A Simple Experiment to Enhancing Student Learning of Pressure in Fluid Power Course

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ABSTRACT

Pressure of fluid is the most important concept in fluid power course for mechanical engineering technology students. It is very difficult for students to understand that the pressure of the fluid when the fluid is moving is different than the pressure of fluid at rest. This paper discussed one laboratory exercise, which used an acrylic tube with a shut off valve at the bottom to demonstrate that the pressure change when the water in the acrylic tube is flowing out of the valve comparing to the water at rest. Pressures are measured at three locations: bottom of the tube opposite to shut off valve, before the shut off valve and after the shut off valve. The apparatus and the laboratory exercise are described. The experiment help students to better understand the physical meaning of Bernoulli Equation for an ideal fluid, which implies that the sum of potential, pressure and kinetic energy remain constant.

INTRODUCTION

Many Mechanical Engineering Technology (MET) students at Penn State Erie tend to struggle with some of the basic concepts in thermal-fluid science courses. One reason for this issue is the characteristics of the thermal-fluid sciences. Using the sight sense is an important way for people to explore the world. People see lots of moving objects in their daily life, thus it is very easy for them to understand the concept of velocity. In thermal-fluid sciences, there are lots of concepts that are not visible, such as pressure, heat transfer, internal energy, enthalpy etc. Since students have few daily life experiences to relate to, it is difficult for them to understand these concepts. MET students tend to learn by doing. Students with this learning style benefit from theoretical coursework that is heavily reinforced with hands-on laboratory experiences. Although there are several lab components in these courses, they do not always address the core concepts that the students are struggling with. Classroom exercises are developed to help students better understand certain important concepts in thermal-fluid sciences. This paper presents the development of classroom exercises for the pressure of fluid. Pressure of fluid is the most important concept in fluid power course for mechanical engineering technology students. It is very difficult for students to understand that the pressure of the fluid when the fluid is moving is different than the pressure of fluid at rest.

Felder and others have noted that individual learning styles need to be recognized when developing educational materials [1,2,3]. The “hands-on” active learning exercises being developed by the authors should be beneficial to students with concrete learning styles. In fact, in general Crouch, et al [4] has shown that having students make a written commitment to their thoughts is a more effective teaching tool than just having them watch a demonstration. The target audience for these exercises is MET students taking a thermal-fluid science courses. Technology students tend to have concrete learning styles, so an active approach should be appropriate for those students.

Development Plan and Challenges:

The activity of the classroom exercise is adopted from the Workshop Physics model [5] which is listed below:

• use peer instruction and collaborative work;

• keep students actively involved by using activity-based guided-inquiry curricular materials;

• use a learning cycle beginning with predictions;

• emphasize conceptual understanding;

• let the physical world be the authority;

• evaluate student understanding;

• make appropriate use of technology;

• begin with the specific and move to the general.

The exercises described in this paper are intended to go beyond simple in-class demonstrations. We intend to use a guided inquiry approach in the design of the exercises. In this method the students must be actively involved in the learning experience. These will not be simple demonstrations. Students are required to do several tasks. In general, they will work in teams and be asked to complete a pre-exercise worksheet which will require them to make predictions about outcomes based on their past experiences, pre-conceived notions and possible previous coursework. As the exercise is taking place the students should be involved in an active discussion about what they are seeing, and why things are happening as they are. Finally they will be asked to complete a post-exercise worksheet which will contain many of the same questions that were on the pre-exercise worksheet. Additional questions will be asked to judge if they can transfer the outcomes of the exercise to other situations.

From previous experience with the Engineering of Everyday Things project [6], the hardware portion is the easy part. Identifying the concept and creating appropriate worksheets is the difficult part, and will probably take several iterations. It is important that the worksheets are clear and enhance the students learning instead of causing confusion. Poor worksheet design can easily result in the students spending more time trying to figure out what is being asked than in actually thinking about the concept.

One of the key features of the worksheets will be one or more questions to determine if the students can transfer the knowledge they should be gaining from the exercises to other situations which do not necessarily look like the exercise. This transfer of knowledge will be further examined on regular test at a different time to help determine if the exercise had any positive effect on the students' learning.

OVERVIEW OF THE PROPOSED EXERCISE

This section gives a brief description of the exercise, the concept that the exercise focuses on and the current state of development.

Students learned from fluid statics that the pressure at the bottom of stationary water column is the product of specific weight of the water and water column depth. However, the pressure determination can be difficult for students when the water is flowing. Bernoulli equation is the most used equation in fluid mechanics and it is also the one be abused the most. There are three terms in the equation: pressure head, velocity head and elevation head. Velocity head and elevation head are relatively easy for students to understand. However, pressure head can be confusing. The most straight forward method to determine the pressure head at certain location is to use a pressure gauge. When the water flows out from the nozzle at the bottom of the water column, the water pressure at the exit of the nozzle will be zero gauge pressure. This is very difficult for students to understand because of the dramatic change between the pressure of the stationary water and the one of the flowing water.

