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Experimental Flow Field Analysis of Internal Spiral Grooving at Different Pitches on Air Cooled Heat Exchanger

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Abstract

This paper deals with heat transfer and flow field analysis of trapezoidal fins of air-cooled heat exchanger (ACHE). The performance parameters such as heat transfer rate, Reynold's number, Nusselt number, pressure drop and heat exchanger effectiveness for five types of setup were investigated. The experimental set-up consist of a five different setups one with simple air-cooled heat exchanger (ACHE) without grooving, second with internal spiral grooving pitch of 5mm, third with internal spiral grooving pitch of 10mm, forth internal spiral grooving pitch of 15mm and fifth with internal spiral grooving pitch of 20mm with rectangular fin respectively using aluminum as tube and fin material. All experiments were carried out at different temperature for both free and forced air convection for counter to cross flow air cooled heat exchanger. The obtained results show that heat transfer rate increases with decrease in pitch that is distance of internal spiral grooving at different temperature. This is attributed to fact that with the increase in spacing between the tubes the change in temperature of tube surface decreases. Also increasing trend has been shown for Reynolds number and Nusselt number along with reduced pressure drop at different temperature. Furthermore highest heat exchanger effectiveness was obtained for 5mm pitch internal spiral grooving heat exchanger. The outcomes of this paper corroborate that, heat exchanger with 5mm pitch internal spiral grooving can be used as best optimum spacing between grooving.

Keywords: *Rate of heat transfer, Effectivness, Thermal efficiency, Spiral grooving, Rectangular Fins, Reynold Number, Pressure Drop.*

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I. Introduction

A heat exchanger is a thermal device that transports energy by heat transfer between moving fluids at different temperatures. Heat exchangers are widely used in many different applications and industries worldwide, varying from space, energy, heating, ventilation and air conditioning, and transportation. The exemplary illustration of a hotness exchanger is found in a gas powered motor in which a circling liquid known as motor coolant courses through radiator loops and wind streams past the curls, which cools the coolant and warms the approaching air. The operating principle of an Air-cooled heat exchangers ACHE is straightforward. Hot process fluid enters one end of the ACHE and flows through tubes, while ambient air flows over and between the tubes, which typically have externally finned surfaces. The process heat is transferred to the air, which cools the process fluid, and the heated air is discharged into the atmosphere. There are two basic types of ACHE's: 1. forced draft — the fan is located below the process bundle and air is forced through the tubes, 2. induced draft — the fan is located above the process bundle and air is pulled, or induced, through the tubes.

In order to improve the heat transfer efficiency and safe operation of heat transfer equipment's, many techniques have been proposed on the surface modification of hot tubes such as treated surfaces, rough surfaces, extended surfaces, grooves, dimples, flutes, swirls, etc., [1, 2]. The chief purpose of using modification technique inside and outside of the hot tube is to provide best thermal protection, minimal usage of coolant and reduced pressure drop in different devices like heat ex-changers, heat sinks, turbines, boilers, etc., [3-5]. Grooves are additionally an efficacious heat transfer enhancement technique generally utilized in present heat exchangers as reported by different researcher. Also material plays very crucial role in the designing and performance enhancement of heat exchanger. In this article, an attempt has been made to enhance the thermal performance and to find optimum internal spiral grooving pitch in the tube to be kept for efficient heat transfer.

II. Literature Review

Chang, Tae-Hyun et al. [1] studied thermal performance and pressure drop are considered as major factors. Both, thermal performance and pressure drop are dependent on the path of fluid flow and types of baffles in different orientations respectively. Increasing the complexity of baffles enhances heat transfer which also results in higher pressure drop which means higher pumping power is required. This reduces the system efficiency. This paper presents the numerical simulations carried out on different baffles i.e. single segmental, double segmental and helical baffles. This shows the effect of baffles on pressure drop in shell and tube heat exchanger. Single segmental baffles show the formation of dead zones where heat transfer cannot take place effectively. Double segmental baffles reduce the vibrational damage as compared to single segmental baffles. The use of helical baffles shows a decrease in pressure drop due to the elimination of dead zones. The less dead zones result in better heat transfer. The lower pressure drop results in lower pumping power, which in turn increases the overall system efficiency. The comparative results show that helical baffles are more advantageous than other two baffles.

