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Hydrodynamic and Thermal Analysis in Pipe Flow using ANSYS Software

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Abstract: **This paper describes the thermal analysis of fluid flowing through a sudden expansion of pipe. Also the relation between velocity and pressure has been taken into consideration with changing the expansion ratio. All analysis has been done by using ANSYS 14.5 in axi-symmetric 2D model, using K-eplison equation for the turbulent flow. Pressure and velocity contour has been shown in this paper and fluid is considered as AIR.**

Keywords: Heat transfer, sudden expansion, ANSYS FLUENT, CFD.

I. INTRODUCTION

Whenever fluid flow through a sudden expansion passage there is a sudden drop in velocity which leads to increase in the pressure. Different pipe geometry has different loses and different application. Sudden enlargement, gradually enlargement etc. has different loses and different velocity and pressure relations. In this paper sudden enlargement of pipe have been considered with different expansion ratio. For the sudden expansion of pipe there are some energy loses also which have not been considered in this paper. In year 2009 Vikram Roy considered the re-attachment length phenomenon for sudden expansion of pipe by changing the velocity and expansion ratio respectively. In the case of sudden expansion velocity at the inlet is maximum throughout and decreases suddenly after sudden enlargement. If the heat is given to the surface of the pipe we can increase pressure drop with increase in velocity. As we all know pressure is inversely proportional to the velocity and this has been proved in this paper too. To increase the velocity at outlet we have to decrease pressure. In this paper velocity at the outlet has been increased with decrement in the pressure with decreasing skin friction coefficient at outlet of the passage.

II. MATHEMATICAL MODELLING

Continuity Equation also called conservation of mass. Consider fluid moves from point 1 to point 2. The overall mass balance is Input – output = accumulation. Assuming that there is no storage the Mass input = mass output. The momentum equations are sometimes also referred as Navier-Stokes (NS) equation. They are most commonly used mathematical equations to describe flow. The simulation is done based on the NS equations and then K-Epsilon model.

CONTINUITY EQUATION

$$\frac{\delta(\rho\bar{u})}{\delta x} + \frac{1}{r}\frac{\delta(\rho r\bar{v})}{\delta r} = 0$$

MOMENTUM EQUATIONS

Axial component (z-component)

$$\rho\bar{v}\left[\frac{\delta\bar{u}}{\delta r} + \bar{u}\frac{\delta\bar{u}}{\delta x}\right] = \frac{\delta\bar{p}}{\delta x} + \frac{\delta}{\delta x}\left(\mu_{eff}\frac{\delta\bar{u}}{\delta x}\right) + \frac{1}{r}\frac{\delta}{\delta r}\left(\mu_{eff}\frac{\delta\bar{u}}{\delta r}\right) + \frac{\delta}{\delta x}\left(\mu_{eff}\frac{\delta\bar{u}}{\delta x}\right) + \frac{1}{r}\frac{\delta}{\delta r}\left(\mu_{eff}\frac{\delta\bar{u}}{\delta r}\right) \quad (2.2)$$

Radial component (r-component)

$$\rho\left[\bar{v}\frac{\delta\bar{v}}{\delta r} + \bar{u}\frac{\delta\bar{v}}{\delta x}\right] = -\frac{\delta p}{\delta z} + \frac{\delta}{\delta x}\left(\mu_{eff}\frac{\delta\bar{v}}{\delta x}\right) + \frac{1}{r}\frac{\delta}{\delta r}\left(r\mu_{eff}\frac{\delta\bar{r}}{\delta r}\right) + \frac{\delta}{\delta x}\left(\mu_{eff}\frac{\delta\bar{u}}{\delta r}\right) + \frac{1}{r}\frac{\delta}{\delta r}\left(r\mu_{eff}\frac{\delta\bar{v}}{\delta r}\right) - 2\mu_{eff}\frac{\bar{v}}{r^2} + \rho\frac{\bar{w}^2}{r} \quad (2.3)$$

Tangential Component (Θ- component)

$$\rho\left[\bar{v}\frac{\delta\phi}{\delta r} + \bar{u}\frac{\delta\phi}{\delta x}\right] = \frac{\delta}{\delta z}\left[\mu_{eff}\frac{\delta\phi}{\delta x}\right] + \frac{1}{r}\frac{\delta}{\delta r}\left[r\mu_{eff}\frac{\delta\phi}{\delta r}\right] - \frac{2}{r}\frac{\delta}{\delta r}\left[\mu_{eff}\phi\right] \quad (2.4)$$

Here $\bar{u}$, $\bar{v}$ and $\bar{w}$ are the mean velocity components along *z*, *r* and θ directions respectively and the variable $\phi = r\bar{w}$.

