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Investigate the wall conduction effect on Smooth Trapezoidal V fin and tube type compact heat exchanger using Numerical and Experimental technique

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Abstract

Heat exchanger units are types of equipment, from which the user expects an energy saving and reliable operation with minimum maintenance problems. One aspect of the hydraulic system design is prevention of overheating of the hydraulic oil. Heating of hydraulic fluid in operation is caused by inefficiencies.The NTU and LMTD methods are based on the idealization of zero longitudinal heat conduction in the wall in the fluid flow direction. When heat transfer takes place in heat exchanger, at the one stage, the temperature distribution flattens due to longitudinal conduction. It reduces the mean outlet temperature of cold fluid and increases the mean outlet temperature of hot fluid which results in reduced thermal effectiveness. Project aims at design development of oil cooling heat exchanger with a single pass three copper tube design where in oil to air heat exchange will be done using copper fins bent either in the sharp v- bents or smooth trapezoidal bents which will bridge the gap between two copper pipes. The flow of air over these fins will achieved by application of axial blower. The objective of project will be to determine the temperature gradient of oil(ΔT) , pressure drop across fins, Overall heat transfer coefficient , Heat dissipation from heat exchanger in watt/hr , and effectiveness of heat exchanger at various mass flow settings of oil .The Project work is embodied as to the determination of heat load of system and development of mathematical model to determine the capacity of the heat exchange system and selection of size and number of pipe modules for fractional heat load.

KEYWORDS: Heat exchanger, sharp v bent fins, smooth trapezoidal bent fins .

1. Introduction

The NTU and LMTD methods are based on the idealization of zero longitudinal heat conduction in the wall in the fluid flow direction. When heat transfer takes place in heat exchanger, at the one stage, the temperature distribution flattens due to longitudinal conduction. It reduces the mean outlet temperature of cold fluid and increases the mean outlet temperature of hot fluid which results in reduced thermal effectiveness. After careful review of literature available analogous to the above stated problem it was found that diversified solutions are available to solve the overheating problem or effective heat transfer in devices but no dedicated oil cooler is not available, hence there is a need to develop one such device as a hydraulic oil cooler with help of compact heat exchanger and different arrangement of fins. The research work will propose, develop, design and analyze the performance of one such system with smooth trapezoidal Vfin structure.
Research aims at design development of oil cooling heat exchanger with a single pass three copper tube design where in oil to air heat exchange will be done using copper fins bent in smooth trapezoidal bents which will bridge the gap between two copper pipes. The flow of air over these fins will achieved by application of axial blower. The objective of research will be to determine the temperature gradient of oil (ΔT), pressure drop across fins,Overall heat transfer coefficient, Heat dissipation from heat exchanger in watt/hr, and effectiveness of heat exchanger at various mass flow settings of oil.
The Research work is embodied as to the determination of heat load of system and development of mathematical model to determine the capacity of the heat exchange system and selection of size and number of pipe modules for fractional heat load .Design and validation of the heat transfer ability of fin structures using ANSYS .Fabrication of heat exchanger with smooth trapezoidal bent fin modules .PID development for cross flow of oil through the cooling system with oil to air cooling by election of appropriate blower mechanism .Development of test rig with overheating conditions analogous to 0.8 HP power pack., Testing of the heat exchanger system enhanced cross flow hydraulic oil cooler on test rig to determine the performance parameters of the heat exchanger.

