Turbo Technology for Injection and Ejection

Valve Technology. Working closely with a valve specialist, an injection molding machine manufacturer has optimized the machine axes of its high-speed series and translated the specifications into a piston geometry. This systematic individualization of the axis and control valves further accelerated the – already high – dynamics for injection and ejection.

Fig. 1. The hybrid-drive high-speed El-Exis SP injection molding machine – in this case with 2,000 kN clamping force – has further improved dynamics compared to the preceding series
(photos: Sumitomo (SHI) Demag)

HANS-JÜRGEN POPP
THORSTEN KÖHLER

With the presentation of the El-Exis series in 1998, Demag Ergotech introduced an injection molding machine with decentralized electric drives for the rotational movements and a powerful hydraulic accumulator for the linear movements. In its development into the current El-Exis SP series ("Speed Performance", **Fig. 1**), the company, which changed its name to Sumitomo (SHI) Demag Plastics Machinery GmbH after its takeover (2008) by the Japanese SHI Group, conducted a finely detailed simulation of the injection hydraulics and ejector unit and defined the specification for the valves.

The high-speed machine has become widely established since its market introduction at K 2010, and has gained market shares in all regions for the production of closures and thin-walled plastics packaging. The El-Exis SP is currently available in the clamping force range from 1,500 to 7,500 kN. Across all sizes, it features type D68x servo-proportional valves on the two axes mentioned above **(Fig. 2)**. According to Moog GmbH, Böblingen, Germany, this is the best and fastest valve in the manufacturer's portfolio for use on plastics injection molding machine. It is used in different dimensions on all axes of the El-Exis SP. To implement the high requirements of high-speed injection molding in machine technology, the engineers at Sumitomo (SHI) Demag at the Schwaig site in Germany have optimized this valve in close cooperation with Moog through an individually modified piston geometry. With the El-Exis SP, a high degree of dynamics and precision was obtained that would not have been possible with the aforementioned standard valves.

Computer Simulation of the Control Loop

In the optimization, the injection valve was adapted to the injection axis and the ejector valve to the ejector axis. For this purpose, the experts of the two partners represented the drive axes with a complete simulation of the respective control loop with axis, valve, oil column, weights and kinematics on the computer. On the injection axis, for example, the control loop includes

- the masses of all individual components,
- the polymer in the screw flights and in front of the screw,
- the oil viscosity,
- the pressure losses,
- the valve characteristics and
- the controller structure.

Translated from Kunststoffe 9/2012, pp. 36–39
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE111124

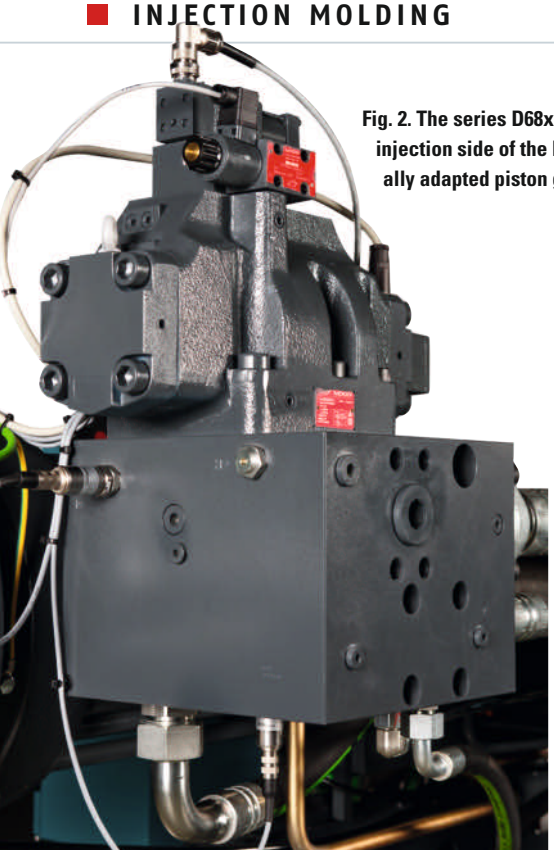

Fig. 2. The series D68x servo-proportional valve at the injection side of the El-Exis SP includes an individually adapted piston geometry

Not only the acceleration, but also the braking movement, poses a challenge for the hydraulics, since active braking of the injection axis permits ultra-short changeover times and extreme positioning accuracy.

