iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** X **Month of publication:** October 2016

DOI:

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

CFD Investigation on Thermal Characteristics of Air in a Square Duct using Perforated RIBS

Veeresh Chavan[1], Anandkumar S Malipatil[2]
[1,2]*Department of PG Studies, Department of Thermal Power Engineering VTU RO Kalaburagi-585105 India*

Abstract - In the present work thermal characteristics of air in a square duct with perforated ribs having Aspect ratio (A.R) 2, 3 and 5 were investigated. Analysis is carried out by using a CFD tool. The flow and thermal characteristics of air in a square duct with different geometrical configurations of perforated ribs are studied. Primary objective is to analyze the effect of varied aspect ratios of the perforated ribs with varied pitch on the thermal characteristics and to estimate the pressure ratios in the square duct. This work is repeated for different configurations of perforated ribs and the results are reported for Aspect ratio (A.R) of 2,3,5 and pitch of 120mm, 180mm, 48mm and 72mm with holes of 3,4,8 in numbers each of 2mm diameter. From the present analysis it is observed that velocities are maximum in the domain for the aspect ratio of 2 due to obstruction in the channel. It is observed that for model with higher aspect ratio and longer pitch results in lower pressure drop and better heat transfer rate for the given inlet flow conditions.
Key words - Aspect ratio, Perforated ribs, Pitch, Square duct, Thermal characteristics.

I. INTRODUCTION

There are many uses in engineering industry that require addition or removal of heat and there are different type of heat exchanger devices that are utilized to carry out these applications. Heat exchanger techniques are widely used in process industries, refrigerators, car radiators, air conditioning equipments, thermal power house etc. The basic principle of heat exchanger is to accomplish flow of heat from hot fluid to cold fluid which is done according to Newton's Law of Cooling. Perforated ribs arrays inside internal channels are regularly utilized as a part of heat exchanger systems to increase the heat transfer in turbine blade cooling channels. The impact of perforated ribs from the channel bottom on the heat transfer are analyzed. In this particular study we are utilizing perforated ribs to control the flow field and they can give a beneficial impact on the thermal performance.

Many analysts widely considered and conducted various experiments inner flow of air in various test sections like circular, non circular channels triangular, rectangular, polygonal, square, trapezoidal etc. Square channels are considered keeping in order to get effective freezing of turbine blades and vanes. In order to help heat transfer between energy shipping liquid and its surface perforated ribs are used. Vortex generator is used to upgrade heat exchange by making longitudinal vortices and these is made by putting obstacles in the stream course and henceforth these obstacles are known as vortex generators. Here perforated ribs are used as vortex generator.

II. REVIEW

Abhishek.R.H and Anandkumar S Malipatil (2016) [1] they experimentally studied that friction factor ratio decreases with rise in Reynolds number in case of smooth channel but from the graphs it is seen that square duct having perforated ribs vortex generators the friction factor ratio increases as Reynolds number increases because in these ducts better mixing of air takes place and the vortex generator blocks large amount of air in ducts at higher Reynolds number.

Anandkumar S Malipatil and Shravankumar.T.Sagar (2016) [2] studied the effect of Pitch to height ratio(*p/e*) on friction factor ratio in rectangular duct with perforated ribs obtained. With different aspect ratios, different heights of the ribs and various pitch lengths can be done. And upon comparing all the results it is concluded that; friction factor ratio decreases upon increasing the Pitch to height ratio (*p/e*). Friction factor0ratio at p/e=4 is 86% and at p/e=16 is 51% hence it decreases around 34%.

MaziyarJalaal, Ahmad Khoshnevis, FaramarzTalati, EsmaeilEsmaeilzadeh (2009) [3] [4] has conducted experiment on a three dimensional channel with a heater and inspected the impact of complete surface perforation on thermal development. They computed utilizing two types of perforations those were slot and hole perforations and equation is solved using the FLUENT 6.3 software with Reynolds number ranging from 6000 to 40000. They came to conclusion that by utilizing the perforation that is holes in ribs heat transfer expanded. The heat transfer expands by expanding the perforation angle. In any case, diameter of the hole in the rib is exceptionally noteworthy requirement, by keeping the perforation area as kept before and changing only the hole diameter it will acts divergent since more air spreads over the perforation. In correlation with solid cases, Perforation opposes the block against

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

the flow and the impact is diminishment in the friction factor. The point of Inclination of perforation won't make any impressive impact on pressure drop. Both heat transfer and pressure drop over the channel can be enhanced by expanding perforation diameter in both solid and perforated ribs as the Reynolds number increases then the Friction factor decreases.

