[Soni* *et al.*, 6(6): June, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

CFD ANALYSIS OF SOLAR AIR HEATER FOR ENHANCEMENT OF HEAT TRANSFER

Kalpana Soni[*1] & Surendra Bharti[2]

[*1]Research Scholar, Department of Mechanical Engineering, Millennium institute of Technology Bhopal,(M.P), India

[2]Asst. Professor, Department of Mechanical Engineering, Millennium institute of Technology Bhopal, (M.P), India

DOI: 10.5281/zenodo.814587

ABSTRACT

Energy is the basic ingredient to sustain life and development. Work means moving or lifting something, warming or lighting something. There are many sources of energy that help to run the various machines invented by man.A 3-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 roughened wall having combination of circularand square transverse wire rib roughness. The effect of Reynolds number, roughness height, roughness pitch, relative roughness pitch and relative roughness height on the heat transfer coefficient and friction factor have been studied.In order to validate the present numerical model, results have been compared with available experimental results under similar flow conditions. CFD Investigation has been carried out in medium Reynolds number flow (Re ¼43800e18, 000). Average Nusselt number increases with an increase of Reynolds number.The maximum value of average Nusselt number is found to be 43.577 for relative roughness pitch of 5 and for relative roughness height of 0.06 at a higher Reynolds number, 10,000. Average friction factor decreases with an increase of Reynolds number. The maximum value of average friction factor is found to be 1.698 for relative roughness pitch of 5 and relative roughness height of 0.06 at a lower Reynolds number, 5000.

KEYWORDS: CFD Analysis, Absorber plate, Enhancement Factor, Reynolds's No. , Nusselt No.

I. INTRODUCTION

Heat transfer enhancement is a subject of considerable interest to researchers as it leads to saving in energy and cost. Because of the rapid increase in energy demand in all over The world, both reducing energy lost related with ineffective use and enhancement of energy in the meaning of heat have become an increasingly significance task for design and operation engineers for many system. In the past few decades numerous researches have been performed on heat transfer enhancement. These researches focused on finding a technique not only increasing heat transfer, but also achieving high efficiency. Achieving higher heat transfer rates through various enhancement techniques can result in substantial energy saving, more compact and less expensive equipment with higher thermal efficiency. Heat transfers enhancement technology has been improved and widely used in heat exchanger application; such as refrigeration, automotive, process industry, chemical industry, etc. One of the widely-used heat transfer enhancement technique is inserting different shaped elements with different geometries in channel flow.

This work basically described the characteristics of the heat transfer and friction is a square duct where various shaped ribs are placed transversely to the main stream direction on one wall. The shape of ribs investigated is square, triangular, chamfered and semicircular. The objective of this research are to full fill three aspects i.e., to assess the occurrence of hot spot on the rib roughness wall by investigating the effects of rib shapes on the local heat transfer result for prediction of the flow and heat transfer characteristics in ribbed passages, and to compare the thermal performance of the four type of ribbed duct. The specific objective of the paper are to identify the appropriate governing equation for the problem, develop a computer code to create a computational grid spots on the rib roughened wall by investigating the effect of rib shapes on the local heat transfer and compare the thermal performance of the four type of the ribbed duct finally.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

The basis of any active heat transfer enhancement technique lies in the utilization of some external power in order to permit the mixing of working fluid, the rotation of heat transfer surface and the vibration of heat transfer surface or of the working fluid and the generation of electrostatic field. While mechanical aids (mixing of fluid and rotation of heat transfer surface) are used in appropriate applications such as surface scraping, baking and drying processes, electrostatic techniques have been demonstrated on prototype heat exchangers only. It uses electrically induced secondary motions to destabilize the thermal boundary layer near the heat transfer surface, thereby substantially increasing the heat transfer coefficient at the wall. Generally, active heat transfer enhancement methods have not been well.

The major heat transfer enhancement techniques that have found widely spread commercial applications are those which possess heat transfer enhancement elements. All passive techniques aim for the same, namely to achieve higher values of the product of heat transfer coefficient and the heat transfer surface area. A distinguish between the way how the heat transfer enhancement is achieved, is common in the heat transfer community. Hence also in the present work, a terminology similar to the literature is followed although for practical applications are irrelevant how the heat transfer enhancement is achieved.Heat transfer enhancement by inserting ribs is commonly used application in tubes. Ribs improve the heat transfer by interrupting the wall sub layer. This yield flow turbulence, separation and reattachment leading to higher heat transfer rates. Due to the existence of ribs effective heat transfer surface increases.

The phenomenon of Heat transfer Enhancement

1. Breaking of laminar sub layer.
2. Creation of local wall turbulence.
3. Decrease in the thermal resistance.

II. LITERATURE SURVEY

There are various research papers that are used in my studies are fallows:

- **Yadav and Bhagoria [Feb. 2015]** Performed 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 roughness on heat transfer and fluid flow have been investigated. The Reynolds number, relative roughness pitches (P/e) and relative roughness height (e/D) are chosen as design variables. A two-dimensional CFD simulation is performed using the ANSYS FLUENT 12.1 code. The Renormalization-group (RNG) k-ε model is selected as the most appropriate one. Results are validated by comparing with available experimental results. It is apparent that the turbulence created by small diameter of transverse wire ribs result in greater increase in heat transfer over the duct.
- **Yadav and Bhagoria [Aug. 2015]** Performed of an artificial roughness in the form of repeatedribs on a surface are an effective technique enhances the rate of heat transfer. 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 commercial finite-volume CFD code ANSYS FLUENT (ver. 12.1) is used to simulate turbulent airflow through artificially roughened solar air heater. The Navier-Stokes equations and the energy equation are solved in conjunction with a low Reynolds number RNG k-e 3 turbulence model. Twelve different configurations of square sectioned rib (P/e ¼ 7.14 e 35.71 and e/D ¼ 0.021 e 0.042) have been considered. The flow Reynolds number of the duct varied in the range of (3800-18000) most suitable for solar air heater. It has been found that the square sectioned transverse rib roughened duct with P/e ¼ 10.71 and e/D ¼ 0.042 offers the best thermo-hydraulic performance parameter for the investigated range of parameters.
- **Yadav and Thapak[May 2014]** Solar air heater is the cheapest and extensively used solar energy collection device for drying of agriculture products ,space heating, seasoning of timber and curing of industrial products. The use of an artificial roughness on a surface is an effective technique to enhance the rate of heat transfer to fluid flow in the duct of a solar air heater. Use of artificial roughness in solar air heater has been topic in research for the last thirty years. The investigate the relative performance of different types of artificially roughened solar air heater. The objective of this article is toper form such a study. In this article twenty known different shape sand orientations of roughness elements are considered for comparative analysis. In order to obtain the results numerically, codes are developed in MATLAB-7.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