For physical modeling, the program package SimulationX (supplier: ITI Gesellschaft für ingenieurtechnische Informationsverarbeitung mbH, Dresden, Germany), with its extensive parts library, was used. The part changes, in particular the optimization of the characteristic curve of the injection valve, and the drafting of the controller, were performed with Matlab/Simulink (supplier: The MathWorks GmbH, Ismaning, Germany), a standard tool for design, analysis and layout of complex systems and closed-loop controllers, which is widely used in university research and industrial development.

The simulation of the control loop in the computer yields, for example, the elasticities and damping. Once the control loop has been defined, the valve is integrated and the closed-loop control is simulated. The optimum piston geometry resulting from the simulation was individually adapted to the El-Exis SP. The control piston geometry influences the flow resistances of the hydraulic axis, during both injection and braking. The respective control piston was modified for the corresponding axis such that it meets all the requirements of the specification. Subsequent tests in the trial field in Schwaig have shown that the computer simulation corresponds perfectly to the results obtained in practice on the real machine **(Fig. 3)**: The controllers operate highly dynamically and precisely in all pressure ranges.

Through a combination of hydraulics with the possibilities of the latest NC5 open-loop control generation, the developers derived the best controller design for both axes. Thus, the software controller was created, which can represent all the curves entered for the valve. Beyond injection and ejection, the new closed-loop controller ensures that the El-Exis SP (Speed Performance) also accelerates the movement of the clamping unit in comparison to its sister series El-Exis S **(Fig. 4)**.

Greater Precision during Injection, Changeover and Holding Pressure

The more dynamically and precisely an injection molding machine operates, the more precisely the part can be produced. High dynamics expand the possibilities for pressure profile control throughout the cycle: The pressure stages are executed rapidly and accurately – both during injection and during active braking, that is to say during changeover to holding pressure. The increased possibilities with the new valve **(Fig. 5)** reduce the fluctuations from cycle to cycle and improve the repeatability of the process.

Injection, which features path-dependent closed-loop control with the aid of the screw position, is followed, from the changeover point, by the pressure-dependent control of the holding pressure, which crucially determines many quality criteria. The high precision and dynamics of the valve permit instant

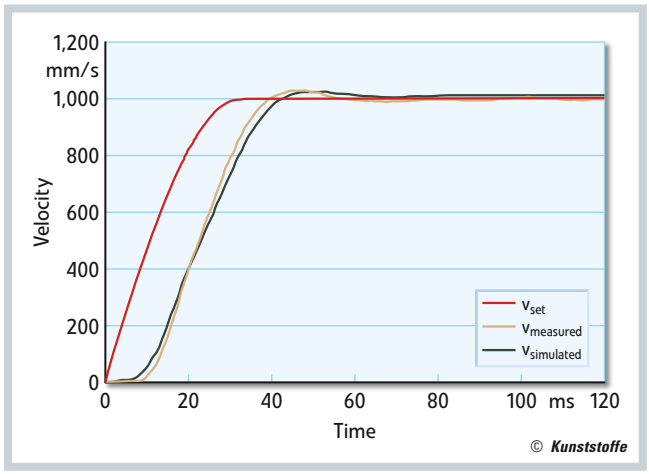

Fig. 3. Start of injection with the required high dynamics: a comparison of the measurement on the machine with the simulation results confirms the quality of the simulation model

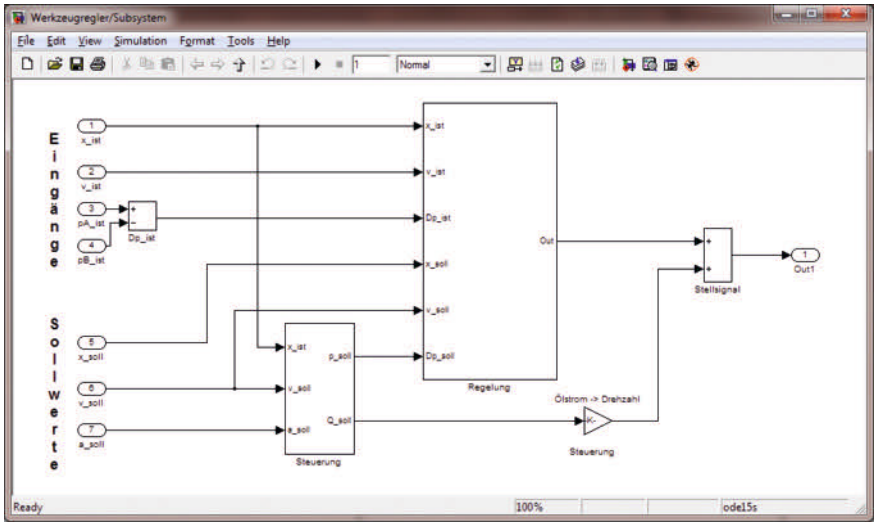

Fig. 4. Model of the clamping control in Matlab/Simulink with the central blocks of open-loop and closed-loop control

