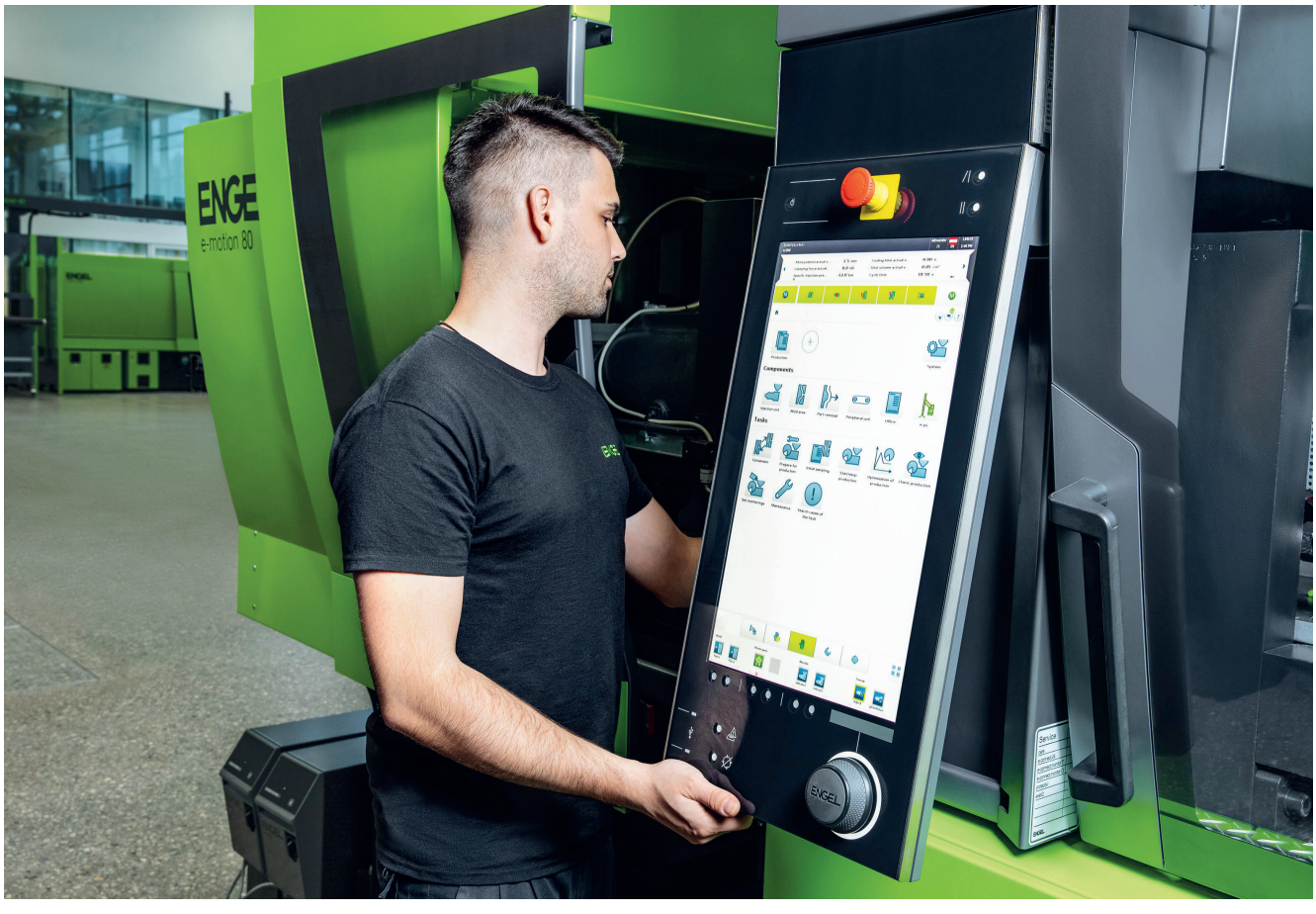
Simple Determination of Process Windows and Quality beyond Parameter Limits

Keeping Setting Parameters under Control

The prerequisite for a stable production process and a constant high product quality is the correct setting of all process parameters on the injection molding machine. But errors also often occur. Engel's new "Parameter Limits" feature provides a remedy. It supports injection molders in keeping the parameters constant within a process window.



With the new Parameter Limits feature, tolerance ranges for up to 150 process parameters can be fixed directly in the machine control system for up to 150 process parameters. A change of the selected setpoint values is then only possible within the defined process window. © Engel

The quality of the parts is crucial for an injection molding company's competitiveness. A modern interpretation of the quality concept requires looking at the topic in a holistic way. Not only the measurable product quality of the part is important, but additionally also an integrated quality assurance and comprehensive quality management (**Fig. 1**). Quality stands for the quality of all processes that lead to manufacture of the part, starting with a survey of customer requirements, part development and mold design, through organization of the production process, to continuous process optimization.