- **Lanjewar, Bhagoriya, Sarvaiya[Feb 2014]** Carried out an experimental investigations on heat transfer and friction factor characteristics of rectangular duct roughened with W-shaped ribs. Author reported that thermo-hydraulic performance improved with angle of attack of flow and relative roughness height and maxima occurred at angle of attack 60^0.Performed experiments to determine the effect of relative roughness pitch, relative roughness height and wedge angle on the heat transfer and friction factor in a solar air heater roughened duct having wedge shaped rib roughness. Authors found maximum enhancement of Nusselt number up to 2.4 times while the friction factor up to 5.3 times for the range of parameters investigated.
- **Prasad and Saini [2013]:** Developed the relations to, calculate the average friction factor and Stanton-number for artificial roughness of absorber plate by small diameter protrusion wire. They used these relations to compare the effect of height and pitch of roughness element on heat transfer and friction factor with already available experimental data. The friction factor for one side rough duct is determined by assuming that the total shear force in the one side rough duct is approximately equal to combined shear force from three smooth walls in a four sided smooth duct and the shear- force from one rough wall in a four sided rough duct. They used the friction similarity law and heat momentum transfer analogy.
- **Karwa, SAINI, Solanki [2013]** Studied and found that the artificial roughness in the form of chamfered ribs groove on the absorber plate result in considerable enhancement of heat transfer. This enhancement is, however, accompanied by a substantial increase in the friction factor. It is therefore desirable to select the roughness geometry such that the heat transfer coefficient is maximized while keeping the friction losses at the minimum possible value. Considering the heat transfer and friction characteristics can fulfill this requirement the collector simultaneously.
- **Lanjewar and Bhagoriya [2012]** performed 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 roughness on heat transfer and fluid flow have been investigated. The Reynolds number, relative roughness pitches (P/e) and relative roughness height (e/D) are chosen as design variables. A two-dimensional CFD simulation is performed using the ANSYS FLUENT 12.1 code. The Renormalization-group (RNG) keε model is selected as the most appropriate one. Results are validated by comparing with available experimental results.
- **Prasad and Mullick [2011]** Developed a protruding wires on the underside of the absorber plate of an unglazed solar air heater for cereal grains drying to improved the heat transfer characteristics and hence the plate efficiency factor. Investigate on solar air heater with protruding wires in underside of the absorber plate. They found improvement of 9% (from 63% to 72%) in plate efficiency (FP) for Reynolds number of 40,000. The plate efficiency is 44.5% higher in cross corrugated sheet with protruding wire than plane galvanized iron sheet.
- **Verma and Prasad [2008]** Developed of a heat transfer in the solar air heater ducts can be achieved by several means like using baffles, fins, ribs and groves. Until now, various attempts have been made to investigate the effects of these geometries on the enhancement of the heat transfer rate; however it is achieved at the cost of the increase in the pressure drop across the surfaces on which the scene elements are mounted. This paper is an attempt to summarize and conclude the investigation involving the use of small height elements and surface protrusions on absorber plate and channel walls as artificial roughness elements of various geometries and its effect on heat transfer and friction factor through experiments. It also summarizes the various correlations which have been developed for Nusselt number (Nu) and Friction factor (f) and reported in the previous investigations. The comparative study has been done to understand the results of these investigations for solar air heaters with different roughness elements on its absorber surface.
- **Bopche and Tandale [2007]** Performed for the thermo-hydraulic performance of solar air heaters with inverted U-shaped ribs on the absorber plate. They concluded that their roughness element is efficient in heat transfer even at lower Reynolds number (Re-5000). They further concluded that the turbulence is created only in the viscous sub-layer resulting in higher thermo-hydraulic performance than smooth solar air heaters.
- **Karmare and Tikekar [2006]** performed CFD investigation of fluid flow and heat transfer in a solar air heater duct with metal grit ribs as roughness elements on the absorber plate. Commercial CFD code FLUENT 6.2.16 was used as a solver. Standard k-e turbulence model was used to simulate turbulent airflow through artificially roughened solar air heater. Circular, triangular and square shape rib grits with the angle of attack of 54^0, 56^0, 58^0, 60^0 and 62^0 were tested for the same Reynolds number.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Authors reported that amongst the different shapes and orientations analyzed, the absorber plate of square cross-section rib with 58^0 angle of attack gave the best results. The percentage increase in the heat transfer for 58^0 rib inclination plate over smooth plate was found to be about 30%. In order to validate CFD results, experimental investigations were carried out in the laboratory.

- **Gupta [2006]** Investigated the effect of roughness and operating parameters on thermal as well as on the hydraulic performance of roughened solar air heaters and compared the thermo-hydraulic performance of roughened solar air heaters with that of conventional smooth solar air heaters. The optimum design and operating conditions were determined. On the basis of thermo-hydraulic considerations it was found that the systems operating in a specified range of Reynolds number (3800e18000) showed better thermo-hydraulic performance. Authors reported that the roughened solar air heaters were thermo-hydraulically advantageous for lower Reynolds numbers. Beyond a certain limiting value of Reynolds number, a smooth solar air heater will perform thermo-hydraulically better, although the thermal efficiency of a roughened solar air heater might be more than that of a smooth heater. This limiting Reynolds number was found to lie in the range of 3800e18000.
- **Chandra [2005]** Investigated the effect with varying number of transverse ribbed walls with the parameters Re¼ 10,000–80,000; P/e¼ 8; e/D_h¼ 0.0625 channel length to the hydraulic ratio (L/D_h)¼ 20 for fully turbulent flow in the square channel. They concluded that one ribbed wall has the heat transfer increase of 2.43–1.78 for Re¼ 12,000– 75,000, with two opposite ribbed walls the increment was 2.64–1.92, with three ribbed walls, the increment of 2.81–2.01 and with four ribbed walls, an increment of 2.99–2.12 which is the maximum when compared to all the types. The maximum increase in the friction factor was found to be 9.50 with four sided ribbed walls and minimum with one ribbed wall of 3.14.They also compared the performance factor {(Str/Stss)/(fr/fss)} of four cases and concluded that, it is highest at 1.78– 1.17 for one wall ribbed surface.
- **Gandhi and Singh [2005]** Performed a numerical investigation to investigate the effect of artificial surface roughness on flow through a rectangular duct having bottom wall roughened with repeated transverse ribs of wedge shaped cross-section. Two dimensional numerical modeling of the duct flow using FLUENT showed reasonably good agreement with the experimental observations except for the friction factor. Numerical results obtained by commercial computational fluid dynamics (CFD) code FLUENT were compared with the experimental results.

Solar Air Heater: Solar energy is available freely and an indigenous source of energy provides a clean and pollution free atmosphere. The simplest and the most efficient way to utilize solar energy are to convert it into thermal energy for heating applications by using solar collectors. Solar air heaters, because of their inherent simplicity are cheap and most widely used collector devices. Solar air heaters are being used for many applications at low and moderate temperatures. Some of these are crop drying, timber seasoning, space heating etc.

The components of solar air heater are:-

i. Transparent glass cover.
ii. Absorber plate or heated wall.
iii. Insulation bottom.

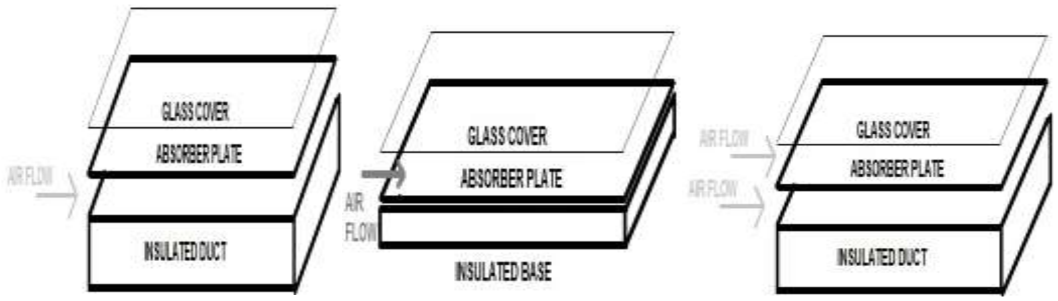


Fig.1. (a) *Fig.1. (b)* *Fig.1. (c)*

III. PROBLEM FORMULATION

In this analysis, a 3-D computational roughened SAH is made, which is similar to the computational domain of Yadav and Bhagoriya. The computational domain is simply the physical region having the dimensions of length

461mm, height 20mm and width 100mm. The computationaldomain is a simple rectangle of length 461 mm and consisted of three sections, namely, entrance section (L1 = 225 mm), test section (L2 = 121 mm) and exit section(L3 = 115 mm). In the present numerical work, 3-D equilateral circular sectioned transverse ribs have been considered as roughness element. The equilateral circular sectioned transverse ribs are considered on the underside of the top absorber plate while other sides are considered as smooth surfaces. Rib height is taken in the range of 0.5-2mm.

