Analysis of Heat Enhancement of Plate Heat Exchanger Efficiency by Internal Thread

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Abstract— The heat exchangers are generally used to transfer heat from one medium to another medium.An experiment was conducted in Bhopal Sahakari Dugdh Sangh (BSDS) on Plate Heat Exchanger. A Plate Heat Exchangers are used to pasteurize milk in BSDS, in which the warm water is used to transfer heat towards milk by which milk is pasteurized. The temperature of pasteurization milk is set on 78°C in BSDS plant for milk properties, when the temperature of pasteurized milk become below 78°C the milk come in raw milk tank to again pasteurize. By which we got the working plate heat exchanger efficiency of BSDS is 75%. We enhance the working plate heat exchanger efficiency of BSDS by placing different internal thread (Pitch 1cm and 0.5cm) in inlet warm water pipe. We got the working efficiency of Plate Heat Exchanger in this internal threads are 81.01% and 77.11%. The experiments proposed for counter flow models of the fluids. After modification by internal thread in Plate Heat exchanger set up we got inner thread of 0.5cm pitch give more turbulence than inner thread of 1cm pitch. We compared these modified working efficiency to without modified working efficiency of plate heat exchanger which is used in BSDS. We got that the working efficiency of BSDS plant is increased by placing inner thread of 0.5cm pitch.

Key words: Plate Heat Exchanger; Internal Threads; Pitches; Counter Flow; Temperature, BSDS

I. INTRODUCTION

The heat transfer rate in flow passage is increased by three techniques such as passive, active techniques and compound technique. Passive techniques are more preferable because of its simplicity in design and fabrication also the cost for fabrication is low in comparison with active and compound techniques. It includes the surface roughening or geometrical modifications in the flow channel which alters flow distribution and promotes more heat transfer. Another technique used is active technique, these techniques are complex to design and implement because it requires external input to disturb the flow. It includes mechanical aids, surface vibration, fluid vibration, electrostatic fields, and injection, suction and jet impingement. A number of experimental investigations have done on internal thread. The flow disturbance is maximum for side by side arrangement of internal threads due to higher vortex generation than inline array. The internal threads of 0.5cm is more efficient than internal threads of 1cm. with the peak end at upstream and round end at downstream produces more mixing of fluid which promotes the heat transfer rate. A parametric study is performed with k-ε turbulence model to determine the effects of Reynolds number and Nusselt number on heat transfer enhancement, and have computed heat transfer coefficients in a channel with one side internal threads.

II. LITERATURE REVIEW

The objective of paper [1] is to review the different techniques, which have been used to enhance the heat transfer rate in heat exchanger devices such as solar air heater, cooling blades of turbine and so on using single phase heat transfer fluids. The results of recent published articles with the development of new technologies such as Electro hydrodynamic (EHD) and Magneto hydro dynamics (MHD) are also included. Enhancement of heat transfer in heat exchanger can achieved by means of several techniques. These techniques are grouped into the active and passive method. In the active methods, system need some external power, however, passive method utilize surface modification either on heated surface or insertion of swirl devices in the flow field. Active methods are very complex because of external power supply, although these methods have great potential and can control thermally. Passive methods include artificial roughness, extended surface, winglets, insertion of swirl devices in the flow which alters the flow pattern causes to disturb the thermal boundary layer, and consequently high heat transfer. Passive methods are dominant over active methods because it can easily employed in existing heat exchangers. In this paper, an effort has been made to categorize the active and passive methods and review the various heat transfer techniques applied in heat exchangers. Important results have been listed for ready reference. It has been concluded that either active or passive methods have been employed alone. Based on literature, a combined method has also been recommended which include both active and passive methods.

The main objective of Heat transfer devices [2] have been used for conversion and recovery of heat in many industrial and domestic applications. Over five decades, there has been concerted effort to develop design of heat exchanger that can result in reduction in energy requirement as well as material and other cost saving. Heat transfer enhancement techniques generally reduce the thermal resistance either by increasing the effective heat transfer surface area or by generating turbulence. Sometimes these changes are accompanied by an increase in the required pumping power which results in higher cost. The effectiveness of a heat transfer enhancement technique is evaluated by the Thermal Performance Factor which is a ratio of the change in the heat transfer rate to change in friction factor. Various types of inserts are used in many heat transfer enhancement devices. Geometrical parameters of the insert namely the width, length, pitch, etc. affect the heat transfer.

