CHAPTER I
INTRODUCTION

1.1 Background

Filtration is the process of separating solids from a fluid using a porous medium that only allows the fluid to pass through. This operation is widely applied in various industries to purify products, separate phases, or treat waste. The filtration process is influenced by the properties of the solid–liquid mixture, the characteristics of the filter medium, and operating variables such as pressure, time, and filtration area. One common industrial equipment used is the plate and frame filter press, which operates in batch and uses pressure to speed up the formation of a wet solid deposit (*cake*).

To evaluate filtration performance, it is important to observe key parameters that reflect the characteristics of the process. In this study, three main parameters are the focus: specific cake resistance, equivalent filtrate volume, and optimum filtration time. These parameters are used to assess the flow resistance caused by the cake, the filtration capacity, and the time efficiency of the process. The values obtained for comparing operating conditions and validating the practical results to theory.

1.2 Problem Statement

In this experiment, filtration and washing operations will be carried out to determine the filtration parameters, including specific cake resistance, optimum filtration time, and equivalent filtrate volume. These operations will be performed using a plate and frame filter press.

1.3 Practicum Objectives

1. Determine the effect of time on the filtration process.
2. Determine the effect of the number of plates on the filtration process.
3. Study the effect of different variables on the filtration parameters.
4. Compare the theoretical and practical optimum times in the filtration process.

1.4 Practicum Benefits

1. Students are able to operate a plate and frame filter press.
2. Students understand the principles of the filtration process.

3. Students are able to determine specific cake resistance, equivalent filtrate volume, and optimum time in both filtration and washing operations.

CHAPTER II
LITERATURE REVIEW

2.1 Definition of Filtration

Filtration is the process of separating solid particles from a fluid by passing the fluid through a filter medium, where the solids are retained. The fluid can be either a liquid or a gas, and the output from the filter can consist of the fluid, the solids, or both (McCabe et al., 1993). The filter medium, or septum, acts as a barrier that allows the fluid to pass while retaining most of the solids. The fluid that passes through the filter medium is called the filtrate (Green & Perry, 2008).

Fluid flows through the filter medium due to a pressure difference across it. Filters can therefore be classified into those operating above atmospheric pressure and those operating at atmospheric pressure. Pressures above atmospheric can be generated by gravitational force on a liquid column, by pumps or blowers, or by centrifugal force (McCabe et al., 1993).

In industrial applications, commonly used filters include pressure filters, vacuum filters, and centrifugal separators. Filtration processes can be carried out in batch or continuous, depending on whether solid removal is steady or intermittent. In batch filtration, fluid flow must be stopped periodically to remove the accumulated solids. In continuous filtration, both solid removal and fluid flow proceed without interruption (McCabe et al., 1993).

Filters are generally categorized into three types: cake filters, clarifying filters, and crossflow filters. This experiment uses a cake filter. Cake filters separate solids from a slurry with concentrations ranging from 1–40% (Green & Perry, 2008), producing either crystalline cake or sludge. This is different from clarifying filters, which trap solid particles within the filter medium, and crossflow filters, which separate suspended particles using a filter with very small pores (McCabe et al., 1993). At the start of cake filtration, solid particles enter the pores of the filter medium and deposit along with other particles over time, forming a cake on the surface of the medium. As this cake layer builds up, the filtration process becomes dominated by the resistance of the cake rather than by the pores of the filter medium itself (McCabe et al., 1993).

