International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 04 | April -2020 ISSN: 2582-3930

Investigation of the thermal performance of Inline and staggered Plate Fin Tube Heat exchangers using ANSYS Fluent models

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Abstract –Plate fin and tube heat exchangers (PFTHEs)are widely used in heating, ventilation and air conditioning systems. The paper presents the comparison of two Plate fin heat exchangers models using Ansys Fluent 19.0 and studies their performance characteristics. In this paper, the model of Inline tubes PFTHEs is compared with the staggered tube PFTHEs for the same fluid velocities and boundary conditions. Water is flowing through each tube and air is flowing through the fin passage in both the case. The result shows that the rate of heat transfer is found to increase from 16.94 W for inline PFTHEs to 27.94 W for staggered PFTHEs. The Fin efficiency is also found to increase from 44.1 % for the inline PFTHEs to 59.3 % for the staggered PFTHEs.

***Key Words*:**InlinePlate fin and tube heat exchangers, staggered Plate fin and tube heat exchangers, Ansys Fluent models, Fin efficiency.

1.INTRODUCTION

Plate fin and tube heat exchangers (PFTHEs) are widely used in various heating, ventilation and air conditioning systems like air compressors, intercoolers, fans coil and air coolers. PFTHEs are the type of compact heat exchangers high thermal efficiency, light weight, compactness and good economic performance as compared to other heat exchangers. Therefore, it is necessary to optimise the design of these heat exchangers to improve their overall performance by improving their heat transfer rate.

In PFTHEs, the set of tubes are provided through which the liquid such as water, glycol solutions, oils etc. is flowing along the tube axis and the fluid such as air, exhaust gas, coolant etc. is flowing in perpendicular direction to the tube axis. DawidTaler[1] studied the transient model of double row, two pass PFTHE considering different heat transfer co-efficient in first row and second row of the tubes. The heat transfer co-efficient is found to decrease from first row to other rows which provide us the idea of the heat transfer rate in PFHTE.SasaMarkovic[2] showed the co-relation to find the air side pressure drop in PFTHEs and is effect on heat transfer covering wide range on parameters. A.M. González[3] studied the effect of PFTHEs different materials on the heat transfer co-efficient, average nusselt number and their effect with increasing the air velocity for the inline PFTHEs arrangement. It was concluded that the aluminium fins gives the better performance with compared to other materials. WahibaYaïci[4]predicted the effect of inlet air flow distribution on the air side heat transfer and pressure drop and geometrical parameters of staggered PFTHEs were undertaken on heat exchangers with different longitudinal tube pitches, transversal tube pitches, and fin pitches. The 3D CFD simulations reveal that air flow distribution and the effects of geometrical parameters significantly impact the design and performance of PFTHEs.

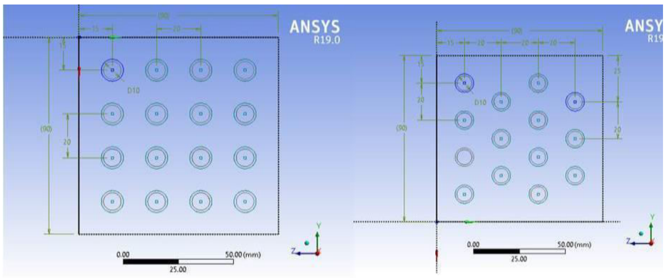
JieWen[5] designed and investigated the performance of a novel compact small tube diameter PFTHEs using log mean temperature difference method which can be used in aero-engines. An empirical relationfor outside heat transfer co-efficient is also developed. Jong Min Choi[6] investigated the heat transfer characteristics of variations of fin pitches, the number of tube rows, fin alignment, and vertical fin space. Two separate correlations for the j-factor were developed for the inline and the staggered fin alignment in the discrete plate finned-tube heat exchangers to predict the measured data within a relative deviation of 2.9%. Anna Korze[7] numerically modelled a single row and double row PFTHEs was developed using Finite Volume method and Finite Element method and experimentally validated. Based on thermal and hydraulic measurements of a double row car radiator the experimental correlations were determined to calculate the Nusselt number on the air- and water-side.

