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Determination of Optimum Pressure loss and Flow Distribution at Pipe Bifurcation and Trifurcation

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***Abstract:** The friction losses in pipe junction is important in many situations like flow distribution in pipes and penstocks. The design of a efficient branching with desired flow distribution having minimum hydraulic loss need to be developed. An experimental approach is selected to evaluate the friction losses at the junction of the pipe branching '$K = \Delta P$'. It is desired to know at what split flow ratio and pipe junction geometry the pressure loss at junction is minimum. The paper focuses in determination of pressure losses and flow distribution at pipe branching using the experimentally at various flow rates and pressures. The complexity of pressure drop at pipe junction is high particularly at high Reynolds number. An attempt has been made to study experimentally, the pressure loss at pipe bifurcation and trifurcation with three different angles of branching 20°, 25° and 30°. The pipe line pressure is varied between 50 KPa to 200 KPa. The experimental data and analysis for 25.4mm main and 19.05 mm bifurcation and trifurcation pipes show the correlation between pressure loss coefficient (K) with a split flow ratios $\left(\frac{Q_2}{Q_1}\right)$, $\left(\frac{Q_3}{Q}\right)$, $\left(\frac{Q_4}{Q_1}\right)$. It is found that the turbulence at pipe junction, angle of branching, and diameter ratio are mainly responsible for losses and separation of flow. The overall bifurcation and trifurcation loss coefficient (K) and individual branch loss coefficients (K_{12}, K_{13}, K_{14}) have been computed and correlation between pressure ratio, split flow ratio and loss coefficients have been developed. The optimum value of overall pressure loss coefficients are obtained for different flow ratios. The experimental findings also suggest that the head loss at the bifurcation and trifurcation junction will be minimum when nearly equal discharge flow in branched pipes. New correlations have been developed. The experiments conducted at different pipe line pressures also indicate that the overall bifurcation and trifurcation loss coefficient (K) is high for higher line pressures.*

***Keywords:** Bifurcation and trifurcation, split flow ratio, optimum loss co-efficient.*

I. INTRODUCTION

Pipe networks are very common in industries, where fluid or gases to be transported from one location to the other. The pressure loss may vary depending on the type of components coming across in the network, material of the pipe, and the fluid that is being transported through the network. The placement of valves, pumps and turbines is important to overcome the pressure loss caused by the other components in the network. This is one of the important reasons why this study was conducted. The union of two streams of different velocities results in mixing of the streams and changes in both velocity and pressure of both streams.

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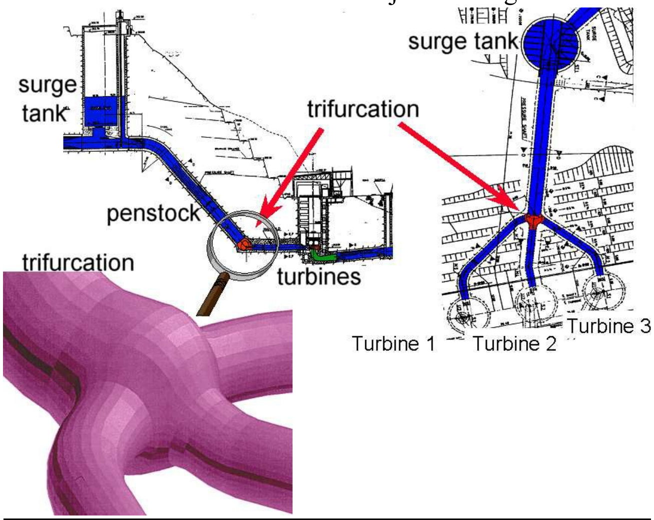
The exchanges of fluid momentum results energy transfer from faster moving to lower components with a single flow path. There is also a need for flow parameter to account for the distribution of flow between the junction legs.



