International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 08 | Aug -2017 www.irjet.net p-ISSN: 2395-0072

Experimental Investigation on heat transfer of cylindrical oblique fin micro-channel heat exchanger for Automobile Engine cooling system

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Abstract - *Today, demand of automobile vehicles has been increased tremendously. Micro channels have been used in electronics cooling and in air conditioning applications as condensers. Few studies have been done in the application of micro channels in automotive heat exchangers, particularly the radiator. The presents work focuses on experimental study of innovative water cooling system of motorcycle using cylindrical oblique fin micro channel heat exchanger. The experiments were carried out on test rig. To determine heat transfer coefficient, effectiveness between Straight & oblique fin micro channel heat exchanger for various flow rates .The results show that the heat transfer efficiency obtained from the 12°oblique fin micro channel higher than Straight fin micro channel heat exchanger. The size of alternative micro channel heat exchanger radiator is reduced, made it easy to manufacture, and cut down its cost compared than conventional liquid coolers utilize a radiator type arrangement which requires considerable space, volume and weight. The obtained results are in good agreement with relevant studies.*

***Key Words*: Micro channel, radiator, heat exchanger, engine cooling**

1. INTRODUCTION

Todays, demand of automobile vehicles has been increased tremendously. There is a lot of competition existing between automobile industries. Therefore, it's a great challenge for automotive industries to provide an efficient and economical engine. There are various factors affecting the efficiency of engine namely, fuel supply systems, Lubrication system, Transmission system, Cooling system, Climatic conditions, Size of cylinder head, Ignition timing. In case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases is a very high as 2000 to 2500°c.

1.1 Effect of overheating of engine component

- Film of the lubricating oil will get oxidized, thus producing carbon deposits on the surface.
- Burning of oil film between the moving parts and this will result leading to piston seizure and piston scuffling
- Setting of thermal stresses in piston and cylinder.
- Sticking of piston rings in grooves.

1.2 Necessity of cooling system

To avoid overheating and effects of it mentioned above, the heat must be removed from engine components and transferred to atmosphere. Maximum cooling is also not required as it reduces the thermal efficiency. Thus, the objective of cooling system is to maintain engine running at its most efficient operating temperature. There are two types of cooling system, air cooling system and water cooling system. In case of two-wheeler, engine cooling is done with air cooling system and now the advent super bikes having engine capacity over a 200cc uses water cooling system using radiator. Almost all radiators are placed at the front-most position of the vehicle so as to maximize the airflow across the radiator as the vehicle is moving, for removing the most heat possible from the engine. The Radiator arrangement requires considerable space, volume and weight. The flat surface of the radiator results into maximum air resistance. Now there is motivation to reduce the size of automotive radiators primarily to reduce the pressure drag caused by a large flat frontal area. Thus, there is need of another innovative method like micro channel heat exchanger for cooling of liquid to increase the efficiency and reduce the size of radiator in engine cooling system.

1.3 Research Objectives

1. Design and Fabrication of cylindrical oblique fins and straight fins micro-channel heat exchanger & Development of test rig to evaluate performance of individual heat exchanger set up.
2. To investigate heat transfer performance, Analysis and testing of cylindrical oblique fins and straight fins micro-channel heat exchanger
3. Thermal analysis of heat exchanger modules using ANSYS
4. Comparative experimental study of heats exchanger setups following parameters: Overall Heat transfer coefficient, Heat extraction ability, Effectiveness and Pressure Difference (ΔP)
5. Plot comparative graphs of above parameters under various air flow rates & water flow rates

2. Literature review

D. B. Tuckerman and Pease first introduced the concept of micro channel heat sink. They proposed & demonstrated that use of micro channel is effective method for dissipation of heat for silicon integrated circuits. Micro channels have a much higher heat transfer surface area to fluid volume ratio. As the hydraulic diameter decreases in a micro channel, the heat transfer coefficient increases, providing an excellent cooling mechanism. They offer several advantages such as high convective heat transfer coefficient, ease of implementation, compactness, lightweight, higher surface area to Volume ratio and small coolant inventory requirement [1], Gus Thomas Checketts and Yong X. Tao investigated the micro channel technology with applications in heavy-duty automotive radiator heat exchangers. The presented research captures the need for the design improvement of radiator heat exchangers in heavy-duty vehicles in order to reduce aerodynamic drag and improve fuel economy. [2]. Lee, Y. J., Lee, P. S., P. K. Singh Were Investigated heat transfer rate & pressure drop analysis across the flow of fluid in oblique micro channel heat exchanger. They concluded that silicon based enhanced oblique micro channel have maximum heat transfer performance enhancement [3]. Yan Fan, Poh Seng Lee, Li-Wen Jin, Beng Wah Chua was considered that, novel cylindrical oblique fin micro channel mounted on a cylindrical heat source like an enveloping jacket. Due to this periodic cylindrical oblique fin construction, a hydrodynamic boundary layer developed at the leading edge of the next downstream fin. Results in decrease the average thermal boundary layer thickness, increase the heat transfer performance [4].

