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The hydraulic system simulation of the diaphragm pump power end based on simulink

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ABSTRACT

It describes the structure and working principle of diaphragm pump design, Hydraulic system state equations are derived by power bond graph, the dynamic characteristics of hydraulic components or systems are simulated in the integrated simulink environment, the simulation results show that the impact of pressure systems, the impact speed and response time can meet the expectations and requirements. the design parameters is optimized depending on the results.

KEYWORDS

Simulink; Hydraulic drive; Diaphragm; Power end.

INTRODUCTION

The dynamic characteristics of the hydraulic system is demonstrated in the process which the system lost its original equilibrium and reach a new equilibrium state[1]. The main studied problem of the hydraulic system dynamic performance includes two aspects[2], on the one hand, the stability, involving the instantaneous peak and pressure fluctuations in the high-pressure system (pipe or cavity); the other is the transition quality problem, including the response quality and response speed of the implementing agencies and control agencies (such as load and hydraulic components).

It involves the transfer function analysis, simulation, experimental research, digital simulation method and so on[3]. The Power Bond Graph method is one of them, the simple and concise way to establish the dynamic mathematical model, the bond graph symbols are the generalized network symbols, it can be used to simulate many types of physical systems, such as mechanical and electrical systems, etc. particularly, widely used in the dynamic characteristics of the hydraulic systems[4].

THE DIAPHRAGM PUMP STRUCTURE AND WORKING PRINCIPLE IN SOME TYPE

The diaphragm structure type includes the single and double-acting piston, the different cylinders piston and the vertical or horizontal piston. All types have the identical consist of transmission, power end, fluid end, hydraulic auxiliary system, the material compensation systems, the control systems, the eliminating and isolating vibration device[5-6].

The Figure 1 shows the diaphragm pump’s double cylinders and double acting structure, as shown in Figure 1 in some types:

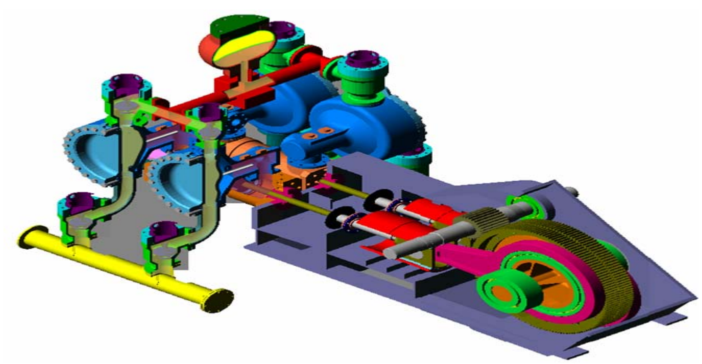

Figure 1 : The diaphragm pump’s double cylinders and double acting structure

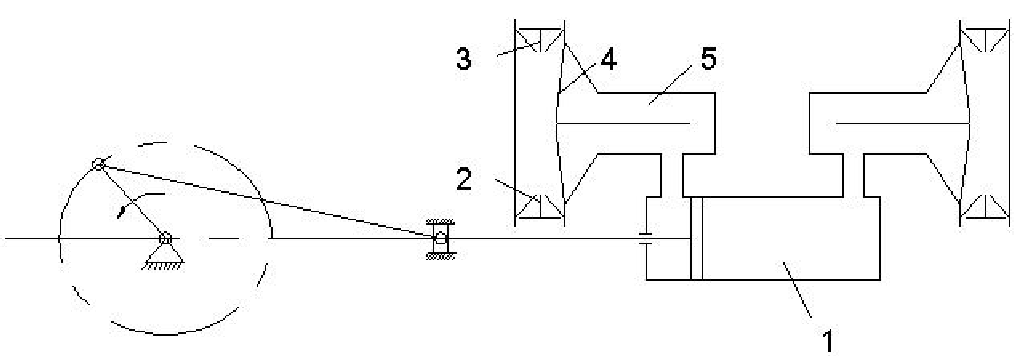

Figure 2 : The conventional diaphragm pump power end Schematic diagram

The reciprocating diaphragm pump power end describes a slider-crank mechanism, including discharge and suction process[7], as is shown in the Fig Figure 2.

THE HYDRAULIC SYSTEM SIMULATION

The designed hydraulic system shows in the Figure 3, when reversing, the hydraulic cylinder 1 draining, the NO.2 staying.

