1

PERFORMANCE ANALYSIS AND OPTIMIZATION OF PLATE TYPE HEAT EXCHANGER IN DAIRY INDUSTRIES

Niyant P. Thakkar, Mithilesh Kumar

Uka Tarsadia University, Department of Mechanical Engineering, Surat, India

ABSTRACT: The corrugated Plate type heat exchanger is widely used in various processes of industries. The present experimental studies were performed on a corrugated plate heat exchanger for single phase flow (water-to-water) configurations in an institute laboratory to determine the performance of plate type heat exchanger, i.e., overall heat transfer coefficient, heat transfer rate, effectiveness, cold side efficiency, and hot side efficiency. The temperatures of the heat exchanger at the inlet and outlet ports, the volumetric flow rates of the hot and cold fluids, and the pressure drops between the inlet and outlet ports are measured during the experiments. Due to the complex corrugated surface design flow is highly turbulent. This makes the design of plate heat exchanger using empirical correlations to deviate from actual. Sometimes the flow medium cannot distribute uniformly which affects the performance of plate heat exchanger. The findings from this work enhanced the current knowledge in plate heat exchangers. This script is focused on the study of one corrugated type of gasketed-plate heat exchanger which is used in local dairy industry. These experimental data were used to find the optimized condition to operate heat exchanger in dairy industries.

KEYWORDS

Plate Heat Exchanger, Design parameters, Optimization, Dairy processes

Introduction

Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single or multi component fluid streams [1]. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact by the arrangement of Heat Exchanger. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In several heat exchangers, the fluids are separated by a heat transfer surface, and ideally, they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply recuperators. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids via thermal energy storage and release through the exchanger surface or matrix are referred to as 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 [2]. Common examples of heat exchangers are shell-and tube exchangers, automobile radiators, condensers, evaporators, air preheaters, and cooling towers. There could be internal thermal energy sources in the heat exchangers, such as in electric heaters and nuclear fuel elements. Combustion and the chemical reaction may take place within the heat exchanger, such as in boilers, fired heaters, and fluidized-bed exchangers,etc. Some mechanical devices may also be used in some exchangers such as in scraped surface exchangers, agitated vessels, and stirred tank reactors [14].

Dairy industries consumed energy for milk pasteurization process. For this process, it used Heat exchangers, Boilers, compressors and various other energy consuming devices. Energy saving can be performed at the dairy for stated devices. Heat Exchanger is a device that is used to transfer thermal energy between two or more fluids, between a solid surface and a fluid, or between solid particulate and a fluid, at different temperature and at thermal contact. Plate type Heat Exchanger is a compact device used to transfer heat in Dairy industries. The plate heat exchanger can be used to improve the performance of energy usage.

Content

In the literature review, the results of extensive literature research in the field of heat transfer enhancement in dairy industries are presented. The literature review includes numerical as well as the experimental work undertaken from time to time along with the development of the plate type heat exchanger for enhancing the heat transfer rate. The experiment and detailed study on these Heat exchangers is also included in this chapter:

Literature Review

Gajanan et al. (2016) carried out the experiments on corrugated plate heat exchanger (PHE) for water as both hot and cold fluids. The experiments were conducted for 30° corrugation angle with 15 mm channel spacing hot fluid and 5 mm spacing of cold fluid. The thermal analysis and pressure drop calculation were done for different cold channel spacing's of 2.5 mm, 5 mm, 7.5 mm, 10 mm, 12.5 mm and 15 mm with fixed corrugation angle 30°. It was found that the heat transfer rate and pressure drop decreases as channel spacing increases, also heat transfer rate and pressure drop increases as the corrugation angle increases.

Fatih Akturk et al. (2015) designed and constructed a gasketed-plate heat exchanger (GPHE) test set-up to perform experimental measurements for thermal and hydrodynamic performance analyses of plate heat exchangers. This study showed that every plate design needs its specific correlations for heat transfer and pressure drop calculations.

Vishal et al. (2013). analyzed experimental heat transfer data for single phase flow configurations in a corrugated plate heat exchanger for different chevron angle plates. The effect of variation of chevron angles with other geometric parameter on the heat transfer coefficient will be studied. Reynolds number ranging from 50 to 10000 and Prandtl number ranging from 3 to 75 will be taken for a given experiment. Based on the experimental data, a correlation will estimate for Nusselt number as a function of Reynolds number, Prandtl number and chevron angle. Experiments were performed to measure the temperature and mass flow rates at all port with varying flow condition.