Afzal et al. [2] experimentally studied the optimum spacing between grooved tubes is reported in this paper. Two grooved tubes having pitch of 10 mm and 15 mm and a plain tube were considered for the heat transfer analysis. The spacing between two tubes with same pitch was varied from 10 mm to 35 mm with a step size of 5 mm. Velocity of air flowing over the tube surfaces was changed from 0.4 m/s to 1 m/s using a blower fan. Based on Nusselt number (*Nu*) the optimum spacing between the tubes was decided. The optimum spacing between grooved tubes of pitch 10 mm and 15 mm was compared with that of plain tubes. From the experimental analysis it was noticed that with increase in air velocity (increase in Reynolds number) the tube surface temperature reduced irrespectiveof any tube considered. *Nu* increased with increase in air velocity for all the tubes. The important conclusion drawn from the present study was that, there exists a limiting spacing (optimum) between the tubes above which no change in *Nu* was observed. Spacing of 30 mm was found to be the optimum spacing between the tubes irrespective of its surface geometry modifications.

S Basavarajappa et al. [3] Experiments investigated the effect of nanofluid on turbulent heat transfer and pressure drop inside concentric tubes. Water and SiO_2 with mean diameter of 30 nm were chosen as base fluid and nano-particles, respectively. Experiments were performed for plain tube and five roughened tube with various heights and pitches of corrugations. Results show that adding the nano-particles in tube with high height and small pitch of corrugations augments the heat transfer significantly with negligible pressure drop penalty. It is discussed on relative Nusselt number and thermal performance of heat exchanger.

Jie Qu et al. [4] discussed the heat transfers of PCM and enhance the thermal performances of PCM used two type of novels are 3D-OHPs (4 layers 3D-OHP and 3 layers 3D-OHP) and PCM coupled with multiple 2D-OHPs. Phase change materials (PCM) have been mostly use in thermal managements because its have high latent heat and low price. Phase change materials are use Oscillating heat pipes(OHP) and effective thermal transfer devices for heat transfer. Its due to enhance the thermal performances. In this experimental manuscript both novels 3D-OHPs and regular OHPs are hired for the PCM thermal performance. By knowing this research paper Results shows that paraffin wax/3D-OHP systems are needed extra times for finally melting of paraffin wax than paraffin wax/OHPs system. In the solidification process two systems are performed better than simply paraffin wax. The solidification times of the pure paraffin wax and paraffin wax/4-layers 3DOHP are taken only 0.29 times where as the paraffin wax/4 OHP systems are 0.48 times taken. Such as the paraffin wax/3D-OHP systems are superior performances.

Hassan Jafari Mosleh et al. [5] experimentally and numerical investigated the pulsating heat pipes(PHPs) as substitutes for fins in a representative air-cooled heat exchanger(ACHE).Because of low temperatures difference between the cooling air and internal airflow. In which R134a was selected as the best working fluid from the heat transfer stand point. Than PHPs are filled with working fluid, the coefficient of heat transfer and temperature difference have been increased. In this condition the performances of the PHP-tubes are noted without working fluids are similar to the fin tube. When the axial fans are stopped due to small gap between the fins and produce poor thermal performances of the fin. By knowing this research paper results shows that using PHPs instead of fins improves heat transfer efficiency. In which Firstly fins and PHP-tubes are tested without any exterior flow over the main tubes and the tests are conducted in natural convection situations.

III. Experimental Set-Up & Procedure

The experimental set-up of a counter to cross flow air cooled heat exchanger using aluminum tube as material is shown in Fig 3.1. This design has constant number of aluminum fins attached with the heat exchanger, number of fins used are 101. Dimension of the proposed design is a simple aluminum tube with thickness of outer wall is 3 mm with internal diameter of 26 mm and outer diameter of 32 mm. The overall length of the proposed tube is 1 meter. The whole setup is designed in accordance with aerodynamic principal to maintain ambient air with or without forced convection of air.

