

History of Development of Injection Molding Machine Technologies and Future Perspectives

Hikomasa Uezono Katsuhiko Fujii Kiyoshi Ochi Takahide Omobayashi

—Synopsis—

Over half of a century has passed since we began our injection molding machine business operations in technical collaboration with the German companies Ankerwerk in 1961 and Krauss Maffei in 1963. Injection molding machines have evolved from being hydraulically-driven to become superior electrically-driven, energy-saving machines that provide precise, stable molding conditions. In 2004, JSW introduced the J-AD series, its 4th generation of all-electrically-driven injection molding machines. Thereafter, JSW continued to develop a number of specialty machines that met market needs, such as the J-AD-USM ultra-high speed injection specification series of machines, and machines in collaboration with subsidiary Meiki Co. in 2010. Now in the present, we have just released the 5th generation J-ADS series in March 2015. Over the past 10 years we have also poured our efforts into the development of process technologies. We advanced our proprietary DSI process technology to create the HP-DSI process, acquired a commanding market share in Japan for the MuCell foaming molding process. Screw and barrel technology and control technology are the core technologies of injection molding machines, and we have continued to develop, improve, and bring to the market these technologies along with the releases of new machines to stand apart from our competitors. In order to develop into a Global Top 5 company, we must develop differentiated technologies that impress our customers and continue moving the progress of technological development forward.

1. Preface

A quarter of a century has past since electrically-driven injection molding machines first entered the market with slogans for stable high-precision molding as well as energy savings. Throughout these 25 years, we have seen advancements at a component level, such as the capacity enhancement of servo motors which are a core component, and high load support in ball screws, but not technological innovation in the injection molding machines themselves. This has resulted in further commoditization and even fiercer price wars, especially in Japan. Therefore, we launched the J-AD Series in the market in 2004 and have striven thereafter to develop and improve our process technologies, such as HP-DSI and MuCell that aimed to differentiate this technology, while also developing our own original control technologies. In addition, we have worked to jointly developed machines, such as the opposed 2M machine, to leverage a synergistic effect with Meiki Co., Ltd. through a business partnership in 2008 and acquisition as a subsidiary in 2010.

This report introduces technological developments after the J-AD Series entered the market in 2004 around the four aspects of machine development, process technologies, screw technologies and control technologies in addition to describing the J-ADS Series, which is the fifth generation of electrically-driven injection molding machines released into the market in March 2015.

2. Technological Development of Injection Molding Machines

2.1 Series Shifts of Injection Molding Machines (Fig.1)

We entered into a technological alliance with two German companies -- Ankerwerk in 1961 and Krauss Maffei in 1963 -- to not only develop and manufacture small- to large-size injection molding machines but also accumulate technology. These injection molding machines used hydraulics as a driving force while adopting a toggle mechanism for the clamping unit and an in-line screw system for the injection unit. This series established a concrete base in the injection molding machine

industry. However, as times changed together with great demand for reductions in the environmental impact, hydraulic injection molding machines had a series shift from the Japan Steel Works and Ankerwerk V-series (Photo.1) to the N, NA, N-BII, J-S, J-SII, J-E, J-EII, and J-EIII until the final transition from shipments of vertical type electric servo drive injection molding machines at the beginning of 2012 to electrically-driven injection molding machines.

We solidified development of electrically-driven injection molding machines with superior environmental performance, such as energy savings and no hydraulic oil, before everyone else in 1984 and released the J-EL series full electric servo drive injection molding machine for sale four years later in 1988. At the time, we were confronted by a variety of technological challenges in motorizing injection molding machines. However, repeated improvements and refinements led to the release of the J-ELII series in 1995, the J-ELIII series in 2000, and the long-selling fourth generation J-AD series in 2004.

2.2 J-AD Series

The J-AD series became a rare long seller in the injection molding machine industry. Behind this success was a diverse line-up of products that gradually released small- to large-size and vertical models, had machine specifications superior to competitors as well as offered a timely additional line-up of injection molding machines with unique specifications that matched market needs.