Dardour et al. (2009). presented a theoretical analysis of a concurrent plate heat exchanger and the results of its numerical simulation. Knowing the hot and the cold fluid streams inlet temperatures, the respective heat capacities and the value of the overall heat transfer coefficient, a 1-D mathematical model based on the steady flow energy balance for a differential length of the device is developed resulting in a set of N first order differential equations with boundary conditions where N is the number of channels. For specific heat exchanger geometry and operational parameters, the problem is numerically solved using the shooting method.

O Rielly et al. (2017) analyzed energy usage across dairy processing co-operatives around Ireland. The comparative analysis for several dairies has been performed. Its aims to support the dairy co-operatives dealing with a new horizon of energy consumption in various departments of dairy by benchmarking the present day energy usages of seven large processing co-operatives unit. It is achieved by gathering, compiling and assessing the energy and production data. This process identified and compared the high energy consumed sections of Dairy.

Jamal, & Syahputra, (2016) presented a model of the heat exchanger temperature control using an artificial intelligence approach. Artificial intelligence based controllers used in this study is a fuzzy logic controller. The heat exchanger is a device used to perform the process of mixing a fluid having a different temperature. The temperature control becomes very important. Fuzzy logic control is applied to the heat exchanger so that the mixed fluid having a constant temperature. Model of fuzzy logic control in this study combined with neural network techniques. The results show that the control of the fuzzy logic controller capable of stabilizing the temperature of the heat exchangers well.

Soufiyan et al. (2009) undertakes a detailed exergy analysis of an industrial-scale yogurt drink production plant using actual operational data. Exergy efficiency and exergy destruction rate of each subcomponent of four main subsystems of the plant. The analysis was performed to quantify thermodynamic inefficiencies of all subcomponents of the plant in order to identify the breakthrough points for further energy savings. This survey of the plant can be an important step for future improvements of dairy processing plants from the sustainability and productivity viewpoints. This study clearly showed the effectiveness of exergy analysis for determining irreversibilities and losses occurring in dairy processing plants in order to improve their thermodynamic performances.

Taghizadeh-Tabari, Heris, Moradi, & Kahani, (2016) studied a Plate Heat Exchanger to increase its efficiency by using Nanofuilds, as it is a very important thermal component used in Dairy Industries. The Test rig for investigation of thermal parameters is used. In order to evaluate the positive and negative aspects of the nanofluid applications in the PHE simultaneously, a parameter of performance index was introduced, and the results confirmed the potential of this type of nanofluid in PHE, by looking at the ratio of convective heat transfer enhancement to the pressure drop.

Conclusions derived from Literature Review

It was observed from the literature that for the heat exchanger analysis, researchers have considered various options for the augmentation of thermal performance. The present computational fluid dynamics research work was undertaken to explore the effect on heat exchanger performance.

Literature shows fluid flow arrangements and designs in PHE for the analysis are studied: The aim of the analysis /is to compare the effect of the different arrangements in Plate Heat Exchanger to know the performance of it in various conditions.

The performance of PHE can be improved by analyzing it, so it is scope to find energy conservation in PHE. So, this analysis can be used in dairy industries to reduce energy consumption by energy conservation.

Aim

The following aims should be fulfilled by the present study:

1. To identify, understand, evaluate, interpret & report on energy usage by milk section of local dairy.
2. To study the experimental analysis of Plate type heat exchanger in dairy.
3. To study on the sizing & rating of in milk section of Plate type heat exchanger.
4. To conserve the energy use by the plate heat exchanger.

Material and Method

Experiment on Heat exchanger:

To understand the sizing process of the plate heat exchanger (PHE), an experiment has been done at University.

Description of Apparatus:

The apparatus consists of Plate type exchanger with two control valves. The arrangement is provided to run one exchanger at one time. Valves are provided to control the flow rate of hot and cold water. For flow measurement, Rota meter are provided at the inlet of cold water and outlet of the hot water line. A magnetic drive pump is given to circulate the hot water from a recycled type water tank, which is fitted with a heater and digital temperature controller.

Utilities required for the Experiment:

- Electricity supply: Single phase, 220 V AC, 50 Hz, 32 Amp MCB with earth Connection.
- Water supply: Continuous @ 5 LPM at 1 Bar.
- Floor drain required.
- Floor area required: 1.5 m x 1.0 m.