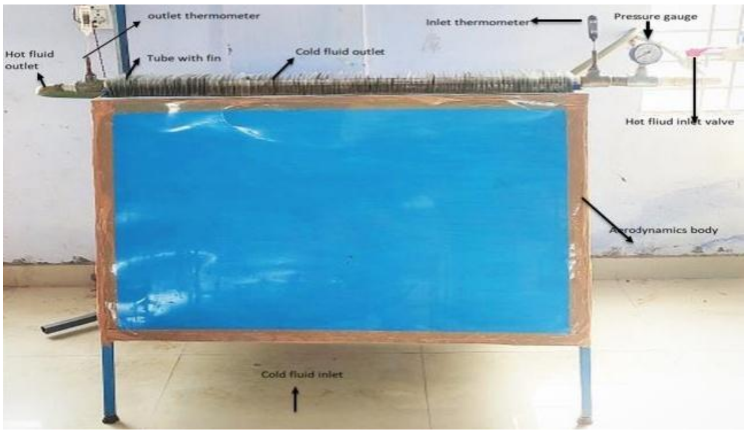

Fig 3.1 Pictorial view of experimental setup

The experiment is started with flow of hot water from water tank through water heater placed at an appropriate height so that it is able to maintain the water flow under gravity. For the measurement of temperature and pressure a thermometer and a pressure gauge is fitted respectively on the inlet and outlet of proposed heat exchanger of tube sheet. As the hot water flows inside the tube a cooled or ambient air is blown over the outer surface of the tube with the help of fan. Finally, pressure and temperature are measured with the help of pressure gauge and thermometer respectively at the outlet. The Flow of water is maintained by the help of valves used at inlet ant outlet of the setup. This whole process is repeated at different temperature for both free and forced air convection for five different setups. One with simple air-cooled heat exchanger (ACHE) without grooving, second with internal spiral grooving pitch of 5mm, third with internal spiral grooving pitch of 10mm, forth internal spiral grooving pitch of 15mm and fifth with internal spiral grooving pitch of 20mm with rectangular fin respectively.

IV. Results And Discussion

The experiment was conducted on five different setups at different temperature for both free and forced air convection. One with simple air-cooled heat exchanger (ACHE) without grooving, second with internal spiral grooving pitch of 5mm, third with internal spiral grooving pitch of 10mm, forth internal spiral grooving pitch of 15mm and fifth with internal spiral grooving pitch of 20mm with rectangular fin respectively.

The performance parameters such as heat transfer rate, Reynold's number, Nusselt number, pressure drop and heat exchanger effectiveness for five types of setup were calculated and results obtained are graphically presented.

4.1 Effect of Fluid Temperature on Heat Transfer Rate at Different Pitch for Air Cooled Heat Exchanger

The effect of fluid temperature on heat transfer rate at different pitch that is 05mm, 10mm, 15mm, 20mm internal spiral grooving tube and simple tube (without grooving) of a counter to cross flow air cooled heat exchanger for free and forced convection is shown Fig. 4.1 and Fig. 4.2 respectively.

4.1.1 Effect of Fluid Temperature on Heat Transfer Rate at Different Pitch for Air Cooled Heat Exchanger for Free Convection

The variation of heat transfer rate and temperature at different pitch of a counter to cross flow air cooled heat exchanger for free convection is shown Fig. 4.1

