ANALYSIS OF FLOW AND HEAT TRANSFER OF SOLAR FLAT PLATE COLLECTOR BY USING COMPUTATIONAL FLUID DYNAMICS

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ABSTRACT

Energy crisis is becoming a major problem which is faced by all over the world. In order to control this energy crisis problem many research are performed using renewable energy sources like using solar energy instead of electrical and fuel energy, because solar energy is free of cost and environmentally friendly. There have been many studies to improve the performance of the solar water heater. Heating water for domestic purpose is a simple and effective way of utilizing solar energy. Initial cost of solar water heating system is high but we get zero green energy cost..The specific objective of this study is to analyses the heat transfer through solar flat collector with used différent types of insertion. Also experimental study on the flow pattern of water inside riser tubes are investigated and obtained results experimentally analyse validation withComputational Fluid Dynamics.The approche for study basically consists of used experimental setup and used ANSYS Fluent for determining the flow pattern inside riser tubes.Solar energy is radiant light and heat from the Sun harnessed using a range of ever-evolving technologies such as solar heating, photo voltaics, solar thermal energy, solar architecture and photosynthesis. It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on the way they capture and distribute solar energy or convert it into solar power. This research mainly focuses on the different researches adopted for improvement in performance of solar flat plate collector water heater.

Keyword: -*Water, Thermometer, Experimental setup, CFD.*

1. INTRODUCTION

Solar energy is given from sun rays in the form of electromagnetic waves. The sun provides the energy needed to sustain life in our solar system. It is clean, inexhaustible, and universally available source of renewable energy. Solar energy is used by various well known natural effects and appears in nature some other forms of energy. The power from the sun intercepted by the earth is approximately 1.8×10^{11} MW which is many thousant of times larger than the present consumption rate on the earth of all commercial energy sources. The which is largest member of the solar system is a sphere of intensely hot gaseous matter having average distance of 1.495×10^{11} m.

Renewable energy sources have the capacity to play a significant role in replacing conventional fuels in four district zone such as electric power production , transportation of fuels , hot water production and off grid power services. Now a days 80% of the energy is produced by the fossil fuels .The distribution of fossil fuels around the world is uneven. Middle east countries posses more than half of the known oil reserves. This facts leads to economical instabilities around the world , which effects the whole geopolitical system. The impact it has on the environment as well as on human cannot be disputed. The increase in the rate of combustion of oil and coal will accelerate the deforestation rate. This major problem of energy crisis which is faced by all over the world. In order to control this energy crisis problem many researches has been performed using renewable energy sources like usingsolar energy instead of electrical energy and fuel energy.

Because solar energy free of cost. A solar collector intercepts the incident solar radiation, converts it into heat and finally transfers this heat to a working fluid for an end use system. The natural or free circulation solar water heating systems is most applicable in smaller installation. These are natural choice for domestic solar water system. The circulation of water between the solar collector and the heat store is given by gravity or thermosyphon action whereas in the forced convection system an electric pump is used for water circulation. The sun is a big natural fusion reactor with its constituent gases as the containing vessel retained by the gravitational forces. The developments are being carried out continuously in the field solar energy utilization. The different techniques were adopted such as used of cover materials, absorber plate materials, absorber and glazing coating etc. along with the changes in the design, fluid used for heat transfer.The used of conventional energy resources and its bad impact on environment have created renewed interest for the use of non conventional energy resources.

2. MATERIALS AND METHODS

2.1 Passive heat transfer augmentation technique:-

Passive Technique generally uses surface or geometrical modification to the flow channel by incorporating insert or additional devices. Promote higher heat transfer coefficient by disturbing or altering the existing flow behavior (except for extended surfaces) which also leads to increase in the pressure drop. Following methods are generally used

a) Inserts
b) Extended surface
c) Surface modification
d) Use of Additives

a) Insert :

Inserts refer to the additional arrangements made as an abstacle to fluid flow so as to augment Heat transfer.Different types of inserts are:

1) Twisted Tape and Wire coils 2) Ribs and Baffles

Fig : 2.1 Twisted tapes

2.2 DISCRIPTION

A solar water heater consist of a collector to collect solar energy and an insulated storage tank to store the hot water. The solar energy incident on the obsorber panel coated with selected coating, transfer the heat to the riser pipes underneath the absorber panel. In this riser tubes we inserted the twisted tape types of inserts to make the flow turbulent because they promot higher heat transfer coefficient by disturbing the existing flow behavior which also leads to increase in the pressure drop. The water passing through the riser tubes gets heated up and is delivered to

the storage tank. The material is used for the tubes is of copper. Twisted tape insert is also manufacturing from copper. The experimental setup consists of the following components.

