International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 08 | August -2020 ISSN: 2582-3930

Design Analysis and Comparative Performance Evaluation of Change in Pitch of Helical Copper Pipe Heat Exchanger

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***ABSTRACT*:**

The heat exchangers most widely used are shell and tube heat exchangers which are larger in size and offer lesser heat transfer rate. Also, in shell and tube heat exchanger dead zone is produced which further reduces heat transfer rate and in order to improve heat transfer rate some active techniques are required.

Helical heat exchanger is more compact, offer better heat transfer rates and heat transfer rate can be further improved by passive techniques. Its shape offers advantages such as more fluid contact, elimination of dead zones, and secondary turbulence.

Paper work discusses the design & analysis of copper tube of the heat exchanger where in the copper tube is wound in a helical shape and hot fluid is always passed from top of the heat exchanger.

The modeling is done using Unigraphix Nx-8 and analysis has been done using Ansys work bench 16.0 . Test and performance comparison has been done in Parallel flow configuration for three pitch positions namely 0(close coil), 10mm and 20 mm respectively.

INTRODUCTION

A heat exchanger is a device used to transfer heat between one or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air.

Fig 1: Helical Copper Coil Heat Exchanger

1. MECHANICAL DESIGN:

Fig: 2. 3-d model of copper coil

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Mechanical design of components of the system are determined by various techniques.

a) Theoretical Method:

i. Using various formulae and empirical relations

b) Analytical Method:

i. 3-D modeling of set-up using Unigraphics

ii. Computer Aided Engineering (CAE) of critical component and meshing using Hypermesh/ Ansys /Thermal Analysis software techniques

c) Mechanical design validation using ANSY Software for produced sample components of the system will be designed and validated

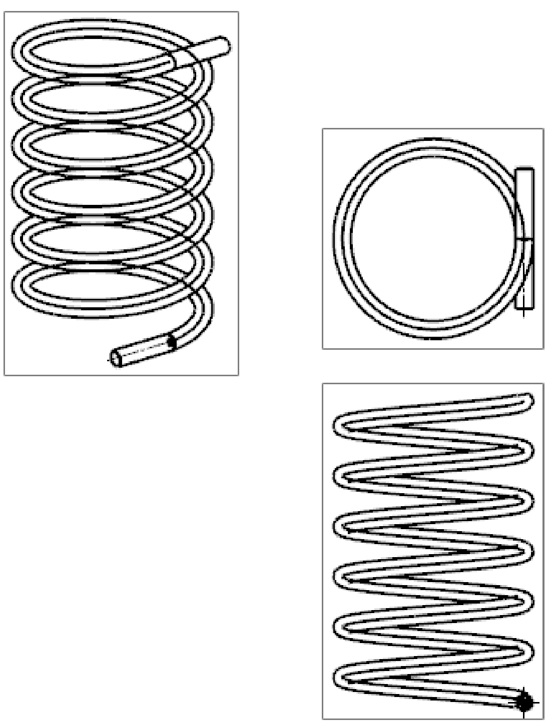


Fig: 3. Geometry of Copper Coil

2. DESIGN & ANALYSIS OF HELICAL COPPER COIL

The material selected for out application is

Material	Conductivity W/mK	Classification	Notes
COPPER	345	Mod. strength	Extremely dimensionally stable in water

The moderate strength application is selected as the operating pressure will be low ,ie maximum upto 4 bar, hence a material with better thermal conductivity is selected to achieve maximum heat transfer in given area.

Material of tube =Copper (allowable stress 186 N/mm2)

Hoope's stress due to pressure :-Maximum pressure induced in =4 bar= 0.4Mpa

$$fc_h = \frac{\mathbf{P\ xd}}{\mathbf{2t}}$$

$$fc_{act} = \frac{0.4 \times 6.4}{2 \times 1}$$

$$\Rightarrow \mathbf{fc_{act} = 1.28\ N/mm^2}$$

As $fc_h < fc_{all}$; helical coil pipe is safe.