2. Literature Review

In thermal hydraulic performance of a compact heat exchanger having rectangular wavy fins and two Row of circular tubes [3] A numerical approach was used and the computational domain was implemented using symmetry and periodic condition were considered extended inlet and outlet section for accuracy. The impinging flow on the fin surface was found responsible for the differences between the heat transferred at every

side of the fin. The differences disappearing when the average value was calculated.
(Rubén Borrajo-Pérez et all.)
In Performance Evaluation of Plate-Fin-And Tube Heat Exchanger with Wavy Fins [1] has seen thatThe wavy surface can lengthen the path of airflow and cause better airflow mixing. In order to design better heat exchangers and come up with efficient designs, a thorough understanding of the flow of air in these channels is required. Hence author has been focused on the heat transfer and friction characteristics of the air side for wavy fin and tube heat exchange.(Sandip S. Kale, V.W.Bhatkar et all)
When the airside heat transfer and friction characteristics of 14 enhanced fin-and-tube heat exchangers with hydrophilic coating had experimented under wet conditions [5] the effects of number of tube rows, fin pitch and inlet relative humidity on airside performance are analyzed.The result of this experiment had shown that The test results show that the influences of the fin pitch and the number of tube rows on the friction characteristic under wet conditions are similar to that under dry surface owing to the existence of the hydrophilic coating.(XiaokuiMaa,et all)

3. Gap in Literature

After careful review of literature available analogous to the above stated problem it was found that diversified solutions are available to solve the overheating problem or effective heat transfer in devices but no dedicated oil cooler has analyzed for calculating the wall conduction effect using smooth trapezoidal fin structure, hence there is a need to develop one such device as a hydraulic oil cooler with help of compact heat exchanger and different arrangement of smooth trapezoidal fins. The research work will propose, develop, design and analyze the performance of one such system with smooth trapezoidal fin structure.

4. Experimental Methodology

Oil to air heat exchanger with single pass, three copper tube designs, lined with smooth trapezoidal shape fins with an axial blower to solve over-heating problems.
The concept of the bent fin heat exchanger hydraulic cooler is an oil to air cooler that uses smooth trapezoidal bent fin modules with an axial blower system as shown in figure below:

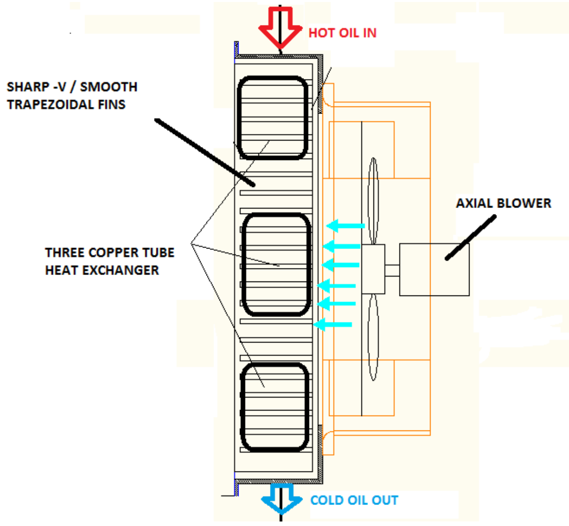


Fig 1.General Arrangement of Heat Exchanger and Cooling Fan

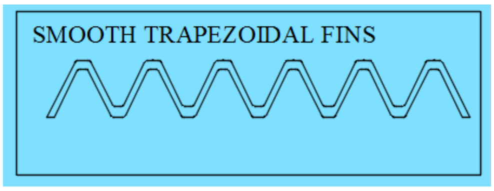


Fig2. Smooth Trapezoidal wavy fin module

Working

Hot oil enters into the heat exchanger through the top copper tube which slightly flattened to fit the fins, then it passes to central tube by diversion of path at right angles and finally through the outer tube to exit cooled oil for reuse in the power pack. Cross flow heat exchanger from oil to air is achieved by passing air over the fins arranged in between the top- central tube and Central- bottom tube. The in arrangement will be as Smooth Trapezoidal Bent shapes. The axial blower is 230-volt AC blower that takes cold air in the system axial and discharges it in axial direction. This cold air is then directed on to the wavy fins mounted on the heat exchanger modules. The oil cooler takes in hot oil with help, of hydraulic pump whereas the cold oil from the oil cooler is discharged back to the oil tank in case of power packs. The oil cooler can be mounted externally to the oil tank system thereby ensuring contamination free operation as the oil tank be sealed.

