

APPLICATION OF THE “ASR SERIES” AC SERVO MOTOR DRIVEN HYDRAULIC PUMP TO INJECTION MOLDING MACHINES

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ABSTRACT

Injection molding machines typically use hydraulic or electric systems, the selection of which depends on the performance, energy saving, investment cost, etc. Although hydraulic systems have the major disadvantage that they are less energy-efficient, it is well known that they have the advantage of high response and high thrust required for the control of pressurization and pressure holding. This paper introduces a control system and an AC servo motor driven hydraulic pump that are full-hydraulic and can achieve higher energy saving efficiency and performance. It also reports the current market trend toward the application of the system in Japan and overseas.

KEY WORDS

AC servo motor driven, Bidirectional hydraulic pump, Hybrid, Energy saving, Space saving

INTRODUCTION

As the need for energy saving has grown, hydraulic control and circuitry have evolved accordingly. The development and application of load sensing pumps and valves and electronically controlled variable displacement pumps have all contributed to improved performance and energy saving for injection molding machines. The advantages of hydraulic systems - simple structure, easy application to larger injection molding machines, long service life, and low lifetime cost - are offset by the energy cost.

As servo motors achieve higher thrust and smaller size, electric systems with high energy saving efficiency and cleanliness compared with hydraulic systems have become a mainstream drive source for injection molding machines in Japan.

This paper introduces a hydraulic pump control system (also referred to as a hybrid system since it is driven by an AC servo

motor). The system provides pressure and flow control to achieve a level of energy saving equivalent to electric systems, thus overcoming the major disadvantage related to hydraulic systems.

AIM OF THE DEVELOPMENT OF THE ASR SERIES

- Concept of the development of Yuken's rotational speed control system

The concept for development is to maximize the “advantage of hydraulic control” established over years, to achieve a level of energy saving equivalent to full-electric systems, and to provide higher performance than that of conventional injection molding machines. Based on this concept, the development of the ASR series aimed to provide higher performance than that of electronically controlled variable displacement swash plate type piston pumps and achieve a level of energy saving equivalent to

electric systems by directly controlling the rotational speed of a bidirectional hydraulic pump with an AC servo motor.

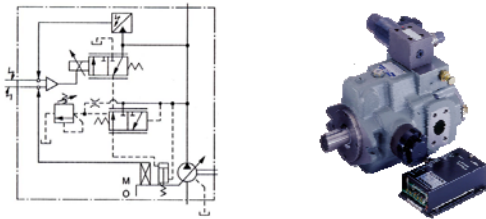


Figure 1 Proportional Electro-Hydraulic Variable Displacement Piston Pump

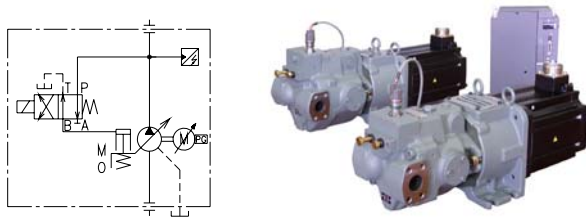


Figure 2 AC Servo Motor Driven Hydraulic Pump

- Specific goals of the development

- (1) Energy saving: Achieving low power consumption equivalent to that of electric injection molding machines and/or half or less than half of that of variable displacement pump control
- (2) Performance improvement: Providing higher response and improving stability during operation at low pressure and low speed
- (3) Low noise: Achieving a lower noise level than that of electric injection molding machines
- (4) Low heat generation: Significantly reducing the tank volume (space saving), eliminating the necessity of oil cooling, or allowing the natural radiation of heat
- (5) Improvement of reliability and product quality
- (6) Cost: Reducing the TCO of hydraulic molding machines (including initial investment, running cost, and maintenance cost)
- (7) Full utilization of hydraulic technology: Regardless of whether the toggle type or the direct pressure type is used, maximizing the advantage of each molding machine manufacturer. Also, easily retrofitted onto existing hydraulic molding technology.

PRODUCTS AND SPECIFICATIONS

Following the A series, a well proven drive source for injection molding machines, the ASR series has a pump size (displacement) of 16 to 145 cc/rev. The ASR series also includes a dual displacement type for high speed injection or for operation with smaller motor capacity. The ASR series operates at 16 to 21 MPa, a typical range of operating pressures of injection molding machines determined based on experience.