DawidTaler[8] proposed a modified method estimating the mean value of thermal contact resistance in PFTHEs using Computational CFD method and validated it experimentally. The method allows an accurate prediction of the total gas-side temperature difference in a heat exchanger. DawidTaler[9] developed a method of numerical modeling of PFTHE for a car radiator. The developed techniques were implemented in digital control system of the water exit temperature in a PFTHE. XiaoqinLiu[10] studied experimentally the air side heat transfer performance of the perforated PFTHE with large pitches under frosting conditions. It was found that the heat exchangers with the perforated fins generated less frost mass compared with the plain fin under the same heat transfer rate.AbdulkerimOkbaz[11] investigated experimentally the performance of PFHTE for the different tube row numbers, fin pitches and under operating conditions.Arvind Gupta [12] investigated numerically the implementation of punched winglet as a vortex generator for improving the thermodynamic performance of PFTHEs. There is a heat transfer augmentation of up to 34% for the considered range of Reynolds number in case of fin-tube heat exchanger employing punched rectangular winglet with hole having Common Flow Up configuration located in the upstream location, over the non-punched case of winglet with hole in the same configuration and location.

Idewa M.C. Santosa[13] investigated the overall heat transfer co-efficient for the finned tube CO_2 gas coolers using CFD modelling. He concluded that the performance of the gas cooler can be improved up to 20 % through optimization of the gas cooler circuit design.Xinyu Zhang [14] developed the 3D CFD model on finned tube CO2 gas coolers to find the effect of uniform and mal-distribution inlet air flow on the coil performance. The simulation results reveal that different types ofinlet airflow velocity profiles have significant effects on the gas cooler performance.HosseinJavadi[15] investigated the thermal performance of different helical U-tube ground heat exchangers using CFD models. It was found that a single Utubeheat exchanger has the worst thermal performance and the minimum pressure drop in comparison with allhelical ground heat exchangers.M.V.V. Mortean[16] analysed the heat transfer and pressure drop of a diffusion bonded stainless steel cross flow heat exchanger. The hydrodynamic results showed the headers were responsible for at least 50 % of the heat exchanger pressure drop.

2. MODEL AND SIMULATION METHOD

The present study shows the simulation of the two arrangements of cross flow PFTHEs using AnsysFluent 19.0 software. In the first arrangement, all the tubes are arranged in the in-line arrangement one after the other while in second arrangement the tubes are arranged in staggered arrangement. The detail dimensions of both the arrangements of PFTHEs, the spacing between the tubes, their locations are shown detail in figure 1below.



Case 1 Inline arrangement of the PFTHE   Case 2 Staggered arrangement of the PFTHE

Fig -1: Arrangement of Tubes in PFTHEs

The plate fins and all the tubes are made up of the aluminium in both heat exchangers arrangement. The water is flowing inside the tubes while air is flowing over the tubes through the fin plates. There are four square fins plates connected over this tube of size 90 mm x 90 mm respectively as shown in Fig. 2.

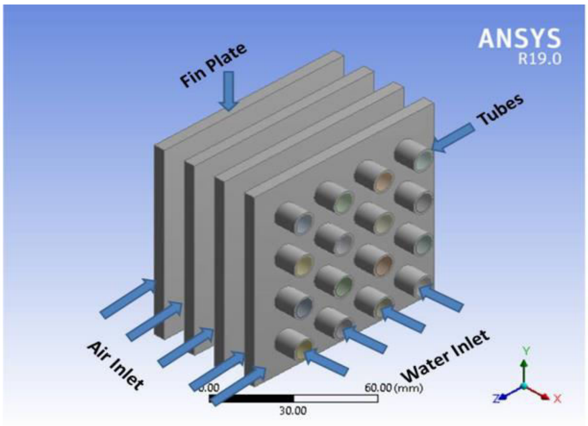


Fig -2: Model of the Inline PFTHE arrangement

The meshing of the model plays a very important role in determining the accurate solutions. The quality of the mesh in any simulation has a great impact on the results obtained and need to be done very precisely. The Fig. 3 shows the meshing of the staggered PFTHEs model used.