3. DESIGN AND DEVELOPMENT OF SYSTEM

Fig-1: Micro channel heat exchangers Parts & Assembly

The cylindrical oblique micro channel heat exchanger consists of a hollow inner pipe of aluminium through which the hot water is passed. Fin holder is placed inside outer casing pipe and water flows in annular spacing between inner pipe and outer casing pipe. The hot water is in contact with bent aluminium fins held in slots of FDM fin holder. The arrangement of fins is done such that maximum surface area is achieved in minimum space. Micro channel is fixed on base plate.

Total no of fins used =48, Size of fin → length= 30 mm, Width = 12 mm, thickness = 0.8 mm.
Diameter of inner pipe =25 mm
Diameter of outer casing pipe =40 mm
Height of channel =120 mm,
Diameter of FDM fin holder =35 mm,
Diameter of base plate=110 mm

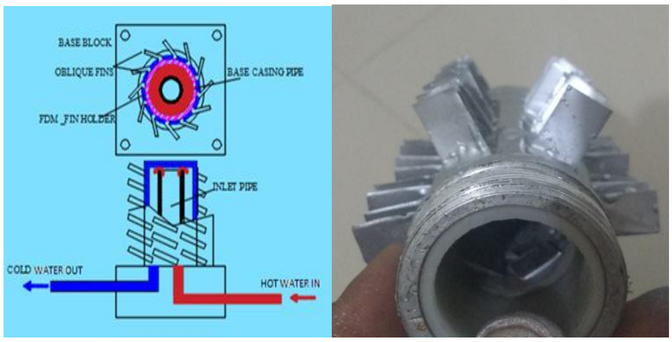

Fig-2: Schematic & Actual Photograph of Micro channel

3.1 Details of the individual fin structure modules

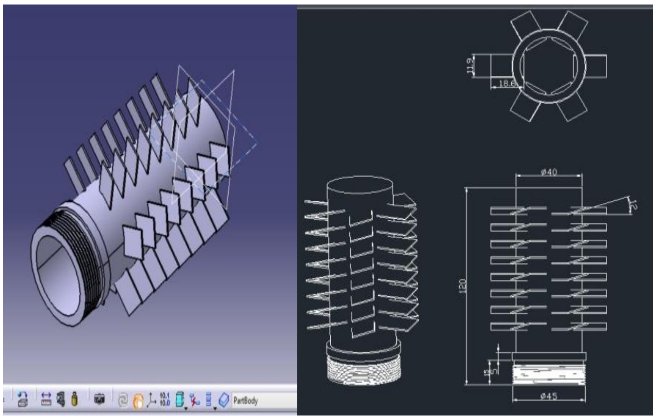

Fig-3: Oblique fin micro channel heat exchanger with 12° fin angle

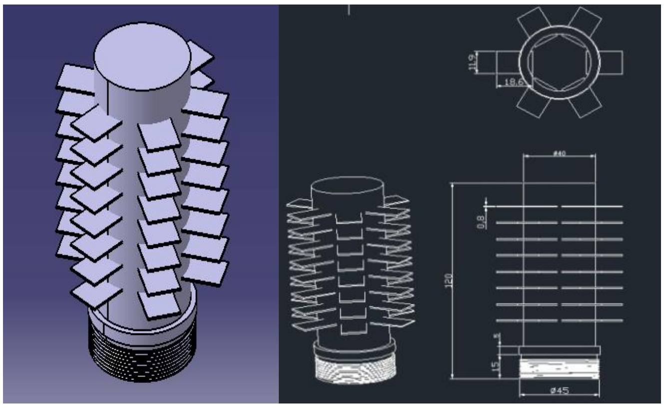

Fig-4: Straight fin micro channel heat exchanger

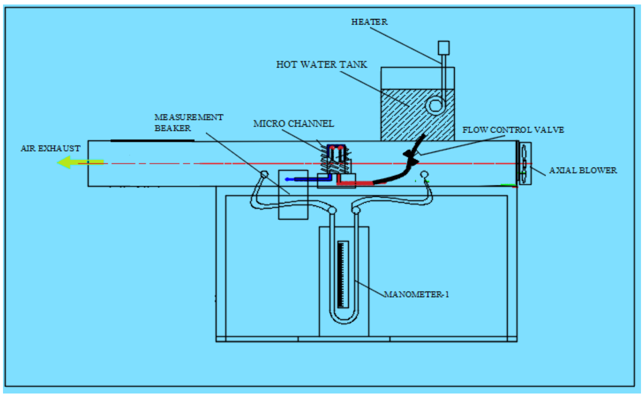

Fig -5: Schematic sketch of experimental set-up

The experimental set-up primarily consists of Hot water tank, Air duct, supporting frame. Inside the Air duct oblique fin micro channel heat exchanger is fitted on the base plate which is fixed. U tube manometer is fitted below the Duct to measure the pressure difference across test model. The axial blower is takes cold air in the Air duct and discharges it in axial direction. This cold air is then directed on to the Oblique fin micro channel, where heat is transferred from channel to atmospheric air. Cylindrical Micro channel heat exchanger consists of Inner pipe, outer casing pipe, FDM fin holder on which fins are staggered in slots.

3.2 Experimental procedure for trial

1. Heat the water in the tank by using heater up to desired temperature, and then shut down the heater.
2. Measure the temperature of water by using temperature indicator and confirm it is at required level.
