DEMONSTRATION OF PUMP PERFORMANCE

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Abstract ? Energy conservation is a recurring theme in a fluid mechanics course for juniors in Mechanical Engineering Technology at Purdue University in West Lafayette. Variable speed drives are particularly emphasized because they offer an opportunity to reduce power consumption by up to 70% at off-peak flow conditions. Real-time data from a remotely accessible pump network has been used in a lecture setting to illustrate VSD's to undergraduate students.

FOCUS ON ENERGY CONSERVATION

The Department of Energy provides a clear rationale for this paper. "Electric motors supply most of the so-called drive energy in the United States and consume more than half of the nation's electricity. Electric motors are used in pumps, fans, and compressors, and for materials processing and handling. A typical industrial motor operating a large percentage of the time consumes five to ten times its capital cost in electricity every year. That's like spending $100,000 a year on gas for a $10,000 car. This also means that small gains in efficiency translate into big gains in savings." [1]

One of the greatest opportunities for "easy" savings is fluid distribution systems. Studies show that using variable speed drives (VSD's) to throttle flow can reduce motor energy use by 10% to 70%. [2] With this data in mind, energy efficiency and VSD's have become an important topic in a required fluid mechanics course for Mechanical Engineering Technology (MET) students. Readers can consult reference [3] to learn more about VSD technology.

REMOTELY ACCESSED LAB

Applied Fluid Mechanics (MET 313) is a required course for MET students in their junior year at Purdue University in West Lafayette, IN. The course has 3 one-hour lectures each week. The prerequisites are Heat Power (MET 220) and Fluid Power (MET 230). Since students enter the course with a solid background in thermal & fluid systems, MET 313 goes beyond basic piping design problems. Energy conservation strategies for real world fluid systems are an important topic.

A variety of remotely accessible laboratory equipment is used for lecture experiments. Figure I is a simple graphic interface for monitoring a small circulating pump that is part of a lab-based solar heating system. The pump, along with a variable speed drive that is not shown in Figure I, is controlled by a commercially available building automation system that is accessed over the Internet. Although the picture is a little small, Figure I also shows that real time sensor readings of pump speed (rpm), flow (gpm), pressure (psi), and power consumption (kW) are superimposed on top of the pump picture. Refer to references [4] and [5] for a detailed explanation of building automation systems and remotely accessible labs.

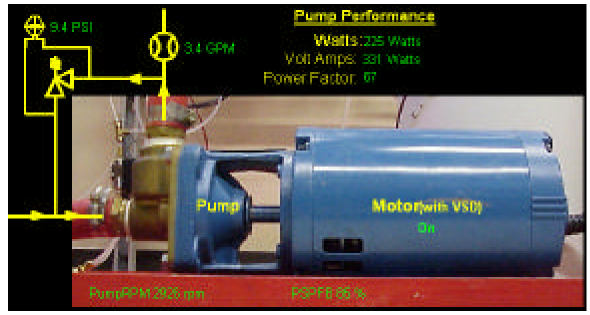

FIGURE. I
REMOTELY ACCESSIBLE PUMP WITH VARIABLE SPEED DRIVE

COLLECTING PUMP PERFORMANCE DATA

The graphic interface shown in Figure I is projected onto a large screen and used to conduct a pump experiment in a lecture with approximately 40 students. The instructor orchestrates the experiment while students record data. When the instructor enters an "80" into the VSD output window, an 8 Volt DC control signal is sent to the variable speed drive, which in turn commands the pump motor to operate at 80% of its rated speed.

Table I is an example of pump performance data collected by students during a lecture experiment. The data collection process was fairly simple. While the pump was operating at full speed, measurements of pump speed (rpm), system flow (gpm), pressure (psi), and power consumption (W) were made. The VSD was used to slow down the pump by 5%, and then another set of speed, flow, pressure, and power measurements were made. About 10 of the 20 data points collected during the experiment are shown in Table I.

Once all the data was collected, it was observed that the pump power did not reach "zero" at "zero" speed because the variable speed drive is a fixed part of the power measurement. To account for this, students subtracted a constant value of 50 Watts from each power measurement to cancel out the constant power consumption of the VSD, hence the "corrected" label shown above the power measurement.