- Thermocouples: -Themocouples are used to sense the the temperature. Themocouples are widely used type of temperature sensor and can also be used as a mean to convert thermal potential difference into electric potential difference.
- Control valve:- Control valve are used to regulate the mass flow rate of water. The control valve placed in the flow path of water and is given the knob having graduation in degrees.
- U tube manometer:- One U tube manometer is used to measure pressure drop across the duct.
- Digital temperature indicator:- Digital temperature indicator is used to get the temperature from different place of duct.

Features of flat plate collector:

1) Simplicity in design. 2) Easy maintenance requirement

3) Low cost 4) Effectiveness

2.3 Collector orientation

The orientation of flat plate collector is based on two consideration

- Azimuth angle: The Azimuth angle for fixed surface in the northern hemisphere is due to south. In Northern Hemisphere where sokoto is located , the collector orientation should be facing south.
- Tilt angle : The tilt angle for fixed flate plate collector is to tilt the surface to horizontal by an angle equal to the latitude of the location. Since thelattitude of sokoto is 45˚ the collectors were tilted to this angle.

2.4 Specification of Twisted Tape

a) Material : Aluminium
b) Width of twisted tape = 12mm
c) Length of insert = 100 cm
d) Thickness of insert = 3mm
e) Twist ratio = 3.2

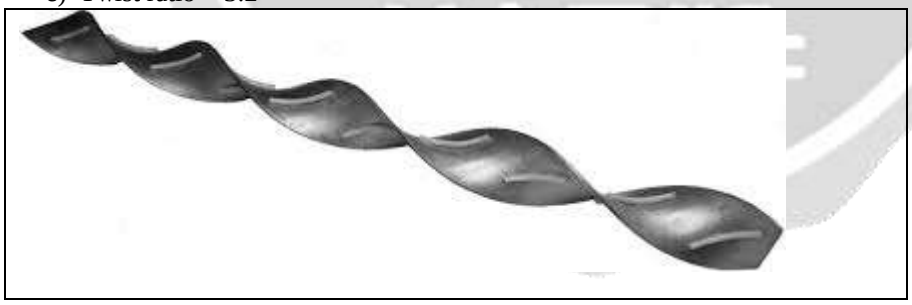


Fig. 2.2Aluminium Twisted Tape

2.4 Introduction of CFD

Computational Fluid Dynamics (CFD) is a computer-based tool for simulating the behavior of systems involving fluid flow, heat transfer and other related physical processes. It works by solving the equations of fluid flow over a region of interest, with specified conditions on the boundary of that region. Understanding the motion of liquids and gasses is crucial in many branches of engineering. Until recently, studies of fluids in motion were confined to the laboratory, but with the rapid growth in processing power of the personal computer, software applications now bring numerical analysis and solutions of flow problems to the desktop. In addition, the use of common interfaces and workflow processes make fluid dynamics accessible to designers as well as analysts.

Computational Fluid Dynamics (CFD) has become an integral part of the engineering design and analysis environment of many companies that require the ability to predict the performance of new designs or processes before they are ever manufactured or implemented. CFD solutions from ANSYS, Inc. are based on the proven technology of ANSYS CFX software. Companies around the world have trusted CFX computational fluid dynamics software to contribute to their success for more than 20 years.

Fluid dynamics is used in industries including aerospace, automotive, chemical processing, power generation, heating, ventilation, air conditioning, biomedical, oil and gas, marine and many others. From ventilation comfort in large buildings to the tiniest scale in micro-pumps and nanotechnology, a wide range of problems can be addressed due to the scalable nature of fluid dynamics. Expertise in assisting companies increase performance through simulation-driven design for pumps, fans, turbines, compressors and other rotating machinery has been incorporated in all elements of ANSYS CFX software, making it a leader in this demanding field. Specialized models for combustion, reacting flows and radiation, among others, help provide the insight into equipment and processes.