An exercise is developed to enhance students understanding of the pressure of fluid. Figure 1 shows the schematic of the apparatus used for this exercise, an acrylic tube with a shut off valve at the bottom. The tube is 3 feet tall and there is a nozzle at the bottom of the tube and the nozzle is controlled by a shut off valve. There are three manometers used to measure the pressure of water at locations A, B and C. A ruler is mounted along the water column to measure the height of the water column and the readings of the manometers. A is located at the opposite side of the nozzle and at the same elevation of the nozzle. B and C are located before and after the shut off valve, respectively. The students are asked to predict the reading of the three manometers for two cases. One case is the valve on nozzle is closed and water in the tube is stationary. The other case is the valve is open and water in the tube is flowing out.

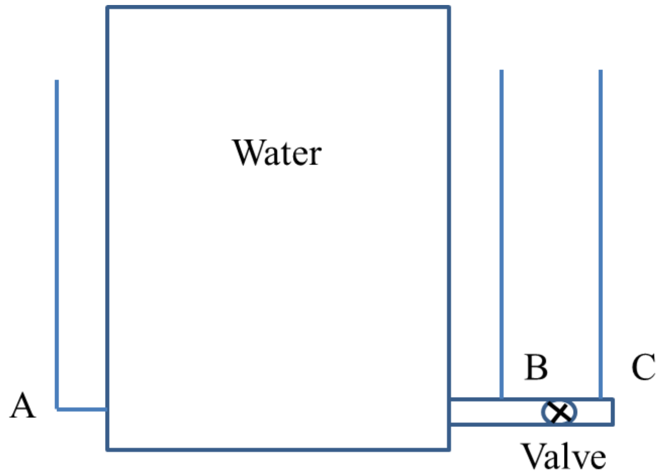

Figure 1. Apparatus for the pressure exercise.

CONCLUSIONS

This paper presents an in-class exercises that help MET students to understand the fluid pressure because it is very difficult for students to understand that the pressure of the fluid when the fluid is moving is different than the pressure of fluid at rest. The exercise development and apparatus are presented. The plan is to have the apparatus ready for fall of 2016.

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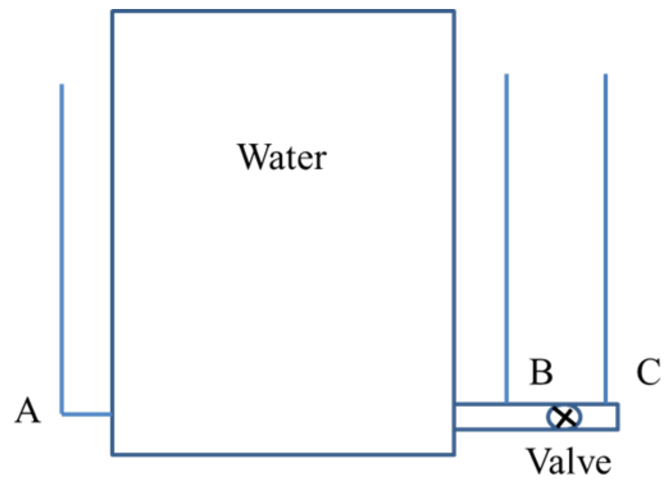
Appendix: Example Exercise – Pressure exercise:

Pre-Exercise Worksheet

The questions on this Quiz will not affect your course grade. The questions are designed to allow us to understand your learning as a result of performing the lab exercise. Work in groups of three students.



The sketch above depicts a cylinder with a nozzle at the bottom of the cylinder. There are three manometers used to measure the pressure of water at locations A, B and C. Before the cylinder is filled with water, answer the following questions:

1. With the valve of the nozzle at the off position, compare the water level of the water in the cylinder, manometer A and B.

2. Turn on the valve and water flow out of the nozzle, what will be the reading of manometer C?

3. Turn on the valve and water flow out of the nozzle, compare the water level of the water in the cylinder, manometer A, B and C.

4. How to calculate the average velocity of the nozzle using Bernoulli equation?

Post-Exercise Worksheet

Fill the cylinder with water, answer the following questions:

1. Measure the diameters of the cylinder and nozzle.

2. With the valve of the nozzle at the off position, compare the water level of the water in the cylinder, manometer A and B. Calculate the pressure at location A and B.

3. Turn on the valve and water flow out of the nozzle, what is the reading of manometer C? Explain the result.

4. Turn on the valve and water flow out of the nozzle, compare the water level of the water in the cylinder, manometer A, B and C. Explain the result.

5. Calculate the average volumetric flow rate out of the nozzle when the water level in the cylinder drop from E to F (E and F are water column heights). Use two methods to determine the average volumetric flow rate. One method is to use the volume of water flowing out of the nozzle divided by the time taken for this process. The other method is Bernoulli equation. Compare the results of these two methods.