Experimental procedure:

1. *Starting Procedure:*
    - Close all the valves.
    - Open the lid of the hot water tank, fill the tank with water and put the lid back to its position.
    - Ensure that switches given on the panel are at OFF position.
    - Connect electric supply to the set up.
    - Set the desired water temperature in the DTC by operating the increment or decrement and set button of DTC.
    - Open by pass valve and switch ON the pump.
    - Switch ON the heater and wait till the desired temperature achieves.
2. *Procedure for plate type exchanger:*
    - Connect cooling water supply to the set up.
    - Connect the outlet of cooling water from the heat exchanger to drain.
    - Connect cold water pipe line at cold water inlet of the exchanger.

- Open the cold water inlet valve for circulation of cold water and adjust the Flow rate.
- Connect the hot water pipe line at hot water inlet of the exchanger.
- Allow hot water to flow through the heat exchanger and adjust the flow rate by the Control valve & by-pass valve.
- At steady state (constant temperature) record the temperatures & flow rate of hot and cold water.
- Repeat the experiment for a different flow rate of hot & cold water.
- Repeat the experiment for the different temperature of hot water.

The following readings of observation table have been taken by using an experimental procedure stated above:

Sr. No.	Hot Water Side			Cold Water Side		
	Flow rate, F_H (LPH)	Inlet Temperature T1 (°C)	Outlet Temperature T2 (°C)	Flow rate, F_C (LPH)	Inlet Temperature T3 (°C)	Outlet Temperature T4 (°C)
1.						

TABLE 1. Observation table for an experiment on Plate type Heat Exchanger at University

By using details of table Heat transfer rate, LMTD and overall heat transfer coefficient can be calculated from the following equations:

$T_H = (T_1+T_2)/2$, (°C)

$T_C = (T_3+T_4)/2$, (°C)

The properties of both fluids like specific heats and densities at temperature T_H and at temperature T_C from data book.

Area of plates (A_p) = Numbers of Plates (N) × Length of the plate (L) × Width of Plate (B), (m^2)

$\Delta T_i = T_1 - T_3$, (°C)

$\Delta T_O = T_2 - T_4$, (°C)

$Q = M \times C_p\,(T_o - T_i)$

$$\Delta T_m = \frac{\Delta T_o - \Delta T_i}{\ln \frac{\Delta T_o}{\Delta T_i}}$$

$$U = \frac{Q}{A \Delta T_m}$$

By performing the various practical parameters of hot and cold fluid and the overall heat transfer coefficient can be found. The value of log means temperature difference can also be found. The same procedure was performed at the dairy to find an overall heat transfer coefficient of the chiller.

Analysis of Chiller at Dairy

The design of gasketed-plate heat exchangers is highly specialized in nature considering the variety of designs available for the plates and arrangements that may possibly suit various duties. Unlike tubular heat exchangers for which design data and methods are easily available, a gasketed-plate heat exchanger design continues to be proprietary in nature. Manufacturers have developed their own computerized design procedures applicable to the exchangers that they market.

The chiller at dairy has two inlets and two outlets of the milk and water .The pasteurized milk cooled by the cold water which is as shown in figure 2. The pasteurized milk cooled by the cold water which is as shown in the figure in the SCADA system, which is utilized to control the performance of Plate type Heat Exchanger[8].

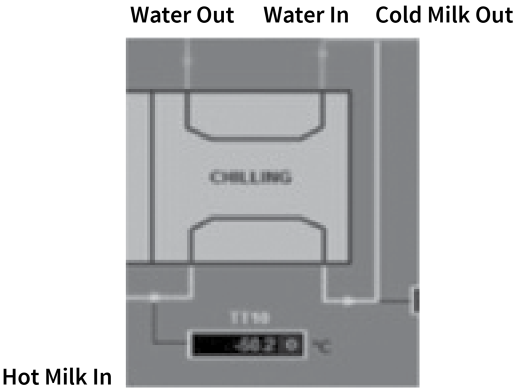

FIGURE 1. Chiller at Dairy

Supervisory Control and Data Acquisition is a control system architecture which uses the computers, networked data communications and graphical user interfaces for high-level process supervisory management, but uses other peripheral devices such as a programmable logic controller and discrete PID controllers to interface with the process plant or machinery.

The milk inlet temperature T_1 and milk outlet temperature T_2 are found from raw milk temperature. The heat transfer and effectiveness is also calculated by the following procedure for each and every reading.

For every reading,

- Temp of milk entering the cooling section,

  $T_1 = t_p - (t_p - t_r)\,\eta_r$
- Temp of milk leaving the cooling section, T_2

  Heat transfer, $Q_1 = m_h \times C_{ph} \times (T_1 - T_2)$
- Temp of water entering the chiller, T_3
- Temp of water leaving the chiller, T_4
- Hot side heat transfer, $Q_2 = m_h \times C_{ph} \times (T_4 - T_3)$
- Heat transfer area of the plate, A

  $\Delta T_1 = T_1 - T_4$

  $\Delta T_2 = T_2 - T_3$
- Logarithmic mean temperature difference,

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)}$$

The heat transfer of chevron gasketed-plate heat exchanger is evaluated. The heat transfer enhancement will strongly depend on the chevron inclination angle ß, relative to the flow direction. Heat transfer and the friction factor increase with ß.