A special motor and driver for pump driving have been developed with the characteristics of torque vs. rotational speed

appropriate for providing high speed and high load for the control of injection molding machines. The motor and driver also have an enhanced function for overload protection.

The ASR series has adopted a piston pump as the hydraulic pump and an AC servo motor as the driving motor for the following reasons.

- Piston pump
 - Efficiency and leakage in a low speed range (pressure gain)
 - Variable displacement
- AC servo motor
 - High response and high torque for low speed operation

Table 1 ASR Series

Item	Series					
	ASR1	ASR2	ASR3	ASR5	ASR10	
Power Capacity						
	C	C	E	G	J	
Flow	Max. Flow L/min	40	55	90	130	200
	Hysteresis	1 % or less				
	Repeatability	1 % or less				
Pressure	Max. Operating Pres. MPa	21	16	21		
	Min. Adj. Pres. MPa	0.1				
	Hysteresis	1 % or less				
	Repeatability	1 % or less				
Motor	Rated Output kW	4.5	6	8	11	15
	Insulation	Class F				
	Cooling	Totally-enclosed self-cooling			Totally-enclosed fan-cooling	

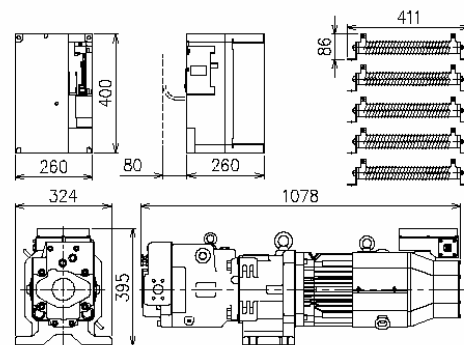


Figure 3 Appearance of ASR10

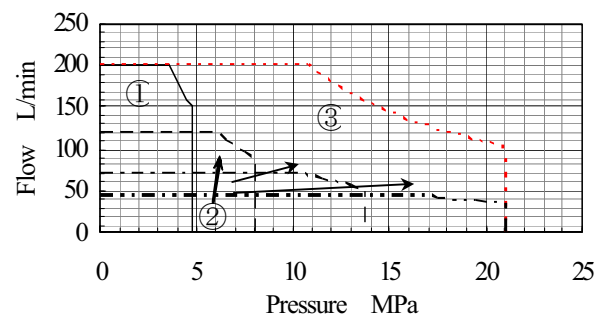


Figure 4 Pressure vs. Flow Characteristics of ASR10

APPLICATION EXAMPLES

- (1) Configuration of hydraulic circuits and components for Injection molding machines (Figure 7)
- (2) Data obtained from actual operation (torque, rotational speed, etc.) (Figure 8)

REQUIREMENTS FOR DRIVE SYSTEMS AND CAPABILITIES OF THE ASR SERIES

Generally, full-electric systems are regarded as high-precision and high-performance systems compared with hydraulic systems. However, full-electric systems are based on full-closed loop control unlike hydraulic systems that utilize open loop control; considering this difference in the basic principles, the comparison above may not be appropriate. The development of the ASR series has assumed that the open loop control method may be more appreciated in overseas markets, especially in China, Taiwan, and Korea. Based on this assumption, the focus of the development has been on the improvement of system performance. The major features of the ASR series are described below.

(1) Control range (pressure and flow rate)

The ASR series pump is driven by a servo motor, and it is advantageous to operate it with as high rotational speed as possible. Taking into account the pump's suction characteristics, the maximum rotational speed has been set at approximately 2500 rpm. This setting allows for a significant expansion of the flow control range.

In respect of pressure control, variable displacement swash plate type piston pumps operate with self pressure control, with a restriction on the minimum adjustment pressure. Our system, on the other hand, basically uses zero pressure as the minimum adjustment pressure. It should be noted that, for practical use, the minimum adjustment pressure is determined by tank pressure.

