Hydraulic Transport in Biological Systems (BSEN 3310)

Fluid mechanics is the study of fluids both in motion and at rest. Prior to this course, I knew of water pumps, air conditioners, and piping systems in chemical plants. This course provided me with a better understanding of fluid behaviors and many different fluid systems, such as those I had wondered about before. For example, during this course I gained a better understanding of the pipe systems in chemical plants. Coming into this course, I already had learned how to calculate whether the flow inside a pipe is laminar or turbulent from my Heat and Mass Transfer course. Laminar or turbulent flow is determined by calculating the Reynolds number, which is the ratio of the internal forces over the viscous forces.

$$Re = \frac{\rho V_{avg} D}{\mu}$$

where: $Re = Renolds\ Number, \rho = fluid\ density, V_{avg} = average\ flow\ velocity, D = characteristic\ length, \mu = dynamic\ viscosity$

A fluid in laminar flow is one that flows smoothly or in consistent regular paths, in comparison to a fluid in turbulent flow which is mixing or flowing in an irregular path. The type of flow is often what influences which equations you can use. In addition to needing to know what type of flow you have in your pipes, you may also need to know the mass and volume flow rates, which I learned in my Thermodynamics course:

$$\dot{m} = \rho \dot{V} = \rho v A$$

This is where mass is calculated either by the density multiplied by the volumetric flow rate, or the density times the velocity times the flow area. The mass and volume flow rate are essential for making sure the laws of conservation of mass and energy are upheld during calculations. It is also important to know what is going on in your system, as a designed system may only be able to handle a certain mass or volume flow rate.

In this course, I expanded my learning as I found that a coefficient of compressibility for fluids is important. The coefficient of compressibility represents the pressure variation in relation to volume or density when temperature is constant.

$$K = -V\left(\frac{\partial P}{\partial V}\right)_T = \rho\left(\frac{\partial P}{\partial \rho}\right)_T$$

Knowing whether a fluid is incompressible or not effects which equations can be used. In a pipe system, it is extremely important to know the pressure at many points in the system. In a chemical plant, a differential manometer would likely be used to measure the pressure drop across a flow section, like shown in Figure 3-21 from the textbook.

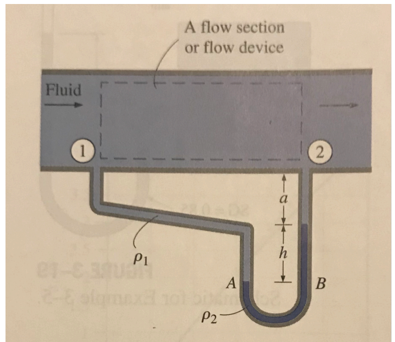

FIGURE 3–21
Measuring the pressure drop across a flow section or a flow device by a differential manometer.

The equation to calculate the pressure difference in this situation can be simplified as:

$$P_1 - P_2 = (\rho_2 - \rho_1)gh$$

A manometer is well suited to measure the pressure drop across a flow section like this, which you would see in a chemical plant, because the manometer is able to measure the drop in pressure without disrupting the flow, and it should be noted that this is for a horizontal case, if the pipe were vertical, gravity would be acting on the fluid in a different direction and you would not be able to use a manometer.

This course also taught me more about the entrance region, and how a boundary layer is formed by the particles of a fluid as it enters a circular pipe at a uniform velocity (see Figure 1). The boundary layer affects other fluid particles by slowing them down via friction, but to keep mass flow rate throughout the pipe constant, the particles toward the center of the pipe increase in velocity. This causes the fluid to develop a velocity gradient.

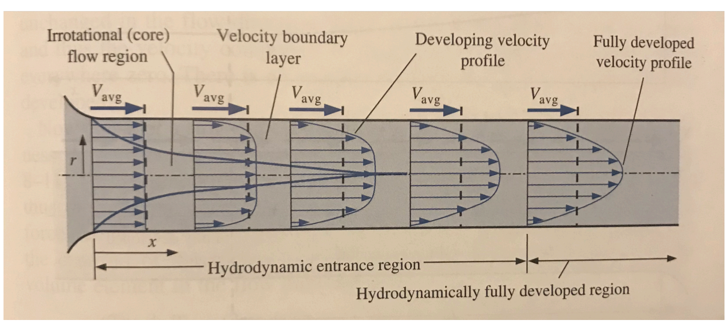

Figure 1. Diagram showing the development of the velocity boundary layer in a pipe.

The hydrodynamic entry length of the entrance region has different equations, depending on whether the fluid is in laminar or turbulent flow. The basic concept is that the entry length of a fluid in laminar flow will be much longer than that of a fluid in turbulent flow.

This course was one of the more challenging courses I have taken, as I took the lecture portion of the course when I was still in the Chemical Engineering department but then took the lab two years later once I had switched to Biosystems. However, I had retained a lot of the knowledge from the lecture portion of the course, which helped greatly for the labs. Yet at the same time, I feel I have a much better understanding of the course because of taking the lab and lecture separately, because having to revisit topics like Bernoulli's equation, pressure drop equations, and obstruction flowmeters for the labs. Reviewing the information and getting to put it into practice helped me have a better understanding of the concepts.

As my career aspirations involve working with plants, it is likely that I will be growing plants in a hydroponic or aquaponics system, and then many of the applications I learned from this class would be applicable. Having changes in flow could affect the growth of plant roots in a flow systems, and building a channel that cannot sustain certain flow rates could cause leaks or cause the channel to completely break. It will also be important to be able to calculate how the addition of plants and substrates affects the flow in a channel, and the drag each plant and its roots create.

REFERENCES

Cengel, Y.A., & Cimbala, J. M. (2006) *Fluid Mechanics Fundamentals and Applications* (2nd Edition.) New York, NY: McGraw-Hill.