Limitless Coining

Injection coining helps reduce residual stresses in optical components; such part stresses can be tested right on the injection molding machine using polarizing films or 3-D glasses (photos/grafics: Arburg)

Optical Parts (2). There are a number of reasons for producing optical components by injection coining: complex requirements on the parts themselves, high-grade volume production, high output and, in essence, the profitability of the process. Various process versions are available to predictably fulfill such requirements. The correct machine and mold technology will ensure trouble-free operation.

THOMAS WALTHER
ROLF-UWE MÜLLER

The injection coining process invariably implies altering cavity volume during the dwell pressure phase. In terms of the machinery, this involves a simultaneous movement of both the injection unit and the mold including the mold components. Thus the form has to be configured in such a way that the cavity is sealed even when the mold is not completely closed.

Cavity volume is altered during and/or subsequent to the injection and dwell pressure phases. As the injection process begins, the mold is generally not completely closed. Only after the cavity has been supplied with melt, will the mold halves be closed completely. Consequently, less pressure is required to fill the cavity, thus reducing the pressure gradient during the filling phase as well. As the mold closes, uniform pressure is then exerted over the entire cavity surface of the shrinking part, so that the pressure level within the cavity remains ideally uniform (**Fig. 1**). The lower filling pressure requirement enables larger flow-path-to-wall-thickness ratios, thus eliminating voids and sinkholes, if applicable, and reducing both shrinkage and warping. Among other advantages, residual stress within the part can be reduced and birefringent effects minimized.

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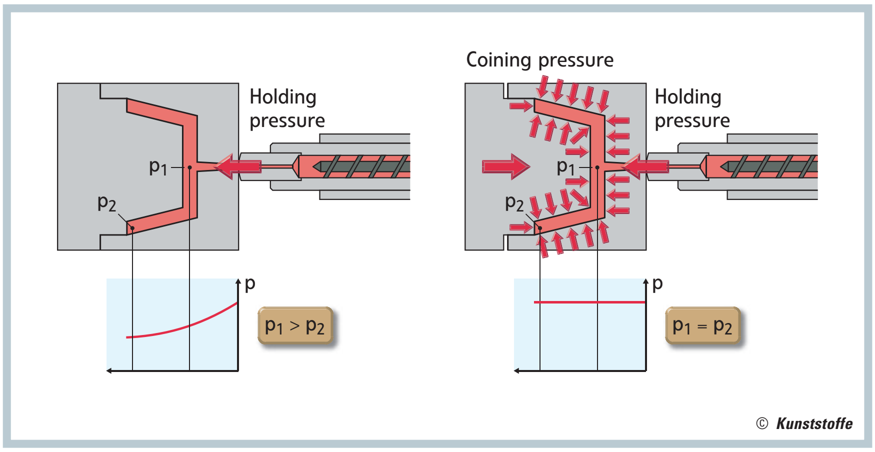

Fig. 1. Typical for injection molding: internal pressure gradient in the part between the gate and the end of the flow path (left); advantage during injection molding: clamping unit pressure acts uniformly as long as there is a coining gap (right)

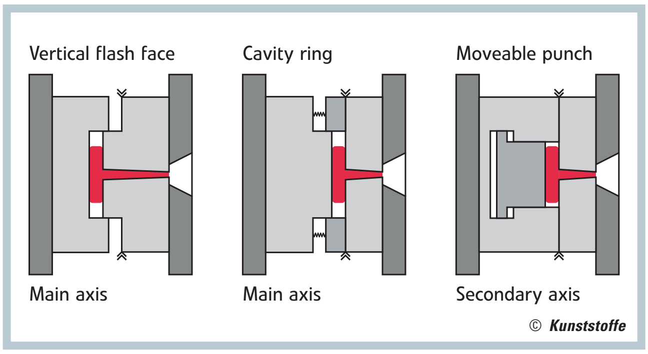

Fig. 2. Injection coining can be implemented using various mold concepts

The fundamental difference between the effect of dwell pressure via the gate during injection molding and the wide-surface pressing action on the part during injection coining can be achieved by many different ways and methods. That is why there are numerous versions of the coining process, and their number continues to grow due to the continued development of machine controls.

Main and Secondary Axes

In mold technology, the distinction between so-called main and secondary axes coining refers to the movement axes of the injection molding machine. By the main axes of the injection molding machine, we mean injection and dosing as well as mold opening and closing. The secondary axes include ejection and nozzle moving as well as core pulling.

