Energy Saving in Injection Molding Machine

Professor Dr.-Ing. Shigeru Ikeo

Faculty of Science and Technology , Sophia University, Kioicho 7-1, Chiyoda-ku, Tokyo, 102-8554 Japan, E-mail: s_ikeo@sophis.ac.jp

Mr. Jun Ogawa

Former Graduate Student of Graduate School of Science and Technology , Sophia University, Kioicho 7-1, Chiyoda-ku, Tokyo, 102-8554 Japan

Professor Dr.-Ing. Kazuhisa Ito

Mechanical Engineering, Graduate School of Engineering, Shibaura Institute of Technology, Fukasaku 307, Minuma-ku, Saitama-shi, 337-8570 Japan

Abstract

In the field of household appliance, it is required to produce very thin and wide parts (e.g. the thickness is less than 1mm, width is 0.3m and lengh 20mm) by injection molding machine. In order to produce such thin parts, it is necessary to use pressure control even in injection process instead of speed control for the sake of energy saving. In this paper, using simplified experimental setup the energy saving effects of hydraulic drive and electric drive are compared for various conditions in which the length of speed control phase and the pressure control phase are changed. And the advantage of the hydraulic drive is shown for producing such thin parts. Also the advantage is confirmed by numerical simulation. .

KEYWORDS: energy saving, injection molding, pressure control

1. Introduction

In these days, plastic parts produced by injection molding machine are used in many fields such as car industry, electrical appliance industry, information industry and so on. The electric injection molding machines are increasing their share today in comparison with hydraulic machine. It is said that electric drive systems are cleaner and energy saving compared with hydraulic drive systems. In the field of household appliance, it is required to produce very thin and wide plastic parts (e.g. the thickness is less than 1mm, width is 0.3m and length 20mm) by injection molding machine. In conventional injection molding, during the injection process the injection speed is controlled and during the dwelling process the pressure is controlled. But, when the very thin and wide plastic parts are produced by injection molding, the pressure increases extremely high during injection process, because the melted plastics cannot flow smoothly into the thin and wide mold due to the flow resistance. So a new control method was proposed. In new control method the pressure is controlled even in the injection process /1/. Therefore the ratio of pressure control time to the cycle time becomes larger compared with conventional method.

In this paper, using simplified model test equipments which simulate only the injection process and the dwelling process, the hydraulic drive system and the electric drive system are compared from the view point of energy consumption.

2. Experimental setup

In this paper using simple drive pattern shown in **figure 1**, hydraulic, electric drive systems are examined and compared from the viewpoint of energy consumption.

2.1. Hydraulic drive system

As the hydraulic drive system, we compared the following three systems.

A : Fixed displacement pump with relief valve.

B : Fixed displacement pump with speed control using AC servo motor.

C : Two displacements pump with speed control using AC servo motor.

Figure 2 shows the hydraulic circuit. The system A keeps pressure constant by a relief valve. The displacement is constantly 16[cc/rev] and the rotational speed is kept constant. The system B keeps pressure constant by pump speed control. The displacement is also constantly 16[cc/rev].^

