

Experimental Investigation of Dimpled Tubes in Double Pipe Heat Exchanger

^{#1}Saurabh R. Verma, ^{#2}Prakash M. Khanwalkar, ^{#3} Sandeep S. Kore



¹saurabhverma312@outlook.com
²pmkhanwalkar.scoe@sinhgad.edu
³sskore.sae@sinhgad.edu

^{#1,2}Mechanical Engineering Department, Sinhgad College of Engineering, Savitribai Pune University

^{#3}Mechanical Engineering Department, Sinhgad Academy of Engineering, Savitribai Pune University

ABSTRACT

Heat exchanger may be defined as equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running cost. Heat exchangers are mostly used devices in many areas of the industries such as material processing, food preparation refrigerators, radiators for space vehicles, automobiles and air conditioning etc A lot of methods are proposed to increase the thermal performance of heat transfer devices such as treated surfaces, rough surfaces, swirling flow devices, coiled tubes, and surface tension devices. For example, dimple, on surfaces results in breaking of thermal boundary layer which results in heat transfer enhancement. In this work augmented surface are achieved by placing circular dimples along the tube. The main objective of work is to perform thermal analysis of tube in tube heat exchanger using dimpled tube and validate the results obtained from the experimentation work. The working fluids used is water on both sides of the two concentric pipes. The ranges of temperature covered are between 28°C to 61°C and mass flow rates of 200Lph on the cold side is kept constant. The change in temperature is obtained by changing the mass flow range by 100 on hot side of the exchanger. Parameters to be used are, dimple diameter(d) of 3mm, dimple depth(e) 0.5mm and pitch (p) of 15, 20 mm, 25mm. The experimental results reveal that heat transfer coefficient is greater in dimpled tubes as compared to smooth tubes

Keywords— Dimpled tube, Heat transfer coefficient, Heat transfer enhancement, Heat exchanger

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

Heat exchanger may be defined as equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running cost Heat exchangers are mostly used devices in many areas of the industries such as material processing, food preparation refrigerators, radiators for space vehicles, automobiles and air conditioning etc Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. The major challenge in

designing of heat exchanger is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. Techniques for heat transfer augmentation are relevant to several engineering applications. In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment. When designing cooling systems for automobiles and spacecraft, it is imperative that the heat exchangers are especially compact and lightweight. Also enhancement devices are necessary for the high heat duty exchangers found in power plants. These applications as well as numerous others have led to the development of various enhanced heat transfer surfaces.

In general, enhanced heat transfer surfaces can be used for these purposes: (1) to make heat exchangers more compact in order to reduce their overall volume, and possibly their cost, (2) to reduce the pumping power required for a given heat transfer process or (3) to increase the overall UA value of the heat exchanger. A higher UA value can be exploited in either two ways: (1) to obtain an increased heat exchange rate for fixed fluid inlet temperatures, or (2) to reduce the mean temperature difference for the heat exchange, this increases the thermodynamic process efficiency which can result in a saving of operating costs

Furthermore, as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. These problems are more common for heat exchangers used in marine applications and in chemical industries. In some specific applications, such as heat exchangers dealing with fluids of low thermal conductivity (gases and oils) and desalination plants, there is a need to increase the heat transfer rate. The heat transfer rate can be improved by introducing a disturbance in the fluid flow but in the process pumping power may increase significantly and ultimately the pumping cost becomes high.

Use of dimples on the surface can significantly intensify the heat transfer enhancement. Introducing the dimples on the surface not only increase the surface area available for heat transfer but also reduces the hydrodynamic resistance for the fluid flow over the surface. The vortices formed inside the dimples results in thinning and to disturb the thermal boundary layer formed over the surface during coolant flow and serve ultimately to bring about enhancement of heat transfer between the fluid and its neighbouring surface at the price of less increase in pressure.

In this study, the effects of pitch on the heat transfer coefficient in the fully developed turbulent flow of dimpled tubes are examined. The Reynolds numbers are ranged from 6600 to 33450 with hot/coldwater as working fluid. The experimental results of the heat transfer enhancement are presented in the subsequent section.

II. HEAT TRANSFER AUGMENTATION TECHNIQUE

The heat transfer augmentation techniques [11] are generally classified in three broad categories:

A. Active Method

This method involves some external power input for the enhancement of heat transfer and has not shown much potential owing to complexity in design. Some Examples of Active Method are Surface Vibration, Fluid Vibration, and Electrostatic Fields.

