ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Enhancement of Heat Transfer in Horizontal Tube Using Inserts through CFD Analysis

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ABSTRACT:

The main aim of this thesis is to analyze the heat transfer in turbulent flow to horizontal tube using different types of inserts. The Reynolds number ranged from 6000 to 14000. The five different types of inserts used. 1) Plain rod 2) Spiral over rod 3) Spiral and square blocks over rod 4) Spiral and rectangle blocks over rod 5) Spiral and pyramid blocks over rod. The data from ANSYS is used to calculate Friction factor and Nusselt number in the presence of inserts. The theoretical values are compared with the analysis values. The analysis is done to know which type of insert among the five inserts gives the maximum heat transfer rate. 3D models of the horizontal tube with inserts are done in Pro/Engineer and analysis is done in Ansys.

1. INTRODUCTION:

Conventional resources of energy are depleting at an alarming rate, which makes future sustainable development of energy use very difficult. As a result, considerable emphasis has been placed on the development of various augmented heat transfer surfaces and devices. Heat transfer augmentation techniques are generally classified into three categories namely: active techniques, passive techniques and compound techniques. Passive heat transfer techniques (ex: tube inserts) do not require any direct input of external power. Hence many researchers preferred passive heat transfer enhancement techniques for their simplicity and applicability for many applications. Tube inserts present some advantages over other enhancement techniques, such as they can be installed in existing smooth tube that exchanger, and they maintain the mechanical strength of the smooth tube.

The process of improving the performance of a heat transfer system is referred as the heat transfer enhancement technique.

In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment .The major challenge in designing a heat transfer is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. The subject of heat transfer growth in heat exchanger is serious interest in the design of effective and economical heat exchanger. Augmentation techniques increase convective heat transfer by reducing thermal resistance in a heat exchanger. A decrease in heat transfer surface area, size, and hence weight of heat exchanger for a given heat duty and pressure drop.

1.1 Heat Transfer Augmentation Techniques:

1.1.1 PASSIVE TECHNIQUES:

- Treated surfaces are heat transfer surfaces that have a fine-scale alteration to their finisher coating. The alteration could be continuous or discontinuous, where the roughness is much smaller than what affects single-phase heat transfer, and they are used primarily for boiling and condensing duties.
- Rough surfaces are generally surface modifications that promote turbulence in the flow field, primarily in single-phase flows, and do not increase the heat transfer surface area. Their geometric features range from random sand-grain roughness to discrete three dimensional surface protuberances.
- Extended surfaces, more commonly referred to as finned surfaces, provide an effective heat transfer surface area enlargement. Plain fins have been used routinely in many heat exchangers.

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1.1.2 ACTIVE TECHNIQUES:

- Mechanical aids are those that stir the fluid by mechanical mean or by rotating the surface. The more prominent examples include rotating tube heat exchangers and scraped-surface heat and mass exchangers.
- Surface vibration has been applied primarily, at either low or high frequency, in single phase flows to obtain higher convective heat transfer coefficients.
- Fluid vibration or fluid pulsation, with vibrations ranging from 1.0 Hz to ultrasound, used primarily in single-phase flows, is considered to be perhaps the most practical type of vibration enhancement technique.
- Injection, used only in single-phase flow, pertains to the method of injecting the same ora different fluid into the main bulk fluid either through a porous heat transfer interface or upstream of the heat transfer section.

1.2Performance Evaluation Criteria:

Besides the relative thermal–hydraulic performance improvements brought about by the enhancement devices, there are many factors that should be considered to evaluate the performance of particular heat transfer equipment. The quick development of numerical techniques and software, such as CFD codes, has improved the ability of engineers to solve highly sophisticated engineering problems. Using CFD codes for modeling the heat and fluid flow is an efficient tool for predicting equipment's performance. The CFD offers a convenient means to study the detailed flows and heat exchange processes, which take place inside the tube. Many efforts have been undertaken to use the CFD modeling for designing heat transfer enhancement devices. Two types of tube inserts consisting of a full-length typical twisted tape at different twisted ratios and a twisted tape with various free space ratios were used in their experiments.