III. INPUT PARAMETERS

Analysis of the result has been done in ANSYS Fluent 14.5. These equations are solved by converting the complex partial equation into simple algebraic equation.

Two dimensional geometry was used to study the flow in pipe for solving the mass, momentum, and energy equations. The phase velocities were defined at the inlet boundary of the pipe upstream. The κ-ε turbulence models with standard wall functions were used to solve the problems. The gravitational acceleration of 9.81 m/s^2 in upward flow direction was used.

The geometry was done in the GAMBIT with measurements, larger pipe diameter and length 3m and 12m smaller pipe diameter and length as 1m and 3m respectively. Defining the required inlet, outlet and wall conditions to the geometry and mesh under tetrahedron. The following figure shows the geometry before and after meshing respectively:

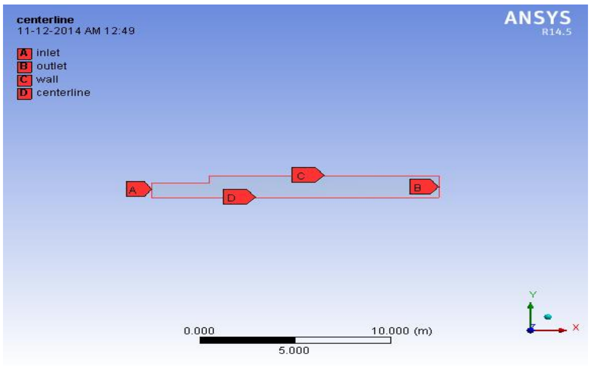


Fig 3.1: Geometry for sudden expansion

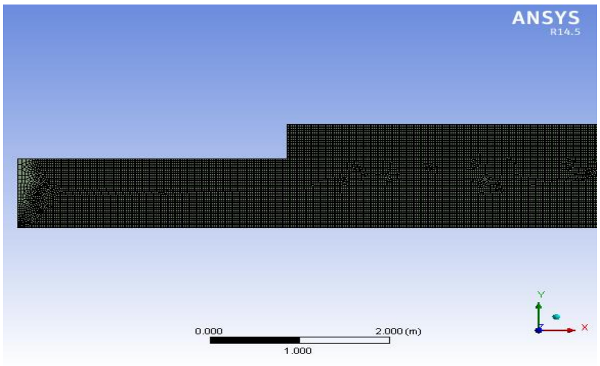
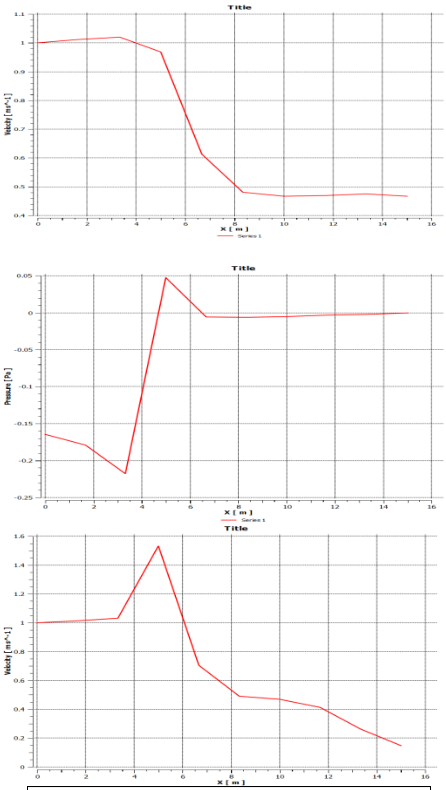


Fig 3.2: Mesh geometry for sudden expansion

IV. RESULT AND DISCUSSION

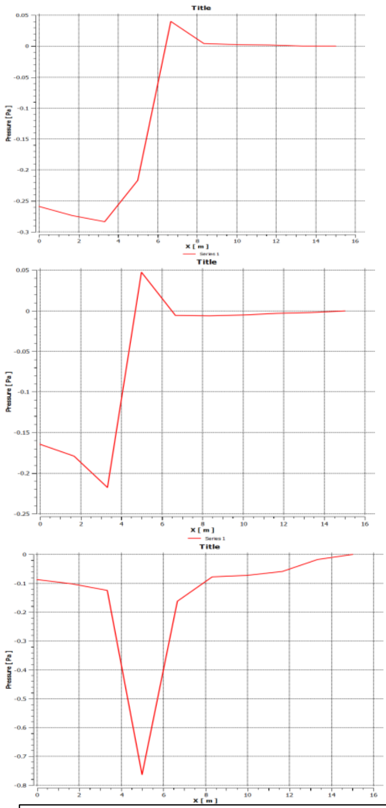
Keeping the inlet diameter constant 2m and changing the diameter of pipe after expansion 3m, 4m and 5m respectively by keeping the inlet velocity constant 1m/sec.