3. Start axial blower fans.
4. Start water flow by using valve and adjust the specific flow rate of water by using flow control valve.
5. Take mass flow readings of water by using beaker and stopwatch. Collect the water at outlet and measure time for the specific volume of water.
6. Measure temperature of cold water after drawn out from test model by using temperature indicator.
7. Take temperature readings of air before blow on the fins and after blow on the fins.
8. Measure the height difference in U-tube Manometer.
9. Repeat above procedure for all tests Model heat by varying the flow rate of air in axial blower.

4. OBSERVATION

Table-1: Mass Flow Rate of Water for Straight fin micro-channel

Sr. No	Volume in Beaker (ml)	Time (Sec)	Mass Flow Rate (Kg/sec)
1	200	31	0.006355
2	200	26	0.007577
3	200	21	0.009381
4	200	19	0.010368
5	200	17	0.011588

Table-2: Mass Flow Rate of Air for Straight fin micro-channel

Sr. No	Velocity of Air m/s	Volume flow Rate m3/s	Mass Flow Rate (Kg/sec)
1	3.26	0.073280	0.089768
2	3.79	0.085367	0.104575
3	4.57	0.102743	0.125860
4	5.15	0.115837	0.141901
5	6.04	0.135983	0.166579

Table-3: Temperature Readings of Water and Air for Straight fin micro channel

Sr. No.	Cold air Inlet Temp. (T_{ci}) ⁰C	Cold air outlet Temp (T_{co}) ⁰C	$(\Delta T)_C$ Air ⁰C	Hot Water Inlet Temp. (T_{hi}) ⁰C	Hot water outlet Temp. (T_{ho}) ⁰C	$(\Delta T)_H$ Water ⁰C
1	28	32	4	70	56	14
2	28	32.5	4.5	69	53	16
3	28	33.5	5.5	70	52	18
4	29	35.2	6.2	69	46	23
5	29	36	7	70	44	26

Table-4: Result Table for Various Performance Parameters for Straight Fin Micro channel

SR. NO.	mCpΔT (Hot water) KW	mCpΔT (cold Air) KW	LMTD	Overall Heat Transfer Coefficient U (W/m^2k)	Effectiveness
1	0.371707	0.360866	32.457	97.88289	0.333333
2	0.506502	0.472939	29.985	144.3748	0.390244
3	0.705485	0.69569	29.24	206.217	0.4285
4	0.996343	0.884184	23.409	363.7811	0.575
5	1.258807	1.171885	21.786	493.8508	0.634146

Table-5: Mass Flow Rate of Water for 12° Oblique fin micro-channel

Sr. No	Volume in Beaker (ml)	Time (Sec)	Mass Flow Rate (Kg/sec)
1	200	21	0.006452
2	200	18	0.007692
3	200	15	0.009524
4	200	12	0.010526
5	200	17	0.011765

