International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

Optimisation of Pressure Loss and Flow Distribution at Pipe Bifurcation

Dr. Nagaraj Sitaram[1]
[1]Professor, Department of Civil Engineering ,School of Engineering Technology, Jain University, Jakkasandara Post, Kanakapura Taluk, Karnataka, India

Abhijeeth Nagaraj[2]
[2]Post Graduate Student, Dept. of Mechanical Engg., Bangalore Institute of Technology, KR Road, V.V Puram, Bengaluru, Karnataka, India

Abstract

Pipe networks are very common in industries where liquids or gases to be transported from one location to the other. Combining and dividing pipe junctions are of interest to hydraulic engineers in pipe network particularly in water distribution system. The dividing junction involves additional geometric parameters compared to components with a single flow path. There is also a need to know the pressure loss at the junction and parameters which influences these losses. The paper focuses in determination of pressure losses and flow distribution of pipe bifurcation using the experimental technique at various flow rates and pressures. The experimental data and analysis for 100mm main and 75 mm bifurcated pipes show the correlation between pressure loss coefficient (K) with a split flow ratio $\left(\frac{Q_2}{Q_1}\right)$, $\left(\frac{Q_3}{Q}\right)$, $\left(\frac{Q_4}{Q_1}\right)$*. The experiments have been conducted for four different bifurcation angles- 10º, 15º, 20º, 30º. The bifurcation loss coefficient (K) also depends up on the line pressures, bifurcation angles, and ratio of main to branch pipe diameters. The experimental findings also suggest that the head loss at the bifurcation junction will be minimum when equal discharge flow in branched pipes. The hydraulic behaviour of the right and left branches for equal angle of bifurcation is also studied.*

Keywords: Pipe, Dividing junctions, pressure loss, bifurcation, split flow ratio, equal discharge, loss co-efficient.

1. Introduction

The division of two streams at different velocity results in loss of energy at the junction and changes to velocity for a given pressure. A hydraulic engineer is interested to know the split flow ratios and pressure loss for a given configuration of bifurcation which is mainly used in pipe networks and house plumbing.

The determination of pressure loss coefficient (K) at bifurcation depends upon the geometric parameters like pipe area ratio, diameter of the pipe and angle of bifurcation, fluid parameters like density of the fluid, viscosity and temperature of the fluid, and flow parameters like pressure and discharge. The loss of energy at the pipe bifurcation is mainly due to separation and reattachment of the fluid flow patterns near the bifurcation. The exchange of the fluid momentum and energy transfer at bifurcation junction totally depends upon the angle of bifurcation, line pressure in the pipes, diameter ratios of the main and branch pipes. The paper aims at the determination of loss of co-efficient at the bifurcation for various pressures and flow rates for a given angle of bifurcation (θ = 10°, 15°, 20°, 30°). Also to determine the flow ratio for which pressure loss co-efficient is minimum.

The various configurations of bifurcation are shown in figure below:

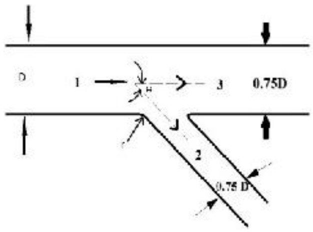

Figure 1 Right bifurcation

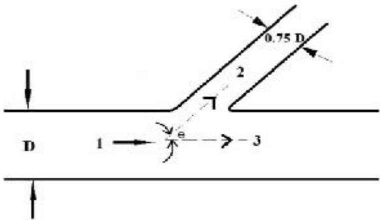

Figure 2 Left bifurcation

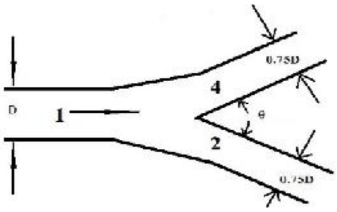

Figure 3 Y bifurcation

2. Theory

The discharge valves in branch pipes are measured and added together to obtain the flow in main pipe based on the conservation of mass called continuity equation. The total energy for each pipe is determined based on line pressure. Energy at 1 will always be more than energy at 2 and 3 respectively in figure 4. As per the different bifurcation conditions given in figures 1 to 3, the equations are:

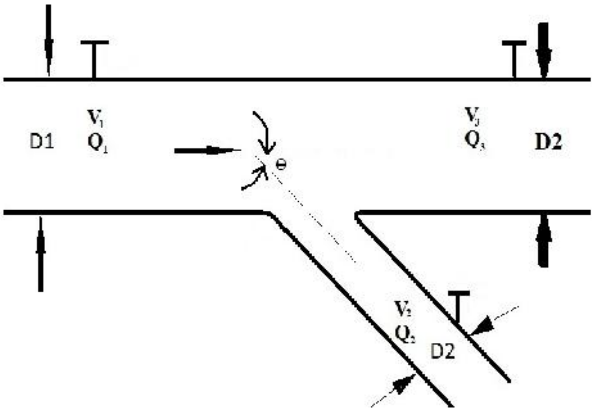

Figure 4 Right bifurcation

$$Q_1 = Q_2 + Q_3 \quad (1)$$

$$Q_1 = Q_2 + Q_4 \quad (2)$$

$$Q_1 = Q_3 + Q_4 \quad (3)$$

The loss of co-efficient at each pipe is computed by Blevins equation (1984)

$$K_{12} = \frac{\Delta P}{\left(\frac{1}{2}\right) * U1^2 * \left(\frac{Q_2}{Q_1}\right)^2} \quad (4)$$

$$K_{13} = \frac{2000 * \Delta P}{U1^2 + 0.67 + 0.56\left(\frac{U_2}{U_1}\right)^2} \quad (5)$$

$$K_{23} = \frac{2000 * \Delta P}{U1^2 + 0.67 + 0.56\left(\frac{U_3}{U_1}\right)^2} \quad (6)$$

$$K_{14} = \frac{2000 * \Delta P}{U1^2 + 0.67 + 0.56\left(\frac{U_4}{U_1}\right)^2} \quad (7)$$

The overall loss co-efficient (K) in bifurcation junction is defined based on the branch discharge ratio and branch loss coefficients:

$$K = K_{12}\left(\frac{Q_2}{Q_1}\right) + K_{13}\left(\frac{Q_3}{Q_1}\right) \quad (8)$$

The total energy (E) for all horizontal pipes ($Z_1=Z_2=Z_3=Z_4$) is computed by,

$$E_1 = \left(\frac{p_1}{\yen_w}\right) + \left(\frac{V_1^2}{2g}\right) \quad (9)$$

$$E_2 = \left(\frac{p_2}{\yen_w}\right) + \left(\frac{V_2^2}{2g}\right) \quad (10)$$

$$E_3 = \left(\frac{p_3}{\yen_w}\right) + \left(\frac{V_3^2}{2g}\right) \quad (11)$$

$$E_4 = \left(\frac{p_4}{\yen_w}\right) + \left(\frac{V_4^2}{2g}\right) \quad (12)$$

The outflow energy (O) of flow is computed by,

$$O_1 = p_1Q_1 + \circ\left(\frac{Q_1V_1}{2}\right)^2 \quad (13)$$

$$O_2 = p_2Q_2 + \circ\left(\frac{Q_2V_2}{2}\right)^2 \quad (14)$$

$$O_3 = p_3Q_3 + \circ\left(\frac{Q_3V_3}{2}\right)^2 \quad (15)$$

$$O_4 = p_4Q_4 + \circ\left(\frac{Q_4V_4}{2}\right)^2 \quad (16)$$

2.1 Losses at Pipe Bifurcation:

- The bifurcations are provided in pipes to change the direction and division of flow through it. An additional loss of head, apart from that due to fluid friction, takes place in course of flow through pipe bend.
- The fluid takes a curved path while flowing through a pipe bifurcation as shown in Figure 5. The flow near the sharp corners creates turbulence and separation.

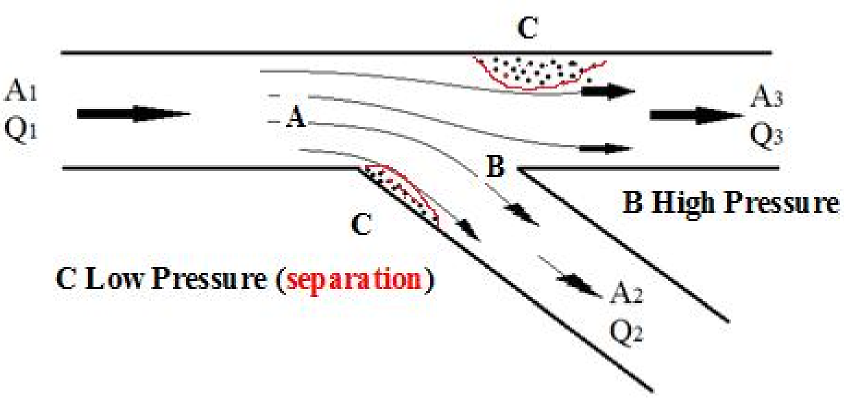

Figure 5 Losses in Right Bifurcation

This results in an increase in pressure near the outer wall of the bend, starting at some point 'A' (Figure 6) and rising to a maximum at some point 'B'. There is also a reduction of pressure near the inner wall giving a minimum pressure at C and a subsequent rise from C to B.