- Total heat transfer,

$$Q = \frac{Q_1 + Q_2}{2}, \text{ w}$$

- Overall heat transfer coefficient,

$$U = \frac{Q}{(A \times LMTD)}, \text{ w/m}^2\text{°C}$$

- Number of Transfer Unit,

$$NTU = \frac{U \times A}{m_h \times C_{ph}}$$

- Capacity ratio,

$$C = \frac{m \times C_h}{m \times C_c}$$

- Effectiveness,

$$E = \frac{1 - e^{(1-C)} \times NTU}{(1 - C \times e^{(1-C)} \times NTU)}$$

The performance of a chevron plate heat exchanger depends upon the surface enlargement factor corrugation profile, channel aspect ratio, $2b/P_C$, gab b, the temperature dependent physical prop¬erties and especially the variable viscosity effects.

Attempts have been made to develop heat transfer and pressure-drop correlations for use with given plate heat exchangers. In this exchanger, the fluids are much closer to countercurrent flow. The construction and geometry of plate used in the heat exchanger at the dairy are illustrated by the following figures. Total 109 numbers of identical plates are used in pasteurizer. These plates are closely spaced and are made up of SS316 material.

The rating of given Heat exchanger evaluated by following formulas [2]:

1. Effective number of the plate (N_e)

$N_e = N_t - 2 = 109 - 2$

N_t = Number of total plate

= 107

2. Effective flow length (L_{eff})
3. Plate pitch (p) $p = b + t$
4. One channel flow area (A_{ch}), $A_{ch} = b \times L_w$
5. Single plate heat transfer area (A_p)

$$A_p = \frac{\text{whole plate area}}{\text{No. of plate}}$$

= Projected area

6. The corrugations increase the surface area of the plate as compared to the original flat area of the plate. To determine the increase of the developed length in relation to projected length, a surface enlargement factor Ø, is then defined as the ratio of the developed length to the flat or projected length.

Enlargement factor (Ø)

$$Ø = \frac{\text{DEVELOPED LENGTH}}{\text{PROJECTED LENGTH}}$$

7. The hydraulic diameter of the channel D_h is defined as

$$D_h = \frac{4 \text{ x channelflowarea}}{\text{wettedperimeter}} = \frac{4A_C}{P_w}$$

$$D_h = \frac{4\,(b)(L_w)}{2\,(b + L_w)} \approx \frac{2b}{Ø}$$

8. Number of channel per pass (N_p)

$$N_{cp} = \frac{N_t - 1}{2N_p}$$

The Pressure drop, mass velocity, and other non-dimensional numbers can be found for hot and cold fluid. From that data, some important conclusions have been derived.

9. Mass velocity (G_{ch})

$$G_c = \frac{m}{b \text{ x } L_w}$$

10. Reynolds number (R_e)

$$R_{ec} = \frac{G_c D_h}{\mu}$$

11. Nusselt number (N_u)

$$Nu = \frac{hD_h}{k} = C_h\left[\frac{D_h G_c}{\mu}\right]^n \left[\frac{C_p \mu}{k}\right]^{1/3}$$

12. Heat transfer co-efficient (h)

$$h_c = \frac{Nu_c k}{D_h}$$

13. Pressure drop analysis

The total pressure drop is composed of the frictional channel pressure drop Δp_c and the port pressure drop Δp_c. The friction factor f f is defined by the following equation for the frictional pressure drop Δp_c.

$$\Delta p_c = 4\, f\, \frac{L_{eff} N_p}{D_h} \frac{G_c^{\,2}}{2\rho} \left(\frac{\mu_b}{\mu_w}\right)^{-0.17}$$

Where L_{eff} is the effective length of the fluid flow path between inlet and outlet ports and must take into account the corrugation enlargement factor Ø this effect is included in the definition of friction factor. Therefore, $L_{eff} = L_V$ which is the vertical part distance, the friction factor is given by,

$$f = \frac{K_p}{Re^m}$$

14. Port pressure drop

The pressure drop in the port ducts

$$\Delta p_p = 1.4 N_p \frac{G_p^{\,2}}{2\rho}$$

Where,

$$G_p = \frac{m}{\frac{\pi D_p^{\,2}}{4}}$$

Where m is the total flow rate in the port opening and D_P is the port diameter.

