Mold, Hot Runner and Process Technology

One Tool, One Shot, Three Parts

Family molds offer great potential for reducing costs. They are capable of producing multiple parts of different size and wall thickness in a single shot. The challenge lies in the design of the molds and the process control. Synventive solves this task with cavity-independent pressure control.

Three at once: a six-axis robot removes the final injection-molded assembly, consisting of door trim, map pocket and sill. © Foboha / Christoph Raetzke

The term "family mold" has been used in toolmaking for decades. In contrast to multi-cavity molds, where the focus is on the quantitative scalability of manufacturing identical parts, different parts are placed in one parting plane of a family mold and completed in the same injection molding cycle. One option is that a complete assembly can be removed from the family mold and assembled directly (**Title figure**) [1]. The following distinction is made for the potential parts of family molds:

- mirrored parts, and
- parts that will be joined to form an assembly later.

Examples of mirrored parts are the side mirrors or scuff plates on cars. One example of a combined assembly from an automotive application is the door trim panel assembly, consisting of the waist rail, map pocket, and trim panel. Other typical applications are parts with identical or similar functions, such as a housing or the front and rear bumpers. In contrast to conventional manufacturing of injection molded parts in individual molds, only one injection molding machine is used, saving space and usually allowing for parallel production, reducing the cycle time, and generating lower running and setup costs.

Providing the individual components simultaneously also enables a leaner and more efficient logistics process for the manufacturing of assemblies. Family molds can eliminate the often time-consuming color matching of the individual parts depending on the required quality.

Challenges in the Design of Family Molds

While family molds for mirrored parts present similar challenges as multi-cavity molds, family molds for assemblies require additional factors to be considered for the tool design. This is due to the differences in the parts concerning

- their projected areas and the resulting different buoyancy forces,
- the different ratios between flow path and wall thickness.

The key challenges in designing family molds are summarized in **Figure 2**.

There are different approaches to overcoming these process challenges. In addition to the complex manual adjustment of the needle opening using a cascade approach, the further cavity-independent pressure control in the hot runner with DynamicFeed technology is a cost-efficient and user-friendly alternative.

Machines, Automation and Software Work Hand in Hand

The tests are conducted at the Molding Solutions Customer Experience Center, Foboha GmbH in Haslach im Kinzigtal, Germany. All integrated process solutions for research and development tasks, customer tests, and small production runs can be implemented at the Molding Solutions business. The following systems are used for the tests:

- injection molding machine Duo 17060/2700 manufactured by Engel Austria GmbH,

- six-axis robot easix KR120 R3900 ultra K manufactured by Engel Austria with end-of-arm tool from Gimatic S.r.L,
- DynamicFeed controller and external hydraulic unit (HPU), 3rd generation, manufactured by Synventive Molding Solutions GmbH,
- 128-zone hot runner control device type Gammaflux G24, manufactured by GF Controls GmbH.

The test series use the PPcompound 9120 black 13200 molding compound, a rubber (elastomer-)modified PP often used for interior parts and manufactured by Sabic Deutschland GmbH & Co. KG.

The family mold is a test mold that can be used to conduct injection molding tests that closely resemble production conditions, using a door trim panel as a product example. The mold was developed and built in cooperation with Müller Modell- und Formenbau GmbH & Co KG (Müller Wallau). The injection molding tool is equipped with an extensive sensor system for internal tool pressure and temperature from Priamus System Technologies. It enables scientific examination of a number of problems in mold, hot runner, and process technology.

For example, the DynamicFeed technology in this test setup is shown in **Figure 3** using one of the three cavities. The DynamicFeed valves are installed in the compound transfer elements of a bridge manifold, through which the submanifolds of the respective cavities of the family mold are supplied. The valves can control the required pressure for each cavity in the submanifolds along a target pressure curve. The valve allows cavity-independent control of the pressure profile. A melting pressure signal in the respective submanifold and a position signal for the associated hydraulic actuator are the input variables for the controller [2].

The system shown in **Figure 3** is the retrofit variant of DynamicFeed technology, where the valves are supplied with an external hydraulic unit. Integrated solutions for the hydraulic supply to the servo valves are also possible, depending on the machine manufacturer.