(2) Response characteristics (when compared with full-electric or valve-based systems)

Inertia load applied to pump rotors is generally lower than that applied to servo motors. Therefore, the start-up response largely depends on the capability of servo motors. In the development of the ASR series, a goal has been set to provide response characteristics that are superior to those of variable displacement swash plate type piston pumps and are equivalent/superior to those of full-electric systems. Our system has a flow start-up time of 40 to 60 ms.

If higher response is required for direct driving with a servo motor, it is feasible to increase the pump displacement and reduce the maximum rotational speed.

As the injection rate of injection molding machines increases, a shorter start-up time is demanded. The start-up time is 8 to 10 ms for systems using hydraulic servo valves, 40 to 60 ms for our system and full-electric systems, and 60 to 120 ms for variable displacement swash plate type piston pumps. Thus, there are definitive differences in response characteristics between these categories.

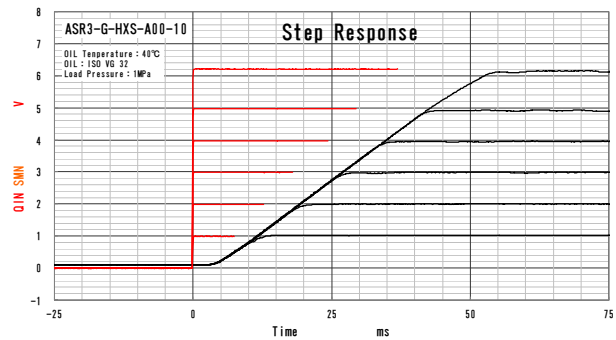


Figure 5 ASR3's Step Response

(3) Repeatability

A principle requirement of injection molding machines is that variations in the weight of molded products are stable. As a matter of course, the repeatability of speed and pressure is an important factor in terms of hydraulic control. The repeatability is especially important upon switching from speed control to pressure holding since it is related to load.

(4) Fluid temperature drift, LQC, Q-Comp

Conventionally, hydraulic systems have the major disadvantage that the flow rate varies due to fluid temperature drift, affecting the stability of products. However, as our system does not depend on valve control, it can significantly reduce this problem compared to conventional systems. In addition, our system eliminates the necessity of flow rate compensation during low pressure operation or due to load pressure variations, which has been the basis for conventional variable displacement swash plate type piston pumps.

(5) Energy saving

Most of energy consumption by injection molding machines is accounted for by driving power and electric power for nozzle heaters. A major concern has been to reduce driving power consumption. The hydraulic driving system presented in this paper basically "consumes power only when necessary" and is equivalent to electric systems in this respect. In addition, our system has been improved by replacing the control using an induction motor driven pump for conventional hydraulic driving systems with a control using an AC servo motor driven pump. There are many reports that the application of our system, which is driven by an AC servo motor, to injection molding machines may reduce power consumption by 70 to 80 % compared to fixed displacement pumps or by 40 to 60 % compared to variable displacement pumps, depending on the molding condition.

The data below shows pump efficiency based on total power consumption for each driving motor type. The data reveals a significant difference in efficiency between the AC servo motor driven pump and the induction motor driven pump.

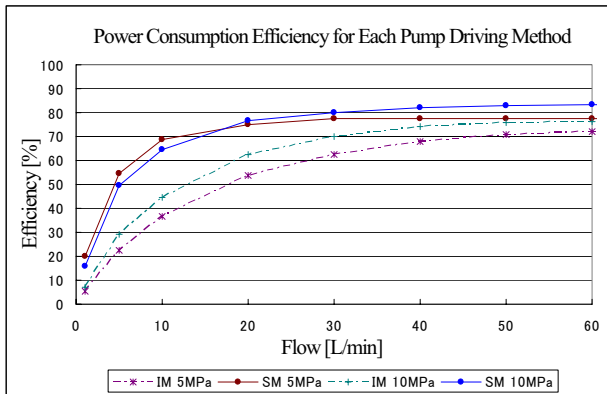


Figure 6 Power Consumption Efficiency for Each Pump Driving Type

FUTURE DEVELOPMENT

Japan has taken a technological lead in the market of injection molding machines. Particularly, great advancement has been made in the field of small/mid-size precision molding machines for IT and electronics parts and in the field of full-electric systems for large-size injection molding machines. Ten years have passed since full-electric systems appeared in the market, but our perspective is that hydraulic systems, particularly including the system introduced in this paper, are attracting attention and being rapidly adopted in Japan and worldwide because of their advantages, such as cost-effectiveness, reliability (failure tolerance), and application to larger-size injection molding machines. Urgent challenges related to our system include achieving further higher response and developing high flow pumps and servo motors for supporting larger-size injection molding machines. At the same time, price reduction is a major issue since hydraulic systems are widespread in the market, and price competition has already become harsh. This trend is apparent in the development of systems focusing on the improvement of energy saving performance.

