Study of Water Flow through Gradual Expansion Joint of Pipe

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Abstract : **The aim of this work is to study flow properties at Gradual Expansion junction of pipe, Head loss suffered by the flow after passing through Gradual Expansion junction and to study reliability of the classical engineering formulas used to find head loss for Gradual Expansion junction of pipes. In this we have compared our results with CFD software packages with classical formula and made an attempt to determine optimum cone angle.**

Index Terms— Gradual Expansion, CFD, Optimum cone angle, Head loss.

I. INTRODUCTION

Pipe networks are very common in industries, where fluid or gases are to be transported from one location to the other. The head loss (pressure loss) may vary depending on the type of components occurring in the network, material of the pipe and type of fluid transported through the network. In industries the networks are usually large and require very precise pressure at certain points of network. It is also sometimes essential to place valves, pumps or turbines of certain capacity to control pressure in the network. The placement of valves, pumps and turbines is important to overcome pressure loses caused by other components in the network. This is one of the important reasons why this study was conducted.

Various joints are very common component in pipe networks, mainly used to distribute (diverge) the flow from main pipe to several branching pipes and to accumulate (converge) flows from many pipes to a single main pipe. Depending on the inflow and outflow directions, the behavior of flow at the various junctions also changes.

In fluid dynamics, head is the difference in elevation between two points in a column of fluid, and the resulting pressure of the fluid at the lower point. It is possible to express head in either units of height (e.g. meters) or in units of pressure such as Pascal. When considering a flow, one says that head is lost if energy is dissipated, usually through turbulence; equations such as the Darcy-Weisbach equation have been used to calculate the head loss due to friction.

Head losses are of two types major and minor. Major head losses (also called Frictional losses) are due to rough internal surface of pipe and occur over length of pipe. They are mainly due to friction. Minor losses are losses due to the change in fluid momentum. They are mainly due to pipe components due to bends, valves, sudden changes in pipe diameter, etc. Minor losses are usually negligible compared to friction losses in larger pipe systems. Presence of additional components offers resistance to flow and turbulence. In this work, our aim is to study behavior of fluid through gradual expansion geometry of pipes, head losses caused by gradual expansion geometry of pipes and change in pressure loss with change in angle of the gradual expansion geometry of pipes & find out an optimum angle for different expansion ratio at which head loss would be minimum.

II. LITERATURE SURVEY

Study performed by Vikram Roy. [1]

Vikram Roy. [1], under the title of Analysis of the Turbulent Fluid Flow in an Axi-symmetric Sudden Expansion. The numerical analysis of the turbulent fluid flow through an axi-symmetric sudden expansion passage has been carried out by using modified k-epsilon model, taking into consideration the effects of the streamline curvature. The variations of the size and strength of the recirculation bubble for different Reynolds numbers and expansion ratios have been analyzed. The recirculation bubble generated due to the sudden expansion of the passage is observed to reduce in size and strength with the increase in the Reynolds number. But the size and strength of the recirculation bubble increases with the increase in the expansion ratio. The radial distributions of the turbulent energy and the axial velocity have been obtained.

Study performed by IULIAN FLORESCU. [2]

IULIAN FLORESCU. [2], under the title of study about the fluid losses in the branching pipes, the researcher proposes a method for analyzing the dynamics of real fluid flow through pipe bends. The method can contribute to an optimal design of pipe networks. Along with linear load losses, local losses are particularly important for these piping systems, their analysis for determining coefficients of load losses being of prime importance. Besides the classical experimental attempts to study these tests try a method of theoretical analysis based on flow simulation, more accessible to different variants of the pipes. The variation of major structural and functional parameters of the flow is emphasized by the simulation of the flow.

Study performed by Snehamoy Majumder. [3]

Snehamoy Majumder. [3], under the title of Turbulent Fluid Flow Analysis by RANS-Method in an Axi-Symmetric Sudden Expansion, the researcher perform a numerical investigation has been done to analyze the turbulent fluid flow through a sudden expansion. It has been observed that the recirculation bubble exist in twin structures. The primary recirculation bubble was observed to increase by the increment of the expansion ratio. However the reattachment length is observed to vary in a complex way; increases at first with the *Re* then it decreases gradually with respect to *Re*. It has been observed from the variation of C_f that the recirculation with a flow having less inlet velocity and intensity of turbulence is much smaller than in the fully turbulent flow with considerably higher inlet velocity as well as turbulence intensity. It is also concluded that strength of the recirculation bubble is increased with the expansion ratio, keeping *Re* constant.

