Heat Enhancement of Plate Heat Exchanger Working Efficiency by using Turbulators in Dairy Milk Pasteurization System

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Abstract— The heat exchangers are generally used to transfer heat from one medium to another medium. The heat exchanger are generally used for space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment. A Plate Heat Exchanger is a type of heat exchanger that uses metal plates to transfer heat between two fluids. An experimental was conducted in Bhopal Sahakari Dugdh Sangh (BSDS) on Plate Heat Exchanger. Plate Heat Exchangers are used to pasteurize milk in BSDS, in which the hot water is used to transfer heat towards milk by which milk is pasteurized. The temperature of pasteurization milk is set on 78°C in Bhopal Sahakari Dugdh Sangh 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 Bhopal Sahakari Dugdh Sangh is 55.05%. We enhance the working plate heat exchanger efficiency of Bhopal Sahakari Dugdh Sangh by placing different Turbulators (Twist tape turbulator, Brock turbulator and Wire turbulator). In inlet hot water pipe. We got the working efficiency of Plate Heat Exchanger in these Turbulators are 71.01%, 62.64% and 63.31. The experiments proposed for counter flow models of the fluids. After modification by Turbulators in Plate Heat exchanger set up we got that Twist Turbulators is better Turbulators than other turbulator.

Key words: Plate Heat Exchanger; Turbulator; Counter Flow; Temperature

I. Introduction

A plate heat exchanger, PHE, is a compact heat exchanger where thin corrugated plates (some 0.5 mm thick, bended 1 or 2 mm) are stacked in contact with each other, and the two fluids made to flow separately along adjacent channels in the corrugation. The closure of the staked plates may be by clamped gaskets, brazing (usually copper-brazed stainless steel), or welding (stainless steel, copper, titanium), the most common type being the first, for ease of inspection and cleaning. Additionally, a frame (end-plates and fixing rods) secures together the plate stack and connectors (sometimes PFHE, standing for plate-and-frame heat exchanger, is used instead of PHE). Plate assembly is sketched in below fig. Suitable channels, sometimes helped by the gaskets, control the flow of the two fluids, and allow parallel flow or cross flow, in any desired number of passes, one pass being most used. They have large conductance coefficients (up to K=6000 W/(m2·K) for liquid-to-liquid use), are ideally suited for low-viscosity fluids, the number of plates can be adjusted to the needs, and the transfer surface accessible to cleaning (the latter two advantages only for gasket assemblies; in any case, the gaskets should be changed if dismounted). The projected area of plates is usually taken as nominal heat transfer area, in spite of the real curved surfaces and lost space in gaskets and ports.

A turbulator is a swirl flow device that turns a laminar flow into a turbulent flow. Swirl flow devices causes swirl flow or secondary flow in the fluid .A variety of devices can be employed to cause this effect which includes tube inserts, altered tube flow arrangements, and duct geometry modifications. Dimples, ribs, helically twisted tubes are examples of duct geometry modifications. Tube inserts include twisted-tape inserts, helical strip or cored screw–type inserts and wire coils. Periodic tangential fluid injection is type of altered tube flow arrangement. Among the swirl flow devices, twisted- tape inserts had been very popular owing to their better thermal hydraulic performance in single phase, boiling and condensation forced convection, as well as design and application issues. Which is shown in below fig.

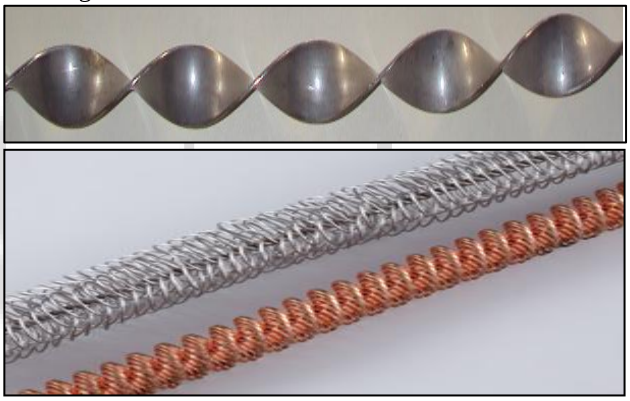

Fig. 1: Turbulators (Twist Tape & Wire)

II. Literature review

Tabish Alam et al [1] The objective of this paper 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.

