COST 526

"Automatic Process Optimization in Materials Technology"

(APOMAT)

Half-Yearly Report

To be sent to **V.Tesch@access.rwth-aachen.de** until **February 28, 2004**

1. Reporting Period	**1.7.2003 – 31.12.2003**
Project title	**Advanced Parameter Optimization Methods Preliminarily Used for Casting Processes** (SI1)
Project leader Organization	Dr. Bogdan Filipič Jožef Stefan Institute, Ljubljana, Slovenia
Main collaborators involved	• Tea Robič Jožef Stefan Institute, Ljubljana, Slovenia • Prof. Božidar Šarler, Robert Vertnik Nova Gorica Polytechnic, Slovenia • Emil Šubelj Acroni Steelworks, Jesenice, Slovenia • Prof. Erkki Laitinen Department of Mathematical Sciences, University of Oulu, Finland

2. Funding Situation

Amount of money received specifically for COST	0 kEuros
Other resources partially used for the project	3 kEuros

3. International Collaboration

(mention group and type of work done in collaboration during the reporting period)

Participation in the Working Group Meeting in Krakow + project progress report

■ YES

□ NO

Project leader Bogdan Filipič participated in the 4th Joint Working Group Meeting in Krakow, Poland, held 27–28 November 2003. He organized a session of WG4 on optimization methodologies and reported on the progress of the project in a presentation entitled *A comparative study of optimization algorithms in tuning coolant flows on a steel casting machine*.

In September 2003, Prof. Erkki Laitinen and Bogdan Filipič have prepared a proposal for a Slovenian-Finnish project *Numerical Optimization of Continuous Casting of Steel* and submitted it to the Slovenian Ministry of Education, Science and Sport, and the Academy of Finland. If approved, this will enable further exchange of researchers in the area of material process optimization between the Jožef Stefan Institute and the University of Oulu in the period 2004–2005.

4. Industry participation

(mention name of companies and work done in collaboration during the whole project)

Optimization calculations for the Acroni Steelworks, Jesenice, Slovenia, were carried out. A focus was on comparing various optimization techniques to find the most efficient way of process parameter tuning (see description in *Progress within the reporting period*).

5. Meetings, visits, exchange of scientists, short-term scientific missions	Location, date
Visit of prof. Thiemo Krink from Department of Computer Science, University of Aarhus, Denmark. We have carried out empirical studies of stochastic methods on noisy optimization problems and submitted a joint publication.	Ljubljana, 1–5 December 2003

6. Progress within the reporting period

(Not exceeding 3 pages, including tables and figures)

We continued the optimization calculations started in the previous reporting period. However, the focus was not only on finding high-quality setting of process parameters, but also on finding them in as few iterations as possible. Empirical evaluation of candidate solutions via the casting process simulation is the most complex part of the optimization procedure. To reduce it, we implemented several optimization algorithms, applied them to a specific parameter tuning task, and analyzed their convergence rates.

The task was to tune 12 spray coolant flows in the secondary cooling zone with respect to empirical metallurgical cooling criteria in order to ensure higher product quality. The cast steel was AC0113 with the slab cross-section of 1.03 m x 0.20 m. Parameter search space was discretized in the way presented in the previous report. The quality function was a weighted sum of the individual metallurgical criteria. Our own integrated simulator-optimizer environment was used with the following optimization algorithms incorporated:

- local optimization (random descent, steepest descent and next descent variants),
- downhill simplex,
- conjugate gradient,
- evolutionary algorithm.

Performance of these algorithms is shown in Figure 1, where the plots represent averages over five runs of each algorithm. Note that lower cost values represent better solutions. It can be seen that all tested algorithms were able to find coolant flow settings significantly better than determined manually. The algorithms converged towards similar settings, but the difference was in the convergence rate. The next descent local optimization performed the best and for the tested problem instance about 50 process evaluations were on average sufficient to converge. This result indicates the fitness landscape for this problem is smooth which is in accordance with the parameter sensitivity studies performed at earlier stages of the project.