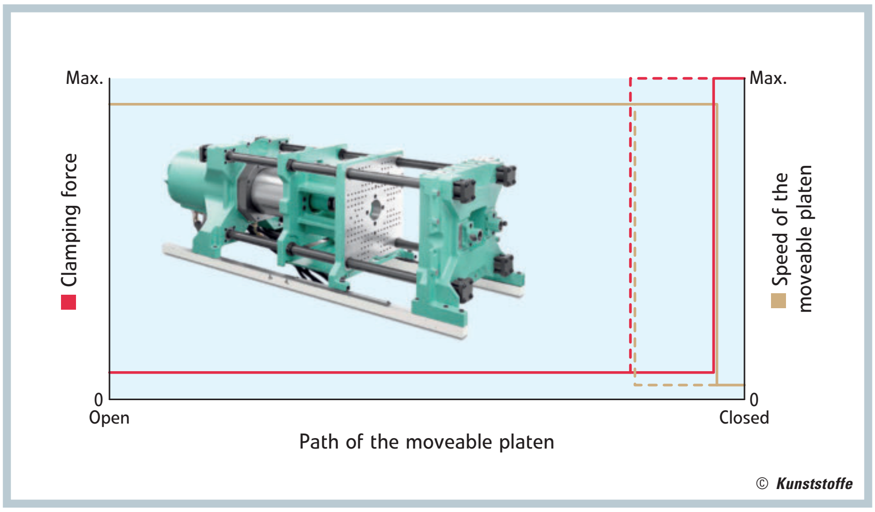

Fig. 3. Fully hydraulic clamping units enable coining paths that correspond to the clamping unit's maximum travel; given an acting counterforce, maximum coining force is available at every point on the path

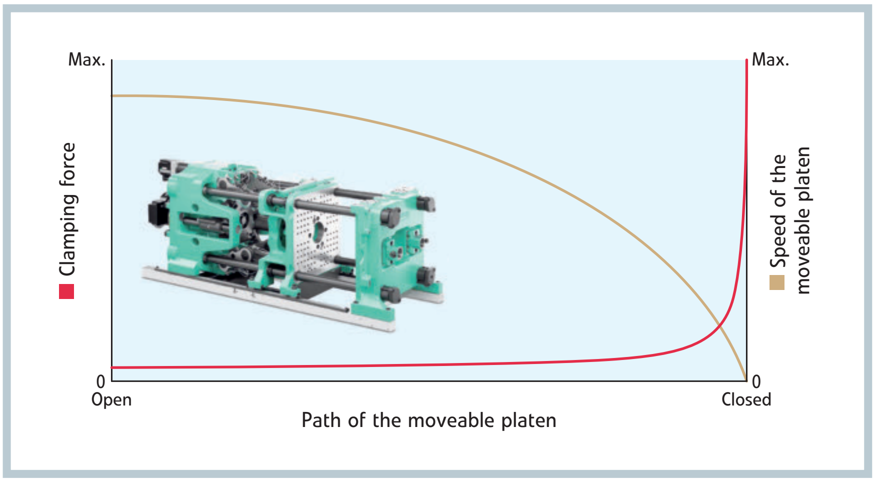

Fig. 4. Due to toggle kinematics in electric clamping units, coining pressure can build up only toward the end of the closing path

Main axes coining means that cavity volume is influenced by clamping unit movement (**Fig. 2**). The cavity can be sealed by a vertical flash face, for instance. In this case, the core involved dips into the matrix, thus sealing the cavity outwardly. Or else it is possible to create a seal via an axially moveable cavity ring or coining frame. When the mold is not completely closed, the ring acts on the parting line, sealing the cavity outwardly. The cavity ring can be pressed on by a spring or hydraulically. The ring is axially moveable for the coining sequence. This approach is especially suited for flat parts with uniform wall thickness. Undercuts or punctures perpendicular to the direction of coining present a problem. Even partial surfaces can be coined using the main axis. In such cases, mold concepts with cavity rings are utilized. In this design type, the mold opening forces are absorbed by the frame, backed up in turn by hydraulics and/or spring action. The maximum permissible backup force acting on the cavity ring is considerably lower than holding force. Therefore, when partial surfaces are coined via the main axis, the processing window is quite limited.

For secondary axis coining, the mold is completely closed (also **Fig. 2**). Here cavity volume is altered via moveable zones (punch) within the cavity. Core functions control the punch hydraulically. The molding machine's ejector mechanism can also be utilized in the coining process. Secondary axis coining is especially suitable for partial surfaces, since any mold opening forces that do not act in uncoined areas are absorbed by the machine's holding force.

Coining via the clamping unit offers considerably higher force reserves compared with punch coining in the mold. Moreover, the clamping unit's measurement system provides for much better process monitoring than when core functions are utilized. This is because the quality achievable, in terms of process reproducibility, depends essentially on the reproducibility of axis movements.

