The Effect of Operating Speed on the Efficiency of Centrifugal Pumps

John Nico San Jose, Mechanical Engineering

Mentor: Dr. Paul Nissenson

Kellogg Honors College Capstone Project

Objective

To observe and characterize the performance of the pumps in the Cal Poly Pomona Fluids Lab and reconcile their behavior with that presented in fluids textbooks.

Background

Numerous fluids books discuss the pump similarity laws. The pump similarity laws are a set of equations that help predict the performance characteristics of similar pumps within the same family under different operating conditions. The pump similarity laws are listed below.

$$\left(\frac{Q}{\omega D^3}\right)_1 = \left(\frac{Q}{\omega D^3}\right)_2 \qquad \left(\frac{gh_a}{\omega^2 D^2}\right)_1 = \left(\frac{gh_a}{\omega^2 D^2}\right)_2 \qquad \left(\frac{\dot{W}_{shaft}}{\rho\omega^3 D^5}\right)_1 = \left(\frac{\dot{W}_{shaft}}{\rho\omega^3 D^5}\right)_2 \qquad \eta_1 = \eta_2$$

Where Q is flow rate, ω is impeller speed, D is some characteristic diameter, g is gravity, h_a is actual head rise, $\dot{W}_{shaft}$ is shaft power, and ρ is density. The 1 and 2 represent two different pumps from the same family. The first equation shows what is called the "flow coefficient", which is simply a dimensionless parameter that will help determine the performance. The last equation suggests that the relationship between the magnitude of the peak efficiencies of two pumps in the same family is that they are equal to one another ($\eta_1 = \eta_2$). However, over the course of multiple quarters, data acquired by Cal Poly Pomona students in the Cal Poly Pomona Fluids Lab has suggested that the peak efficiency for the same pump varies at different speeds, contrary to that suggested by numerous fluids books.

