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Investigating the Head Loss (Pressure Drop) and Flow Rate with Different Inlet Injectary Angle in Junction and Analysis by using Mathematical Modelling and Software

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Abstract: This topic is generally deals with investigation of head loss (pressure loss) and flow rate suffered by the flow after passing through T-junction and to study the accuracy of classical engineering formulas used to find head loss for T-junction of pipes. In this topic we have compared our results with software packages with classical formula. In this work we have studies head loss in T-junction of pipes with different inlet injectary angles and different inlet velocities, head loss in T-junction of pipes when the angle of the junction is slightly different from 90 degrees and T-junction with different radius of curvature of branches in junction. One of the important purposes of this study is study the change in pressure loss with change in angle of T-junction. [5]. Generally the junction is having two inlet and having one outlet as we say in this topic we study the T-junction for combined flow with different angles in inlet like 90,60,45,30 degree.
Keywords: Combined flow, Flow rate, Head loss, Injectary angles, Radius of curvature, Velocity.

I. INTRODUCTION

Pipe connections are generally used for supply as well as transportation of gases and fluids. These connections are mainly having bunch of pipe connected to each other are in large number. (figure 1.1. shows the water supply connections in large city and industries.). This pipe connections are generally having with addition to pipes and connections also consists of T-junctions, bends, elbows, expansions, valves, contractions, pumps, turbines and many other components. All these additive components cause loss in pressure due to change in momentum of the flow caused due to friction and pipe components. This means conversion of flow energy in to heat due to friction or energy lost due to turbulence. [5]

The connections of pipe are very common in industries, where gases or fluid are to be transported from one location to the other required location. The pressure loss (head loss) is 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. [5]

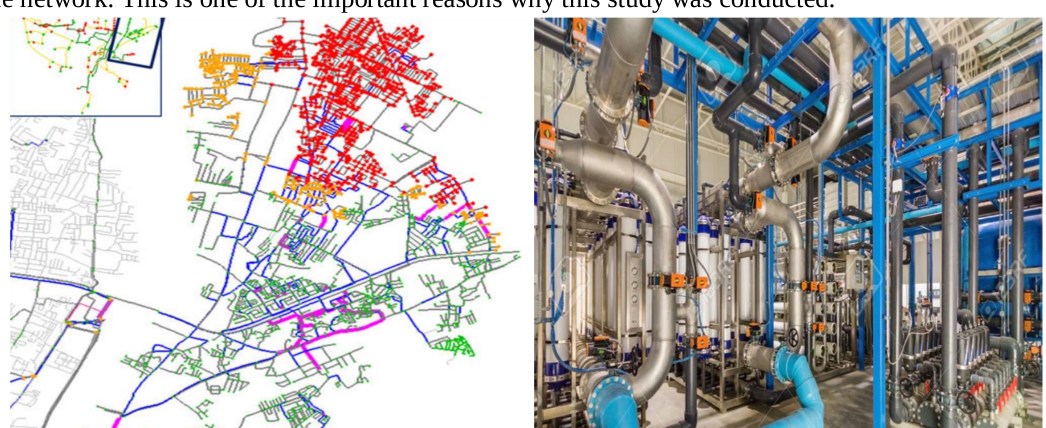

Fig. 1.1: Water Distribution in city and industries.

In this paper we have studied a very common a small component of pipe connection is T-junction ('Tee'). T-junction is a very common component in pipe connection mainly used to distribute the flow from main pipe Depending on the inflow and outflow directions, the behavior of flow at the junction also changes. The following figure 1.2 shows some possibilities of fluid entering and leaving the junction. [5]

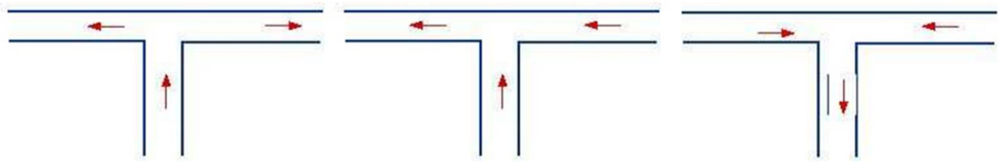

Fig.1.2: Various possibilities of fluid entering and leaving the junction [5]

In present work we will numerically calculate the fluid flow in T-junction of pipes with the results obtained by software were compared with available classical formula and formulas constructed by assuming T-junction to be made up of same components. This comparison also helped in verification of some loss coefficients used in classical formula.

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 Pascals. 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. [5]

In this work, our aim is to study behavior of fluid at T-junction of pipes, head losses caused by T-junction and change in pressure loss with change in angle of the junction.

II. LITERATURE REVIEW

A. Head losses

Head is a term used to specify measure of pressure of total energy per unit weight above a point of reference. In general, head is sum of three components; elevation head (the elevation of the point at which the pressure is measured from above or below the arbitrary horizontal observation point i.e. relative potential energy in terms of an elevation), velocity head (kinetic energy from the motion of water) (it is mainly used to determine minor losses) and pressure head (equivalent gauge pressure of a column of water at the base of the piezometer). [5]

In cases where the fluid is moving with very low velocity or stationary fluid, we ignore the velocity head because the fluid is either stationary or moving with very low velocity and in the cases where the fluid is moving with very high velocity (cases where the Reynolds's number exceeds 10) the elevation head and pressure head are neglected. [5]

Head loss in fluid flow in pipes means loss of flow energy due to friction or due to turbulence. Head losses result in to loss in pressure at final outlet. The pressure loss is divided in two categories of Major (friction) losses and Minor losses. These losses are dependent on both the type of fluid and the material of the pipe.

Head loss is a measure to calculate reduction or loss in head. Head loss is mainly due to friction between fluid and walls of the duct (in our case it is pipe), friction between adjacent layers of fluid and turbulence caused by presence of pipe network components like T-junction, elbows, bends, contractions, expansions, pumps, valves. Head losses result in to loss in pressure at final outlet, thus also known as pressure loss. Pressure losses are divided in to two categories of major losses and minor losses.