Longitudinal stress due to pressure :-

Maximum pressure induced in system = 4 bar= 0.4Mpa

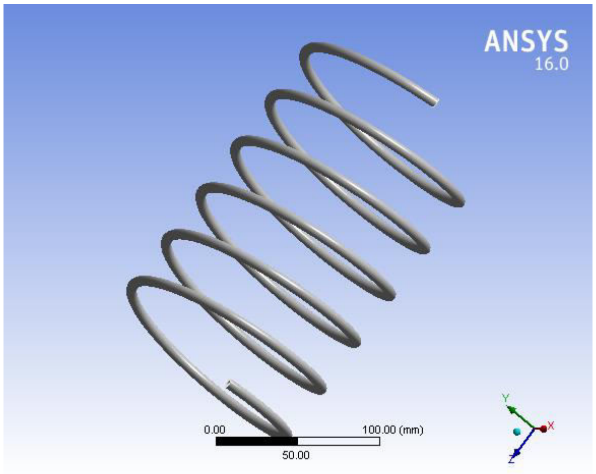
$$\mathbf{fc_l = \frac{P\ xd}{4t}}$$

$$fcl_{act} = \mathbf{\frac{0.4 \times 6.4}{4 \times 1}}$$

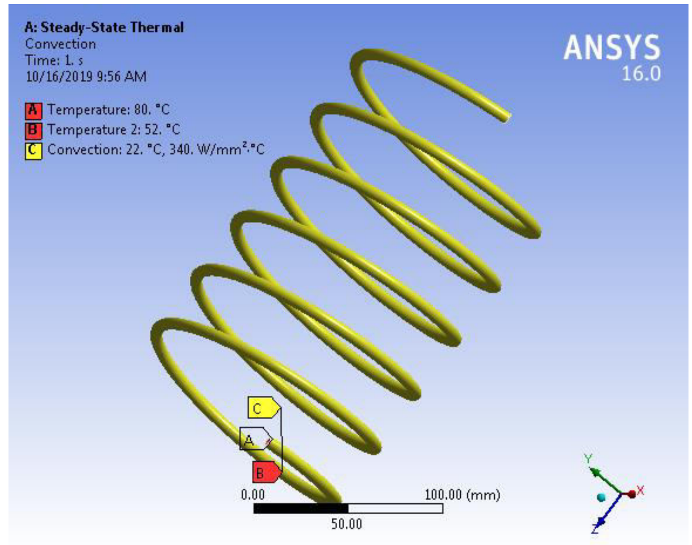
$$\mathbf{fcl_{act} = 0.64\ N/mm^2}$$

As $fc_l < fc_{all}$; helical coil pipe is safe

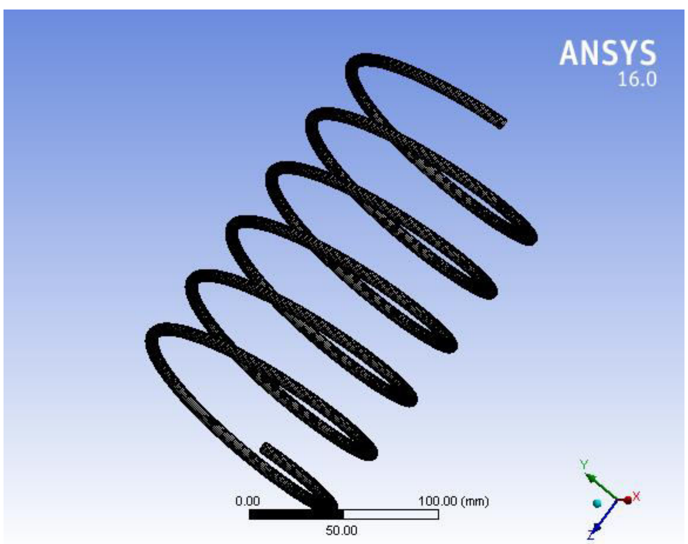
3. ANALYSIS OF THE COIL :



The geometry was developed using unigraphix Nx-8 and the step file was used as input to the ansys.