Study performed by G. Satish. [4]

G.Satish. [4], under the title of Comparison of flow analysis of a sudden and gradual change of pipe diameter using fluent software, the researcher found that The flow through sudden and gradual change of pipe diameter(enlargement and contraction) was numerically simulated with water by unsteady flow in k-epsilon scheme. The major observations made related to the pressure and velocity contours in the process of flow through these pipes. Sudden enlargement creates more severe formation of flow eddies than sudden contraction. Also, the losses are more at the point where the enlargement in the pipe begins. In the sudden contraction, vane contracta's are formed at the point of contraction and effect of viscosity is negligible on the pressure drop through sudden contraction. The pressure drop increases with higher inlet velocity and hence with higher mass flow rate. This point is the most susceptible point for pipe damage. So, to increase the life of the pipe in cases of sudden contraction & enlargement, the pipes must be designed in view of the above observations making the corners more round so as to minimize the losses in the pipes.

III. EXPERIMENTAL SET- UP AND OPERATING PROCEDURE

OPERATING PROCEDURE

The following operating procedure is adapted for conducting the experiment.

1. Adjust the Pipe at the desired height.
2. Set the water tank on the adjustable stand.
3. Fill the water tank.
4. Adjust discharge measuring tank at the outlet.
5. Placed the flow regulator valve on the certain distance before and after gradual contraction and gradual expansion joint of pipe.
6. Switch on the power supply.
7. While taking the reading for gradual contraction joint keep the gradual expansion joint closed and vice-versa.
8. Measure the discharge 'Q' for 60 second at different inlet pressures i,e on 10 kg/cm^2,15 kg/cm^2,20 kg/cm^2,25 kg/cm^2&30 kg/cm^{2}for gradual contraction & expansion joint.
9. After measuring the discharge, with the help of mass flow rate equation calculate inlet and outlet velocities at different pressure.

IV. RESULTS & DISCUSSION

Experimental Results

The followings results are obtained after conducting the experiment for different pressure and different diameter ratio of gradual contraction & gradual expansion joint of pipe.

Case - 1. Gradual Expansion Ratio =1.5, Inlet Pipe Diameter (d1) = 12.5 mm,
Outlet Pipe Diameter (d2) = 18.75 mm, Length = 1 m.

Experimental Results of Gradual Expansion Ratio =1.5.

Gradual Expansion Ratio=1.5

Inlet Pressure	Discharge(Q)	Inlet Velocity	Outlet Velocity	Heahd Loss ($h_L=k(v_1^2/2g)10^{-5}$)					
P1	ml/mil	v_1(m/sec)	v_2(m/sec)	60^0	40^0	30^0	20^0	15^0	10^0
10	170	0.023	0.01	1.56	1.29	1.05	0.67	0.35	0.17
15	142	0.019	0.0085	1.06	0.88	0.71	0.45	0.23	0.12
20	106	0.014	0.0063	0.58	0.48	0.4	0.25	0.13	0.07
25	100	0.013	0.006	0.5	0.41	0.34	0.22	0.11	0.06
30	68	0.009	0.0041	0.24	0.2	0.16	0.1	0.053	0.03

Interpretation: From the above results it can be interpreted that head losses are minimized by reducing the cone angle & optimum cone angle for the Gradual Expansion Ratio=1.5 should be 10^0.

Case - 2. Gradual Expansion Ratio =2, Inlet Pipe Diameter (d1) = 12.5 mm,
Outlet Pipe Diameter (d2) = 25 mm, Length = 1 m.

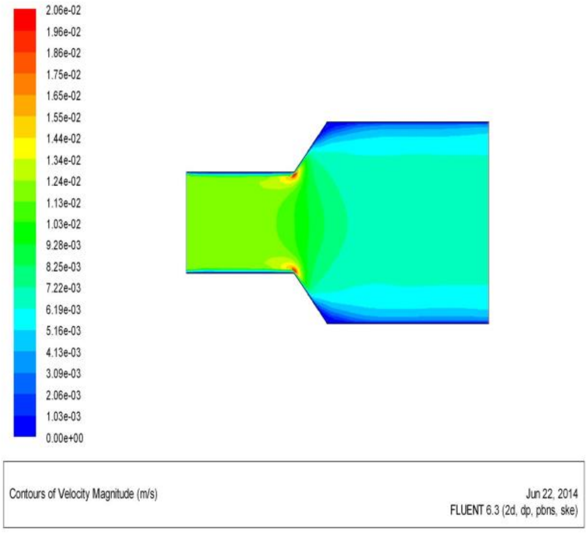
Experimental Results of Gradual Expansion Ratio =2.

