Proposal of Hexagonal Ducts for Analysis

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Abstract

Energy conservation is deals with reduction of consumption of energy by optimizing energy service and for these the components used in energy service should be optimum. One of the energy service components is duct. Ducts play vital role in field of HVAC system as well as other flow device and so we can reduce the loss of energy by optimizing it. For optimizing the duct one of the passive methods is modification of the geometry of duct. This paper gives a proposal to modify the geometry of duct with hexagonal shape by taking care of different factors with predictive results. This paper describes what the geometry factors are and how it will affects the performance of a duct.

Keywords: *Ducts, duct geometries, geometrical parameters, heat transfer and fluid friction.*

1. Introduction

Ducts and pipes are passage closed circumferentially and use to transport the fluid from one location to another location in a specified way[1]. Generally passage with Circular cross section referred as pipe, passage with non circular cross section (like rectangular and hexagonal) referred as duct and circular cross section passage with small diameter referred as tube. In this article we refer word ducts instead of duct, tube and pipe. Efficient Performance of ducts depends upon many performance parameters based fluid flow parameter and heat transfer. Fluids Mean Axial Velocity, Wall Shear Stress, Hydrodynamic entrance length ,Momentum Kinetic and Energy Flux Correction Factor followed fluid flow parameters where as Mean Temperatures Convection heat transfer coefficient (h), Reynolds number, Nusselt Number, Peclet Number (Pc),Prandtl Number etc followed to heat transfer parameters[2].. These parameters are dependent upon many factors such as duct materials, duct geometries, environment conditions and purpose for it used. Ducts have also some geometrical performance parameters like aspect ratio, A/P ratio, perimeter etc.

When duct use for transportation of fluid and as a tube of heat exchanger then many problems also occur such as frictional loss, turbulence, heat transfer etc and this problem cause to loss of energy, vibrations, noises which reduce the efficiency of plant and increases the running cost, maintaining cost and also increases in pollutions[3]. These losses interlinked with many factors like materials used for duct manufacturing, surrounding conditions, fluid properties and also geometrical parameters of duct[4-7]. So need to optimize the duct to reduce losses and improve its performance. The performance is based on its application for example we need to transfer maximum amount of heat when ducts are used as tube of heat exchanger whereas need to reduce transfer of heat when it is used as supply system such as steam pipe, HVAC ducts.

2. Identification to parameters and problems to be Analyze

2.1 Parameters

As per easier to analysis I divided this parameters as Follow

A. Aspect ratio- Aspect ratio is one of the dimensionless geometry factors and defines as maximum dimension of geometry in major axis divided by maximum density in minor axis. It can also presents as ratio of width to height of the geometry. From figure 1 the aspect ratio is calculated as

$$Aspect\ ratio = \frac{L_1}{V_3}$$

B. A/P ratio – Area to perimeter ratio (A/P) is the ratio of area of cross section of duct to inner perimeter of duct. It is taken from hydraulic diameter and four times of A/P ratio is referred as hydraulic diameter in case of fluid flow with completely wetted perimeter. As a example A/P ratio of figure 1 can be calculated as

$$\frac{A}{P} = \frac{Ac}{6H_2}$$

C. Perimeters- It is very common word define as the total circumference length. From figure 1 it is given as

$$p = Sum\ of\ dimension\ of\ sides = 6L_1$$

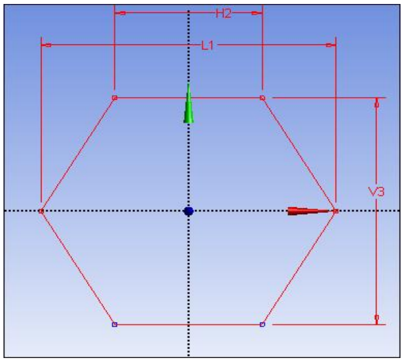


Figure 1duct Cross section and dimension of hexagonal

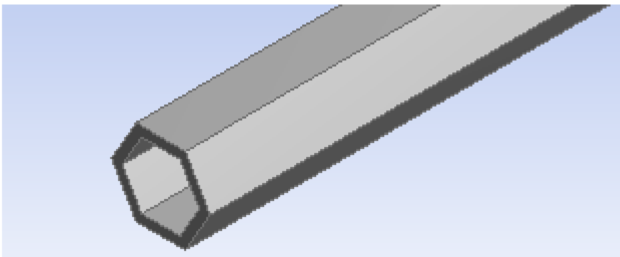


Figure 2 Hexagonal Duct

2.2 Problem to be consider

A. *Frictional Losses-* Friction between fluid layers and between fluid layer and duct surface causes to reduction in fluid velocity. On basis of geometrically analysis it depends upon all parameters (A/P , aspect ratio and perimeter). As perimeter increase the area of friction increase hence increase in friction. Friction factor given by following equations

$$f = \frac{K}{Re}$$

K varied from 48 to 96 depends upon aspect ratio. Hence as aspect ratio increase then increase in K and increase in friction factor. Similarly Re depends upon A/P ratio. Hence higher in A/P ratio reduce friction loss

.

