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Analysis for Pressure Drop Reduction from Ducts using Hexagonal Geometry

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Abstract: Ducts are widely used in field of fluid transmission and during this transmission process pressure as well as thermal energy of fluid reduced which results the loss of energy, so that reduction of these loss may be beneficial for all. Loss of thermal energy can be controlled by use of insulation but pressure loss not controlled. For reduction of this loss of pressure energy from duct hexagonal duct is implemented in this paper. In this paper pressure loss as well as heat transfer both are analysed for circular, rectangular and hexagonal duct for three case of mass flow rate for working fluid water. Result found on analysis is that the hexagonal duct has lowest pressure drop. So it is concluded that it is beneficial to use the hexagonal duct in case of reduction of pressure loss as well as heat loss.
Keywords: Duct, Hexagonal duct, Pressure loss, Heat loss, Temperature gain.

I. INTRODUCTION

Ducts and pipes are used for transport fluid from one location to another location in a specified way for example transmission of steam from boiler to turbine , transmission of air from central A/C to place to be cool, transmission of cooling water from cooling tower to condenser, transmission of drinking water from water tank to home etc [1]. During the transmission process of fluid some amount of energy lost due to friction and heat loss to surrounding and that is the results of unsatisfactory work of pipe and duct. For example during the transmission of steam from boiler to turbine ,steam loss some amount of kinetic energy due to friction and loss some amount of thermal energy by transferring the heat to surrounding an results decrease the enthalpy of steam and decrease in enthalpy causes reduction in thermal efficiency of plant and losses. So need to overcome these losses to maintain the efficiency of any fluid transmission system. Following are some method reduce friction as well as heat loss from pipe.

A. Use thermal insulator of optimum thickness
B. Transmit fluid from shortest distance
C. Use low thermal conductive materials
D. Use smooth duct material
E. Keep the velocity as low as possible to reduce frictional loss
F. Gradually increase or decrease the area instead of suddenly increase or decrease to reduce friction losses [2-3]

Above methods are very useful to reduce the losses from pipe and duct. In this research work two terms used one pipe and second one is duct. Pipe and ducts have same basic function to transmit the fluid but they have some basic difference. The word pipe referred for circular cross section of geometry where the word duct referred for non circular cross section of geometry. Pipe generally used for transmission of liquid where as duct for transmission of gaseous fluid [4-5]. Pipe either made from be metallic material or non metallic materials depends upon application [6]. Fluid friction loss depends upon many factor such as duct geometry (length, perimeter area, hydraulic diameter), fluid properties (velocity of fluid, viscosity , density) duct material properties (roughness) etc. Temperature is affecting the properties of fluid which also cause in variation of losses. For example the viscosity and density of fluid both decrease with temperature and decrease in viscosity and density is results of reduction of pressure drop. So caring the scope of temperature, the temperature variation is also analysed and variation of properties with temperature are also considered. Fluid flow is varies with some physical quantities and dimensionless number. The physical quantity are such as wall shear stress, Hydrodynamic entrance length, Mean fluid velocity and dimension less numbers are Reynolds number, Fanning friction factor etc. [7-8].

II. SET UP DESCRIPTION

Initial set-up such as geometry dimension and there related calculation, Boundary condition, meshing details, duct material details and fluid properties described below-

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A. Geometry Descriptions

All geometry of ducts has equal flow area of 1623.8 mm^2. Length of duct was taken as 10m, Side of hexagon taken 25 mm so that corresponding area is equal to 1623.8 mm^2 and radius and sides of other geometry arranged correspond to 1623mm^2. Thickness of duct was taken 5 mm. Hydraulic diameters calculated by formula 4 times of area into inverse of perimeter [9-10]. Table 1 show the geometrical details.

TABLE 1 GEOMETRY DETAILS

Geometry Details				
Geometry	Area	Sides/Radius	Perimeter	Hydraulic diameter
Hexagon	1623.8	25	150	43.30133333
Square	1623.8	40.2964	161.1856	40.2964
Circle	1623.8	45.47	142.7758	45.47

