Manufacturing The Experimental Set-Up And Analyzing The Enhancement In Heat Transfer Rate By Various Passive Methods

Pandey S.C.[1], Lopes N.N.[2], Yadav R.S.[3], Wagh R.S.[4], Chavan S.V.[5]
[1, 2, 3, 4, 5]Department of Mechanical Engineering
[1, 2, 3, 4, 5] Sinhgad Institute of Technology, Kusgaon (Bk), Lonavala

Abstract- *Transfer of heat is a very common natural phenomenon. The study of heat transfer has helped us construct various technologies. From an engineer's point of view the term 'rate of heat transfer' holds a very special place. This project undertakes the task of studying, understanding and implementing the methods used for the enhancement of heat transfer. There are numerous practical examples where it can be undertaken. In this study we attempt to achieve the objective of heat transfer enhancement in a receiver tube. From implementation point of view the results of the analysis can used to improve the efficiency of various applications ranging from Parabolic Trough Collector (PTCs) to Heat Exchangers. The three fundamental of achieving this are- i) Active Method ii) Passive Method iii) Compound Method. This paper focuses on the various passive methods and determines the most effective. The abstract idea of the project is to analyze and compare and determine the most optimum of the passive method viz. dimples, protrusions, inserts, baffles.*

Keywords- Convection, Dimples, Heat exchanger, Heat transfer enhancement, Passive Methods, Protrusions, etc.

I. INTRODUCTION

In engineering we are often interested in the 'Rate of heat transfer'. We see it in the form of conduction, convection, radiation or a combination of these. Transfer of heat to a flowing liquid is a common practical usage. This project is inspired from trying to improve this basic usage. Be it a heat exchanger or a receiver tube in a parabolic trough collector, the problem of enhancing the heat transfer rate to the fluid flowing inside a tube is worth considering. There have been numerous studies on this in last few decades. A lot of remarkable simulations and experiments on the efficiency of heat collection of parabolic trough receivers (PTRs) have been studied since 1980s. In order to reduce the number of receiver elements needed in the lines, the heat transfer rate from external heat flux to the tube should be enhanced. In general, the heat transfer augmentation methods are classified into three broad categories: active method, passive method and compound method. Active method involves some external input for the heat transfer enhancement while the passive methods always modify the geometric structure of the flow channel by incorporating inserts or additional devices. Compound method is the combination of the above two methods.

Various works have been published on the usage and effect of various passive methods. The solar power generation today is primarily based on two types: a) Using Photo-voltaic cells and b) Using Solar Thermal Generators. One of the primary methods of achieving it by the use of Concentrated Solar Power (CSPs). The PTCs are one of the primary modes under CSPs for power generation. A lot of work is being done in this field to enhance the heat transfer rate in the receiver tube of PTCs so as to make them more efficient. This may serve as one of the major applications of this project. A lot of work has been done and remains to be done in the field. We also come across almost every major passive method used. Inserting twisted tapes, the influence of twist ratios and clearance ratios, use of phase change materials, use of fins, use of helical fins, ribs, protrusions, dimples, inserting metal foams, inserting vortex generators, use of baffles, change in fin profile, using nano-fluids, inserting annular grooves and a few combinations of these are all the methods we come across. This paper has shortlisted a few of these based on the feasibility and also on the basis of which methods have been shown to demonstrate a higher effect on heat transfer enhancement and perform comparative experimental study of these methods. The objective of this paper is to determine the most suitable Passive method for enhancing the heat transfer rate in a receiver tube. The effects of various methods have been well documented across all the literature we came across. But we did not find any sort of comparative study of the effects of the various passive methods on heat transfer enhancement. Thus, we aim to determine by comparatively studying the effects of the mostly used passive methods. The scope of the research in this paper could be understood from the following key features: i)Procuring the modified receiver tubes for the study. ii) Fabrication and experimental testing of the modification under the required conditions. iii) Comparison of the modifications with respect to heat transfer enhancement, cost, and specific area of application, advantages and dis-advantages. iv) Suggestions for adapting the methods in various industrial applications. Enhancement by methods is found to happen for sure but the optimization will depend on the conditions and requirements of the applications.

