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Breathing Exercises for Process Optimization

Software Determines the Required Clamping Force Based on Mold Breathing

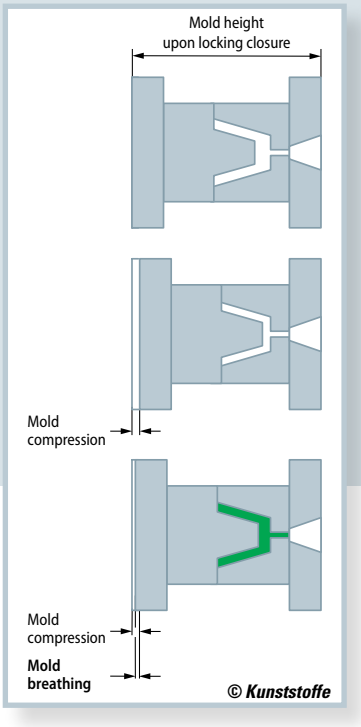
Self adapting, decentralized systems improve process capability and product quality and are an important component in the smart factory, which is the focus of Engel's "inject 4.0" program. In the form of "iQ clamp control", injection molding machine manufacturer Engel is presenting a new software tool at Fakuma 2015 that automatically determines the optimum clamping force for each mold based on mold breathing.

The "iQ clamp control" software is the second product in the iQ product family. The first was "iQ weight control," which Engel Austria GmbH of Schwertberg, Austria, released at Fakuma 2012 [1]. The fact that the control unit on the injection molding machine regulated the switchover point and injection profile in real time during the ongoing injection process, thus automatically compensating for fluctuations in the raw material and the ambient conditions, was an innovation at the time. In the meantime, the software has established itself on the market with more than 600 installations on injection molding machines with electrical injection units [2, 3]. The lessons learned from practical deployment are continually fed back into ongoing development. For example, the latest generation of the software can also automatically adjust the holding pressure during the ongoing process in addition to adapting the switchover point and injection profile.

From the outset, the objective was to lay the foundation for a family of soft- »

A Brief Explanation of Mold Breathing

The starting point is the mold height upon force-free positive locking closure of the two mold halves.
When the clamping force is built up, the mold is deformed. The mold height and the volume of the mold cavity are slightly reduced as a result of mold compression.
Part of the deformation is compensated for by the opening pressure exerted by the melt during injection. The increase in the mold cavity size thus caused is referred to as mold breathing. The resulting change in the mold height, which is approximately equivalent to mold breathing, can be determined by "iQ clamp control".



ware products through this development. The prefix "iQ" stands for "intelligent quality"; this means that expert knowledge is integrated into the injection molding machine's control unit with the aim of sustainably improving the quality of the production process and thus of the finished products.

A New Member of the Family

The iQ software products support the user with at least one of the following three factors:

- Transparency – due to an understandable visualization of the process status based on significant parameters portrayed in a clear-cut way.
- Assistance – with the goal of reducing the workload of the machine operator, for example by automatically setting target values.
- Efficiency – by improving productivity and repeatability and reducing rejects, for example through automatic readjustment of process parameters in real-time.

Visitors to the Engel Symposium 2015 were given a sneak preview of the new member of the iQ product family [4]. At Fakuma 2015, the software is now being presented to the general public for the first time. The focus of the development work for "iQ clamp control" was on the injection molding machine's clamping unit. The software's features can be summarized as follows: the software computes and monitors mold breathing, automatically optimizes the clamping force and regulates the mold breathing peak value when changes in the process occur by adapting the clamping force.

New Process Signal without Additional Hardware

During the injection process, the inflowing melt exerts pressure that pushes the two halves of the mold apart by a couple of thousandths or hundredths of a millimeter. This process is known as mold breathing (**see Box**).

Development engineers at Engel have discovered a method for using the existing sensor system on the injection molding machine to compute mold breathing during the ongoing process. To this end, the entire clamping system including the mold is conceived of as a spring, and the stiffness of the spring is determined during clamping force buildup.

During injection, the tension in the spring increases slightly due to mold breathing; the clamping force increases minimally compared with the set value. This increase must then be determined as precisely as possible. To achieve this, the changes in clamping force are measured during several dry cycles performed at

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the start of production and the results are stored as reference curves. During ongoing production, the current clamping force curve is compared with the reference cycles and the difference in clamping force is converted into the mold breathing value with the help of the known spring stiffness (**Fig. 1**).

