Experimental and CFD Estimation of Heat Transfer in Copper Tube For Heat Exchanger

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Abstract - *This project deals with the analysis of heat transfer augmentation for fluid flowing through pipes using CFD. Theme of the project is to improve the convective heat transfer coefficient by simply making combination of the passive augmentation techniques. The experimental setup is prepared to study of the effect of surface roughness of copper tube and giving him venture shape in the flow together on the heat transfer rate of heat exchanger. Internal threading of Whitworth type is to be done on the copper tube having inner diameter 25 mm, outer diameter 38 mm and having pitch 4 mm in the copper tube. Test tube is tested on the varying Reynolds number ranging from 4200 to 9200. Constant heat flux is provided by mica heaters which are in five numbers wrapped to the copper tube at equidistance's for heating the tube.*

Water is taken as the working fluid. Six K type's thermocouples soldered to the test tube at 167 mm apart for measuring the tube surface temperature at six places at the tube. After steady state condition comes. By comparing the three cases viz. Smooth tube, threaded tube, venture shape tube. The values of Nusselt number, Friction factor, Thermal enhancement factors are obtain experimentally and these parameters compared for smooth tube before threading, after threading and venture shape tube.

Various correlation are used to validate the experimental result with CFD Analysis and it is found that there is good agreement in between them. Heat transfer rate observed highest in the test tube having internal threads along in the flow as compared to smooth tube and venture shape tube.

***Key Words*: Heat Transfer Augmentation, Reynolds No, Nusselt No, copper tube, Friction Factor, CFD.**

1. INTRODUCTION

The conversion, utilization, and recovery of energy in industrial, commercial, and domestic application usually involve a heat transfer process. Improved heat exchange, over and above that in the usual or standard practice, can significantly improve the thermal efficiency in such applications as well as the economics of their design and operation. The need to increase the thermal performance of heat based equipments (for instance, heat exchangers), thereby effecting energy, material, and cost savings as well as a consequential mitigation of environmental degradation has led to the development and use of many heat transfer enhancement techniques. These methods are referred to as augmentation or intensification techniques.

Enhancement techniques essentially reduce, for example, the thermal resistance in a conventional heat exchanger by promoting higher convective heat transfer coefficient with or without surface area increases (as represented by fins or extended surfaces). As a result, the size of a heat exchanger can be reduced, or the heat duty of an existing exchanger can be increased, or the exchanger's operating approach temperature difference can be decreased. The latter is particularly useful in thermal processing of biochemical, food, plastic, and pharmaceutical media, to avoid thermal degradation of the end product. On the other hand, heat exchange systems in spacecraft, electronic devices, and medical applications, for example, may rely primarily on enhanced thermal performance for their successful operation.

In the present work, heat transfer enhancement for fluid flowing through a pipe is to be analyzed using Computational Fluid Dynamics (CFD).

The impressive improvements in computer performance, matched by developments in experimental / Numerical methods, have resulted in a growing confidence in the ability of CFD to model complex fluid flows. CFD techniques have been applied on a broad scale in the process industry to gain insight into various flow phenomena, examine different equipment designs or compare performance under different operating conditions.

2 Experimental Model

2.1 Set-up description

The schematic of experimental set-up is shown in Figure 2.1.1, Test section consist of copper tube (I.D.=25mm, O.D.=38mm, t=6.5mm) of length 1000mm. Six k type thermocouples were soldered at six equally spaced point which were separated by 167 mm distance and two thermocouples were placed at inlet and outlet stream to measure stream inlet and outlet temperature. This copper tube was wrapped by mica heaters of 1500 Watts capacity in order to maintain constant heat flux. The mica heater wrapped on test section was surrounded by glass wool insulation and after that steel cover was placed. The required heat input was given through Dimmer-stat. A U-tube manometer was used to measure the pressure drop across the tube; water was used as a manometric fluid. The distance between two pressure tapping was 1100mm. Same procedure was repeated for two test section having 1) venture shape with conversion and diversion portion length 350mm each, throat 300mm.2) Internal threading of pitch (p=4mm). The Whitworth (B.S.W) thread was used for threading throughout the length of copper tube i.e. L=1000mm. The experimental set-up mainly consists of

