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An Investigation of Counter to Cross Flow Air-Cooled Heat Exchanger Using Dissimilar Fins Pitch with Internal Round Grooving”

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ABSTRACT

The presented dissertation is an experimental setup for heat exchangers designs first one is a simple tube air cooled heat exchanger without grooving, second one is air cooled heat exchanger with internal circular grooving and third one is internally curricular grooved air cooled heat exchanger with rectangular fins. In case of third design we are taking seven variations insuccessive rectangular fins to evaluate the performance of the heat transfer efficiency of the proposed heat exchangers by changing the distance of fins and hence the number of fins used in the proposed heat exchanger. We are changing the distance between the fins and its number until we get a constant or almost constant temperature drops. The proposed distance between the fins are 0.5 cm, 1.0 cm, 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm in seven proposed setup for the air cooled heat exchanger with 200, 102, 68, 52, 42, 35 and 29 fins respectively.

From the proposed analysis we establish that the heat transfer rate is highest in internal circular grooving with rectangular fins at the distance between two fin is 0.5 cm. The heat exchanger effectiveness is also higher in internal circular grooving with rectangular fins at the distance between two consecutive fins 0.5 cm than other arrangements. We can conclude that the heat exchanger with fins which is placed at 0.5 cm is more advantageous from heat transfer viewpoint. But on the basis of economical point of view, the heat exchanger with rectangular finswhich is placed 3.5 cm is more desirable because the number of fins required is very less compared to other arrangement. The overall better performance i.e. more desirable from heat transfer as well economical point of view of heat exchanger is the heat exchanger with rectangular fins which is placed at 10 mm because less number of fins are required and betterheat transfer compared to others. The effectiveness of the exchanger is also not large. The overallfin effectiveness have obtained for internal circular grooving with rectangular fins setup are 27.59, 14.56, 10.04, 7.91, 6.58, 5.56, and 4.86 at the distance between two consecutive fins are
0.5 cm, 1.0 cm, 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm, 3.5 cm respectively. The efficiency ofrectangular fin is 96.87 %.
The average value of heat transfer rate of a counter to cross flow air cooled heat exchanger for first design simple tube without grooving is 283.41 watt and 289.10 watt for natural convection (without fan) and forced convection (with fan) respectively. On the other hand for second design with internal circular grooving its value is 285.51 watt and 290.00 watt for natural convection (without fan) and forced convection (with fan) respectively. Finally in third design of internal circular grooving with rectangular fins we have seven variation of fin distance and the value of heat transfer rate of counter to cross flow ACHE is 7062.95 watt, 3969.78 watt, 2724.15 watt, 2149.25 watt 1785.03 watt, 1533.43 watt, and 1325.34 watt in natural convection (without fan) for 0.5 cm, 1.0 cm, 1.5cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm respectively. When talking about the value of heat transfer rate in forced convection (with fan) its values are 7100.40 watt,3995.30 watt, 2740.54 watt, 2162.26 watt, 1797.63 watt, 1540.00 watt, and 1331.60 watt for 0.5
cm, 1.0 cm, 1.5cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm respectively.

Keywords: *Heat exchangers, Air Cooled, Fins, Transfer rate, Forced Convention*

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I. INTRODUCTION

The Basic of Heat Exchanger

Heat exchangers are one of the generally utilized supplies in the process enterprises. Heat exchangers are utilized to move heat involving two cycle stream. One can understand their utilization to any cycle which includes cooling, warming, build up, bubbling or dissipation will involve a heat exchanger for these reasons. Cycle liquids, normally are warmed or cooled prior to the cycle or go through stage change. Distinctive heat exchanger is named by their application. Pro instance, heat exchanger being utilized to consolidate is known as condenser, likewise heat exchangers used for bubbling objects are called boiler. Execution and productivity of heat exchanger is estimated throughoutthe measure of heat transfered utilizing slightest region of heat move and weight drop. An all the more healthier introduction of its proficiency is finished by ascertaining generally heat move coefficient. Weight slump and zone required for a specific measure of heat move, gives knowledge concerning the capital expense and force prerequisites (successively expense) of heat exchangers. Normally, there is loads of writing as well as speculations to plan a heat exchangers as indicated by the necessities. A decent plan is all used to heat exchangers by means of slightest conceivable region and compel go down to satisfy the heat transfer requirement.

