Advances in Design and Development of Heat Exchangers: A Review

Ankush S. Patil[1], H. S. Farkade[2]

[1] *P.G. Student, Dept. of Mechanical Engineering, Govt. College of Engineering, Amravati, Maharashtra, India.*
[2] *Assistant Professor, Dept. of Mechanical Engineering, Govt. College of Engineering, Amravati, Maharashtra, India.*

---***---

Abstract - *Heat exchangers are the devices or equipment which are used to transfer heat from one medium to another medium without mixing them. The objective may be either to remove heat from a fluid or to add heat to a fluid. In great extent the research is going on for further enhancing the heat transfer through heat exchangers. In the present paper, research done by various researchers to increase the effectiveness of heat exchanger has been discussed. Through detailed analysis it has been observed that corrugated plate heat exchanger have maximum rate of heat transfer.*

Key Words: Corrugated plate heat exchanger, CFD, Parallel flow, Counter flow, LMTD, Heat transfer Effectiveness.

1.INTRODUCTION

Devices which are used to transfer heat between two same or different fluids without mixing them are called heat exchangers. The Heat gets transferred from hot fluid to the cold fluid by convection. For achieving high efficiency, the rate of heat transfer between the fluid and metal should be maximum. The one way to enhance it is by increasing the surface area of heat exchanger. Heat exchangers are majorly classified as Recuperators and Regenerators. Recuperators are also called as surface generators. Recuperators are another important type of heat exchanger which extract and delivers heat on the either sides of partition wall (Generally in the form of Tubes and Pipes). Automobile or car Radiator, Oil cooler, condenser, superheaters, economiser are the examples of Recuperators. Regenerators are further sub-divided into direct and indirect contact type heat exchangers. Indirect contact type of heat exchanger are further classified into tubular, extended surface and plate type of heat exchanger. Among all, plate type heat exchangers are mostly used in industries such as automobile industries, dairy, chemical industries, power processing industries, pharmatical industries. The plate heat exchanger may be plane or may have some distortions in it. Creating uniform rising and falling in waves is very normal. and it is known as corrugated plate heat exchanger. Corrugated plate heat exchanger is of sinusoidal shape which contains crest and trough due to which rate of heat exchanger increases. The overall performance, effectiveness and the rate of heat transfer of corrugated plate heat exchanger is much higher as compared to the plane plate heat exchanger.

2. LITERATURE REVIEW

Corrugated plate heat exchangers are used to transfer heat but its manufacturing is very typical as compared to the plate heat exchangers. Corrugate plates contain sinusoidal shape plates which contain crest and trough which are typical to manufacture. Any fault in design will reduce the rate of heat transfer. With advances in numerical techniques and computation power, Computational Fluid Dynamics (CFD) can be used to predict the performance of machines in design phase only without manufacturing them. Many commercial software's are available in the market. By using CFD, information about the output temperature, velocity, pressure and other non-dimensional parameters can be obtained. CFD is not only useful to predict the performance but it also helpful to determine the effect of change in any design parameter on its output. In Computational Fluid Dynamics, geometry of machine is created and meshing is done for domain. Meshing helps in the discretization of the domain into small elements. Governing equations are applied on these discrete elements to find numerical solutions regarding pressure distribution, temperature gradients etc.

2.1Experimental Studies on Corrugated Plate Heat Exchanger

Mohammed and Abed numerically studied laminar forced convection heat transfer and fluid flow characteristic in a corrugated channel. Temperature of the channel walls was maintained constant which was higher than fluid temperature. Effect of wavy angle and Reynolds number were studied on fluid flow and heat transfer. The range of the Reynold`s number was carried out for the solution was found out to be 500 to 2500, wavy angles range was from 0° to 60° and Prandtl number was 0.7. It was found that the optimum values of the heat transfer enhancement and pressure drop were 3.6 and 1.11 times higher than those from the plane channel at wavy angle $\lambda = 40°$, respectively [1].