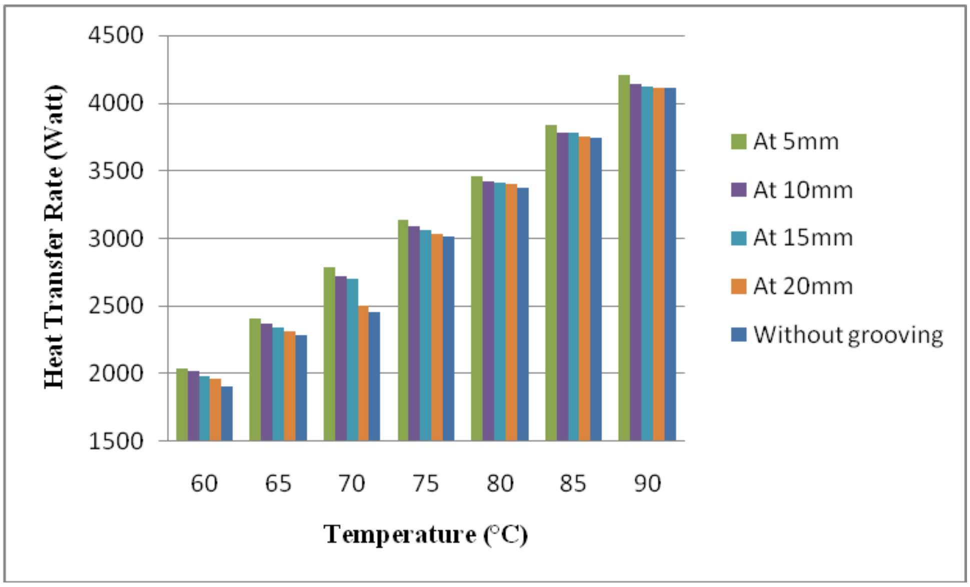

Fig. 4.1 Effect of fluid temperature on heat transfer rate at different pitch for air cooled heat exchanger for free convection

From the experimental investigation it was observed that heat transfer rate increased with increase in temperature. It was found that heat transfer rate increases with decrease in pitch that is distance of internal spiral grooving. Also it was observed that heat transfer rate was more for internal spiral grooving than simple tube without grooving. This behavior can be attributed to fact that closer pitch size of grooves on the tube surface enhances the convective heat transfer coefficient which further increases the rate of heat transfer [11]. Further maximum heat transfer rate was observed at 5mm pitch (internal spiral grooving).

4.1.2 Effect of Fluid Temperature on Heat Transfer Rate at Different Pitch for Air Cooled Heat Exchanger for Forced Convection

The variation of heat transfer rate and temperature at different pitch of a counter to cross flow air cooled heat exchanger for forced convection is shown Fig. 4.2.

From the experimental investigation it was observed that heat transfer rate increased with increase in temperature. It was found that heat transfer rate increases with decrease in pitch that is distance of internal spiral grooving. Also, it was observed that increased heat transfer rate was obtained for forced convection as compare to free convection. This is attributed to fact that with the increase in spacing between the tubes the change in temperature of tube surface decreases [11]. Furthermore maximum heat transfer rate was observed at 5mm pitch (internal spiral grooving).

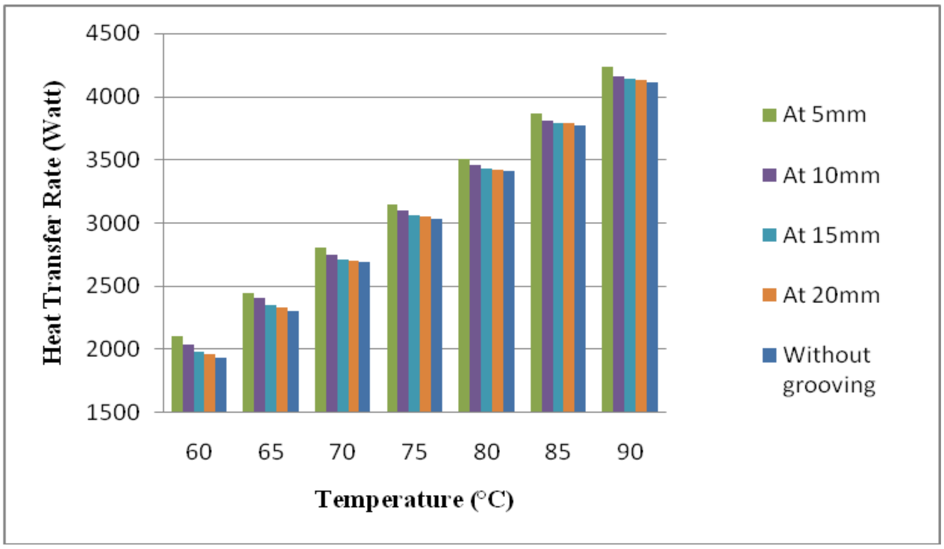

Fig. 4.2 Effect of fluid temperature on heat transfer rate at different pitch for air cooled heat exchanger for forced convection