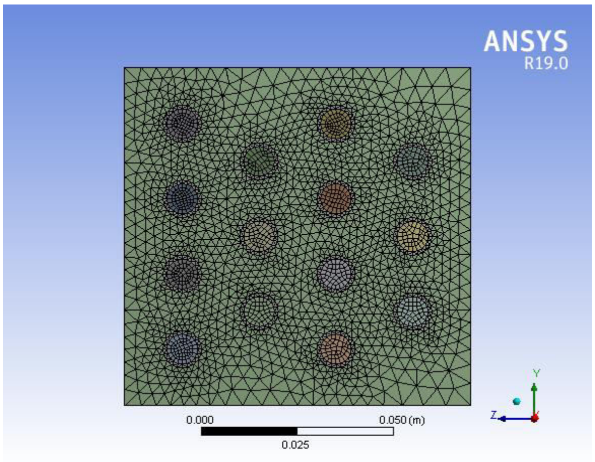
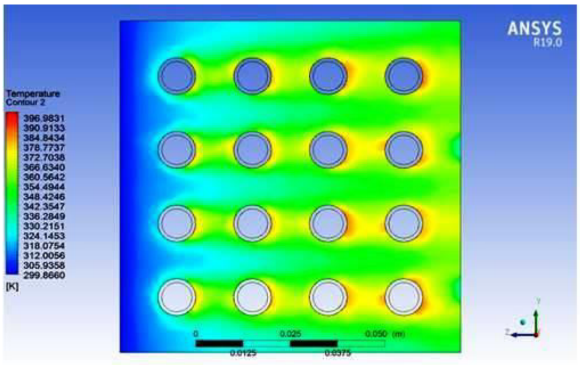


Fig -3: Meshing of the Staggered PFTHE model

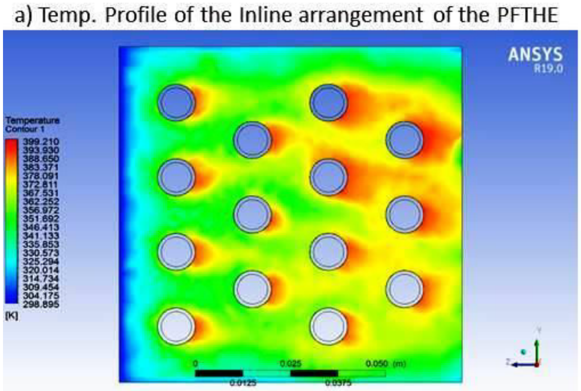
Both the PFTHEs models are simulated under similar conditions for the air velocity of 0.5 m/s and water velocity of 0.2 m/s in the cross flow arrangement. The k-Ɛ model is selected for the fluid modeling.

3. RESULT AND DISCUSSIONS

The air is flowing over the tubes and fin plates at 300 K while the water enters the tube at 400 K at inlet. During the flow, the heat is transferred from water to air through the heat exchanger. There is an enhancement in the heat transfer from the heat exchanger in the staggered PFTHE as compared to the inline PFTHE which can be seen in the air temperature distribution as shown in Fig. 4 below.