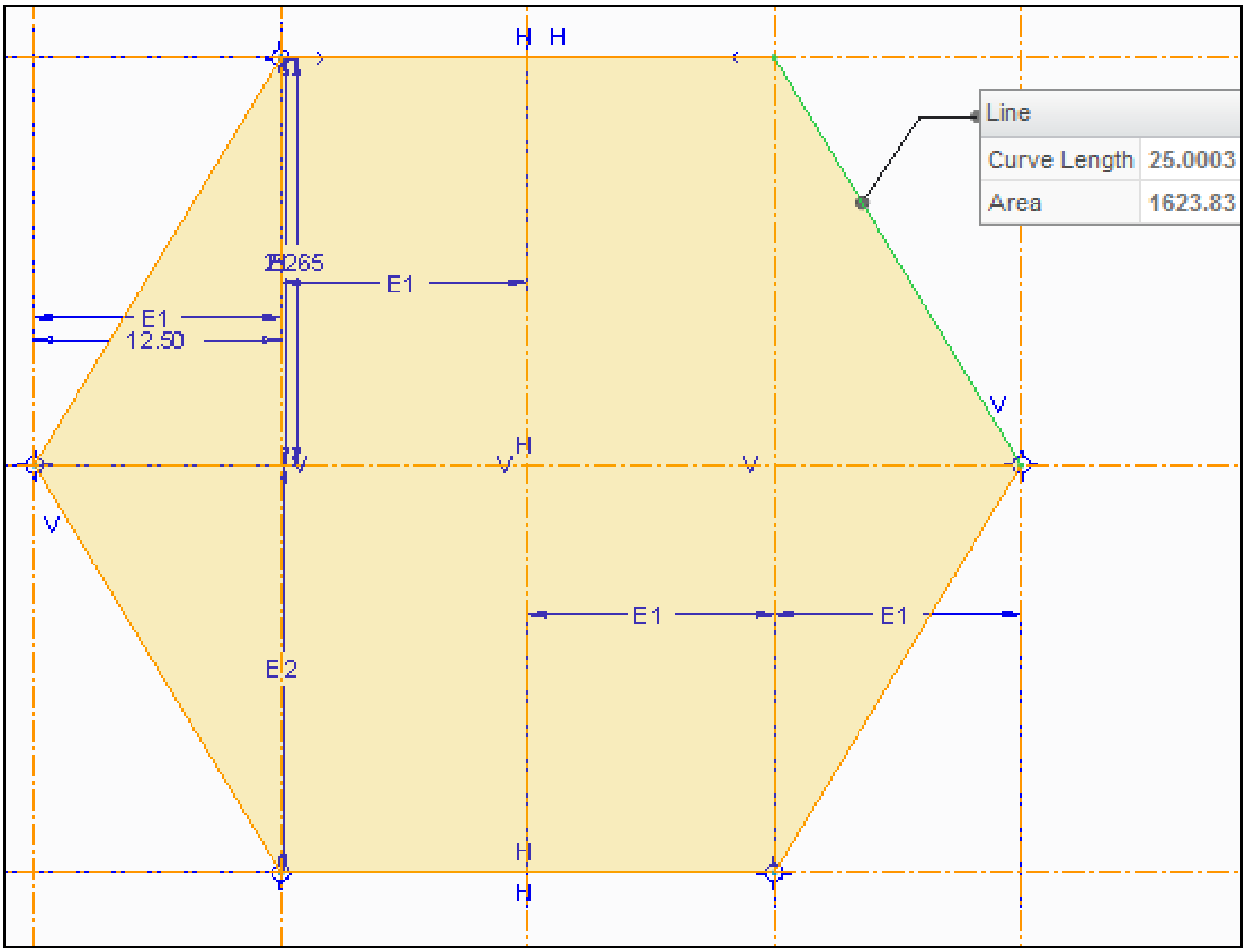

Figure 1 Geometry details of hexagon

B. Boundary Conditions

Table 2 shows the boundary conditions which applicable for all geometry of duct. Three mass flow rate taken 3Kg/sec, 4Kg/sec and 5 Kg/sec. It is assume that summer condition and temperature of surrounding taken as silly high so considering this situation the wall temperature maintained at 310k. Conduction through wall is also considered and stainless steel is taken as the wall material. At duct outlet pressure taken 1atm i.e. 0 gauge pressure.

TABLE 2 BOUNDARY CONDITIONS

Boundary conditions of Heat Exchanger Tube				
Geometry	Mass Flow Rates(Kg/sec)	Inlet Temp(K)	Outlet Gauge Pressure(Pa)	Wall Temperature(K)
Hexagon	5	288	0	310
	4	288	0	310
	3	288	0	310
Square	5	288	0	310
	4	288	0	310
	3	288	0	310
Circle	5	288	0	310
	4	288	0	310
	3	288	0	310

C. Properties of duct Materials

Table 3 shows the duct materials properties like Thermal conductivity, Density and specific heat. Stainless steel is select as a duct material because it have lower thermal conductivity. Hence conduction heat transfer rate will be lower.

TABLE 3 PROPERTIES OF DUCT MATERIALS

Pipe Material Details			
Material	Thermal conductivity	Density	Specific Heat
Stainless steel	16.23(W/m.K)	8978 Kg/m^3	381 j/Kg-K

D. Fluid properties

Table 4 shows the thermal properties of fluid. The properties are taken as per mean bulk temperature. The properties are taken by trial and error method.

TABLE 4 PROPERTIES OF WORKING FLUID

Properties of Fluid(Water)	
Density(Kg/sec)	1000
Viscosity(Kg/m-s)	0.001006
Thermal conductivity(W/m-K)	0.6
Specific heat(j/Kg-k)	4178

E. Meshing Details

After drawing the geometry it meshed in Ansys fluent. The details of meshing shown in table 4.All meshed geometry has Orthogonal quality nearly 0.9 which indicate the excellent mesh quality. Orthogonal mesh quality lies between 0 and 1 and quality closed to zero has poor quality of meshing. Skewness of meshing also kept in good mesh grade [11].

TABLE 5 MESHING DETAILS

Meshing Details				
Geometry	Relevance center	Smoothing	Inflation	Element size (mm)
Hexagon	High	Fine	Program controller	0.005
Square	High	Fine	Program controller	0.005
Circle	High	Fine	Program controller	0.005