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TABLE I
PUMP PERFORMANCE DATA

pump speed rpm	system flow gpm	pump differential pressure psi	corrected electric power W
3376	4	11.7	233
3265	3.7	10.9	204
3018	3.4	10	171
2797	3.1	8.9	142
2538	2.8	8.3	116
2280	2.5	7.2	93
2040	2.3	6.1	72
1865	2	5.1	54
1634	1.6	4.2	39
1339	1.4	3.5	26

STUDENTS ANALYZE PUMP PERFORMANCE

Students enter the pump data from Table I into a computer spreadsheet to evaluate a number of common assumptions about resistance to flow and overall pump performance. For example, students evaluate a system curve by plotting the pressure and flow data as shown in Figure II. The vertical axis is resistance to flow, typically expressed typically in psi or feet of water. The horizontal axis is flow rate, typically in gallons per minute. Students develop a smooth curve through by applying a power curve fit to the data.

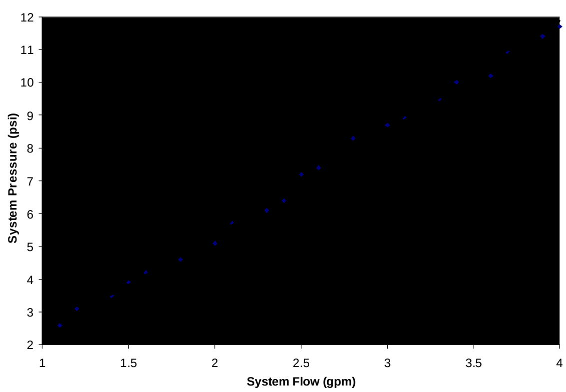

FIGURE. II
SYSTEM CURVE IS APPROXIMATELY LINEAR WITH RESPECT TO FLOW

Although it is typically assumed that pump pressure varies with flow squared, Figure II shows students that the experimental data is closer to a linear function. This is most likely due to laminar flow in the piping network. The squared relationship between pump pressure and flow assumes fully turbulent conditions. Reference [6] provides additional insight to deviations from accepted pump affinity laws, which make simple predictions about how flow, pressure, and power vary with pump speed.

Students complete Figure III to learn about the crucial relationship between power consumption and pump speed. The vertical axis of the graph is power consumption in Watts. The horizontal axis is pump speed in rpm. A power curve through the experimental data shows something less than the cubed relationship predicted by the pump affinity laws. As suggested earlier the deviation is most likely due to flow conditions that are less than fully turbulent. Students still gain an appreciation for the potentially large energy savings by using a VSD (as opposed to a flow control valve) for achieving variable flow.

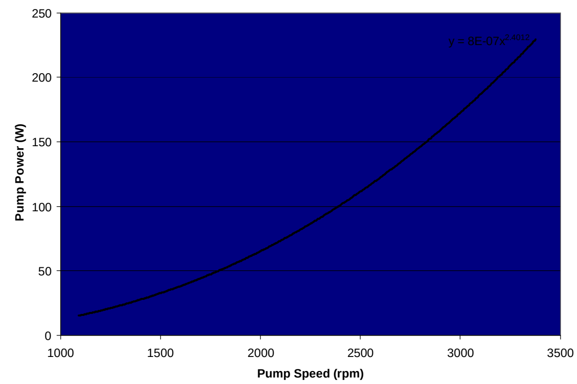

FIGURE. III
POWER CURVE IS NOT QUITE CUBIC WITH RESPECT TO SPEED

CONCLUSION

Fluid mechanics is difficult to teach to undergraduate students. The topic appears dry and overly analytical, particularly when it is taught in a lecture environment. Remotely accessible laboratory equipment offers a unique opportunity to capture a student's attention by showing practical applications. An experiment that evaluates how flow, pressure, and power consumption vary with pump speed has been developed and used by large numbers of undergraduate students. Once students look at real data, they have a better grasp of the potential energy savings when VSD's (as opposed to valves) are used to vary the flow in fluid systems.

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