Optical part in polarized light
(photos: Arburg)

"Injection-Compression Molding Unsuccessful"

Process Optimization. This is frequently the result of an attempted commissioning of an injection-compression mold with spring-loaded cavity frame, because the time required for this work is regularly underestimated. The test samples are failures because the injection-compression process was set-up without sufficient basic information. But such disappointments can be avoided if the user observes a few basic principles.

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Many of you will know the situation. During the commissioning of an injection mold, designer and product manager stand expectantly around the injection molding machine awaiting the first samples of the new product. The plastics molder is concentrating on setting the injection parameters, plasticizing parameters, cylinder heating and mold temperature control system for the start-up of the new mold.

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No particular attention is paid to the clamping unit as long as the injection molding machine provides sufficient clamping force.

It is not unusual for plastics processors to handle the commissioning of an injection-compression mold in the same way as a standard injection mold – and hereby underestimate the significantly greater time requirement for such a case. As a result, the plastics molder at the machine is under time pressure to supply the first samples and so tries to install an injection-compression process without sufficient basic information. It is therefore hardly surprising that the commissioning of an injection-compression mold under such circumstances is often initially unsuccessful and makes the plastics molder look incompetent.

Particularly when commissioning injection-compression molds with spring-loaded cavity frames which in combination with main axis compression molding are in widespread use in the industry, it is important that the designer provides the plastics molder with the necessary mold design data during the mold trials. The required mold design data are essentially:

- The maximum compression stroke of the mold,
- the total spring force for which it is designed, and

- the maximum permissible compression force.

Theoretically, these data should be known when constructing the mold. In practice however, we often find that the spring force is either not calculated correctly or not at all, and that the designers give no thought to the maximum permissible compression force. This article focuses in particular on these three crucial considerations.

The Compression Force Acts Directly on the Melt

In conventional injection molding, programming too high a clamping force has no influence, in principle, on the process apart from poorer venting of the mold cavities. The locking force acts on the main parting line of the mold and has the sole function of sealing the cavity under the pressure prevailing in the mold to prevent the melt from escaping.

In injection-compression molding, the locking force or compression force acts directly on the plastic melt through the compression stamp. If this is not properly programmed, the cavity pressure can in some cases easily exceed the permissible surface pressure of the mold steel – in the worst case this can result in deformation of the mold inserts or of the supporting mold platen.

If the cavity frame contains projected areas such as runners or partial cavity surfaces, too high a compression force can result in the mold cavity pressure generating a lifting force in these projected areas which is stronger than the closing force of the spring assembly. As a consequence, the melt is forced out through the mold parting line. The real reason for this flash formation is often not recognized, and is generally attributed to a malfunction of the injection molding machine or lack of skills on the part of the plastics molder.

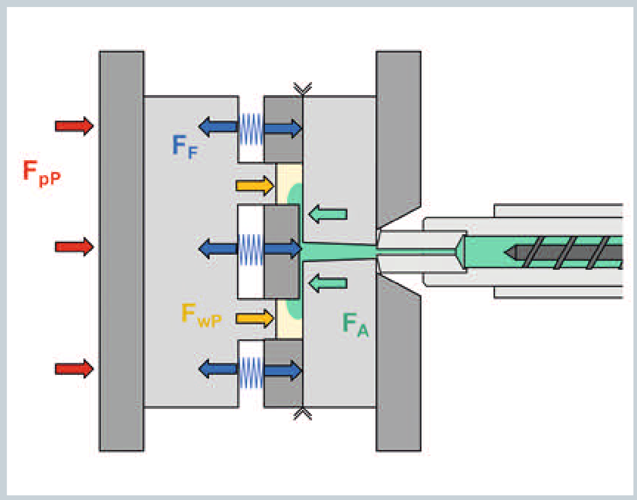

Fig. 1. Active forces: If the cavity frame comprises projected surface areas which generate a lifting force, the spring assembly must be designed to withstand the maximum expected mold cavity pressure. F_{pP} = Programmed compression force; F_{wP} = Effective compression force; F_A = Lifting force; F_F = Spring force

Total Spring Force and Compression Stroke

When designing the mold, the compression force required to act on the part during the compression phase can be calculated on the basis of the product-specific projected surface areas and also allowing for the typical mold cavity pressure range of the plastic used. If the cavity frame comprises projected surface areas which are subjected to the mold cavity pressure during compression, the spring assembly which ensures the sealing of the main parting line must be designed to withstand the maximum expected mold cavity pressure **(Fig. 1)**.

In order to prevent overfeeding or flashing of the injection-compression mold, and hence damage to the sealing surfaces during the start-up phase, the characteristic curve of the mold springs should be measured before the cavity is filled with melt. Experience has shown that the force of the springs actually measured is often lower than the force specified by the designer, and in many cases is not constant over the entire compression stroke. In order to check the specified data, the plastics molder can use the dry cycle program of the injection molding machine to draw up a mold-specific characteristic curve of the spring force which shows the total spring force in relation to the compression position.

