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Study Of Heat Transfer On The Square Duct Through W Type Turbulators

G. Sandeep Reddy & Sri Aparna

[1]Received the B.Tech degree in Mechanical Engineering from St. Peters engineering college, medchal, JNTU, Hyderabad, Telangana, India, and perusing M.Tech in Thermal Engineering From Elenki Institute Of Engineering & Technology, Jntu, Telangana Hyderabad, India

[2]M.Tech, Assistant professor**,** Elenki Institute Of Engineering & Technology, Telangana Hyderabad, India

ABSTRACT

Several cooling techniques have been developed to enhance heat transfer in square duct. Different rib arrays inside square channel are widely used to enhance heat transfer rate. The reason that ribs increase the fluid flow turbulence near the wall, disrupt the boundary layer and also increase the heat transfer area. In this paper analysis is carried out for two different angles of tabulators which are placed in the duct and the four models of ducts are also designed to verify the better cooling system. Here the tabulators of W shaped are located on top as well as bottom of the wall also. The analytical solution carried out on the square ducts having diameter of 0.05m. Here the working fluid is considered as air. In this thesis the heat transfer characteristics of the square ducts with internal W shaped rids with different angles and different models are considered.

The models are developed using CATIA V5 software and thermal and CFD analysis is considered in ANSYS 14.5 version.

Reynolds Number	Velocity (m/s)	Turbulence (%)
10000	2.531	2.000
15000	3.796	0.889
20000	5.062	0.500

INTRODUCTION

HVAC means ‘Heating, Ventilation and Air-conditioning’. It is also be known as climate-control mechanism to regulate humidity and temperature in a living environment. A basic knowledge of HVAC systems includes the principles of system operations, an understanding of the factors that determine the capacity of the equipment and the various components of HVAC system.

LITERATURE REVIEW

The need of high performance thermal system in many engineering applications need to find various techniques to improve heat transfer in system. In convention area heat transfer improved by means of various augmentation techniques. Means increase the heat transfer area by ribs, protrusion and roughness. However, the thermal/hydraulic performance of the ribs is affected by many factors including the holes in a rib, size and spacing. Since 1980's many experimental have been carried out on heat transfer in cooling passage tube and duct.

Like ribs, jet impingement and other passive heat transfer enhancement methods, insertion of baffle in cooling systems has been used for various types of industrial applications such as internal cooling systems of gas turbine blades, electronic cooling devices, shell-and-tube type heat exchangers, thermal regenerators, and labyrinth seals for turbo-machines.

All gas turbine engines has three basic components compressor, combustion chamber and the turbine. The turbine extracts the power to operate the compressor and sends the gases to either a power turbine for shaft work or to a nozzle for thrust. During this process in the compressor there is increase in the power absorbed while in the turbine they act to decrease. To overcome these losses, more air and fuel flow are required.

Wilkie [7] was one of the first to publish results of experimentation on the effects of rib roughened ducts on heat transfer. The interest in cooling operations in nuclear reactor fuel elements resulted in the findings he collected and published. Through variatiors in duct equivalent diameter (d), rib height (e) and rib pitch or spacing **(p)** he found correlations between the Stanton number, the Reynolds number, the p/e ratio and the e/d ratio. The Stanton number is defined as h/(u**p**CP) where h is the heat transfer coefficient, u is the velocity in the free stream at the outer edge of the boundary layer, **p** is the fluid density and C is the specific heat at constant pressure. The results showed Stanton number varied less with Reynolds number for small values of e/d (<.012), and behaved much as on a smooth surface at larger values of e/d (>.012). In addition, he found the value of the p/e ratio giving maximum Stanton numbers varied with e/d and Reynolds number but tended to approximately the value six at large e/d irrespective of Reynolds number.