In this way, a new and meaningful process signal is made available directly on the machine control unit without additional hardware. Because mold breathing is caused by the internal pressure acting in the cavity of the mold, its curve is very similar to the curve of average cavity pressure calculated for the projected area of the molded part (**Fig. 2**). It therefore provides injection molders with a good basis for analyzing, optimizing and monitoring the injection molding process. The monitoring packages for the Engel CC300 control unit make it possible to monitor either the chronological profile of the mold breathing as an envelope curve or the peak mold breathing value including relevant parameters for alarms and intervention thresholds. This helps to significantly reduce the risk of quality issues such as burrs and reliably protect the mold against overfilling.

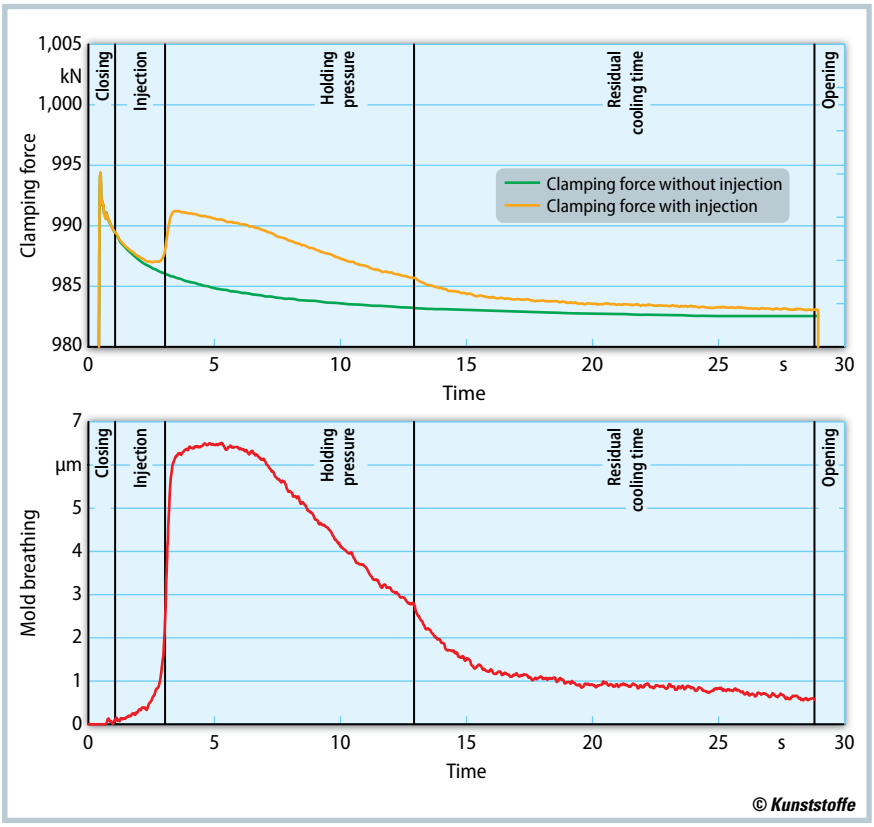

Fig. 1. Determining mold breathing. Top: Due to the opening pressure that the melt exerts, the clamping force increases during injection by a few kilonewton compared with the reference force curve without injection. Bottom: The difference between the clamping force curves can be used to calculate the mold breathing value with the help of the spring stiffness value of the overall system. The achievable level of precision is in the range of a few tenths of a micrometer

Clamping Force Optimization – Automatic and Objective

Until now, the clamping force has been optimized – if at all – by observing mold breathing on the dial of a gauge mounted at the parting line. However, it must be taken into consideration that such measurement results depend heavily on the placement of the gauge on the mold as well as on the type of mold. On top of this, each setup engineer will interpret the results differently on the basis of personal experience. While one engineer may judge a breathing value of 0.03 mm to be permissible, another may consider a value of 0.01 mm to be too large. Thus the results are very subjective, which explains why machine operators often simply set the maximum available clamping force. However, this can lead to problematic mold venting, increased wear and unnecessary use of energy.