B. Passive Method

This method does not need any external power input, the additional power needed to enhance the heat transfer is taken from the available power in the system, which ultimately leads to a fluid pressure drop. The heat exchanger industry has been striving for improved thermal contact (enhanced heat transfer coefficient) and reduced pumping power in order to improve the thermohydraulic efficiency of heat exchangers. Some Examples of Passive Method are using Treated Surfaces, Rough Surfaces, Extended Surfaces, Coiled tubes.

C. Compound Method

If two or more techniques can be utilized simultaneously to produce an enhancement larger than that produced by only one Technique than it can be said as Compound Method. A compound method is a hybrid method in which both active and passive methods are used in combination. The compound method involves complex design and hence has limited applications.

III. EXPERIMENTAL SETUP

The experimental work was conducted to look at the influence of a dimpled tube for heat transfer enhancement in a concentric tube heat exchanger. Three dimpled tubes of different pitch ratios were used for comparison with standard plain tube. The schematic diagram of the tube in tube exchanger and dimple tube is shown in Fig.1 and Fig. 2. The dimple surfaces were arranged in inline arrangement with angle of 90° between the dimples and pitch ratios (p/D) of 0.6, 0.8, and 1.0. The dimple diameter (d) and dimple depth (e) were kept a constant value of 3mm and 0.5mm respectively. The dimpled tubes were made of aluminium with length of 1400mm and tube diameter(D) 25mm installed in tube in tube exchanger as an inner tube using hot water as working fluid.

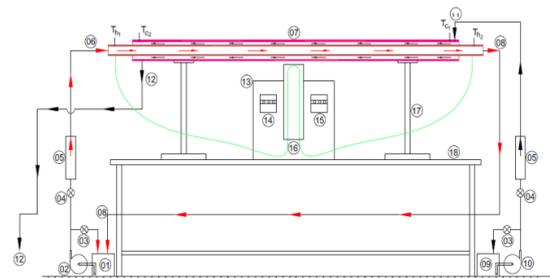


Fig.1: Schematic arrangement of Experimental Setup



Fig 2: Dimple tube with pitch ratio of 0.8

IV. DATA DEDUCTION

The hot water flows through inner tube and cold water flows through outer tube in a counter flow double pipe heat exchanger. The hot and cold water inlet and outlet temperatures are taken for various hot side flow rates (200-1000lph) and constant cold flow rate (200lph). The readings were taken for plain tube as well as dimpled tube. The parameters includes inner tube convective heat transfer coefficient, mass flow rate, velocity, Reynolds number, bulk hot water temperature, average heat transfer rate. Depending upon the various results collected from the above parameters various plots are drawn for turbulent flow upto

33450 Reynolds number. All the thermo-physical properties are calculated as mean bulk temperatures

The heat transfer rate for cold water in the test section, Q_c can be expressed as

$$Q_c = m_c C_{pc} (T_{co} - T_{ci}) \tag{1}$$

Where, m_c is the flow rate of cold water, C_{pc} is the specific heat of water; T_{co} and T_{ci} are outlet and inlet cold water temperatures respectively.

The heat transfer rate for hot water in the test section, Q_h can be expressed as

$$Q_h = m_h C_{ph} (T_{ho} - T_{hi}) \tag{2}$$

Where, m_h is the flow rate of hot water, C_{ph} is the specific heat of water; T_{ho} and T_{hi} are outlet and inlet hot water temperatures respectively.

Since, there are some heat losses on the outer surface of the test section. The average heat transfer rate (Q_{ave}) is calculated.

$$Q_{ave} = (Q_c + Q_h) / 2$$

The experimental Nusselt number can be calculated from the equation given as below,

$$Nu = h_i D_i / k \tag{3}$$

The theoretical Nusselt Number is calculated from Dittus Boelter correlation [9]

$$Nu = 0.023 Re^{0.8} Pr^n \tag{4}$$

Where $n = 0.3$ for cooling of fluids
 $n = 0.4$ for heating of fluids

For fluid flows in a concentric tube heat exchanger, the heat transfer coefficient (h_i) is calculated from

$$Q_{ave} = U A_i \Delta T_{LMTD} \tag{5}$$

Where
 $A_i = \pi D_i L$

The tube side heat transfer coefficient is then determined (by neglecting of the thermal resistance in the aluminium tube wall) using