II. LITERATURE REVIEW

Chang et. al.[3] in 2015 conducted numerical analyses were conducted to investigate the heat transfer enhancement performances of molten salt in a twisted tape inserted tube with circumferentially non-uniform heat flux. Effects of clearance ratio and twist rate were analysed. The heat transfer in the receiver tube is found to be significantly increased with decrease in clearance ratios. Similar effects are seen when twist ratio is decreased. The enhancement effects are found to slow done with increase in Reynolds number.

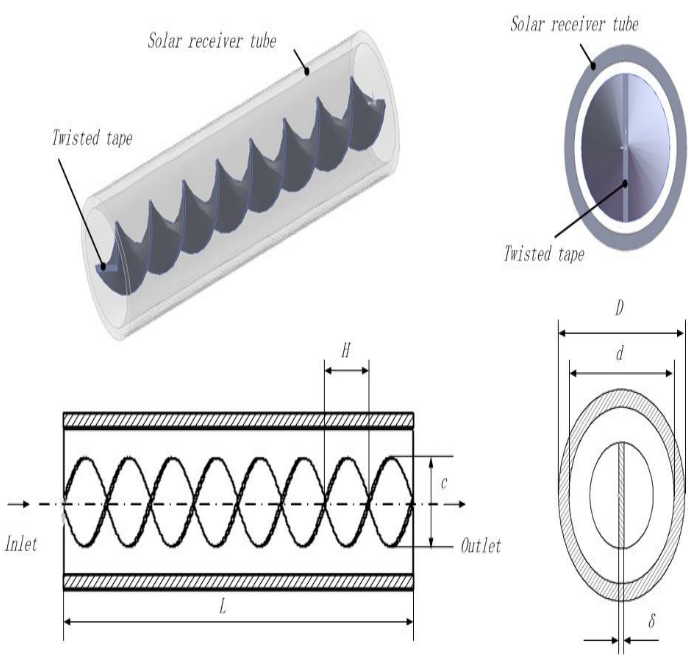

Fig.1 Geometry of solar receiver tubes with twisted tape inserts [3]

Li et. al. [4] in 2015 states that vacuum tubular receiver is the core component of parabolic trough collector (PTCs). The paper investigates the methods to improve the convective heat transfer inside the inner tube. The focus is on the heat transfer fluid (HTF) side. A numerical simulation was performed on the fully developed turbulent flow and heat transfer in the inner tube with and without helical fins, protrusions and dimples. The results showed that receiver tubes with dimples have superior performance of heat transfer augmentation compared with that with protrusions or helical fins.

Wang[7] in 2013 presented the effect of regularly spaced twisted tape (*RS-TT*) on the heat transfer, friction factor and thermal performance factor behaviour in a heat exchanger along with those of full length twisted tape. The full length twisted tape with two different twist ratios (y = P/W= 6.0 and 8.0), and the regularly-spaced twisted tape (*RS-TT*) with two different twist ratios (y = 6.0 and 8.0) and three free space ratios (s = S/P= 1.0, 2.0 and 3.0) were employed for comparative study. The results showed that the heat transfer rate and friction factor increased with decreasing twist ratio and space ratio. It also concluded that full length twisted tapes offered higher heat transfer rate, friction factor and thermal performance factor than RS-TT ones under similar conditions. Eiamsa-ard S. et. al. [8] in 2014 presented a numerical computation results on turbulent flow and coupled heat transfer enhancement in a modified parabolic trough solar absorber tube. All the average Nusselt number and the average friction factor increase with the increase of each geometric parameter, while the average wall temperature and thermal loss decrease with the increase of each geometric parameter but with different variation trends. He et. al. [9] in 2012 studied the numerical computation results on turbulent flow and coupled heat transfer enhancement in a parabolic trough solar absorber tube and also experiments and simulations on the thermal performance of parabolic trough receivers (PTR). One of the most important objectives is to enhance the heat transfer from the external solar flux to the inner absorber tube, so that the number of receiver elements needed in the lines can be reduced.