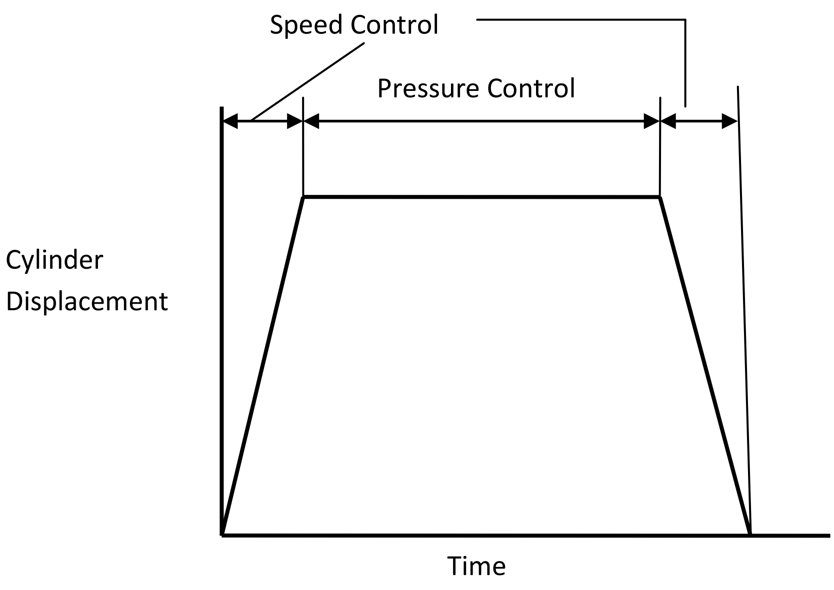

Figure 1: Cylinder drive pattern

The system C also keeps pressure constant by pump speed control. In this system two displacements can be selected according with the required flow rate (16[cc/rev] or 6[cc/rev]). During the speed control phase, the displacement of 16[cc/rev] is selected and during the pressure control phase 16[cc/rev].

2.2. Electric drive system

Figure 3 shows the electric drive system. The AC servomotor used in the hydraulic system and a ball-screw are used. The hydraulic cylinders are used as a load by closing the valve during the pressure control phase.

2.3. Experimental parameters

We set the cylinder force by changing the pressure in cylinder head chamber and the cylinder speed by changing the rotational speed of AC servomotor. The stroke of cylinder was 200[mm]. **Table1** shows the experimental parameters.

For each drive system, under 64 cases of parameters the cylinder stroke, pressure in the cylinder head chamber, rotational speed of Ac servo motor and required electric power are measured.

Cylinder Thrust [N]	2450, 4900, 7350, 9800
Cylinder Speed [m/s]	0.175, 0.350, 0.525, 0.700
Ratio of Pressure Control Time to Cycle Time [%]	20, 40, 60, 80

