International Journal of Thermal Engineering (IJTE)
Volume 8, Issue 1, January – December 2020, pp. 1–8, Article ID: IJTE_08_01_001
Available online at
http://iaeme.com/Home/issue/IJTE?Volume=8&Issue=1
ISSN: 2347-3932

COMPARATIVE ANALYSIS OF HEAT TRANSFER AND FRICTIONAL CHARACTERISTICS IN A CIRCULAR TUBE FITTED WITH & WITHOUT PERFORATED V-NOZZLE TURBULATORS

Shubhangi A. Manwatkar
Department of Mechanical Engineering, Indira College of Engineering & Management, Parandwadi, Pune, India

ABSTRACT

The conventional sources of energy have been depleting at an alarming rate that makes future sustainable development of energy use very difficult. The heat exchanger applications like refrigeration, aerospace, automotive, process industry, solar water heater, etc., where the heat transfer enhancement technology has been developed and widely applied. Heat transfer enhancement technology has been enhanced and widely applied to the various heat exchanger applications like refrigeration, aerospace, automotive, process industry, solar water heater, etc.

By fitting with V-nozzles, the heat transfer in the circular tube could be promoted while it brings about the energy loss of the fluid flow. The increase in friction factor is much higher than the increase in Nusselt number at the same Reynolds number. The turbulence-promoter/turbulator devices such as Perforated Conical-Ring (PCR) is the one that are enhancing the heat transfer rate in a heat exchanger system.

On the basis of thermal performance factor, the PCRs can enhance heat transfer more efficient than the typical Conical Rings (CR). With the rise of Reynolds number, the Nusselt number increases and the maximum heat transfer is obtained for the smallest pitch arrangement.

In the proposed work, v-nozzle turbulators are used with and without perforated shape, circular holes and diamond holes for the forced convection of Reynolds number range 8000 to 20000. The proposed work uses the circular pipe fitted with the plain v-nozzle turbulators having PR=3, l=138mm and D=46 mm, the circular tube fitted with the perforated diamond shape v nozzle turbulators having two number of holes with D=46 mm, d=23 mm and the circular tube fitted with the circular perforated shape v nozzle turbulators having four number of holes with D=46 mm, d=23 mm. The objective of to the proposed work is to increase Thermal performance factor and reduced the friction factor by enhancing the heat transfer coefficient.

Key words: Heat transfer augmentation, turbulators, V-nozzle; Reynolds number

Cite this Article: Shubhangi A. Manwatkar, Comparative Analysis of Heat Transfer and Frictional Characteristics in a Circular Tube Fitted with & Without Perforated V-Nozzle Turbulators. *International Journal of Thermal Engineering*, 8 (1), 2020, pp. 1–8.
http://iaeme.com/Home/issue/IJTE?Volume=8&Issue=1

1. INTRODUCTION

The process of improving the performance of a heat transfer system is known as the heat transfer enhancement. The process of improving the performance of a heat transfer system is known as Heat transfer enhancement. It considerably means increasing the heat transfer coefficient.

The performance of heat exchanger depends on how effectively heat is utilized. The high performance of heat exchangers plays a vital role in many practical applications such as vehicles, aerospace, cooling of electric equipment, refrigeration and air conditioning, and many more. Reduction of the size of the heat exchanger may be possible due to improvement in the performance of heat exchanger [1][2].

Many active and passive techniques are currently being employed in heat exchangers, with twisted tape inserts providing a cost-effective and efficient means of augmenting heat transfer [6][7].

The rectangular bar with diverging, converging conical strip insert has a minimum friction factor and good Nusselt number when compared with rectangular bar with converging and rectangular bar with diverging conical strip inserts [10]. The V-cut twisted tape offered a higher local Nusselt number, local friction factor and also thermal hydraulic performance compared to plain twisted tape.

Heat transfer enhancement in a tube flow using ribs, dimples wire coils and twisted tape is mainly due to flow blockage, partitioning of the flow and secondary flow. Flow blockage increases the friction factor and leads to increased viscous effects because of a reduced free flow area [11]. The heat transfer and friction factor behaviour of newly fabricated staggered and non- staggered conical strip insets. The conical strip insert produces much swirl flow corresponding to the twist ratios (Y = 2, 3 and 5). The experimental results are focused on with the help of regression analysis the correlations developed for Nusselt number and friction factor are in good agreement [12].