B. ***Heat Transfer-*** In case of fluid transportation is should be minimum and in case of heat exchanger it should be maximum. On basis of geometrically analysis it depends upon the perimeter, A/P ratio and aspect ratio.

$$Q_{Cond} = K.p.L.\frac{dT}{t}$$

$$Q_{Conv} = h.p.L.dT$$

$$Nu = f(Re, Pr) = \frac{hD_H}{k}$$

From above equations it is clear that the heat transfer depends upon A/P ratio(D_h=4A/p). if d_h increase then increase in value of h decrease and heat transfer will be less. Similarly as perimeter(p) increase then heat transfer will higher.

3. Geometrical parameters of various geometry

Let us select nearly equal cross sections of duct geometry about 1600 unit^2. Hence circle has radius 22.5unit and area about 1590 which is near to 1600 unit^2. Side of other geometry keeping equals as possible. Square has sides 40 unit triangular has sides 56.56 unit. Hexagonal ducts have sides 25unit. Where rectangular has side 50and 32unit. So table is prepared accordingly.

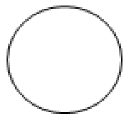
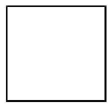
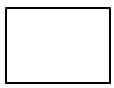
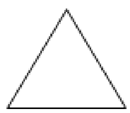
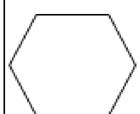
GEOMETRICAL PARAMETERS OF DUCTS								
Shape	Geometry	Area	Dimensions	Maximum Dimensions		Aspect Ratio	Perimeter	A/P Ratio
				In Major Axis	In Minor Axis			
CIRCLE		1590	Radius = 22.5	45	45	1	141.37	11.24708
SQUARE		1600	Sides=40	40	40	1	160	10
RECTANGULAR		1600	Sides=50 & 32	50	32	1.5625	164	9.756098
TRINGULAR		1600	Sides=56.56	56.56	49	1.154285714	169.7	9.428403
HEXAGONAL		1600	Sides=24.8	49.63	42.98	1.154723127	149	10.73826

Figure 3 Calculated Parameter of Geometries

Table -1 is preparing as per nearly same cross sectional area and side are equal as possible. Then there maximum dimension in major and minor axis are calculated by mathematical formula. Then perimeters and, A/P ratio and aspect ratio calculated simultaneously. And finally table is ready. This table helps us to insure which comparing the parameters of the geometry.

4. Comparison of parameters And Analysis of problem

A. Predictive Effect of perimeter in fluid friction and heat transfer

Figure 4 indicate that circular duct have smaller perimeter where as hexagonal duct have perimeter higher then circular but less then square and rectangular duct. As per perimeter increase the contact surface between fluid and duct circumference increase. So the frictional losses increase. Hence frictional losses higher in rectangular, square and triangular duct but circular duct , circular and hexagonal duct have relatively has small friction losses due to perimeter.

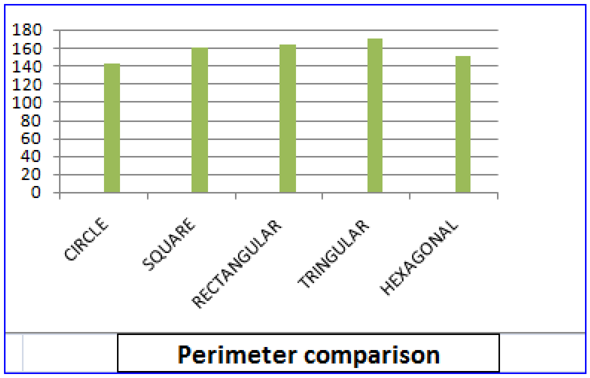


Figure 4 Comparison Based on Perimeter

Similarly from equation 2, heat transfer is directly proposal to perimeter. Hence the rectangular square and triangular duct will transfer maximum amount of heat to surrounding whereas the hexagonal and circular duct transfer smaller heat to surrounding.

B. Predictive Effect of A/P ratio in fluid friction and heat transfer

A/P ratio is the form of hydraulic diameter and which is directly proposal to Reynolds number. From equation 1 & fluid friction decease with increase in Reynolds number. Circular duct have highest A/P ratio hence as per basis of A/P ratio the fluid friction is higher in square rectangular and triangular ducts where as hexagonal ducts have mean fluid friction.