2 and 3m dia.

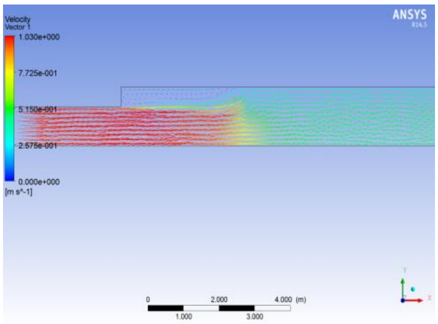
2 and 4m dia.

2 and 5m dia.

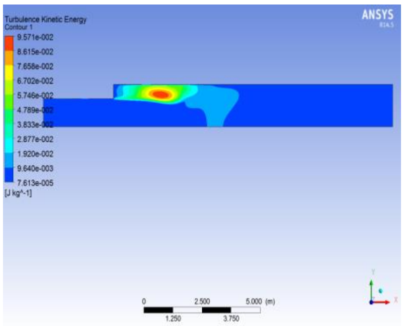


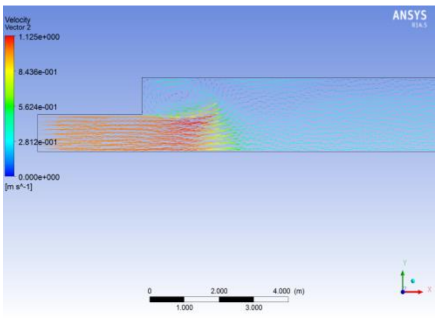
4.1- velocity graph for different expansion ratio

4.2- Pressure graph for different expansion ratio

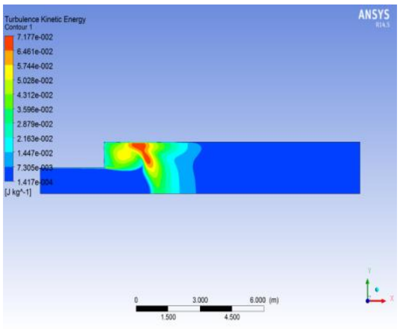


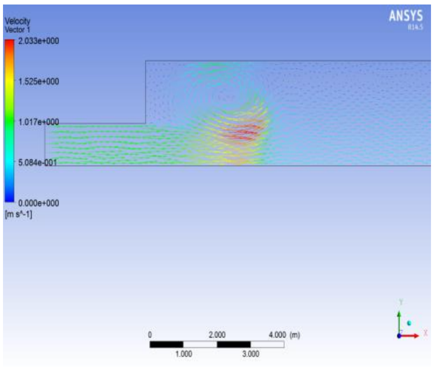
2 and 3m dia.



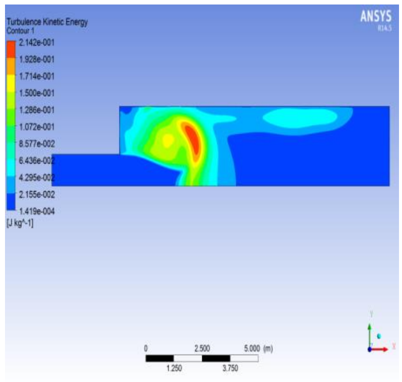


2 and 4m dia.





2 and 5m dia.



4.3- velocity vector for different expansion ratio

4.4- Turbulency contour for different expansion ratio

DISCUSSION

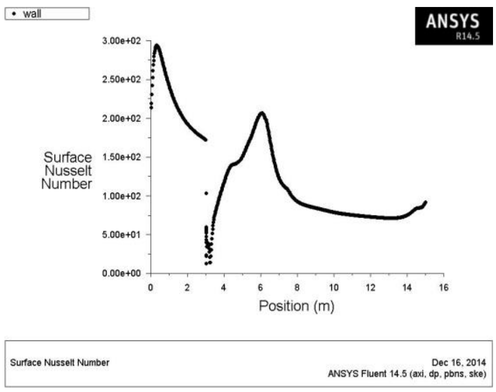
The effect of expansion ratio for velocity, pressure, recirculation bubble and turbulency has been analysed in above results. Fig 4.1 and 4.2 showing the effect of expansion ratio on velocity and pressure respectively. As expansion ratio increases velocity drop increases with increasing in the pressure after expansion. Fig 4.3 and 4.4 show the effect on bubble formation after the expansion for different expansion ratio and turbulency for different expansion ratio respectively. As expansion ratio increases recirculation dia. increases with increase in turbulency area.

