A Review on Performance Analysis of Air to Air Heat Exchanger.

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Abstract

Air to air heat exchangers are considered to be an effective and low-cost way for heating and cooling loads. They find applications mostly in aero engines for cooling purpose along with air conditioning application where air is being used as the cooling medium, but the system suffers with low performance rates. This can be overcome by use extended surfaces or any other sophisticated techniques. Apart from this these air to air heat exchangers can also be used as air pre-heater, thermal oxidizers, electrical equipment cooling. The fluid flow is either co-current or counter current in nature. This paper tends to bring into notice the performance of air to air heat exchanger in various operating conditions.

Keywords: *Aero Engine, Air Conditioning, Thermal Oxidizers.*

1. Introduction

As per industry the heat exchanger is been used to transfer heat from one fluid to another while the two fluids are at different temperature. The heat transfer may take place through a material medium or in some cases a common matrix is been provided which can absorb the heat from the hot fluid and reject the same when the matrix comes in contact with the cold fluid. There are various kinds of heat exchanger available and their selection and sizing depends on the heat load. The widely used heat exchangers for heavy duty are shell and tube or a plate fin heat exchanger. For small heat loads double pipe heat exchangers can be thought of, if the mass flow rates are high enough then series or parallel arrangement can be tried. Apart from rating sizing of the heat exchanger is an important task as the geometric factor play an important role not only performance wise but also in an economic manner. Also for the cases where condensation or evaporation is involved the heat load is high thus the design of the heat exchanger becomes quite critical because in such cases the pressure drop should also been taken into consideration.

Intense researches have been conducted in order to optimize the performance and also the cost effectiveness. In case of air to air heat exchanger, the heat exchanger has wide range of applications from industry to aero engines. But the only problem associated with this heat exchanger is, the heat transfer coefficient associated with air is quite low thus the heat exchangers are big. This problem needs to be overcome by use of extended surfaces or some other techniques.

2. Literature Survey.

Designing a heat exchanger with optimum qualities like pressure drop, heat transfer rates etc. need to be within the acceptable ranges. Thus a proper amount of cases are to be studied. The surveys consists of exploring areas like thermal, renewable and sustainable energies.

Seamus Garvey, Bharath Kantharaj, Micheal Simpson investigated a air to air heat exchanger having a non-constant cross sectional area. The research consisted of designing, mathematical modelling and complete analysis of efficient air to air heat exchanger. For the analysis purpose a hexagonal mesh is considered for the cross section. An algorithm was been prepared which would perform number of iterations to find the dependable geometric parameters which would provide the best combination for a low ratio of volume of the heat exchanger to heat transfer rate. From the analysis which the researchers conducted they came across a conclusion that if the dependable geometric parameter was been scaled up by a factor of n then the volume of the heat exchanger per kW of heat transfer would rise by a value of n^2. It was been found that for 1 kW of energy transfer volume up to 84.8 cm^3 was been required.

Haiwang Li, HaoranHuang ,Jie Wen worked on making a different configuration of air to air heat exchanger which is to be used to cool the electronic components. They used the bleed air from the engine compartment as the coolant in the air to air heat exchanger which is been used to cool the hot air coming from the high-pressure compressor. The heat exchanger is been designed using LMTD method and the results are been validate by experimentation. The heat exchanger was developed such that it weighed only 2.04 kg and can provide a temperature drop of about 200K (in certain condition). The researchers were able to develop a correlation based on Wilson plot to evaluate the heat transfer coefficient associated with it.

M.I. Nizovtsev, V. Yu. Borodulin, V. N. Letushko investigated the heat transfer in air to air heat exchanger for a periodic change in airflow from the room. A heat balance was been conducted between the air flow from the room and the packing material of the heat exchanger. The results which are been obtained from the analytical method is in great agreement with the experimental results. The researchers investigated the changes in efficiency of the heat exchanger with flow rates, they found that the operational efficiency varies increases with decrease in the air flow rate and the change is linear. Also the changes in the flow rates on either side of the heat exchanger can regulate the temperature of the air which is been supplied to the room. From the experimentation the authors concluded that the operational efficiency of the heat exchanger does not depend on the absolute temperatures of indoor or outdoor condition.

