History of Development of Injection Molding Machine Technologies and Future Perspectives

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—Synopsis—

With prospect for the coming era when the variety and production of plastics would be increasing, JSW started manufacturing injection molding machines (V-series) through technical alliances with German manufacturers Ankerwerk (in 1961) and Krauss Maffei (in 1963), with respect to compact- and medium-size machines and large-size machines, respectively.

Later takeoff from the original designs was accomplished by the release of N-series, in which our independent ideas and principles were largely reflected. Hydraulic-driven JSW injection molding machines were subsequently delivered to the market, re-modeled to J-S series then J-E series.

Since 1988, when J-EL series, one of the front runners of electric-driven injection molding machines, were released, developments in servo drivers were continued, and in 2004 the fourth generation electric machines, J-AD series, equipped with full electric servo drive systems, were sent into the market. J-AD series have now covered a clumping force range from 35 to 2,500 tons.

1. Introduction of Injection Molding Machine Technology

In 1960, Japan was under the high economic growth policy. In plastic industry, one of the major industries at that time, the production volume increased rapidly as their product type increased. The industry grew in an ideal way; rationalized mass production facilities achieved lower price which increased demands for the products. The increase of demand for plastic products lead to the growth of processing industry. The industry diversified to molded products such as film, sheet, electric wire, and pipe, and injection or compression molded products such as daily goods, home electronic appliance parts, and auto parts. Under that situation, JSW established technical alliances with German manufacturer Ankerwerk on injection molding machine in April 1961. The structural characteristics of the alliances are: 1. Single-screw-inline injection unit, 2. Single-toggle clamping unit. This technical alliances provided JSW with fresh knowledge on manufacturing technology such as designing and machining, in addition to understanding on mechanisms with complicated hydraulic pressure and electric circuit, and acquisition of molding technology. Also, JSW established technical alliances with German manufacturer Krauss Maffei on large-size injection molding machine in April 1963.

2. Technological Development of Injection Molding Machine

2.1 JSW-Ankerwerk V-series

JSW-Ankerwerk V10 to V42 models stormed the market as the first single-screw-inline injection molding machine in Japan and achieved a good reputation. The sales reached 250 units in 1964 and these machines rapidly established a secure position in the injection molding machine industry. Ankerwerk's designing transformed from the initial single-toggle to double-toggle with all models except compact models, and developed to high speed and high-performance as the performance of injection unit peripheral devices were strengthened.

JSW started with manufacturing injection molding machines precisely according to the original model designed mainly by Ankerwerk. However, to satisfy requests from the highly developing market,

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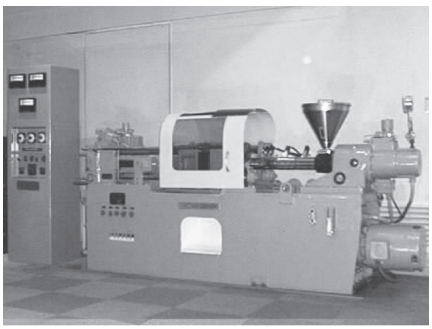


Photo. 1 V-series

JSW attempted to accumulate the technologies while changing the specifications, and developed its original models which were comparable to V19, V22, V28, and vertical machine VT14.

2.2 N-series

N140 (launched in 1969) was the first model that had departed from Ankerwerk¹s original model by bringing large-scale independent development ideas to JSW-Ankerwerk machines. The main improvements were low-noise design, hydraulic pressure block pipes, doubled adjustment speed of mold thickness, and better plasticizing capacity. For compact models, JSW proactively developed machines suitable for precise molding using engineering plastics which was expanding in the molding market at that time.

These machines gained a good reputation in the market because of their excellent performance, and the annual shipment exceeded 500 units in 1970.

2.3 NA-series

In April 1971, JSW terminated the technical alliances with Ankerwerk after 10-year commitment and decided to develop products independently. Due to this, the engineering department reexamined the existing models based on the accumulated technologies, while considering full-scale cost reduction by VE and IE methods aiming at stronger competitiveness in costs. They valued high-speed and easy-maintenance in performance, and in costs, realized innovations such as reduction of the work and assembly processes and achieved cost reduction by more than 20 % in each models. NA-series was developed in this way and its annual shipment reached 900 units in 1973, resulting in that our machines gained the second largest share in the market.

2.4 Large-size Injection Molding Machine (Initial Model)

JSW-Krauss injection molding machine had models with clamping force of 550 to 3000 t, and JSW started sales of V110-700 in 1963 with no major problems. This model was modified to offer clamping force of 800 t and was modified repeatedly as required while undergoing minor changes. The model name was revised to V110-800, V110B-800, and V110C-800 at each modification. Other models such as V78, V165, and V195 were modified in the same way. Also, other JSW-Krauss machines such as N550, N650, and N3000 were manufactured.

However, JSW-Krauss machines caused many maintenance problems such as oil leak, also their mold performance became significantly older as time went and their reputation declined. Therefore, after the recontract of technical alliances in 1973, JSW made an effort to develop new models by its own technology. Then, it manufactured N550A and 5N800C in 1974, and N1250C in 1975, resulting in complete departure from Krauss's technology. The clamping system of N550A was developed based on the design theory of compact- and medium-size machines. It was cost-effective and adopted double-toggle method that offered high opening/closing speed. N800C was developed especially aiming to compete the same type machines of other manufacturers. It featured improved performance specifications, prevention from hydraulic pressure shock which is the actual cause of oil leak, and also low-noise. Although the clamping mechanism adopted special direct pressure method, mold feeding, mold thickness adjustment, and locking machanism were all refurbished. Subsequently, N1250C was completed based on the same design of N800C.

