Smart Molding Simplifies Molding Jobs — New Si-V Series Electric Injection Molding Machines

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OVERVIEW: Plastic products have become so ubiquitous that it is difficult to find products that do not contain at least some plastic parts. Injection molding is one of the most common methods used to produce these plastics products. Hitachi, Ltd. affiliate Toyo Machinery & Metal Co., Ltd. supplies a wide range of injection molding machines to a variety of industries, extending from small models used to produce micro-precision parts to large models for auto parts production. The latest Si-V series incorporates a function called Smart Molding to achieve reliable molding with fast cycle times, simple setup, and low energy consumption.

INTRODUCTION

IN 2010, Toyo Machinery & Metal Co., Ltd. celebrated both the 50th anniversary of its first plastic IMM (injection molding machine) and the 25th anniversary of its first all-electric IMM. Toyo is a specialist producer of IMMs and has built up a vast amount of technology and knowhow over the half century the company has been involved in the industry.

The new Si-V series was developed to coincide with this anniversary and was based on a development concept called "smart molding" which combines Toyo's accumulated technology with the latest control software and hardware. As more than 60% of Toyo's IMMs are exported, the new models were also designed to comply with safety standards around the world.

SMART MOLDING

The smart molding concept is not a new molding method or function but rather a general term for Toyo's objectives with the Si-V series which were to simplify and shorten the production setup process by identifying the optimum set of molding parameters while also saving energy.

Fig. 1—Si-V Electric Injection Molding Machine. The Si-100 V has a mold clamping force of 980 kN.

The quality of moldings produced using plastics injection molding is heavily dependent on the skill of the molding technician. Plastication, metering, mold filling, and solidification cooling are invisible processes which take place inside mechanical components such as the heat barrel*1, nozzle, and mold. The technician only gets feedback about the molding quality after the moldings come out of the machine. This means that the only way for the technician to determine the cause of any molding faults is to check the moldings after they are produced and then adjust the molding parameters for the next cycle until an acceptable product is produced. The ability to perform this checking and adjustment is an essential skill for molding technicians. With smart molding, however, the machine performs this difficult task automatically, thereby greatly reducing the reliance on the technician. V-mode control, just pack control, and molding navigation are key functions developed for smart molding and are described later in this article.

These functions transform the highly complex task of parameter setting that previously depended on the technician's skill into a simple mode setting job. By standardizing the process for setting molding parameters, smart molding provides shorter setup time and consistent output of quality moldings.

*1 An industry-first see-through heat barrel developed by Toyo as a tool for product development. It allows the technician to observe the plasticizing process directly.

NEW SYSTEM 500 CONTROL SYSTEM

Mechanically, injection molding machines are a mature product with little scope for structural changes. In terms of control systems, however, there remains considerable room for further development. The latest and most innovative control system developed by Toyo is featured in the Si-V series IMMs.

Precise High-speed Control of Injection Motion

The high-performance CPU (central processing unit) in the new system achieves five times faster response than the previous PLCS-12 control system used in the Si-IV series. This makes the new control system the fastest in the industry. It achieves more reliable molding quality by minimizing the variation in positions, timings, and pressures during the transitions between injecting and holding.

Fig. 2 shows a comparison of molding weight variation for the new Si-V and previous Si-IV series under the same operating conditions (using equivalent injection units with same clamping tonnage and mold). The Si-V series clearly produces much less variation in weight.

Digitizing Technician Expertise

V-mode control (variable response function)

In addition to conventional multi-step injection speed control and injection speed slope control, the system is equipped with a new automatic acceleration/deceleration control system called V-mode control. V-mode control allows the user to select one of three acceleration/deceleration patterns which provide a near-ideal pattern of injection acceleration and deceleration. This removes the need for the molding technician to use trial and error to determine the optimum molding conditions by adjusting the speed slope until good quality molding is achieved.

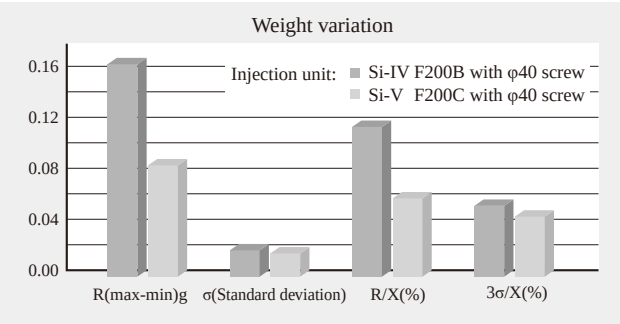

Fig. 2—Comparison of Product Weight Variation Using Conventional Control System and SYSTEM 500.
In addition to the molding weight, the different measures of variation are all significantly smaller compared to the conventional control system.