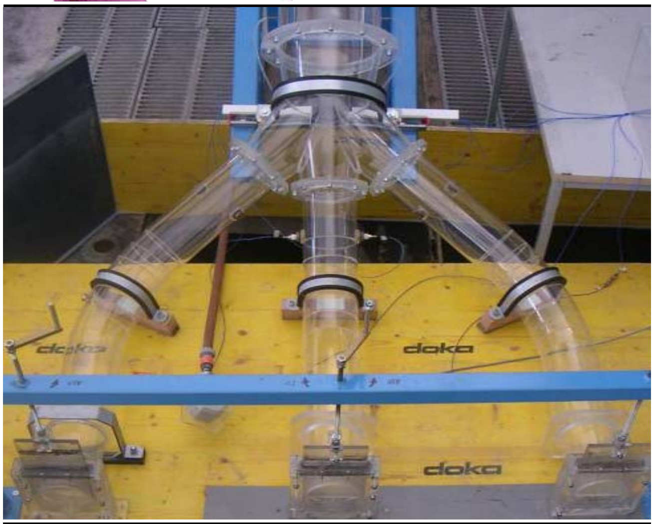


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Fig 1. General layout of pipe Bifurcation and Trifurcation.

Major energy losses due to combining and dividing flow arises separation and subsequent turbulent mixing. Under study should meet maximum flow efficiency under the physical constraints of fabrication. The flow efficient profile was then analyzed to capture the stress amplification near junction.

Minor loss is a term used to describe losses that occur in fittings, expansions, contractions etc. Fittings commonly used in the industry include bends, tees, elbows, unions, and of course, valves used to control flow. Major losses of head in a piping system are the direct result of fluid friction in pipes and ducting. The resulting head losses are usually computed through the use of friction factors. Friction factors for ducts have been compiled for both laminar and turbulent flows.

The branching are part of the architectural complex that forms the hydroelectric plant, which together with others, parts and equipment has the purpose to produce electricity using the hydraulic potential existing in a damming or a river. Whereas the optimal operating point of the pipeline systems, the losses must be reduced to obtain the best operating condition, with fields of stable flow. These conditions can be defined from tests in preliminary models to obtain appropriate geometries, with controlled load losses and variations of flow supplying the turbines.

This practice leads to high pressure losses occurring at the pipe junction and reduces the available head (H_{net}) to turbine for power generation (P), and thereby reducing the overall efficiency the hydro power plant as given by Eq.(1)

$$P = \frac{\gamma_w Q H_{net}}{75}\eta_o \quad \text{...(1)}$$

1.1 Objectives

- *T*o compute the pressure loss coefficients 'K' at pipe bifurcation and trifurcation.
- The loss co-efficient and flow ratio for bifurcation and trifurcation for a given pressure ratio and geometry.
- To investigate the pressure losses occurring at the pipe bifurcation and trifurcation and develop general guidelines for determination of split flow ratios.
- To draw nomograms for best operation of the penstock system.
- Design of good bifurcation /trifurcation with desired flow distribution with minimum hydraulic loss need to be developed.
- To determine the profile which gives maximum discharge and minimum head loss

II. METHODOLOGY

The friction losses in the penstocks while conveying water from the overhead reservoir to the power house are of considerable importance. It is a common practice to use larger diameter pipes for at the power house to feed the water to individual turbines. The computation is based on the principle of conservation of mass called continuity equation. Thus for a fluid flowing through a pipe at all the cross section the quantity of fluid per second is constant.

Fig2. Experimental setup.

According to law of conservation of mass, $\rho_1 A_1 V_1 = \rho_2 A_2 V_2$

The equation is applicable to the compressible as well as incompressible fluids and is called "Continuity equation". if the fluid is incompressible then $\rho_1 = \rho_2$.

The equation reduces to, $A_1 V_1 = A_2 V_2$. If the net head of water and discharge at inlet is 'h' and 'Q' respectively then from the continuity equation for the equal discharge among branch pipes, expected discharge through each nozzle = $\frac{Q}{2}$ or $\frac{Q}{3}$, The evaluation of real velocity at the outlet of the jet can help us to evaluate the loss of head by using energy equation. The inlet energy per unit time = Work done by Pressure per unit time + Kinetic Energy

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$$Inlet\ Energy / Time = P_1Q_1 + \frac{\rho Q_1 U_1^2}{2} \quad ....(2)$$

$$Outlet\ Energy / Time = \frac{\rho Q_2 U_2^2}{2} + \frac{\rho Q_3 U_3^2}{2} + \frac{\rho Q_4 U_4^2}{2} \quad ....(3)$$