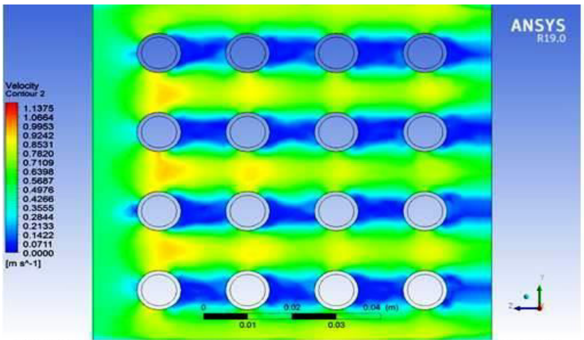
a) Temp. Profile of the Inline arrangement of the PFTHE



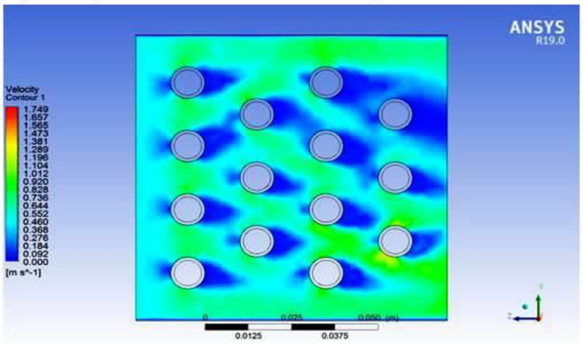
b) Temp. Profile of the staggered arrangement of the PFTHE

Fig -4: Temp. Profile of both the PFTHEs arrangement

The rate of convective heat transfer from the plate fin surface depends on the Reynolds number and the velocity of flow of air through the fin surface. It can be seen from the Fig.5 that the turbulence of the air is increased considerably which enhance the rate of heat transfer by proper mixing of the fluid.



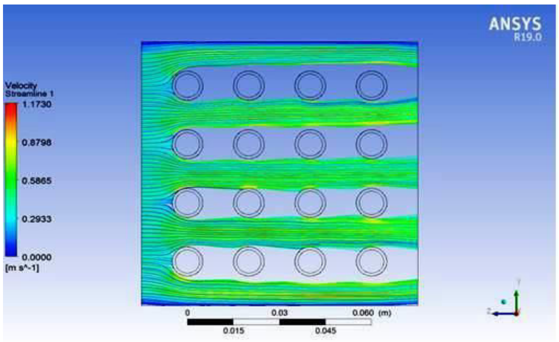
a) Velocity Distribution of the Inline arrangement of the PFTHE



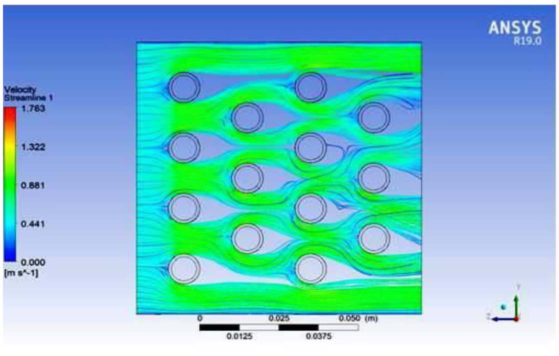
b) Velocity Distribution of the staggered arrangement of the PFTHE

Fig -5: Velocity Distribution of both the PFTHEs model

The Fig. 6 shows the Streamlines distribution for the air flow over both the heat exchanger arrangements which gives an indication of enhancement in air mixing in staggered PFTHE arrangement.



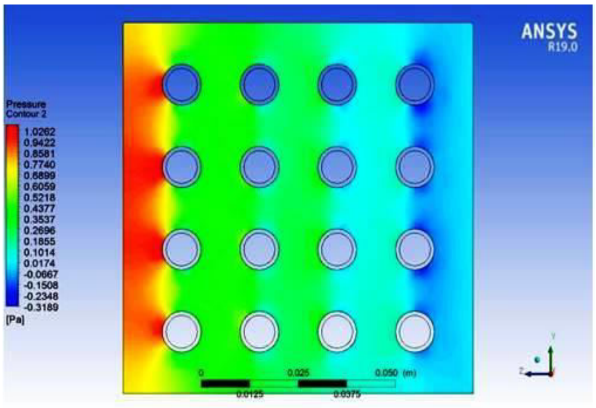
a) Streamlines of the air flow for the Inline arrangement of the PFTHE