Table-6: Mass Flow Rate of Air for 12° Oblique fin micro-channel

Sr. No	Velocity of Air m/s	Volume flow Rate m3/s	Mass Flow Rate (Kg/sec)
1	3.26	0.073280	0.089768
2	3.79	0.085367	0.104575
3	4.57	0.102743	0.125860
4	5.15	0.115837	0.141901
5	6.04	0.135983	0.166579

Table-7: Temperature Readings of Water & Air for 12° oblique fin micro channel

Sr. No.	Cold air Inlet Temp. (T_{ci}) °C	Cold air outlet Temp (T_{co}) °C	$(\Delta T)_C$ Air °C	Hot Water Inlet Temp. (T_{hi}) °C	Hot water outlet Temp. (T_{ho}) °C	$(\Delta T)_H$ Water °C
1	28	34	6	70	48	22
2	28	35.5	7.5	69	44	25
3	28	36.5	8.5	70	42	28
4	28.5	37.3	8.8	69	39	30
5	28.5	38.5	10	70	37	33

Table-8: Result Table with Various Performance Parameters 12° oblique fin micro channel

SR. NO.	mCpΔT (Hot water) KW	mCpΔT (cold Air) KW	LMTD	Overall Heat Transfer Coefficient U (W/m²k)	Effectiveness
1	0.593042	0.541299	26.374	192.1868	0.52381
2	0.803429	0.788232	22.246	308.681	0.60976
3	1.114	1.075158	20.33	468.44	0.6666
4	1.319329	1.254971	16.2	696.0688	0.74074
5	1.622088	1.674121	15.48	895.607	0.79518

Table-9: Pressure Drop Readings in U-tube Manometer across Micro channel

Sr. No.	Straight Fin Micro channel Pa	Oblique Fin Micro channel 12° Pa
1	29.4199	4.9033
2	39.2266	9.8066
3	44.1299	11.7679
4	44.1299	12.7486
5	49.0332	14.7099

5. RESULT AND DISCUSSIONS

5.1 Experimental Results

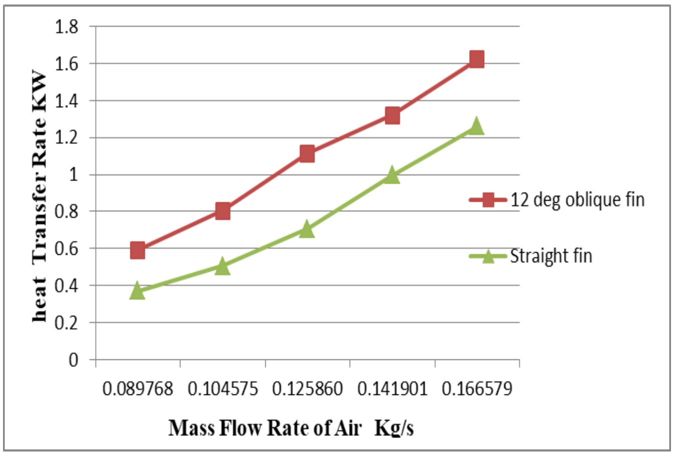

Chart -1: Effect of Mass Flow Rate on Heat Transfer Rate

From chart 1, it is observed that rate of heat transfer is increses with increse in mass flow rate of air.Maximum heat transfer rate is observed in oblique fin micro channel heat exchanger.

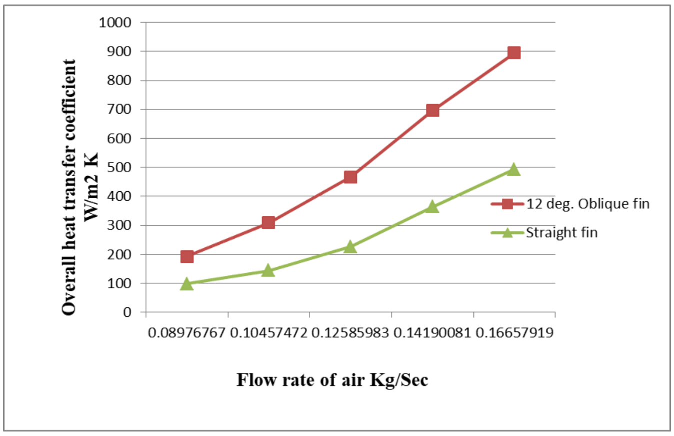

Chart -2: Effect of Mass Flow Rate on Overall Heat Transfer Coefficient

From Chart 2, it is observed that overall heat transfer coefficient increases with increasing mass flow rate. Maximum overall heat transfer coefficient is 895 W/m^2 K for 12^0 Oblique fin micro channels.