ρ : Density of water $1 g/cm^3$, Q_1: Discharge in main pipe, γ_w : Unit weight of water $1000 kg/m^3$,

Q_2, Q_3, Q_4 Discharge in Branching, U_1, U_2, U_3,, U_4: Velocities in branch pipes

III. OBSERVATIONS AND DISCUSSION

The variation between the loss co-efficient with discharge ratio for bifurcation and trifurcation shows decreasing trend in initial range of discharge ratio and increases gradually for higher values of discharge ratio such variations are attributed to flow turbulence. The formula adopted is tabulated in Table 1. The loss co-efficient is found to increase for initial discharge ratio and attain a parabolic shape with minimum value of K in the middle range of discharge ratio and increases parabolic ally for higher values of discharge ratios. Hence the effect of line pressure is significant. The effect of stream lining is more pronounced in high pressure. The loss co-efficient shows parabolic trend for angles of bifurcation and trifurcation 20^0,25^0 and 30^0 shows minimum value of K at middle values of split flow ratio. The split flow discharge to 20^0,25^0 and 30^0 angle of bifurcation and trifurcation shows concluding trend due to high pumping capacity and more pressure developed in distribution system. As the flow increases in the particular branch, split flow ratio of the remaining branch shows same trend for 20^0,25^0 and 30^0 angle of bifurcation and trifurcation. The readings are tabulated in Table No 2 and 3.

Table 1

Details	Formula
Pressure loss coefficient K_{12}	$2000(\Delta P)/U_{12}+0.67+0.56(U_2/U_1)^2$
Pressure loss coefficient K_{13}	$2000(\Delta P)/U_{12}+0.67+0.56(U_3/U_1)^2$
Pressure loss coefficient K_{14}	$2000(\Delta P)/U_{12}+0.67+0.56(U_4/U_1)^2$

Table 2 (Trifurcation)

Sl No	Time for flow of 10 ltr of water in the branch pipe No 2	Time for flow of 10 ltr of water in the branch pipe No 3	Time for flow of 10 ltr of water in the branch pipe No 4	Discharge in branch pipe No 2	Discharge in branch pipe No 3	Discharge in branch pipe No 4	Total discharge	Ratio	Velocity in branch No 1	Velocity in branch No 4	Loss coefficient	Loss coefficient	Loss coefficient	Combined k	Ratio
	$T_{2\,(Sec)}$	$T_{3\,(Sec)}$	$T_{4\,(Sec)}$	Q_2=10000/T_2 (Cm^3/s)	Q3=10000/T_3 (Cm^3/s)	Q_4=10000/T_4 (Cm^3/s)	Q_1 = Q_2+Q_3+Q_4 Cm^3/s	Q_2/Q_1	U_1 Cm/s	U_2 Cm/s.	$K_{1\text{-}2}$	$K_{1\text{-}3}$	$K_{1\text{-}4}$	K	Q_3/Q_4
1	406.80	25.60	26.36	48.88	390.63	379.36	818.86	0.06	161.58	15.56	0.69	1.02	0.99	0.99	1.03
2	204.60	26.39	27.07	7.00	378.93	369.41	755.34	0.01	149.05	2.23	0.69	1.06	1.03	1.04	1.03
3	120.30	27.50	28.21	28.21	363.64	354.48	746.33	0.04	147.27	8.98	0.70	1.04	1.01	1.01	1.03
4	95.90	28.43	29.23	136.84	351.74	342.11	830.69	0.16	163.92	43.55	0.73	0.95	0.93	0.90	1.03
5	73.08	29.30	30.68	178.13	341.30	325.95	845.37	0.21	166.81	56.69	0.75	0.92	0.90	0.88	1.05
6	56.14	31.20	32.47	208.25	320.51	307.98	836.74	0.25	165.11	66.28	0.78	0.90	0.88	0.86	1.04
7	48.02	32.72	34.06	265.53	305.62	293.60	864.76	0.31	170.64	84.51	0.82	0.86	0.85	0.85	1.04
8	37.66	36.50	38.50	265.53	273.97	259.74	799.25	0.33	157.71	84.51	0.85	0.86	0.83	0.85	1.05
9	31.24	35.10	42.80	320.10	284.90	233.64	838.65	0.38	165.49	101.88	0.90	0.86	0.79	0.85	1.22
10	27.99	42.90	43.90	357.27	233.10	227.79	818.16	0.44	161.45	113.71	0.97	0.80	0.79	0.87	1.02
11	16.31	35.60	37.82	613.12	280.90	264.41	1158.43	0.53	228.59	195.14	1.09	0.76	0.75	0.93	1.06
12	22.34	52.40	51.30	447.63	190.84	194.93	833.40	0.54	164.45	142.47	1.11	0.76	0.75	0.95	0.98