The relationship between the injection molding process and part quality is physically based. However, the complexity of this process allows for hardly any simple correlations between individual process parameters and the quality criteria of the part. In addition, it must be taken into account that the

running injection molding process is influenced by different factors. They include fluctuations of the raw material properties, wear in the mold and on the injection molding machine, as well as changes in ambient conditions [1]. The consequences are deviations in the process and also as regards part quality. In general, various process parameters correlate with the quality data of the part. For example, the warpage of a part is determined by, among other things, the injection velocity, holding pressure, melt temperature and mold temperature, moreover the part geometry and material also decide how greatly the process settings impact the part warpage.

Ensuring a Constant High Quality

To ensure a constant high quality during injection molding, various methods are available. The oldest is the control of defined quality criteria on the part. For some applications, 100 % control is specified by customers or by law. Though control of the finished part is a very reliable method, it has a number of disadvantages. Thus, not all aspects of the part quality can be tested; in addition, the method is expensive because it requires either complicated automation or high personnel costs. In addition, the quality problems can only be ascertained if bad parts have already been produced, which cannot be reconciled with the requirement for sustainable energy- and resource-efficient production.

Another method that has been used for many years is monitoring of the actual values of the production process. This method is economical, provides rapid information about the current process quality and allows the relationships between the injection molding process and part quality to be better understood. With the process data protocol, Engel offers, for example, an option with a proven track record over many years. However, it is disadvantageous that it is difficult to produce a quantitative relationship between process actual values and part quality, since the process parameters often do not correlate with the part quality and, when they do, not in a linear way [1, 2].

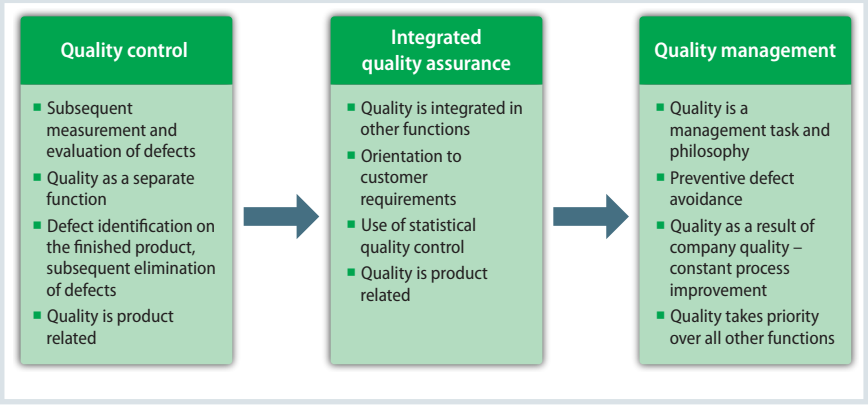


Fig. 1. Development of quality assurance: according to the present understanding of quality, the part quality is already assured during the production process [3] Source: Engel; graphic: © Hanser

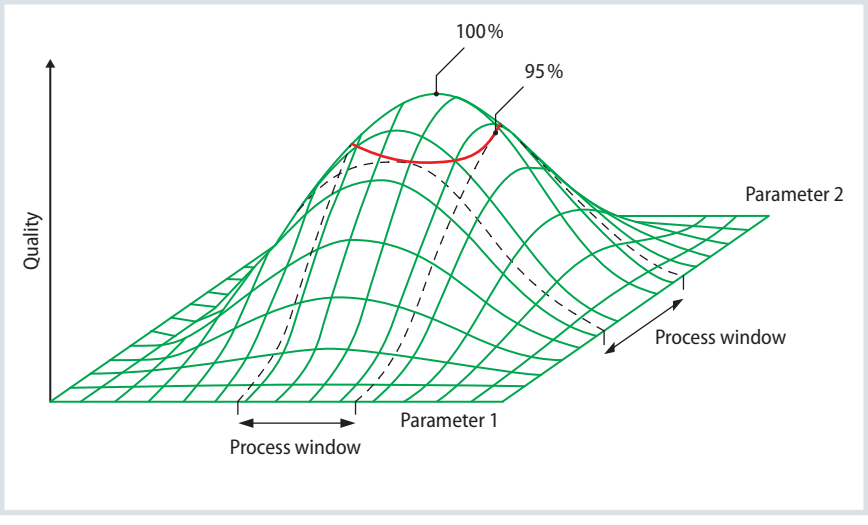


Fig. 2. The limits between which the process parameters are adjusted can be derived from the part's quality requirements. Source: [4]; graphic: © Hanser

The more recent methods include active compensation of process fluctuations through the adaptive control of the injection molding process. For example, with the iQ weight control assistance system, Engel offers the possibility of keeping the shot weight constant from cycle to cycle by adjusting the injection profile, the changeover point and the holding pressure. This allows compensation of fluctuations of the raw material properties and the ambient conditions, as well as of influences due to mold and machine wear [2].