The optimum enhancement efficiency of 310 % is found for converge-diverge conical turbulators fitted with triangle fins at pitch ratio PR=1.0.

The impacts of the pitch ratio, y, and the spring ratio, s, on thermo-hydraulic characteristics are analysed. It was observed that the thermo-hydraulic performance parameter, η, increases for all considered geometry.[14] The reverse flow device or the turbulator is widely employed in heat transfer engineering applications. The reverse flow is also called “re-circulation flow.

The heat transfer coefficient and momentum transfers is enhances by the effect of reverse flow and boundary layer eruption (dissipation).

By increasing the effective axial Reynolds number and decreasing the cross-section flow area and also increasing the mean velocity and temperature gradient results the reverse flow with high turbulent flow that can improve convection of the tube wall.

It can beneficial to produce the higher heat fluxes and momentum transfer due to the large effective driving potential force but also higher pressure drops. The strengths of reverse flow and the reattached position are the main interest in many heat transfer applications such as combustion chambers, heat exchangers, gas, electronic devices turbine blades etc.

2. EXPERIENTAL SETUP

The experiments were carried out in an open-loop experimental facility as shown in the Fig. 1. The loop consisted of a 0.5 kW blower, orifice meter to measure the flow rate, and the heat transfer test section. The copper test tube has a length of L=1300 mm, with 47 mm inner diameter (D), 51 mm outer diameter (Do), and 2 mm thickness (t) as depicted in Fig. 2.

To provide a uniform heat flux boundary condition, the tube was heated by continually winding flexible electrical wire.

A variance transformer was controlled the electrical output power to obtain a constant heat flux along the entire length of the test section and by keeping the current less than 3.0 A.

To minimize convective heat loss to surroundings, the outer surface of the test tube was well insulated and necessary precautions were taken to prevent leakages from the system.

With a multichannel temperature measurement unit in conjunction with the PT-100 thermocouples, the inner and outer temperatures of the bulk air were measured at certain points as can be seen in Fig. 1.

Seven thermocouples were tapped on the local wall of the tube and the thermocouples were placed round the tube to measure the circumferential temperature variation, which was found to be negligible. The mean local wall temperature was determined by means of calculations based on the reading of PT-100 thermocouples.

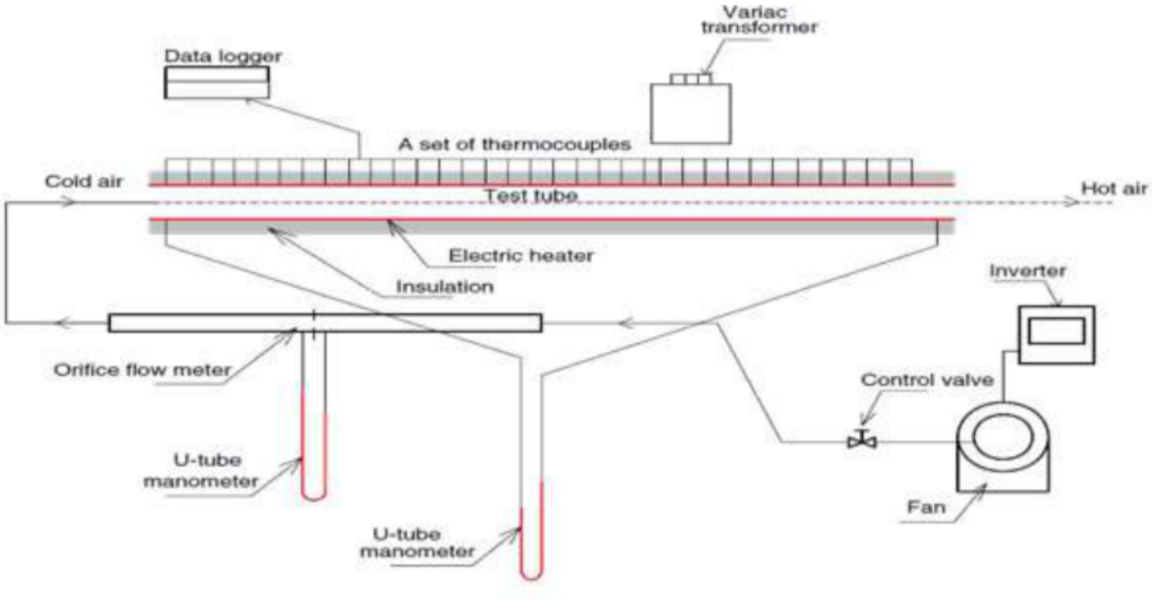

Figure 1 Schematic diagram of experimental heat transfer setup

In the Fig. 1, the inlet bulk air at 25 °C from a 0.5 kW blower was directed through the orifice meter and passed to the heat transfer test section. The air flow rate was measured by an orifice meter [9].

