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Experimental Study of Fluid Flow Losses at Several Turning Angles

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Abstract. This research, entitled Experimental Study of Fluid Flow Losses at Turns 30°, 45°, 60° and 90°, is a review of fluid (water) flow in closed channels. Fluid (water) flow in opened and closed channels is influenced by the condition of the container in which the fluid flows. One form of this influence is the occurrence of a condition which is generally known as flow loss. This condition is certainly undesirable because it will cause problems, technically the manifestation is a decrease in pressure including the speed of fluid flow. To find out the real conditions of flow losses, it is necessary to carry out research stages. The research stages were carried out in the form of system design, measurement, testing and data analysis. The system is designed with a pump device, where the fluid is pumped from a holding container, then flows into the installation area or closed channel which is made using ½" PVC pipe and is equipped with a Pressure Gauge measuring instrument to measure pressure and a Flow meter to measure flow discharge, placing bends. with angles of 30, 45, 60 and 90 degrees. Indication of loss is indicated by a decrease in pressure measured at the pressure gate, while indication of a decrease in flow velocity is calculated using an equation with the flow input variable measured from the flow meter.

Keywords: Fluid Flow, Turns, Flow Discharge.

1. Introduction

The pressure in a fluid flow is one of the important variables that needs to be considered carefully when designing the installation of a clean water supply system, because this variable will have a direct effect on the smooth flow of the fluid [1]. Installation conditions that can cause a decrease in pressure are bends, because naturally bends will prevent the fluid from flowing smoothly. The situation of turning on a fluid flow installations can be identified based on the angular magnitude of the change in flow direction. By simulating several angular values in the test, the characteristics of the fluid flow when flowing through a bend can be known. In general, this condition is also known as flow loss.

Arumugam et al. [2] stated that friction losses in pipes, for incompressible fluid flows, usually assume that the density, viscosity and temperature do not change so that the specific weight is constant. For a certain pipe diameter and length, the pressure loss in the pipe is due to the friction effect as a function of the Reynolds number [3], [4]. Changes in the Reynolds Number will result in large changes in flow pressure variations. The Reynolds number is defined as the ratio of inertial forces to fluids viscous forces. Liu et al. [5] stated that pipes as a means of transporting fluids from storage to use require piping installations with various pipe diameter sizes. When making pipe installations, bends will always be found which will result in flow loss. This research aims to determine flow losses at 45° and 90° bends. Variables that were not studied but can influence the research results (control variables) include: pipe diameter (m), pipe area (m^2), and water flow m^3/sec. Data collection to measure flow loss in this research is by measuring the difference in water height in a manometer. The research data obtained is the difference

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between manometers, water discharge, flow speed, and the amount of flow loss [6]. The measurement results were analyzed using theoretical formulas.

Arun et al. [7] stated that miter pipe is a form of pipe pieces connected together to form a curve. Generally, this miter pipe is used at temperatures and pressures that are not very high. An example of its use is in air conditioning and clean water piping installations in hotel buildings, office and industrial buildings, many of which use the 90^o miter pipe model [8]. When fluid flows through a 90^o bend, it will cause quite large head losses, so the way to overcome this is to make the bend gradually until you reach a 90^o bend. This is the advantage of miter pipes, but the question is how much the fluid flow head loss will decrease with each additional number of pipe pieces.

Based on these results, it can be concluded that the greater the number of pipe pieces, the smaller the loss coefficient and head loss, so that pipe installation power can be used more efficiently [9]. Shi et al. [10] stated that fluid flow is part of the science of fluid mechanics which plays an important role in designing piping systems. Piping is a means of fluid transportation that is widely used in industry. Fluid flowing in a pipe will experience energy loss (head loss) due to friction between the fluid and the fluid and the fluid and the pipe. Loss of energy in the fluid in a piping system can also be caused by the pipe path that the fluid passes through, such as bends in the pipe, narrowing of the pipe (contraction), and enlargement of the pipe (expansion) [11], [12]. The experiment was carried out with a pipe model that had been assembled. The experimental results show that the surface area of the pipe diameter as a means of transporting fluid flows greatly influences the head loss (Hf) value.

Yang et al. [13] stated that when fluid flows through a piping installation system, many pressure losses occur which are referred to as major pressure losses and minor pressure losses (losses due to fluid passing through a branch). The division of fluid flow at the branch is an irreversible process. This unsustainability in engineering applications will reduce system performance. This study seeks to determine how much loss occurs in the branching of the pipe is to measure the loss coefficient that occurs.