As we probably aware it is a modern test to improving the effectiveness of heat exchangerand the heat move. Air-cooled heat exchanger is broadly utilized in an assortment of ventures, for example, warm force plants Chemical treatment facilities, ORC Plant, Oil and Gas, Steel Industry and numerous different applications. In this arrangement hot liquid is streaming inside the cylinder, and encompassing air ignores the external facade of the cylinder as cooling liquids. The cooling wind currents over the outside of inside scored balance tube with a fan to upgrade the heat move region. As we know that the rate of the heat transfers are the function of surface area of fins and air velocity passing over that surfaces. ACHEs are unremarkably used wherever a method system generates heat that should be removed, that there's no native use. They are a –green‖ answers as compare to shell and tube heat exchanger along with cooling towers as a result of they are doing not need an auxiliary water system (water lost tanks to float and evaporation, and there are no chemicals required for water treatment).

1.1 Heat Exchanger Classification

At current heat exchanger is accessible in numerous setups. Contingent on their application, measure liquids, and method of heat move and stream, the heat exchangers be able to be arranged. The heat exchanger can move heat all the way through direct contact with liquid or through backhanded way. They can likewise be grouped based on the shell and cylinder passes, kinds of confuses, course of action of cylinders (Triangular, quadrangle and so on.) and smooth or confounded surfaces. These are likewise ordered through stream game plans while liquids be capable of streaming similar way (Parallel), inverse to one another (Counter stream) and typical to one another (Cross stream). The choice of a specific heat exchanger arrangement relies upon a few elements. These variables may incorporate, the territory prerequisites, upkeep, stream rates, and liquid stage.

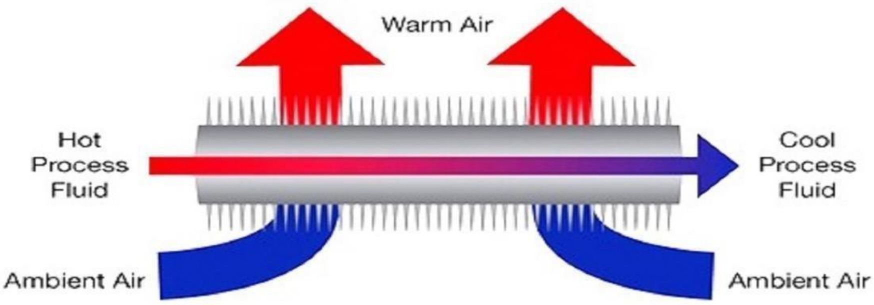


Fig.1.1 Operating Principle of ACHE

and evaporation, and there are no chemicals required for water treatment). Wherever there's a no utility like water offered as a cooling medium. They are typically used when outlet temperature is more than the maximum expected surrounding temperature. They will be used with closer room temperatures, however, they usually become pricey as compared to an assortment of a cooling towers and a water cooled heat exchanger. The fig.1.1 describes the functioning principle of ACHEs

II. LITERATURE REVIEW

A literature review is a kind of survey on several research papers who had been done. The main motive of this chapter is to review the research paper which includes the present knowledge and finding the theoretical and methodological approaches on a particular topic.It is also to attain the goal of a particular analysis and then to examine in which field of operations is to be carried out. The object of this chapter is to analyze various papers and establish the best approaches for them. Various research papers have been overview relatedto heat transfer through fins with internal grooving and detail has discussed below.

Literature Review on Heat Exchanger

P.Bharadwaj A.D.Khondge, et al. (2009) have done experimentally strong-minded the pressure drops and the heat transfer features of flowing water in a 75 start spiral grooving tubes with warped tape. The fluid flow was considered laminar to fully turbulent. The groove is done in clockwise direction with regard to the flow direction. The heat transfer increases owing to spiral grooving and doubled with inserting warped tape having twisted ratio Y 10.15, 7.95 and 3.40 by Compared with a smooth tube. By this research paper, It is observed that the twist direction (clockwise direction or anticlockwise direction) influence the thermo hydraulic properties. Comparisons by means of a smooth tube with constant pumping powers show that in the spiral grooving tubes with and without twisted tapes, Heat transfer inhances noticeably in laminar flow and passably in turbulent in range of Reynold number. The spiral grooving tubes without twisted tape takes maximum heat transfersincrement of 400 percentage in laminar flow and 140 percentage in turbulent ranges.

