Book of Abstracts
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Dynamic optimization of baking operations using refinement method

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1. Summary

Baking is the major process in bakery production where product transformations are initiated by heating and which results in final product qualities as crispness, brownness, crumb and water content. The baking process is described by a set of non-linear differential and algebraic equations [2]. For quality driven process design, optimal heating strategies are determined from input trajectories as a function of baking time. Control vector parameterization (CVP) is an effective method for the calculation of the input trajectories. However, for accurate optimization with a large number of parameters of the control vector computation time is long. Stepwise refinement of the CVP is proposed as an alternative to reduce the computation time.

Keywords: Baking, refinement, optimization, operation strategy

2. Extended Abstract

For the baking application, single run optimization with 45 control vector parameters requires about 18400 seconds to approach the optimal trajectory (Fig 1a). The computation time is related to the number of optimized input parameters, but the

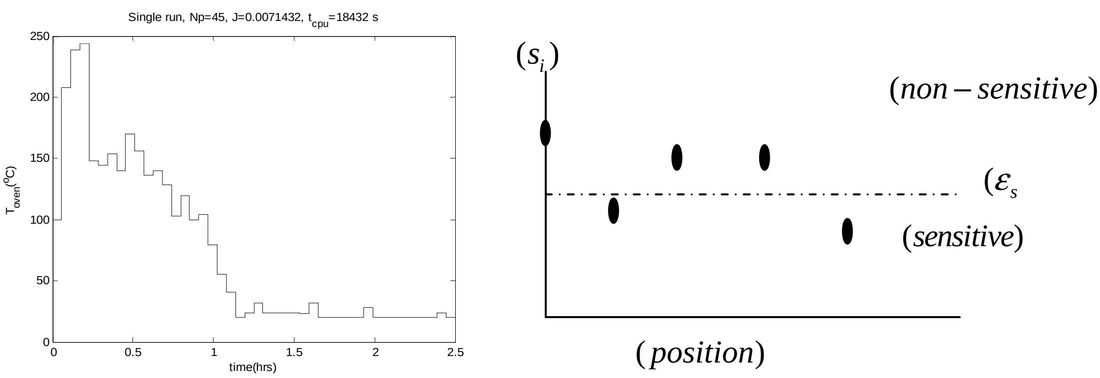

Figure 1. (a) Single run of control vector parameterization for 45 numbers of parameters, (b) the principle of refinement based on sensitivity value

objective function is not sensitive for changes of all parameters. A part of the parameters hardly contribute to the improvement of the objective function but require extra function evaluations and increase the computation time. Therefore, a refinement method is applied by adapting only the sensitive input parameters, while the others are kept constant (Fig 1b). To do so, a threshold value of sensitivity is used. Optimization calculations have been done for a piece-wise constant control vector, which is started with only six parameters. Figure 2 shows optimization progress for four succeeding levels of refinement. Table 1 gives the objective function values and computational time for the single run optimization of figure 1, for a refinement at all CVP-points [1] and the proposed refinement based on the threshold value. The proposed method is respectively about 4 and 2 times faster than single run optimization and the refinement method on all CVP-points, respectively. Moreover the objective function value is also more beneficial.

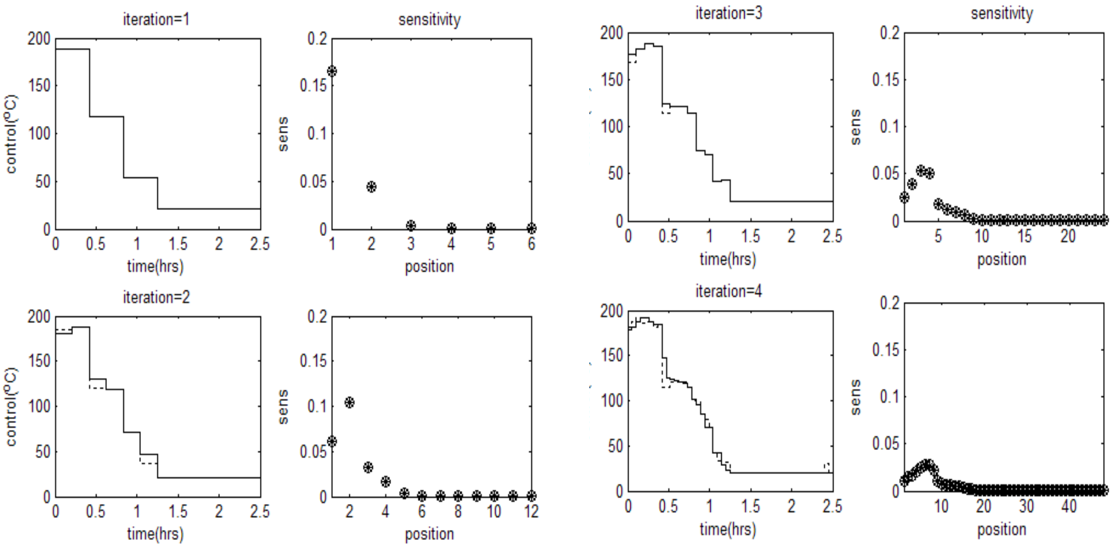

Figure 2. Baking temperature trajectory refinement for 4 iterations; refinement on all CVP-points (--) and refinement with threshold value (-).

Table 1. Computational time and performance index for three different methods

Iteration	Refinement on all CVP-points			Refinement with threshold value			Single run	
	Nu	J	t_{CPU} (s)	Nu	J	t_{CPU} (s)	Nu	J
1	6	0.00718145	382.2	6	0.00718145	382.2	45	0.0071432
2	12	0.00697551	869.3	6	0.00697542	537.9		
3	24	0.00692146	1718.9	12	0.00692135	1078.5		
4	48	0.00686000	4941.5	24	0.00684551	2245.1		
Total t_{cpu}			*7911.8*			*4243.8*		*18432*

Nu= Number of input parameters, J=performance index (calculated from square error from the setting value),
t_{cpu}= computation time(s)

References

[1].García,M.S.G, Balsa-Canto,E., Alonso,A.A. and Banga,J.R. 2006. Computing optimal operating policies for the food industry, *Journal of Food Engineering, 74(1), 13-23*

[2].Hadiyanto, Asselman, A., van Straten, G., Boom, R.M., Esveld, D.C. & van Boxtel, A.J.B., 2007, Quality Prediction of bakery products in the initial phase of process design, *Innovative Food Science and Emerging Technologies, in press*