Numerical Investigation on 90 Degree Transverse Nozzle Shaped Perforated Ribs With Different Nozzle Angles And Relative Roughness Height

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Abstract- *a two-dimensional computational fluid dynamics (CFD) analysis of a solar absorber plate has been carried out using circular nozzle shaped perforated transverse 900 ribs as artificial roughness on the absorber plate. The relative roughness pitch(P/e= 7.14–17.86), nozzle angle (12, 14, 18, 21 degrees), Reynolds number (Re = 3800–18,000) are chosen as design variables for analysis. A uniform heat flux of 1000 W/m2 is maintained on the surfaceof absorber plate. computational code, ANSYS FLUENT 15.0.0 with renormalization group K-epsilon turbulence model was chosen. An enhancement in Nusselt number and friction factor with decrease in circular relative roughness pitch difference ratio (P/e) is presented and discussed with reference to base paper results. The effect of nozzle shaped perforation and Reynolds number on enhancement of Nusselt number and friction factor is also presented. Optimum configuration of roughness element for artificially roughened solar air heater has been determined in terms ofthermo-hydraulic performance parameter. The nozzle angle of 14° on circular nozzle shaped perforated transverse 900 ribs and circular relative roughness pitch difference ratio of 25 providebest thermo-hydraulic performance of 2.047 consideringthe maximum heat transfer and minimum pressure drop.*

Keywords- Computational Fluid, Artificial roughness, Thermo-hydraulic performance parameter, Friction factor

I. INTRODUCTION

Due to depletion of fossil fuels and the fuels like coal, crude oil ,LPG ,coal tar and so on for vitality age like electrical vitality ,mechanical vitality and in aviation applications ideally hurts nature and ozone layer of our earth because of this perilous impact happens in our condition and causes the impact of green house ,significant issues like for ventilation in ventures ,workplaces ,houses essentially a cooling framework is favored and other criteria on the off chance that we find in refrigeration framework cloroflouro carbon is utilized this substance is likewise utilized as a part of aircrafts and satellites propelling frameworks this substance assumes an imperative part in these such applications as a noteworthy piece of fuel ignition to stay away from these impacts a sun based vitality assumes a critical part now daily's sunlight based board worked aircrafts were made to preserve our non-renewable energy sources and to shield our condition from unsafe fuel burning smoke in ventilation and air drying process sun oriented pipe assumes a vital part the gathered perspective of sun based channel, sun based pipe made of various materials fundamentally on the off chance that we see the aluminum made sun based conduit it has progressive warmth exchange rate under working conditions amid wind stream it assumes real part in drying air and in warming and dehumidification of air by utilizing sun oriented vitality as a source fundamentally it is amassed with pipe play out its activity towards drying air in sun based pipe plate to accomplish better warmth exchange rate a harshness parameter were considered to expand warm exchange and to diminish contact factor for better convection amid working condition unpleasantness assumes vital part in sun based pipe the harshness shape additionally indicates impact of warmth exchange rate amid stream of liquid as an air the warm conductivity of a sun oriented pipe plate is to be high so it could disperse a warmth to the liquid stream medium as quickly as time permits Increasing vitality request in world and utilization of vitality, on support of practical advancement, worldwide populace and enhanced innovations, has compelled to think to spare vitality so it ought to reduces the vitality sources in each modern, business and residential application. Execution of a sunlight based air warmer is seriously gets thoroughly influenced on support of low warm limit of liquid and safeguard to air convective warmth exchange coefficient, which requires outline plans, and to the span conceivable, requital. For this reason surface capability, which specifically incorporates the warmth exchange surface, are locked in on the inward side of safeguard plate that collaborates with air. The consideration of artificial roughness in variable forms of shapes and sizes is the most effective and economical way for improvement of the performance of a solar air heater. The emergence and cessation of mankind is dependent on solar energy. The easiest processes gives support life on globe, such as photosynthesis and the rain cycle, are operated from solar energy. Earlier of its history mankind feels that an economical use of solar energy is in mankind's benefit. Human being requires a used energy at a high rate for this nourishment and well-being ever since he came on the earth a few million years ago. Primarily human requires energy permanently in the form of food and nutrition. He acquires this by eating plants or animals which he harried. Eventually he created fire and his energy requirements increased as he make use of wood and other biomass to supply the energy desires for preparation. Worldwide energy consumption has been increasing apace, indeed virtually exponentially, since the economic Revolution. This increasing trend of energy consumption has been accelerated by enhancements within the quality of life, which nearly directly relates to the number of energy consumption as results of the industrial enterprise of developing nations and therefore the population increase within the world. At present, most of the energy demand worldwide is met by the combustion of fossil fuels (i.e., coal, crude oil oils, fossil fuel, etc.), that became a vital and integral a part of fashionable civilization, being more and more relied upon since the economic revolution. Solely a really little proportion of the energy comes from nuclear and hydro power, and a way smaller portion from renewable energy sources, like solar, wind, hydro, geothermal, tidal wave, and so on. The dominance of one energy system tends to weaken a selected side of the atmosphere, economy and society; and might cause permanent environmental harm or perhaps environmental catastrophe if dominant for too long, with devastating consequences for the economy and society. Every energy system has its own adverse impact on the atmosphere, economy and society as set by the second law of physics. However, if that impact is little enough and is among the tolerance vary, environment, economy and society will absolutely face up to the adverse impact and might absolutely get over it. Thus, a very property energy system (or inexperienced energy) may be achieved with the diversification and localization of energy sources and systems, which might also offer security for the energy provide and distribution. Though one energy system may be property, heterogeneous energy systems with native resources will offer a bigger quantity of property energy than one energy system will, with higher security of energy. Therefore, it's counseled to push energy diversity because the sensible and much possible approach for property development and energy security. Our planet faces vital challenges within the ordinal century as a result of energy consumption is predicted to double globally throughout the primary half this century. Featured with progressively strained oil provides, humanity should look to different sources of energy, like solar, to assist United States meet the growing energy demand. Solar and different kinds of renewable energy supply a sensible, clean, and viable resolution to satisfy our planet's growing environmental and energy challenges. Radiation is that the most vital natural energy resource as a result of it drives all environmental processes working at the surface of the planet. The Sun provides the planet with a huge quantity of energy.

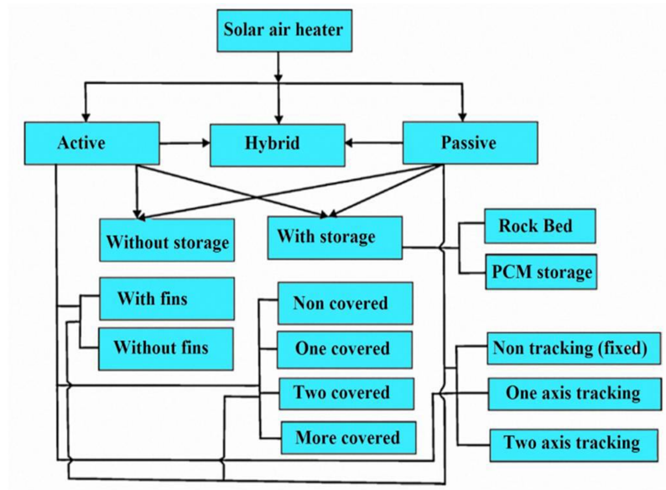

Figure 1.1 Classification of solar air heater

II. SOLAR ENERGY COLLECTORS

SOLAR ENERGY

Solar energy is energy that comes from the sun. On a daily basis the sun radiates, or sends out, a colossal quantity of energy. Solar power could be a terribly giant, inexhaustible supply of energy. It's the best potential of all the sources of renewable energy.