In many cases, roughness gives better performance than the twisted tape as seen in case of flow with large Prandtl Number. The artificial roughness can be developed by employing a corrugated surface which improves the heat transfer characteristics by breaking and destabilizing the thermal boundary layer. This paper provides a comprehensive review of passive heat transfer devices and their relative merits for wide variety of industrial applications.

As a novel coolant [3], the ethylene glycol-water (50 wt.%:50 wt.%) with graph nano platelets nano fluids (GnPEGW) were prepared at four weight concentrations (0.01, 0.1 0.5 and 1.0 wt.%), and heat transfer and pressure drop characteristics in a miniature plate heat exchanger (MPHE) were investigated. All nano fluid samples were prepared and diluted by ultrasonic vibration, and their thermal conductivity and dynamic viscosity were measured by a transient plane source method and a rotational rheometer, respectively. Firstly, the convective heat transfer coefficient (HTC) and pressure drop correlations were predicted under the condition that water was employed as working fluid in both the hot and cold sides of the MPHE. Then, the effects of GnP concentrations of nanofluids on the thermal and hydraulic performances have been determined for the MPHE with the nanofluid in hot side and the water in cold side. Parametric evaluation and performance comparison of the MPHE using GnPEGW were analyzed via various operating conditions. Experimental analysis showed that: the proposed correlations from water can predict the experimental data of the base fluid and GnP-EGW nano fluids. In the proper concentration range from 0.01 to 0.1 wt. %, the GnP-EGW nanofluid has an acceptable pressure drop penalty but a higher heat transfer performance compared with the base fluid in the MPHE, which reveals that it might be a potential cooling medium.

In the present study [4], numerical as well as experimental investigations have been done on the plate heat exchanger using hybrid nanofluid (Al_2O_3 +MWCNT/water) at different concentration to investigate its effect on heat transfer and pressure drop characteristics. Discrete phase model has been used for the investigation using CFD software and results have been compared with the experimental result as well as result of the homogenous model. Effects of different operating parameters (nanofluid inlet temperature, flow rate and volume concentration) have been studied on coolant outlet temperature, heat transfer rate, convective and overall heat transfer coefficients, Nusselt number, friction factor, pressure drop, pumping power, effectiveness and performance index. Velocity and temperature profiles have been also studied for base fluid, nanofluid and hybrid nanofluid. By using hybrid nanofluid, heat transfer coefficient enhances by 39.16% (merit) with negligible increase in pumping power of 1.23% (demerit). An enhancement in heat transfer and pressure drop characteristics; and hence on the effectiveness of plate heat exchanger has been observed while using hybrid nanofluids instead of base fluid.

A plate type heat exchanger [5] consists of plates instead of tubes to separate the hot and cold fluids. Because each of the plate has very large surface area, the plates provide each of the fluids with an extremely large heat transfer area. Due to the high heat transfer efficiency of the plates, plate type heat exchanger is very compact when compared to a shell and tube heat exchanger with the same heat transfer capacity. In this paper efforts have been made to study the performance of Plate type heat exchanger with miscible and immiscible systems. The experimental studies involved in the determination of outlet temperature of both cold and hot fluid for various flow rates. The water-water system, water-acetic acid system, water ethylene glycol system, water-toluene system and water-kerosene system at 9%, 10%, 20% & 25% composition were used to determine the performance of plate type heat exchanger i.e. overall heat transfer coefficient(U), effectiveness, cold side efficiency(c) and hot side efficiency(h). These experimental data were used to develop neural networks using general regression neural network (GRNN) Model. Further, these networks were tested with a set of testing data and then the simulated results were compared with the actual results of the testing data and found that the experimental data are very close to the simulated data.