Fig. 3—Comparison of Standard Control and Just Pack Control. The graph compares how the holding pressure varies when using standard control (upper line) and Just Pack Control (lower line) respectively. The blue-colored area shows how the standard control applies excessive holding pressure.

Just Pack Control (precision control of holding pressure)

Accurate control of the holding pressure after the first injection is needed to completely fill the mold with the melt material. This method works particularly well for thin-walled optical products such as light guides. Precise holding pressure control suppresses flash and minimizes the residual stresses that can cause warping.

Fig. 3 shows the measured pressure using standard mode (upper line) and just pack mode (lower line). The shaded area between the two lines indicates the excess pressure above what is needed.

Molding navigation function (parameter setting assistance)

The machine's user interface prompts the operator to enter all of the required parameters one by one.

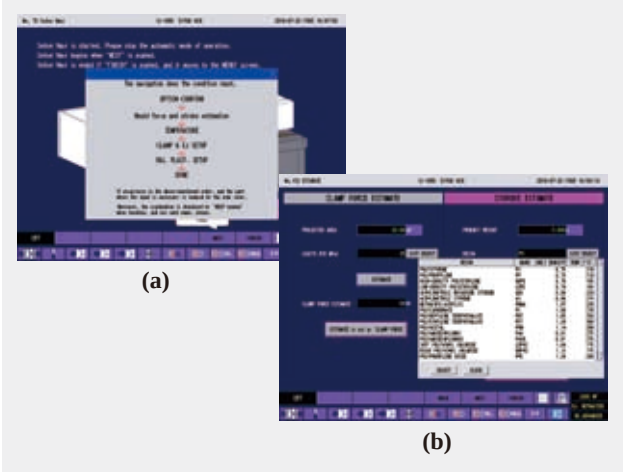

Fig. 4—Molding Navigation Screens.
Required entry fields in the startup screen are highlighted in pink.

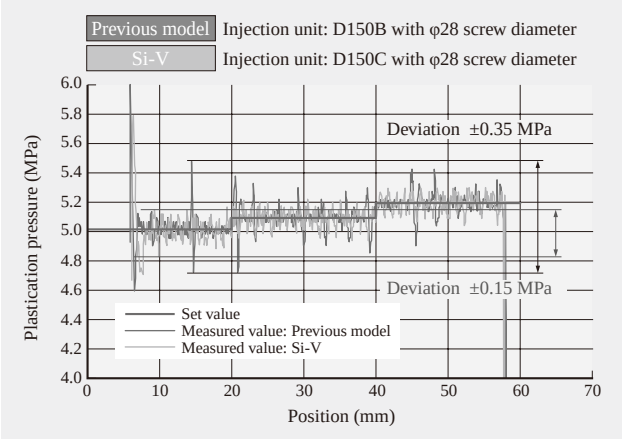

Fig. 5—Melt Pressure Fluctuation during Plastication.
The graph compares the variation in measured values when the melt pressure is incremented in 0.1-MPa steps using the new and old control systems. Stability is approximately twice as good on the new system.

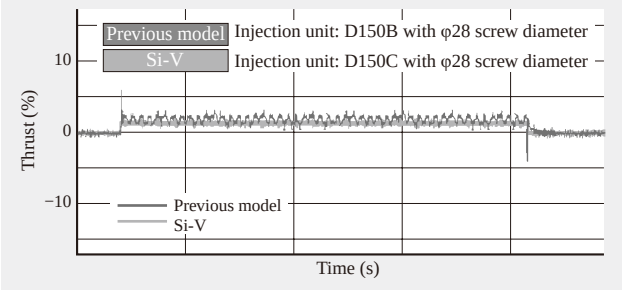

Fig. 6—Two-fold Improvement in Control Accuracy of Screw Thrust in Low-speed Range.
The thrust force stability during low-speed injection is approximately twice as good on the new system.

Fig. 4(a) shows the molding navigation start-up screen and Fig. 4(b) shows the calculation screen used to determine the required clamping force and injection stroke. This function is valuable not only for novices unfamiliar with the operation of Toyo IMMs but also for experienced operators who can use it to review the "basic molding condition settings[*2]."