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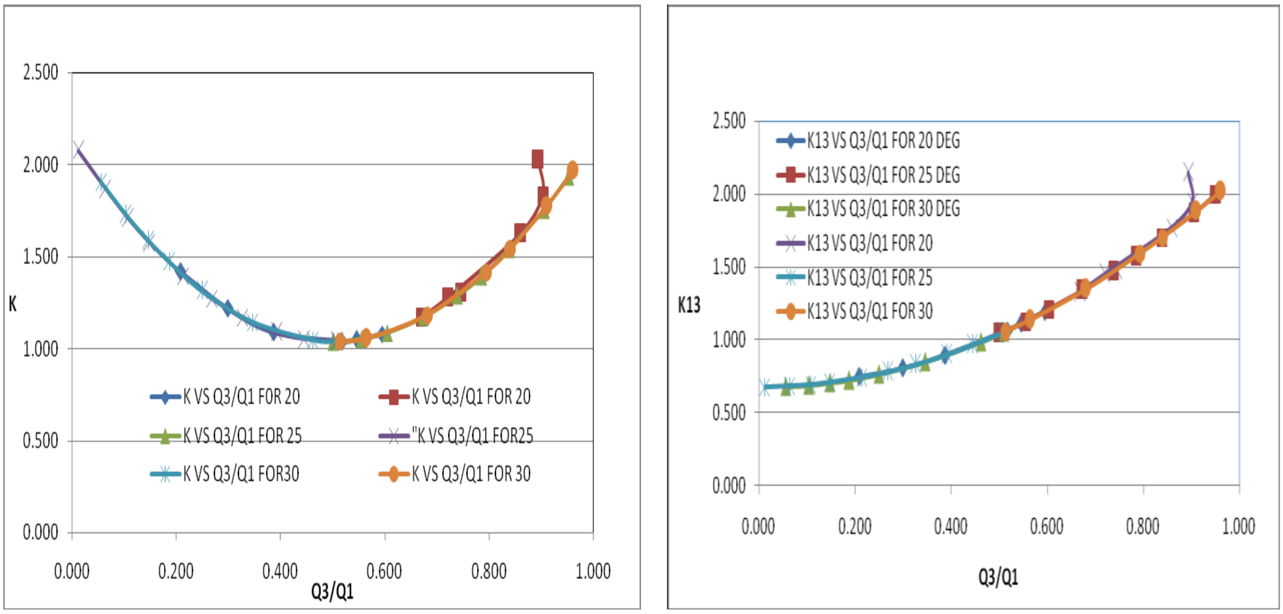

Fig 3: Loss co-efficient Vs Discharge ratio

The fig 3 shows the variation of combined loss co-efficient K with discharge ratio Q_3/Q_1. The value of K decreases as the discharge ratio increases in the initial stage and attains the value of min 0.45 and further increases in the split flow ratio the combined K increases and attains the value of 1.20, whereas the loss coefficient between the main pipe and branch pipe No 3 increases exponentially and attains the value of 1.20 for all angle of trifurcations.