2. Method

In this research, the equipment to be used is divided into four parts, namely:

a. Pipeline Installation Equipment
b. Water Pump Equipment
c. Flow Velocity Measuring Equipment
d. Pump Pressure Measuring Equipment

The equipment system used in this research is shown in Figure 1 below. After the construction of the research installation is complete (including the installation of the bends that have been made), the activity continues with data collection in the form of measuring the pressure and discharge of water flow. To measure pressure and water flow at each turn in research installations, a systematic approach is followed. Firstly, 90 degree turns are installed in the designated areas. Holding containers are then filled as needed to ensure a consistent water supply. Subsequently, the main tap is opened to allow water circulation when the water pump is activated. Before commencing the measurements, the Flowmeter area designation is recorded or photographed both before and after the turn (F1 & F2).

The next step involves activating the water pump by pressing the Switch-On switch and starting the timer (Stopwatch-HP). Simultaneously, the water flow pressure gauge (Pressure Gauge) indications are recorded or photographed in the areas before and after the bend (P1 & P2) at regular 5-minute intervals over a duration of 8 times. Additionally, the water flow volume measuring instrument (Flowmeter) indications are documented in the areas before and after the turn (F1 & F2) at the same 5-minute intervals for a total of 8 times.

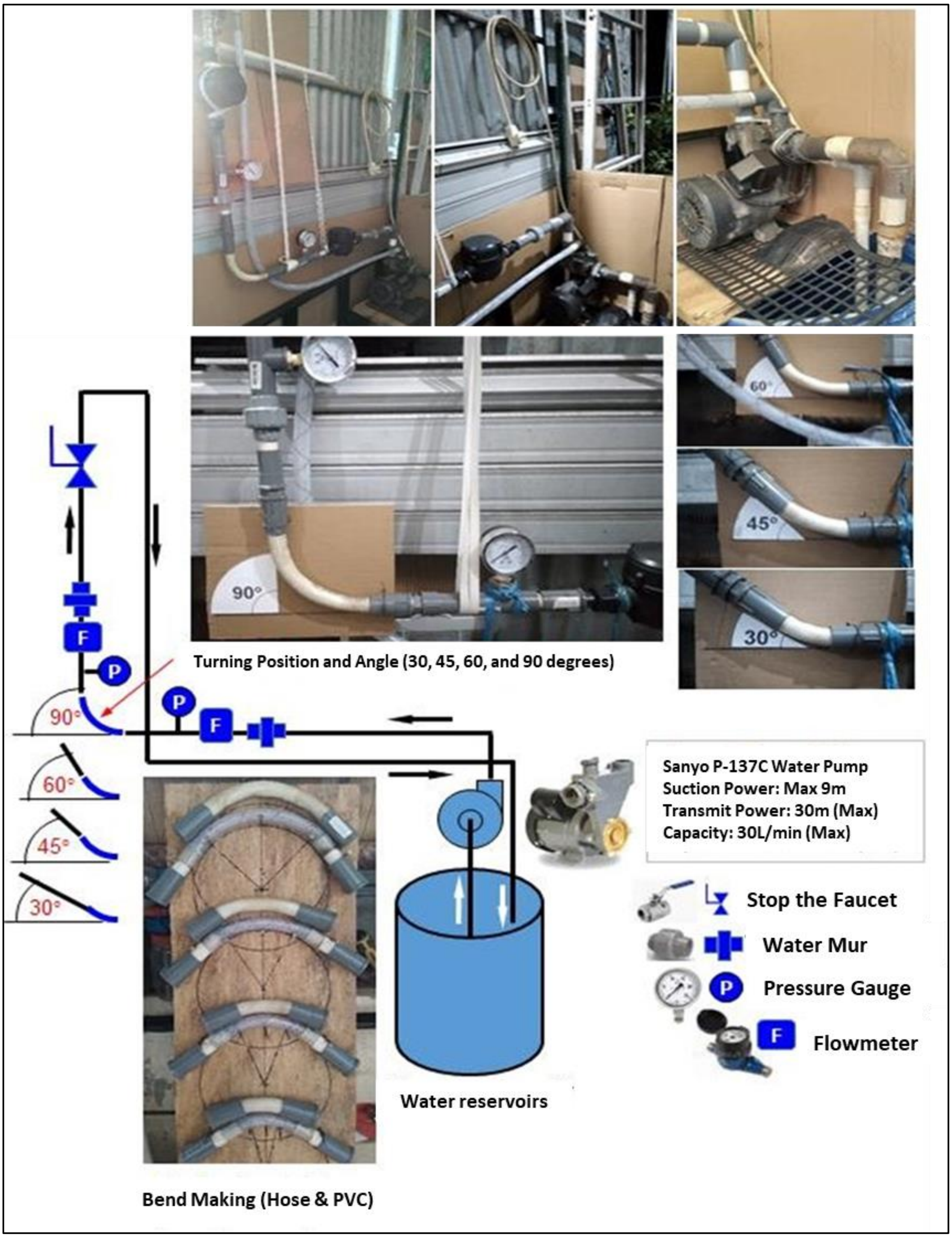

Figure 1. Schematic Image of the Flow and Pressure Measurement Equipment System