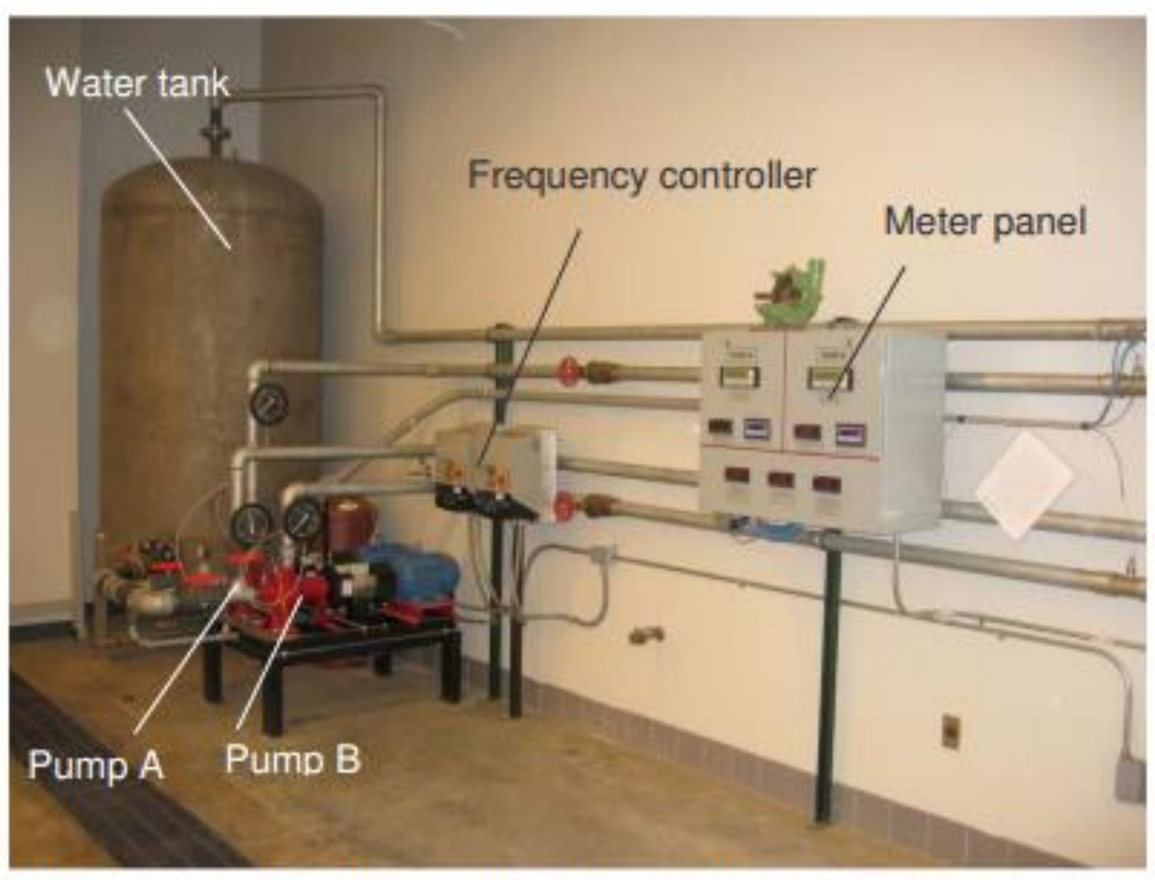
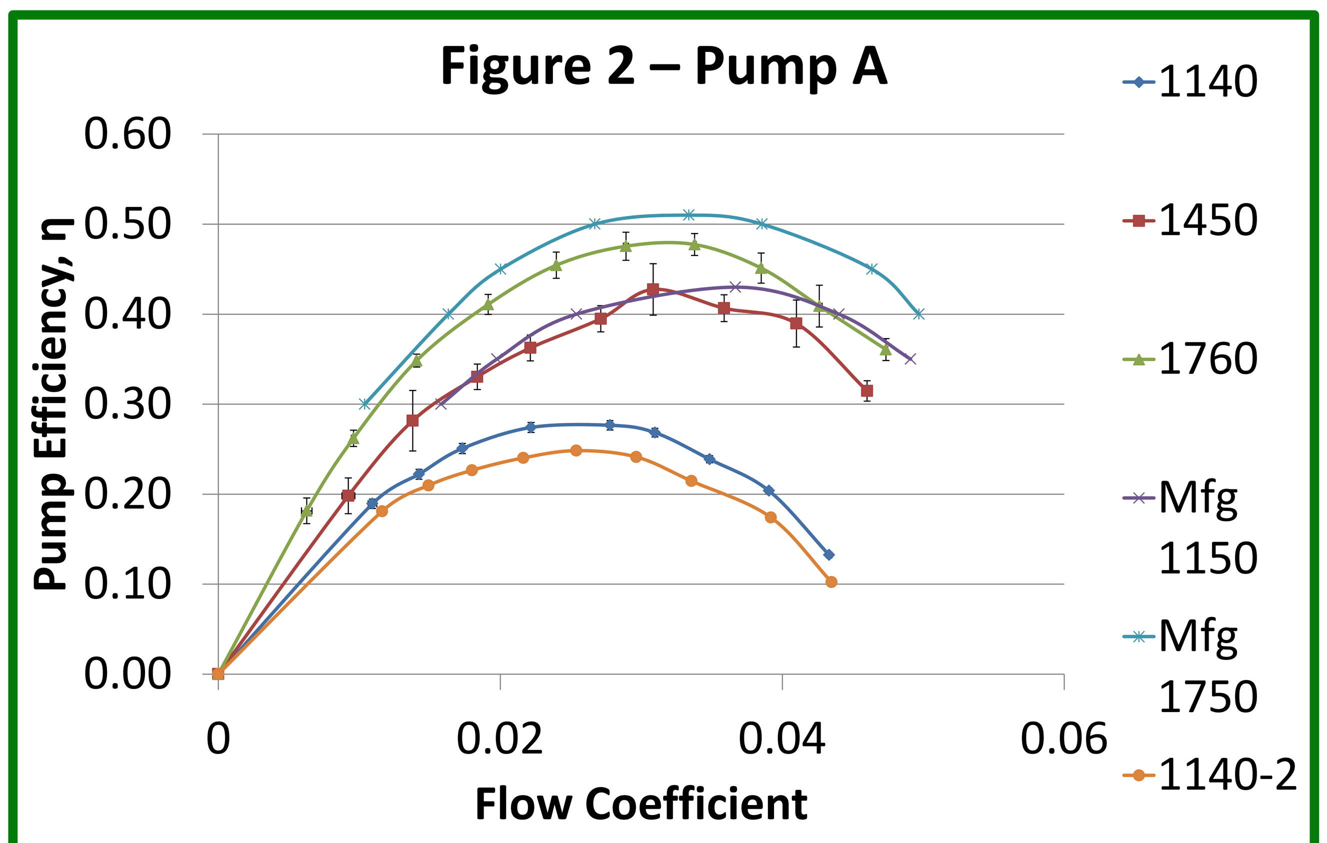