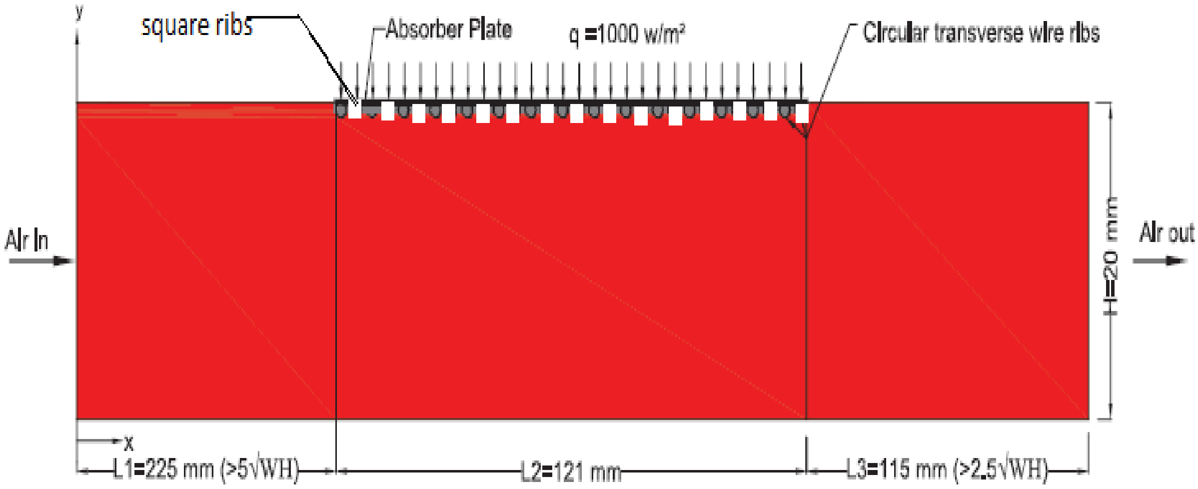


Fig. 2.computational domain for solar air heater

IV. METHODOLOGY

Computational Fluid Dynamics

Computational fluid dynamics (CFD) is a computer-based simulation method for analyzing fluid flow, heat transfer, and related phenomena such as chemical reactions. This project uses CFD for analysis of flow and heat transfer. Some examples of application areas are: aerodynamic lift and drag (i.e. airplanes or windmill wings), power plant combustion, chemical processes, heating/ventilation, and even biomedical engineering (simulating blood flow through arteries and veins). CFD analyses carried out in the various industries are used in R&D and manufacture of aircraft, combustion engines, as well as many other industrial products.

It can be advantageous to use CFD over traditional experimental-based analyses, since experiments have a cost directly proportional to the number of configurations desired for testing, unlike with CFD, where large amounts of results can be produced at practically no added expense. In this way, parametric studies to optimize equipment are very inexpensive with CFD when compared to experiments.

The CFD tools required for carrying out a simulation and the process one follows in order to solve a problem using CFD. The hardware required and the three main elements of processing CFD simulations: the pre-processor, processor, and post-processor.

Three-dimensional Model Description

A 3-dimensional model the shape of a rectangular duct is developed for solar air heater Analysis .The model geometry is created pre-processor using. The model geometry will be created using pre-processor ANSYS DESIGN MODELER. The physical dimension set to be 461mm length, 100 mm width, and 20mm height.

In this CFD analysis **seven** different rib roughness height models have been simulated. Each rib height model is performed with **three** combination of Reynolds number ranging between5000 to 10000.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Operating parameters	Range
Uniform heat flux, ‘q’	1000 w/m^2
Reynolds number, ‘Re’	5000,8000,10000 (3 values)
Prandtl number, 'Pr’	0.71
Relative roughness pitch, ‘P/e’	20,13.33,10,8,6.66,5.71,5 (7 values)
Relative roughness height, ‘e/D’	0.015,0.0225,0.030,0.075,0.045, 0.0525,0.060 (7 values)
Duct aspect ratio, ‘W/H’	5

CAD Model

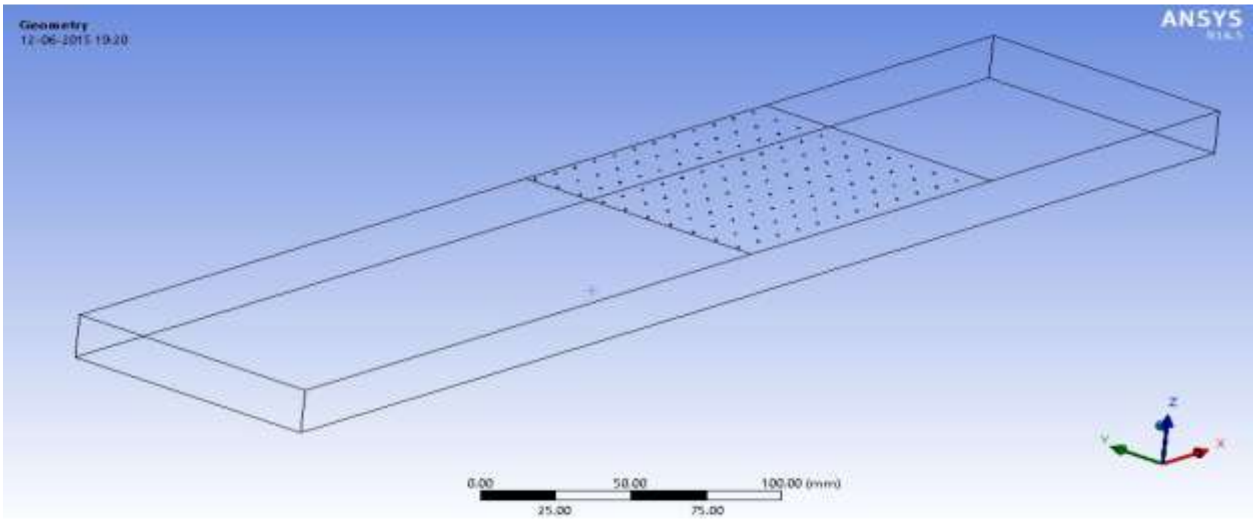


Fig.3..3-D domain SAH DUCT with combination of circular and square rib with e =0.5 mm

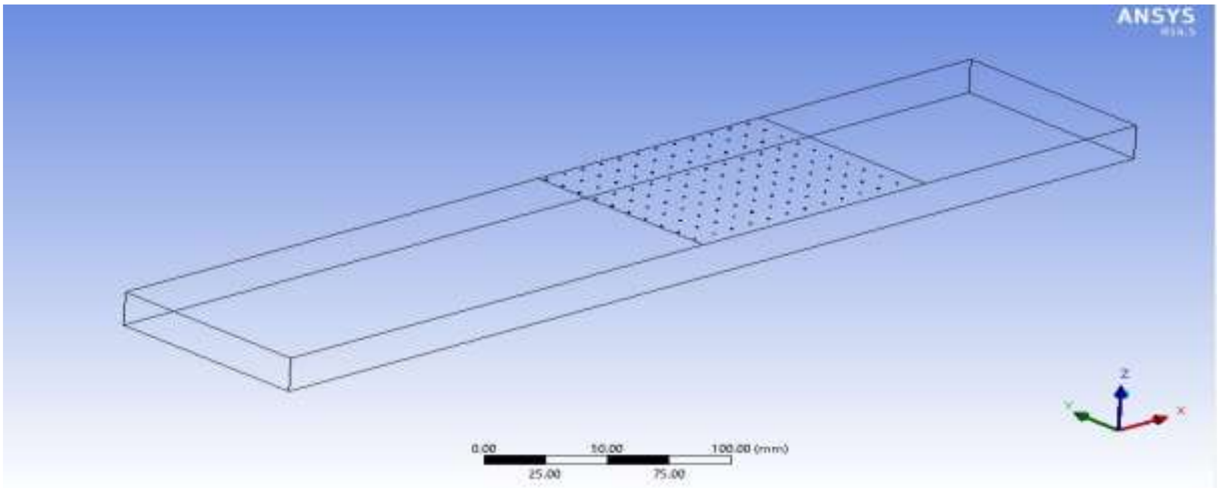


Fig. 4. 3-D domain SAH DUCT with combination of circular and square rib withe =0.75mm