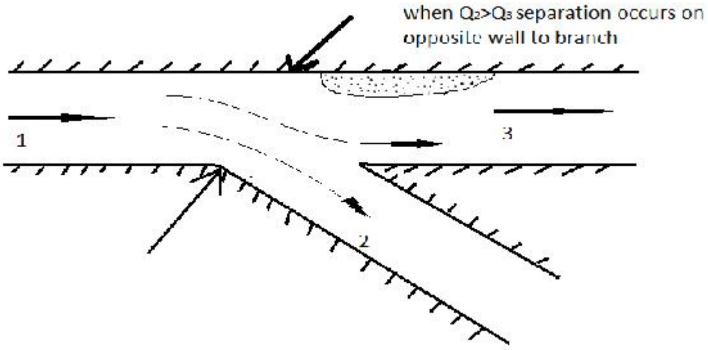

Figure 6 Right Bifurcation in Pipe flow

Therefore between A and B and between C and towards outflow the fluid experiences an adverse pressure gradient (the pressure increases in the direction of flow).

Whenever a fluid flows in a curved path, force acting radially inwards on the fluid to provide the inward acceleration, known as centripetal acceleration. Fluid particles in this region, because of their close proximity to the wall, have low velocities and cannot overcome the adverse pressure gradient and this leads to a separation of flow from the boundary and consequent losses of energy in generating local eddies. Losses also take place due to a secondary flows in the radial plane of the pipe because of a change in pressure in the radial depth of the pipe.

This flow, in conjunction with the main flow, produces a typical spiral motion of the fluid which persists even for a downstream distance of fifty times the pipe diameter from the central plane of the bend. This spiral motion of the fluid increases the local flow velocity and the velocity gradient at the pipe wall, and therefore results in a greater frictional loss of head than that which occurs for the same rate of flow in a straight pipe of the same length and diameter.

The additional loss of head due to friction the loss of head will occur due to change in direction, change in diameter and pipe bends. The bend loss and is usually expressed as a fraction of the velocity head as:

$$H_{bend} = \left(\frac{KV^2}{2g}\right) \qquad (17)$$

Where 'V 'is the average velocity of flow through the pipe. The value of 'K' depends on the total length of the bend and the ratio of radius of curvature 'R' of the bend and pipe diameter 'D' and is given as:

$$K = f\left(\frac{R}{D}\right) \qquad (18)$$

The radius of curvature R is usually taken as the radius of curvature of the centre line of the bend. The factor 'K' varies slightly with Reynolds number 'Re' in the typical range of Re encountered in practice, but increases with surface roughness.

3. Experimental Setup

The experimental setup consists of half Horse Power pump, 600 mm manifold to maintain the constant pressure in the pipe line. A 100 mm pipeline is used as main pipe which bifurcates into 75 mm pipelines of galvanized iron material. The pressure gauges and flow meter are installed to know the line pressure and the values of discharge in each pipe varied from 10° to 30° (4-variants in bifurcation angle). The flows through the pipes are discharged to a recirculating collecting tank. The readings for pressure and discharge are taken for a given bifurcation angle at various flow rates. The temperature of water is noted at the beginning and end of the experiment.

Figure 7 Experimental setup

3.1 *Valve control combination:*

The check valves, pressure gauges and flow meter are provided in each pipe. The valves are controlled to achieve the desired flow rate and pressure in each pipe. The conditions of valves are varied to obtain pressure loss coefficient (K) for each combination (Refer Figure 1 to 3).

- Valve 1, 3 are fully open
- Valve 2 is controlled
- Valve 4 is closed
- Temperature = $24^{O}C$ -$27^{O}C$

4 Results and Discussions

Obtained data is analysed to obtain the hydraulic loss of co-efficient for individual pipes (K_{12} and K_{13}) and for the junction (K) based on equation 8.