Table 1: Parameters

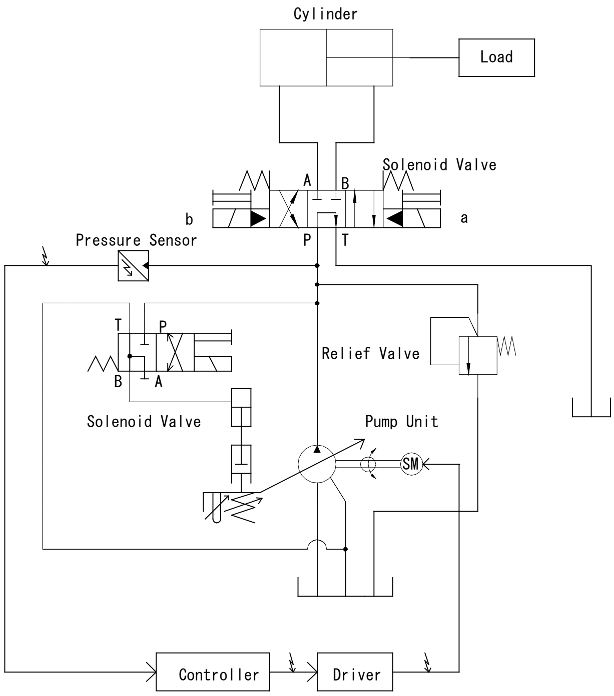

Figure 2: Hydraulic drive system

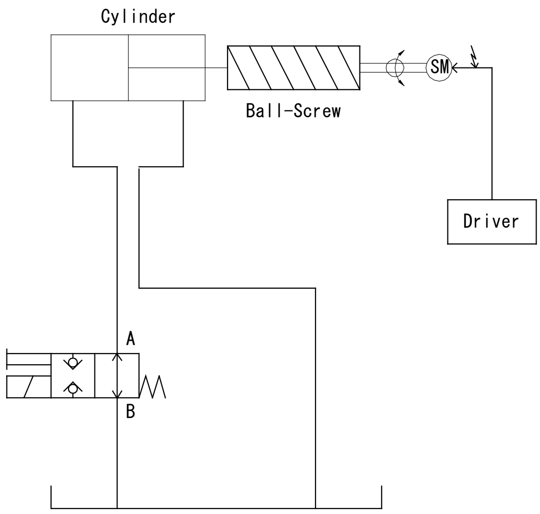

Figure 3: Electric drive system

3. Experimental results

Figure 4 to figure 6 show examples of experimental results. Figure 4 shows the result with system A, figure 5 with system B, figure 6 with system C. By integrating the electric power curve numerically for cycle time, we can get the consumed energy in a cycle. **Figure 7** shows the comparison of consumed energies between three hydraulic systems for the case of cylinder force 9800[N] and the cylinder speed 0.700[m/s]. Figure 7 also shows relation between ratio of pressure control time to cycle time and energy consumption. **Figure 8** shows a comparison between two hydraulic drive systems A and B, and electric drive system. The cylinder force is also 9800[N] and the cylinder speed is 0.700[m/s].

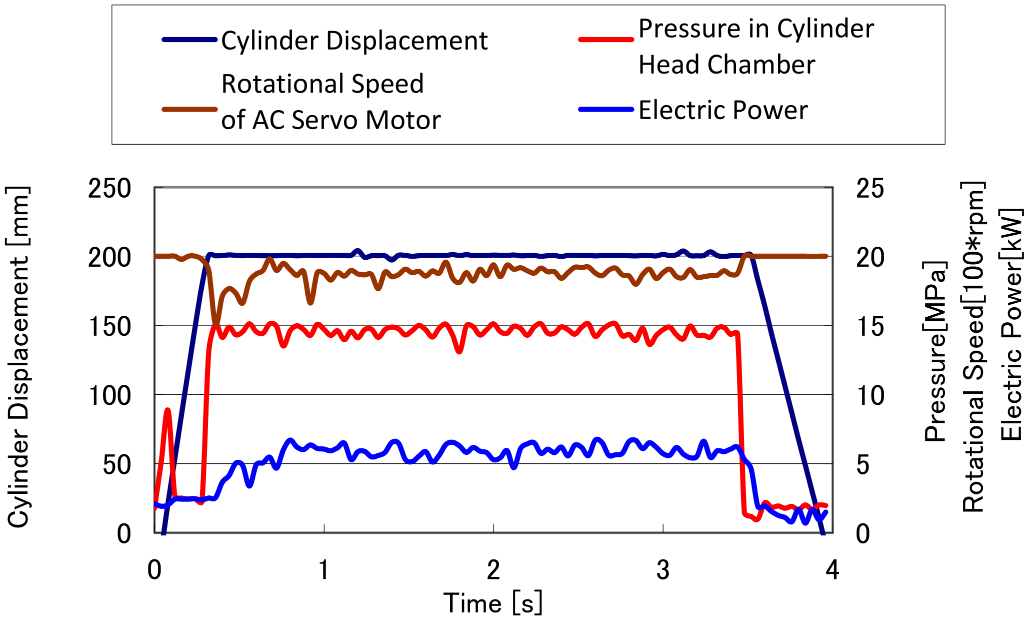

Figure 4: Experimental result of system A (thrust 9800N, cylinder speed 0.7m/s, ratio of pressure control 80%)