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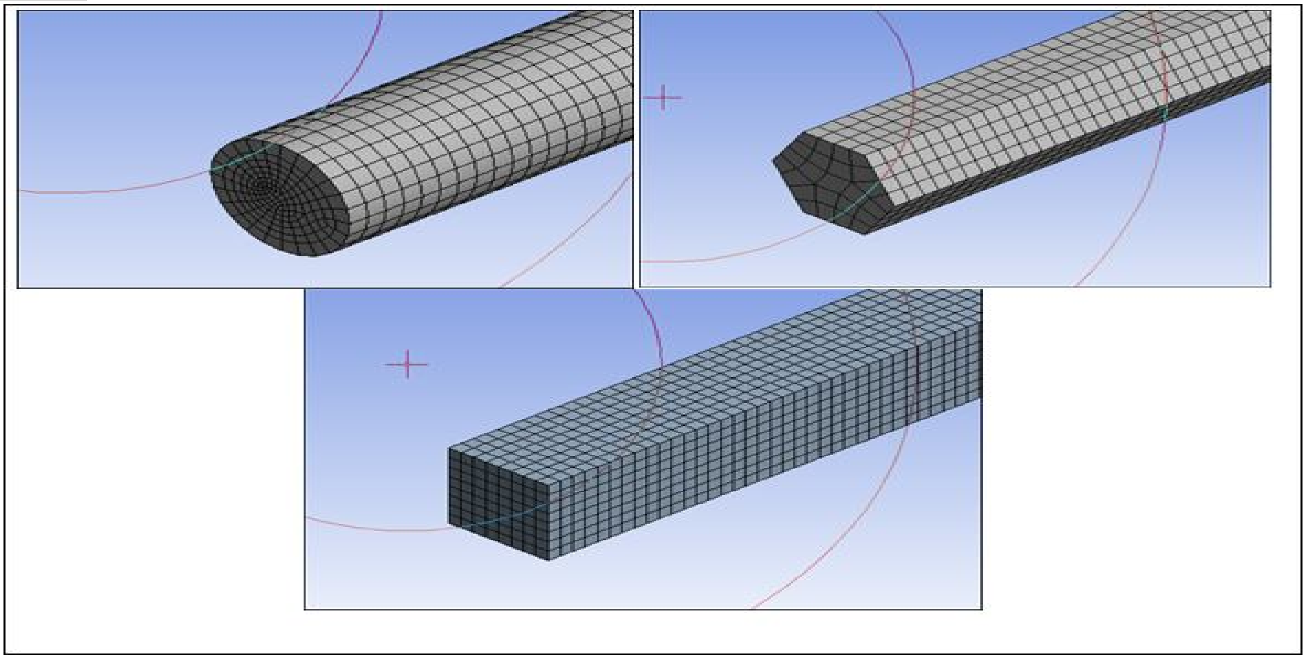

Figure 2 Meshing

III.SOLUTION

The all calculation is carried out with the help "ANSYS Fluent 14.5". ANSYS Fluent 14.5 is computational fluid dynamics software package to stimulate fluid flow problems. It uses the finite volume method to solve the governing equations for a fluid. Whole Solution is carried out with by energy equation, and k epsilon model. Solution also considers wall treatment, thermal effects and viscous heating model. Solution is carried out by SIMPLE scheme and least square cell spatial discretization based method.

IV.FLOW ANALYSIS IN HEXAGONAL DUCT

A. Velocity Distribution

Fluid enters in duct with uniform velocity at z direction. As distance covered by fluid, the maximum velocity settled toward centre and minimum velocity toward the wall. Figure 3 is the fluid velocity variation inside hexagonal at distance 5m from inlet.
Figure 4 shows the centreline velocity distribution along the length of pipe. Hydrodynamic entrance length is about 1.5m from entry.