In addition, the valve gate nozzles for the respective submanifolds are controlled with a cascade control integrated into the machine during the remainder of the test. Signals relevant to safety and the machine are sent to the controller through a machine interface. The DynamicFeed process can be operated on the controller itself, on an external, independent control terminal, or with a solution integrated into the machine controller.

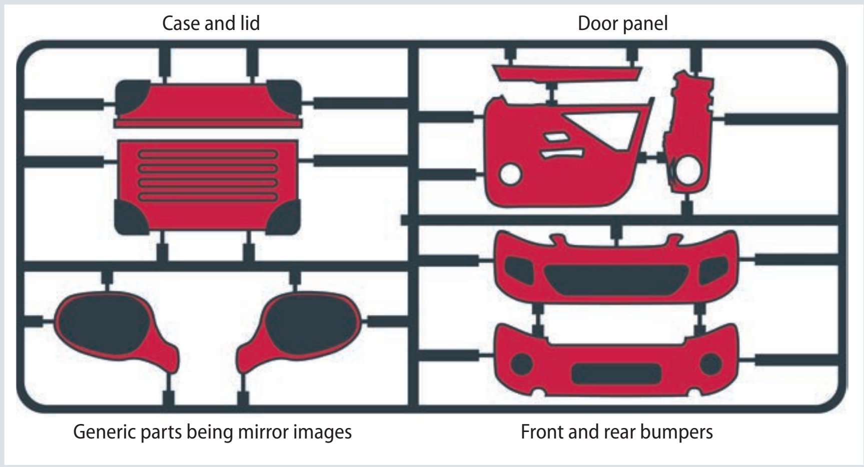

Fig. 1. Examples of injection molded parts in a family configuration. The trial mold described in this article can be seen at the top right. © Moldings Solutions

Comparing Conventional and Pressure-Based Process Control

Figure 4 shows the pressure curves of the individual cavities with conventional and pressure-based operations. Both modes of operation use the machine's cascade controller that sequentially actuates the valve gate nozzles of the individual cavities. In addition to a direct connection on the part, valve gate nozzles 7, 8, and 11 in the example of the door trim panel (**Fig. 4, bottom**), the cold runner connections are also implemented with valve gate nozzles 10, 12, 13, and 14. A variety of different filling scenarios can be implemented on the parts with this variable configuration. The colored bars in the diagram's background identify the switching times for the valve gate nozzles during the injection phase.

During the test procedure described in the following, the door trim panel – the largest part – is filled first, and all parts reach the end of the flow path simultaneously (**Fig. 4, left**). Then the system switches to the holding pressure phase. This process structure corresponds to »

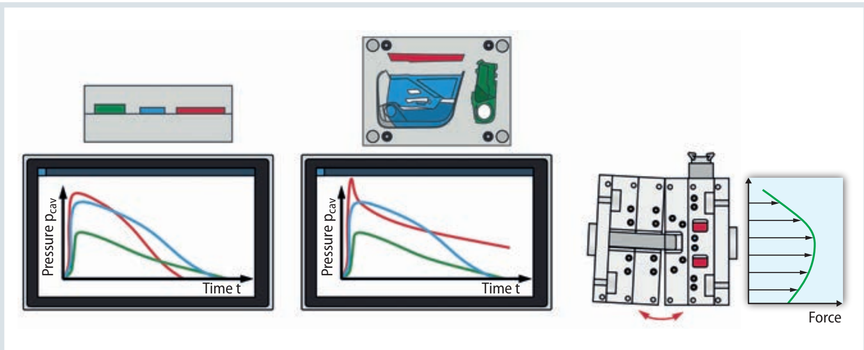

Fig. 2. The colors red, blue, and green represent different parts of a door trim panel assembly and the associated pressure curves in the individual cavities. With the simultaneous start of the cavity filling, the different wall thicknesses/flow path ratios of the individual cavities result in different internal cavity pressures and, therefore, in different pressure requirements (left). Different component volumes of the individual cavities result in the end of the respective flow path being reached too early and the individual cavities being locally overloaded (middle). The variances in the projected areas of the individual cavities produce an asymmetrical load on the mold, resulting in a shorter tool life and increased wear on the closing unit of the injection molding machine (right). © Molding Solutions