In respect of higher response, full-electric systems that achieve an injection rate of 800 mm/s in 15 ms are already available in the market. This fact means that the response provided by such systems is approaching the region covered by hydraulic servo valves. The future development for achieving higher response will be addressed considering this trend.

For large-size injection molding machine applications, the best development option may be total flow control, but this will need to be judged against cost.

To improve precision and performance, the modification of our system into a full-closed loop type will be looked at. This modification will entail the creation of a common view with overseas machine and control panel manufacturers.

Our system will be accepted in the field of both full-electric and full-hydraulic injection molding machines. The system was first marketed and adopted for injection molding machines in 2006 and started to prevail in 2007. One of the world-class injection molding machine manufacturers has announced a production plan for 2008, stating that its production mix will be 50 % full-hydraulic systems, 35 % hybrid systems (our ASR system), and 15 % full-electric systems. It can be said that this estimate predicts the share of each drive method in the future.

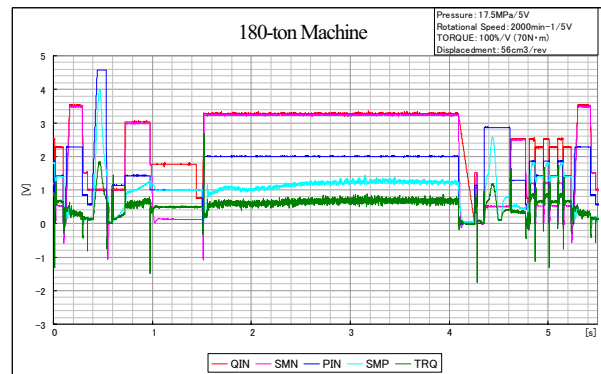


Figure 8 Operating Characteristics of Injection Molding Machines

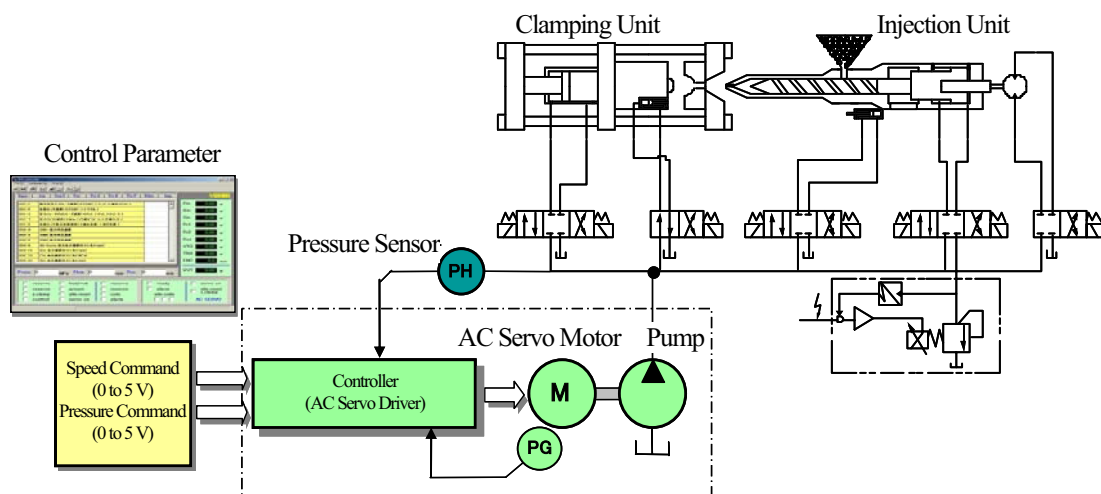


Figure 7 Basic Configuration of Injection Molding Machine