Clamping Unit Design

Each different clamping unit design has its own advantages for use in the coining process. Fully hydraulic clamping units enable coining paths that correspond to →

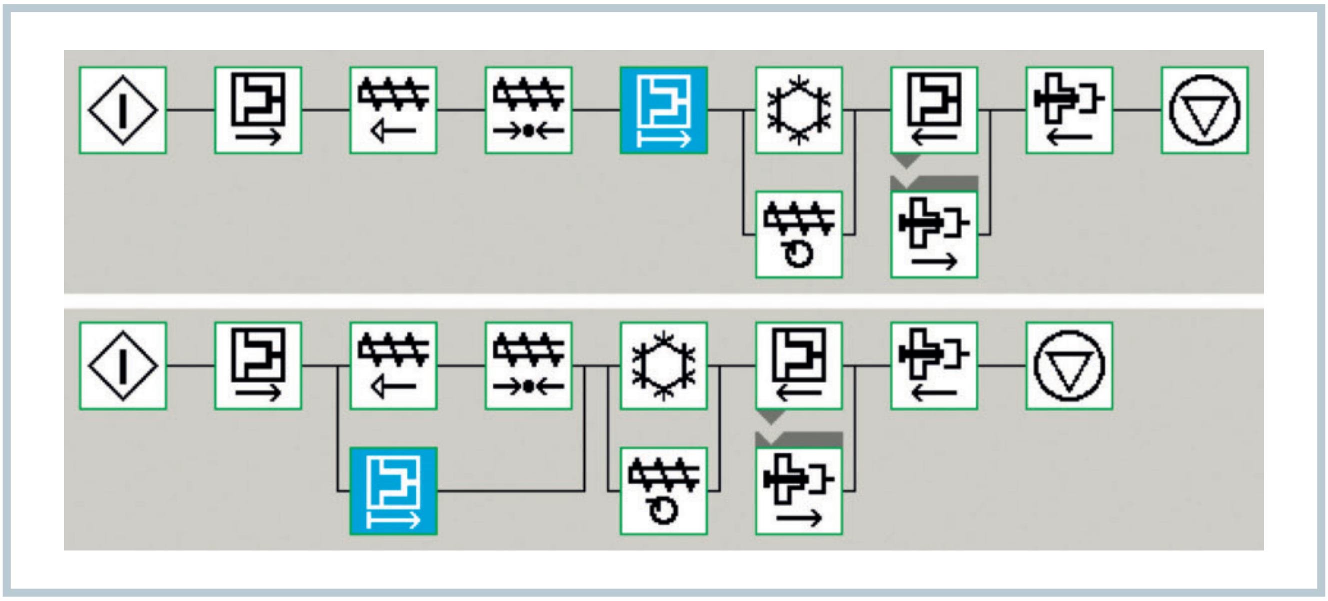

Fig. 5. One example of sequential clamping coining via the main axis (top sequence) is the production of thick-walled blanks for eyeglass lenses; in simultaneous screw-path dependent closing coining via the main axis (bottom sequence), the coining process takes place simultaneously with the cavity filling sequence, whereby the process itself is started when a programmed screw position has been reached

the clamping unit's maximum traversing distance. They can apply maximum coining force at any point of travel, given an active counter force which is also usually equal to maximum clamping force **(Fig. 3)**. Moreover, these clamping units are equipped with longitudinal measuring systems that normally exhibit a measurement resolution of 0.1 mm, thus ensuring a coining position precision on the order of one tenth of a millimeter.

Due to the toggle kinematics of toggle-type electric clamping units, clamping force and traverse speed always depend on the opening stroke **(Fig. 4)**. Full clamping force is not achieved until the toggle is locked. Thus high coining forces can be achieved only if the coining path is short.

Some electrically driven machines must be equipped with very powerful drive motors in order to provide adequate coining forces. Typical coining paths achievable by electrically driven clamping units lie in a range of 1 mm. Reaction speed and coining speed are relatively high, however, since the time required for hydraulic pressure buildup is entirely missing here. Moreover, positioning accuracies can be achieved in a range considerably smaller than one hundredth of a millimeter. Reproducibility is also considerably higher than with fully hydraulic designs, thanks to longitudinally regulated drive systems.

