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EXPERIMENTAL ANALYSIS OF PERFORMANCE CHARACTERISTICS OF MINI CHANNEL HEAT EXCHANGERS

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ABSTRACT

The development of applications requiring cooling of components in a confined space has resulted in providing wide range of studies in the field of fluid flow and heat transfer in mini channel heat exchangers. This study work deals with the experimental evaluation of effectiveness of counter flow mini channel heat exchangers for circular cross sectional geometry. The heat transfer fluids used in the mini channel heat exchanger for the purpose of transfer of heat are oil (SAE20W40) and water. Usually, low Reynolds number flow is found in the heat exchanger. The heat exchanger used in the current experiment have a hydraulic diameter of 5mm and a length of 500mm. The effectiveness of the heat exchanger with circular cross sectional geometry was found out experimentally. The Number of Transfer Units (NTU) Method is used here to calculate the rate of heat transfer, in the case when LMTD (Logarithmic Mean Temperature Difference) method cannot be used. The variation of effectiveness with Reynolds number was also made a subject of investigation while performing the experiment.

Key words: Counter Flow, Heat Exchanger, LMTD, NTU, Reynolds Number

I. INTRODUCTION

Micro and mini channel heat exchangers are generally used in the heat flux removal in microprocessor cooling, compact heat exchangers, cooling of high power electronic equipment and even compact fuel cells. Mini channel heat exchangers are mainly used in refrigeration and air conditioning sector. As per present scenario, efforts are made to improve the Co-efficient of Performance of the system, decreasing the total refrigerant charge in the system and decreasing the size of equipment.

The flow inside a mini channel is expected to be laminar flow due to small hydraulic diameter. Experimental and numerical study on a micro channel heat exchanger was done by Dang**.** The Nusselt number remains constant as the assumption of fully developed laminar flow and the heat transfer coefficient in internal flows varies inversely with channel hydraulic diameter. In his study, Agostini studied about the co-efficient of friction and heat transfer co-efficient of R134. Hasan in his study evaluated the influence of channel geometry on the performance of a counter flow mini channel heat exchanger. The friction factors, pressure gradients and heat transfer co-efficients are very high in micro channel flows because the available amount of surface area for a given flow volume is high. Use of mini channels results in decreased internal volume of heat exchangers with a notable reduction in refrigerant charge.

Counter Flow Heat Exchanger

Two fluids used in the counter flow heat exchanger flow in opposite direction to each other. The temperature difference between these two fluids remains more or less constant. Due to the flow being a counter flow, the heat exchanger gives maximum rate of heat transfer for a given surface area. So this kind of heat exchangers are most favored for the purpose heating and cooling of fluids.

II. AIM OF THE STUDY

The aim of this experimental work is to evaluate the effectiveness of the circular channel heat exchanger. The effect of Reynolds number on the effectiveness of mini channel heat exchanger is also analyzed by varying the Reynolds number of flow of hot and cold fluids used in the mini channel heat exchanger.

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III. HEAT TRANSFER ANALYSIS

The transfer of heat in heat exchanger occurs usually in the form of convection in each fluid and conduction through the wall of the tube between the two fluids. The use of mini channel heat exchanger for cooling purpose of electronic components was analised by Jemmy S. Bintoro**.** The rate of heat transfer between the two fluids used in the heat exchanger at a section in a heat exchanger depends on the value of the temperature difference at that section, which varies along the heat exchanger. Various methods for the analysis of the heat exchanger are

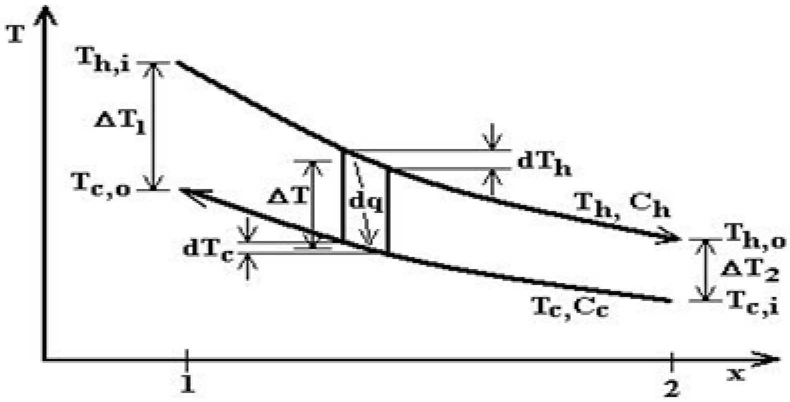

Fig. 1 Temperature Distribution in Counter Flow Heat Exchanger

LMTD Method for Heat Exchanger Analysis

Thermal analysis of any heat exchanger involves variables like inlet and outlet fluid temperatures, the overall heat transfer coefficient, total surface area and the total heat transfer rate. Since the hot fluid is transferring a part of its energy to cold fluid, there will be an increase in enthalpy of cold fluid and a corresponding decrease in enthalpy of hot fluid.