Gradual Expansion Ratio=2									
Inlet Pressure	Discharge(Q)	Inlet Velocity	Outlet Velocity	Heahd Loss ($h_L=k(v_1^2/2g)10^{-5}$)					
P1	ml/mil	v_1(m/sec)	v_2(m/sec)	60^0	40^0	30^0	20^0	15^0	10^0
10	172	0.023	0.0058	1.8	1.5	1.24	0.78	0.43	0.21
15	150	0.02	0.005	1.36	1.14	0.93	0.59	0.32	0.16
20	120	0.016	0.004	0.87	0.73	0.6	0.37	0.2	0.1
25	100	0.013	0.0033	0.57	0.48	0.39	0.24	0.13	0.07
30	66	0.0089	0.0022	0.27	0.22	0.18	0.1	0.064	0.03

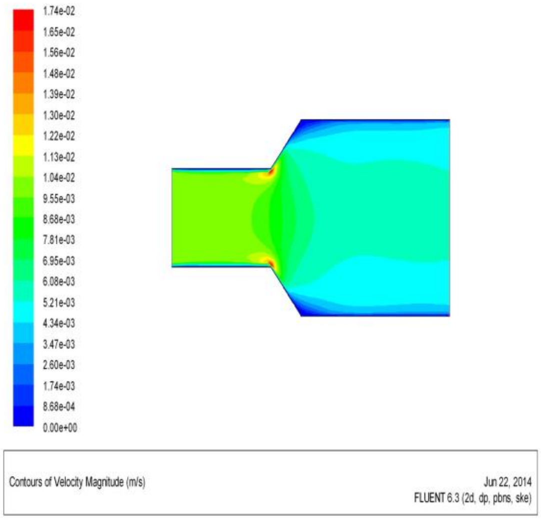
Interpretation: From the above results it can be interpreted that head losses are minimized by reducing the cone angle & optimum cone angle for the Gradual Expansion Ratio=2 should be 10^0.

CFD RESULTS POST-PROCESSING

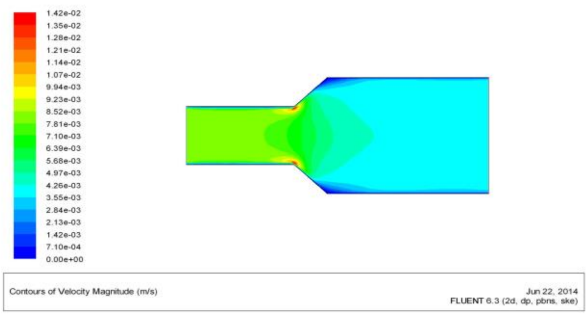
Velocity Contours for Gradual Expansion Ratio=1.5



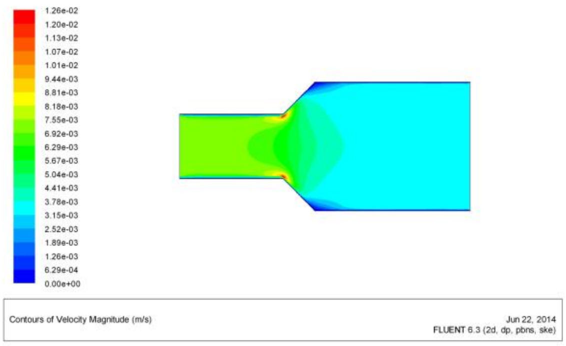
Contour of Velocity at pressure 10 kg/cm^2



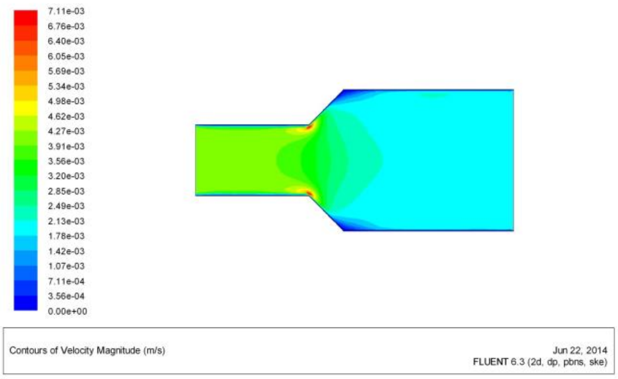
Contour of Velocity at pressure 15kg/cm^2