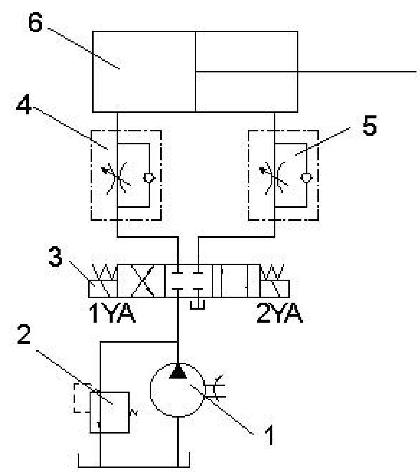

Figure 3 : The designed System structure diagram

1-constant pumps; 2-relief valve; 3-solenoid valves; 4,5-control valve; 6-cylinder

Most of the element composition of the hydraulic system is standard hydraulic components. Therefore, it is possible to establish different levels of these hydraulic components (such as the ideal, static and dynamic) model block, the bond graph model of the system components can be assembled by using block to get. This method which build the system model is named the System Model Assembly Method (SMAM for short)[8]. The establishing steps follows below:

(1) desctibe their word nugget, according to the constituent elements of the system;

(2) assemble the key word diagram using the word block following the relationship between the constituent elements;

(3) For the purposes of the research system, use the key graphical element of appropriate levels to replace the word element model block.

Through Literature[5] or the other related manuals, available standard components word nugget, including of Hydraulic pumps, hydraulic cylinders, pressure relief valve, throttle valve, four-way valve and piping, etc. as follows in the Figure 4,

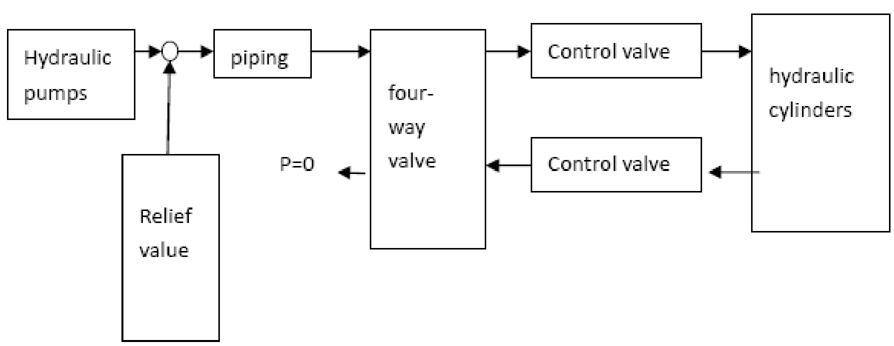

Figure 4 : The assembled Words model block diagram of hydraulic components

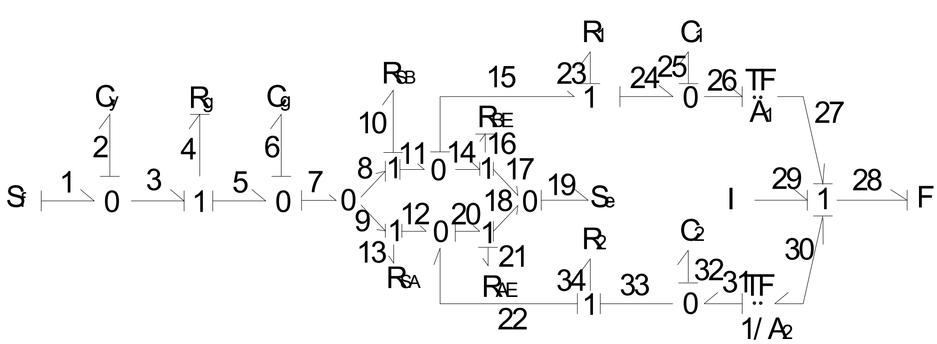

Figure 5 : Hydraulic system dynamics model diagram

C_Y, the liquid pump capacity;,C_1, the hydraulic cylinder rod chamber fluid volume;C_2, the hydraulic cylinder chamber fluid volume without rod. R_g, the fluid resistance; R_e, the friction resistance of the flow control valve 1;R_2 the friction resistance of the flow control valve 2;I,the equivalent mass of the piston and its rod pieces; $S_{f,}$ the output flow of the pump; $S_{e,}$the system's backpressure; F, the system's load; R_{SB},R_{BE},R_{SA},$R_{AE,}$ electromagnetic directional valve's fluid resistance. As follows below are the characteristic equations of each storage element.