4.2 Effect of Fluid Temperature on Reynolds Number at Different Pitch for Air Cooled Heat Exchanger

The variation of Reynold Number and temperature at different pitch of a counter to cross flow air cooled heat exchanger for free and forced convection is shown Fig. 4.3

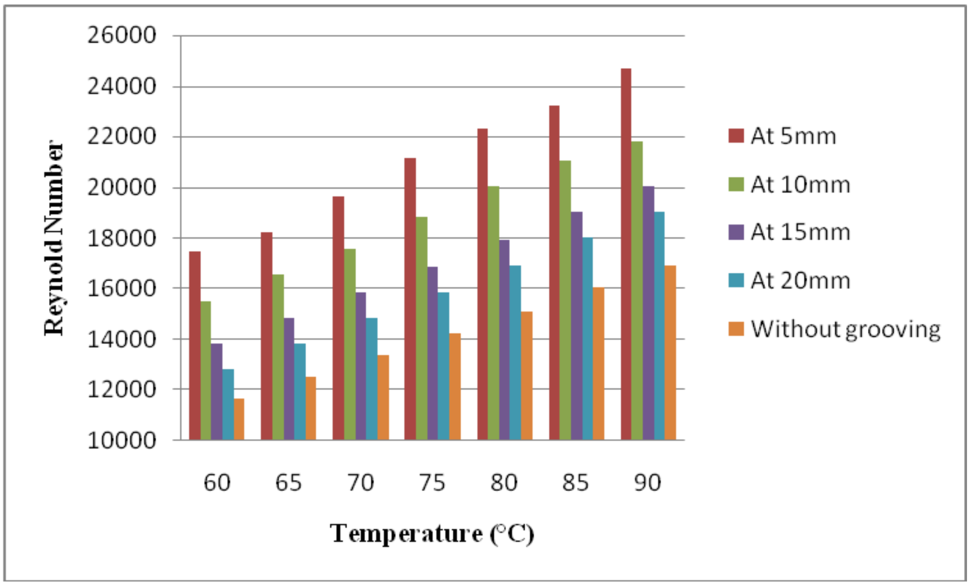

Fig. 4.3 Effect of fluid temperature on Reynolds number at different pitch for air cooled heat exchanger

Figure 3.3 shows that Reynold number increase with increase in temperature. Also it was found that Reynold number increases with decrease in pitch that is distance of internal spiral grooving. This shows that the turbulence formation advanced due to artificial turbulence exerted by internal spiral grooving. This increases the swirl flow across the range of Reynolds numbers [15]. Further maximum Reynold number was observed at 5mm pitch (internal spiral grooving).

4.3 Effect of Fluid Temperature on Nusselt Number at Different Pitch for Air Cooled Heat Exchanger

The variation of Nusselt Number and temperature at different pitch of a counter to cross flow air cooled heat exchanger for free and forced convection is shown Fig. 4.4

From the experimental investigation it was observed that Nusselt number increased with increase in temperature. Also it was found that Nusselt number increases with decrease in pitch that is distance of internal spiral grooving. with increase in Re the Nu also increases irrespective of tubes with and without grooves [11]. This is mainly due to increase in convective heat transfer coefficient of fluid flowing between the tubes [15]. Further maximum Nusselt number was observed at 5mm pitch (internal spiral grooving).