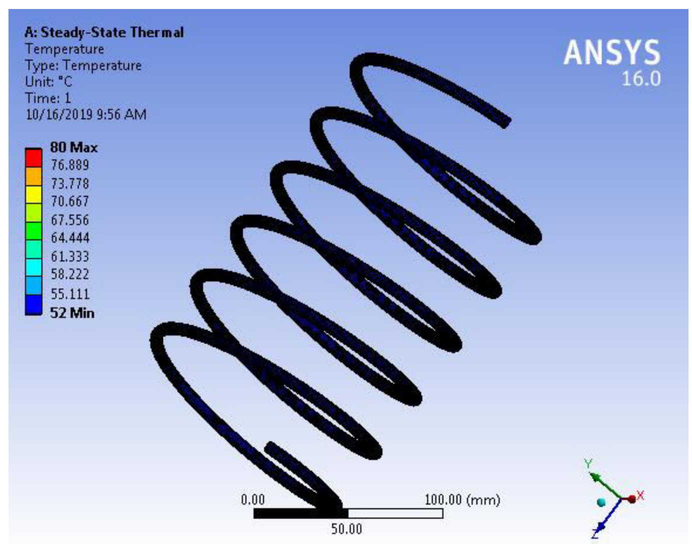


The heat loads are applied to the coil as above

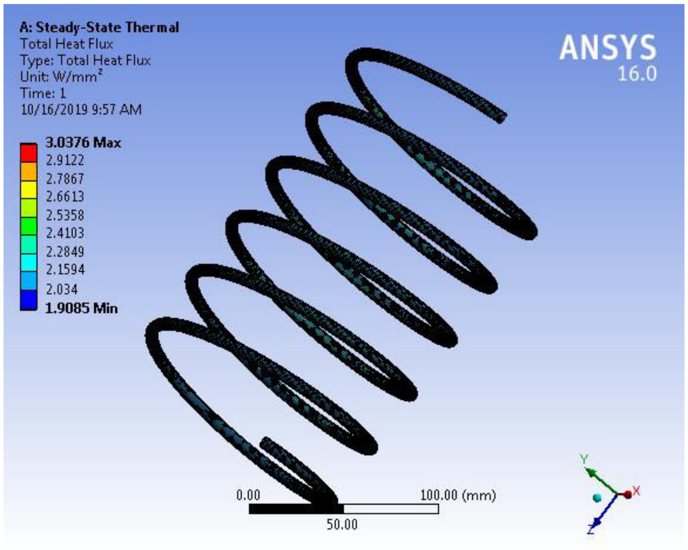


Meshing was done using free mesher and the number of elements and nodes are defined as below :

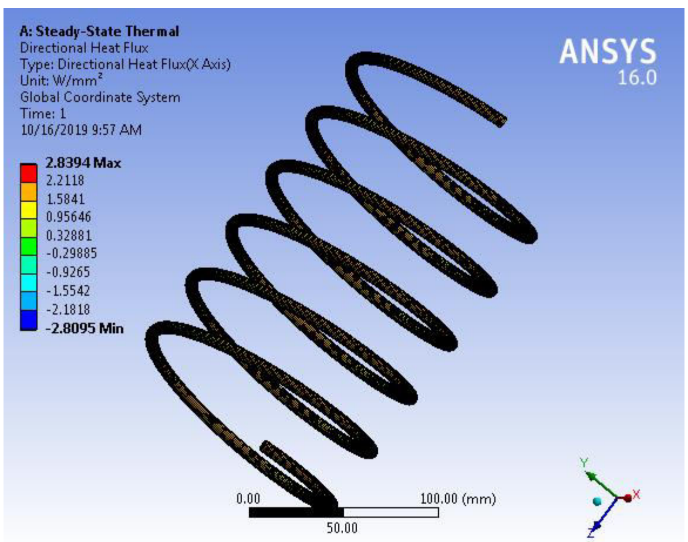
Statistics	
Nodes	353313
Elements	56810
Mesh Metric	None



The temperature distribution in the coil is given as above ranging from 80 ^{0}C to 52^{0}C



The total flux is 3.0376 watt transferred from the coil.