$$:\left.\begin{array}{ll} e_2=\dfrac{q_2}{C_y} & (a) \\ e_{25}=\dfrac{q_{25}}{C_1} & (b) \\ e_{33}=\dfrac{q_{32}}{C_2} & (c) \\ v_{20}=\dfrac{p_{29}}{I} & (d) \\ e_6=\dfrac{q_6}{C_g} & (e) \end{array}\right\} \quad (1)$$

$$\left.\begin{array}{ll} f_4=\dfrac{e_4}{R_g} & (a) \\ f_{10}=\dfrac{e_{10}}{R_{SB}} & (b) \\ f_{16}=\dfrac{e_{16}}{R_{BE}} & (c) \\ f_{13}=\dfrac{e_{13}}{R_{SA}} & (d) \\ f_{21}=\dfrac{e_{21}}{R_{SA}} & (e) \\ f_{23}=\dfrac{e_{23}}{R_1} & (f) \\ f_{35}=\dfrac{e_{34}}{R_2} & (g) \end{array}\right\} \quad (2)$$

Eq1 storage elements characteristic equation Eq2 resistive element characteristic equation

The following equation has been obtained for the node 0,1, and the F converter:

$$\left.\begin{array}{ll} e_1=e_2=e_3 & (a) \\ f_1=f_2+f_3 & (b) \end{array}\right\} \quad (3)$$

$$\left.\begin{array}{ll} e_3=e_4+e_5 & (a) \\ f_3=f_4=f_5 & (b) \end{array}\right\} \quad (4)$$

$$\left.\begin{array}{ll} e_5=e_6=e_7 & (a) \\ f_5=f_6+f_7 & (b) \end{array}\right\} \quad (5)$$

$$\left.\begin{array}{ll} e_7=e_8=e_9 & (a) \\ f_7=f_8+f_9 & (b) \end{array}\right\} \quad (6)$$

$$\left.\begin{array}{ll} e_8 = e_{10} + e_{11} & (a) \\ f_9 = f_{10} = f_{11} & (b) \end{array}\right\} \quad (7)$$

$$\left.\begin{array}{ll} e_{11} = e_{14} = e_{15} & (a) \\ f_{11} = f_{14} + f_{15} & (b) \end{array}\right\} \quad (8)$$

$$\left.\begin{array}{ll} e_{15} = e_{23} + e_{24} & (a) \\ f_{15} = f_{23} = f_{24} & (b) \end{array}\right\} \quad (9)$$

$$\left.\begin{array}{ll} e_{24} = e_{25} = e_{26} & (a) \\ f_{24} = f_{25} + f_{26} & (b) \end{array}\right\} \quad (10)$$

$$\left.\begin{array}{ll} e_{17} = e_{18} + e_{19} & (a) \\ f_{17} = f_{18} = f_{19} & (b) \end{array}\right\} \quad (11)$$

$$\left.\begin{array}{ll} F_1 \cdot \dfrac{1}{A_1} = e_{27} & (a) \\ v_{21} \cdot A_2 = f_{27} & (b) \end{array}\right\} \quad (12)$$

$$\left.\begin{array}{ll} e_{27} = e_{28} + e_{29} + e_{30} & (a) \\ f_{27} = f_{28} = f_{29} = f_{30} & (b) \end{array}\right\} \quad (13)$$

$$\left.\begin{array}{ll} F_2 \cdot \dfrac{1}{A_2} = e_{31} & (a) \\ v_{21} \cdot A_2 = f_{31} & (b) \end{array}\right\} \quad (14)$$

$$\left.\begin{array}{ll} e_{31} = e_{32} = e_{33} & (a) \\ f_{31} = f_{32} + f_{33} & (b) \end{array}\right\} \quad (15)$$

$$\left.\begin{array}{ll} e_{33} = e_{34} = e_{22} & (a) \\ f_{33} = f_{34} + f_{22} & (b) \end{array}\right\} \quad (16)$$

$$\left.\begin{array}{ll} e_{20} = e_{21} + e_{18} & (a) \\ f_{20} = f_{21} = f_{18} & (b) \end{array}\right\} \quad (17)$$

It can be obtained for the system state equation with the formula (1)~(17):

$$\left.\begin{array}{ll} \dot{q}_{25} = -\dfrac{p_{29}}{I} A_1 + (\dfrac{q_6}{C_g} - \dfrac{q_{25}}{C_1}) / (R_{SB} + R_1) & (a) \\ \dot{q}_{32} = \dfrac{p_{30}}{I} A_2 + (\dfrac{q_{32}}{C_2} - S_e) / (R_{AE} + R_2) & (b) \\ \dot{q}_6 = \dfrac{S_f}{C_y R_g} - (\dfrac{q_6}{C_g} - \dfrac{q_{25}}{C_1}) / (R_{SB} + R_1) & (c) \\ \dot{p}_{29} = \dfrac{q_{25}}{C_1} A_1 - F - \dfrac{q_{32}}{C_2} A_2 & (d) \end{array}\right\} \quad (18)$$