15. The total frictional pressure drop

$$(\Delta p_t) = (\Delta p_c)_h + (\Delta p_p)_h$$

$$(\Delta p_t) = (\Delta p_c)_c + (\Delta p_p)_c$$

16. Overall heat transfer without fouling

$$\frac{1}{U_c} = \frac{1}{h_h} + \frac{1}{h_c} + \frac{t}{k_w}$$

17. Overall heat transfer with fouling

$$\frac{1}{U_c} = \frac{1}{h_h} + \frac{1}{h_c} + \frac{t}{k_w} + R_{fh} + R_{fc}$$

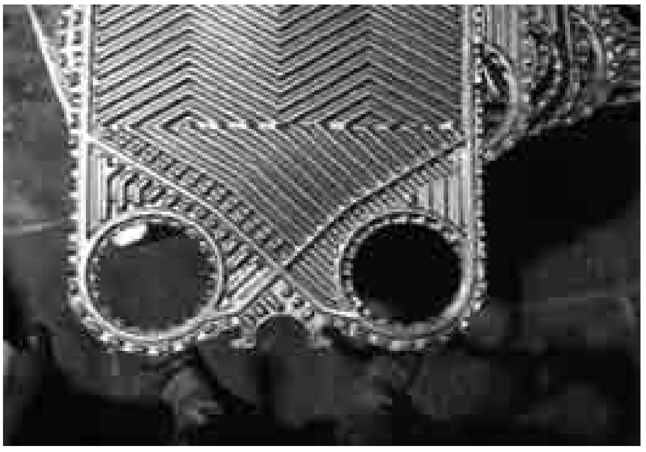

FIGURE 3. Plate construction of Heat Exchanger

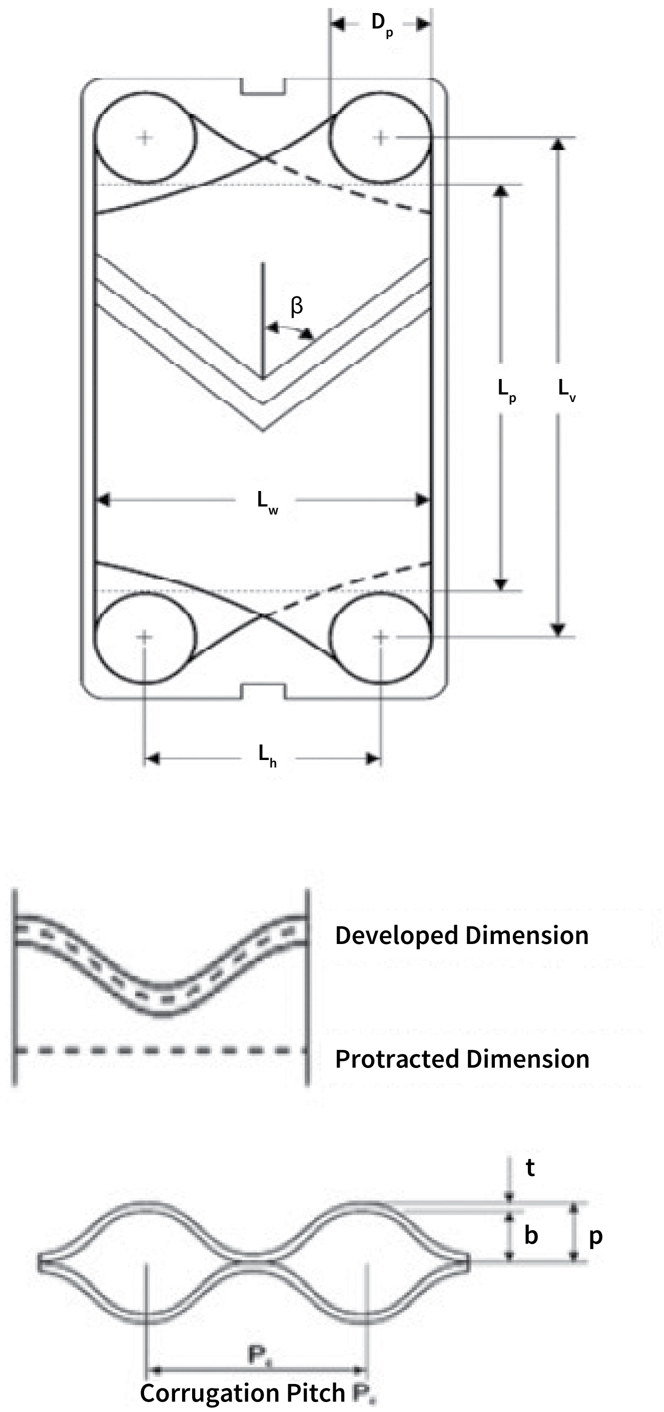

FIGURE 2. Plate Geometry

From the above stated formulas sizing and rating of Plate heat exchanger has been found [2]. The overall heat transfer coefficient, Pressure drop, Thermal properties and various other parameters for heat exchanger were measured. To analyze the performance of heat exchanger numbers of readings of temperatures and mass flow rates are measured over a period of time [11].