Yang and Hwang (2003) [5] showed the numerical expectation of turbulent fluid flow and heat transfer characteristics for rectangular duct with porous baffle. In this study the turbulent governing equation are solved by a control volume-based finite difference method with turbulent model associated with wall function to describe the turbulent structure. The numerical results demonstrate that the flow design around the porous- and solid -type were different due to various transport phenomena, and it is essentially impacts the local heat transfer distributions.

III. METHODOLOGY

A. CAD Models Of Square DUCT With Perforated RIBS

The models are designed by using the computer aided drawing software and are analyzed by using a commercial CFD tool. This models are prepared and disceretized using CFD-Grid generation tool.

TABLE I: SPECIFICATION OF SQUARE DUCT WITH PERFORATED RIBS

Length of square duct	530mm
Breadth of square duct	30mm
Height of square duct	30mm
Aspect ratio	2,3,5
Height of perforated ribs	15mm,10mm,6mm
Diameter of holes	2mm
Temperature of base plate	353K

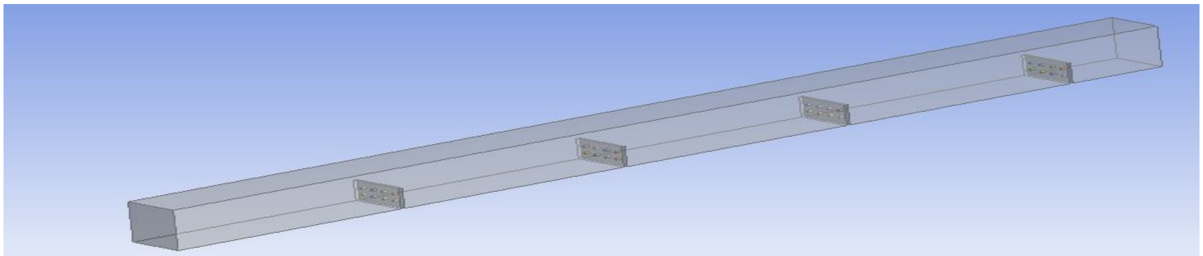


Fig 1: CAD MODEL of AR 2, Pitch 120mm, 8 holes 2 mm dia.

B. CFD procedure

Computational flow domain: The computational flow domain of square duct with perforated ribs is designed with the help of geometry factors and the flow takes place inside the square duct as an air domain.

C. Mesh Generation

TABLE II: MESH DETAILS Of AR 2, PITCH 120mm, 8 HOLES 2mm dia.

Type	Tetra-hedral mesh
No. of elements	19293
No. of Nodes	13976

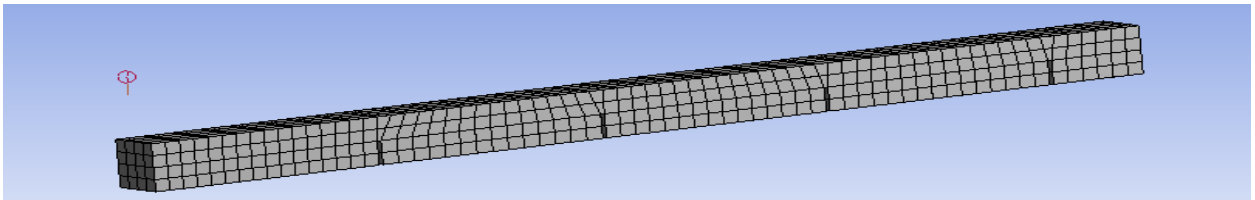


Fig 2: MESH MODEL of AR 2, Pitch 120mm, 8 holes 2 mm dia.

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

D. Boundary Conditions

Boundary conditions are mentioned on computational domain of square duct with perforate ribs. It is seen from fig 3.14 that the pressure gradually decreases from inlet to outlet and base plate temperature is at 353K.