The directional heat flux is as shown in the figure above of 2.839 watt

4. EXPERIMENTAL SET UP AND PROCEDURE :

- **Procedure of Trial :**

i. Start the heater and let the temperature of water in overhead tank reach a suitable temperature say 90^0
ii. Start the flow control valve for hot water
iii. Start the Flow control valve for cold water
iv. Start pump
v. Note the flow rate of water at the hot side using beaker and stopwatch arrangement
vi. Note the flow rate of water at the cold side using beaker and stopwatch arrangement
vii. Note the temperature at hot water inlet and outlet

Test and trial on the heat exchanger in Counter flow configuration

I) Closed coil :

Observation table Mass flow rate reading for Hot side

Volume (ml)	Time (sec)	Flow rate (Liter/sec)	Flow rate (kg/sec)
200	42	0.004762	0.00469
200	39	0.005128	0.005051
200	36	0.005556	0.005472
200	34	0.005882	0.005794
200	32	0.00625	0.006156

Observation table for mass flow rate on Cold side :

Volume (ml)	Time (sec)	Flow rate (Liter/sec)	Flow rate (kg/sec)
200	18	0.011111	0.011111
200	16	0.0125	0.0125
200	14	0.014286	0.014286
200	12	0.016667	0.016667
200	11	0.018182	0.018182

Observation table For Temperature readings Counter flow Closed coil

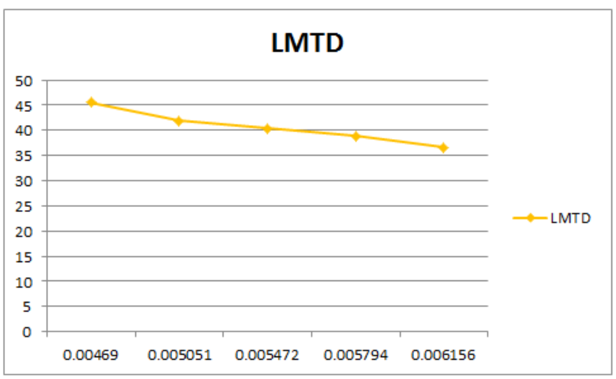
Hot water inlet (Thi)	Hot water outlet (Thi)	Cold water inlet (Tci)	Cold water outlet (Thi)
80	73	28	34
78	70	28	36.3
78	68	28	37.2
79	66	28	39.1
80	64	29	41.6

RESUL TABLE

(Counter flow Ho : closed coil Pitch)

SR NO.	Mass flow rate	LMTD	U W/ m^2k	Effectiveness
1.	0.00469	45.49817	74.89733917	0.134615385
2.	0.005051	41.84982	77.50379045	0.16
3.	0.005472	40.39868	85.50610945	0.2
4.	0.005794	38.94228	96.16080366	0.254901961
5.	0.006156	36.67374	98.79071673	0.31372549

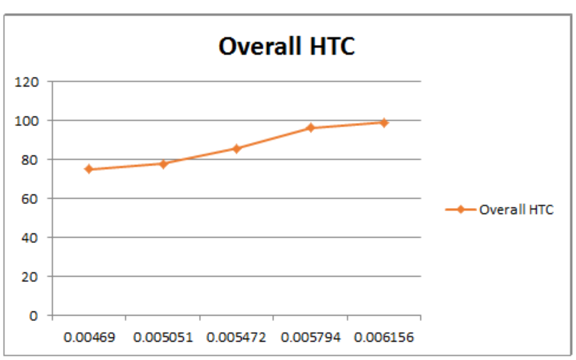
Graph of LMTD Vs mass flow rate Closed coil



mass flow rate (kg/sec)