Munoz J. and Abanades A. [10] in 2011 studied the effect of utilization of internal finned tubes for the design of parabolic trough collectors with computational fluid dynamics tools. From this paper it is clear that the effect of the utilization of internal finned tubes for the design of parabolic trough collectors with computational fluid dynamics tools has been analyzed.

Kundu[11] in 2015 stated that the increase in fin height in a longitudinal fin, heat transfer area increases but at the same time, the driving force for the motion of the fluid increases. It was found that the heat transfer rate was less than the rectangular cross-section by keeping a constant outer diameter. Along with other constraints of heat exchanger design. But when the total volume of fin was kept constant, using trapezoidal fins the heat transfer rate was found to increase.

Yonghui et. al. [6] in 2015 applies and investigates a compound heat transfer enhancement technique, the combination of ribs, dimples or protrusions to a U-shaped square channel. This paper focuses on the effects from gas turbine point of view and thus, also introduces rotational effects. The effect of rotation on fluid flow and heat transfer performance was investigated along with the combination structure of ribs, dimples or protrusions. The effect of rotation on rib-protrusion channel was found to be more intense than rib-dimple channel.

Liu et. al.[13] in 2014 states that the laminar and turbulent forced convection heat transfer and flow characteristics of nano-fluids in small smooth tubes are numerically simulated using two kinds of multiphase-flow models. The study results show that little deviation exists between the simulated results and the traditional predicting correlations for low concentration nano-fluid, which indicates that low concentration nano-fluid has no meaningful nano-effect on forced convection heat transfer. From this paper it is clear that Solid–liquid mixture model and Eulerian model are employed to simulate the heat transfer and flow characteristics of nanofluid in a tube based on the detailed experimental condition with wide range of Reynolds number and volume concentration, and the calculated results are compared with the experimental data and the traditional simple flow correlations. Wang et. al. [15] in 2014 states that the conjugate heat transfer numerical method is employed to investigate the average heat transfer and fluid flow characteristics of the staggered circular tube bank fin heat exchanger. The studied annular groove's radial and circumferential locations have a fairly limited effect on the average heat transfer and fluid flow characteristics, but the local flow field is closely dependent on the annular groove's radial and circumferential locations. Lazim et. al. [17] in 2015 states that the various techniques have been tested on heat transfer enhancement to upgrade the involving equipment, mainly in thermal transport devices. This article shows the determination of the thermal performance of unique smooth corrugation profile. The Performance Evaluation Criteria were calculated for corrugated tubes, and the simulation results of both Nusselt number and friction factor were compared with those of standard plain and corrugated tubes for validation purposes. Basically, we saw that there are three approaches available to enhance the rate of heat transfer i.e. active method, passive method and compound method. A power source is essential for the active method and certain surface modifications or extension and inserts or fluid additives are used in the passive method, while the compound method is a combination of the above two methods such as surface modification with fluid vibration.

III. STUDIES AND FINDINGS

The receiver tube was modified as shown in Fig. 2. The experimental trials were conducted on these modified tubes. .A schematic of the proposed set-up is shown below. We have chosen water as the working fluid for this project. The set-up consists of water tank which supplies water to the receiver tube. The receiver tube is detachable. Various modified versions of the receiver tube, employing the passive method respectively are attached for experimentation. Heater is provided to supply heat energy to the tube. The thermocouples is placed at strategic points on the tube for temperature measurement. The mass-flow rate and the pressure is varied. Pressure gauges measures the pressure of liquid. Finally the water from the tube gets collected in a water reservoir. Thus the Nusselt number and friction factor were calculated for each of these tubes. This gave a relation of the enhancement in heat transfer rate as compared to the pressure drop in each of the cases.