3. EXPERIMENTAL SETUP & EXPERIMENTATION

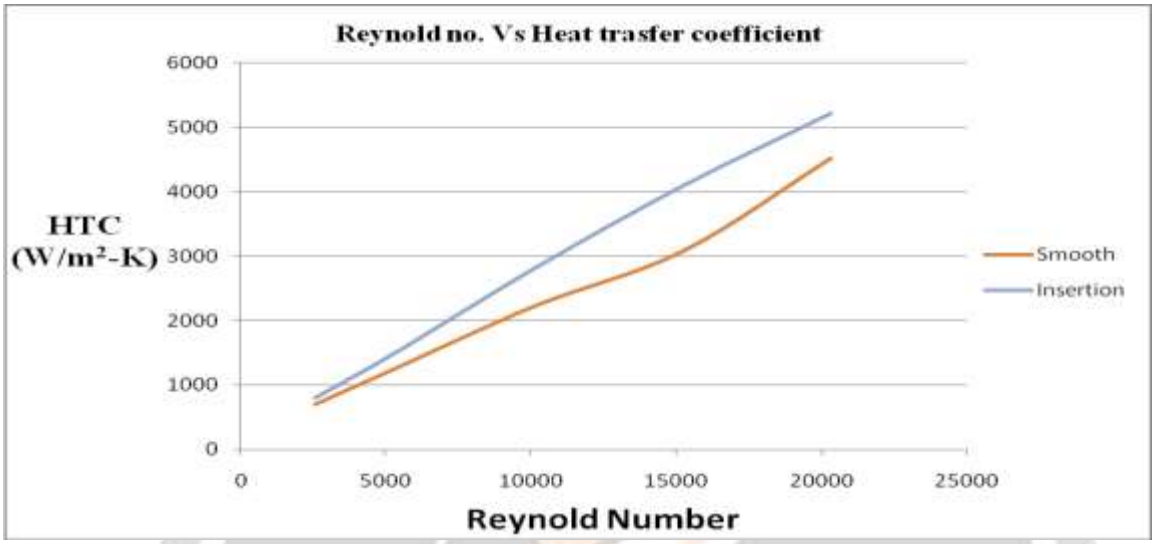
The schematic diagram of the solar flat collector along with the tank under consideration is shown in fig. 3.1, along with thermocouple locations. The flat plate collector is mounted inclined 45˚ and facing north south near to 100 liters tank. The experiment part consists of a 2.0 m of flat plat collector which is having six number riser tube of outer diameter 1.27cm made up from the copper with a length of 1.87m and a wall thickness 1.2 cm. These riser tubes are consist of copper heat collecting surface of thickness 0.20 mm. The wall temperature distribution of the riser pipe of collector plate measured using K-type thermocouple with an uncertainty of +-0.1˚ C. In addition the temperature of water flowing inside the tube are also measured with the help of digital thermometer. The riser pipe is connected to the copper tubes of outer diameter 5mm (drawn outside from the collector panel). This outside drawn copper tubes are attached with the value by means of flaring nut for measuring the pressure inside each riser tubes. The pressure gauge used for measure the pressure inside the tube is attached to the value through charging cable.The flow of water from tank is controlled with help of ball valve cock which is having certain opening for maintain the flow of water entering into the collector plate. This ball valve cock having the marking for different flow rate.

Fig.3.2Test Rig. Of Flat plate solar water heater with insertion of twisted tape

4. RESULT AND DISCUSSION

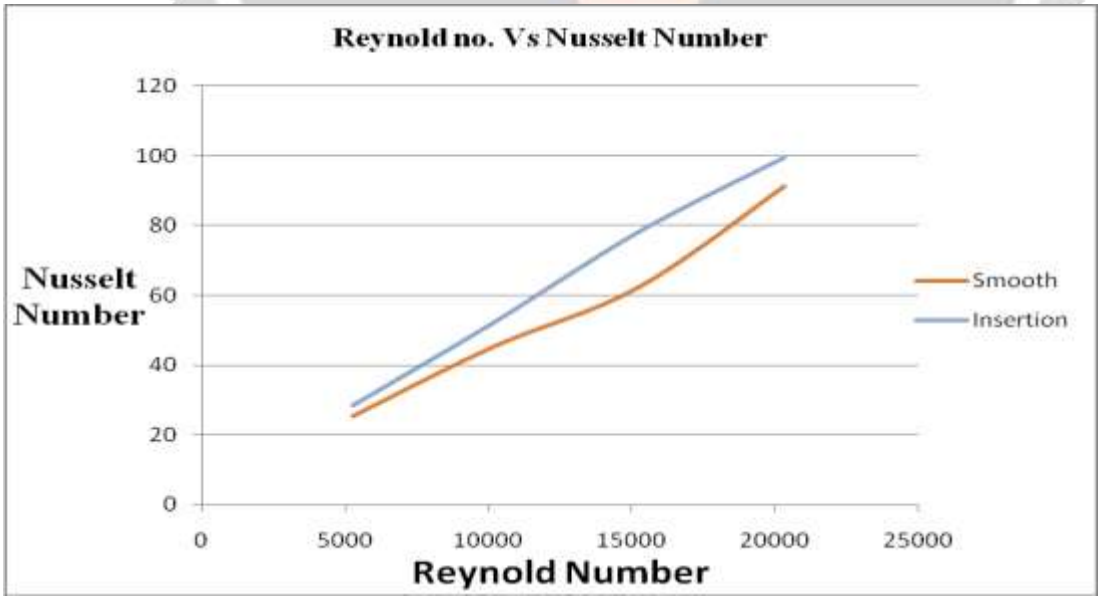
A. Effect of Reynold Number on Heat transfer coefficient

From the Fig. 4.1, it is observed the heat transfer coefficient increases with increase in Reynolds number. As Reynolds number increases, the water flow will cause more turbulence, so due to which the heat transfer rate will increase. From the Fig. 4.1 it is observed that the tube without insert gives less heat transfer coefficient than with the use twisted tape inserts.Twisted tape insert create more turbulene in the tube which increases the heat transfer coefficient. Twisted tape insert gives maximum value of heat transfer coefficient as compared to the smooth tube.