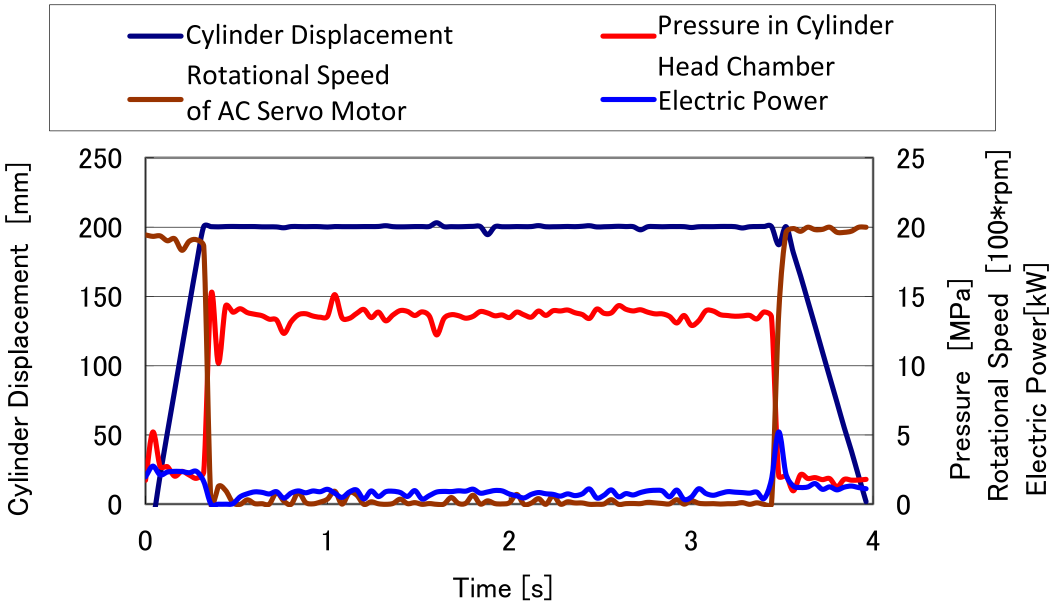

Figure 5: Experimental result of system B (thrust 9800N, cylinder speed 0.7m/s, ratio of pressure control 80%)

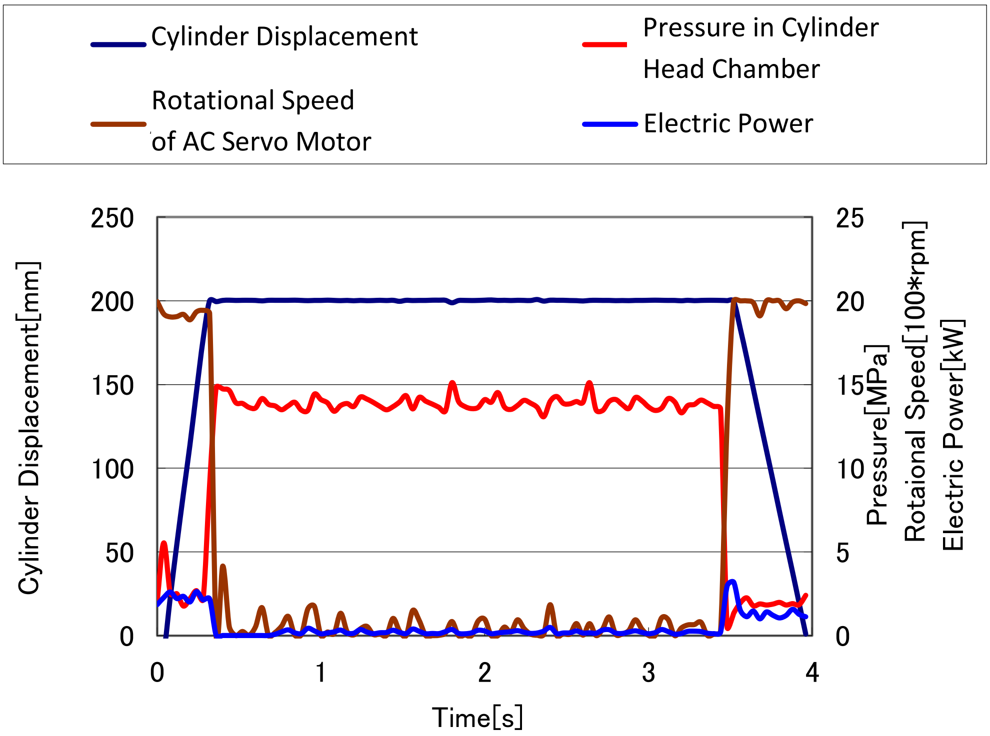

Figure 6: Experimental result of system C(thrust 9800N, cylinder speed 0.7m/s, ratio of pressure control 80%)