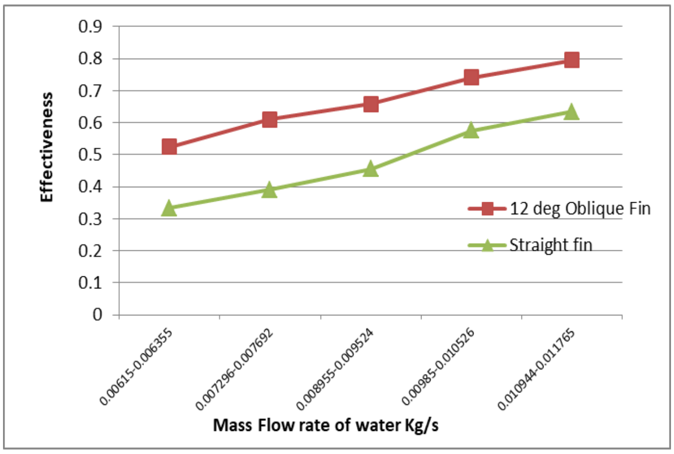

Chart -3: Effect of Mass Flow Rate on Effectiveness

From Chart 3, it is observed that effectiveness increases with increasing mass flow rate. Maximum Effectiveness is 0.79 for 12^0 Oblique fin micro channels.

5.2 Thermal analysis results

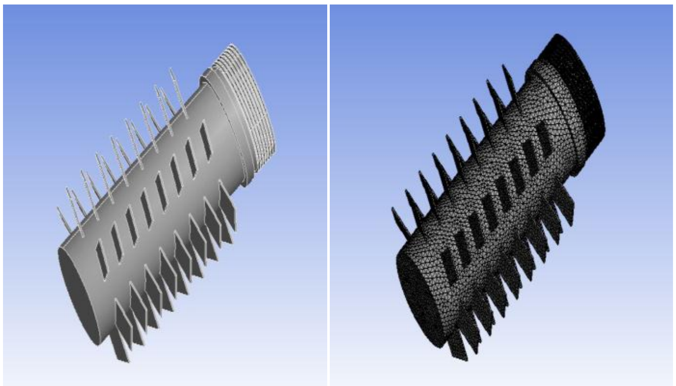

Fig-6: Computational Domain and unstructured tetrahedral meshing for Simulation of oblique fin micro channel

From Fig.6, No of Nodes = 159581 , No of Elements=90451

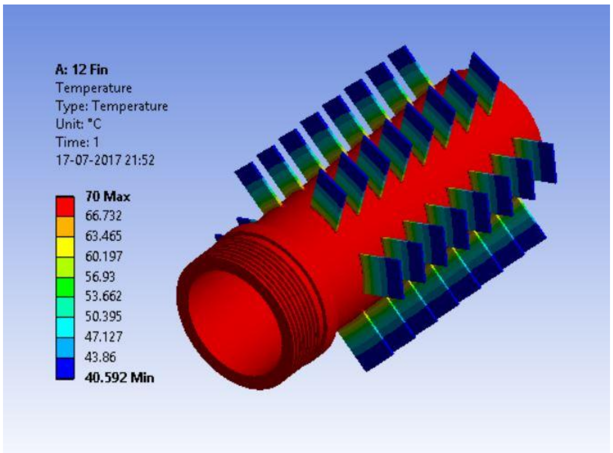

Fig-7: Temperature variation Contour for 12^0 oblique fin micro channel.

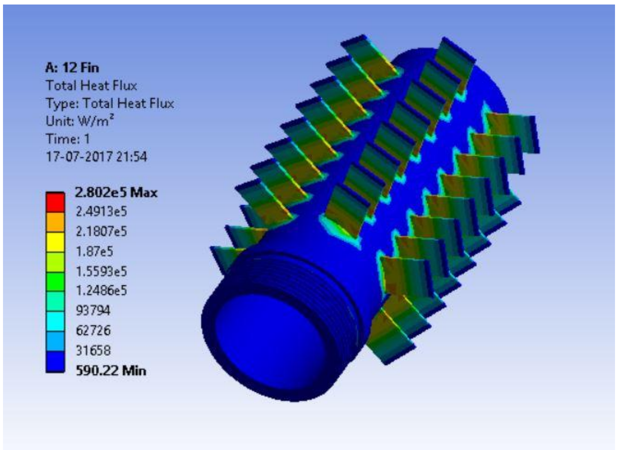

Fig-8: Heat Flux variation Contour for 12^0 oblique fin micro channel.