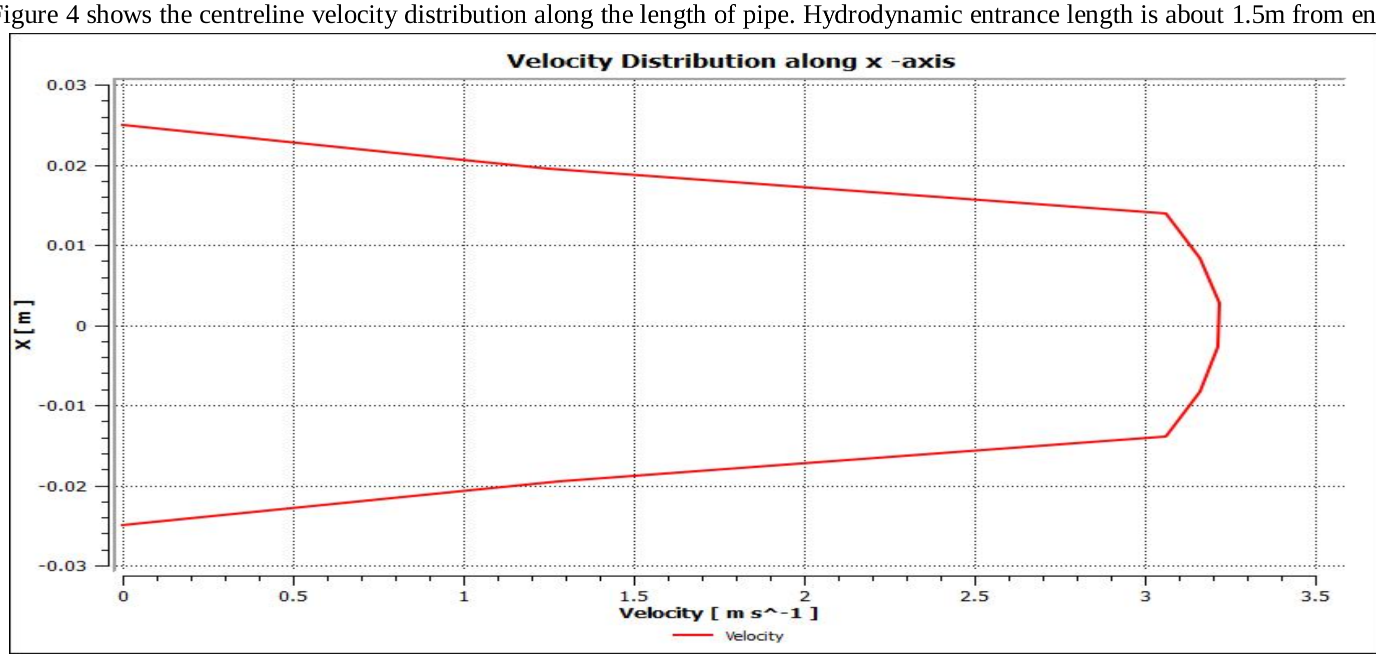

Figure 3 velocity distribution in hexagonal duct along vertical

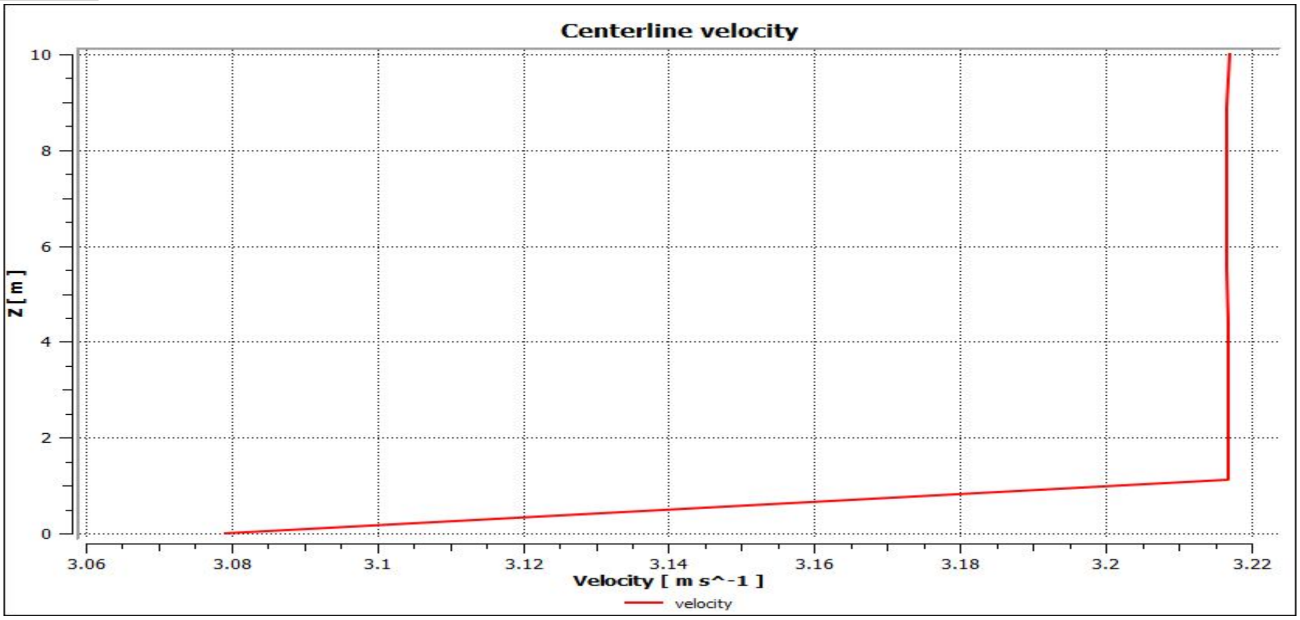

Figure 4 Velocity distribution along length

B. Temperature Distribution

Figure 5, 6, 7 shows the temperature distribution along major axis, minor axis and along. The temperature inside duct continually increases with along with pipe length. Maximum temperature settled toward farthest wall from centre and minimum temperature settled toward the centre of duct.