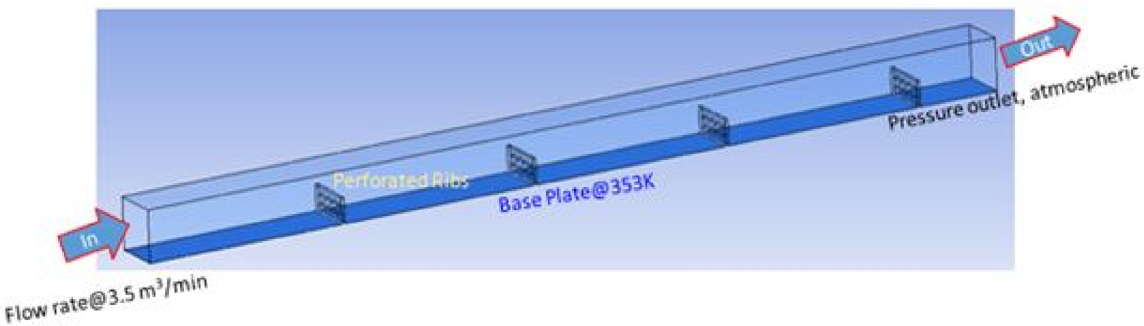


Fig 3: Boundary conditions of square duct with perforates ribs

TABLE III
BOUNDARY CONDITIONS

Inlet	Mass flow inlet at 0.875 kg/s
Upper plate	300K
Outlet	Pressure outlet
Wall boundary conditions	Base Plate at 353K

TABLE IV
FLUID PROPERTIES

Working Fluid	Air
Density	1.22 kg/m^3
Viscosity	1.78e-5 kg/m-s
Thermal Conductivity	0.0242 w/m K
Specific Heat	1006j/kg K

IV. RESULTS AND DISCUSSION

A. For AR 2 and Pitch 120mm.

1) Streamline

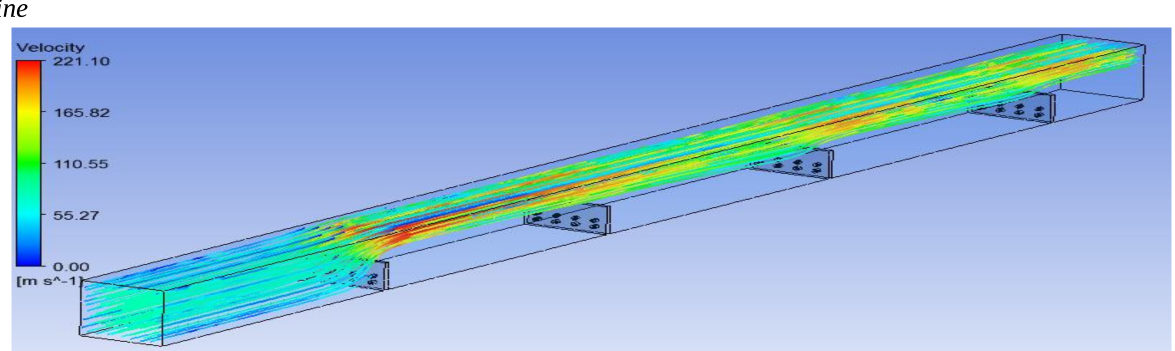


Fig 4: Streamlines coloured by Velocity, AR 2, Pitch 120mm

Fig4. Shows that streamlines of air coloured by velocity for AR 2, with a pitch of 120. It can be seen that the velocity is least at inlet and higher at outlet as it passes through the perforated ribs. The maximum velocity (221.10 m/s) is obtained at upper plate.

2) Temperature

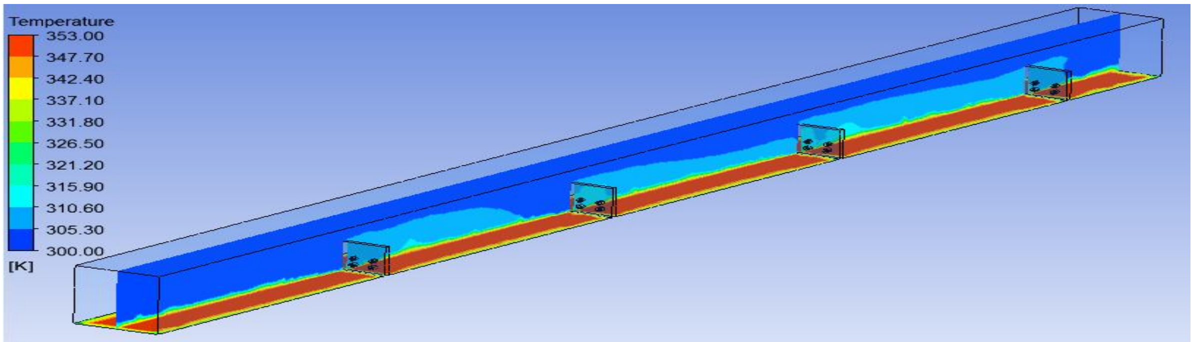


Fig 5: Temperature plots along Plane-1, AR 2, Pitch 120mm

Fig5. Shows that the temperature plots and it is seen that the temperature of 353K is maximum at the base plate and the temperature of 315K is achieved after passing through the perforated ribs.