$$1/U = 1/h_i + 1/h_o \tag{6}$$

Where the annulus side heat transfer coefficient (h_o) is estimated by using the correlation of Dittus-Boelter;

$$N_{uo} = h_o D_h / k = 0.023 Re^{0.8} Pr^{0.3} \tag{7}$$

Then,

$$h_o = k / D_h \cdot N_{uo}$$

Where

$$D_h = D_o - D_i$$

The dimpled tubes of different pitch ratios are validated by following correlation [7]

$$Nu = 0.04 Re^{0.76} (p/D)^{-0.59} Pr^{0.3} \tag{8}$$

V.RESULT & DISCUSSION

In this section, the following results are, respectively presented, the validation of plain tube, validation of dimple tube, and effect of pitch ratio.

A. Validation of Smooth tube

Prior to the testing the dimple tube, the Nusselt number in a plain tube were measured. The experimental results were calculated, and then compared with the results given by the well known correlations under the similar condition, in order to evaluate the validation of the plain tube. The comparison is shown in figure 3. The experimental results were found to be in agreement with Dittus- Boelter correlation. It is noted that Nusselt number differs upto to 18%.

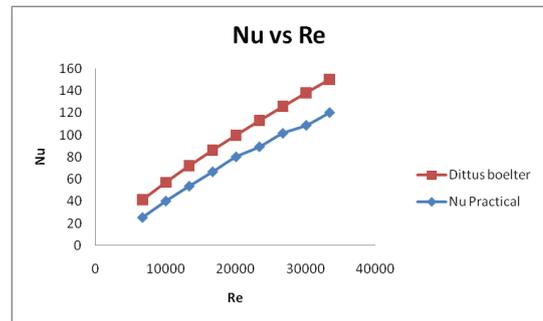


Fig 3: Smooth Tube Validation

B. Validation of dimpled tube

The experimental set up with dimpled tubes with different pitch ratio(0.6,0.8,1.0) is validated with the following correlation(8) which is found to predict the experimental Nusselt number fairly as depicted in Figure 4.(a),(b),(c)

