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Control vector parameterization with sensitivity based refinement applied to baking optimization

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A B S T R A C T

In bakery production, product quality attributes as crispness, brownness, crumb and water content are developed by the transformations that occur during baking and which are initiated by heating. A quality driven procedure requires process optimization to improve bakery production and to find operational procedures for new products. Control vector parameterization (CVP) is an effective method for the optimization procedure. However, for accurate optimization with a large number of parameters CVP optimization takes a long computation time. In this work, an improved method for direct dynamic optimization using CVP is presented. The method uses a sensitivity based step size refinement for the selection of control input parameters. The optimization starts with a coarse discretization level for the control input in time. In successive iterations the step size was refined for the parameters for which the performance index has a sensitivity value above a threshold value. With this selection, optimization is continued for a selected group of input parameters while the other nonsensitive parameters (below threshold) are kept constant. Increasing the threshold value lowers the computation time, however the obtained performance index becomes less. A threshold value in the range of 10–20% of the mean sensitivity satisfies well. The method gives a better solution for a lower computation effort than single run optimization with a large number of parameters or refinement procedures without selection.

Keywords: Baking; Optimal operation strategy; Refinement; Sensitivity; Product quality; Optimization

1. Introduction

Quality driven process design can help to meet the challenges of the food industry to produce high quality products. Moreover, the approach also can create flexibility to produce a wide range of products. In quality driven process design, one starts with a process model, which describes the conversion process from ingredients and process conditions, to the product. Next, the product specifications are translated to an objective function. An optimization procedure is applied to find the required product treatment as a function of time and time dependent process conditions. Finally, the treatments are translated into processing equipment (Hadiyanto et al., 2008; Garcia et al., 2006).

Quality driven process design has been applied for bakery applications (Hadiyanto et al., 2008). Here the oven temperature, radiation temperature and microwave are used as control variables. The challenge is to find a heating strategy, i.e. the variation of these control variables in time (fixed oven) or in residence time (tunnel oven). The heating strategy must be designed such that desired qualities, as brownness, crispness, size and crumb can be realized. The calculation of the heating strategies is based on baking models and an objective function which reflects the deviation of the realized qualities from the setting values at the end of the baking process.

To solve the optimization problem for the processing time indirect and direct methods for dynamic optimization are available. Indirect methods are based on the calculus of varia-

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