Graph: 4.1 Reynolds number V_S Heat transfer coefficient

B. Effect of Reynolds Number on Nusselt Number

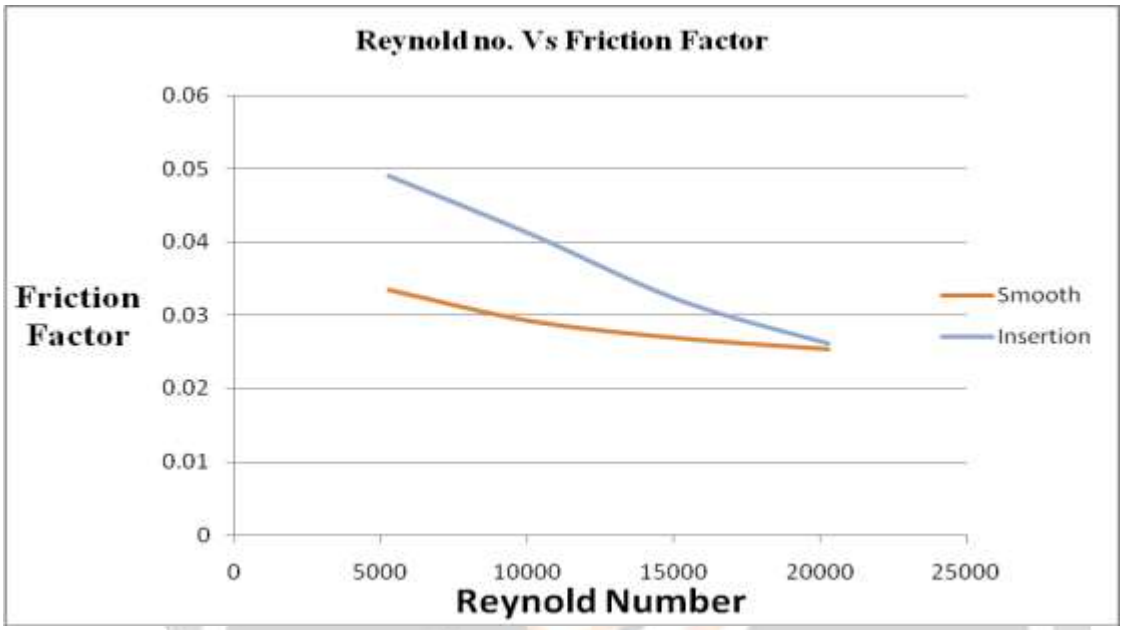


Graph: 4.2 Reynolds number V_S Nusselt Number

From Graph.4.2, it is observed that there is increase in Nusselt number with Reynolds number. As Reynolds number increases the water flow will cause more turbulence due to which heat transfer rate will increase. As heat transfer

rate is directictly proportional to Nusselt number, so increase in heat transfer coefficient with increase in Nusselt number .From Fig.4.2, it is observed that maximum Nusselt number is obtained from twisted tape as compared to the smooth tube.