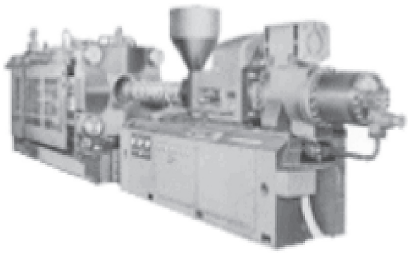


Photo. 2 Large-size Injection Molding Machine

2.5 N-BII Series

In order to satisfy the demand for precise molding for machine parts and electric parts, JSW developed with its own technology and launched new compact- and medium-size injection molding machine, N-BII series in 1975. This series was aimed at improved control accuracy and high-cycle, featuring hydraulic motor for screw driving, and control systems N-TACS and N-PACS equipped as

option. They were sold as long as eight years until 1982 as long seller machines and consolidated our strong position in this industry.

On the other hand, JSW launched large-size injection molding machine N-CII series in 1976. This series had a special direct-press configuration equipped with individual hydraulic cylinders which fed moldings and raised the pressure in the clamping unit, and locking cylinders which locked the mechanism before raising the pressure. These were equipped for easy manufacture of deep containers such as container and washing machine tub, which were major molded products at that time.

Photo. 3 N-BII Series

2.6 J-S Series

For compact- and medium-size injection molding machine, in 1980, the latter part of the sales period for N-BII series, JSW developed and launched J-S series which was fully remodeled from N-BII series. The model of this series featured the world's first microcomputer equipped in the controller which enabled to set and change the molding condition easily. Also, it drew attention in the industry with its multi-step injection control which vastly improved the machine control accuracy. For hydraulic technology, JSW developed its first controller μPACS-2000 to enable to set the flow amount of operation oil remotely and eliminate the difference of molding conditions between each machine determined by operators and improved the stability in molding process. Furthermore, we adopted the mixing screw used for extrusion molding in injection molding machines attempting to improve the quality of molded products. Since 1982, the models were categorized into three grades (J-SA, SB, and SC) depending on the accuracy level of molded product to satisfy more specific needs from customers. Also, this J-S series models were adopted for molding of audiocassettes and VHS cassettes, and contributed to expand sales.

On the other hand, for large-size injection molding machine, N-CII series (launched in 1976) was being considered to require remodeling to manufacture plastic auto parts which were becoming more common at that time. Its clamping unit had a special direct pressure configuration, and took longer time in molding cycle and consumed more electricity compared to machines of other manufacturers. To solve these problems, opening/closing stroke large enough to mold deep containers was realized by shortening the machine total length, and developed J-S series, large-size machine with clamping unit which had outer winding 5-point-toggle configuration. Also, responding to requests for energy-saving machines after the second oil shock, JSW developed an automatic selection system of hydraulic pump, which realized the lowest power consumption in large-size machine at that time.

For vertical injection molding machine, to enable precise molding of engineering plastic which was gradually becoming more common, JSW developed and launched JT series in 1982. This series featured improvements such as a microcomputer mounted in a controller, high-speed turntable, and highly accurate stop position.

2.7 J-SII Series

For compact- and medium-size injection molding machine, JSW launched J-SII series with controller μPACS-3000 which adopted 8-bit microcomputer in 1985. This controller offered easier operation, and higher visibility and reproducibility in conditions setting as collective concentrate display panel of molding conditions. Additionally, SSIIA-series was launched as upper model, and by equipping hydraulic accumulator, it was widely adopted for manufacturing thin-wall molding products such as video cassette case and floppy disk shell whose production amount increased rapidly. Also, on the technology aspect of screw and cylinder, 60S and 80C were developed by improving the performance of N alloy 50 and 60 which had a good reputation as corrosion- and wear-resistant cylinder. Their durability was effective to mold special resin material such as engineering plastic which contains glass fiber, and ceramic material.

On the other hand, for large-size injection molding machine, JSW launched J-SII series in 1983, which included controller μPACS-3000 and whose total length was largely shortened. This series gained a good reputation as energy-saving and high-cycle model suitable for manufacturing deep and large-size containers such as washing machine tub and beer container. Additionally in 1985, JSW developed J-SSII series which offered more rigid stationary platen, movable platen, and housing to

manufacture molded products which grew in size, mainly auto parts such as automobile bumper and instrument panel. This series was manufactured for five years until 1988 having the largest sales volume (30 % share) as injection molding machine and established a secure position in the industry. Also, it is notable that JSW manufactured a machine which offered clamping force of 6000 t as a model of this series and delivered to a large-size merchandise molding manufacturer.

For vertical injection molding machine, the specifications of old JT-series machines were reexamined, and JT-II series with controller EPACS-300T exclusively for vertical injection molding machine, was launched in 1985. This series achieved some positive technology result and established a track record as a machine exclusively for semiconductor sealing which was advancing technology at that time.

Photo. 4 J-SII Series

2.8 J-E Series

For compact- and medium-size injection molding machine, J-SII series was fully remodeled to J-E series and launched in 1988. This series adopted inner winding 5-point-toggle mechanism which shortened the total machine length based on the technologies accumulated by developing J-SII series, and also adopted non-intermittent grease supply bush which removed the burden of lubrication the toggle bush. Controller μPACS-5000 of this series was advanced model which was equipped with CRT display, and sufficiently utilized the computer control functions such condition setting, injection waveform monitoring, and molding condi-tion memorizing performed fully remotely on the screen. Also, this series incorporated double flight screws which enhanced uniform kneading performance to enable precise and high-speed developing at an accelerating rate. This series sub stantially contribut-ed to improvement of comprehensive molding accuracy and productivity.

On the other hand, for large-size injection molding machine, J-E series which was renewed mainly on its electric equipment such as mounting new controller μPACS-5000, was launched in 1989. This series was usable for gas injection which was drawing attention as a new molding method, and was sold until 1993.

For vertical injection molding machine, in 1988, three years later than horizontal injection molding machine, JT-IIK series equipped with controller μPACS-300T was launched. This series was sold as long as seven years until it was remodeled in 1994. It was mainly delivered to automobile related companies in Chukyo district and became our long seller vertical injection molding machine by its stable molding performance.