1) *Major Losses:* Losses due to friction between fluid and internal pipe surface. These losses occur over the length of pipe. They can be easily determined by Darcy-Weisbach equation. Frictional loss is that part of the total head loss that occurs as the fluid flows through straight pipes
2) *Minor Losses:* Losses occur at points where there is change in momentum. They mainly occur at elbows, bends, contractions, expansions, valves, meters and similar other pipe fittings that commonly occur in pipe networks.

The major head loses may be large when the pipes are long (e.g. pipe network occurring in water distribution in a city) and minor losses will also have a large contribution because of attachments and fittings occurring in these networks. Thus, we can say that head loss in reality are unavoidable, since no pipes are perfectly smooth to have fluid flow without friction, there does not exist a fluid in which flows without turbulence.

The head loss for fluid flow is directly proportional to the length of pipe, the square of the fluid velocity, and a term accounting for fluid friction called the friction factor. The head loss is inversely proportional to the diameter of the pipe. Head loss is unavoidable in pipe networks with real fluids, since there is no pipe with perfectly smooth inner surface and there is no fluid that can flow without turbulence. [5]

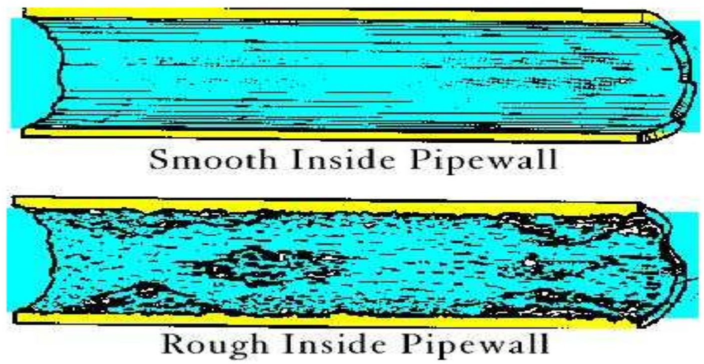

Fig. 2.1: Fluid behavior when pipe is smooth or rough from inside [5]

B. Head Loss Coefficient For T- Junction

The pressure loss caused by the T-junction depends on inner radius of the branches, velocity of fluid entering or leaving from the junction and the angle of the junction (there are various approaches for this calculations; some cases are presented in the following text). There are some classical formulas for pressure loss co-efficient for T-junctions. Most of these formulas depending on angle of T-junction, inlet and outlet velocities. [5] To compute head loss coefficients, we have used formulas derived by Andrew Gardel.

In this section we shall mention the classical formulas and the formulas that were constructed by assuming T-junction to be made up of same components.

T-junction is generally consisting of two types of flow explain as follows:

1) *For Dividing Flows:* These formulas are used for the situation where flow from a single branch flows to the other two remaining branches. The picture in the figure 2.2 gives more clear idea about such flow situations.

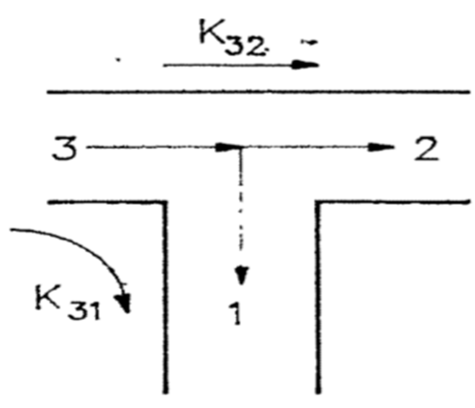

Fig. 2.2 Dividing Flow [6]

The empirical formula obtained by Gardel (1957). His idea was to calculate pressure loss coefficients separately for each inlet (loss coefficient for flow from inlet-3 to outlet-2 and loss coefficient for flow from inlet-3 to outlet-1), so for each flow situation we have two loss coefficients (K31 and K32). These formulas were derived by applying momentum balance to the main pipe section of the junction and equation of continuity to the whole T-junction. Then energy balance is applied individually for each inlet. [6]

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The formula obtained by Gardel is, [4] [6] [7]

$$\mathbf{K31} = 0.95(1-q)^2 + q^2\left[\left(1.3\cot\left(\frac{180-\emptyset}{2}\right) - 0.3 + \left(\frac{0.4-0.1a}{a^2}\right)\left(1-0.9\left(\frac{r}{a}\right)^{0.5}\right)\right] + 0.4q(1-q)\left(\frac{1+a}{a}\right)\cot\left(\frac{180-\emptyset}{2}\right)$$

$$K32 = 0.03(1-q)^2 + 0.35q^2 - 0.2q(1-q)$$

It can be clearly observed that there is no effect of area ratio or radius of pipe on the loss coefficient K32.

Where,

q = flow ratio, Q1/Q3
a = area ratio, A1/A3
r = radius at branch to main junction
∅ = angle of junction