C. Effect of Reynolds Number on Friction factor

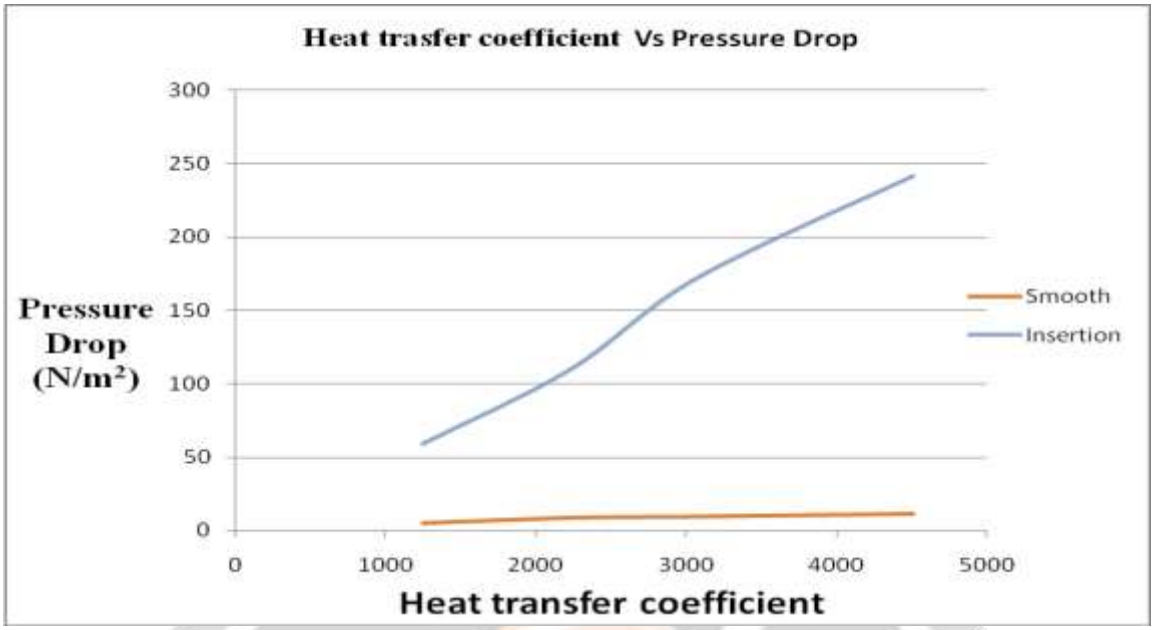


Graph:4.3 Reynolds number V_S Friction Factor

From the Graph.4.3 it is observed that Reynolds number increases there is decrease in friction factor is observed. This is because friction factor is inversely prortional to the velocity. So velocity increases with increase Reynolds number and friction factor will decreases. From the Fig.4.3 it is observed that least friction factor is observed in smoth tube as compared to twisted tape insert.

D. Effect of Heat transfer coefficient on Pressure Drop

From the Fig. 4.4 it is observed that as Heat transfer coefficient increases there is increase in pressure drop is observed. This is because as Reynold Number increases, the water will flow cause more turbulence, so due to which the heat transfer rate will increases with increase in pressure drop. Twisted tape insert create more turbulence in tube which increases the heat transfer coefficient due to this increase in the pressure drop.