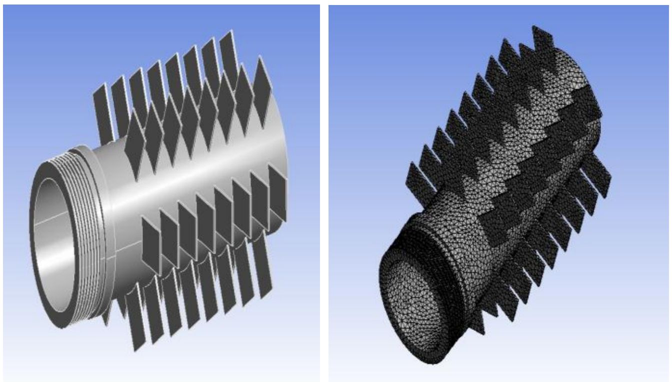

Fig-9: Computational Domain and unstructured tetrahedral meshing for Simulation of Straight fin micro channel

From Fig.9, No of Nodes = 159750 , No of Elements=90593

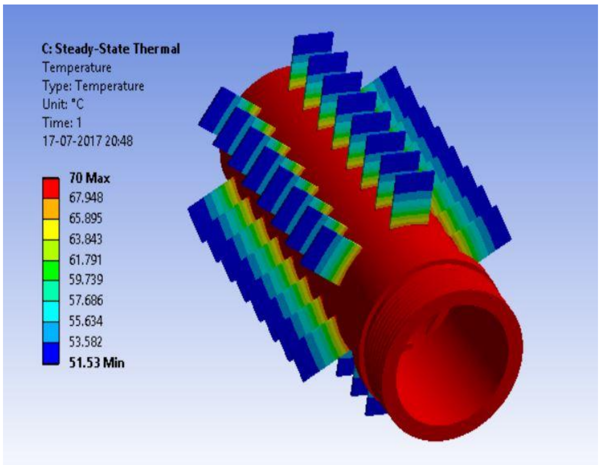

Fig-10: Temperature variation Contour for Straight fin micro channel

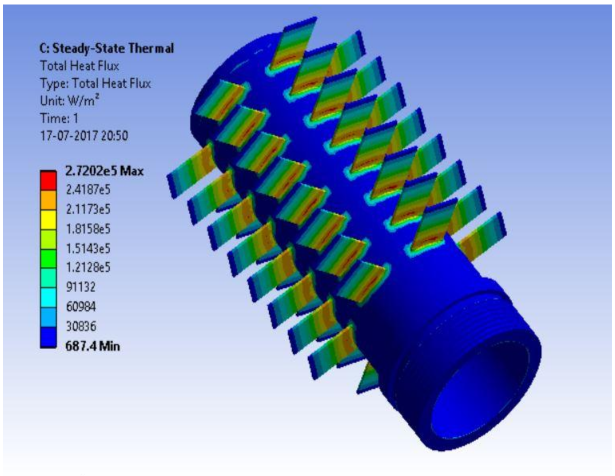

Fig-11: Heat Flux variation Contour for Straight fin micro channel.

Table-10: Comparison Temperature Reading of Experimental and ANSYS Result

Test Model	Experimental Results				ANSYS Results			
	Hot Water		Cold Air		Hot Water		Cold Air	
Temp. in 0 C	Max	Min	Max	Min	Max	Min	Max	Min
12^0 oblique fin micro channel heat exchanger	70	42	28	36.5	70	40.5	28	36.5
straight fin micro channel heat exchanger	70	52	28	33.5	70	51.5	28	33.5

Table-11: Comparison of Experimental and ANSYS Result

Test model	12^0 oblique fin micro channel heat exchanger		straight fin micro channel heat exchanger	
Performance Parameters	Experimental	ANSYS	Experimental	ANSYS
Temperature Difference(ΔT_H)	28	29.5	18	18.5
Log Mean Temperature Difference LMTD	20.33	19.01	29.24	28.93
Heat Transfer Rate KW	1.114	1.173	0.7054	0.7245
Overall Heat Transfer Coefficient (U)	468.4	500.1	206.21	214.04
Effectiveness	0.6666	0.702	0.4285	0.4404