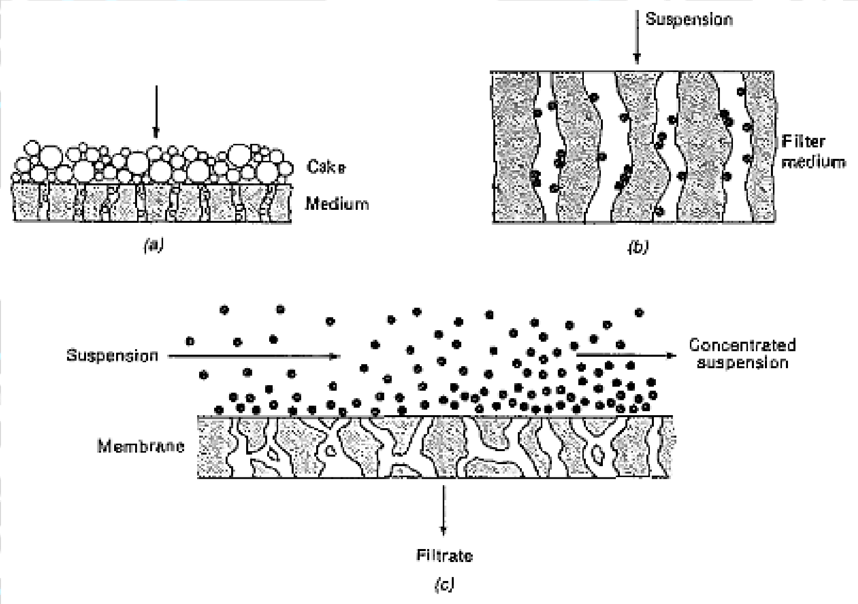

Figure 2.1 Filtration mechanism: (a) cake filter; (b) clarifying filter; (c) crossflow filter

According to Green & Perry (2008), the theory of filtration is based on the Hagen–Poiseuille equation, which is simplified to the following form:

$$\frac{1}{A}\cdot\frac{dV}{d\theta}=\frac{\Delta P\cdot g_c}{\gamma\cdot\left(\alpha\cdot w\cdot\frac{V}{A}+R_m\right)} \tag{2.1}$$

With:

A	= Filter surface area (m^2)
V	= Filtrate volume (m^3)
θ	= Filtration time (s)
ΔP	= Pressure drop (Pa)
γ	= Filtrate viscosity (Pa·s)
α	= Specific cake resistance (m/kg)
w	= Cake weight per volume of filtrate (kg/m^3)
R_m	= Filter medium resistance (m^{-1})

2.2 Plate and Frame Filter Press

A filter press is a type of filtration equipment commonly used in the batch pressure filter category for cake filters. A filter press consists of a set of plates designed to provide a series of spaces or compartments where solids can accumulate. These plates are covered with filter media, also known as filter cloth, on both sides, arranged vertically in a metal frame, and compressed using a hydraulic machine or manually (McCabe et al., 1993).

The plate and frame filter press is one type of filter press. This type of filter is flexible, can be used at high capacity, high pressure, and is the most economical (Kriegel, 1938). Slurry is fed into each compartment under pressure from one side, causing the liquid to pass through the filter cloth and exit through the discharge pipe. There are holes in the plates, so when the plates are arranged, a continuous channel is formed along the filter press. This channel is designed for the feed to flow through the plates so that when pumped, the feed first fills the entire plate before moving on to the next set of plates (Badger & Banchero, 1955).

Filtration can continue until the filtrate no longer flows out of the drain or the system pressure suddenly increases. This indicates that the plates are saturated with solids and no more slurry can flow (McCabe et al., 1993).

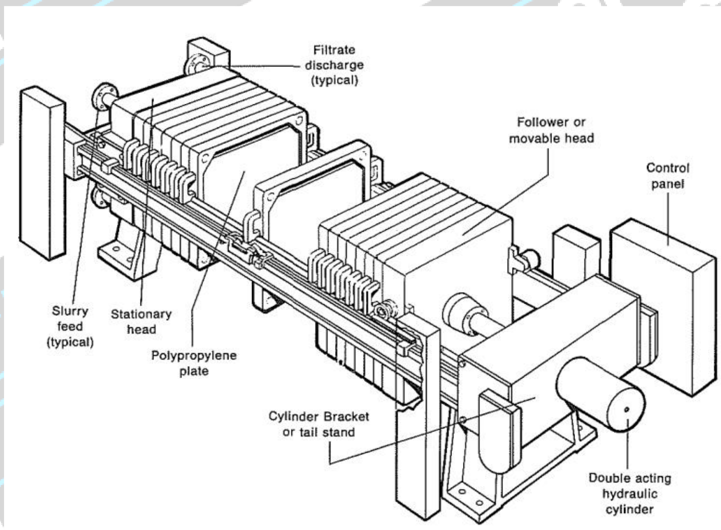

Figure 2.2 Plate and frame filter press

2.3 Specific Cake Resistance

Specific cake resistance is a measure of the hydrodynamic resistance of the cake formed on the filter media to fluid flow. Its value depends on the pore structure, size, and shape of the particles. Simply, this value describes how difficult it is for fluid to penetrate the cake layer.