Chirag Maradiya, Jeetendra Vadher et al [2] Heat transfer devices 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, twist ratio, twist direction, etc. affect the heat transfer. For example counter double twisted tape insert has TPF of more than 2 and combined twisted tape insert with wire coil can give a better performance in both laminar and turbulent flow compared to twisted tape and wire coil alone. 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.

Zhe Wang, Zan Wu et al [3] As a novel coolant, 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.

Atul Bhattad et al [4] In the present study, numerical as well as experimental investigations have been done on the plate heat exchanger using hybrid nanofluid (Al2O3 +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.

M.Thirumarimurugan et al [5] A plate type heat exchanger 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.

Abhishek Nandan et al [6] Plate heat exchanger 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.

M. Faizal et al [7] Experimental studies 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 parallelly, 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 flowrates 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 Formulation

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 & 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 twist tape turbulator to increase the working efficiency of plate heat exchanger by increasing the temperature of hot water. The hot water temperature increased by twist Turbulators installed in tubular pipe before entering the hot water in plate heat exchanger. Experimental setup is shown in fig.1.2.

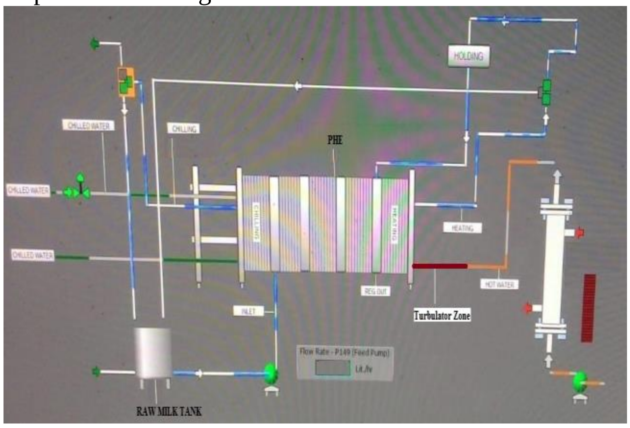

Fig. 1: Line Diagram of Plate Heat Exchanger used in BSDS

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 twist turbulator of different pitches are enclosed inside the hot water inlet pipe one by one to identify the variation of temperature of pasteurization milk. The turbulator enclosed in 50cm of hot water tube shown in fig.1.2, and clearly turbulator zone are explain by line diagram with thermocouples shown in fig.1.3. 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.

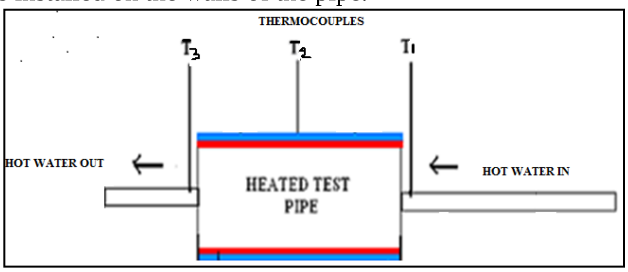

Fig.2 Thermocouples Set Up in Hot Water Pipe

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 turbulators are enclosed in the inlet pipe at the time of experiment performed. The temperature of hot water is increased by enclosing turbulators 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 types of turbulators one by one and take the temperature reading of hot water and milk inlet and outlet temperature on digital temperature apparatus regarding respective turbulators. 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

$\dot{M} = \rho\,A\,V$

$\rho = 962.924\ kg/m^3$

4) Heat transfer from hot water to milk

$q = \dot{M}\,C_p\,(T_{mo} - T_{mi})$

$C_p = 4.194$ 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:

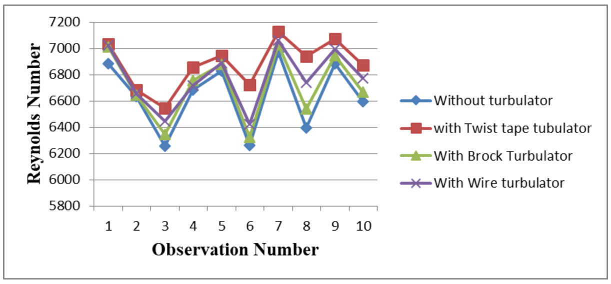

Fig. 3: Reynolds Number (Re) Vs Observations

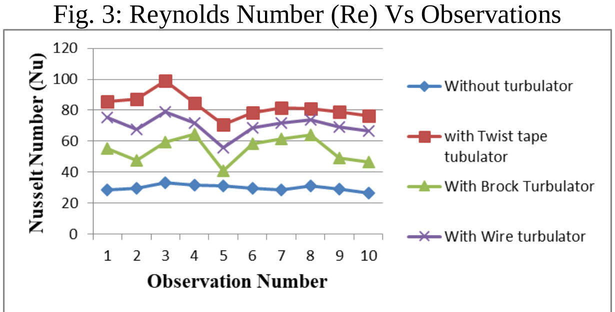

Fig. 4: Nusselt Number (Nu) Vs Observation Number

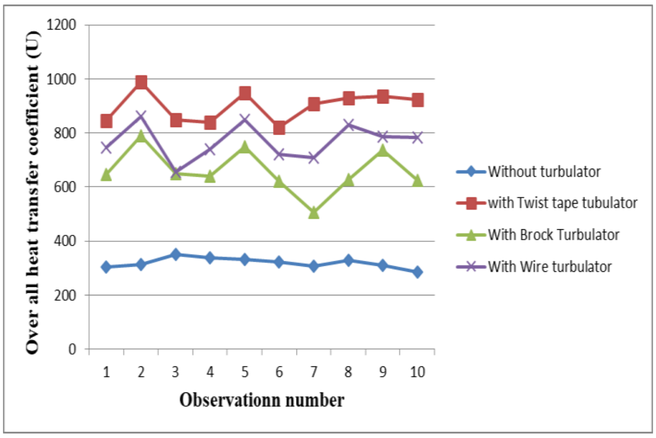

Fig. 5: Overall Heat Transfer Coefficient (U) Vs Observations Number

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 achieved that pasteurize milk temperature become above 78°C nine times out of respective ten observations. This is done when we used Twist tape turbulator of pitch 1cm. We got 71.01% working efficiency of Plate Heat Exchanger by modification which is more than without modification of Plate Heat Exchanger. By the help of this experiment approx 16% working efficiency of Plate Heat Exchanger is increased. And we also checked these all values by other turbulators (Twist tape, Brock and Wire) and we fond that the twist tape turbulator is better one We did not consider those values of outlet milk temperature which is below 78°C. It is because the pasteurize milk temperature is set at 78°C for its chemical process.

REFERENCES

[1] Tabish Alam, Man-Hoe Kim. "A comprehensive review on single phase heat transfer enhancement techniques in heat exchanger applications". Renewable and Sustainable Energy Reviews 81 (2018) 813–839.

[2] Chirag Maradiya, Jeetendra Vadher, Ramesh Agarwal. "The heat transfer enhancement techniques and their Thermal Performance Factor". Beni-Suef Univ. J. Basic Appl. Sci. xxx (2017) xxx–xxx.

[3] Zhe Wang, Zan Wu et al. "Experimental comparative evaluation of a graphene nanofluid coolant in miniature plate heat exchanger." International Journal of Thermal Sciences 130 (2018) 148–156.

[4] Atul Bhattad et al. "Discrete phase numerical model and experimental study of hybrid nanofluid heat transfer and pressure drop in plate heat exchanger." International Communications in Heat and Mass Transfer 91 (2018) 262–273.

[5] M.Thirumarimurugan et al. "Simulation Studies on Plate Type Heat Exchanger using ANN." International Journal of Chem. Tech Research CODEN (USA): IJCRGG ISSN: 0974-4290 Vol.1, No.2, pp 349-354, April-June 2009.

[6] Abhishek Nandan et al. "A Review on Heat Transfer Improvent of Plate Heat Exchanger." Int. Journal of

Engineering Research and Applications ISSN: 2248-9622, Vol. 5, Issue 3, (Part -3) March 2015, pp.21-26.
[7] M. Faizal et al. "Experimental studies on a corrugated plate heat exchanger for small temperature difference applications." Experimental Thermal and Fluid Science 36 (2012) 242–248.
[8] Dnyaneshwar B.Sapkal et al. "Computer Aided Design CFD Analysis of Heat Exchanger." International Journal of Innovative and Emerging Research in Engineering Volume 2, Special Issue 1 MEPCON 2015.
[9] Oana Giurgiu et al. "Plate heat exchangers - flow analysis through mini channels." Energy Procedia 85 (2016) 244 – 251.
[10] Koen Grijspeerdt et al. "Application of computational fluid dynamics to model the hydrodynamics of plate heat exchangers for milk processing." Journal of Food Engineering 57 (2003) 237–242.
[11] Chandan Kumar Sethi. "CFD Analysis on Effectiveness of a Plate Type Heat Exchanger Using Sea Water and Engine Oil." International Journal of Advanced Mechanical Engineering. ISSN 0973-6085 Volume 12, Number 1 (2017) pp. 191-198.
[12] T.S. Khan et al. "Experimental investigation of single phase convective heat transfer coefficient in a corrugated plate heat exchanger for multiple plate configurations." Applied Thermal Engineering30 (2010) 1058-1065.
[13] Vikas Kumar et al. "Effect of variable spacing on performance of plate heat exchanger using nano fluids." Energy 114 (2016) 1107e1119.
[14] Wei Lu et al. "Analytical solutions of force convective heat transfer in plate heat exchangers partially filled with metal foams." International Journal of Heat and Mass Transfer 110 (2017) 476–481.
[15] M. Rossato et al. "Heat transfer and pressure drop during condensation of low-GWP refrigerants inside bar and-plate heat exchangers." International Journal of Heat and Mass Transfer 114 (2017) 363–379.
[16] Kifah Sarraf et al. "Complex 3D-flow analysis and corrugation angle effect in plate heat exchangers." International Journal of Thermal Sciences 94 (2015) 126e138.
[17] Caner Turk et al. "Experimental analysis of a mixed-plate gasketed plate heat exchanger and artificial neural net estimations of the performance as an alternative to classical correlations." International Journal of Thermal Sciences 109 (2016) 263e269.
[18] Jan Waj et al. "Influence of metallic porous micro layer on pressure drop and heat transfer of stainless steel plate heat exchanger." Applied Thermal Engineering (2015), doi:010.1016/j.applthermaleng.2015.08.101.
[19] Ya-Nan Wang et al. "A Study on 3D Numerical Model for Plate Heat Exchanger." Procedia Engineering 174 (2017) 188 – 194.
[20] Tang Xinyi et al. "Experimental and Numerical Study on Heat Transfer Enhancement of a Rectangular Channel with Discontinuous Crossed Ribs and Grooves." fluid dynamics and transport phenomena Chinese Journal of Chemical Engineering, 20(2) 220— 230 (2012)
[21] Xiao-Hong Han et al. "A numerical and experimental study of chevron, corrugated-plate heat exchangers." International Communications in Heat and Mass Transfer 37 (2010) 1008–1014.