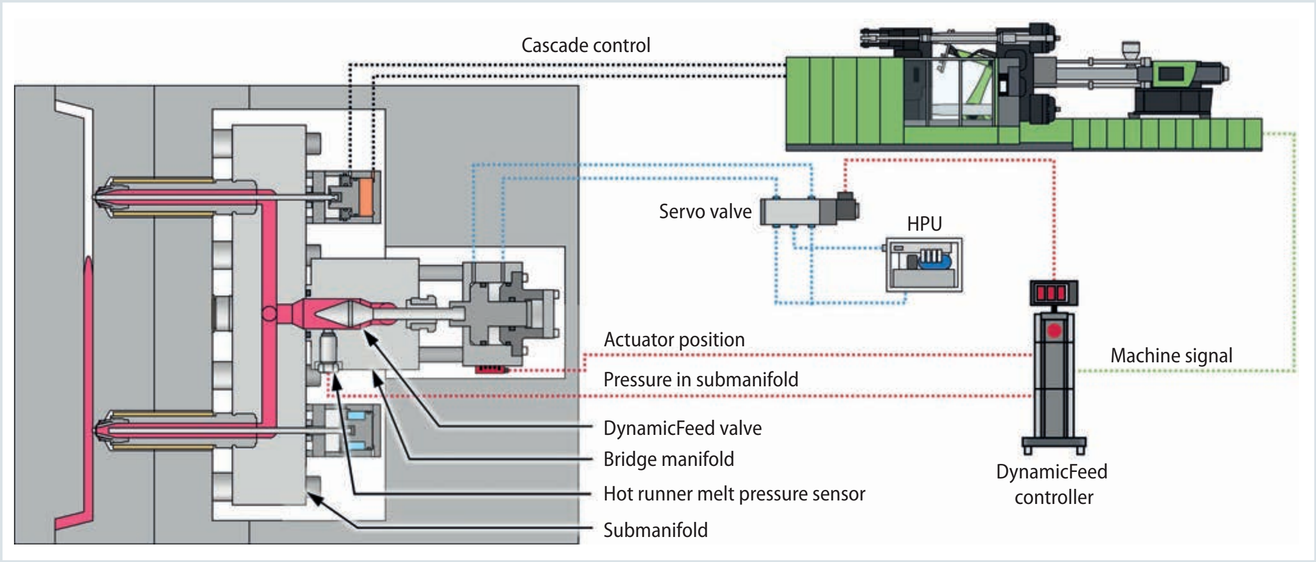

Fig. 3. Diagram of the trial construction in the Foboha Customer Center. © Moldings Solutions

the conventional operation for family mold applications described in the literature [3]. The pressure curves shown are measured in the hot runner bridge manifold in the direction of flow to the individual cavity. Based on the setting of the cascade control, pressure can therefore be measured before the needles open. While the cascade control is actuated based on the screw position, it has been converted for the time axis in the diagram.

To compare the conventional process control (green, pressure control off, and DynamicFeed valve completely open) and the DynamicFeed process control (red, pressure control on), test settings with comparable maximum pressures (700 to 750 bar) were selected in each case. In addition, the closing force was set high enough to avoid mold-breathing effects in both tests.

Individual Cavities Are Filled Independently of Time and Pressure

In conventional process control, the injection process is conducted with the same pressure increase in all submanifolds. The jumps in the pressure curve result from the injection profile, the sequential needle opening, and the pressure interactions of the submanifolds connected through the hot runner bridge manifold – described as the "principle of communicating vessels" in popular science [4].

The injection profile is also staggered for pressure-based operations with DynamicFeed technology to keep the pressure provided by the plasticizing unit at a controllable level. With DynamicFeed technology, independent target pressure profiles can be defined for the respective individual cavities. This makes it possible to build up targeted pressure in the respective submanifold to achieve filling of the individual cavities independent of time and pressure. The pressure profile can be smoothed further with an alternative, staggered target pressure set by the DynamicFeed controller.

The pressure-based process control allows for simplified process settings compared to the conventional operation with only the cascade control (**Fig. 5**). This means that the melting pressure can be controlled during the injection phase separately for each cavity, and the pressure built up in the hot runner at this point can be used for holding pressure for components with smaller shot volumes. Furthermore, factors such as viscosity fluctuations, variances in the plasticizing and injection process, and other disturbances can be adjusted with the individual pressure curves' settings.