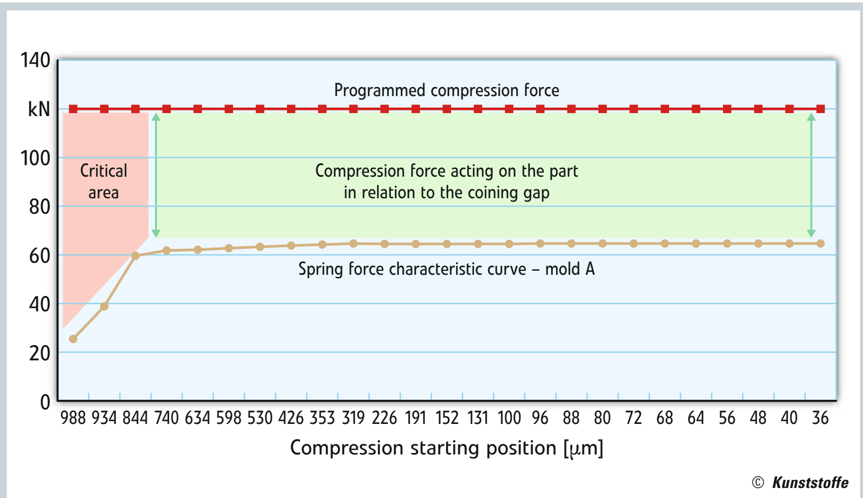

Fig. 2. Spring force characteristic curve recorded in dry cycle mode (mold A). Designed spring force: linear 60 kN over 1,000 µm. In a force-controlled compression process using a programmed compression force of 120 kN, a compression force of approx. 60 kN prevails over the entire compression stroke

Commissioning the Mold and Characteristic Curve of the Spring Force

The following charts show actual recordings of the characteristic curves of the spring force which were measured during the commissioning of two different production molds (A and B) for optical parts. In one case **(Fig. 2)**, a maximum compression stroke of 988 µm and a practically linear curve of the spring constant up to a compression gap of 844 µm are evident. In a force-controlled compression process using a programmed compression force of 120 kN, a compression force of approx. 60 kN is thus available over the entire compression stroke. For process planning purposes this means that the compression process conditions of the clamping unit remain the same, irrespective of the current compression position. Hence when optimizing the process, the influence of the in-

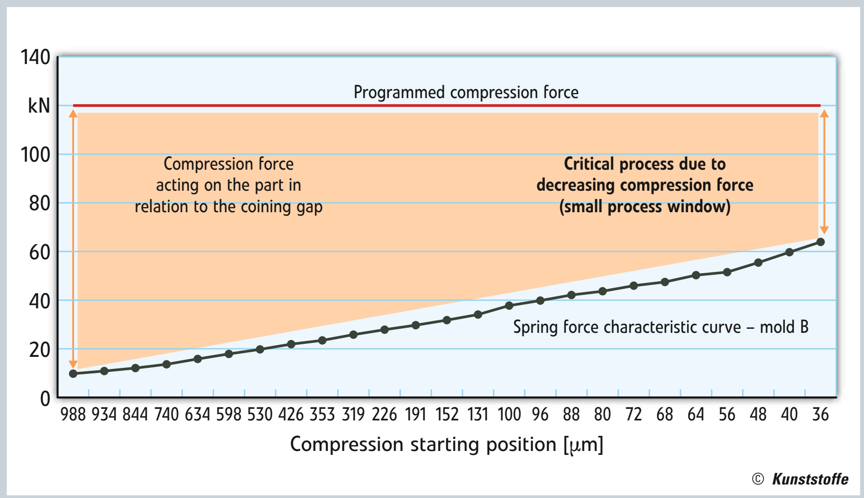

Fig. 3. The characteristic curve of the spring force recorded in dry cycle mode (mold B) is not constant and the spring preloading force calculated as necessary by the designer is exceeded and fallen short of to a considerable degree. Designed spring force: 40 kN linear over 1,000 µm

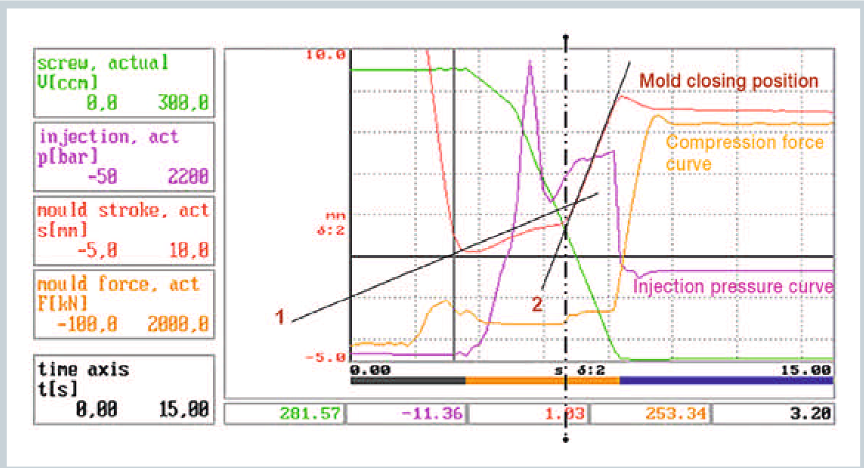

Fig. 4. Recording of the production process: The machine operator interpreted both gradients (1 and 2) to be a reaction of the mold closing movement to the mold cavity pressure

jection process parameters can be clearly assigned to a specific parameter.