Data about the Sun

- Age Almost 5 billion years
- Mean distance from 1.496 x 108 km earth
- Period of rotation 25 day at the equator
- Diameter 1.392 x 106 km (109 x the earth's diameter)
- Mass 1.993 x 1030 Kg (333000 x earth's mass)
- Temperature 15 000000 K at centre& 6000 K on surface
- Energy radiation 3.85 x 1023 kW
- The earth receives 170 x 1012 kW

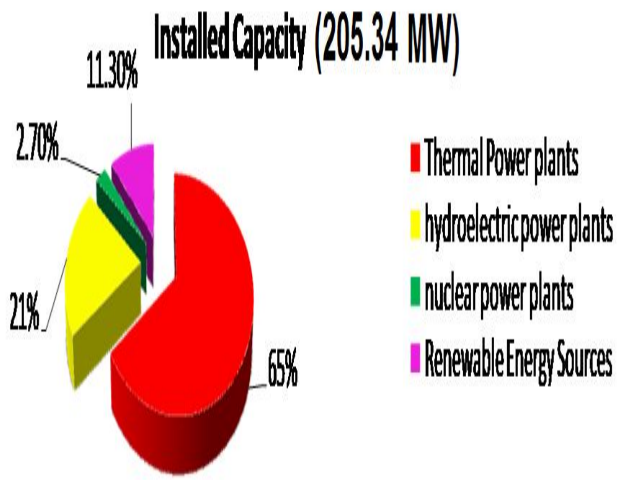

Figure 2.1 Energy consumption charts of variable energy sources

Solar collectors are the key component of active solar-heating systems. Solar collectors gather the sun's energy, transform its radiation into heat, then transfer that heat to water, solar fluid, or air. The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems.

Solar energy collectors are classified as:

(1) Flat plate collectors.
(2) Concentrating collectors.

If the area of interception of solar radiation is same as the area of absorption, the collector is known as flat plate collector.

2.1 Flat Plate Collectors

Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 100°C.

The major components of Flat Plate collectors are:

- The absorber plate used for absorbing solar radiations, normally metallic with a black surface. A wide variety of other materials can be used with air heaters. It is usually one plate or an assembly of metal sheets or plates forming a nearly continuous surface coated with radiation absorbing black paint, black porcelain enamel or a metallic oxide.
- A transparent cover which may be one or more sheets of glass or radiation transmitting plastic film or sheet. As the number of covers increases, the loss of heat from top of collector decreases while intensity of radiation incident on absorber plate also decreases.
- Tubes, passages or channels are integral with the collector absorber plate or connected to it, which carry the water, air or other fluid to transfer energy from absorber plate to the fluid.
- Insulation, provided at the back and sides to minimize heat losses.
- The casing or container, which encloses the components and protects them from the weather.

2.2 Concentrating Collectors

A concentrating collector utilizes a reflective parabolic-shaped surface to reflect and concentrate the sun's energy to a focal point where the absorber is located. To work effectively, the reflectors must track the sun. These collectors can achieve very high temperatures because the diffuse solar resource is concentrated on a small area. In fact, the hottest temperatures ever measured on the earth's surface have been at the focal point of a massive concentrating solar collector. Concentrating collectors have been used to make steam that spins an electric generator in a solar power station. This is sort of like starting a fire with a magnifying glass on a sunny day.

III. PERFORMANCE EQUATIONS FOR A SOLAR COLLECTOR

The performance of solar collector is described by an energy balance that indicate the distribution of incident solar energy into useful energy gain (Qu) and heat losses like bottom (Qb) and top (Qt) as shown in Fig.1.2. The details of the performance analysis of a solar collector are discussed by Duffie and Beckman [31] and Goswami [41].The heat transfer in a solar collector takes place by simultaneous radiation, convection and conduction. The heat transfer from the top takes place by convection and radiation while from the side and bottom is by conduction. The net rate of useful energy collected per unit area is the difference of the amount of solar energy absorbed and the energy loss by the collector to the surroundings

IV. LITERATURE REVIEW

Yadav and Bhagoria (2013) [5] - This investigation the study of heat transfer and fluid flow processes in an artificially roughened solar air heater by using computational fluid dynamics (CFD). The effects of small diameter of transverse wire rib artificial roughness on heat transfer and fluid flow have been investigated. The situation for optimum performance has been determined in term of thermal enhancement factor. A maximum value of thermal enhancement factor has been found to be 1.65 for the range of parameters investigated. We found Nusselt number are also increases with an increase of Reynolds number..

Yadav and Bhagoria (2013) [6] - This investigation is solar air heater is one of the basic equipment through which solar energy is converted into thermal energy. Computational fluid dynamics (CFD) investigation is also carried out to select best turbulence model for the design of a solar air heater. CFD simulation result to found to be in good arrangement with experimental result and with the standard theoretical approaches. A two-dimensional CFD analysis has been carried out to study heat transfer and fluid flow behavior in a rectangular duct of a solar air heater with one artificial roughened wall having circular transverse wire rib roughness.

Yadav and Bhagoria (2013) [7] - This investigation is conducted to analyze the two-dimensional incompressible Navier-Stokes flows through the artificially roughened solar air heater for relevant Reynolds number ranges from 3800 to 18,000.Atwo-dimensional CFD model of an artificially roughened solar air heater having equilateral triangular sectioned rib roughness on the absorber plate has been proposed and used to predict the heat transfer and flow friction characteristics. Further, we found the Nusselt number tends to increase as the Reynolds number increases in all cases.

Yadav and Bhagoria (2014) [8] - A numerical investigation on the heat transfer and fluid flow characteristics of fully developed turbulent flow in a rectangular duct having repeated transverse square sectioned rib roughness on the absorber plate has been carried out.The two-dimensional fluid flow and heat transfer processes in a rectangular duct of a solar air heater with one artificial roughened wall having square sectioned transverse rib roughness are analyzed numerically, and a detailed description of the average heat transfer and flow friction factor, i.e. Nusselt number and friction characteristics, are obtained. Further, we found the Nusselt number tends to increase as the Reynolds number increases in all cases.

V. COMPUTATION FLUID DYNAMICS

5.1 Introduction

Computation Fluid Dynamics (CFD) is the branch of fluid science which deals with a variation occurs on fluid flow, basically computational fluid dynamics opt an finite volume method as methodology and for base equation it follows the Eulerian equation, i.e. when gravity forces were not considered, pressure force and viscous force are used to simulate the desired fluid flow problem.

5.2 Fluent Solver

Computation Fluid Dynamics consists of several domains to solve fluid flow problem like CFX, fluent (poly flow), fluent (blow moulding), fluent, fluent solver works under computational fluid dynamics, it obeys the three governing equation with respect to base equation (Eulerian equation) i.e. energy equation, momentum equation and continuity equation by applying or solving through this algorithm, the further results were obtained and variation could be determine.

5.3 Finite volume method

Finite Volume Method is used to solve the fluid flow problems by obtaining the convergence of Eulerian equation and governing equation, this method works on volume of fluid or volume of fraction, it consists of energy equation, momentum equation and continuity equations with respect to pressure force, viscous force or gravity force to solve the fluid flow problem, in case of heat exchanger, radiation, turbulence, laminar flows, acoustics and also deals with aerodynamics, HVAC

5.4 Governing equations:

5.4.1 Continuity equation:

$A_1V_1=A_2V_2$

A_1 = area of inlet

V_1= velocity at inlet

A_2= area of outlet

V_2= velocity at outlet

This equation shows the flow is pressure based or density based i.e. if a flow is pressure based the vortices and stream line of fluid is normal, if the flow is density based the fluid flow and stream line is in a high pressure.