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Meshing Model

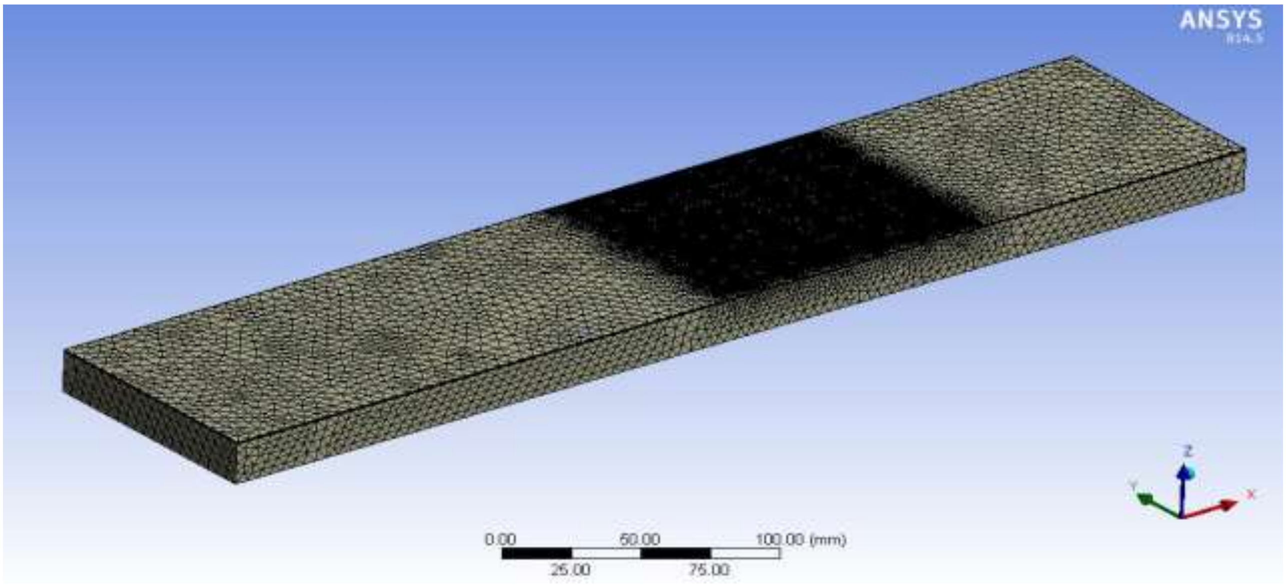


Fig.5Plate-square-circular-p10-e-0.5-mesh

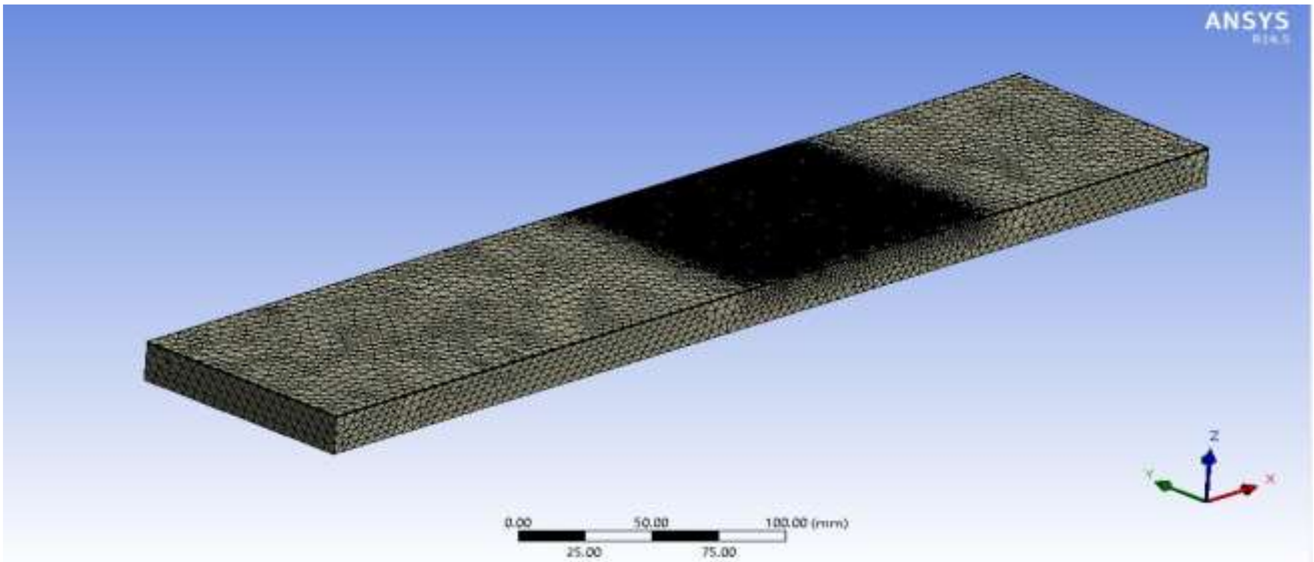


Fig.6Plate-square-circular-p10-e-0.75-mesh

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

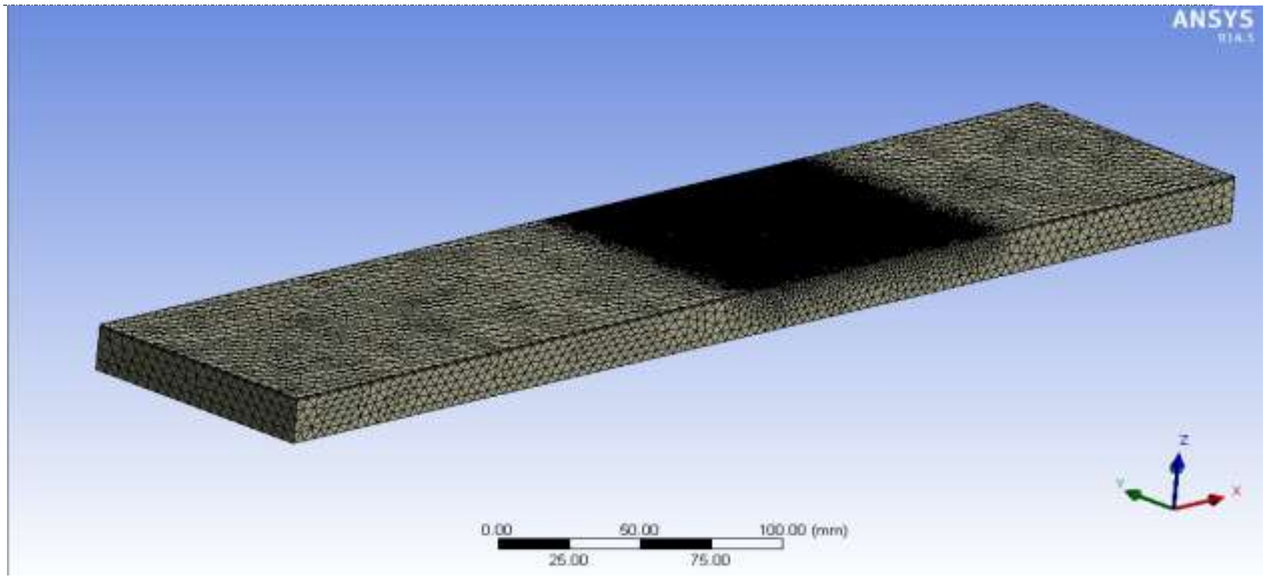
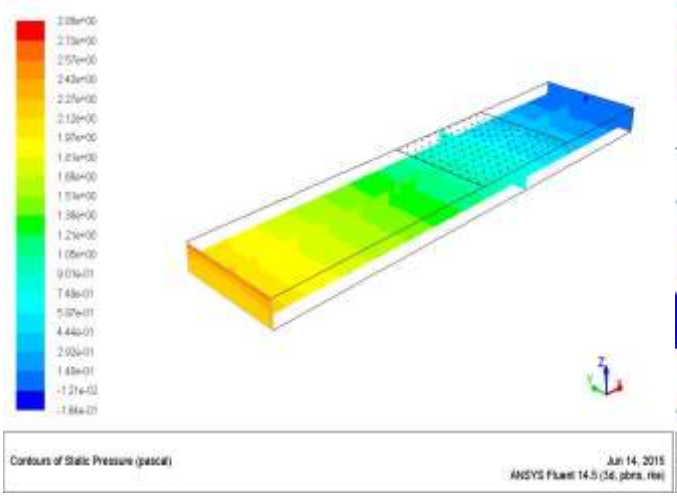


Fig.7Plate-square-circular-p10-e-1.25-mesh

V. RESULT AND DISCUSSION

The predicted airflow velocity, pressure and temperature profiles during Forced-air flow over rib geometry in the duct which were consider in this research work. The CFD analysis has been performed for combination of circular and square ribs on absorber plat of SAH and result has been compared with the case of smooth duct operating under the same Conditions to evaluate the enhancement in heat transfer.