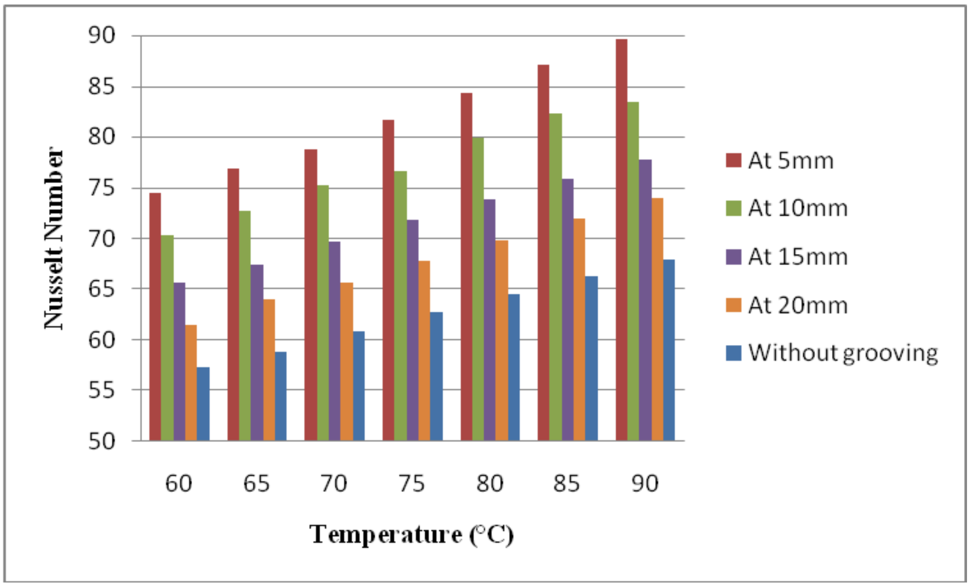

Fig. 4.4 Effect of fluid temperature on Nusselt number at different pitch for air cooled heat exchanger

4.4 Effect of Fluid Temperature on Pressure Drop at Different Pitch for Air Cooled Heat Exchanger

The variation of pressure drop and temperature at different pitch of a counter to cross flow air cooled heat exchanger for free and forced convection is shown Fig. 4.5

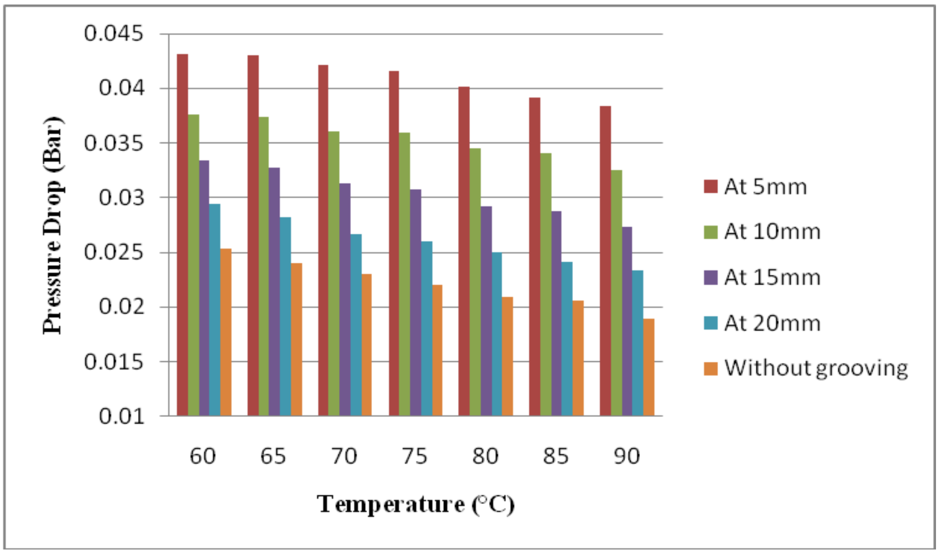

Fig. 4.5 Effect of fluid temperature on pressure drop at different pitch for air cooled heat exchanger

From the experimental investigation it was observed that pressure drop decreased with increase in temperature. Also it was found that pressure drop increases with decrease in pitch that is distance of internal spiral grooving. Further maximum pressure drop was observed at 5mm pitch (internal spiral grooving). the rising temperature causes the fluid viscosity to decrease and the pressure drop of the heat exchanger then reduces [15]. And the heat transfer rate has the trend increasing with the rising of the average temperature. Conversely, the pressure drop decreases [11].