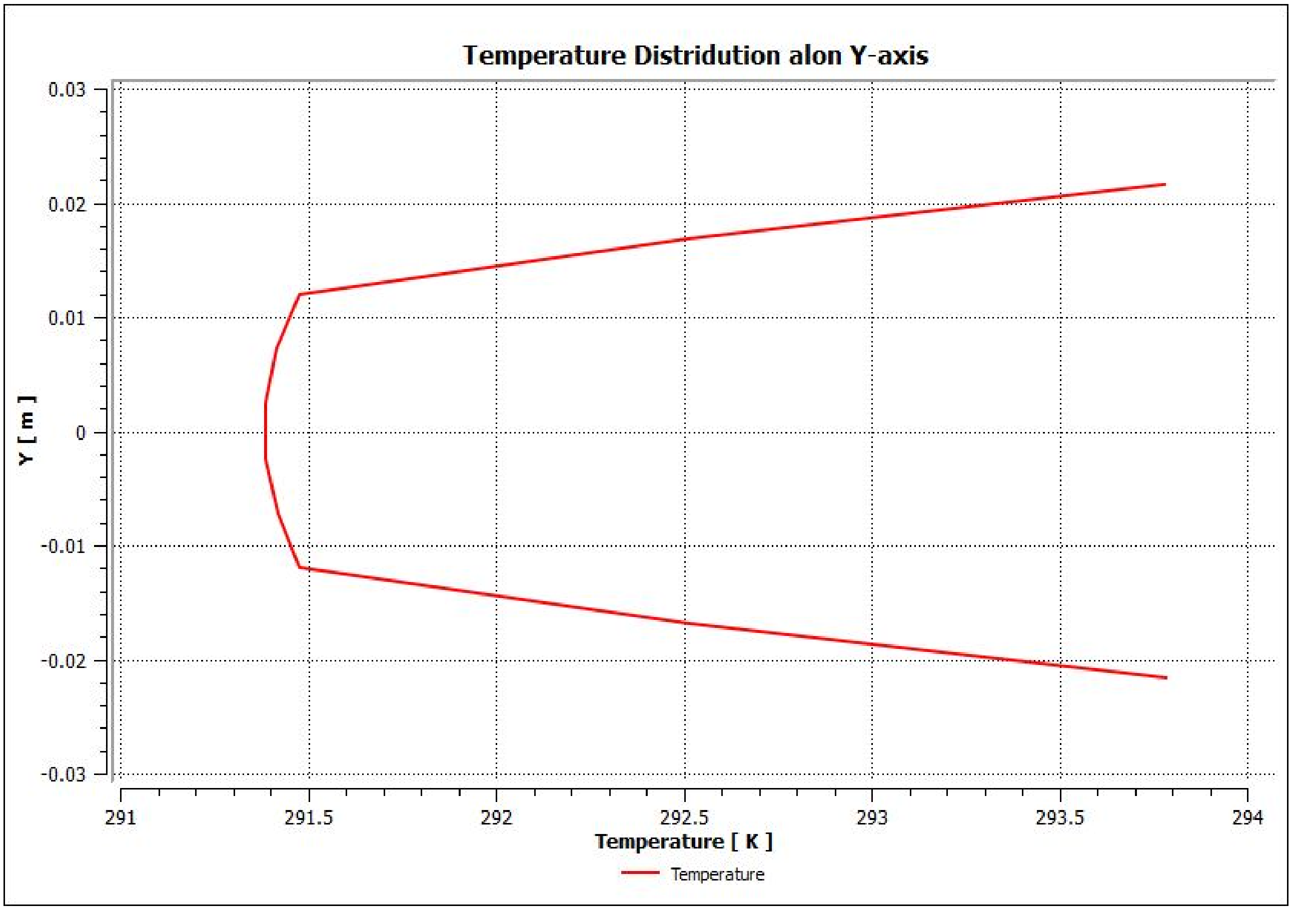

Figure 5 Temperature distribution in hexagonal duct along vertical

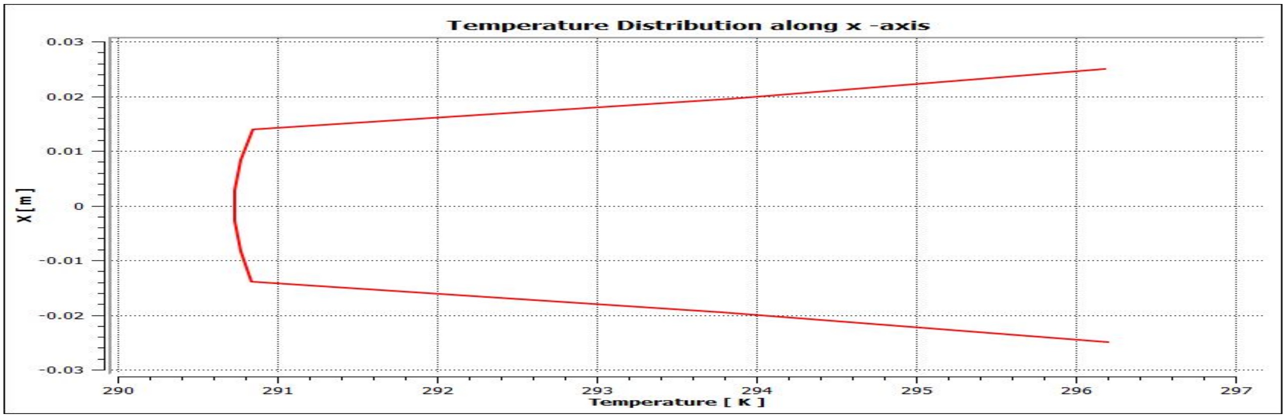

Figure 6 Temperature distribution in hexagonal duct along horizontal

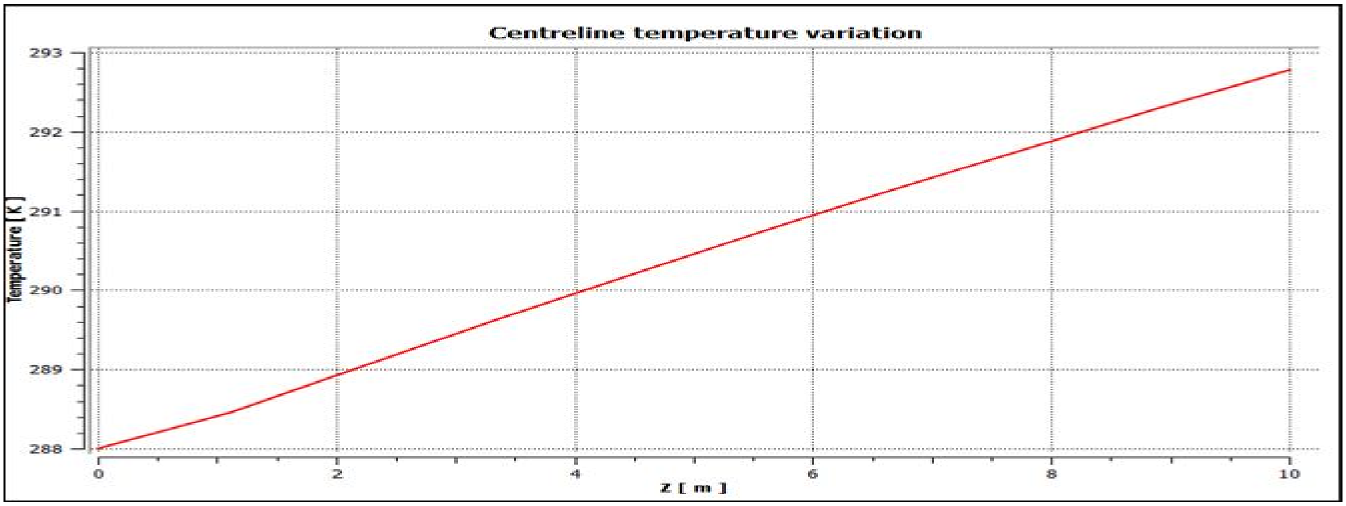

Figure 7 Velocity distribution in hexagonal duct along length

C. Variation of Temperature Drop With Mass Flow Rate

Figure8 shows the variation of temperature with mass flow rate. As mass flow rate increase