Graph. 4.4 Heat transfer coefficient V_S Pressure Drop

5. CFD ANALYSIS OF DIFFERENT FLOW

A. Velocity, Pressure and Temperature Distribution at 1 LPM

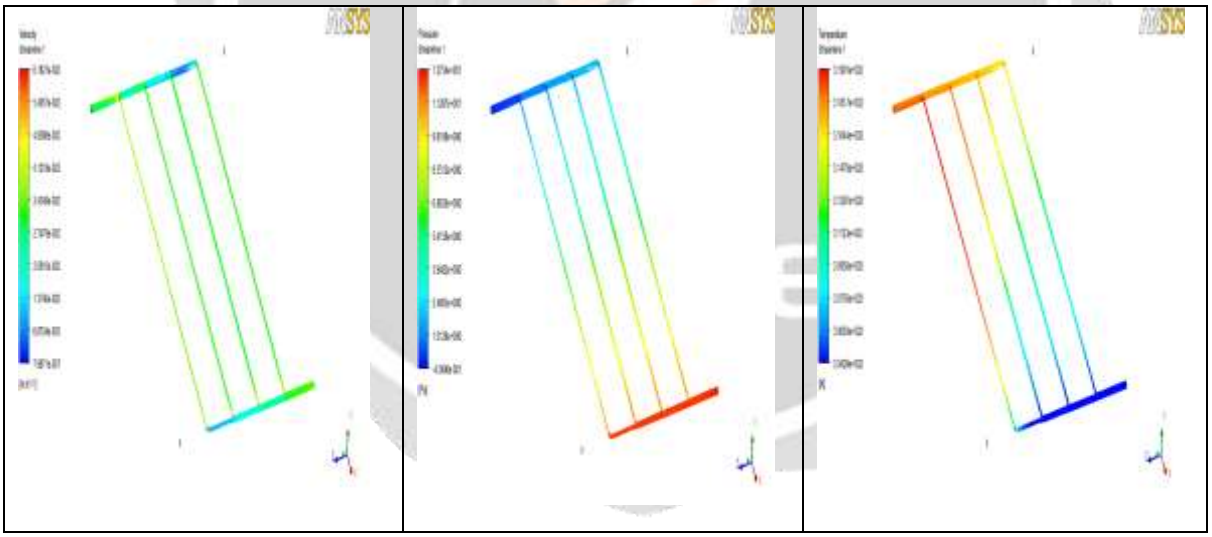


Fig. 5.1Velocity, Pressure and Temperature Distribution at 1 LPM

B. Velocity, Pressure and Temperature Distribution at 2 LPM

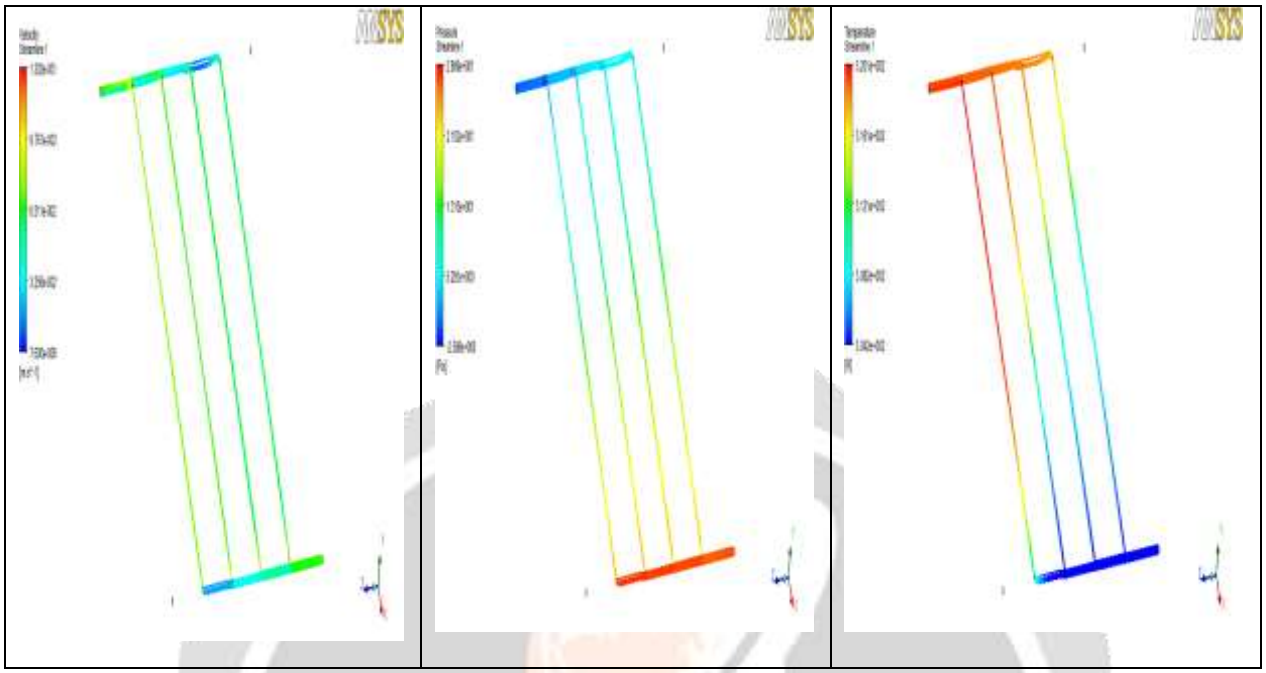


Fig. 5.2Velocity, Pressure and Temperature Distribution at 2 LPM

C. Velocity, Pressure and Temperature Distribution at 4 LPM

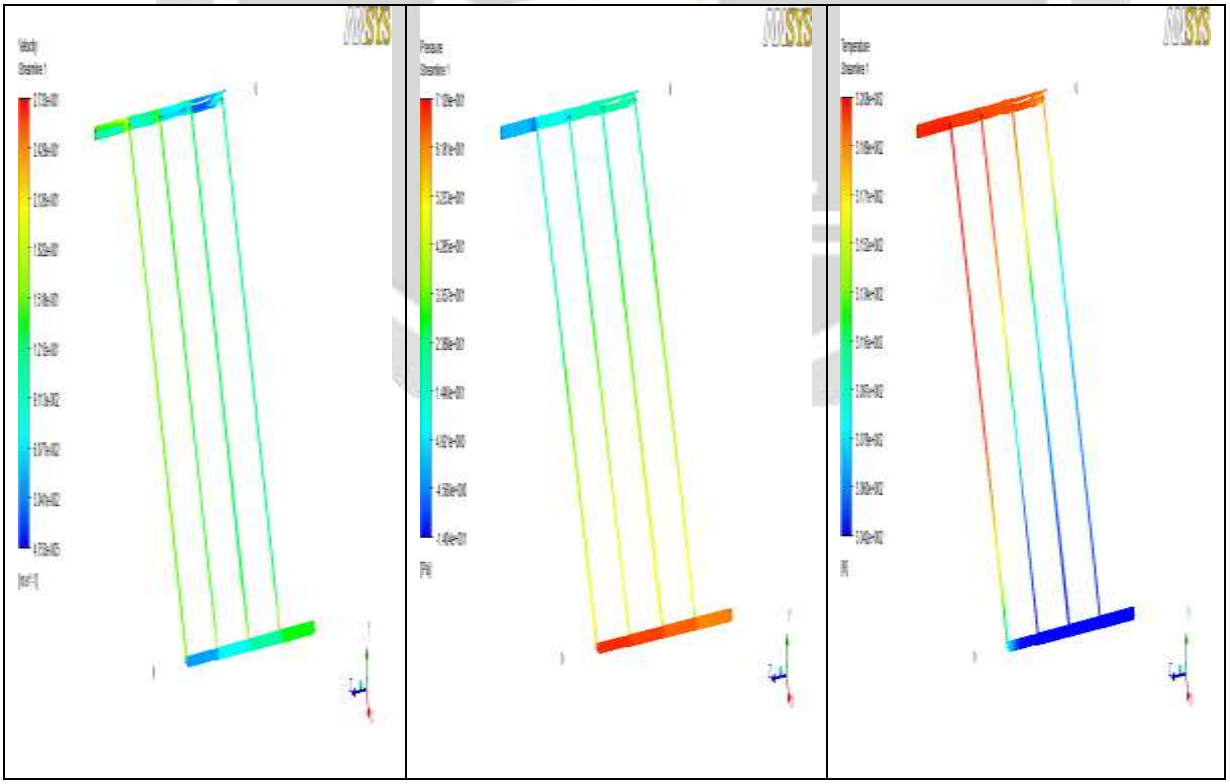


Fig. 5.3Velocity, Pressure and Temperature Distribution at 4 LPM

6. CONCLUSIONS

Experimental investigation have been carried out in the circular tube to computational fluid dynamics on the heat transfer enhancement, Reynolds number, Nusselt number and Friction factor .From the experimentation, following conclusion are made.

- The maximum heat transfer coefficient in tube with twisted tape insert is consequently increased 3076.411 W/m^2 k to 4097.83W/m^2 k CFD with increase in Reynold Number 15232.25 to 16119.29 at 6 lpm. The percentage increment in heat transfer coefficient is 33.20 %. This is due to the fact that the rise of Reynold Number leads to increase in degree of turbulence intensity and the improvement of convective heat transfer by using twisted tape shaped of inserts as compared to the smooth tube. This means that twisted tape provide superior chaotic mixing and more efficient interruption of thermal boundary layer. Hence Nusselt Number or heat transfer coefficient becomes higher with higher Reynold Number.
- Due to inserts in tube there is increase in pressure drop is observed. The increase in Average pressure drop of water from 38.934 N/m^2 to 622.998$N/m^{2.}$ This is because as Reynold Number increases, the water flow will cause more turbulence, due to which the heat transfer rate will increase with increase in pressure drop