The data collected using ANSYS FLUENT 14.5 included the temperature distribution, pressure distribution and airflow velocity at all node points in the model duct. We can see the following result-



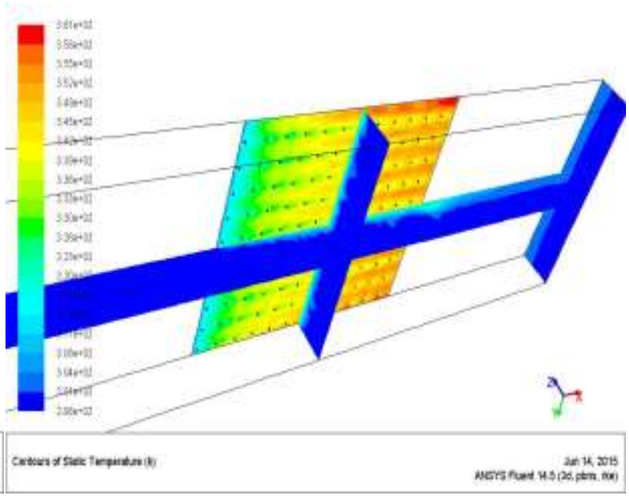
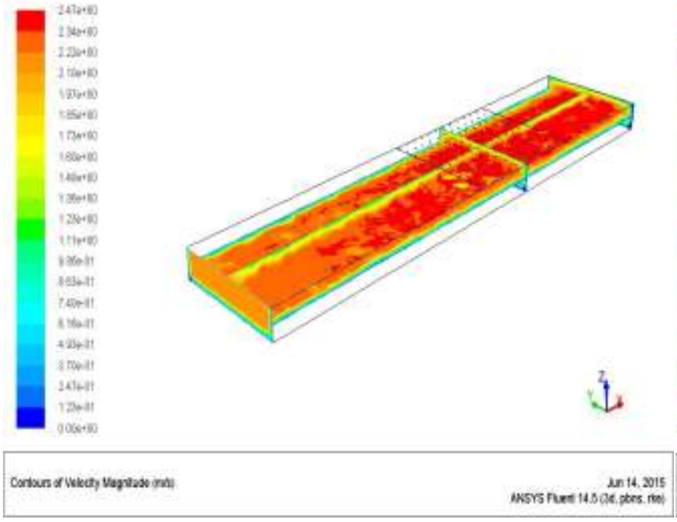


Fig. 8.1 Plate-square-circular-p10-e-0.5-re-5000-pressure Fig.8.2 Plate-square-circular-p10-e-0.5-re-5000-tempreture

RESEARCHERID
THOMSON REUTERS
[Soni* *et al.*, 6(6): June, 2017]
IC™ Value: 3.00
ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7



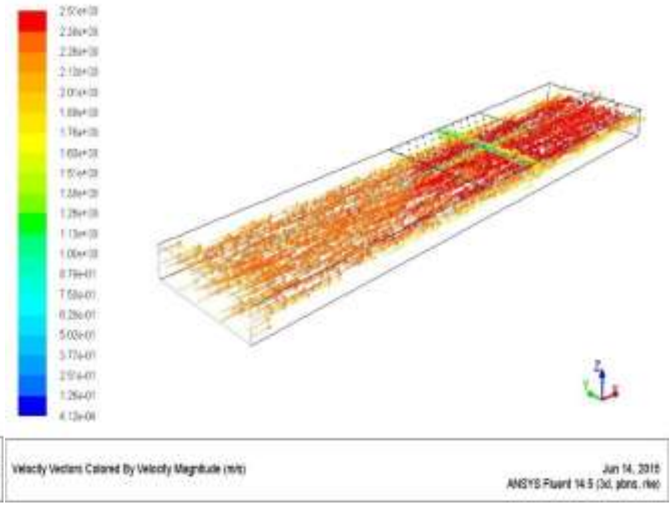
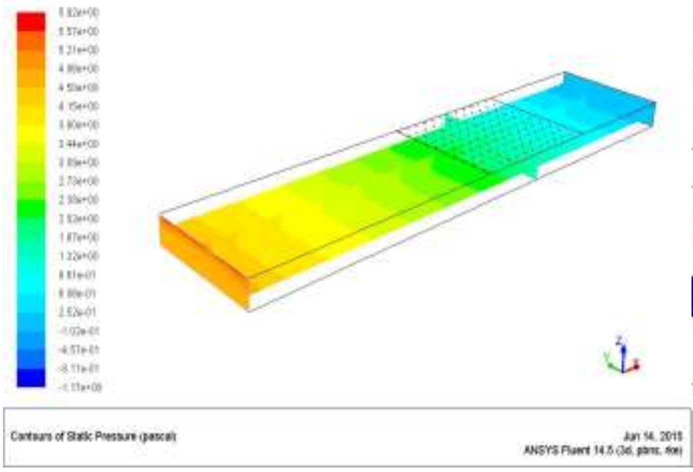


Fig.8.3 Plate-square-circular-p10-e-0.5-re-5000-velocityFig.8.4Plate-square-circular-p10-e-0.5-re-5000-velocity vector



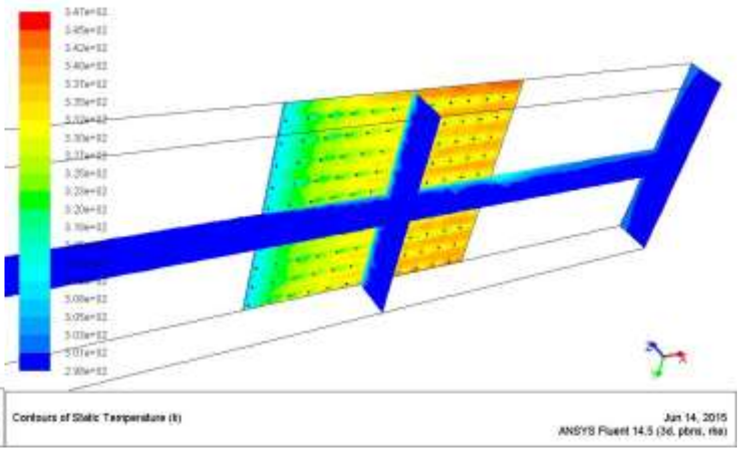
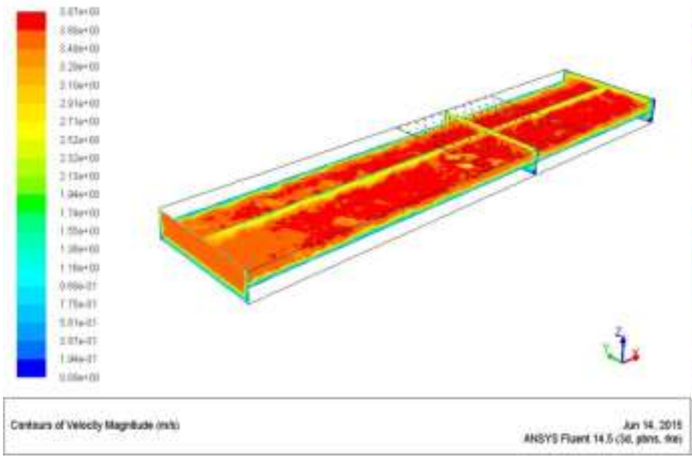


Fig.9.1 Plate-sq-circ-p10-e-0.5-re-8000-pressure Fig.9.2 Plate-sq-circ-p10-e-0.5-re-8000-temperature



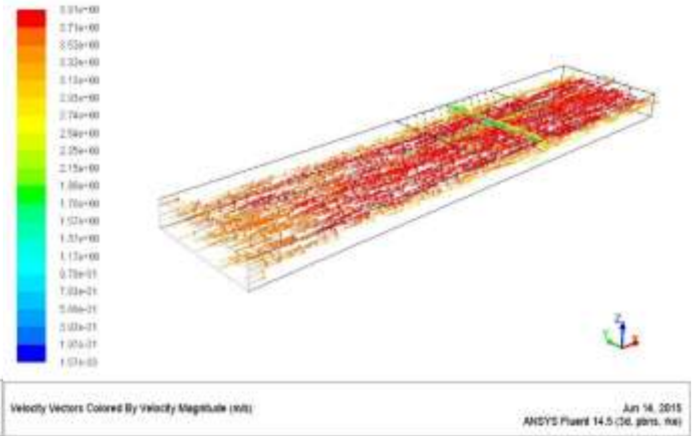


Fig.9.3 Plate-sq-circ-p10-e-0.5-re-8000-velocity Fig.9.4 Plate-sq-circ-p10-e-0.5-re-8000-velocity vector