*3) Pressure**

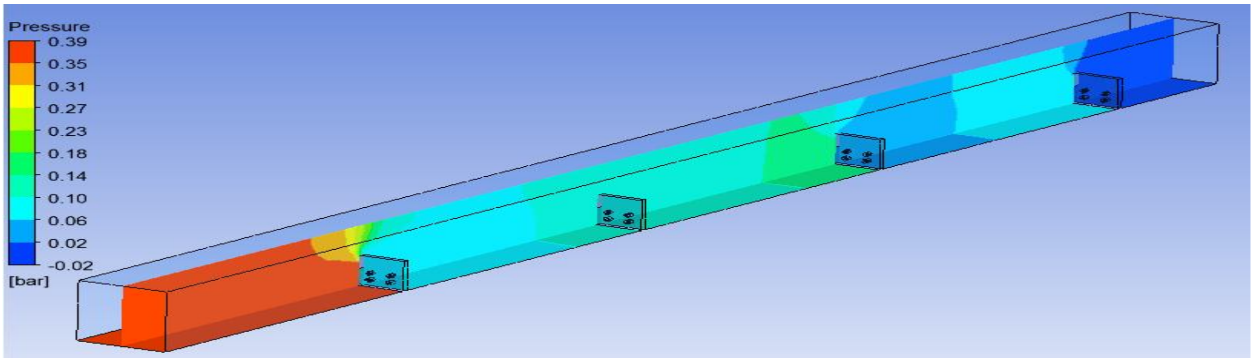


Fig 6: Pressure plots along Plane-1, AR 2, Pitch 120mm

Fig6. Shows that the pressure plots with AR 2 and it is observed that the pressure is gradually decreases from inlet to outlet, and after passing through the each perforated ribs it is observed that pressure is of about 0.10 bar.

*4) Velocity**

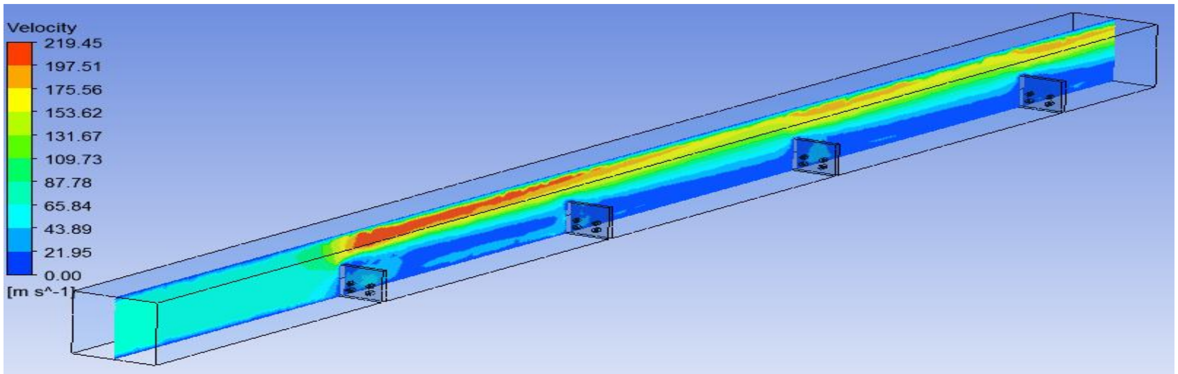


Fig 7: Velocity plots along Plane-1, AR 2, Pitch 120mm

Fig7 Shows that the velocity plots with AR 2 and it is observed that the velocity of air is more at the inlet and on the upper plate and after passing through the perforated ribs it will decreases as it reaches the outlet. The maximum velocity achieved is 219.45 m/s.