This may be expresses as,

$$q = C_h(T_{hi} - T_{ho}) = C_C(T_{co} - T_{ci})$$

Where, $C_h = mc_{ph}$ and $C_C = mc_{pc}$

Generally, the temperature difference prevailing between hot and cold fluids varies along the length of the heat exchanger and is convenient to have a logrithmic mean temperature difference ΔT_m

The heat transfer, $q = UA\Delta T_m$

Logrithmic Mean Temperature Difference (LMTD), $\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)}$

ΔT_1 *and* ΔT_2 Represent the difference of temperature between two fluids at the two ends of the heat exchanger

3.2 Effectiveness NTU Method for Heat Exchanger Analysis

This method is used for calculating the rate of heat transfer in heat exchangers when there is inadequate information to calculate logrithmic mean temperature difference. In this case,The heat transfer surface area of heat exchanger is known but the outlet temperatures of the hot and cold fluids are not known. This method is based on a dimensionless parameter which is called the heat transfer effectiveness. Heat transfer effectiveness is the ratio of actual heat transfer to maximum possible heat transfer in that heat exchanger.

$$\epsilon = \frac{q}{q_{max}}$$

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Actual heat transfer,

$$q = C_h(T_{hi} - T_{ho}) = C_c(T_{co} - T_{ci})$$

Maximum possible heat transfer in a heat exchanger is
$q_{max} = C_{min}(T_{hi} - T_{ci})$

Effectiveness, $\in = \frac{C_h(T_{hi}-T_{ho})}{C_{min}(T_{hi}-T_{ci})} = \frac{C_c(T_{co}-T_{ci})}{C_{min}(T_{hi}-T_{ci})}$ Where, $C_h = mc_{ph}$ and $C_C = mc_{pc}$

For $C_h = C_c$,

Effectiveness, $\in = \frac{(T_{co}-T_{ci})}{(T_{hi}-T_{ci})}$ q = $\in q_{max} = \in C_{min}(T_{hi} - T_{ci})$

So, the effectiveness of a heat exchanger enables to determine the heat transfer rate without knowing the fluid outlet temperatures. The effectiveness of a heat exchanger depends upon the geometry of the heat exchanger and its flow arrangement.

Then Effectiveness relation of the heat exchanger contains two dimensionless groups, Number of transfer units, also calledNTU and Heat Capacity ratio C,

NTU = $\frac{UA}{C_{min}}$

NTU is directly proportional to the Area (A), for a specified value of U (overall heat transfer co-efficient) and C_{min}. NTU represents the heat transfer surface area A. Higher is the value of NTU larger will be the heat exchanger.

In heat exchanger analysis, it is also easy to define another dimensionless quantity called capacity ratio as

$C = \frac{C_{min}}{C_{max}}$

It can be said that effectiveness of a heat exchanger is a function of value of NTU and capacity ratio

For counter flow, NTU = $\frac{1}{c-1}\ln\frac{\epsilon-1}{\epsilon C-1}$

For C = 1, NTU= $\frac{\epsilon}{1-\epsilon}$

IV. PASSIVE ENHANCEMENT TECHNIQUES

Some of the basic techniques used for passive enhancement are secondary flows, flow disruption, surface treatments, and entrance effects. Many of these techniques can be easily implemented on a micro channel or a mini channel.

V. ACTIVE ENHANCEMENT TECHNIQUES

Active techniques involve the application of external input for heat transfer enhancement in the form of power, electricity, RF signals or external pumps. Mainly used active enhancement techniques are vibration and electrostatic fields.

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VI. EXPERIMENTAL SET-UP

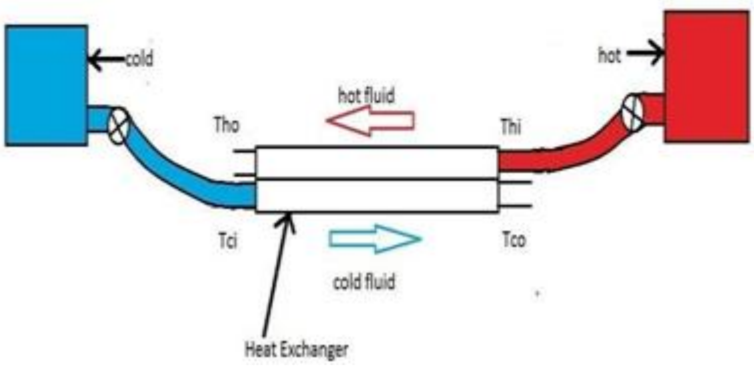

Fig.2 Schematic Diagram of Experimental Setup

Table.1 Properties of SAE20W40 oil

Thermal conductivity	**0.14W/mk**
Density	**850 kg/m^3**
Dynamic viscosity	**0.072 NS/m^2**