Marjan et.al has made an experimental study over corrugated plate heat exchanger by using multi-walled carbon nanotubes (MWCNT). To investigate friction loss, heat transfer coefficient by convection, Nusselt number, pumping power and pressure drop in a counter flow corrugated plate heat exchanger different water-based nano-fluids such as Gum Arabic-treated multi-walled carbon nanotubes (MWCNT-GA), functionalized MWCNT with cysteine (FMWCNT-Cys) and silver (FMWCNT-Ag) were employed as coolants. From the experimentation it was found that by increasing Pecelet number, Reynolds number, or fraction of nonmaterial improve marks in the characteristics heat transfer of the nanofluid increased. In all investigated cases, it has been found that power consumption and heat transfer rate is less for water compared to nanofluids. Besides that it has been also found that for a specific pumping power, heat removal in nanofluids is higher as compared to water. Therefore, performance of the heat exchanger can be enhanced by choosing MWCNT water as the working fluid [2].

Khan and Kumar described performance and exergy of corrugated plate heat exchanger in parallel or in counter flow. Plate had sinusoidal wavy surface with corrugation angle of 45°C. Heat exchanger contained 3 Channels. Hot fluid flow at the middle channel which was cooled by water through outer channels. Hot water temperature was in the range of 40°C to 60°C. Reynolds number was in the range of 900< Re > 1300 for hot and cold fluid. After performing experiment performance or effectiveness of corrugated plate heat exchanger for counter flow was found out to be 44.5% more as compared to parallel flow arrangement. As well as exergy loss in counter flow is 7.2% less as compared to parallel flow [3].

Rao et.al in their investigation used corrugated plate heat exchanger with corrugation angle 30°, 40°, 50°. Water was taken as heating medium while Glycerol was taken as test fluid. The inlet and outlet temperature of hot fluid and test fluid was measured by means of four thermocouples. From the experimental investigation it was found that 50° corrugation angle heat transfer increased. It is also found that 60% Glycerol had high rate of heat transfer as compared to the 50%, 60% and water. Hence in investigation it has been found that with the increase of corrugation angle as well as with the increase of viscosity of fluid heat transfer rate increases [4].

Rao et.al has done an experimental study in three different types of corrugated plate heat exchangers and their length is 30 cm whereas width is 10 cm. Three different corrugation angles were used in this study which were 30°, 40° and 50°. Water was taken as heating fluid. The temperature of the wall was measured along the length of heat exchanger at seven different locations by thermocouples. The outlet and inlet temperatures of test fluid and hot fluid were measured by means of four more thermocouples. In this study effect of corrugation angle on heat transfer rates has been discussed. After completion of the experiment, heat transfer coefficient at different corrugation angle heat exchanger is compared to each other and it has been observed that the heat transfer coefficient of 50° corrugation angle heat exchanger is higher as compared to 30° and 40° corrugation angle heat exchanger. At higher corrugation angle, high turbulence is created due to which heat transfer rate becomes higher [5].

Kumar et.al has made an attempt to investigate the performance and effectiveness of corrugated plate heat exchanger. Experiment was conducted on three channels 1-1 passes of corrugated plate heat exchanger. Hot fluid was made to flow at the middle channel while the cold fluid flow at top and bottom channel in counter and in parallel flow. Plate had a sinusoidal shape at an angle of 30° corrugation angle. Temperature of hot fluid was in the range of 50°C to 70°C whereas temperature of the cold fluid was in the range if 30°C to 40°C inlet. It was found that the effectiveness of counter flow heat exchanger is 48% higher than the parallel flow. As well as exergy loss was also calculated and found 33% less in counter flow arrangement as compared to the parallel flow arrangement [6].

Rao et.al made experimental studies on a sinusoidal corrugated plate heat exchanger where water was taken as test fluid. Two stainless steel sheets of thickness of 1 mm were used to fabricate plate heat exchanger for performing test channels. It had clearance of 5 mm and length 30 cm. Total 3 heat exchangers were fabricated by using these plates with corrugation angles of 30°, 40° and 50°. From the experiment it has been found that corrugation angle affected the heat transfer rate and pressure drop. During experiment it was found that pressure drop of fluid increases as the corrugation angle of plate increases due to which friction factor decreases. Turbulence is generated in the channel due to increase in pressure drop. From the result it has been found that as the angle of corrugation increases, pressure drop of fluid increases due to which rate of turbulence increased which lead to increase the rate of heat transfer [7].

Kumar et.al has made an experimental investigation of plate heat exchanger for predicting the exergetic performance and heat transfer characteristics of corrugated plate. Effect of various operating parameters on pressure drop, exergetic performance, friction factor, exergy loss, effectiveness, and dimension less exergy loss are discussed. Results show that with the increase in Number of Transfer Units (NTU) effectiveness of Plate heat exchanger increases. The exergy loss of corrugated type PHE increases with increasing of Reynold's number of cold and hot fluid side, by increasing the inlet temperature of hot water and by decreasing the inlet temperature of cold water. Study shows that the dimensionless exergy loss increased with the increase of friction factor and Number of Transfer Units (NTU) [8].