Reducing the Closing Force with Pressure-Based Process Control

The pressure-based process setup with DynamicFeed enables staggering the individual cavities' filling time and limiting the pressure level, reducing the

Info

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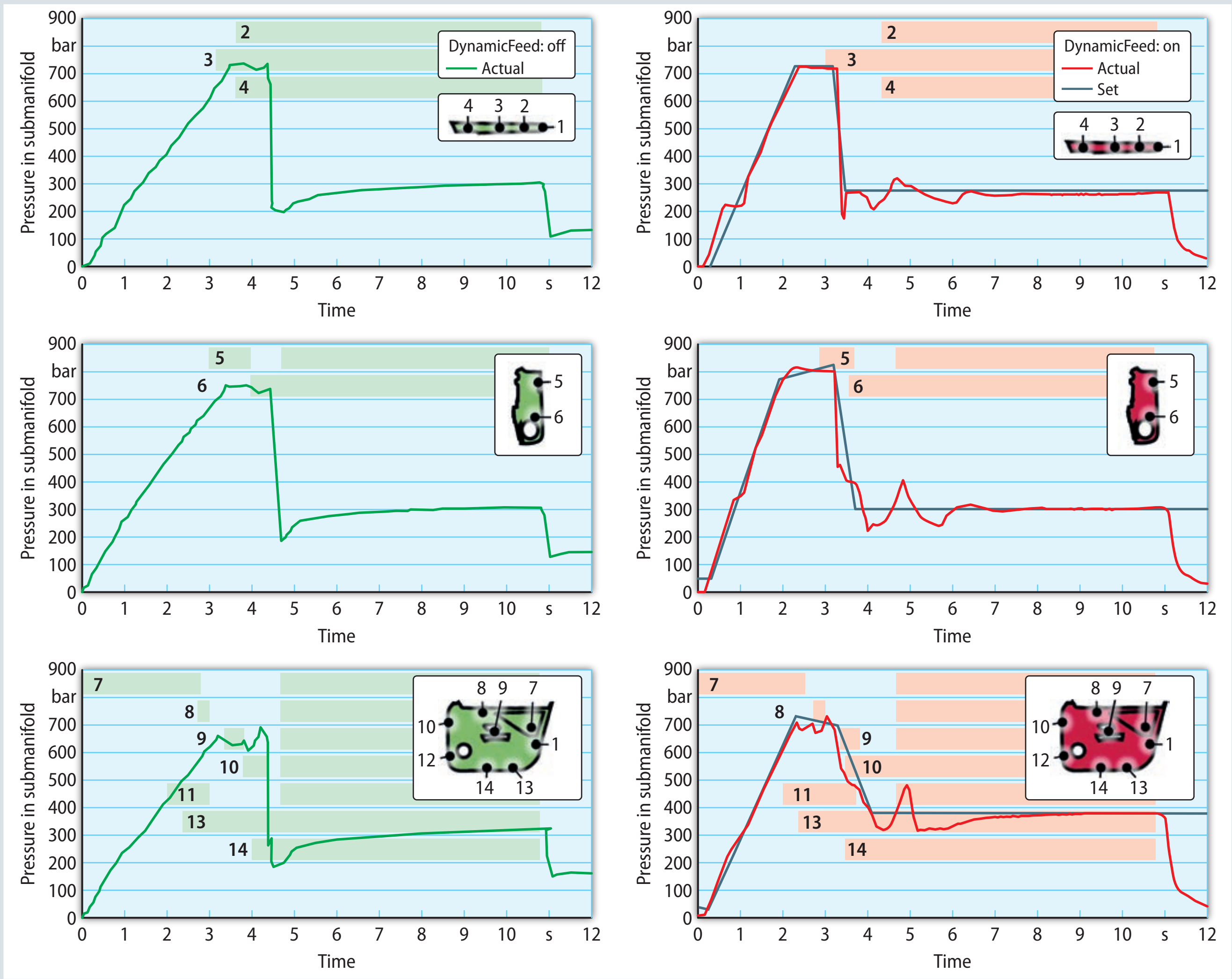

Fig. 4. Pressure curve in the DynamicFeed bridge and cascade controller through SGM. © Moldings Solutions

overall closing force if this technology is used for family molds.