For the comparison of the performance of counter flow mini channel heat exchangers for circular cross sectional geometry, an experiment was designed and performed. The setup for the experiment consisted of a counter flow mini channel heat exchanger, reservoirs for cold and hot fluids, valves for cold and hot fluids, conducting tubes and collecting tanks and a data acquisition system. The heat transfer fluids used in the experiment are SAE20W40 oil and water. Counter flow heat exchanger with circular cross sectional geometry is used as the channel for fluid flow. The heat exchangers were made up of copper. Each of them is having a hydraulic diameter of 5mm and a length of 500mm. The two reservoirs having a capacity of more than three liters were used for supplying hot and cold oil. The reservoir supplying hot fluids was provided with a heater and a thermo couple. The physical properties of SAE20W40 oil is as illustrated in the table.1.

However both the reservoirs have the same head, because of the higher temperature, hot fluid has a greater Reynolds number compared to the cold fluid. The hot fluid and cold fluid both have a Reynolds number of 4. Figure 2 shows the actual set up of the experiment. The inlet and outlet temperatures of the oil supplied from the reservoir to the heat exchanger were measured by using j-type thermocouples and a Data Acquisition System (DAS). The heat exchanger surface was well insulated and the mass flow rate of oil through the heat exchanger was measured by using a measuring jar. The cold fluid was kept at ambient temperature of 303K and the hot fluid was at a temperature of 330K.The effectiveness of the counter flow mini channel heat exchangers were calculated from the temperature readings obtained from the data acquisition system.

VII. EXPERIMENTAL OUTCOME

Experimental investigation of counter flow circular mini channel heat exchanger draws attention to many details. Experimental analysis was done with inlet temperatures of the hot and cold fluid at 330K and 303K respectively. The temperatures were measured by using the data acquisition system and mass flow rate of the oil through the heat exchanger was measured by using a measuring jar. From the mass flow rate, velocity of hot and cold fluids was found out. Due to the very low mass flow rate and high viscosity, the Reynolds number was found to be very low. The Reynolds number for hot and cold fluid was 6 and 4 respectively. The effectiveness

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was calculated using the inlet and outlet temperatures of the hot and cold fluids and the value of effectiveness is 0.45. The following graphs represent how the effectiveness and NTU vary with Reynolds number.

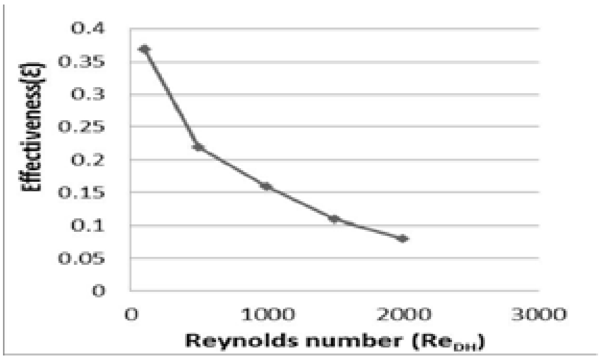

Fig.3 Variation of Effectiveness with R_e

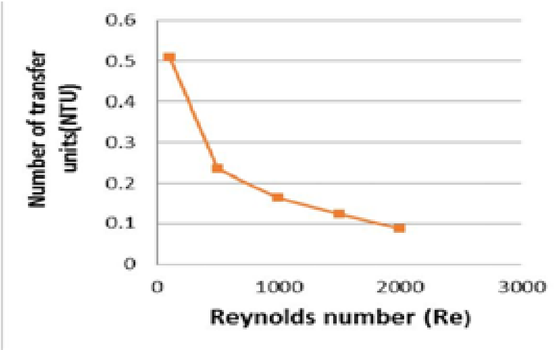

Fig.4 Variation of NTU with Reynolds Number

VIII. CONCLUSION

The effectiveness of counter flow mini channel heat exchangers with circular cross section was determined by performing the experiment. The study on the variation of effectiveness with change in the value of Reynolds number was done and it was found that effectiveness values are higher for the lower values of Reynolds number and it decreases with an increase in Reynolds number. A comparison between water and SAE20W40 oil was made and it was found that water served as a better heat transfer fluid than oil. Still oil will remain as a better option at higher temperatures at which water will vaporize

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