Team Project Report

Prepared By

Team No. 09

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4 Introduction:

Hydraulic systems are defined and pressurized by fluids to enable considerable workflow. The mechanical design and pressure determinants, on the other hand, are greatly influenced by this efficient system, which raises the system's constant flow rate. The design and operation of the hydraulic clamp and drilling machine are clearly explained in this project. The simulation method and the flow diagram, on the other hand, are also used to describe this efficient design. The project's overall process is also being attempted to be broken down into distinct portions and defined by various structures. Additionally, the project deals with the fundamental tasks connected to the hydraulic drilling system's drilling mechanism. parts of the circuit.

4.1 Problem description

Physical modeling of a hydraulic circuit to accommodate clamping and drilling in sequence was developed in MATLAB Simscape. 4-way 3-position solenoid-actuated directional valve with two double-acting cylinder actuators connected in a sequence were used to clamp the device and drill a hole in a workpiece in sequence. The hydraulic circuit has two sequence valves for each cylinder in addition to the pump and pressure relief valve. The parameters affecting the circuit were calculated, analyzed and results are shown in the following document. The schematic is shown below.

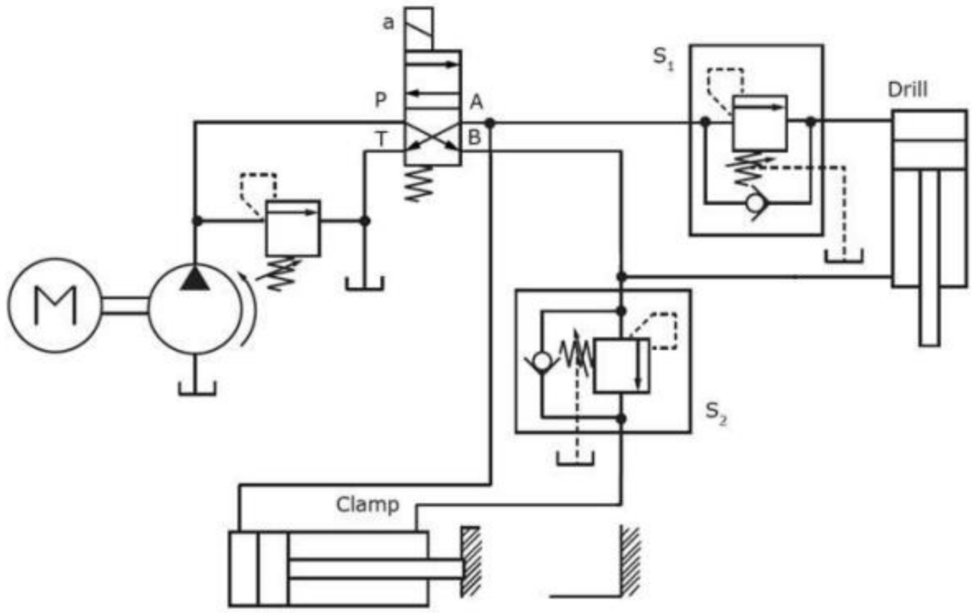

Figure 1 Problem Description

4.2 Given Data:

Drill Speed (v_d): 500 mm/min

Drill Thrust force (F_d): 1500 N

Drill Stroke (S_d) : 300 mm

Workpiece Thickness (t): 200 mm

Workpiece length (l): 400 mm

Workpiece width (b): 500 mm

Workpiece Material: Carbon steel (Young Modulus of Elasticity (E) =203 Gpa)

Clamp Stroke (S_c): 600 mm

Clamp Force (F_c): 500 N

4.3 Working of given hydraulic system

Here we have selected ideal flow source to generate constant flow rate in the system. Initially when 4/3 DCV is at 1st position when P-B and A-T are made. So fluid first go to clamping cylinder as It will face more resistance (designed accordingly) in the direction of drilling cylinder through sequence valve S1,and fluid flows in the direction of least resistance. So clamping cylinder extends first , holds work piece with required force and after that drilling extension takes place to performe drilling action on work piece.

When 4/3 DCV is at 2nd position when P-A and B-T connections are made ,retraction strokes takes place in sequence of drilling and clamping due to properly designed sequence valve S2 setting.

Pressure relief valve is used to maintain maximum system pressure due to circuit maximum physical capability. So it pressure try to increase more than pressure relief valve setting it opens and maintain the pressure in desired limit.

4.4 Development of Simscape model

- Calculations were done to obtain the physical parameters of the circuit. Like, Pressure, Size of the cylinder pressure relief valve settings, flow rate, etc.
- Analyzed various components and its working to fine tune the obtained parameters.
- Created a flow chart to design the circuit in simscape.
- Built model and defined parameters into simscape
- Tested and played with various parameters in order to get the desired result.

