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Comparative CFD and Simulative Analysis of Flow Behaviour to Calculate Losses in Different Geometrical Pipes

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ABSTRACT

In order to transport the fluid effectively without suffering much energy loss it becomes very important to understand the frictional losses in fluid flow. And here basically two very crucial types of Losses are discussed such as Major Energy Loss (this occur due to friction) and other one is Minor Energy Loss (this is due to sudden expansion, sudden contraction and bend in a pipe). This study will focus on calculating Losses like Major and Minor loss in turbulent fluid flow through pipes of different geometries (expansion, contraction and bend). And the whole study will be performed using three different techniques: - firstly being experimentally performed in Fluid Mechanics & Machinery Laboratory, secondly at nodal centre of IIT DELHI using programme Virtual Labs, a project initiated by the MHRD, Govt. of India, and thirdly using ANSYS FLUENT a simulation and modelling software. The results obtained by using the three above discussed methods would be used for result validation and pointing the most effective method to calculate losses in flow through pipes.

KEYWORDS: *Major Loss, Minor Loss, CFD, Fluent, ANSYS, Virtual Lab.*

INTRODUCTION

Transporting of Fluids through piping network is very common in industries throughout the world; here fluid and gases are transported from one point to another. The pressure loss depends on the type of flow of the fluid in the network, pipe material, and the fluid flowing through the pipe. When any fluid flows through a pipe, the velocity adjacent to the pipe wall is zero and the velocity gradually increases from the wall to the centre of pipe. Maximum velocity is observed at the centre of the pipe. Due to increase in the velocity gradient, shear stresses are produced in the fluid due to its viscosity. This viscous action attributes to loss of energy which is commonly known as loss due friction or frictional loss.

A pipe is a closed conduit through which fluid flows under the pressure. When in the pipe, fluid flows, some of energy is lost to overcome hydraulic resistance which is basically caused due to:-

1. The viscous friction effect associated with molecules of fluid itself.
2. The local resistance which result from flow disturbances caused by sudden expansion and contraction in pipe.
3. Obstruction in the form of valves, elbows and other pipe fittings or Curves and bend in the pipe.
4. Entrance and exit disturbances.
5. Due to resistance between the viscous surface of liquid and surrounding pipe surface.

A. TYPES OF FLUID FLOWS

1. Laminar flow: -

The type of flow is critical in fluid dynamics to solve any problems. Laminar flow that is also sometimes called as streamline flow occurs when a fluid particle flows in a straight line parallel to a pipe walls comparatively with low velocity without any disturbance between the layers. Reynolds number is an important parameter to know the type of flow in the tube. The flow with Reynolds number less than 2300 is considered to be a Laminar flow for a pipe. In laminar flow, the velocity, pressure and other flow properties at each point in fluid remain constant. This kind of flow is rare in practice in water systems.

2. Turbulent flow: -

It is a type of flow in which fluids undergoes irregular fluctuations and mixing. The magnitude and direction are continuously changing in the turbulent flow due to the speed of fluid at a point. The flow of wind and rivers are the example of this kind of flow. Reynolds number is greater than 4000 and has high velocity in this flow. It is the most common type of flow and has to face the difficulty to view with an open eye, fluctuations are very difficult to detect, and laser can be used for the detection. Mathematical analysis for this flow is very difficult, so experimental measurements are applied.

3. Transitional flow: -

It is a type of flow with the medium velocity having the Reynolds number greater than 2300 and lesser than 4000.

B. LOSSES IN FLOW THROUGH PIPES

When a fluid flow through a pipe, the fluid experiences some resistance due to which there are some loss in energy of fluid.

This loss of energy is classified as:

1. Major Energy losses
A. Darcy-Weisbach formula

2. Minor losses
A. Bend in Pipe
B. Sudden contraction
C. Sudden expansion
D. Pipe fitting

C. FORMULAS FOR CALCULATION OF LOSSES IN FLOW THROUGH PIPES

1. **Darcy-Weisbach formula**:-

$$h_f = \frac{flv^2}{2gD}$$

Where,

h_f= loss in head due to friction in unit of length

f= friction factor

D = Pipe Diameter

V = Flow velocity

2. **Minor losses;-**

$$h = k\frac{v^2}{2g}$$

Where K is the loss coefficient

2.1 Loss of head due to sudden expansion

$$h_e = k_e\frac{{v_1}^2}{2g}$$

2.2 Loss due to sudden contraction

$$h_C = k_C\frac{{V_2}^2}{2g}$$

2.3 Loss of head due to bend in pipe

$$h_b = k_b\frac{v^2}{2g}$$

D. OBJECTIVES OF STUDY

The main objectives of study are:-

- Calculation of Major loss using Darcy's equation for measuring frictional losses.
- Calculation of the minor losses (due to sudden expansion, sudden contraction and bend) for measuring variation in velocity and pressure.
- Study effect of Pipe Material and Fluid Viscosity on fluid flow.
- Results validation and comparison for predicting the most effective technique for calculation of losses in fluid flow through pipes.