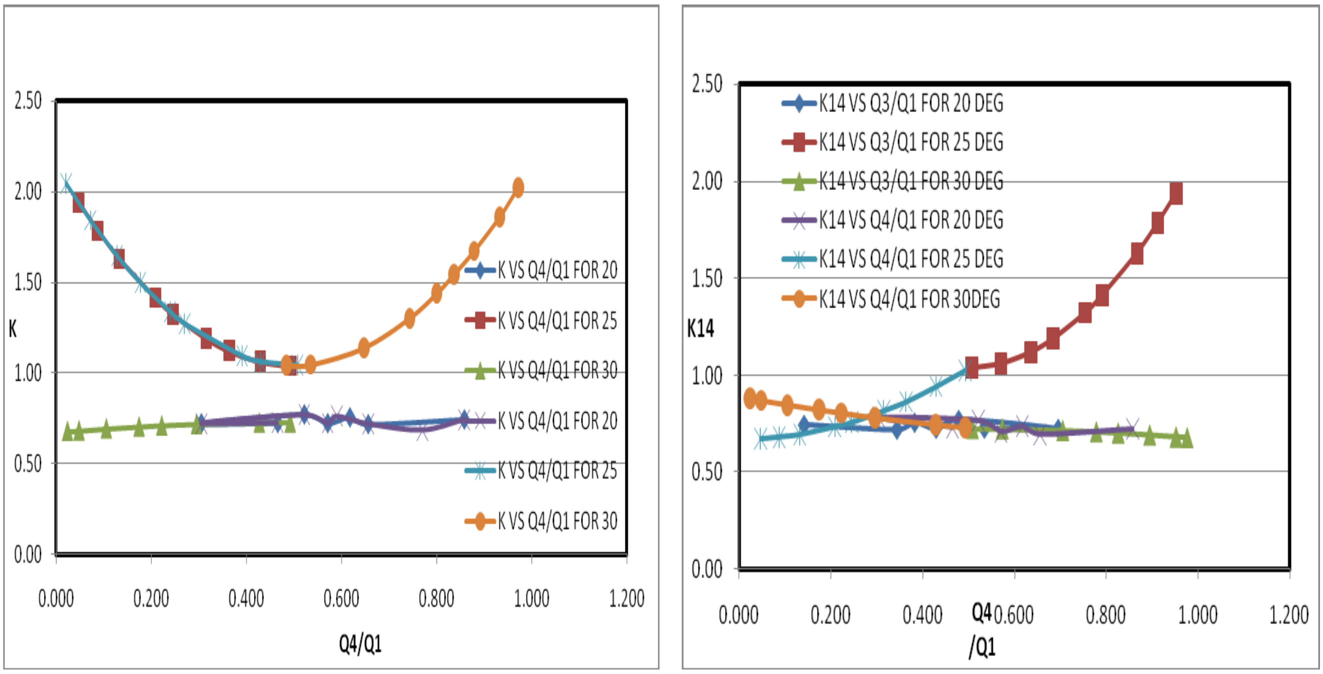

Fig 4: Loss Loss co-efficient Vs Discharge ratio

The fig 4 shows the variation of combined loss co-efficient K with discharge ratio Q_4/Q_1. The value of K decreases as the discharge ratio increases in the initial stage and attains the value of min 0.45 and further increases in the split flow ratio the combined k increases and attains the value of 1.20.Whereas the loss coefficient between the main pipe and branch pipe No 4 increases exponentially and attains the value of 2.0 for all 20^0 25^0 and 30^0 angle of trifurcations.

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Table 3(Bifurcation)