1.3 Types of Inserts:

Hence this study gives the overview of different techniques to enhance the heat transfer characteristics by producing turbulent flow in circular pipe with insertions of different types of inserts or geometries.

1. Twisted wire brush inserts
2. Twisted tape
3. Perforated twisted tapes
4. Double counter twisted tapes
5. Pipe with internal thread

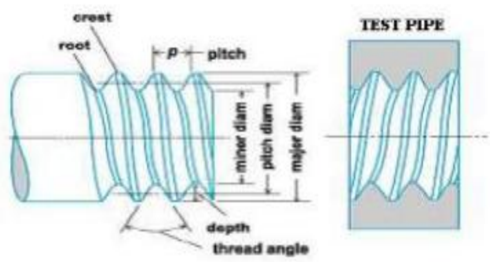

Fig 1.1 Pipe with internal thread

Heat exchangers are used in different processes ranging from conversion, utilization & recovery of thermal energy in various industrial, commercial & domestic applications. Some common examples include steam generation & condensation in power & cogeneration plants; sensible heating & cooling in thermal processing of chemical, pharmaceutical & agricultural products; fluid heating in manufacturing & waste heat recovery etc. Increase in Heat exchanger's performance can lead to more economical design of heat exchanger which can help to make energy, material & cost savings related to a heat exchange process. The need to increase the thermal performance of heat exchangers, thereby effecting energy, material & cost savings have led to development & use of many techniques termed as Heat transfer augmentation. These techniques are also referred as Heat transfer Enhancement or Intensification. Augmentation techniques increase convective heat transfer by reducing the thermal resistance in a heat exchanger. Use of Heat transfer enhancement techniques lead to increase in heat transfer coefficient but at the cost of increase in pressure drop.

So, while designing a heat exchanger using any of these techniques, analysis of heat transfer rate & pressure drop has to be done. Apart from this, issues like long term performance & detailed economic analysis of heat exchanger has to be studied. To achieve high heat transfer rate in an existing or new heat exchanger while taking care of the increased pumping power, several techniques have been proposed in recent years and are discussed in the following sections.

2. LITERATURE SURVEY

Heat Transfer Enhancement in Tube-in-Tube Heat Exchanger using Passive Techniques by Parag S. Desale,Nilesh C. Ghuege

The heat exchanger is an important device in almost all of the mechanical industries as in case of process industries it is key element. Thus from long time many researchers in this area are working to improve the performance of these heat exchangers in terms of heat transfer rate, keeping pressure drop in limit. This paper is a review of such techniques keeping focus on passive augmentation techniques used in heat exchangers. The thermal performance behavior for tube in tube heat exchanger is studies for wire coil inserts, twisted tape inserts and their combination. These inserts are tested individually and in combine form and results were compared.

Experimental Investigations on Augmentation of Turbulent Flow Heat Transfer in a Horizontal Tube Using Square Leaf Inserts by S. Naga Sarada, P. Ram Reddy, Gugulothu Ravi

The present work deals with the results of the experimental investigations carried out on augmentation of turbulent flow heat transfer in a horizontal tube by the means of tube inserts, with air as working fluid. Experiments were carried out initially for the plain tube. Nusselt number and friction factor obtained experimentally were validated against those obtained from theoretical correlations. Secondly experimental investigations using five kinds (900, 600FW, 600BW, 300 FW, 300 BW) of louvered square leaf inserts were carried out to estimate the enhancement of heat transfer rate for air in the presence of insert.

Heat transfer enhancement using passive enhancement technique by Vinay Kumar Patel, N. K. Sagar

Among many techniques (both passive and active) investigated for augmentation of heat transfer rates inside circular tubes, a wide range of inserts has been utilized, particularly when turbulent flow is considered. The inserts studied included coil wire inserts, brush inserts, mesh inserts, strip inserts, twisted tape inserts etc. CFD investigations on enhancement of turbulent flow heat transfer with twisted tape inserts in a horizontal tube under forced convection with air flowing inside is carried out using ANSYS FLUNT..