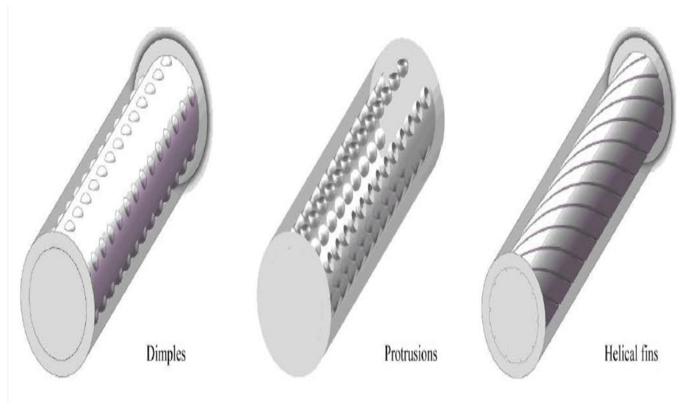

Fig. 2 Schematic Diagram of various receiver tubes with dimples, protrusions and helical fins

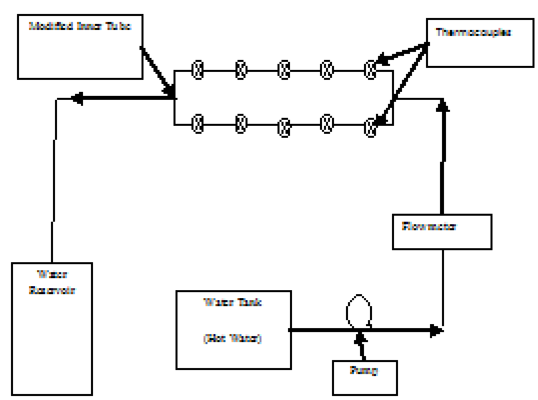

Fig. 3 Block Diagram of the Experimental Set Up

IV. RESULTS

The Nusselt number and friction factor were calculated for each of these tubes. This gave a relation of the enhancement in heat transfer rate as compared to the pressure drop in each of the cases. The heat transfer rate was found to be more enhanced in tube with dimples as compared to others. Modification in the form of baffles, introduced by us were also found to perform well but it needs more study. The baffles performed as expected but also lead to higher pressure drop as compared to dimples.

V. CONCLUSION

The passive methods do enhance the heat transfer but effectiveness will vary according to the requirements of the intended application. Similarly the baffles may perform better with optimized design and need more study. The comparison of combined effects and the individual effects also needs to be studied.

ACKNOWLEDGEMENT

We acknowledge the support of Dr. V. V. Shinde, Head of Department, Mechanical Engineering and the Prof. A. G. Kamble - Project Co-ordinator, Department of Mechanical Engineering.

REFERENCES

[1] S.A. Odejide, - ‘Fluid flow and heat transfer in a collapsible tube with heat source or sink’, Journal of the Nigerian Mathematical Society 34 (2015) Pp. 40–49

[2] M.A. Teamah*, M.M. Khairat,- ‘Heat transfer due to impinging double free circular jets’, Alexandria Eng. J. (2015), http://dx.doi.org/10.1016/j.aej.2015.05.010

[3] C.Chang*, C.Xu, Z.Y.Wu, X.Li, Q.Q.Zhang, Z.F.Wang,- ‘Heat transfer enhancement and performance of solar thermal absorber tubes with circumferentially non-uniform heat flux’, Energy Procedia 69 (2015) Pp. 320 – 327

[4] Z. Huang, G.L. Yu, Z.Y. Li*, W.Q. Tao,- ‘ Numerical study on heat transfer enhancement in a receiver tube of parabolic trough solar collector with dimples, protrusions and helical fins’, Energy Procedia 69 (2015) Pp. 1306 – 1316

[5] D.J. Malan*, R.T. Dobson, F. Dinter,-‘ Solar thermal energy storage in power generation using phase change material with heat pipes and fins to enhance heat transfer’, Energy Procedia 69 (2015) Pp. 925 – 936

[6] Zhongyang S, Yonghui X*, Di Z, Numerical predictions on fluid flow and heat transfer in U-shaped channel with the combination of ribs, dimples and protrusions under rotational effects, International Journal of Heat and Mass Transfer 80 (2015) 494–512

[7] Wang P*, Liu DY, Xu C. – ‘Numerical study of heat transfer enhancement in the receiver tube of direct steam generation with parabolic trough by inserting metal foams’. Applied energy 2013; Pp. 102:449-460.