The LMTD is seen to drop with the increase in mass flow rate

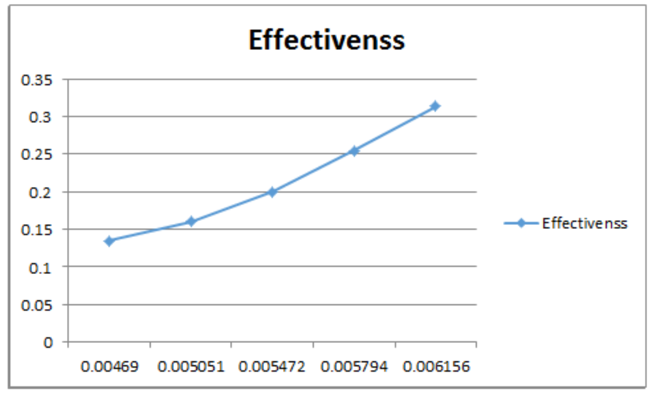
Graph of Overall HTC Vs mass flow rate Closed coil



mass flow rate (kg/sec)

The Overall HTC is seen to increase with the increase in mass flow rate.

Graph of Effectiveness Vs mass flow rate Closed coil



mass flow rate (kg/sec)

The Effectiveness is seen to increase with the increase in mass flow rate

II(Counter flow H1 : 10mm coil Pitch) :

Observation table Mass flow rate reading for Hot side

Volume (ml)	Time (sec)	Flow rate (Liter/sec)	Flow rate (kg/sec)
200	42	0.004762	0.00469
200	39	0.005128	0.005051
200	36	0.005556	0.005472
200	34	0.005882	0.005794
200	32	0.00625	0.006156

Observation table for mass flow rate on Cold side :

Volume (ml)	Time (sec)	Flow rate (Liter/sec)	Flow rate (kg/sec)
200	18	0.011111	0.011111
200	16	0.0125	0.0125
200	14	0.014286	0.014286
200	12	0.016667	0.016667
200	11	0.018182	0.018182

Observation table For Temperature readings Counter flow Closed coil

Hot water inlet (Thi)	Hot water outlet (Thi)	Cold water inlet (Tci)	Cold water outlet (Thi)
80	71.4	28	33.2
78	69.5	28	35.4
78	66.3	28	36.9

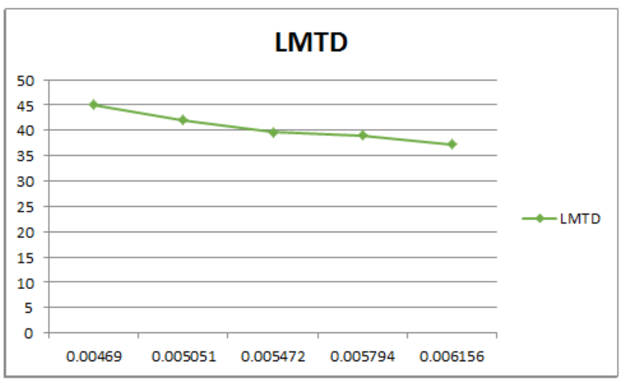
79	64.8	28	37.8
80	62.6	29	38.9

RESULTABLE

I (Counter flow H1 : 10MM coil Pitch)

SR NO.	Mass flow rate	LMTD	U W/ m^2k	Effectiveness
1.	0.00469	45.07863	74.20671432	0.165384615
2.	0.005051	42.0476	77.87007134	0.17
3.	0.005472	39.68354	83.99247052	0.234
4.	0.005794	38.9586	96.20110814	0.278431373
5.	0.006156	37.22416	100.2734306	0.341176471