In the second case – a mold designed for a spring force of 40 kN over a compression stroke of 1,000 µm (**Fig. 3**) – we can see that the characteristic curve of the spring force is not constant and that the spring preloading force calculated as necessary by the designer is exceeded and fallen short of to a considerable degree.

Process Analysis in Dry Cycle Mode

When planning the process this presents a great risk firstly of the runner system being overfed during the injection phase, and secondly of all the cavities being overfed or over-compressed during the initial compression phase because here the compression force is too high. In the second compression phase the shrinkage is inadequately compensated because the reduced compression force now acting on the part is too low. The problem for the plastics molder with this behavior of the spring characteristic curve is that the influence of the injection process parameters cannot be clearly assigned to part-specific quality characteristics.

Practical experience has shown that injection-compression molds in particular, require interdisciplinary communication between Production and Design Engineering. Ideally a mold should be commissioned in two stages. In the first phase, the behavior of the mold in combination with the clamping unit and the chosen compression method should be tested in dry cycle mode, before the mold designer specifies the maximum permissible compression force. Only in the second phase is the mold to be filled with melt. With the findings from the behavior in dry cycle mode, the share of the influence of the mold filling process can now be clearly identified in the process diagram.

The process diagram illustrated in **Figure 4** shows an injection-compression process conceived for the production of a thick-walled part. The mold closing movement can be broken down into two gradients. The machine operator regarded the two gradients as a reaction of the mold closing movement to the mold cavity pressure and therefore optimized the process accordingly – without success. It was not possible however, to clearly identify how individual process parameters influence the molding quality.

Only the process analysis in dry cycle mode revealed that the mold movement is not the result of the prevailing mold cavity pressure, but that the mold is forced open by the spring assembly of the cavity frame during the injection phase until an equilibrium is obtained between the programmed compression force and →

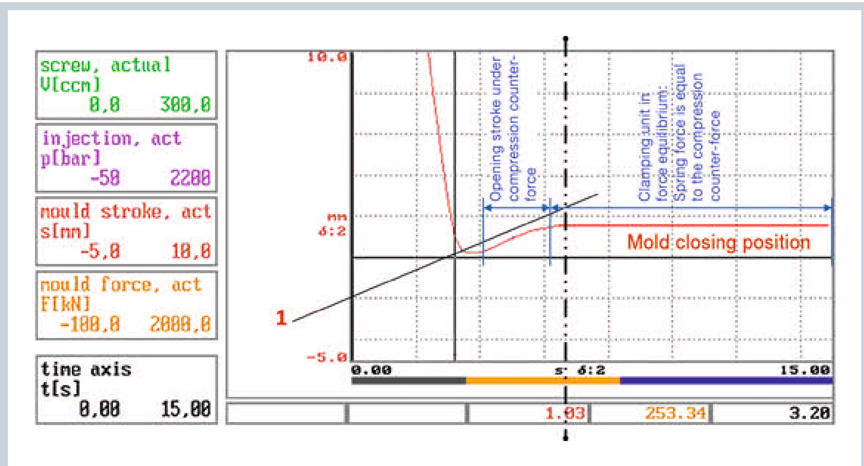

Fig. 5. Only a process analysis in dry cycle mode of the machine revealed that the mold is forced open by the spring assembly of the cavity frame during the injection phase until an equilibrium is obtained between the programmed compression force and the spring force

the spring force **(Fig. 5)**. Gradient 1 represents an uncontrolled enlargement of the cavity during the injection phase. Melt adhering to the wall which should be pressed against the surface area of the embossing stamp under constant or increasing cavity pressure is instead subjected to pressure relief due to the enlargement of the cavity, and this results in a poorer replication of the mould surface. Furthermore, the fact that the mold movement (red line) does not continue in a linear manner, but goes into a horizontal line, shows that the characteristic curve of the mold spring force is not linear either.

Conclusion

The characteristic curve of the spring assembly of a cavity frame visualizes the programmable value range suitable for the starting position for the compression process. The compression force to be programmed in the machine controller is the sum of the measured spring force of the spring assembly and the calculated compression force acting on the molded part.

This basic information – compression force and spring force together with the findings of the machine run in dry cycle – enable the plastics molder to carry out the commissioning of an injection-compression mold successfully. It should be noted, however, that up until this point attention has been focused only on the mold function, not on the compression process. It is now up to the mold designer to communicate the required compression process to the plastics molder so that he can program the process sequence competently. ■

THE AUTHOR

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