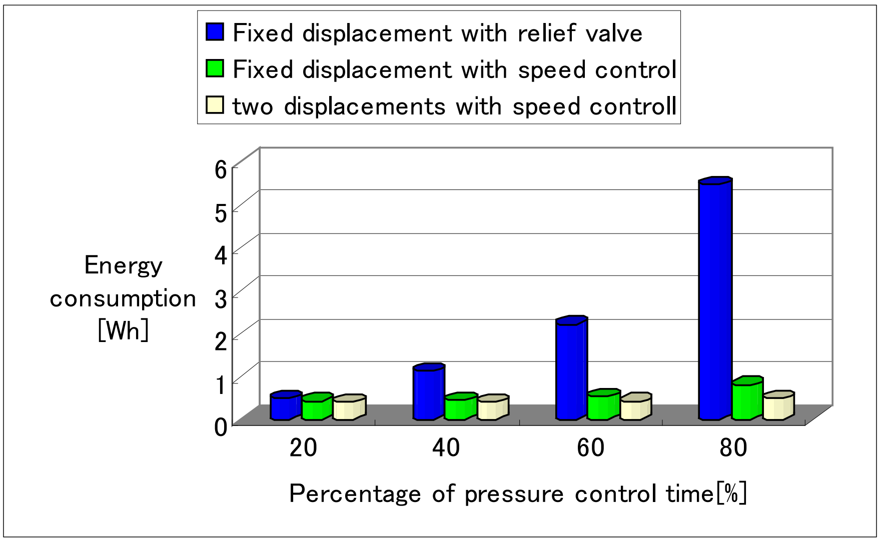

Figure 7: Comparison of three hydraulic systems

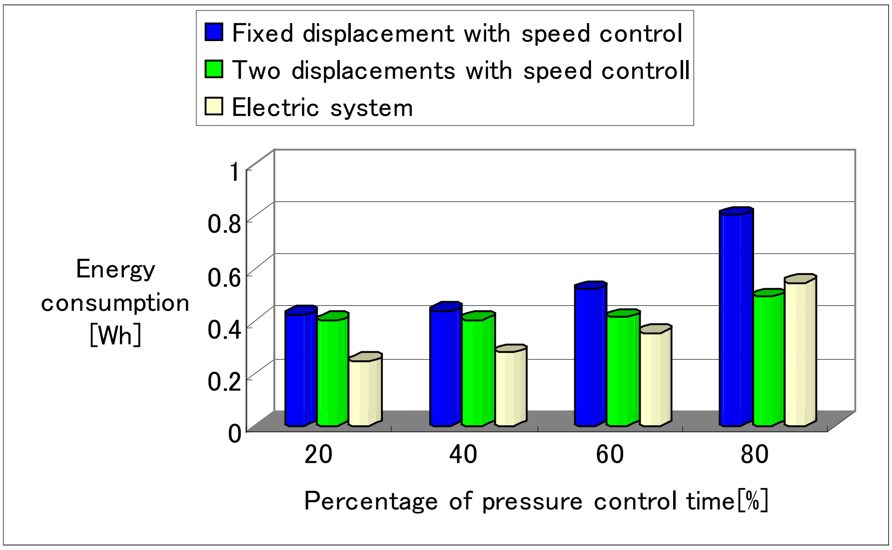

Figure 8: Comparison of hydraulic systems and electric system

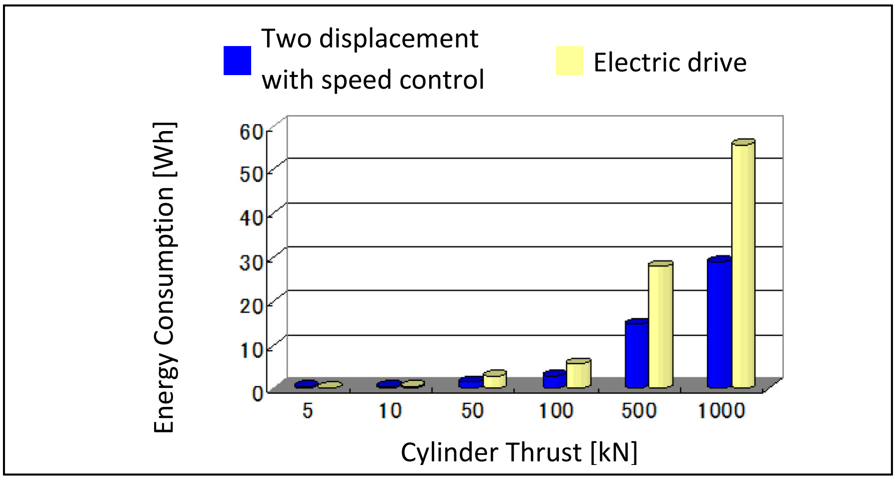

Figure 9: Effect of cylinder thrust (simulation)

4. Discussion

First we discuss about three hydraulic drive systems (figure 7). Only a little flow is needed in pressure control phase, but in the drive system A the pump rotates constant speed and wastes energy through the relief valve. In the system A and B, the rotational speed of the pump is reduced by the AC servo motor. Therefore the energy efficiency of the systems B and C is much better than the system A. In addition to the speed control, the displacement volume is also reduced in the system C. So the energy consumption of system C is the lowest of the three and is the most excellent hydraulic drive system.

It is seen from figure 8 that the electric drive system is better than hydraulic drive system when the ratio of pressure control time is less than 80[%]. On the other hand, when a rate of pressure control time is more than 80[%], the hydraulic drive system C is better. The reason is as follows: In the flow control phase, the hydraulic drive system converts the electric energy to the fluid energy first. Next the cylinder converts the fluid energy to mechanical energy. In this case, the energy conversion takes place twice and the energy loss occurs at each conversion. On the other hand, the electric energy is converted to mechanical energy directly. So the energy loss is less. However, in pressure control phase the hydraulic system can keep pressure constant in circuit easily by using a valve. On the other hand, electric system needs constant torque to