4.5 Experimental Analysis of Effectiveness of Air Cooled Heat Exchanger at Different Pitch

The variation of effectiveness of a counter to cross flow air cooled heat exchanger at different pitch is shown Fig. 4.6

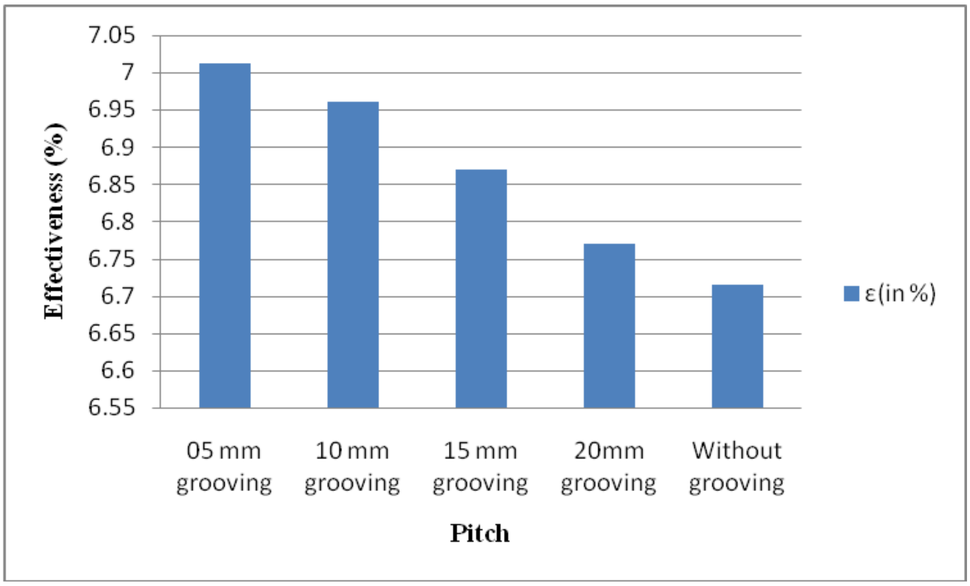

Fig. 4.6 Effectiveness of Air Cooled Heat Exchanger at Different Pitch

Fig. 4.6 shows that decrease in heat exchanger effectiveness was observed with increase in pitch that is distance of internal spiral grooving. Also it was observed that heat exchanger effectiveness was more for internal spiral grooving than simple tube without grooving. The above mentioned analysis that making internal grooves in the tube with appropriate pitch size may increase the heat transfer rate which further increases the heat exchanger effectiveness. Similar facts were previously reported by researchers [11].

V. Conclusions

This experimental study examined and analyzed the various internal spiral grooving heat exchanger at different pitches with rectangular fins. Key findings from this study are as follows:

1. The heat transfer rate increases with increase in temperature at different pitch of internal spiral grooving. It was found that heat transfer rate increases with decrease in pitch that is distance of internal spiral grooving. Also, it was observed that increased heat transfer rate was obtained for forced convection as compare to free convection.
2. Increased Reynolds number was obtained for different pitch of internal spiral grooving at different temperature. it was found that Reynold number increases with decrease in pitch that is distance of internal spiral grooving. This shows that the turbulence formation advanced due to artificial turbulence exerted by internal spiral grooving. This increases the swirl flow across the range of Reynolds numbers.
3. With increase in Renolds number the Nusselt number also increases irrespective of tubes with and without grooves. This is mainly due to increase in convective heat transfer coefficient of fluid flowing between the tubes.From the experimental investigation it was reported that Nusselt number increased with increase in temperature. Also it was found that Nusselt number increases with decrease in pitch that is distance of internal spiral grooving.
4. The heat transfer rate has the increasing trend with the rising of the temperature. Conversely, the pressure drop decreases. Also it was found that pressure drop increases with decrease in pitch that is distance of internal spiral grooving. Further maximum pressure drop was observed at 5mm pitch (internal spiral grooving). the rising temperature causes the fluid viscosity to decrease and the pressure drop of the heat exchanger then reduces. And the heat transfer rate has the trend increasing with the rising of the average temperature. Conversely, the pressure drop decreases.