Figure 6 shows the weight change for the parts as a function of the closing force. It is evident that mold breathing occurs at much lower closing forces with pressure-based process control.

Compared to conventional process control, the pressure-based approach with high closing forces results in lower part weights because it avoids local overloading in the individual cavities. This also becomes evident from comparing the weight deviation with the same closing force setting, which is 0.3% for the door trim panel, 1.15 % for the waist rail, and 1.0% for the map pocket in our example.

The detailed view of the loudspeaker grille from the door trim panel (**Fig. 6, left**) also shows that local overmolding can be avoided despite the significantly lower closing force than conventional operation.

Melt Pressure Control Reduces Mold Breathing

DynamicFeed can significantly reduce mold breathing. The elongation curves shown in **Figure 7** compare two test settings with comparable closing forces of 18,500 kN (control off) and 19,000 kN (control on). Tie bar elongation is recorded on the tie bars of the injection molding machines over the entire injection molding cycle and not adjusted by the machine. Only the maximum value during the injection or holding pressure phase is evaluated in the diagram below.

Different local elongation values occur in the tie bars due to the position of the parts within the parting plane. The greater local portion of the projected area results in the highest buoyancy force at measuring positions 1 and 2 and causes the greater tie bar elongation to be compensated locally. The tie bar elongation sensor registers no significant elongation at measuring position 3. In this area of the parting plane, the portion of the projected area is too low due to the part positioning and properties (large opening in the map pocket). With the process settings shown, tie bar elongation can be reduced from 1.1 mm to 0.56 mm at measuring point 1 and from 0.56 mm to 0.2 mm at measuring point 2, with the same part quality and properties.

This reduction of the (local) closing force results in significantly reduced strain on the mold and machine, increasing the components' service life. In addition, parts requiring a high closing force with conventional process control can be manufactured in "smaller" injection molding machines with DynamicFeed technology, depending on the application. »

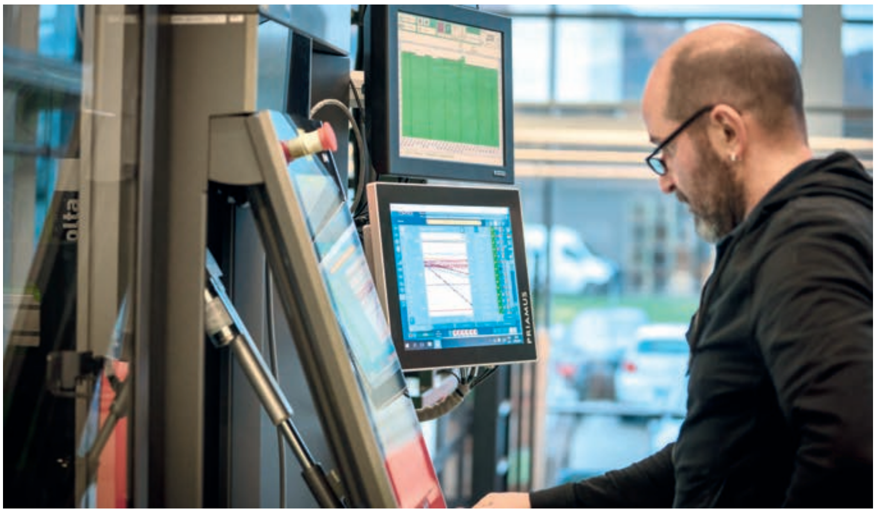

Fig. 5. The DynamicFeed technology permits individual melt pressure regulation in real-time.

Bottom Line and Outlook

Using control systems in the hot runner, mold, and injection molding machine has become essential to ensuring the continually increasing requirements for component quality while lowering production costs. Due to factors such as differently projected areas of the individual parts or vastly differing flow path/wall thickness ratios, the challenges for process control can be overcome by using DynamicFeed technology. A pressure profile determined by the hot runner while independent of the cavity makes it possible to fill and produce the individual cavities. This pressure-based technology can be used on all injection molding machines and integrated into the machine or retrofitted.

The tests and implemented applications described here have shown that the closing force can be reduced by up to 25 % in family mold applications. This makes it possible to use existing (smaller) injection molding machines for family mold applications that exceed the machine closing force in conventional operation. The reduced closing force also lowers the strain on the individual components, resulting in longer service life and lower maintenance costs.