[8] P.Eiamsa-ard, N.Piriyarungroj, C.Thianpong, S.Eiamsa-ard*,- ‘ A case study on thermal performance assessment of a heat exchanger tube equipped with regularly-spaced twisted tapes as swirl generators’, Case StudiesinThermalEngineering3(2014) Pp. 86–102

[9] Cheng ZD, He YL*, Cui FQ. – ‘Numerical study of heat transfer enhancement by unilateral longitudinal vortex generators inside parabolic trough solar receivers.’ International journal of heat and mass transfer 2012; 55:5631-5641.

[10] J Muñoz*, A Abánades.- ‘Analysis of internal helically finned tubes for parabolic trough design by CFD tools’, Applied Energy 88 (2011) Pp. 4139–4149

[11] B Kundu – ‘Beneficial design of unbaffled shell-and-tube heat exchangers for attachment of longitudinal fins with trapezoidal profile’, Case Studies in Thermal Engineering5 (2015) Pp. 104–112.

[12] EW Tow, JH Lienhard*- ‘Heat transfer to a horizontal cylinder in a shallow bubble column’, International Journal of Heat and Mass Transfer 79 (2014) Pp. 353–361

[13] YJ Chen, YY Li, ZH Liu*- ‘Numerical simulations of forced convection heat transfer and flow characteristics of nanofluids in small tubes using two-phase models’, International Journal of Heat and Mass Transfer 78 (2014) Pp. 993–1003

[14] F Bozzoli*, L Cattani, S Rainieri, G Pagliarini- ‘Estimation of local heat transfer coefficient in coiled tubes under inverse heat conduction problem approach’, Experimental Thermal and Fluid Science 59 (2014) Pp. 246–251

[15] ZM Lin, LB Wang*, YH Zhang- ‘Numerical study on heat transfer enhancement of circular tube bank fin heat exchanger with interrupted annular groove fin’, Applied Thermal Engineering 73 (2014) Pp. 1465e1476

[16] M Xie, Z Xue*, W Qe, W Li- ‘Experimental investigation of heat transfer performance of rotating heat pipe’, Procedia Engineering 99 (2015) Pp. 746 – 751

[17] Kaneem Z.S., Jafer M.N., Lazim T.M. -'Heat transfer enhancement in two-start spirally corrugated tube', Alexandria Engineering Journal (2015), pp. 54, 415–422

[18] Tahseen T.A., Rahman M.M., Ishak M. - 'Experimental Study on Heat Transfer and Friction Factor in Laminar Forced Convection over Flat Tube in Channel Flow', Procedia Engineering (2015), 105, pp. 46 – 55

[19] Whalley R.D., Abed W.M., Dennis D.J.C., Poole R.J. - 'Enhancing heat transfer at the micro-scale using elastic turbulence', Theoretical and Applied Mechanics Letters (2015), 5, pp. 103–106

[20] Abed A.M. , Sopian K., Mohammed H.A., Alghoul M.A., Ruslan M.H., Mat S. , Shamani A.N.-'Enhance heat transfer in the channel with V-shaped wavy lower plate using liquid nanofluids', Case Studies in Thermal Engineering (2015), 5, pp. 13–23

[21] Shekhar C., Nishino K.- 'Oscillation and heat transfer in upward laminar impinging jet flows',International Journal of Heat and Fluid Flow (2014), 50, pp. 316–329

[22] Boumaza M., Omara A.- 'Numerical investigation of transport phenomena properties on transientheat transfer in a vertical pipe flow', Journal of King Saud University-Engineering Sciences (2015), 27, pp. 119-12