	Sec.	Sec.	Cm³/sec.	Cm3/sec.	Cm³/sec.	--	--	Cm/sec.	Cm/sec.	Cm/sec.	Kg/cm²	Kg/cm²	Kg/cm²	--	--	--		
	T_3	T_4	Q_3=10000/T_3	Q4=10000/T4	$Q_1 = Q_3+Q_4$	Q_3/Q_1	Q_4/Q_1	U_1	U3	U_4	P_1	P_3	P_4	P_3/P_1	P_4/P_1	$K_{1\text{-}3}$	$K_{1\text{-}2}$	Combined K
Sl No	Time for flow of 10 ltr of water in the branch pipe No 2	Time for flow of 10 ltr of water in the branh pipe No 3	Discharge in branch pipe No 2	Discharge in branch pipe No 3	Total discharge	Ratio	Ratio	Velocity in branch No 1	Velocity in branch No2	Velocity in branch No 3	Pressure in branch No 1	Pressure in branch No 2	Pressure in branch No 3	Ratio	Ratio	Loss coefficient	Loss coefficient	
		Q3 fully open Q4 controlling Q2 CLOSED						Angle 25°										
1	12.82	13.15	780.031	760.456	1540.487	0.506	0.494	303.497	247.865	241.645	1.500	0.750	0.800	0.500	0.533	1.060	1.040	1.050
2	12.75	14.15	784.314	706.714	1491.028	0.526	0.474	293.752	249.226	224.567	1.550	0.800	0.850	0.516	0.548	1.090	1.014	1.054
3	11.83	19.02	845.309	525.762	1371.071	0.617	0.383	270.119	268.608	167.068	1.600	0.950	1.000	0.594	0.625	1.242	0.901	1.111
4	11.19	25.10	893.655	398.406	1292.061	0.692	0.308	254.553	283.970	126.599	1.650	1.080	1.120	0.655	0.679	1.385	0.825	1.212
5	10.35	58.40	966.184	171.233	1137.416	0.849	0.151	224.086	307.017	54.411	1.700	1.250	1.350	0.735	0.794	1.739	0.717	1.585
								Angle 30°										
1	13.70	14.70	729.927	680.272	1410.199	0.518	0.482	277.828	231.944	216.165	1.500	0.750	0.700	0.500	0.467	1.080	1.030	1.056
2	12.11	16.78	825.764	595.948	1421.711	0.581	0.419	280.096	262.397	189.370	1.550	1.000	0.950	0.645	0.613	1.175	0.941	1.077
3	11.80	20.62	847.458	484.966	1332.424	0.636	0.364	262.505	269.291	154.104	1.600	1.100	1.050	0.688	0.656	1.274	0.879	1.130
	11.05	27.48	904.977	363.901	1268.878	0.713	0.287	249.986	287.568	115.634	1.650	1.200	1.200	0.727	0.727	1.425	0.804	1.247
4																		
5	10.05	137.80	995.025	72.569	1067.594	0.932	0.068	210.330	316.182	23.060	1.700	1.450	1.450	0.853	0.853	1.947	0.688	1.861
	Q4 fully open Q3 controlling Q2 CLOSED							Angle 25°										
1	12.28	12.35	814.332	809.717	1624.049	0.501	0.499	319.959	258.765	257.298	1.500	0.750	0.800	0.500	0.533	1.051	1.046	1.048
2	14.45	12.25	692.042	816.327	1508.368	0.459	0.541	297.169	219.905	259.398	1.550	0.800	0.870	0.516	0.561	0.994	1.112	1.058
3	17.34	11.87	576.701	842.460	1419.161	0.406	0.594	279.594	183.254	267.703	1.600	0.950	0.970	0.594	0.606	0.927	1.199	1.089
4	22.20	11.20	450.450	892.857	1343.308	0.335	0.665	264.650	143.136	283.717	1.650	1.100	1.100	0.667	0.667	0.850	1.329	1.168
5	35.20	10.54	284.091	948.767	1232.858	0.230	0.770	242.889	90.274	301.483	1.700	1.200	1.250	0.706	0.735	0.764	1.548	1.367
6	104.60	10.08	95.602	992.063	1087.666	0.088	0.912	214.285	30.379	315.241	1.750	1.400	1.400	0.800	0.800	0.696	1.897	1.792
								Angle 30°										
1	13.70	14.70	729.927	680.272	1410.199	0.518	0.482	277.828	231.944	216.165	1.500	0.750	0.700	0.500	0.467	1.080	1.030	1.056
2	14.23	13.80	702.741	724.638	1427.378	0.492	0.508	281.213	223.305	230.263	1.550	0.800	0.730	0.516	0.471	1.042	1.066	1.054
3	16.51	13.34	605.694	749.625	1355.319	0.447	0.553	267.016	192.467	238.203	1.600	0.800	0.800	0.500	0.500	0.983	1.138	1.069
4	21.22	12.50	471.254	800.000	1271.254	0.371	0.629	250.454	149.747	254.210	1.650	1.100	1.000	0.667	0.606	0.888	1.268	1.127