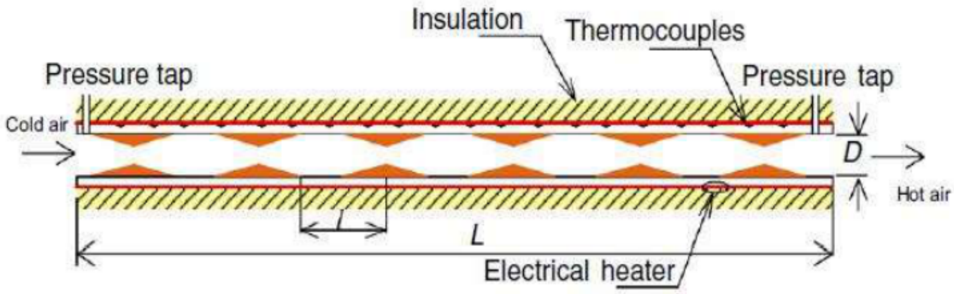

Figure 2 Test tube fitted with V-nozzle Turbulators

With specific gravity 0.981, Monomeric fluid was used in U-tube manometers to ensure reasonably accurate measurement of the low pressure drop encountered at low Reynolds numbers. With inclined U-tube manometers, the pressure drop of the heat transfer test tube was measured.

Fig. 2 represents the V-nozzle arrangement used in the present work. The V-nozzle was made of aluminium 138 mm in length and its end and throat diameters were 46 mm and 24 mm, respectively. The V-nozzles were placed with pitch ratio PR=3.0 with pitch lengths, l=138 mm for experiment.

The volumetric air flow rates from the blower were adjusted by varying motor speed, situated before the inlet of test tube. During the experiments, the bulk air was heated by an easily adjustable electrical heater wrapping along the test section. Both the inlet and outlet temperatures of the bulk air from the tube were measured by PT-100 thermocouple It was necessary to measure the temperature at 7 stations altogether on the outer surface of the heat transfer test pipe for finding out the average Nusselt number [7]. For each test run, it was necessary to record the data of temperature, volumetric flow rate and pressure drop across the test section and air flow velocity were measured for heat transfer of the heated tube with V-nozzles. The average Nusselt numbers were calculated and discussed where all fluid properties were determined at the overall bulk mean temperature [8].

3. MATHAMATICAL CALCULATION

In the present work, the air is used as working fluid that flowed through a uniform heat flux and insulation tube. It is observed that the steady state of the heat transfer rate is to be equal to the heat loss from the test section which can be expressed as:

$$Q_{air} = Q_{Conv} \tag{1}$$

In which,

$$Q_{air} = mCpa(T_o - T_i) \tag{2}$$

From the test section, the convection heat transfer can be written as:

$$Q_{conv} = hA(T_w - T_b) \tag{3}$$

Whereas,

$$T_b = (T_0 - T_i)/2 \tag{4}$$

And

$$T_w = \sum T_w/6 \tag{5}$$

Where, T_w is the local wall temperature that has been evaluated at the outer wall surface of the inner tube. The averaged wall temperatures are calculated from 6 points which are lined between the inlet and the exit of the test pipe.The average heat transfer coefficient, h and the mean Nusselt number, Nu are estimated as follows:

$$h = mCpa(T_0 - T_i)/A(T_w - T_b) \tag{6}$$

$$Nu = hD/k \tag{7}$$

The Reynolds number is given by

$$Re = UD/v \tag{8}$$

Friction factor, f can be written as

$$f = \frac{\Delta P}{\left(\frac{L}{D}\right)\rho\left(\frac{U^2}{2}\right)} \tag{9}$$

4. EXPERIMENTAL RESULTS

In this experimental work, non-perforated v-nozzle turbulators are used also with and without perforated shape like circular holes and diamond holes v-nozzle turbulators are used for the forced convection of the Reynolds number range 8000 to 20000. This work uses the circular pipe fitted with the plain v-nozzle turbulators having PR=3, l=138mm and D=46 mm and the circular tube fitted with the perforated diamond shape v nozzle turbulators having two number of holes with D=46 mm, d=23 mm and the circular tube fitted with the circular perforated shape v nozzle turbulators having four number of holes with D=46 mm, d=23 mm The behaviour of different kinds of v nozzle are studied to improve the thermal performance. The result of the research work enhanced the heat transfer coefficient, increased thermal performance factor and reduced the friction factor. Through experimentation it has been observed that the heat transfer rate increases in the different v nozzle with a significant rate. This increase in the heat transfer is depends on the many factor but heat transfer coefficient plays vital role in it.