The specific cake resistance value can be determined using graphical methods, as shown in Figure 2.1. The curve equation is obtained using Equation 2.1 as a linear line equation:

$$\frac{d\theta}{dV} = \frac{\gamma \cdot \alpha \cdot w}{\Delta P \cdot g_c \cdot A^2} V + \frac{\gamma \cdot R_m}{\Delta P \cdot g_c \cdot A} \tag{2.2}$$

Based on equation 2.2, the slope and intercept of the graph can be expressed as:

$$\text{slope} = \frac{\gamma \cdot \alpha \cdot w}{\Delta P \cdot g_c \cdot A^2} \tag{2.3}$$

$$\text{intercept} = \frac{\gamma \cdot R_m}{\Delta P \cdot g_c \cdot A} \tag{2.4}$$

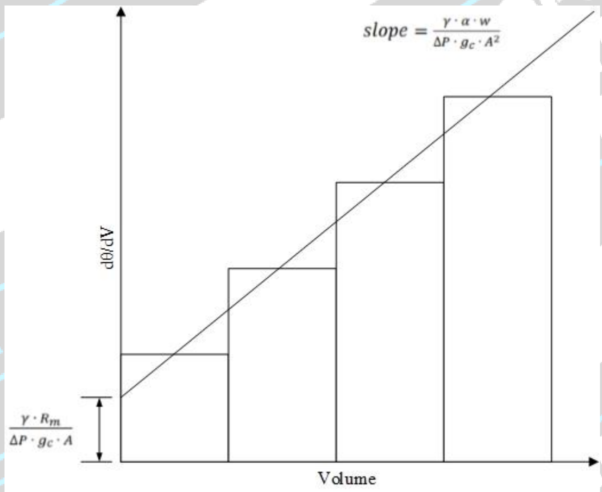

Figure 2.3 dθ/dV vs V graph

Thus, the specific cake resistance value can be determined using equation 2.3 as follows:

$$\alpha = \text{slope} \times \frac{\Delta P \cdot g_c \cdot A^2}{\gamma \cdot w} \tag{2.5}$$

2.4 Equivalent Filtrate Volume

The equivalent volume is the volume of filtrate that forms a cake with resistance equivalent to the resistance of the filter media. Simply, this value represents the resistance of the filter media expressed in terms of volume so that it can be calculated mathematically with the resistance of the cake.

The equivalent filtrate volume value can be determined by integrating equation 2.2, becoming:

$$\theta = \frac{\gamma \cdot \alpha \cdot w}{2 \cdot \Delta P \cdot g_c \cdot A^2} V^2 + \frac{\gamma \cdot R_m}{\Delta P \cdot g_c \cdot A} V \tag{2.6}$$

Equation 2.6 describes the total filtration time required to produce a filtrate volume of V, which is influenced by cake resistance and filter media resistance. To determine the equivalent filtrate volume as a substitute for filter media resistance, equation 2.6 needs to be defined as a quadratic equation, with K as a constant.

$$\theta = K(V + V_e)^2 \tag{2.7}$$

$$\theta = KV^2 + 2KV_eV + {V_e}^2 \tag{2.8}$$

By comparing the terms of equation 2.8 with 2.6, the values of K and V_e can be determined.

$$K = \frac{\gamma \cdot \alpha \cdot w}{2 \cdot \Delta P \cdot g_c \cdot A^2} \tag{2.9}$$

$$2KV_e = \frac{\gamma \cdot R_m}{\Delta P \cdot g_c \cdot A} \tag{2.10}$$

$$2 \times \frac{\gamma \cdot \alpha \cdot w}{2 \cdot \Delta P \cdot g_c \cdot A^2} \times V_e = \frac{\gamma \cdot R_m}{\Delta P \cdot g_c \cdot A} \tag{2.11}$$

$$V_e = \frac{R_m \cdot A}{\alpha \cdot w} \tag{2.12}$$

Equation 2.12 shows the same value as the division of equation 2.4 by 2.3. Thus, the equivalent filtrate volume can be defined by:

$$V_e = \frac{\text{intercept}}{\text{slope}} \tag{2.13}$$

2.5 Optimum Filtration Time

The optimum filtration time is the most efficient total time for producing filtrate in a filtration process. If the filtration process is continued beyond this time, the filtration process becomes inefficient due to a drastic slowdown in the filtration rate accompanied by an insignificant increase in filtrate volume due to the filter media becoming saturated with cake.