Example: loss coefficient for 90 degree T- Junction Dividing flow

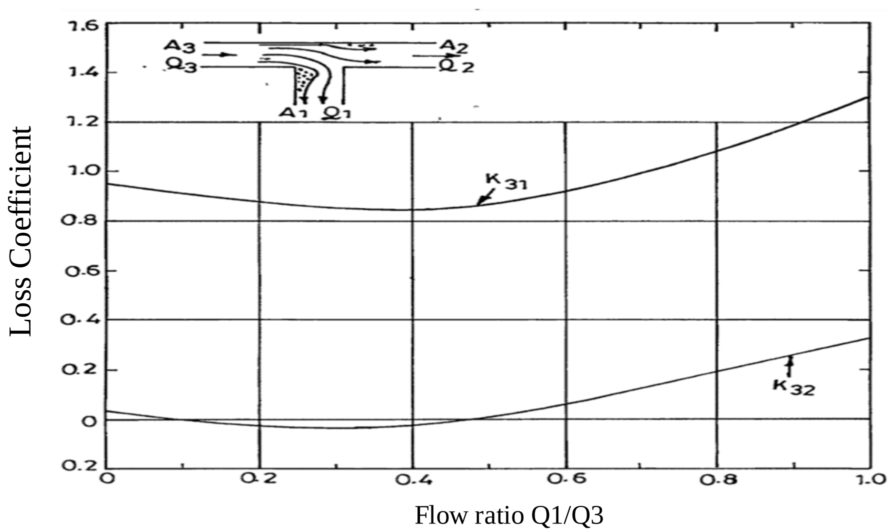

Fig. 2.3 Loss coefficients for sharp edged 90° dividing 'T' [6]

2) *For Combining Flows:* These formulas are used for the situation where flow from two branches combine in the remaining branch. The figure (2.4) gives more clear idea about such flow situations.

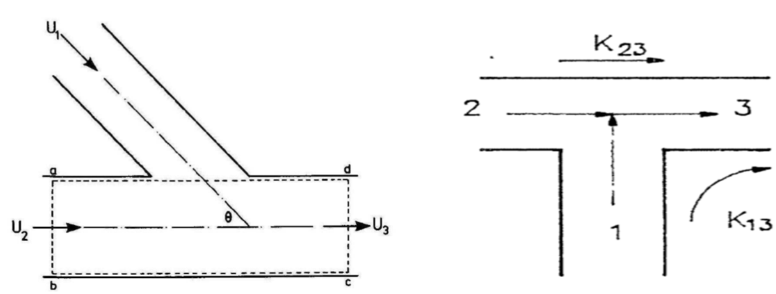

Fig. 2.4 combining flow [6]

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The empirical formula obtained by Gardel (1957). His idea was to calculate pressure loss coefficients separately for each inlet (loss coefficient for flow from inlet-1 to outlet-3 and loss coefficient for flow from inlet-2 to outlet-3), so for each flow situation we have two loss coefficients (K13 and K23). These formulas were derived by applying momentum balance to the main pipe section of the junction (section (5.3)) and equation of continuity to the whole T -junction. Then energy balance is applied individually for each inlet.

The formula obtained by Gardel is, [4] [6] [7]

$$\boldsymbol{K13} = -\boldsymbol{0.92}(\boldsymbol{1}-\boldsymbol{q})^{2} - \boldsymbol{q}^{2}\left[(\boldsymbol{1.2}-\boldsymbol{r}^{0.5})\left(\cos\left(\frac{\emptyset}{\boldsymbol{a}}\right)-\boldsymbol{1}\right)+\boldsymbol{0.8}\left(\boldsymbol{1}-\left(\frac{\boldsymbol{1}}{\boldsymbol{a}^{2}}\right)\right)-(\boldsymbol{1}-\boldsymbol{a})\cos\left(\frac{\emptyset}{\boldsymbol{a}}\right)\right] + (\boldsymbol{2}-\boldsymbol{a})\boldsymbol{q}(\boldsymbol{1}-\boldsymbol{q})$$

$$\boldsymbol{K23} = \boldsymbol{0.03}(\boldsymbol{1}-\boldsymbol{q})^{2} - \boldsymbol{q}^{2}\left[\boldsymbol{1} + (\boldsymbol{1.62}-\boldsymbol{r}^{0.5})\left(\boldsymbol{cos}\left(\frac{\emptyset}{a}\right)-\boldsymbol{1}\right) - \boldsymbol{0.38}(\boldsymbol{1}-\boldsymbol{a})\right] + (\boldsymbol{2}-\boldsymbol{a})\boldsymbol{q}(\boldsymbol{1}-\boldsymbol{q})$$

Where,

q = flow ratio, Q1/Q3

a = area ratio, A1/A3

r = radius at branch to main junction

∅ = angle of junction

Example: loss coefficient for 90 degree T- Junction Combined flow

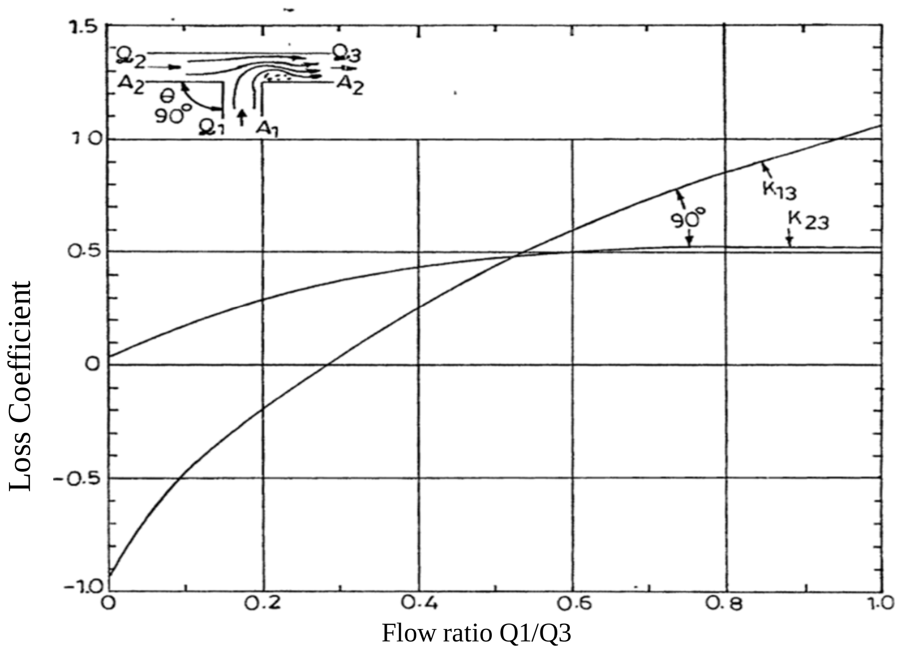


Fig. 2.5 Loss coefficients for sharp edged 90° combined 'T' [6]

Combined head loss coefficient (Ke) is calculated by

Ke=K13 (Q3/Q1) + K23 (Q3/Q2)

Where,

Ke= Combined head loss coefficient

K13= Head loss coefficient for flow from inlet-1 to outlet-3

K23= Head loss coefficient for flow from inlet-2 to outlet-3

Q1=Discharge from inlet 1

Q2= Discharge from inlet 2

Q3= Discharge from outlet 3

III. CASE STUDY

We studied the fluid flow from T-junction for combined flow and investigating the head loss (pressure drop) from junction for three different cases explain as follows.