4.1. Reynolds Number

From Fig. 3, shows that the heat transfer coefficient for the perforated diamond v-nozzle is more as compare to perforated circular and non-perforated v-nozzle tube. The heat transfer rate is increases as the Reynold no. increases. This increases in the heat transfer rate occurred due to the more turbulence.

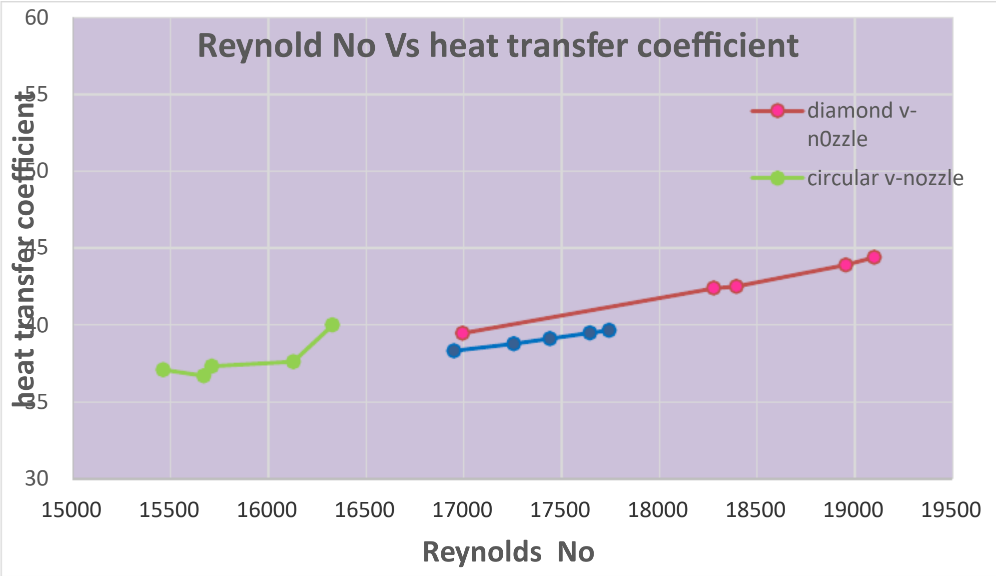

Figure 3 Reynolds number vs Heat transfer coefficient

4.2. Nusselt Number

The calculation of heat transfer coefficient is depending on the Nusselt no. as the Nusselt no increases as the Reynolds no increases as shown in Fig. 4, the Nusselt no obtained for the perforated diamond v-nozzle are very much higher than the non-perforated v-nozzle. The heat transfer increases as the Nusselt no increases and shown in the fig. the increase in the Nusselt no clearly indicates that the heat transfer rate increases by using the perforated v-nozzle turbulators.