5) Heat Flux

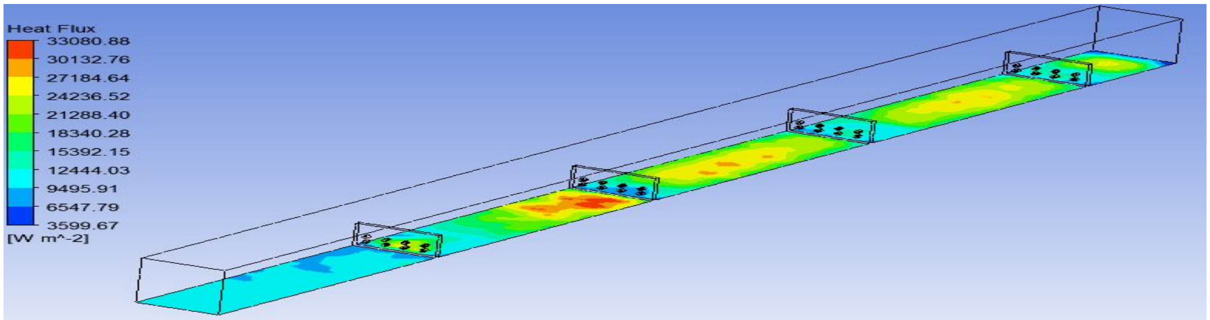


Fig 8: Heat flux plots along Plane-1, AR 2, Pitch 120mm

Fig8: Shows that heat flux plots with AR 2 and 120mm pitch. It is seen that the maximum heat flux in the domain found to be 33080 W/m² and heat flux distribution throughout the base plate is not uniform.

V. CONCLUSIONS

CFD analysis is carried out to understand the thermal characteristics of air in a square duct using perforated ribs with varied Aspect ratios of 2, 3 and 5 for varied pitch of 120mm,180mm,48mm and 72mm with holes of 3,4,8 in numbers each of 2mm diameter. Contours are plotted for Temperature, Pressure and Domain velocity at various planes and following conclusions were drawn.

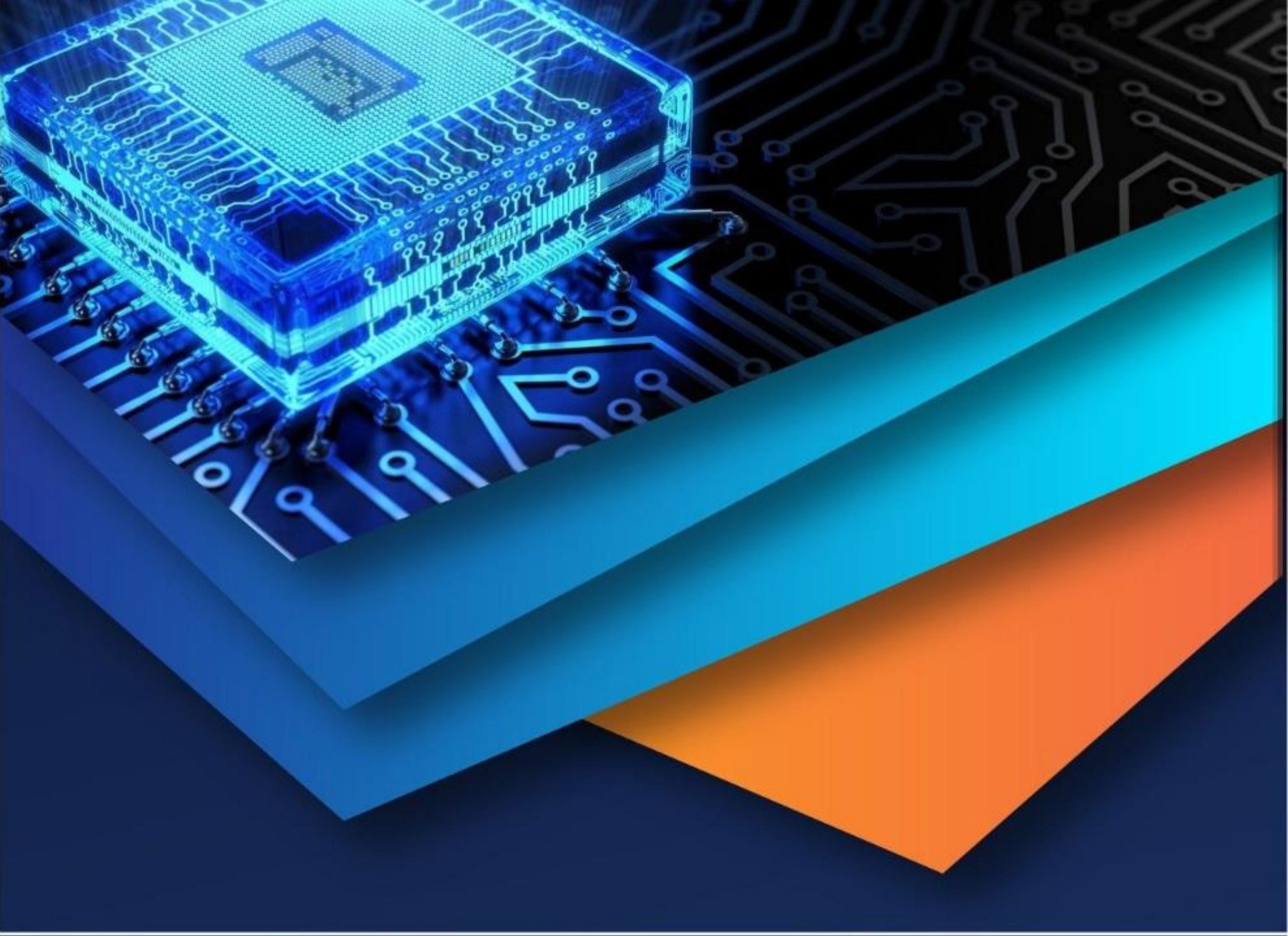
A. It is observed that velocities are maximum in the domain for the aspect ratio of 2 due to obstruction in the channel.
B. From pressure contours it is observed that higher the aspect ratio lower the pressure drop in the channel.
C. Pressure drop in the domain for the Aspect ratio of 5 found to be very minimal and the air flow distribution found to be throughout the channel resulting better heat transfer rate.
D. From the above observations it could be concluded that higher the Aspect ratio and larger the pitch lower the pressure drop and higher rate of heat transfer in the domain.

