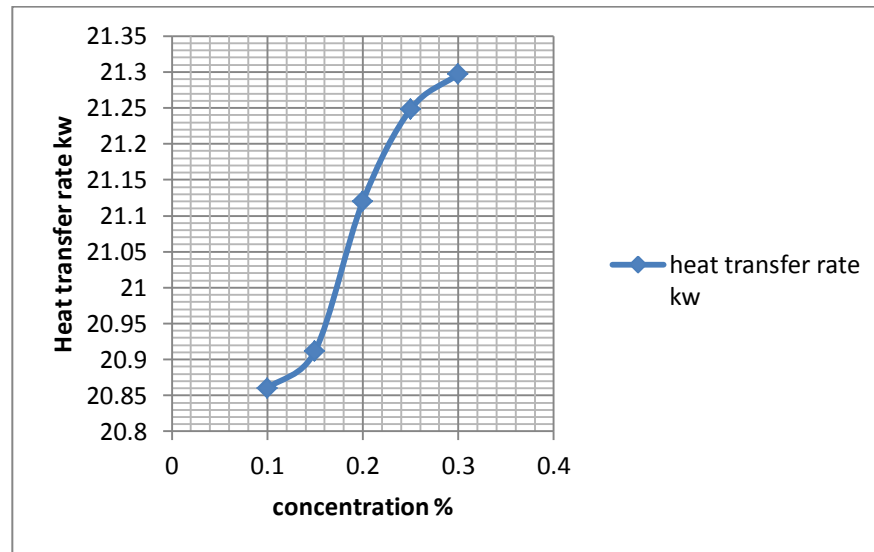


Chart 3.concentration Vs heat transfer rate

Chart 4. shows the differens of concentration with respect overall heat transfer coefficient. Increase in concentration results into increase in overall heat transfer rate of fluid.

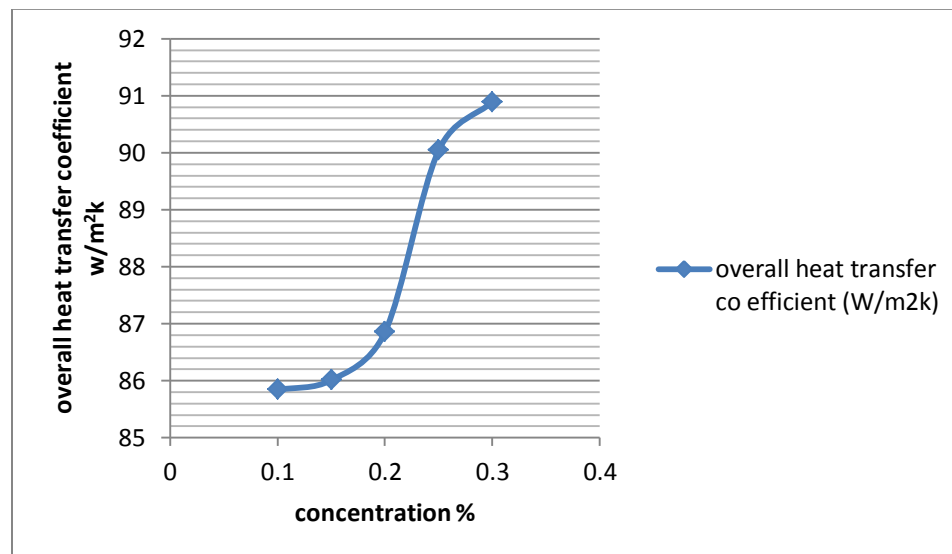


Chart 4. concentration Vs overall heat transfer coefficient

For the nano fluid based heat transfer different results are based of different parameter such as heat transfer rate, over all heat transfer coefficient, mass flow rate, specific rate, thermal conductivity

Chart 5 show with the concentration with specific heat, thermal conductivity, heat transfer rate, overall heat transfer coefficient while increase the concentration the performance will be increased

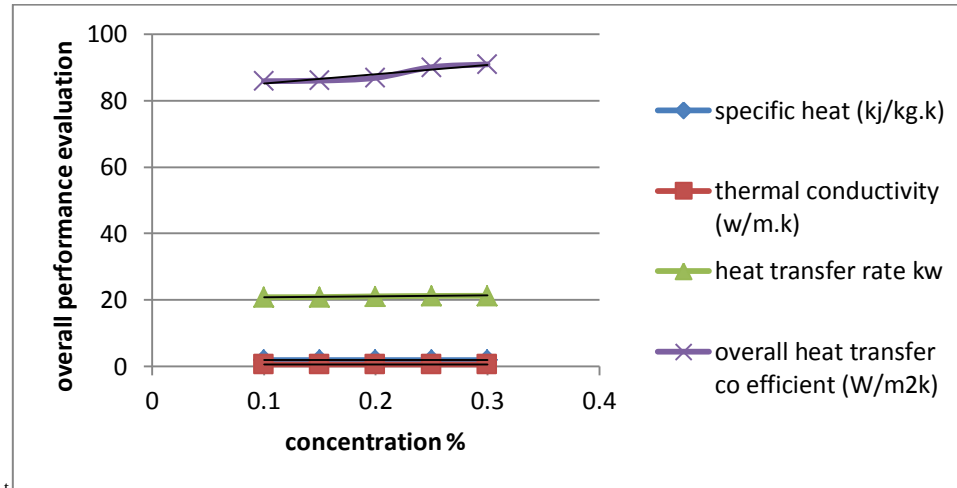


Chart 5. Overall performance evaluation Vs concentration

-IX.CONCLUSION

This research work is focused on heat transfer analysis of corrugated PHE and also to investigate experimentally the performance of corrugated PHE with regard to convective specific heat, thermal conductivity, heat transfer coefficient, heat exchanger effectiveness and the following performance are finding by varying mass flow rate of working fluid. And This experimental investigation on corrugated PHE can be extended with various fluids. This work can be further extended for heat transfer analysis by further process.

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