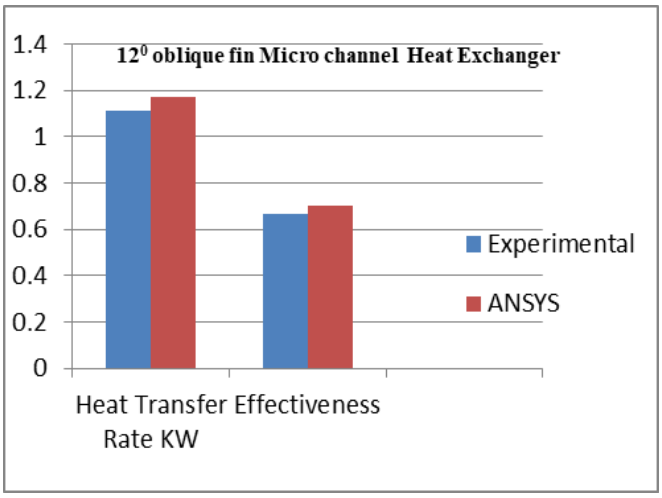

Fig-15: Comparison of Heat Transfer Rate and Effectiveness

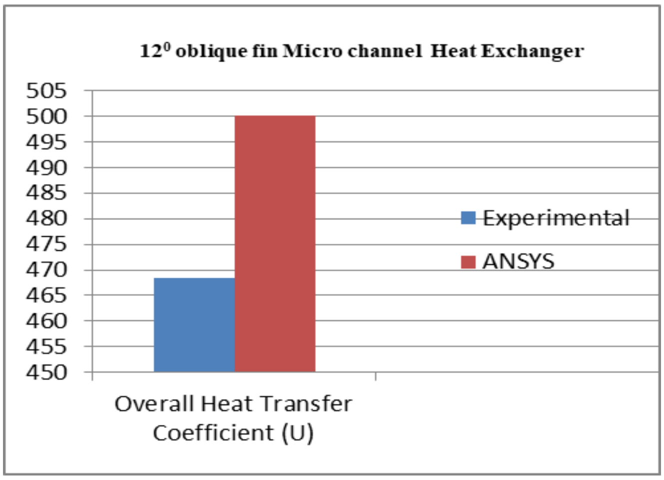

Fig-16: Comparison of Overall Heat Transfer Coefficient

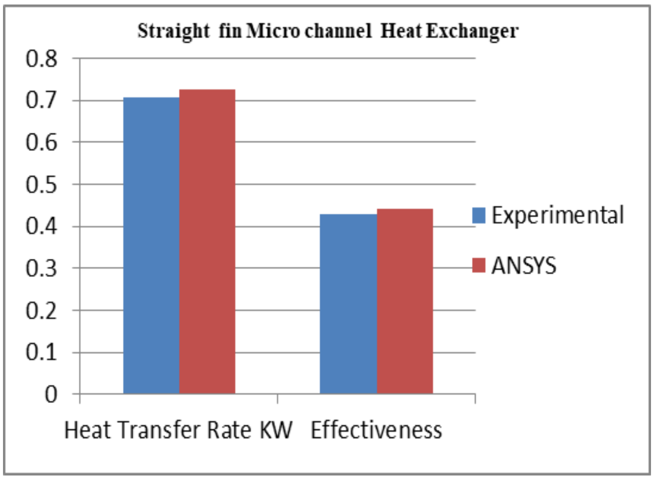

Fig-18: Comparison of Heat Transfer Rate and Effectiveness

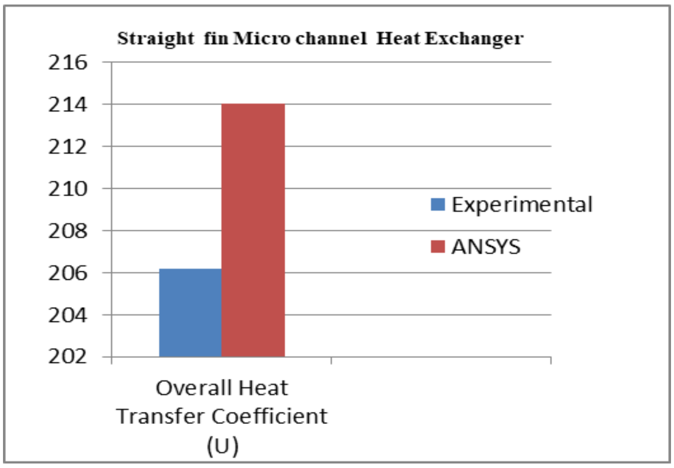

Fig-19: Comparison of Overall Heat Transfer Coefficient

Discussion:

