TECHNICAL PAPER

Optical quality characteristics under control - Software-assisted optimisation of the process window for attributive quality characteristics

Optically perfect and dimensionally accurate components can only be achieved with an optimally adjusted injection moulding process. Especially in the case of optical characteristics it is essential to find a process window which is as broad as possible, so that drifts in the process do not result in rejects. Knowledge of the process limits also provides confidence that perfect quality can be delivered, with enough reserves for further optimisation.

Simple changes to the adjustment according to the „trial and error“ principle are still widespread. Even for experienced process technologists it is difficult to estimate in advance just how many attempts will be required and even whether a suitable process setting can be found. In contrast, with systematic optimisation of process parameters a few selective trials are performed in sequence and the quality of the components which are produced with these settings are examined.

The basis for this can be a statistical test plan [1], or the machine setter can use historical data for the relevant component as a basis. With the Stasa QC software developed by Stasa Steinbeis Angewandte Systemanalyse GmbH, evaluation of this data and the corresponding creation of process models for quality characteristics (e.g. moulding dimensions and weight, as well as optical characteristics such as burrs or shrink marks) is carried out automatically, so that effort is saved for the evaluation of the large quantities of data.

Optimisation of the permissible process window

At its facility in Frickenhausen, Greiner Bio-One produces polystyrene roller bottles using the injection blow moulding method (Fig. 1). With this method, a preform is first produced using a conventional injection moulding method and in the second step this is pressed into the final bottle shape on the same machine by means of blow moulding [2].

These roller bottles are used in the biomedical sector for the cultivation of cells as bulk cultures, e.g. for production of viral vaccines and comply with the quality standards of the US Pharmacopoeia Convention (USP) [3]. The complete end product is certified as USP Class VI. Accordingly, the roller bottles must meet extremely stringent requirements, especially for optical surface quality, because even the smallest irregularities in the transparent plastic wall of the bottle can lead to misinterpretations in the biomedical analysis when the cell cultures are examined microscopically through the wall of the bottle.

Figure 1: Polystyrene roller bottles (cat. no. 680 0XX) have to be of high optical quality, because in the microscopic examination of the cultivated cell cultures, even the smallest irregularities in the transparent plastic wall may result in incorrect analyses.

To achieve further improvement in the quality of these roller bottles, Greiner Bio-One wished to achieve a broader process window through changes to the process settings. The main focus was on avoiding possible optical orientation errors in the plastic, which are visible under the microscope (Fig. 2). Initially, experienced process engineers attempted to optimise the process settings manually using conventional methods. Various quality characteristics are used to assess this procedure (Table 1).

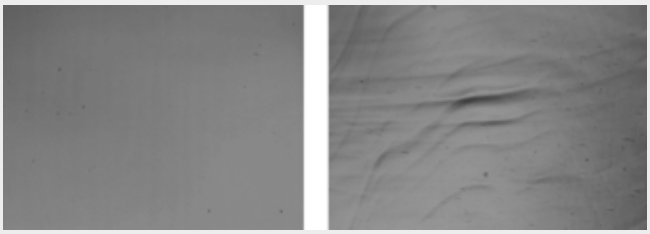

Figure 2: The microscope image of the surface of the roller bottle shows an optically perfect surface on the left and orientation errors in the plastic surface on the right.

Quality Feature	Type	Attribute
weight	measurable	
center of stretch	attributive	ok / not ok
wall thickness roller bottle	attributive	ok / not ok
orientation in the roller bottle (orientation error)	attributive	1, 2, 3, 4, 5 (1-3 permissible, i.e. ok)
air bubble	attributive	

Table 1: For each cavity, five quality features are evaluated for optimisation of the process settings for injection blow moulding of the roller bottles

The use of Stasa QC software appeared to be too tedious due to the complexity of the two-stage injection blow moulding process with a total of 15 relevant setting parameters. After two days of unsuccessful attempts using the conventional trial-and-error method, the managers at Greiner Bio-One decided to perform the optimisation of the process systematically with Stasa QC, in order to move things forward.

