Graduate Certificate in Hydraulic Engineering

* Pipe Flow and Hydraulic Transients

Pipe Flow and Hydraulic Transients: Key Terms and Vocabulary

Pipe flow refers to the movement of fluids through a pipe or a network of pipes. The study of pipe flow is crucial in various engineering applications such as water supply systems, irrigation networks, oil and gas transportation, and firefighting systems. In this explanation, we will discuss some key terms and vocabulary related to pipe flow and hydraulic transients in the context of the Graduate Certificate in Hydraulic Engineering.

1. Fluid Properties
Fluids are classified into two categories: liquids and gases. The properties of fluids, such as density, viscosity, and compressibility, play a significant role in determining the behavior of fluids in motion. Density is the mass per unit volume of a fluid, while viscosity is the internal resistance to flow. Compressibility is the ability of a fluid to change its volume under pressure.
2. Pressure and Head
Pressure is the force per unit area exerted by a fluid on its surroundings. In pipe flow, pressure is usually expressed in terms of head, which is the height of a column of fluid that would produce the same pressure. The total head is the sum of the pressure head, elevation head, and velocity head.
3. Flow Regimes
The flow regime in a pipe depends on the Reynolds number, which is the ratio of inertial forces to viscous forces. Laminar flow occurs at low Reynolds numbers, where the fluid flows in parallel layers with no mixing. Turbulent flow occurs at high Reynolds numbers, where the fluid mixes and swirls, resulting in higher energy losses.
4. Hydraulic Gradient Line (HGL) and Energy Grade Line (EGL)
The HGL is a line that represents the pressure head at various points along a pipe. The EGL is a line that represents the total energy per unit weight of the fluid at various points along a pipe. The difference in elevation between the HGL and EGL represents the velocity head.
5. Friction Losses
Friction losses are the energy losses due to the friction between the fluid and the pipe wall. Friction losses depend on the pipe diameter, roughness, flow velocity, and fluid properties. The Darcy-Weisbach equation is commonly used to calculate friction losses.
6. Major and Minor Losses
Major losses are the energy losses due to friction in the pipe, while minor losses are the energy losses due to fittings, valves, and other accessories in the pipe. Minor losses are usually calculated using empirical formulas.
7. Pipe Network Analysis
Pipe network analysis is the study of the behavior of fluid flow in a network of pipes. The analysis involves the calculation of flow rates, pressures, and energy losses in each pipe and at each junction in the network.
8. Hydraulic Transients

Hydraulic transients, also known as water hammer, are pressure surges that occur in a pipe due to a sudden change in flow velocity. Hydraulic transients can cause pipe failure, valve damage, and other system failures. The study of hydraulic transients involves the analysis of pressure waves and the calculation of transient pressures in the pipe.

9. Surge Pressure and Water Hammer

Surge pressure is the maximum pressure that occurs during a hydraulic transient, while water hammer is the pressure wave that travels through the pipe. Surge pressure and water hammer can cause significant damage to the pipe and the surrounding structures.

10. Surge Suppression Techniques

Surge suppression techniques are used to mitigate the effects of hydraulic transients. These techniques include the use of surge tanks, air vessels, and pressure relief valves. Surge tanks are used to absorb the surge pressure, while air vessels are used to cushion the pressure wave. Pressure relief valves are used to limit the pressure in the pipe during a transient.

Example:
Consider a water supply system that consists of a pump, a pipe, and a reservoir. The pump delivers water to the pipe, which transports the water to the reservoir. The pipe has a diameter of 200 mm and a length of 1000 m. The roughness of the pipe is 0.015 mm. The flow rate in the pipe is 0.5 m/s. Calculate the friction losses in the pipe using the Darcy-Weisbach equation.

Solution:
The Darcy-Weisbach equation is given by:

$$h_f = f * (L/D) * (V^2/2g)$$

where:
h_f = friction loss (m)
f = friction factor
L = length of the pipe (m)
D = diameter of the pipe (m)
V = flow velocity (m/s)
g = acceleration due to gravity (m/s^2)

The friction factor, f, can be calculated using the Moody chart or the Colebrook-White equation. In this case, we will use the Colebrook-White equation:

$$1/\mathrm{sqrt}(f) = -2 \log10[(e/D) + (2.51/Re * \mathrm{sqrt}(f))]$$

where:
e = pipe roughness (m)
Re = Reynolds number

The Reynolds number is given by:

$$Re = (D * V) / \nu$$

where:
ν = kinematic viscosity (m^2/s)

For water at 20°C, ν = 1.006 x 10^-6 m^2/s.

Substituting the given values, we get:

Re = (0.2 * 0.5) / (1.006 x 10^-6) = 993664

Now, we can calculate the friction factor using the Colebrook-White equation:

1/sqrt(f) = -2 log10[(0.015/0.2) + (2.51/993664 * sqrt(f))]

Solving for f, we get:

f = 0.019

Substituting the values in the Darcy-Weisbach equation, we get:

h_f = 0.019 * (1000/0.2) * (0.5^2/2 * 9.81) = 24.5 m

Therefore, the friction losses in the pipe are 24.5 m.

Challenge:
Consider the same water supply system as in the example. Suppose that a valve at the end of the pipe is suddenly closed, causing a hydraulic transient. Calculate the surge pressure and water hammer in the pipe using the Joukowsky equation:

Δp = ρ * a * V

where:
Δp = surge pressure (Pa)
ρ = fluid density (kg/m^3)
a = wave speed (m/s)
V = flow velocity (m/s)

Assume that the wave speed in the pipe is 1000 m/s and the fluid density is 1000 kg/m^3. Calculate the surge pressure and water hammer in the pipe.

Solution:
Substituting the given values in the Joukowsky equation, we get:

Δp = 1000 * 1000 * 0.5 = 500000 Pa

Therefore, the surge pressure is 500 kPa.

The water hammer is the pressure wave that travels through the pipe. The wave speed in the pipe is 1000 m/s, which means that the wave takes 1 second to travel the length of the pipe:

t = L/a = 1000/1000 = 1 s

The duration of the pressure surge is twice the time taken by the wave to travel the length of the pipe:

Δt = 2 * t = 2 s

The water hammer is the maximum pressure that occurs during the surge:

WH = Δp * Δt = 500000 * 2 = 1000000 Pa

Therefore, the water hammer is 1 MPa.

Conclusion:
In this explanation, we have discussed some key terms and vocabulary related to pipe flow and hydraulic transients in the context of the Graduate Certificate in Hydraulic Engineering. We have provided examples and practical applications of these concepts, as well as challenges for further learning. The study of pipe flow and hydraulic transients is crucial for the design and operation of various engineering systems, such as water supply systems, irrigation