CFD analysis of heat transfer augmentation for flow through a tube using wire coil inserts by ShaliniPatra

The need to increase the thermal performance of heat transfer equipment (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. This project deals with the analysis of heat transfer augmentation for fluid flowing through pipes using CFD. Using CFD codes for modeling the heat and fluid flow is an efficient tool for predicting equipment performance. CFD offers a convenient means to study the detailed flows and heat exchange processes, which take place inside the tube.

Enhancement of heat transfer using varying width twisted tape inserts by S. Naga Sarada , A.V. Sita Rama Raju , K. KalyaniRadha, L. Shyam Sunder

The present work shows the results obtained from experimental investigations of the augmentation of turbulent flow heat transfer in a horizontal tube by means of varying width twisted tape inserts with air as the working fluid.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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In order to reduce excessive pressure drops associated with full width twisted tape inserts, with less corresponding reduction in heat transfer coefficients, reduced width twisted tapes of widths ranging from 10 mm to 22 mm, which are lower than the tube inside diameter of 27.5 mm are used. Experiments were carried out for plain tube with/without twisted tape insert at constant wall heat flux and different mass flow rates. The Reynolds number varied from 6000 to 13500. Both heat transfer coefficient and pressure drop are calculated and the results are compared with those of plain tube.

An experimental investigation of turbulent flow heat transfer through tube with rod-pin insert byM. A. K. Chowdhuri , R. A. Hossain , M.A.R. Sarkar

An experimental investigation has been carried out to study the turbulent flow heat transfer and to determine the pressure drop characteristics of air, flowing through a tube with insert. An insert of special geometry is used inside the tube. The test section is electrically heated, and air is allowed to flow as the working fluid through the tube.

3. INTRODUCTION TO CAD:

From history of our industrial society, many inventions have been patented and whole new technologies have evolved. Perhaps the single development that has impacted manufacturing more quickly and significantly than any previous technology is the digital computer. Computers are being used increasingly for both design and detailing of engineering components in the drawing office. Computer-aided design (CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. CADis most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system. Computer-aided design systems are powerful tools and in the mechanical design and geometric modeling of products and components.

There are several good reasons for using a CAD system to support the engineering design. Software allows the human user to turn a hardware configuration into a powerful design and manufacturing system. CAD/CAM software falls into two broad categories,2-D and 3-D,Based on the number of dimensions are called 2-D representations of 3-D objects is inherently confusing. Equally problem has been the inability of manufacturing personnel to properly read and interpret complicated 2-D representations of objects. 3-D software permits the parts to be viewed with the 3-D planes-height, width, and depth-visible. The trend in CAD/CAM is toward3-D representation of graphic images. Such representation approximates the actual shape and appearance of the object to be produced; therefore, they are easier to read and understand.

3.1 3D MODELS OF DIFFERENT INSERTS

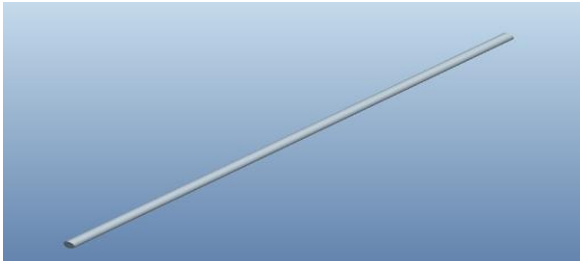


FIG 3.1 3D PLAIN ROD

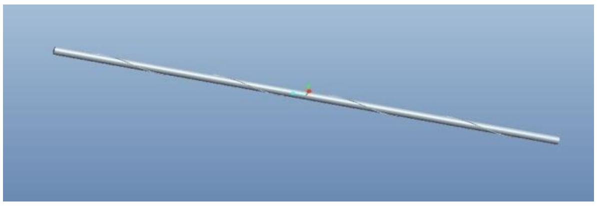
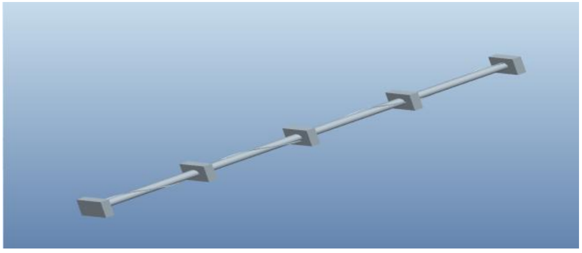