This study shows the detailed analysis of plate Heat Exchanger and the optimization technique used in this study would be future work. The optimization technique used to optimize the overall heat transfer coefficient.

Result and Discussion

By taking readings at the dairy the following graphs are generated, which is used to derive the conclusions.

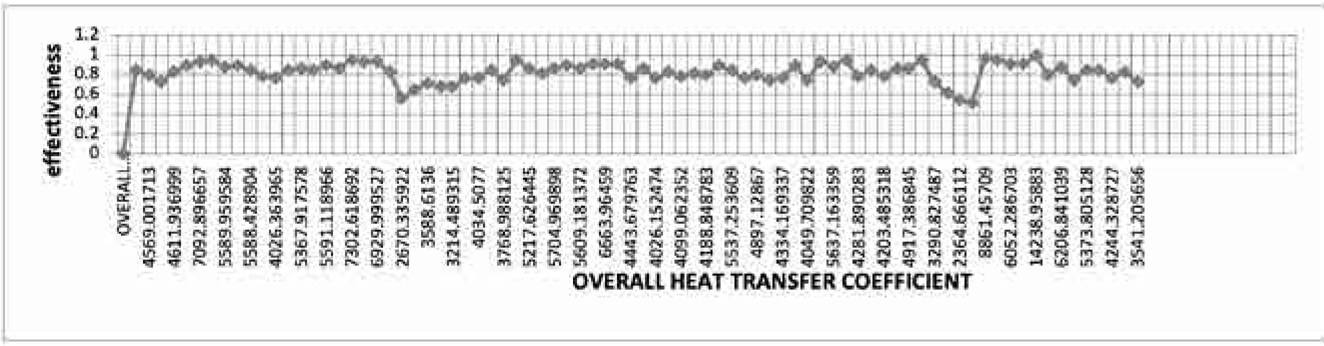

FIGURE 4. Graph between overall heat transfer coefficient vs effectiveness for plate type heat exchanger

The graph between overall heat transfer coefficient vs. effectiveness is used to define the working condition of the plate heat exchanger. For the complete analysis of plate heat exchanger pressure drop and mass flow rate of hot and cold fluid were shown on the graphs as given below.

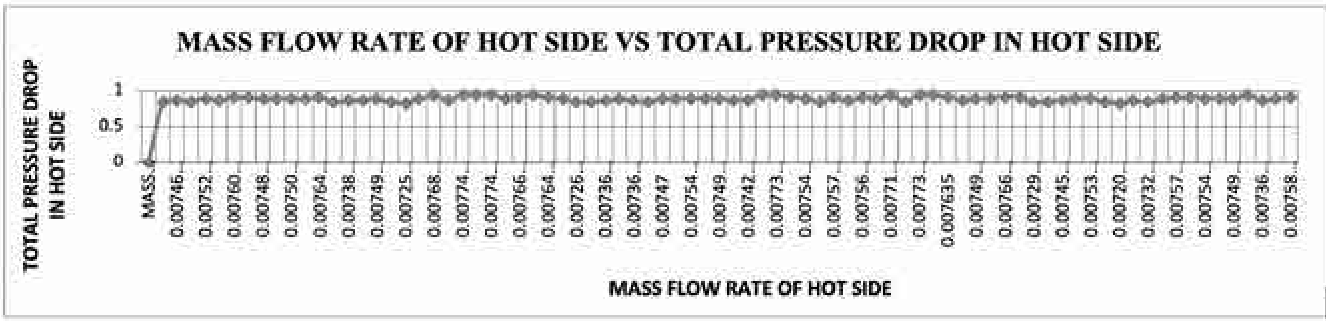

FIGURE 5. Graph between Mass Flow rate of the hot fluid (Milk) VS Pressure drop in hot fluid for Plate Type Heat Exchanger

