



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, 2003**

<b>1. Reporting Period</b>	<b>1.7.2002 – 31.12.2002</b>
Project title	Advanced Parameter Optimization Methods Preliminarily Used for Casting Processes (SI1)
Project leader Organization	Dr. Bogdan Filipic Jozef Stefan Institute, Ljubljana, Slovenia
Main collaborators involved	<ul style="list-style-type: none"> <li>• Nova Gorica Polytechnic, Slovenia (Prof. Bozidar Sarler, Robert Vertnik)</li> <li>• Acroni Steelworks, Jesenice, Slovenia (Emil Subelj)</li> <li>• Department of Computer Science, University of Aarhus, Denmark (Prof. Thiemo Krink, Rasmus K. Ursem)</li> </ul>

<b>2. Funding Situation</b>	
Amount of money received specifically for COST	4 kEuros
Other resources partially used for the project	2 kEuros

<b>3. International Collaboration</b>
(mention group and type of work done in collaboration during the reporting period)
Participation in the Working Group Meeting in Budapest + project progress report
<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
Project leader Bogdan Filipic participated in the 2nd Joint Working Group Meeting in Budapest and reported on the progress of the project at the meeting of WG2. As the leader of WG4, he organized a session on optimization methodologies with three speakers.
In addition, as part of the Slovenian-Danish scientific exchange, he visited the Department of Computer Science of the University of Aarhus that is active in evolutionary computation and its practical applications. There he presented the context of the automatic process optimization in materials technology as addressed by COST 526, and his work done so far in process parameter optimization for continuous casting of steel. The Danish partners have agreed to start a collaboration in this domain focused on the optimization methodology issues. Prof. Thiemo Krink from the University of Aarhus is also willing to participate at a future COST 526 Working Group Meeting as a guest speaker.

<b>4. Industry participation</b>
(mention name of companies and work done in collaboration during the whole project)
We continued the collaboration with the Acroni Steelworks at Jesenice, Slovenia, in the domain of process parameter optimization in continuous casting of steel. For the AISI-304 steel that was used in previous experiments of numerical process simulation and optimization, the impact of individual process parameters on empirical metallurgical cooling criteria was analyzed. Furthermore, for the extended version of the Acroni caster simulator developed by our partners at the Nova Gorica Polytechnic an interface to the evolutionary optimization algorithm was implemented and the simulator-optimizer loop made ready for further calculations.



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<b>5. Meetings, visits, exchange of scientists, short-term scientific missions</b>	<b>Location, date</b>
Two research visits of Bogdan Filipic at the Department of Computer Science, University of Aarhus, Denmark	30. 7. – 10. 8. 2002 and 16. – 22. 11. 2002

**6. Progress within the reporting period**

(Not exceeding 3 pages, including tables and figures)

**Introduction**

We work on model-based optimization methodology for casting process and our industrial application area is continuous casting of steel. We have an operational version of the optimization environment consisting of a numerical caster simulator and an evolutionary optimization algorithm. It has already been used with success in process parameter optimization for certain steel grades at the Acroni Steelworks. At present stage we are focused on two issues specific to the optimization methodology: reducing the computational cost of the iterative optimization procedure and better understanding of the impact of process parameters on individual metallurgical cooling criteria. The objectives of the work, the metallurgical criteria and the quality function used in the experiments in this reporting period were identical to those from the previous period (see the half-yearly report for 1.1.2002.– 30.6.2002). We report on a recent empirical analysis done in order to get useful information about the parameter space, on the improvements of the optimization environment and plans for the next period.

**Empirical analysis of the parameter space**

The core optimization technique used so far in our simulator-optimizer environment was an evolutionary algorithm with real-coded parameters and traditional blind variation operators. The motivation for starting with this approach was that we deal with a multidimensional problem (up to 30 process parameters) and have no information about the fitness landscape. The results obtained so far with this approach and verified at the steel plant indicate that significant improvements of process parameter settings are possible that contribute to higher product quality. A disadvantage of the current optimization environment is however its high computational complexity which arises from numerically demanding process simulation. Considering problem-specific information in the optimization procedure could reduce the number of evaluations needed to get acceptable solutions. Furthermore, as numerous empirical criteria are involved in assessing the continuous casting process, the metallurgists are interested in better understanding of their physical background and the impact of individual process parameters on the criteria.