(1) Inlet section,

(2) Test section,

(3) Outlet section,

(4) Control panel,

(5) U Tube Manometer

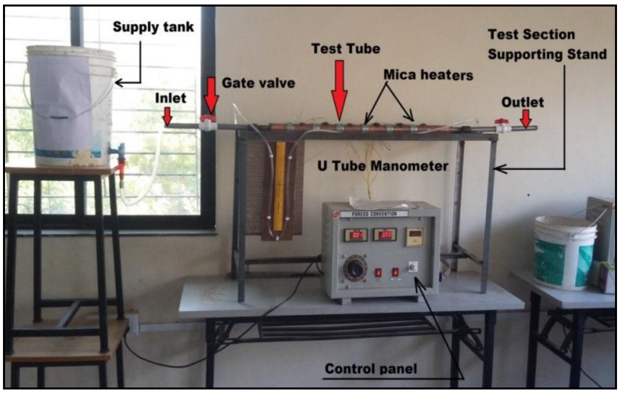

Figure 2.1.1: Experimental Setup

2.2 Test section

1) Smooth Tube 2) Venture Tube

Fig 1 It is smooth (plane) tube. Tube has dimension I.D. 25mm, O.D. 38mm and 1m in length.

Fig 2 Length is divided into 3 segments. Convergent 350mm, throat 300mm and divergent 350mm.

3) Threaded Tube

Fig 3 It is threaded tube have pitch 4mm.

3) CFD Modelling

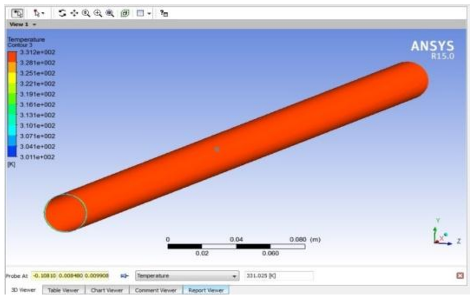

Fig 3.1 Geometry of smooth tube

The geometry i.e. smooth cylindrical smooth tube of required dimensions was created using ANSYS Design Modeler as shown.

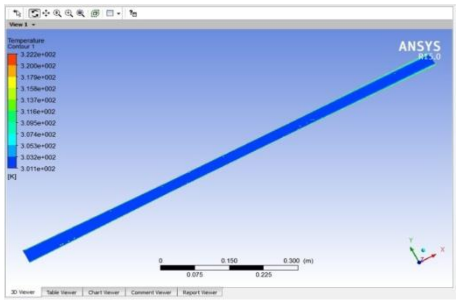

Fig 3.2 Venture Tube

4) PERFORMANCE ANALYSIS

4.1 Experimental procedure

Inlet section of set up is connected to the gate valve of water tank which takes water and pumped through test section. The flow rate of water is controlled by gate valve and was measured manually using stop watch and beaker. The flow rate varied using gate valve for different values of Reynolds number and kept constant during experimentation. After switching on the heater power the sufficient time was given to attain the steady state condition. In each run data were taken for water flow rate, water inlet, outlet and tube outer surface temperature and pressure drop readings.

- Open the supply valve and adjust the flow by means of gate valve and to some desired difference in the manometer level.

- Start the heating of test section with the help of dimmer stat and adjust desired heat input with the help of voltmeter and ammeter.

- Take readings of thermocouples at an interval of 10 minutes, until steady state is reached.

- Wait for steady state and take reading of all thermocouples at steady state.

- Note down heater input.

- Above Same procedure was repeated for remaining two test section.

4.2 CFD Operation

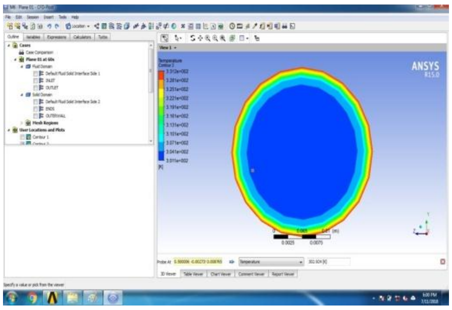

Fig 4.2.1 Smooth tube

After applying all boundary condition smooth tube geometry view in Y-Z plane.

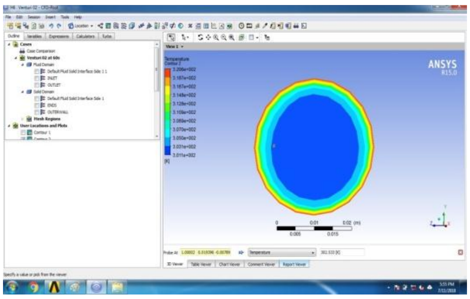

Fig 4.2.2 Venture tube

All iterations readings were taken after steady state condition reach in each case. Just nearly 30 sec after heating.