- Friction factor reduces from (0.2093 to 0.15298) as the Reynolds number increases there is decrease in friction factor is observed. This is because friction factor is inversely proportional to the velocity. So velocity increases with increase Reynolds number. This friction factor found maximum in twisted tape inserts and minimum friction factor is obtained in smooth tube.
- The heat transfer rate in Smooth tube (without insert) and CFD is nearly equal i.e7835.62W and 7085.26W respectively. The percentage error in heat transfer coefficient is 9.58 %.

7. REFERENCES

1. Fabio Struckmann, “Analysis of a solar flat plate collector”,:Project Report 2008,Sweden.

2. Dr. Karima E. Amori, thermal improvement of solar hot water system using acceleratedriser in flat plate collector, The Iraqi Journal for Mechanical and Material Engineering, Special Issue (B) *TJER 2012, Vol. 9, No. 1, 1-10*.

3. R. Herrero Martín, A. GarcíaPinar , J. Pérez García, Experimental heat transfer research in enhanced flat-plate solar collectors, world renewable energy congress 2011-sweden, 8-13 may 2011, linkoping Sweden.

4. Madhukeshwara. N “An investigation on the performance characteristics of solar flat plate collector with different selective surface coatings”, international journal of energy and environment, Volume 3, Issue 1, 2012 pp.99-108.

5. Mustafa, Ismail. N.R collectors innovation to increase performance solar water heater, International Journal of Research in Engineering and Technology eISSN: 2319-116 ,pISSN: 2321-7308.

6. Maughal Ahmed Ali Baig“ Heat transfer Augmentation in concentric tube heat exchangerUsing twisted tapes” International journal of engineering research and application (IJERA)ISSN: 2248-9622 VOL. 3 Issue 3 May- June 2013, pp.1491-1496.

7. E. Ekramian, S.Gh. Etemad, M. Haghshenasfard “Numerical Analysis of Heat Transfer Performance of Flat Plate Solar Collectors” *Avestia Publishing Journal of Fluid Flow, Heat and Mass Transfer Volume 1, Year 2014 Journal ISSN: 2368- 6111.*

8. Razali Thaib, Hamdani, Irwansyah and Zaini“Investigation performance of solar water heater system using paraffin wax” ARPN Journal of Engineering and Applied Science VOL. 9, NO.10, OCTOBER2014 ISSN 1819-6608.