5.4.2 Momentum Equation

This equation justified that the flow of fluid consists of definite mass and product of velocity with respect to mass to determine the momentum of fluid flow.

$$\frac{\partial}{\partial x_j}\left(\rho u_i u_j\right) = \frac{\partial}{\partial x_j}\left(\mu \frac{\partial u_i}{\partial x_j}\right) - \frac{\partial p}{\partial x_j}$$

5.4.3 Energy Equation

This equation works on present simulation model when heat flux and radiation were applied on boundary condition to determine the temperature variation on fluid flow and on heat transfer solid element to determine temperature variation.

$$\frac{\partial}{\partial x_i}(\rho u_i T) = \frac{\partial}{\partial x_j}\left(\frac{k}{C_p}\frac{\partial u_i}{\partial x_j}\right) \tag{4.2}$$

5.5 Procedure for solving problem with fluent:

- Pre- processor
- Solver
- Post- processor

5.5.1 Pre-processor

It is a process on which model is created for simulation, meshing of the domain is done and boundary conditions were applied i.e. inlet, outlet, heat flux, wall, etc.

5.5.2 Solver

It is used to apply the governing equation and base equation on pre-processor to determine the variation on fluid flow.

5.5.3 Post processor

It is used to determine the results obtaining from fluent solver in a form of contour plots, in a form of a velocity and stream line contour plots etc.

5.5.3 Turbulence Modeling

Turbulent flows are characterized by fluctuating velocity fields. These fluctuations mix transported quantities such as momentum, energy, and species concentration, and cause the transported quantities to fluctuate as well. Since these fluctuations can be of small scale and high frequency, they are too computationally expensive to simulate directly in practical engineering calculations.

FLUENT provides the following choices of turbulence models:

➢ Spalart-Allmaras model
➢ k-ε models

- Standard k-*ε* models
- Renormalization-group (RNG) k-*ε* models
- Realizable k-*ε* models

➢ k-ω models

Standard k-ω models
Shear-stress transport (SST) k-ω models

➢ v2-f model (addon)
➢ Reynolds stress model (RSM)

Linear pressure-strain RSM model
Quadratic pressure-strain RSM model
Low-Re stress-omega RSM model

➢ Detached eddy simulation (DES) model

Spalart-Allmaras RANS model
Realizable k- *ε* RANS model
SST k- ω RANS model

➢ Large eddy simulation (LES) model

Smagorinsky-Lilly subgrid-scale model
WALE subgrid-scale model
Kinetic-energy transport subgrid-scale model

5.5.4 Choosing a Turbulence Model

It is an unfortunate fact that no single turbulence model is universally accepted as being superior for all classes of problems. The choice of turbulence model will depend on considerations such as the physics encompassed in the flow, the established practice for a special class of problem, the level of accuracy required, the available computational resources, and the amount of time available for the simulation.

VI. MODELING AND ANALYSIS

Geometry is framed in demonstrating programming UNIGRAPHICS and its foreign made to the ANSYS workbench where lattice is finished, and sends out the work to FLUENT 15.0. The limit conditions, material properties, and including properties are set through parameterized case records. Familiar tackles the issue until either as far as possible is met, or the measure of emphases determined by the client is accomplished. The procedure for resolving the problem is:

- Create the geometry.
- Meshing of the domain.

- Set the material properties and boundary conditions.
- Obtaining the solution

6.1 PREPARATION OF THE CAD MODEL

The measurements of the computational area sun based pipe depended on the work by Rajesh Maithani, J.S. Saini. After this procedure the imperative are connected and along these lines the model is accomplished in demonstrating programming UNIGRAPHICS The accompanying section (4.1.1) demonstrates the parameters of sun based air radiator channel roughened misleadingly with V-ribs and Semicircular V-ribs.

6.1.1 Modeling of duct with smooth absorber plate

The geometry of conduit with smooth safeguard plate is made and coincided on UNIGRAPHICS. At that point subsequent to putting the limit conditions this fit record is keep running on FLUENT 15.0 and the outcome acquired from familiar are utilized for approval of the outcome with the base paper.

6.1.2 Solver setting and Boundary Conditions

In CFD examination before the running of geometry on FLUENT 15.0, solver defining and limit conditions are given. In the present case taking after solver defining and limit conditions are connected

VII. RESULT AND DISCUSSION

Contour plots of 14 degrees with different reynolds no.

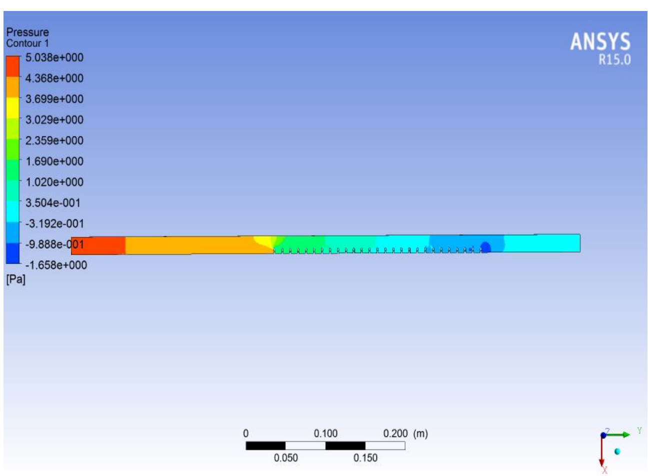

Figure 7.1 Pressure distribution in nozzle perforated 900 transverse ribs plate duct with 3800 Reynolds number.

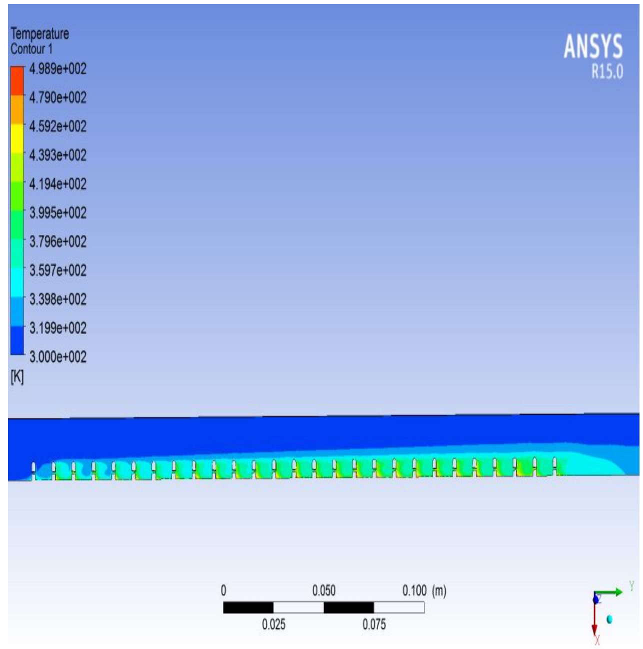

Figure 7.2 Pressure distribution in nozzle perforated 900 transverse ribs plate duct with 3800 reynolds number.

