CHAPTER 1
INTRODUCTION

1.1 Background

In industrial applications, piping networks possess a crucial role in ensuring the operation stability of fluid distribution and production systems. Proper planning during the early stages of installation is essential and must be given priority in order to minimize the risk of system failures that may hinder performance or even cause complete operational shutdowns (Wirandi et al., 2024). It is crucial to have careful planning backed by reliable data and validated information regarding key system components, including pump specifications, piping characteristics, and protective devices, to ensure that the system performs optimally. One of the hazardous and commonly encountered phenomena in piping systems is the water hammer effect (Prasetya et al., 2016).

Piping networks are designed not only to transport fluids efficiently but also to withstand various hydrodynamic phenomena, one of which is water hammer. This phenomenon is commonly identified as a sudden surge in pressure that typically occurs due to rapid valve closure or unexpected pump stoppage (Nuraeni et al., 2020). Water hammer often result in long-term instability as well as immediate negative impacts on the piping system. The effects pose a serious risk to the reliability of fluid transport, which serves as the backbone of many industrial processes (Nugraha & Ikhwan, 2017). If not handled properly, the pressure fluctuation generated by water hammer may reach fatal levels. Abrupt changes in pressure intensity can cause partial damage or rupture of pipes, which may lead to complete system downtime (Nahan et al., 2023).

This research focuses on evaluating the sudden pressure surge caused by water hammer in order to determine the ideal valve closure time and water discharge needed to mitigate excessive pressure intensities. High water hammer pressure may lead to severe pipeline failure and pump shutdown, resulting in expensive maintenance costs and operational losses. The analysis in this research utilizes the theoretical Joukowsky water hammer pressure equation (P_{wh}) along with the combined calculation of effective head (H_{eff}) as the basis for evaluating variations in valve closure time and flow rate.

In addition to theoretical analysis, practical measurements are also conducted to provide comparative results. Real-time parameters such as pipeline pressure and flow rate are recorded using measurement instruments on the experimental apparatus to assess the dynamic behaviour of the system directly. The relations between these parameters, supported by findings from previous studies, form the foundation of this research, which is titled "Experimental Study of Water Hammer Pressure Intensity in a Pump-Valve System with Variative Valve Closure Times and Flow Rates."

1.2 Problem Formulation

Based on the issues outlined in the background, the research problems can be formulated as follows:

1. What is the effect of varying valve closure time on the intensity of water hammer pressure in a pump–valve system?
2. What is the effect of different water flow rates on the intensity of water hammer pressure in a pump–valve system?
3. How does the value of effective head in a pump–valve system influence the intensity of water hammer pressure?

1.3 Research Objectives

Based on the formulated research problems, the objectives of this study are as follows:

1. To analyse the effect of varying valve closure time on the intensity of water hammer pressure.
2. To analyse the effect of different water flow rates on the intensity of water hammer pressure.
3. To analyse the significance of effective head in a pump–valve system on water hammer pressure intensity.

1.4 Research Benefits

The benefits expected from this research are as follows:

a. Theoretical benefits:
    1. This study is expected to contribute to the scientific literature related to water hammer analysis in piping systems.
    2. This study is expected to enhance understanding of the relationship between hydraulic parameters (flow rate, head, time, and pressure) and the response of piping systems when subjected to sudden increases in pressure intensity.
    3. This study is expected to serve as a reference for both theoretical and practical calculations related to the water hammer phenomenon.

b. Practical benefits:
   1. For the author
      This study is expected to improve the author's understanding of water hammer behaviour in piping systems.
   2. For practitioners
      This study is expected to provide practical insights into the occurrence and characteristics of water hammer.
   3. For the general public
      This study is expected to offer a clearer understanding of the water hammer phenomenon in piping systems.

1.5 Research Scopes

Based on the research problem formulations, the scope and limitations of this research are as follows:

1. The analysis focuses solely on water hammer caused by sudden valve closure.
2. The pump used is a single-stage centrifugal pump MQC 175 with a maximum discharge of 100 L/min.
3. The piping system consists of an impeller, discharge line, suction line, and shaft, with a discharge pipe height of 1,75 m.
4. Valve closure time variations are set to 1,0 s, 1,5 s, and 2,0 s, controlled using a ball valve on the discharge line.
5. Flow rate variations follow previous studies, with selected values of 38,67 L/min, 33,26 L/min, and 26,61 L/min, adjusted through the valve on the suction line.
6. The working fluid is PDAM tap water, assumed constant at 25°C with density (ρ) of 997,0 kg/m^3 and viscosity (μ) of 0,89 MPa·s (0,89 cP).
7. Pump efficiency is ignored because this study isolates the main variables (flow rate and valve closure time) as the determining factors of water hammer intensity, while efficiency only influences energy consumption and not the transient pressure.
8. The research assumes ideal theoretical and experimental conditions at a fluid temperature of 25°C flowing through a PVC pipe with a diameter of 1 inch (25,4 mm).
9. The study focuses only on unsteady (transient) flow behaviour during water hammer events and does not consider steady-state flow conditions or long-term oscillation effects beyond the scope of testing.