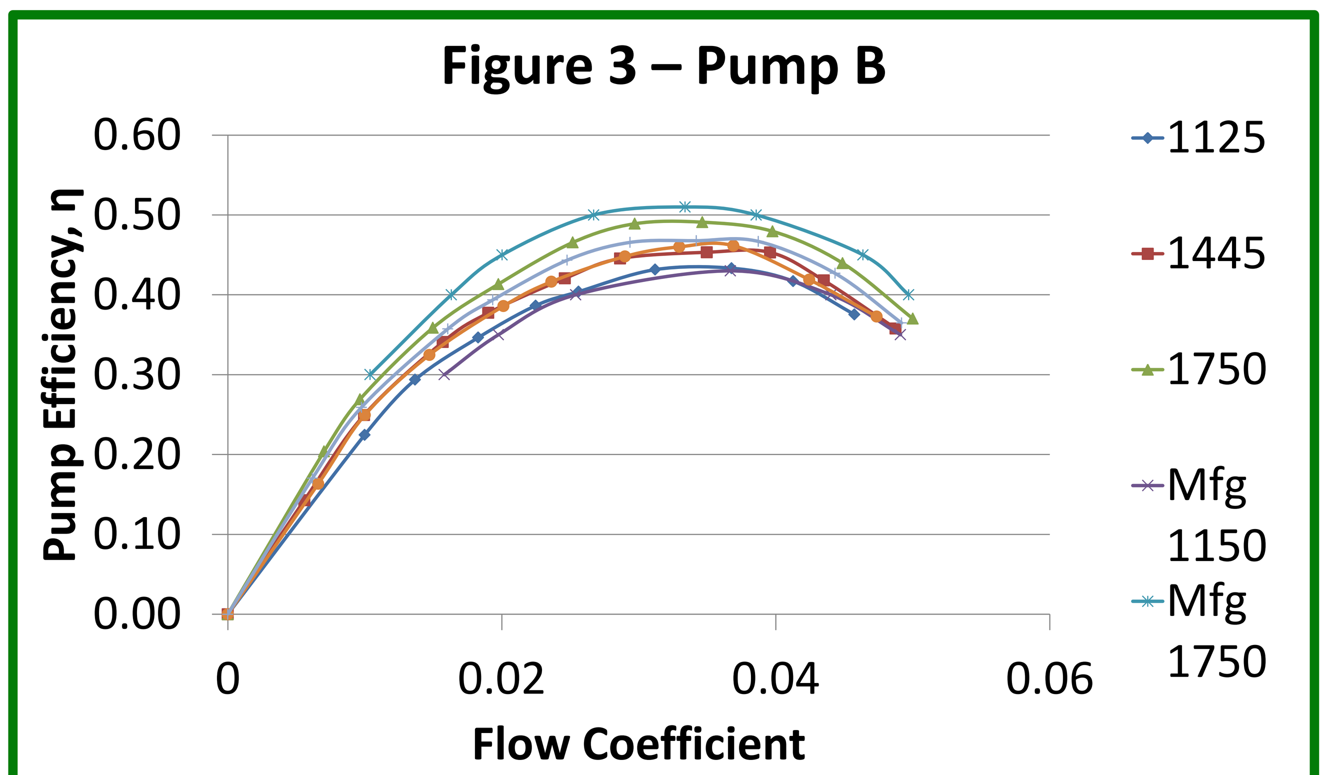