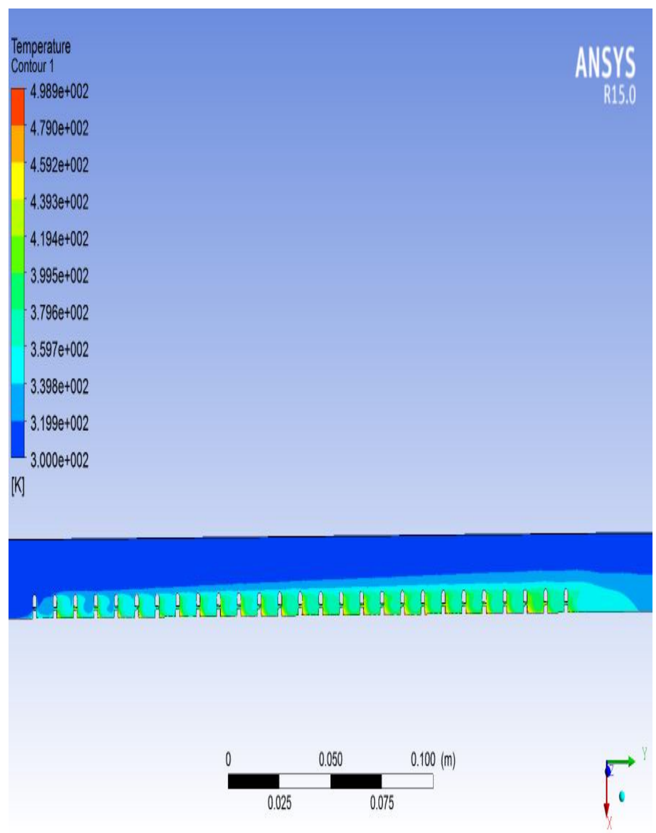

Figure 7.3 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 3800 reynolds number.

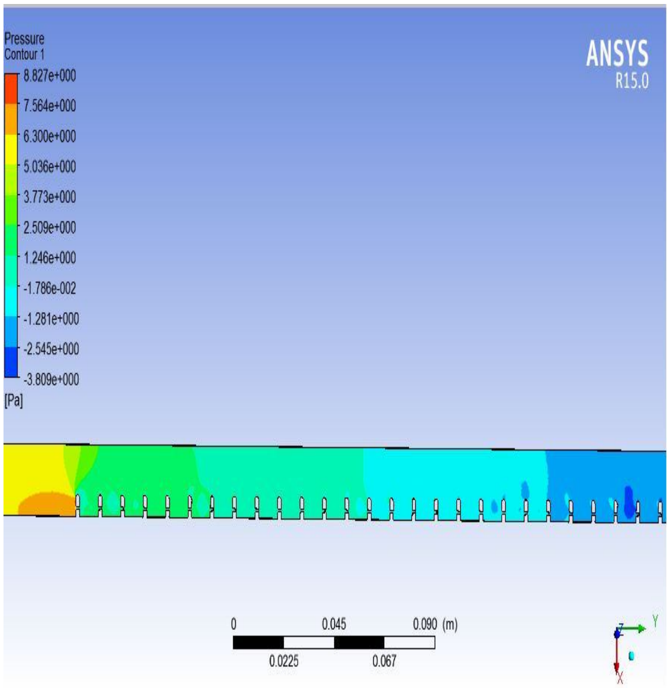

Figure 7.4: Pressure distribution in nozzle perforated 900 transverse ribs plate duct with 5000 reynolds number.

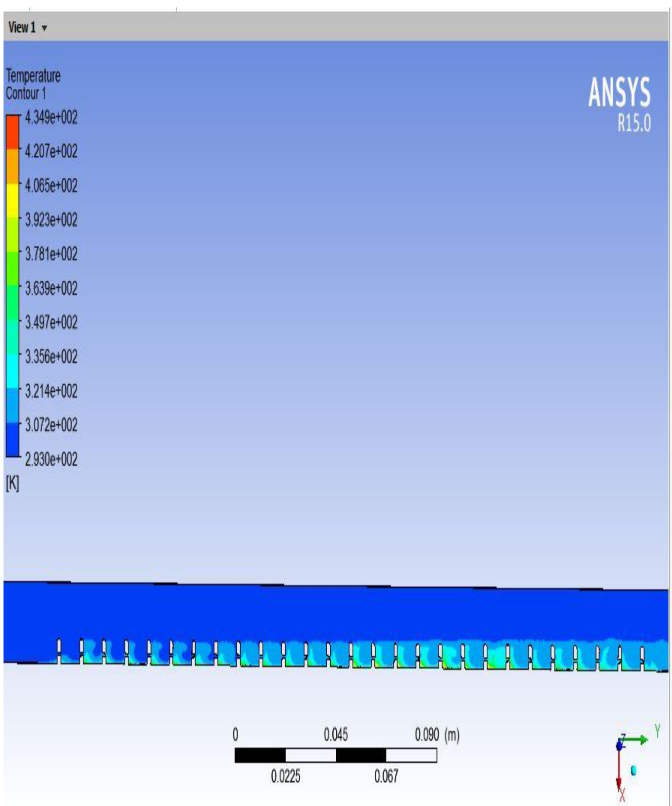

Figure 7.5: Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 5000 reynolds number.

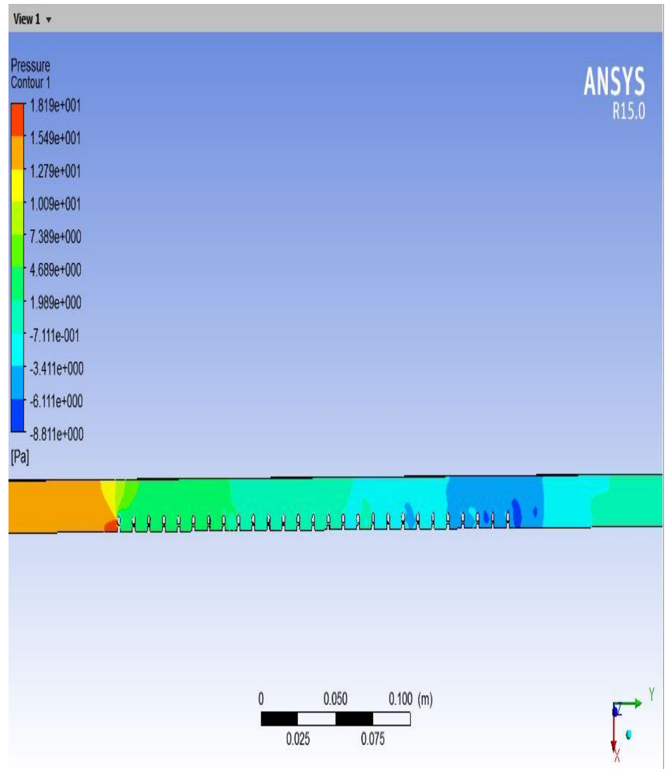

Figure 7.6: Pressure distribution in nozzle perforated 900 transverse ribs plate duct with 8000 reynolds number.

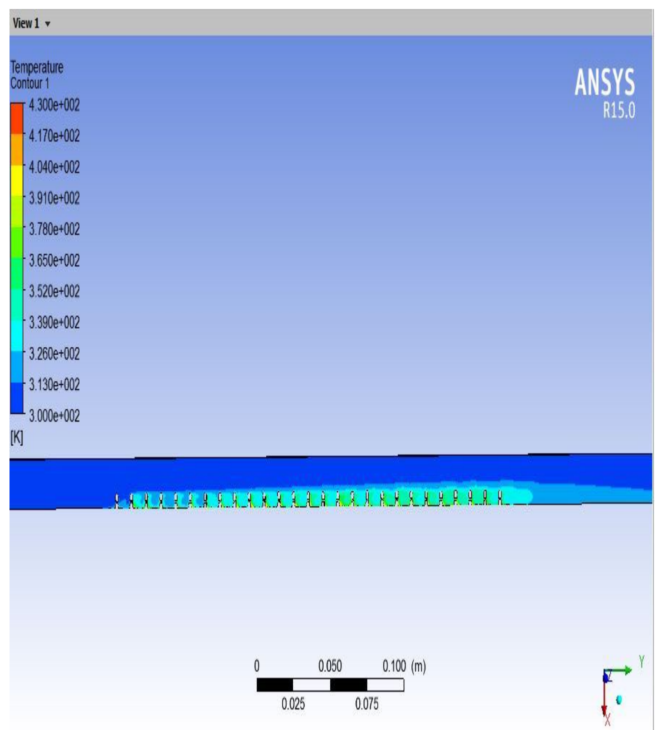

Figure 7.7: Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 8000 reynolds number.