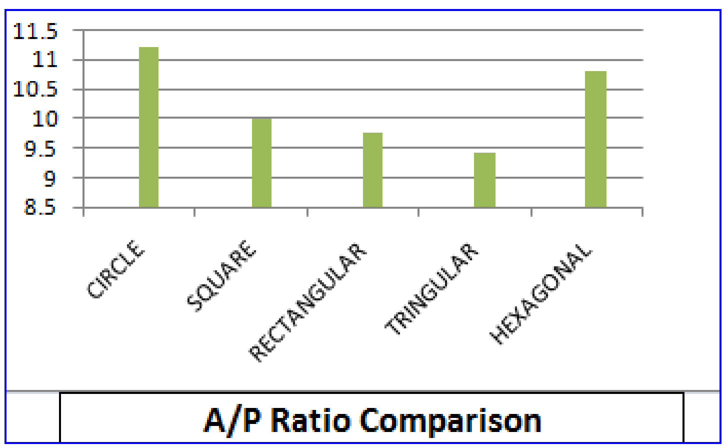


Figure 5. Comparison Based on A/P Ratio

In case of heat transfer A/P ratio increase the rate of heat transfer as function of Reynolds number. Hence as per A/P ratio circular duct transfer higher heat where as rectangular and triangular duct transfer smaller heat transfer to surrounding.

C. **Predictive Effect of aspect ratio in fluid friction and heat transfer**

-From figure 2 shows that rectangular duct have highest aspect ratio where as circular and square ducts have smaller aspect ratio and hexagonal ducts have medium aspect ratio, then from equation 1 we found that that the friction losses due to aspect ratio is highest in rectangular duct. But the value of k defferent for various geometry . According to cengel textbook for respectively aspect ratio of ducts geometry it is found that the friction factor smaller for triangular, square and rectangular duct but higher for circular ducts[8].

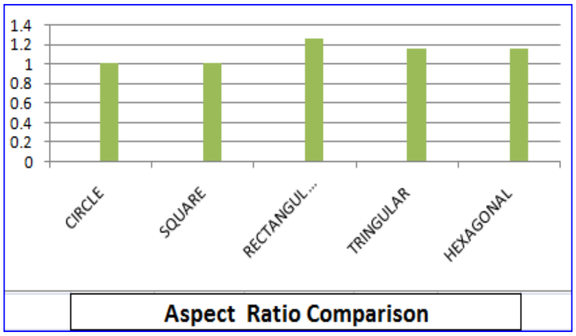


Figure 6 Aspect Ratio Comparison

In case of heat transfer according to P. Wibulswasheat, Deepak Saksena, Linqi Shui,[9-11] transfer increase with increase in aspect ratio. Hence prediction says that circular ducts will transfer less amount of heat to surrounding and rectangular ducts will transfer higher rate heat to surrounding as per effect of aspect ratio.

6. Results

By comparison of data and formula following most important result obtain which is shown in form of table for ease to understand the effect of various parameters. Table show that that heat transfer and friction factor both medium in hexagonal duct. Results are categories in three categories i.e. higher, medium and lower. Higher indicate that particular parameter is highest for particular problem in that geometry in which it assign as compare to other geometry.

On Basis of perimeter		
Geometry	Heat Transfer	fluid friction
Circle	Lower	Lower
Square	Higher	Higher
Rectangular	Higher	Higher
Triangular	Higher	Higher
Hexagonal	Medium	Medium

Figure 7 Predictive Comparison on Basis of Perimeter

On Basis of A/P Ratio		
Geometry	Heat Transfer	fluid friction
Circle	Lower	Lower
Square	Higher	Higher
Rectangular	Higher	Higher
Triangular	Higher	Higher
Hexagonal	Medium	Medium

Figure 8 Predictive Comparison on Basis of A/P

On Basis of Aspect Ratio		
Geometry	Heat Transfer	fluid friction
Circle	Lower	Higher
Square	Lower	Lower
Rectangular	Higher	Lower
Triangular	Medium	Lower
Hexagonal	Medium	Medium

Figure 9. Predictive Comparison on Basis of Aspect Ratio

7. Conclusion and Proposal to Hexagonal Duct

Prediction says that Circular duct transfer less heat to surrounding so it suitable for transport system but not feet for heat exchanger but it should be noted that Circular not efficient in high clearance ratio and small pressure drop. Prediction presents that rectangular duct transfer maximum heat to surrounding hence it is undesirable for fluid transport system and also these have higher fluid friction that is causes of loss of kinetic energy, vibrations so it should not feet. In consideration of hexagonal prediction says that duct have both fluid friction and heat transfer mean of the both. Hence it can be suitable for both cases.

Most important points in these analyses is that Hexagonal duct is middle in these comparison in case of heat transfer as well as fluid friction. So hexagonal ducts are second best option for transport system and some geometrical improvements can make best fluid transportation duct to save heat energy.
Similarly in case of heat exchanger it may be good choice instead of circular duct because it will transfer higher rate of heat as compare to circular duct.

These are the geometrical analysis of ducts and conclusion is that hexagonal duct has some advantages over circular ducts and rectangular ducts. So deep analysis and improvements in it can made is best choice for both i.e., transportation of fluid as well as tubes of heat exchanger.

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