In the Eq18, q_6、q_{25}、q_{32} represent the6,25,32 keys' s variable flow; p_{29} represents the 29 key's potential variables; $\dot{q}_1$、$\dot{q}_6$、$\dot{p}_{29}$、$\dot{q}_{25}$、$\dot{q}_{32}$ represent the first derivative of the variables in the equation of state respectively.; A_1、A_2respectively represent the area of the rod cavity, the area without the rod cavity

THE HYDRAULIC SYSTEM SIMULATION

The system's simulation

The Eq 18 can be expressed as a simulink with the sub-models in the Matlab Simulink library toolbox[6~8], the designed simulation model is shown as follows:

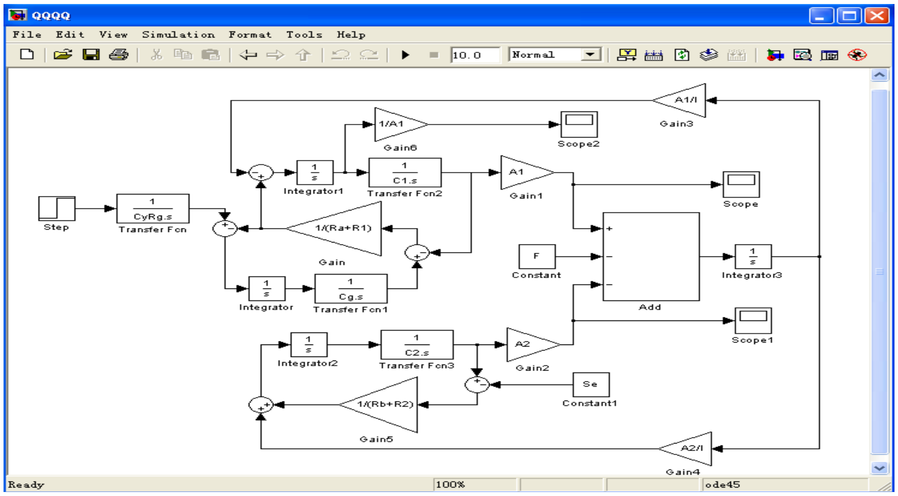

Figure 6 : The Simulink simulation block diagram

The Simulation results and analysis

In its design, the load force value reach 406944N with the maximum work pressure. In the same conditions, other simulation parameters are determined as follows:

$$S_f = 9.41\times10^{-3} m^3/s \;;\; C_1 = 8.75\times10^{-13} m^5/N \;;\; C_g = 7.59\times10^{-12} m^5/N \;;$$

$$C_2 = 9.37\times10^{-12} m^5/N \;;\; A_1 = 1.77\times10^{-2} m^2 \;;\; A_2 = 1.33\times10^{-2} m^2 \;;$$

$$I = 65.7kg \quad R_g = 0.9832 m^2\cdot s^{-1} \quad R_{SB} = 0.8537 m^2\cdot s^{-1} \quad R_{AE} = 1.206 m^2\cdot s^{-1}$$

$$R_1 = 2.045 m^2\cdot s^{-1} \quad R_2 = 1.6835 m^2\cdot s^{-1}$$

Input the parameters in the Matlab Command Window, run the Simulink block diagram, then, it is obtained for the dynamic pressure and velocity curves at each point, which is shown in Figure 7~9:

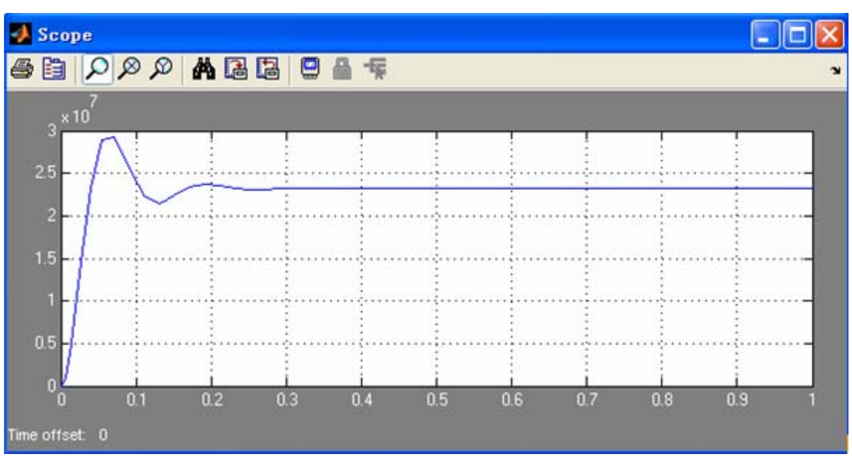

Figure 7 : The hydraulic cylinder chamber pressure changes dynamic curve with rod

