A Review on Convective Heat Transfer Augmentation Using Non Metallic Insert

Mr. G S Bhosale [1], Mr. S S Kale [2], Dr. Bimlesh Kumar[3]

[1]G S Bhosale M-Tech Student of Mechanical Department, N.K. ORCHID College of Engineering and Technology, Solapur, Maharashtra, India.
[2]Prof. S S Kale Mechanical Department, N.K. ORCHID College of Engineering and Technology, Solapur, Maharashtra, India.
[3]Dr. Bimlesh Kumar, Principal ,Government Polytechnic , Purnea, Patna, Bihar, India.

---***---

Abstract - Convective heat transfer augmentation techniques are used in many industrial applications such as process industries, thermal power plants, heating ventilation and air conditioning system, refrigeration system, radiator of automobile etc. Heat transfer augmentation techniques can be classified as active, passive and compound. The main objective of this study is to understand heat transfer augmentation using passive techniques. In passive techniques inserts are used to increase convective heat transfer coefficient (h) with decrease in thermal resistance. This study is review of progress in the field of heat transfer augmentation using non metallic inserts in past few years. In this study different research work, methodology and results obtained in the field of heat transfer augmentation are discussed. Different types of inserts, their geometry and effect of their geometry on rate of heat transfer are discussed in this study. The performance of non metallic insert (acrylic twisted tape) is found to be better than metallic (aluminium) insert by 51.36% [4]. Nusselt number is found to increase to 112 and 187 percentage for Bakelite differential annular type insert and non metallic acrylic twisted tape insert respectively than plain tube [1]. It is found that heat transfer rate is enhanced more for the twisted tape having small pitch to diameter ratio and small angle of twist [3].

Key Words: Heat transfer augmentation, Insert, Flow divider insert, twisted tape inserts, twist ratio, friction factor.

1 .INTRODUCTION

Heat transfer is transfer of energy from one object to other due to temperature difference. Heat transfer process is used in many industries such as food process, chemical, automobile and thermal industries which directly influence the economy of these industries. Enhancing the performance of heat transfer devices leads to energy material and cost saving. The study of increased heat transfer performance is known as heat transfer augmentation. In this main focus is kept on increasing convective heat transfer coefficient (h). Heat transfer augmentation techniques can be classified as active, passive and compound techniques. In active techniques, there is need of external power for enhanced heat transfer on other hand passive techniques do not require any external power. The combination of active and passive technique is known as compound technique. As compared to active technique, passive technique is cost and performance efficient. So, in this paper heat transfer augmentation using passive techniques are studied in detail.

In passive techniques convective heat transfer coefficient is increased by decreasing thermal resistance so that there is enhancement in heat transfer. This can be achieved either by increasing the effective heat transfer area or by generating turbulence in the fluid flowing through the device. For increasing effective area, some modifications are done inside the pipe such as introduction of rough surfaces or extended surfaces. The turbulence is generated by using inserts or turbulators.

Friction factor(f): It is one of the parameter used for judging performance of enhancement technique. Friction factor relates the pressure drop to other properties of flow , velocity and geometry of pipe. Friction factor is a dimensionless number. For laminar fully developed flow friction factor is function of only Reynolds number. For turbulent fully developed flow friction factor is function of Reynolds number and (e/D) ratio. e/D is roughness parameter for inner wall of pipe also known as relative roughness and it is the ratio of mean height of roughness of pipe to diameter of the pipe.

$$f = \frac{\Delta PL}{\left(\frac{L}{D}\right)\left(\frac{\rho v^2}{2}\right)}$$

Overall enhancement ratio(η) and enhancement efficiency(ψ):

These two factors give us information about performance of system used to enhance the heat transfer. The performance is evaluated by comparing results obtained using and without using inserts.

$$\eta = \frac{\left[\frac{Nu_i}{N_u}\right]}{\sqrt[3]{\left[\frac{f_i}{f}\right]}}$$

$$\psi = \frac{h_i}{h}$$

In passive techniques of heat transfer augmentation, values of Nusselt number , friction factor, overall enhancement ratio and enhancement efficiency are calculated for a pipe with and without using insert. As Nusselt number is directly related to convective heat transfer coefficient so it will give information about enhancement in heat transfer.