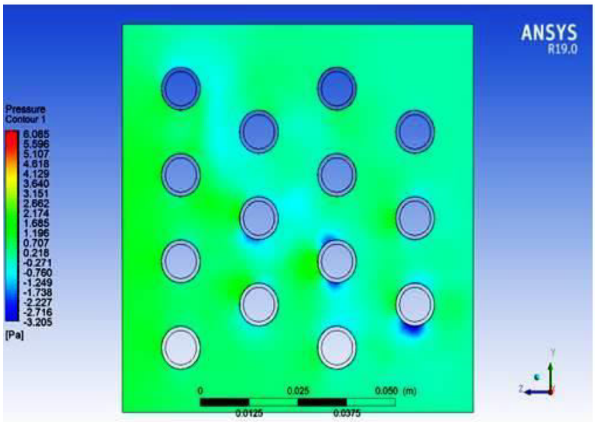
b) Streamlines of the air flow for the staggered arrangement of the PFTHE

Fig -6: Streamlines of air flow over both the PFTHE model

The Fig. 7 shows the pressure distribution across the air passagein both the heat exchangers which indicates the more pressure drop take place in case of inline PFTHE. The pressure across the staggered arrangement is almost uniform due to enhance mixing of the air during the flow.



a) Streamlines of the air flow for the Inline arrangement of the PFTHE



b) Streamlines of the air flow for the staggered arrangement of the PFTHE

Fig -7: Pressure Distribution of both the PFTHEs model

The Fig 8. shows the variation of outlet air temperature of both the inline and staggered PFTHEs over the air passages provided between the plate surfaces fin surfaces which shows the rise in outlet air temperature take place in case of staggered PFTHE as compared to inline PFTHE due to increase heat transfer. The average air temperature of outlet air for inline PFTHE is found to be 342^0K while for the staggered PFTHE is 349^0K.

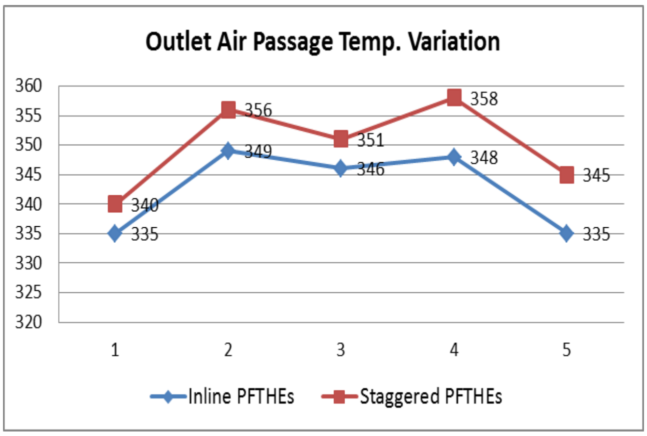


Fig -8: Variation of Outlet air Temperature across air flow passage

4. CONCLUSIONS

The CFD model of the inline PFTHEs and staggered PFTHEs are compared and stimulated using Ansys Fluent 19.0 software. It is found that the water side heat transfer co-efficient is found to increase from 35.51 W/m2K for Inline PHTFEs to 55.72 W/m2K for staggered PFTHEs. The air side heat transfer co-efficient is also found to increase from 11.94 W/m2K for inline PFTHE to 19.64 W/m2K for staggered PFTHEs. The rate of heat transfer from the fin surface is found to increase from 16.94 W for inline PFTHEs to 27.94 W for staggered PFTHEs. The Fin efficiency is also found to increase from 44.1 % for the inline PFTHEs to 59.3 % for the staggered PFTHEs. Thus, the overall performance of the staggered PFTHEs is found to increase considerably compared to inline PFTHEs case.

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BIOGRAPHIES

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