9. S. Vijayakumar,Enhancement of Heat Transfer Rate in a Solar Flat Plate Collector Using Twisted Tapes and Wire Coiled Turbulators, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:2, 2014.

10. S. Rajasekaran, Performance analysis of coated solar flat plate collector, International Conference on Energy Efficient Technologies For Automobiles (EETA' 15), ISSN: 0974-2115.

11. D. Lee, A. Sharma, (2007). "Thermal performances of the active and passive water heating systems based on annual operation" Solar Energy, 81, 207–215.

12. B. N. Mankar, Experimental Investigation of Flat Plate Solar Water Collector by Flow Pulsation and Metal Blocks, International Journal of Engineering Research &Technology (IJERT) ISSN: 2278-0181 Vol. 4 Issue 05, May-2015.

13. WatcharinNoothong "Effect of Twisted-Tape Inserts on Heat Transfer in A Tube"‖, The 2nd Joint International Conference on ―Sustainable Energy and Environment (SEE 2006), 21-23 November 2006.

14. Anil Singh Yadav Effect Of Half Length Twisted-Tape Turbulators On Heat Transfer And Pressure Drop Characteristics Inside A Double Pipe U-Bend Heat Exchanger‖, Jordan Journal of Mechanical and Industrial Engineering, Volume 3, Number 1, March. 2009, ISSN 1995-6665, Pages 17- 22.

15. J. U. Ahamed et al. ―Forced Convection Heat Transfer Performance of Porous TwistedTape Insert,Engineering e-Transaction (ISSN 1823-6379) Vol. 5, No. 2, December 2010, pp 67-79.

16. Bodius Salam, Heat Transfer Enhancement in A Tube Using Twisted Tape Insert, Proceedings of the 13th Asian Congress of Fluid Mechanics, 17-21 December 2010.

17. Sami D. Salman et Cfd Analysis of Heat Transfer and Friction Factor Characteristics in a Circular Tube fitted With Parabolic-Cut Twisted Tape Inserts‖ Australian Journal of Basic and Applied Sciences, 7(7): 69-76, 2013

18. Naresh B. Dhamane "Heat Transfer Analysis Of Helical Strip Insert With Regularly Spaced Cut Sections Placed Inside A Circular Pipe"‖ International Journal of Modern Engineering Research (IJMER) Vol. 2, Issue.5, Sep.-Oct. 2012 pp-3711- 3716.

19. Ranjitha P, Soma shekar V, Jamuna A B "Numerical Analysis of Solar Flat Plate Collector for Circular Pipe Configuration by using CFD Vol2 issue 12 IJERT December(2013).

20. Basavanna S , K S Shashishekar "CFD ANALYSIS OF TRIANGULAR ABSORBER TUBEOF A SOLAR FLAT PLATE COLLECTOR*Int. J. Mech. Eng. & Rob. Res.2013 ISSN 2278 – 0149Vol. 2, No. 1, January 2013.*

21.Prashant M Khanorkar, CFD analysis of natural convection flow through vertical pipe, Int.J. Mech. Eng. & Rob. Res. 2013, ISSN 2278 – 0149 Vol. 2, No. 3, July 2013.

22 .P.W.Ingle, Dr. A. A. Pawar, Prof. B. D. Deshmukh, Prof. K. C. Bhosale "CFD Analysis of Solar Flat Plate Collector"International Journal of Emerging Technology and Advanced Engineering ,ISSN 2250-2459, Volume 3, Issue 4, April 2013.

23. Puneeth kumar H P, Dr. S B Prakash"CFD ANALYSIS OF WIND PRESSURE OVERSOLAR PANELS AT DIFFERENT ORIENTATIONS OF PLACEMENT" International Journal of Advanced Technology in Engineering and Science Volume No.02, Issue No. 07, July 2014.

24. Amraoui. M. A., Aliane. K. Numerical analysis of a three dimensional fluid flow in a flat plate solar collector International Journal of Renewable and Sustainable Energy2014; 3(3): 68-75Published online June 20, 2014.

25. K. VasudevaKaranth, Numerical and experimental study of a solar water heater for enhancement in thermal performance, International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.

26. AliasgharOwlaIveli, Numerial Analysis In Order To Optimize the Geometrical Dimensions of the Solar Energy Storage Tank Considering Thermally Stratified An Increasing Tank Efficiency, Indian J.Sci.Res.1(2),599-610, 2014,ISSN:0976- 2876(Print),ISSN: 2250-0138.