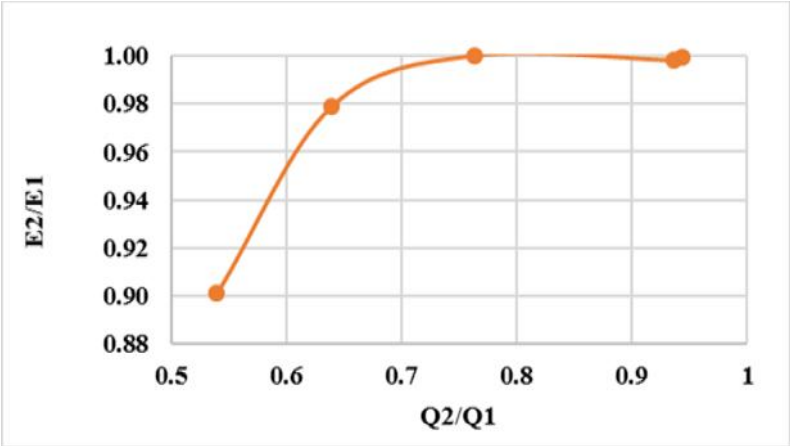

Figure 8 Energy Ratio Vs. Split Flow Ratio

As the split flow ratio in branch pipe-2 increases the flow energy in the branch pipe-2 also increases as shown in the Figure 8. The non-dimensional parameters like energy ratio (E_2/E_1),
Flow ratio (Q_2/Q_1), pressure ratios (P_2/P_1) are computed.

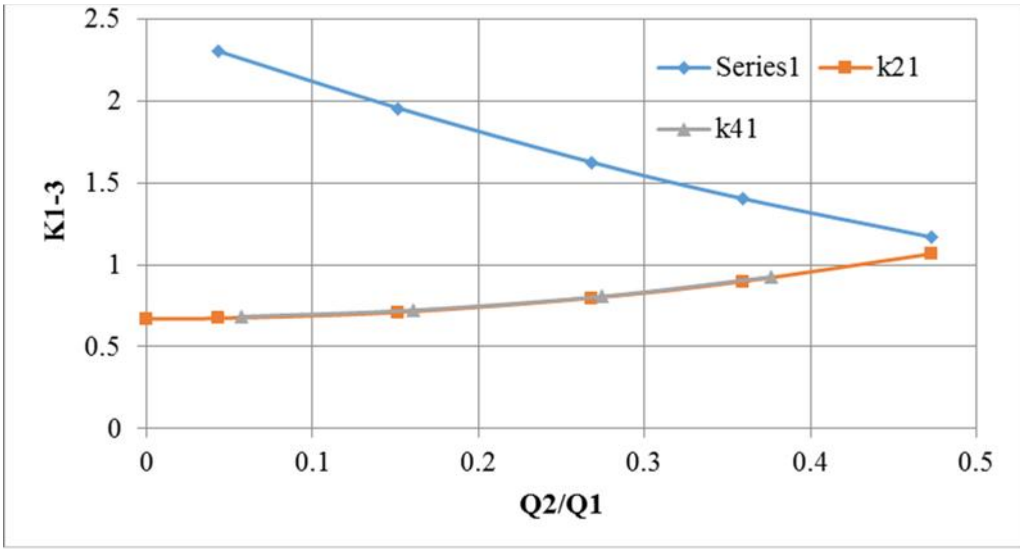

Figure 9 Pressure Loss Coefficient Vs Discharge Ratio

Figure 10 shows the variation of loss coefficients of branch pipes with their respective split flow ratios. The loss coefficients for the straight pipe (branch 3) in relatively more as compared to the branched pipes 2 and 4 whose 10°& 20°.The graph also shows as the flow in the bifurcated pipes tend to equalize

(i.e. $\left(\frac{Q_2}{Q_1}\right)=\left(\frac{Q_3}{Q_1}\right)=\left(\frac{Q_4}{Q_1}\right) \cong \mathbf{0.5}$. The overall loss coefficients (K) at bifurcation tend to reduce to minimum.