The pressure-based process control also ensures consistent quality of formed parts subject to fluctuations in the process – for example, due to viscosity changes. DynamicFeed technology is important for managing process fluctuations when using recycled materials. Future analyses will examine the combination of the technology with an automated cascade control, which can achieve a much simpler setup and configuration process. ■

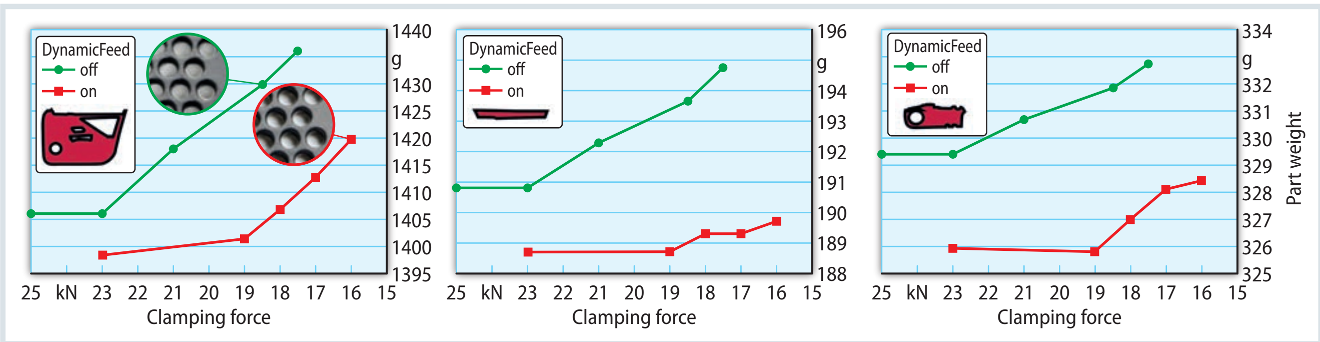

Fig. 6. Weight change of the parts depending on the closing force. © Molding Solutions

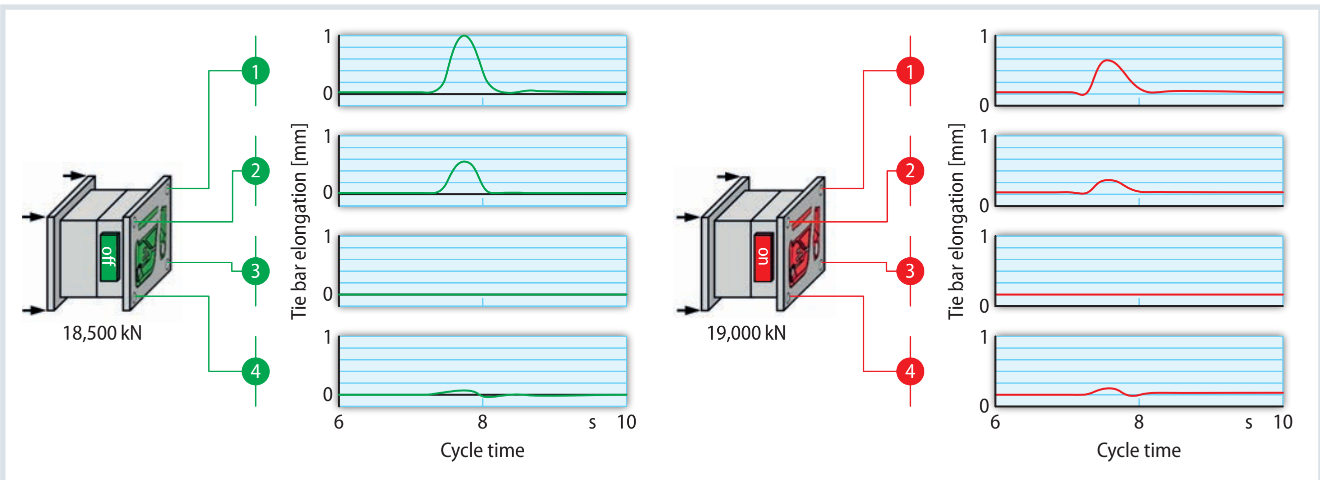

Fig. 7. Mold breathing with comparable closing force, with and without DynamicFeed. © Molding Solutions