Photo.1 V-series

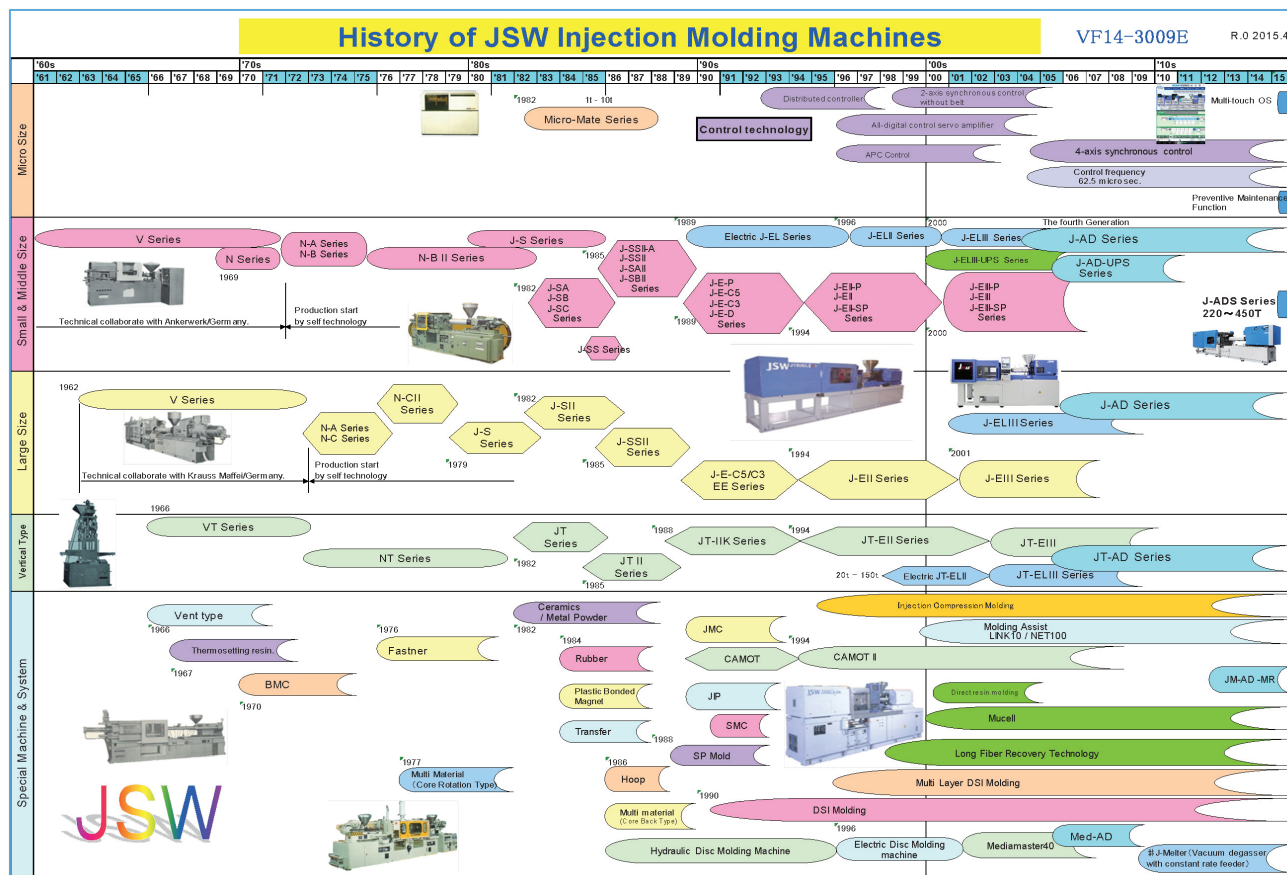


Fig.1 Series Shifts of Injection Molding Machines

2.2.1 Small-size J-AD Machines (Photo.2)

The small-size J-AD machine was developed to target the thin-walled precision product field and adopted high-spec injection specifications as the standard machine contrary to competitors. Attaining sufficient performance with a conventional control was difficult to meet the high-spec injection specifications for the small-size J-AD machine. Therefore, leveraging our strengths in developing and manufacturing control technologies and circuit boards, we succeeded in the development of an optimal high-speed servo control circuit for an injection molding machine. This control circuit was built into the J-AD series as the SYSCOM3000 Controller (Fig.2). The SYSCOM3000 controller realized the fastest control cycle in the industry at 62.5 μ s, which is its greatest feature. This innovation has contributed greatly to stable high-precision molding in the high-speed injection molding machine industry. In addition, the simultaneous multi-screen display allows a visibility and intelligibility to realize a control that is easy to operate by adopting a vertical 15-inch touch panel in the operational section of the controller.

The J-AD series also employs a unique JSW injection control built-in standard to achieve even greater stable high-precision molding. A wide



Photo.2 Small-size J-AD Machines

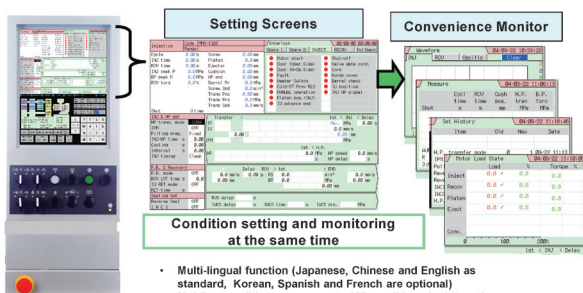


Fig.2 The SYSCOM3000 controller

- Multi-lingual function (Japanese, Chinese and English as standard, Korean, Spanish and French are optional)
- Molding condition storage up to 120 conditions by internal memory, up to 1,000 conditions by optional USB memory.

range of control systems are built-in to use as standard options only available in electrically-driven injection molding machines, such as the IWCS control that stabilizes the density of molten resin through screw rotation after plasticizing is complete, software control to prevent peak pressure right before pressure transfer in the injection process, and APC control to limit overshooting and undershooting in the pressure control during the injection process.

Thereafter, the small-size J-AD machine built a history as a long seller with performance outshining everything else even today.

2.2.2 Medium-size J-AD Machines

The medium-size J-AD machine was first released in June 2006 with the J350AD machine that has 350 tf of clamping force before completing its expansion into a four model series of medium-size J-AD machines in March 2007. The medium-size J-AD series includes machines that can be used more safely thanks to greater rigidity in the clamping unit and the bed based on improvements to molding stability represented by the built-in high-speed servo control cycle following the concepts of the small-size J-AD machine. We create optimal designs via FEM analysis technologies, especially for the platen and the bed, to improve variations in thickness for actual moldings of flat plates by 17% as well as reduce vibrations of stationary platens during high-speed opening and closing at least 30%.

2.2.3 Large/Ultra Large-size J-AD Machines (Photo.3)

Large/ultra large-size J-AD machines completed the expansion of the full electric servo drive injection molding machine from 850 tf of clamping force in October 2009 and 1,300 tf of clamping force in January 2011 to the world's highest clamping force at 3,000 tf in January 2012. These machines were developed around the keywords "high-cycle molding," "energy savings" and "molding stability" to satisfy market needs from larger and thinner molded products for industries from automobiles, office equipment and appliances to general goods in addition to offering even greater productivity and molding stability.

In terms of high-cycle molding, this series has realized faster opening and closing speeds through the adoption of toggle-type clamping structures

with superior high-cycle molding and energy savings in addition to the pursuit of optimal toggle designs. We have also evolved the screw design to dramatically enhance high-cycle performance by developing screws that satisfy lower temperature uniform plasticization, higher mixing and higher plasticizing performance.