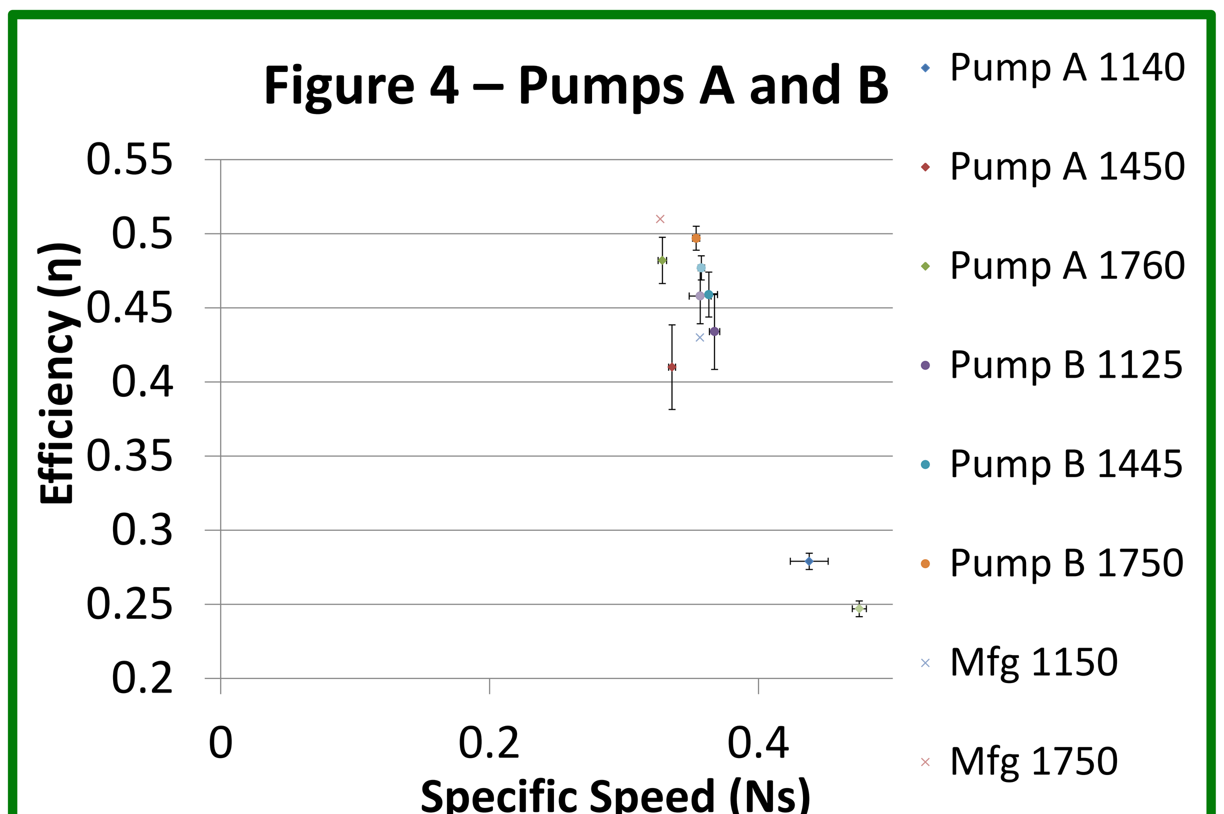
Figure 1: The centrifugal pump performance experiment apparatus