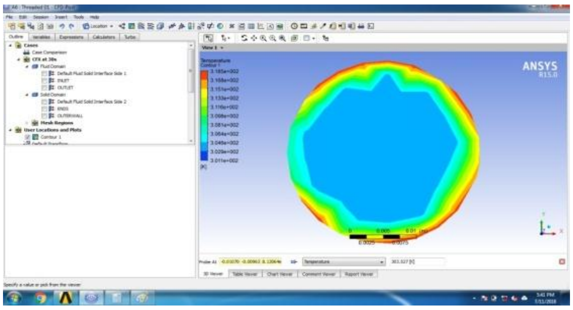

Fig 4.2.3 Threaded tube

After reaching steady state condition total eighteen iteration makes for Reynolds no. range 4200 to 9200.

4.3 Performance parameter with Reynolds number

(1) Nusselt number with Reynolds number.

A graph is plotted between Nusselt number and Reynolds number to study the variation of Nusselt number with Reynolds number.

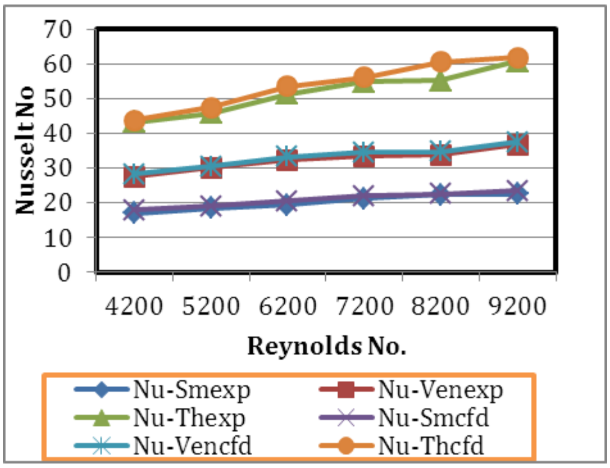

Chart 1 Comparison between Nusselt Numbers Obtained Experimentally and CFD technique.

Chart shows the comparison between Nusselt number obtained experimentally and CFD analysis, correlation for smooth tube, venture tube and threaded tube. It was observed that the value of Nu(Experimental) is less than that of Nu(CFD). As the heat is transferred through convection mode, so while performing experimental and numerical calculations, it can be expected that Nu(Experimental) is less than that of Nu(CFD). The variation of Nusselt number with Reynolds number in smooth tube and two different test tube having internal threading of pitch (p= 4 mm) and Venture tape is defined. It was observed that for all cases, Nusselt number increases with increasing Reynolds number. Also it was observed that for tube with internal threads the heat transfer rate was higher than those for smooth tube. From the graph it was cleared that the test tube having internal threads the heat transfer rate is much higher than those of previous two cases. i.e. (Smooth tube and Venture tube).

Table 1 Observation table showing Nusselt number

Re	Nu-Smexp	Nu-Smcfd	Nu-Venexp	Nu-Vencfd	Nu-Thexp	Nu-Thcfd
4200	17	17.96	27.4	28.3	43.2	43.8
5200	18.5	19.03	30.1	30.5	45.8	47.5
6200	19.5	20.46	32.2	33.2	51.4	53.5
7200	21.2	22.02	33.3	34.5	54.9	56.2
8200	22.3	22.52	33.8	34.7	55.3	60.5
9200	22.4	23.37	36.7	37.6	60.8	61.8

(2) Friction factor with Reynolds number.