In terms of energy savings, this series has contributed to reductions in power consumption and CO₂ emissions by adopting the optimal toggle designs described previously in addition to power regeneration systems similar to hybrid automobiles to regenerate energy accumulated through mechanical operations such as injection and clamping into electric energy.

In terms of molding stability, we have improved the control cycle described previously in addition to developing proprietary multi-axis synchronous control technology able to move four ball screws with four-axis servo motors that each move synchronously. These technologies contribute to stable molding by making high-power and high-precision servo systems a reality.



Photo.3 Ultra Large-size J-AD Machines

2.2.4 Vertical Type JT-AD Machines (Photo.4)

Vertical type JT-AD machines began sales of rotary machines with 40 tf and 70 tf clamping force from November 2006 and a rotary machine with the world's highest clamping force of 220 tf was released as a vertical type electric servo drive injection molding machine in 2009 to complete the development in the series. Vertical type injection molding machines often are installed in-line as part of the manufacturing line to be a machine primarily for insert molding and need to be low to the floor to lower the pass line of molded parts. Moreover, this was developed as a machine able to satisfy the requirements for a more compact machine size, faster opening/closing and table rotation speeds to improve productivity.



Photo.4 Vertical Type JT-AD Machines

2.2.5 J-AD-USM Ultra High-speed Injection Specification Machine

The popularization of the Internet and the prevalence of portable devices such as cellular phones, smartphones, compact gaming consoles and notebook computers are marvelous. This evolution of technology sparked greater miniaturization and weight savings. Machines that have good injection specifications for filling responsiveness of resin at high speeds and high pressures had become necessary to make components such as light guide plates and media cards used in these devices thinner.

To address these various needs, we completed the J-AD-60H-USM machine that realized an 800 mm/sec high-speed and high-response injection performance in 2008 by decreasing the low inertia of the device and increasing the output of the motor based on the mechanical structure of a standard machine.

60H-USM machines improve start-up of the injection speed (acceleration) by 2.5 times compared to conventional high-speed injection compliant machines to reach a maximum speed of 800 mm/sec in 13.5 ms. (Fig.3) We further improved and refined the machine thereafter to allow the machine to reach a maximum speed of 1,000 mm/sec today. Furthermore, higher speed control was also required due to the improved injection speed start-up, but we were able to facilitate stabilized injection performance through the high-speed servo control technology described previously. Thereafter, enlarging and thinning of devices advanced, even for the light guide plates following the enlargement of tablet terminals such as

Netbooks, and large-capacity as well as high-speed high-response injection performance became a necessity. Therefore, the J-AD-180H-USM machine was released as an additional model in 2010. The J-AD-180H-USM machine required two-axis ball screws and servo motors to secure better injection performance than the 60H, but we were able to develop and utilize proprietary high-speed synchronous control technology.

The machines were also equipped standard with electric toggle-type injection compression molding as technology to mold thin products such as light guide plates. The toggle-type molding offers high-speed compression specifications built-in standard with increased capacity of the servo motors for clamping as well as optimized pulley ratio to support ultra high-speed injection in addition to enabling control of the mold position with an accuracy at least ten times that of direct pressure molding. A unique [Injection Synchronization] function able to synchronize the screw position and clamping force (compression force) during injection has been added to attain molding products free of distortions and thickness variations.

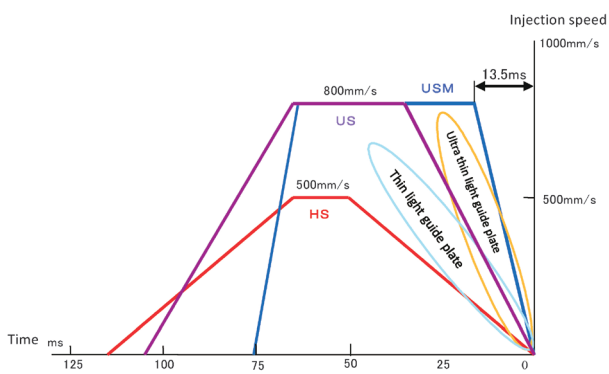


Fig.3 60H-USM machines improve start-up of the injection speed (acceleration)

2.3 Opposing Multi Color Hybrid Injection Molding Machine (Fig.4)(JM1600AD-MR)

We established an alliance with Meiki Co., Ltd. In February 2010 and released an opposing multi-color hybrid injection molding machine combining special direct-pressure clamping unit technology from Meiki Co., Ltd. and the technology of our electric servo drive injection unit in July 2012. This machine targeted automotive component manufacturers that specialize in head and tail light moldings. As needs for these products to be uncoated and lineless grew, the technology was developed expecting growth in American and

Korean vehicles.

The machine has a middle platen between the stationary platen and movable platen able to mount the molds on both sides as part of the mechanical structure. The middle platen has a rotation mechanism, and different types of resins are injected from the stationary platen and movable platen. The middle platen can create moldings for multi-color products in one cycle and improves productivity to act as a stack mold by repeatedly inverting 180 degrees to execute moldings and filling two times the total number of cavities.

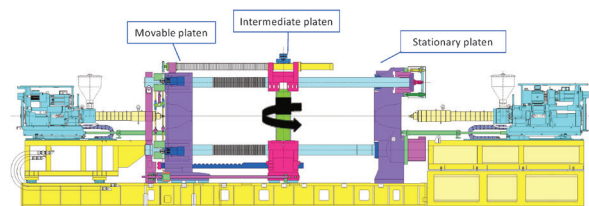


Fig.4 Opposing Multi Color Hybrid Injection Molding Machine

2.4 J-ADS Series (Photo.5)

The J-ADS series is the fifth generation of electrically-driven injection molding machines developed with the concept of “maximum peace of mind for all of our customers.” Four medium-size models were released in March 2015.