To investigate these issues, a preliminary empirical analysis of the parameter space was performed for continuous casting of stainless steel AISI-304 with the slab cross-section of 1.06 m x 0.20 m. The parameters involved in the study were spray coolant flows in the caster secondary cooling system, (see Table 1 for the analyzed parameter space). The impact of process parameters on the criteria was checked by changing the value of a selected parameter and keeping other parameters fixed. Changes of the metallurgical criteria were monitored as functions of the changing parameters. It turned out that these dependencies are monotone on the observed intervals as illustrated by two examples shown in Figures 1 and 2. The same holds for the case of the surfaces obtained by calculating the values of criteria as functions of two process parameters. This indicates the fitness landscape contains

regularities where gradient-based methods could be very efficient. In attempts to reduce the number of parameter evaluations, these findings will be used to either hybridize the current optimization algorithm or even switch to less complex algorithms if they turn out to be successful in finding acceptable solutions.

Table 1: Parameter search space for spray coolant flows (in l/min)

Parameter	Minimum value	Maximum value	Step size	Possible values
Spray coolant flow 1	110	150	10	5
Spray coolant flow 2	70	110	10	5
Spray coolant flow 3	190	270	10	9
Spray coolant flow 4	150	210	10	7
Spray coolant flow 5	95	135	10	5
Spray coolant flow 6	110	150	10	5
Spray coolant flow 7	65	85	10	3
Spray coolant flow 8	70	110	10	5
Spray coolant flow 9	55	75	10	3
Spray coolant flow 10	60	100	10	5
Spray coolant flow 11	50	70	10	3
Spray coolant flow 12	50	70	10	3

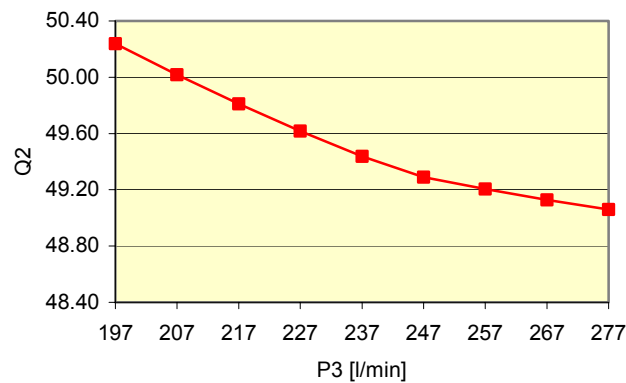


Figure 1: Maximum slab surface cooling rate in the spray cooling zone (Q2) vs. spray coolant flow 3 (P3)

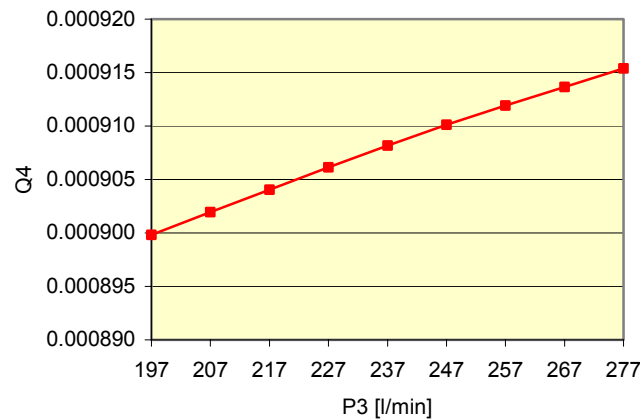


Figure 2: Maximum negative deviation of the slab surface temperature in the spray cooling zone (Q4) vs. spray coolant flow 3 (P3)

### Improvements of the optimization environment

An extended version of the continuous caster simulator, developed at the Nova Gorica Polytechnic, was integrated with the optimization algorithm and the interface established between the two modules. The new version of the optimization tool will make it possible to consider additional empirical criteria proposed by the metallurgists and to optimize the process with respect to various combinations of the criteria.

### Future work

The work on the project will continue in two directions. As far as the methodological issues are concerned, extensive tests of optimization techniques on selected problem instances will be carried out to obtain the best results possible given limited computational time. From the practical perspective, a set of additional steel grades whose product quality is of critical importance to our industrial partner will undergo optimization calculations.

## 7. List of publications

### a) Published

B. Filipic: Simulation-based optimization of material properties. *Proceedings of the 5th International Multi-Conference Information Society 2002*, Ljubljana, Slovenia, 2002, pp. 94–97.

### b) Submitted for publications

### c) In preparation

B. Filipic, B. Sarler: Model-based evolutionary optimization of process parameters in continuous casting of steel.