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

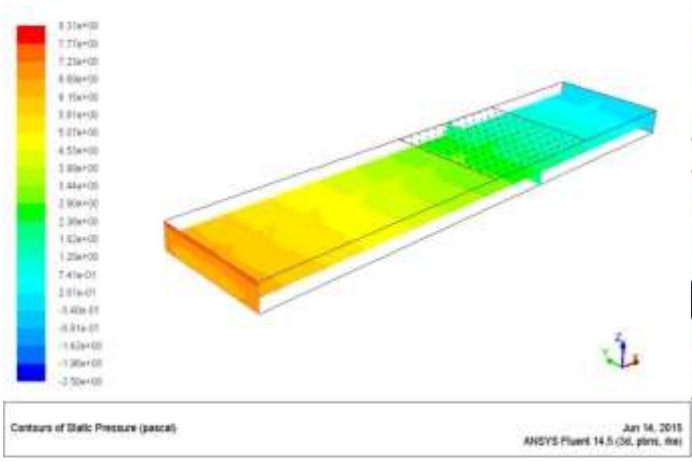


Fig.10.1 Plate-square-circular-p10-e-0.5-re-10000-pressure

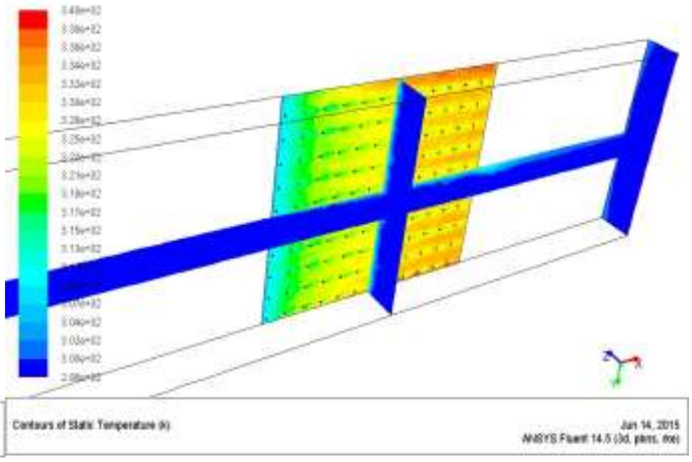


Fig.10.2 Plate-square-circular-p10-e-0.5-re-10000-temperature

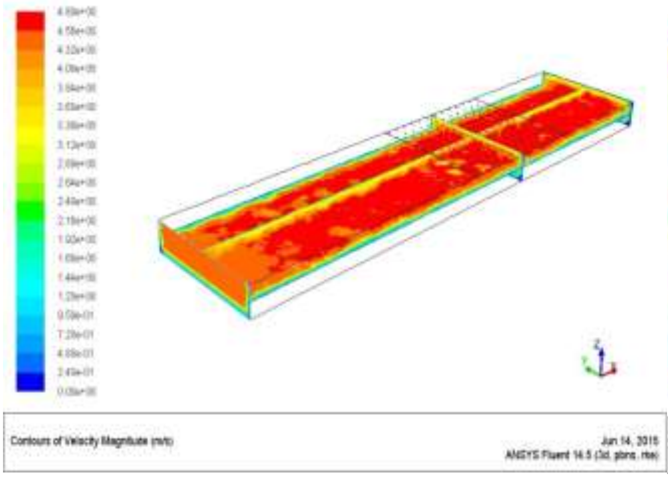


Fig.10.3 Plate-square-circular-p10-e-0.5-re-10000-velocity

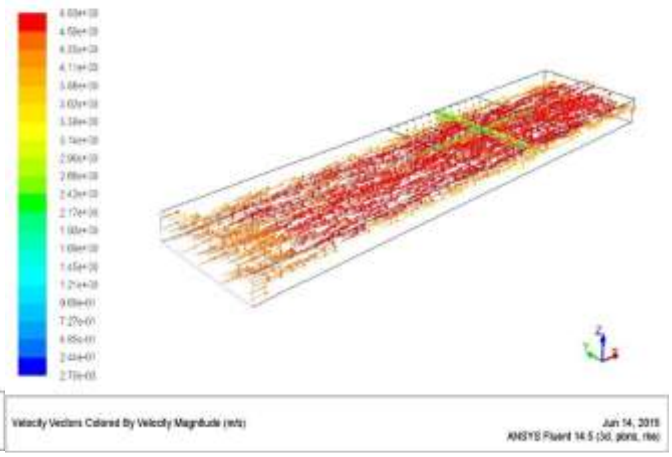


Fig.7 Plate-square-circular-p10-e-0.5-re-10000-velocity vector

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

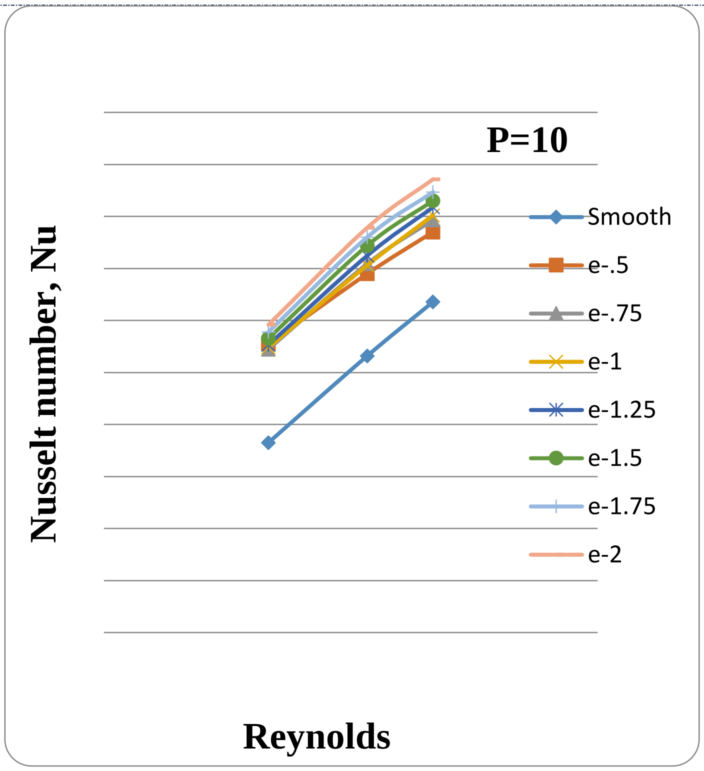


Fig.11

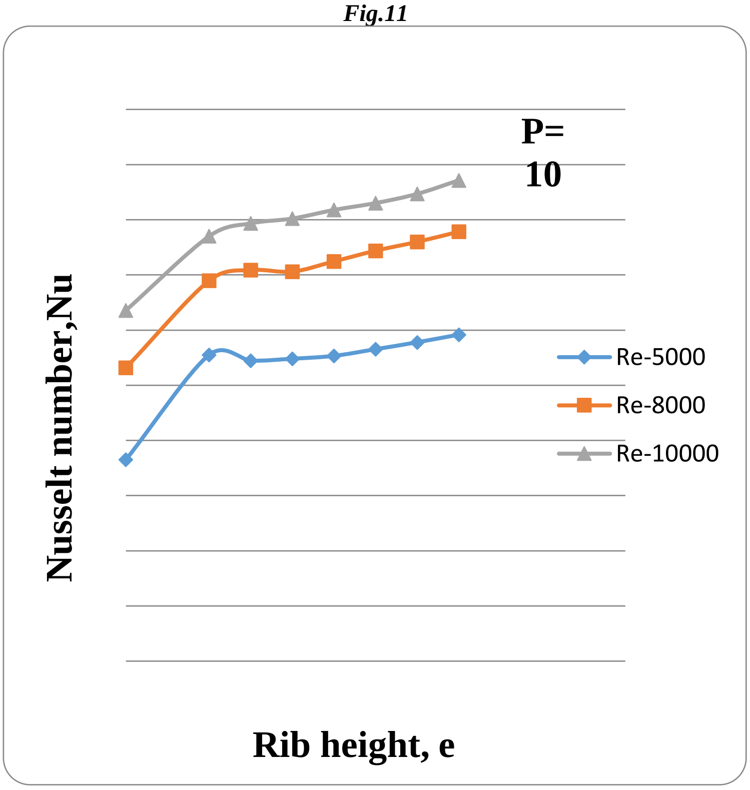


Fig. 12

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

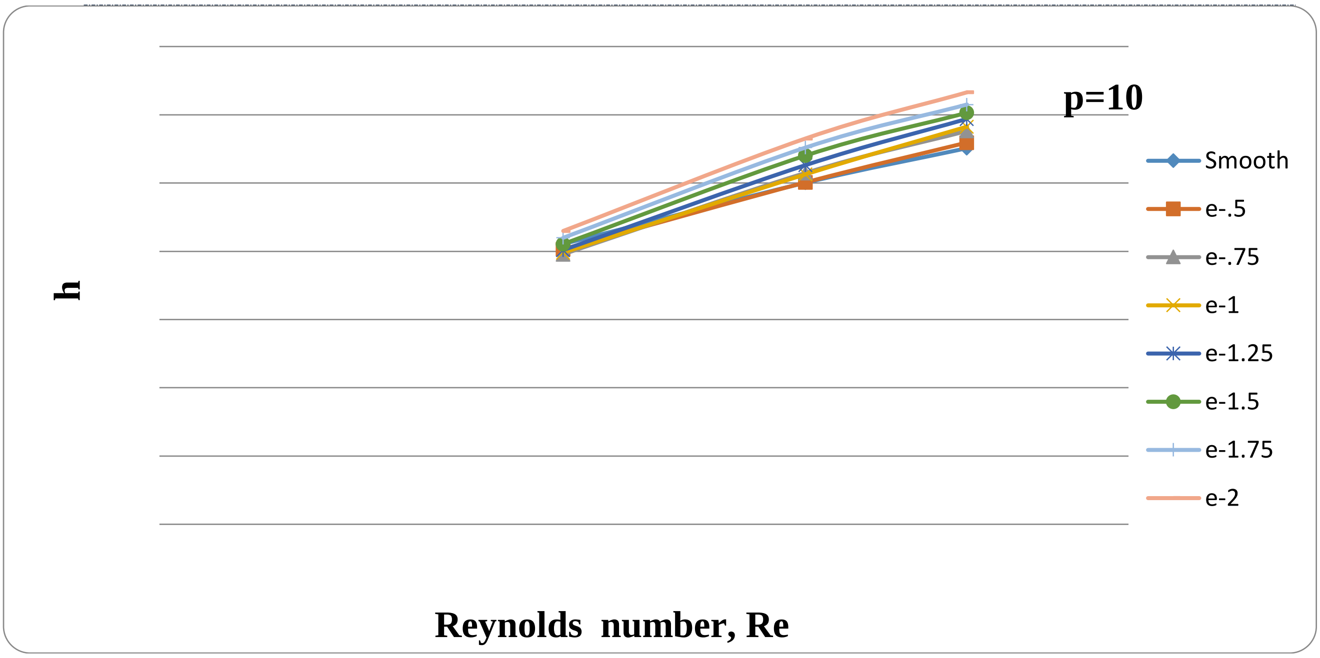


Fig. 13

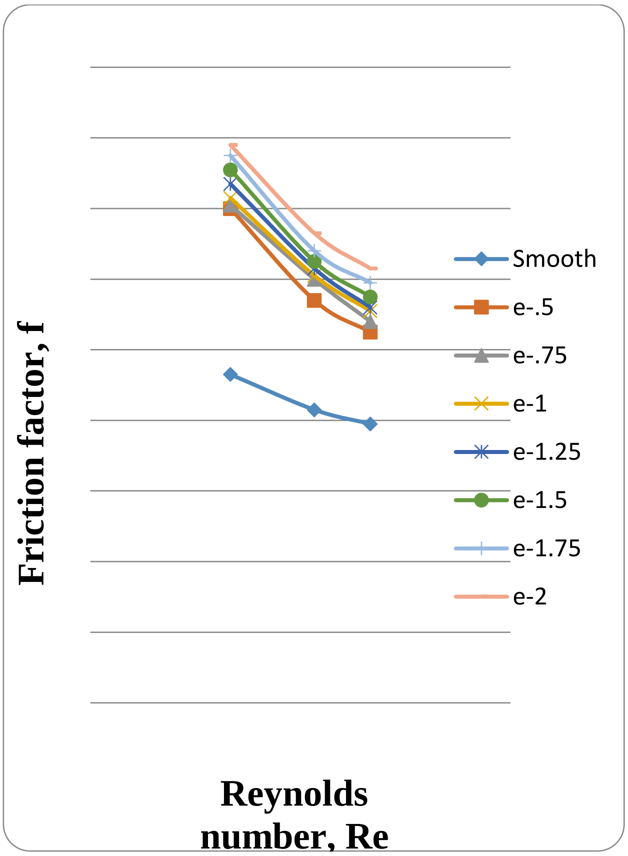


Fig. 14

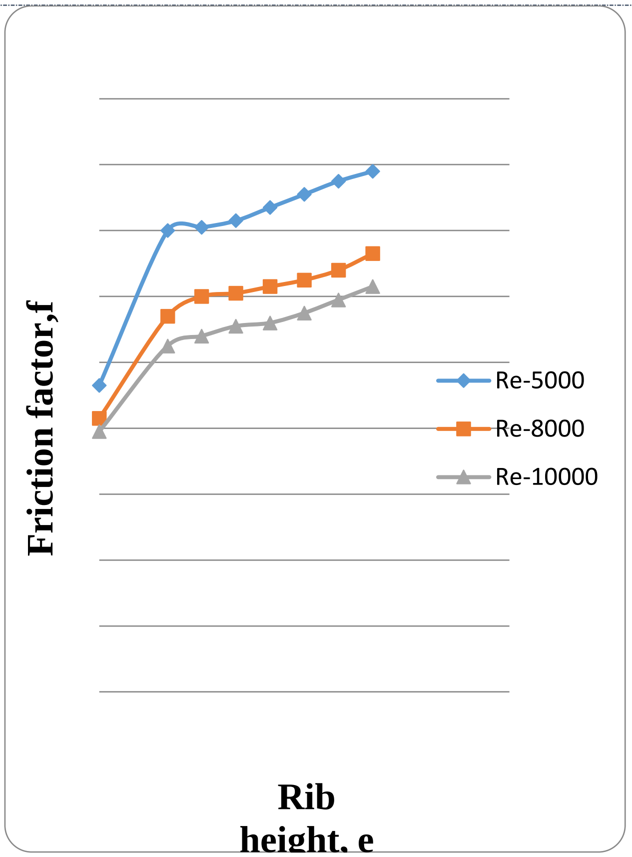


Fig. 15

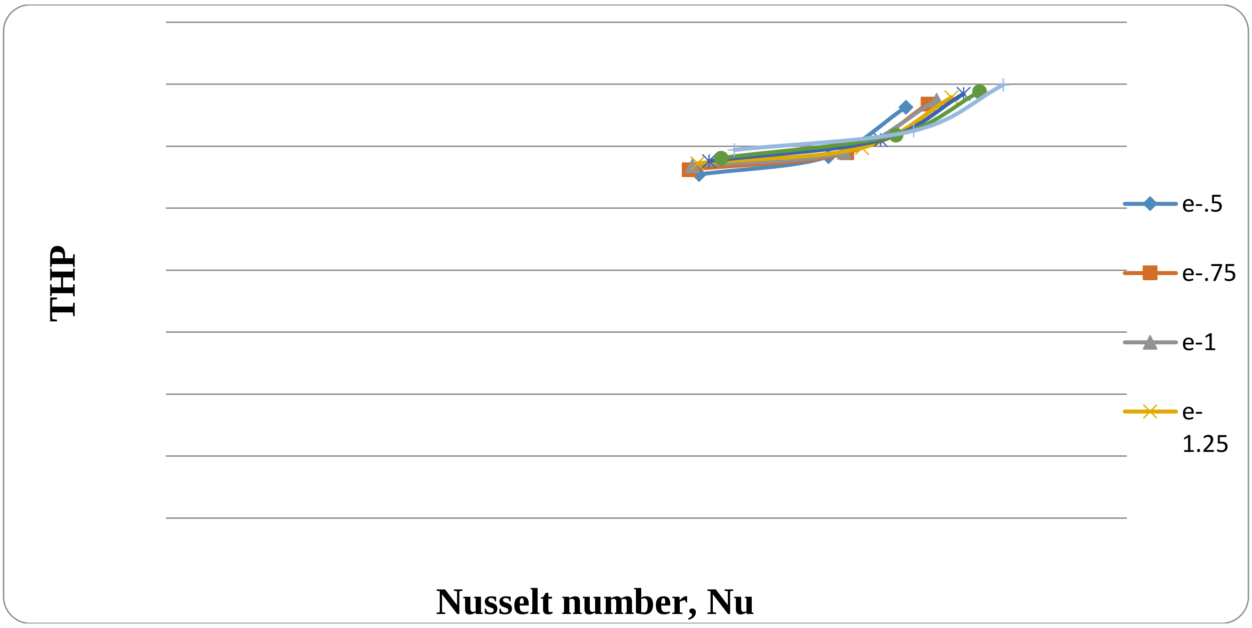


Fig. 16

We can see in fig. 11 the average Nusselt number increases with increase in Reynolds number in all cases for different value of rib roughness height.. We can see in fig. 12 the average Nusselt number increases with increase in rib height in all cases for fixed value of Reynolds number. We can see in fig. 14 the average friction factor decreases with increase in relative Reynolds number in all cases for value of rib roughness height.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

We can see in table 7.2 maximum value of Nusselt number enhancement ratio has been found to be 1.62 times compared to smooth duct corresponds to relative roughness height (e/D) of 0.06 and relative roughness pitch (P/e) of 5 at Reynolds number 5000 in the range of parameter investigated. We calculated the Nusselt number for fixed value of relative roughness height (e/D=0.015 to .06) and relative roughness pitch (P/e=20 to 5).

VI. RESULTS COMPRESSION

A 3-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 roughened wall having combination of circular and square transverse wire rib roughness. The effect of Reynolds number, roughness height, roughness pitch, relative roughness pitch and relative roughness height on the heat transfer coefficient and friction factor have been studied.

Specification	Previous Results	Current Results
Reynolds Numbers Range	3800-18000	3800-18000
Rib Roughness on The Absorber Plate	TRANSVERSE SQUARE SECTIONED RIB	CIRCULAR AND SQUARE SECTION TRANSVERSE RIB
Transverse Rib Roughened Duct With P/E ¼ (Value Must Be Minimum For Better Thermal Enhancement Factor)	10.71	5
Transverse Rib Roughened Duct With E/D ¼ (Value Must Be Maximum For Better Thermal Enhancement Factor)	0.042	0.06

VII. CONCLUSION