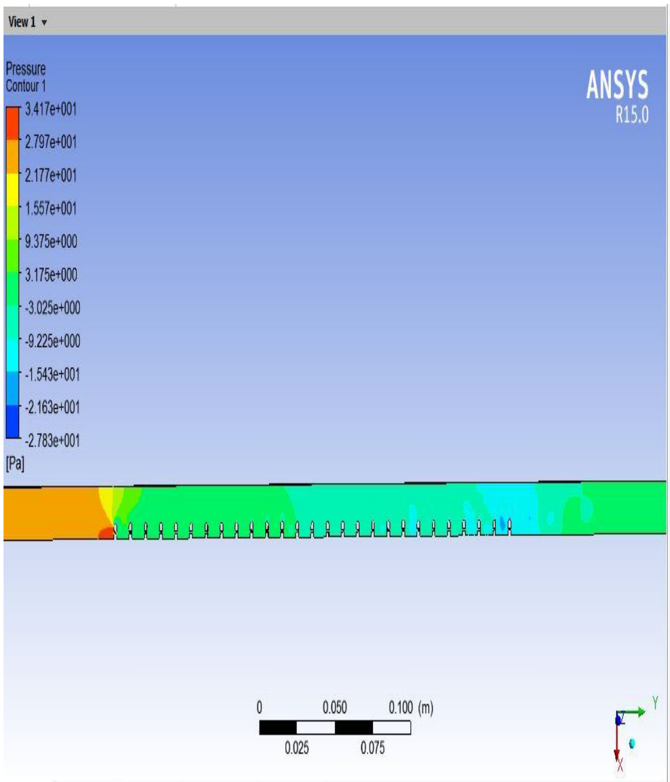

Figure 7.8: Pressure distribution in nozzle perforated 900 transverse ribs plate duct with 12000 Reynolds number.

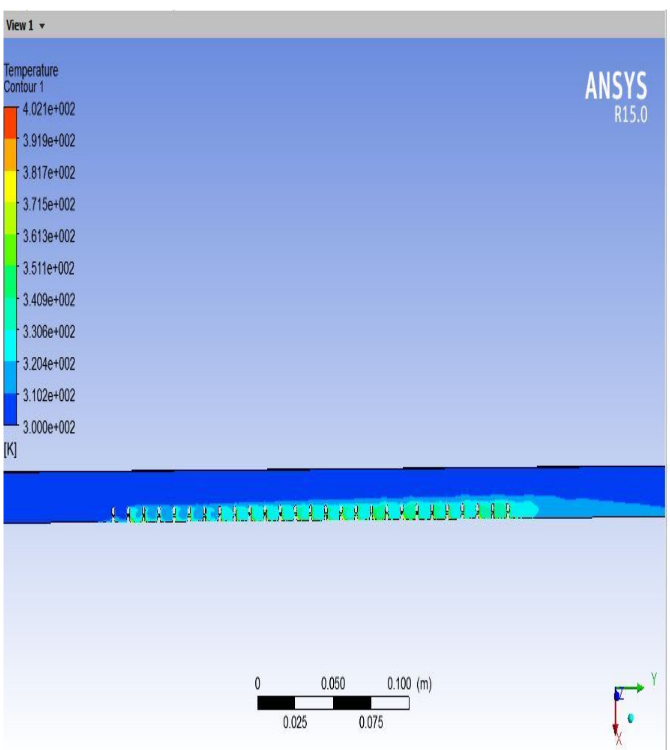

Figure 7.9: Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 12000 Reynolds number.

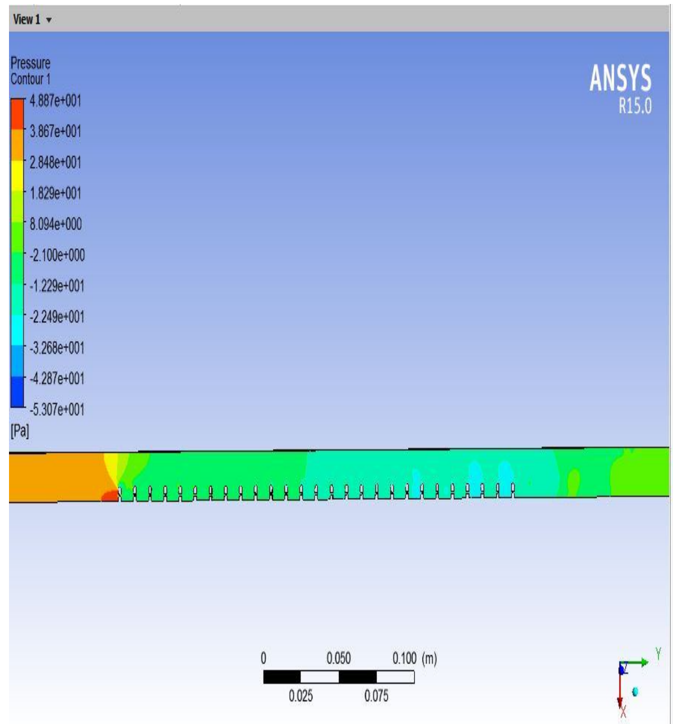

Figure 7.10 Pressure distribution in nozzle perforated 900 transverse ribs plate duct with 15000 Reynolds number.

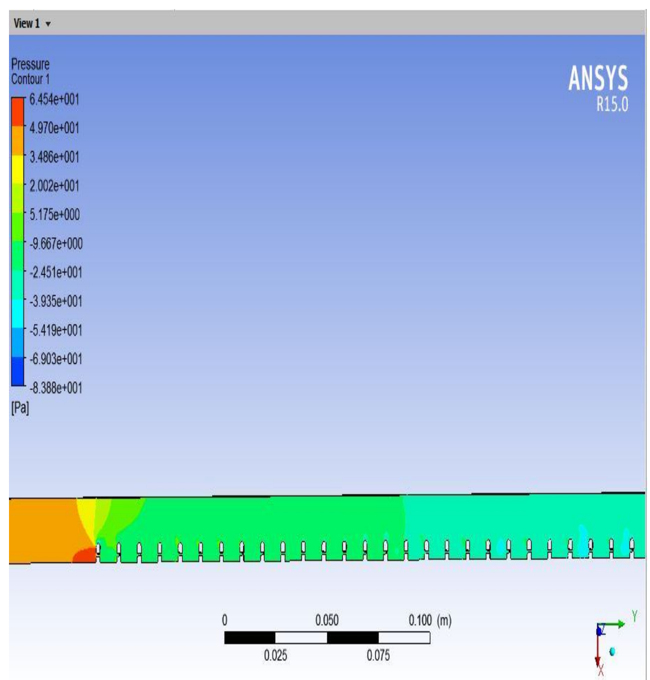

Figure 7.11: Pressure distribution in nozzle perforated 900 transverse ribs plate duct with 18000 reynolds number.