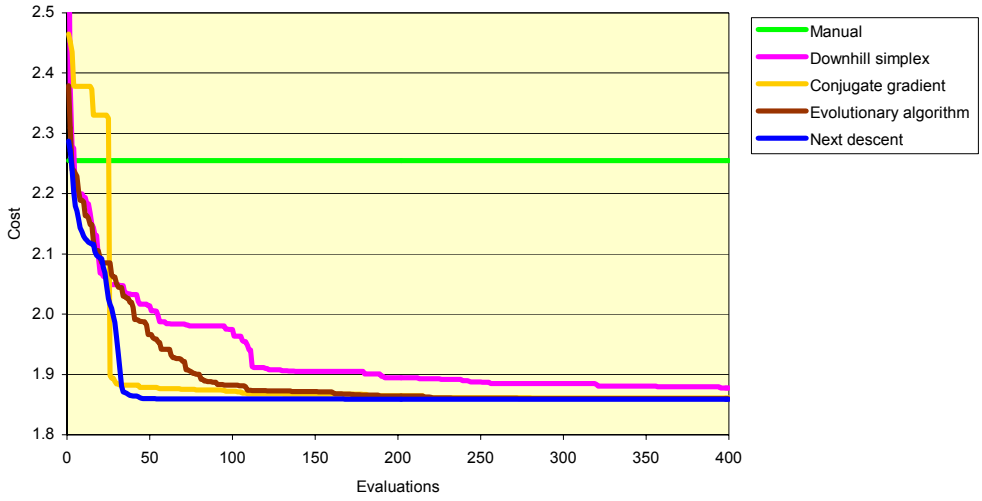

Figure 1: Performance of the tested algorithms in optimizing 12 spray coolant flows for continuous casting of steel AC0113 (average of five runs of each algorithm)

Of the greatest importance to process engineers at the steel plant were the resulting coolant flows. Figure 2 shows their values in comparison with manual settings. The optimized settings are now under evaluation for practical use on the casting machine.

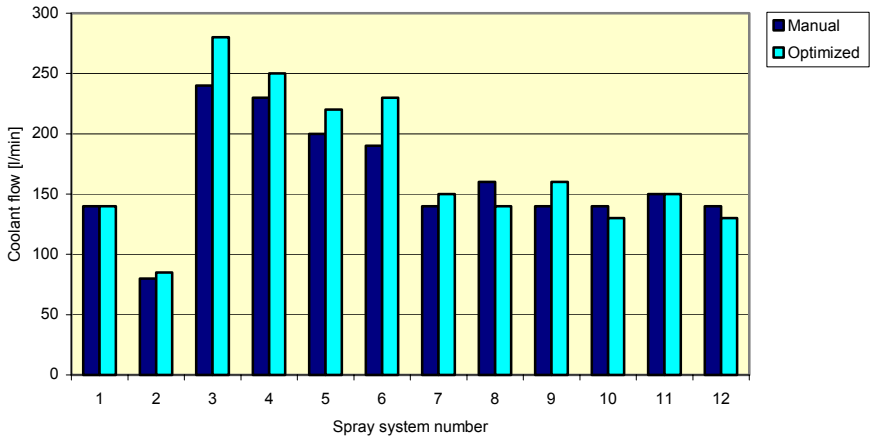

Figure 2: Optimized coolant flow settings compared with manual settings

Despite the demonstrated improvement, the results of this study should be viewed as preliminary. Systematic tuning of algorithm parameters would probably further improve the results and additional optimization methods could be tried. Moreover, the problem specificities, such as the size of the discretization step, also play an important role in the performance of individual methods. Additional challenging questions we hope to answer in the future work are how to appropriately present the results to the end-users, how to interpret them and how to evaluate their gain in practice.

7. List of publications

a) Published

b) Submitted for publication

B. Filipič, T. Robič: A comparative study of coolant flow optimization on a steel casting machine. Submitted to the Congress on Evolutionary Computation CEC 2004, Portland, Oregon.

T. Krink, B. Filipič, G. B. Fogel, R. Thomsen: Noisy optimization problems – a particular challenge for differential evolution? Submitted to the Congress on Evolutionary Computation CEC 2004, Portland, Oregon.

c) In preparation

T. Robič, B. Filipič: Searching for an efficient parameter tuning method for steel casting.