E. EXPERIMENTAL SETUP

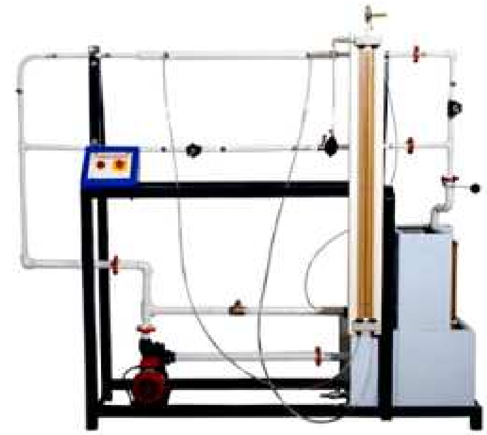

Fig.1:- shows experimental apparatus for pipe losses

F. THEORETICAL FORMULATION (USING VIRTUAL LABS)

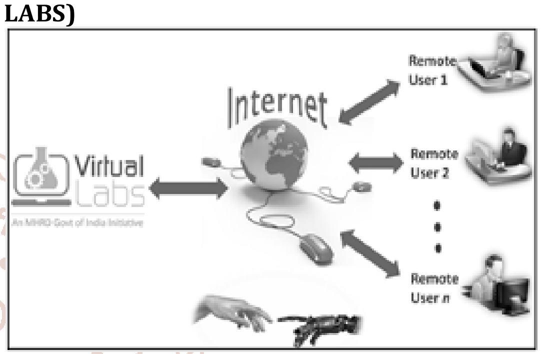

Fig2:- shows process of Virtual Labs(Theoretical Results) for pipe losses

G. RESULT ANALYSIS

S. No	Diameter of Pipe	Experiment Results	Virtual/ Theoretical Results	CFD Results
1	0.050	0.101	0.490	0.3715
2	0.040	0.035	0.325	0.310
3	0.025	0.002	0.029	0.027

Table:- 1 shows comparison of results for Major Losses

S.No	Head Loss	Diameter Of Pipe	Experiment Results	Virtual/ Theoretical Results
1	He	0.025-0.050	0.336	0.2973
2	Hc	0.050-0.025	0.756	0.2825
3	Hb	0.05	0.0615	0.0551

Table:-2 shows comparison of results for minor losses

H. BAR CHART ANALYSIS

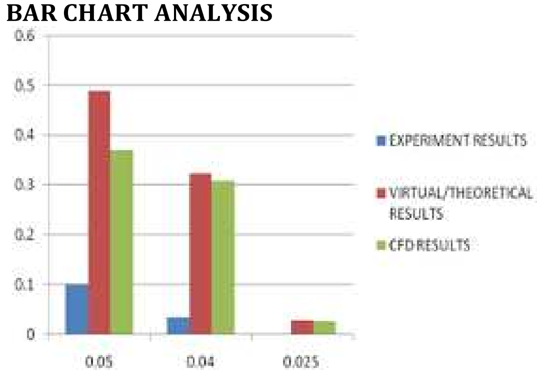

Fig.3:- shows comparison of results for Major Losses

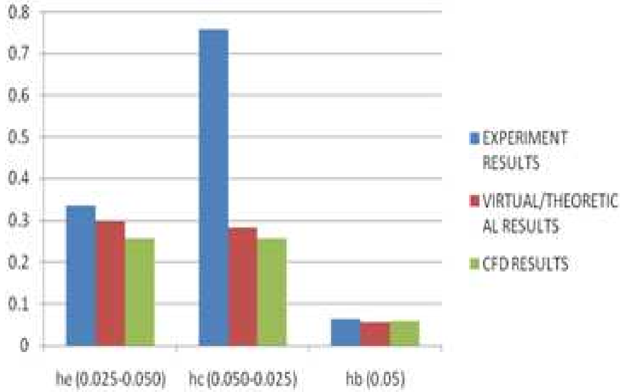

Fig.4:- shows comparison of results for Minor Losses

I. CFD ANALYSIS

Computational Fluid Dynamics (CFD) is the simulation of fluids engineering systems using modeling (mathematical physical problem formulation) and numerical methods (discretization methods, solvers, numerical parameters, and grid generations, etc.) Here, FLUENT workbench was used for making the analysis.

I.1 SAMPLE CFD PROCESS

In this a sample of cfd process is shown using figures, each geometry consist of 4 figures. And as our study was related to Straight Pipe, Sudden expansion, Sudden Contraction and Sudden Bend so these will make a total of 12 such photos. So for illustrative purpose only Sudden Bend figures are shown.