5 Calculations:

5.1 Forward Stroke:

5.1.1 Cylinder Bore diameter

We have 4 equations for designing purpose but 5 parameters need to be calculated, so we have to assume at least 1 parameter. We have chosen to assume Pressure because it can be defining parameter for material selection purpose.

Firstly, it has been Assumed that the operational pressure (P) for both the check valves $P_c = P_d$ is 250 psi, from that all other parameters have been calculated.

$$\text{Pressure(P)} = {}^{\text{Force(F)}}/_{\text{Area(A)}}$$

$$\text{Flow rate(Q)} = \text{Area of piston} \times \text{Velocity of piston}$$

In the given circuit, drilling cylinder piston area (A_d) and clamping cylinder piston area (A_c) are unknowns.

It can be said from the above equation that higher the piston area, lower will be the pressure or vice versa.

$$\text{Pressure} \propto {}^{1}/_{\text{Area of bore}}$$

$$\text{Bore Area} \propto {}^{1}/_{\text{Velocity of piston}}$$

From the assumed pressure,

$$P = {}^{Fd}/_{Ad} = {}^{Fc}/_{Ac}$$

$$250 = {}^{F_d}/_{A_d} = {}^{F_c}/_{A_c}$$

$$250 = {}^{1500 \times 0.2248}/_{A_{db}} \qquad\qquad 250 = {}^{500 \times 0.2248}/_{A_{cb}}$$

$$A_d = 1.3488\ \text{in}^2 \text{(Drill side)} \qquad\qquad A_c = 0.4496\ \text{in}^2 \text{(Cap side)}$$

Assuming that area ratio (r)= 0.5 for both the cylinders,

$$\text{Drill rod side area } A_{dr} = A_{db} \times 0.5$$

$$\text{Clamp rod side area } A_{cr} = A_{cb} \times 0.5$$

5.1.2 Velocity of clamping,

As pump flow rate (Q) is same in all ducts,

$$\text{Flow rate (Q)} = A_{db} \times V_d = A_{cb} \times V_c$$

$$\text{So, } 1.3488 \times 500 = 0.4496 \times V_c$$

$$\text{Thus, } V_c = 1500\ \text{mm/min.}$$

5.1.3 Flow rate

Now, Flow rate (Q) $= A_{Cd} \times V_d$

$$= 1.3488 \times (0.0254)^2\ (m^2) \times 500 \times 10^{(-3)}\ (m/min)$$

$$= 0.435 \times 10^{-(3)}\ m^3/min$$

Flow rate (Q) $= 0.435$ lpm

5.1.4 sequence valve S_1

S1 should be taken anything above 250 psi(clamping cylinder operation pressure), so that clamp can have full extension before drill stroke starts.

This is because we have assumed operational pressure is 250 psi, and by designing S_1 to be more than operational pressure we allow clamping cylinder to finish its forward stroke first and then the flow is allowed to be passed from S_1 to extend drilling cylinder.

Taking, $S_1 = 260$ psi.

5.2 Return stroke

Velocity $\propto {}^{1}/_{\text{Area}}$

Therefore, as area is halved during return stroke (Area ratio is 0.5). Velocity is doubled during return stroke

$V_{cr} = 3000$ mm/min. $V_{dr} = 1000$ mm/min.

5.2.1 Pressure during return stock

It is assumed that the total mass (m_p) of drill piston and rod is 10 kg.

So, force required to lift the piston and cylinder rod of drill,

$$F_g = m_p \times g,$$

$$= 10 \times 9.81\ N$$

$$F_g = 98.1\ N$$

Pressure during return stroke of drill cylinder,

$$P_{dr} = {}^{98.1}/_{(1.3488/2)} \times 0.2248 \text{ psi}$$

$P_{dr} = 32.7 psi \sim 33 psi$ (Pressure required to operate return stroke of drill)

So, the pressure sequence valve S2 will be equal to 33 psi (for maintaining drill and clamp retraction in sequence).

5.3 Workpiece

5.3.1 Spring constant k_c for Clamping cylinder at upper bound

Given Young's modulus (E) = 203 Gpa

$$E = {}^{\text{Stress}(\sigma)}\!/_{\text{Strain}(\varepsilon)}$$

$$= {}^{(F_c/A_c)}\!/_{\left(\frac{x}{L_{clampside}}\right)}$$

$$x = \frac{500 \times 0.4}{0.5 \times 0.2 \times 203 \times 10^9} = 9.852 \times 10^{-6}\ mm$$

Now,

$$F_c = k_c x$$

$$k_c = \frac{500}{9.852 \times 10^{-6}} = 50.7511 \times 10^9 \text{ N/mm}$$

It will act as spring constant of work piece (represented as hard stop at clamping cylinder end ,in simscape) at upper bound.