The enhanced fin heat exchanger has the facility of single modules

Fig3 (a) Experimental Set Up

Fig3 (b) Heat in Exchanger in Duct

5.General Equations

1) Mass Flow Rate of oil

$$(Volume / (Time \times 1000)) \times 0.913$$

Where, Specific gravity= 0.913

2) Heat Transfer rate by oil

$$m \times 1.7 \times \Delta T$$

Where, m=Mass Flow Rate of oil
Specific Heat of Oil= 1.7

3) Heat Transfer rate by air

$$m \times 1.005 \times \Delta T$$

Where, m= Mass Flow rate of Air
Specific Heat of water=1.005

4) Overall Heat Transfer Coefficient U

$$U = ((m \times 1.7 \times 1000) \times 1000 / (0.14 \times \Delta Tair))$$

6. Observation tables

Heat Transfer rate by Oil and Air

Table 1

Volume of oil	Time (Sec)	Kg/Sec	Inlet Temp (T1)	Outlet Temp (T2)	ΔT
50	48	0.000951	80	68	12
50	39	0.001171	80	66.5	13.5
50	31.5	0.001449	80	63.2	16.8
50	25	0.001826	80	59.8	20.2
50	22	0.002075	80	56.7	23.3
50	18	0.002536	80	55.4	24.6

Table 2

Mass of air	Time (Sec)	Inlet Temp (T1)	Outlet Temp (T2)	ΔT
0.145666	48	28.5	32.5	4
0.123816	39	28.5	33.8	5.3
0.105967	31.5	28.5	34.2	5.7
0.075229	25	28.5	34.9	6.4
0.064945	22	28.5	35.3	6.8
0.054361	18	28.5	36	7.5

Table 3

Heat Transfer rate for Oil	Heat Transfer rate for Air	Overall Heat Transfer Coefficient (U)
0.019401	0.58558	34.64504
0.026863	0.65951	36.20387
0.041389	0.60703	51.86633
0.062705	0.48388	69.98308
0.082191	0.43700	86.33482
0.10606	0.40975	101.0097

7. Result and Discussion

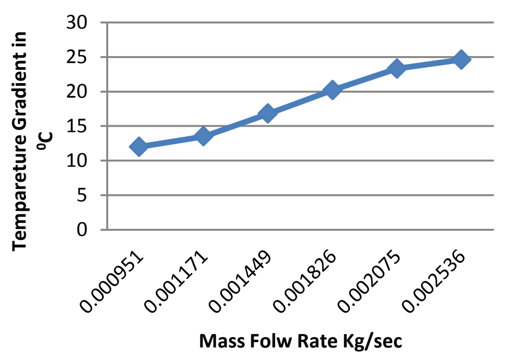


Fig 4.Mass Flow rate of oil Vs Temperature Gradient of oil

Fig4 shows temperature gradient of oil gets increases as increase in mass flow rate of air.

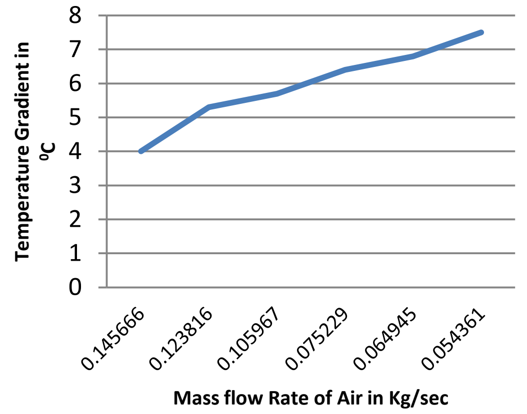


Fig5. Mass Flow Rate of Oil Vs Temperature Gradient

Fig5 shows temperature gradient of air gets increases as decrease in mass flow rate of oil.

