Name
Section #

Lab 3: Pressure-Flow Relationship Across a Needle Valve

Introduction

The purpose of this experiment was to characterize how pressure and flow are related for a needle valve. The expected relationship was $Q = k\sqrt{\Delta p}$, where Q is volumetric flow rate through the valve, Δp is pressure across the valve, and k is the valve coefficient. This equation assumes that the downstream flow velocity is much greater than the upstream velocity. The valve coefficient for one specific needle valve was found as a function of the valve setting.

Methods

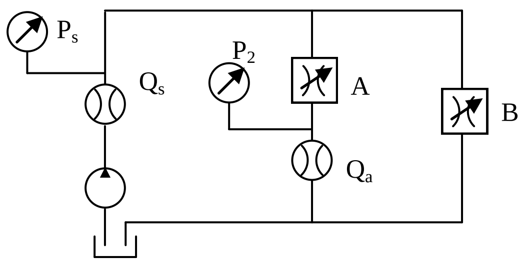

Figure 1: Hydraulic circuit used in Lab 3

The circuit used in this lab (shown in Figure 1) includes two needle valves, denoted A and B. The flow through valve A was varied by changing the closure of valve B, and the pressure across and flow through valve A was measured. The valve coefficient for valve A, k_A, was found using the method of least squares. This procedure was repeated for several settings of valve A, measured in turns of the valve A knob, to determine how k_A changes with the setting of valve A.

Results

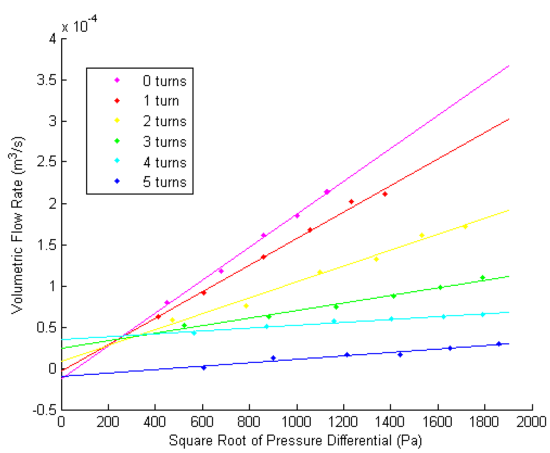

Figure 2: Pressure-flow relationships for various settings of valve A (knob turns: 0 turns => fully open)

Each of the colored data sets shown in Figure 2 represent the changes in pressure and flow for valve A that occurred while the setting of valve B was varied. Each of these data sets was measured at a different setting of valve A, measured in turns of the knob of valve A, where zero knob turns indicate that valve A was fully open. The square root of the pressure differential is plotted on the dependent axis so that a linear fit can be calculated, with the slopes of the fit lines equal to the valve coefficients for each of the settings of A.

The linear fit parameters, including the calculated valve coefficients, k_A, are summarized below in Table 1:

Table 1: Linear fit parameters of the pressure-flow relationships for valve A

		Linear Fit	
Turns of the Knob (turns)	Color of Data Set in Figure 2	slope = k_A (m^(7/2) / kg^(1/2))	y-intercept (m^3/2)
0 (fully open)	magenta	2.00e-7	-1.27e-5
1	red	1.61e-7	-4.11e-6
2	yellow	9.63e-8	8.16e-6
3	green	4.56e-8	2.48e-5
4	cyan	1.74e-8	3.50e-5
5 (nearly closed)	blue	2.06e-8	-9.90e-6

The calculated valve coefficients were then plotted as a function of turns of the knob of valve A, shown below in Figure 3:

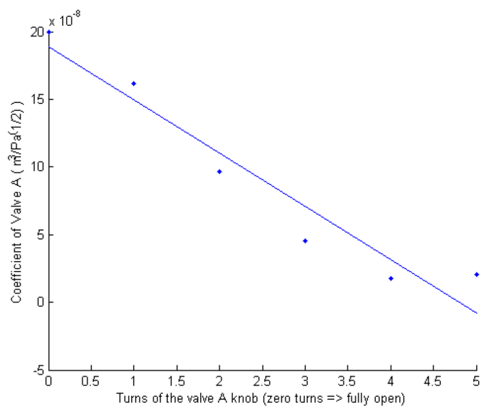

Figure 3: Valve coefficients k_A as a function of turns of the knob of valve A

A linear fit was then found to relate k_A and turns of the knob, resulting in the equation:

$$k_A = -3.94e-8 * (\text{knob turns}) + 1.89e-7 \text{ [m^(7/2) / kg^(1/2)]}$$

Discussion

The data shown in Figure 2 support the assumption that flow rate through a needle valve is linearly proportional to the square root of the pressure drop. The values of k_A found for different settings of valve A suggest a linear relationship between valve coefficient and knob turns, but the accuracy of the fit line is questionable (Figure 3.) Increasing turns of the knob represent decreasing orifice area of valve A. The valve coefficient represents the orifice area, as well as the discharge coefficient and fluid density. As valve A closes, the orifice area and discharge coefficient should decrease, which is supported by the data in Figure 3.

Conclusion

The valve coefficient was found for a needle valve as a function of turns of its knob from fully open to fully closed: k_A = -3.94e-8 * (knob turns) + 1.89e-7 [m^(7/2) / kg^(1/2)]. However, this equation's accuracy is questionable and more data should be collected to verify the relationship.