Hydraulic clamping units are used mainly for longer coining paths from 1 to 10 mm. The achievable positioning accuracy is generally sufficient for such applications. For applications with coining

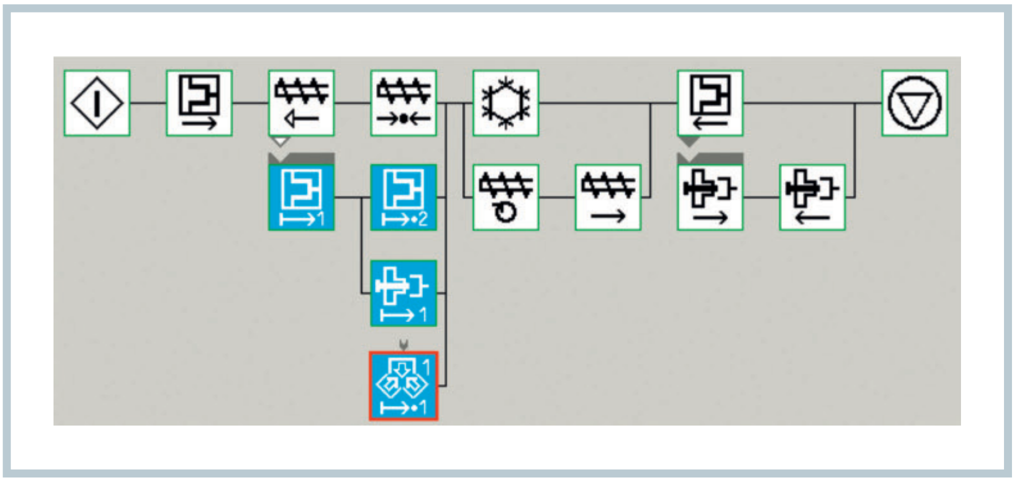

Fig. 6. The Selogica machine control enables the required coining sequence to be programmed freely and individually: multi-step, repeating, simultaneous, via the main and/or secondary axis as well as in combination with force and speed regulation

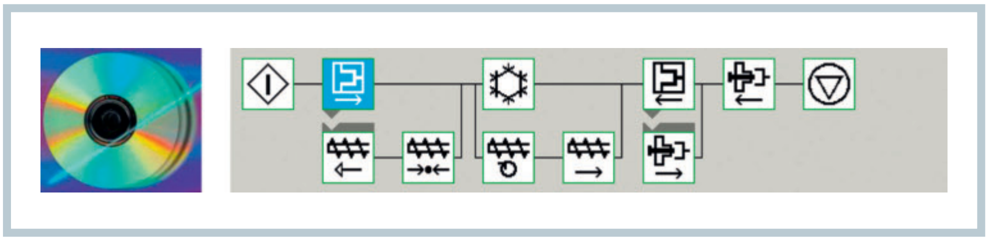

Fig. 7. The production of CDs is one example of flying start injection

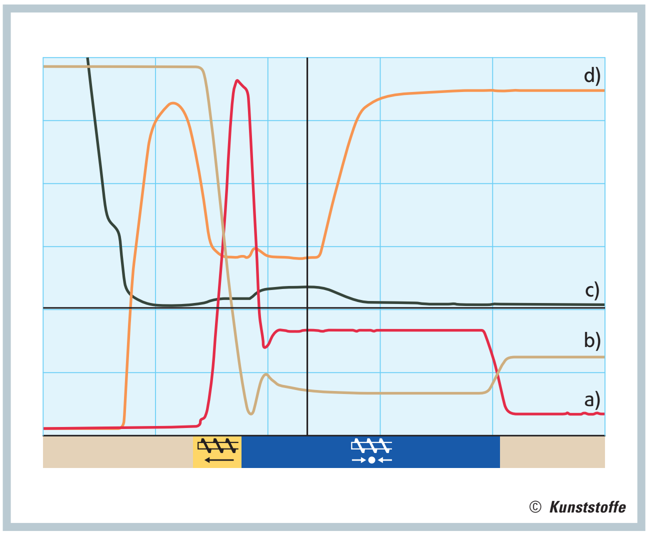

Fig. 8. A possible processing sequence for active breathing: a) injection pressure, b) screw path, c) mold path and d) holding force

paths in the 1 mm range, however, electrically driven toggle systems cannot be beat in terms of reaction time, speed, positioning accuracy and repeat accuracy. In optical component production, the drive systems do not exclude, but rather supplement each other as required by the application.

Process Versions within Injection Coining

The basic peripheral conditions for injection coining are determined by mold design and machine technology, whereby the numerous process versions are consequences of drive technology and machine control. The process versions are generally characterized by three degrees of freedom: coining axis type, direction of coining and temporal sequence **(Table)**.

The first differentiating feature is the mold technology applied, since it determines which mechanical coining axes are required. In addition to the clear distinction between main and secondary axes coining, a combined approach is also conceivable if such a mold design is feasible. The second degree of freedom is the direction of coining. Depending on whether cavity volume is increased or decreased during the process, we speak of opening or closing coining. Temporal sequence is then relative to cavity filling, i.e., to screw motion.