5.3.2 Damping coefficient for drilling cylinder during extension stroke

$$F_d = c_d V_d$$

$$c_d = \frac{1500 \times 60}{500}$$

$$c_d = 180\ Ns/mm$$

It will act as damping coefficient of damper (representation of work piece at drilling cylinder end).

5.4 Pressure relief Valve

It can be designed as per system capabilities let's say for this it is 400 psi.

6 Calculated parameters

Parameter	Value	Unit
Pump Flow Rate	0.435	L/min
Pressure Relief Valve Setting	350	psi
Sequence Valve 1	260	psi
Sequence Valve 2	35	psi
Clamp Cylinder Cap Area	0.4496	in^2
Drill Cylinder Cap Area	1.3488	in^2
Clamp Cylinder Rod Area	0.2248	in^2
Drill Cylinder Rod Area	0.6744	in^2

Table 1 Summary table

7 Circuit design

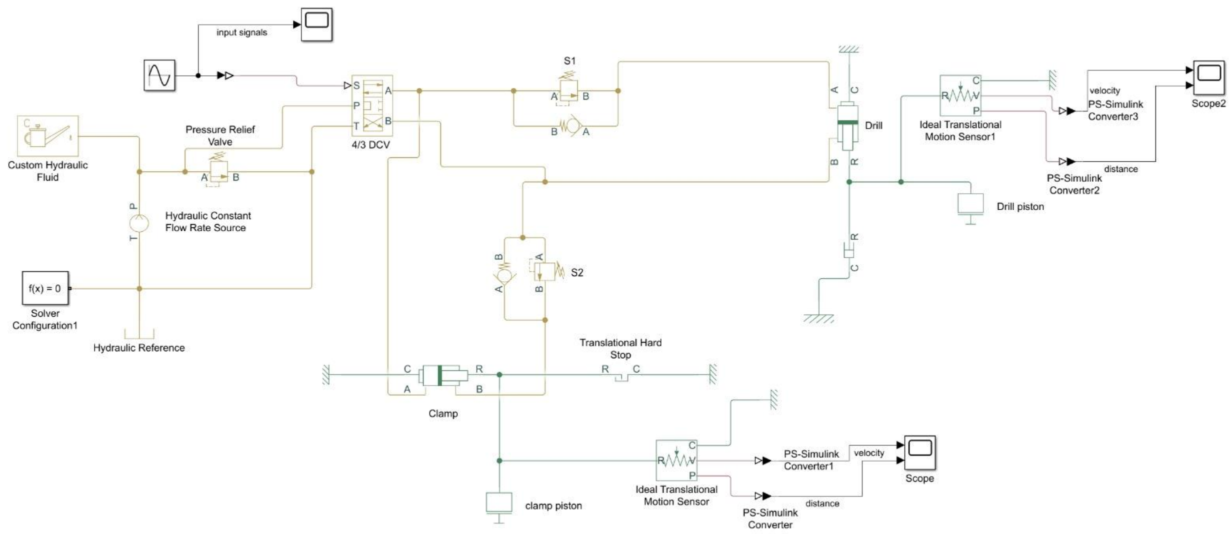

Figure 2 Simscape hydraulic circuit

The hydraulic circuit for drilling and clamping is represented by the simscape model shown above.

1. A sine wave with amplitude 100 and frequency 0.02 rad/sec is fed into the directional valve as an input signal.
2. A unidirectional pump is powered by a constant flow rate source.
3. Because the 4-way 2-position valve is not accessible in Simscape, a 4-way 3-position direction valve is employed.
4. Pressure values of 250PSI and 33PSI are placed on two sequence valves, S1 (related to drilling) and S2 (connected to clamping).
5. The drilling cylinder is represented by a double-acting hydraulic cylinder coupled to a damper and a mass and the clamping cylinder is represented by a double-acting hydraulic cylinder coupled to a hard stop and a mass.
7. A ideal translational motion sensor is used to observe the motion of drilling and clamping cylinder piston.