Table -1: Nomenclature

P	density of fluid (kg/ m³)
V	Fluid velocity (m/s)
d	Diameter of tube(m)
μ	Dynamic viscosity of fluid (Ns/m²)
K	Thermal conductivity(W/m·K)
Cp	Specific heat (J/kg k)
h	Convective heat transfer coefficient(w/m²k)
e/D	Roughness factor
L	Characteristic length (m)
Nu_i	Nusselt number with insert
Nu	Nusselt number in plain pipe or tube
f_i	friction factor with insert
hi	convective heat transfer coefficient using insert(w/m2k)
h	convective heat transfer coefficient for plain tube (w/m2k)
p/d	Pitch to diameter ratio
TR	Twist ratio

2. LITERATURE SURVEY

S.G. Mushan et al. [1]: This experimental study is based on passive technique of heat transfer augmentation. In this study two types of insert are used namely Bakelite differential annular insert and flow divider type non metallic acrylic twisted tape insert. Air is used as working fluid for this experimental investigation. Constant heat flux is applied to test section (plain pipe). Firstly, an experimental investigation is carried out on plain tube to obtain Nusselt number and friction factor. Obtained values are compared with values obtained using correlations (Dittus-Boelter and Blasius) to validate experimental setup. Two tests were carried out to calculate Nusselt number and friction factor in pipe using non metallic inserts. Values of Nusselt number and friction are obtained by varying Reynolds number from 5000 to 17000. Nusselt number and friction factor obtained by using non metallic inserts are compared with values obtained for plain tube case. Also overall enhancement ratio and enhancement efficiency are calculated for both the inserts. In this experiment it is observed that for Bakelite insert, Nusselt number increased by 12%, friction factor found to be in range 0.5 to 0.6 and overall enhancement was observed in range 0.54 to 1.12. For acrylic twisted tape insert, Nusselt number increased by 87%, friction factor was observed in the range 0.06 to 0.08 and overall enhancement ration was observed in range 1.10 to 1.58.

D.R. Hase et al. [2]: This research work is based on passive technique of heat transfer augmentation using Nylon flow divider insert (non metallic insert). The non metallic flow divider type insert creates turbulence which increases heat transfer rate. The angle between two consecutive blades is kept 90 degrees. Constant heat flux is applied to test section (plain pipe) and experimental investigation is carried out for different mass flow rates of air to calculate Nusselt number and friction factor. Firstly, an experimental investigation is carried out on plain tube to obtain Nusselt number and friction factor. Obtained values are compared with values obtained using correlations (Dittus-Boelter and Blasius) to validate experimental setup. After validating the setup, experimental investigation is carried out by inserting nylon flow divider insert in test section to calculate Nusselt number and friction factor. Obtained values of Nusselt number and friction factor for both above mentioned case are compared with each other. Also , overall enhancement ratio and enhancement efficiency are calculated for nylon flow divider insert. In this study it is observed that friction factor is high at low Reynolds number and it decreases with increase in Reynolds number. In this experiment it is observed that Nusselt number increased by 70%, Overall enhancement ratio was above unity and enhancement efficiency observed in the range 1.5 to 2.0.

Sandeep P. Nalavade et al. [3]: This research work gives results of experimental and numerical investigation of friction factor and forced convective heat transfer characteristics for air flow in a heated pipe using novel flow divider type turbulators. The turbulator consist of aluminium divider plates mounted on a central rod having twist angle of 90 degrees. Experiment is carried out for turbulent flow regime for Reynolds number range 7000 to 21000. In this research work two things are studied i) Effect of pitch to diameter ratio of turbulators on heat transfer, friction factor and overall thermal performance ii) Effect of and of twist of turbulators on heat transfer, friction factor and overall performance factor. In this experiment pitch to diameter ratio parameters (p/d=0.54, 0.72 and 1.09) are investigated with angle of twist 90 degrees. The experimental investigation is checked to study the impact of pitch to diameter ratio on convective heat transfer and pressure loss in fluid flow behaviour. CFD simulation is carried out to find the effect of change in angle of twist of turbulators. In this experiment constant heat flux is given to the test section (GI pipe). Data such as temperature of tube wall, air inlet, air outlet and the differential pressure drop across the test section and pressure head at orifice meter are recorded. The above data are used to calculate Nusselt number, friction factor and thermal performance factor for different Reynolds number.