FIG 3.2 3D SPIRAL OVER ON ROD



3.4 3D SPIRAL AND SQUARE BLOCKS OVER ON ROD

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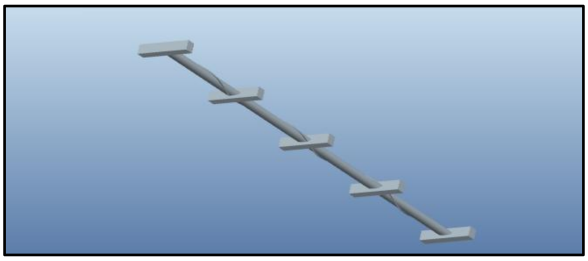
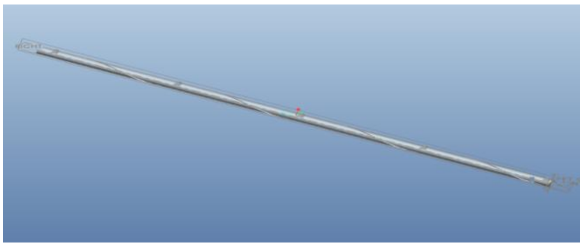


3.6 3D SPIRAL AND RECTANGULAR BLOCKS OVER ON ROD



3.8 3D SPIRAL AND PYRAMID BLOCKS OVER ON ROD

4. INTRODUCTION TO FEA:

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M.J.Turner, R.W. Clough, H C.Martin, and L.J.Top established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

5. INTRODUCTION TO CFD:

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

Table 5.1 properties of air at 331 k

s.no	Fluid property	value
1.	density	1.225 (kg/m^3)
2.	Specicific heat	1008 (J/kg k)
3.	Thermal conductivity	0.0285 (W/m^2 k)
4.	Dynamic viscosity	0.00001983 (Pa-sec)

THEORETICAL RESULTS

Table 5.5 Theoretical Results

S.no	Velocity	Reynolds Number	Nusselt Number	Friction Factor
1.	48.56	5998.92	21.01	0.008976
2.	80.93	9999.61	31.61	0.007900
3.	113.31	13999.33	41.38	0.007262

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6. CFD ANALYSIS ON HORIZONTAL TUBE WITH INSERTS:

To Perform CFD Analysis On Horizontal Tube With Inserts Using ANSYS FLUENT 14.5 For Various Reynolds Number Ranging From 6000 To 14000. The Different Inserts Used Are Listed As Follows

1. Plain rod
2. Spiral over on rod
3. Spiral and square blocks over on rod
4. Spiral and rectangular blocks over on rod
5. Spiral and pyramid blocks over on rod