Kadir Bilen et al. (2009) investigated upon exploratory assessment of surface heat move similarly as crushing typical for totally made wild wind stream in dissimilar scored tube. Test was performed for various scored shape (like round, trapezoidal and rectangular) for Reynold numbers ranges 10,000–38,000. The extent of chamber length to expansiveness is 33. The glow move similarly as scouring brand name was likely evaluated by the spilling in different scoring tubes. The entropy minimization technique similarly as the warm displays was used to find out the ampleness of the cutting chambers. The outcomes of this investigation were as the glow move rate increase with redesigning Re on account of the more thin cutoff layer for all segments. f is self-governing of Re. Nusselt numbers and crushing components for all cutting chambers are a component of the stream condition. The most extraordinary heat move increase is found 63% in a round score, 58% in trapezoidal areas and 47% in rectangular indent differentiated and a smooth chamber.

Hung-Yi Li et al. (2009) was survey the displays of plate cutting edge heat sink in a cross flow. The warm insurances similarly as the weight drops in heat sinks are investigated by the Reynold amounts of cooling air, balance stature, and equalization width. We derive that by overhauling the Reynold numbers it could lessen the warm restriction of the glow sinks. In this paper, it have been viewed as probably the displays of plate balance heat sink under cross-stream cooling for an arrangement of Reynold numbers, edge height and parity width. We shut from this investigation paper; the temperature of heat sinks lessens from base to top and from focus to outside. Heat sinks with the greatest sharp edge have the best warm presentations at predictable parity width. The warm display corrupted with constructs the cutting edge width. Weight drops enhances as the Reynolds numbers, balance width, and edge height increase.

III. RESEARCH GAP

The present review includes various factors related to internal as well as external grooving tubes and different geometries fins with air-cooled heat exchanger and different flow directions. The rate of heat transfers, mass flow rate, and other parameters were studied from the above literature review including various experimental and computational methods.

- From the above literature analysis, we analyzed that various authors performed the operation on the heat exchanger by taking different tubes materials with internal as well as external grooving of different profiles (like spiral, triangular and trapezium) and different fins geometries (like rectangular, square, trapezoidal and circular).
- Some authors studied the performance of heat exchanger with grooving and fin jointly, while others demonstrated the performance of heat exchanger with grooving and fins separately.
- It has been found that a lot of work has been conceded out in the field of air-cooled heat exchanger with internally grooving and fins, but many research related to the air cooled heat exchanger with internally grooving and fins still not happened or may be in the current process that is why there is lot of scopes to work on this field.
- So we will look into this direction by taking aluminum annular tube counter to cross- flow internal circular grooving and rectangular fins with air cooled heat exchanger.

IV. Design Procedure for Heat Exchanger

During the Procedure for design Heat Exchanger of the project, the design methodologyused will be as shown in figure 4.1
Steps required for designing of a conventional Heat Exchanger is summarized in followingsteps
Step 1. Initially, select the desired design requirement for the heat exchanger and calledthem as base data.
Step 2. Determination of the heat load on tubes and shells side.

Step 3. This step is dedicated for selection of appropriate heat exchanger configuration based on type of material for heat exchanger its dimension, fin size and shape, and grooving introduced etc.
Step 4: This step is dedicated for the calculation of main performance parameter of the heat exchange, calculation starts with following steps.

(a) Count of the corrected effective temperatures difference (CMTD) for the heat loads. To start with, the logarithmic mean temperatures difference (LMTD) is resolved for ideal counter current stream.

(b) For heat exchangers with different goes, due to the non-ideal counter current stream, the temperature proficiency factors, F, must be determined. F ought to be greater than 0.75! Utilizing the temperature productivity factors, F, the CMTD is resolved. CMTD = F x LMTD

(c) Assessment of the necessary heat exchangers region For the determined heat loads
and the accessible powerful temperature contrast, the necessary heat exchangersregion is assessed utilizing the assessed by and large heat move coefficient, U.

(d) Assurance of the stream speed utilizing the segments, VR and VM.

(e) Count of the convective heat transport coefficient on the cylinder and shells side.

- **Step 5**: If base data is satisfied go to **Step 6** otherwise go to **Step 3**.

4.1 Performance Parameter

In this section, detail of basic parameters used for the performance analysis of Air cooled Heat Exchangers (ACHE) such as heat transfer; thermal resistance etc. is going to becovered.