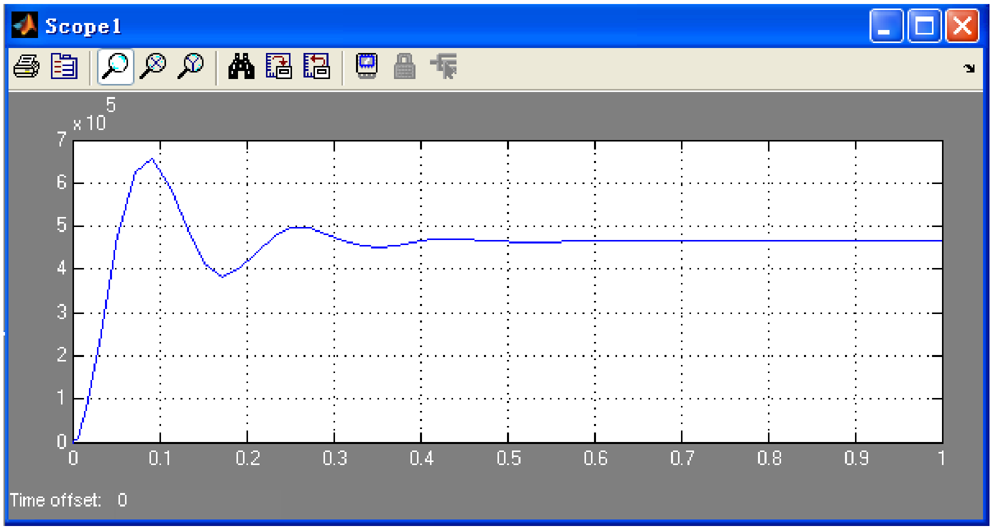

Figure 8 : The hydraulic cylinder chamber pressure changes dynamic curve without rod

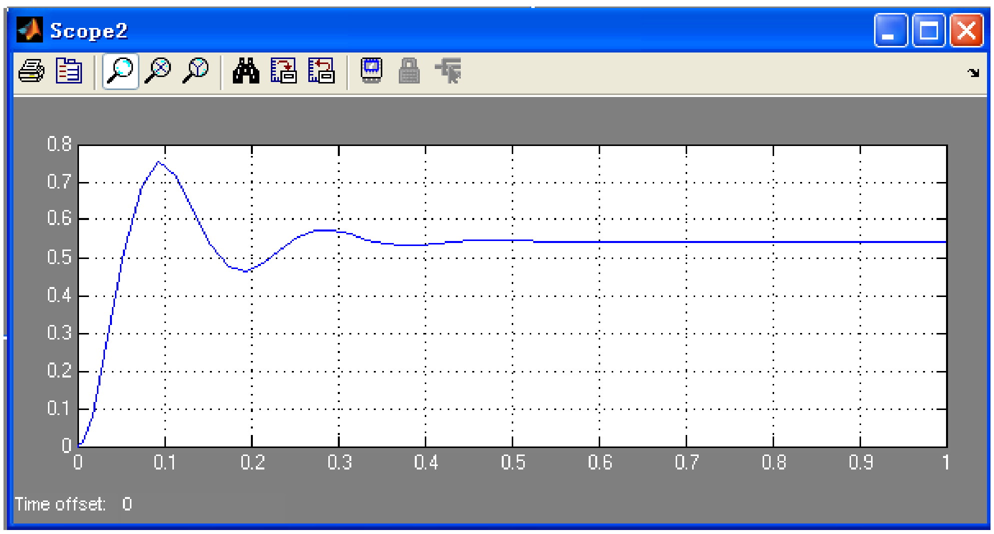

Figure 9 The hydraulic cylinder piston velocity changes dynamic curve

From the simulation and calculation results, it shows that the system's response can be up to expectations and requirements, which includes the pressure impact, velocity impact, and response time.

CONCLUSION

It describes the basic definition of power bond graph, the main components of the system are established with the power bond graph, including of hydraulic pumps, relief valves, four-way slide valve, and hydraulic cylinder, constructs the dynamic model of the hydraulic system with the method of the assembly method, conducts the dynamic simulation with the software of Simulink. It shows the designed diaphragm pump power end hydraulic system meets the expectations and requirements.

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