On the basis of the calculated mold breathing values, "iQ clamp control" provides an objective, fully automatic procedure that determines the required clamping force within the limits specified by the operator, without any other setpoints needing to be defined. Optimization can be enabled during the ongoing process. At the push of a button, the machine automatically changes the clamping force setpoint and registers the change in the mold breathing peak value. Based on a stored algorithm, the data acquired in this way is used to automatically determine the required clamping force without the clamping force or mold breathing reaching a critical level at any point in time »

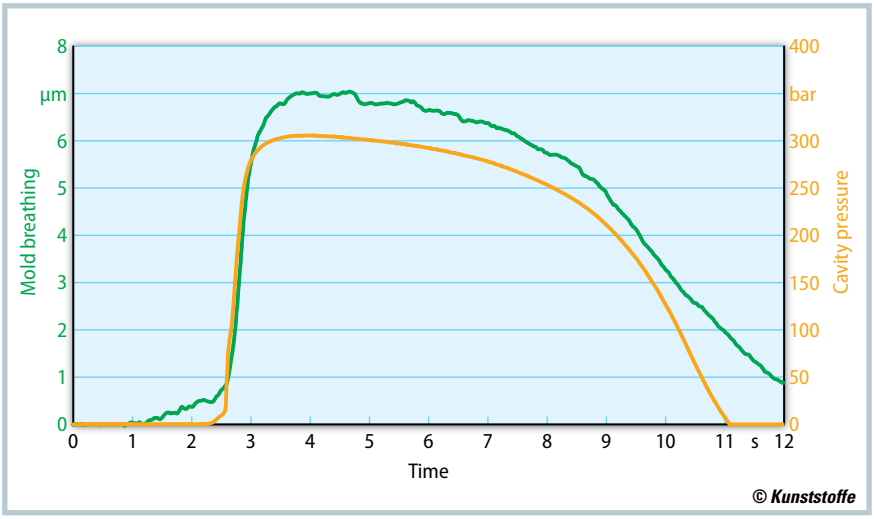

Fig. 2. Comparison between the mold breathing and the cavity pressure curve. Because mold breathing originates from the opening pressure of the melt, the curves of the two signals show similar characteristics

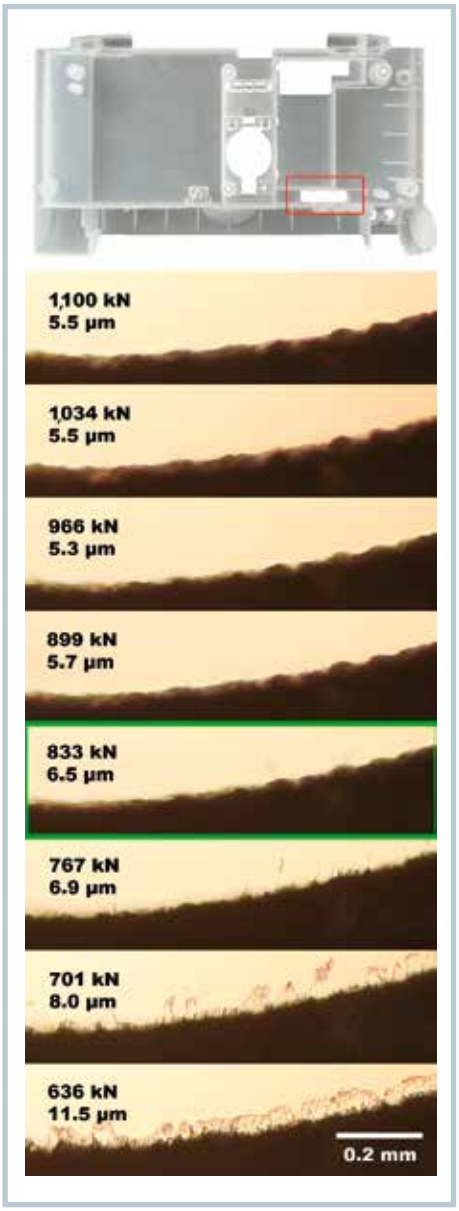

Fig. 3. Burr formation on a medical housing part was investigated in the region of the marked opening. The fine burr that occurs upon clamping force reduction only becomes visible in a transmitted light photograph under a microscope (series of images at the bottom stating the clamping force and peak breathing values). The clamping force as optimized by "iQ clamp control" is 830 kN

(figures: Engel)

(**Fig. 3**). This results in a number of benefits for the operator and the process:

- knowledge of the clamping force actually required under the current process conditions,
- maximal conservative use of the mold and machine,
- improved venting (**Fig. 4**) and
- reduced energy consumption.