then decrease in temperature drop of fluid. So reduce the temperature drop keep mass flow as high as possible

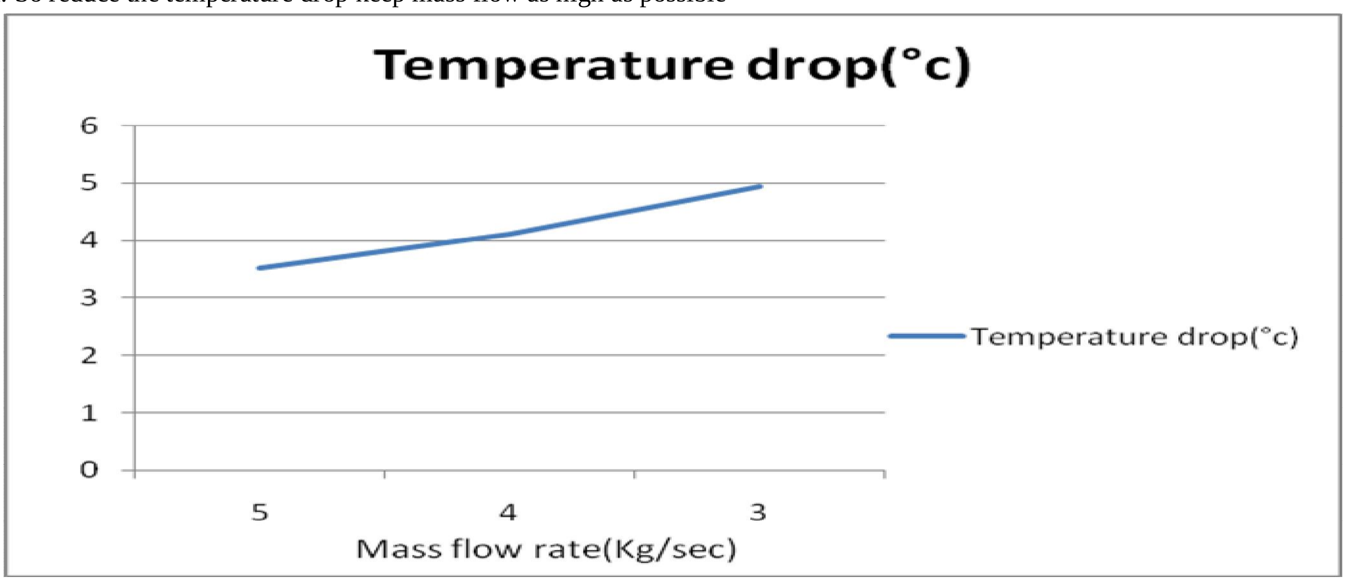

Figure 8 Effect of mass flow rate on Temperature drop

D. Variation of Pressure drop with Mass Flow Rate

Pressure drop is also compared for different mass flow rare. As mass flow rate increase, the pressure drop also increased, so in case of reduction of mass flow rate keep mass flow rate at small as possible.