Systematic procedure

Stasa QC provides a tailored test plan for practical use. This specifies which process settings are to be systematically changed in order to obtain as much information as possible about the relationships between process setting parameters and quality characteristics with as little effort as possible.

In the present case, due to the complex two-stage process with 15 process setting parameters, the test plan proposed by the software consisted of 25 trial settings. Due to the large number of process setting parameters, this test plan is considerably more extensive than is normal for injection moulding processes, where usually only between five and seven process settings need to be varied. Test plans then typically consist of between ten to twelve trials.

After carrying out the test plan and measuring the quality characteristics, Stasa QC automatically determines the interactions between the process parameters and the quality characteristics and generates corresponding models. These enable interactive simulation and visualisation of the relationships between the settings and quality. In this way, time can be saved by carrying out further „virtual“ trials on a PC, from which the optimum process settings can be calculated at the touch of a button, e.g. the setting at which the specified tolerances can be maintained with the minimum cycle time.

The optical quality characteristics and the weight of the roller bottles which are produced according to the test plan were determined directly after each cycle and adopted by the software. Evaluation of the gathered data is carried out fully automatically in Stasa QC. After clicking „Create operating point model“, it is determined whether there is a linear or non-linear relationship between the process parameter settings for each quality characteristic and the corresponding model is set accordingly and trained. With a further click on „Start operating point optimisation“ the optimum process settings and the permissible process window can be determined.

Even the optimum process setting can be deliberately influenced, e.g. to reduce the energy consumption for each cycle. With this, users can concentrate on their process know-how and interpretation of the results. The tedious evaluation of the data and its documentation is carried out by the software. The modelling and optimisation algorithms developed by Stasa, which are implemented in Stasa QC have proved themselves in a wide range of practical applications [4-8].

Figure 3: Result of operating point optimisation with Stasa QC for Greiner Bio-One roller bottles. The graphic display of the relationships between process parameter settings (right) and quality features (left) provide an overview of the process (red: optimum operating point and process window) and at the same time enables interactive simulation of the process. The values for the process setting parameters have been obscured in order to protect process know-how (Photo: Stasa)

The results (in this case optimisation of the operating point) are displayed in an easy to understand interactive diagram: on the left, the quality characteristics with the tolerance ranges highlighted in green and on the right the process setting parameters with the corresponding setting limits in the test plan (Fig. 3). The optimum process setting is indicated as a red line; the process window for the limits of process capability is indicated with a red background. The process parameter settings can be changed at will in the software within the limits which are defined in the test plan; the effect on the quality features is immediately visible on the left hand side.

The results confirm the suitability even for complex applications

At Greiner Bio-One, the optimum process settings which were suggested by Stasa QC, as well as the initial setting, produced roller bottles with perfect optical quality. In particular, with the attribute „1“, the orientation errors are in the best possible permissible categories „1“ „2“ and „3“. In fact, the available process window was able to be enlarged considerably in comparison with the initial setting. The result which were forecast by Stasa QC were successfully confirmed in practical trials.

In spite of a test plan with 25 trial settings, the effort for systematic optimisation was manageable: One and a half days were required from the creation and running of the test plan up to the evaluation of the results. A great advantage is that this effort can be planned in advance, in contrast to the unpredictable effort which is involved in conventional trial-and-error methods.

The results show that even optimised processes offer potential for improvement and that the systematic method is worthwhile.

Conclusion

Systematic optimisation of injection moulding processes offer enormous practical advantages. The effort is predictable and in many cases is less than conventional methods. The result and the trials which are performed are documented simultaneously. The evaluation is understandable and in spite of the complexity of the method, provides detailed insights into the injection moulding process. The injection moulding experts can concentrate on their actual task and are not encumbered with statistical evaluations or manual documentation of the process. Although they are continuously improving their knowledge of the process, use of software tools such as Stasa QC allow them to concentrate on other elements of their work and are therefore essential.

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