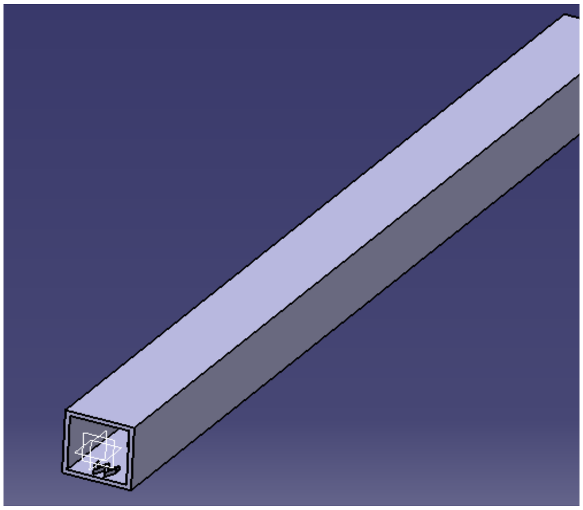
Norris [8] also detailed the effect of these "turbulators" in his investigation. After testing various shapes, he concluded that although the local heat-transfer coefficient varied in a very non-uniform manner in the stream-wise direction, there was a value of the pitch-to-width ratio for the square turbulator which gave an optimum value for the average heat transfer as well as friction factor. Increasing the ratio above this level served only to decrease these values. Also, he developed a relationship between the friction factor of his test apparatus and the friction factor of a smooth duct, and found an optimum value existed for this ratio. Increases above this value did not give increased heat transfer.

EXPERIMENTAL INVESTIGATION

The flow system interest is a horizontal square duct with W-broken ribs repeatedly placed. Here the design considerations are taken as:

1. 45deg W shaped rib placed at lower duct
2. 50deg W shaped rib placed at lower duct
3. 55deg W shaped rib placed at lower duct

4. 45deg w shaped rib placed at lower and upper duct
5. 50deg W shaped rib placed at lower and upper duct
6. 55deg W shaped rib placed at lower and upper duct



Basic view of 45 deg W shaped rib placed at lower duct

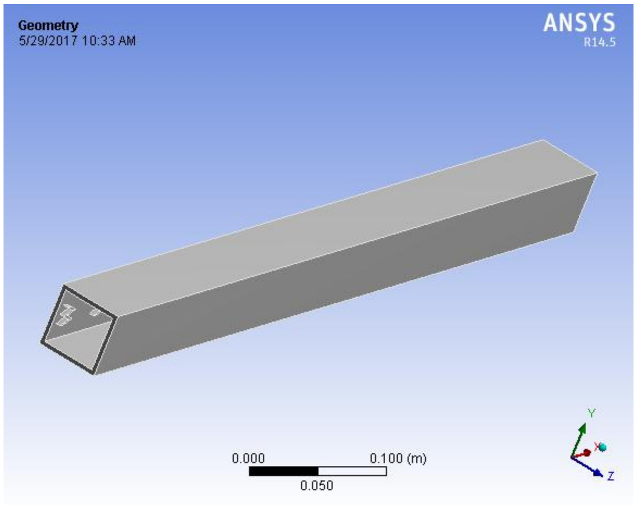
CFD ANALYSIS OF 45 DEGREES SINGLE SIDE "*W*" SHAPED SQUARE DUCT

Save Catia Model as .iges format

→→ Ansys → Workbench→ Select analysis system → Fluid Flow (Fluent) → double click

IMPORT GEOMETRY

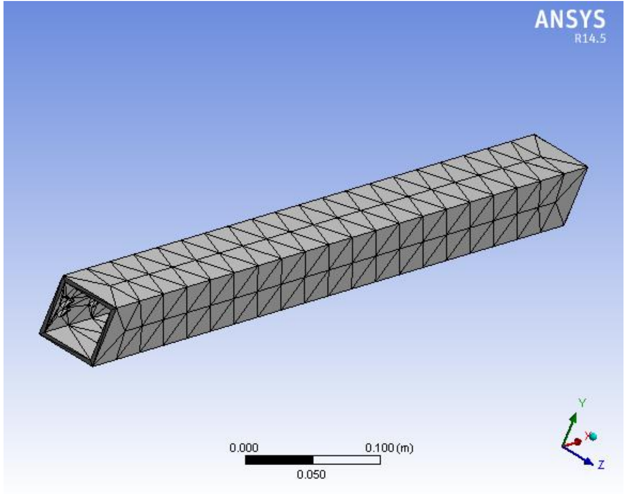
→→Select geometry → right click → import geometry → select browse →open part → ok



Import Geometry

MESHED MODEL

→→ Select mesh on work bench → right click →edit
Select mesh on left side part tree → right click → generate mesh →



Meshed Model

SPECIFYING BOUNDARIES CONDITIONS

File →export → fluent →input file (mesh) → enter required name → save.