Photo.5 J-ADS Series

2.4.1 Medium-size J-ADS Machines

The J-ADS series is a machine that adopts a high rigidity/high precision clamping unit, newly developed energy-saving barrel and new SYSCOM5000i controller in the pursuit of “peace of mind” for our customers.

(1) High-rigidity/high-precision clamping unit

We introduced a multitude of improvements for a uniform amount of deformation for the entire

platen face and succeeded in improving the variations in surface pressure of the mold parting roughly 55% in addition to implementing the high-rigidity clamping unit from the conventional machine. This clamping unit improves the thickness distribution of molded products and is expected to solve problems with burning by gas.

(2) Newly developed energy-saving barrel

The barrels of injection molding machines need considerable strength to handle the high pressure. We developed barrel materials that have a material strength 1.5 times conventional materials and succeeded in decreasing the outer barrel diameter. Stronger materials and a smaller outer diameter was able to improve the heat transfer efficiency and reduce the power consumption during continuous molding 10% while also improving the control of the resins temperature, including an improved heating cycle, while also attaining stable molding performance.

(3) New SYSCOM5000i controller

We conducted development based on the belief greater ease of use was our top priority, such as the adoption of an intuitive and intelligible interface that uses many operation sensations and pictographs similar to smartphones. The new SYSCOM5000i controller is packed with various functions to improve customer productivity and bring “peace of mind” to our customers, such as a predictive and preventative maintenance function that calculates replacement periods of consumables and notifies users of inspection timings for ball screws, cooling fans, and other components, as well as a display for the power consumption and a molding assist function for users new to molding.

2.4.2 Small-size J-ADS Machines

We introduced an additional line-up of six small-size models on October 2016 after the release of the medium-size J-ADS machine.

We implemented a variety of available molds and a new type of downsized clamping mechanism to allow the application of even large mold sizes. Adopting a second generation flat press platen and separate platen as well as improving the surface

pressure variations of mold partings is contributing to reductions in the clamping force, improvements in the molded product quality and lower mold maintenance costs. In addition, we have been able to further reduce running costs by employing a SYSCOM5000i controller similar to the medium-size J-ADS while also equipping an additional “Eco Mode” that improves the energy-saving efficiency according to the molding conditions.

3. Molding Process Technology

The Japanese manufacturing industry has a long history calling for industrial hollowing, but trends such as the return of production bases to Japan are rejuvenating Japan pushed by the recent weaker yen. This is also true with the plastic injection molding industry. Many companies are manufacturing products in Japan to increase added value in particular, except in regards to mass-production and mass-consumption products. Following these trends in the molding industry, we are focusing on greater efficiency in manufacturing and emphasize the development of new molding process technology and composite molding technology to satisfy customer needs as a company. This section describes some examples of these technologies.

3.1 Die Slide Injection (DSI) Molding Method

Fig.5 shows the DSI process. The DSI process molds the primary mold components first (half pieces of hollow molded components) with the primary injection, and then opens the mold. Molds move to a position where the primary mold components face each other with a die slide mechanism built into the injection molding machine. The mold is closed again and a secondary injection of resins in a band-like layer bonds the aligned primary molded components to combine them into a molded product. In this way, because the two halves are fused in the mold without the temperature dropping right after the primary molding, a highly precise molded product can be attained without the concern of dimensional changes in the bonding surface due to thermal contraction.

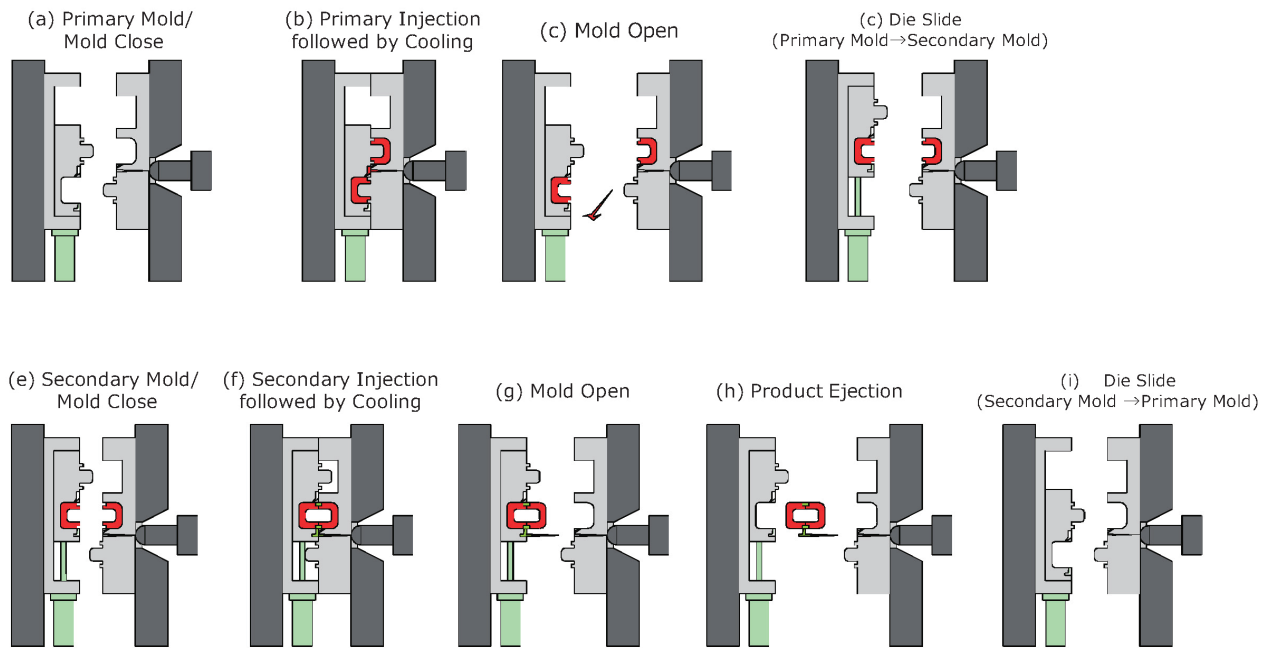


Fig.5 DSI process

3.2 Hot Plate-DSI (HP-DSI) Molding Method

The DSI molding method is a breakthrough process to manufacture hollow molded products. However, the bonded section when combining these halves is only on the outside of the molded product while the rib inside is difficult to fuse. In addition, resins with low bonding properties cannot be utilized in the DSI molding process. A process able to solve these two issues is the HP-DSI molding method. Fig. 6 shows the HP-DSI molding process. The HP-DSI process molds the primary mold components first (half pieces of hollow molded components) with the primary injection, and then opens the mold. Molds move to a position where the primary mold components face each other with a die slide mechanism built into the injection molding machine. The mold is closed up to the gap set in the parting surface of the mold and a heater