Case 1 – When different inlet injectary angles provided to junction as 90, 60, 45 and 30 degree.

Case 2 – When velocities at inlet is changing as 1.2, 1.5, 1.8. In (m/sec)

Case 3 – When radius of curvature at branch to main junction is changing.

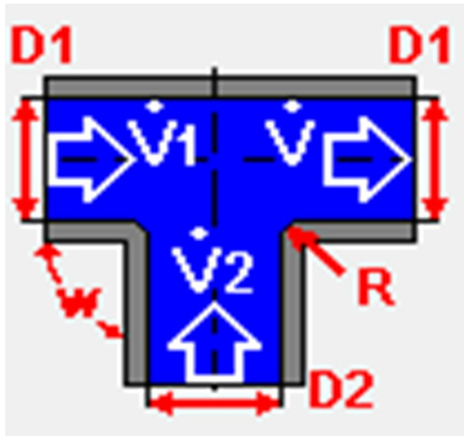


Fig. 3.1 Combined Flows 'T'

Initial data assumed for T - junction as follows:

D1= Inner diameter of main pipe = 40 mm

D2= Inner diameter of branch pipe = 40 mm

V1 = Velocity of flow at inlet 1

V2= Velocity of flow at inlet 2

V = Velocity of flow at outlet

R = Radius of curvature at branch to main junction.

W = Angle of junction at branch to main junction

A. Case 1

When different inlet injectary angles provided to junction as 90, 60, 45 and 30 degree.

Investigating the loss of head in junction when different inlet injectary angle provided to junction, calculating the head loss by classical formula and software and comparison made between them as.

Angle(degree)	Head loss(m)software Result	Head loss(m) classical Formulae
90	0.09	0.1018
60	0.04	0.05
45	0.02	0.03
30	0.01	0.0161

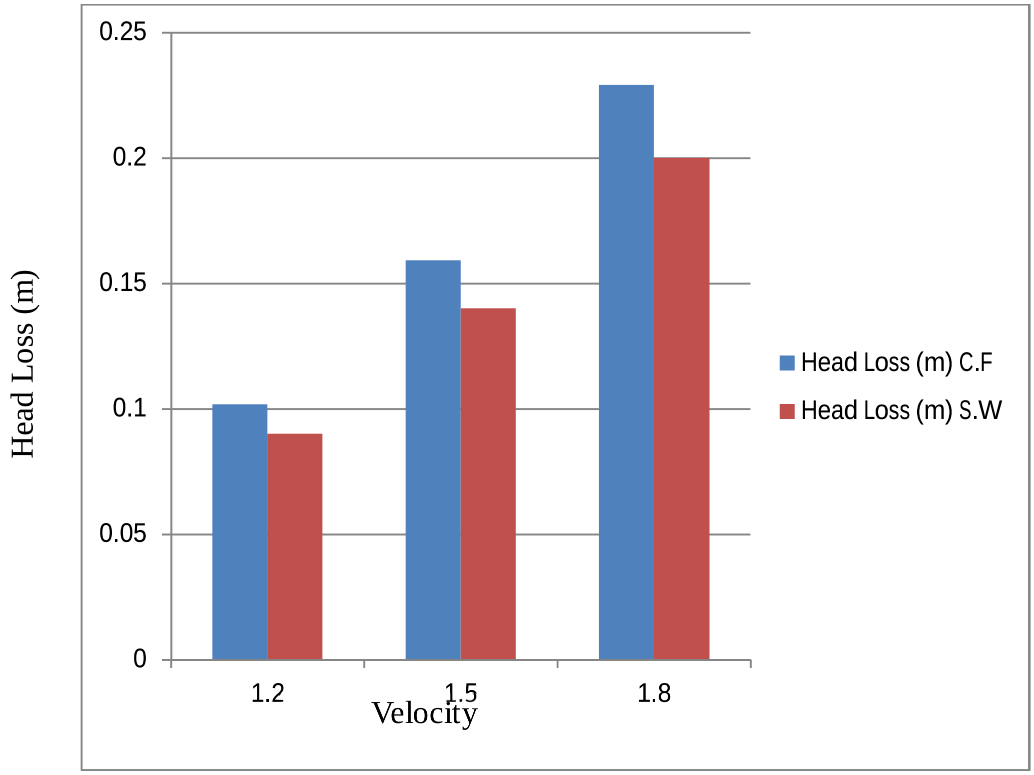
Table 3.1 Head loss comparison for various angles of ‘T’ with Software result and classical formulae.