4.2 Heat Transfer Modes

The system through which heat is transfer in corporal hardware is very mind blowing; not withstanding, there give off an impression of being two rather fundamental and particular sorts of heat transfer measures: conduction, convection and radiation.

Conduction is the exchange via sub-atomic movement of heat linking one aspect of a body to another aspect of a similar body or by one body as well as another in physical contacts with each other. In liquids, heat is led by almost versatile crashes of the atoms or via a vitality dispersion measure. Hypothesis of heat conduction in solids recognizes conveyors and non-conductor or dielectric of power. In dielectrics, heat is led via grid waves brought about through nuclear movement; in electrical channels, free electron carrying on practically similar to gas atoms contributes moreover to warm conduction.

At the point when a temperature angle exist inside a standardized substances, there are a vitality move from the more temperature district to the low temperature area. Heat is moved by conductions, and the heat transport rate per unit zone is relative to the ordinary temperature inclination, i.e.
$Q = -KA\, dT/dx$ (4.1)

Where the heat transition, Q, is the proportion to the heat move rate, Q, through the zone An, and dT/dx is the temperature angle toward heat stream. At the point when the proportionalitycoefficients are embedded,
$Q = -KA\, dT/dx$ (4.2)

The positive coefficient, k, is known as the warm conductivity of the material, and the short sign is installed so the second standard of thermodynamics will be satisfied, i.e., heat must stream downhill on the temperature scale. Consider the issue of one-dimensional predictable state conduction in a plane mass of homogeneous material having consistent warm conductivity with each face held at a consistent uniform temperature (Fig. 4.2).

4.3 METHODS AND MATERIALS

The proposed designs of Heat Exchangers are carried out using an experimental setupcreated in our lab for the analysis of different performance parameters such as heat transfer rate, air velocity, air humidity and pressure drop etc. the proposed heat exchange is made up of aluminum on comparing it with stainless steel we find various advantages of aluminum over stillness steel viz.

(a) Strength weight ratio of aluminum is much better than stainless steel its weight is around one third of the weight of stainless steel and hence aluminum is widely used in designing of heat exchanger.

(b) Aluminum fuel efficiency is also better as compare of stainless steel hence extensively used in industries for heat exchanger.

(c) Because of aluminum good conductivity and high voltage overhead power it is widely used in lines.

(d) Cost of aluminum is one of the most important factor which give its an edge over stainless steel .

(e) Workability of aluminum is much better than that of the stainless steel .

Because of the above mentioned advantages we are choosing aluminum as our material for the fabrication of our heat exchanger along with the rectangular fin.
The method of experiment is started with flow of hot water from water heater which is fitted with a water tank 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 of proposed heat exchangers. Seeing that the hot water flows inside the tube a cooled or ambient air is blown over the external surfaces of the tube by way of the help of fan explained in investigational set-up section with diagrams. The whole setup are designed in keeping aerodynamic principal in mind so that ambient air can flow without problem even fan is used to provide forced convection of air. Finally pressure and temperature is measured with the help of pressure gauge thermometer respectively at the outlet as well. This whole process is repeated for different temperatureand with and without forced air convection for three different setups. One with simple air cooled heat exchanger (ACHE), second with grooved ACHE and finally third having grooved ACHE with rectangular fin setup.

V. DESIGN OF PROPOSED HEAT EXCHANGER

The proposed design is basically based on the outcome of the best results from three proposed setup of heat exchangers viz.

(a) Simple heat exchanger without grooving
(b) Heat exchanger with internal circular grooving
(c) Internally circular grooved Heat exchanger with rectangular fin. In this design there areseven cases:

i. Internally grooved Heat exchanger with rectangular fins and fin pitch is 5 mm.
ii. Internally grooved Heat exchanger with rectangular fins and fin pitch is 10 mm.
iii. Internally grooved Heat exchanger with rectangular fins and fin pitch is 15 mm.
iv. Internally grooved Heat exchanger with rectangular fins and fin pitch is 20 mm.
v. Internally grooved Heat exchanger with rectangular fins and fin pitch is 25 mm.
vi. Internally grooved Heat exchanger with rectangular fins and fin pitch is 30 mm.
vii. Internally grooved Heat exchanger with rectangular fins and fin pitch is 35 mm.