Plate heat exchanger [6] has found a wide range of application in various industries like food industries, chemical industries, power plants etc. It reduces the wastage of energy and improves the overall efficiency of the system. Hence, it must be designed to obtain the maximum heat transfer possible. This paper is presented in order to study the various theories and results given over the improvement of heat transfer performance in a plate heat exchanger. However, there is still a lack in data and generalized equations for the calculation of different parameters in the heat exchanger. It requires more attention to find out various possible correlations and generalized solutions for the performance improvement of plate heat exchanger.

The Experimental studies [7] were performed on a corrugated plate heat exchanger for small temperature difference applications. Experiments were performed on a single corrugation pattern on 20 plates arranged parallels, with a total heat transfer area of 1.16298 m2. The spacing, DX, between the plates was varied (DX = 6 mm, 9 mm, and 12 mm) to experimentally determine the configuration that gives the optimum heat transfer. Water was used on both the hot and the cold channels with the flow being parallel and entering the heat exchanger from the bottom. The hot water flowrates were varied. The cold side flowrate and the hot and cold water inlet temperatures were kept constant. It is found that for a given DX, the average heat transfer between the two liquids increases with increasing hot water flowrates. The corrugations on the plates enhance turbulence at higher velocities, which improves the heat transfer. The optimum heat transfer between the two streams is obtained for the minimum spacing of DX = 6 mm. The pressure losses are found to increase with increasing flowrates. The overall heat transfer coefficients, U, the temperature difference between the two stream at outlet, and the thermal length are also presented for varying hot water flow rates and DX. The findings from this work would enhance the current knowledge in plate heat exchangers for small temperature difference applications and also help in the validation of CFD codes.

III. Problem Statement

We have found some basic problem in Plate Heat Exchanger in Bhopal Doogdh Sangh Bhopal at the time of pasteurization of milk in Plate Heat Exchanger. In Plate Heat Exchanger the milk pasteurization temperature is fixed 78°C to pasteurize. When the pasteurization temperature become below the 78°C the raw milk will not pasteurize and return to raw milk tank and again it goes to Plate Heat Exchanger to pasteurize. We observed this type of problem become five or six round of pasteurization. Then the rate of pasteurization of milk is decrease and also the efficiency of Plate Heat Exchanger is low. For the rating of Plate Heat Exchanger, we have many correlations between the heat transfer coefficient and effectiveness. The main objective is the evaluation of performance parameters of a counter flow plate heat exchanger.

IV. Experimental Apparatus and Instrumentation

The test apparatus for this study hot fluid is flow in counter flow in plate heat exchanger in Bhopal Sahakari Doogdh Sangh. As shown in Fig.1, the main components Plate Heat Exchanger systems are test section, inlet outlet pipe, flow diversion valve, plates, and a heater. During an experiment, We analysed in plate heat exchanger which used by Bhopal Sahakari Dugdh Sangh that the outlet pasteurization temperature of milk is fixed on 78°C but we observed that when the temperature of pasteurized milk become below 78°C, the pasteurized milk would not go for next process. It comes to the raw milk tank again to pasteurize. Therefore we observed that the working efficiency of plate heat exchanger is decrease. We used the internal threads at different pitches to increase the working efficiency of plate heat exchanger by increasing the temperature of hot water. The hot water temperature increased by internal threads installed in tubular pipe before entering the hot water in plate heat exchanger. Experimental setup is shown in fig.1.2.