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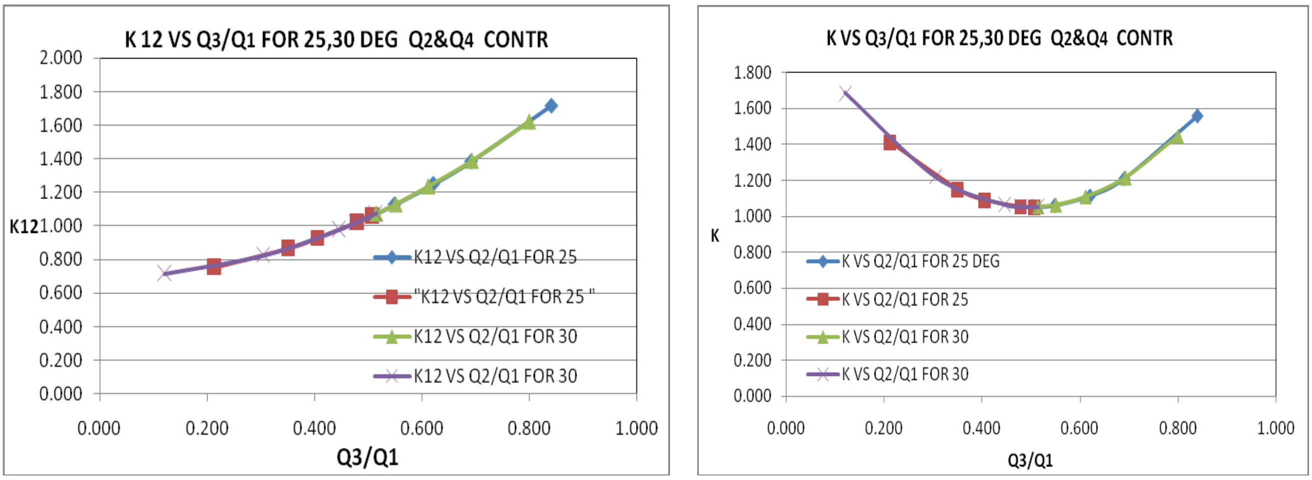

Fig 5: Loss co-efficient Vs Discharge ratio.

The curve shows the higher value of the loss coefficient at the low discharge and high discharge in the pipe 3 the minimum value of head loss coefficient is obtained at the discharge ratio of 0.1.This indicates the loss due to pipe bifurcation is more for low discharge ratio of Q_3/Q_1.The value of k_{12} increases as Q_3/Q_1 increases for all angle of bifurcation.

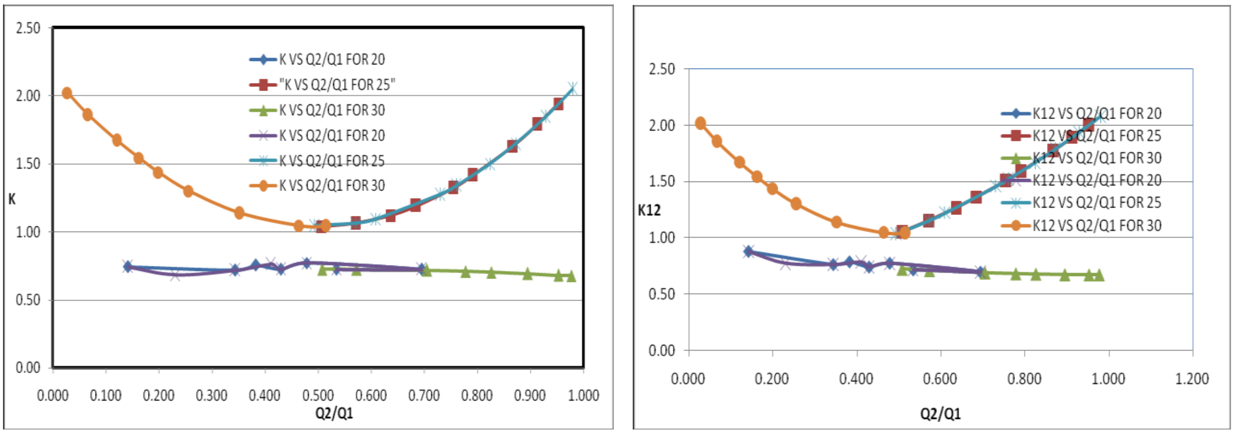

Fig 6: Loss co-efficient Vs Discharge ratio.