2.9 J-EII Series

For compact- and medium-size injection molding machine, distributed controller SYSCOM1000 which could build a control circuit effectively, was newly developed. This controller was developed to correspond to the model structure expanding to new machine types such as large-size, electrical, plastic magnet, and vertical. J-EII series with this controller mounted was launched in 1994. Aimed increasing international concern over the environment issues, compact-machine of this series adopted variable hydraulic pump to reduce more power consumption and responded to request from the industry for energy-saving. Also, N-alloy 2000F corrosion- and wear-resistant cylinder was developed to improve the durability, and automated the grease supply to toggle bush to improve for easier maintenance. These features equipped as standard specification reduced the molding manu-facturers' burden for maintenance. Additionally, ahead of other manufacturers, JSW incorporated an expert system in a controller to supplement molding condition setting, as a perfect solution for reduction of expert molding engineer. Furthermore, in 1995, J-EII-SP model was launched as the top grade model as high-speed machine exclusively for thin-wall products such as food container, CD box, and MD shell.

On the other hand, for large-size injection molding machine, J-EII series with distributed high-performance controller SYSCOM1000 mounted was launched in 1994, accompanied to the development of the controller. Because of its high quality, this series became the standard model of large-size toggle injection molding machine in Japan.

For vertical injection molding machine, in 1994, JT-IIK series was remodeled to JT-EII series in which distributed high-performance controller SYSCOM1000 was mounted same as in horizontal injection molding machine. This series features

smaller installation dimension, and faster operation and higher accuracy of turntable realized by improving hydraulic pressure and mechanism compared to the previous series. Also, wear-resistant cylinders and screws were equipped as standard specification in order to process engineering plastic with glass fiber contained which was expanding in use.

2.10 J-EII, ELIII to Latest AD Series

In 1996, the last model of J-EII series, which was the smallest 18 t and 30 t, was developed for manufacture of precision parts such as connector parts. After that, because the worldwide reduction of CO_2 gas emission was passed as a resolution in Kyoto conference, and ISO14001 environmental management standards were established, the demands were vastly increased especially for energy-saving electric injection molding machines. The development of next hydraulic injection molding machine was suspended, and compact machine (55 to 110 t) of electric series J-ELII was developed intensively. Then hydraulic machine gradually disappeared from microcompact machine industry in three to four years.

Fig. 1 shows the configuration of hydraulic injection molding machine, and **Fig. 2** shows the configuration of electric injection molding machine.

An electric injection molding machine featured significant reduction in power consumption realized by mounting servo motors for each of the following operations: injection, plasticizing, mold opening/closing, clamping, and ejecting. Servo motors enabled the effective power transmission and to operate each device only when necessary.

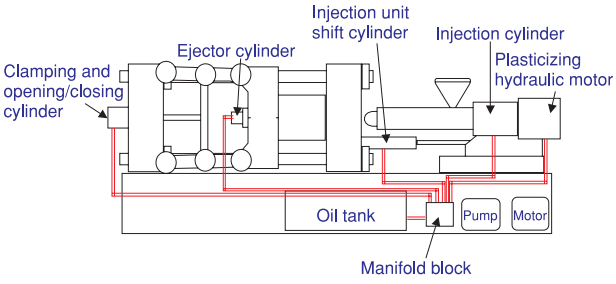


Fig. 1 Configuration of Hydraulic Injection Molding Machine

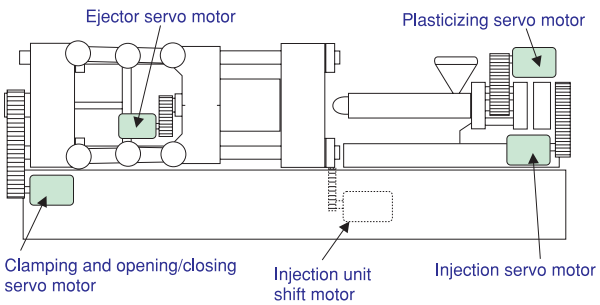


Fig. 2 Configuration of Electric Injection Molding Machine

Until 1999, JSW attempted to expand J-EII series into microcompact- and medium-size classes (35, 180 to 450 t). J-ELIII series was launched in 2000, and after that, electric injection molding machine expanded into the large-size machine industry, mainly in auto industry. JSW adopted the mechanism which converts rotating motion into linear motion by using ball screws driven by a servo motor, and there were various technological problems in development of larger machines. One of those problems, multi-axis synchronous control was successfully developed and JSW launched 650 t machine in 2000, 850 t and 550 t, then 1300 t and 1000 t in 2001, 1800 t in 2004, and the world's largest 2500 t electric machine in 2007, while expanding its share to be recognized as "JSW" of large-size electric injection machine. In 2004, the fourth series of electric injection molding machine, J-AD series was launched in the market to restore the share in the small precise molding industry. This series was safety-conscious machine which complied with the safety regulations instituted by Japan Society of Industrial Machinery Manufacturers. Also, 140 t class was newly added to the lineup aiming at molding of mobile phone shells. The series of compact-size machine was completed in 2005, and the series of medium-size machine was completed in March 2007.

For vertical machine, the old hydraulic machine used to adopt direct pressure clamping unit. In 1998, bell crank toggle was adopted and the series of vertical electric injection molding machine was launched. After that, model expansion was attempted for JT-ELIII, and JT-AD series which was developed on the concept of low-flame-height and compact-size was launched in 2006, realizing the configuration which was easily integrated to the manufacturing line in automobile, office automation equipment, and electronic industries. On quantity of ordered unit, the ratio of electric injection molding machine in all JSW's injection molding machines exceeded 80 % in 2006 and is approaching 90 %.

For controller (control system), SYSCOM1000 was mounted in J-EII and J-ELII series. However, more progress was required such as larger memory capacity, faster process speed and communication speed. Then JSW newly started the development of 32-bit high-speed controller, and completed SYSCOM 2000 and mounted in J-ELIII series which was

launched in 2000. This controller gained a good reputation from the customers because of its operation panel style (three-level inclined surface figure), usability, and performance, and is still adopted in some models continuously. JSW also developed a controller called SYSCOM3000 to be mounted in J-AD series which was launched in 2004. This controller was developed with the highest emphasis on the stability of precise molding performance especially in high-speed injection molding industry, and its control cycle was 62.5 μ sec which was the fastest in the world. Additionally, a novel idea to mount a 15-inch liquid crystal panel vertically was realized resulting in better usability. Also, improvement of network functions were attempted following the spread of personal computer (PC) and internet. J-AD series in which these were mounted received the jury's special award of the Machinery Industrial Design Award in 2005. In 2006, following the global expansion of the product environmental regulation, JSW developed boards which did not contain chemicals restricted by EU RoHS and mounted them in machines.

Photo. 5 J-AD Series

Photo. 6 JT-AD Series

2.11 Recent Special Injection Molding Machines

2.11.1 Disc Injection Molding Machine

For disc injection molding machine, the world's first fully-electric machine J35ELII-DK was launched. Then the clamping force was increased to 40 t aiming to improve the molding quality of disc, and J40ELIII-DK (Mediamaster) was launched. In 2002 and 2003, this series was sold in large quantity, taking advantage of DVD boom.

Photo. 7 Disc Injection Molding Machine

However, demand for the machines of this series have been stagnant since 2004, because sufficient quantity of machine was already delivered and the market demand for disc stopped increasing. For this period, JSW started the development of next-generation disc injection molding machine which can manufacture HD-DVD and BLU-LAY. In May 2007, J45AD-DK was launched ready to regain the position in the market.

2.11.2 J-AD-UPS Injection Molding Machine

To fulfill the demands for thin-wall molding, UPS model adopted the hydraulic full-close control with ACC (accumulator) in the injection unit which was developed based on the clamping unit of electric injection molding machine. It is a hybrid machine which offers the highest speed (1000 mm/sec) and high response (10 msec). J55ELIII-UPS was launched in 1999 and its lineup of up to 180 t was completed in 2001. This model was expanded to 220 t class in 2003, to 350 t in 2005, and 450 t in AD-series in 2007, being adopted for manufacturing media card, battery case of mobile phone, speaker corn, thin-wall light guide panel, food container, and others. The demand for this model is expected to be expanded for its performance which will remain in Japan as high quality molding technology.

Photo. 8 Hybrid Injection Molding Machine (J-AD-UPS Model)

2.11.3 Plastic Power Direct Injection Molding Machine

In 2000, a new machine was developed by combining J350ELII and TEX30a for direct molding of plastic powder. This machine is adopted for molded products related to bonded magnets.

2.11.4 J-AD(ELIII)-2M Injection Molding Machine

Due to expansion of DSI and 2M-DSI molding, 2M model (injection machine with two injection units) was modified from hydraulic to electric-powered. It was expanded to 110 t, 220 t, 450 t, and 650 t, and is adopted for sandwich molding which is being approved again recently for effective reuse of waste materials.

2.11.5 Injection Molding Machine with Ventilation Equipment

Injection molding machines with ventilation equipment are being revaluated. Because resin types which produce gases are increasing due to its diversification, and ventilation equipment can solve the problems such as gas bubbles produced from remaining water in transparent resin. These machines were introduced by demonstration of molding light guide panels in IPF2005, and molding connectors in Platex Osaka, 2007, resulting in attracting many users' interests. And modification and expansion to vertical injection molding machines are also being attempted on this type of machine recently.

2.11.6 Lens Injection Molding Machine

Plastic has become more common than glass for lenses which are used for reading and writing CD and DVD, and for mobile phones and digital cameras. Due to this, molded products are required to be more accurate. JSW used the highest designing and processing technologies such as highly-accurate pressure holding control, highly-accurate clamping unit, and lens screws to develop the lens injection molding machine as brand-building model and launched them to the world in 2005.

3. Molding Process Technology

JSW have been working on development of various molding processes such as DSI, MuCell molding, and long fiber resin molding. Some of them will be introduced in this section.

3.1 DSI Technology

DSI technology is injection molding technology to produce hollow objects precisely by sliding a part of the mold halves as shown in **Fig. 3**. Because a part of the mold halves slides during the process, this technology is called "Die Slide Injection," and developed and utilized for manufacturing various hollow molded products. Compared to other hollow molding methods such as blow molding, DSI technology enables better dimension accuracy and lighter weight of products. And by assembling multiple molded parts to one product inside the mold halves, resin parts can be modularized and more energy can be saved during molding process. These high added values are attracting attentions to this method.

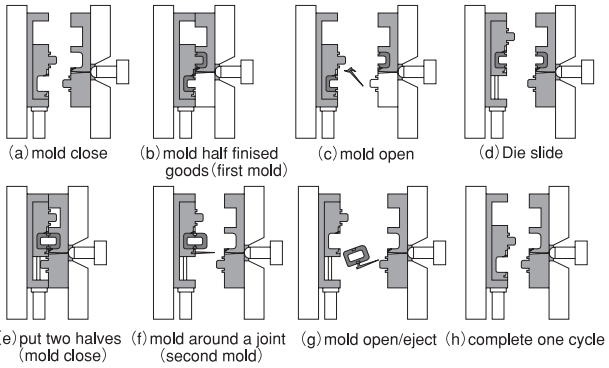


Fig. 3 DSI Process

JSW holds the basic patent of DSI technology and have a licensing agreement with over 100 companies. The type of molded products applicable for this technology exceeds far 400. **Photo. 9** shows a sea-fishing buoy, which was firstly applied with DSI technology. After this, DSI technology was applied to an intake manifold (**Photo. 10**), one of the main auto engine parts, and has been widely adopted by auto manufacturers since 1996. JSW continues

Photo. 9 Sea-fishing Buoy

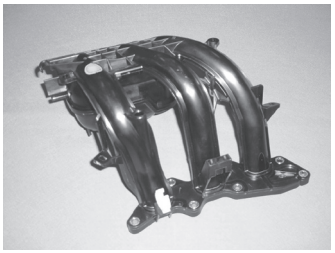


Photo. 10 Intake Manifold

working on the development of application technologies such as internal vapor deposition and internal coating in order to satisfy various requirements from its customers.

3.2 MuCell Molding Technology

JSW introduced MuCell molding technology (ultra-fine foam molding technology) which uses super-critical fluid such as CO_2 and N_2, earlier than other manufacturer in 1999, and manufactured and sold more than 20 units of MuCell injection molding machine. MuCell molding has following features: (1) applicable for lightweight manufacture, (2) short molding cycle, (3) no chemical foaming agent required, (4) low-temperature molding, (5) short cycle time, (6) low injection pressure, (7) low clamping force, (8) less shrinkage (9) improved dimension stability, (10) high foaming pressure. Ultrafine foam (**Photo. 11**) inside of molded products improves transcription of mold halves. Taking advantage of especially this feature, recently this technology is spreading among customers who emphasize the dimension accuracy in ultraprecise molding.

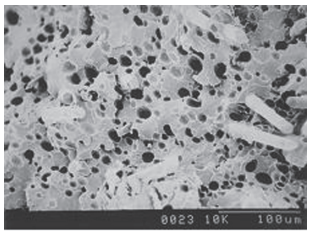


Photo. 11 MuCell Molded Product/Ultrafine Foam

Photo. 12 shows connector parts (PBT + GF15 %) used in ECU (engine control unit) of automobile. It shows that MuCell reduces shrinkage by 75 % or more, compared to the regular injection molding machine. Also, for a helical gear shown in **Photo. 13**, regular injection molding could clear only up to JIS/4 class. However, MuCell molding vastly improved the accuracy resulting in clearing JIS/1 class. The effect can be seen from the cylindricity measurement result of helical gear shown in **Fig. 4**. Other than that, it has been sought to improve MuCell for better product appearance using the counter pressure method and the heat and cool method, and apply MuCell for producing exterior parts.

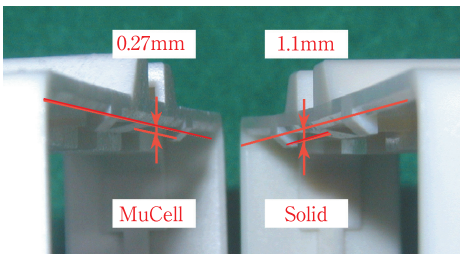
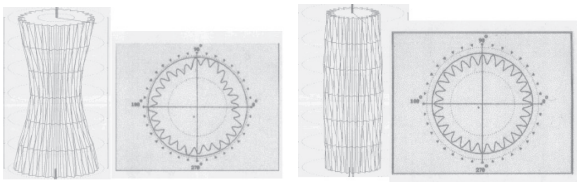


Photo. 12 Comparison of Shrinkage

Photo. 13 Helical Gear



(a) Regular Molding (b) MuCell Molding

Fig. 4 Comparison of Cylindricity

3.3 Long-Fiber Resin Molding Technology

Our long-fiber resin molding machine, after a long-term effort to develop screw cylinders, was adopted for manufacture of front-end modules of automobile (**Photo. 14**) and door modules. Then it was widely adopted for manufacture of rear door modules and others. For long-fiber resin molding related to automobiles, PP and PA-base long-fiber pellets (**Fig. 5**) which contain long glass fibers (8 to 12 mm) are used. And, glass fibers of 2 to 4 mm-long are left inside molded products, to strengthen the propaties of molded products. JSW developed the exclusive injection unit which causes the minimum damage to fibers, resulting in gaining a good reputation from the customers. **Fig. 6** shows the GF average fiber length at each position after pouring in 12 mm long-fiber pellets from the hopper. It shows that fibers are only 2 mm-long in the pellet

Photo. 14 Front-end Module

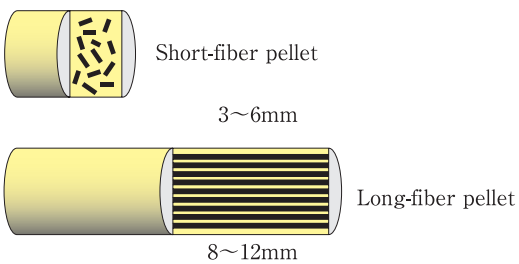


Fig. 5 Difference between Short- and Long-fiber Pellets

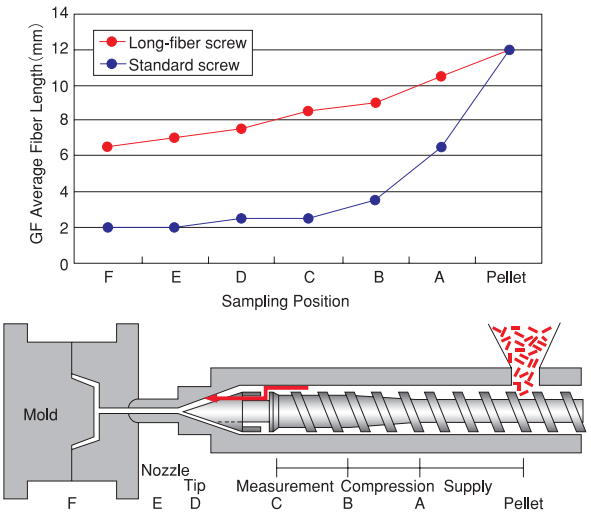
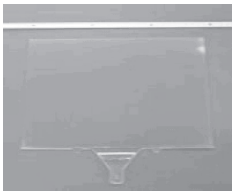


Fig. 6 Effect of Long-fiber Screw

processed with a standard screw, and they are 6 mm or longer with a long-fiber screw. Long-fiber resin molded products are expected to be widely applied for auto parts, and we will work on to improve this technology and to have it widely approved as process method for producing substitute for metal parts.

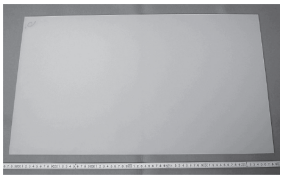
3.4 Light Guide Panel/Disffusing Panel Molding Technology

Liquid crystal displays used for laptop computers and TV set are getting thinner and larger year to year, and light guide panel (**Photo. 15**) and diffusing panel (**Photo. 16**), the key parts of LCD, are required to offer higher functions. JSW recognized customers' needs also in this industry earlier than others, then improved machine rigidity and accuracy, developed the screw cylinder exclusively for optical plastics, and adopted molding technology such as injection compression molding, resulting in obtaining a great trust in the market for its light guide panel and diffusing panel in the market. However, drastic technology innovation is expected in the display industry, such as adopting LED light source and raising the usage of organic EL, and we have to keep watching the latest technological trend properly and develop timely products and molding processes continuously.