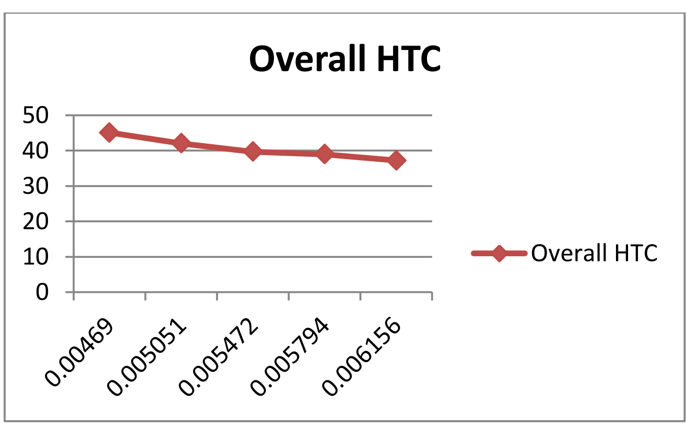
Graph of LMTD Vs mass flow rate Closed coil



mass flow rate (kg/sec)

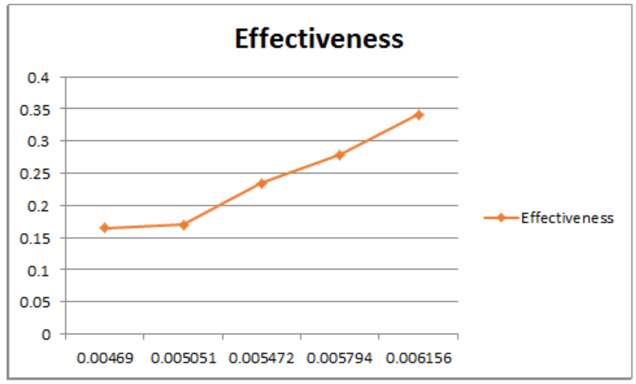
The LMTD is seen to drop with the increase in mass flow rate

Graph of Overall HTC Vs mass flow rate Closed coil:



The Overall HTC is seen to increase with the increase in mass flow rate

Graph of Effectiveness Vs mass flow rate Closed coil :



mass flow rate (kg/sec)

The Effectiveness is seen to increase with the increase in mass flow rate

II(Counter flow H2 : 20 mm coil Pitch)

Observation table Mass flow rate reading for Hot side

Volume (ml)	Time (sec)	Flow rate (Liter/sec)	Flow rate (kg/sec)
200	42	0.004762	0.00469
200	39	0.005128	0.005051
200	36	0.005556	0.005472
200	34	0.005882	0.005794
200	32	0.00625	0.006156

Observation table for mass flow rate on Cold side :

Volume (ml)	Time (sec)	Flow rate (Liter/sec)	Flow rate (kg/sec)
200	18	0.011111	0.011111
200	16	0.0125	0.0125
200	14	0.014286	0.014286
200	12	0.016667	0.016667
200	11	0.018182	0.018182

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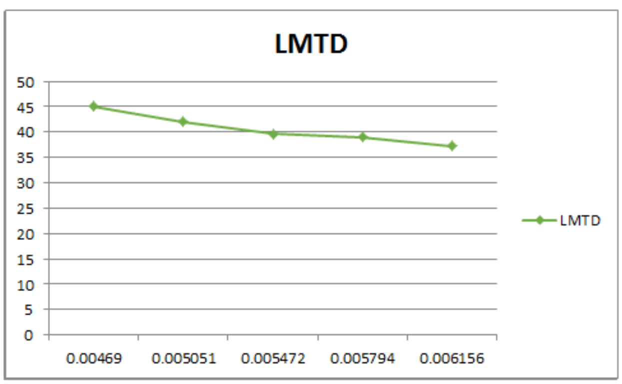
Observation table For Temperature readings Counter flow Closed coil :