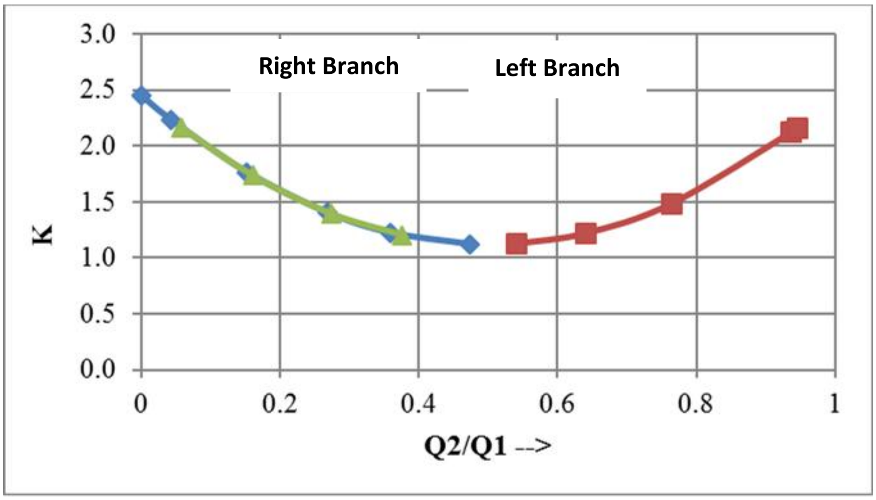

Figure 10 Pressure Loss Coefficient Vs Discharge Ratio

Figure 10 gives a comprehensive value for a combined loss co-efficient at bifurcation (K) with the split flow ratio and also clearly signifies that pressure loss behaviour is symmetrical for right and left bifurcation for a given θ. It also clearly indicates as the split flow ratio are nearly equal, the pressure loss co-efficient is minimum and the value is near unity.

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

The pressure distribution in a typical bifurcation is shown through the results obtained from Computational Fluid Dynamics in figure 11.

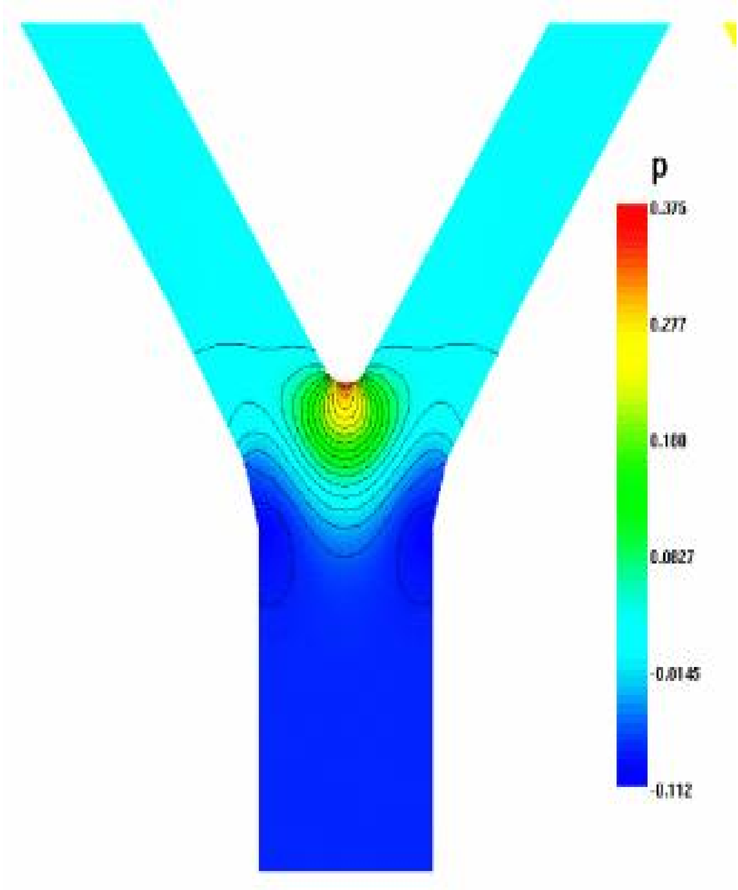

Figure 11 Pressure distribution from Computational Fluid Dynamics

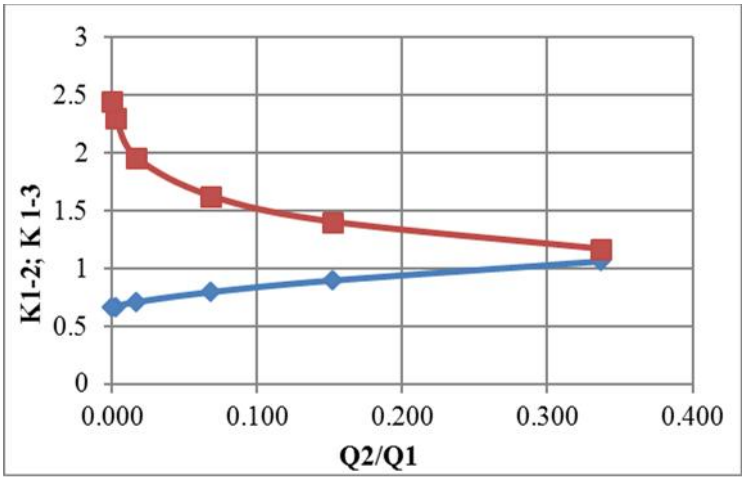

Figure 12 Branch Pressure Loss Coefficient Vs Ratio of Outflow Energy

The nature of the figure 11 is similar to figure 12. It indicates that the pressure loss coefficients also related to the out flow energy at the various branches and the value is optimized when the flow is splits into equal discharge.