B. Case 2

When velocities at inlet is changing as 1.2, 1.5, 1.8.in (m/sec)

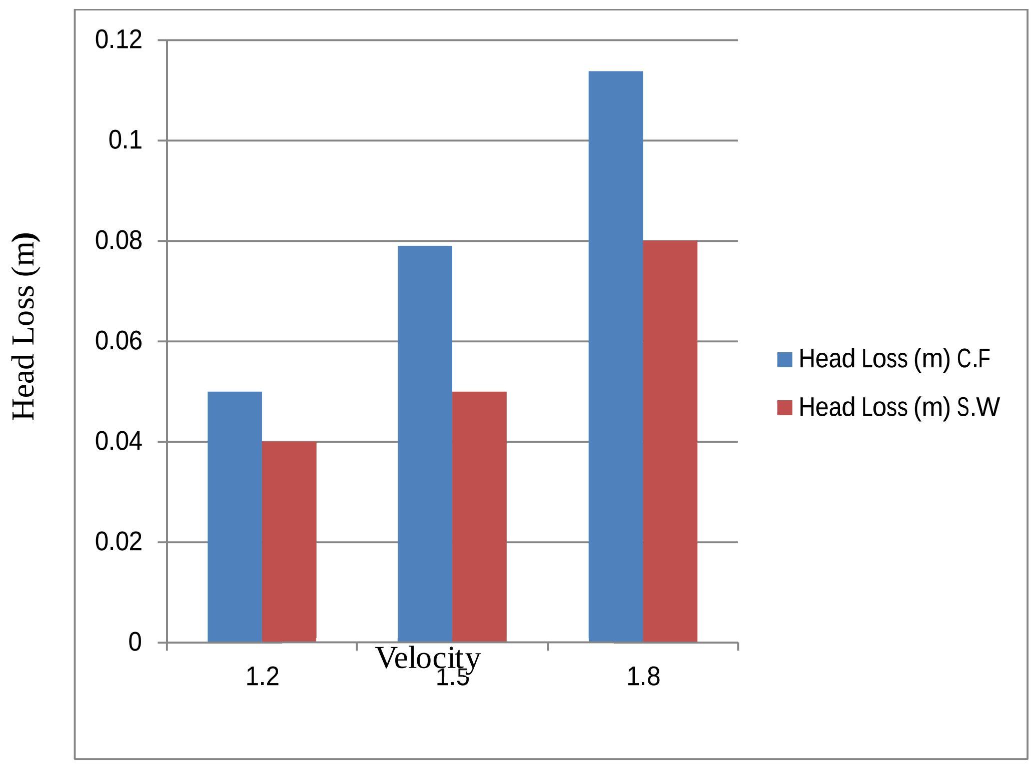
Investigating the loss of head in junction when different inlet velocities provided to junction, calculating the head loss by classical formula and software and comparison made between them as.

1) 90 Degree



Graph 3.1 Velocity vs Head Loss

2) 60 Degree



Graph 3.2 Velocity vs Head Loss

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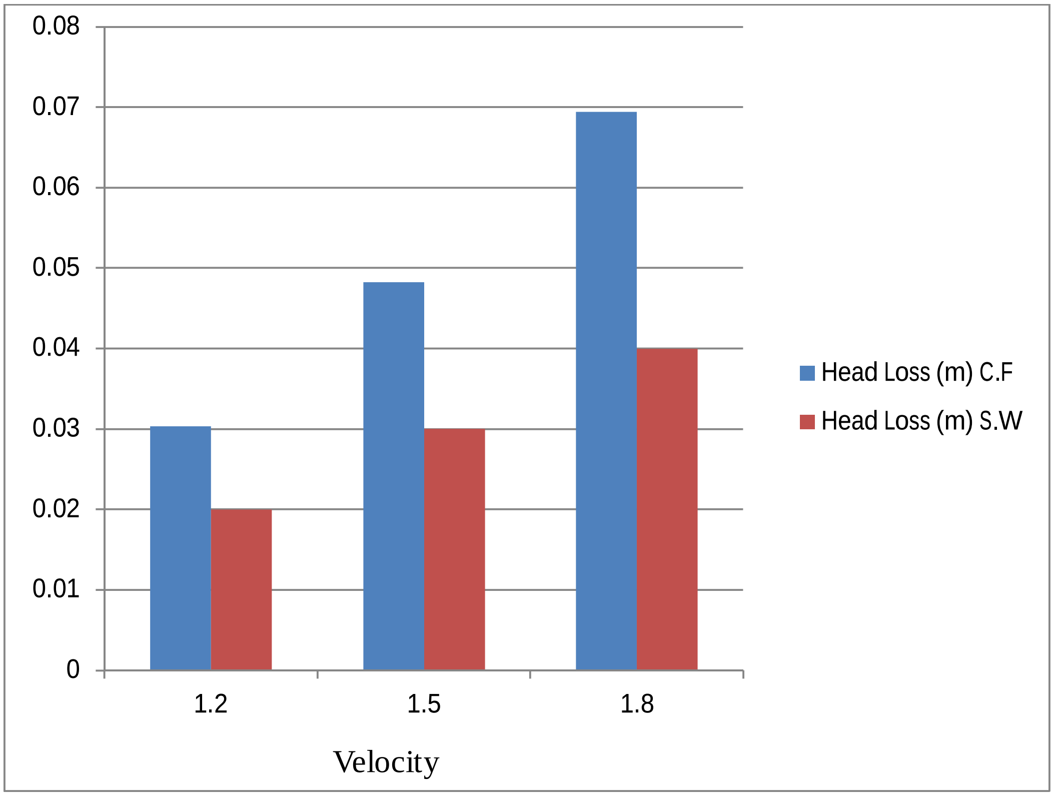
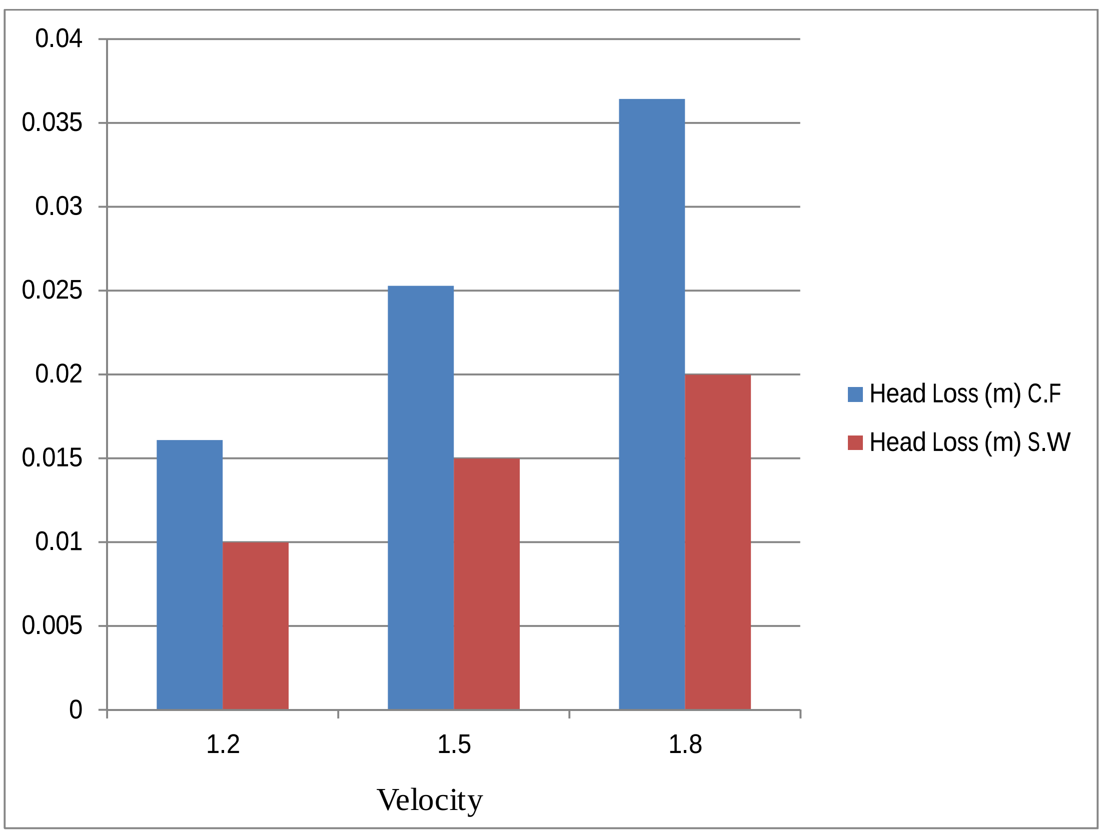
3) 45 Degree



