Experimental Study of Secondary Energy Losses in Smooth Pipes

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Robby Yussac Tallar[1]*, Hanny Juliany Dani[1], Daud Rahmat Wiyono[1], Yonathan Adi Saputra[1] and Gerard Christian Joelin[1]

[1]*Department of Civil Engineering, Faculty of Engineering, Universitas Kristen Maranatha, Indonesia*

**Corresponding author: robbyyussac@yahoo.com or robby.yt@eng.maranatha.edu*

Abstract
Smooth pipes are closed and circular conduits through which fluids are transported under pressure. Secondary energy losses in smooth pipes occur due to several factor such as inlet, valves, enlargement, construction, bend, outlet. Therefore, the purpose of this study was to determine and analyze secondary energy losses on smooth pipes by experimental study. Several stages of research have been set up for this study and some tests were carried out at the Hydraulics and Fluid Mechanics Laboratory of the Civil Engineering Study Program, Maranatha Christian University. Secondary energy losses analysis using the Bernaulli Formula compared to Chezy Formula and Darcy-Weisbach Formula were used to obtain results. The experimental results indicated that all Reynolds Number (Re) value in smooth pipe is 6177 which more than 4000 which all flow regimes categorized as turbulent flows. The experimental results show that the secondary loss due to valve was approximately 0; due to the first bend was 6cm; and due to the second bend was 5.15cm. The anaylsis results of secondary energy losses in smooth pipes has shown a preponderance of the interrelated equations by Darcy-Weisbach Equation and Chezy Equation concerning friction factor in smooth pipes. Thickness of boundary layer (k) of smooth pipe is the most determining variable to categorize the pipe roughness as hydraulically smooth pipes. However, the experimental results presented a set of benchmark data for further research in smooth pipes.

Keywords: *Experimental study, smooth pipes, secondary energy losses.*

1. Introduction

Fluids in the form of liquids can be transported from one place to another through a carrier construction in the form of both natural and artificial channels that are both open and closed as in pipes. Therefore, the common definition of pipes is closed and circular conduits through which fluids are transported under pressure. In its planning, fluid distribution in the pipe must take into account the energy loss that occurs. Energy losses in the smooth pipe are divided into two types: primary energy losses and secondary energy losses. Primary energy losses in pipes occurs due to friction between the fluid and the pipe wall or pipe wall roughness which is closely related to pipe materials both smooth and rough such as PVC, steel, iron, glass, wood, etc. Meanwhile, secondary energy losses in smooth pipes occur due to several factor such as inlet, valves, enlargement, construction, bend, outlet.

A large amount of research was conducted to achieve a general and precise formulation of the various types of energy losses in pipelines. [1,2]. Some studies were focused on characteristics of type of flow in pipes either laminar or turbulent [3,4]. Other studies also conducted on primary energy losses in rough pipes [5,6]. Few studies were concentrated on secondary energy losses or in smooth pipes. Therefore, the purpose of this study was to determine and analyze secondary energy losses on smooth pipes by experimental study.

2. Materials and methods

2.1 Experimental procedures and preliminary materials

The experiments were conducted in 14m long with 2cm diameter of smooth pipe with various types of secondary energy losses at Fluid Mechanics and Hydraulics Laboratory, Universitas Kristen Maranatha. Water was fully flowing through the smooth pipe with constant discharge (Q) 0.000171 m^3/sec. Figure 1 shows the layout of smooth pipe in this study. The hydraulic gradient line can be implemented in this experiment. Figure 1 shows the layout of smooth pipe for running the experiments. First of all, the analysis of datum should be done, and the result can be seen in Table 1. After that, the calculation of elevation head also performed and the result can be seen in Table 2. Next step is the analysis of pressure head and velocity head that can be seen in Table 3 and Table 4.

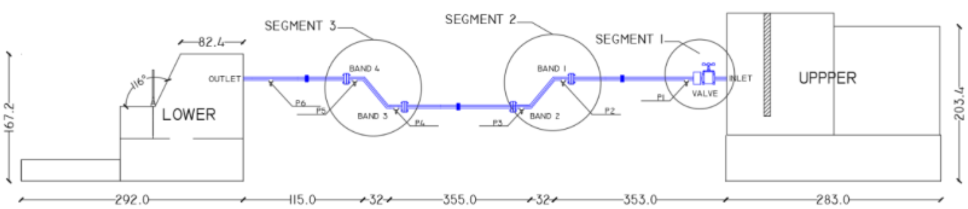

Figure 1. The layout of smooth pipe

Table 1. Calculation average of datum

Position	Datum (cm)
1	210.2667
2	
3	

Table 2. Calculation of elevation head

Position	T (cm)	Diameter Ø (cm)	z (cm)
Upper	157,442	3	155,9417
Piezometer 1	157,842	3	156,3417
Piezometer 2	157,892	3	156,3917
Piezometer 3	107,042	3	105,5417
Piezometer 4	105,842	3	104,3417
Piezometer 5	156,967	3	155,4667
Piezometer 6	155,992	3	154,4917

