Abstract—The goal of this project was to provide a solid foundation for the development of a directional control valve operated by solenoids to open and close four independently controlled poppet valves. Simulations were performed to model a Yuken proportional control valve; this provided a way to simulate different parameters before or without physical testing. Data compiled from the simulations will provide valuable information leading into the testing phase and prototype phase for future groups continuing to improve this concept. Simulations proved to be successful in modeling the Yuken valve and demonstrating actuation using a bucket arm. Further developments led to more accurate results, closely modeling that of the Yuken valve. Further improvements can be made to the simulation and concept in the future.

Keywords—control; valve; hydraulics; simulation; solenoid

I. INTRODUCTION

Hydraulic valves are integral in controlling the flow of fluids in hydraulic/pneumatic pump systems, generally directing the energy source by controlling the path in which it is taken; often they are utilized in engines, directing oil/fuel flow. However, there is one major drawback from using this type of valve: fixed spool geometry. For each application of a particular hydraulic valve, specific orifice geometries are used and must be machined for their specific application, often times making them impractical and cost ineffective. Situations where orifice sizes must be changed to affect hydraulic/pneumatic flow require a more effective method that cuts out the machining process and is applicable to a variety of situations where orifice geometry differs. An example is a four-way spool valve that controls the flow between pumps between a cylinder and tank. Orifice size restricts versatility of this particular valve, and overall efficiency. Replacing this with independently controlled valves (meter-in/meter-out approach) would greatly increase the applications of one particular four-way valve [1]. Although this is not a new approach, it is relatively untested with many improvements that can still be made. Several companies linked to manufacturing and engineering have come out with patented variations of independently controlled valves with varying success. The uses for this type of hydraulic system would greatly benefit a variety of fields/areas such as medical, construction, agriculture, etc.

The general theory behind independently controlled valves involves electronically controlled solenoids that control orifice size and flow rate. Sensors will pick up on changes to orifice size that need to be made and to send/receive signals from the user via programs. This method may be more expensive, but it will be more effective since the program can potentially be changed instead of replacing the entire valve system for a different application.

II. METHODS AND MATERIALS

As described in the introduction, this four-way valve is capable of eliminating the need for resizing orifices and creating a regenerative circuit in its third position (Fig. 2). Ideally, the entire process could be automated where the valve responds to stimuli such as internal pressure and applied load, changing the orifice size based on the output needed. This is done using solenoids that energize to open certain ports; the amount it opens depends on the amount of current flowing through the coil.
A majority of the progress made this year was centered around the simulation of the valve concept, modeling similarly to the directional control valve donated by Yuken. Programming was done in Mathworks Simulink, which has components that hydraulic systems would have (e.g., pressure relief valves). Creating the circuit to behave like the Yuken valve was a difficult process due to a lack of key components in Simulink to model after components in the Yuken valve. However, despite this setback an accurate representation of the valve was created in Simulink (Fig. 3).

![Simulink hydraulic circuit](image1)

**Figure 3.** Hydraulic circuit in Simulink that can actuate a bucket arm. The center block structure represents the Yuken valve system.

Future groups will be responsible for adjusting the simulation as they see fit, and testing the Yuken valve at a testing facility to compare the results of pressure drop versus flow rate to the Yuken data, as well as test the responsiveness of the solenoids, open/close times, etc.

### III. RESULTS

Simulink is capable of producing a variety of useful data. One such example is the displacement of the valves controlled by the solenoids “a” and “b” (Fig. 4).

![Displacement diagram](image2)

**Figure 4.** Displacement of solenoid operated valves “a” and “b” over time

The flow rate through these solenoid operated valves can also be measured (Fig. 5). There are many more measurements that can be obtained from Simulink including data that can be compared to Yuken data.

![Flow rate graph](image3)

**Figure 5.** Flow rate through solenoid operated valves “a” and “b” over time.

### IV. DISCUSSION

Based on the results, it can be seen that the simulation acts similarly to how a real valve would behave. However, it is important to note that any simulation will not be exactly like testing the actual valve. In fact, the results would most likely be significantly different due to uncertainty. Simulink can account for friction coefficients and other sources of energy loss, but not the unpredictability of fluid flow in real-time. There were several aspects of the Yuken valve that could not be accounted for in the simulation, which would also skew direct data comparisons between the two.

### V. CONCLUSION

As it currently stands, the simulations have proven to be successful in creating a stepping stone for future groups in continuing the development of this concept. Because of the inability to include certain parameters of the Yuken valve in the simulation, arbitrary values had to be used. If this can be accounted for, the simulation would be even more reliable. Even with this setback, the simulation provides a very useful method of testing new ideas safely before applying them to the real world.

If future groups are able to build off of the simulation and bring the idea to fruition, it could lead to improvements and breakthroughs in a concept that is fairly new.

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### REFERENCES