Contour plots of 18 degrees obtained from fluent 15.0.0

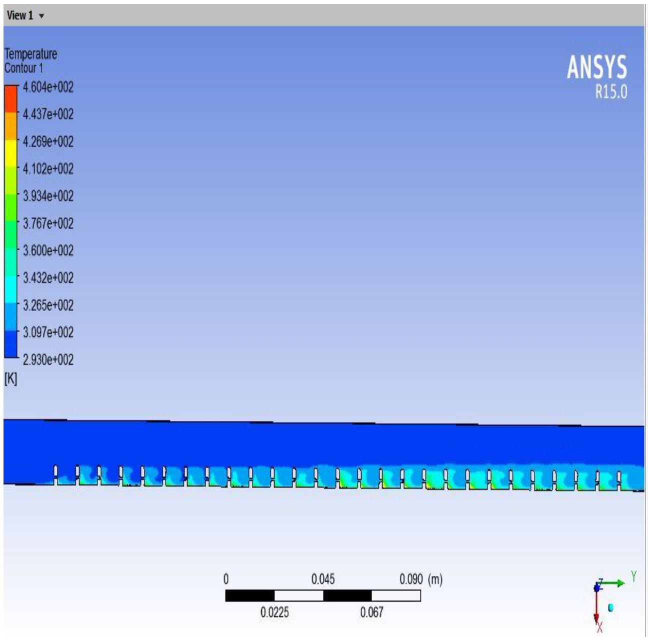

Figure 7.12 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 3800 reynolds number.

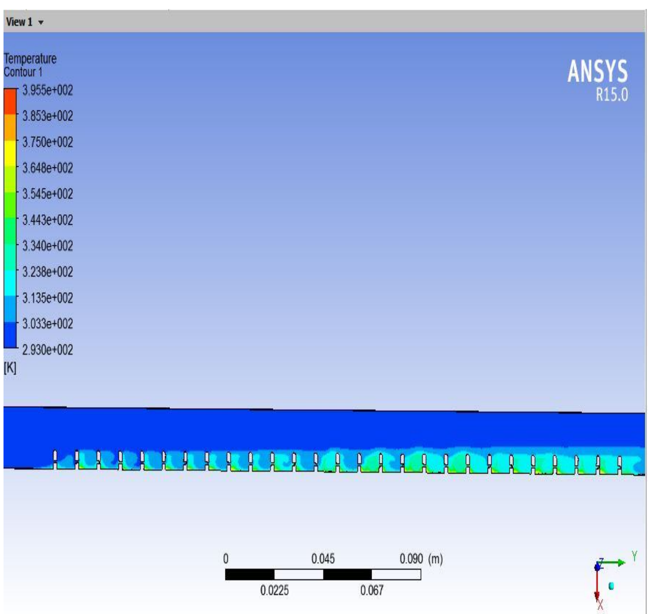

Figure 7.13 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 5000 reynolds number.

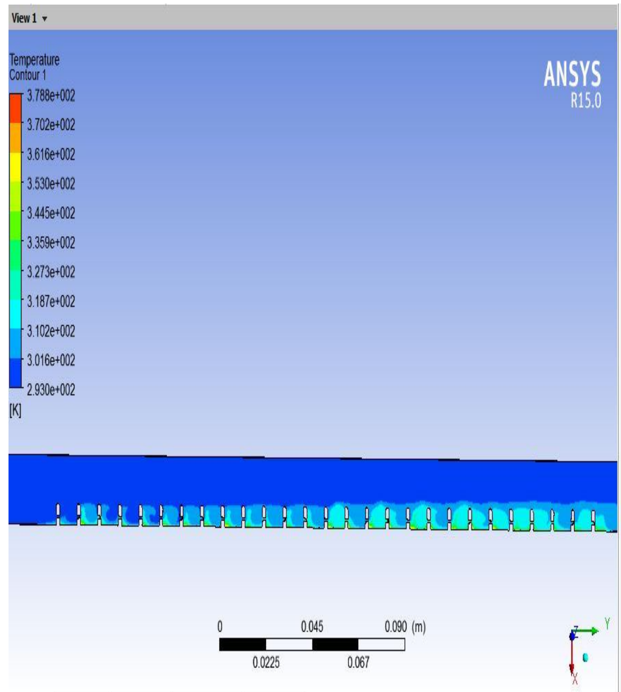

Figure 7.14 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 8000 reynolds number

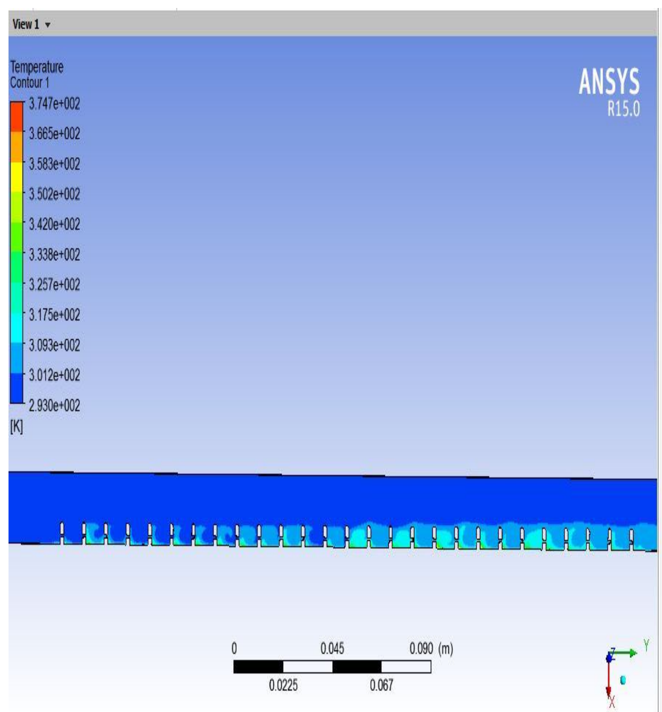

Figure 7.15 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 12000 reynolds number.

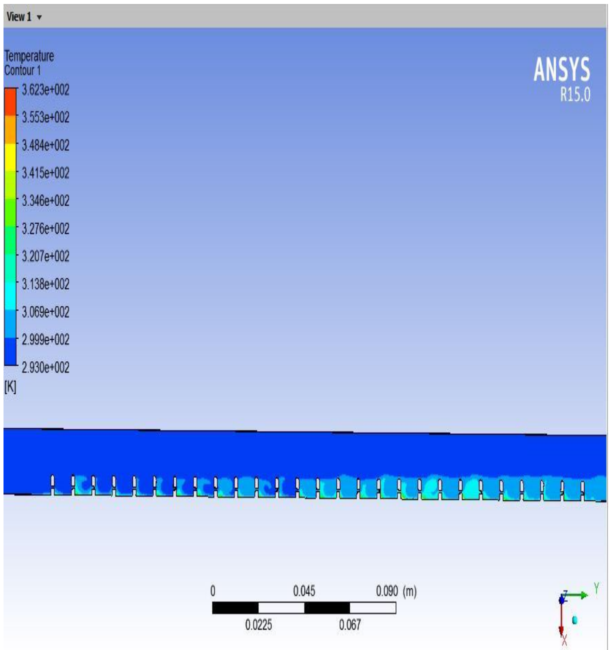

Figure 7.16 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 15000 reynolds number.