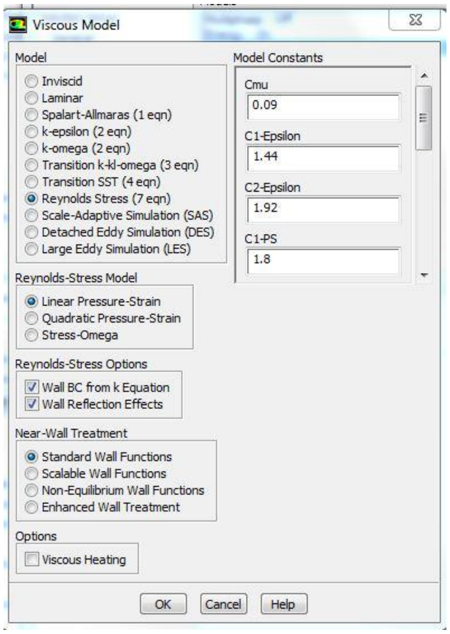
→→ Ansys → fluid dynamics → fluent → select 2D or 3D → select working directory → ok

→→file → read → mesh → select file → ok.

General →Pressure based

Model → energy equation → on

Model → Viscous → Edit



Model
○ Inviscid
○ Laminar
○ Spalart-Allmaras (1 eqn)
○ k-epsilon (2 eqn)
○ k-omega (2 eqn)
○ Transition k-kl-omega (3 eqn)
○ Transition SST (4 eqn)
● Reynolds Stress (7 eqn)
○ Scale-Adaptive Simulation (SAS)
○ Detached Eddy Simulation (DES)
○ Large Eddy Simulation (LES)

Model Constants
Cmu: 0.09
C1-Epsilon: 1.44
C2-Epsilon: 1.92
C1-PS: 1.8

Reynolds-Stress Model
● Linear Pressure-Strain
○ Quadratic Pressure-Strain
○ Stress-Omega

Reynolds-Stress Options
☑ Wall BC from k Equation
☑ Wall Reflection Effects

Near-Wall Treatment
● Standard Wall Functions
○ Scalable Wall Functions
○ Non-Equilibrium Wall Functions
○ Enhanced Wall Treatment

Options
☐ Viscous Heating

Viscous Model

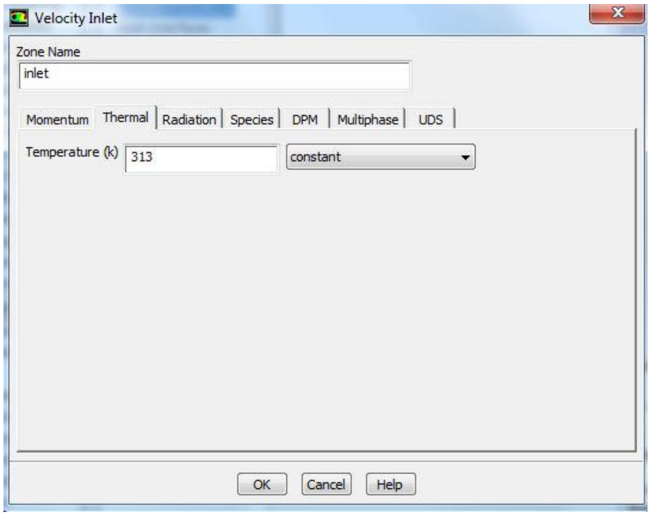
Materials → new → create or edit → specify Fluid material → air