Graph 3.3 Velocity vs Head Loss

4) 30 Degree



Graph 3.4 Velocity vs Head Loss

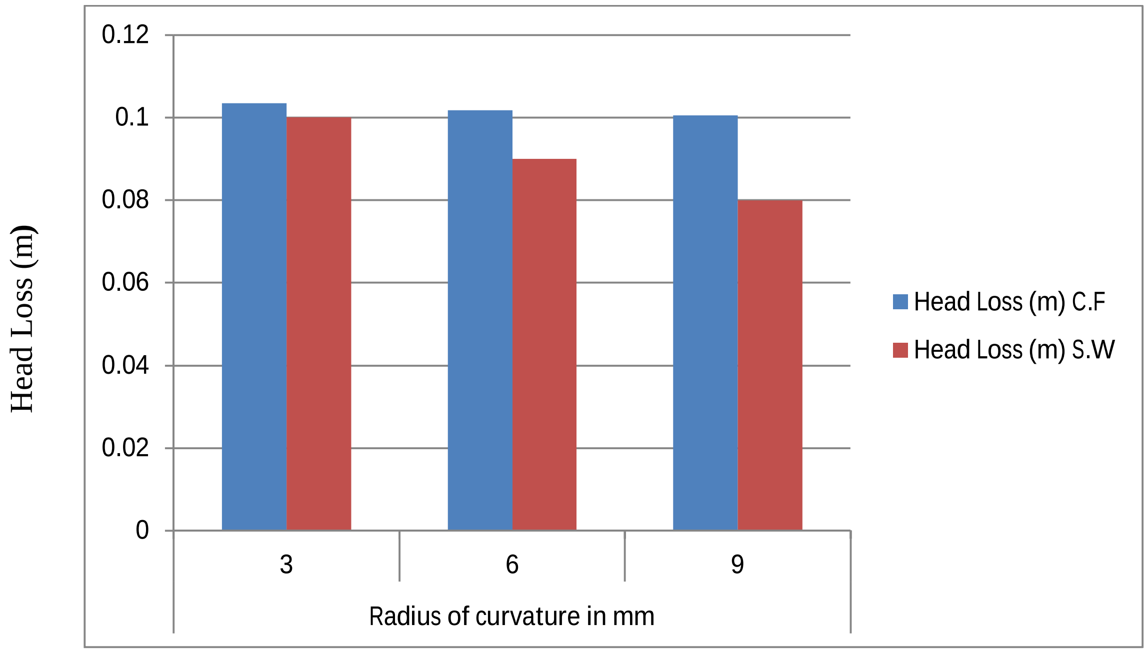
C. Case 3

When radius of curvature at branch to main junction is changing.

