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Numerical Investigation of Turbulent Airflow in Heat Exchanger Tube Equipped with Perforated Conical Rings (NOZZLES)

[1]K.Chandana, P.Nanajee[2], P.Ganesh[3], B.Siva[4], B.Murali Krishna[5],B.Sai Sankar[6]

[1] Associate Professor, Dept of Mechanical Engineering, Visakha Institute of Engineering and Technology.
[2,3,4,5,6] B. Tech Final Year Students, Dept of Mechanical Engineering, Visakha Institute of Engineering and Technology.

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Abstract - Numerical investigation of turbulent air flow in heat exchanger tube equipped with perforated conical rings (nozzles). The main aim of this project to conduct thermal analysis on heat exchanger tubes to find the Reynolds number and rate of heat transfer and overall heat transfer coefficient by equipping it with perforated conical rings (nozzles). Nozzles, conical rings are popular heat transfer enhancement tools due to their simple installation, low cost and efficient performance. They can simply improve the thermal efficiency of the system and also used to investigate thermal characteristics of heat exchanger tube. This can be achieved by sending the air with turbulence into the heat exchanger tube equipped with nozzles and 3d simulation is conducted to analyses and compare with the standard values.

***Key Words*:** Heat exchanger, Perforated rings, Reynolds number, Overall heat transfer coefficient.

1.INTRODUCTION

1.1 Heat Transfer Mechanisms:

We defined heat as the form of energy that can be transferred from one system to another as a result of temperature difference. A thermodynamic analysis is concerned with the amount of heat transfer as a system undergoes a process from one equilibrium state to another. The science that deals with the determination of the rates of such energy transfers is the heat transfer. The transfer of energy as heat is always from the higher- temperature medium to the lower-temperature one, and heat transfer stops when the two mediums reach the same temperature.

Heat can be transferred in three different modes: conduction, convection, and radiation. All modes of heat transfer require the existence of a temperature difference, and all modes are from the high-temperature medium to a lower-temperature one. Below we give a brief description of each mode.

1.1.1 Conduction:

Conduction is the transfer of energy from the more energetic particles of a substance to the adjacent less energetic ones as a result of interactions between the particles. Conduction can take place in solids, liquids, or gases. In gases and liquids, conduction is due to the collisions and diffusion of the molecules during their random motion. In solids, it is due to the combination of vibrations of the molecules in a lattice and the energy transport by free electrons. A cold canned drink in a warm room, for example, eventually warms up to the room temperature as a result of heat transfer from the room to the drink through the aluminium can by conduction.

1.1.2 Convection :

The convection heat transfer mode comprises of energy transfer due to specific molecular motion (diffusion), energy is transferred by bulk, or macroscopic, motion of the fluid. This motion is associated with the fact that, at any instant, large numbers of molecules are moving collectively or as aggregates. Such motion, in the presence of a temperature gradient, contributes to heat transfer. Because the molecules in aggregate retain their random motion, the total heat transfer is then due to the superposition of energy transport by random motion of the molecules and by the bulk motion of the fluid.

1.2 Types Of Convection:

Free or Natural convection:

When fluid motion is caused by buoyancy forces that result from the density variations due to variations of thermal ±temperature in the fluid. In the absence of an internal source, when the fluid is in contact with a hot surface, its molecules separate and scatter, causing the fluid to be less dense. As a consequence, the fluid is displaced while the cooler fluid gets denser and the fluid sinks. Thus, the hotter volume transfers heat towards the cooler volume of that fluid. Familiar examples are the upward flow of air due to a fire or hot object and the circulation of water in a pot that is heated from below.

Forced convection :

When a fluid is forced to flow over the surface by an internal source such as fans, by stirring, and pumps, creating an artificially induced convection current.

Heat transfer coefficient:

The heat transfer coefficient or film coefficient, or film coeffectiveness in thermodynamics and in mechanics is the proportionality constant between the heat flux and the thermodynamic driving force for the flow of heat (i.e., the temperature difference, T):

$$\dot{Q} = hA(T_2 - T_1) \quad \Delta$$

The overall heat transfer rate for combined modes is usually expressed in terms of an overall conductance or heat transfer coefficient, U. In that case, the heat transfer rate is:

2. Methodology

Heat exchangers are the mostly used equipment in industry both for cooling and heating. It has an advantage of working at high pressure and temperature and easy to enlarge. It also has low maintenance costs.