VI. ACKNOWLEDGEMENT

I wish to express my special gratitude to my guide Prof. Anandkumar.S.Malipatil, Department of Thermal Power Engineering, Dept., of PG Studies, VTU regional office, Kalaburagi for his inspiration constant supervision, direction and discussions in successful completion of this project.

REFERENCES

[1] Anandkumar S Malipatil, Shravankumar.T.Sagar, “Flow Analysis of Air in a Rectangular Channel Using Perforated Rectangular Rib”, International Journal for Research in Applied Science & Engineering, Volume 4 Issue I, January 2016.
[2] Abhishek.R.H, Anandkumar S Malipatil, “Flow Characteristics of Air in Square Channel Using Perforated Ribs” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) Volume 13, Issue 1 Ver. II (Jan. - Feb. 2016), (PP 106-112).
[3] MaziyarJalaal, Ahmad Khoshnevis, FaramarzTalati, EsmaeilEsmaeilzadeh “Analysis of Heat-Transfer Enhancement and Design Parameters of Heat-Sink with Perforated Rectangular Ribs”, 12th Fluid Dynamics Conference, Babol Noshirvani University Of Technology, 28-30 April 2009.
[4] Ahmad Khoshnevis, FaramarzTalati, MaziyarJalaal, EsmaeilEsmaeilzadeh “Heat Transfer Enhancement of Slot and Hole Shape Perforations In Rectangular Ribs of a 3-D Channel”,17th. Annual (International) Conference on Mechanical Engineering-ISME2009 May, 2009, University of Tehran, Iran
[5] Y. T. Yang and C. Z. Hwang, “Calculation of turbulent flow and heat transfer in a porous-baffled channel”, Int. J. Heat Mass Transfer, 2003, Vol. 46, pp. 771-780.
[6] Han, J.C., Park, J.S. and Lei, C.K. (1985). Heat Transfer Enhancement in Channels With Turbulence Promoters, ASME Journal of Eng. for Gas Turbines and Power, vol.107, (pp.628-635).
[7] Çalışkan, S. (2013). Flow and heat transfer characteristics of transverse perforated ribs under impingement jets, International Journal of Heat and Mass Transfer 66 (pp.244-260).
[8] Karwa, R., Maheshwari, B.K., Karwa, N. (2005). Experimental study of heat transfer enhancement in an asymmetrically heated rectangular duct with perforated baffles, International Communications in Heat and Mass Transfer 32 (pp.275–284).
[9] Abdullah H. AlEssa and Mohammed Q. Al-Odat “Enhancement of Natural Convection Heat Transfer From a Fin by Triangular Perforations of Bases Parallel And Toward Its Base”, The Arabian Journal for Science and Engineering, Volume 34.
[10] Liang-Bi Wang, Wen Qaun Tao, Qiu- Wang Wang, Tsun Tat Wang “experimental study of developing turbulent flow and heat transfer in ribbed convergent divergent square duct” International Journal of Heat and fluid flow 22(2001)603-613.
[11] Thakur Sanjay Kumar, “Experimental investigation of local heat transfer in a square duct with truncated ribs”, Experimental heat transfer, 18:179-197(2005), Taylor and Francis.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY