Abstract

Pre-control is a quality control tool which assesses the ability of a process to produce pieces within given specifications. One of the contexts in which it is used is the set-up approval of short-run processes. It works by checking successive sampled observations against the tolerance limits and the so-called *pre-control limits*, using cumulative counts to yield a conclusion about the suitability of the process. It is a simple, quick technique which is easy to apply.

The fact that in its original form, the technique of pre-control does not take the natural variability of the process being monitored into account, together with its simple design, mean that its behaviour is not as effective as is desirable under certain circumstances, in terms of the false alarm rate and the power to detect unacceptable deviations, which leads some authors to reject its use. For this reason, there are different proposals in the literature focused on improving the behaviour of the original technique by modifying its operating rules to a greater or lesser extent.

The enhancement of pre-control as a tool for process qualification is addressed in this Ph.D. thesis through the optimal determination of the parameters governing its behaviour, using Mixed-Integer Nonlinear Programming techniques. The goal is to develop a methodology to automatize the procedure of selecting the value of the pre-control parameters in order to satisfy the user's requirements as closely as possible. This Optimisation approach, unprecedented in pre-control, has been successfully applied to other quality control techniques in recent

decades, thereby producing better decision-making tools.

To achieve this goal, firstly an exhaustive review of the different proposals regarding pre-control in the literature is outlined.

The problem to be solved is then defined and a Mathematical Programming model which is specifically designed to obtain the so-called *optimal pre-control plans* is developed. A complete numerical experiment using general-purpose optimisation software is described, showing the effectiveness of the proposed model and, at the same time, revealing the existence of significant differences between the results provided by the different algorithms being considered, due in part to the two-fold nature —nonlinear and integer— of the problem, and also the inability of these algorithms to guarantee convergence to a global optimum, due to the existence of nonconvexities.

All of these things justify the design of specific algorithms to obtain optimal pre-control plans, which is another goal of this Ph.D. thesis. Before this, a study of the mathematical properties of the optimization model which was previously built is outlined, improving knowledge about the *optimal pre-control problem*.

This knowledge is used in the development of an *exact* algorithm called `OPCenum` to solve the problem, combining an implicit enumerative strategy with a local search based on derivative-free root-finding methods. The algorithm is implemented and tested on the same instances which were considered in the previous numerical experiment.

The tests reveal the effectiveness and efficiency of the algorithm `OPCenum` as a method to obtain optimal pre-control plans for some given requirements.

The development of a graphical interface to make the algorithm more user-friendly, the adaptation of the problem to asymmetric distribution functions and to other fields such as reliability, and the development of a complementary approach where pre-control is considered as a tool to assess process capability are the main future research lines arising from the results obtained in this Ph.D. thesis.

Keywords: *Pre-control, quality control, process qualification, optimisation, mixed-integer nonlinear programming, enumerative search, root-finding methods.*