Sequential operation begins by traversing to the coining point, then filling the melt in the cavity followed by the coining sequence **(Fig. 5 top)**. In simultaneous coining, by contrast, these process steps mesh with each other **(Fig. 5 bottom)**. Simultaneous coining has a decisive advantage, in terms of mold filling, since the melt front never comes to a halt, thus reducing the danger of flow marks.

The conditions for initiating the coining sequence can be chosen individually, depending on the mold, the part, the process and the available sensor technology. Modern machine controls provide the following starting conditions:

- Lag-time dependent,
- screw-position dependent,
- injection-pressure dependent,
- internal mold-pressure dependent,
- mold wall-temperature dependent and
- dependence on an external signal.

Universal Coining

The Selogica machine control by Arburg GmbH + Co KG of Lossburg, Germany, enables the user to program the required coining sequence freely and individually **(Fig. 6)**. Main and secondary axes can then be utilized in a single sequence. However, coining only becomes universal when also combined with force and speed regulated programming. This makes currently known and implemented special cases available to the user in a compact, logical and thus easily configured sequence control without his having to apply one special process after another.

An example of such a coining application in the ophthalmic industry is the production of low-stress, true-to-form thick-walled blanks for eyeglass lenses that are coined sequentially via the main axis. A mold equipped with a coining frame is used which is closed except for a defined gap. The screw supplies the melt at low pressure, thereby traveling to its forward stop. When the mold closes (coining), the melt spreads out into the cavity. The mold utilized is equipped with rapid-change shaping inserts. Lens thickness can be set by varying the coining gap. This approach requires no simultaneous movements of the clamping unit and screw by the drive technology.

Coining axis	Main axis
	Secondary axis
	Combined main and secondary axes
Direction of coining	Clamping coining
	Opening coining
	Combined opening/closing coining
Temporal sequence	Sequential
	Simultaneous

Table. This overview shows the versions of the injection coining process

Flying Start Injection and Active Breathing

The special process referred to as flying start injection does not necessarily require a coining mold. This method essentially involves screw-path dependent simultaneous clamping coining by the main axis. While the mold is closing, the injection process is started by path dependent screw motion, i.e. This approach can be used for symmetrical, centrally gated flat parts **(Fig. 7)**. The injection pressure required for the filling phase is reduced, and melt distribution is supported by the mold closing sequence. This approach is →

Article Series

Glass is being increasingly replaced by plastics for optical applications. However, due to their varying wall thicknesses, function parts do not fit the guidelines for shaping plastics parts. Not only expertise in processing technology and mold making, but an understanding of optics and measurement technology as well are decisive for production. The first installment of this article series "Optical Parts (1): For True Insight", appeared in ***Kunststoffe*** international 10/2009, pp. 40-43.

applied for thin-walled parts with high flow-path/wall-thickness ratios in order to influence mold filling and part quality. It is also capable of further shortening the cycle time for conventional, fast running processes, since injection is triggered while the mold is still open. In both cases, the machine has to be equipped in such a way that its clamping and injection units can move simultaneously.

Still another special process, so-called active mold breathing, is used for flat part geometries with conventional injection molds. Its main feature is simultaneous opening/clamping coining via the main axis.

During the mold filling phase, the clamping unit's holding pressure is regulated down by a multi-step programmable holding profile **(Fig. 8)**. This enables controlled mold breathing over a range of a few hundredths of a millimeter. The part exhibits no overfeed, since the border layer of the injection molding has already cooled off. Clamping pressure is increased again during the dwell phase. The result is a minimum coining stroke while pressure is acting over the entire part surface. Particularly for transparent, flat parts, birefringence can be reduced and part planarity increased. Residual stresses are also minimized, which has positive effects when the parts are subsequently galvanized **(Title photo)**.

Conclusions

Generally speaking, only injection molding machines with a high positioning accuracy and very good reproducibility should be used for injection coining. The coining technology should be selected on the basis of mold concept and configuration. Depending on the application, both hydraulic as well as electric machines can be used. The Selogica control for all Arburg injection molding machines has been conceived for sophisticated coining mold concepts and thus enables "universal" coining. With its sequence control, coining sequences can be programmed simply, compactly and logically. ■

THE AUTHORS

DR.-ING. THOMAS WALTHER, born 1969, is the head of application technology at Arburg GmbH + Co KG of Lossburg, Germany.

DIPL.-ING. (FH) ROLF-UWE MÜLLER, born 1961, is an optics specialist engaged by Arburg as a consultant for application technolog