Thus the ANSYS Results is calculated for 12^0 oblique fin and straight fin Micro channel Heat Exchanger.The heat released from 12^0 oblique fin Micro channel Heat Exchanger is 1.173Kw and that from straight fin Micro channel Heat Exchanger is 0.7245 kw which is less when compared with 12^0oblique fin Micro channel .Whereas experimental Results is 1.114 kW for 12^0oblique fin Micro channel and 0.7054 kW for straight fin Micro channel. Therefore, range of variation is within 10% .Hence Results are validated. The temperature variation contour of both the micro channel has shown in fig.7 and fig.10 ,it is seen that the maximum and minimum temperature for 12^0 oblique fin Micro channel and straight fin have entered in the Table-10 which is simulated from the ANSYS Workbench result. Comparative graphs of Experimental and Ansys results are plotted for both heat exchanger .Hence; it is observed that 12^0 oblique fin Micro channel gives better heat transfer rate compared with that of straight fin Micro channel Heat Exchanger.

6. CONCLUSIONS

- A novel cylindrical oblique fin micro channel heat exchanger was proposed to engine cooling system for reducing size & increase heat transfer rate.
- In this research work, experimental study has been carried out to find heat transfer characteristic of micro channel heat exchanger.
- In this system effectiveness is increased with increasing the mass flow rates. Maximum effectiveness observed is 0.795 for 12^o Oblique fin micro channel. This indicates that the oblique fin micro channel heat exchanger is more efficient at higher mass flow rates as compared to straight fin micro channel heat exchanger.
- The Overall heat transfer coefficient for 12^o Oblique fin micro channel is also increases by 78% with increase in mass flow rate it means heat transfer capability increases with in mass flow rate.
- Analysis has been done by varying the fin angle and it is found that 12^0 oblique fin Micro channel gives the better heat transfer rates than the straight fin Micro channel Heat Exchanger.
- Since air flows smoothly over oblique fins so that rate heat transfer is improves slightly compared with straight fins channel.
- Rate of heat transfer can be improved by varying the Fin angle, fin pitch, fin length, total no of fins etc.
- By changing the materials of micro channel, heat transfer rate can be improved.
- By changing the mass flow rate of fluid, rate of heat transfer can be improved.
- By changing the inlet temperature and medium used in heat exchanger, rate of heat transfer can be improved.
- As oblique fin geometry allows less pressure drop & oblique angle provide more effective permitted area for effective heat transfer.
- The results obtained from experimental set up and analytical software is close to each other.
- The proposed oblique fin heat exchanger will reduce the size of cooling system as compared to conventional radiator ultimately reduce frontal area & weight of radiator and increases the fuel economy by reducing air resistance.

REFERENCES

1. D. B. Tuckerman and R. F.Pease, “High-Performance Heat Sinking for VLSI”, IEEE Electronic. Device Letters. Vol. EDL-2, pp. 126–129, 1981.

2. Checketts Gus Thomas 2014 “Microchannel Radiator: An Investigation Of Microchannel Technology With Applications In Automotive Radiator Heat Exchangers “ Master of Science Thesis, University of North Texas

3. Y.J. Lee, P. K. Singh , P.S. Lee, Fluid flow and heat transfer investigations on enhanced microchannel heat sink using oblique fins with parametric study , International Journal of Heat and Mass Transfer 81 (2015) ,pp. 325–336

4. Yan Fan, P.S. Lee, Li-Wen Jin, Beng Wah Chua, A simulation and experimental study of fluid flow and heat transfer on cylindrical oblique-finned heat sink, International Journal of Heat and Mass Transfer 61 (2013) ,pp. 62–72.

5. Yan Fan, PohSeng Lee, Li-Wen Jin, BengWah Chua, Experimental investigation on heat transfer and pressure drop of a novel cylindrical oblique fin heat sink, International Journal of Thermal Sciences 76 (2014) pp.1-10.

6. Prof. A U. Pimpalkar, Miss. D U. Pimpalkar, Miss R S. Rathod Prof. S P. Bhivagade. "Advance Water Cooling System In Two-Wheeler Bike Engine: Case Study" International organization of Engineering Research & Development Journal (IOERD) ISSN: 2455-9075,Vol.1 ,Issue 2 May 2016

7. Yan Fan, PohSeng Lee, Li-Wen Jin, BengWah Chua,A simulation and experimental study of fluid flow and heat transfer on cylindrical oblique-finned heat sink, International Journal of Heat and Mass Transfer 61 (2013) ,pp. 62–72.