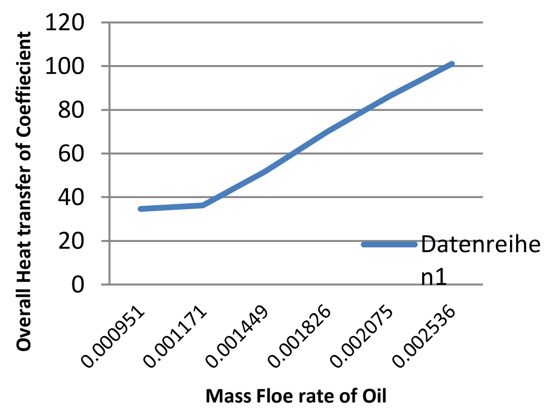


Fig6. Mass Flow rate of Oil Vs U

FIh6 shows overall heat transfer coefficient get increases as increase in mass flow rate of oil.

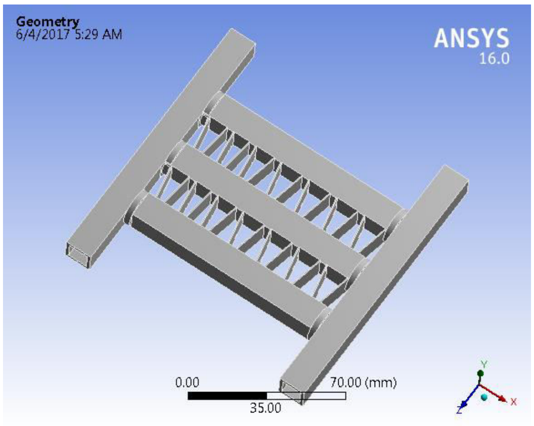
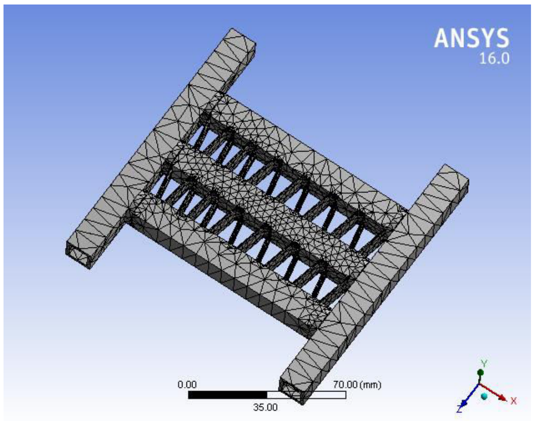


Fig7. Geometry of wavy fin and tube type compact heat exchanger

Fig7 shows the geometry of wavy fin and tube type compact heat exchanger. The modeling of the set up was done using Unigraphix Nx-8 and the step203 file was used as the exchange file for importing model geometry into ANSYS work bench. Materials were defined to be copper alloy with corresponding properties.



Statistics	
Nodes	32658
Elements	17435
Mesh Metric	None

Fig8. Heat exchanger Geometry with Nodes,Elements and Mesh Metric

Fig8.showsthe geometry imported into workbench was then meshed using ANSYS workbench free meshed with the meshing displaying 32658 nodes and 17435 elements , here relevance of the mesh structure was set to zero and medium size meshing was used.

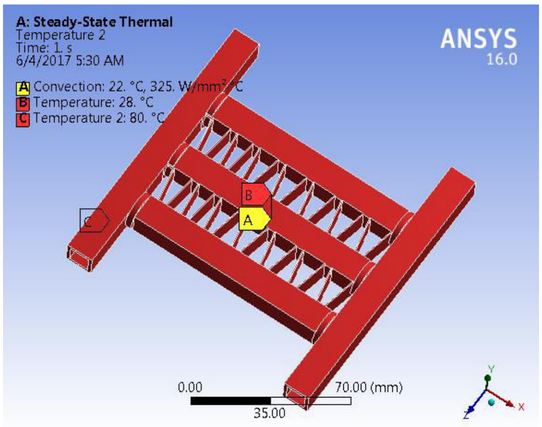


Fig9.Steady State Thermal Temperature 2

Fig9. Shows the loading diagram of the fin structure depicts the boundary conditions where in the overall body being made of copper alloy is given a convection of 325 w/m2k for the given material where as the outside surface of the heat exchanger is in contact with ambient air which is at 28 degrees and th hot oil inside the structure is at 80 degrees . This loading has been done analogous to the conditions of the device in the test rig set up