The optimal filtration time can be determined graphically, specifically when there is a significant decrease in filtrate volume during filtrate sampling at each unit of time. By substituting equations 2.3 and 2.12 into equation 2.6, the filtration time can be defined as:

$$\theta = \text{slope} \times \left(\frac{V^2}{2} + V_e \cdot V\right) \tag{2.14}$$

2.6 Washing Operation

After the filtration process is complete, washing is necessary to separate the filtrate that is still trapped in the cake so that it is not carried over to the next process in the industry (Badger & Banchero, 1955). A simple washing process can be carried out by flowing the wash liquid through the same channel as the slurry, although this may cause erosion of the cake and uneven washing due to the high fluid velocity near the inlet point, which gradually decreases along the filter press (Richardson et al., 2002).

The dye concentration in the wash water exiting the filter is analyzed to determine how far the washing operation has progressed. Washing is stopped when the color concentration in the wash water becomes constant. This is done to minimize damage to the filter cloth, particularly contamination. The washing process is carried out using water or air, or a mixture of both, to remove particles trapped in the micro-pores (Gray, 2014).

CHAPTER III
METHODOLOGY

3.1 Experimental Design

3.1.1 Practicum Framework

The filtration lab procedure begins with a filtration operation using a slurry produced from x%wt of CaCO3 in 5L of water. The filtration process. The filtration process is stopped when there is no water left in the tank. Then, continued with a washing operation. During the washing operation, the valve is ensured to be in the same condition as in the filtration operation. The washing process is stopped when there is no water left in the tank. Next, the cake weight, as well as the density and viscosity of the slurry are measured.

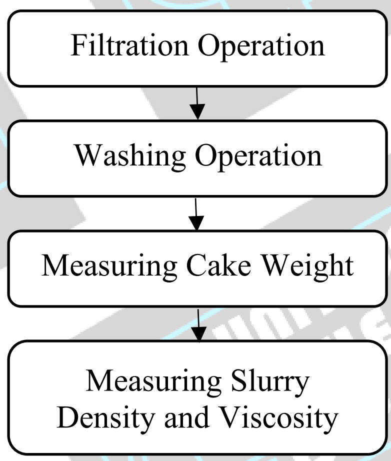

Figure 3.1 Practicum framework

3.1.2 Variable Determination

Fixed variable :

Independent variable :

3.2 Materials and Equipment Used

3.2.1 Materials

1. Water
2. $CaCO_3$
3. Textile dyes

3.2.2 Equipment

1. Filter press
2. Plate and frame
3. Filter cloth
4. Analytical balance

5. Viscometer Ostwald
6. Picnometer
7. Oven
8. Porcelain dish
9. Tank

3.3 Equipment Setup

The filtration lab equipment consists of a filter press equipped with a pump. Additional equipment required includes:

1. Slurry tank
2. Feeding pump
3. Compressor
4. Oven
5. Analytical balance

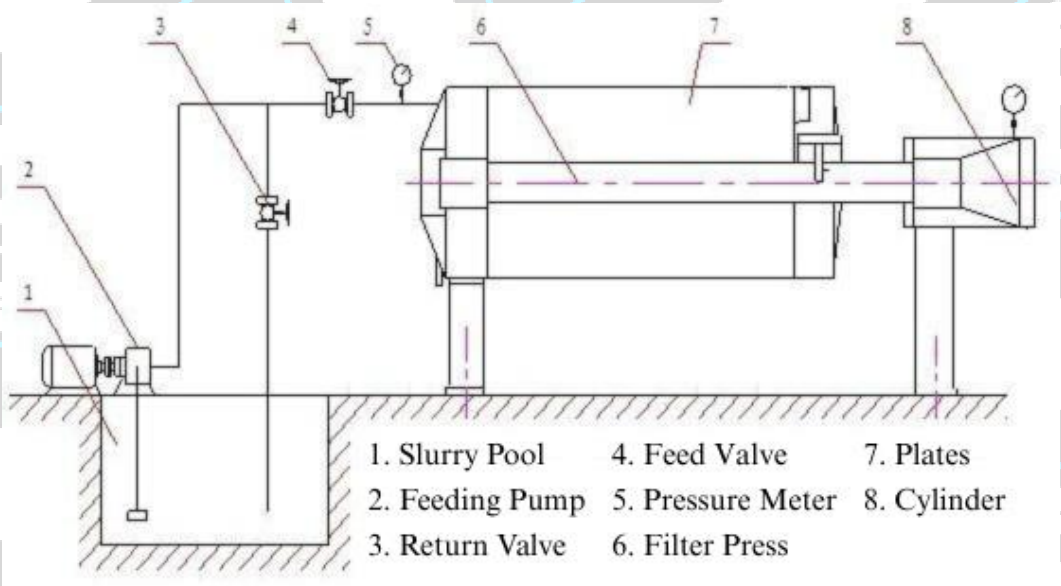

Figure 3.2 Filtration equipment arrangement (McCabe et al., 1993)

3.4 Response

Time, filtrate volume, and cake weight after filtration and washing operation.

3.5 Data Needed

1. Time
2. Filtrate volume
3. Density of Slurry and water
4. Viscosity of Slurry and water viscosities
5. Cake weight

3.6 Practicum Procedure

A. Practicum Preparation

1. Clean the filter cloth on the plate and frame using water.
2. Put the plate and frame onto the filter press.
3. Weigh the required amount of $CaCO_3$ according to the experimental variable and 2 gr of textile dye.
4. Fill the tank with water up to 5 L.

B. Plate and Frame Preparation

1. Tighten the mechanical lock from the center of the plate and frame toward the right end.
2. Secure the white lock on the hydraulic pump.
3. Increase the pressure in the hydraulic system by pumping until it reaches 450 kg/cm^2.
4. Further tighten the mechanical lock from the center toward the right end.
5. Lock the hydraulic pressure and release the hydraulic pump handle. The plate and frame will be clamped together, and the equipment is now ready.

C. Slurry Density and Viscosity Measurement

$$\rho_s = \frac{m_{\text{pikno isi}} - m_{\text{pikno kosong}}}{V_{\text{pikno kosong}}} \tag{3.1}$$

$$\gamma_s = \frac{t_s \times \rho_s}{t_a \times \rho_a} \times \gamma_a \tag{3.2}$$

With:

γ_s = slurry viscosity (Pa·s)

γ_a = water viscosity (Pa·s)

ρ_s = slurry density (kg/m^3)

ρ_a = water density (kg/m^3)

t_s = slurry flow time (s)

t_a = water flow time (s)

D. Slurry Viscosity Determination

1. Fill the viscometer with the liquid up to the specified level.
2. Draw the liquid using a tube to a specific mark.
3. Start the stopwatch as the liquid passes form point b to point a.
4. Record the flow time.
5. Calculate the viscosity of the liquid.

E. Filtration Operation

1. Prepare an x% $CaCO_3$ slurry in 5 L of water (calculate the required amount of $CaCO_3$ using the %wt formula).

$$\text{gr } CaCO_3 = \frac{\%wt \times (m_{air} + m_{pewarna})}{100 - \%wt} \tag{3.3}$$

2. In sequence, mix water, $CaCO_3$, and textile dye in the tank. Add $CaCO_3$ by sprinkling it evenly and slowly. Manually stir the slurry with a rod.
3. Turn on the compressor and wait until the pressure reaches 4 kg/cm^2. The compressor pressure must not exceed 7 kg/cm^2.
4. Open the compressor valve. Then, simultaneously open the tank valve and the filter valve to allow the slurry to enter the filter press. Wait until the slurry is completely fed.
5. Observe the condition if the filter press and compressor.
6. Turn off the compressor when the process is complete.

F. Washing Operation

1. Refill the tank with 5 L of water.
2. Turn on the compressor and wait for the pressure to reaches 4 kg/cm^2. The compressor pressure must not exceed 7 kg/cm^2.
3. Open the compressor valve. Then, simultaneously open the tank valve and the filter valve to allow the water enter the filter press. Wait until the water is completely fed.
4. Observe the condition of the filter press and compressor.
5. Turn off the compressor when the process is complete.

G. Cake Weight Measurement

1. Loosen the plate and frame using the hydraulic pump.
2. Remove the cake collected on the filter cloth and place it in a pre-weighed porcelain dish.
3. Weigh the collected cake.
4. Oven-dry the cake at 110°C for 60 minutes.
5. Re-weigh the oven-dried cake.
6. Continue oven-drying the cake for 3 additional cycles of 10 minutes each.
7. Weigh the cake again after the final drying cycle.

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