Table 3. Calculation of pressure head

Position	Velocity (cm/sec)	h_n (cm)
Entrance	60,032	139,958
Piezometer 1	60,032	128,058
Piezometer 2	60,032	117,008
Piezometer 3	60,032	161,858
Piezometer 4	60,032	150,608
Piezometer 5	60,032	94,333
Piezometer 6	60,032	79,408

Table 4. Calculation of velocity head

Position	Velocity (cm/sec)	$V^2/2g$ (cm)
Entrance	60,032	1,8368
Piezometer 1	60,032	1,8368
Piezometer 2	60,032	1,8368
Piezometer 3	60,032	1,8368
Piezometer 4	60,032	1,8368
Piezometer 5	60,032	1,8368
Piezometer 6	60,032	1,8368

Table 5 shows that the analysis of piezometric head for each position of piezometer along smooth pipe.

Table 5. Calculation of piezometric head

Piezometer	h (cm)
Inlet	295.900
Piezometer 1	284.400
Piezometer 2	273.400
Piezometer 3	267.400
Piezometer 4	254.950
Piezometer 5	249.800
Piezometer 6	233.900

2.2 Data analysis

The first stage of analysis is determining the flow type by analyzing the Reynolds Number (Re). The flow velocity, diameter of pipe and kinematic viscosity (v) are the variables to define the value of Re. Bernoulli Equation is then used to calculate the value of total head energy losses differences of smooth pipe (ΔHf). Further, friction factor (f) was defined by using the Chezy Equation and inserted into Darcy-Weisbach Equation. The results can be seen on Table 6.

Table 6. The Results of friction factor in smooth pipes

Segment	ΔH_f (cm)	C	f
1	11,50	140,4998	0,3976
2	6,00	200,8923	0,1945
3	5,15	216,8380	0,1669

3. Results and discussion

3.1 Results and discussion

Based on the analysis, it is found that head losses in smooth pipe especially secondary losses refers to the pressure drop (due to friction) as a fluid flow through a pipe. Head losses represents how much pressure will be lost due to the orientation of the pipe system. There are some bends that show the difference value of secondary energy losses. Moreover, the pressure of the fluid flow reduces as it goes through these bends due to a change in the direction of the fluid. The pressure of the fluid flow reduces due to frictional forces acting on the pipe's surface on the fluid. Head losses are affected by the input velocity of the fluid flow, the density of the fluid, and the pipe system's orientation (the number of bends and whether the bend is horizontal or vertical). Several mathematical models are used to calculate the function of total head loss. Some models are designed exclusively for laminar or turbulent flow, whereas others can be utilized for a wide range of Reynolds Numbers.

Table 7. Calculation of head energy

Position	Velocity (cm/sec)	h_n (cm)	H (cm)
Inlet	60.032	139.958	141.80
Piezometer 1	60.032	128.058	129.90
Piezometer 2	60.032	117.008	118.85
Piezometer 3	60.032	161.858	163.70
Piezometer 4	60.032	150.608	152.45
Piezometer 5	60.032	94.333	96.17
Piezometer 6	60.032	79.408	81.25

Secondary energy losses caused by singularities in smooth pipe are also known as minor head losses. This is owing to the fact that the value of long pipes can be overlooked in comparison to the value of friction. However, for short pipes, their impact can be enormous. Table 8 shows the results of secondary energy losses in smooth pipe.

Table 8. Calculation of secondary energy losses

Position	Experimental Results (cm)	Empirical Equations	% Difference
Inlet	55,255	60,032	4,143
Valve	0,363	0,433	8,79
Bend 1	0,394	0,433	4,715

Bend 2	0,437	0,433	0,459
Bend 3	0,433	0,433	0
Bend 4	0,504	0,433	7,577
Outlet	2,112	1,836	7

4. Conclusion

The current study evaluated secondary energy losses in smooth pipe induced by total disturbance generated by fittings such as valves and bends. The Reynolds number was used to determine whether a fluid flow was laminar or turbulent. Meanwhile, a transition flow is a fluid flow that exists between two points. The Reynolds number for a laminar flow should be less than 2000, whereas the Reynolds number for a turbulent flow should be larger than 4000. The experimental results showed that the total Reynolds Number (Re) value in a smooth pipe is 6177, which is greater than 4000, indicating that the flow is turbulent. The analysis results of secondary energy losses in smooth pipes has shown a preponderance of the interrelated equations by Darcy-Weisbach Equation and Chezy Equation concerning friction factor in smooth pipes. Later, thickness of boundary layer (k) of smooth pipe is the most determining variable to categorize the pipe roughness as hydraulically smooth pipes. Because such smooth pipes are vulnerable to aging and mossy effects, it is particularly difficult to measure the accuracy of pipe roughness. It was also found that the friction factor value of secondary energy losses due to valve that proposed by the manufacturer is no more valid since the experimental result and Bernoulli Equation indicated a quite different value. However, the experimental results presented a set of benchmark data for further research in smooth pipes.

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Conflict of interest

All authors declare that they have no conflicts of interest.

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