Investigating the loss of head in junction when radius of curvature at branch to main junction is changing provided to junction, calculating the head loss by classical formula and software and comparison made between them as

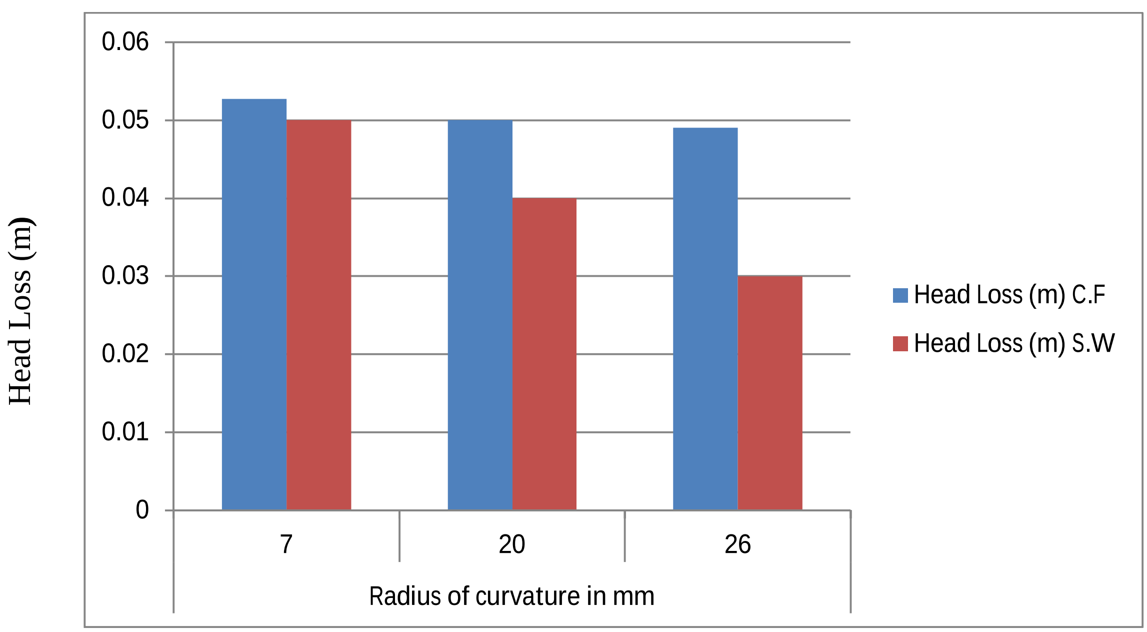
This case is consist of head loss calculation for 90, 60, 45, 30 degree when all angles are provided with different radius of curvature at branch to main junction and all the calculation are done by classical formulae and software and comparison is made between them as

1) 90 Degree



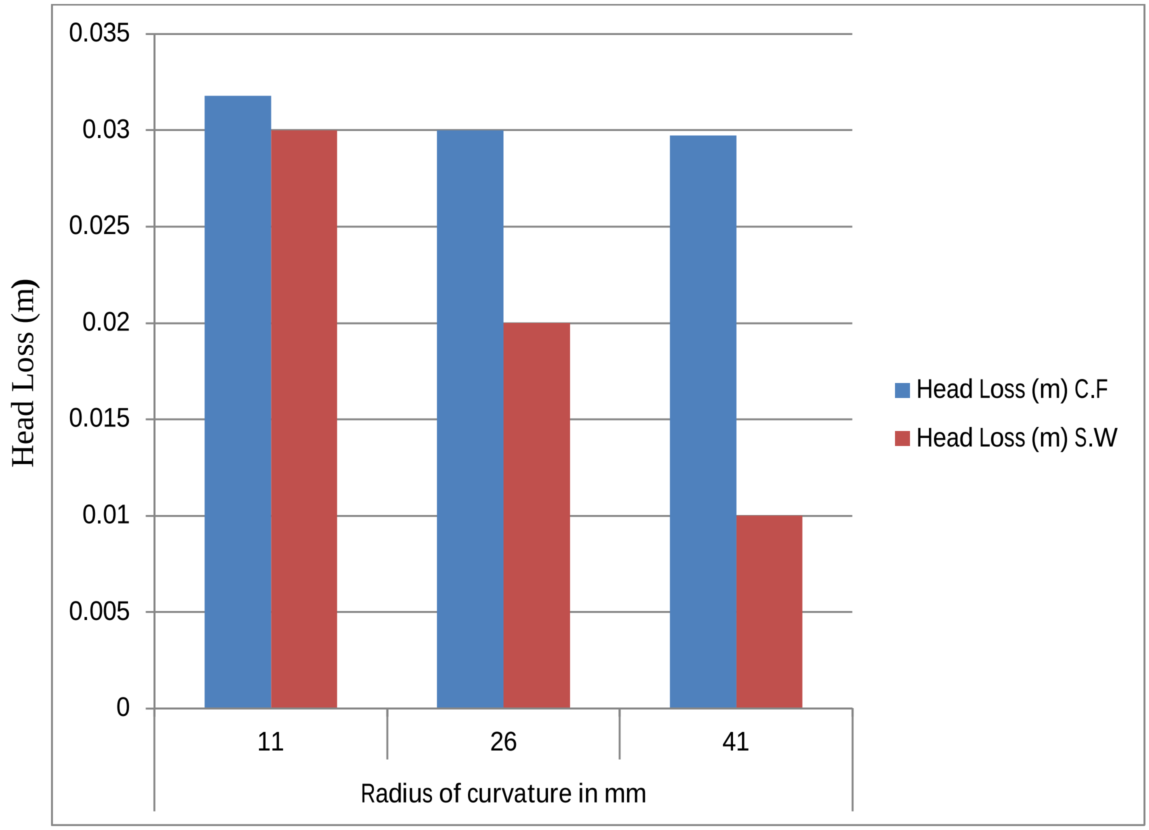
Graph 3.5 Radius of curvature vs Head Loss