In order to validate the present numerical model, results have been compared with available experimental results under similar flow conditions. CFD Investigation has been carried out in medium Reynolds number flow (Re ¼3800e18, 000). The conclusions are drawn from present analysis are Average Nusselt number increases with an increase of Reynolds number. The maximum value of average Nusselt number is found to be 43.577 for relative roughness pitch of 5 and for relative roughness height of 0.06 at a higher Reynolds number, 10,000. Average friction factor decreases with an increase of Reynolds number. The maximum value of average friction factor is found to be 1.698 for relative roughness pitch of 5 and relative roughness height of 0.06 at a lower Reynolds number, 5000..

VIII. REFERENCES

[1] Yadav A.S, Bhagoria J.L, A CFD based heat transfer and fluid flow analysis of a solar air heater provided with circular transverse wire rib roughness on the absorber plate, Energy 55 (2016) 1127–1142
[2] Yadav A.S, Bhagoria J.L, Modeling and simulation of turbulent flows through a solar air heater having square sectioned transverse rib roughness on the absorber plate, Sci. World J. 2013 (2016).
[3] Lanjewar A, Bhagoria J.L, Sarvaiya R.M "Augmentation of heat transfer coefficient by using 900 broken transverse ribs on absorber plate of solar air heater". Renewable Energy 36 (2011) 4531–4541. (2015).
[4] Prasad K and Saini J.S, A experimental investigation in transverse ribs on the absorber plate by assuming that the total shear force, Heat and mass transfer 40 976-993 (2015).

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

[5] Karwa R, Solanki S.C, Saini S.C, Thermo-hydraulic performance of solar air heaters having integral chamfered rib roughness on absorber plates 26 (2001) 161–176 (2014)
[6] Bhagoriya J.L, Lanjewar A,Heat transfer coefficient and friction factor correlations for rectangular solar air heater duct having transverse wedge shaped rib roughness on the absorber plate, Renewable Energy 25 (2013) 341– 369.
[7] Prasad K, Mullick S.C, Heat transfer characteristics of a solar air heater used for drying purposes, Appl. Energy 13 (2) (2013) 83–93.
[8] Saini R.P, Verma J, An experimental setup on the fluid flow and heat transfer of solar air heater duct having dimple –shaped artificial roughness, Energy 33 (2012) 1277–1287.
[9] Verma S.K, Prasad B.N, Investigation for the optimal thermo-hydraulic performance of artificially roughened solar air heaters, Renewable Energy 20 (2012) 19–36.
[10] Bopche S.B, Tandale M.S, Experimental investigations on heat transfer and frictional characteristics of a turbulator roughened solar air heater duct, Int. J. Heat Mass Transfer 52 (2011) 2834–2848.