A new method targets the basis of the process setting, the preset setpoint values of the injection molding process. By means of the Parameter Limits feature, it ensures that the setpoint values lie within a defined process window at any time and therefore the quality criteria of the part do not fall outside the specified limits. This method can be easily combined with the actual value monitoring as well as the complete product testing.

Reliably Avoiding Process Rejects

A process window describes the range within whose limits the process must run in order to attain the part quality required by the customer. In the optimization of the injection molding process, the setpoint values are set on the injection molding machine in order to come as close as possible to the quality optimum (100 %) (**Fig. 2**). The much easier method would be to define a concrete process point, however this has proved impracticable. Because of continuous changes, for example in the raw material and ambient conditions, the process values often have to be adjusted in order to ensure the quality. As long as these adjustments take »

Fig. 3. The selected process parameters are clearly presented on their own page in the CC300 control system. © Engel

place within a process window, the high demands on quality can be ensured in the great majority of cases.

Quantitatively, the relationship between setpoint values and part quality can be determined by means of a statistical design of experiments (DoE). Here, the setpoint values of individual process parameters are systematically varied and the resulting part quality is recorded. A statistical analysis is performed to determine from which values the part quality no longer meets the required specification. In **Figure 2**, for example, this is the case if the quality values lie below 95 %. The process window then results from the lower and upper setpoint values of a parameter that still allow the required part quality to be reached.

Precise Measuring of the Process Window and the Permitted Tolerance

In practice, it is defined in the design of the part what dimensional deviations can be tolerated so that the functional and aesthetic requirements can still be met. Based on this, the injection mold is often designed with a certain geometrical and material-dependent reserve in order to compensate the warpage that is to be expected. If the warpage at a place on the part is a critical quality criterion, it is determined in the DoE which parameters have how much influence on it. Those parameters that, because of experience and the physical process understanding, have the biggest influence are systematically varied and the manufactured components are measured. This is then used to calculate the process window for the parameters considered in the DoE. A DoE is the centerpiece of a process validation, as specified, for example, in medical technology and also increasingly required in other industries, too.

Once the process window is defined, this information must be available at the injection molding machine on production start. The operating personnel conventionally have access to the threshold values – if at all – as a print out or in digital form outside the injection molding machine control. It is not always known to the machine operator where the limits of the process window currently are. Thus, despite elaborate preparatory work, it may be that rejects are produced unnoticed for a long time.

As a solution for this, Engel has developed the Parameter Limits feature in order to enter the process window directly on the injection molding machine and ensure that the threshold values are reliably maintained during operation of the machine in production. For up to 150 individually selectable process parameters, a process window can be specified by means of the software in the CC300 operating panel in Engel injection molding machines. All numerical process parameters whose setpoint values can be varied by the machine operator come into consideration.

All the selected parameters are displayed to the machine operator on a summary page (**Fig. 3**). They are subdivided into four groups analogous to the phases of the injection molding process, and individual groups can be added. The setpoint value currently set for each parameter is displayed. In addition, the value obtained from the process optimization or validation is entered for which the optimum part quality was obtained. This value serves as a reference for the permitted deviations that are entered as absolute or percentage tolerance. Alternatively an upper and lower

Fig. 4. If a change of a setpoint value, for example the dosage volume, is necessary, it is displayed to the machine operator via a dialog box. © Engel

threshold value can be directly entered, according to which the tolerance is automatically calculated. The operator can thus keep an eye on the entire process window, the currently set values and the associated reference value.

Saving the Process Window in the Settings Data Record

This feature can be easily activated by ticking a box. The process parameters can then no longer be set to values outside the process window. All the settings made are then saved in the partial data record. The process windows are thus immediately available again when the mold is set up again in the injection molding machine control system.

Parameter Limits can only be activated or deactivated by authorized personnel. The feature thus links the quality of the production organization to the quality of the part. If it is activated and the change of a setpoint value is necessary, the machine operator has access to a dialog box showing the range within which the setpoint value can be changed (**Fig. 4**). Making changes to the process window is also only permitted to authorized personnel.

The control function monitors the setting of setpoint values and reduces the risk of operating errors. It thus contributes to preventing the production of rejects and energy- and resource-efficient work, especially if guaranteeing the process window is combined with actual value monitoring via the process data protocol.

With Parameter Limits, Engel offers another possibility for ensuring the part quality by means of the process quality, and linking quality to the production organization. The quality of the injection molding process is a focus of Engel's development work, which will once again be evident at K 2022 in Düsseldorf, Germany, in October. ■

Info

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References & Digital Version

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