8 Results

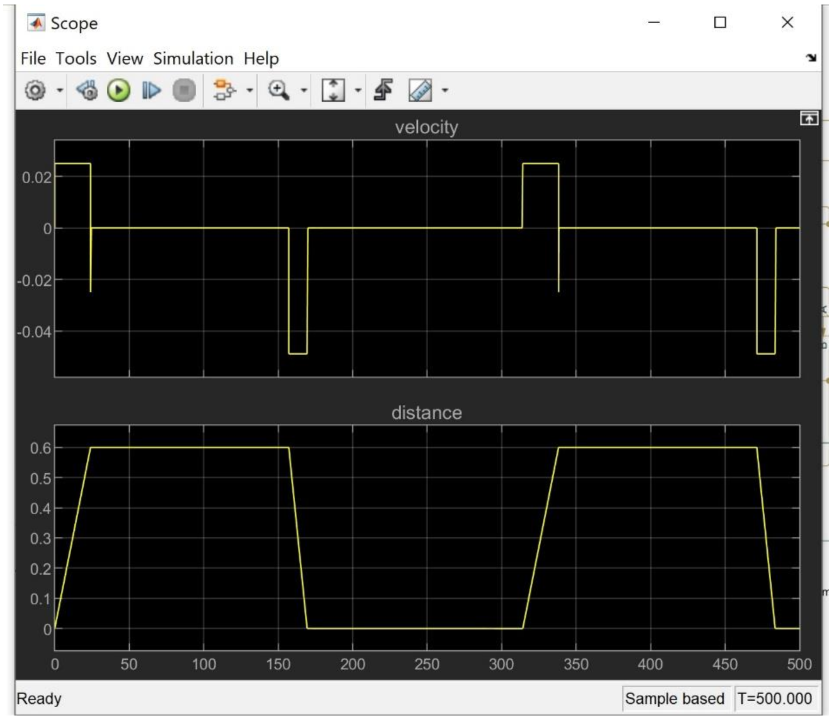

Figure 3 Clamping Cylinder

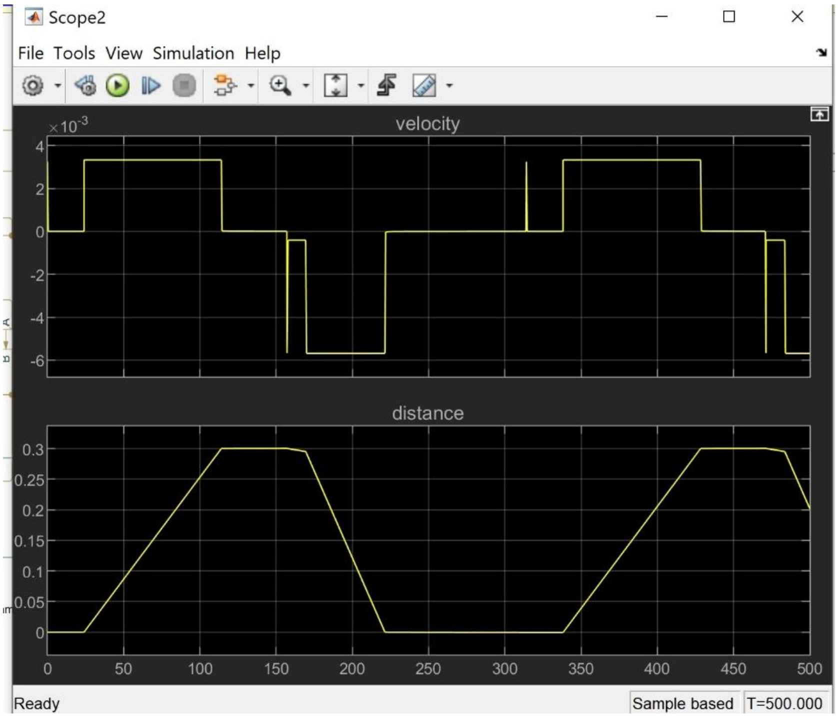

Figure 4 Drilling Cylinder

9 Conclusion

The clamping and drilling operations were successful, according to the project results. Team modelled the design while keeping the specifications of the two hydraulic cylinders in mind. Nonetheless, it is not suggested in practise to use the same specification hydraulic cylinders to decrease inventory because drilling force is significantly greater than clamping force. The pressure required to operate each hydraulic cylinder will be different. Therefore, the following modifications were suggested.

9.1 Modifications.

In order to make both cylinder size same to reduce inventory, some changes need to be made.

If we take same size cylinder for both drilling and clamping that leads to same force generated by both of them, as Force= Pressure*Area. So, in order to get desired force output at respected place we have to make modification in input pressure. In order to do that we have to reduce the pressure input at clamping cylinder as its force requirements is lesser. So, we can add pressure reducing valve between 4/3 DCV and clamping cylinder, before fluid enters the clamping cylinder, with some predefined calculated setting (say 250PSI here). So as soon as required pressure and thus required Force output is reached the pressure reducing valve closes and maintains that pressure throughout the extension stroke of the clamper. One disadvantage can be observed here, as both of the cylinder has same size/area, flow rate and thus operation speed also will be same for both cylinder, which might not be desirable in some cases if we want to minimize total time wastage, due to raise in time of clamping cylinder extension stroke.