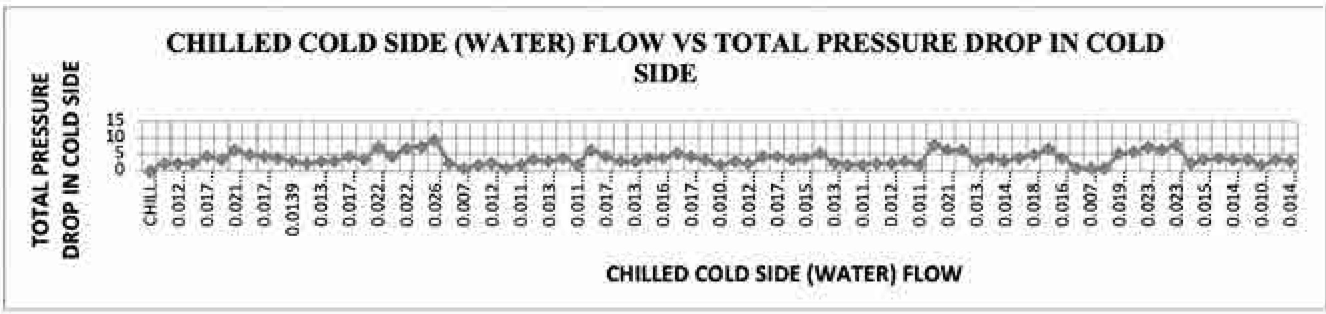

FIGURE 6. Graph between Mass Flow rate of the cold fluid (chilled water) VS Pressure drop in cold fluid for Plate Type Heat Exchanger

Also, non dimensional numbers like Reynolds number and Nussle numbers are also considered for the study. The further analysis of the Plate type exchanger can be performed to improve the productivity and sustainability of Dairy [12].

The following table is prepared for each and every reading which has been taken during the experiment on Plate Type Heat Exchanger.

Result Table for one reading

The effective number of the plate (N_e)	107
Effective flow length (L_{eff})	1.227m
Plate pitch (p)	4mm
Number of channel per pass (N_p)	52
Mass velocity (G_{ch})	G_c=9.961m/s G_h= 5.557 m/s
Reynolds number (R_e)	R_{ec} = 27150 R_{eh} = 13694
Nusselt number (N_u)	Nu_C = 602.9 Nu_h = 331.64
Heat transfer co-efficient (h)	h_c = 52352.08 W/m^2.k h_h = 2046.67 W/m^2.k
Pressure drop analysis	P_c = 1.74 bar P_h = 0.717 bar
Port pressure drop	P_{pc} = 0.76 bar P_{ph} = 0.2433 bar
Total frictional pressure drop	P_{th} =0.9603 bar P_{tc} = 2.5 bar
Overall heat transfer without fouling	10141.88 w/m^2 .k
Overall heat transfer with fouling	9868.65 w/m^2 .k

TABLE 2. Result table for Plate Heat Exchanger

Above stated graphs are used to derive the following conclusions.

Conclusion:

After completion of all experimentation and calculation work on the corrugated plate type heat exchanger the preeminent mass flow rate & temperature readings of both fluids could be determined, so the maximum heat transfer coefficient can be achieved which leads to energy savings.

The optimum condition has been derived from running the Heat exchanger where heat transfer co efficient is 14238.95 w/m^2.K with the effectiveness of 0.9964 with a temp of milk inlet and outlet 13.8°C and 4°C as well as chilled water temp of inlet and outlet are 18°C and 10.28°C.

The following conclusions are also derived from this study:

1. From the result, it can be finding out that Reynolds's number changes the variation in pressure drop occurred.
2. It has been noticed that during varying the mass flow rate of the hot side (Milk) fluid the changes in a pressure drop on hot side fluid (Milk) is notice approximately the same.
3. On the same, if the variation is occurred in the mass flow rate of cold side fluid (water), the changes in pressure drop are high, so it leads to loss of the energy of the flui though the mass flow rate on the cold side fluid should be constant or may not fluctuate during the process.

Acknowledgment

We express our deep sense of gratitude to Mr. Vishal P. Bhagatwala, Assistant Professor of F.E.T.R, Bardoli for providing precious guidance and inspiring discussion.

Gajanan D, S. Premkumar D, B. Sreedhara Rao, R.C. Sastry (2016). Optimization of channel spacing for the heat transfer performance of corrugated plate heat exchangers. 2395 -0056.

Fatih Akturk*, Nilay SEZER-UZOL**, Selin ARADAG** and Sadik KAKAC(2015). Experimental Investigation and Performance Analysis of Gasketed-Plate Heat Exchangers. 1300-3615.