Boundary conditions → Inlet → Edit

Velocity: 5.062 m/s

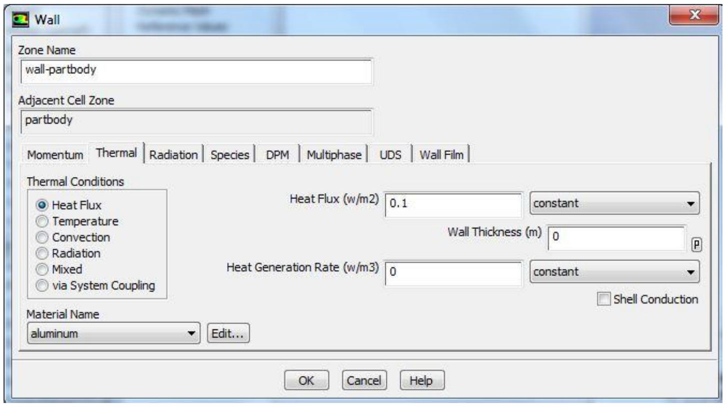
Thermal → Temperature: 313 K

Heat flux → 0.1w/m^2



Zone Name: inlet

Temperature (k): 313 constant



Zone Name: wall-partbody

Adjacent Cell Zone: partbody

Thermal Conditions
● Heat Flux
○ Temperature
○ Convection
○ Radiation
○ Mixed
○ via System Coupling

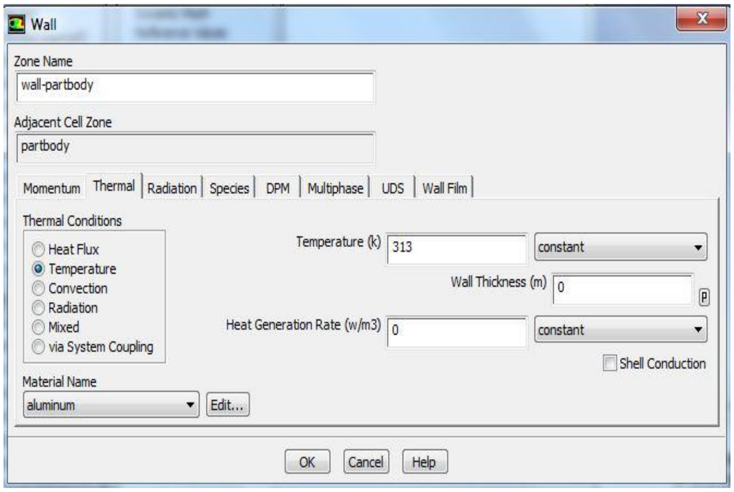
Heat Flux (w/m2): 0.1 constant

Wall Thickness (m): 0

Heat Generation Rate (w/m3): 0 constant

☐ Shell Conduction

Material Name: aluminum



Zone Name: wall-partbody

Adjacent Cell Zone: partbody

Thermal Conditions
○ Heat Flux
● Temperature
○ Convection
○ Radiation
○ Mixed
○ via System Coupling

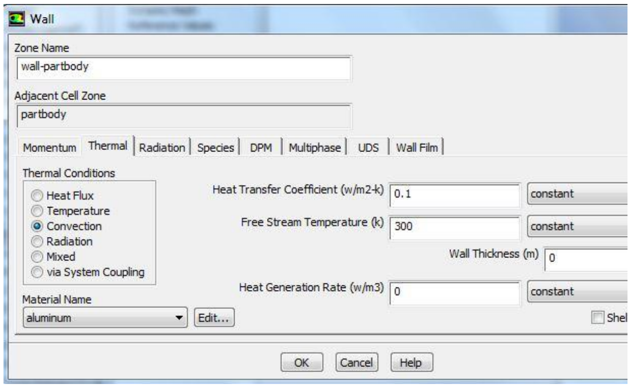
Temperature (k): 313 constant

Wall Thickness (m): 0

Heat Generation Rate (w/m3): 0 constant

☐ Shell Conduction

Material Name: aluminum


Wall

Zone Name: wall-partbody

Adjacent Cell Zone: partbody

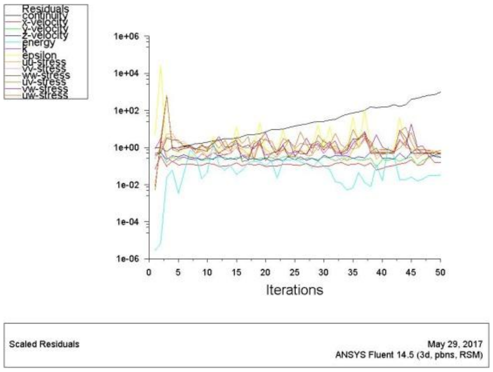
Thermal Conditions
○ Heat Flux
○ Temperature
● Convection
○ Radiation
○ Mixed
○ via System Coupling