V. THERMAL ANALYSIS

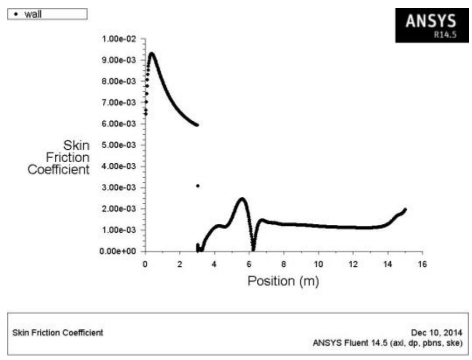
Keeping the geometry constant and If we heat the pipe through which the fluid is flowing then we can decrease the drop in velocity with increment in the pressure drop.

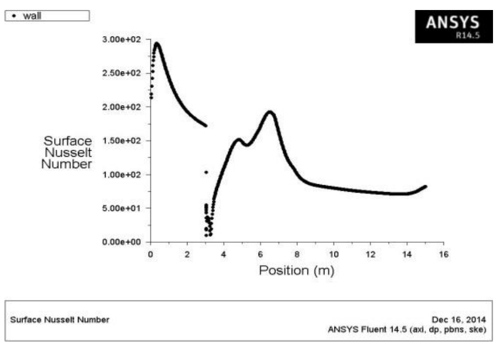
If we keep the inlet velocity same as 1m/sec and geometry same with inlet and outlet diameter 2m and 3m and giving different temperature at wall of the pipe.

RESULTS AND DISCUSSION

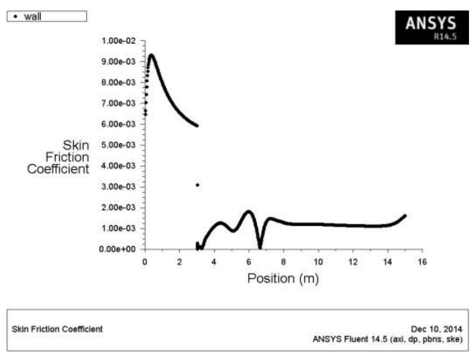


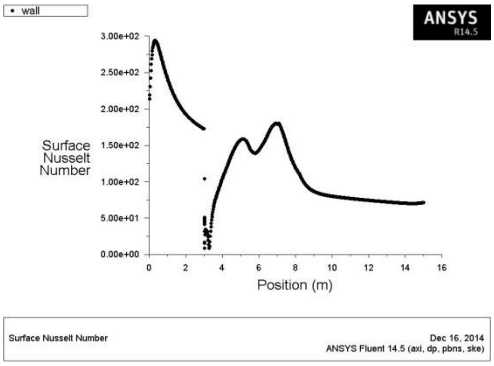
500K





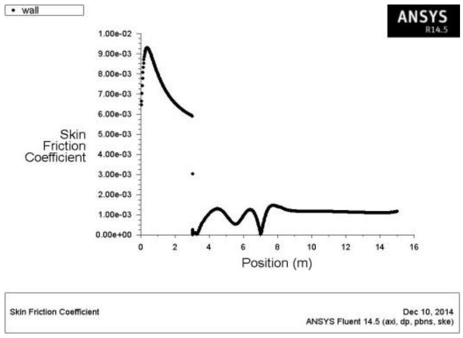
600K





5.1.1. Surface Nusselt number for different temperature.

700K



5.1.1. Skin friction coefficient for different temperature.

DISCUSSION

As we increase the surface Nusselt number increases after expansion with decrease in skin friction coefficient at outlet. As the skin friction coefficient decreases then outlet velocity will increase and pressure at outlet will decrease. By heating the outlet velocity can be increased by decreasing the outlet pressure.

CONCLUSION

The analytical results obtained by the ANSYS fluent software are presented to analyse the dynamic behaviour of a turbulent flow using the k-ε model. Based on the CFD analysis of the flow inside the pipe the following conclusion can be drawn.

- ❖ Skin friction coefficient decreases along with the length of pipe and becomes constant after entering the fully developed regime.
- ❖ Loses are more at the point where the enlargement in the pipe begins.
- ❖ In increasing the expansion ratio by keeping velocity constant the size and strength of the recirculation bubble increases.
- ❖ Turbulency increases with increasing the inlet velocity.
- ❖ Skin friction coefficient decreases with increase in temperature.

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