Product : 14 inch x 0.6 mm
thin-wall light guide panel
(dot/prism)
Molding machine : J350EL Ⅲ-UPS-370H(K)
Resin : PMMA

Photo. 15 Light Guide Panel



Product : 32 inch x 2.0 mm
diffusing panel
Molding machine : J650EL Ⅲ
Resin : MS resin

Photo. 16 Diffusing Panel

3.5 Other Molding Technology

As one of the ultrafine molding technologies, JSW challenged to fablicate a plastic ferrule (**Photo. 17**), a main part of optical connector. A ferrule is ultra-pricise optical part which requires submicron accuracy. JSW devoted all mold building, molding, and measuring technologies of that time, and accomplished building the semi- and full-automatic production systems. However, because the economy declined in the US due to bursting of the IT bubble economy and the price of ceramic ferrule decreased, these systems did not receive the real demand as a result.

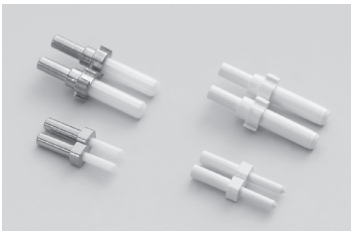


Photo. 17 Ferrule

4. Mold Supporting Technology

On the development related to the integrated injection molding supporting system, JSW have provided customers with the following systems: CAMOT-Integral, review molding conditions by accurate resin flow analysis; Super CAMOT, easy-to-follow instructions to solve the molding failure; i-CAMOT which is accessible anytime-anywhere on JSW's website to review molding conditions; and LINK 10 which enables to manage up to 10 injection molding machines. Additionally to those works, JSW have developed the screw plasticize fluctuation analysis and the plastic foaming analysis. And these tecnologies contribute to speed up development time of injection molding machines and molds.

Recently, for quantitative evaluation of molding stability, JSW provided the centralized system CAMOT NET100, which can collect shot data up to 100 units of injection molding machine. This system confirm the operation condition of molding machines, and collect, analyze shot data with one host computer over network. The measurement items on shot data include injection pressure, temperatures of each heating zone, and also other necessary items

can be added. Therefore, this system is useful for quality control in mass-production, as well as in reviewing molding conditions. Also, it has a remote control function, which displays the controller screen of injection molding machine on a PC screen. And it used for supervising the detailed operation condition remotely. With CAMOT-RMS (remote management system) function, the client PC can access the server computer of NET100 system via the Internet. Because of these functions, CAMOT NET100 is used as remote supporting system for injection molding machines located other molding plant to control the operation conditions and product quality, and identity the cause of the molding failure.

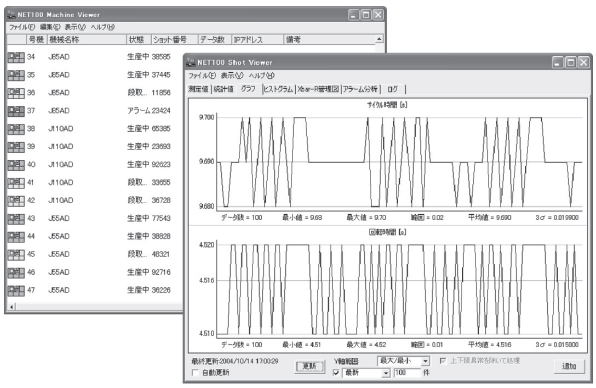


Fig. 7 Machine Operation Condition List and Shot Data Trend Graph on CAMOT NET100 system

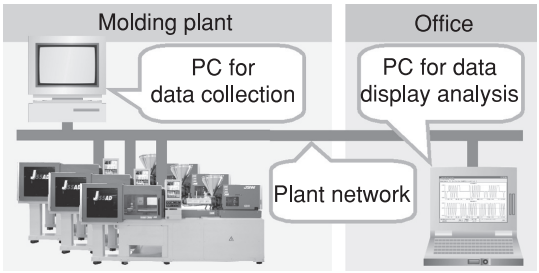


Fig. 8 Model case of CAMOT NET100 System

5. Screw Cylinder Development

As customers' requirements to molded product specifications became higher, resins were developed and improved rapidly. JSW placed emphasis on and have developed screw cylinders, the important technology to follow these change of resin. The main of development is roughly divided into technological developments of rigid metal materials and of screw design. Material Research Laboratory (now Muroran Research Laboratory) and Machinery Research Laboratory tied up to brush up N-alloy series in addition to wear- and corrosion-resistant bimetallic cylinder N2000F and also cooperated with the manufacture deptartment. to enable N2000F to be applied to large-diameter cylinders which can be used in machine with 2500 t of clamping force. Also for applicable screw materials, selections have increased to wear- and corrosion-resistant material LSP2, added elements inside resin, LSP-H, and LSP4.

For screw design, standard screws have developed to balance all of stability performance, plasticizing capacity, and color change performance at high level, while being improved continuously. At the same time, resin types increased and screw designs have been diversified exclusively for some types of resin such as LCP, PVC, and long-fiber resins.

Recently demand for vent screws have been increased especially in compact machine industry. This is because of problems such as molding defects caused by moisture and volatile matter generated from materials, and declined productivity caused by clogged air vent in mold halves. To solve these problems, small-diameter vent screws which are usable in high-pressure have been developed. **Photo. 18** shows various screws for compact- and medium-size machines.

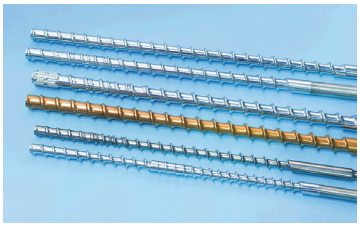


Photo. 18 Variety of Screws

Also, for screws of large-size machine, it must be especially mentioned that they perform high plasticizing capacity operation when powered by electricity. **Fig. 9** shows the comparison of plasticizing capacity between electric machine and hydraulic machine. It shows that these screws substantially contribute to reducing molding cycle of electric machine.

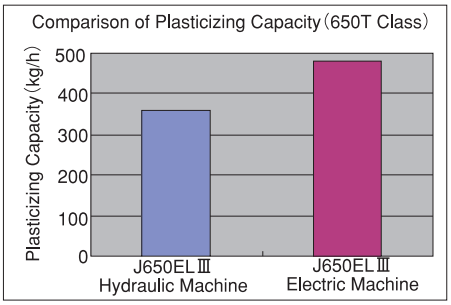


Fig. 9 Comparison of Plasticizing Capacity

Furthermore, Elemental Technology Group was established in 2005 attempting to research and

develop in this field. To progress dimension designing of cylinder and screw faster and more scientifically, JSW attempted to introduce simulation technology using CAE and others.

Fig. 10 shows the screw tip model and resin temperature distribution example, and **Fig. 11** shows the heat conduction analysis example in a cylinder hopper flange.

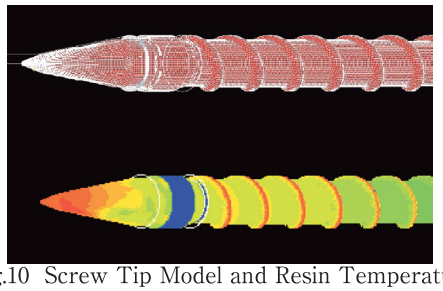


Fig.10 Screw Tip Model and Resin Temperature Distribution Output

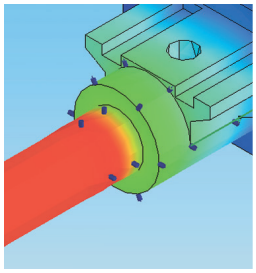


Fig. 11 Heat Conduction Analysis in Cylinder Hopper Flange

6. Latest Control Technology

For new control technology, JSW co-developed the optimum pressure holding prediction control unit (AD-PAC) with Machinery Laboratory and succeeded in commercializing it as one of the ultraprecise molding methods.

For electric injection molding machine, J-ELII and later series are equipped with the following control systems as standard specification for more stable molding; the injection compression control which is effective for preventing from warpage and strain, and the soft pack servo control which suppresses the injection peak pressure before the holding pressure.

Also, a high-performance pressure feedback control APC (Advanced Pressure Control) has been mounted to control injection, holding pressure, and back pressure. This control is to predict and estimate the resin fluctuation in an injection cylinder. JSW attempted to improve injection speed, quick pressure response, and tracing ability by suppressing unnecessary pressure, especially when moving to the next process, for example, from injection to holding pressure and when starting screw rotation. And it also attempted to improve molding process by reducing remaining strain on products.

For latest technology, JSW developed IWCS control which stabilize the screw rotation density just before starting injection. IWCS control stabilizes product weight and cushion values. It operates the screw rotation motor in normal and opposite rotation direction after screw rotation, in order to control the resin at constant density before starting injection.

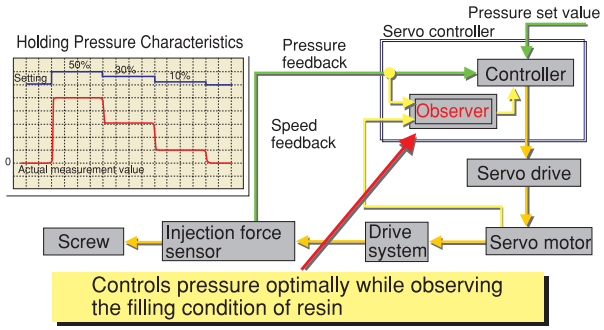


Fig. 12 APC Control Block Diagram

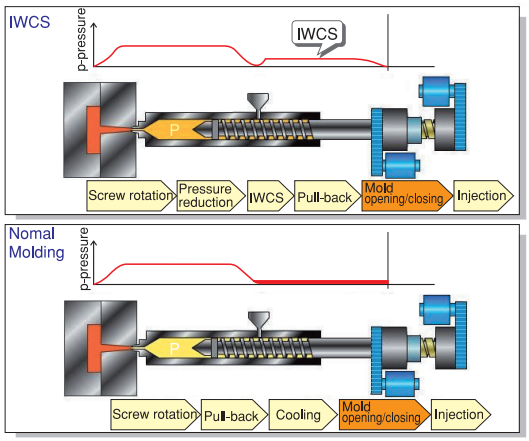


Fig. 13 Structure of IWSC Control

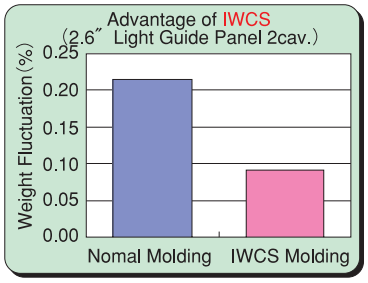


Fig. 14 Advantage Example of IWCS Control

On the other hand, to ensure that these controls properly operate, a high-speed servo control circuit was mounted on J-AD series, which realized high-speed control of 62.5 μsec control cycle. This modification substantially reduced pressure fluctuations at the injection pressure to holding pressure and others and improved the molding quality, and contributed to development of control systems for various stable precise molding one after another.

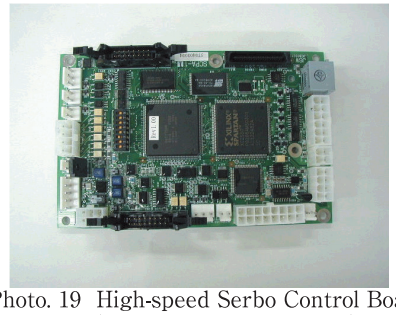


Photo. 19 High-speed Serbo Control Board
(62.5 μsec Control Cycle)

7. Designing Technology

During the technological development of mold platens, high rigidity and strength had been especially emphasized. Aiming to apply the FEM analysis, 3D design was adopted at parts level from the early period, and lightweight and high-rigid products have been provided for years. Also for unit design, by using both 2D-CAD (two dimension) and 3D-CAD (three dimension) from the planning period, the planning time was shortened and the drawing quality was improved. At the same time, three-dimensional data have been utilized for various purposes such as service parts drawings.

Also, JSW applied quality analysis methods such as FMEA and FTA to realize better quality, and utilized them for preliminary consideration as well as for problem solution. And we also adopted tolerance analysis and worked on developing products which satisfy our customers, while widely considering customers' requirements for higher quality from the aspect of process ability.

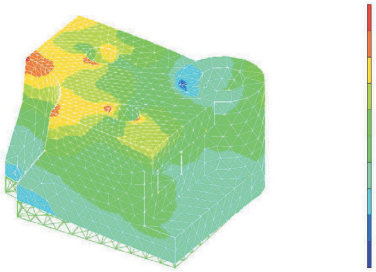


Fig. 15 Example of FEM Analysis

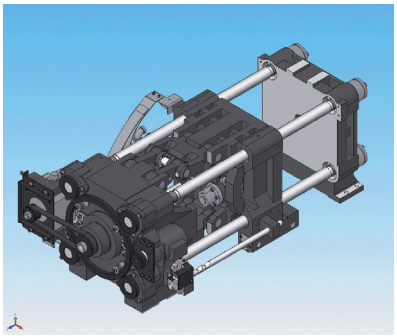


Fig. 16 Clamping Unit 3D Model

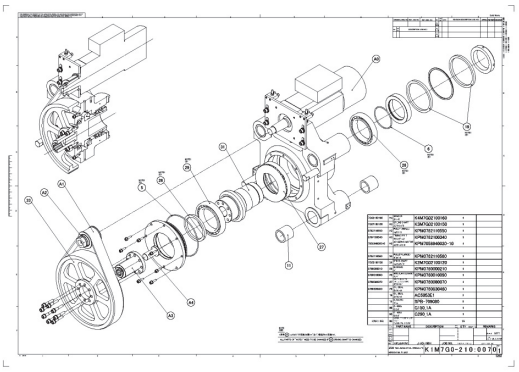


Fig. 17 3D Service Parts Drawing

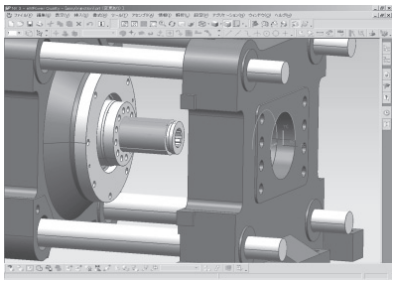


Fig. 18 3D Model for Tolerance Analysis
(Analysis Content: Difference
in Injection Unit Assembly)

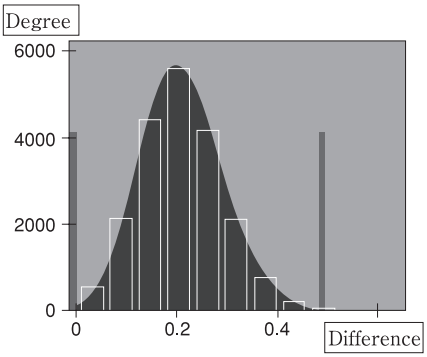


Fig. 19 Tolerance Analysis Result 1
(Frequency Distribution Table)

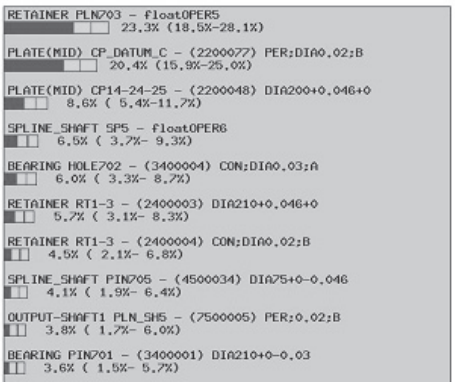


Fig. 20 Tolerance Analysis Result 2
(Contributing Ratio List)

8. Market Trend

It is expected that automobile and IT related industries would be a leading force in the market, and regional market sizes would be fluctuating as the globalization of those industries progresses. The market is predicted to expand from current Japan, China, Southeast Asia, and East Asia, while including promising countries such as India and Russia. As applicable fields of plastic materials are expanded, customers' needs will be diversified and advanced. Therefore, it will be difficult to satisfy all specifications required from the customers by attaching optional units to the current base machine. Especially for machines with high added value which require highly precise specifications, it is predicted that more and more dedicated machines will be produced.

9. Technological Development Direction

Since 2000, injection molding machines manufactured in Taiwan, Korea, and China have been growing sales because of their low prices. Their technologies have been catching up those in Europe and Japan, and they are threatening us considerably, especially in China market. In order to sustain the existence value of Japanese injection molding machines in this situation, we have to catch the trend of market demand, and realize the customers' requirements for specifications earlier than other manufacturers.

To practice this, it is crucial for us to accumulate basic technology related to molten parts of resin. Also, we have to continue working on for technological development; proactively modify basic platforms to dedicated machines, without being satisfied with the current technologies such as producing ultraprecise and ultra thin-wall molded parts, and super high-cycle molding. To add further values to molded products, new methods will be important factors such as complex molding by using various materials and colors effectively, and technology-combined molding which uses additionally processed plastic.

Today environmental problems such as ecological destruction and depletion of the natural resources have been drawing international attention, and the world trend is to use eco-friendly products such as plastic products combined with woods and papers and plant-derived biodegradable plastic products. JSW is currently developing injection molding machine which include screw cylinders suitable for manufacture of these products. It is only partial yet, however, will be full-scale development in the near future.

Another issue is that the number of highly-skilled molding engineer is predicted to decrease because manufacturing bases are being shifted from inside Japan to low-labor-cost countries. To solve this issue, we have to build a system which judges a lot of information by itself as much as possible and control the conditions automatically. JSW will continue the development of these technologies, and advance the injection molding technology all over the world by Japanese technology.