changeover and a pressure reduction within 35 ms and less for a pressure difference of 800 bar.

Large Process Window during Ejection

During the production of fast-cycle parts, as much freedom as possible is necessary in how the part is ejected so that the machine operator can represent the best demolding situation for parts that drop out by gravity or are removed from the mold. The simulation of the ejector situation and adaptation of the ejector valve on the El-Exis SP combine greater positioning accuracy of the ejector with increased ejector acceleration. This allows the operator to individually design and precisely adjust the ejection process with flexible velocity control with rapid acceleration and braking processes within a large process window.

Contact

Moog GmbH
D-71034 Böblingen
Germany
TEL +49 7031 622-0
→ **www.moog.de**

Sumitomo (SHI) Demag
Plastics Machinery GmbH
D-90571 Schwaig
Germany
TEL +49 911 5061-0
→ **www.sumitomo-shi-demag.eu**

The ejector operates highly dynamically **(Fig. 6)** and, for example in the production of screw caps, ensures a defined demolding movement and precise dropping of the parts in the mold opening region. If the parts drop vertically into the shaft like a curtain, high ejector velocity is required, since, in a very shot stroke, the ejector must reach the same velocity with which the machine approaches the mold. Thus, it demolds, for example screw caps, virtually in a stationary position relative to the machine.

Active Acceleration and Higher Production Efficiency

In the past, the axes of the El-Exis were equipped with a controller parameter set that permits the machine operator only to adapt the paths and velocities. Other changes could only be made by a service engineer on the spot at the customer's premises. Thanks to a new function, the customer can now adapt his machine himself to individual requirements: "activeAdjust" offers the user the possibility of accelerating each individual machine movement tailored to the process and part, and thereby to shorten the cycle time.

The same applies to ejector movement and changeover from injection pressure to holding pressure. These movements can be accelerated or slowed with slide controls in the open-loop control unit. Moreover, individual controllers allow the gradient of the velocity ramps to be influenced. This ramp adjustment permits the production process to be precisely adjusted, specific to a particular application and mold, by the purposeful coordination of injection, changeover, ejector dynamics and clamping unit. In total, this results in reduced dry-running times for shorter cycles and greater productivity

On a high-performance machine, the mechanical, hydraulic and electronics systems and closed-loop control technology must interact in a precisely coordinated manner. In this case, →

therefore – unlike in the classical technology – mechatronic technology was used. The complicated simulation and optimization of the hydraulic axes on the high-end El-Exis SP machine was worthwhile: all in all, with its greater injection and braking dynamics, its shorter cycle times and accelerated precision ejector movement, it increases the production efficiency for manufacturers of plastics packaging materials.

Positive Resonance

Some voices from the market demonstrate the acceptance of the accelerated series. For example, Schöttli AG of Diessenhofen, Switzerland, frequently presents high-performance molds on an El-Exis SP at trade shows. For example, at NPE 2012 in Orlando, FL, USA: a 96-cavity mold for lightweight "X-light" screw caps with a weight of only 1.0 g runs on an El-Exis SP 450-3000 with less than 2.0 s cycle time. The production cell can thus produce over a billion screw caps per year in normal operation. Johannes Strassner, managing director for sales and marketing of the mold maker says: "We were impressed by the precision and dynamics of the El-Exis SP during injection, and its flexibility for representing a wide variety of demolding situations."

One of the biggest plastics processors in Germany, Pöppelmann GmbH & Co. KG of Lohne, manufactures food packaging (among other applications) on some new machines of this series. According to Werner Schick, production manager: "The advantages of the El-Exis SP in these applications are its high dynamics and low energy consumption together with the shortest possible cycle time." Roger Boog, head of production engineering with SwissPrimePack AG, Niederuzwil, Switzerland, also values the injection dynamics of the El-Exis SP, which helps to fill the thin-walled parts of enhanced industrial packaging reliably.