VI. RESULT AND DISCUSSION

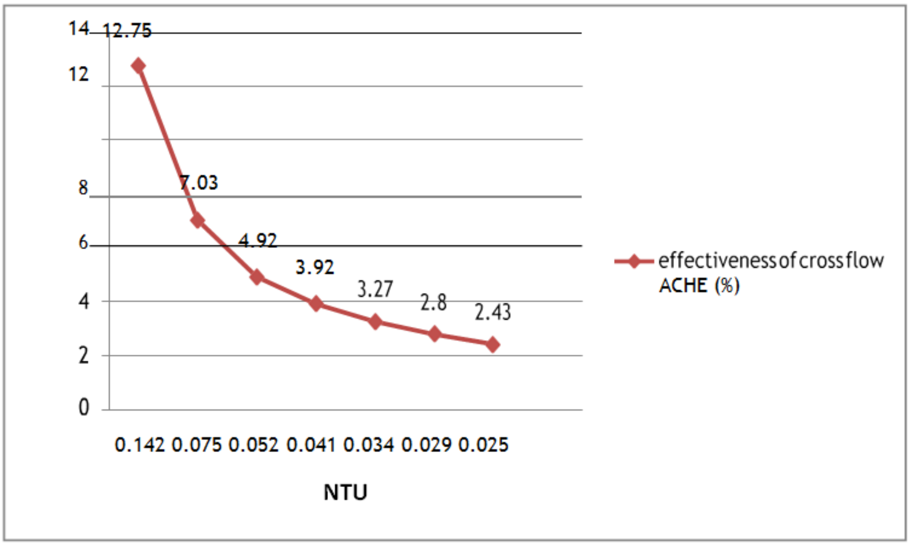
6.1 OVERALL EFFECTIVENESS OF FINS

From the previous chapter analysis we found that the overall fin effectiveness have obtained for internal circular grooving with rectangular fins setup are 27.59, 14.56, 10.04, 7.91, 6.58, 5.56, and 4.86 at the distance between two consecutive fins are 0.5 cm, 1.0 cm, 1.5 cm, 2.0cm, 2.5 cm, 3.0 cm, 3.5 cm respectively.

- The effectiveness of fin $\in_{fin} = 1$, indicates that the addition of fins to the surface does not affect the heat transfer. The effectiveness of fin $\in_{fin} < 1$, indicates that the fin acts as insulation. The effectiveness of fin $\in_{fin} > 1$, indicates that the fins are increasing heat transfer rate from the surface. So finned surfaces are designed on the basis of maximizing effectiveness for a specified cost or minimizing cost for a preferred effectiveness. When we are calculating performance of proposed heat exchanger with internal grooving and fin we get the fin efficiency (η_{fin}) is 96.87%as calculated.

- The overall effectiveness for a finned surfaces is defined as the ratio of the total heat transfer from the finned surface to the heat transfer from the without finned surfaces.

$$\text{Effectiveness of overall fins} = \frac{q_{total,fin}}{q_{total,No\ fin}} = \frac{A_{UN\ fin} + (\eta_{fin} \times A_{fin})}{A_{No\ fin}}$$



Graph 7.1 Variation of heat exchanger effectiveness with NTU

It depends on the fin density i.e. number of fins per unit length as well as effectiveness of individual fins. Its measure the performance of finned surface.

The variation of overall fin effectiveness with distance between two consecutive fin is shownin graph below. From this graph, it shows that the values of overall effectiveness of fins are decreases when the distance between two consecutive fins increases.

VIII. CONCLUSION

From the previous chapter analysis we conclude the following:

- The heat transfer rate is maximum in internal circular grooving with rectangular fins air cooled heat exchanger at the distance between two consecutive fin is 5 mm.
- The heat exchanger effectiveness of internal circular grooving with rectangular fins air cooled heat exchanger at the distance between two fin 5 mm is higher than other arrangements.
- We can conclude that the heat exchanger with fins which is placed at 5 mm is more desirable from heat transfer point of view. But on the basis of economical point of view, the heat exchanger with rectangular fins which is placed 35 mm is more desirable because the number of fins required is very less compared to other arrangement.
- The overall better performance i.e more desirable from heat transfer as well economical point of view the heat exchanger which is the internally circular grooved with rectangular fins air cooled heat exchanger at fin pitch 10 mm because less number of fins are required and better heat transfer compared to others. The effectiveness of the exchanger is also not large.
- The efficiency of rectangular fin is 96.87%.

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