2.1 Copper :

As a metal, copper is ductile and malleable and valued for its high thermal and electric conductivity. Copper occurs naturally but its greatest source is in minerals like chalcopyrite and bornite, and you can easily identify it by its reddish- gold colour.

Fig -2.1: Copper tube

2.2 Aluminium:

Light Weight. Aluminium is a verylight metal with a specific weight of 2.7 g/cm^3, about a third of that of steel, Corrosion Resistance, Electrical and Thermal Conductivity, Reflectivity, Ductility, Strength at Low Temperatures, Impermeable and Odourless, Non-magnetic.

Fig -2.2: Aluminium material

2.3 U-Tube Mano Meters :

This manometer is very easily constructed. It consists of a tube of glass bent into a U shape. It is then filled with a fluid. The density of the fluid dictates the range of pressures that can be measured. Both ends of the tube are pressure ports. If one port is left open to the atmosphere and the other port is connected to the pressure to be measured, the device acts as a gauge pressure meter. If both ports are connected to two different unknown pressures, the instrument acts as a differential pressure gauge.

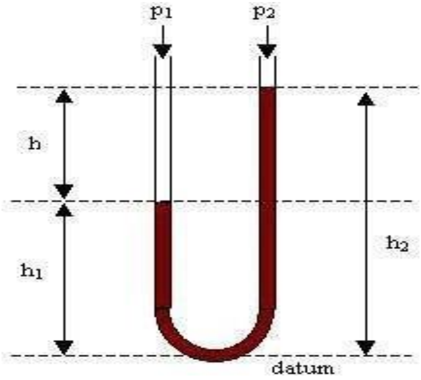


Fig -2.3 : U Tube Manometer

2.4 Experimental set up :

The experimental setup consists of a copper tube equipped with conical rings (nozzles) fitted with stainless steel disks mounted with K-type thermocouples. A blower with a capacity of 1.5 m^3/min is attached to the tube along with the heater capacity of 480w.

Fig -2.4: Forced convection heat transfer setup.

2.5 Venturimeter :

Venturimeters are flow measurement instruments which use a converging section of pipe to give an increase in the flow velocity and a corresponding pressure drop from which the flowrate can be deduced. They have been in common use for many years, especially in the water supply

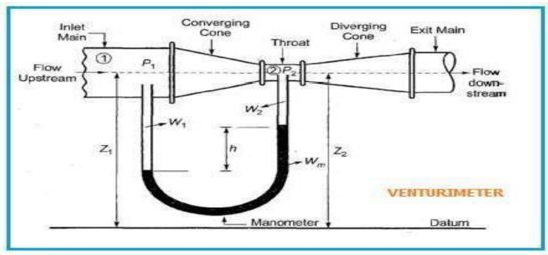


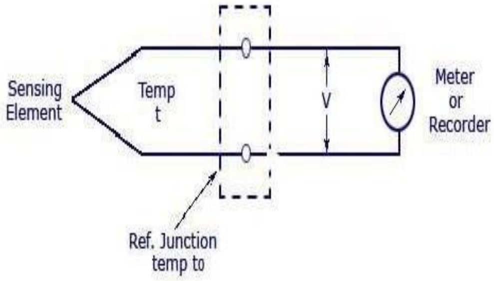
Fig -2.5: Venturimeter

2.6 K-type thermocouple :

The type K is the most common type of thermocouple. It's inexpensive, accurate, reliable, and has a wide temperature range. The type K is commonly found in nuclear applications because of its relative radiation hardness. Maximum continuous temperature is around 1,100C.

Fig -2.6: K Type Thermocouple

2.7 Nozzle:



A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe.

Fig -2.7: Nozzle

Design & Ansys simulation

2.8 Design

The Catia software is open the part design to be designing copper tube and nozzle. A copper tube with geometry is first drawn in the catia software. Then a conical nozzle with required dimension is first drawn and then perforated hole is provided