Heat Transfer Coefficient (w/m2-k): 0.1 constant
Free Stream Temperature (k): 300 constant
Wall Thickness (m): 0
Heat Generation Rate (w/m3): 0 constant

Material Name: aluminum

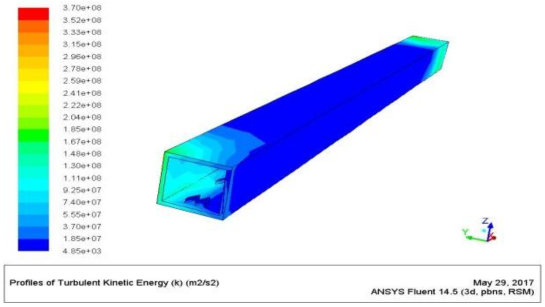
Boundary Conditions

GRAPHICAL REPRESENTATION



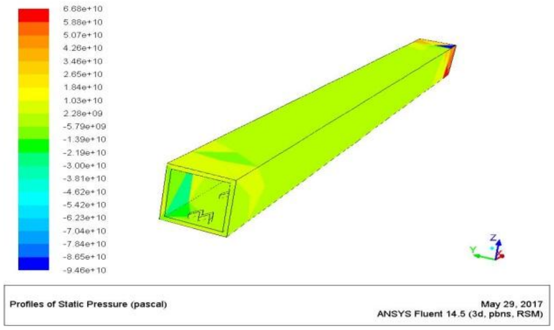
Scaled Residuals
May 29, 2017
ANSYS Fluent 14.5 (3d, pbns, RSM)

Graphical Representation



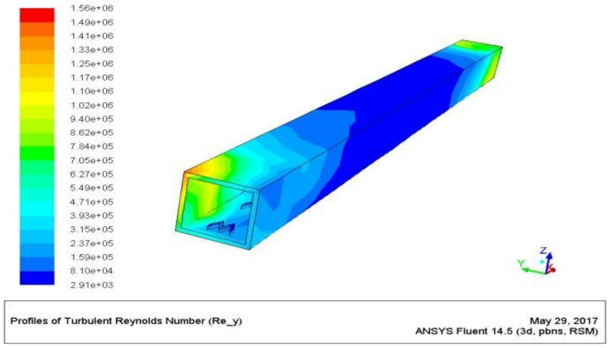
Profiles of Turbulent Kinetic Energy (k) (m2/s2)
May 29, 2017
ANSYS Fluent 14.5 (3d, pbns, RSM)

Kinetic Energy



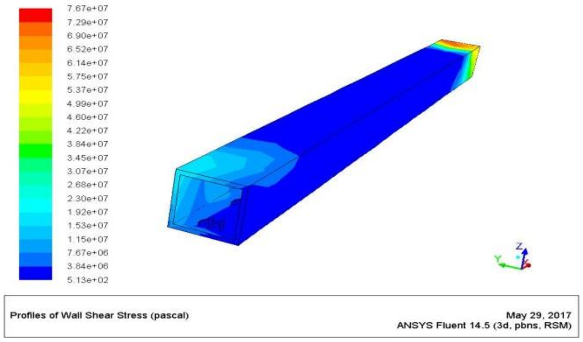
Profiles of Static Pressure (pascal)
May 29, 2017
ANSYS Fluent 14.5 (3d, pbns, RSM)

Pressure



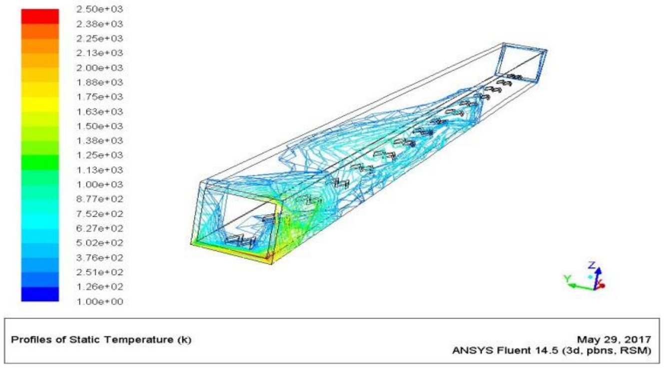
Profiles of Turbulent Reynolds Number (Re_y)
May 29, 2017
ANSYS Fluent 14.5 (3d, pbns, RSM)