Jixiang et.al has investigated about heat transfer and flow characteristics on corrugated plate heat exchanger by shifting upper and lower plate and varying Reynold's number $2000 \leq Re \leq 10000$. Hydraulic performance of corrugated plate heat exchanger changed due to the effect of phase shift and Reynold's number which was numerically investigated. Based on the numerical results relation between heat transfer coefficient, Nusselt Number Nu and flow friction factor f are established. By using streamlines, flow characteristics were visualized. By increasing the phase shift, Nusselt Number and friction factor decreases. By increasing Reynold's number and friction factor of goodness factor G decreases. While Nusselt is opposite change trend. The distribution of streamlines is closely related to the performance of thermal hydraulic. When the streamline distorts is more the resistance loss is greater and the heat transfer rate is high. These channels of phase shift from 0° to 90° had better overall performance, and the 0° channel had the optimal performance in lower Reynolds number region [9].

2.2 CFD Analysis of heat exchanger

Zena et.al has carried out an investigation over cross flow heat exchanger using CFD. Aim of this study was to determine the heat transfer coefficient of fin and without finned tube heat exchange. Heat exchanger contained one tube coil of copper with eight passes. Air was used as a fluid to flow over the tube whereas water was used as a fluid flow in tube. From CFD study it has been observed that the heat transfer coefficient of finned tube heat exchanger was more as compared to the without finned tube heat exchanger [10].

Dnyaneshwar et.al focused on the modeling a copper plate heat exchanger for milk pasteurization in a food industry using high temperature for a short time. This paper presents analytical and CFD analysis of pressure drop of counter flow for milk and water over copper and steel plate type heat exchanger for determining the energy required for circulating fluid. Knowing all operations parameters problem was first solved theoretically by LMTD. After that comparison between CFD and analytical result it was done. It was found that energy required for the circulation of water & milk is very low in copper plate type of heat exchanger as compared to the steel plate type of heat exchanger [11].

Giurgiua et.al numerically studied two different models on plate heat exchanger. Geometry of plate influence rate of heat transfer. One plate heat exchanger contains mini channels at 30° while other plate heat exchanger contain mini channels at 60°. In result from CFD and numerical analysis it has been found that plate heat exchanger with 60° mini channels give high rate of heat transfer as compared to 30° mini channel heat exchanger [12].

Kumar et.al investigated the performance of baffle shell and tube heat exchanger by using CFD tool ANSYS. The work was carried out to determine the performance of heat exchanger by changing the inclination of baffles in shell and tube heat exchanger. Three different baffles inclination angles namely 0°, 45° and -45° were used in CFD modeling to find the impact of baffle inclination angle on the characteristics of heat transfer and also on fluid flow. As the result of CFD comes out it had been observed that the steady state heat flux comes out to be more in the case of +45 degree baffles case than -45 degrees baffles case. The heat flux comes of 0 degree baffles come out intermediate between 45 and -45 degrees cases [13].

Ruoxu et.al investigated on counter flow parallel heat exchanger & simulated it numerically. A representative repeating unit cell of the multichannel heat exchanger was used as computational domain that included a cold channel and a hot channel separated by plates. COMSOL model was used for simulation for oil to water heat exchanger. Oil and water was used as a fluid. Oil was used at the temperature of 330 K with an inlet velocity 0.04 m/sec and water is used at 300 K with the velocity of 0.05 m/sec. To calculate each channels Reynold's number the properties of water at 25°C and those of oil at 40°C (Such as specific heat, viscosity, thermal conductivity, density) were defined. In the channels Reynold's number was found to be 224 and 6.44 for the respective cold and hot channels. As a result of it hot oil entered the hot channel with an average inlet temperature of 330 K and exits from the channel at an average output temperature of 323.7 K. Cold water entered the cold channel at 300 K as an average inlet temperature and comes out at 310 K from the channel as an average outlet temperature. The calculated pressure drop in the cold channel was 0.0763 Pa and in the hot channels was 68.0 Pa respectively whereas corresponding average temperature drops in the cold and hot channels were 10.5 K and 6.3 K. the inlet velocity of oil decreased to 0.02 m/s and the water inlet velocity is increased to 0.05 m/s in order to increase temperature and decrease pressure in the hot channel without significantly increase pressure in the cold channel [14].

Melvinraj et.al has investigated on a parallel flow heat exchanger corresponding ribbed tube heat exchanger has also been modeled and numerically analysed. For designing and analysis purpose Pro-e and ANSYS 14.5 has been used respectively. The effectiveness of two heat exchangers has been compared using CFD. The ribbed heat exchanger effectiveness is more than that of simple heat exchanger. Due to the shape of ribbed helical tube fluid flow is not parallel but in swirls, which increases turbulence and thereby increasing the effectiveness [15].

Kansal and Sahabat deals with the study of shell and tube heat exchanger by using KERN method and CFD simulation. Main aim of this work is to determine effectiveness of shell and tube heat exchanger. Methanol has been used as a hot fluid in shell side its inlet temperature is 368 K whereas water was used as fluid flow in tube at the inlet temperature of 298 K. From simulation it has been found that outlet temperature of methanol is 313 K and 315.53 K from KERN method and CFD respectively. Whereas outlet temperature of water is 313K and 308.43 K from KERN and CFD respectively. From KERN method the effectiveness of heat exchanger was found out to be 0.79 and from CFD it has been found to be 0.76. Both the results are in close agreement with each other [16].

Abdur and Jameel had developed baffle shell and tube heat exchanger. In this simulation the inclination angle of baffle plate used was at 0°C, 10°C, 20°C. By using the commercial software tool STAR CCM+ v6.06 the flow field and temperature has been found out. From CFD simulation results it was concluded that shell-and-tube heat exchanger inclined at 20° baffle has better performance as compared to 10°C and 0°C inclination angle. The maximum baffle inclination angle can be 20°, if the angle is increased beyond 20°, the center row of tubes are not supported [17].

Gupta and Nagraj carried out CFD simulation to determine the performance of shell and finned tube heat exchanger by using the waste heat recovery application. The performance of heat exchanger is determined by using ANSYS 13.0. In this paper an attempt has been made to predict the performance of heat exchanger by using different fluid and then result has been compared to each other. In this study effectiveness, rate of heat transfer, energy extraction rate have been determined. In this study the geometric modeling of the shell and tube heat exchanger is done by using ANSYS. And by using the ANSYS meshing. Meshing has been carried out. Exhaust gases has been used in shell side at temperature of 1200C which were coming from the exhaust of 15Hp gas turbine. Flowing fluid in tubes is taken as water or castor oil (whose boiling temperature is 3130C) shell side velocity has been kept constant and tube side velocity has been varied. As investigation of shell and fin tube heat exchanger is carried out in ANSYS 13.0. It has been observed that the temperature variation of castor oil is better as compared to water. And this happened because of the thermal properties of castor oil. The effectiveness of fin heat exchanger with castor oil is more as compared conventional heat exchanger. And rate of extraction energy also quite suitable which means sufficient amount of waste energy is recovered [18].

2.3 CFD with validation

Gaidhane and Bhosale has made an attempt to increase the rate of heat transfer in cross flow heat exchanger (automobile radiator) by using nano-fluid with base. From many years conventional coolants base fluids (water, ethylene glycol and glycerol) have been used in cross flow heat exchanger (automobile radiator); however, these offered low thermal conductivity. In this study a new type of heat transfer fluid called Nano-fluids has been described. It increases the rate of heat transfer due to the reason of high liquid thermal conductivity, liquid viscosity, and heat transfer coefficient. Proposed work concentrates on developing experimental system to investigate the enhancement of heat transfer in a cross flow heat exchanger by using hybrid nano-fluid as a coolant and its CFD analysis has also been done. From CFD and experimental analysis it has been observed that addition of nanoparticles to a base fluid increases the viscosity significantly and the thermal conductivity moderately. By increasing nano-fluid inlet temperature the overall heat transfer coefficient decreases. But by increasing the volumetric flow rate of nano-fluid significantly rate of heat transfer coefficient increases [19].

Yasuyuki et.al has studied over the heat exchanger which can use temperature difference of source and sink of ocean thermal energy system (OTEC). Plate heat exchanger in OTEC has poor efficiency. In order to determine heat exchanger which can provide more efficiency by using OTEC, herringbone heat exchangers were used for experimentation and numerically they are also simulate same. In the result it was found that heat transfer rate of herringbone heat exchanger was better as compared to plate heat exchanger [20].

Thawkar and Farkade has been carried out experimental and CFD investigation at twisted elliptical heat exchangers to find the effect on overall heat transfer of coefficient. The purpose of this study is to determine the feasibility of tubes which are twisted elliptically used in applications such as automobile radiators, air conditioners or similar type of multipass applications. The main aim of this experimentation is to determine the friction factor and overall heat transfer coefficient in arrangement of multi-pass twisted elliptical tubes, with water as a working fluid. The computational model was validated with the experimental model. Major diameter and minor diameter of twisted elliptical tubes were 18 mm and 12 mm respectively which were used in twisted elliptical tubes with 60 mm twist pitch. Pure copper was used as material. In turbulent zone Reynolds numbers were varied ranging from 50000 to 350000. Different flow rates of water 0.055 kg/s, 0.147 kg/s, 0.095 kg/s, 0.2 kg/s were obtained from experimental data. From the experimental study and CFD result on twisted elliptical tube was clear that temperature difference decreases with the increase in mass flow rate as well as overall heat transfer coefficient increases with the increase of Reynolds number and pressure drop increases with the increase of Reynold`s number [21].

Azaria et.al has made an attempt experimentally and numerically investigated laminar convective heat transfer coefficient by using nanofluid water name Al_2O_3 in circular tube at constant and uniform heat flux on the wall. Three different models, constant physical properties single-phase (CP-SP) model, a variable physical properties single-phase (VP-SP) model and two phase discrete particle model were used. From experimental and simulation results it has been found that the thermal performance of nano-fluids is higher than that of the base fluid. The heat transfer enhancement increases with the increase of Reynold`s number and volume concentration of particles. Beside it, higher heat transfer coefficients were detected in the case of 2 phase model and in VP-SP model. In the result it has been found that the two-phase model experimental data matches with prediction data significantly and with this predicted data model can be built with confidence [22].

Kapse and Arakerimath have investigated heat transfer coefficient in rectangular plates using various shapes such as bare plate, tubular and spherical wing using different material such as Copper, Brass and Mild Steel plates and to simulate result by using computational fluid dynamics. Mathematical modeling of the results has also been found. From Analysis it is observed that heat transfer coefficient of bare copper plate is found to be greater than other samples and Reynolds number of Tubular M.S Plate while Nusselt number of Spherical M.S plate is found higher [23].

Mohamed investigated heat transfer performance and flow development on V-corrugated channels. In this investigation he kept wall heat flux equal to 290 W/m2, air was used as working fluid, phase shifts change by channel heights (S = 12.5, 15.0, 17.5 and 20 mm). From the simulation result it has been observed that the thermal performance of wider channels was good as compared to narrow channels. The pressure drop decrease and heat transfer rate increase in V-corrugated channels as the phase shift and channels height increase. In the result it has been also found that rotational flow and turbulence augmentation produces as drag forces exerted on the flow field [24].

Nagrani et.al presented experimentally the total heat transfer rate by Elliptical Annular Fin (EAF) and Circular Annular Fin validated by CFD and experimental analysis as well as optimization of EAF was done using Genetic Algorithm (GA). Experimentally in the result it has been found that the temperature of annular fin surface goes on decreasing gradually along with the projected surface area in the direction of the major axis. The GA result has proved that EAF is more effective than circular fin for the same area of cross section when SF value is less than 0.5, irrespective of efficiency. The maximum fin effectiveness is obtained when the radius of the circular tube smaller, shape factor is low and the minor axis touches the circumference of the circular tube [25].

Hwang Seong Won et.al investigated rate of heat transfer of tubular type of heat exchangers by varying shape of fins from a plain fin to a slit and louver type. Experimental data of Delta winglet vortex generators shows that with the addition of fin tubes to heat exchanger reduces pressure loss at heat transfer capacity of nearly the same level. Delta winglet vortex generators efficiency varies with the variation of shape and size as well as with the location of implementation. In this paper Delta winglet vortex generator analyzed and its rate of heat transfer is determined in CFD tool. Form the investigation on CFD it has been found that the pressure loss of delta winglet vortex generators decreases with the addition of fins. As well as at high Reynold`s number or at high velocity the performance of heat transfer also increased [26].

3. CONCLUSIONS

A lot of research work has been done in the field of heat exchangers. Conventional methods are found to be very expensive and time consuming. CFD has emerged as boon for researchers. With the help of CFD, one can determine effectiveness, heat transfer rate detailed parameters easily. Among all types of heat exchangers corrugated heat exchangers are found to have highest rate of heat transfer.

REFERENCES

[1] Abed Waleed Mohammed, Ahmed Mohammed Abed, 2016 ," Numerical Study Of Laminar Forced Convection Heat Transfer And Fluid Flow Characteristics In A Corrugated Channel" , Journal Of Engineering And Development , Volume 14 ,Issue 3 ,PP 70-85.

[2] Goodarzi Marjan, Amiri Ahmad, Goodarzi Mohammad Shahab, Safaei Mohammad Reza, Karimipour Arash, Languri Ehsan Mohseni, Dahari Mahidzal, 2015 , "Investigation Of Heat Transfer And Pressure Drop Of A Counter Flow Corrugated Plate Heat Exchanger Using MWCNT Based Nanofluids" ,International Communication In Heat And Transfer,PP 172-179.

[3] Khan Mohd. Rehan, Kumar Ajeet, 2015 "An Experimental Study of Exergy In A Corrugated Plate Heat Exchanger'', International Journal Of Mechanical Engineering And Technology, Volume 6, Issue 11, PP–16-22.

[4] Rao b.Sreedhara, Mayuri M. Krishnakant, V Himanshu, 2015 "HeatTransfer Studies In Wavy Corrugated Plate Heat Exchanger'', International Journal Of Advanced Research In Engineering And Technology ,Volume 6 ,Issue 11 ,Pp 72-79.

[5] Rao B. Sreedhara, Svaron, Krishna MVS Murali, Sastry R C, 2014, "Experimental Studies On Pressure Drop In A Sinusoidal Plate Heat Exchanger: Effect Of Corrugation Angle "International Journal Of Research In Engineering And Technology, Volume 3, Issue 2, PP 121-126.

[6] Kumar Ashish, Rai Ajeet Kumar, Sachanvivek, 2014 "An Experimental Study Of Heat Exchanger In A Corrugated Plate Heat Exchanger'', International Journal Of Mechanical Engineering And Technology,Volume 5, Issue 9, PP.286-292.

[7] Rao B.Sreedhara, S Varun, G D Suryawanshi, Prof.Sastry.RC, 2014, " Experimental Heat Transfer Studies Of Water In Corrugated Plate Heat Exchanger And Effects Of Corrugation Angle'', International Journal Of Scientific Engineering And Technology, Volume 3 ,Issue 7 ,PP 902-905.

[8] Tiwari Arun Kumar, Ghoshpradyumna And Sarkarjahar, 2014 "Combined Energy And Exergy Analysis Of A Corrugated Plate Heat Exchanger And Experimental Investigation", International Journal Of Exergy, Volume 15, Issue 4, PP 395-411.

[9] Yin Jixiang, Yang Gang, Li Yang, 2012, "The Effect Of Wavy Plate Phase Shift Flow And Heat Transfer Characteristics In Corrugated Channels", International Conference On Advances In Energy Engineering ,PP-1566-1573

[10] Kadhim zena K. , Kassimmuna S. , Hussan Adel Y .Abdul , 2016, "CFD Study For Cross Flow Heat Exchanger With Integral Finned Tube" , International Journal Of Scientific And Research Publication,Volume 6 ,Issue 6 ,PP-668-677.

[11] Sapkal Dnyaneshwar B. , Deshmukhsamir J, Kolhekarrucha R. , 2015,"Computer Aided Design CFD Analysis Of Plate Heat Exchanger",International Journal Of Innovative And Emerging Research In Engineering , Volume 1 ,Issue 1 ,PP-88-92.

[12] Giurgiua Oana, Pleșaa Angela, Socaciualavinia , 2015 , " Plate Heat Exchangers - Flow Analysis Through Mini Channels" ,Energy And Environment , PP-244-251.

[13] Pandita Manoj Kumar , Prof Gupta Ashok Kumar, Lahadotiyakailash Kumar ,2015 , "CFD Analysis Of Single Shell And Single Tube Heat Exchanger And Determining The Effect Of Baffle Angle On Heat Transfer" ,International Journal Of Engineering Science And Research Technology, Volume 4 ,Issue 6 ,PP-445-450 .

[14] Jiaruoxu, Hu Junling, And Elbalsohiabubaker E.M , 2014, " Analysis OfnA Counter Flow Parallel-Plate Heat Exchanger" , ASEE Zone 1 Conference ,University Of Bridgeport ,Bridgeport ,CT ,USA.

[15] R Melvinraj C, C Vishal Varghese, Wilson Vicky, Thazhatha Thomas Jerry, Kakkasserymithunk,Simon J , 2014, "Comparative Study Of Heat Exchangers Using CFD , Int. Journal Of Engineering Research And Applications" Volume 4 ,Issue 5 ,PP-118-120.

[16] Kansal Santosh , Fatehmohd.Shabahat , 2014 , " Design And Performance Evaluation Of Shell And Tube Heat Exchanger Using CFD Simulation" , International Journal Of Research And Technology ,Volume 3 ,Issue 7 ,PP-1663-1666.

[17] Rahim Abdur , Jameels.M.Saad , 2012 ,Shell Side Cfd Analysis Of A Small Shell-And-Tube Heat Exchanger Considering The Effects Of Baffle Inclination On Fluid Flow , Proceedings Of The National Conference On Trends And Advances In Mechanical Engineering,YMCA University Of Science & Technology, Faridabad, Haryana, PP-167-173.

[18] G Priyanka ,Nagraj M. R. , 2012 , "CFD Analysis Of Shell And Tube Heat Exchanger With And Without Fins For Waste Heat Recovery Applications" , International Journal Of Science And Research (IJSR) .

[19] Mr. B Ganesh. Mhaske , Prof. Palande D. D. ,2015 ,"Experimental And CFD Analysis Of Tube In Tube Helical Coil Heat Exchanger" , International Journal Of Engineering Research & Technology ,Volumke4 ,Issue 8, PP-360-365.

[20] Thawkar Vivekp ,Farkadehemant S , 2015 "Experimental And CFD Analysis Of Twisted Tube Heat Exchanger Under Forced Convection" ,International Journal Of Science And Research ,Volume 4, Issue 5 ,PP137-142.

[21] Azaria., Kalbasi M. And Rahimim, 2014,"CFD And Experimental Investigation On The Heat Transfer Characteristics Of Alumina Nanofluids Under The Laminar Flow Regime", Brazilian Journal Of Chemical Engineering ,Volume 32 ,Issue 2 ,PP-469-481.

[22] Kapse snehal C. , Dr. Arakerimathr.R , 2014"CFD Analysis & Experimental Study On Heat Transfer Enhancement By Various Shapes Of Wings And Material With Forced Convection" ,International Journal Of Engineering And Computer Science ,Volume 3 ,Issue 9 ,PP 8242-8244..

[23] Sakr Mohamed, ,2014, "Convective Heat Transfer And Pressure Drop In V-Corrugated Channel With Different Phase Shifts", Volume 51 , Heat Mass Transfer Coventry University UK ,PP 129-141.

[24] Nagarani N. , Mayilsamy K. , And Murugesan A., 2013,"Experimental, Numerical Analysis And Optimization Of Elliptical Annular Fins Under Free Convection", International Journal Of Science And Technology, Volume 37, Issue2, PP 233-239.

[25] Hoettiba , R., Mohamed , A.M.I., Morad , K., Mikhael , 2009 " N.N ,Numerical Investigation Of The Effect Of The Corrugation Pitch And Height On The Fluid Flow And Heat Transfer Characteristics Inside Corrugated Ribbed Passage" ,Port Said Engineering Research Journal Faculty Of Engineering Suez Canal University , Volume 13 ,Issue 2 ,PP1-21.

[26] Johnson Jibin, V M Abdul Anzar, Shaniabith, P Harifrahiman, Hashmihameed T S, Nithin V S ,2015 , "CFD Analysis Of Double Pipe Heat Exchanger" , International Journal Of Science, Engineering And Technology Research , Volume 4 ,Issue 5 ,PP 1283-1286.

[27] Hwang Seong Won, Kim Dong Hwan, Min June Keeand Jeongji Hwan ,2012"CFD Analysis Of Fin Tube Heat Exchanger With A Pair Of Delta Winglet Vortex Generators" ,Journal Of Mechanical Science And Technology ,Volume 26, Issue 9 ,PP-2949-2958.