keep pressure constant. So the hydraulic drive system C is better for the case when the ratio of pressure control phase to the cycle time is large. Since we cannot increase the thrust force from the limitation of experimental setup, we examined the case of larger thrust force by numerical simulation. **Figure 9** shows the effect of thrust force. Since the simulation results for cases of 5 and 10kN are similar to the experimental result, the validity of the simulation is confirmed. It is seen from figure 9 that for the case of large thrust force the hydraulic drive is better from the view point of energy consumption. Also it is seen from the comparison of experimental results that for the case of fast cylinder speed the electric drive is better.

5. Conclusion

In order to produce very thin and wide parts, it is necessary to use pressure control even in injection process instead of speed control for the sake of energy saving. In this paper, using simplified experimental setup the energy saving effects of hydraulic drive and electric drive are compared for various conditions in which the length of speed control phase and the pressure control phase are changed. And the advantage of the hydraulic drive is shown for producing such thin parts. Also the advantage is confirmed by numerical simulation.

(1) Two displacements pump system with speed control is the most excellent hydraulic system.

(2) We can use the hydraulic system for the case with long pressure control time in a cycle time and for the case of large cylinder thrust, and the electric system in a short pressure control time and for the case of high cylinder speed.

It is important to use both of them aptly.

6. Bibliographical References

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