Hot water inlet (Thi)	Hot water outlet (Thi)	Cold water inlet (Tci)	Cold water outlet (Thi)
80	71.4	28	33.2
78	69.5	28	35.4
78	66.3	28	36.9
79	64.8	28	37.8
80	62.6	29	38.9

RESULTABLE (Counter flow H2 : 20mm coil Pitch)

SR NO.	Mass flow rate	LMTD	U W/ m^2k	Effectiveness
1.	0.00469	46.73583	76.7626986	0.17338462
2.	0.005051	44.36364	81.4872055	0.184
3.	0.005472	43.71476	88.86453461	0.249
4.	0.005794	42.44276	100.8868449	0.289431373
5.	0.006156	40.23356	104.0129043	0.352276471

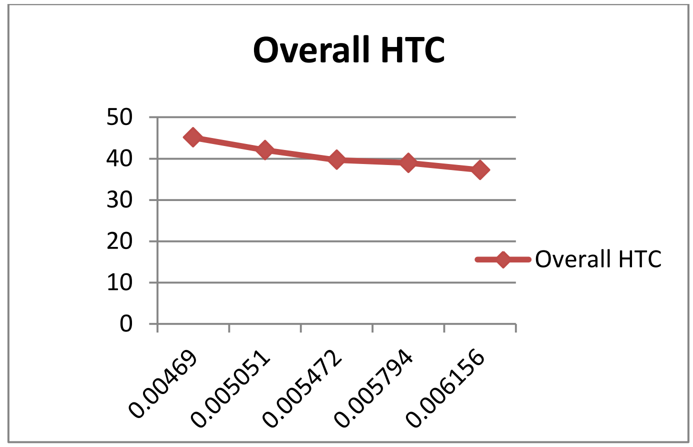
Graph of LMTD Vs mass flow rate Closed coil :



mass flow rate (kg/sec)

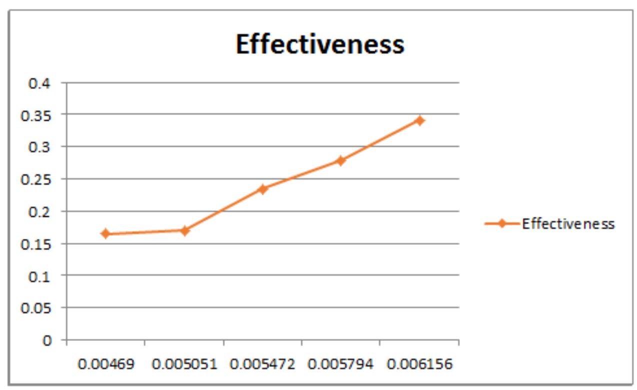
The LMTD is seen to drop with the increase in mass flow rate .

Graph of Overall HTC Vs mass flow rate Closed coil



The Overall HTC is seen to increase with the increase in mass flow rate

Graph of Effectiveness Vs mass flow rate Closed coil



mass flow rate (kg/sec)