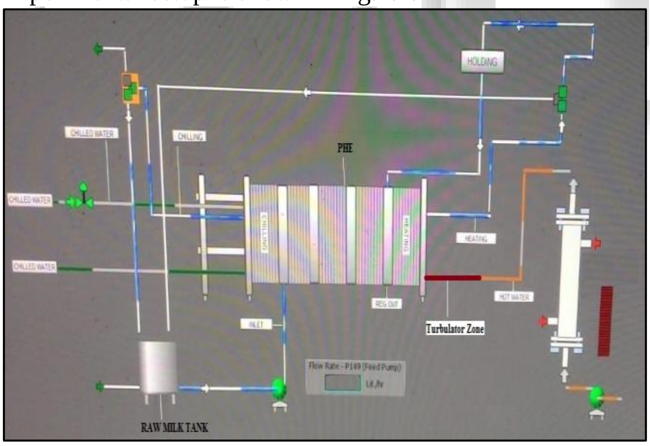

Fig. 1: Line diagram of Plate Heat Exchanger used in BSDS

The Plates of Plate Heat Exchanger are made up of Aluminium material. All the geometrical dimensions are in term of channel height while the heat transfer coefficients are presented in term of channel hydraulic diameter. Steam is delivered from the steam boiler. This steam is used to heat water which in turns heats the product to pasteurization temperature. The 228 plates are used in above Plate Heat Exchanger set up of and the plate dimensions are: length of plate is 1.22m and width is 0.34m. The diameter of pipe is 0.63cm by which hot water and milk flow in to PHE. The internal threads of different pitches are enclosed inside the hot water inlet pipe one by one to identify the variation of temperature of pasteurization milk. The internal threads enclosed in 50cm of hot water tube shown in fig.2, and clearly internal thread zone are explain by line diagram with thermocouples shown in fig.1 T_2 thermocouple at a distance of 30cm from the origin of the inlet of hot water pipe is installed on the walls of the pipe.

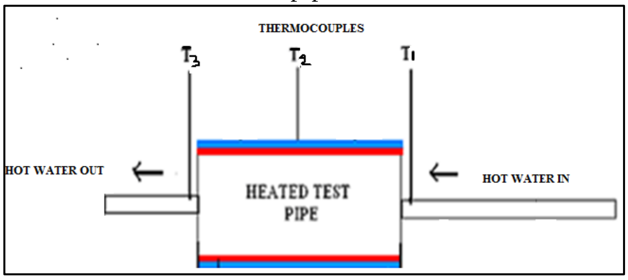

Fig. 2: Thermocouples set up in hot water pipe

V. Experimental Procedure

The plate heat exchangers are used to milk pasteurization in Bhopa Sahakari Doogdh Sangh. The water is heated in heater and then comes to plate heat exchaenger towards the hot water inlet pipe. The internal thread are enclosed in the inlet pipe at the time of experiment performed. The temperature of hot water is increased by enclosing internal thread inside the pipe. At same time the raw milk enter in to plate heat exchanger to pasteurize from other end. The raw milk and hot water flow in counter flow direction in plate heat exchanger. After that hot water provide heat to raw milk to pasteurize but the pasteurize temperature is fixed at 78°C for milk chemical process. After grabbing 78°C temperature for 15 minutes in plate heat exchanger the pasteurized milk go for other operation in Bhopal Sahakari Doogdh Sangh. If the temperature of pasteurize milk become lower than 78°C then the milk will not go for other operation, it come in raw material tank by flow diversion valve to again pasteurize.

We set the different pitches of internal threads one by one and take the temperature reading of hot water and milk inlet and outlet temperature on digital temperature apparatus regarding respective pitches of internal threads. There are some reading data note and solve it for heat transfer, Reynolds number and Nusselt number.

1) *Discharge of hot water*

$$Q_w = 3Q_m$$

2) *Velocity of water flow in inlet pipe*

$$A = (\pi/4) \times (D)^2$$
$$Q = A\,V$$
$$V = Q / A$$

3) *Mass flow rate of hot water in inlet pipe*

$$\dot{M} = \rho\, A\, V$$
$$\rho = 962.923\ \text{kg/m}^3$$

4) *Heat transfer from hot water to milk*

$$q = \dot{M}\, C_p\, (T_{mo} - T_{mi})$$
$$C_p = 4.194\ \text{kJ/kg k}$$

5) *LMTD (Logarithmic Mean Temperature Difference)*

$$\Theta_i = T_{hi} - T_{mo}$$
$$\Theta_o = T_{ho} - T_{ci}$$
$$\Theta_m = \frac{\theta i - \theta o}{\ln \theta i/\theta o}$$

6) *Over all heat transfer coefficient l*

$$q = U\, A\, \Theta_m$$
$$U = q / A\, \Theta_m$$

7) *Reynolds's Number (Re)*

$$Re = (\rho \times D \times v)/\mu$$

8) Over all Nusselt Number

Nu = UD / K

We solve the above parameter by taking the reading in my experimental work in Bhopal Sahakari Doogdh Sangh and then compare the parameter on respective parameter Vs observation number for all tabulators. The parameter's graphs are shown by Figure 3, Figure 4 & Figure5.