Upon completion of the measurements, the water pump is switched off by pressing the Switch-Off-Water pump switch. To ensure accuracy and reliability, the entire process, including the installation of turns and recording of measurements, is repeated for turns at 60 degrees, 45 degrees, and 30 degrees. This meticulous procedure ensures a comprehensive analysis of water flow and pressure at various turns, contributing to a thorough understanding of the research installations' hydraulic performance.

3. Result and Discussion

After going through the system testing stages, the following data was obtained as in table 1 which is the result of measuring the pressure and flow rate before and after bends with variations in bends of 90°, 60°, 45° and 30°, presented in Table 1 as follows:

Table 1 Pressure and water flow before & after the turn

No	Turn 90°			Turn 60°		
	P1	P2	Q1=Q2	P1	P2	Q1=Q2
1	1.2	1.0	260	0,9	0.8	285
2	1.2	1.0	260	0,9	0.8	285
3	1.2	1.0	260	0,9	0.8	285
4	1.2	1.0	260	0,9	0.8	285
5	1.2	1.0	260	0,9	0.8	285
6	1.2	1.0	260	0,9	0.8	285
7	1.2	1.0	260	0,9	0.8	285
8	1.2	1.0	260	0,9	0.8	285
No	**Turn 45°**			**Turn 30°**		
	P1	**P2**	**Q1=Q2**	**P1**	**P2**	**Q1=Q2**
1	0.8	0.7	300	0.7	0.6	325
2	0.8	0.7	300	0.7	0.6	325
3	0.8	0.7	300	0.7	0.6	325
4	0.8	0.7	300	0.7	0.6	325
5	0.8	0.7	300	0.7	0.6	325
6	0.8	0.7	300	0.7	0.6	325
7	0.8	0.7	300	0.7	0.6	325
8	0.8	0.7	300	0.7	0.6	325

To complete the presentation of the data in the table above, the following data is also presented on the results of pressure and water flow measurements for each variation of bend in graphical form, the details are as follows:

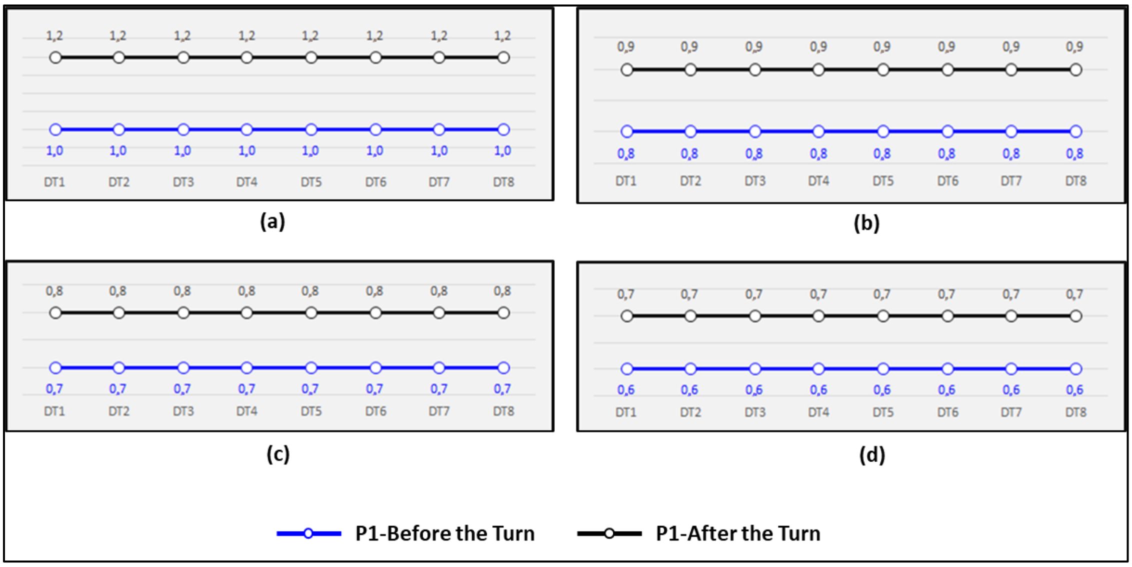

Figure 2 (a to d) Presents Data from Measurements of Water Flow Pressure

The analysis of water flow pressure conditions before and after the bend (P1 & P2) for each variation of bend angle, as derived from Table 1 and Figure 2 (a to d), reveals distinct patterns. At a 90 degree bend, the initial pressure before the turn (P1) is recorded at 1.2 kg/cm^2, decreasing to 1.0 kg/cm^2 after the bend (P2). For a 60 degree bend, the initial pressure (P1) is slightly lower at 0.9 kg/cm^2, with a post-bend pressure (P2) of 0.8 kg/cm^2. At a 45 degree bend, the initial pressure (P1) further decreases to 0.8 kg/cm^2, reaching 0.7 kg/cm^2 after the turn. Finally, for a 30 degree bend, the initial pressure (P1) is 0.7 kg/cm^2, diminishing to 0.6 kg/cm^2 after the bend.

Based on the results, it is evident that as the bend angle decreases, there is a consistent trend of decreasing water flow pressure. This suggests that sharper bends in the pipeline lead to greater resistance, resulting in a decline in pressure. Such insights are crucial for understanding the hydraulic behavior of the system and optimizing its design for efficient water flow.

The observed trends in water flow pressure conditions align with previous research findings in fluid dynamics. Numerous studies have investigated the impact of bend angles on pressure drops and flow characteristics in pipelines. Comparing our results to prior research, it is consistent with the general understanding that sharper bends induce higher resistance, subsequently leading to a reduction in water flow pressure. For instance, a study by Wang et al. [14] explored the effects of bend angles on pressure distribution in pipeline systems and found a similar decrease in pressure with increasing bend angles. Their research indicated that the abrupt change in direction at sharper bends contributes to increased turbulence and frictional losses, corroborating the findings of our study.

Furthermore, a comprehensive analysis by Yue et al. [15] delved into the relationship between bend angles and pressure losses in various fluid transport systems. Their work highlighted the importance of considering bend angles in the design process to minimize energy losses and optimize hydraulic efficiency. The current study, with its focus on different bend angles, supports and extends the insights provided by these earlier works. The condition observed or obtained is: the greater the bend angle, the greater the measured water flow pressure.

Next is calculating the value of the pressure change that occurs due to the small head loss (kg/cm^2) in each round can be seen in Figure 4.

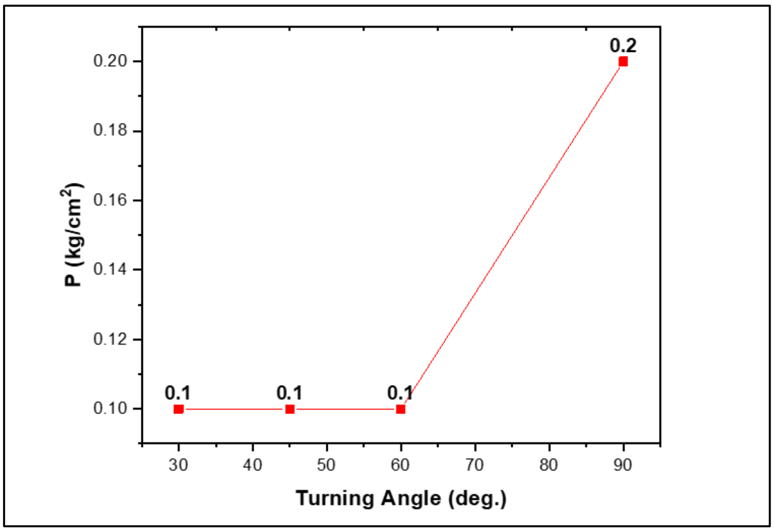

Figure 3 Decrease in Water Flow Pressure/Minor Head Losses (kg/cm^2) at Each Turn

The values presented in Figure 3 represent the difference or decrease in water flow pressure before and after each turn, calculated using the equation $\Delta P = P1 - P2$. For instance, utilizing the data from measurements at a 90-degree bend, as indicated in Table 1 and Figure 1a, the calculated ΔP is 0.2 kg/cm^2 (1.2 – 1.0). Interpreting this result, ΔP provides valuable insight into the pressure drop across the bend, indicating the extent of energy loss within the pipeline. In the case of a 90-degree bend, the positive ΔP value suggests a reduction in pressure, signifying that there is an inherent resistance to the flow as the water negotiates the turn. This information is crucial for engineers and designers in optimizing pipeline layouts and minimizing energy losses, ensuring efficient water transportation within the system.