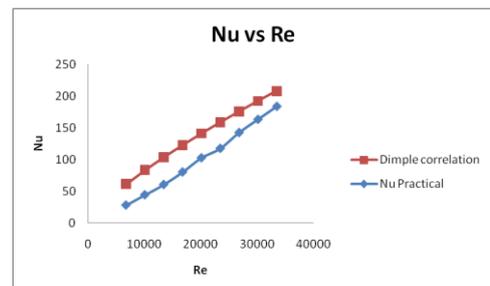


Fig 4(a): Dimple tube pitch ratio of 0.6

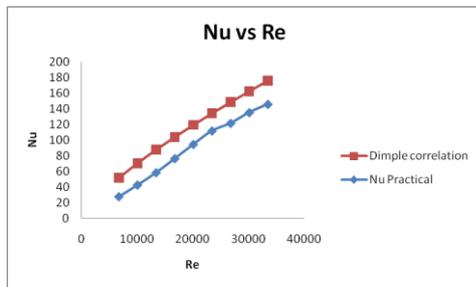


Fig 4(b): Dimple tube pitch ratio of 0.8

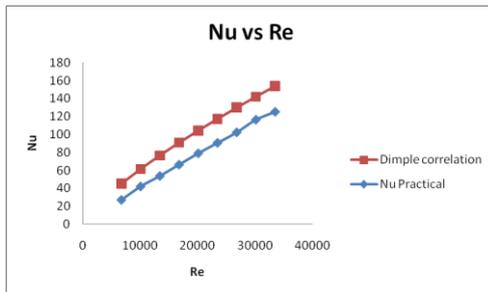


Fig 4(c): Dimple tube pitch ratio of 1.0

C. Comparison of Heat transfer coefficient of Smooth tube and Dimpled tubes

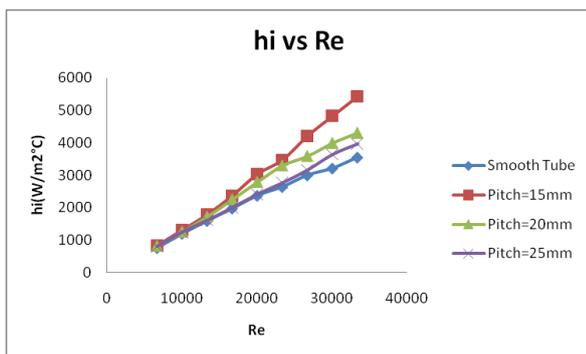


Fig 5: Heat Transfer coefficient vs. Reynolds number

From the above figures we can also conclude that with increase in pitch ratio the value of Nusselt number decreases or vice versa. This is because of the higher flow mixing effect for the dimpled tube with the lower pitch ratio, leading to greater turbulence intensity. The heat transfer rate is also increasing with decreasing pitch ratio

VI. CONCLUSION

An experimental study of fully developed turbulent flow in a dimpled tube has been performed. The influences of the pitch ratio and twist ratio on the heat transfer rate have also been investigated. Depending on the pitch ratio the heat transfer rate has been increased

ACKNOWLEDGMENT

The motivating factor for this project was the inspiration given to me by my honorable guide Prof. P.M. Khanwalkar. He has given many valuable suggestions and guided me by encouraging generously throughout. I wish to convey my gratitude to my guide. His mild mannered demeanor, his tolerance in dealing the problems and his encouragement has been a constant source of inspiration for me. He had contributed to a great measure in mounting all the hurdles

faced by me during the completion of the project. I also like to thank Dr. S.S. Kore for giving in-depth knowledge regarding my topic and showing proper path for timely completion of my project. I gratefully acknowledge our Principal Dr. S.D. Lokhande and P.G. Head Dr. Y.P. Reddy for making available the necessary facilities required for my project. At last I thank all those who directly or indirectly helped me in completing this project successfully.

REFERENCES

- [1] Juin Chen, Hans Muller-Steinhagen, Geoffrey G. Duffy "Heat transfer enhancement in dimpled tubes" Applied Thermal Engineering 21 (2001), pp 535-547
- [2] Yu Wang, Ya-Ling He, Yong-Gang Lei, Jie Zhang "Heat transfer and hydrodynamics analysis of a novel dimpled tube" Experimental Thermal and Fluid Science 34 (2010), pp 1273-1281
- [3] David J. Kukulka, Rick Smith, Kevin G. Fuller "Development and evaluation of enhanced heat transfer tubes" Applied Thermal Engineering 31(2011), pp 2141-2145.
- [4] Pedro G. Vicente, Albero Garcia, Antonia Viedma "Experimental study of mixed convection and pressure drop in helically dimpled tubes for laminar and transition flow" International Journal of Heat and Mass Transfer 45 (2002), pp 5091-5105.
- [5] Pedro G. Vicente, Albero Garcia, Antonia Viedma "Heat transfer and pressure drop for low Reynolds Turbulent flow in helically dimpled tubes" International Journal of Heat and Mass Transfer 45(2002), pp 543-553
- [6] S. Suresh, M. Chandrasekar, S. Chandra Sekhar "Experimental studies on heat transfer and friction factor characteristics of CuO/water nano fluid under turbulent flow a helically dimpled tube" Experimental Thermal and Fluid Science 35(2011), pp 542-549.
- [7] Chinारuk Thianpong, Petpices Eiamsa-ard, Khwanchit Wongcharee, Smith Eiamsa-ard "Compound heat transfer enhancement of a dimpled tube with a twisted tape swirl generator" International Communications in Heat and Mass Transfer 36 (2009), pp 698-704.
- [8] Antony luki.A, Ganesan.M "Flow Analysis and Characteristics Comparison of Double Pipe Heat Exchanger Using Enhanced Tubes" IOSR Journal of Mechanical and Civil Engineering, pp 16-21
- [9] F.P. Incropera, P.D. Witt, T.L. Bergman, A.S. Lavine, Fundamentals of Heat and Mass Transfer, John-Wiley & Sons, 2006.
- [10] [A. Garcia](#), J.P. Solano, [P.G. Vicente](#), A. [Viedma](#) "The influence of artificial roughness shape on heat transfer enhancement: Corrugated tubes, dimpled tubes and wire coils" Applied Thermal Engineering(2012)pp196-201
- [11] S. Liu, M. Sakr, A comprehensive review on passive heat transfer enhancements in pipe exchangers, Renewable and Sustainable Energy Reviews 19 (2013) 64-81