Contour of Velocity at pressure 20 kg/cm^2



Contour of Velocity at pressure 25 kg/cm^2



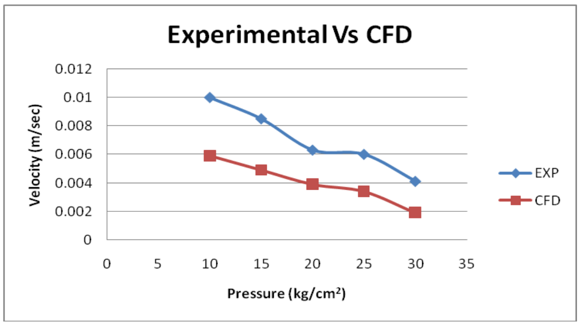
Contour of Velocity at pressure 30 kg/cm^2

Interpretation: Above diagrams shows that there is sudden change in velocity at the sharp edges from the entrance of larger pipe.

COMPARISON OF EXPERIMENTAL RESULTS WITH CFD RESULTS

Comparison of the CFD Results with the Experimental Results for Gradual Expansion Ratio=1.5

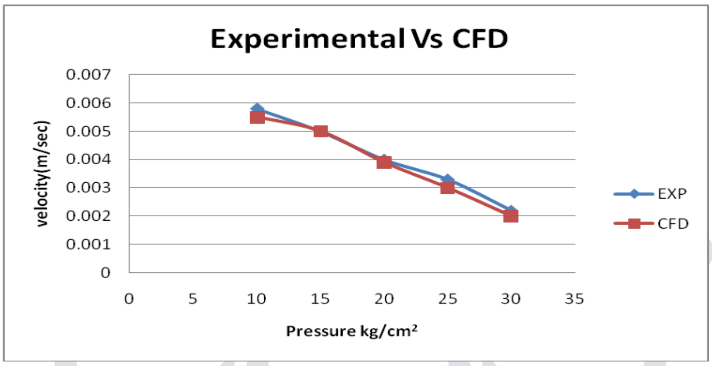
Gradual Expansion Ratio=1.5				
Inlet Pressure	**Discharge(Q)**	**Inlet Velocity**	**Outlet Velocity**	**CFD Result**
P1	**ml/mil**	**v_1(m/sec)**	**Exp. Resultv_2(m/sec)**	**v_2(m/sec)**
10	170	0.023	0.01	0.0059
15	142	0.019	0.0085	0.0049
20	106	0.014	0.0063	0.0039
25	100	0.013	0.006	0.0034
30	68	0.009	0.0041	0.0019



Discussion: From the above Graph it has been found that, by increasing the pressure, velocity gets decreases, & the results of Experimental Analysis & CFD Analysis are very near to each other.

Comparison of the CFD Results with the Experimental Results for Gradual Expansion Ratio=2

Gradual Expansion Ratio=2				
Inlet Pressure	**Discharge(Q)**	**Inlet Velocity**	**Outlet Velocity**	**CFD Result**
P1	**ml/min**	**v_1(m/sec)**	**v_2(m/sec)**	**v_2(m/sec)**
10	172	0.023	0.0058	0.0055
15	150	0.02	0.005	0.005
20	120	0.016	0.004	0.0039
25	100	0.013	0.0033	0.003
30	66	0.0089	0.0022	0.002



Experimental Vs CFD for gradual expansion ratio =2

Discussion: From the above Graph it has been found that, by increasing the pressure, velocity gets decreases, & the results of Experimental Analysis & CFD Analysis are very near to each other.

V. CONCLUSION

The experimental set-up was designed and fabricated at D.M.I.E.R.T, Wardha. Extensive experimentation as well as CFD Analysis was performed and sufficient data was generated and analyzed, to establish Velocity characteristics for the water flow through Gradual Expansion joint of pipe. The main conclusions of the present work are as under.

1. By comparing our results with the existing available literature, it has been found that, as compared to sudden expansion joint head loss is minimum in case of gradual expansion joint of pipe.
2. In case of Gradual Expansion junction, to reduced the head loss and find out an optimum cone angle we considered various cone angles and found that head loss is negligible at the cone angles of $10^{0.}$ Therefore, an optimum angle for Gradual Expansion junction at the diameter ratio of 1.5 & 2 should be 10^{0}.

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