References

[1]. Jian Wang et al., Experimental investigation of heat transfer and flow characteristics in finned copper foam heat sinks subjected to jet impingement cooling, Applied Energy, VOL-241 ,PP: 433–443, 2019.

[2]. De-Shau Huang et al, Design of fins with a grooved heat pipe for dissipation of heat from high powered automotive LED headlights, Energy Conversion and Management ,VOL-180 ,PP: 550–558, 2019.

[3]. Hai Wang et al.Heat transfer performance of a novel tubular oscillating heat pipe with sintered copper particles inside flat-plate evaporator and high-power LED heat sink application, Energy Conversion and Management, VOL-189 ,PP:215–222, 2019.

[4]. Demis Pandelidis et al., Performance comparison between counter- and cross-flow indirect evaporative coolers for heat recovery in air conditioning systems in the presence of condensation in the product air channels, International Journal of Heat and Mass Transfer, VOL-130, PP: 757–777, 2019.

[5]. Lei Wang et al., Optimization of the counter-flow heat and mass exchanger for M-Cycle indirect evaporative cooling assisted with entropy analysis, Energy, VOL-171, PP: 1206-1216, 2019.

[6]. Kadir Bilen, Murat Cetin, Hasan Gul, Tuba Balta,“The investigation of groove geometry effect on heat transfer for internally grooved tubes.Applied Thermal Engineering, Volume 29, Issue 4, 2009.

[7]. P. Bharadwaj, A.D. Khondge, A.W. Date, “Heat transfer and pressure drop in a circular grooved tube with twisted tape insert” International Journal of Heat and Mass Transfer, Volume 52, Issues 7–8, 2009.

[8]. Nakaso K, Mitani H and Fukai J Convection heat transfer in a shell-and-tube heat exchanger using sheet fins for effective utilization of energy International Journal of Heat and Mass Transfer 82 581–591, 2015.

[9]. Park K T, Kim H J and Kim D K, Experimental study of natural convection from vertical cylinders with branched fins Experimental Thermal and Fluid Science 54 29–37, 2014.

[10]. Chang, Tae-Hyun, Lee, Kwon-Soo, Chang, Ki-Won, Kim, Sang Min, & Lee, Chang-Hoan, Heat transfer characteristics of a short helical plate in a horizontal circular tube, Journal of Mechanical Science and Technology, 33(8), 3613-3620. 2019.

[11]. Afzal, A., Mohammed Samee, A.D., Abdul Razak, R.K, Optimum spacing between grooved tubes: An experimental study. *J Mech Sci Technol* 34, 469–475, 2020.

[12]. S Basavarajappa, G Manavendra and S B Prakash, “A review on performance study of finned tube heat exchanger”, Journal of Physics: Conference Series, Vol. 1473, No. 1, 2020.

[13]. Jie Qu et al., Experimental investigation on thermal performance of phase change material coupled with three-dimensional oscillating heat pipe (PCM/3DOHP) for thermal management application, International Journal of heat and Mass Transfer, VOL-129, PP: 773–782, 2019.

[14]. Hassan Jafari Mosleh et al., Experimental and numerical investigation of using pulsating heat pipes instea of fins in air-cooled heat exchangers, Energy Conversion and Management, VOL-181, PP:653–662 , 2019.

[15]. Pankaj N. Shrirao, Rajeshkumar U.Sambhe and Pradip R.Bodade, “Convective Heat Transfer Analysis in a Circular Tube with Different Types of Internal Threads of Constant Pitch” International Journal of Engineering and Advanced Technology (IJEAT), Volume-2 Issue-3, PP: 335-340, 2013.

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