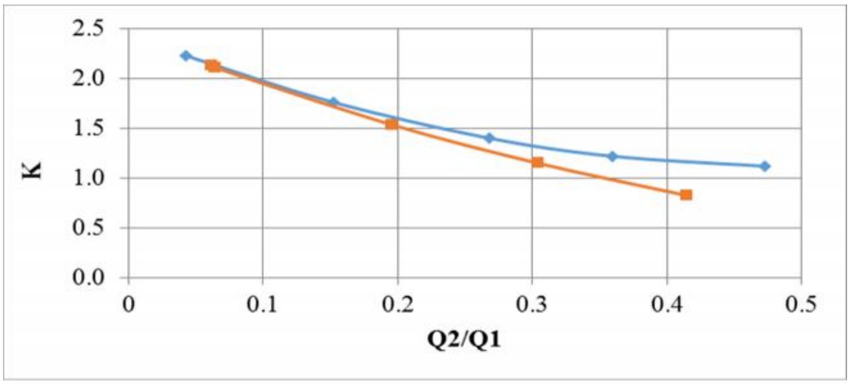

Figure 13 Combined Loss Co-efficient Vs Split Flow Ratio for extreme angles

Table - 1 Experimental Data

Discharge Pipe 2 Q_2 (cm^3/s)	Discharge Pipe 3 Q_3 (cm3/s)	Net Discharge $Q_1=Q_2+Q_3$ (cm3/s)	Ratio Q_2/Q_3	Ratio Q_3/Q_1	Energy Ratio at Inlet E_2/E_1	Energy Ratio at Inlet E_3/E_1	Energy Ratio at outlet O_2/O_1	Energy Ratio at outlet O_3/O_1
373.6921	416.4931	790.1852	0.47291	0.52708	0.983	0.522	0.337	0.460
283.6879	505.8169	789.5048	0.35932	0.64067	0.977	0.691	0.152	0.821
201.4099	550.055	751.4649	0.26802	0.73197	0.979	0.730	0.068	1.215
115.8883	647.6684	763.5567	0.15177	0.84822	0.987	0.740	0.017	1.873
32.06567	712.7584	744.824	0.04305	0.95695	0.982	0.788	0.003	2.662

4. Conclusions

Detailed experiments are conducted to understand the pressure loss at pipe bifurcation with various parameters. The loss behaviour at the pipeline bifurcation has been tested for right, left and central bifurcation. It is observed that for a given bifurcation angle, the loss coefficients for the right and left bifurcation are nearly same. *The experimental findings also suggest that the minimum loss at the pipe line junction will occurs when the split flow ratios are equal.* Also the loss co-efficient increases as the branch angle increases. The head loss at the pipe bifurcation junction is contributed by both the individual pipes and angle of bifurcation. In case of straight pipe bifurcation, the contribution of head loss is relatively more by the straight pipe compared to branch pipe. It is planned to conduct more experiments with angles of bifurcation 12.5°, 15°, 25° and 30°.

References

- Achantha Ramakrishna Rao, Bimlesh Kumar (2009). Energy losses at pipe trifurcation. *Urban Water Journal*, Vol.6 (4).
- Albert Ruprecht, Tomas Helmrich, Ivana Buntic (2003). Very large eddy simulation for the prediction of unsteady vortex motion. *12th International Conference on Fluid Flow Technologies*, 3-6.
- Blevins, R D. (1984) *Applied fluid dynamics handbook*. Van Nostrand Reinhold Co., New York, USA.
- Bransilav Basara, Herwig A Grogger. (2000) Experimental and numerical study of the flow through trifurcation, *Advanced Stimulation Technologies*.
- RK Malik, Paras Paudel, (2009) 3D Flow Modelling of the Trifurcation Made in Nepal, *Hydro Nepal*, 56-61 (9).
- Miller, D.S (1990). *Internal flow systems 2nd Edition*. Gulf Publishing Company, Houston, USA