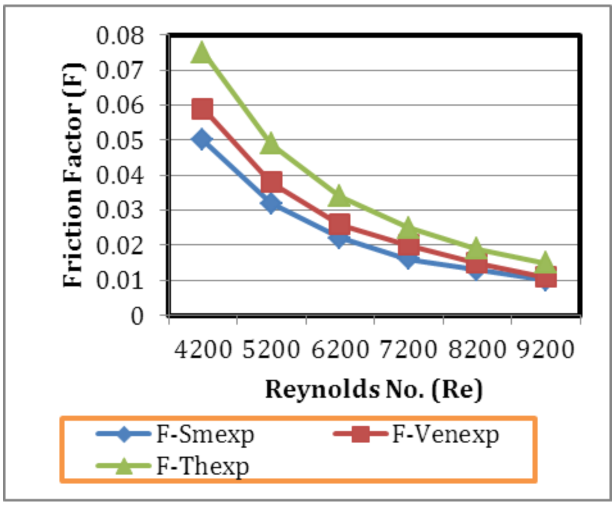

Chart 2 Variation of Friction Factor with Reynolds Number

Chart shows the variation of friction factor with Reynolds number for smooth tube, venture tube and threaded tube. From the graph obtained it is cleared that F (Experimental) is greater than that of F (CFD). The friction factor for the test tube having Venture shape is more than that of smooth tube and, maximum for threaded tube. From the graph it was cleared that as the Reynolds number increases there is decrease in friction factor so we conclude that as velocity goes on increasing, friction factor is inversely proportional to the velocity. This shows that the turbulence formation advanced due to artificial turbulence exerted by internal threads. The friction factor of test tube having threading is highest as compared to the other two cases of smooth tube and venture tube. In last case (Threaded) it found more scope for heat transfer as compared to previous two cases which create the distinct swirl of flow which causes the enhancement in heat transfer rate.

Table 2 Observation Table shows Friction Factors.

Re	F-Sm exp	F-Ven exp	F-Th exp	F-Sm cfd	F-Ven cfd	F-Th cfd
4200	0.05	0.059	0.075	0.046	0.055	0.071
5200	0.032	0.038	0.049	0.03	0.034	0.043
6200	0.022	0.026	0.034	0.02	0.023	0.032
7200	0.016	0.02	0.025	0.014	0.018	0.022
8200	0.013	0.015	0.019	0.011	0.013	0.016
9200	0.01	0.011	0.015	0.009	0.01	0.012

(3) Variation in Heat Transfer Coefficient with Reynolds number.

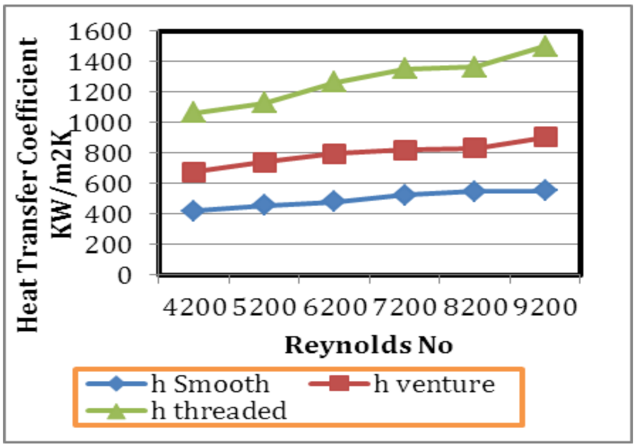

Chart 3 Variation in Heat Transfer Coefficient with Reynolds number

From Chart it is clear that as the Reynolds number increases, heat transfer coefficient also increases. Heat transfer coefficient is more in threaded tube flow. There are increases in Reynolds number, the turbulence created more in threaded tube compared to venture tube case again when we compared to the smooth tube.

Table 3 Observation Table shows Heat Transfer Coefficient.

Re	h Smooth	h venture	h threaded
4200	419.25	676.88	1064.84
5200	456.25	741.64	1129.7
6200	480.11	795.25	1266.95
7200	524.03	822.18	1354.74
8200	550	833.95	1364.04
9200	553.42	905.24	1499.13

5 CONCLUSIONS

An experimental and thermal investigation has been done under this project to study of effects of surface roughness (passive augmentation) technique on the various heat transfer properties like heat transfer coefficient, thermal enhancement factor, friction factor are to be analyzed.

The following conclusions drawn after observing graphs plotted in the previous chapters are

1. The heat transfer increases with the test tube having internal threading as compared to smooth tube and venture shape tube. The result shows that heat transfer rate increases with increasing Reynolds number.

2. The heat transfer rate for the case no. 3 (test tube having threading) is highest. This is only because, by applying passive augmentation technique, depth provided in the threading swirl flow produces which causes more heat to transfer.

3. Friction factor increases for the test tube having internal threads, compared to other two cases because swirl flow exerted in the case no. 3.

4. When we compared smooth tube, venture tube and internal threaded tube, we can conclude that more friction losses will occurred in case no. 3 than case no. 1 & case no. 2, this is due to fact that in threading, obstacles are produces to flow.

5. Here we can conclude that, Nusselt no. enhancement in case no 2 & 3 is more as compared to enhancement in friction factor. i.e. Rate of increase of Nusselt no. is more than the rate of increase in friction factor. This justify that, we can use the internal threads in circular pipe.

6. The performance of copper tube in heat exchanger can be improved by applying passive augmentation technique which can improve energy efficiency of heat exchanger.