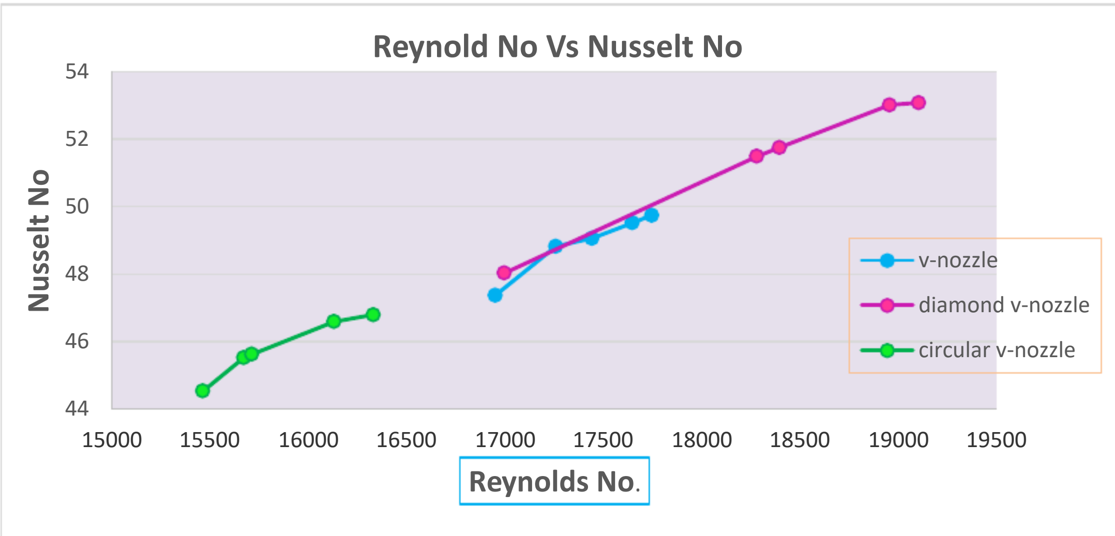

Figure 4 Reynolds number vs Nusselt Number

4.3. Friction Factor

The friction factor is also an important factor for the heat exchanger the increases in the friction factor reduces the life of the components. The Fig. 5, shows the friction factor at various Reynold no increases and this friction factor is lower in the perforated diamond v-nozzle tube and higher in the circular perforated v-nozzle and non-perforated v-nozzle tube.

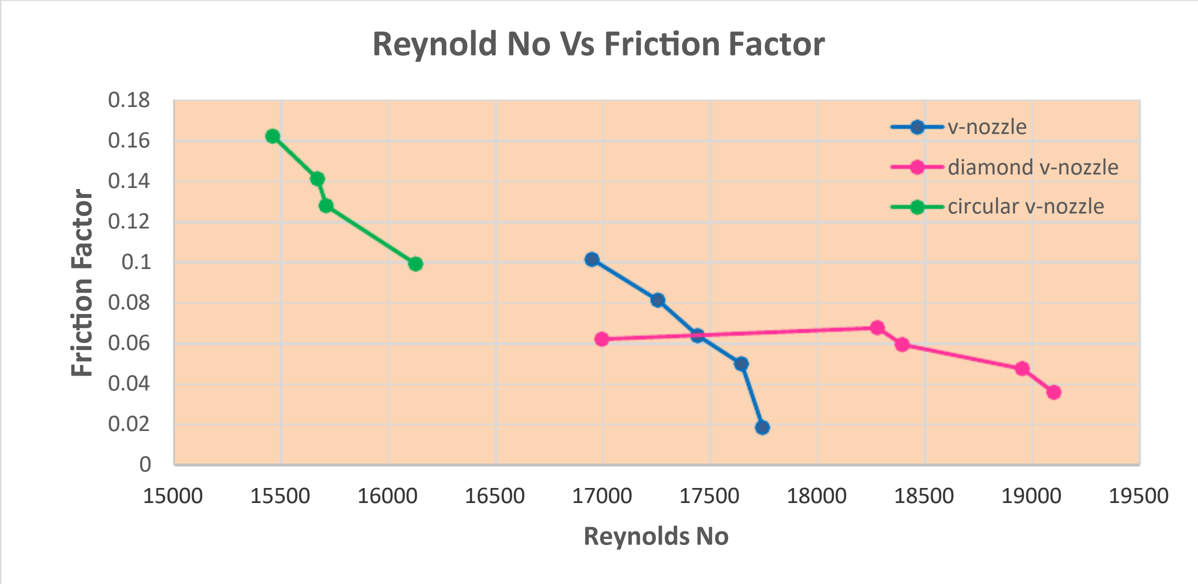

Figure 5 Reynolds number vs Nusselt Number

5. CONCLUSION

Experimental worked have been carried out to study the effects of the different perforated v-nozzle turbulators on heat transfer, friction factor and enhancement efficiency, in a result of the experimental work enhanced the heat transfer coefficient. It Increases Thermal performance factor and reduced the friction factor. We used the v-nozzle with the pitch ratio 0f 3.0 and found the heat transfer augmentation

The results are:

1. The heat transfer in the circular tube could be promoted by fitting with perforated V- nozzle and non-perforated V-nozzle. The mean heat transfer rates obtained from using the perforated V-nozzle 141% over non perforated v-nozzle turbulator. The heat transfer coefficient for the perforated diamond v-nozzle is more as compare to perforated circular and non- perforated v-nozzle tube. The graph shows that the heat transfer rate is increases as the Reynold no. increases. This increases in the heat transfer rate occurred due to the more turbulence.

