Imperial Journal of Interdisciplinary Research (IJIR)
Vol-3, Issue-4, 2017
ISSN: 2454-1362, http://www.onlinejournal.in

Variation of Relative Height Irregularity (k/δ) With Pipe Material

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Abstract*: The hydrodynamic behaviour (i.e., whether the pipe behaves as rough or smooth) depends on height of roughness irregularities and formation of laminar sub-layer which varies with pipe materials, sizes and with discharges. In this study the hydrodynamic behaviors are studied and observe the variations with pipe materials. The Condition for Pipe Behaving as Smooth or Rough are taken from Nikuradse's experiment. It is seen that both at low and high discharge M.S. Pipe is hydro dynamically rough and PVC Pipe as well as G.I. Pipe are hydro dynamically smooth at both high and low discharge.*

Keywords*: pipe, size, discharge, roughness irregularity (k/δ), material.*

1. Introduction

A pipe is a closed conduit through which a fluid flows. The water pipes supplying water in the houses. Pipes can be natural (veins and arteries) as well as artificial. Pipes can transport both liquid and gases. A typical piping system involves pipes of different diameters connected to each other by various fittings or elbows to route the fluid, valves to control the flow rate, and pumps to pressurize the fluid. The terms pipe, duct, and conduit are usually used interchangeably for flow sections. In general, flow sections of circular cross section are referred to as pipes (especially when the fluid is a liquid), and flow sections of noncircular cross section as ducts (especially when the fluid is a gas).

2. Objective of the Study

The hydrodynamic behavior (i.e., whether the pipe behaves as rough or smooth) depends on height of roughness irregularities and formation of laminar sub-layer which varies with pipe materials, sizes and with discharges. If the average height *k* of irregularities, projecting from the surface of boundary is much less than, the thickness of the laminar sub-layer, the boundary is called smooth boundary. If the Reynolds number of the flow is increased then the thickness of laminar sub-layer will decrease. If the thickness of laminar sub-layer becomes much smaller than the average height *k* of irregularities of surface the boundary will act as a rough boundary. Here the hydrodynamic behaviors are studied and observe the variations with materials and flow conditions.

3. Theory

The hydrodynamic behavior (i.e., whether the pipe behaves as rough or smooth) depends on height of roughness irregularities and formation of laminar sub-layer which varies with pipe materials, sizes and with discharges. If the average height ***k*** of irregularities, projecting from the surface of boundary is much less than, the thickness of the laminar sub-layer, the boundary is called smooth boundary. If the Reynolds number of the flow is increased then the thickness of laminar sub-layer will decrease. If the thickness of laminar sub-layer becomes much smaller than the average height ***k*** of irregularities of surface as shown in the figure and the boundary will act as a rough boundary. In this study the hydrodynamic behaviors are studied and observe the variations with materials and flow conditions.

Let k is the average height of the irregularities projecting from the surface of a boundary as shown in figure. If the value of k is large for a boundary then the boundary is called a rough boundary and if the value of k is less, then boundary is known as smooth boundary. This is the classification of rough and smooth boundary base on boundary characteristics. But for proper classification, the flow and fluid characteristics are also to be considered.

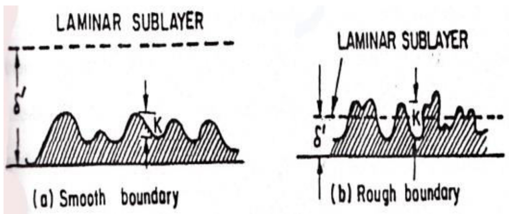

Fig. 3.1: *Smooth and rough boundary in pipe*

For turbulent flow analysis along a boundary, the flow is divided in two portions. The first portion consists of a thin layer of fluid in the intermediate neighborhood of the boundary where viscous shear force predominates while the shear stress due to turbulence is negligible. This portion is known as the laminar sub-layer. The height up to which the effect of viscosity predominates, this zero is denoted by δ. The second portion of flow, where shear stresses due to turbulence are large as compared to viscous stress is known as turbulent zone.

If the average height k of irregularities, projecting from the surface of boundary is much less than δ, the thickness of the laminar sub-layer is as shown in the figure and the boundary is called smooth boundary. This is because outside the laminar sub-layer the flow is turbulent and eddies of various sizes present in turbulent flow try to penetrate the laminar sub-layer and reach the surface of the boundary. But due to great thickness of laminar sub-layer the eddies are unable to reach the surface irregularities and hence the boundary as a smooth boundary. This type of boundary is called hydro-dynamically smooth boundary.

Now if the Reynolds number of the flow is increased then the thickness of laminar sub-layer will decrease. If the thickness of laminar sub-layer becomes much smaller than the average height k of irregularities of surface as shown in the figure and the boundary will act as a rough boundary. This is because the irregularities of the surface are above the laminar sub-layer and the eddies present in turbulent zone will come in contact with the irregularities of the surface and the lot of energy will be lost. Such a boundary is called hydro-dynamically rough boundary.

4. Condition for Pipe Behaving Smooth and Rough

From Nikuradse's experiment:

1) If k/δ' is less than 0.25 or $k/\delta' < 0.25$, the boundary is called hydro-dynamically smooth boundary.
2) If $k/\delta > 6.0$, the boundary is hydro-dynamically rough.
3) If $0.25 < k/\delta' < 6.0$, the boundary is in hydro-dynamically transition.

5. Results

Table 5.1 below shows the pipes used of different materials with various diameters for the determination Variation of Relative Height Irregularity (k/δ).

Table 5.1 Experimental Pipe Used

Pipe no.	Pipe material	Diameter (m)	Length (m)
1	MS	0.0127	2.45
2	MS	0.01905	2.45
3	MS	0.02	2.45
4	MS	0.03175	2.45
5	MS	0.0381	2.45
6	MS	0.0445	2.45
7	GI	0.0127	2.45
8	PVC	0.0127	2.45

Table 5.2 Variation of Relative Height Irregularity (k/δ)

Pipe materials	Low discharge	High discharge
	Relative height irregularity (k/δ)	Relative height irregularity (k/δ)
M.S. Pipe	13.254	14.598
PVC Pipe	0.026	0.009
G.I. Pipe	0.003	0.001

At low and high discharge $k/\delta > 6$, so nature of M.S. Pipe is hydrodynamic ally rough at both high and low discharge

At low and high discharge $k/\delta < 0.25$, so nature of PVC Pipe is hydro dynamically smooth at both high and low discharge

At low and high discharge $k/\delta < 0.25$, so nature of G.I. Pipe is hydro dynamically smooth at both high and low discharge

The results obtained is shown by the following histogram

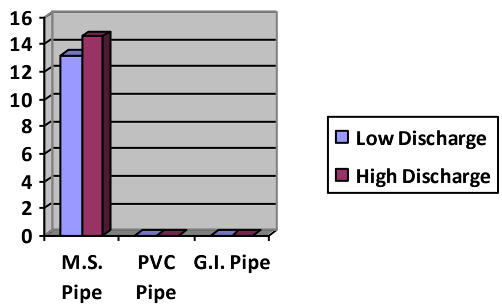

Fig. 5.1: *Variation of Relative Height Irregularity (k/δ) With Pipe Material*

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