NEW INJECTION EQUIPMENT

High-performance Digital Load Cell

The Si-V employs a high-performance digital load cell to measure pressures more quickly and precisely. This together with the low-friction guide structure and high-performance CPU (see "Precise High-speed Control of Injection Motion") provides significantly better control of plasticizing pressure.

Fig. 5 compares the variation in measured pressures in response to 0.1-MPa step changes in the pressure settings on the new and old machines. The results show that the Si-V keeps the pressure within a narrower range (±0.15 MPa).

Fig. 6 compares the variation in thrust force when the injection driving device is operating with a low injection speed. A two-fold improvement in control accuracy has been achieved thanks to the lower friction in the sliding parts of the injection unit which makes control of thrust force at low speed much easier than before.

*2 The "basic molding condition settings" are based on the molding manual taught at seminars for the nationally licensed plastics molding skill examination. They are the de facto standard for molding condition settings and are used at Toyo's technical school.

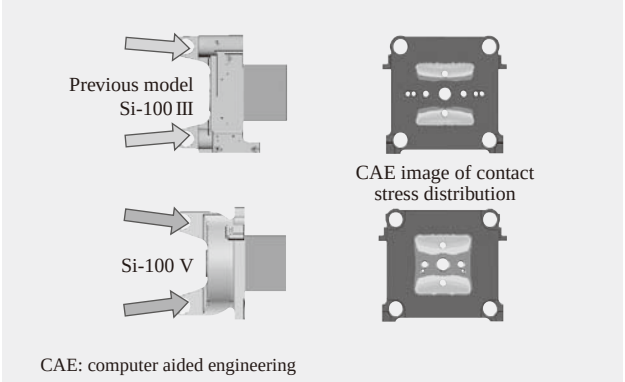

Fig. 7—Movable Plate Analysis.
The V-clamp results in a more uniform distribution of contact stress.

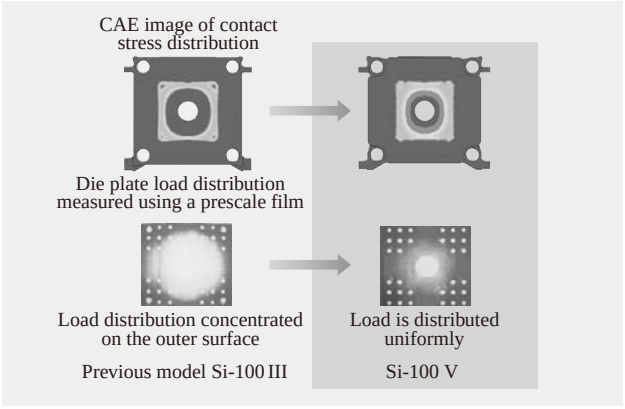

Fig. 8—Stationary Plate Analysis.
The distribution of clamping load on the mold is more uniform.

ADOPTION OF PROVEN CLAMPING DEVICE

Toyo developed a new clamping unit called the V-clamp through a long collaboration with Kyoto University, one of the most prestigious universities in Japan. Having proved successful on the Si-IV series where it was first used, the new unit was also adopted on the Si-V series.

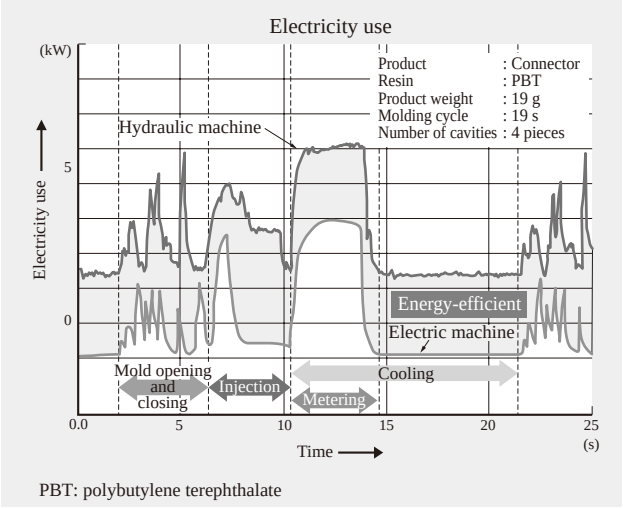

Fig. 9—Electricity Use.
The graph shows the difference in electricity usage by hydraulic and electric molding machines in each process.