Reynolds number 14000
Spiral and rectangular blocks over on rod

6.39 Nusselt number

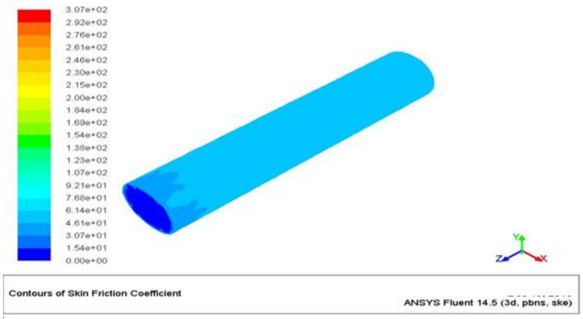

Fig 6.40 friction coefficient

FRICTION COEFFICIENT FOR SPIRAL AND PYRAMID BLOCKS OVER ON ROD

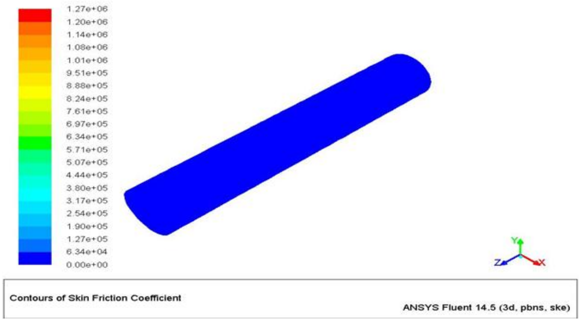

Fig 6.51 Friction Coefficient

REYNOLDS NUMBER - 14,000
Table 7.7 Analysis Results:

Pipe Type	Nusselt Number	Friction factor	Heat transfer rate(W)
Plain rod	52.018	48.40	5.2535928
Spiral over on rod	52.007	21.20	0.43825935
Spiral over on rectangle	52.018	47.80	6.8288705
Spiral on square	51.8711	20.87	-1.0898772
Spiral over on pyramid	52.018	188.4	-0.043541745

COMPRISON GRAPHS OF DIFFERENT INSERTS FOR VARIOUS REYNOLDS NUMBER

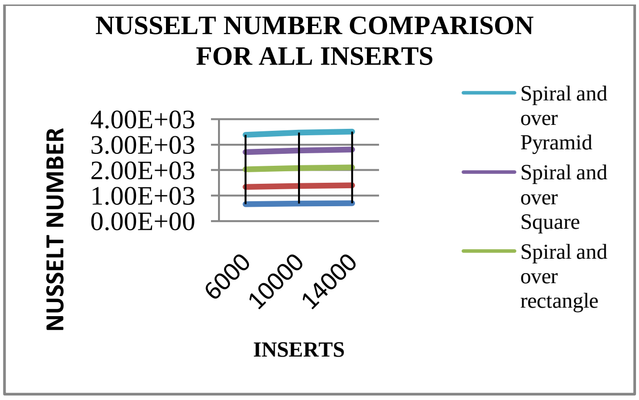

Fig 6.2 Nusselt Number Comparison

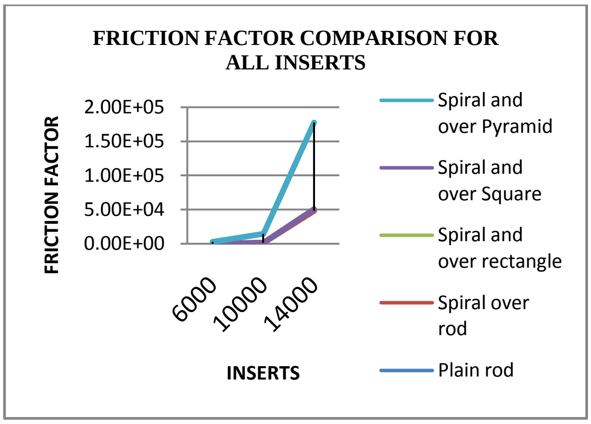

Fig 6.3 Friction Factor Comparison

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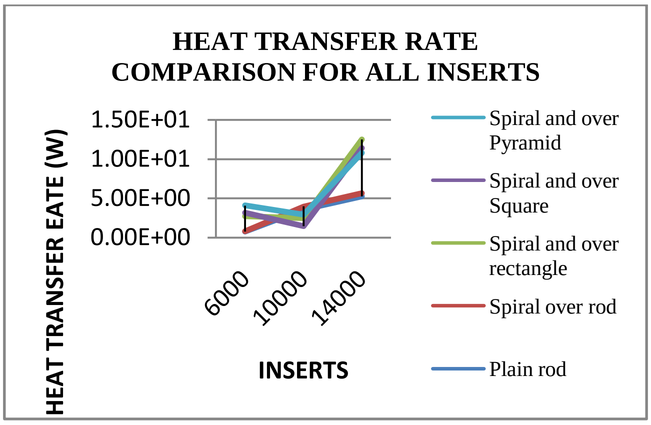

Fig 6.5 Heat Transfer Rate Comparison

CONCLUSION:

The five different types of inserts used 1) Plain rod 2) Spiral over on rod 3) Spiral and square blocks over on rod 4) Spiral and rectangle blocks over on rod 5) Spiral and pyramid blocks over on rod.CFD analysis is done for different Reynolds's number varying from 6000, 10000 and 14000. Finite element analysis is done in Ansys to determine Nusselt number, friction factor, heat transfer rate and mass flow rate and comparison is done between the inserts. Form the analysis results; the following conclusions can be made: The Nusselt number is more for spiral over on rectanglular than other inserts, friction factor, Nusselt number are more for spiral and pyramid over rod. But the heat transfer rate is more for spiral and rectangular blocks over on rod. When compared the results for different Reynolds number, Nusselt number is more at Reynolds number 14000 and decreasing with decrease of Reynolds number. Friction factor, mass flow rate, pressure are more at Reynolds number 14000 and it is increase of Reynolds number. The heat transfer rate is more at Reynolds number 14000.

REFERENCES:

[1]A. Garc, J.P. Solano, P.G. Vicente, A. Viedma, Enhancement of laminar and transitional flow heat transfer in tubes by means of wire coil inserts, International Journal of Heat and Mass Transfer 50 (2007) 3176–3189.

[2]S.S. Hsieh, F.Y. Wu, H.H. Tsai, Turbulent heat transfer and flow characteristics in a horizontal circular tube with strip-type inserts: Part I. Fluid mechanics, International Journal of Heat and Mass Transfer 46 (2003) 823–835.

[3]M.M.K. Bhuiya, M.S.U. Chowdhury , M. Islam , J.U. Ahamed , M.J.H. Khan , M.R.I. Sarker , M. Saha, "Heat transfer performance evaluation for turbulent flow through a tube with twisted wire brush inserts", Elsevier, International Communications in Heat and Mass Transfer 39 (2012) pp- 1505–1512.

[4]Halit Bas, VeyselOzceyhan, "Heat transfer enhancement in a tube with twisted tape inserts placed separately from the tube wall", Elsevier, Experimental Thermal and Fluid Science 41 (2012), pp- 51–58.

[5]M.M.K. Bhuiya , M.S.U. Chowdhury, M. Saha, M.T. Islam, "Heat transfer and friction factor characteristics in turbulent flow through a tube fitted with perforated twisted tape inserts", Elsevier, International Communications in Heat and Mass Transfer 46 (2013) 49–57.

[6]M.M.K. Bhuiya, A.S.M. Sayem, M. Islamc, M.S.U. Chowdhury, M. Shahabuddin, "Performance assessment in a heat exchanger tube fitted with double counter twisted tape inserts", Elsevier, International Communications in Heat and Mass Transfer (2013) pp-1-9.

[7]Pankaj N. Shrirao, Dr. Rajeshkumar U. Sambhe, Pradip R. Bodade, "Experimental Investigation on Turbulent Flow Heat Transfer Enhancement in a Horizontal Circular Pipe using internal threads of varying depth", IOSR Journal of Mechanical and Civil Engineering, Volume 5, Issue 3 (Jan. - Feb. 2013), PP 23-28.

[8]Bodius Salam, Sumana Biswas, Shuvra Saha, Muhammad Mostafa K Bhuiya, "Heat transfer enhancement in a tube using rectangular-cut twisted tape insert", Elsev.

[9]S.K.SahaA.Dutta“ Thermo hydraulic study of laminar swirl flow through a circular tube fitted with twisted tapes” Trans. ASME Journal of heat transfer June 2001, Vol-123/ pages 417-427.

[10]Watcharin Noothong, Smith Eiamsa-ard and PongjetPromvonge” Effect of twisted tape inserts on heat transfer in tube” 2nd joint international conference on “sustainable Energy and Environment 2006” Bangkok, Thiland.

[11]Paisarn Naphon “Heat transfer and pressure drop in the horizontal double pipes with and without twisted tape insert” 2005 Elsevier Ltd.

[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” International Communications in Heat and Mass Transfer Vol. 33, Dec 2006.