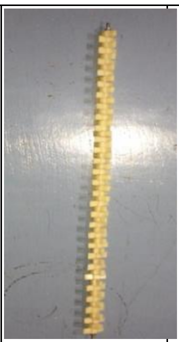
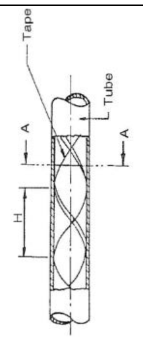
M.M.Herlekar et al.[4]: This experimental study is based on passive technique of heat transfer enhancement using non metallic flow divider type insert along with air as a working fluid. For validation of the experimental setup , first experiment is carried out on a plain tube to obtained Nusselt number and friction factor. The obtained values from experiment are compared with values obtained from empirical correlation(Dittus – Boelter). It is observed that the values from experimental investigation are in good agreement with the values obtained from empirical correlation. In the second part, experimental investigation is carried out by using newly developed flow divider type metallic (aluminium) and non metallic (acrylic) of same geometry for different flow rates and heat input. After performing above experiments obtained values of Nusselt number and friction factor are compared with values obtained for plain tube to understand how much heat transfer rate is enhanced. In this experiment constant heat flux is given to test section and mass flow rate of air is varied. Reynolds number is varied from 7000 to 16000 i.e. experiment is carried out for turbulent flow regime. All the properties of air are calculated at mean bulk temperature of the air.

S. Naga Sarada et al.[5]: This research study shows the results obtained from experimental investigations of heat transfer augmentation in turbulent flow flowing through a pipe. Effect of varying width of twisted tape on heat transfer enhancement is studied using air as working fluid. It is observed that there is excessive pressure drop for full width twisted tape, here twisted tape having width small than inner diameter are used. Twisted tape having width in range 10mm to 22mm are used for experimental investigation. Twisted tapes of twist ratios 3,4 and 5 and of 5 different widths i.e. 26mm full width, 22mm,18mm,14mm and 10mm are used. Firstly, experiment is carried out on plain horizontal tube by applying constant heat flux and varying the flow rate of air to obtained values of Nusselt number and friction factor. These values are compared with values obtained from empirical correlation(Dittus-Boelter) for validation of setup. After validating the experimental setup same experiment is carried out in horizontal tube using straight inserts and insert of different width (26mm full width,22mm,18mm,14mm and 10mm) . Each insert is inserted axially into the test section. The insert in the pipe produce resistance to flow and increases turbulence.In this experiment Reynolds number is varied from 6000 to 13500

H.V. Chavan et al.[6]: This paper is based on passive techniques of heat transfer augmentation using twisted tape inserts of various twist ratios(3.78,3.89,4.22) using air as working fluid. Experiment is carried out to find values of Nusselt number and friction factor for twisted tape having different twist ratios. Due to introduction of insert large turbulence is generated in the flow which generates large mixing of the fluid that enhances heat transfer. The length and width of insert is 1000mm and 45mm respectively. In this experiment constant heat is supplied to test section. Experimental investigation is carried out on plain tube to calculate Nusselt number and friction factor for different flow rate of air also Reynolds number is varied from 5000 to 25000. The obtained values are compared with values obtained from empirical correlation for validation of experimental setup. After validating experimental setup, the twisted tapes of different twist ratios (3.78,3.89 and 4.22) are inserted and Nusslet number and friction factor are calculated for different mass flow rate of air by varying the Reynolds number. It is observed that the heat transfer rate is enhanced by using twisted tape insert. Heat transfer enhancement may ouccr due to two reason a) Tape reduces hydraulic diameter which causes and increased heat transfer coefficient b) Twist tape causes tangential velocity component. Hence , speed of flow is increased , particularly near the wall. Heat transfer enhancement may be due to increased shear stress at wall.