REFERENCES

[1] Deepa Shrivastava, Rahul Mishra, "CFD Analysis of Heat Transfer For Tube-In- Tube Heat Exchanger" IJRTER, ISSN 2455-1457, Volume 03, Issue 08; August – 2017.

[2] Shalini Patra, 109CH0089, National Institute of Technology, Rourkela, "CFD Analysis of Heat Transfer Augmentation For Flow Through A Tube Using Wire Coil Inserts" 2013.

[3] R. J. Yadav, A. S. Padalkar, "CFD Analysis for Heat Transfer Enhancement inside a Circular Tube with Half-Length Upstream and Half-Length Downstream Twisted Tape" Hindawi Publishing Corporation, Journal of Thermodynamics, Volume 2012, Article ID 580593, 12 pages, doi:10.1155/2012/580593.

[4] Vivek P. Thawkar, Hemant S. Farkade, "Experimental and CFD Analysis of Twisted Tube Heat Exchanger under Forced Convection" International Journal of Science and Research (IJSR), ISSN (Online): 2319-7064, Volume 4 Issue 5, May 2015.

[5] Mr. Dnyaneshwar B. Sapkal, Dr. Samir. J. Deshmukh, "Computer Aided Design Analysis of Plate Type Heat Exchanger", International Journal of Engineering research & Technology (IJERT), IJERTIJERT, ISSN: 2278-0181, Vol. 3 Issue 7, July – 2014.

[6] Swati Singh, Gurpreet Singh and Amit Singla, "Experimental Studies on Heat Transfer Performance of Double Pipe Heat Exchanger with using Baffles and Nanofluids", Indian Journal of Science and Technology, Vol 9(40), October 2016.

[7] Dawid Taler and Jan Taler, "Simple heat transfer correlations for turbulent tube flow", E3S Web of Conf. 13, 0200 (2017), DOI:10.1051/e3sconf/20171302008.

[8] D. Bhandari, Dr. S. Singh, "Analysis of Fully Developed Turbulent Flow in a Pipe Using Computational Fluid Dynamics", International Journal of Engineering research & Technology (IJERT), Vol. 1 Issue 5, July – 2012, ISSN: 2278-0181.

[9] A. Azari1, M. Kalbasi and M. Rahimi, "CFD and Experimental Investigation On The Heat Transfer Characteristics of Alumina Nanofluids Under The Laminar Flow Regime", Brazilian Journal of Chemical Engineering, ISSN 0104-6632, Vol. 31, No. 02, pp. 469 - 481, April - June, 2014.

[10] Syed Mohammed Arif, Prof. Rashed Ali, Dr. Dhanraj P. Tambuskar, Prof. Divya Padmanabhan, "CFD Analysis of Heat Transfer in Helical Coil", International research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 03, Mar -2017.

[11] J.S. Jayakumar, S.M. Mahajani, J.C. Mandal, P.K. Vijayan, Rohidas Bhoi, "Experimental and CFD estimation of heat transfer in helically coiled heat exchangers", Elsevier journal, chemical engineering research and design 86 (2008) 221–232.

[12] Smith Eiamsa-ard, Chinaruk Thianpong, Pongjet Promvonge, "Experimental investigation of heat transfer and flow friction in a circular tube fitted with regularly spaced twisted tape elements", Mahanakorn University of Technology, Bangkok 10530, Thailand.

[13] Avinash Savekar, Dhiraj Jangid, Madhura Gurjar, Vikrant Patil, C. M. Sewatkar, "Analysis of Heat Transfer in Pipe

with Twisted Tape Inserts", 2nd International Conference on Fluid Flow, Heat and Mass Transfer Ottawa, Ontario, Canada, April 30 – May 1, 2015 Paper No. 143.

[14] Dipak Patil, "Passive Heat Transfer Augmentation Methods in a Circular Tube: A Review" International Journal of Innovative Research in Science, Engineering and Technology(IJIRSET), Volume 6, Special Issue 1, January 2017, An ISO 3297: 2007 Certified Organization, ISSN (Online) : 2319 - 8753 ISSN (Print) : 2347 – 6710.

[15] Akshay Jain, "Performance Enhancement And Thermodynamic Analysis of Copper Tube Using CFD: A Review", International Journal of Recent Innovation in Engineering and Research, e- ISSN: 2456 – 2084, Volume: 03 Issue: 06 June – 2018.

[16] Heat and Mass Transfer Data Book, Eight Multi Coloured Edition 2014, New Age International Publishers.