Vishal R. Naik, V.K. Matawala(2013). Experimental Investigation of single phase Chevron Type Gasket Plate Heat Exchanger.

Dardour. H., S. Mazouz, and A. Bellagi (2009). Numerical Analysis of Plate Heat Exchanger Performance in Co-Current Fluid Flow Configuration. IJPMS magazine

Xie, G.N., B. Sunden, Q.W. Wang (2008) Optimization of compact heat exchangers by a genetic algorithm. Applied Thermal Engineering 28 895–906.

Jamal, A., & Syahputra, R. (2016). Heat Exchanger Control Based on Artificial Intelligence Approach. International Journal of Applied Engineering Research (IJAER), 11(16), 9063-9069.

Taghizadeh-Tabari, Z., Heris, S. Z., Moradi, M., & Kahani, M. (2016). The study on application of TiO2/water nanofluid in plate heat exchanger of milk pasteurization industries. Renewable and Sustainable Energy Reviews, 58, 1318-1326.

Soufiyn, M. M., & Aghbashlo, M. (2017). Application of exergy analysis to the dairy industry: A case study of yogurt drink production plant. Food and Bioproducts

Processing, 101, 118-131.

O'Reilly, A. J. (2017). Dairy processing heat and energy recovery: an analysis of energy usage within the dairy processing sector in Ireland.

Soufiyan, M. M., & Aghbashlo, M. (2017). Application of exergy analysis to the dairy industry: A case study of yogurt drink production plant. Food and Bioproducts Processing, 101, 118-131.

Taghizadeh-Tabari, Z., Heris, S. Z., Moradi, M., & Kahani, M. (2016). The study on application of TiO2/water nanofluid in plate heat exchanger of milk pasteurization industries. Renewable and Sustainable Energy Reviews, 58, 1318-1326.

Ramesh K. Shah,Dusan P. Sekulic(2003). Fundamentals of Heat Exchanger Design.

References

Gajanan D, S. Premkumar D, B. Sreedhara Rao, R.C. Sastry (2016). Optimization of channel spacing for the heat transfer performance of corrugated plate heat exchangers. 2395 -0056.

Fatih AKTURK*, Nilay SEZER-UZOL**, Selin ARADAG** and Sadik KAKAC(2015). Experimental Investigation and Performance Analysis of Gasketed-Plate Heat Exchangers. 1300-3615.

Vishal R. Naik, V.K. Matawala(2013). Experimental Investigation of single phase Chevron Type Gasket Plate Heat Exchanger.

Dardour. H., S. Mazouz, and A. Bellagi (2009). Numerical Analysis of Plate Heat Exchanger Performance in Co-Current Fluid Flow Configuration. IJPMS magazine

Xie, G.N., B. Sunden, Q.W. Wang (2008) Optimization of compact heat exchangers by a genetic algorithm. Applied Thermal Engineering 28 895–906.

Jamal, A., & Syahputra, R. (2016). Heat Exchanger Control Based on Artificial Intelligence Approach. International Journal of Applied Engineering Research (IJAER), 11(16), 9063-9069.

Taghizadeh-Tabari, Z., Heris, S. Z., Moradi, M., & Kahani, M. (2016). The study on application of TiO2/water nanofluid in plate heat exchanger of milk pasteurization industries. Renewable and Sustainable Energy Reviews, 58, 1318-1326.

Soufiyn, M. M., & Aghbashlo, M. (2017). Application of exergy analysis to the dairy industry: A case study of yogurt drink production plant. Food and Bioproducts Processing, 101, 118-131.

O'Reilly, A. J. (2017). Dairy processing heat and energy recovery: an analysis of energy usage within the dairy processing sector in Ireland.

Soufiyan, M. M., & Aghbashlo, M. (2017). Application of exergy analysis to the dairy industry: A case study of yogurt drink production plant. Food and Bioproducts Processing, 101, 118-131.

Ramesh K. Shah,Dusan P. Sekulic(2003). Fundamentals of Heat Exchanger Design.

Niyant P. Thakkar, Mithilesh Kumar
Uka Tarsadia University, Department of Mechanical Engineering, Surat, India

Nomenclature

U	Overall heat transfer coefficient, W/m^2 °C
T	Temperature of fluid
M	Mass flow rate of fluid
C_p	Specific heat of fluid
ΔT_m	Log mean temperature difference
ΔT	Temperature difference
A	Area of given object

Subscripts

0	Reference value
i	Reference value

Greek Symbols

€	NTU Effectiveness

Non-dimensional Numbers

Re	Reynolds number, [UD/]
Nu	Nusslet Number, [hL/k]