3. OBSERVATIONS AND RESULTS FOR VARIOUS INSERTS IN HEAT TRANSFER AUGMENTATION

Author name	Type of flow	Geometric view of insert	Observation	Comment
S.G. Mushan et al. [1]	Turbulent		Nu increased and f decreased with increase in Re. Nu is increased by 12%	Heat transfer rate is enhanced by12%
S.G. Mushan et al. [1]	Turbulent		Nu increased and f decreased with increase in Re. Nu is increased by 87%	Heat transfer rate is enhanced by 87%

D.R. Hase et al. [2]	Turbulent		Nu increased and f decreased with increase in Re. Nu is increased by 70%	Heat transfer rate is enhanced by 70%
Sandeep P. Nalavade et al. [3]	Turbulent		Values of Nu and f are highest for p/d=0.54, value of Nu is highest for 30° angle of twist	Insert having small p/d and small angle of twist give better heat transfer augmentation Insert having small p/d and small angle of twist give better heat transfer augmentation
M.M.Herlekar et al.[4]	Turbulent		Values of Nu increased and f decreased with increasing Re. Nu is increased by 111%	Heat transfer is 2.11 times more than the plain tube
S. Naga Sarada et al.[5]	Turbulent		Value Nu is highest for TR=3 and 26mm full width tape , value of f is highest for TR=3 and 26 mm full width tape	For small TR and full width tape enhancements as well as frictional losses are high.
H.V. Chavan et al.[6]	Turbulent		Values of Nu and f are observed highest for twist ratio 3.78	Heat transfer enhancement rate is highest for tapes of small twist ratio at the same time pumping cost is more

4. CONCLUSIONS

- Performance of non metallic acrylic twisted tape insert is better than Bakelite differential annular insert by 66%.
- The turbulator with pitch to diameter ratio (p/d) 0.54 and 30°angle of twist (θ) performs better. Hence, heat transfer rate is more for the turbulator having small twist ratio and small angle of twist.
- Acrylic (non metallic) insert gives better enhancement results than aluminum (metallic) insert by 51.36 %. This is because acrylic insert provide more turbulence to the flow of the fluid. Acrylic has high heat capacity than aluminum.
- The rate of heat transfer is depend on width of the insert used. As width of tape decreases values of Nusselt number hence convective heat transfer coefficient decreases and friction factor also decreases.

5. REFERENCES

[1] S.G. Mushan,B.E. Patil, N.K. Sane, D.V. Ghewade, March 2017, " Heat augmentation Using Non-metallic Insert in Forced Convection", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X PP. 81-88

[2] D.R. Hase, N.K. Sane, D.V. Ghewade, March 2017, " Heat Augmentation Using Non-metallic Flow Divider Type Inserts in Forced Convection", IOSR Journal of

Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X PP. 62-67

[3] Sandeep P. Nalavade, Chandrakant L. Prabhune, Narayan K. Sane, November 2018, "Effect of novel flow divider type turbulators on fluid flow and heat transfer", 2451-9049/ 2018 Elsevier Ltd

[4] M.M. Herlekar, D.B. Nalawade, D.A. Kamble, January 2019, "Convection Heat Transfer Augmentation from Twisted Tape Insert of Non-conducting Material", JASC Journal of Applied Science and Computations ISSN: 1076-5131 Volume VI, Issue I

[5] S.Naga Sarada, A.V. Sita Rama Raju, K. Kalyani Radha, L. Shyam Sunder, 2010, " Enhancement of heat transfer using varying width twisted tape insert", IJEST International Journal of Engineering, Science and Technology Volume 2, no.6,2010,pp.107-118

[6] H.V. Chavan, Prathmesh A. Tapdiya, S.S. Birvatkar, S.U. Mundhe, V.S. Sharma, May 2017, " Heat transfer enhancement by using twisted tape insert", IRJET International Research Journal of Engineering and Technology e-ISSN 2395-0056, p-ISSN 2395-0072 Volume 4, Issue 5

[7] Halit Bas, Veysel Ozceyhan , March 2012, " Heat transfer enhancement in a tube with twisted tape inserts placed separately from the tube wall", Experimental Thermal and Fluid Science 41(2012) 51-58

[8] Sagar Paneliya, Sukshum Khanna, Umang Patel, Parth Prajapati, November 2019 " Systematic investigation on fluid flow and heat transfer characteristic of a tube equipped with variable pitch twisted tape", 2666-2027/ 2019 Published by Elsevier Ltd.

[9] Z.F. Huang, A. Nayakama, K. Yang , W. Liu, December 2009, " Enhancing heat transfer in the core flow by using porous medium insert in a tube", 0017-9310/ 2009 Elsevier Ltd

[10] S. Liu, M.Sakr, December 2012, " A comprehensive review on passive heat transfer enhancements in pipe exchangers", 1364-0321/ 2012 Elsevier Ltd.