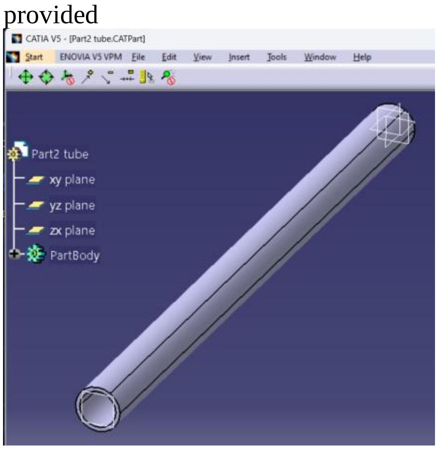


Fig-2.8 copper tube

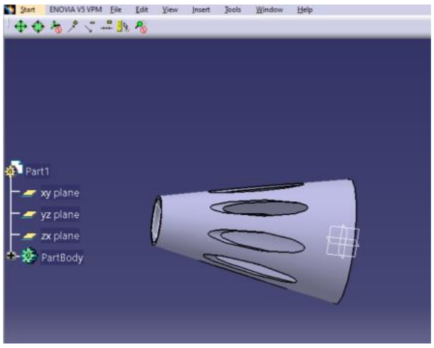
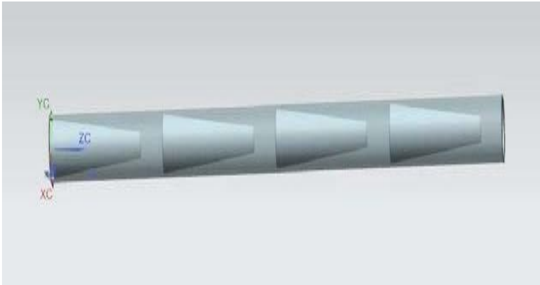


Fig -2.9 Nozzle



2.9 Ansys simulation:

The Ansys software is opened and an analysis to be performed in fluid flow fluent. A copper tube with geometry is first drawn in the Ansys software. Then a conical nozzle with required dimension is first drawn and then perforated hole is provided. Then the meshing is done as shown in the below fig 2.10.

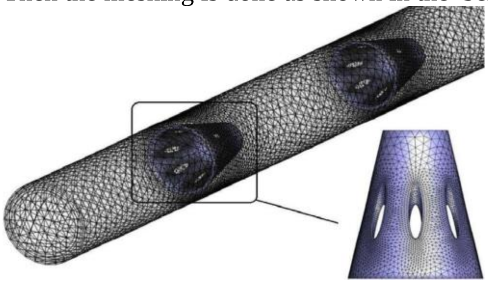


Fig -2.10: Meshing in ansys analysis

3.Observation and result

3.1 Observations

S.No.	Power (watts)	Manometer readings (cm)	t1 (^{0}c)	t2 (^{0}c)	t3 (^{0}c)	t4 (^{0}c)	t5 (^{0}c)	t6 (^{0}c)
1	65	2.6	70	46	44	42	38	42
2	67	2.6	71	47	45	43	39	43
3	71	2.6	73	46	44	41	38	42
4	82	2.6	81	50	47	43	40	44

Table:1 - observation table

3.2Results :

Nozzle 1:

- T_{ms} = 323.5k
- T_{ma} = 313k
- T_m =318.25k

- ❖ Velocity = 6.74m/s.
- ❖ Reynolds number = 16837.5
- ❖ hexp = 62.15 w/m^{2}c
- ❖ hthe=18.097w/m^{2}c
- ❖ Nusselt number (Nu)= 43.12

Nozzle 2:

- ❖ Tms = 324.5k
- ❖ Tma = 314k
- ❖ Tm =319.25k
- ❖ Velocity = 6.74m/s.
- ❖ Reynolds number = 16945.19
- ❖ hexp = 63.49 w/m^{2}c,
- ❖ hthe=19.052 w/m^{2}c
- ❖ Nusselt number (Nu) = 43.35

Nozzle 3:

- ❖ Tms = 324k
- ❖ Tma = 313k
- ❖ Tm =318.5
- ❖ Velocity = 6.74m/s
- ❖ Reynolds number = 16950.12.
- ❖ hexp = 60.60 w/m^{2}c
- ❖ hth=19.096 w/m^{2}c
- ❖ Nusselt number (Nu)= 43.42

Nozzle 4:

- ❖ Tms = 328.25k
- ❖ Tma = 315k
- ❖ Tm =321.25k
- ❖ Velocity = 6.74m/s
- ❖ Reynolds number = 16975.16
- ❖ hexp = 60.60 w/m^{2}c
- ❖ hth=19.14w/m^{2}c
- ❖ Nusselt Number (Nu)= 43.58

3.3 Results from Ansys :

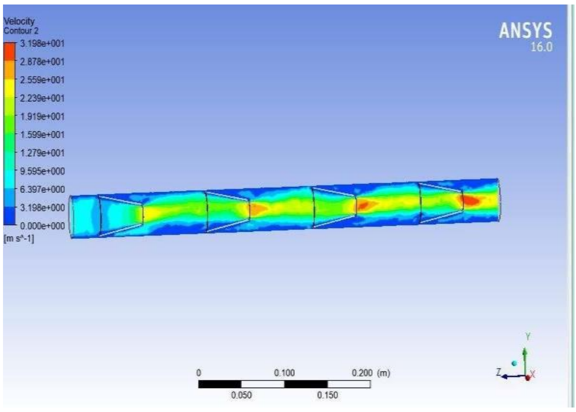
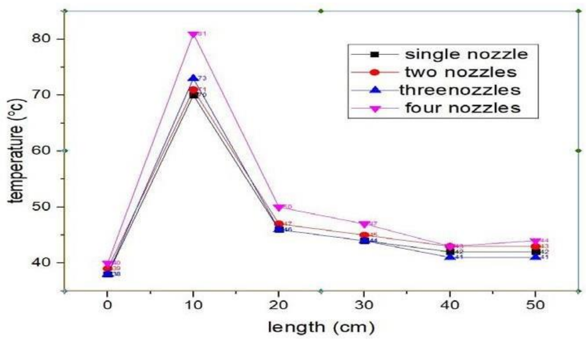
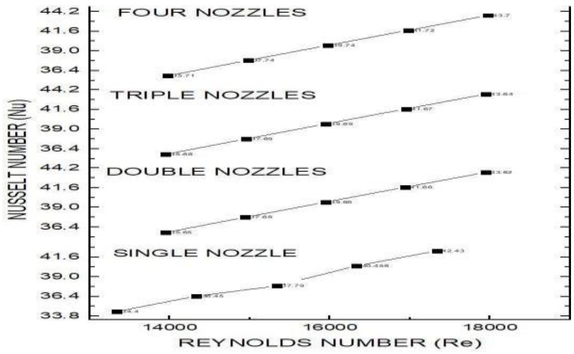


Fig -3.1 Ansys simulation for velocity with four nozzles

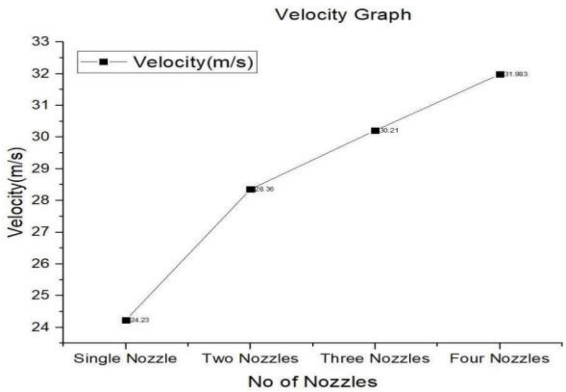
GRAPHS:



Graph 1: Stack Graph of all nozzles.



Graph 2: Stack Graph of Reynolds number for all nozzles with varying Y-Axis values.



Graph 3: Graph for nozzles And velocity profile

4. Conclusion & Future Scope

4.1 Conclusion

The present paper reports numerical results on turbulent flow and heat transfer characteristics in a heat exchanger tube equipped with PCRs at different number of holes. The numerical analysis are performed for turbulent air flow with Re over the range of 4000 and 15,000. The most important findings of this work are as follows:

1. The recirculation, detachment and attachment of turbulent air flow significantly improve heat transfer due to thermal boundary layer disruption and better fluid mixing of turbulent fluid flow through heat exchanger tube in the presence of PCRs.
2. The heat transfer co-efficient increases with increase in nozzles.

3. Further investigations can be performed to analyse the effect of using perforated conical rings combined with other types of turbulators to improve the thermal performance of heat exchangers.

4.2 Scope for Future work :

This type of enhancement can be used in thermal industries to increase the heat transfer rate.

The air can be replaced with nanofluids to increase the overall heat transfer rate. This enhancement can also be used in many thermal industries.

This equipment is easy to install, less cost and easy maintenance and can be equipped with heat exchangers to increase their effectiveness.

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Authors

Korla Chandana
Associate Professor
VIET, Visakhapatnam

Pappala Nanajee
B.Tech Mechanical Engineering
VIET, Visakhapatnam

Parapati Ganesh
B.Tech Mechanical Engineering
VIET, Visakhapatnam

Bachala.Siva
B.Tech Mechanical Engineering
VIET, Visakhapatnam

Bevara.Murali Krishna
B.Tech Mechanical Engineering
VIET,Visakhapatnam

Busala.Sai Sankar
B.Tech Mechanical Engineering
VIET,Visakhapatnam