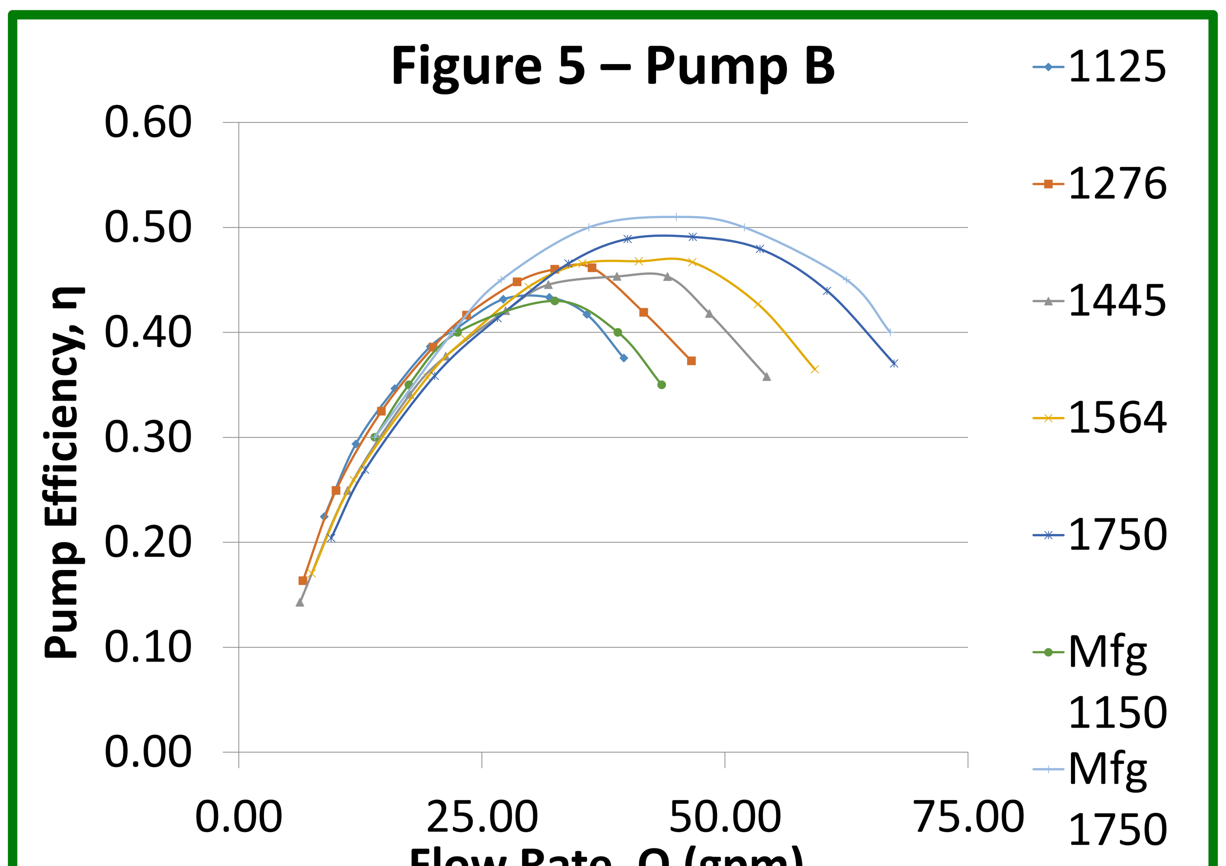
Experimental Procedure

1. Open the valve for the pump system corresponding to the pump being tested.
2. Turn on the pump and adjust to desired impeller speed.
3. Vary flow rate from 0 to 100% at approximately 10% intervals, then record values of flow rate Q, pressure drop ΔP, torque T, and impeller speed ω, as well as approximate uncertainties.
4. Repeat for each impeller speed.









Results

Further investigation revealed a chart in Karassik's *Pump Handbook* that displayed peak efficiency as a function of both specific speed (another dimensionless parameter) and flow rate, for radial-flow pumps, which is not mentioned in other fluids books.

Figures 2 and 3 show that the maximum efficiencies at each speed occur at almost the same flow coefficient. Figure 4 shows that the maximum efficiencies occur at almost the same specific speeds as well.

Figure 2 shows that pump A running at low speeds produces a significantly lower maximum efficiency than other speeds.

Conclusions

As a pump's impeller speed increases, so does its maximum efficiency value. Also, the flow rate value at which maximum efficiency occurs increases with speed.

The lower maximum efficiency value of pump A at low flow rates is likely due to a problem in the pump system or sensors, which in turn is likely to stem from the fact that the pumps in the fluids lab have not been maintained since being installed.

References

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Karassik, Igor J. *Pump Handbook*. New York: McGraw-Hill, 1986. Print.

Fluid Mechanics Laboratory Manual, 1st printing, Winter 2013, Cal Poly Pomona, Figure 1, p. 22.