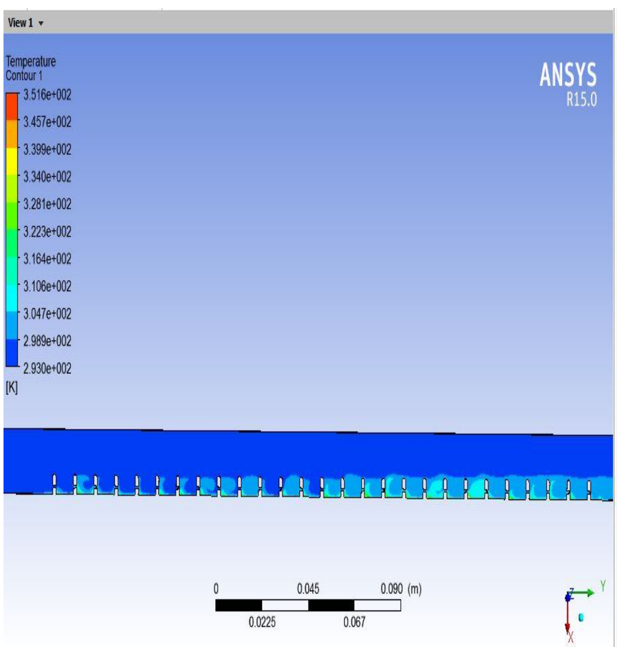

Figure 7.17 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 18000 reynolds number.

Contour plots of 21 degrees

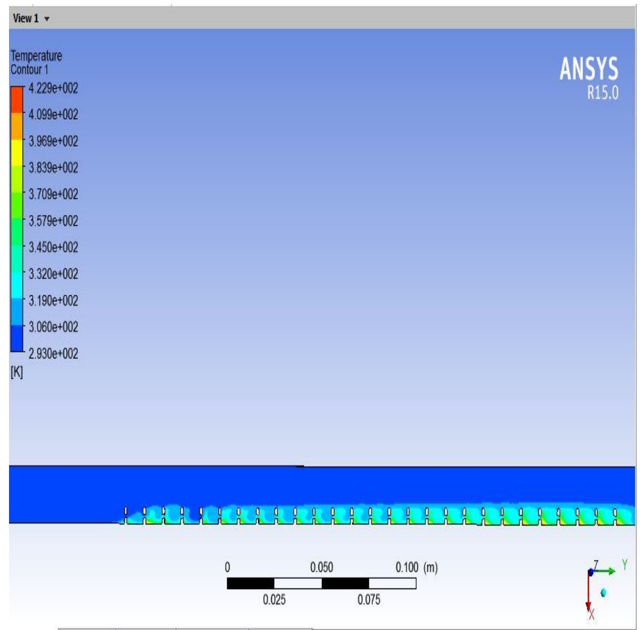

Figure7.18 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 3800 reynolds number.

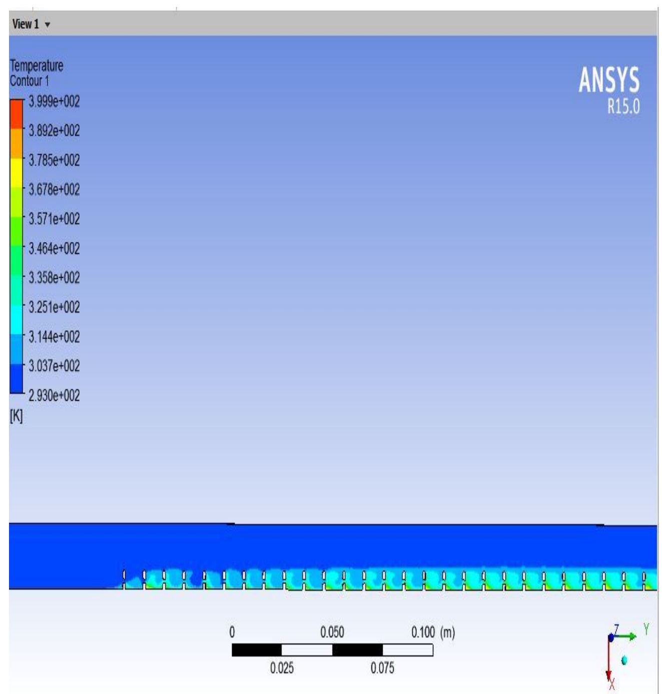

Figure 7.19 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 5000 reynolds number

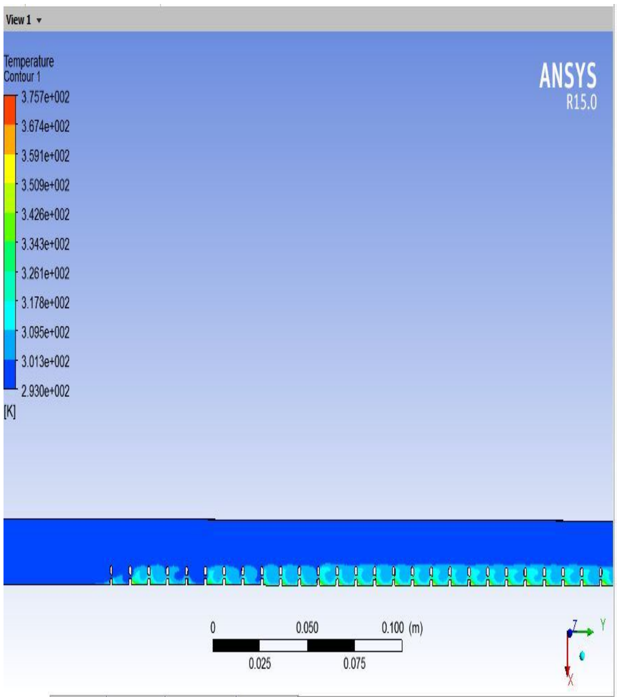

Figure 7.20 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 8000 reynolds number

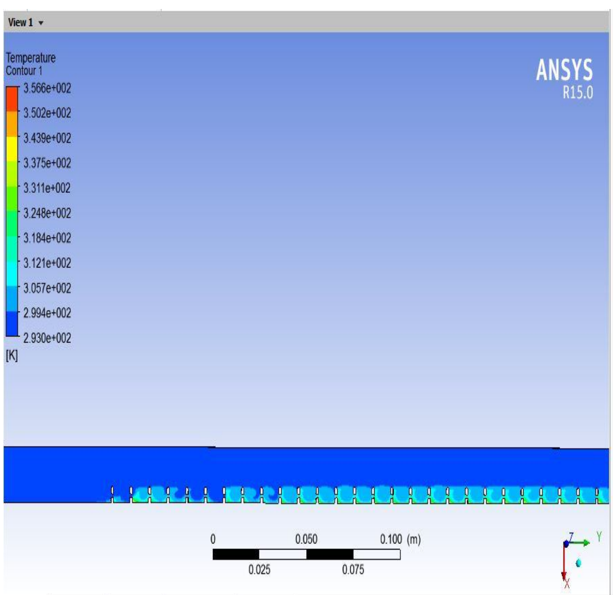

Figure 7.21 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 12000 reynolds number