Lu Haiying, Lv Duo, Yu Xiao, Dong Wei studied the pressure drop and thermal performance of air to air heat exchanger for aero engine application.

The study consist of the performance comparison of newly designed air to air heat exchanger with the present one on the basis of pressure drop and thermal analysis. Different arrangement of tube bundles were been experimented and the same were been simulated in CFD. The results showed that the pressure drop was been improved by 10% and the heat transfer rate increased by 25% of the base model. The research also concludes that making use of the elliptical tubes can reduce the pressure drop providing an optimization in the thermal performance of the heat exchanger.

3. Case Study

This paper will introduce to the case study consisting of work done on air to air heat exchanger in the field of aero engines. The study consists of developing a heat exchanger to provide air at a low temperature which can be further be used for cooling of the electronic components of the air craft. For this purpose, the hot air from the high-pressure compressor is been used which is been cooled. Earlier it used to work in a process like the air from the high-pressure compressor would pass from a heat exchanger where coolant is being used as the fuel. But this leads to deteriorate the fuel quality. Thus, it becomes important to use some other method. For this reason, the air from the engine bypass is been used to for initial cooling of the air then as per the conventional way the further cooling is been done with the help of the fuel. As the application is aviation related the compactness of the heat exchanger is of prime importance along with the range of temperature drop the it will provide. Thus to simulate the same arrangement the experimental setup was been made, the experimental results were been analytically been verified. The experimental results show a great agreement with the analytical results. For the analytical purpose LMTD (logarithmic mean temperature difference) method was been used.

4. Experimental Setup

The experimental setup consists of an air source. This source is then being divided into two loops, a low temperature loop and a high temperature loop. The high temperature loop is used to simulate the condition of high temperature air from the compressor. The low temperature loop resembles the air from the engine bypass. For the high temperature loop, the air from the source is first passed through the air filter to remove the impurities if any, then a flow meter is been used to regulate the flow rate of air. This are is passed through a heating unit up to a temperature of 500K by use of electric heater. Exiting the heater, the air enters a 4m long pipe to maintain a uniform flow. Similar to the high-temperature loop, the air in the low temperature loop is passed through the air filter and then through the flow meter. These two streams are then been supplied to the heat exchanger. The back pressure of the streams is been controlled is been controlled by electromagnetic valve. The hot stream after passing through the heat exchanger flows through a water cooled heat exchanger. The low temperature stream is been exhausted to the atmosphere. The test section is been covered with insulating material having thermal conductivity of 0.012 W/mK

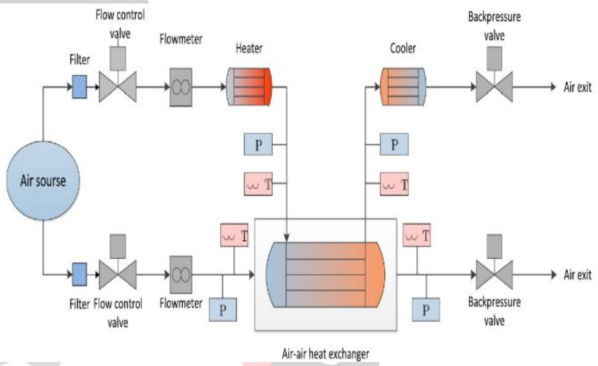

Fig.1 Experimental Setup

5. Test Section

The exchanger was been designed carefully keeping is mind that it should not be big in size as well as the weight of the heat exchanger must be within specific limits. Stainless steel material was been used. The outer dimensions of the heat exchanger were as such, 175mm in length, 145mm in width and 140mm in height. The outer diameter of the tubes is 5mm and a thickness of 0.3mm. Each tube would contribute six passes and a length of 625.6mm. The outer dimensions of the inlet and the outlet header were 135mm in length, 32mm in width and 32mm in height. The heat exchanger weighs 2.04 kg.