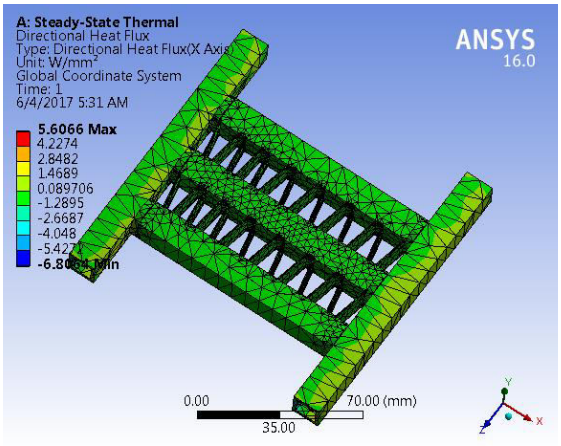


Fig10. Steady State Thermal-Directional Heat Flux X-Axis

Fig 10 shows the figure above shows the directional heat flux in x-axis considering that the entry oil takes place from left to right , the maximum heat flow in that direction is 5.606 watt and minimal seen from surface indicators to be 0.08 watt.

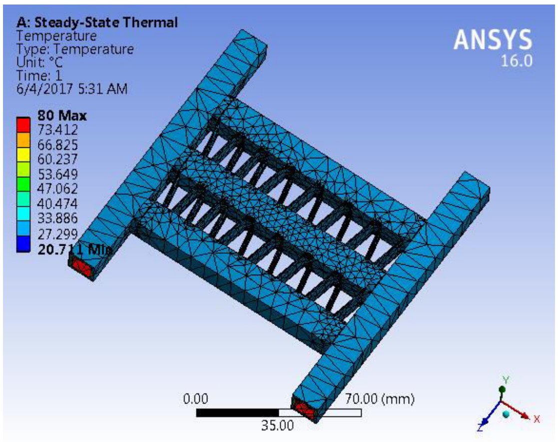


Fig11. Steady State Thermal Temperature

Fig11 shows the temperature distribution along the heat exchanger has been given in the figure above where in after heat load on 80 degrees is given to inner side of the tube the average surface temperature of heat exchanger as on range of 33.886 to 40 .473 as indicated by the color codes thus implicating that the air temperature that will be observed in the experimental reading should be in the range of 32 to 38 degrees

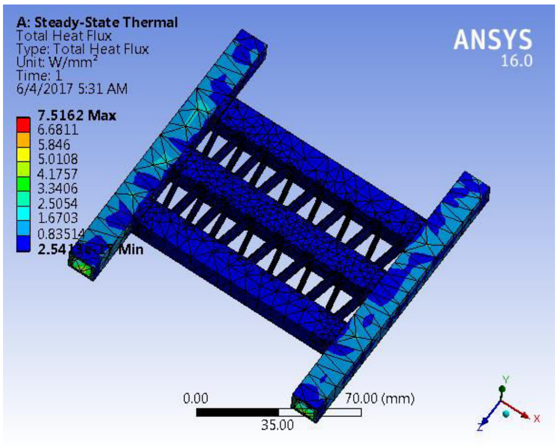


Fig12. Steady State Thermal Total Heat Flux

Fig12 gives the maximum heat flux possible for the given conditions which is 7.5162 watt

8. Conclusions

The temperature of air during experiment at the exit of the set up ranges between 32 to 36 degrees which is accordance to the analytical results of the system where in range is 32 to 38 degrees; hence the analytical results are validated. Also the mass flow rate oil is directly proportional to temperature gradient of oil and overall heat transfer coefficient of oil while mass flow rate of air is inversely proportional to temperature gradient of air.

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