The Effectiveness is seen to increase with the increase in mass flow rate

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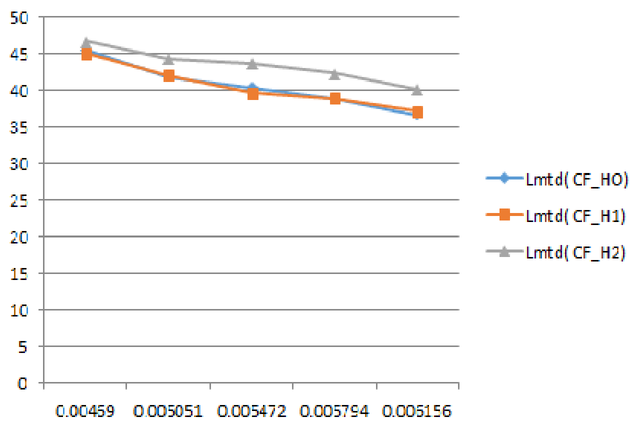
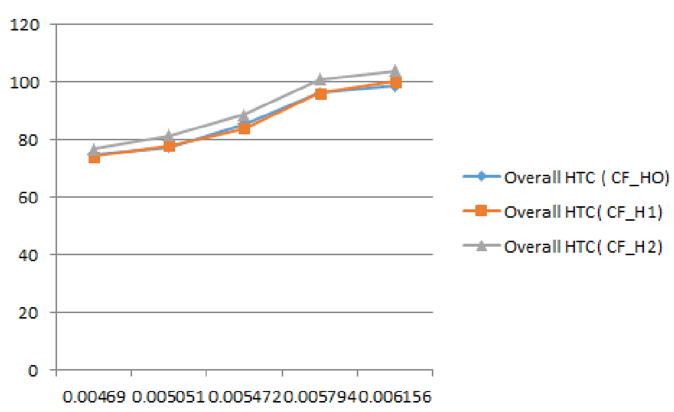
Comparison Graphs of LMTD Vs Flow Rate:



mass flow rate

The comparison shows that the LMTD of 20 mm pitch configuration is the highest amongst the three configurations.

Comparison Graphs of Overall Heat Transfer Coefficient Vs Flow rate

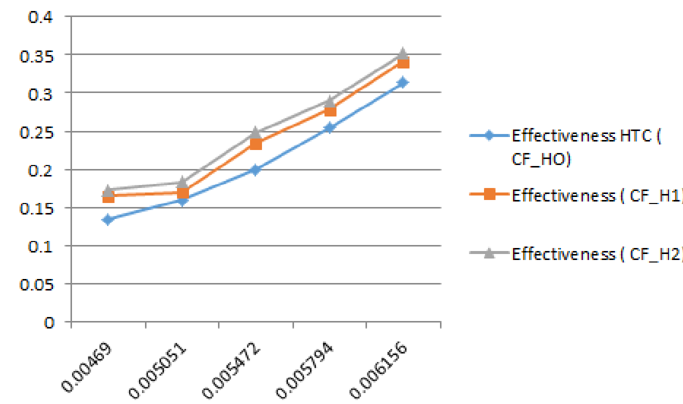


mass flow rate

The comparison shows that the Overall heat transfer coefficient of 20 mm pitch configuration is the highest amongst the three configurations.

This is as a result of increased lead angle and gradient which increases the intermixing of particles.

Comparison Graphs of Effectiveness Vs Flow rate



The comparison shows that theeffectivenss of the 20 mm pitch configuration is better than that of other two configurations , this is as a result of increased lead angle and gradient which increases the intermixing of particles.

5.REFERENCES:

1. N.E.Wijeysundera, J.C.Ho and S.Rajasekar, in the Year 1996 - The Effectiveness Of A Helical Coil Heat Exchanger
2. J. C. Ho, N. E. Wijeysundera, S. Rajasekar and T. T. Chandratilleke , 1995-. Performance of a Compact, Helical Coil Heat Exchanger.
3. N. Ghorbani a, H. Taherian b, M. Gorji c, H. Mirgolbabaei, 2009, Experimental study of mixed convection heat transfer in vertical helically coiled tube heatexchangers.
4. J.S. Jayakumar, S.M. Mahajani, J.C. Mandal, P.K. Vijayan, RohidasBhoi, Experimental and CFD estimation of heat transfer in helically coiled heat exchangers.
5. Parametric Analysis of Helical Coil Heat Exchanger - Pramod S. Purandarea, Mandar M. Leleb, RajkumarGuptac, International Journal ofEngineeringResearch&Technology (IJERT) Vol.1Issue 8, October -2012
6. Numerical study of finned type heat exchangers for ICEs exhaust waste heat recovery M. Hatami n , D.D. Ganji, M. Gorji-Bandpy, 2014
7. Distribution of heat flux density in Helical heat exchangers TH. BES and W. ROETZEL ,1992