Reynolds Number



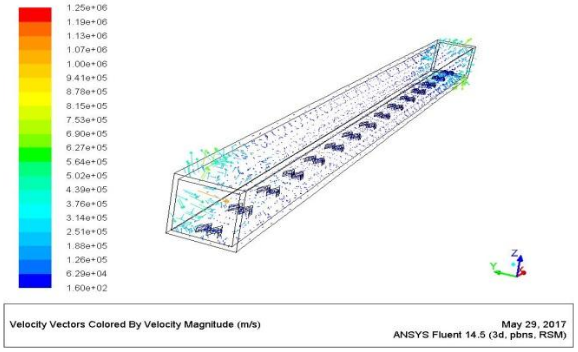
Profiles of Wall Shear Stress (pascal)
May 29, 2017
ANSYS Fluent 14.5 (3d, pbns, RSM)

Stress



Profiles of Static Temperature (k)
May 29, 2017
ANSYS Fluent 14.5 (3d, pbns, RSM)

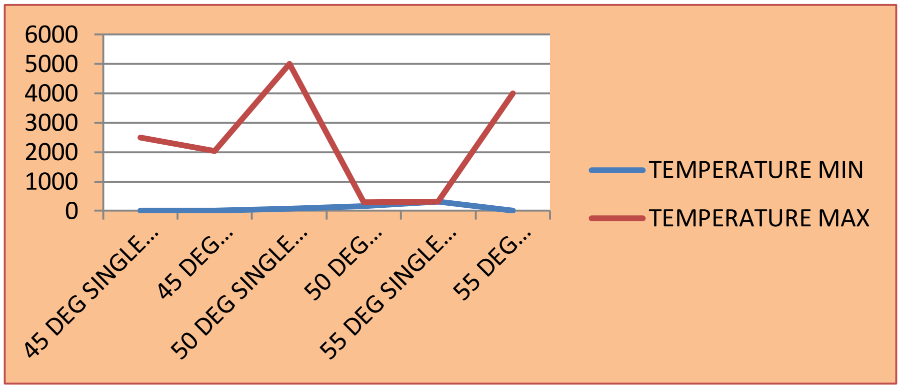
Temperature



Velocity

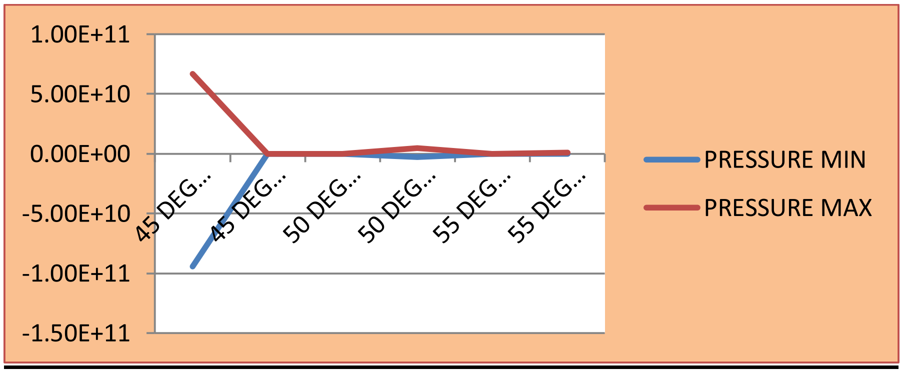
GRAPHS

TEMPERATURE COMPARISON



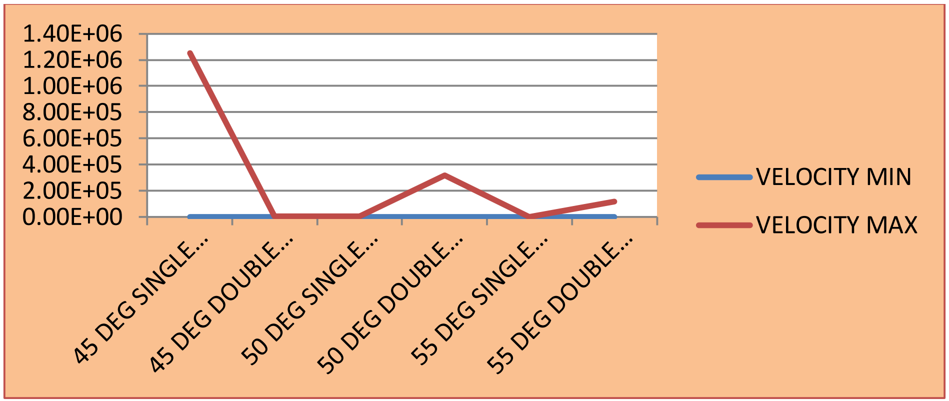
Temperature Comparison

PRESSURE COMPARISON



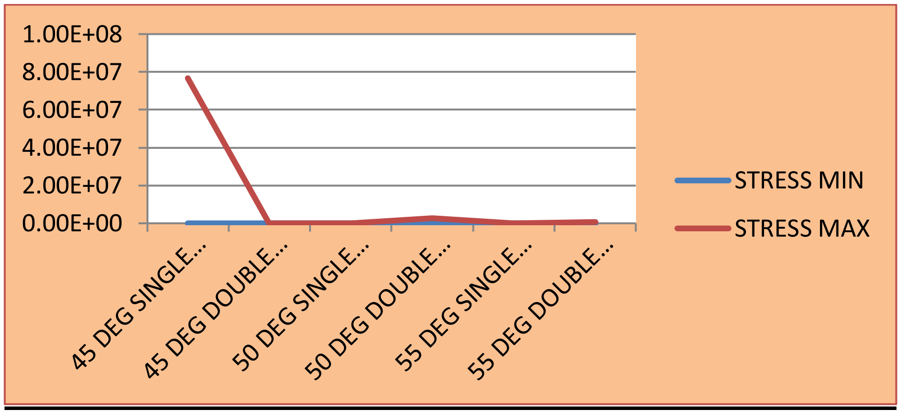
Pressure Comparison

VELOCITY COMPARISON



Velocity Comparison

STRESS COMPARISON



Stress Comparison

TABLES

	TEMPERATURE		PRESSURE		VELOCITY		STRESS	
	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
45 Deg Single Side	2.50E3	1.00E	6.68E10	-9.46E10	1.25E6	1.60E2	7.67E7	5.13E2
45 Deg Double Side	2.04E3	1.01E0	2.34E6	-5.40E6	6.17E3	1.38E0	1.73E3	00
50 Deg Single Side	4.99E3	6.42E1	7.08E4	-9.52E4	2.50E3	7.08E-1	2.38E2	00
50 Deg Double Side	2.92E2	1.71E2	4.56E9	-2.64E9	3.19E5	4.79E1	2.68E6	00
55 Deg Single Side	3.13E2	3.13E2	6.39E1	7.01E2	5.44E0	1.12E-1	1.73E-1	00

55 Deg Double Side	3.99E3	1.00E0	7.36E8	-3.56E8	1.19E5	9.28E1	5.80E5	00

Comparison of Temperature, Pressure, Velocity and Stress

CONCLUSION

The heat transfer characteristics of the square ducts with internal W shaped ribs or turbulators with different angles and different models are considered. The square ducts with *W* type turbulator with three different angles such as 45, 50, 55 deg *W* shapes are designed using CATIA V5 software. These W shaped turbulators are placed in two models, one in single sided and other in double sided square duct. CFD analysis is done using ANSYS software. The working fluid considered is air.

From the results obtained, we observe that the temperature and stress are very less for 55 deg *W* shaped turbulator placed in single sided and double sided square ducts. But if we consider the pressure and velocity 45 deg *W* shaped turbulator placed in single sided square duct is having the best result.

By observing the obtained data, here the stress and temperature play vital role in square ducts, so if we consider the square duct with single sided *W* shaped turbulators we can obtain the better performance with the better results.

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