Teaching Methods of Hydraulic Components Based on Hydraulic-electrical Analogy

Yue-song LI* and Yan-bin ZHANG
School of Mechatronics Engineering, Henan University of Science and Technology, China
*Corresponding author

Keywords: Analogy teaching method, Hydraulic components, Electrical components.

Abstract. In order to solve the problem that the hydraulic components are abstract and their functions are difficult to understand, the analogy teaching method of hydraulic components is introduced in this paper based on the functional similarity of the electrical components and hydraulic components. Firstly, the comparison of fundamental laws and concepts of electrical components and hydraulic components are introduced. Then the corresponding hydraulic components and electrical components, which have the similar function, are given respectively. Finally, the performance analysis methods of cone valve and spool valve based on the bridge network theory are introduced and the performance of spool valve is given.

Introduction

As the basis of design and analysis of hydraulic system, the hydraulic components is the key and difficult points in hydraulic teaching [1-3]. The teaching methods of this part is always important in the hydraulic teaching research.

The analogy method can make the knowledge organize and make the abstract content visualized. It can help the learners understand the similarities and differences between the concepts and the laws, so that they can understand and grasp the new concepts and new things quickly. Therefore, the analogy teaching method not only can stimulate students’ interest in learning and improve their learning efficiency, but also enable learners to master the scientific learning methods.

The survey shows that students have deeply studied on the electricity before learning the hydraulic system and they are very familiar with electricity. Because the electrical and hydraulic components have many similarities in the basic theorem and functions, the method of analysis and learn of the hydraulic components based on the electrical transmission components is necessary. The method of hydraulic teaching in this paper will make the hydraulic beginners quickly grasp the function and usage of hydraulic components.

Analogy of Fundamental Physical Quantity

In electrical technology, current, voltage and resistance are the basic physical quantities. The current transfer meets Kirchhoff’s current law, the voltage depends on the external load, the current and the resistance. The power of electrical component equals the product of voltage and current. In hydraulic technique, flow, pressure and liquid resistance are the basic physical quantities. The flow transfer meets the flow continuity equation. The pressure difference in hydraulic components depends on the fluid resistance, the flow and the external load. The hydraulic power equals the product of voltage and current. Therefore, the current and flow rate, voltage and pressure, impedance and fluid resistance are the corresponding physical quantities.
Analogy of Components

Analogy of Components in Function

In the hydraulic system, hydraulic components are divided into hydraulic power source, hydraulic actuator, hydraulic control components and hydraulic auxiliary components. A hydraulic power source is usually a hydraulic pump, its role is converting the mechanical energy into the hydraulic energy. The hydraulic actuator is the hydraulic cylinder or the hydraulic motor, its role is converting the hydraulic energy into the mechanical energy. Hydraulic control components are the control valves adjusting pressure, flow rate and flow direction of the oil. Hydraulic auxiliary components play an auxiliary role, mainly refers to oil tanks, pipe, accumulator, filter, cooler, etc..

In the Electrical system, the power source is used for supplying an electrical power for the electrical system, including generators, batteries, etc.. Electric actuator is used for converting the electrical energy into mechanical energy, including electromagnets, motors, etc. The electrical control components have many types, including switches, transformers, amplifiers, transistors, etc.

According to the role of hydraulic components and electrical components, the analogy of components in function can be shown in table 1.

Table 1. Comparison of electrical and hydraulic components.

<table>
<thead>
<tr>
<th>Hydraulic cylinder</th>
<th>Hydraulic Motor</th>
<th>Constant current source</th>
<th>Check valve</th>
<th>2/2 way directional control valve</th>
<th>3/4 way directional control valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bi-proportional electromagnet</td>
<td>DC Motor</td>
<td>Hydraulick pump</td>
<td>Diode</td>
<td>switch</td>
<td>bipolar switch</td>
</tr>
<tr>
<td>reducing valve</td>
<td>pilot operated check valve</td>
<td>Accumulator</td>
<td>Adjustable fluid resistance</td>
<td>Fluid resistance</td>
<td>electrical resistance</td>
</tr>
<tr>
<td>transformer</td>
<td>silicon controlled</td>
<td>Capacitor</td>
<td>Adjustable electrical resistance</td>
<td>Relief valve</td>
<td>Voltage stabilizing diode</td>
</tr>
</tbody>
</table>

Performance Analysis of Hydraulic Component Based on the Analysis of Bridge Network

The analogy methods of hydraulic Components based on Electrical Components can be used not only in principle, but also in the performance analysis, for example, the bridge analogy analysis method of hydraulic control valve. The following will introduce the bridges of hydraulic cone valve, the spool valve and its performance analysis method[4-6].

Figure 1 are structure and the bridge of hydraulic cone valve. The bridge is consist of an adjustable resistance and a fixed resistance. The adjustable resistance is the equivalent resistance of cone valve. Figure 1(b) shows the pressure in hydraulic cylinder’s left cavity depends on the adjustable resistance, hence the hydraulic cylinder can be controlled by controlling the opening of the cone valve.
Figure 2 are the structure and the bridge of spool valve. The bridge is consist of four adjustable resistances. The adjustable resistances are the equivalent resistance of spool’s ports. Figure 2(b) shows the differential pressure applied on the load depends on the adjustable resistances, the differential pressure and flow rate through the load can be controlled by controlling the opening of the ports[6].

Based on Figure 2 and the flow equation of continuity, the following equations can be derived

\[ q_2 = q_1 - q_4 = C_d A_1 \sqrt{\frac{2}{\rho}} (p_s - p_1) - C_d A_2 \sqrt{\frac{2}{\rho}} p_1 \]  

(1)

\[ p_L = p_1 - p_2 \]  

(2)

\[ q_4 = q_3 - q_1 = C_d A_2 \sqrt{\frac{2}{\rho}} p_2 - C_d A_1 \sqrt{\frac{2}{\rho}} (p_s - p_1) \]  

(3)

where, \( C_d \) is flow coefficient; \( \rho \) is oil density; \( p_s \) is oil pressure, \( p_1 \) and \( p_2 \) are the pressure of left and right receiver holes, respectively.

When the spool moves left, the load flow is written by

\[ q_L = C_d A_1 \sqrt{\frac{1}{\rho}} (p_s - p_L) \]  

(4)

When the spool moves right, the load flow is written by

\[ q_L = -C_d A_1 \sqrt{\frac{1}{\rho}} (p_s + p_L) \]  

(5)

If rectangular ports are used with an area gradient of W for each ports, as shown in Figure 3 and considering the valve stroke is \( y \), the pressure-flow equations becomes

\[ q_L = C_d W y \sqrt{\frac{1}{\rho}} \left( p_s - \frac{y}{\delta} p_L \right) \]  

(6)

and is plotted in a normalized manner in Figure 4. The quantity \( y_m \) is the maximum valve stroke.
**Conclusion**

Based on the theory of electric components and bridge, the analogy teaching method of hydraulic components can communicate knowledge between electrical and hydraulic in the basic law and function and make the teaching content deep, rich and methodized.

**Acknowledge**

This research was financially supported by the National Science Foundation [grant number 51605145] and Education and Teaching Reform Project of Henan University of Science and Technology.

**References**