is inserted to apply heat to fuse the surfaces. The mold is closed again after removing the heater to bond and combine the pieces into a molded product. The following describes the benefits of the HP-DSI molding method.

- (1) Reduces defects in the bonding quality with fewer adverse effects to integrate bonds inside of the molds right after molding.
- (2) Reduces the number of processes to allow molded components to be integrated inside of the mold.
- (3) Eliminates intermediate inventory of primary molded components.
- (4) Facilitates three-dimensional bonds on non-flat surfaces.
- (5) Facilitates bonds even on ribs inside of hollow pieces.

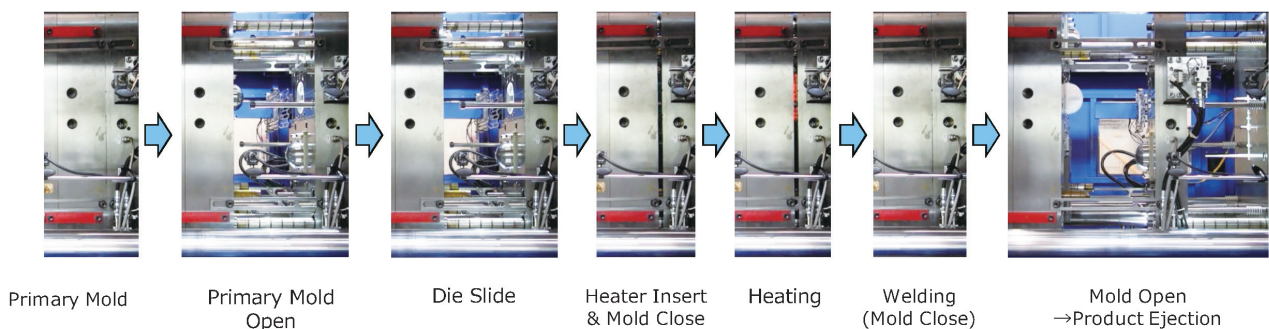


Fig.6 HP-DSI molding process

Moreover, the HP-DSI molding method provides strong bonds superior to other bonding methods such as vibration welding methods. However, there are still some challenges, including the need to design dedicated heaters for each product geometry and the inability to support complex rib shapes such as those that cannot be reproduced with the minimum bend radius of the heater. A swing-type heater is the solution to these challenges. Photo 6 shows an example of a swing-type heater. The heater operates like a swing by driving the heater forward and backward together with an eccentric cam using servo motors. The swing operation of the heater can apply uniform heat to the welding.

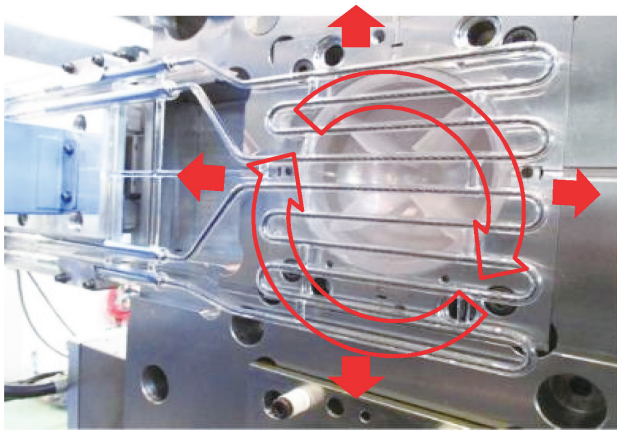


Photo.6 HP-DSI swing-type heater

3.3 Decorative Molding Technology via MuCell® and Laminated Molding

The MuCell® injection molding method is a microcellular foam injection molding technology to achieve a plastic foam part that has isolated cells with an outer diameter of 10 to 200 μm . This technology is a physical foam molding technology that uses nitrogen and carbon dioxide rather than a chemical foaming agent such as azodicarbonamide (ADCA). This process has gained attention due to reductions in the environmental impact and recyclability. Fig.7 shows the MuCell injection molding process.

- (1) This process mixes the melted plastic material by injecting nitrogen or carbon dioxide in a supercritical state to the melted plastic in the barrel.
- (2) In the process to fill the mold, nitrogen or carbon dioxide dissolved into the melted plastic cannot sustain a dissolved state and generates bubble nuclei.

- (3) The bubble nuclei that are produced grow, press the plastic material against the sides of the mold due to the internal pressure of formed gas, dilute, cool, and then harden.

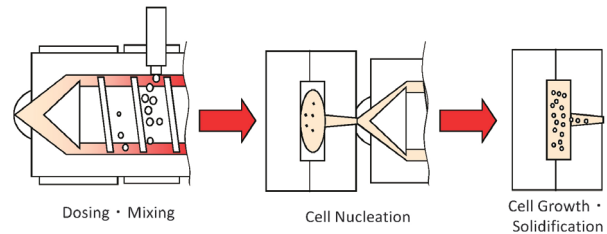


Fig.7 MuCell injection molding process

Customers can expect the same benefits for products as injection foam molding that uses a chemical foaming agent, such as weight reductions and fewer warps and sink marks, because the MuCell injection molding method is a foam molding process. However, the greatest feature of the MuCell injection molding method is the use of nitrogen or carbon dioxide in a supercritical state as a foaming agent. This type of foaming agent is expected to provide the following benefits as well.

- (1) Benefits related to the molding process such as a reduction in injection pressure and clamping force due to a dramatically lower viscosity apparent in the melted plastic
- (2) Benefits related to a lower environmental impact such as the ability to avoid harmful effects of the plastic materials as well as recyclability
- (3) Benefits related to superior versatility such as the use of engineered and super engineered plastics

The MuCell injection molding method also has challenges inherent to foam molding, such as lower strength in molded products and lower surface quality, because it is a foam molding process. The decorative molding technology via MuCell and laminated molding processes introduced in this report is one method to address issues such as a lower surface quality. Photo.7 shows the decorative molding system via MuCell and laminated molding that was exhibited at the IPF2014. The system is composed of a SCF unit and gas sponge as well as a film installation stand to equip film for MuCell molding in addition to the main injection molding

machine and standard peripheral devices such as the mold temperature controller and the product takeout robot. The molding executed this time equipped the installation stand with an ABS plastic film that has a thickness of approximately 0.4 mm, the insert was seated in the mold by the product takeout robot when opening the mold, and then the MuCell injection molding was executed. Photo.8 is a molded product molded with the actual machine exhibited at the IPF2014. The molded product molded using the MuCell injection molding method are not very suitable for decorative products that come into people's view because the surface quality is worse than standard molded products. However, the surface quality of molded products is improved by affixing a film to achieve a light, high-design decorative product. This process even supports diverse products made in small lots as well because wide-ranging designs can be supported by simply changing the film to insert.

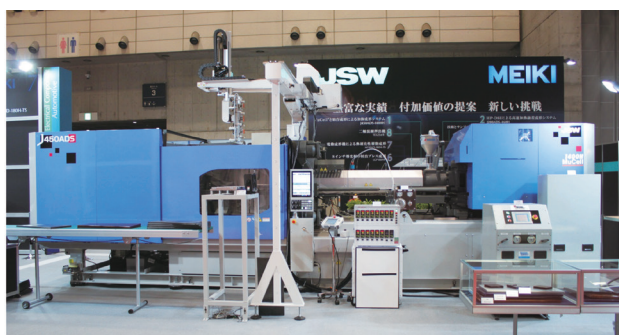


Photo.7 Decorative molding system via MuCell

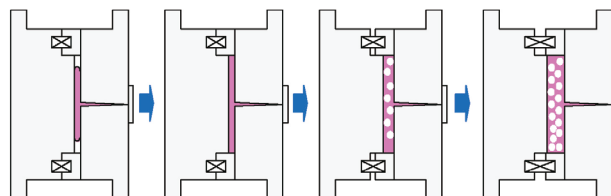


Photo.8 Decorative Molded Product by Lamination Forming

3.4 MuCell® and Expansion Molding

The foaming ratio is limited to roughly 1.1 times low foam molded products in the short shot method, which is one type of foam molding. This type of molding cannot satisfy user requirements for a 20% to 30% weight reduction ratio. Conversely, the expansion molding method allows a two to three times higher foaming mold. Fig.8 shows the expansion molding process. The internal pressure difference inside of cavities is small thanks to

synchronous decompression inside of the cavities in each part compared to the standard short shot method. This achieves a uniform foaming body as shown in Photo.9 in addition to dramatically improving the foaming ratio two to three times.



- ①Injection:
Inject the melted resin with foam material into the cavity.
- ②Filling:
Resin shall basically be fully filled.
- ③Expansion:
Open the mold to the set amount (expansion), decompress the inner pressure, and increase the mold product volume by the foam pressure.
- ④Multistep Expansion:
Stop, retain and expand again.

Fig.8 Expansion molding process

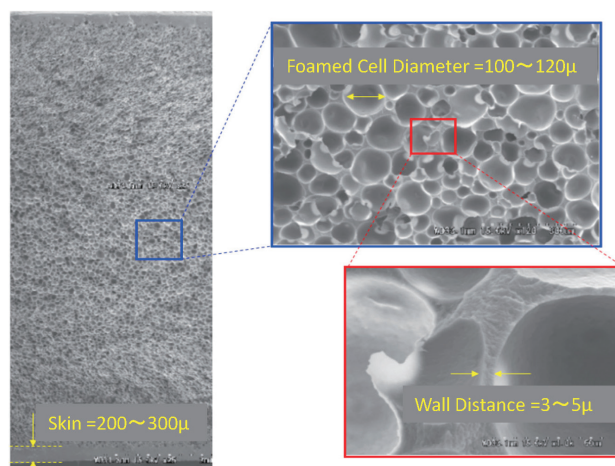


Photo.9 Cell Observation Photograph of the Expansion Molded Product

4. Development of Screws and Barrels

The development of screws and barrels up until now was conducted in conjunction with the development of new machine models. We have been working in the development of screws and barrels in parallel with the development of J-AD large- and ultra large-size full electric servo drive injection molding machines since 2004, and we are introducing newly developed screws to the market. Recently, however, diversification of usable plastic materials that aim to improve functionality of injection molded products is accelerating and a lot

of development is advancing without links to new development of machine models, such as screws dedicated to specific plastics.

This page introduces the MIII-D screw for the large-size J-AD machine as well as the energy-saving barrel for the medium-size J-ADS machine as examples of development advancing in conjunction with the development of new machine models while the screw with an irregular pitch for optical molding materials such as computer plastics is introduced as an example of development for a screw dedicated to a specific plastic. In addition, as part of the factors causing screw wear, the CL screw developed as a measure to not only improve material quality but also address factors making solutions in the melting process difficult are introduced together with the visualized barrel that realizes the visualization of phenomena causing various defects in moldings which need to be solved.

4.1 MIII-D Screw

The performance generally required in screws and barrels is wide ranging. However, the new screw for the large-size MIII-D machine has adopted the advantages of the MIII screw employed in the older series to improve the performance as distinct prescribed properties around five items; (1)high dispersion performance, (2)high plasticizing performance, (3)lower-temperature plasticization performance, (4)recoloring performance and (5) plastic compatibility performance. An outline drawing of the MIII-D screw is shown in Fig.9. This basic structure establishes a sub flight slightly lower than the main flight between the pitch of the main flight of the compression zone and metering zone.

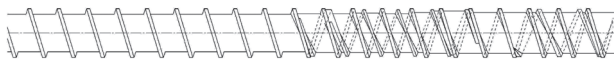


Fig.9 An outline drawing of the MIII-D screw

4.2 Energy-saving Barrels

The barrels of injection molding machines require wear and corrosive resistance able to handle a variety of plastic materials as well as the strength to endure the high pressure of several hundred MPa. Therefore, our barrels have a two layer structure composed of a base material layer with superior strength and toughness as well as a

layer of lining with superior wear and corrosive resistance. Energy-saving barrels have a smaller outer diameter than conventional products thanks to the application of a new material with 1.5 times the strength of conventional materials on the base material layer. The reduction of the outer diameter of the barrel is able to reduce the heater capacity to attach, which has realized a 10% reduction in power consumption compared to conventional structures.

4.3 Screws with an Irregular Pitch

Screws with an irregular pitch were developed for the purpose of limiting the occurrence of molding defects, including carbonization and yellow discoloration in optical molding materials such as computer plastics. Fig.10 shows the difference in the exterior of a standard screw and a screw with an irregular pitch. Screws with an irregular pitch are designed to change following the axial direction of the flight pitch and prevent sudden changes in the channel cross-sectional area to stop a high shearing force in plastic materials.

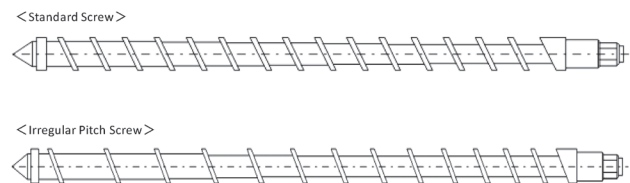


Fig.10 Difference in the exterior of a standard screw and a screw with an irregular pitch

4.4 Contact Less (CL) Screws⁽¹⁾

CL screws were developed as a measure to combat screw wear caused by factors related to the melting process. Fig.11 shows a schematic diagram for the stepped pad of the thrust axial bearing. The CL screw applies the logic for this lubrication force to the flight of the screw. Fig.12 shows the results of measurements taken of the outer screw diameter before and after employing the CL screw in an actual production plant. The validity of this screw was confirmed by almost no wear in the screw flight during molding over a period of two years after employing the CL screw compared to the several millimeters of wear in the screw flight over the same period of time before employing the CL screw.

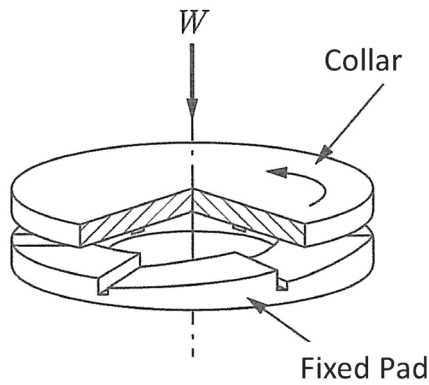


Fig.11 Stepped pad of the thrust axial bearing

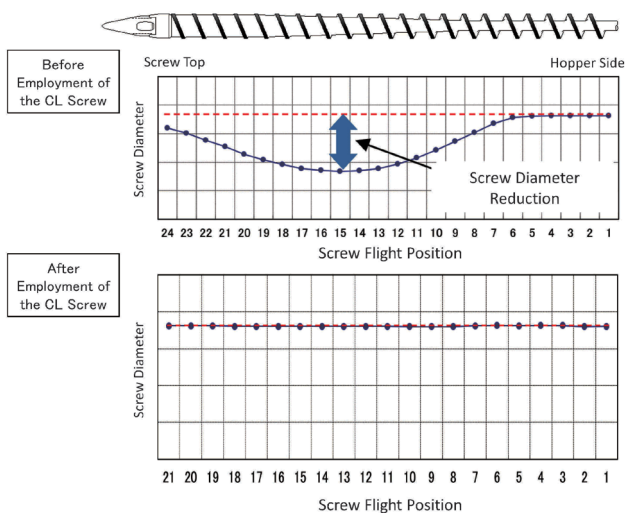


Fig.12 Results of measurements taken of the outer screw diameter before and after employing the CL screw (2 years, after 540,000 shots)

4.5 Visualized Barrel⁽²⁾

Over the last ten years, we have worked to bring the phenomena causing defects in molds to light (visualization). Photo.10 shows the visualized barrel developed by JSW. The diameter of the screw is 66 mm and observation windows extrapolated from sight glass are installed in five areas on the side of the barrel to allow the process to be observed from the screw supply zone to the metering zone. An example image of observation taken through an observation window is shown in Fig.13.

The development of the visualized barrel also makes the visualization of the behavior in the back-flow prevention ring attached to the end of the screw possible. There are several limitations in the use of the visualized barrel such as the injection pressure and barrel temperature, but use of this barrel is expected to be effective in providing insight to various phenomena.

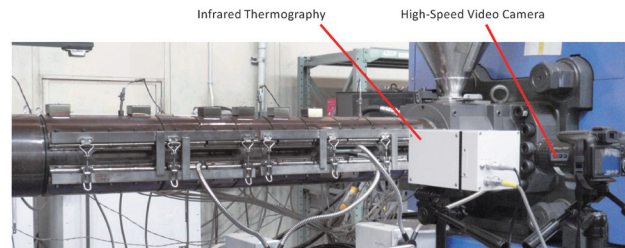


Photo.10 Visualized Barrel □66mm□

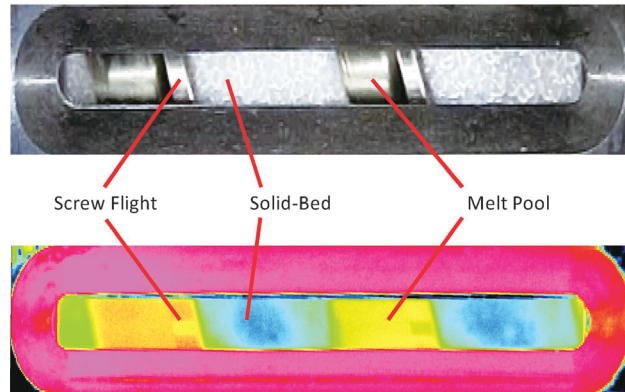


Fig.13 Example image of observation taken through an observation window (Upper: Visualized image, Bottom: Infrared image)

5. Control Technologies

The advancement in full electrically-driven injection molding machines from small- to ultra large-sizes means the importance of electrical control technologies is growing for mechanical drive performance, such as injection, plasticization, responsiveness of the open/close drive axis, high-cycle molding and high load support capacity. In particular, technology for our proprietary large-capacity servo system is being employed in machines from the J2500AD (24,600 kN clamping force), which is an ultra large-size full electric servo drive injection molding machine. The exterior drawing of the injection unit is shown in Fig.14 and a block diagram of the control system is shown in Fig.15. The structural components of the servo system utilize the same structural components both in the medium- and large-size machines. The necessary thrust for ultra large-size machines is achieved through synchronous control of four-axis servo motors. The multi-axis servo system is connected through high-speed communication. The entire machine is built upon a 13-axis servo system. In addition, the system operates with energy savings and minimal equipment capacity by

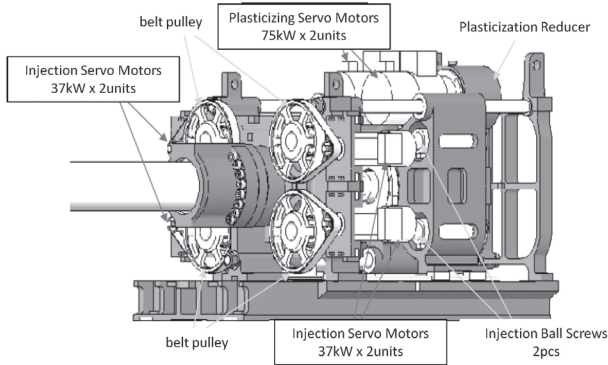


Fig.14 The injection unit is shown

service history, as a product customers can use over the long term. Functions supporting lower power consumption according to the molding conditions have also been newly introduced to support energy-saving needs.

Synchronous heat control has been equipped for the barrel temperature control since the J-AD series to prevent burning and deformation of plastics at the start of heating. However, a new temperature control board accelerating the control cycle ten times has been built into the J-ADS series to ensure more highly accurate temperature stability.

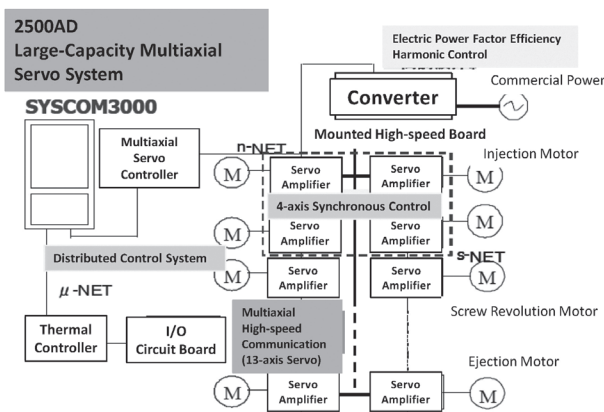


Fig.15 Block diagram of the control system



Fig.16 SYSCOM5000i

equipping a large-capacity high-efficiency converter as standard as well as through a power regeneration function to realize high power with a minimal power supply.

The J-AD series has our SYSCOM3000 built in as the controller and, since its launch into the market in 2004, has received praise for its usability. The J-AD series has built a long-standing track record. Moreover, the SYSCOM5000i developed with the objective of further improving usability has been built into machines since the J-ADS series released in 2015 (Fig.16). These characteristics have been implemented for the first time as injection molding machines for multi-touch operating systems used in a wide range of products from smartphones to tablet terminals in order to create a user interface able to set molding conditions easily as well as provide intuitive operations of the machines. In addition, injection molding machines have enhanced maintenance capabilities, including functions to predict the product lifespan as well as functions to display the

6. Conclusion

This report has introduced our technological development since 2004 by looking independently at model development, process technologies, screw technologies and control technologies. In March 2015, the new J-ADS machine entered the market and differentiated itself with soft technology such as the SYSCOM5000i at its core, and we believe the current trend lacking advancement in revolutionary hard technology will continue. On the other hand, the demand for greater functionality of plastic molded products such as metal alternatives are growing in the market. There is also a greater tendency to use engineered and super engineered materials for the plastic materials. Molding machine manufacturers are requiring molding process technologies compatible with these products as well as the development of long-lasting and cheaper screws and barrels that

assume use of these plastic materials. This development is a pressing challenge for JSW.

Finally, we must realize the development of distinctive technologies as soon as possible that are able to bring sensation to customers in order to escape a red ocean market where commoditization is progressing. We will put all of our strength into furthering technical development without compromise to become one of the top five companies by 2020.

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