Relevant previous research in fluid dynamics has also explored the significance of pressure differentials across bends. A study by Du et al. [16] investigated pressure variations in curved pipelines and emphasized the importance of understanding ΔP to enhance the overall efficiency of fluid transport systems. Their findings, similar to our results, underscore the impact of bend angles on pressure drop and the need for tailored design considerations.

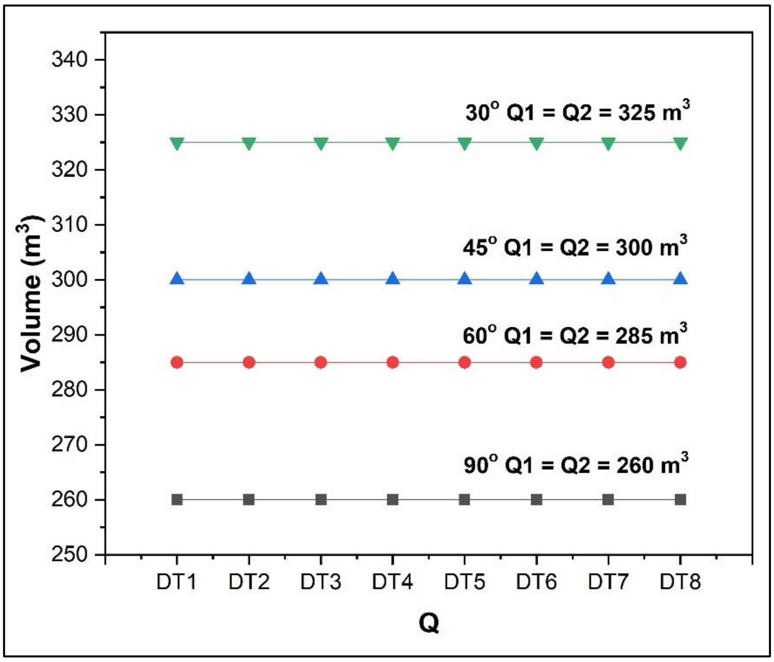

Figure 4 Volume of Water Flow (m^3) at each Variation of Bend

The water flow volume conditions before and after each turn (∠90°, ∠60°, ∠45°, ∠30°) are derived from Table 1 and illustrated in Figure 4. Notably, for a 90-degree bend, the measured water flow volume (Q1 & Q2) remains constant at 260 m^3. As the bend angle decreases, there is an observable increase in the measured volume, with ∠60° having a volume of 285 m^3, ∠45° at 300 m^3, and ∠30° at 325 m^3. Furthermore, by examining Figure 4, the vertical distance (X) from the bend side of the channel is observed to follow the sequence ∠90° > ∠60° > ∠45° > ∠30°. This implies that, for water flow volume, the conditions are ∠90° < ∠60° < ∠45° < ∠30°, indicating a correlation between bend angle and measured water flow.

Interpreting these findings, the inverse relationship between bend angle and water flow volume suggests that sharper bends in the pipeline lead to a reduction in the measured volume of water flow. The observed pattern aligns with the notion that greater resistance and increased turbulence in sharper turns contribute to a decrease in the effective volume of water passing through the bend. This information is crucial for hydraulic system optimization and designing pipelines that facilitate more efficient fluid transport, particularly in scenarios where maintaining a consistent flow volume is essential.

Previous studies by Elmenshawy et al. and Arun et al. explored similar relationships between bend angles and water flow characteristics [17], [18]. Their findings highlighted the influence of bend geometry on fluid dynamics and supported the notion that sharper bends induce greater frictional losses and alterations in water flow volume.

4. Conclusion

From the research that has been carried out, the value of flow loss or pressure reduction caused by bends is obtained (ΔP = P1-P2), respectively: for 90° bends, ΔP = 0.2 kg/cm^2 and for bends 60°, 45° and 30°, ΔP = 0.1 kg/cm^2. Generally, clean water piping installations, both in public buildings and household scale buildings, use ½" PVC material using 90° bends.

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6. Author's Declaration

Author contributions and responsibilities - The authors made major contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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Availability of data and materials - All data is available from the author.
Competing interests - The authors declare no competing interests.
Did you use generative AI to write this manuscript? - I do not use AI assistance in my manuscript.
Declaration of generative AI and AI-assisted technologies in the writing process - During the preparation of this work the author did not use AI to write, edit, or other things related to the manuscript.

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