I.2 Modeling

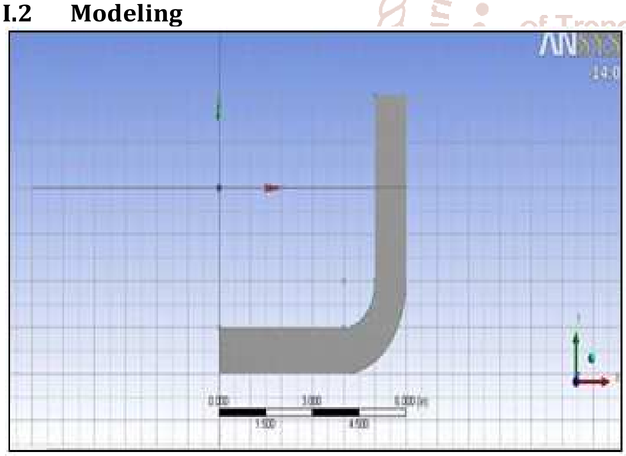

Fig.5:- shows modelling for Bent Pipe

I.3 Meshing

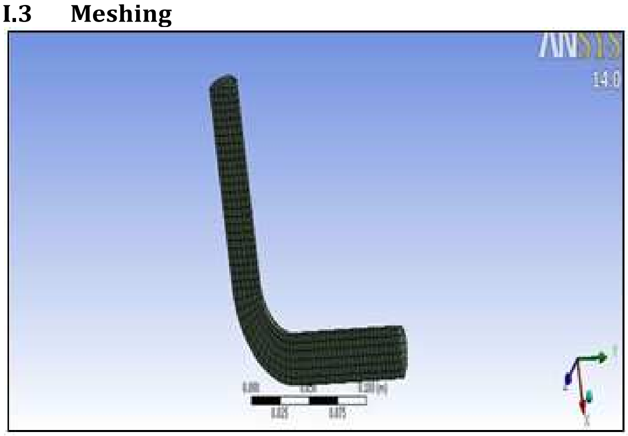

Fig.6:- shows meshing for Bent Pipe

I.4 Pressure

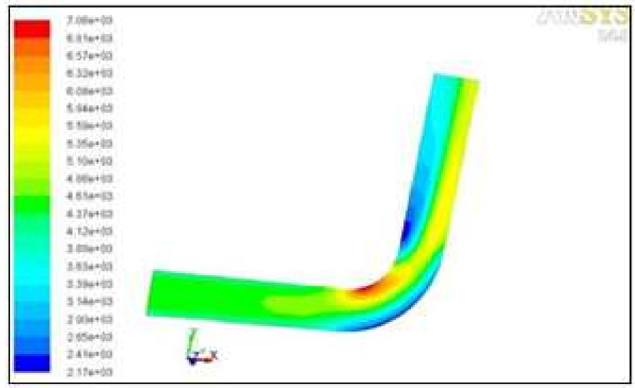

Fig.7:- shows pressure contours for Bent Pipe

I.5 Velocity

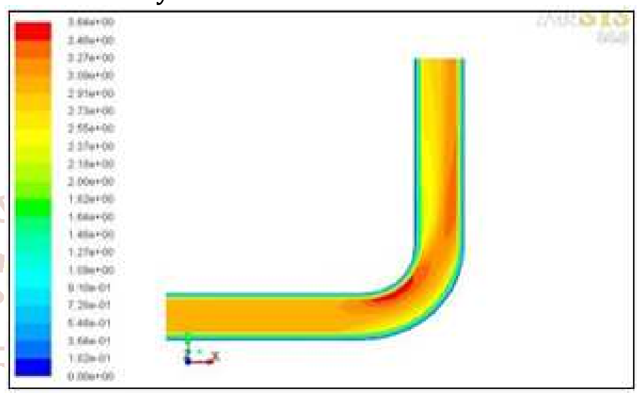

Fig.8:- shows velocity contours for Bent Pipe

J. CONCLUSION

1. Frictional Loss co-efficient is more in Virtual Lab results than the result obtained from experiments and ANSYS. In this the results obtained from both ANSYS and Virtual/Theoretical are almost same.
2. Loss co-efficient of expansion is more in experimental results than the result obtained from Virtual Lab and ANSYS . In this the results obtained from both ANSYS and Virtual/Theoretical are almost same.
3. Loss co-efficient of contraction is slightly more in experimental results than the result obtained from Virtual Lab and ANSYS. In this the results obtained from both ANSYS and Virtual/Theoretical are almost same
4. Loss co-efficient of bends is slightly more in experimental results than the result obtained from Virtual Lab and ANSYS. In this the results obtained from both ANSYS and Virtual/Theoretical are almost same.
5. Finally concluded that ANSYS has an edge over the other methods as it is flexible to change according to need and generates results more close to theoretical results. And is free from experimental errors that happen due to friction and leakages etc.

K. FUTURE SCOPE

1. Study of program with thermal effect
2. FEM Analysis of pipe flow and comparing with FDM Analysis result in case when Dynamic Viscosity, Laminar flow that are dependent on Temperature.
3. Varying effect study with change in length of pipe
4. Varying effect study with change in material of pipe

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