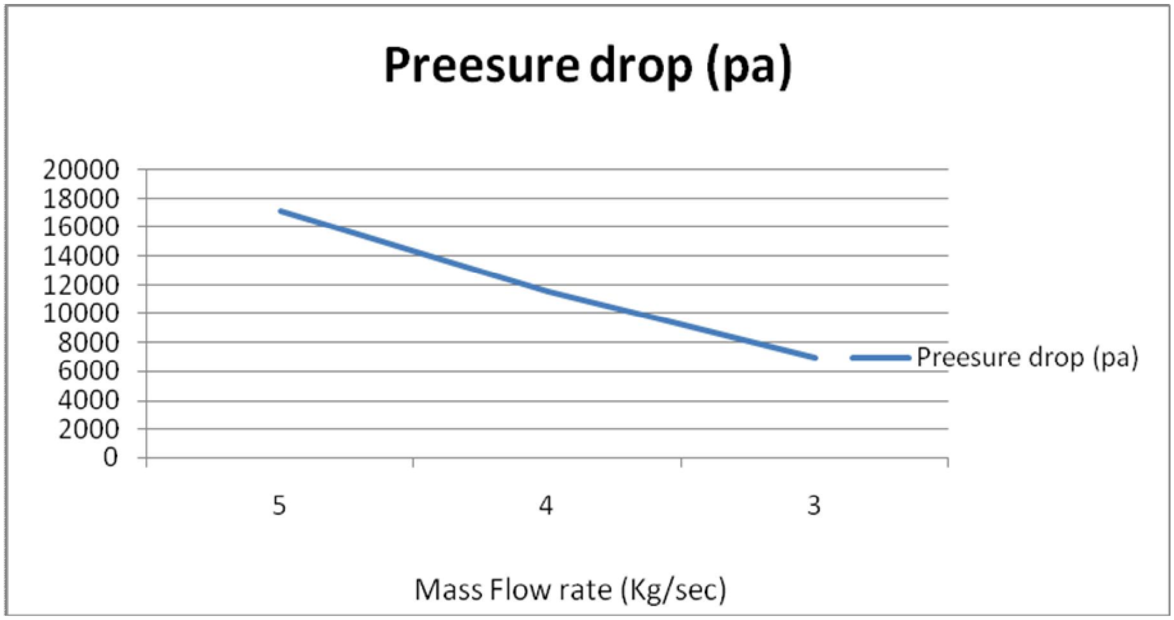

Figure 9 effect of mass flow rate on pressure drop

V. RESULT COMPARISON AMONG GEOMETRIES OF DUCT

A. Pressure Drop

Pressure drop found lowest in hexagonal duct as compare to circular and square duct for all mass flow rate and it is positive result. In circular and square pressure drop is about similar. So our aim of reduction of pressure drop is achieved. Figure 10 shows the pressure drop comparison among geometries.

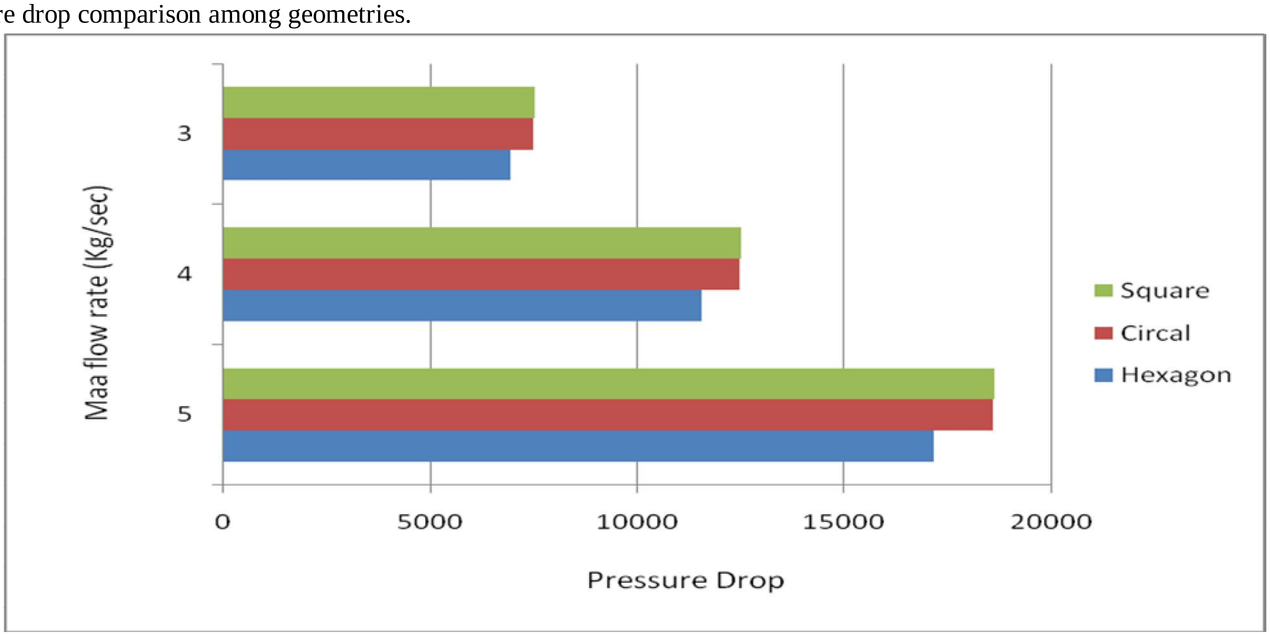

Figure 10 Comparison of Pressure drop

B. Temperature Drop

Change in temperature of water is minimum in circular cross section where it is maximum in square. Hexagon has change in temperature is smaller then square but silly much as compare to circle. It seems that the outlet temperature different of circle and hexagon are controlled within 0.5 degree centigrade.

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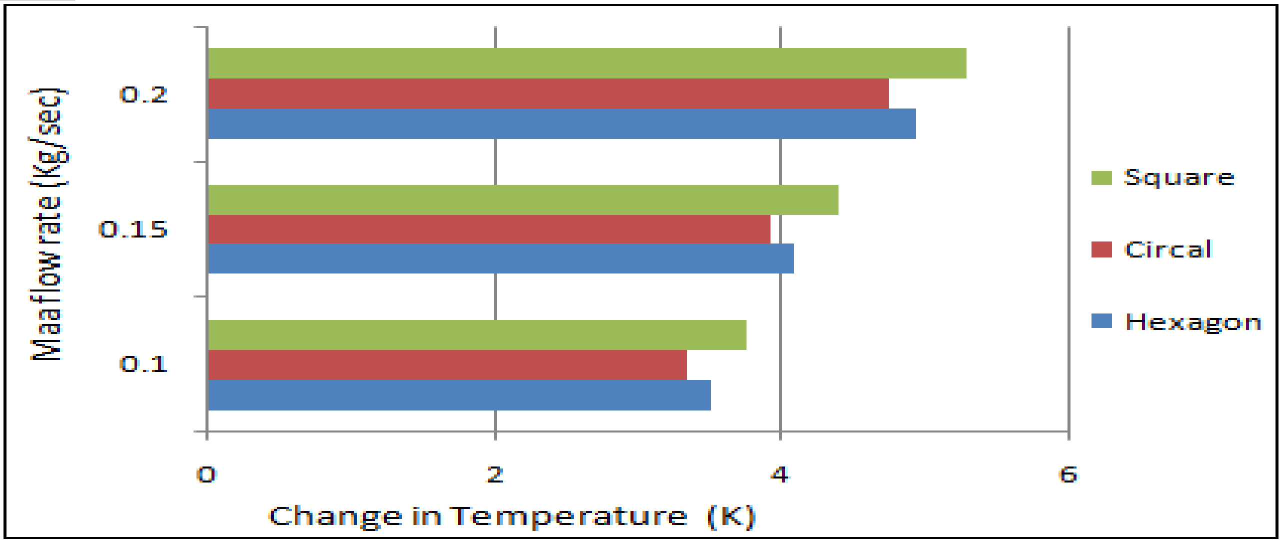