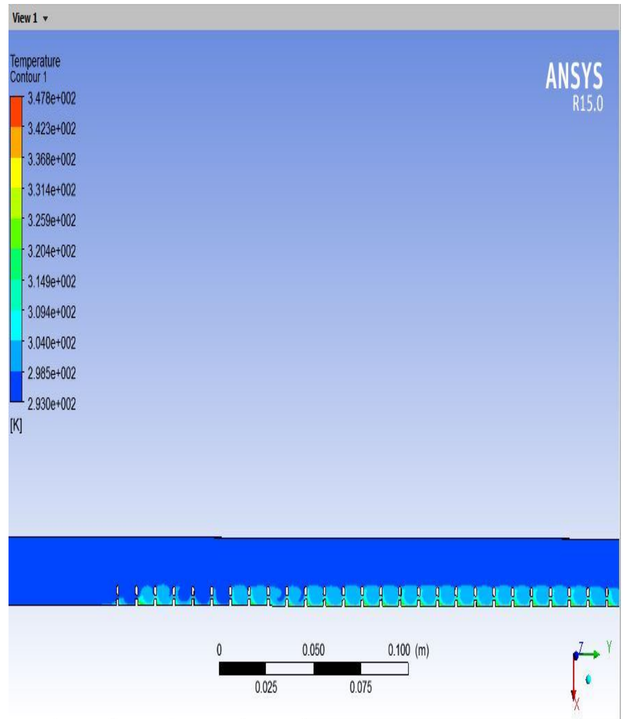

Figure 7.22 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 15000 reynolds number

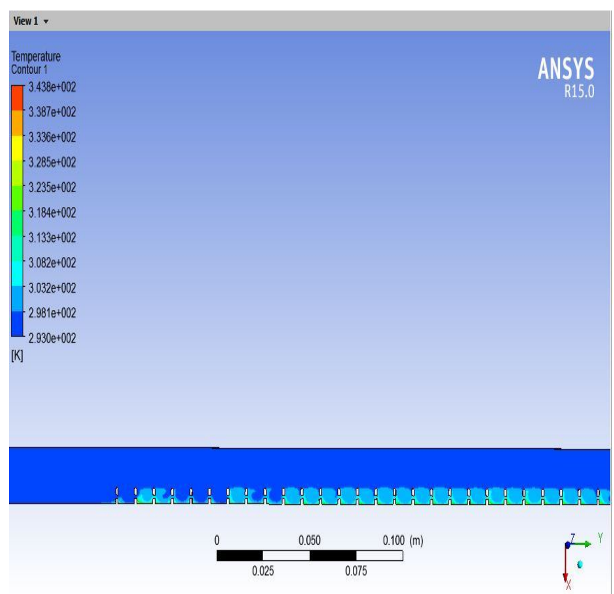

Figure 7.23 Temperature distribution in nozzle perforated 900 transverse ribs plate duct with 18000 reynolds number

Result of Nusselt Number for 140 nozzle perforated 900 transverse ribs with rib height 1.6 and pitch difference 10, 15, 20, 25 mm

Relative Roughness Pitch ratio (Nusselt Number) 14 Degrees				
Reynolds no.	P/e= 6.25	P/e= 9.375	P/e= 12.5	P/e= 15.625
3800	43.66	44.8	43.3	45.2
5000	53.88	58.25	59.7	61.2
8000	74.85	88.6	89.25	96.52
12000	111.8	126.58	123.52	124.22
15000	132.5	142.69	144.85	145.74
18000	153.9	164.5	186.88	187.96

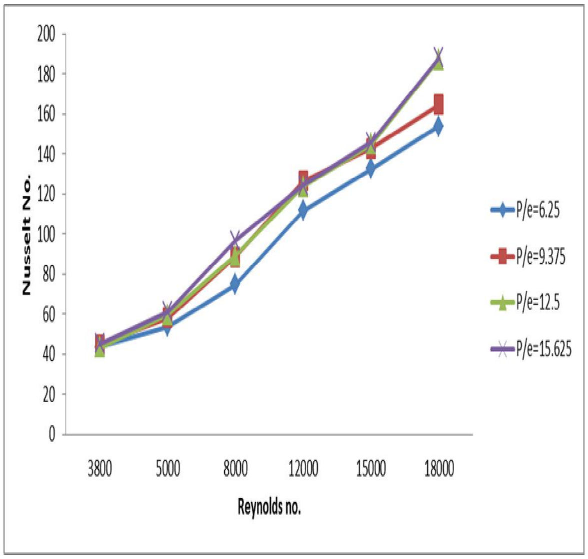

Figure 7.24 Graph shows Relative Roughness Pitch ratio (Nusselt Number) 14 Degrees

Relative Roughness Pitch ratio (Friction Factor) 14 Degrees				
Reynolds no.	P/e= 6.25	P/e= 9.375	P/e= 12.5	P/e= 15.625
3800	0.042	0.035	0.0315	0.030
5000	0.036	0.032	0.0303	0.02
8000	0.0335	0.02	0.024	0.024
12000	0.0255	0.0249	0.023	0.0215
15000	0.0245	0.026	0.0215	0.0205
18000	0.0208	0.023	0.0205	0.0196

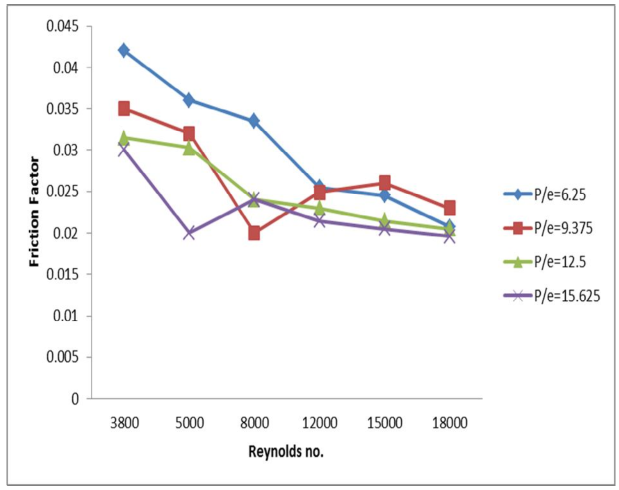

Figure 7.25 Graph shows Relative Roughness Pitch ratio (Friction Factor) 14 Degrees

VIII. CONCLUSION

8.1 CONCLUSION

Perforated circular nozzle shaped transverse 900ribs blockages developed on 2 – dimensional computational domain which is exposed to uniform heat flux in heat wall section have been investigated with respected to heat transfer and friction factor and thermo hydraulic performance characteristics. The effect of nozzle angle of perforation holes, relative pitch difference ratio, pitch difference on Nusselt number and friction factor has been studied for flow Reynolds number range of 3800–18,000. The major findings of this study are given below:

(1) Perforated circular nozzle shaped transverse 900ribsroughness was been found to result in higher heat transfer as compared to smooth absorber plate with same open area ratio.
(2) Maximum enhancement in Nusselt number and friction factor is found to correspond to a circular relative pitch difference ratio value of p/e=15.625.
(3) The maximum increment in the value of Nusselt number has been observed at a nozzle angle perforation of 14 degrees; however the lowest observed value of friction factor corresponding to circular relative pitch difference of 25.
(4) Providing the perforation in 900 transverse ribs results in considerable enhancement in Nusselt number. Average enhancement in Nusselt number for perforated circular nozzle shaped blockages is found to be 31.4% higher over smooth absorber plate while friction factor of perforated blockages gets decreased by 33% of the value as found in perforation.

(5) In comparison to smooth duct, the presence of transverse 900 perforated blockages with nozzle shaped holes yields Nusselt number up to 7.76times while friction factor rises up to 27.84 times.
(6) Maximum enhancement of Nusselt number occurs at open area ratio (b) of 20%, relative roughness pitch ratio (p/e=15.625), and pitch difference (P) of 25, while minimum friction factor is found corresponding to circular relative pitch difference ratio of 5%.
(7) Approximately, 50% improvement in thermo hydraulic performance is achieved by using perforated circular nozzle shaped transverse 900 ribs blockages over Smooth absorber plate and chamfered rib.

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