The fig 6 shows the variation of combined loss co-efficient K and branch loss coefficient K12 with discharge ratio Q2/Q1. The value of K and K12 decreases as the discharge ratio increases in the initial stage and higher the angle higher is the loss and attains the min value of 1.00 for the discharge ratio of 0.5 for both loss coefficient of combined K as well as loss coefficient between main pipe and branch No2.and the loss coefficient increases as the discharge ratio further increase decreases turbulence and eddies formation.

IV. CONCLUSION

The flow ratios in the pipe have been studied in pipe bifurcation and trifurcation for different pressure flow rates and bifurcation and trifurcation angles. The value of loss coefficient increases as the flow increases in the main pipe. The pressure loss coefficient attains optimum value when the discharge is nearly equal in branch pipes. The value of pressure loss coefficient increases as the bifurcation and trifurcation angle increases. The Reynolds number of flow for the experiment is from transition to fully turbulent region. The effect of pipe line pressure for the value of loss coefficient is under study. The bifurcation and trifurcation is symmetrical the loss coefficient behavior of the right side branch pipe is similar to the left side branch pipe. The value of combined loss coefficient varies parabolically for different angles of bifurcation. The value of branch loss coefficient increases as the discharge ratio of branch to main pipe increases for all angles of bifurcation. The value of loss coefficient is increases as the bifurcation angle increases.

REFERENCES

1. Amit Anakiya, Hiren Prajapati, Sunil Prajapati (2014) Analysis of the penstock for pit turbine using computational fluid dynamics IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 3 Ver. V (2014), PP 36-42
2. Albert Ruprecht, Thomas Helmrich, Ivana Buntic, Very large eddy simulation for the prediction of unsteady vortex motion, Conference on Modeling Fluid Flow (CMFF'03) The 12th International Conference on Fluid Flow Technologies Budapest, Hungary, September 3 - 6, 2003
3. Aguirre C.A, Ramirez R.G, Head losses analysis in symmetrical trifurcations of penstocks - high pressure pipeline systems cfd Camacho Instituto de Engenharia Mecânica, Universidade federal de Itajubá.
4. Lu, J., Chang, T., Chiew, Y., Hung, S., and Hong, J. (2011). Turbulence characteristics of flows passing through a tetrahedron frame in a smooth open-channel. Advances in Water Resources, 34(6), 718–730.
5. Malik R K & Paras Paudel (2009) 3D flow modeling of the first trifurcation made in Nepal (Hydro Nepal Issue)
6. OBASI1, N.L., OLOKE2, D.A., "Flow Distribution Design Charts for Bifurcation at Convex Channel Curvature", International Journal of

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& Sciences Publication Pvt. Ltd.

Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 2, Issue 12, December 2012).

7. Paritosh R. Vasava, "Fluid Flow in T-Junction of Pipes", Lappeenranta University Of Technology.
8. RK Malik, Paras Paudel , "3D Flow Modeling of the First Trifurcation Made in Nepal" HYDRO NEPAL ISSUE NO. 5 JULY, 2009.
9. Mohammed Abdulwahhaba, Prof. Niranjan Kumar Injetib, Ass. Prof. Sadoun Fahad Dakhilc, 'CFD SIMULATIONS AND FLOW ANALYSIS THROUGH A T-JUNCTION PIPE" Mohammed Abdulwahhab et al. / International Journal of Engineering Science and Technology (IJEST).
10. Senoo T., Deguchi K. and Nagata M. "BIFURCATION OF INTERNALLY HEATED FLOW IN A VERTICAL PIPE" 9th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics 16-18 July 2012.
11. Ji Dongyu, Li Lamei "Structure Force Analysis for Reinforced Concrete Bifurcation Pipe of Dongjiang Hydropower Station", International Conference on Mechatronics, Electronic, Industrial and Control Engineering (MEIC 2014).
12. Y. Zhu , X.Y. Luo, R.W. Ogden, "Asymmetric bifurcations of thick-walled circular cylindrical elastic tubes under axial loading and external pressure" International Journal of Solids and Structures 45 (2008) 3410–3429.
13. R.K. Jade, "An experimental and numerical study of two-way splits and junctions in mine airways", 12th U.S./North American Mine Ventilation Symposium 2008 – Wallace (ed) ISBN 978-0-615-20009-5.