[11] Chirag Maradiya, Jeetendra Vadher, Ramesh Agrawal, October 2017, " The heat transfer enhancement techniques and their Thermal Performance Factor", 2314-8535/_ 2017 Production and hosting by Elsevier B.V. on behalf of Beni-Suef University

[12] A.R. Martin, C. Saltiel, J. Chai, W. Shyy, January 1998, "Convective and radiative internal heat transfer augmentation with fiber arrays", International Journal of Heat and Mass Transfer 41(1998) 3431-3440

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

[14] Smith Eiamsa-ard, Pongjet Promvonge, November 2009, "Performance assessment in a heat exchanger tube with alternate clockwise and counter-clockwise twisted-tape inserts",International Journal of Heat and Mass Transfer 53 (2010) 1364–1372

[15] A.V. Gawandre, M.M. Dange, D.B. Nalawade, March 2014, "Heat Transfers Enhancement with Different Square Jagged Twisted Tapes", International Journal of Engineering Research and Applicaions ISSN: 2248-9622, vol.4, Issue 3, pp.619-624

[16] Siva Rama Krishna, Govardhan Pathipaka, P. Sivashanmugam, October 2008, " Heat transfer and pressure drop studies in a circular tube fitted with straight full twist", Experimental Thermal and Fluid Science 33(2009),PP.431-438

[17] Bodgan I. Pavel, Abdulmajeed A. Mohamad, June 2004, " An experimental and numerical study on heat transfer enhancement for gas heat exchangers fitted with porous media", International Journal of Heat and Mass Transfer 47(2004), pp.4939-4952

[18] Mohan Gupta, Kamal Sharma, February 2019, "Experimental Observation of Heat Exchange and Pressure Drop By Using Many Inserts in Round Tube", International Journal of Innovative Technology and Exploring Engineering, ISSN:2278-3075, Volume-8 , Issue-4

[19] S.Eiamsa-ard, K.Wongcharee, P.Eiamsa-ard, C. Thianpong, September 2009, " Heat transfer enhancement in a tube using delta-winglet twisted tape inserts" 1359-4311/ 2009 Elsevier Ltd

[20] Kurhade Anant Sidhappa, Sonal S. Hande, Swarup B. Patil, Vivekanand R. Maske, March 2016, " HEAT TRANSFER ENHANCEMENT BY USING TWISTED TAPE INSERTS WITH CIRCULAR HOLES IN FORCED CONVECTION", International Journal of Innovations in Engineering Research and Technology, ISSN: 2394-3696 volume 3, issue3

[21] Pravin S. Nikam, R. Y. Patil , D.A. Patil ,S.G.Chaudhari, August 2016, "Heat Transfer Enhancement through a Pipe by Inserting V-Shape Aluminium Turbulator" , International Journal of Engineering and Techniques, ISSN: 2395-1303 Volume 2 Issue 4,pp.54-61

[22] A. H. Dhumal , G. M. Kerkal , K.T. Pawale, May 2017, "Heat Transfer Enhancement for Tube in Tube Heat Exchanger Using Twisted Tape Inserts", International Journal of Advanced Engineering Research and Science (IJAERS),ISSN: 2349-6495,Volume 4 Issue 5

[23] C Rajesh Babu, Santhosh Kumar Gugulothu , August 2015, "CFD ANALYSIS OF HEAT TRANSFER ENHANCEMENT BY USING PASSIVE TECHNIQUE IN HEAT EXCHANGER", International Journal of Recent advances in Mechanical Engineering (IJMECH) ,Vol.4, No.3

[24] Sudha Brahma Naidu P , P. S. Kishore, September 2017, "HEAT TRANSFER ENHANCEMENT USING CIRCUMFERENTIAL FINNED TWISTED TAPE HEAT EXCHANGER", International Journal of Research – GRANTHAALAYAH, ISSN- 2350-0530,volume 5, issue 9, pp. 152-163

BIOGRAPHIES

Mr. Bhosale G S
(M-Tech Student Mech Dept.)
N.K.ORCHID College of Engg. &Tech., Solapur, Maharashtra, India

Mr. Kale S S
(Professor of Mechanical Dept.)
N.K.ORCHID College of Engg. &Tech Solapur, Maharashtra, India.

Dr. Bimlesh Kumar
(Principal), Government Polytechnic, Purnea, Bihar, India.