Figure 11 Comparison of Change in Temperature of Water

C. Rate of heat transfer

As temperature drop in circle is lowest so that heat transfer is also lowest in circle. Heat transfer is transferred maximum through the wall of square. Heat transfer from wall of hexagon and circle is about closes to each other.

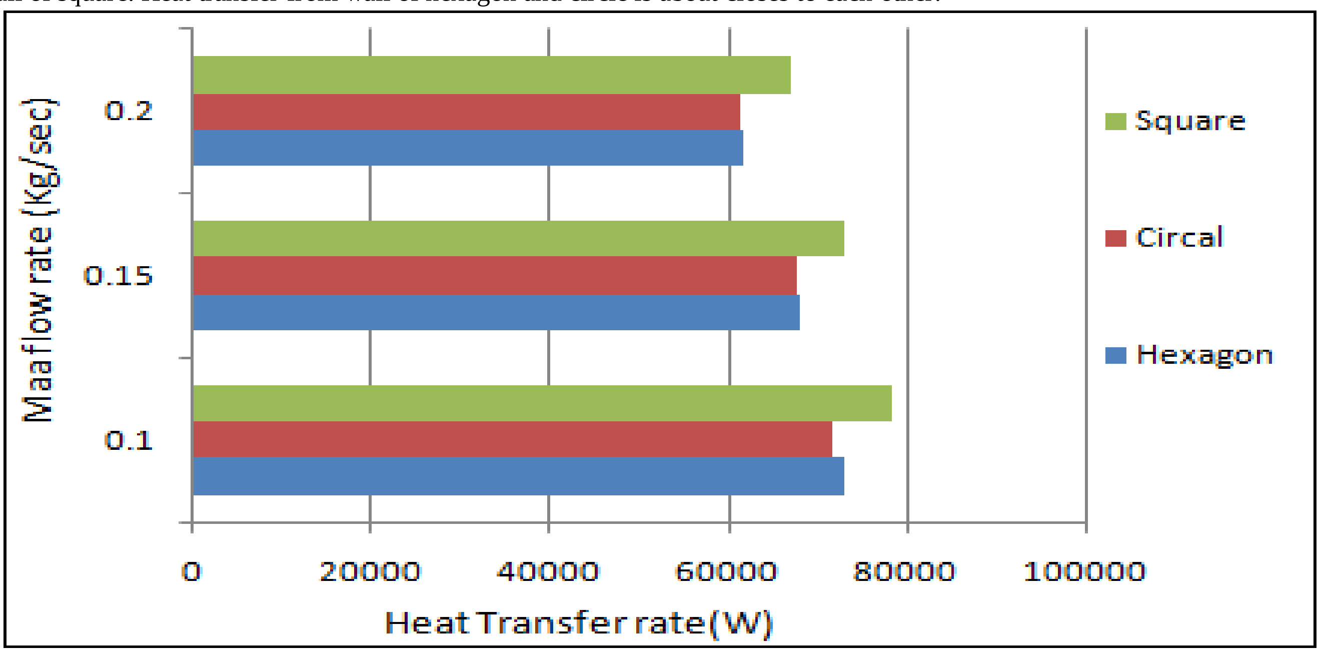

Figure 12 Comparison of average heat transfer through wall

VI. CONCLUSION AND APPLICATION OF HEXAGONAL DUCT

In this analysis we conclude that the hexagonal duct having lowest pressure drop as compare to circular and square duct. Hence it may be beneficial for fluid flow. When fluid flow inside the hexagonal duct then fluid supplied with high speed. Temperature drop is silly high in hexagonal duct as compare to circular duct. Following are the other conclusion of research work

A. Pressure drop of fluid deceases with increase in mass flow rate. Hence for reduce pressure loss keep mass flow rate as smaller as possible
B. Temperature drops of fluid increase with decrease in mass flow rate.
C. As per the temperature of cooling fluid increases, then decrease in viscosity.
D. Circular duct have higher pressure loss as compare to hexagonal and square duct.

E. Maximum temperature of fluid in hexagonal duct settled at farthest wall from centre As per results following may be the application field of hexagonal duct.

F. In hexagonal duct have lowest frictional losses; hence it can be applicable for supply of cooling water from cooling tower to condenser.

G. For supply of drinking water from water tank to home.

H. In A/C system, supply of cooling air from central A/C to place to be cool.

I. In home, from central tank to different place (like bathroom & kitchen).

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