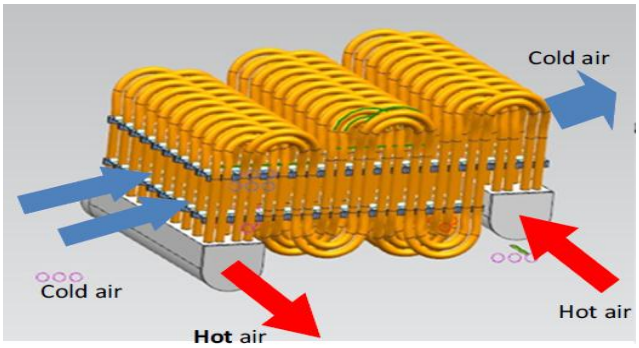

Fig 2. (Detailed Structure of Heat Exchanger)

Around 40 were been fabricated and arranger accordingly. To strengthen the arrangement two groups of supporting plates were been installed. To ensure the firmness liquid solder was been coated at the joints. Finally the unit was been sent to vacuum furnace for brazing.

Fig 3. (Detailed Structure of Heat Exchanger)

6. Numerical Method

As discussed earlier LMTD method was been incorporated for the analytical results of the heat exchanger. The basic heat transfer correlation were been used.

$Q=m_h*c_{ph}*(T_{hi}-T_{ho})=m_c*c_{pc}*(T_{co}-T_{ci})$

It is easy to calculate the logarithmic mean temperature difference for the counter current or co-current flows but in this case the flow is cross flow. Thus a correction factor is been included.

For circular cross section tubes the overall heat transfer coefficient is been calculated from the basic formula. The heat transfer rate can also be calculated from,

$Q= U_0*\Delta T_{lm}*A$

Initially area is been calculated then it becomes easy to define the structure of the heat exchanger. For using LMTD method we should know at least three temperatures. In this case, we know the inlet temperatures of both the fluids thus, we assume the outlet temperature of either of the fluid. Based on this we can calculate U_o, ΔT and Q. The heat transfer rate obtained from both the equations are compared, if the difference is large then the temperature is assumed again, the process is been continued until the difference is negligible. The pressure drop and heat transfer rate are been calculated from the correlations available.

7. Results and Discussion

The comparison is been done on the basis of the heat transfer rate and pressure drop and also the results obtained from the analytical and experimentation are been compared.

Pressure Drop Analysis:-

The pressure drop on hot air side and cold air side is been studied.

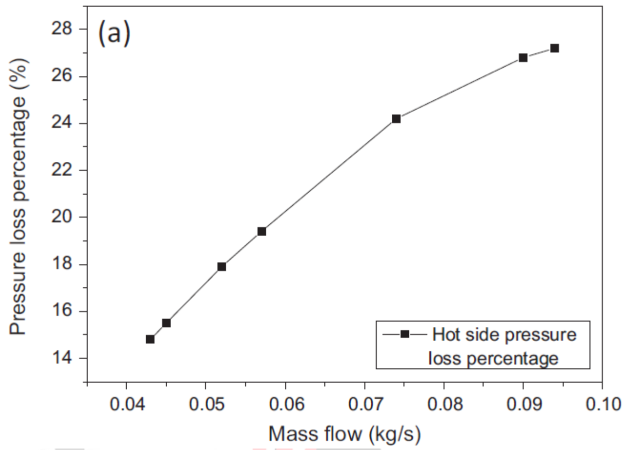

Fig 4. (Pressure Drop on Hot Air Side)

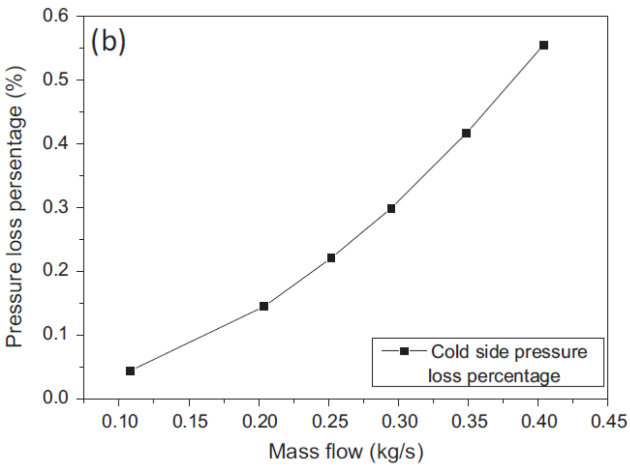

Fig 5. (Pressure Drop on Cold Side)