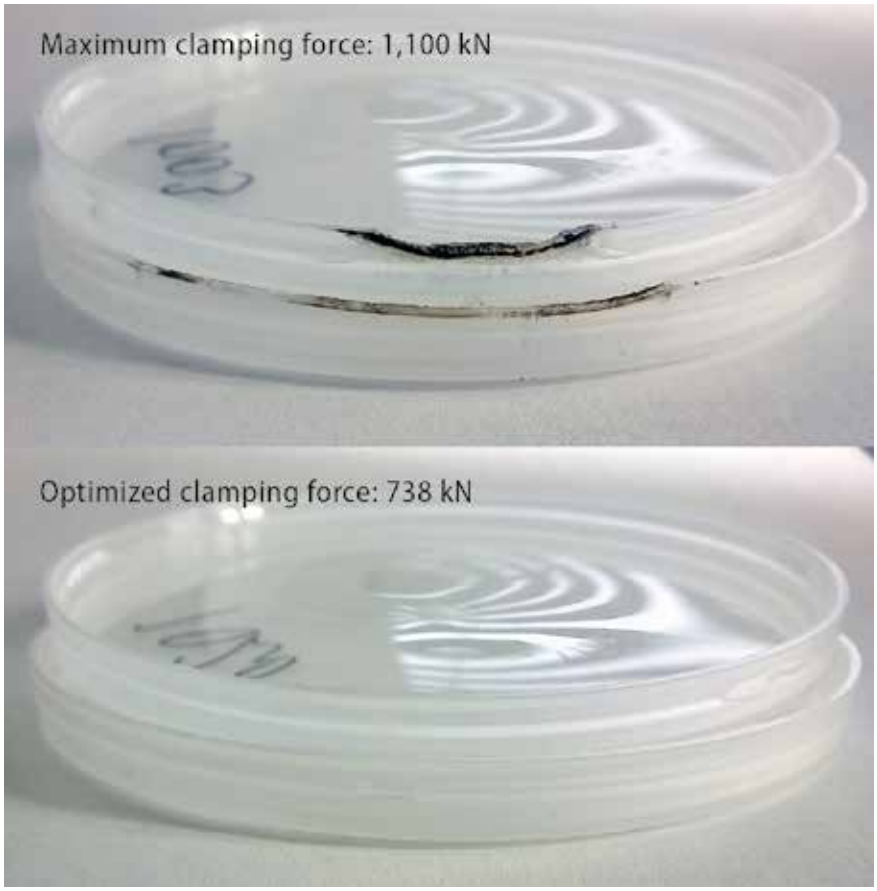

Fig. 4. Packaging cap made of polypropylene: at the maximum clamping force of 1,100 kN, cavity venting is insufficient – serious burns at the end of the flow path are the consequence (top). Thanks to "iQ clamp control", the clamping force was automatically reduced to approximately 740 kN, thus improving the venting and eliminating the burns (bottom)

Setting Component Properties in a Targeted Way with Mold Breathing

Of course, optimization reduces the available reserve clamping force. Mold breathing also changes during the ongoing process due to process deviations and adaptations made by the operator. The software stores the peak breathing value achieved after clamping force optimization and automatically defines matching tolerance thresholds. If mold breathing leaves the permissible range, the clamping force is automatically adapted in the next cycle until the breathing value again lies within the tolerance thresholds.

Additionally, the operator can manually define the desired peak breathing value, which the machine then adopts by automatically changing the clamping force within specified limits. This can be useful, for example to achieve specific component properties or further improve venting.

Conclusions

The "iQ clamp control" software fulfils all three criteria for iQ products. By introducing a meaningful process parameter in the form of mold breathing, it increases process transparency, assists the machine operator by determining the clamping force in a fully automated manner, and boosts production efficiency by keeping mold breathing constant through the automatic adaptation of the clamping force when changes in process conditions occur. In an initial step, the new software is offerd for Engel injection molding machines with electrical clamping units and clamping forces up to 2,200 kN. ■