Reiner Drübert is satisfied, too. The head of Almo-Erzeugnisse Erwin Busch GmbH in Bad Arolsen, Germany, a manufacturer of disposable medical articles which belongs to B. Braun Melsungen AG, says: "The machine is characterized by good reproducibility and high dynamics in the injection process and mold movement. The open-loop control system is clearly designed and intuitive to operate." ■

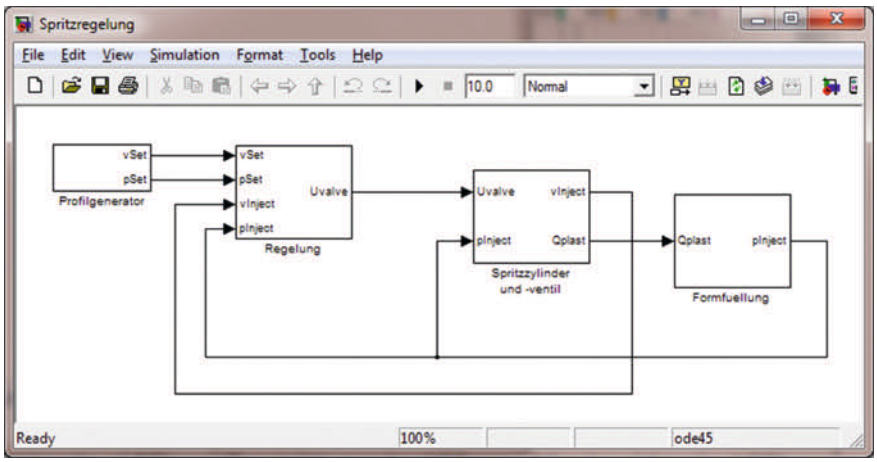

Fig. 5. Simulation model of the injection unit in Matlab/Simulink with the central blocks of setpoint input, closed-loop control, injection unit and injection mold

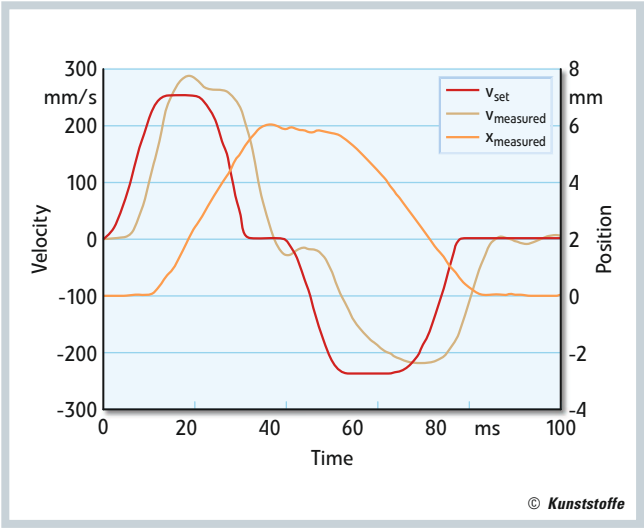

Fig. 6. The ejector moves very dynamically: At a setpoint stroke of 5.5 mm (orange line, right-hand axis), it takes only 80 ms for the forward and backward stroke. The actual velocity (beige) follows the simulation (red) very precisely

THE AUTHORS

DIPL.-ING. HANS-JÜRGEN POPP, born in 1960, is head of technology at the Schwaig site of the injection molding machine manufacturer Sumitomo (SHI) Demag Plastics Machinery GmbH.

DIPL.-ING. (FH) THORSTEN KÖHLER, born in 1982, is application engineer for controlled solutions at Moog GmbH in Böblingen, Germany.

! Valve Technology

D68x series servo-proportional valve from Moog (photo: Moog)

The D68x series from Moog, principally characterized by high valve dynamics which is the result of the rapid, direct-operated spool-type pilot valve. Another advantage of this pilot valve is the low leakage oil losses when the control spool is in the central position. This results in energy savings on the machine during those phases in the cycle when the valve is not operating. This advantage is particularly beneficial for machines that are continually in operation and has a positive influence on the energy balance. The high quality standards at Moog ensure that both valve dynamics and control piston geometry are kept within tightly specified limits in the series.