[11] Gupta D,Investigations on fluid flow and heat transfer in solar air heaters with roughened absorbers, Ph.D. thesis, University of Roorkee, India, 2010.
[12] Karmare S.V, Tikekar A.N. Heat transfer and friction factor correlation for artificially roughened duct with metal grit ribs, Int. J. Heat Mass Transfer 50 (2009) 4342–4351.
[13] Yadav A.S, Bhagoria J.L, A CFD based heat transfer and fluid flow analysis of a conventional solar air heater, J. Eng. Sci. Manage. Educ. 6 (2) (2008) 138–147.
[14] Yadav A.S, Bhagoria J.L, Numerical investigation of flow through an artificially roughened solar air heater, Int. J. Ambient Energy, 2007
[15] Yadav A.S, Bhagoria J.L, A numerical investigation of turbulent flows through an artificially roughened solar air heater, Numer. Heat Transfer A, 2006
[16] Yadav A.S, Bhagoria J.L, Heat transfer and fluid flow analysis of an artificially roughened solar air heater: a CFD based investigation, Front. Energy, 2005.
[17] Singh S, Chander S, Saini J.S, Heat transfer and friction factor correlations of solar air heater ducts artificially roughened with discrete V-down ribs, Energy 36 (2004) 5053–5064.
[18] Yadav A.S, Bhagoria J.L, A CFD based thermo-hydraulic performance analysis of an artificially roughened solar air heater having equilateral triangular sectioned rib roughness on the absorber plate. Heat and mass transfer 70 1016–1039 (2003).
[19] M.M. Sahu, J.L. Bhagoria "Augmentation of heat transfer coefficient by using 900 broken transverse ribs on absorber plate of solar air heater". Renewable Energy (2002).
[20] Hans V.S, Saini R.P, Saini J.S, Heat transfer and friction factor correlations for a solar air heater duct roughened artificially with multiple V-ribs, Sol. Energy 84 (2001) 898–911.
[21] Gupta D, Solanki S.C, Saini J.S, Thermo hydraulic performance of solar air heaters with roughened absorber plates, Sol. Energy 61 (1) (1997) 33–42.
[22] Varun, Saini R.P, Singal S.K, Investigation of thermal performance of solar air heater having roughness elements as a combination of inclined and transverse ribs on absorber plate, Renewable Energy 33 (1996) 1398–1405.
[23] Layek A, Saini J.S, Solanki S.C, Heat transfer and friction characteristics for artificially roughened ducts with compound tabulators, Int. J. Heat Mass Transfer 50 (1995) 4845–4854.

CITE AN ARTICLE

Soni, K., & Bharti, S. (2017). CFD ANALYSIS OF SOLAR AIR HEATER FOR ENHANCEMENT OF HEAT TRANSFER. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 6*(6), 430-444. doi:10.5281/zenodo.814587