2. The friction factor reduces with as the Reynolds no increase and this friction factor is lower in the perforated diamond v-nozzle tube and higher in the circular perforated v-nozzle and non-perforated v-nozzle tube.

3. The enhancement efficiency increase with increasing Reynold number. The maximum value of enhancement efficiency obtained from using 1.90.

REFERENCES

[1] Eiamsa-ard S. and Promvonge P., Enhancement of Heat Transfer in a Circular Wavy Surfaced Tube with Helical Tape Inserts, International Energy Journal, Vol.8, pp 29-36, 2007.

[2] Dr. Mohammed Najm Abdullah, Heat Transfer and Pressure Drop in Turbulent Flow through an Ecentric Converging – Diverging Tube with Twisted Tape Inserts, Journal of Engineering and Development, Vol.16, No.2, pp 178-192, June 2012.

[3] KittisakYongsiri, Eiamsa-ard S., Chinaruk Thianpong and Promvonge P., Effect of Turbulent Decaying Swirl Flow on Heat Transfer Enhancement in a Tube, International Conference on Sustainable Energy and Environment (SEE 2006), pp 21 -23, November 2006, Bangkok, Thailand.

[4] Promvonge P. and Eiamsa-ard S., Heat Transfer Enhancement in a Tube with Combined Conical Nozzle Inserts and Swirl Generator, Energy Conversion and Management, Vol.47, pp 2867-2882, 2006.

[5] K. Yakut, B. Sahin, S. Canbazoglu, Performance and flow-induced vibration characteristics for conical-ring turbulators, Applied Energy 79 (1) (2004) 65–76.

[6] S. Eiamsa-ard, P. Promvonge b, “Experimental investigation of heat transfer and friction characteristics in a circular tube fitted with v-nozzle turbulators” Journal of International Cummunications in Heat and Mass Transfer, Volume 33, Issue 5, May 2006, Pages 591–600.

[7] Deepali Bankar, N.R.Pathare,” Analysis of heat transfer and friction characteristics in a circular tube fitted with V-Nozzle Turbulators, Journal of ICETET ,19-21 Nov. 2010 , Pages 675 – 679.

[8] Dr.Akeel Abdullah Mohammed, Heat Transfer and Pressure Drop Characteristics of Turbulent Flow in a Tube Fitted with Conical Ring And Twisted Tape Inserts, Engineering and Technology Journal, Vol.29, No.2, pp 226-239, 2011.

[9] Dr.Akeel Abdullah Mohammed, Bashar Ali Mohammed and Raheem Jewi Muhee, Heat Transfer Enhancement in a Tube Fitted with Nozzle Turbulators, Engineering and Technology Journal, Vol.32, Part (A), No.10, 2014.

[10] Ravi Gugulothua Naga Sarada Somanchia K Vijaya Kumar Reddya and Kavya Akkirajub, “A Review on Enhancement of Heat Transfer in Heat Exchanger with Different Inserts”, 5thInternational Conference of Materials Processing and Characterization, Proceedings 4 (2017) 1045–1050.

[11] Amar Raj Singh Suri, Anil Kumar & Rajesh Maithani, “Convective Heat Transfer Enhancement Techniques of Heat Exchanger Tubes: A Review”, International Journal of Ambient Energy 10.1080/01430750.2017.1324816 (2017).

[12] M. Arulprakasajothi, K. Elangovan, K. Hema Chandra Reddy, S. Suresh, “Experimental Investigation On Heat Transfer Effect Of Conical Strip Inserts In A Circular Tube Under Laminar Flow”, Front. Energy DOI 10.1007/s11708-015-0389-z Higher Education Press and Springer-Verlag Berlin Heidelberg (2016).

[13] Khudheyer S. Mushatet And Zahraa K. Ali, “Enhancement The Turbulent Heat Transfer By Using Finned Converging-Diverging Nozzles” ARPN Journal of Engineering and Applied Sciences VOL. 14, NO. 2, JANUARY (2019)ISSN 1819-6608.

[14] Suvanjan Bhattacharyya, Ali Cemal Benim, Himadri Chattopadhyay & Arnab Banerjee, “Experimental Investigation of Heat Transfer Performance Of Corrugated Tube With Spring Tape Inserts”, A Journal of Thermal Energy Generation, Transport, Storage, and Conversion, ISSN: 0891-6152 9(2018).