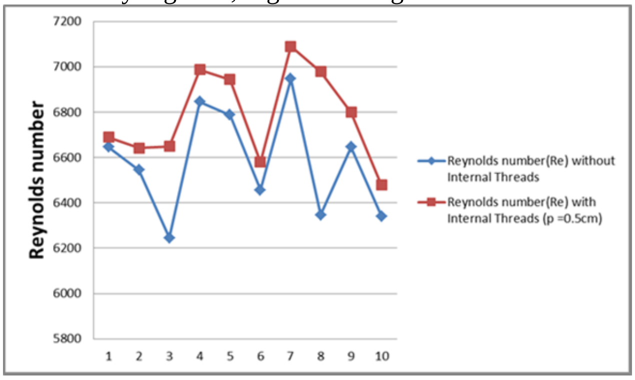

Fig. 3: Reynolds Number (Re) Vs Observations

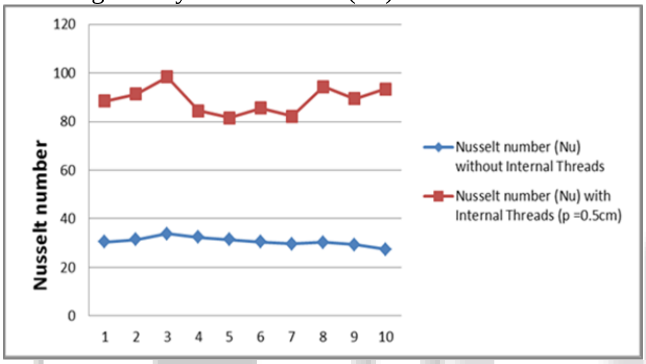

Fig. 4: Nusselt Number (Nu) Vs Observation Number

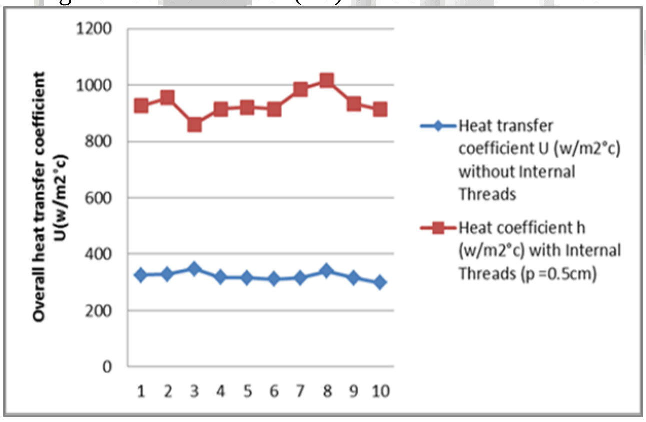

Fig. 5: Overall heat transfer coefficient (U) Vs Observations Number

VI. CONCLUSION

After the successful achievement of a task of the planned modification and introduction of the Plate Heat Exchanger used in Bhopal Sahakari Dugdh Sangh to pasteurize the milk. We concluded following point-

The heat transmission in the Circular pipe could be integral by using inner threads. The heat transfer frequency increases in the Circular pipe with a significant rate as related to without inner threads. This increase in the heat transfer is liable on the many factors but heat transfer coefficient plays vital role in it. The results show that the heat transfer coefficient for the inner threads of pitch p= 0.5 cm is more as compare to the without using any inner threads in pipe. This effect shows that the heat transfer frequency is increases as the Reynolds no. increases. This increases in the heat transfer frequency occurred due to the turbulence.

The core threads of pitch p= 0.5cm reasons the extreme turbulence in the pipe due to which maximum heat transfer to occur. As the pitch of core threads is increases there is less turbulence is occur.

The additional time for the milk pasteurization in Plate Heat Exchanger can be improved by using the turbulence in the system.

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