From the above figures we can conclude that the pressure drop increases with the mass flow rate from the hot as well as the col fluid. The pressure drop for the hot fluid is more than that of the cold fluid. The reason being the hot fluid flows through pipe of smaller cross section and also the geometry is quite complexed having number of bends, owing to this the hot air inside the tubes suffers maximum pressure drop. While the cold air has low pressure drop as the tubes are in aligned arrangement.

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Heat Transfer Analysis:-

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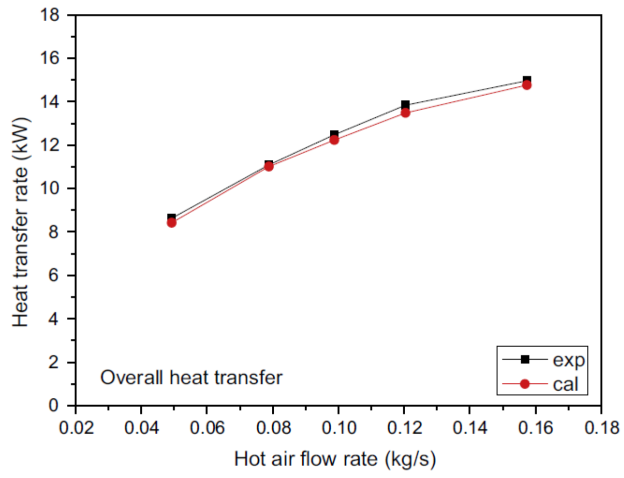

Fig 5. (Overall Heat Transfer on Hot Air Side)

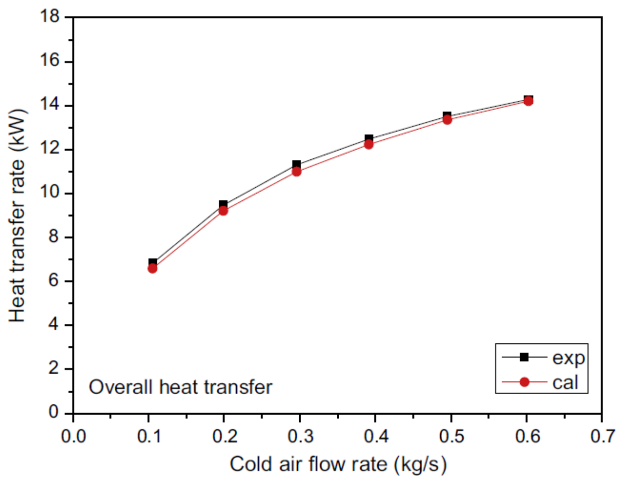

Fig 6. (Overall Heat Transfer on Cold Air Side)

During the experiments the mass flow rate of air was varied from 0.05 kg/sec to 0.2 kg/sec while the mass flow rate on the cold side varied from 0.1 kg/sec to 0.6 kg/sec. it is been observed from the graphs that the heat transfer rate for both the cases increases with the mass flow rates.

8. Conclusion

The case study stresses on the experimental and analytical verification of the results for the air to air heat exchanger for gas turbine application. From the above case study we can draw following conclusions.

(1) The study shows the design and developments of a small and a compact heat exchanger with a capacity to provide a high temperature drop.
(2) Comparison between the experimental and the numerical scheme shows a great agreement which shows that the LMTD method is reliable.
(3) As the weight of the heat exchanger is light enough it can be easily being suggested for more applications.
(4) The calculation of the heat transfer coefficient associated with the fluid is of great concern when such complex geometry is available.

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