2) 60 Degree



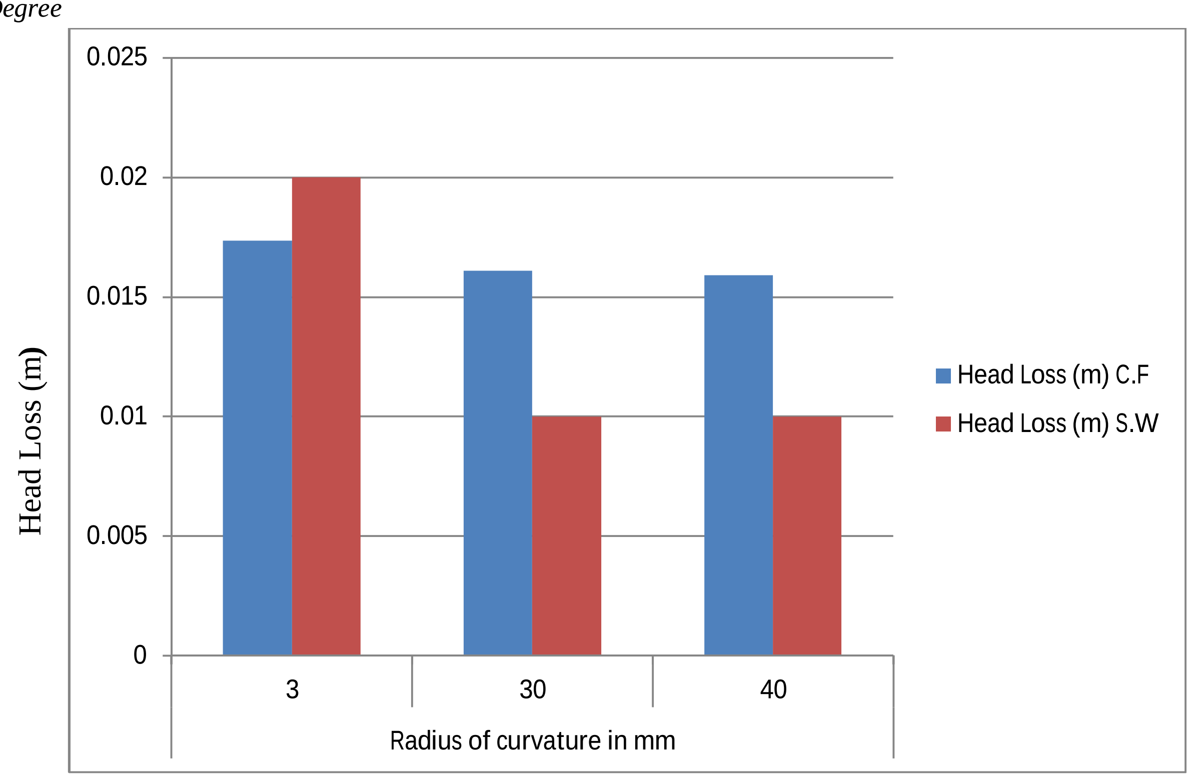
Graph 3.6 Radius of curvature vs Head Loss

3) 45 Degree



Graph 3.7 Radius of curvature vs Head Loss

4) 30 Degree



Graph 3.8 Radius of curvature vs Head Loss

IV. FUTURE SCOPE FOR THE WORK

In this work we only study the T - junction for water at room temperature with smooth inner surface. There are also more scope to work for study the T-junction for rough inner surfaces and T- junction with other fluids.

Also, there is a possible opportunity to work with T- junction when result obtain by software and construct a real time simulation of T-junction with varying angle. But it is a very lengthy process and possible with higher versions of CFD Software.

In this work we calculated the head loss for mathematical result by Gardel equation (1957), but there is no any mathematical formulae consider pipe roughness while calculating head loss foe T- junction, as we know that every material having roughness and varying with material, so while calculating head loss coefficient for T -junction with classical formulae there is always question about its accuracy so there is having huge scope for work to calculate head loss by classical formulae when considering pipe roughness.

In this work when we study the T-junction we aware about an industrial problem concerning to flow fluid in pipes. The problem identified was for maintaining the pressure, flow of fluid at certain location for that other pipe component added in network as valve, pump Initially for that elastic property was used to supply the material and a large forceps was used to reduce the diameter of pipe where the supply was not needed or to be regulated. So, such kind of problems can we solved with this kind of technique.

There is also having a scope to study a T-junction for calculating the head loss, when T- junction provided with different diameter of branch pipe and main pipe, so there is having more possibilities of results obtaining by classical formulae and software by this case, so also having possibilities of obtaining different head loss result by this case and conclusion about accuracy of classical engineering formulae.

There is also having more scope to work with T-junction when we used 3D computational experiments with advanced CFD software for calculating software package results. [5]

V. RESULT AND CONCLUSION

The main aim of this study of T-junction is to investigate the head loss (pressure drop) when flow passing through T-junction for that we consider a T-junction with combined flow as shown in fig. 2.4 generally in this work we consider three cases for T-junction as explain on chapter 3. In this work we calculate the head by classical formulae by Andrew gardel (1957) and software and comparison made between them and finding out the accuracy of classical formulae. [5]

When we consider the T-junction for combined flow, when inlet injectary angles of junction changing between 90,60,45,30 degrees we observed that when the angle of junction increasing from lower to higher as from 30 degree to 90 degree then head loss is also increasing because of resistance to flow increasing. The head loss obtained by software and classical formula where close to each other. Head loss for different angles of T-junction. It was observed that when the angle (∅) is less, head loss suffered is less. This is because there is no significant change in of momentum of the flow between incoming and outgoing flow. It was also observed that when the angle (∅) is more, head loss suffered is more. This is because of change in momentum of the flow while passing through T-junction.

When we consider the T-junction for combined flow, when velocities at inlet is changing as 1.2, 1.5, 1.8. In (m/sec) when the velocity of flow at inlet increasing head loss is also increasing generally head loss obtained by software is less than the classical formulae and there is error between software and classical formulae result.

When we consider the T-junction for combined flow, when radius of curvature at branch to main junction is changing. When radius of curvature at branch to main junction increasing then head loss by this case is decreasing as the radius of curvature is increase head loss is decrease. Hence in this work by study of T–junction we can conclude that when radius of curvature at branch to main junction of T-junction is increasing head loss suffered by T junction is decreasing. And when the inlet injectary angle of T-junction is increasing head loss suffered by T-Junction is also increasing.

VI. ACKNOWLEDGEMENTS

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