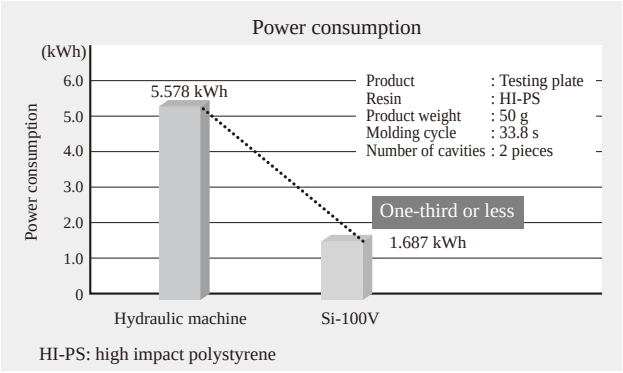

Fig. 10—Power Consumption.
The Si series uses only about one-third as much power as a hydraulic machine.

V-Clamp Clamping Unit

V-shaped toggle with center-press design

The V-clamp is so named because of the V shape of its toggle arms which are slanted more steeply than conventional clamps. This V-shaped configuration presses on the center of the mold to apply the clamping force evenly over the mold.

Optimized die plate design

Toyo also collaborated with Kyoto University to optimize the design of the die plates using an optimization analysis model. This made the die plates thinner while maintaining a wide surface area and high rigidity.

Fig. 7 and Fig. 8 show how evenly the clamping load is distributed over a movable die plate and stationary die plate respectively.

ECO-FRIENDLY MACHINE

Energy-efficiency and environmental friendliness have been key features of Toyo's all-electric IMMs since they were first developed 25 years ago. These features have continued to improve and are evident in the new Si-V series.

Toyo-developed Grease with 88%[*3] Saving in Grease Consumption

The sliding parts of the IMM are designed to not require much grease. In collaboration with a grease manufacturer, Toyo has also developed its own grease which combines more resistance to heat, water and wear with greater adhesiveness.

Together, these design improvements and new grease have reduced grease usage to only about one-tenth that of an earlier series[*4].

Lower Electricity Consumption Key Feature of All-electric Models

Fig. 9 compares the power consumptions per cycle of electric and hydraulic machines and Fig. 10 shows the power savings compared to an equivalent Toyo hydraulic IMM.

Lead-free Circuit Boards

As a result of strenuous efforts to reduce the environmental impact of Toyo's IMMs and conserve the global environment as well as complying with the RoHS (restriction of the use of certain hazardous substances in electrical and electronic equipment) Directive, no lead is used in the Toyo-made circuit boards on the Si-V series.

INTERNATIONAL SAFETY COMPLIANCE

With over 60% of Toyo's machines exported, the Si-V series is designed to comply with safety requirements in whatever country or region the machine is used.

Table 1 lists the safety standards in different countries and regions.

CONCLUSIONS

Further Development of Existing Technology

Although Japanese technology has led the world in the field of plastics injection molding machines, maintaining this predominance in the decade to come will not be easy and it is likely that the technological

*3 Average value with Si-V series
*4 Si-III series

TABLE 1. Safety Standards in Different Countries and Regions
The machines comply with safety standards from major countries and regions.

Country, Region (Organization)	Standards
Japan (JSIM)	JIS K1001
China	GB22530
Europe	CE marking
USA (SPI)	ANSI
South Korea	KC marking

JSIM: The Japan Society of Industrial Machinery Manufacturers
SPI: the plastics industry trade association

gap will be narrowed. In any case, IMM makers in Japan need to continue their successful development of superior technology and expertise. For its part, Toyo intends to continue its work on digitizing technician knowhow (see "Digitizing Technician Expertise") and smart molding (see "SMART MOLDING").

Smart Molding Concept Name

The prefix "smart" has become widely used in recent times in words like "smartphone" and "smart grid." The reasons for choosing this word in Toyo's smart molding concept are as follows.

(1) Smart molding digitizes the skills and knowledge of molding technicians so that even novices can perform difficult molding jobs.

(2) The new SYSTEM 500 controller has faster processing capacity than before and the new load cell provides much finer resolution.

(3) The just pack system fills material into the mold smoothly without causing unnecessary pressure.

(4) The energy-saving design prevents waste of energy.

Because it makes injection molding as simple as possible, the smart molding concept will feature not only in the Si-V series but also in future Toyo models.

ABOUT THE AUTHORS

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